Aircraft
RADIO EQUIPMENT

RESTRICTED

NAVY TRAINING COURSES

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AIRCRAFT RADIO EQUIPMENT

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PREFACE

This book is written for the enlisted men of Naval aviation. It is one of a series of books designed to give them the necessary information to perform their aviation duties.

A knowledge of aircraft radio equipment is of primary importance to aviation radiomen and aviation radio technicians. Their jobs involve the operation and maintenance of aircraft radio equipment, and they are jobs vital to naval aviation. Radio heads the list in wartime communications. It is both an offensive and a defensive weapon.

Starting with the basic principles involved in all radio, this book discusses such fundamentals as the vacuum tube, the elementary transmitter, the elementary receiver and frequency measurement. Then attention turns to the receivers, direction finders and transmitters used in naval aviation. In conclusion, there are sections on interphone communication systems and aircraft radio installations.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Division of the Bureau of Naval Personnel.

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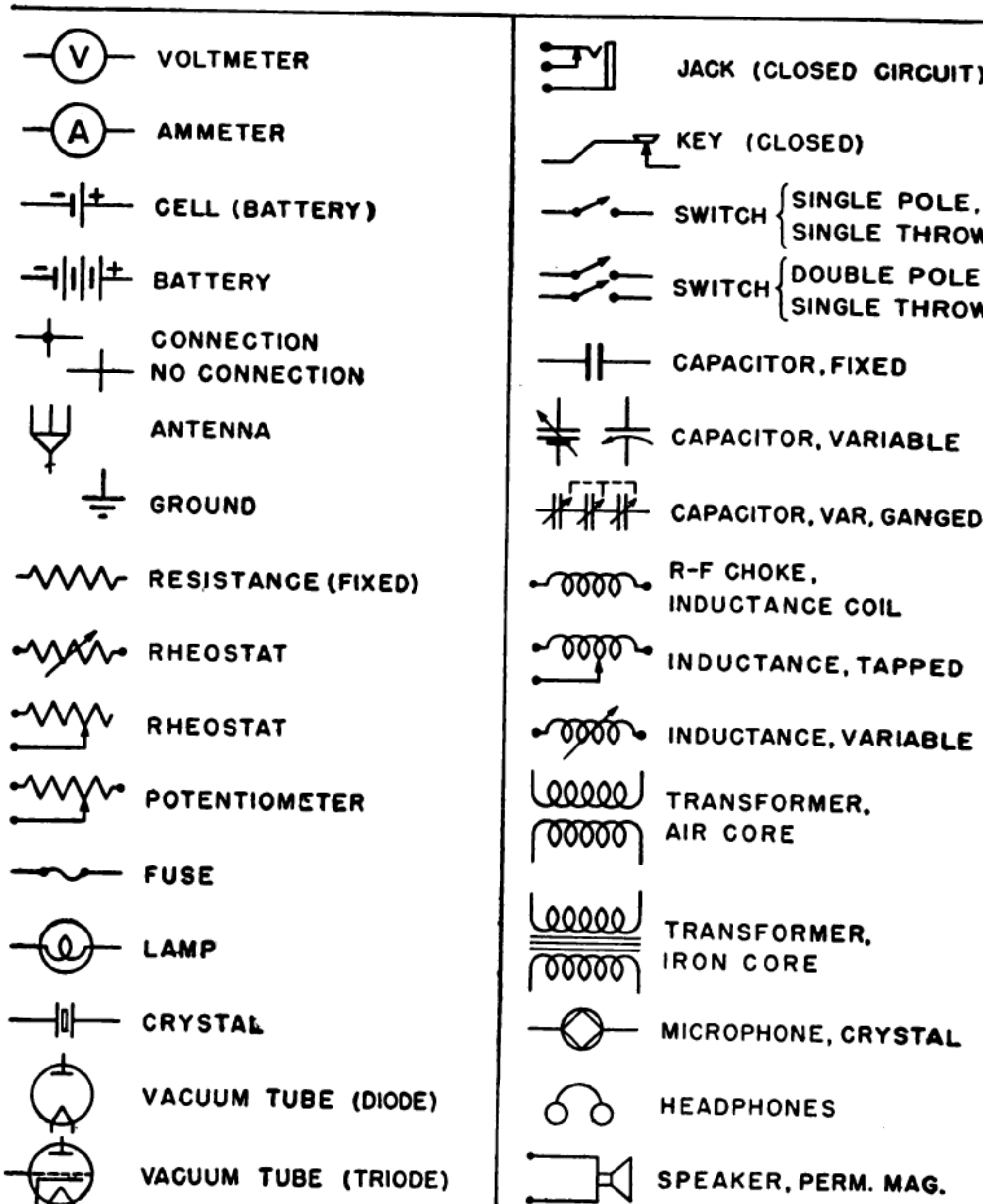
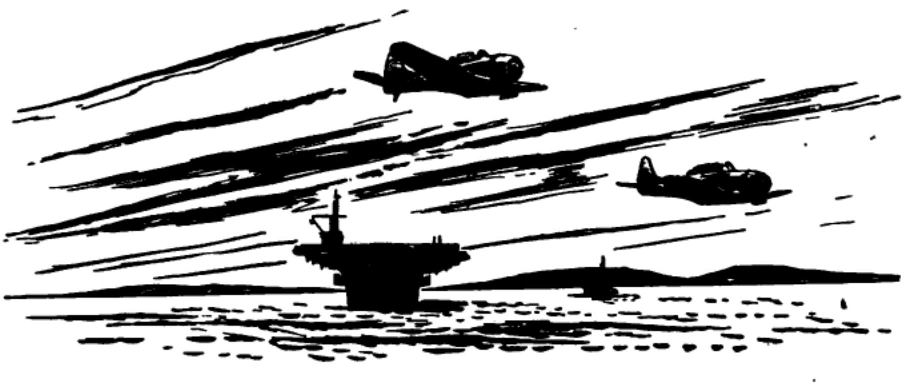
ELECTRICAL & RADIO SYMBOLS

E	= VOLTAGE	v	= VOLTS
I	= CURRENT	a	= AMPERES
R	= RESISTANCE	Ω	= OHMS
f	= FREQUENCY	~	= CYCLES PER SEC.
+	= POSITIVE	−	= NEGATIVE





CHAPTER 1

INTRODUCTION TO RADIO

SHIPS THAT PASSED IN THE NIGHT

Noah depended on a dove. And Columbus, not much further advanced after several thousand years, received his directional signals from a sea gull.

As late as 1898 navigators were still pretty much at sea, communications limited to eyesight, hearing and Lady Luck—a matter of beacons, telescopes, hails and flag-signals. Night and fog comprised a deadly communications menace. Vessels sailed blind, deaf, and dumb. In warfare an enemy's presence might be announced by an engraved invitation from a broadside—in a Sargasso of silence ships might disappear like the *Marie Celeste.* Over the horizon was out.

Today the sky's the limit. Morse, Hertz, Marconi made the boundaries of communication global. Overnight, time and space contracted on the air waves, the world was electrified by the magic word "wireless." Aviation, keeping pace, spanned the hemispheres. And in no aspect has science advanced so far in the past few years as in aircraft radio.

It was not so long ago when the first radio-equipped aircraft took off, precariously trailing a whiplash of antenna wire. As the one-way message came through, the pilot wearing the ear-phones could not repress an exuberant shout. AMERICA WAS THRILLED by the news that aviation radio was a success.

Today, the eyes and ears of the fleet, radio scouts the farthest battleline. Its importance in modern warfare is self-evident. Winging from the experimental stage, it has become the established guide of aviation, the very key on which the lives of pilot and crew depend. In all large Navy flying ships the two-way radio is carried, and smaller-type aircraft are equipped with radio receivers. Radio calls the play. Radio hears the signals. Quarterback and nerve-center of his aircraft, the aviation radioman is keyman, and a skilled aviation radio technician is to a plane what an expert mechanic is to a racing car—emergency player of the team.

It is possible for a beginner to operate present-day radio equipment without making a prolonged study of theory. Yet, perfected as the modern radio is, it remains a complex instrument, and its key importance makes it essential that the operator or technician have plenty of inside SAVVY. Reliable radio communication may be the thread on which an aircraft's life depends, and the hazard of a "squeeze play" in a dog-fight at 15,000 feet may depend on YOU.

CONTACT!

This chapter, like the country chicken arriving on Broadway, starts out from scratch. It assumes you are long on enthusiasm, if short on experience. Some of you may have done a little private experimenting. Tinkered around with crystal sets, or built your own transmitter. Well, if you ARE a "Ham," a little review will brush up your interesting past.

Others of you may have wanted to experiment, but lacked time, place and opportunity. For you this chapter is designed as a brief introduction to WHAT, WHICH and WHY—to give you the low-down on radio and acquaint you with its ways and means.

Your first concern is that fascinating phenomenon—the RADIO WAVE.

ABOUT WAVES

Water waves are TRANSVERSE (up and down). They can be measured by WAVE-LENGTH (distance from crest to crest, or trough to trough.) The path the wave travels in going one wave-length is called a CYCLE. The number of cycles in a given unit of time is called the FREQUENCY. The depth or height of the wave—in short, the size—is called the AMPLITUDE. And the amplitude depends on the force producing the wave.

Light waves and heat waves have somewhat similar characteristics, but travel at the fairly breathless speed of 186,000 miles per second. Sound waves are LONGITUDINAL, traveling at differing velocities through various mediums (approximately 1,090 feet per second through air at 32° F) and cannot travel, as can light and heat, through a vacuum.

Scientists ASSUME that the outer space between the earth and the sun is a vacuum. It is supposed, however, that light and heat waves emanating from the sun are carried by some medium, so Sir Isaac Newton and some others proposed to call this medium "ether."

This is not to be confused with inflammable cleaning fluid or tooth-pulling gas. Scientifically speaking, ether is the medium that transmits light and heat waves through a vacuum. Such waves, and other forms of radiant energy similarly transmitted, are known as ether waves. RADIO WAVES ARE FRONT AND CENTER IN THIS CLASS.

THE RADIO WAVE

When an electric current passes through a wire, it creates a magnetic field. This magnetic field is effective for only a very short distance.

IF, however, the circuit is opened and closed with great rapidity, say 20,000 times a second, a RADIO WAVE IS CREATED.

Say it another way. The cycle, through which a pulsating direct current or an alternating current surges, produces OSCILLATION. This oscillating current creates a disturbance in outer space—presto!—a radio wave.

The radio wave is also known as an ELECTROMAGNETIC WAVE. Like light, it can travel vast distances, and like its mysterious cousins the X-ray and the Gamma (radium) ray, it can penetrate nonmetallic objects.

The practical limits of radio waves vary in wave-length from about 10 miles down to 1/5 of an inch. Those used in ordinary broadcasting are approximately 200 to 600 meters. The length, frequency, and amplitude depend on the types of creative apparatus.

On leaving the transmitting antenna the wave travels out in all directions. That portion which is radiated skyward is called the SKY WAVE. And the portion which travels across the earth's surface is called the GROUND WAVE.

But just exactly what this radio wave IS—you'll have to leave the answer to future radiomen. Scientists today subscribe to several theories. One group believes that these rays are particles of energy shot out into space like infinitesimal bullets from a machine gun. The Quantum Theory holds that the flow of an alternating current through a conductor forces electrons in the "outer orbits" to take up positions in the "inner orbits." During this electronic free-for-all, bundles of energy called "quanta" are radiated into space. A third school of thought combines this theory with the earlier one. Take your pick. The EXACT nature of the radio wave is still unknown.

After all, radio waves travel at the speed of light—186,000 miles a second. If you were going that fast on a bicycle you'd go around the world 7½ times in an eye-wink. And scientists wouldn't know much about YOUR exact nature, either.

Sufficient marvel, then, that they've been able to capture this wave at all. Not to mention tame it, harness it, and drive it as a communication vehicle.

HOW IT WAS CAPTURED

Across the sea in England, at the time of our War of '61, a Scotch scientist named Maxwell was burning the midnight oil over an elaborate mathematical formula.

What would math have to do with a miracle of communication? Already the telegraph had been established. Dispatches traveled along the wires at amazing speed. And the world's eye was on America where blue and gray armies, grappling in fogs of gunsmoke, signalled with the ingenious heliograph and wigwagged messages from that novel innovation of a canny Northern general—the observation balloon.

James Clerk Maxwell, basing his computations on the formulae already devised by Faraday and other probers into the secrets of electricity, laid aside his pen one night with an exclamation.

While the news arrived (3 weeks late) of battles below the Potomac, a small group of scientists heard Maxwell prove by mathematics the POSSIBILITY of producing an electromagnetic wave.

HOW IT WAS HARNESSED

Edison had an idea that if a filament were placed in a glass bulb, the air evacuated from the bulb, and the filament heated by an electric current, he could produce a new kind of lamp. In 1883 America glowed at the invention of the electric light.

The bulb had one troublesome defect. For a time its light would be clear, then the inside of the glass would become smudged by a sooty deposit.

Tinkering over this problem, Edison inserted a metal plate as a ceiling above the filament. Just as a minor experiment, he connected an electric meter between the heated filament and one end of the plate. He was surprised to discover an electric current flowing through the circuit.

Edison could figure out no explanation for this phenomenon, but made note of it before turning to other research. But by lucky accident his experiment, now known as the "Edison effect," hit on the basic principle behind the radio tube—that a filament heated to incandescence in a vacuum bulb emits a stream of electrons which will leap the gap between the filament and a plate.

The discovery was bypassed by a world delighted with electric lamps and hoarse with awe at Bell's telephone.

Then in 1888 the German scientist, Hertz, transmitted the first radio wave to the first receiving set—ACROSS A ROOM! Scientists everywhere awoke to the possibilities of wireless, and by 1901 Marconi had flashed the first message across the Atlantic.

HOW IT WAS DRIVEN

Now go back to the electric telegraph, the first big step in modern communication. Invented by Samuel Morse in 1832, it operated on the principle of electromagnetism.

As you know, when electric current flows in the windings of an electromagnet, the electromagnet becomes magnetized. Stop the current, and the electromagnet is demagnetized. A small bar of iron placed near the electromagnet would be attracted or repelled as the current was switched on or off.

Morse invented a key to control the opening and closing of the circuit, and a "sounder" which was simply an electromagnet at the end of the line, with a spring-levered iron bar which responded with an audible click when attracted by magnetism to a tiny "anvil." He also invented a code, denoting the clicks as dots and dashes (dit=DAH) which could be translated into an alphabet. The line telegraph was established and messages traveled on electrical impulses, literally at the speed of light.

Hertz and Marconi were, then, thinking along these lines—or, rather, visioning a telegraph that operated WITHOUT lines. Morse, himself, had attempted the use of water as a conductor, ingeniously striving to send an electric current under water across a canal.

Hertz, with Maxwell's deductions to work on, foresaw air as the conductor of the electromagnetic wave, and oscillation as the source.

Before these waves could be used for communication purposes, however, four basic problems had to be solved. FIRST, a way must be devised to produce in a circuit the oscillations which created the electromagnetic waves. NEXT, some means must be found to launch the waves into space. THEN, a receiver, in which these waves would induce an electric current, must be constructed. FINALLY, means must be devised by which the current in the receiver could be detected by an electric instrument.

Hertz termed his apparatus for producing electromagnetic waves an "oscillator." It consisted of a pair of metallic plates attached to rods. Each rod was tipped with a metal knob, the two knobs held a fraction of an inch apart. These knobs were connected to the secondary of an induction coil. By completing the primary of the induction coil through a battery, a difference of potential was created between the knobs. Thus an electrostatic field, consisting of lines of force stretching between the two halves of the oscillator, was established.

When the secondary potential difference was further increased, the air between the knobs "broke down" and a spark jumped the gap. The whole oscillator then became inductive, the electric field changing over into a magnetic field, and oscillating currents of a very high frequency resulting.

You may recognize the action as identical to the discharge of a Leyden jar, save that with the passage of the spark, the lines of electric force are snapped off, causing the electric and magnetic fields to radiate outward. Each field traverses the other at right angles, in a direction which is at right angles to the path both are traveling. For illustration, hold up crossed thumbs and walk forward. Your thumbs represent electrostatic and electromagnetic fields, and your walk is their path of travel. Result of these phenomena: a radio wave.

The original "wave detector" or "resonator" consisted merely of a circle of wire severed at one point to create a microscopic air gap. When the resonator was placed in certain positions a few feet from the oscillator, with the latter in operation, minute sparks jumped the gap, thus indicating that electrical energy was being conveyed to the resonator from the oscillator.

Later Hertz constructed sending and receiving antenna. It remained for Marconi and others to perfect commercially practical receiving equipment, and the type of antenna exciter known as a "driver" by which a DAMPED WAVE (radio wave of decreasing amplitude) or a CONTINUOUS WAVE (radio wave of constant, unvarying amplitude) could be transmitted.

Then 40 years of experiment, research and refinements went into the ultramodern instruments in use today. But crude as were the early drivers and resonators, they embodied the essential characteristics of all modern transmitters and receivers. They were the forerunners of your world-wide broadcast—the glimmerings from which your streamlined superheterodyne and intricate naval aircraft radio equipment developed.

THE TRANSMITTER

As you know, a CYCLE is the path a wave travels in going one wave-length. The FREQUENCY is the number of cycles in a given unit of time.

To produce a radio wave, the frequency of the current in a transmitting circuit must be between 18,000 cycles (18 kcs.) and 60,000,000,000 cycles

(60,000 megacycles; abbreviated mcs.) a second. Currents at such frequencies are known as RADIO FREQUENCY CURRENTS.

Ordinary power-line current, usually 25 or 60 cycles per second, is obviously insufficient for radio transmission. Special high-frequency generators had to be developed. For radio-telegraph transmission, the spark, the arc, and the high-frequency alternator were employed.

The spark transmitter, sometimes referred to as a "damped-wave driver" is no longer used in commercial service. Increased efficiency and sending range were procured from undamped, continuous wave (CW) transmission.

Once the necessary frequencies were obtained,

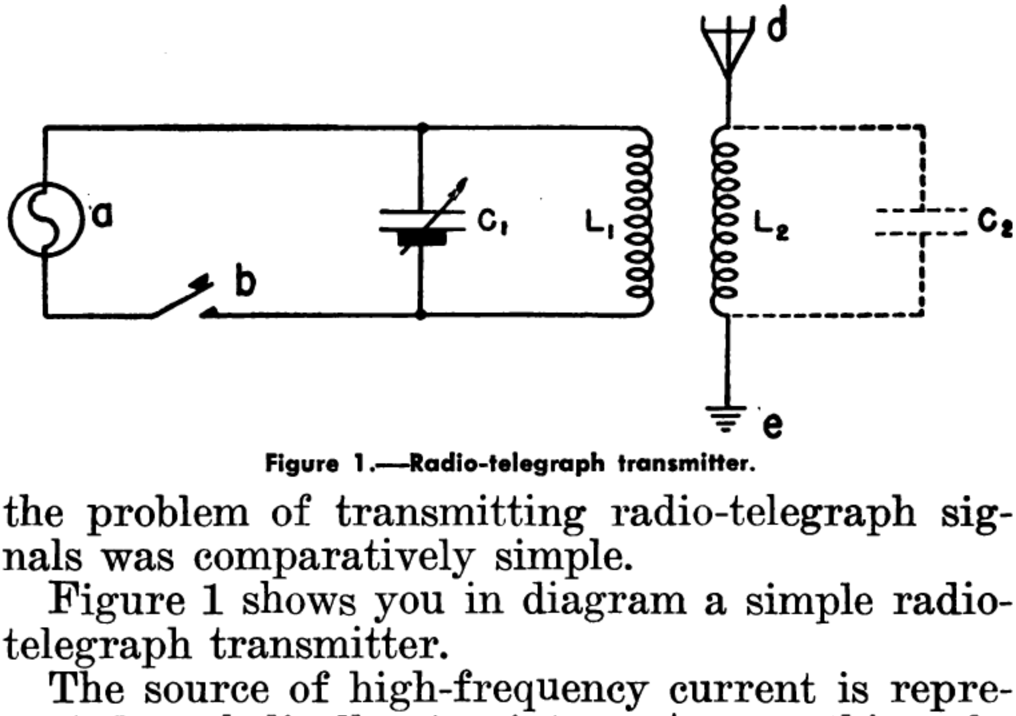


Figure 1.—Radio-telegraph transmitter.

the problem of transmitting radio-telegraph signals was comparatively simple.

Figure 1 shows you in diagram a simple radio-telegraph transmitter.

The source of high-frequency current is represented symbolically at point *a*. Assume this to be a high-frequency alternator.

The current is applied to a TUNED CIRCUIT consisting of a VARIABLE CONDENSER C_1 and an INDUCTANCE COIL L_1.

A telegraph key *b* is connected in one of the output leads of the high-frequency generator *a*.

Similar to the key employed in Morse's telegraph, it opens or closes the circuit, interrupting the current-flow in the circuit.

Near the inductance coil L_1 is another coil L_2 with one end connected to the antenna d and the other end connected to the GROUND e. As this end is generally in contact with the ground, or "grounded," the term is self-explanatory.

The antenna may consist of one or several wires strung horizontally aloft, connected to the inductance coil L_2 by a wire called a "lead in."

The antenna and ground may be considered the plates of a condenser with the air between them serving as the dielectric. This is indicated symbolically by the dotted line C_2.

Observe that the ANTENNA CIRCUIT L_2–C_2 is electrically the same as the TUNED CIRCUIT L_1–C_1.

When the key b closes the circuit, high-frequency current flows through L_1–C_1, and according to the laws of mutual inductance, there is a transfer of high-frequency energy from the coil L_1 to the antenna coil L_2. The high frequency current in the antenna circuit radiates electromagnetic waves into space. With the key closed there is a continuous radiation of electromagnetic waves. Break the L_1–C_1 circuit by opening the key, and the radiation stops.

You can see how code signals are transmitted, the keying similar to that employed in the line telegraph. Closing the key for a short interval transmits a "dot". A longer interval transmits a "dash."

Here you have your elementary transmitter.

THE RECEIVER

There are four essential parts to every radio receiver, no matter how complex its modern design—

First, the AERIAL GROUND SYSTEM which intercepts the transmitted waves.

Second, the TUNER, which selects the radio wave (or program) from the multitude of waves being broadcast.

Third, the REPRODUCER, which changes the energy of the electromagnetic wave to a form perceptible by your senses.

Fourth, the DETECTOR, which changes the energy of the electromagnetic wave into a form by which it operates the reproducer.

Of these, in brief summary, perhaps the detector will prove hardest to understand, therefore you'll examine it last. Theoretically, and in diagram, it comes BEFORE the reproducer.

You are probably already familiar with the ordinary household receiving aerial, once as common to city roof tops as tomcats. This simple antenna, sometimes a single strand of copper wire, was reared with one end aloft, the other end connected to a GROUND. The term "ground" refers to that part of a circuit which is connected to the earth or some metallic object such as a water pipe, or airplane fuselage.

Radio waves, striking this antenna wire, set up an ELECTRICAL PRESSURE which causes a small electrical current to flow up and down the wire.

A "lead in" connected this antenna to the tuning circuit of the receiving set. For the purpose of reducing the resistance in the aerial ground system, the connection was made through a transformer called an ANTENNA COUPLER which also served to increase or "step up" the voltage.

How about your new cabinet or portable radio where no such antenna wire is visible? Well, it's there, even if you can't see it. The aerial ground system, magnified in range if reduced in size, is somewhere inside the cabinet.

Now for the TUNING CIRCUIT.

But of course you know how you "tune in" on a program. Do you want to hear some throbbing soap opera, or will you take your comedy from Fred Allen? You merely turn a dial.

The dial turns the rotary plates of a VARIABLE CONDENSER. Hokum goes out and ha-ha's come in. If you hear a couple of dance bands blurred in the background, you growl and say the set TUNES BROADLY. If the program comes in without interference, you grin and say the set TUNES SHARPLY. In which case, both you and your set have good SELECTIVITY. Meantime, what happened in the tuning circuit?

The answer is concerned with RESONANCE.

You've seen the street-corner genius who plays "Stars and Stripes Forever" on a bunch of assorted drinking glasses. He taps the glasses with a pencil, and each glass gives a different tone. Why? Because the vibrating glasses set up sound waves of differing frequencies, which means that the glasses themselves are vibrating at different frequencies, depending on their size, shape, quality and thickness. The frequency at which a glass or other object vibrates when struck is called its NATURAL FREQUENCY.

Or take a piano tuner. (Maybe on some summer afternoon with a neighbor's window open you've wanted to take one as far away as possible.) Assume he's holding two tuning forks of the same frequency—say they correspond to middle *C* on the piano with a frequency of 256 vibrations per second.

He strikes one fork a ringing blow, then smothers it by stopping its vibrations abruptly. The *C* note remains faintly audible. The sound is coming from the second tuning fork which was set in vibratory motion by the sound waves

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emanating from the first. The second fork had the same natural frequency, and you say the two forks were in RESONANCE with each other. Had he struck an *F* fork or an *E*-flat, the *C* fork would not have responded.

The principle applies to RECEIVER TUNING, which means, simply, putting a receiver in resonance with a certain sending station. Nightly many stations are sending out waves of different frequency. Your tuner must select one of these and reject all the others.

You wish to hear station XYZ instead of ABC and DEF which are broadcasting simultaneously. All right, you adjust your tuner so that the natural frequency of your receiver is the same as that of XYZ's transmitter. Since ABC and DEF are not in resonance with your receiver, their transmitted radio waves are rejected.

The supermodern superhetrodyne employs a method to be examined later. The receiver under discussion is the elementary type such as the old fashioned "crystal set."

What determined the natural frequency of the receiver?

Two old friends—INDUCTANCE L and CAPACITANCE C.

You may think of induction as the electrical disturbance induced in a coil by an electromagnetic wave, and INDUCTANCE is the inherent property of a coil by which it stores up electrical energy. The unit of measurement is the HENRY h.

Capacitance refers to the ability or capacity of a condenser to store up electrical energy. Condensers are commonly referred to as capacitors. The unit of measurement is the FARAD fd.

Now consider the inductance coil of your simple tuning circuit as the secondary coil of the transformer which serves as the antenna coupler.

Its electrical value will depend on the length of the coil, the number of winding-turns, the coil's diameter, and whether it is "air core" or "iron core."

The inductance can be varied by changing any of these given factors.

For the purposes of tuning a receiver, however, it was found more practical to vary the electrical value of the condenser.

The variable condenser consists of sets of metal plates facing each other with a dielectric (such as air, mica, or paper) between. Since the electrical value of a condenser depends on the total area of the plates, the material of the dielectric and the distance of separation between the plates, the easiest method of variation is to change the total area of the plates.

Make one set of plates stationary and the other rotary. Attach the rotary plates to a moveable dial. Turn the dial. The rotary plates, moving in and out between the stationaries, alter the total plate area. Which is what occurred when you tuned out the opera and tuned in Mr. Allen. Technically speaking, you varied the capacitance of your condenser. And by so doing you put your receiver in resonance with the station broadcasting Mr. Allen.

You can think of a tuning circuit as an inductance coil (the secondary of an antenna coupler) connected to a variable condenser. Radio waves, intercepted by the aerial, set up electrical pressure (emf) in the aerial ground system. This causes oscillations (electrical current vibrating back and forth) in the tuning circuit.

The frequency of the incoming wave is determined by the product of the inductance and capacitance ($L \times C$) of the transmitter.

The natural frequency of your receiver is determined by the product of ITS L and C values ($L \times C$.)

When the $L \times C$ of your receiver is the same as the $L \times C$ of the transmitting station, your receiver is in resonance with the transmitter. Yes, by George! You get that station's program (or signal.)

Varying your L will do it, or varying your C will do it, or varying both, so long as the product of your L and C equals the $L \times C$ of the transmitter.

If you want to receive another station, you change your receiver's $L \times C$. As previously

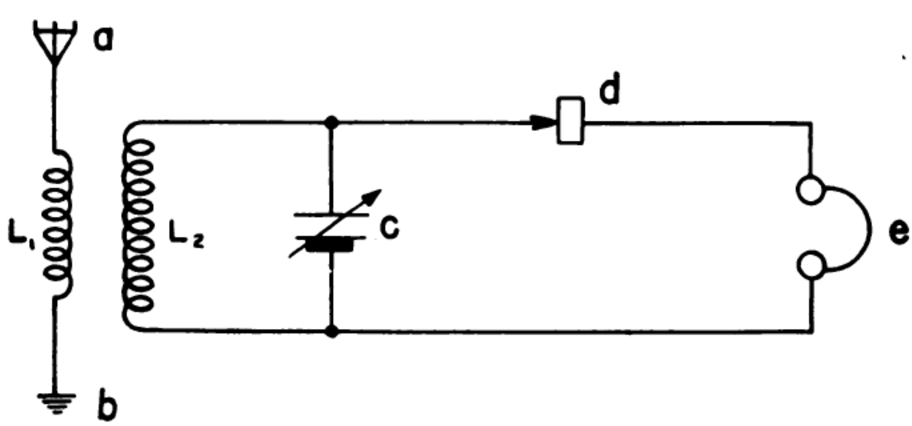


Figure 2.—Schematic diagram of simple receiver.

stated it is easier to "change your tune" by making the C variation.

Now take a glance at figure 2, a schematic diagram of a simple radio receiving set.

You recognize the aerial ground system *a–b*, the inductance coils of the antenna coupler (L_1 the primary, L_2 the secondary) and the variable condenser C.

Bypass *d* for the moment, and go on to headphones *e*. As you suspect you are gazing at the REPRODUCER.

Its function is simple—it changes the electric current to a form of energy which makes it audible.

The receiver of a household telephone is a reproducer. The loudspeaker of a radio is a reproducer. So are the headphones in figure 2, which are, in operation, similar to two telephone receivers clapped on your ears.

Your earphones are similar in construction to telephone receivers, the magnet inside flattened to circular or horseshoes shape for the sake of compactness. There are similar coils and diaphragm.

Sound waves striking the telephone transmitter cause a fluctuating current to flow in the circuit, said current fluctuating in step with the sound waves. This current, sent through the electromagnet coil of the receiver, causes the diaphragm to fluctuate in step. And this fluctuation of the diaphragm creates air waves which your ear hears as sound.

The same goes for your radio headphones (or loudspeaker, which is a sort of magnified earphone).

But wait a minute. There are some sound waves your ear can't hear. You say they are not audible. Audibility depends on their frequency.

Also there are some electric currents which can't operate your earphones. The current produced in your receiving circuit by waves of RADIO FREQUENCY is such a current. It is necessary to change this current to a type which can operate your reproducer.

And that is the function of the DETECTOR.

The detector, at first acquaintance, may seem a tough customer. Actually it's not as complicated as it seems. If you know your electricity, you know that an electric current does not actually flow like water, but consists of the movement of energized, negatively charged particles called ELECTRONS.

There is DIRECT CURRENT (d. c.) in which the electrons maintain an even flow in one direction.

There is PULSATING direct current—a direct current which flows with pulsations, now strong, now weak.

There is ALTERNATING CURRENT (a. c.) in which the electrons flow now forward, now back, periodically reversing their direction.

There are also many types of alternating current—for instance, the RADIO-FREQUENCY (r-f) alternating current which reverses its direction of flow thousands, even millions of times a second.

You don't have to scratch your head to figure out what the r-f current would do to the diaphragm of your earphones. For $\frac{1}{1,000,000}$ of a second the diaphragm would strain in one direction. For $\frac{1}{1,000,000}$ of a second, the diaphragm would strain in another. After half a second of such quick-change, the diaphragm would stall, and your earphone would be cauliflowered. Currents of radio frequency are altogether too fast on the punch for your actual or artificial ear drums.

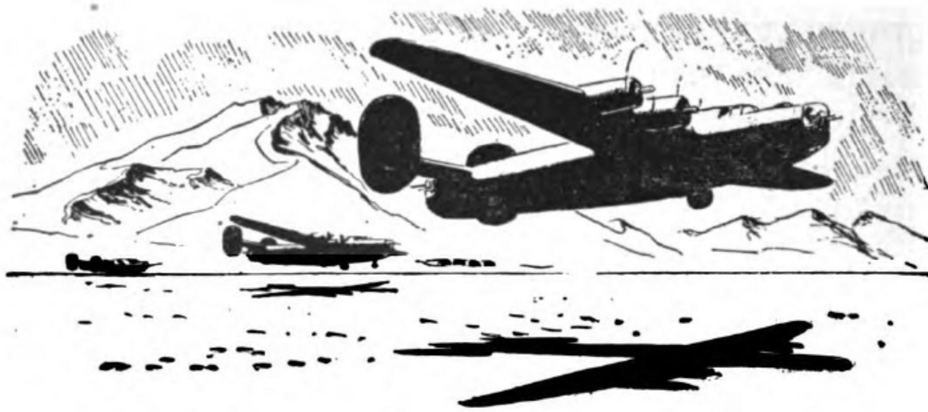
There are ways, however, of changing current from one type to another. A simple way is to conduct the current through a certain kind of mineral, for instance GALENA.

Imagine the detector under discussion as a device employing galena crystals. You don't have to go into the why of it. The CRYSTAL DETECTOR acts as a gate, or you might say a sieve, through which r-f currents are refined to an AUDIO FREQUENCY which can operate the reproducer. Alternating current going through the detector is changed to pulsating direct current by the one-way action of the crystal. Such direct current can be handled by the diaphragms of your headphones, and you hear sound.

You say the radio frequency current has been RECTIFIED by the detector.

Crystal detectors have their bad features, however. They are sensitive and easily put out of adjustment. You have to do a lot of fiddling with a delicate wire called a "catwhisker" to find the point of sensitivity at which they operate.

Today, the old-fashined crystal set is on its way to the museum. And all because of the scientific marvel known as the VACUUM TUBE.



CHAPTER 2

VACUUM TUBE

ELECTRONS

Before you go into the invention that revolutionized radio, go back to one of the inventors of the American Revolution, Benjamin Franklin. Ben was the all-American idea man of his day. He invented bifocal spectacles, the smokeless furnace, a washing machine, the lightning rod, an electric detonator for explosives and a score of handy gadgets. He also set up the United States Weather bureau, proposed daylight saving, improved the postal service, wrote popular songs, learned to play the harp and became a champion swimmer, as well as Minister to France. On the side, he managed to get around town a good deal, and on top of that he found time to go fly his kite. Apparently the ONLY reason he didn't invent the VACUUM TUBE was because the scientists of his day didn't know about ELECTRONS.

Franklin and his colleagues thought of electricity as some invisible force which flowed like liquid through a conductor. They thought this fluid electricty flowed from POSITIVE (+) to NEGATIVE (−) like water seeking its own level.

Later scientists revised this idea, favoring a newer concept—THE ELECTRON THEORY.

Scientists, before establishing something as a fact, demand one thing—PROOF! They do not base a conclusion on tradition or legend or hearsay. Exploring a subject, they gather all the EVIDENCE they can obtain. They make experiments to obtain more evidence, and eventually draw a conclusion they call a HYPOTHESIS.

This hypothesis is open for revision. New evidence may be turned up. Other facts may be discovered. Finally, when the revised hypothesis is widely accepted, yet still not absolutely proved, the scientists agree to it as a THEORY.

When the THEORY is PROVED beyond the last element of doubt, it is established as a LAW.

The ELECTRON THEORY, as an explanation for electricity, has not yet reached the law stage. All the evidence is not in. But it SEEMS to be provable. There is little doubt left, and it provides a working basis for the scientific development of RADIO. In effect, it works, and the proof of any pudding is in the eating.

Ben Franklin, flying his kite, was merely gathering EVIDENCE, and he would have been the first to admit that his concept of fluid electricity was an unproved HYPOTHESIS. It was a long way out in front of the ancient idea that lightning was caused by some angry god banging on the clouds with a blacksmith's hammer. But it was somewhat behind your modern conception of electricity as "energy" created by minute particles of the ATOM set in motion.

THE NEGATIVE ELECTRON

According to the ELECTRON THEORY, one type of these atomic particles has a POSITIVE charge, and is called a PROTON. The other type has a NEGATIVE charge, and is called an ELECTRON.

When you're cutting up an ATOM you're "slicing it pretty thin," but the point to remember is that the ELECTRON HAS A NEGATIVE CHARGE.

The next point to be remembered is that electrons, given a path to travel, ALWAYS MOVE FROM A POINT OF EXCESS TO A PLACE WHERE THERE IS A DEFICIENCY. Pile up a lot of them at one point, and open the way to a point where they are fewer, and the rush is on.

This rush from the point of "many" to the point of "few" concerns the action of electrons, and is not to be confused with "electric current," formerly thought of as some invisible fluid forced by pressure through, or along, a conductor. Electrons do not flow like water through a pipe.

What moves the electrons, then? Well, the force that moves them from one point to another through, or along, a conductor, you call ELECTROMOTIVE FORCE (emf). As you know, the unit of measurement for this force is the VOLT, defined as the emf which produces a current of 1 AMPERE when applied to a resistance of 1 OHM. ELECTROMOTIVE FORCE you may have thought of as PRESSURE. Actually, it is a matter of "many" at one terminal and "less" at the other; in other words, a DIFFERENCE IN PRESSURE—what you technically call the DIFFERENCE IN POTENTIAL.

To clean up the subject of POTENTIAL DIFFERENCE, water still serves as a handy illustration.

Suppose you had twin wells connected by a conduit. The wells are on the same level, and the conduit is controlled by a centrally located stopcock. Your right-hand well is three-fourths full of water. Your left-hand well is only quarter full.

Now you open the stopcock in the conduit.

What happens? Water from the right-hand well rushes through the pipe into the left-hand well, until both wells are HALF full, the water standing on an even level. This water was not pumped. It was moved by a DIFFERENCE IN PRESSURE which existed between the right well and the left well until the water level evened up. Note that there was PRESSURE in both wells but the water was moved by the DIFFERENCE IN PRESSURE.

Note also that the water in the right-hand well, before the conduit was opened, represented a POTENTIAL source of pressure (or energy) and what moved the water, technically speaking, was a DIFFERENCE IN POTENTIAL between the two wells.

Now reduce the illustration to microscopic size. See the wells as two terminals, the conduit as a wire, and the water as ELECTRONS. It is a difference in potential, or POTENTIAL DIFFERENCE between the two points which moves the ELECTRONS.

Then what about the VOLT, that amount of emf necessary to move a current of 1 AMPERE through a resistance of one OHM. All right, suppose the conduit connecting your two water-wells was clogged with refuse. Only a little water might leak slowly through, and if the stoppage was great enough the flow might be prevented entirely. If the refuse was porous, the water would seep through, but it would take a GREATER difference in potential to force the flow and speed it up.

Now consider the refuse in the pipe as similar to RESISTANCE in an electrical conductor. All electrical conductors constitute a RESISTANCE TO ELECTRON FLOW. Some, however, are less resistant than others; metal is an excellent conductor (silver, and copper, particularly) and the term, "conductor" applies to the less-resistant substances specifically. Other substances, such as rubber, glass and mica offer very large resistances, and you name them NON-CONDUCTORS. In conductor and nonconductor, then, the RESISTANCE depends on the substance used, and, for example, in the instance of a wire, the size, shape, quality, and length of the wire constitute the resistance. And for an electric current to force its way through these resistances, a GREATER DIFFERENCE IN POTENTIAL is required in ratio to the resistance offered.

High resistances such as those offered by mica or rubber require a very high potential difference before an electric current may pass. The high resistance offered by air may stop current-flow, and then an increasing potential difference may bridge the gap, a phenomenon visible in the leap of a spark across a gap in a wire.

So you conclude that AN ELECTRIC CURRENT FLOWS WHEN THERE IS A POTENTIAL DIFFERENCE AT TWO POINTS OF A CONDUCTOR, AND WHEN THAT POTENTIAL DIFFERENCE IS GREAT ENOUGH TO OVERCOME THE RESISTANCE OFFERED.

In other words, current depends on ELECTROMOTIVE FORCE and is limited by RESISTANCE. The greater the emf (potential difference) the larger the quantity of flow per second. The greater the resistance, the smaller the quantity of flow per second.

When you think of an ELECTRIC CURRENT, then, you think of ELECTRONS IN MOTION, moved by enough emf to overcome resistance.

Now for the $184 question.

IN WHAT DIRECTION DOES THE CURRENT FLOW?

Bingo! There's one that's kept the electrical Quiz Kids getting their wires crossed for some years. Franklin started it by proposing the idea that current flowed from positive to negative, and designating these points as plus and minus respectively. The battery boys came along and marked their batteries in that fashion, and the electricians worked on the same hypothesis. The trouble is, they forgot it was just a hypothesis. Then science discovered the atom and developed the ELECTRON THEORY. Then somebody forgot to change the markings on the batteries.

That last isn't strictly true, of course. Actually it was thought easier to leave the battery markings as they were—changing the plus and minus signs on a couple of million expensive batteries, and altering all the electrical textbooks was too extravagant for the old days. So the old markings and designations remain in use today, but you consider an "electric current" and "electron flow" as traveling in the same direction. What direction? But figure it out for yourself.

A point where the negatively-charged electrons pile up, or are in excess, has a NEGATIVE (−) charge. And the point toward which they rush is thought of as (+) or POSITIVE. So the movement of electrons is from NEGATIVE to POSITIVE, just the reverse of Ben Franklin's concept of fluid electricity.

Now that you've got that straight, you can define an ELECTRICAL CIRCUIT as the path (or paths) followed by electrons traveling from a source of HIGH POTENTIAL (a negative point) to a source of LOW POTENTIAL (a positive point). In a SERIES CIRCUIT, incidentally, the electrons can follow only ONE path. In a PARALLEL CIRCUIT the electrons can follow TWO OR MORE paths simultaneously.

Another thing you may recall about electrons—UNLIKE FORCES ATTRACT (boy meets girl) AND LIKE FORCES REPEL.

Electrons, being like, REPEL each other. So while electrons are attracted to a point with a POSITIVE charge, like a stag line swarming toward a pretty maid, they will be repelled from a point with a

NEGATIVE charge, like late-comers getting the bum's rush.

You might picture a VACUUM TUBE, then, as a bright and bustling Stage Door Canteen, with a crowd of "negative electrons" swarming from an overcrowded, negatively charged entry at one end toward a "negatively deficient, positive pin-up girl" at the other. More and more negative electrons keep coming in. A crowd of electrons is milling around the entry in what is technically called a SPACE CHARGE. They jostle the late-comers and shove them back. But as others spy the main attraction, they break through the space charge and rush over, pell-mell.

Meantime, you get the big idea—they go from NEGATIVE TO POSITIVE.

And, it was the discovery of this electronic phenomenon that resulted in the invention of the VACUUM TUBE.

FLEMING VALVE

If you hear a British radioman talking about "valves," you will know he's referring to his radio tubes. The term goes back to Ambrose Fleming, the Englishman who invented the vacuum tube.

Fleming had his cue from the "Edison effect." When Edison inserted a metal plate over the incandescent filament in his bulb, he was surprised to notice a current flowing in the circuit between plate and filament, you will recall. That was in 1883. In 1904, Fleming recalled it.

The electron theory was by that time known, and Fleming realized that a heated filament emitted electrons, and that these electrons, leaping from hot filament to cold plate, had established the current in Edison's bulb.

The metal plate had a "deficiency" which attracted the electrons from the filament. What would happen if a GREATER DEFICIENCY were created by placing a STRONGER POSITIVE CHARGE on the plate? Fleming put a battery in the circuit from plate to filament, connecting the + pole of the battery to the plate. Apart from the plate circuit he connected another battery to heat the filament. Now a meter in the plate circuit registered a much greater electron flow.

He tried plate batteries of higher voltage. The more powerful the battery, the greater the positive charge on the plate, the more electrons were thus attracted from the filament, and the greater the registered current-flow.

Then Fleming replaced the battery with an alternating-current generator. The experiment showed an astounding result. The current flowing through the meter was PULSATING direct current, NOT alternating-current.

Fleming saw the answer. During the positive half of the alternating-current cycle, the plate received a positive charge and attracted electrons from the filament. During the negative half of the cycle, the plate was charged negatively and the electrons were repelled, at which moment the current ceased. Thus, only a pulsating direct current could flow in the plate circuit.

And Fleming saw something else. Can you see what it was? Think back. Remember the need of changing a current of radio frequency to a current which can operate your reproducer? The crystal detector? RIGHT! It changed alternating current to pulsating direct current in just such fashion. Now, how about substituting this new and handy device for the awkward and fiddlesome crystal detector?

Instead of an alternating-current generator, connect up a radio tuning circuit. Replace the meter with a pair of earphones. And the VACUUM TUBE becomes a DETECTOR!

Fleming called his vacuum tube detector a valve. Technically, because it has two electrodes (the filament and plate) you'll call it a "two-element" tube, or a DIODE. The filament you will call the CATHODE, and the plate the ANODE.

Employed as a detector, Fleming's vacuum tube was the original granddaddy of scores of radio tubes designed in scores of ways for as many purposes. For it developed into a rectifier, an amplifier, and an oscillator. Modern sound transmission, the national hook-up, the overseas broadcast would be impossible without it. Communication boundaries were shortened to speaking-distance by it. China came within earshot of Chillicothe.

THE DIODE IN ACTION

As first employed, then, the diode was used as a detector to convert radio-frequency oscillations into a form whereby they could operate a reproducer. In this capacity, the tube served as a RECTIFIER—a device for changing alternating current into pulsating direct current.

The simple diode consists of an evacuated glass (or metal) bulb, in shape not unlike its forebear, the electric light bulb. It contains a filament, generally of tungsten, surrounded by a thin sheath of metal which serves as plate.

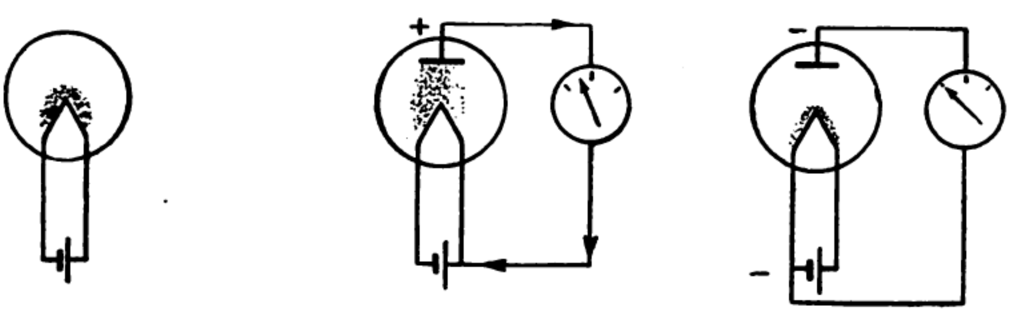
Figure 3 (*A*) shows in diagram what happens when the filament is heated to incandescence. Heat increases the atomic activity of the filament, and you see represented the SPACE CHARGE, that cloud of electrons which, swarming around the filament, repels newcomers being emitted.

Figure 3 (*B*) illustrates the electronic rush to the positively charged plate. You see a battery in the circuit from the plate to the filament, the plate connected to the positive terminal of the filament. This gives the plate a positive charge.

An ammeter indicates the current-flow. As illustrated by the arrows, it flows from filament terminal to plate, across the space in the tube, and around back to the filament. You call the current which passes between the hot cathode and the plate, the PLATE CURRENT.

Observe that the electrons are traveling in the SAME direction. From the filament they rush across the vacuum to the plate, and on back around to the filament.

Now reverse the battery connections as in figure 3 (*C*). Here the plate is connected to the neg-



(A) (B) (C)

Figure 3.—Plate current in a diode.

ative terminal of the filament. Glance at the meter. No current-flow!

Why? The plate is now NEGATIVELY CHARGED, which means there is no "deficiency" of electrons to attract more negative electrons from the heated filament. In fact, the plate REPELLED them, or, you might say, had no room for them. Like repelling like, the electrons call the whole thing off. Therefore no current in your meter.

In practical operation, the diode needs two sources of current supply—a low voltage to heat the filament cathode, and a higher voltage in the plate circuit to draw the electrons to the plate. If batteries are used as current sources, the low voltage filament supply is called the A BATTERY, and the plate supply is called the B BATTERY.

There is a limit, of course, to the amount of current obtainable in a diode tube. As you increase the positive charge on the plate, the PLATE CURRENT increases, and more electrons are drawn from the filament. Figure 4 illustrates the effect of plate voltage on plate current.

In the graph, view *B*, you see the increase in plate current I_p which results from an increase in

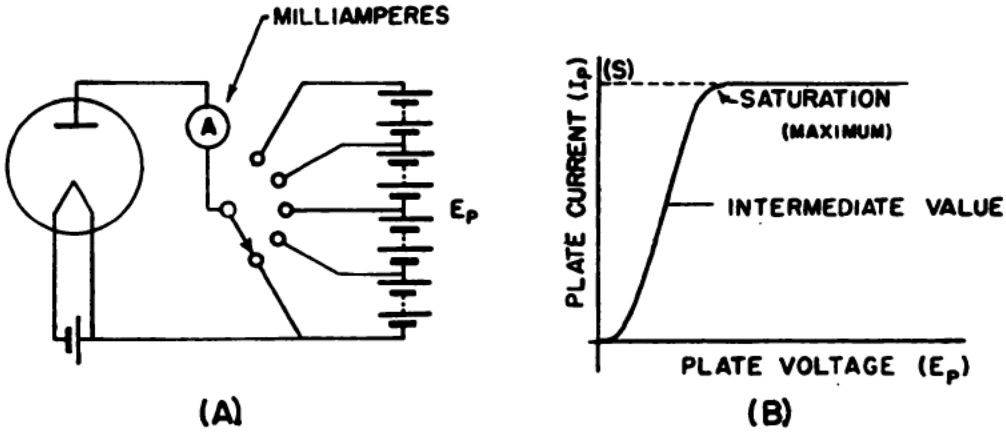


Figure 4.—Effect of plate voltage on plate current.

plate voltage E_p. Note that plate current cannot be increased above a certain value *s* which represents the condition of SATURATION.

The number of electrons emitted by the filament is limited by the filament voltage, which cannot be increased above a specified point without burning out the tube. Eventually (the filament temperature remaining safely fixed) the cathode maintains a constant electron emission. When the plate potential is made high enough to attract all these electrons as rapidly as they are emitted, the condition of saturation is reached. A higher positive charge on the plate is without effect, and the plate current is thereby restricted.

Incidentally, the curve in the illustrative graph is known as the CHARACTERISTIC CURVE of the diode. Other tubes have their own characteristic curves. (Any line you establish through a series of points on a graph is known as a curve, even though it may be a straight line.) Note, too, the little symbol for the diode.

SYMBOLS

Before going on to more vacuum tubes, glance over the table of symbols on page IV. You'll refer to these as you study the schematic diagrams which employ them, and as they are easy to recognize, you will soon learn to identify them.

Also you'll find it worth while, as you go along, to familiarize yourself with the abbreviations, subletters and Greek characters which are used in electronics and radio as a handy shorthand.

If you have the time and a bit of scratch paper around, you might copy the diagrams as you come to them—a quick sketch to print the idea in your memory.

TRIODE

Lee De Forest was an American pioneer in radio who, like Benjamin Franklin, enjoyed using his head. Inventors are never content with what is called the STATUS QUO. They aren't so easily satisfied, and they operate on the challenging principle that there is always "room for improvement."

De Forest was not convinced that the Fleming valve was the last word in vacuum tubes. As a detector it was weak, and the plate current was limited. De Forest wanted to use the B battery to amplify the signal in the headphones, substituting the latter for the meter in the plate circuit.

But the current in the phones must be d. c. and fluctuate in step with the fluctuations of the incoming current of radio frequency. And the small charges on the plate (of alternating current from the tuning circuit) were blotted out by the larger positive charge placed on the same plate by the B battery.

Unable to utilize the diode's B battery to get a louder signal in the reproducer, De Forest experimented with the tube.

The plate current, he reasoned, is limited by the electron flow from filament to plate. What if another electrode were inserted between these two? If placed closer to the filament than the plate, this electrode would have a greater effect on the electron stream than would the plate. A small positive charge on this new electrode would attract electrons just as would a larger charge on the plate. And a small negative charge would repel electrons so that none would go to the plate, there would be a stoppage of plate current, and no current-flow in the plate circuit. In other words, CURRENT-FLOW IN THE PLATE CIRCUIT could be CONTROLLED by small charges on the new electrode.

Theoretically, this should have worked, but it was found that the small positive charge in the new electrode proved so strong that all the electrons were side-tracked and none could reach the plate.

Here's where the head-work came in. De Forest devised an electrode of FINE WIRE MESH which would allow most of the electrons emitted by the filament to pass through to the positive plate. A small positive charge on this electrode would divert some of the electrons, while its added attraction quickened the general rush to the plate, thus increasing plate current. As for a small negative charge, some of the electrons from the filament would be repelled, and only a few would get through the mesh to the plate. Thus current in the plate circuit would be decreased.

If a NEGATIVE CHARGE on the electrode continued to INCREASE, eventually it would REPEL all the electrons from the filament, and PLATE CURRENT would STOP. And conversely, an increasing POSITIVE CHARGE on the electrode, adding its "pull" to the plate's, would ACCELERATE the electron flow and plate current would INCREASE accordingly.

Then the new electrode, connected to the output of a radio tuning circuit and fed by the fluctuating current from the tuner, would control the strong plate current of the tube and make it FLUCTUATE IN STEP. The headphones could now be connected into the plate circuit in series with the B battery, and the signal would be much louder.

De Forest called the new electrode of wire mesh a GRID.

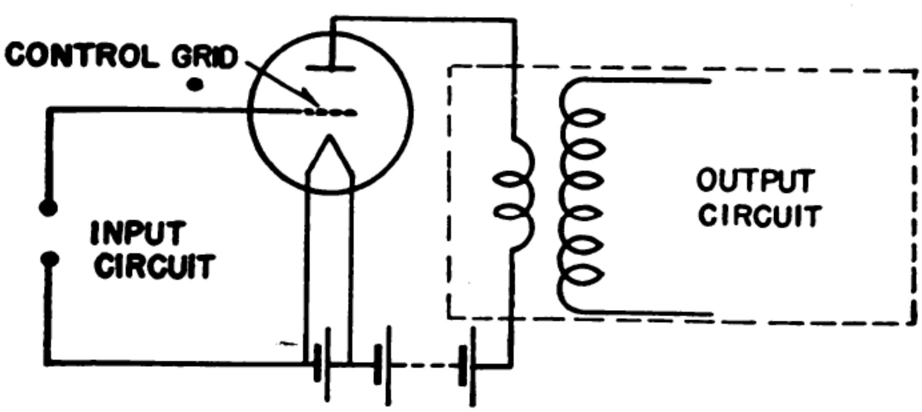


Figure 5.—The triode.

Because the tube now has three electrodes you call it a TRIODE.

You can see the triode illustrated in figure 5.

As illustrated in the diagram, the triode acts as detector and rectifier, just as the diode, changing alternating currents of radio frequency into pulsating d. c. which can operate the reproducer. Also the tube has a new virtue—it permits the amplitude of the signal to be increased.

GRID

As the vacuum tube revolutionized radio, the invention of the grid revolutionized vacuum tubes.

So you'll want to go a little further into the grid and its workings.

First of all you'll want to understand your circuits. The connection formed by the grid and filament you'll call your INPUT CIRCUIT, and the plate will be your OUTPUT CIRCUIT.

Your triode now includes the FILAMENT CIRCUIT (A battery and filament) and the GRID CIRCUIT. The grid circuit of a vacuum tube is the circuit in which that grid is connected. As diagrammed in figure 5, the grid circuit consists of the filament, the electron-stream to the grid, the grid itself, the tuning circuit and the conductor back to the filament.

It was found, however, that the circuit as shown in figure 5 was imperfect for radio detection. In the diode tube, the negative half of the alternating current cycle was eliminated at the moment the plate went negative and plate current was cut off. The resultant pulsating direct current fluctuated in step with the radio frequency current from the tuner, and the signal was accurately reproduced.

But in the triode, connected as in the diagram, the ELECTRON FLOW from filament to positive plate CONTINUES through the mesh, DESPITE a small negative charge on the grid. This allows plate current to flow through the reproducer during the negative half of the alternating current cycle. In effect the alternating current is not completely rectified, and the result is signal distortion.

To overcome this flaw, a CONSTANT NEGATIVE CHARGE was placed on the grid by a low-voltage battery. This charge was too small to repel the electrons from the filament. During the positive half of the alternating current cycle from the tuner, this charge on the grid was further reduced, and more electrons reached the plates. During ıe negative half of the cycle, the charge on the rid became strengthened enough to stop electron ow, which, of course, stopped plate current. By ıis means, the alternating current was fully recified.

The negative charge of GRID VOLTAGE creates what is called GRID BIAS. The battery (connected s in figure 5) its negative post hooked up to the grid, you'll call the C BATTERY.

Now for a closer look at the grid.

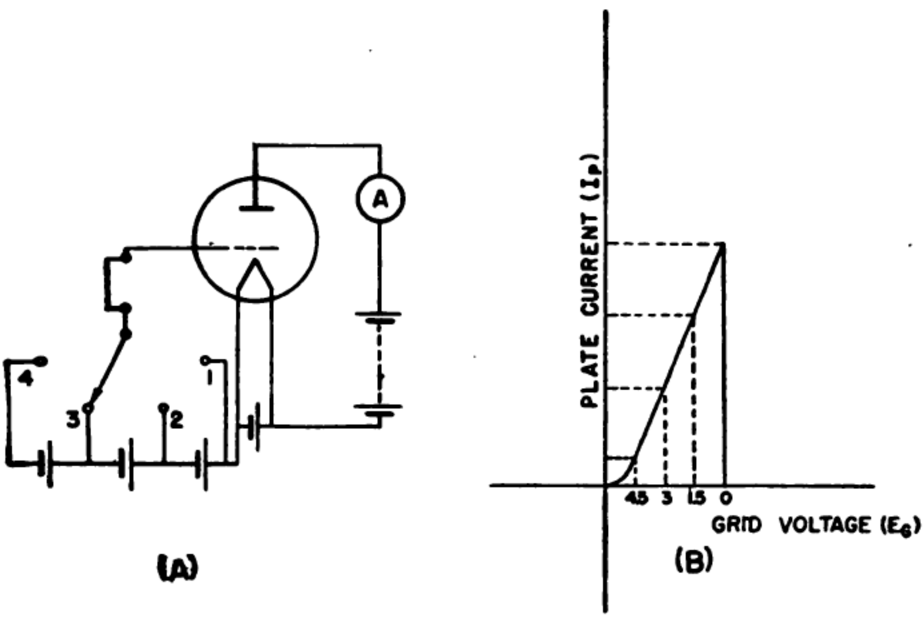


Figure 6.—Effect of negative grid voltage on plate current.

GRID VOLTAGE

Consider figure 6. In 6 *A* you have the C Battery connected in the grid circuit with a switching device that makes it possible to vary the voltage on the grid. A milliammeter is connected in the plate circuit to measure the plate current.

Assume the PLATE VOLTAGE is fixed at 45 volts. If the selector switch is on position 1, the voltage in the grid circuit is zero, but a definite amount of plate current exists.

With the selector on 2, the grid is 1.5 volts negative with respect to the filament. This decreases the plate current to a lower value, which goes still lower if the selector is placed on 3.

On the last position the grid is 4.5 volts negative, which, in certain tubes, would reduce the plate current to zero.

Deduction? A plate current, produced by 45 volts in the plate circuit, can be eliminated by a grid potential of only 4.5 volts. ANY GRID VOLTAGE AFFECTS THE STRENGTH OF THE PLATE CURRENT,

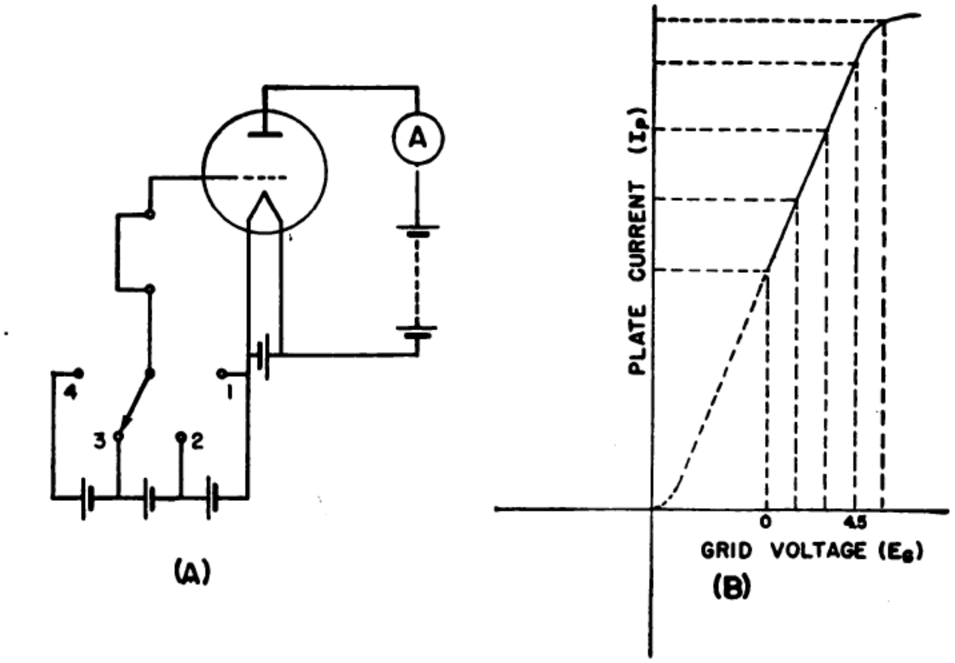


Figure 7.—Plate current characteristic.

AND A DEFINITE AMOUNT OF PLATE CURRENT IS OBTAINED FOR EACH VALUE OF GRID VOLTAGE.

Plot your findings on a graph, and you have a curve as shown in figure 6 *B*. The CHARACTERISTIC CURVE—remember?—that shows the relation between two variables in a vacuum tube when one variable undergoes numerous changes.

What happens to the characteristics of this curve when a positive charge is applied to the grid? Look at figure 7.

As you know, a positive charge on the grid speeds up the flow of electrons from filament to plate.

With the selector at 1, the grid voltage is zero. The selector at 2, the grid becomes 1.5 volts positive with respect to the filament. And the plate current is increasing as the "pull" of the grid is now added to the "pull" of the plate, and more electrons are streaming through the grid-mesh to the plate.

So the PLATE CURRENT INCREASES as the GRID VOLTAGE is POSITIVELY INCREASED. Plot the positive values on your graph, and you have a characteristic curve similar to the one in figure 7*B*.

The curve shows that a small change in grid voltage can affect the plate current when the change is in a positive direction as decidedly as when the change is in a negative direction.

SUMMARY—IF THE GRID VOLTAGE CHANGES IN A POSITIVE DIRECTION THE PLATE CURRENT INCREASES. IF THE GRID VOLTAGE CHANGES IN A NEGATIVE DIRECTION THE PLATE CURRENT DECREASES.

You see how small charges on the grid affect plate current in a triode.

VACUUM TUBE AS AN AMPLIFIER

So far you have considered the vacuum tube as a DETECTOR and a RECTIFIER. You have seen how the DIODE replaced the troublesome crystal detector. And how the TRIODE with its CONTROL GRID improved on the diode by loudening the signal and increasing your set's SENSITIVITY (the ability of a radio receiver to pick up radio waves of low strength).

With the triode on the market, radio engineers now concentrated on the problem of sensitivity, spurred by further demands for DX (long-distance) reception.

One answer was the REGENERATIVE DETECTOR or "feedback circuit" devised by an American, Major Armstrong.

Current from the plate circuit is fed back to the tuning circuit through a coil of wire, which is placed in close proximity to the secondary of the antenna coupler. You call this INDUCTIVE COUPLING, and the coil a PLATE COIL, or TICKLER COIL.

This arrangement of three coils—primary and secondary of the antenna coupler, and the tickler—is referred to as a "three-circuit" tuner. When plate current flows through the tickler coil, a magnetic field is formed around this coil. The field cuts across the turns of the antenna coupler's secondary. An electron stream is set flowing in the tuning circuit. In other words, current from the plate circuit has been reintroduced or "fed back" into the tuner, the fluctuating direct current flowing through the tickler coil creating alternating current in the antenna coupler's secondary which fluctuates in step. In turn, this oscillation is in step with the incoming radio wave. The signal is accordingly reinforced and loudened.

But here a new problem presents itself. The regenerative system, by overcoming the resistance in the tuning circuit, tends to overdo this oscillatory build-up. A strong RADIO WAVE is created, and the receiver, itself, acts as a transmitter. This causes howling and whistling in your reproducer, and you say your set OSCILLATES or "spills over."

The problem of oscillation you'll take up later. In the case of the regenerative detector, it was overcome by connecting a variable condenser between tickler and ground, by using a fixed condenser in combination with a rheostat, and by other means.

Sensitivity was improved, but a better device was at hand. Experimenting with the vacuum tube, the engineers hit on a new idea. Reason it out as they did.

Plate current in a triode fluctuates in step with the r-f current fed into the grid. Small charges on the grid cause large increases in plate current. Meantime the fluctuations keep their proper proportions. So why not feed the plate current of a detector tube into the grid of a SECOND tube? The plate current in the second tube will obviously be an AMPLIFIED reproduction of that from the first. Then why not feed the plate current from the second tube to the grid of a third, and repeat the amplifying process. Why not connect up a fourth tube—or for that matter, a dozen? Each tube will strengthen the current from the one before, and by the time it reaches the reproducer the signal will be obviously amplified.

This is an oversimplification of the problem, for other factors step in. Too much amplification causes distortion. The powerful B battery of the detector's plate circuit may blot out the fluctuations of plate current fed to another tube. Grid current must be considered.

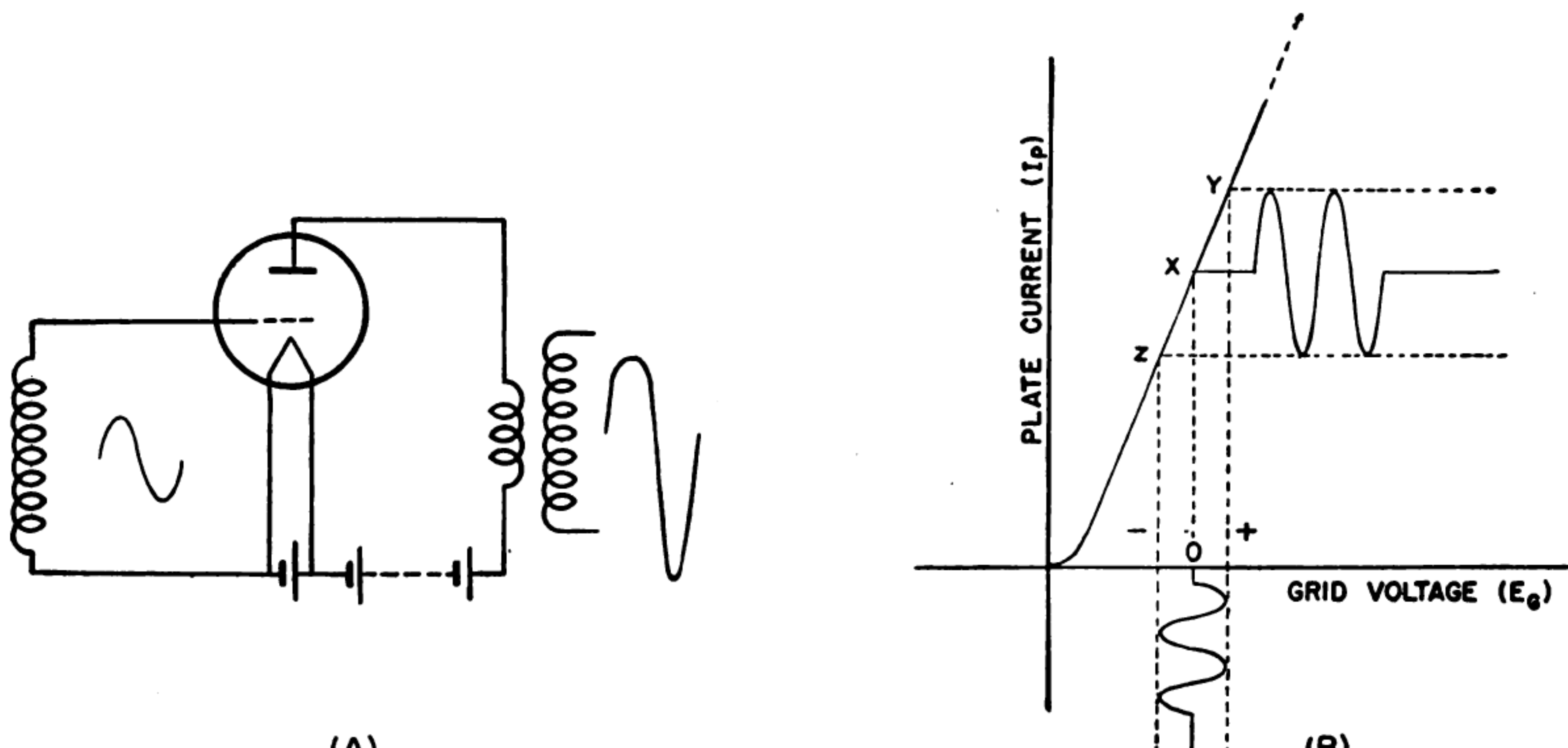
How were these wrinkles ironed out?

VOLTAGE AMPLIFICATION

Look at figure 8*A*. Here you have diagrammed a simple voltage amplifier circuit.

The little, gliding line in the center of the INPUT CIRCUIT, and the line like a neatly bent hairpin tagging the transformer symbol are not mere decorations. Nor are they disconnected connections of the WIRING DIAGRAM of the circuit. They are curves which indicate the WAVE FORM of the alternating current you assume flows in the circuit.

Suppose an imaginary horizontal line is drawn through the middle of such a curve. You think of this as the "line of no current flow." The upper half of the curve you think of as POSITIVE.



(A) (B)

Figure 8.—Voltage amplifier circuit.

The lower half is NEGATIVE. The curve represents one alternating current CYCLE.

Curves whose amplitudes rise and fall in such smooth, sinuous, regular glides are known as SINE CURVES.

Radio waves may be pictured in several other forms, with differing curves. The DAMPED WAVE with decreasing amplitudes, and the MODULATED CARRIER WAVE (MCW) with irregular amplitudes, are typical.

As pictured in figure 8*A*, the SINE CURVES illustrate the wave form of the alternating current fed into the triode, and the resultant wave form as the current is amplified by means of a transformer. You see that the little sine curve has become a bigger sine curve. The amplitudes, or you might say "rise and fall", of the wave have been increased, and the signal has been intensified.

How about the schematic diagram? It represents a simple vacuum tube circuit with an alternating current high potential of one volt on the input circuit. The input circuit is connected directly to the grid and filament of the tube. The primary of a transformer is connected into the plate circuit.

Observe the effect of the voltage on the plate current in the tube.

Whenever the grid voltage is zero, the plate current has a value represented by point *X* on the curve. As the alternating current voltage in the grid circuit increases in a positive direction, the plate current also increases. When the positive cycle of alternating current grid voltage is highest, the plate current rises to the value shown at *Y*. As the alternating current grid voltage drops to zero, the plate current falls to the original value *X*. On the negative half of the cycle, the plate current falls to Z and rises to X when the grid-voltage cycle is completed.

All this means that a small VARIABLE VOLTAGE applied to the grid creates SIMILAR variations in the plate current. These plate current variations can be changed to AMPLIFIED VOLTAGE variations in several ways.

Simplest method is to use a transformer connected as illustrated in the diagram.

The alternating current, rectified by the triode, becomes pulsating direct current. This pulsating direct current, in the transformer's primary winding, produces an expanding and collapsing magnetic field which cuts across the turns of the transformer secondary.

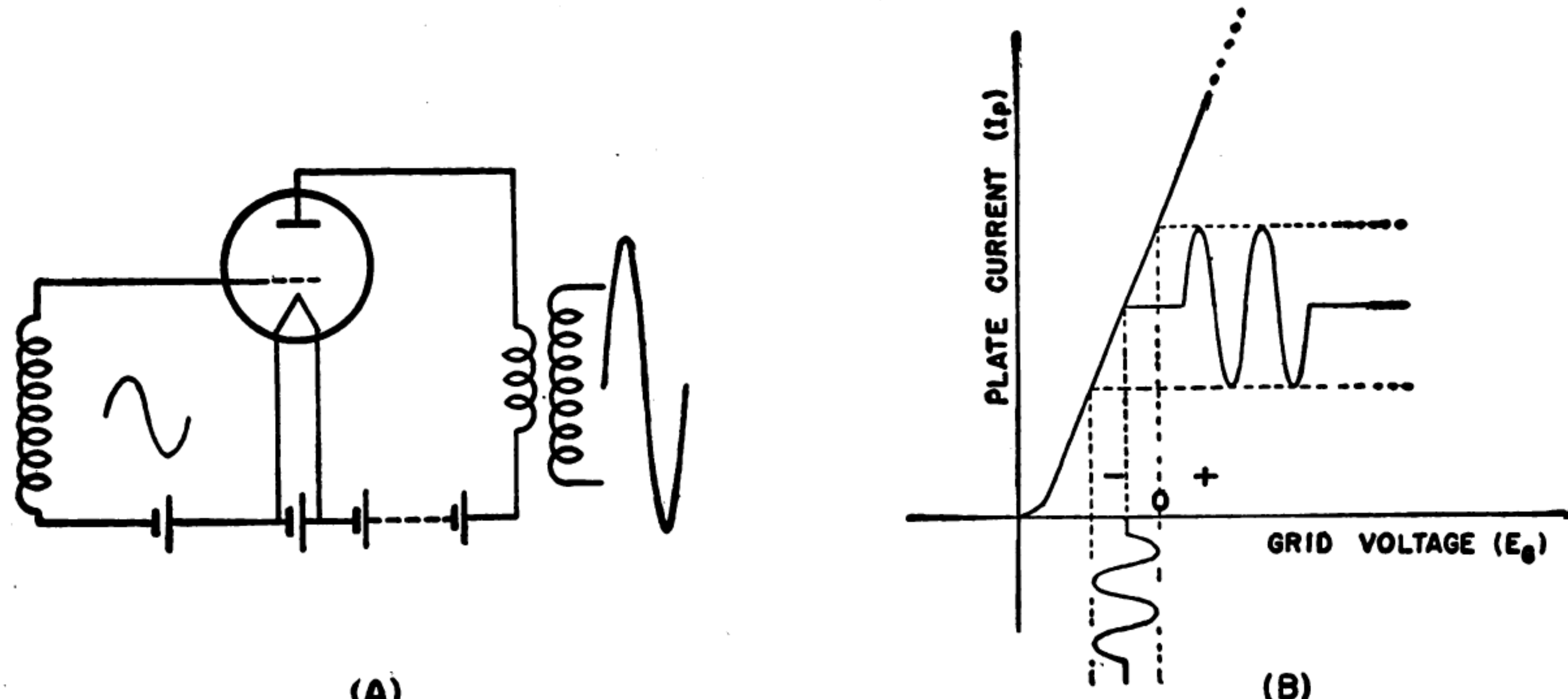
With greater amplitude, the voltage induced in the secondary winding has the same frequency and wave form as the grid voltage.

Plainly, then, the tube functions as an amplifier of alternating current voltage. The diagram shows what you will call a STAGE OF AMPLIFICATION. If greater amplification is desired for *DX* reception, you employ another tube. You say you have a SECOND STAGE of amplification.

Two stages of amplification, coupled together by connecting the transformer secondary of one to the grid of another, are generally sufficient for a complete AMPLIFIER CIRCUIT. But before going into the complete circuit, examine another detail of one stage.

Look at the INDIVIDUAL AMPLIFIER CIRCUIT as diagrammed in figure 8.

The NEGATIVE half of the alternating current cycle makes the grid negative. During this half of the cycle NO CURRENT flows in the input circuit. On the POSITIVE half of the alternation, however, the grid becomes positive and attracts electrons from the filament or cathode. A LARGE CURRENT



(A) (B)

Figure 9.—Effect of grid bias.

flows in the plate circuit during the positive half of the cycle.

GRID CURRENT is not desirable in the simple amplifier circuit. Its flow through the transformer secondary would result in a voltage drop at the terminals. During the positive half of the cycle the output voltage would be less than the voltage amplitude on the negative half of the cycle. The variations in plate current, no longer having the same form as the grid voltage, are distorted.

GRID BIAS is called for.

By means of a 1.5 volt C Battery, as shown in figure 9*A*, the grid can be given a negative charge of the proper value. That's a charge which won't prevent electrons going from filament to plate during the positive half of the alternating-current cycle, but will prevent them during the negative half of the alternating-current cycle. The grid becomes more negative on the negative half and less negative on the positive half of the cycle. Grid current can't flow if the peak value of the grid voltage is not greater than the negative charge. The plate current will also have the same wave form as the grid voltage.

Here your grid bias comes in. Its function is the elimination of distortions caused by grid current. It can also control the volume in your radio receiver, and eliminate distortions produced by variations of plate current.

(In some stages of amplification grid voltage may be very large. The tubes must then be operated at a higher plate voltage, and the grid bias altered to absorb this increased plate voltage.)

Boiled down, the idea of amplification is fairly simple.

You connect the plate circuit of a detector tube to the grid of a second tube.

The plate current in the second tube will be an amplified reproduction of the signal from the detector.

You call such a connection one stage of amplification.

The result is an increase of INTENSITY (loudness) of the signal in the reproducer.

The tube which effects this increase you call an AUDIO-FREQUENCY AMPLIFIER.

AUDIO FREQUENCY

You recall that the current set flowing by a radio wave in your aerial-ground and tuning circuit is a current of radio frequency, alternating millions of times per second.

After being rectified by the detector, it is pulsating direct current but these pulsations are also of radio frequency.

Now the amplifier tube, while increasing the signal intensity, has served to magnify the waveform. The fluctuations correspond to those of the current in the tuner, but, having been enlarged, they are of much greater amplitude.

For illustration you might think of the r-f current as a miniscule midget who moves like a flash. He dashes into the amplifying tube and is changed by magic into a giant, slower of speech and heavy-footed, but still Gulliver with the same profile and features. Previously you couldn't have made out his lilliputian voice, but you can hear him now. And, to tune out this bedtime story, you say the current of radio frequency has been changed to one of AUDIO FREQUENCY.

As an audio-frequency amplifier, the triode made possible the use of the loud speaker.

It also made possible another improvement in your radio receiver.

Now you can get rid of some bulky batteries.

ELIMINATING THE "A" BATTERY

Up to this point you've considered batteries as the source of current supply in your filament, plate and grid circuits. You have called these the A, B and C batteries, respectively.

With the development of modern radio these batteries have generally been discarded. Batteries are cumbersome, need a good deal of nursing, and are subject to deterioration and frequent replacement. Radio engineers sought a means of using ordinary house current to operate household radios.

The difficulty, of course, was the alternating current, which at that time was found unsatisfactory for heating the filament of a vacuum tube, and cannot be fed directly to the plate. (Plate current must be varied by grid-action only.)

First, attempts were made to manufacture a filament which resisted temperature change. Instead of tungsten, a broader ribbon-type of wire was tried, the idea being that its greater mass would maintain a constant temperature and give off a large nonvarying stream of electrons.

Although this method met with some success and such tubes are still in use, it was not entirely satisfactory. High voltage was required to heat this ribbon filament, and temperature variations were not quite eliminated.

A better contrivance was the CATHODE SLEEVE.

This consists of a sheath or sleeve of metal which surrounds but does not touch the filament. The sleeve is coated with certain chemicals, such as oxides of barium or strontium, which increase electron emission.

The sleeve now serves as the CATHODE. And the filament, serving as a stove to heat the sleeve, is referred to as the HEATER.

It is the cathode sleeve which now emits the electrons. You see it symbolized in figure 10 as the poker-shaped bar inserted between filament and grid.

You speak of the tube as the "indirect heater" type.

Being comparatively massive, the cathode sleeve is not subject to quick changes of temperature, and does not follow the temperature variations of the filament "heater." In consequence the PLATE CURRENT is not affected by any cyclic variations in the HEATER CIRCUIT—which was the object behind

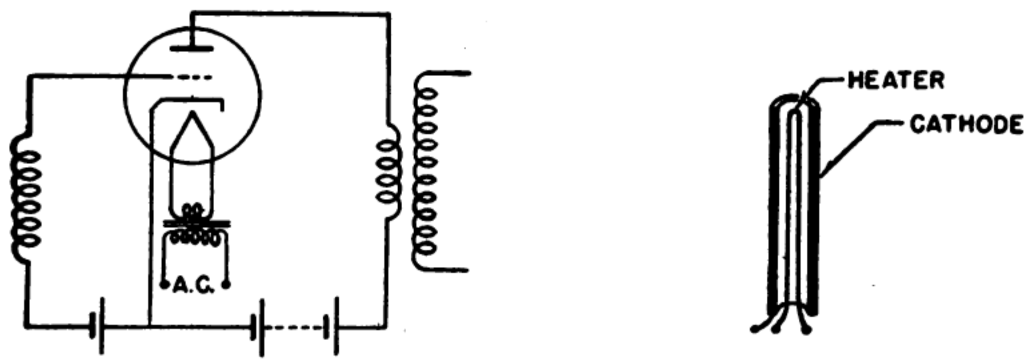


Figure 10.—Indirect heater type tube.

the device. Today, tubes are in use which employ raw alternating current on their filaments.

In figure 10 you see the heater supplied with a low-voltage alternating current from a step-down transformer, such an arrangement as may be used in connection with a household alternating current of 110 volts. The B battery and C battery are still included.

In figure 11 you see a circuit providing GRID BIAS, with the cathode connected to the "grid return" and both A and C Batteries eliminated. Also you have a condenser and a RESISTOR in series with the CATHODE CIRCUIT.

As you see, your filament is completely removed from any circuit conducting radio signals. It merely heats the cathode.

The CATHODE CURRENT in a triode is equal to the plate current. Shunted by the condenser, this current undergoes an *IR* (current×resistance-voltage) drop on going through the RESISTOR. Since the RESISTOR is common to both grid and plate circuits, the dropped voltage is added to the bias for the grid circuit.

The voltage becomes negative at point B. And since the input circuit is connected at this point,

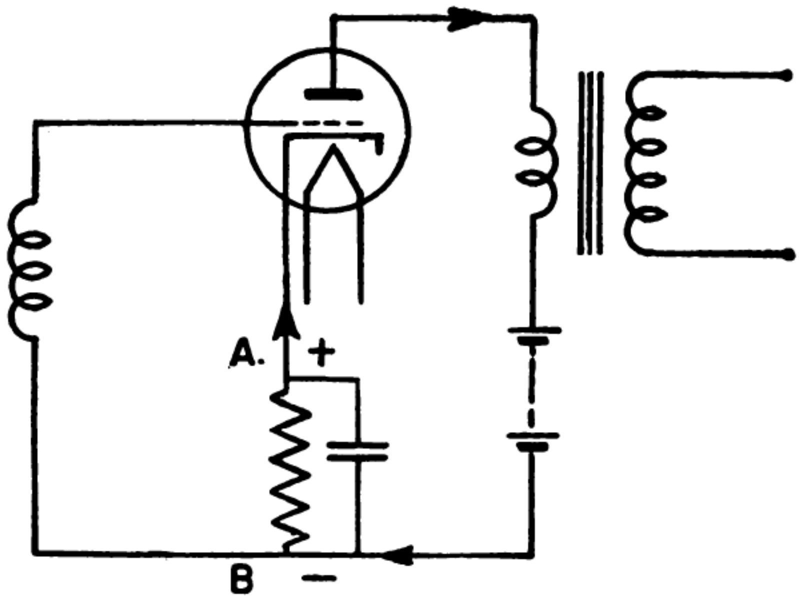


Figure 11.—Cathode voltage drop through grid bias.

the grid is biased negatively by the amount of the voltage drop.

ELIMINATING THE B BATTERY

The cathode sleeve was the solution to the problem of substituting alternating current for the filament battery. The plate supply presented another problem.

As you know, the average house current is alternating current with a voltage of 110 volts, and a frequency of 60 cycles per second. This alternating current cannot be applied directly to the plate of a tube. The plate must have a steady positive charge. Any fluctuations due to variations in voltage cause signal distortion. Therefore the alternating current must be changed to high voltage alternating current and then rectified to a STEADY direct current before it can be fed to the plate of the tube.

In the case of house current a STEP-UP TRANSFORMER was the answer to higher voltage. Such a transformer, its primary connected to the 110-volt alternating current of the house line, can increase the voltage to about 300 volts. You call it a POWER TRANSFORMER.

In modern NAVAL AIRCRAFT RECEIVERS the plate voltage is supplied by a DYNAMOTOR. It is a special type of motor generator combining motor and generator in a single unit. That takes care of the high voltage alternating current, but how is it rectified?

Go back to your DIODE tube which replaced the old-fashioned crystal detector. As detector, it also served to change alternating current of radio frequency into pulsating direct current. And, in this capacity, it acted as a RECTIFIER.

The vacuum tube, conducting current in only one direction, can be used as a RECTIFIER TUBE in a B power supply.

VACUUM TUBE AS RECTIFIER

Look at figure 12, which illustrates the simplest form of RECTIFIER CIRCUIT. Here you see in diagram a power transformer used to step up alternating current to a higher voltage. A diode acts as rectifier tube to change that voltage to direct current.

As this circuit uses only one-half of the alternating current cycle you call the method HALF-WAVE RECTIFICATION.

How does it operate?

On the positive half of the cycle the plate of the tube is positive. The current flows from the power line to the plate circuits indicated. On the opposite half of the cycle the plate goes negative. The electrons emitted by the filament are repelled and no current flows in the "load circuit." As

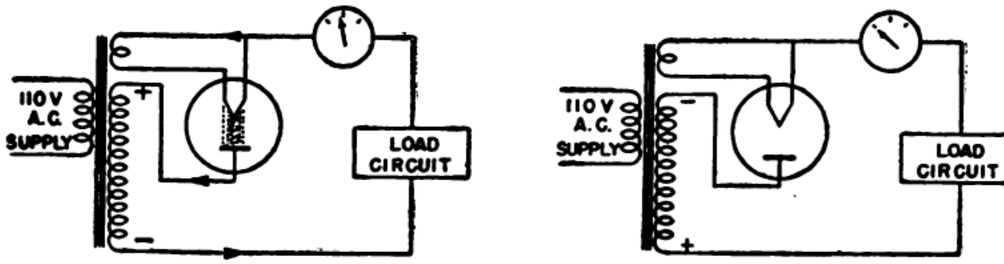


Figure 12.—Half-wave rectifier.

you see, the alternating current is changed into pulsating direct current.

Figure 13 is a voltage graph illustrating half-wave rectification.

The alternating current voltage applied to the

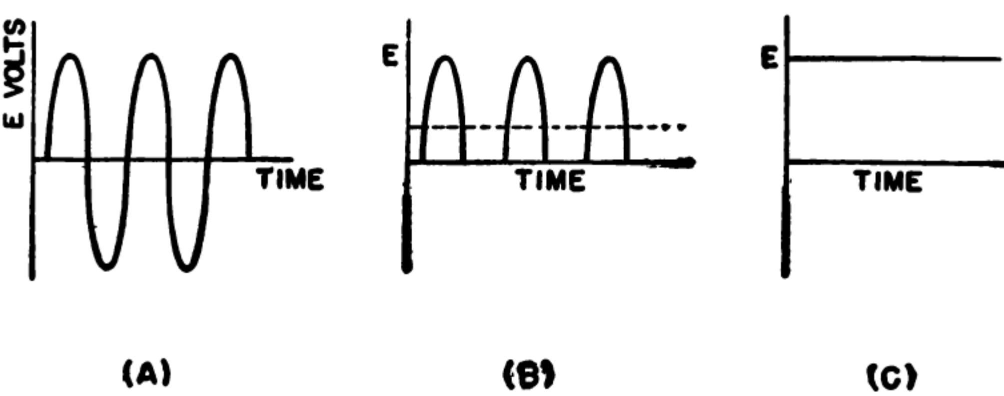


Figure 13.—Half-wave rectifier—voltage graph.

rectifier tube by the transformer secondary gives you a sine curve as in figure 13*A*. In figure 13*B* the "broken" curve illustrates the voltage at the output terminals of the rectifier. You can see how current would flow in a load circuit in which this voltage is applied. Figure 13*C* illustrates the voltage you'd obtain from a battery.

As you can see, the voltage from the rectifier, as pulsating direct current, is not yet a proper substitute for voltage from a plate battery. The current fed the plate must be a STEADY direct current.

This further change is accomplished by a method known as FULL-WAVE RECTIFICATION. Look at figure 14. As you suspect from the title, BOTH HALVES of the alternating current cycle are called into play.

Study the diagram. Here you have a vacuum tube with TWO plates and one filament. A diode with twin plates? Correct, and you call it a DUO-DIODE. It belongs to the family of "multiunit" tubes.

In action, the electrons emitted by the filament are attracted first to one plate, then to the other.

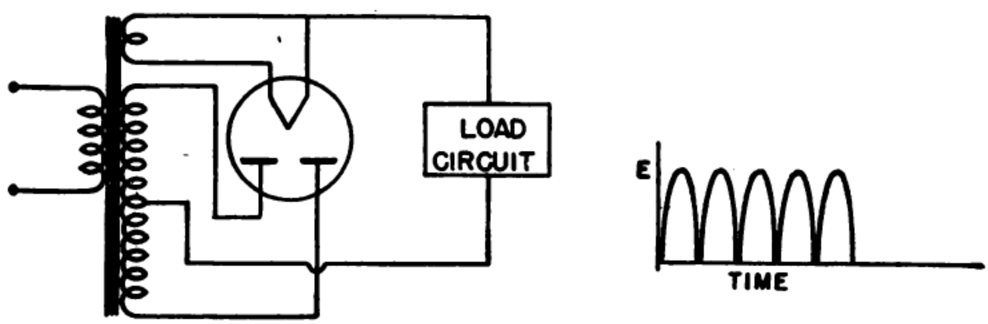


Figure 14.—Full-wave rectifier.

How? The secondary winding of the transformer is "center tapped," and the ends of the winding are connected to the twin plates of the tube. Now apply your alternating current.

When the upper end of the winding is positive, current passes through the connected plate to the filament and so on through the load circuit. Simultaneously the lower half of the transformer secondary, connected to the other plate, is negative, giving that plate a negative charge, which means no current flows in that plate circuit.

Meantime the electrons stream through the first plate circuit to the center-tap of the transformer winding. The lower half of the winding, being negative, repels these electrons and they are forced at this junction into the load circuit.

During the next half of the alternating current cycle the process is reversed. Now the upper end of the winding is negative and the lower end is positive. Current flows through the second plate to the filament. Electrons travel to the second plate, which is now attractively positive, and back around the center-tap into the load circuit.

You can visualize the result as shown in the voltage graph of figure 14. You still have a pulsating character in this voltage, but while the voltage was zero half of the time in your half-wave rectifier, it is zero now for only an instant.

However, that zero instant must still be eradi-

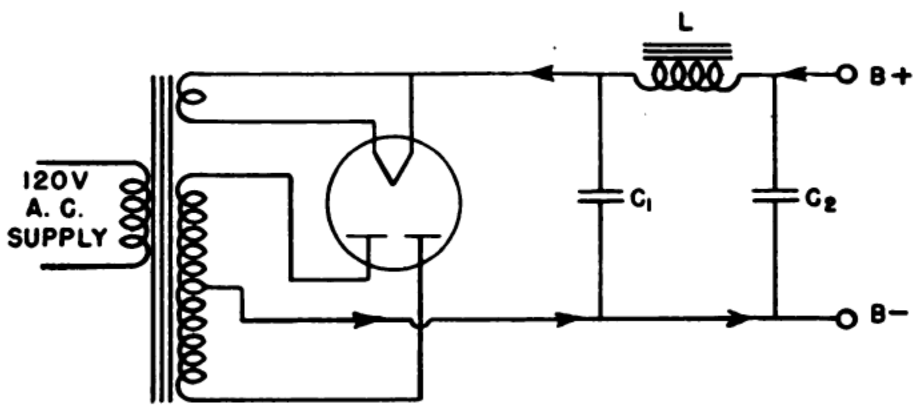


Figure 15.—Full-wave rectifier and filter.

cated. This is accomplished by a FILTER. You can define a filter as an electrical network used to eliminate the variations of pulsating direct current. Your full-wave rectifier makes its use possible.

In figure 15 you see a typical FILTER CIRCUIT.

The electrical network is made up of two condensers (C_1 and C_2) and a FILTER CHOKE COIL (L). The choke, consisting of many turns of wire on an iron core, is also known as an IRON-CORE INDUCTANCE.

Encountering the filter choke coil, the electrons are up against a large RESISTANCE offered by the many turns of wire and the SELF-INDUCTANCE of the coil. This resistance bottleneck forces them to backwash to condenser C_1, where they pile up until there are enough of them to overcome the resistance of the choke oil. Condenser C_2 operates in similar fashion as a sort of tidal reservoir of electrons, replenishing the load circuit during those periods when the rectifier output voltage is falling.

Compare the output voltage at the RECTIFIER

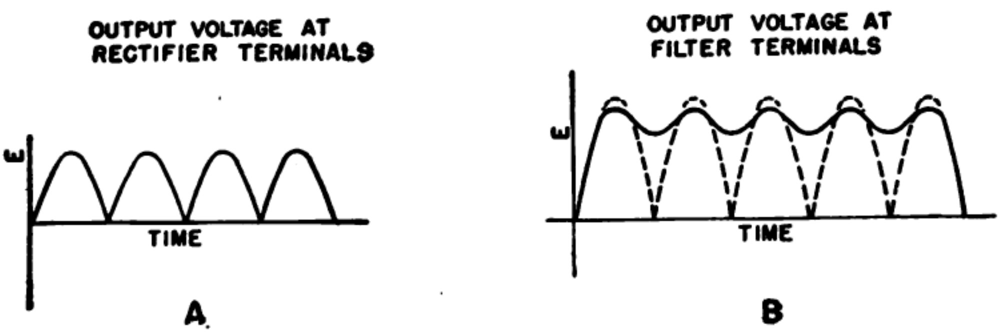


Figure 16.—Comparison of voltage at rectifier and filter terminals.

terminals and the output voltage at the FILTER terminals as illustrated in figure 16.

The difference in wave form is clearly apparent. In figure 16*B* the dotted line represents the rectified wave form, and the unbroken curve is the wave form of the FILTERED voltage. You see that the peaks of the pulsating direct current from the rectifier have been levelled off and the hollows filled in. The original alternating current fed into your circuit has been RECTIFIED and FILTERED.

Now you have the STEADY DIRECT CURRENT which can be fed to the plates of the tubes in your radio receiving circuit. The B battery can be discarded. You call the hook-up of power transformer, duo-diode and filter system a B ELIMI-

NATOR. It permits you to employ power-line current in your household radio, and a dynamotor in connection with your naval aircraft receiver.

VOLTAGE DIVIDER

The DIODE serves as excellent DETECTOR and also RECTIFIER. The TRIODE with its GRID gives you long distance reception—AMPLIFICATION.

The DUO-DIODE steps forward as FULL-WAVE RECTIFIER and battery eliminator.

Later you will see how the "valve" branches out into MULTIUNIT and MULTIELECTRODE tubes.

The point is that only a few tubes in modern radio receivers are of the TRIODE type previously studied. Other tubes have additional elements which require lower voltage.

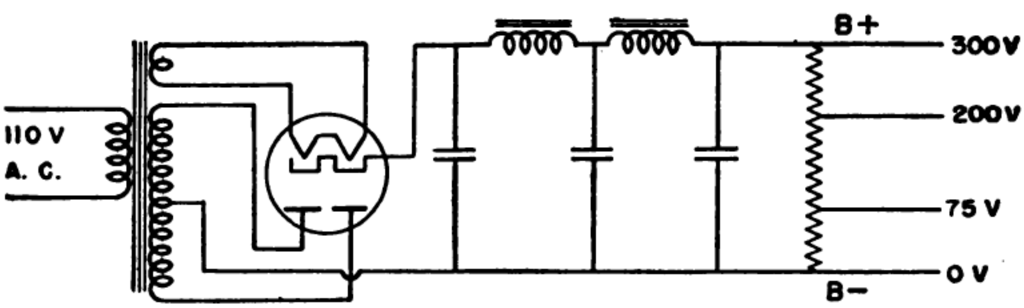


Figure 17.—Power supply and voltage divider.

Power supplies for PLATE VOLTAGE are accordingly equipped with a VOLTAGE DIVIDER to obtain the voltage necessary for different circuits.

You have a power supply with a voltage divider illustrated in figure 17.

In this circuit the RECTIFIER TUBE is a MULTIUNIT tube with two filament heaters, twin plates and an indirectly heated cathode contained in the same envelope. You see also a FILTER SYSTEM employing two CHOKE coils and three condensers. Your attention is invited to the RESISTOR connected across the terminals of the filter output.

Assume that the electrical pressure (emf) at the positive terminal of the filter output is 300 volts. The electrons at the negative terminal will exert a force equivalent to 300 volts of pressure in their effort to reach the positive terminal. Which is to say, the electrons use up the 300 volts pressure in traveling the length of the RESISTOR. Technically speaking, this is called a "drop" of 300 volts.

At any point on the resistor this drop (you call it a DROP IN POTENTIAL) is proportional to the fraction of resistance overcome at that point. In traveling two-thirds of the distance, for example, the positive-bound electrons use up two-thirds of the voltage, and the pressure remaining between that point and the positive terminal is 100 volts. (Actually the voltage will not be exactly proportional to the resistance when applied across a load, but you can leave that problem till later.) You call this particular device a VOLTAGE DIVIDER.

Another type of VOLTAGE DIVIDER is the POTENTIOMETER. This is merely a variable resistor provided with a sliding arm which can be adjusted to tap the resistor at any desired point. A DROPPING RESISTOR placed in series with a load may be similarly employed. (A resistor across a filter, used to improve the regulation of voltage is called a "bleeder.")

The purpose of the dropping resistor is the same as that of the voltage divider—to provide the special voltages required by the numerous types of vacuum tubes.

IT CAN OSCILLATE!

In addition to being detector, amplifier and rectifier, the vacuum tube also proves itself a generator of high frequency current, and as such it becomes an ELECTRONIC ALTERNATOR. In this character it may be used for both sending and receiving. And you call it an OSCILLATOR.

It differs from the usual alternator in one respect. By means of a TUNED CIRCUIT it can be made to generate an alternating current of RADIO FREQUENCY OVER A WIDE RANGE of frequencies. The waves sent out are of equal amplitude for each cycle, and their form would be represented by the sine curve. You call this type of current a CONTINUOUS RADIO-FREQUENCY CURRENT. The wave is a CARRIER WAVE (CW).

It is this continuous radio-frequency current generated by the VACUUM TUBE OSCILLATOR which makes possible your modern broadcast and radio-

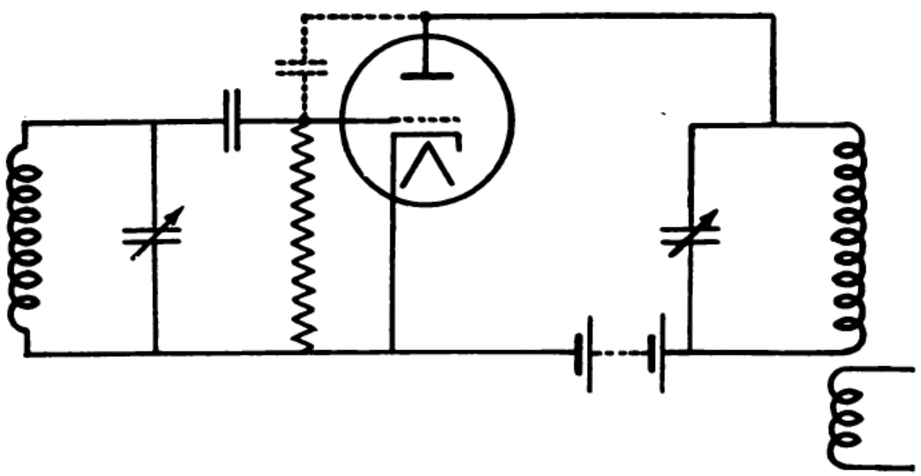


Figure 18.—The simple oscillator.

telephone. Voice and music transmission would be impossible without it.

When amplified and MODULATED by voice currents at the sending microphone, it forms the MODULATED RADIO-FREQUENCY CURRENT which produces the MODULATED RADIO WAVE transmitted by the sending aerial. So the vacuum tube OSCILLATOR plays the part of transmitter!

Not only that, the tube serves as MODULATOR to control the high frequency oscillations generated by the oscillator tubes. The MODULATOR TUBE will attract your attention later.

Figure 18 illustrates a simple form of OSCILLATOR.

The plate circuit and the grid circuit include inductances and variable condensers. When plate voltage is applied, the first surge of current in the plate circuit builds up a charge on the capacity formed by the grid and plate.

This CAPACITANCE creates a path for alternating current from the plate to the grid. The charge on this capacitance causes a slight surge of current in the grid circuit.

Any electrical variation in the grid, however small, is immediately amplified in the plate circuit. The amplified variation causes a stronger pulse to feed back through the plate-to-grid capacitance. This action causes the tube to break into SUSTAINED OSCILLATIONS. The variable condenser in the grid circuit promptly becomes charged. It then discharges through the inductance connected parallel to it.

During the discharge, the magnetic field about the inductance expands. Then it collapses producing opposite polarity in the condenser. When the charge is completed, the condenser discharges in the opposite direction through the coil. The power required to overcome losses in the grid circuit during these oscillations is supplied by the plate battery.

Now the voltage changes that occur in the grid circuit appear in an amplified version in the plate circuit. The continuous play of current between the coil and the condenser in the plate circuit effects the transference of power (by electromagnetic induction) to any secondary circuit which is connected.

In an oscillator circuit the inductance in the grid and plate circuits may have the same value. If so, the variable condensers must be adjusted to have almost equal capacitance. The frequency of the current generated is determined by the values of inductance and capacity, and the rapidity of oscillation is changed by varying either of these factors. Frequency is lowered by increasing, or raised by decreasing, either inductance or capacity. It is easier to vary capacity, hence the variable condensers to obtain moderate changes in frequency. The oscillator is "tuned" to a desired frequency by this procedure. You'll take the "frequency range" of the oscillator to determine the "capacitance range" of the variable condensers.

The small resistor and condenser in the grid circuit are employed to obtain grid bias. On the positive half of an oscillation, grid current flows through the resistor. The voltage drop supplies the necessary grid bias. Note that in an oscillator circuit, unlike certain amplifier circuits, grid current is not objectionable.

In the chapter to follow you will study the OSCILLATOR TUBE and radio transmission in more detail.

MULTIELECTRODE AND MULTIUNIT TUBES

And now, before leaving the vacuum tube, glance over the multielectrode and multiunit tubes.

The multielectrode is so-called because new electrodes were introduced to serve new purposes.

You have the TETRODE (meaning four electrodes) with the SCREEN GRID added to divert electrons from the control grid.

The PENTODE which adds a SUPPRESSOR GRID to the other two.

The PENTAGRID CONVERTER with five grids.

"Multielectrode" specifically refers to any tube containing more than five electrodes.

As you observed from the tube diagrammed in figure 15 it is possible to have two or more complete tubes enclosed in one envelope. Figure 15 displays a double diode. Such tubes are called multiunit tubes. You can have a multiunit tube containing one pentode and one triode, for example, or two triodes.

But no matter how complicated these vacuum tubes may seem, the basic principle goes back to that of the original Fleming valve. A heated cathode emits electrons which are attracted to a positively charged plate!

CHAPTER 3

ELEMENTARY TRANSMITTER

MYSTERY OF THE VANISHING MEN

If Martin Pinzon, a crack navigator, hadn't come along in the "Pinta," Christopher Columbus might have disappeared from history. For the sea gull put him a little off course, so that eventually he cracked up in Haiti, wrecking the "Santa Maria" on the beach and stranding all hands.

As it was, Pinzon took Columbus back to Spain. But the crew, left behind to build a blockhouse, vanished from the ken of men.

What happened to the crew of the "Santa Maria"? The question constitutes a first-class history baffler. The Admiral, returning with a new flagship some months later, couldn't find so much as a cabin boy. There was no sign of the blockhouse and no sign of the sailors. And no one has heard from the latter, then or since.

Now imagine the advantages of a wireless to that crew—even a spark transmitter. They could have sent out messages from cocoanut-time to breakfast. And had receivers been invented to pick up the messages, they might have been rescued to share the Admiral's fame. At least they wouldn't have gone down in history like a German submarine in the last war, "Spurlos Versenkt."

Wireless went far to erase that phrase, "Sunk Without Trace," and modern radio has put an end to it.

SIMPLE RADIO TRANSMITTER

You are probably personally acquainted with a radio receiving set. You've tuned into your favorite program and tuned out some advertising blarney (by varying your set's L×C). You're familiar with fading (that Kennelly-Heaviside Layer), and your teeth may have jarred at static when your set or that of some neighbor began to OSCILLATE and "spill over." If the latter occurred, your set whistled and yowled, and if you had the urge, you looked for the trouble in your FEED-BACK system, blaming your TICKLER COIL. Your REGENERATIVE DETECTOR (or your neighbor's) was overcoming too much resistance. And your set, or the one next door, was acting as a wildcat transmitter.

If it was your neighbor's, you couldn't do much about it. But if it was your own, and you were technically inclined, you corrected the "feed-back action" by moving the tickler coil farther away from the antenna coupler's secondary. Or perhaps adjusting a variable condenser. The idea being to limit the oscillation in the tuning circuit, or, you might say, "slow up" the electron flow, so that enough resistance remained to prevent radiation. And, if you were that well acquainted with the subject, you knew that a simple tuning circuit can oscillate and create electromagnetic waves that go hiking out into space. Which means they were waves of RADIO FREQUENCY—somewhere between 18,000 kilocycles and 60,000 megacycles per second.

The above case implies that your set was a "three circuit tuner" employing feed-back. Your new household radio is probably a "super-het" and needs little tinkering. John Doe and Richard Roe prefer to leave their troubles with Mr. Repairman. The point being that to the average man, as perhaps to you, the RADIO TRANSMITTER is as blank a mystery as the fate of Columbus' crew.

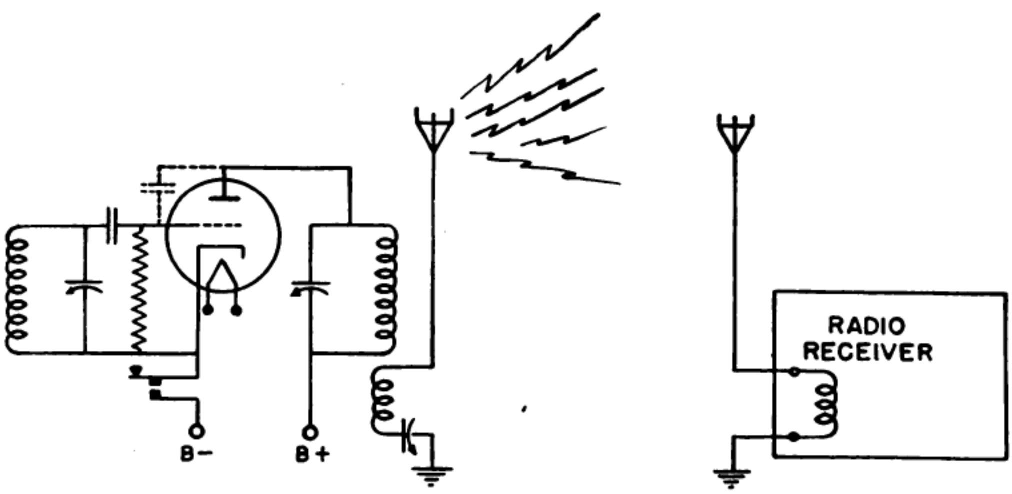


Figure 19.—A simple radio transmitter.

Recall what you've just studied concerning the modern OSCILLATOR TUBE. A lot of radio juice has run under the bridge since the day of the old-time spark transmitter, limited to wireless telegraphy. Modern broadcasting (radio telephony) developed only with the vacuum tube as OSCILLATOR, AMPLIFIER and MODULATOR, making possible voice transmission. The basic purpose of radio transmission, however, remains unchanged. The "ops" have a word for it—SENDING. By means of OSCILLATION a radio wave is generated, and by means of a key or microphone a message is conveyed to a receiver.

The story is one of FREQUENCY and AMPLITUDE, and the process is a matter of MODULATION.

To begin with, then, glance at figure 19, the wiring diagram of a simple, but practical, low-powered radio transmitter.

Comparison with the spark transmitter will show you the fixed condenser and dropping resistor now introduced to your input circuit. You see the a-c generator replaced by oscillator (triode) tube, the cathode connected to the sending key, and the filament heated by an A battery. The output circuit of the oscillator is coupled to a coil placed in a series with the aerial and ground. A condenser in a series with this coil is tuned to obtain maximum power from the oscillator.

The "coil-condenser" circuit illustrated is called a TANK. And the transmitting antenna, one of the MARCONI type, is COUPLED INDUCTIVELY to the bottom of the TANK COIL.

Note the condenser in series with the transmitter's aerial-ground. Its effect is to shorten or lengthen the aerial electrically, thereby compensating for any discrepancy in the other tuning circuits. A TUNED CIRCUIT, you will recall, is a circuit in which the capacity *C* and inductance *L* are adjusted to produce a desired period of oscillation. (Receiver TUNING you think of as an adjustment of *L* or *C* which brings a circuit into resonance with a frequency.)

The condenser illustrated may be the type known as a TRIMMER. Generally the trimmer condenser is very small—two metal plates perhaps one-half inch square, separated by a piece of mica, the dielectric. A screw holds the plates together, and by loosening or tightening the screw you vary the distance between the plates, thereby varying the capacitance. Trimmers are used in connection with larger variable condensers, to adjust radio-frequency transformers, and to balance circuits. In this instance, you have an AERIAL TRIMMER.

Actually the antenna and ground form the plates of a giant condenser, the air between them acting as the dielectric. High-frequency alternating current, sent to this circuit from the oscillator, creates magnetic and electrostatic fields which radiate into space. You recall that this electromagnetic wave leaving the antenna spreads out in all directions, one portion, the GROUND WAVE, traveling along the earth's surface, while the SKY WAVE heads for the ionosphere. The electromagnetic waves, intercepted, create a feeble current of the same frequency in a receiving antenna.

MODULATION

The RADIO FREQUENCY CURRENT in the receiving antenna, although a reproduction of the alterating current in the transmitter as to frequency, is too weak to create sound in any reproducer. As you know, your receiver must rectify it, amplify it, and change it to AUDIO FREQUENCY. As received, it is not unlike a microscopic copy of the original from the transmitter's oscillator. The alternating current generated by the transmitter is known as the CARRIER CURRENT, and the radio wave producing it is called the CARRIER WAVE.

In order for it to convey an intelligent message from the transmitter, the carrier wave must be MODULATED. MODULATION is the name given the process of varying either the frequency or the amplitude of a CONTINUOUS CARRIER CURRENT. The common method is to vary the AMPLITUDE of radio-frequency oscillations by IMPRESSING audio-frequency oscillations upon them.

But first consider unmodulated CW transmission.

Figure 20 illustrates the CARRIER CURRENT patterns of code.

In figure 20 *A* you see a graph of the carrier current induced in the TRANSMITTING ANTENNA by the oscillator. Although the current is NOT modulated, it is varied at the frequency of the oscillator, and the current alternations have the SAME amplitude. This is a straight CW wave.

If you break it into a short and long sound with a key on the oscillator plate supply, you

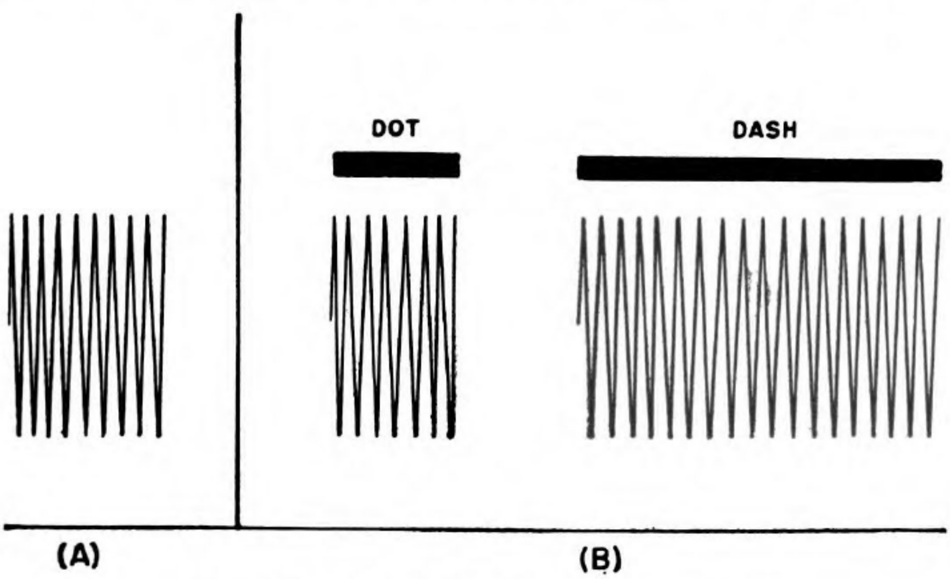


Figure 20.—Carrier current patterns—code.

get the letter "A" (di-DAH) in INTERNATIONAL MORSE as shown in figure 20 *B*. The current produced in the receiving antenna is an exact replica of this.

The method of keying is not unlike that employed in line telegraphy, the signals produced by a key momentarily closing an open circuit. In this case, however, your circuit bears current of radio frequency. You call this method CW (continuous wave) TRANSMISSION, and your sender is a CW TRANSMITTER.

A more modern method of radio telegraphy is INTERRUPTED CONTINUOUS-WAVE (ICW) TRANSMISSION. This is accomplished by AMPLITUDE MODULATION—the process of impressing AUDIO-FREQUENCY fluctuation on the continuous (CW) wave. The changed wave is known as a modulated continuous (MCW) wave.

Two types of audio-frequency variations are commonly employed in modulation. In radio telegraphy, a steady AUDIO-FREQUENCY NOTE (a frequency somewhere between 30 and 15,000 cycles per second) is impressed on the carrier wave. Assume this to be a 1,000 cycle note.

Radiated from the transmitting antenna, short and long trains of this MCW wave (corresponding to the dots and dashes of code) are picked up by a receiver. The detector removes the bottom half of the incoming signal; the r-f carrier wave is eliminated (you call this DEMODULATION) and the original 1,000 cycle audio-frequency note is heard as a series of staccato, short-and-long whistles.

SPEECH TRANSMISSION

In radio telegraphy with a straight CW, the carrier current flows whenever the key is depressed and direct-current voltage reaches the oscillator plate. When the key is lifted, plate voltage ceases in the oscillator, and the carrier current falls to zero. Thus the current is turned on and off.

However, if the oscillator plate voltage merely drops, the carrier current does not cease, but only becomes weaker. Conversely, if oscillator plate voltage is increased, the carrier current also increases.

You can see from this how audio-frequency (AF) variations can be impressed on the carrier wave, making possible speech transmission.

Think back to your telephone transmitter. When you speak into a telephone transmitter, the sound waves, striking a diaphragm, cause variations in the electric current flowing through the circuit. Substitute a microphone, and it becomes apparent that the audio-frequency fluctuations caused by speech or music may be used to modulate a continuous radio wave.

Now take a look at figure 21, a schematic diagram of a radiotelephone transmitter.

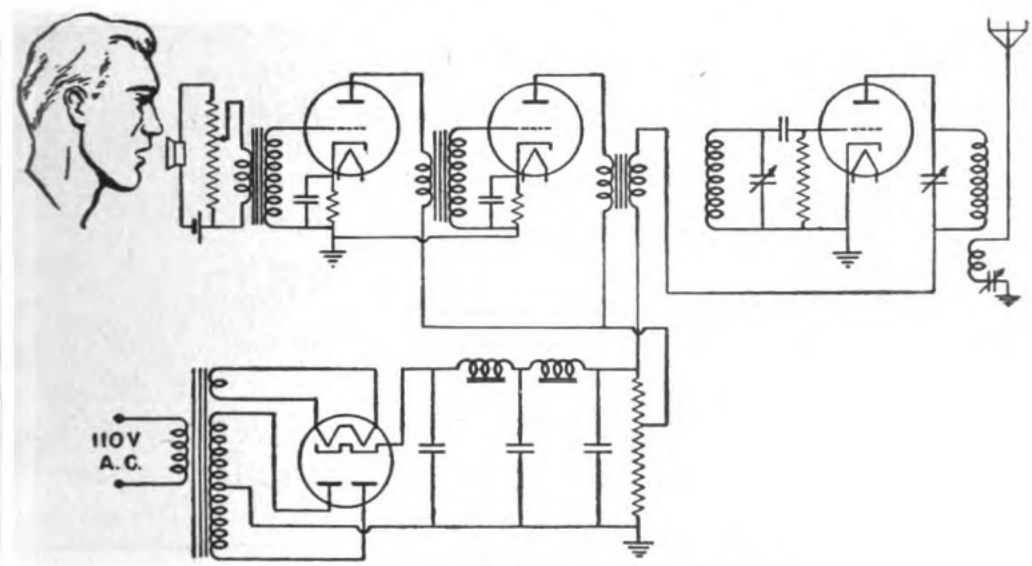


Figure 21.—Radiotelephone transmitter.

Figure 22 gives you a schematic diagram in block form of some interesting radiotelephony carrier patterns.

Section *A* represents the various circuits. Section *B* illustrates the voltage in each circuit, BEFORE sound strikes the microphone. As there is no sound striking the "mike," the output of the speech amplifier (or modulator) is zero. As the power unit is supplying a CONSTANT voltage to the transmitter at all times, the oscillator generates a carrier current in which all voltage peaks have the same amplitude.

Section *C* represents the change produced by a hum in the microphone. Your humming creates a low-frequency AUDIO voltage at the terminals of the MODULATOR OUTPUT TRANSFORMER. This voltage is an alternating-current voltage with a frequency determined by the pitch of sound.

When the upper half of the output transformer is positive, the audio voltage ADDS to the power supply voltage. The voltage at the plate of the oscillator is instantly increased. On the other half of the cycle, the alternating-current audio voltage

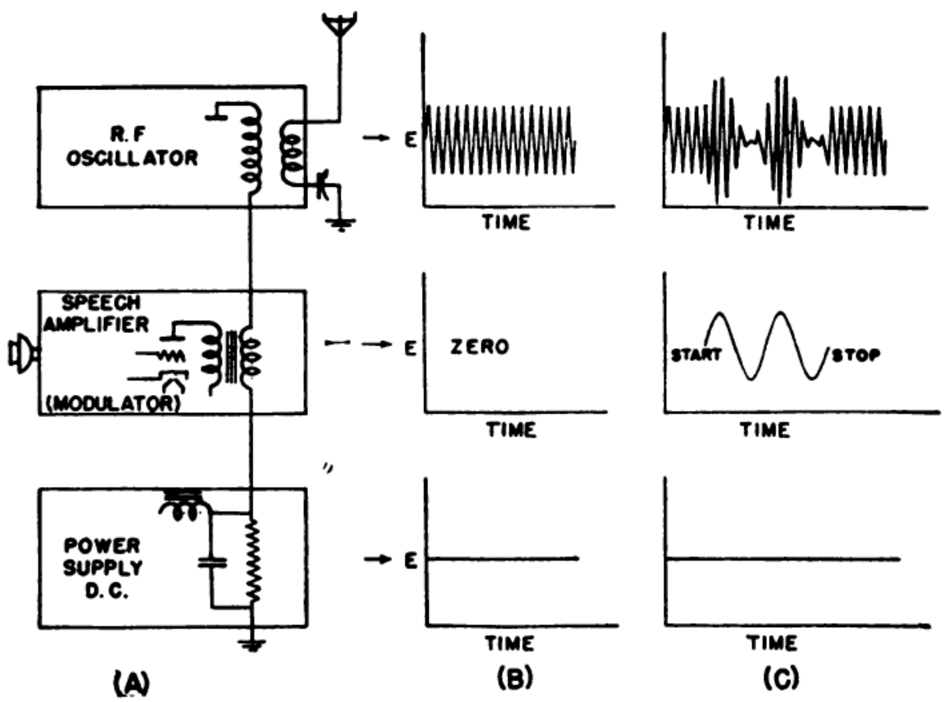


Figure 22.—Radiotelephony carrier patterns.

DETRACTS from, or opposes, the power supply voltage, and the oscillator plate voltage becomes the DIFFERENCE between the two. The oscillator plate voltage is, of course, decreased.

The AMPLITUDE of the RADIO-FREQUENCY CARRIER CURRENT generated by the oscillator is PROPORTIONAL to the oscillator plate voltage. Vary the plate voltage, and you vary the amplitude of the r-f carrier current. When the variation is accomplished with an audio-frequency signal, you call the process AMPLITUDE MODULATION of the carrier.

To summarize—In amplitude modulation, the FREQUENCY of the carrier remains CONSTANT while the amplitude is varied by the impressed audio frequency. Whereas in FREQUENCY MODULATION, the amplitude of the carrier remains constant, and the frequency is varied by the impressed audio-frequency (AF) current.

Both methods have special advantages. Frequency-modulation is comparatively free of static, but because the waves are transmitted in straight lines to receivers, transmission is limited to a shorter distance than that achieved by amplitude-modulation. In general, commercial broadcasting stations continue to use amplitude modulation.

SPEAKING OF TRANSMITTERS

What happens when you speak into the "mike"?

First of all, your voice striking the microphone creates a fluctuating direct current. Meanwhile the oscillator is generating a continuous, carrier wave. Say it has a frequency of 500 kilocycles per second. The fluctuating direct current started by your voice is now impressed on (you might say, mixed with) the carrier. The result is a modulated carrier wave (MCW) whose frequency is 500 kilocycles per second, but whose amplitudes correspond to the form of the fluctuating direct current started by your voice.

Figure 23 gives you an illustration of speech modulation.

Section *A* illustrates the UNMODULATED CARRIER. Section B shows the form of the AUDIO OUTPUT of the modulator. The graph in section *C* shows you how the current which carries your voice is modulated.

You are now able to recognize two characteristics of speech modulation. When you talk into a microphone the wave form of the audio voltage in the output stage of the modulator is rarely uniform. Speech consists of many frequencies which blend to create an irregular audio-frequency current in the modulation output circuit.

The weak r-f current in the receiving antenna varies in exactly the same way. The problem at the receiving end concerns the amplification of this weak current so that it can produce an audio-frequency current strong enough for the headphones.

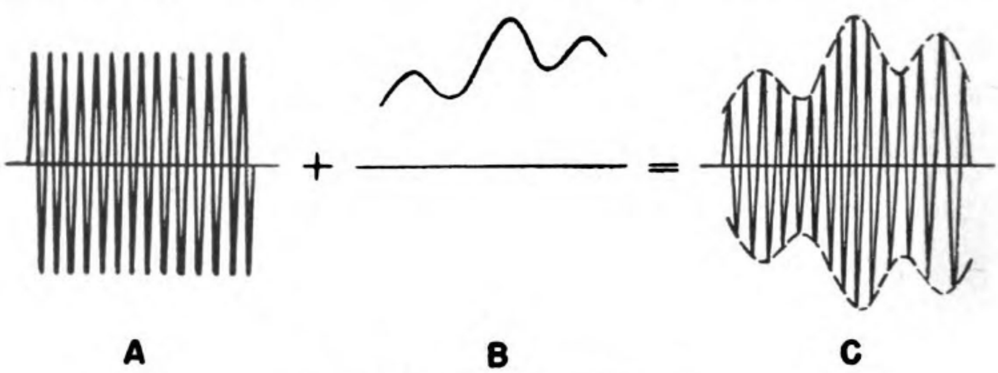


Figure 23.—Speech modulation.

phones. In the preceding chapter you saw this problem solved. All receivers have a detector circuit which eliminates the carrier current and produces an audio-frequency current similar in frequency and wave form to that in the transmitter's modulator circuit. When amplified, this audio-frequency current is applied to headphones or loud speaker. And the original sound at the transmitter—be it a speech, a songbird, or Alexander's Ragtime Band—is reproduced.

You'd rather hear some telegraphic code?

All right, figure 24 gives you in block diagram the system employing the modulated carrier wave (MCW).

This circuit is similar to the radio telephone circuit in figure 21. In this case, however, the microphone has been replaced by an oscillator which feeds an audio-frequency voltage of constant amplitude into the modulator input circuit whenever the key is down.

Sections *B* and *C* illustrate the voltage present in each unit. When the key is UP, the output modulator is ZERO. Since the power supply voltage is constant, the carrier amplitude is constant.

Section *C* illustrates what occurs when the key is operated to transmit letter "A" (International

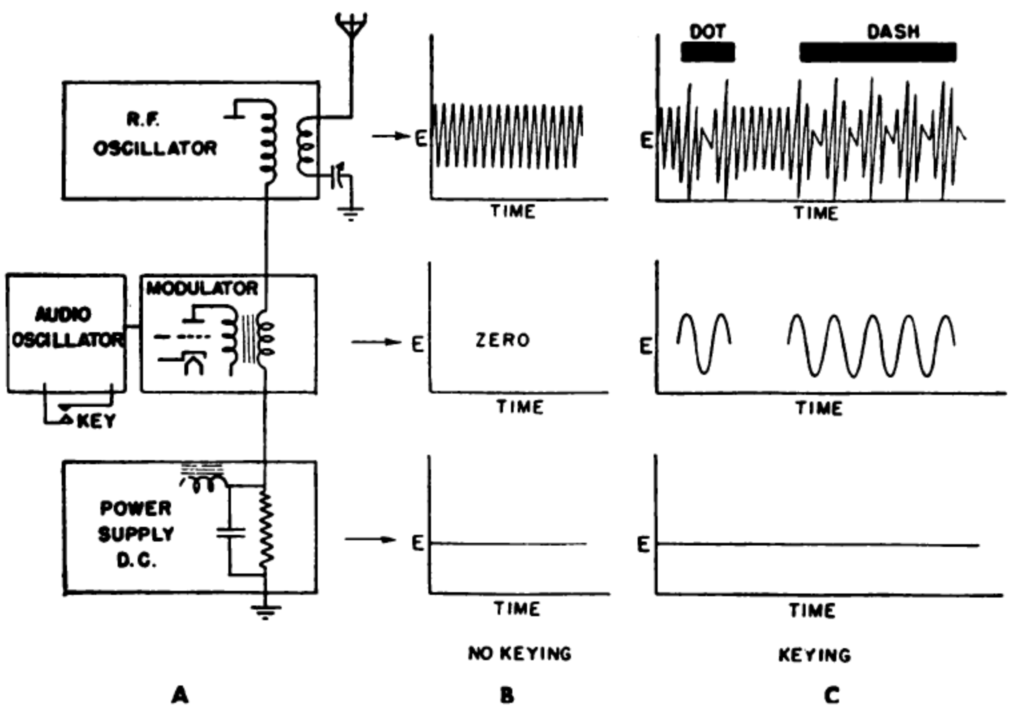


Figure 24.—MCW transmission.

Code). When the key is DOWN, the audio output of the modulator is impressed on the carrier.

Note that in this MCW system the carrier current is always present in the antenna when the transmitter is turned on. Pressing the key down modulates the carrier. In r-f circuits of another type of MCW transmitter in which a key produces a carrier current, the modulator circuit operates continuously. No carrier current is present in the antenna when the key is up.

The wave form of the carrier when the key is down, however, is the same in both systems. In figure 25, you have illustrated the carrier pattern obtained in the second type of MCW transmitter.

Given the same power output, MCW transmission does not have as great a sending range as straight CW transmission. And it differs from straight CW in two other important factors.

First, the sound produced at the receiver has

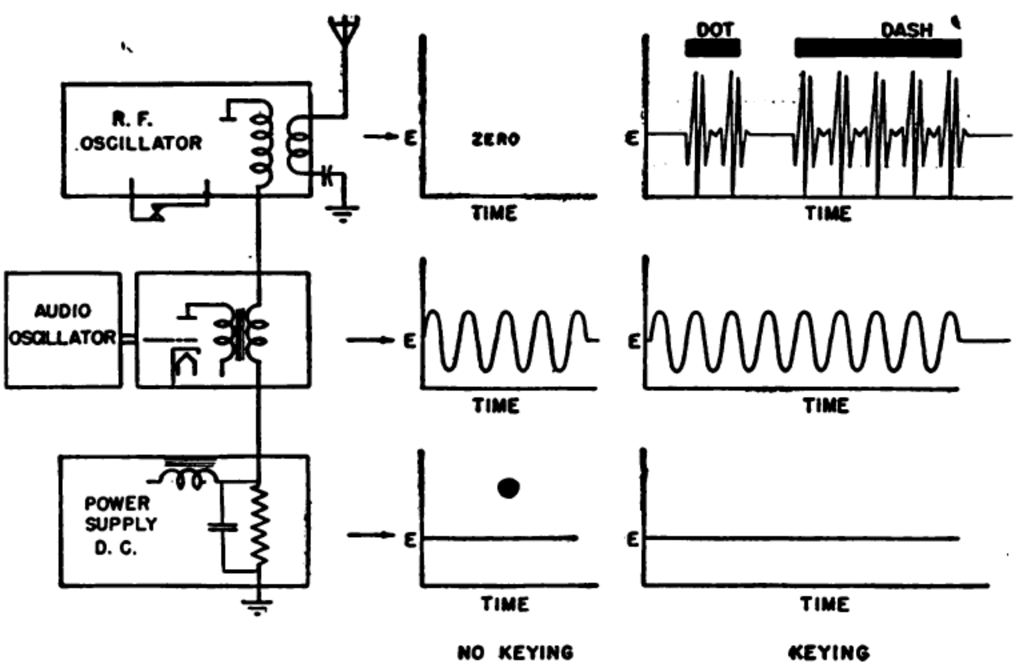


Figure 25.—RF keying of MCW transmitter.

the same pitch as the frequency of the audio voltage fed to the input of the modulator.

Second, this type of transmission results in a broader signal—a distinct advantage as it is easier to locate on the receiver.

It is also possible to receive MCW transmission on a conventional broadcast receiver if the carrier frequency is within tuning range of the receiver.

Because of its advantages, MCW is frequently used in transmissions between naval aircraft.

Meantime, you seldom modulate a modern

transmitter by varying the plate voltage of the oscillator—the frequency of an oscillator has a tendency to shift when its plate voltage is varied.

MASTER OSCILLATOR-POWER AMPLIFIER

When you read this heading, you read a mouthful! It's a good example of why you should learn your abbreviations in radio. Imagine a wireless officer in a Navy bomber under fire having to call to a technician, "Hey, Stanislaus, repair your master oscillator-power amplifier!" The chances are he'd whittle Stanislaus down to

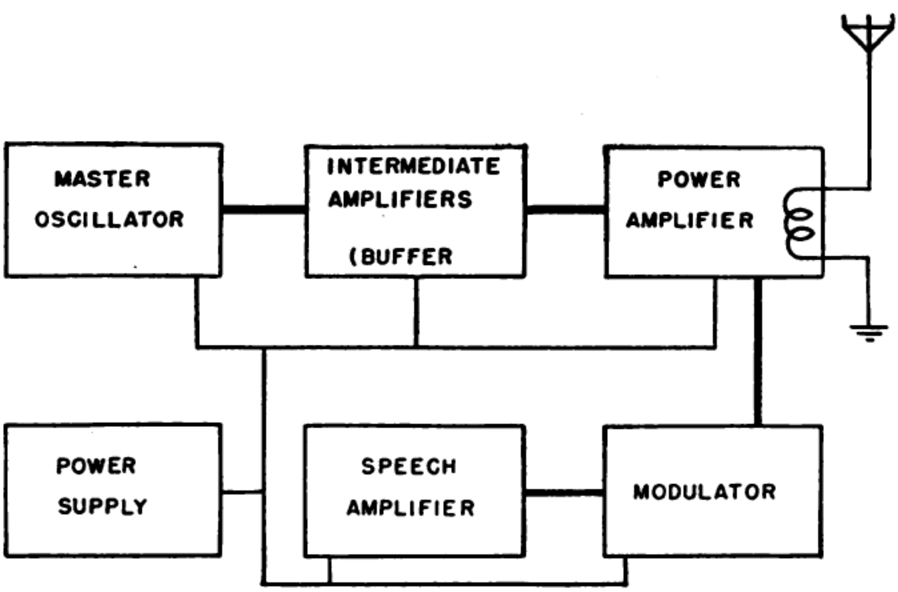


Figure 26.—Master oscillator-power amplifier transmitter.

"Stan," and, in action, the master oscillator-power amplifier becomes an M. O. P. A.

A block diagram of an M. O. P. A. transmitter is shown in figure 26.

In this transmitter the carrier current is generated in a low-powered MASTER OSCILLATOR which feeds the input circuit of a POWER AMPLIFIER.

Several intermediate stages of amplification are employed to bring the carrier current to the power output required for efficient transmission. These intermediate stages serve as a "buffer" between the oscillator and the final power amplifier stage. The SPEECH AMPLIFIER of the MODULATOR UNIT modulates the output of the power amplifier. Since the oscillator is isolated by the intermediate stages, the frequency REMAINS CONSTANT during the modulating process. MOST NAVAL AIRCRAFT USE THE M. O. P. A. SYSTEM.

Here are some other points to remember.

The vacuum tube oscillator generates current at a frequency known as the FUNDAMENTAL. Simultaneously, it generates weaker currents at frequencies which are MULTIPLES of the fundamental. You call these currents HARMONICS.

In transmitters which use an intermediate frequency (IPA) the fundamental or harmonics are used to "excite" the input of the INTERMEDIATE stages. This excitation extends the FREQUENCY RANGE of a transmitter.

In some types of transmitters it is necessary to maintain ONE definite frequency at all times. The oscillators used in such transmitters employ PIEZO-ELECTRIC CRYSTALS.

You may know that certain crystalline substances, when compressed and suddenly released, generate a minute alternating electrical voltage. Practically all crystals exhibit this phenomenal effect. In the electric phonograph, Rochelle salts is a compound commonly used. Tourmaline is sometimes employed, but for the purposes of frequency-control, QUARTZ was found the most satisfactory.

Apply voltage to electrodes on two parallel faces of the crystal, and a mechanical strain occurs in the crystal. In turn, this strain produces a voltage. The effect in the crystal is an oscillating current whose frequency is determined by the NATURAL FREQUENCY of the crystal. This in turn depends on the shape, size, and quality of the crystal, and you can see how crystals can be cut to meet any desired requirement.

Crystals heat with use, and the temperature varies with the shape of the crystal. Elaborate means are employed to house the crystal, the oscillator tube, and the circuit elements in thermostatically controlled fixtures to maintain a constant temperature.

In its holder the crystal is situated between two metallic plates so as to form a condenser, and in a simple circuit may be connected to the grid and cathode of a triode tube. You can see the resemblance between this arrangement and the "tuned-grid, tuned-plate" oscillator—the crystal serving as a tuned circuit. You call this crystal-using device a CRYSTAL OSCILLATOR.

Such oscillators maintain the transmitter on the one frequency desired, and are particularly dependable for their steady frequency output.

TRANSMITTING ANTENNAS

In general, transmitting antennas may be divided into two distinct types, the MARCONI and the HERTZ, named after the scientists who devised them.

Both of these antennas are of the STANDING WAVE OR RESONANT type.

Although it may be but a single wire, an antenna in effect constitutes a TUNED CIRCUIT in which the inductance L and capacitance C are not apparent in the form of inductors and condensers, but are properties of the LENGTH and SHAPE of the wire.

The length of an antenna must conform to (have the natural frequency of) the wave length to be radiated. STANDING WAVES are set up by the oscillations in an antenna when it is in resonance, and the proper length of the antenna may be calculated from the frequency and speed of the radio waves.

The STANDING WAVE (as differing from a wave which moves back and forth) is created when your antenna is in resonance with the frequency of the generator. The current in the center of the antenna is at maximum, and at the ends of the antenna is zero. For illustration, you might think of a loose and swinging clothes line describing a wide arc at the center and remaining fixed at the posts. The wide arcs of the swing represent maximum current, and the post-ends represent zero.

Antennas which operate on a constant current throughout their length basis have no standing waves, are nonresonant, and are given such designations as V and RHOMBIC ANTENNAS.

The HERTZ ANTENNA consists of a conductor suspended free from the earth—it may be a trailing wire—and it is known as a HALF-WAVE ANTENNA, its length calculated at half the wave length of the fundamental frequency.

The MARCONI ANTENNA consists essentially of one or more wires, vertical or partially horizontal, connected to the ground. The ground becomes an active part of the antenna system by making up for about one-half of the theoretically required physical antenna length. It's advantage is one of construction, although it is less efficient than the Hertz type, the latter being better adapted for SHORT WAVE work, while the MARCONI is a LONG WAVE system. In the MARCONI ANTENNA, the length is computed as ONE QUARTER of the wave length of the fundamental frequency.

NAVAL AVIATION ANTENNAS

Antennas used in naval aviation include the VERTICAL antenna, the T-antenna, and the INVERTED

L-antenna. Their names are descriptive, and you will easily recognize each type illustrated in figure 27.

You'll find the VERTICAL ANTENNA (trailing type) and the INVERTED-L on all types of patrol bombers. The T-ANTENNA is installed on fighter aircraft.

Lead-in wires connect these antennas to the operating positions, and they are insulated from the plane by porcelain and other kinds of insulations.

The vertical, trailing-type antenna, and the inverted L-type are generally used with high-

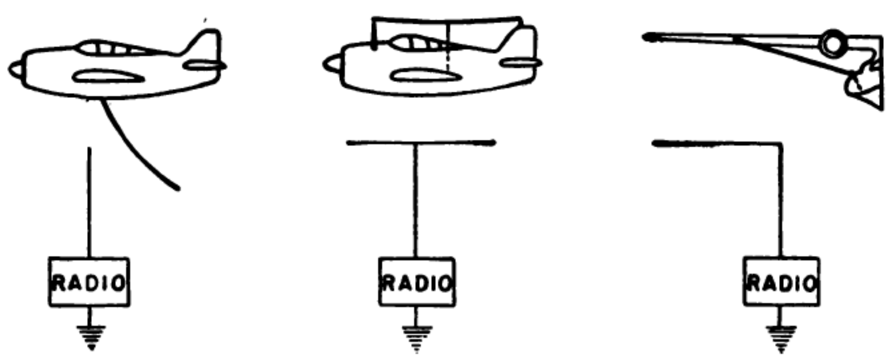


Figure 27.—Antennas.

power transmitters such as the GP and GO series. The T-type antenna is usually employed with low-power transmitters such as the GF series.

And now, before taking temporary leave of transmitters, a brief summary—

Your transmitter, in simplest form, consists of an OSCILLATOR and a KEYING DEVICE.

The oscillator generates a current of radio frequency known as a CARRIER CURRENT which produces an electromagnetic disturbance in space known as a CARRIER WAVE.

By means of a CONTINUOUS (CW) CARRIER WAVE, broken into short and long sounds by a key on the OSCILLATOR PLATE SUPPLY, code can be conveyed to a receiver. You call this process of message-sending RADIOTELEGRAPHY.

RADIOTELEPHONY, the process of speech and music transmission, depends on MODULATION, which is a matter of VARYING either the frequency or the amplitude of a CONTINUOUS WAVE.

In AMPLITUDE MODULATION, the continuous (carrier) wave is maintained at a constant frequency, and sound waves of AUDIO FREQUENCY are impressed on the carrier wave so as to modify the amplitude.

In FREQUENCY MODULATION, the carrier wave is maintained at a constant amplitude, while a wave of AUDIO FREQUENCY, impressed on the carrier, varies the carrier's frequency.

At the receiving end these MODULATED CARRIER (MCW) WAVES are detected, rectified and amplified—which means the waves of r-f frequency are eliminated, and the original audio-frequency current reproduced in loudspeaker or headphones, said current recreating the sound waves sent into the microphone.

In modern transmitters MODULATION is not effected by varying the oscillator plate voltage, but by means of a MASTER OSCILLATOR-POWER AMPLIFIER (M. O. P. A.).

CRYSTAL OSCILLATORS, employed to maintain a constant frequency, operate on the principle of the PIEZO-ELECTRIC EFFECT.

Given the same power output, MCW transmission does not equal the sending range of straight CW, but it has a broader signal which is easier to locate on a receiver, and is frequently used in transmission between naval aircraft.

Your naval aircraft favor the VERTICAL, the T-type, and the INVERTED L-antennas.

CHAPTER 4

ELEMENTARY RECEIVER

SENSITIVITY, SELECTIVITY, FIDELITY

SENSITIVITY refers to your receiver's ability to receive weak signals.

SELECTIVITY is concerned with the ability of your tuner to select one incoming radio signal and reject all others.

FIDELITY refers to your receiver's ability to reproduce FAITHFULLY the audio-frequency currents impressed on the modulated carrier wave (MCW) received.

Paste those words in your hat and keep your eye on them. They're the Three Musketeers or the Three Little Sisters, or the Three Inseparables of radio reception, and without one, and all of them, your receiver wouldn't be the instrument it should be.

Good sensitivity, of course, means good DX (long distance) reception. Good selectivity means sharp tuning. These two always go together—when the first finds too many tuned circuits on the line, it steps aside, so to speak, while the second selects the circuit wanted. Both then make clear the fact they've picked out and amplified the desired signal.

Fidelity, acting in conjunction with selectivity, sees to it there is no blurring, bleating, and cacaphony. An exact reproduction of the signal sent by the transmitter—that's the concern of fidelity.

Now what determines these three qualities?

Well, the sensitivity of a receiver is determined by the amount of radio amplification preceding the detector. The amount of radio amplification depends on the number and type of radio-frequency amplifying tubes employed, or, more simply, the number of stages of amplification. Also the type and location of the antenna is an important factor.

In the old time crystal set, (before amplifier tubes were invented) you had, of course, the simplest type of receiver—merely an aerial, an input tuning circuit, a detector and a pair of earphones. Long distance reception was a neighborhood novelty. The majority of these sets were about as sensitive as the Sphinx, and selectivity, too, was limited to a few nearby stations.

The selectivity of a receiver is improved by the addition of radio-frequency amplifiers, even as the set's sensitivity is increased. You can see how increased sensitivity (meaning better DX reception) gives you a stronger and sharper signal, and therefore better selectivity.

Also the selectivity of the INDIVIDUAL-TUNED COUPLING CIRCUITS between radio amplifiers improves your over-all selectivity. The over-all selectivity is greater than that produced by an individual-tuned coupling circuit.

As for fidelity, a great many factors in a receiving set have a bearing on faithful reproduction. One is the previously noted matter of a uniform response over a band of frequencies. If not obtained, the higher frequencies are "thinned out," and the signal becomes "boomy." A very important factor is the detector, which, if faulty, is often the source of poor reproduction. Your audio system (composed of an audio amplifier and your earphones or loudspeaker) must be able to reproduce accurately the audio-frequency components of the received signal.

MODERN RADIO RECEIVER

Today, the majority of broadcast receivers and many naval receivers are of the SUPERHETERODYNE type. The only other type in general use in naval aircraft radio installations is the t. r. f. (tuned radio frequency) receiver.

You'll study the t. r. f. and SUPERHETERODYNE receivers in this chapter.

First, however, a brief review of receiver theory.

The aerial-ground system collects the transmitted radio waves. The tuner selects the wave (or signal) desired. The reproducer changes the electrical energy to a perceptible form. And the detector changes the energy to a form whereby it can operate the reproducer.

By now you're able to identify these various parts with the instruments composing them. You are acquainted with the aerial-ground system which is connected to the tuning circuit LEAD-IN wire and an ANTENNA COUPLER, the latter, a STEP-UP TRANSFORMER. You can draw the schematic diagram of your TUNING CIRCUIT, including your inductance (the secondary of the antenna coupler) and condenser. You can locate your crystal detector, and connect up your reproducer (earphones). This gives you in diagram the simplest type of radio receiver.

You can make your first big improvement by replacing your crystal detector with a DIODE which acts not only as a detector, but a RECTIFIER. You can improve on the diode by erasing it from your diagram and installing a TRIODE complete with FILAMENT, PLATE and GRID circuits, and their batteries. Your triode gives you a big jump in DX reception. You'll have a "C" Battery, of course, for GRID BIAS, and you'll not forget a RHEOSTAT connected into your filament circuit for VOLUME CONTROL.

Now, wanting to improve your set's sensitivity, you think of the REGENERATIVE SYSTEM, employing "feed back" by means of a TICKLER COIL. This arrangement gives you a "three circuit" tuner, but it has a tendency to overdo the thing and start OSCILLATION in your tuning circuit, which causes your tuner to act as a transmitter, whereupon you hear caterwauling in your earphones. You can do without the cat-fight, so you discard the regenerative system in favor of the newer AUDIO-FREQUENCY AMPLIFIER TUBE.

Know where to connect it up? Correct. It follows your triode detector in the diagram, the plate of your detector connected to the grid of your audio-frequency amplifier through a coupling device, and the plate circuit of your amplifier including your headphones (or loudspeaker). What have you got? ONE STAGE of amplification.

Meantime you recognize in your vacuum tube another inherent advantage. As it serves as a RECTIFIER, why not use it to change power-line alternating current into direct current, thereby allowing you to operate your receiver on household current, and get rid of some troublesome batteries? Fine!

But wait a minute! PULSATING direct current won't do! Your plate must be supplied with STEADY direct current. What's the answer? FULL-WAVE RECTIFICATION! A STEP-DOWN transformer to heat your filament (which serves now as "heater" for the even-temperatured CATHODE SLEEVE), and a FULL-WAVE RECTIFIER TUBE (a DUO-DIODE will serve) with a FILTER CHOKE COIL and FILTER CONDENSERS across the output, and a DROPPING RESISTOR to provide the right amount of voltage to the plates of the tubes in the various circuits. Now you have a steady direct-current power supply, and your arrangement is a B ELIMINATOR. (Your cathode sleeve has helped eliminate the A BATTERY, and your C, or grid bias, battery may be eliminated by means of a VOLTAGE DIVIDER which gives your grid the proper negative charge.)

If you are able to diagram the above from memory, and do it with the necessary TRANSFORMER COUPLINGS, INDUCTANCES, CONDENSERS, RESISTORS, CHOKES and GRID LEAKS accurately represented (you might include an AERIAL TRIMMER, and be sure your POWER TRANSFORMER SECONDARY IS CENTER-TAPPED)—if you can do it on paper, congratulations!

However, you aren't expected to accomplish this feat. It's pretty short notice for such a test, and radio sets, like Rome, aren't built in a day. Don't feel chagrined if your diagram is balled up. So far you're only supposed to identify the functions of the various circuits, to recognize the various symbols, and to know the parts they play in the game. Each circuit, correctly diagrammed will be shown you presently in this chapter.

Meantime your receiving set, as outlined, would operate with a fair degree of sensitivity, selectivity, and fidelity. It sends to the museum the old crystal set with its catwhisker. It banishes the bulky "B" Battery. And with its audio-frequency amplifier, it increases the signal intensity enough to permit the use of a loudspeaker.

But room still remains for big improvements. Your audio-frequency amplifier has intensified the weak signal from the detector, but now a more powerful radio-frequency current is needed by the detector. Distant stations will otherwise be unable to transmit waves with sufficient energy to build up a signal which can be relayed to the audio amplifier. In other words, the need is for a further increase in sensitivity.

RADIO-FREQUENCY AMPLIFICATION

You'll recall the radio-frequency amplifier as one of many vacuum tubes. It comes into its own in the TUNING CIRCUIT of your receiver.

Look back at your receiving aerial. Each radio wave induces in your antenna a weak CARRIER VOLTAGE at a certain frequency. These voltages produce CARRIER CURRENTS which are known as SIGNAL FREQUENCIES.

You think of TUNING as the process of adjusting the condenser (varying the capacitance) to select a carrier voltage of a desired frequency and reject all others. The tubes in your receiver will amplify any voltage impressed on their input circuits, but they have no ability to select a signal of one particular frequency. The inductance and capacitance in your circuit, however, enable you to tune in signals of different frequencies. And it is the specific job of the radio-frequency-amplifier section of your receiver to amplify any one of these selected signal frequencies.

Figure 28 gives you in diagram your receiver input circuit.

You see represented your antenna coupler, the transformer's secondary winding forming your inductance. For capacitance you have a variable condenser. Current is fed to the grid of a triode of the indirect heater type. A bias resistor shunted by a bypass condenser is connected in the cathode circuit to provide a voltage drop for grid bias.

Weak CARRIER CURRENTS in the antenna flow in the circuit made up of the antenna, the primary winding of the transformer, and the ground.

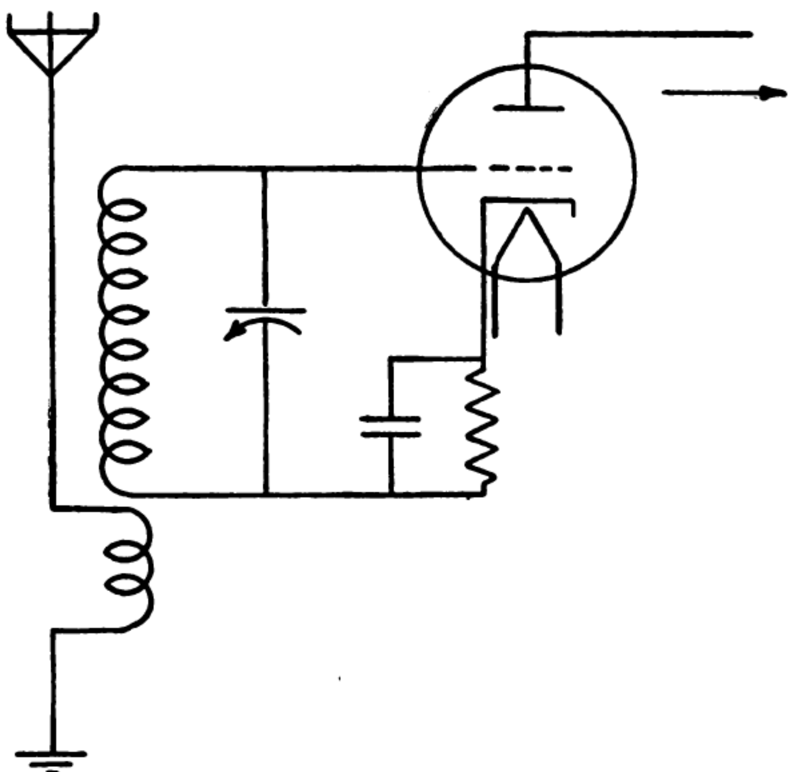


Figure 28.—Receiver input circuit.

Each carrier current in the antenna produces a VOLTAGE in the secondary winding. The combination of secondary winding and variable condenser increases the strength of one particular signal voltage.

The value of used inductance is determined by the portion of the FREQUENCY BAND at which signals are to be received. What is a FREQUENCY

BAND? A frequency band is that specific range of frequencies obtained by a variable condenser when used with a fixed value of inductance, or vice versa.

For a particular inductance the frequency coverage is governed by the maximum and minimum values of the variable condenser. With a fixed inductance and a condenser set for a definite capacity, only signals of one particular frequency will induce appreciable voltage in the secondary.

The tuned circuit in the secondary increases the strength of one desired signal voltage in regard to all others. Some of the undesired signals are much stronger in the antenna circuit—simultaneously with the reception of a weak, distant station, a powerful near-by station may be sending signals on approximately the same frequency. You therefore need a number of tuned circuits to reduce the relative strength of all undesired signals.

T. R. F. AMPLIFIER

The radio-frequency amplifier operates similarly to your audio-frequency amplifier. A small alternating voltage places an alternating charge on the grid of your tube. The grid controls the plate current in the tube—a small charge producing a large effect on the plate current. A transformer is employed to couple one radio-frequency amplifier tube to another in successive STAGES, as in audio-amplification. The transformer usually used for radio-frequency amplification is an AIR-CORE TRANSFORMER with a step-up winding. You will note its resemblance to the antenna coupler. As the secondary is tuned by means of a variable condenser, you will call it a TUNED RADIO-FREQUENCY (t. r. f.) TRANSFORMER. A stage of radio-frequency amplification using a tuned radio-

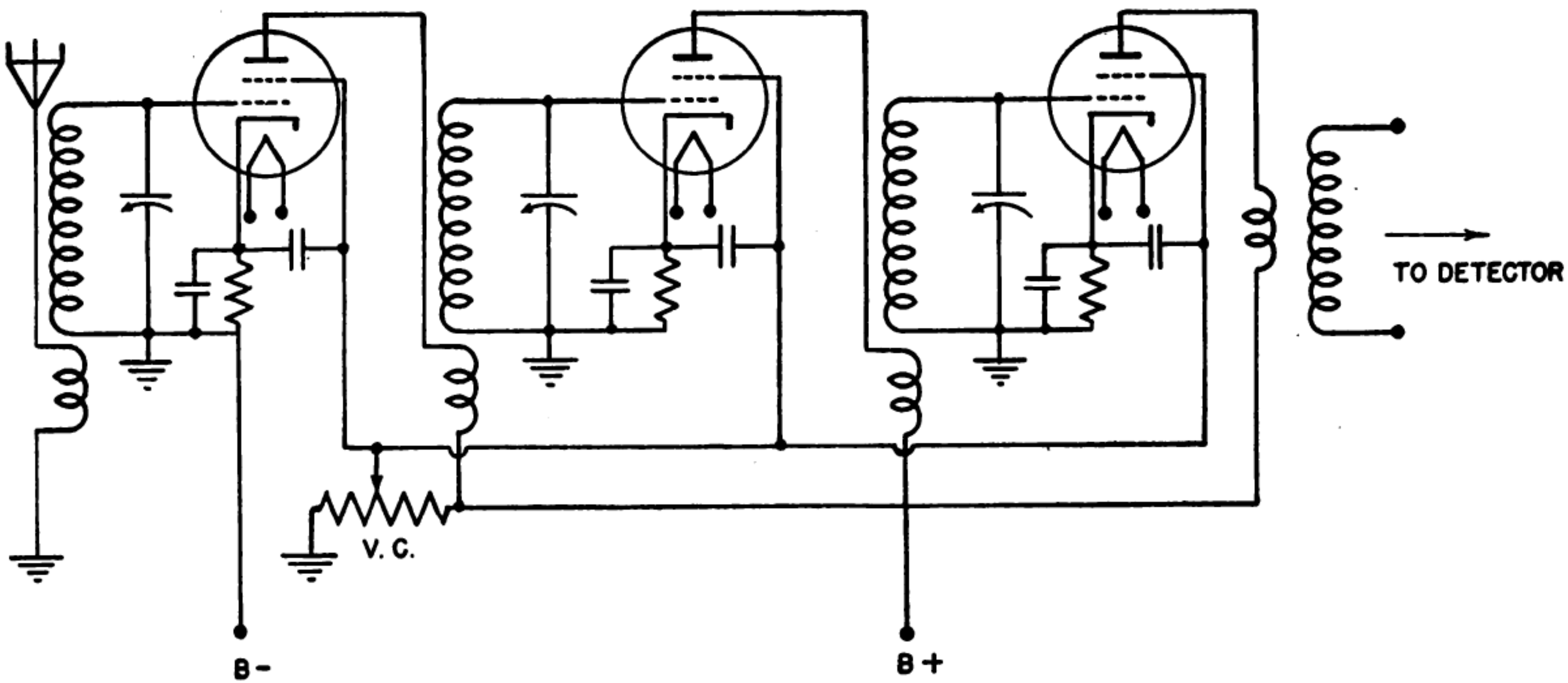


Figure 29.—Tuned radio-frequency amplifier.

frequency transformer with a variable condenser you will call one stage of TUNED RADIO-FREQUENCY AMPLIFICATION.

In figure 29 you have a schematic diagram of a tuned radio frequency amplifier.

The tubes used in this amplifier have four "elements" or electrodes. (Note the filament which heats the cathode is not counted as an electrode.)

Why are they used instead of TRIODES? Well, the triode has a low amplification factor with a tendency to "feed back," and the space charge in a triode wastes about 85 percent of the positive charge on the plate.

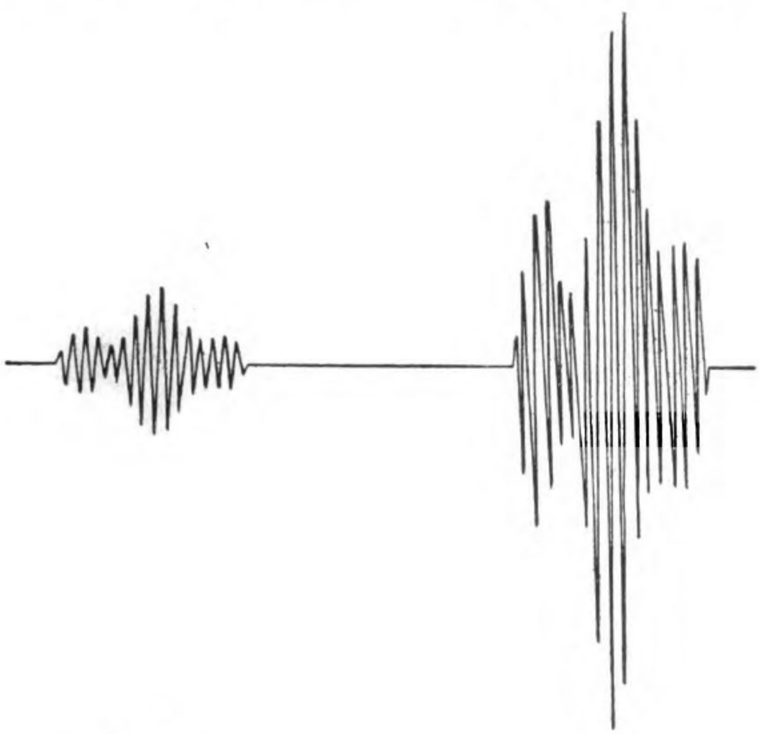
The TETRODE overcomes these drawbacks, having a SECOND grid placed between the original grid and the plate. This fourth electrode is called the SCREEN GRID. In effect, it serves as an electrostatic shield between the CONTROL GRID and the PLATE, thereby reducing what is technically called the "internal capacitance" of the tube. Thus feed-back and oscillation are prevented in your radio-frequency stages. The positive charge on the SCREEN GRID also serves to dissipate the space charge in the tube, and amplification is thereby increased.

The voltage applied to the SCREEN GRID may be used to control this amplification. Hence the POTENTIOMETER in the diagram, which acts as a RESISTANCE to "level off" the voltage placed across it, and gives you VOLUME CONTROL.

You'll observe that the VARIABLE CONDENSERS and COILS in each stage are identical. To facilitate tuning, these condensers are mounted on the SAME SHAFT and are rotated as a unit. The arrangement is known as GANGING, and you call them GANGED CONDENSERS.

By rotating the condensers to a definite position, you obtain a desired frequency. Signals in the antenna circuit at this frequency are thereby selected and amplified in each STAGE OF AMPLIFICATION. A signal voltage within the tuning range is amplified many thousand times by an amplifier of this type.

The FREQUENCY RANGE of your amplifier depends on the type of TUNING CONDENSER you use. You may also choose a different range by substituting



(A) (B)

Figure 30.—Carrier amplification.

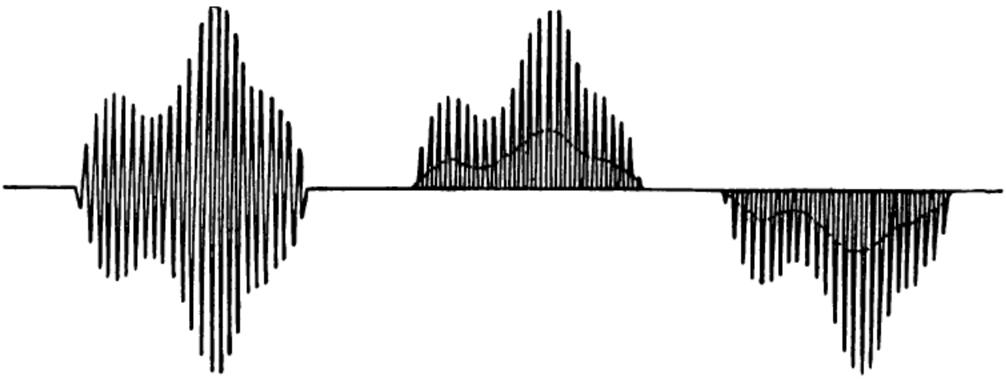
COILS with different inductance values. These coils are usually mounted on plugs so that you may change them readily. Making such a change, you would say you had altered the amplifier's TUNING BAND.

In figure 29 you saw three stages of tuned radio-frequency amplification. You call this device for amplifying radio-frequency currents your TUNED RADIO-FREQUENCY AMPLIFIER.

Now glance at figure 30 for a comparison between the INPUT and OUTPUT voltage of your amplifier.

The illustration shows you that a t. r. f. amplifier increases only the MAGNITUDE of a signal. The signal voltage at the OUTPUT *B* has the same WAVE FORM and the same FREQUENCY as the voltage in the antenna *A*. But the voltage, itself, as shown in the graph, has been amplified about 5 to 1. In actual operation, the amplification is as high as 5,000 to 1.

If a MODULATED CARRIER VOLTAGE, amplified to a high level, is fed to a loudspeaker, no sound results, as you know. Your loudspeaker can't



(A) (B) (C)

Figure 31.—Average current of a rectified carrier.

vibrate at carrier frequencies, and even if it did. the vibrations would not be audible. There remains the problem of creating an AUDIO CURRENT which has the same frequency as the carrier modulation. In other words, your r-f current must be RECTIFIED.

Figure 31 gives you a graph of the current produced by a modulated carrier voltage.

You see that the INDIVIDUAL carrier peaks are at different amplitudes because of modulation. Consider one positive carrier alternation. The current rises and falls in a POSITIVE direction. On the next alternation, the current increases and decreases the same amount in a NEGATIVE direction. The FORM of the two peaks is approximately balanced, and the AVERAGE current for a COMPLETE carrier cycle is zero.

In section *B* of figure 31, all negative carrier alternations have been eliminated by rectifying the carrier. You now have only a series of positive peaks, resulting in a pulsating direct current. The average current indicated in this diagram is not zero, but is approximately the value shown by the dotted line. Note, too, that this average current rises and falls at the frequency of modulation.

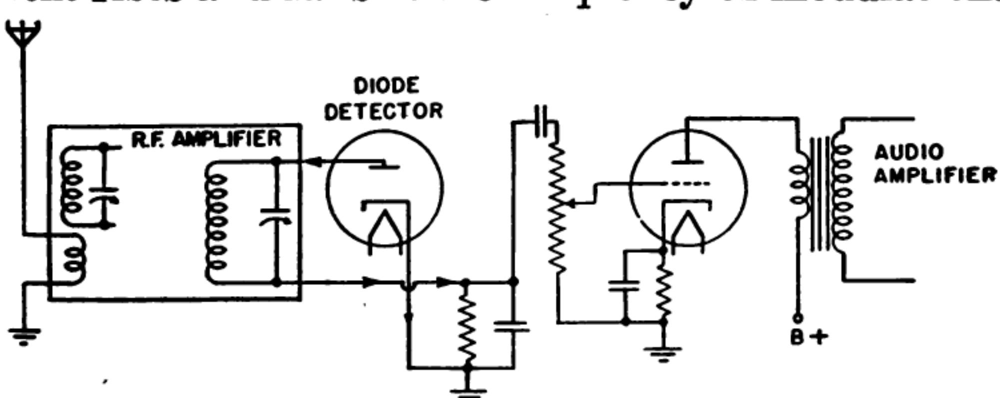


Figure 32.—Diode rectifier circuit.

In like way, all positive alternations can be eliminated, giving you a pulsating direct current with similar characteristics (section *C*). The average value of this current also conforms to the modulation frequency. The RECTIFICATION of a carrier current for the purpose of obtaining a pulsating direct current at modulation frequency you recognize by the term DETECTION. The tube well suited for this purpose is the DIODE.

Figure 32, illustrating a DIODE RECTIFIER CIRCUIT, shows you the hook-up of the DIODE DETECTOR.

The carrier voltage obtained from the radio-frequency amplifier section of the receiver (blocked in) is impressed across the plate and cathode of the diode. Connected in a series with the CATHODE and one side of the RADIO-FREQUENCY OUTPUT CIRCUIT, you have a high RESISTANCE shunted by a CONDENSER. This RESISTOR constitutes a LOAD CIRCUIT.

On each POSITIVE alternation of the carrier voltage, a pulse of current flows through the diode from plate to cathode, voltage developed across the LOAD RESISTOR is pulsating direct-current voltage. The condenser shunted across the resistor tends to "iron out" the r-f peaks.

Follow the modulation frequency of the carrier, and you'll notice that the voltage across the load

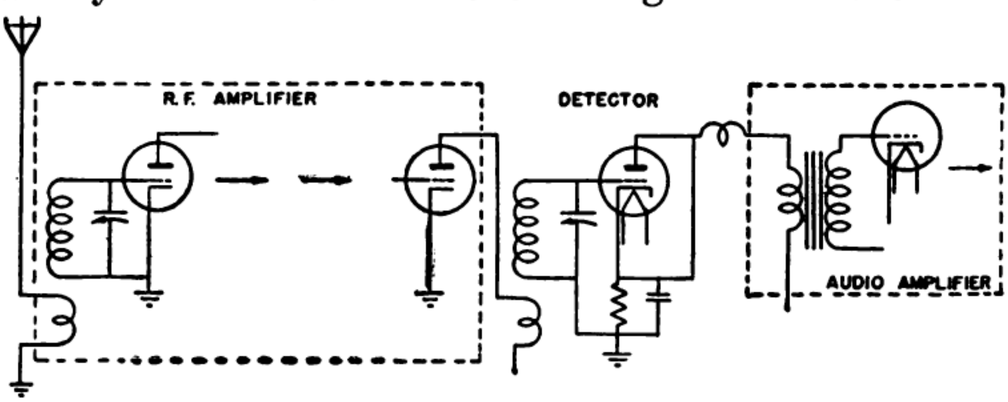


Figure 33.—Plate detector circuit (triode).

resistor varies with the average value of each peak. This pulsating voltage at modulation frequency goes to the input of the AUDIO AMPLIFIER and through the audio-amplifier system to headphones or loudspeaker.

You may also use a TRIODE as a rectifier of carrier voltage, provided you employ the proper amount of NEGATIVE GRID BIAS, as illustrated in figure 33.

Figure 34 shows you that a grid bias increases amplification, and you see represented in diagram the kind of rectification you'll obtain in a single stage. Examine the graph of the plate current variations on the E_g-I_p characteristics of the tube.

The variations in total grid voltage which result from the introduction of a carrier voltage produce similar variations in the plate current. The plate current varies in exactly the same manner as the grid voltage. This condition recurs in each stage of radio-frequency amplification. Make note, however, that the AVERAGE value of the plate current remains constant at all times. Only the INSTANTANEOUS values change.

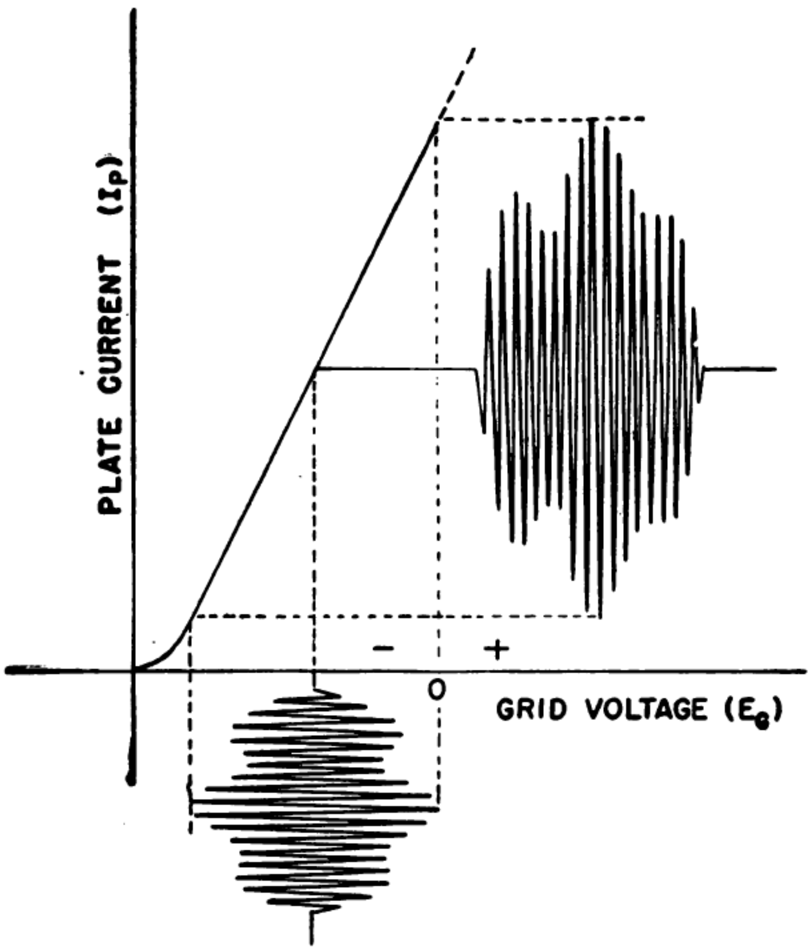


Figure 34.—Carrier amplification—single stage.

Now consider figure 35.

Here you have an illustration of the variations in plate current obtained by a high negative bias on the grid. When no alternating-current voltage is on the grid, the plate current is almost zero. The position on the characteristic curve at which the tube is now operating is referred to as a CUT-OFF.

The positive alternations of the carrier voltage produce similar pulsations in the plate current. The negative alternations, however, are beyond the cut-off, and so reduce the plate current to zero. The AVERAGE current, which pulsates at the frequency of carrier modulations, is represented by the dotted line.

The primary of your audio-frequency transformer changes these pulsations into an AUDIO

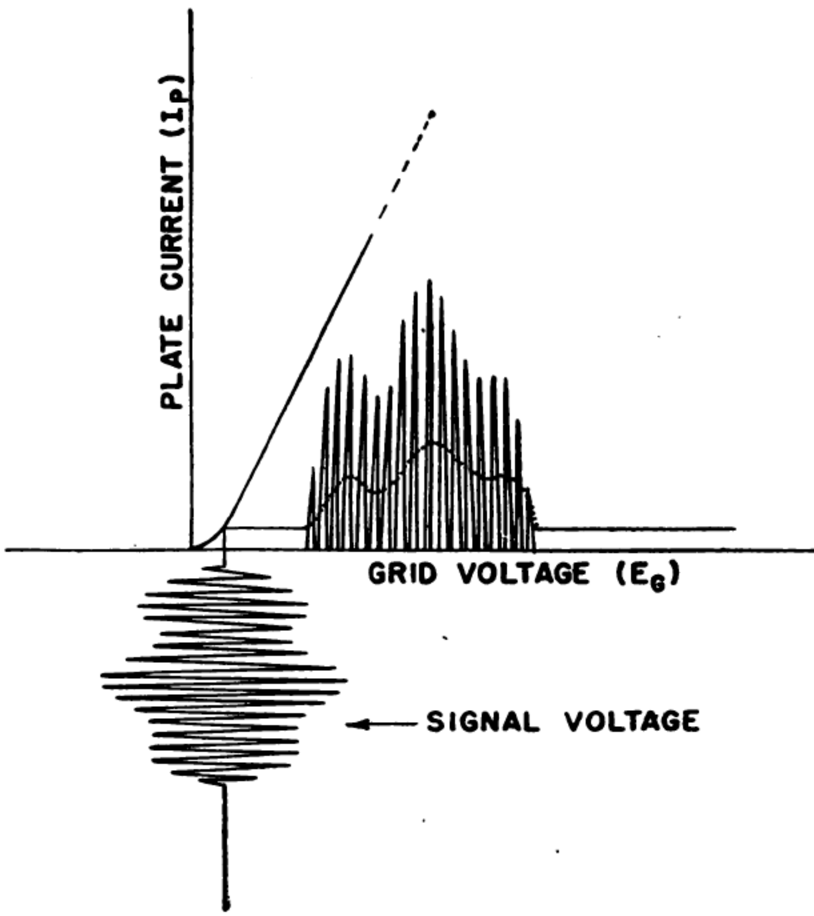


Figure 35.—Plate detection.

voltage of the same frequency at the secondary terminals of your transformer. Further amplification occurs in the remaining stages of the audio-frequency amplifier.

Now, although the principal circuits of your t. r. f. receiver have been developed to a point where they can receive modulated speech and ode signals of MCW, you are unable to receive ode signals transmitted as CW.

Since most code signals are transmitted on a CW, what is lacking in your t. r. f. receiver? What circuits are needed?

You already know how the CW code signal is transmitted by INTERRUPTING the carrier. At the transmitter a carrier wave is emitted whenever the key is down. The graph (fig. 35) shows the

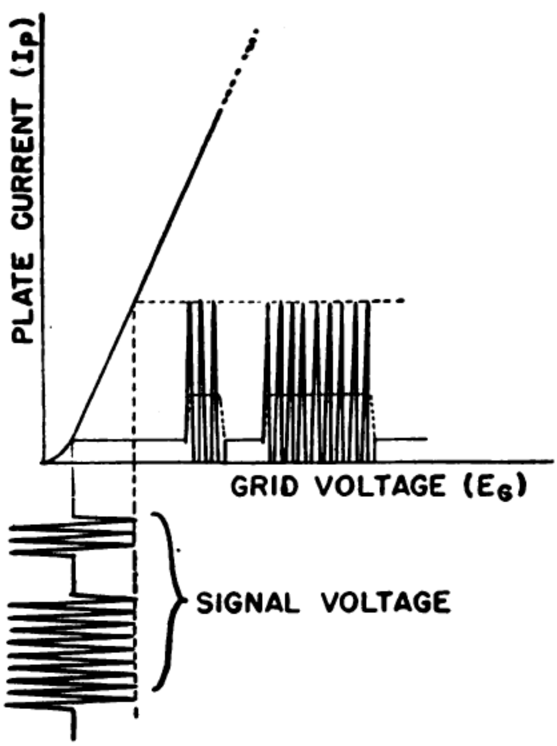


Figure 36.—Detection of CW code signals.

variance of the carrier voltage induced in the receiver antenna. This varying voltage is amplified in the usual way until it reaches the input of your detector.

Figure 36 shows you how DETECTION works.

Graphically you see the plate current variations which occur when the signal voltage reaches the detector grid. The dotted line illustrates the manner in which average plate current rises and falls. If you had a pair of earphones in the plate circuit, the diaphragm would be pulled inward on the "current rise" and would return to normal on the "current fall." This repeated action would produce "clicks" in your phones, BUT you would hear no other sound.

So you see that PLATE CURRENT VARIATIONS have no value at CARRIER FREQUENCY. It is necessary to produce an AUDIBLE sound during the interval of time when the transmitter key is depressed. To obtain this effect, your receiver must have HETERODYNE ACTION.

HETERODYNE ACTION

What does the term mean? Well, HETERODYNING is defined as the PRODUCTION OF BEAT NOTES OR CURRENTS BY MIXING TWO WAVES OR TWO ALTERNATING CURRENTS OF DIFFERENT FREQUENCIES. As applied to reception, you mix with the incoming signal another r-f current whose frequency is such that the DIFFERENCE BETWEEN THE TWO FREQUENCIES IS EQUAL TO THE DESIRED FREQUENCY.

For an easier understanding of HETERODYNING, a word about BEAT NOTES. Go back to the piano tuner introduced in chapter 1. Yes, the old duffer's still on the job. He's finished with sharps and flats, and now he's working on the white keys.

He sticks out a bony finger and strikes middle *C*. The sound has a frequency of 256 cycles per second. Now he strikes the key in front of it, *B* on the piano. This note has a frequency 240 cycles per second. Very pretty.

But the professor has no mercy on the neighbors. Putting two fingers together, he strikes *B* and *C* simultaneously, as in "Chopsticks." The sound resulting is neither *B* nor *C* but a MIXTURE of the two. The professor, listening carefully with a trained albeit whiskered ear, hears this new sound rise and fall in INTENSITY. He times his rise and fall, remarking that it occurs 16 times per second, precisely the DIFFERENCE between the frequencies of *B* and *C*.

You call this rise and fall the BEAT NOTE. And its frequency (or number of beats) is equal to the difference between the frequencies of the notes producing it.

All right, the manufacturing of beat notes is not limited to piano tuners and sound waves. It applies to any kind of waves of different frequencies "beating together." Varying light waves may produce beats. And RADIO WAVES of different frequencies may be similarly mixed together. HETERODYNING is the term given the latter process, and here's an example.

If two CARRIER VOLTAGES of different frequencies are placed on the GRID CIRCUIT of a detector, you get PLATE CURRENT VARIATIONS at a frequency equal to the carrier DIFFERENCE. Assume one voltage has a frequency of 1,000 kilocycles and the other 999 kilocycles. These will give you PLATE CURRENT VARIATIONS at 1 kilocycle (1,000 cycles). The frequency difference in this case is one of AUDIO frequency (that is, a frequency in the range between 30 and 15,000 cycles per second). You call this your BEAT FREQUENCY. The action of two carrier voltages producing this difference frequency is called HETERODYNE ACTION.

You can see how this heterodyne principle can be employed in a t. r. f. receiver to make CW code signals audible. Suppose a code message is being received on 1,000 kilocycles, with the AMPLIFIED SIGNAL VOLTAGE impressed on the GRID of the detector being the same. By means of a low-powered OSCILLATOR TUBE in your receiver, you feed a SECOND signal at 1,001 kilocycles to the detector GRID. The PLATE CURRENT of the detector will then VARY at the DIFFERENCE FREQUENCY, in this case

1 kilocycle. This AUDIO frequency, when amplified and fed to the earphones, will produce, of course an audible sound.

The device which generates the radio-frequency current to be mixed with the incoming signal is called a LOCAL OSCILLATOR. It operates on the pre-viously discussed "feed-back" principle of th regenerative detector. You will recall that in the regenerative system, current flowing in th plate circuit of a triode detector was "fed back" to the tuned circuit by means of a tickler coil This feed-back overcame the resistance of th tuned circuit. And the current of radio frequency flowing in the tuning circuit—in other words, th oscillations of the electrons—was built up.

You determined the frequency of the r-f cur-rent in the tuning circuit by the values of the in-ductance and capacitance (L×C). By adjusting the variable condenser, you varied the frequenc of the current in the tuner.

The method applies to your LOCAL OSCILLATOR By means of a transformer your oscillator's tun-ing circuit is inductively coupled to the gri circuit of the detector. Connect the variabl condenser of the oscillator with the variable con-denser of the detector circuit so that they rotat together (are GANGED) and you can select a capa-citance value which produces in your oscillator a radio-frequency current which at all times wil be a desired number of kilocycles above the fre-quency of the incoming signal. The differenc between these two frequencies is the BEAT FRE-QUENCY. And this will be an AUDIO frequenc which, when amplified, can operate you reproducer.

Here's a specific illustration.

Figure 37 gives you a simplified schematic diagram of a tuned radio-frequency (t. r. f.) receiver employing a local oscillator.

You have your aerial ground, your radio-frequency amplifiers, your detector, your local oscillator, and your audio-frequency amplifying system (which precedes the reproducer). The condensers, as illustrated, are ganged.

The input voltage created by the local ("beat-frequency") oscillator usually differs from the signal frequency by 1000 cycles. Now, if the RECEIVER is tuned to a frequency of 2000 kilocycles,

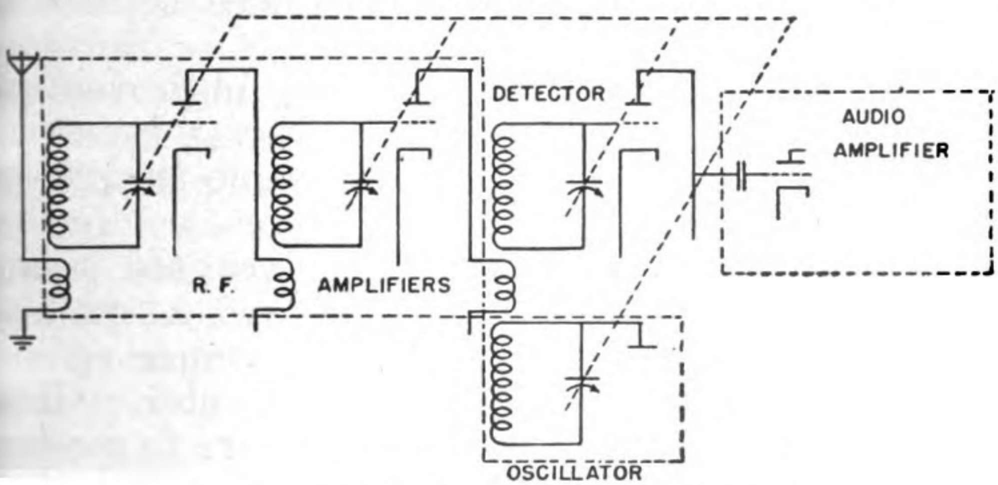


Figure 37.—T. R. F. receiver for CW code reception.

the beat-frequency oscillator will feed a signal of 2001, or 1999 kilocycles to the detector. This gives you a BEAT FREQUENCY of —? 1 KILOCYCLE. And the 1 KILOCYCLE beat-frequency in the detector plate circuit is amplified in the AUDIO AMPLIFIER to produce a 1000 CYCLE (1 kilocycle) tone in the headphones.

By means of a local oscillator, your t. r. f. receiver is now capable of CW code reception.

SUPERHETERODYNE RECEIVER

When you talk about "super-hets" you're a long, long way from that little old, catwhiskered crystal set with the bric-a-brac up in the attic.

You've seen the innovation of the diode detector, and DeForest's triode (advertised as the wonderful "Audion"). You've watched the development of DX reception by means of amplification. You've seen the batteries go out and the old roof aerials come in. And now, with the inclusion of radio-frequency amplifiers and audio amplifiers, of full wave rectifiers and feed-back circuits and local oscillators, your receiver has increased its sensitivity, selectivity, and fidelity to a point where improvement seems impossible.

No, there is always room. Science refuses to stand still.

Your t. r. f. RECEIVER was a big improvement, and is used today in the Navy. NAVAL RECEIVERS OF THE RU SERIES ARE TUNED RADIO-FREQUENCY RECEIVERS.

Commercial t. r. f. receivers advertised a new high in TONE CONTROL, and featured AUTOMATIC VOLUME CONTROL (A. V. C.) as assurance against "fading"—a device to be discussed later. Great as were these improvements, the t. r. f. receiver retained several undesirable features. The main drawback concerns sensitivity. The receiver "tunes sharply" but in so doing narrows its reception range.

To obtain maximum sensitivity and selectivity, your tuning circuit must have a NATURAL FREQUENCY that is exactly equal to the frequency of the TRANSMITTER. The broad coverage of the t. r. f. tuning circuit—including all frequencies in the broadcasting range between 550 and 1600 kilocycles—makes this ideal condition impossible. Some of the sensitivity and selectivity are thereby lost.

If you had a separate t. r. f. amplifier circuit for each frequency selected, a perfect condition could be obtained, but your receiver would obviously fill a room. Studying the problem, radio engineers saw another answer.

• Why not, instead of a separate t. r. f. amplifier circuit for each frequency, have ONE t. r. f. circuit tuned to a PREDETERMINED frequency? Then select the incoming signal desired, change the frequency of the signal current in the receiver to the predetermined frequency, and feed it into the t. r. f. amplifier. Thus you can use t. r. f. transformers which operate at only one frequency without the necessity of a separate set for each incoming frequency. In this way you employ the advantages of t. r. f. reception, and at the same time sensitivity and selectivity are greatly increased.

The result was the SUPERHETERODYNE RECEIVER popular today in Navy and commercial use. It is more selective than the t. r. f. receiver which is unable to have uniform selectivity over a wide frequency range. Employing the principle of beat notes, it provides, without complicated coupling circuits, a means of CONSTANT selectivity over a WIDE FREQUENCY RANGE. As it increases sensitivity and selectivity, it also increases fidelity. So you find it serving, "top performance," in the Navy.

NAVAL RECEIVERS OF THE A. R. SERIES ARE YOUR SUPERHETERODYNES.

In figure 38 you have the simplified schematic of a superheterodyne receiver.

You assume from this diagram that the signal from the antenna is fed to a single stage of radio frequency amplification. The selected signal is then applied to the input of a FIRST DETECTOR. Here the incoming signal MIXES with the signal generated by the LOCAL OSCILLATOR (the first detector tube is also called the MIXER TUBE) and the BEAT FREQUENCY SIGNAL is produced. Tech-

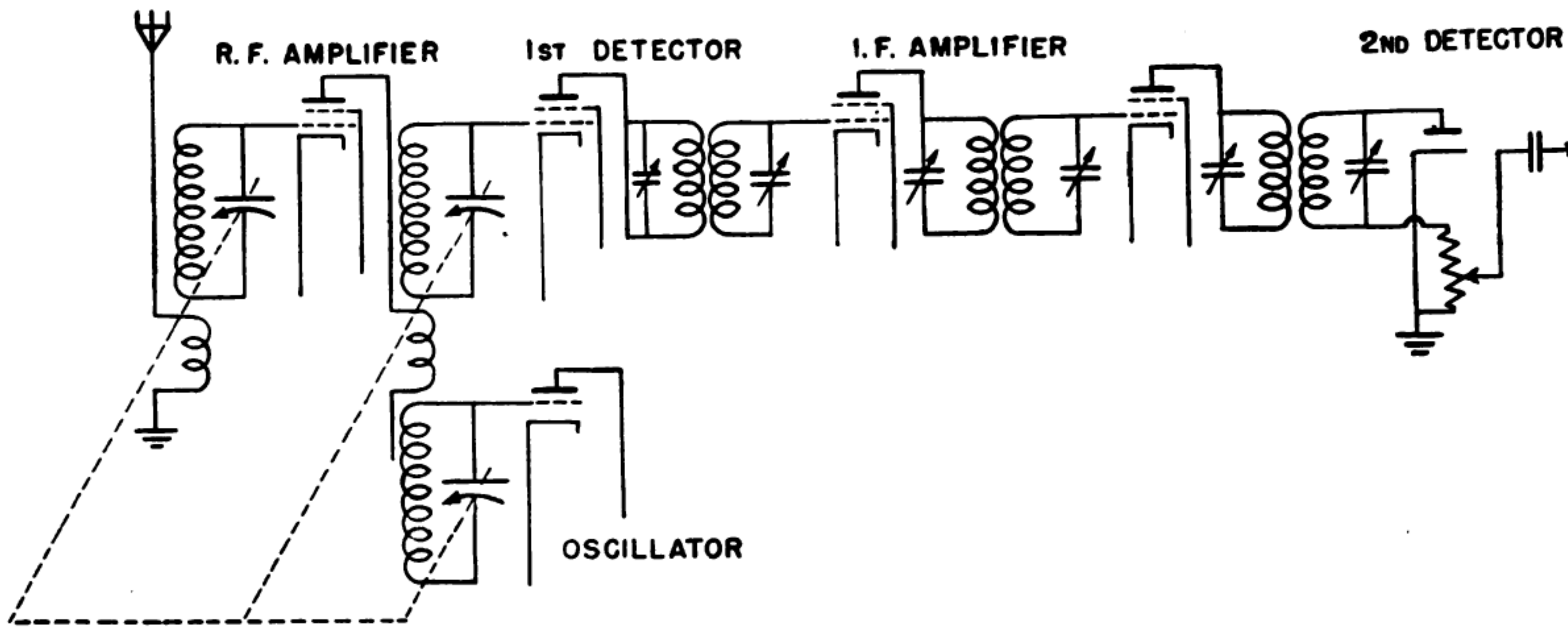


Figure 38.—Simplified schematic—superheterodyne.

nically speaking, you call the beat frequency signal the INTERMEDIATE FREQUENCY (i-f) SIGNAL.

The INTERMEDIATE FREQUENCY is usually of a frequency lower than the frequency of the incoming signal. In other words, the beat-frequency current which comes out of the first detector (mixer) tube is a radio frequency current of a lower frequency than the original transmitted frequency received.

This INTERMEDIATE FREQUENCY signal is now applied to an INTERMEDIATE FREQUENCY AMPLIFIER for further amplification. The i-f amplifier, consisting of a tetrode and i-f transformer, is pretuned to this fixed i. f.

The MODULATION present on the signal in the antenna is reproduced on the i-f signal which is amplified by the intermediate frequency amplifier and impressed on the input of a SECOND DETECTOR. The AUDIO CURRENT created in the plate circuit of the SECOND DETECTOR conforms in frequency and wave-form with the modulation on the original signal. The audio-frequency section of the receiver (not illustrated) is similar to that of your t. r. f. receiver.

The chief advantages of a "super-het" lie in the characteristics of the i-f AMPLIFIER. The frequency of this amplifier, being LOWER than that of the original signal received, proves advantageous because LOW-FREQUENCY tuned circuits are HIGHLY SELECTIVE. Also it is easier to obtain higher GAIN (over-all amplification) with low-frequency circuits.

Also, when an amplifier operates at a FIXED frequency, you find it an easy matter to "peak" or ALINE the individual stages for maximum amplification at one frequency. This is not the case with your t. r. f. amplifiers, for their stages may not remain in ALINEMENT during the tuning procedure—alinement being the process of adjusting the tuned circuits of a t. r. f. receiver so that all of them have the same natural frequency.

In your t. r. f., discrepancies of variation may be overcome by TRIMMER CONDENSERS connected across each variable condenser in the tuning circuits. The trimmers are adjusted to compensate for variations, and make the natural frequency of each tuning circuit identical. This method of matching up the tuning circuits in your receiver is called ALINEMENT. It is not necessary in your "super-het" receiver.

With a BEAT FREQUENCY OSCILLATOR CIRCUIT, your superheterodyne is able to receive "CW" code signals. So employed, the oscillator feeds a signal into the GRID of the SECOND DETECTOR, which is also the OUTPUT STAGE of the intermediate frequency amplifier.

Your beat frequency oscillator, in this case, is not variable as in a tuned radio-frequency receiver. It generates a signal on a fixed frequency of 1 kilocycle above or below the frequency of the i-f amplifier. Intermediate frequency signal and oscillator signal "beat" to form a 1 kilocycle AUDIO CURRENT in the PLATE CIRCUIT of the SECOND DETECTOR. This, of course, is amplified by your audio-frequency amplifier, and so operates your headphones.

MANUAL VOLUME CONTROL

Now consider another problem of radio reception—VOLUME CONTROL.

Volume, as you know, means the loudness or intensity of the reproduced signal. With your old-time crystal set and your receivers of the Prohibition Era (you recall the old loudspeaker atop the box?), volume was pretty much a matter of what you could stand. You'd hear a distant station as a whisper, then suddenly a blare. Nearby stations might come in with a blast that would take out grampa's teeth. Those old receivers did much to name the era the "Roaring Twenties." They had plenty of volume, but were liable to wake the baby at the wrong time, and with volume you generally prefer quality, not quantity.

Tuned radio-frequency receivers and the advent of the super-het practically eliminated the uproar. How was the volume situation brought under control?

In battery sets, a method was developed whereby a RHEOSTAT regulated the current of the detector's filament, thereby controlling the temperature of the filament, hence the number of electrons emitted. Electron emission controls the flow of plate current in the plate circuit, and this current in turn controls the intensity of the signal in the reproducer.

In sets operating on power-line supply, the filament current, you recall, must remain constant and the tube employs a cathode sleeve. Volume was controlled by a POTENTIOMETER of high resistance across the secondary of the first audio transformer.

Another method used with the indirect-heater-type tube was a GRID-BIAS RESISTOR in series with a RHEOSTAT, the latter being varied to vary the charge on the grid, of the radio-frequency amplifier tube. This method of making the grid more or less negative controlled the electron flow from the cathode, thereby controlling amplification.

Other devices were engineered, but in general three methods remain in favor.

The first consists of controlling the strength of the incoming signal—as it is applied to the input circuit of your amplifier. In t. r. f. receivers, this is done by varying the incoming signal—

technically speaking, the input voltage—to your radio-frequency amplifier. In superheterodyne receivers, the signal input to the intermediate frequency amplifier may be varied.

The second method involves changing the audio voltage impressed on the audio amplifier. This means of control is employed by both t. r. f. and superheterodyne receivers. A simple potentiometer circuit is used to vary the impressed signal voltage, as previously described.

The third method is that most commonly used today. It consists of varying the over-all amplification or "gain" of the receiver. In t. r. f. receivers this is accomplished by varying the SCREEN GRID voltage on the radio-frequency amplifier tubes. Since the gain of the amplifier depends on screen-grid voltage, the result is easily achieved. As for your superheterodyne receiver, volume control is acomplished by varying the screen-grid voltage of your intermediate frequency amplifiers.

You may also vary the gain of your amplifier by varying the BIAS on the CONTROL GRID of the tubes in all amplifier stages. A higher NEGATIVE grid bias will lower the over-all amplification. You may use this grid-bias method on the radio-frequency stages of a t. r. f. receiver, or on the intermediate-frequency stages of a super-het.

As the controls are operated by hand the various methods discussed come under the designation, MANUAL VOLUME CONTROL.

In figure 39 you have a simplified schematic of a typical manual volume control circuit.

Ingenious as is the type of circuit diagrammed, it does not settle the problem of volume control, however. It is a long step forward in radio progress, and a fine improvement, for instance, in your household receiver, permitting you to softpedal the program when baby is asleep, and to louden the opera without knocking out grandpa's upper teeth. But aircraft radio reception is another matter.

To begin with, certain areas are better for reception than others. And your AIRCRAFT radio is TRAVELING. Once in the air, it's going places, and it isn't traveling at any slouchy speed, either.

Even in your household radio you may still get an unexpected blast from one station, then dial into another as gentle as a piccolo solo. Why?

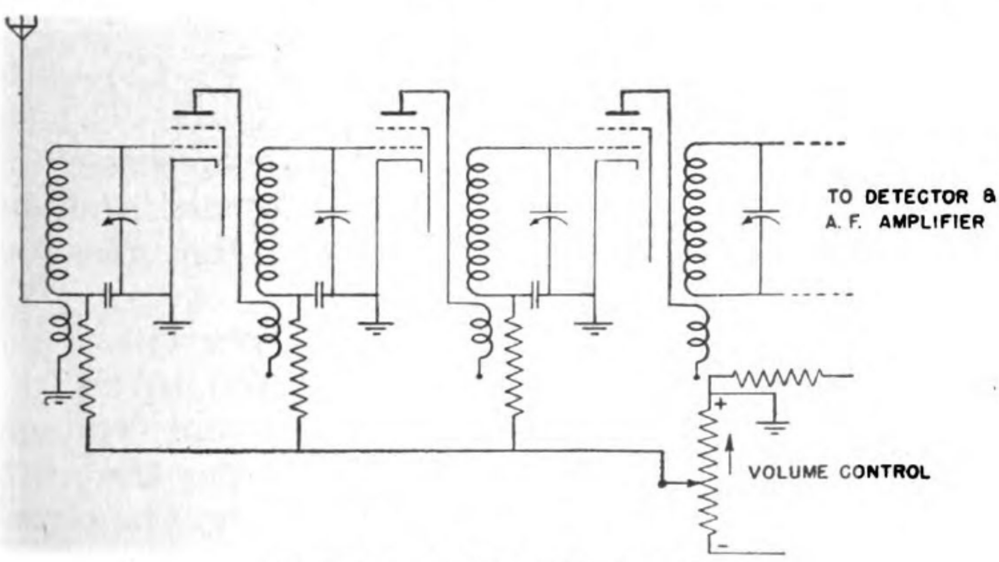


Figure 39.—Volume control circuit.

But you know that certain weather conditions affect reception, and so do geographical conditions. You may have noticed the latter when driving in your car, you wind down a mountain, enjoying your car radio; then the program goes to pieces in a valley, or loudens unexpectedly in the next county. Maybe there was a thunderstorm or an iron mine in the vicinity. At any rate, you had to make constant adjustment of the dial, and perhaps you gave up in annoyance.

Aviation radiomen do not have time for constant fiddling with a volume-control knob.

As you fly over an area of low signal strength, the volume of sound fades out. Zoom in another direction, and the volume loudens. Five hundred miles farther on, the signal may rise and fall, fading in and out with maddening variation. It's your old friend, the "Heaviside Layer," you may say, and if you had to turn the dial every time the volume changed, you'd want to kick your receiver in the Heaviside Layer.

Radio engineers found the answer for you in AUTOMATIC VOLUME CONTROL.

A. V. C.

Automatic volume control (A. V. C.)—also called automatic gain control (A. G. C.)—is simply a device which automatically increases the signal strength when it comes in weak, and decreases the signal strength when it becomes too loud.

The method is fairly simple. A portion of the signal voltage usually before it is fed to the detector, is RECTIFIED to a direct-current voltage. The greater the signal voltage, the larger the rectified direct current voltage. The smaller the signal voltage, the less the direct-current voltage. This rectified direct-current voltage is then fed to the grid returns of the amplifying tubes which are negatively biased.

A greater signal voltage increases the rectified direct-current voltage and make the grids more negative. In turn, this greater negative charge on the grids DECREASES the amplification of the tubes.

The converse is true when a smaller signal voltage, yielding a weaker direct-current voltage, places less negative charge on the grids and thereby INCREASES the amplification.

It is a case of much being made to yield little, and little being made to yield much. In effect, a weak current, rectified, creates only a small grid bias voltage, thereby increasing amplification. And a powerful current, rectified, creates a strong grid bias which decreases amplification.

There are several means of obtaining automatic volume control. One method is illustrated in figure 40.

In the circuit diagrammed, the VOLTAGE OUTPUT of the AMPLIFIER is kept CONSTANT for DIFFERENT VOLTAGE INPUTS, the gain of the amplifier being

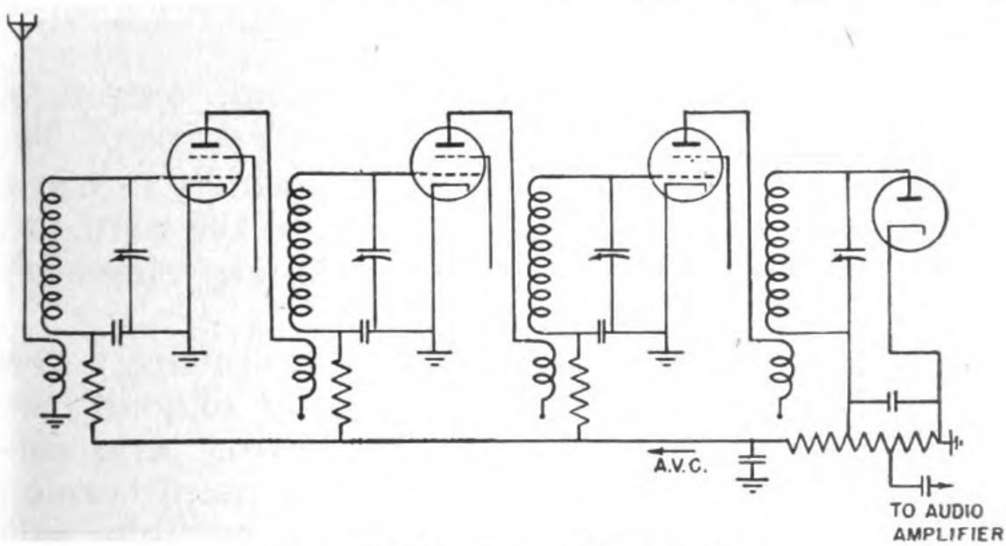


Figure 40.—Automatic volume control.

made to depend on the strength of the INCOMING signal. As previously described, this is accomplished by rectifying the AMPLIFIER OUTPUT to obtain a direct-current voltage which is applied to the AMPLIFIER CONTROL GRIDS. In this way the gain is controlled.

Examine the diagram and you'll see that the amplifier output feeds a DIODE RECTIFIER. The pulsating direct current produced passes through a BIAS RESISTOR. The direct-current voltage developed across this resistor is proportional to the strength of the signal in the antenna. As CONTROL GRID BIAS, a part of this rectifier voltage is applied to the amplifier tubes. An increase in signal strength results in additional negative bias, and increasing the negative bias DECREASES the amplifier gain.

When no signal is being received, the amplifier output is ZERO; you have no voltage across the bias resistor. Under this condition, the amplifier tubes have NORMAL bias, and the over-all gain of the amplifier would be maximum. When a signal is received, the amplifier output is rectified, and a direct-current voltage appears across the bias resistor. This voltage reduces the over-all gain of your amplifier.

What determines, then, the actual output of sound? The balance between TWO FACTORS. The magnitude of the INPUT VOLTAGE, which TENDS to increase the AMPLIFIER OUTPUT. And the reduction of amplifier gain when there is any tendency toward such an increase.

In summary—A weak signal, producing a LOW amplifier output, creates a low value of grid bias, and produces MAXIMUM amplifier gain. And, conversely, a strong signal increases the amplifier output and the grid bias, thus reducing amplifier gain to a MINIMUM.

(You might note that the amplifier output is not proportional to the signal input because the high bias voltage developed reduces the gain of the amplifier. Strong signals ACTUALLY produce slightly more volume than weak signals, but the DIFFERENCE is small because of A. V. C. action.)

IN CONCLUSION

Your SUPERHETERODYNE is now quite a receiver. It improves on your t. r. f. type by an increase in sensitivity and wider selectivity. Its sensitivity permits, in commercial sets, the abolition of awkward aerials, the antenna being included in the cabinet. While selectivity is increased, your set tunes sharply. Interference and fading are greatly reduced. Constant manipulation is eliminated as manual volume control is replaced by A. V. C.

CHAPTER 5

FREQUENCY MEASUREMENT

HOW TO LAND ON MOUNT ARARAT

Back in early times the navigators did their best with compass, log and lead, but they had no way of CHECKING their readings. A compass might become magnetized, or a lead line might shrink in the sun, and the results were often disastrous.

There isn't any record of the measuring instruments used by Old Man Noah, but they seem to have been a trifle out of kilter, for legend has it that he beached the "Ark" on top of Mount Ararat. You'll agree that a barren mountaintop somewhere in Armenia was an odd landing place for a menagerie, and the Old Man must have had some trouble getting the "Greatest Show on Earth" down to town.

In the case of a modern Navy aircraft, such an off-the-trail landing might prove embarrassing. To spare themselves such predicaments, Navy flyers take and give advice by means of radio, and they check their receivers and transmitters by FREQUENCY MEASUREMENT. These measurements are made by FREQUENCY MEASURING INSTRUMENTS.

And one of the most important is the CRYSTAL FREQUENCY INDICATOR, abbreviated C. F. I.

CRYSTAL FREQUENCY INDICATOR

The crystals used in radio are generally QUARTZ CRYSTALS. They are a whole lot more dependable than a two-dollar glass ball and the visions of some tea-room waitress in imitation Gypsy costume.

Consider the OSCILLATOR which controls your transmitter. The slightest change of values in your GRID CIRCUIT would endanger the accuracy of the FREQUENCY which must be absolutely maintained in aircraft communications. Quartz crystals are so dependable that in nearly all aircraft transmitters they are used to control the frequency. You learned about the special ability of quartz crystals to develop an oscillating current and act as a tuned circuit when you studied the PIEZOELECTRIC EFFECT. In such a crystal circuit you have an oscillating current whose frequency is determined by the NATURAL FREQUENCY of the crystal, and QUARTZ CRYSTAL OSCILLATORS are noted for the STEADINESS of their frequency output.

Because of their high dependability quartz crystals are also used as a FREQUENCY MEASURING DEVICE.

You use a frequency measuring device if you wish to set your receiver or transmitter to a PREDETERMINED FREQUENCY and do it ACCURATELY. You also use it to measure the frequency of an INCOMING SIGNAL.

You may use a receiver or transmitter's DIAL CALIBRATION CURVES to set them to an APPROXIMATE frequency. Tuning by means of "turning the knob" is quite simple. But for ACCURACY you require a frequency measuring device, and you employ your CRYSTAL FREQUENCY INDICATOR.

How does it operate?

The crystal frequency indicator (CFI) used in naval aviation radio is a low-powered, miniature transmitter. It differs from the main transmitter in one important aspect. It is adjusted to generate an EXACT SIGNAL of a KNOWN AND DEFINITE FREQUENCY within its frequency limits of 195 to 20,000 kilocycles.

Now assume that you are required to transmit a message on exactly 1010 kilocycles. All right. The main transmitter is set to a frequency of

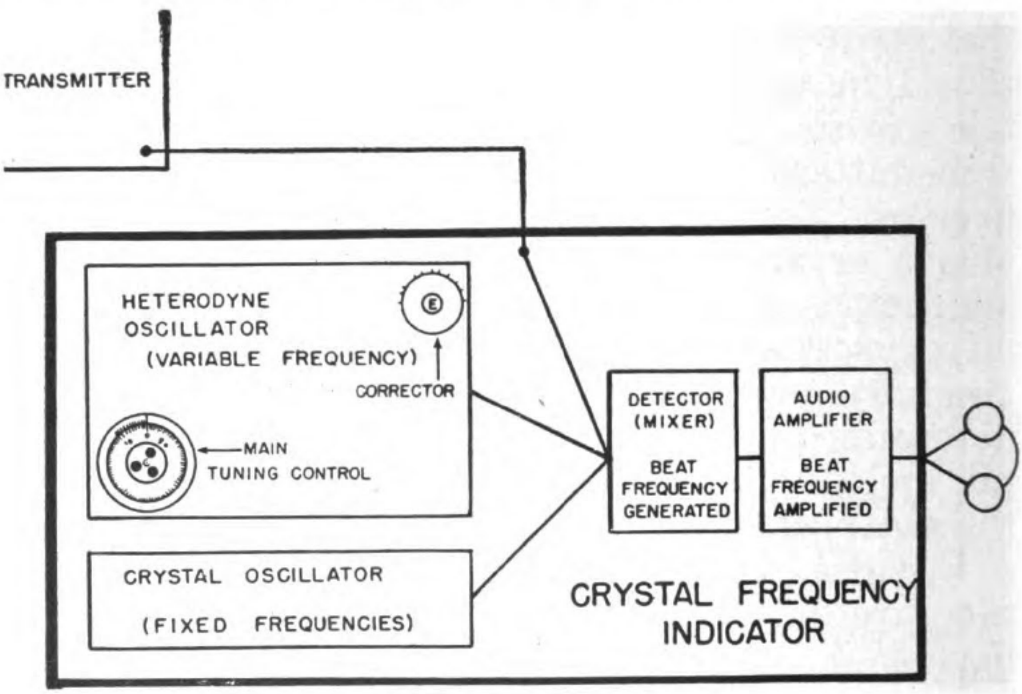


Figure 41.—Crystal frequency indicator.

APPROXIMATELY 1010 kilocycles by means of the manually operated dial. But to place the equipment on EXACTLY 1010 kilocycles, you must use your crystal frequency indicator.

Take a good look at the CFI as illustrated in block diagram (fig. 41).

As you see from the diagram, your crystal frequency indicator consists of a vacuum tube DETECTOR, an AUDIO AMPLIFIER with phones, a CRYSTAL OSCILLATOR, and a HETERODYNE OSCILLATOR, which can be set by a dial to generate a signal of the desired frequency. In this particular case it is assumed that the heterodyne oscillator is set at exactly 1010 kilocycles.

Now the radio-frequency signals from the main transmitter and the heterodyne oscillator are applied to the DETECTOR CIRCUIT. By this means the frequency of the transmitter may be matched to the frequency of the heterodyne oscillator.

In the detector (mixer) circuit, the two radio-frequency signals form a THIRD signal. The frequency of this signal is the DIFFERENCE between the frequencies of the other two signals. The two radio-frequency signals are inaudible, but the DIFFERENCE FREQUENCY (which you recognize as the "beat frequency") will be audible if the two radio-frequency signals are nearly alike in frequency. Mark that. NEARLY alike.

Your CFI is set at exactly 1010 kilocycles. Say that the beat frequency is 1010 MINUS 1005, or 5 kilocycles (5000 cycles). As this is an audio-frequency signal, it can be amplified and heard in the phones as a high-pitched whistle.

Then, if the transmitter's signal frequency is changed, the NOTE heard in the phones WILL ALSO CHANGE. When the transmitter frequency is INCREASED above 1010 kilocycles—in other words, moved farther away from the heterodyne signal at 1010 kilocycles—the BEAT FREQUENCY and PITCH of the whistle BECOME HIGHER. When the transmitter frequency is adjusted LOWER (or closer) to the heterodyne signal, the NOTE BECOMES LOWER.

WHEN THE TWO SIGNALS HAVE EXACTLY THE SAME FREQUENCY, NO SOUND IS HEARD IN THE PHONES. You then have what is known as a ZERO BEAT.

Then what if the transmitter is adjusted to a STILL LOWER beat, that is, one BELOW 1010 kilocycles? The beat frequency and whistle result again, and the pitch becomes higher as the frequency difference between the transmitter and heterodyne oscillator becomes greater.

You can see now how the instrument may be employed to INDICATE frequency. You listen for the little whistle. And you find it easy to locate your ZERO BEAT (or "no sound") position between two areas of sound.

As you already know, the procedure of mixing two signals in a detector circuit to produce a beat frequency is called HETERODYNE ACTION.

But where does the CRYSTAL come in?

First, review the heterodyne procedure.

You set the heterodyne oscillator of your CFI to the exact frequency (1010 kilocycles). You then adjust the main transmitter for a zero beat in your headphones. When you hear zero beat, the main transmitter has the SAME frequency as the heterodyne oscillator, and is ready for operation.

BUT—

This is true ONLY if your heterodyne oscillator can be set to give a signal of any required frequency, and that frequency is absolutely accurate. Unfortunately, a heterodyne oscillator is NOT ALWAYS accurate. Its frequency tends to vary slightly. So it becomes necessary to CHECK the accuracy of the heterodyne oscillator with a CRYSTAL OSCILLATOR.

THE FREQUENCY OF THE CRYSTAL OSCILLATOR IS ABSOLUTELY ACCURATE AT ALL TIMES.

The crystal oscillator generates several signals. The frequencies of these signals are both FIXED and KNOWN. The signal of lowest frequency (1000 kilocycles) you call the FUNDAMENTAL. The other frequencies are multiples of this frequency, and are known as HARMONICS.

The harmonics of the fundamental frequency

(1000 kilocycles) are graduated in a series—2000 kilocycles, 3000 kilocycles, 4000 kilocycles, and so on. They are used as a "yardstick" to calibrate or check the accuracy of the heterodyne oscillator.

The heterodyne oscillator is tuned by a dial which operates a variable condenser. This dial you set to a certain reading in order to obtain the desired frequency. As previously stated, you cannot trust the heterodyne oscillator unless its dial readings have been checked. You can't check the dial at all points, but you CAN check it at the nearest frequency generated by the crystal oscillator. You take it for granted that if the dial is correct at a particular point, it is likely to be correct at nearby points. So, if you make the dial correct at one point, it is safe to use it for nearby readings.

Now assume a frequency of 1010 kilocycles is required. You don't have to work the whole thing out in your head. A CALIBRATION CHART furnished with the instrument will give you the DIAL READING to use in obtaining this frequency.

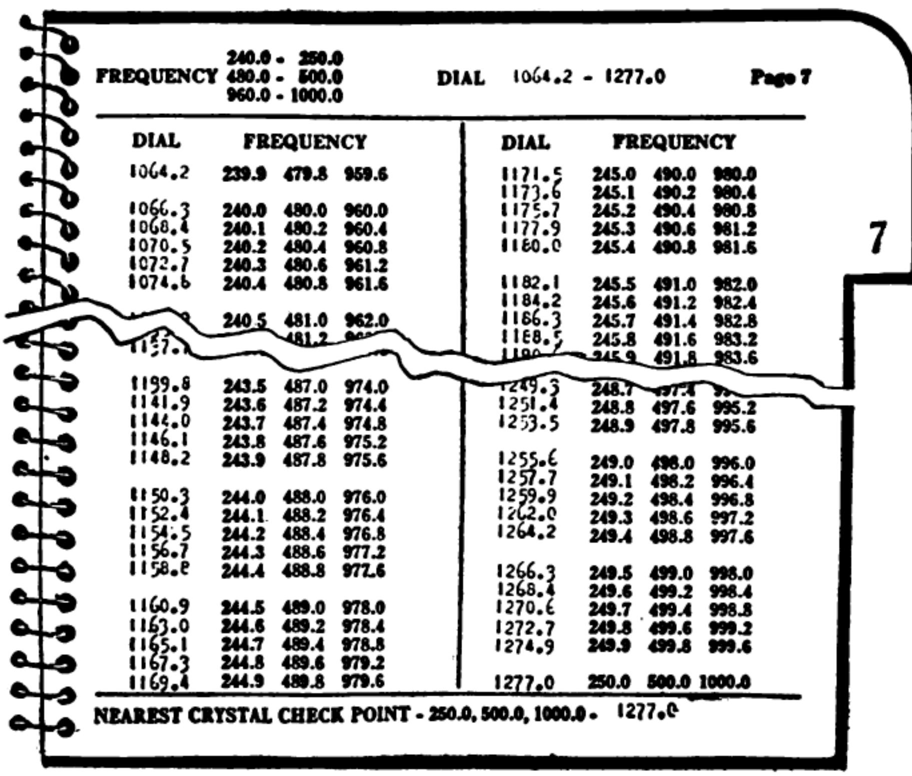
A sample page from your CALIBRATION BOOK is exhibited in figure 42.

Suppose the dial reading for 1010 kilocycles is 1329.8. Before you set the dial to this reading, be sure that your crystal oscillator will give this frequency. It will generate a signal at 1000 kilocycles which is ABSOLUTELY ACCURATE and is not far from 1010 kilocycles.

Now you send signals from the heterodyne oscillator and the crystal oscillator to the MIXER. If you get a whistle in the earphones, you know the heterodyne oscillator is not generating 1000 kilocycles. Do NOT TURN THE MAIN DIAL (see fig. 41.) First, correct the frequency of the heterodyne oscillator by using the CORRECTOR DIAL. Adjust the corrector dial for a ZERO BEAT. Now you will see the heterodyne oscillator is generating 1000 kilocycles at a dial reading of 1277.0.

Since the dial is now correct at 1277.0, it is okay for you to use it at readings nearby. So you can NOW adjust the MAIN DIAL to 1329.8 to obtain your desired frequency of 1010 kilocycles.

The final step, then, is to feed the TRANSMITTER SIGNAL into the MIXER with the 1010 kilocycle signal from the heterodyne oscillator. YOU TUNE THE TRANSMITTER TO A ZERO BEAT WITH THE HETERODYNE OSCILLATOR.



FREQUENCY 240.0 - 250.0 / 480.0 - 500.0 / 960.0 - 1000.0 DIAL 1064.2 - 1277.0 Page 7

DIAL	FREQUENCY		
1064.2	239.9	479.8	959.6
1066.3	240.0	480.0	960.0
1068.4	240.1	480.2	960.4
1070.5	240.2	480.4	960.8
1072.7	240.3	480.6	961.2
1074.6	240.4	480.8	961.6
[illegible]	240.5	481.0	962.0
[illegible]	[illegible]	481.2	[illegible]
1199.8	243.5	487.0	974.0
1141.9	243.6	487.2	974.4
1144.0	243.7	487.4	974.8
1146.1	243.8	487.6	975.2
1148.2	243.9	487.8	975.6
1150.3	244.0	488.0	976.0
1152.4	244.1	488.2	976.4
1154.5	244.2	488.4	976.8
1156.7	244.3	488.6	977.2
1158.8	244.4	488.8	977.6
1160.9	244.5	489.0	978.0
1163.0	244.6	489.2	978.4
1165.1	244.7	489.4	978.8
1167.3	244.8	489.6	979.2
1169.4	244.9	489.8	979.6

DIAL	FREQUENCY		
1171.5	245.0	490.0	980.0
1173.6	245.1	490.2	980.4
1175.7	245.2	490.4	980.8
1177.9	245.3	490.6	981.2
1180.0	245.4	490.8	981.6
1182.1	245.5	491.0	982.0
1184.2	245.6	491.2	982.4
1186.3	245.7	491.4	982.8
1188.5	245.8	491.6	983.2
[illegible]	245.9	491.8	983.6
1249.3	248.7	[illegible]	[illegible]
1251.4	248.8	497.6	995.2
1253.5	248.9	497.8	995.6
1255.6	249.0	498.0	996.0
1257.7	249.1	498.2	996.4
1259.9	249.2	498.4	996.8
1262.0	249.3	498.6	997.2
1264.2	249.4	498.8	997.6
1266.3	249.5	499.0	998.0
1268.4	249.6	499.2	998.4
1270.6	249.7	499.4	998.8
1272.7	249.8	499.6	999.2
1274.9	249.9	499.8	999.6
1277.0	250.0	500.0	1000.0

NEAREST CRYSTAL CHECK POINT - 250.0, 500.0, 1000.0 - 1277.0

7

Figure 42.—Page from calibration book.

This sets the TRANSMITTER to 1010 kilocycles, and it is ready for operation.

That takes care of your transmitter.

Now how does your CRYSTAL FREQUENCY INDICATOR assure the accuracy of your radio receiver?

RECEIVER CALIBRATION

Your RECEIVER is set to an APPROXIMATE frequency by the receiver dial. When greater AC-

CURACY is required, you use the CFI. It is a simple matter to set the CFI to a desired frequency and tune for it on the proper band of the receiver.

You set the HETERODYNE OSCILLATOR of your CFI at the crystal check point nearest to the desired frequency. When you make this check, shift the heterodyne oscillator to the desired frequency. Then couple the output of the CFI to the RECEIVER ANTENNA. By adjusting the receiver dial, the CFI signal can then be tuned in. Your receiver is NOW READY for the reception of any signal on this frequency.

Your crystal frequency indicator is also equipped with an AUDIO OSCILLATOR which may be used when an MCW signal is desired. It's a good idea to use the audio oscillator in this respect because the MCW signal occupies a WIDER BAND and is accordingly easier to locate on the receiver. When the signal is located, the MODULATOR can be turned off to make a setting with a CW signal.

LM-CRYSTAL FREQUENCY INDICATOR

There are several types of crystal frequency indicators. One you should learn to operate is the LM model which has four major circuits to be studied. For a front panel view of this model see figure 43.

Each circuit has its own particular job. The CRYSTAL OSCILLATOR, which uses a 1000-kilocycle crystal provides a constant frequency for checking the frequency of a heterodyne oscillator.

The HETERODYNE OSCILLATOR, with its variable oscillator ranging in two frequency bands of 195 to 20,000 kilocycles, provides a signal for checking the frequency of a transmitter or a receiver. The frequency of the heterodyne oscillator you'll first check against the STANDARD frequency of the crystal oscillator.

• By mixing both signals from the heterodyne and crystal oscillators in the DETECTOR CIRCUIT, you have another check of frequencies. This process checks the frequency of the heterodyne against the fixed frequency of the crystal oscillator.

Finally, you have the MODULATION CIRCUIT. When the modulation switch is on, your AUDIO AMPLIFIER oscillates. It impresses on the signal

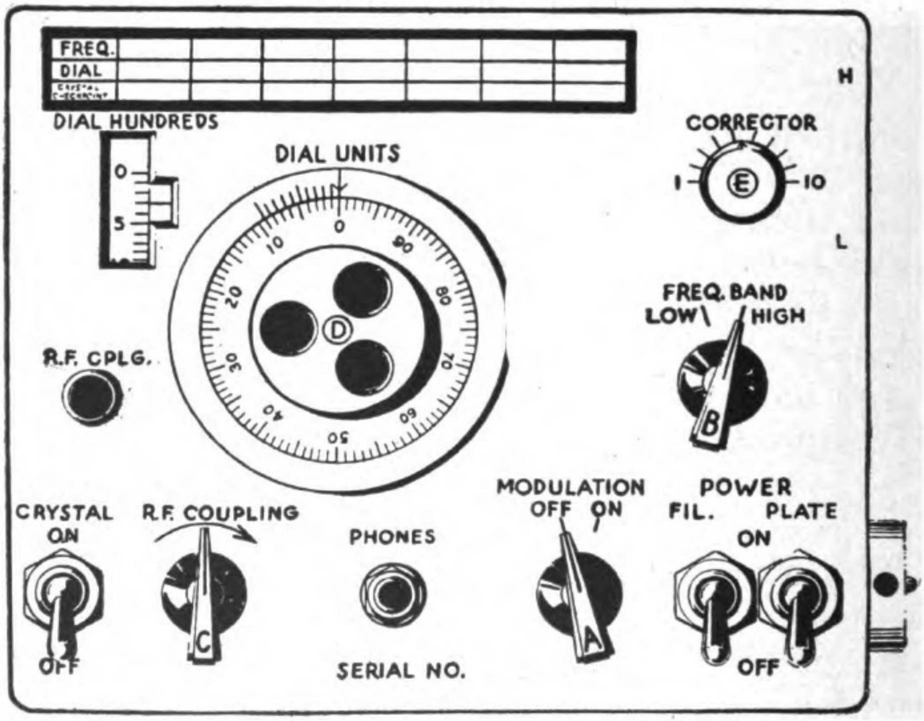


Figure 43.—Front panel view of LM–CFI.

from the heterodyne oscillator an audio voltage of a constant frequency. As you know, if receivers don't have beat-frequency oscillators, the modulation circuit permits the frequency of a RECEIVER to be calibrated.

Now how about the operating controls on the LM-type CFI?

There are eight of them (seven on earlier models.) You should understand each one in order to operate the CFI properly.

Examine the front panel view (fig. 43). You see two POWER SWITCHES—one for the filament and one for the plate voltage supply. To have your CFI at operating temperature, you turn on the FILAMENT SWITCH and allow your CFI 10 minutes to warm up. Then turn on the PLATE VOLTAGE SUPPLY SWITCH.

On the left side of the panel, note the CRYSTAL OSCILLATOR SWITCH. When this switch is turned on, the crystal will oscillate at a standard frequency. When you have calibrated the frequency of the heterodyne oscillator with the crystal oscillator, you must turn off the crystal switch.

Then you have the LOW–HIGH HETERODYNE–OSCILLATOR FREQUENCY BAND–SWITCH on the right side. It is easier to operate than pronounce. When it is in LOW position, you get a selection of frequency within limits of 195 to 2000 kilocycles. In HIGH position, you get a selection of frequency within limits of 2000 to 20,000 kilocycles. Jot these frequency limits down in your memory so you'll have them handy in your mind.

Now take a look at the HETERODYNE OSCILLATOR MAIN TUNING control. It selects the frequency of your heterodyne oscillator according to the calibration book and matches it against the crystal frequency.

Up in the right hand corner you have the CORRECTOR CONTROL. With this you adjust the heterodyne oscillator in order to obtain a ZERO BEAT between the heterodyne and the crystal oscillators. ONCE YOU OBTAIN YOUR ZERO BEAT DON'T READJUST THIS CONTROL. You've got what you want, and, as the song says, who could ask for anything more?

Finally you have your R–F COUPLING CONTROL SWITCH on the lower side of the panel. The strength of the signals coming in from the transmitter oscillator and going from the CFI to the RECEIVER is varied by means of this switch. Just above and to the left of it you'll find the r-f coupling terminal which transfers signals from the transmitter's oscillator to your CFI.

When the modulation control is on, of course, an AUDIO VOLTAGE is impressed on the signal from the heterodyne oscillator.

Now suppose you want to set your RECEIVER on a PREDETERMINED FREQUENCY. You have three methods available. Each one, used individually or in combination, will show the best method to use in order to get the best results. Here they are.

METHOD NUMBER 1—You may obtain an APPROXIMATE FREQUENCY by means of the calibration data on top of the receiver.

METHOD NUMBER 2—A MODULATED SIGNAL from your CFI may be used. This method has two distinct advantages. It affords a more accurate check for frequency than the calibration data on the receiver. It makes for a more rapid adjustment of the desired frequency because it is easier to locate the modulated signal (which covers a broader span on the receiver dial).

Employing this method you take the following steps—

First, correct the heterodyne oscillator to the calibration at the crystal check-point nearest the desired frequency, as given by the CFI calibration book.

Then turn the crystal switch OFF and transfer the phones from the CFI jack to the receiver switch-box.

Next, turn the indicator tuning control of the CFI to the dial setting of the desired frequency as given by the calibration book. DON'T DISTURB

THE CORRECTOR ADJUSTMENT YOU'VE ALREADY MADE.

Now turn the modulation switch ON.

And, concluding the operation, with the r-f COUPLING LEAD wrapped loosely around the RECEIVER ANTENNA POST (no metallic connection), adjust the receiver dial control until you hear a MAXIMUM SIGNAL in the headphones.

Having followed these steps, you have now tuned your receiver to the desired frequency.

METHOD NUMBER 3—A CW signal from the CFI may be used, provided that the CW SWITCH on the receiver switch-box is ON.

Employing this method, you follow practically the same steps you did in the previous method. Then when you get an audible signal in headphones, do this—

Adjust the r-f COUPLING CONTROL to obtain a "comfortable" signal (not too loud, as this tends to broaden the frequency on the receiver.)

Then adjust the RECEIVER TUNING CONTROL to exact ZERO BEAT with the signal from the CFI. Now your receiver is tuned exactly to the desired frequency and is ready for reception of MCW or VOICE.

How about adjusting your TRANSMITTER to a predetermined frequency.

Technically speaking, the adjustment of a transmitter to a predetermined frequency involves the beating of the transmitter's oscillator–frequency against the frequency of the heterodyne circuit in your CFI. This may sound fairly difficult, but the operation isn't.

In adjusting the transmitter, begin by seeing that the CRYSTAL and MODULATION SWITCHES (of your CFI) are OFF.

Then follow the same steps you took in adjusting your receiver, the only difference being that you work with GP, GO, and GF Series transmitters instead of receivers.

The procedure—

Read over the three methods you employed in receiver-adjustment. Follow these steps to the letter (recalling the precaution concerning your crystal switch and modulation switch) and, presto! You can adjust your transmitter to the desired frequency as readily as you adjusted your receiver.

PIN-UPS FOR YOUR MEMORY

As an aid to your memory, tack up these five admonitions on your shaving mirror and go over them for a couple of shaves. (If you've got a steady hand, it's not a bad method for learning something). Anyway, these points are to be remembered when you're setting a receiver or transmitter to a predetermined frequency.

FIRST—Don't bother the corrector knob after you've secured a zero beat between the heterodyne and the crystal oscillator.

SECOND—Always remember to turn the crystal switch OFF when you have checked the heterodyne frequency against the crystal frequency.

THIRD—Concerning a receiver, always remember to insert your phones into the jack on the receiver switch-box AFTER the CFI has been adjusted to the desired frequency.

FOURTH—Recall that when the modulation switch of the CFI is ON, the note in the receiver headphones will be BROADER, and consequently not as accurate a frequency check as CW. In some cases this condition may be desirable, but you want to be aware of it.

FIFTH—Never make a metallic connection between the CFI r-f COUPLING LEAD and the ANTENNA BINDING POST of the receiver. If you happen to do so, the signal from the CFI will be oo strong, and will create a broader expanse of he zero beat on the receiver dial. In this way he chances for error in frequency calibration are ncreased.

Learn those five points without nicking your Adam's Apple!

Here are a couple of precautionary notes concerning your TRANSMITTER. You might pin them up in your memory, too.

If you find yourself faced with adjusting your transmitter—and you're not sure what to do—just FOLLOW OUT THE STEPS YOU USED IN ADJUSTING YOUR RECEIVER.

Should you come up against a transmitter which differs slightly from the ordinary, always remember to retain the headphones in the CFI telephone jack to secure a zero beat between the heterodyne and the transmitter's oscillators.

Remember to keep the modulation switch OFF while checking the frequency of the transmitter.

No metallic connection, either, between the CFI r-f coupling lead and the transmitter CFI BINDING POST. Otherwise the signal in your CFI will be too broad for accurate frequency measurement.

Under no circumstance make a metallic connection between the CFI r-f coupling lead and the ANTENNA binding post of your transmitter. Serious damage to your CFI would result from such a connection.

And keep in mind that your transmitter MUST BE KEYED before the signal will be heard in your CFI headphones.

Remember these rules concerning your transmitter, and you won't clutter your career in radio with difficulties and possible damage.

And here's an important general rule on checking the frequency of a receiver and a transmitter.

ALLOW YOUR CFI TO WARM UP AT LEAST 10 MIN-

UTES BEFORE ATTEMPTING TO MAKE FREQUENCY MEASUREMENTS. THE FREQUENCY OF THE CFI WILL GRADUALLY SHIFT (YOU SAY "CREEP") UNTIL THE CFI IS AT OPERATING TEMPERATURE.

You don't want to start in with a chilly instrument, and get the "creeps."

HETERODYNE OSCILLATOR DIAL

Now that you can recite these operational rules forwards and backwards (don't follow them backwards) turn to another important feature of your CFI.

It is necessary to adjust (and accurately) your heterodyne oscillator to the frequency desired. So you have two dials for the operation. Here they are for your inspection in figure 44*A*.

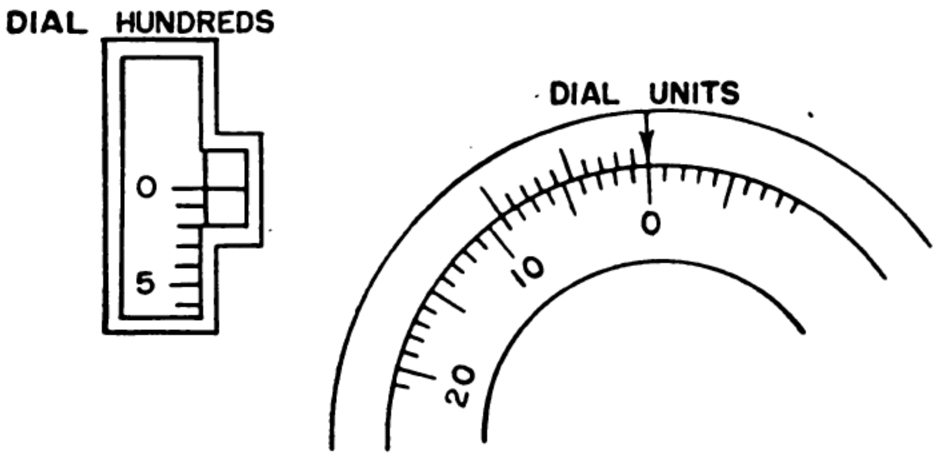
One dial is called the HUNDREDS DIAL (labeled in the illustration "Dial Hundreds.") The large dial (a segment of which is shown) is marked, as you see, DIAL UNITS.

The hundreds dial connects directly to the shaft of the TUNING CONDENSER. It is so placed that its scale may be read through a window which contains an appropriate marker line.

The hundreds dial has 50 divisions on its scale. You can't set it directly. It is operated by rotating the large dial marked dial units.

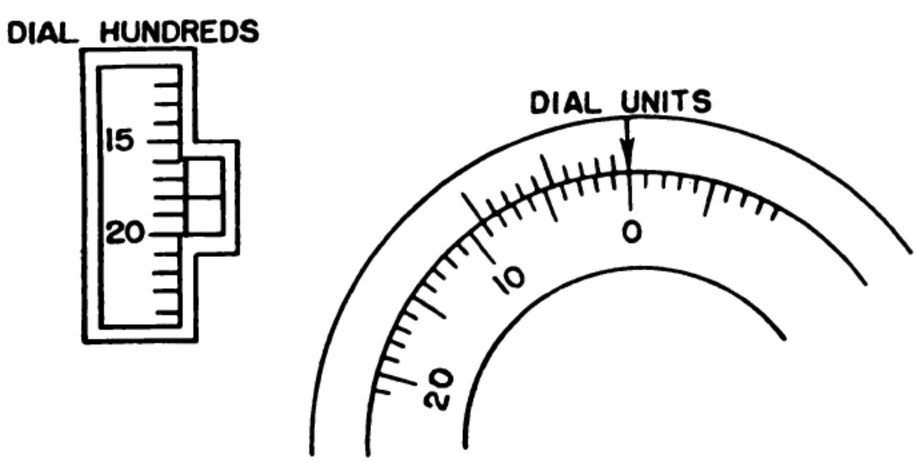
This large dial has 100 divisions on its scale. ONE COMPLETE REVOLUTION of this UNITS-DIAL advances the HUNDREDS DIAL ONE DIVISION. Each division of the hundreds dial is equal to 100 divisions of the units-dial. So the maximum reading of the hundreds dial will be 50×100, or 5,000 degrees.

So that the units-dial may be set at ONE-TENTH of a division, it is provided with a VERNIER SCALE. If you've done any small or large-boat navigating you're acquainted with the vernier on a sextant or perhaps you've seen it employed with precision easuring instruments in the shop. If not, a ERNIER is a short scale made to slide along the visions of a graduated instrument to indicate



(A)

Figure 44A.—Heterodyne dial at 0°.

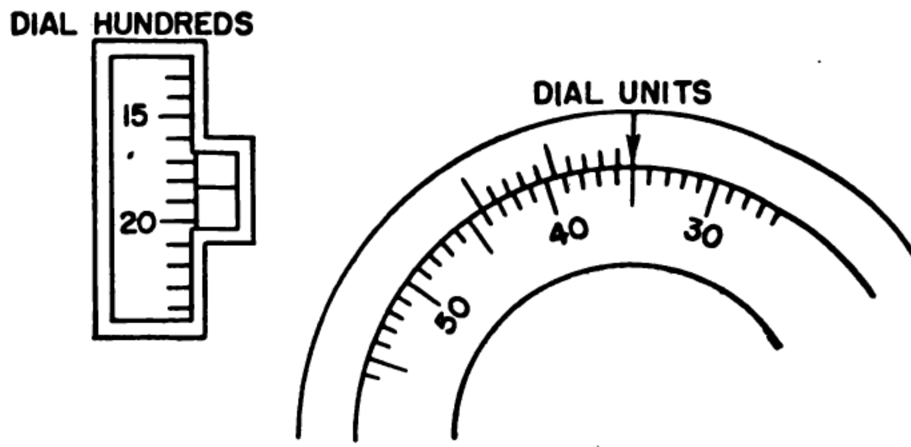


(B)

Figure 44B.—Heterodyne dial at 1800°.

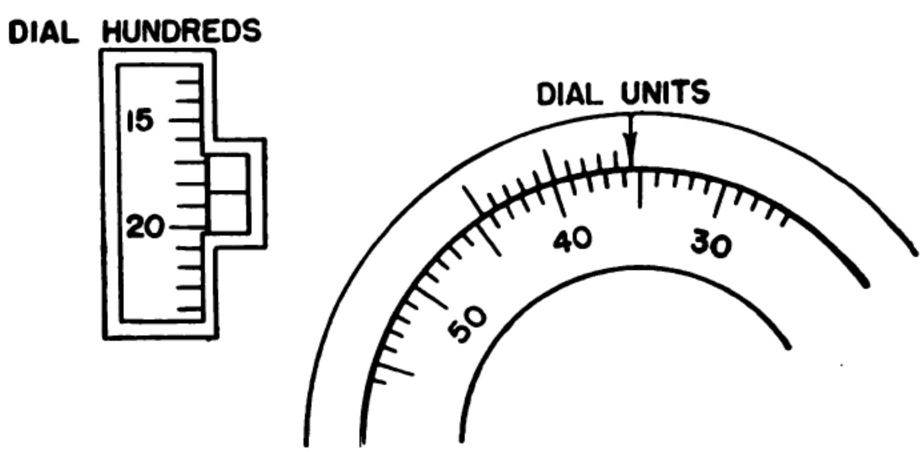
hair-line fractions of such divisions. On your UNITS DIAL the VERNIER is stationary.

Here's an example of how it works. Assume



(A)

Figure 45A.—Heterodyne dial at 1835°.



(B)

Figure 45B.—Heterodyne dial at 1835.4°.

e heterodyne oscillator is to be set at the 1835.4 vision, and further assume that the hundreds al and the units dial are both at 0 at the start the operation. See figure 44*A*.

To obtain your 1835.4° reading, the hundreds al is placed at 18. You do this by making 18 mplete revolutions in a clockwise direction on e units dial.

This gives you the setting shown in figure 44*B*, here you see the 18 indicated on the hundreds al.

Now you advance the units dial until the 35th ivision is lined up with the arrow, as shown in gure 45*A*. As you see, this results in a reading 1835°.

To set the units dial accurately at 1835.4° adance the dial SLIGHTLY past the 1835 position ntil the FOURTH division mark on the VERNIER ALE lines up EXACTLY with one of the divisions n the units-dial. Since the vernier scale has ly nine graduations, it is possible to make only ne of the graduations line up with a graduation n the units dial at any one time. In the present stance, all you have to do is make the fourth ivision line up as illustrated in figure 45*B*.

In practice, bear in mind that the FIRST line to e left of the arrow-marker on the vernier scale a ONE-TENTH marker. Keep that fact in mind, nd you'll have no trouble obtaining the proper linement of your dials for maximum accuracy.

OW TO READJUST HETERODYNE OSCILLATOR CALIBRATION

Accuracy is the business of your crystal freuency indicator. If your CFI is operating roperly, it should be possible to set the heteroyne oscillator to all crystal check-points called or in the calibration book. In some instances e instrument, when subjected to extreme changes of temperature and humidity, loses its accura(and then requires additional adjustment. Th is indicated when you find it impossible to obta: a zero beat on a crystal check-point after usir your corrector dial.

Like Johnny, the ace in the song, you want t get that zero today, so you readjust your heter dyne oscillator to obtain its formerly accurat calibration.

You employ two condensers for this purpos Both of them are accessible at the front of tl panel, and you adjust them with a small screv driver. You recognize their type, of cours TRIMMER condensers. And you'll find the slic ing cover-plates over the adjusting screws signif cantly marked "L" and "H"—"L" for LOW an "H" for HIGH FREQUENCY ADJUSTMENTS.

So here's what to do when you find recalibra tion is necessary—

First, apply power to the instrument and allo it to reach its operating temperature. Ten mir utes is enough.

Then turn the FREQUENCY BAND SWITCH to th LOW position, and turn the MODULATION SWITC OFF.

Next bring the dial-units and hundred-dial scales to the HIGHEST crystal check-point settin (400 kcs.) by referring to the calibration book.

Having done that, set the CORRECTOR DIAL to 4 division (midscale).

Turn the crystal switch ON.

Now uncover the LOW FREQUENCY TRIMMER AI JUSTING SCREW (that's the coverplate marked L Insert a screwdriver through the hole in the pa and rotate the trimmer screw in a clockwise dir tion. This rotates the trimmer capacitor in clockwise direction, and you listen until you ha zero beat in the headphones. The heterody scillator is now set accurately to this crystal heckpoint.

'Cover the trimmer screw (L) and check the bility of the corrector dial to reset the zero beat t ALL SEVEN crystal check-points in the LOW frequency band.

Set the FREQUENCY BAND SWITCH to HIGH and set he Heterodyne oscillator to the HIGHEST crystal heck point. Then reset the corrector dial to 4.5 livision.

Uncover the HIGH FREQUENCY TRIMMER ADJUSTNG SCREW. Insert your screw-driver and rotate he adjusting screw to the right until an accurate ero beat is obtained in the headphones. Then over the opening.

Check the ability of the corrector dial to reset o a zero beat ALL NINE crystal check-points in the HIGH FREQUENCY BAND.

After completing a check of ALL high frequency rystal check-points, be sure to re-check the low frequency crystal check-points to make certain that your high frequency adjustments have in no way affected the low frequency band.

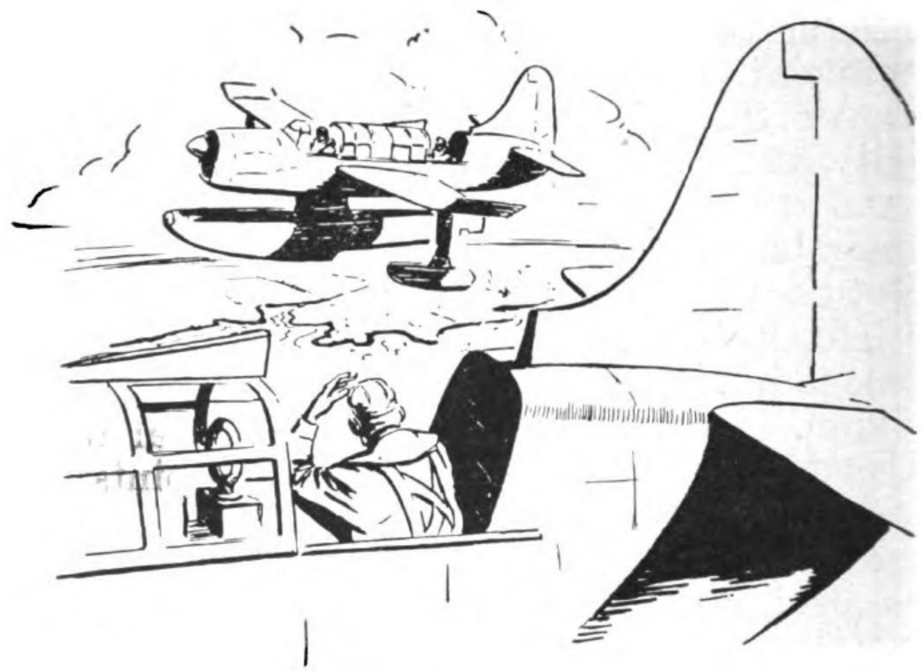
WARNING—

Before operating a crystal frequency indicator, it's a good idea to read the manufacturer's instructions concerning its operation. Your CFI is a fine, precision instrument. As such, it wants fine, precise handling.

What's the job of your CFI? ACCURACY. And your job? Keeping it accurate.

EPITAPH

Here lies Noah, somewhere at
The top of Bleak Mount Ararat.
Beached the Ark there high and dry
He forgot to check his CFI.



CHAPTER 6

NAVAL AVIATION RECEIVERS

SAY IT WITH FLOWERS!

One of the most complicated languages in creation is the Japanese. To begin with there are about 3,000 symbols to the alphabet, and to end with, a Jap never says what he means.

For example, he says peace and means war. There is no specific "yes" or "no" in Japanese—for "yes," he politely sucks breath through his teeth and says, "I am listening." Just in saying, "Good Morning," Mr. Mitsui goes into all sorts of verbal contortions; addressing his servant with a grunt; using another term, only a little more respectful, for his wife; still another for his neighbor; a fourth for the corner policeman; and then, in greeting an officer or superior, adding all sorts of buttery, formal curleycues. Altogether there are six or seven compulsory forms for "good morning" in Japanese.

Some words are elaborately camouflaged. Because his cities are highly inflammable, the Jap is so afraid of fire that he gives it a pretty name, meekly calling a conflagration a bouquet by referring to fire as "the flowers." There is no such tongue-twisting jujitsu to the American language, the essence of which is to say something fast, make it plain, and MEAN it. The same goes for your radio receiver, built to convey a message with

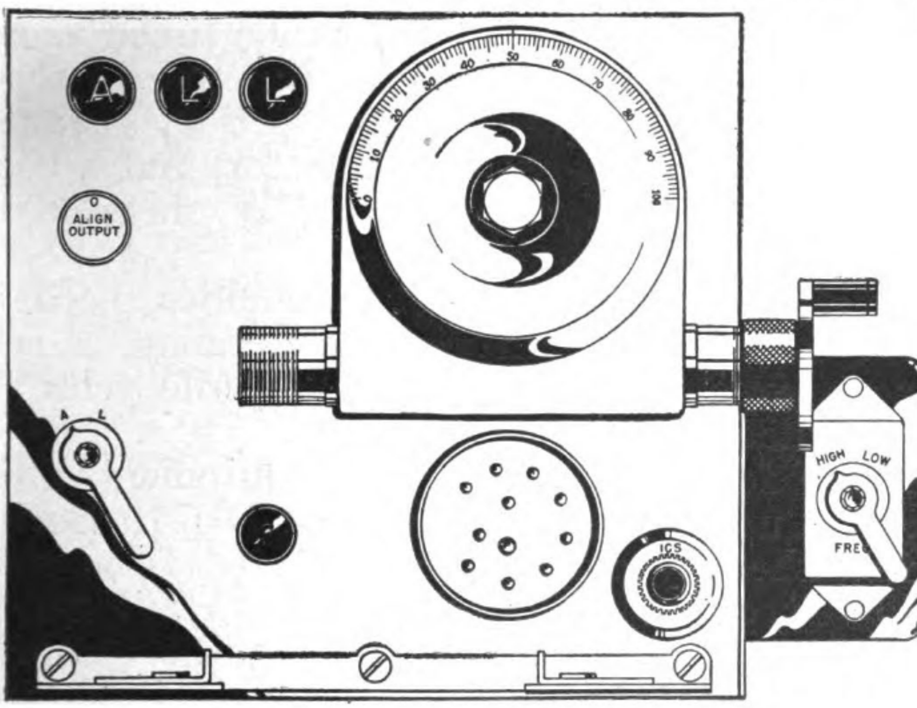


Figure 46.—Front panel view—RU receiver.

speed, clarity and accuracy (you know—FIDELITY.)

You'll get no hissing, blurring and double-talk from your high-class radio receiver. Tune it in properly, and you'll hear it calling a spade a spade. Just as your Navy bombers are talking straight from the shoulder when they fire a Nipponese stronghold—and they don't "say it with flowers."

RU RECEIVER

The model RU–Series receiver, equipped with ASSOCIATED JUNCTION BOXES, a COIL, and a DIRECT-

CURRENT MILLIAMMETER UNIT, is a COMPLETE RADIO RECEIVING SET. Navy men, liking it, have nicknamed it the "Rugy Fu."

It is designed primarily to be operated together with naval aviation transmitters and radio direction finders. It may be used to receive CW (continuous wave), MCW (modulated continuous wave), or VOICE MODULATED transmissions.

In figure 46, you have a front-panel view of this receiver.

The RU is a conventional six-tube tuned radiofrequency (t. r. f.) receiver. It employs three stages of radio frequency amplification, an automatic gain-control circuit, a detector, and a combination audio-amplifier and CW heterodyne oscillator circuit.

By means of plug-in coil assemblies, each of which covers a certain frequency range, a continuous frequency range of 195 kilocycles to 13,575 kilocycles is obtained.

Power for the RU receiving equipment, from Series 4 up to and including the RU–19 Series, is furnished by dynamotors operated from a 12 to 15 volt, or a 24 to 28 volt direct current source, such as an aircraft battery. All units comprising new equipment from RU-Series 4 through Series 11 are interchangeable. The units of an RU–12 equipment, with the exception of dynamotors and junction box, may be interchanged also with any of the other equipment from Series 4 to 11.

Here are some of the controls you'll find on (and with) your RU receiver.

First, there is the AUTO OFF MANUAL SWITCH located in the receiver SWITCH BOX. At the beginning of the tuning operation, you throw the switch to MANUAL.

Then you have the CW–MCW TOGGLE SWITCH.

You set it at CW position if you want to receive CW signals. When adjusting the receiver frequency by means of a modulated signal from the CFI, you throw this switch to MCW. But if the receiver frequency is being checked by means of a CW signal from the CFI, the toggle switch should be thrown to CW. In other words, CW for CW and MCW for MCW.

Next there is your INCREASE OUTPUT CONTROL. Its job? Increasing and decreasing the VOLUME of the signal received. In operation, it should be advanced until the signal in the headphones reaches a comfortable level. "A friend is an ear," and should also be easy on the ear.

Then you have your METER JACK which includes a d-c milliammeter for measuring cathode current in the receiving tubes. And your TELEPHONE JACKS, which allow the insertion of telephones into the output circuit of your receiver. You might want to call up somebody.

By the LOCAL TUNING CONTROL your receiver is tuned to the desired frequency after the proper coil has been selected.

Then you have the ANTENNA LOOP CONTROL SWITCH—place it in "A" POSITION, as in most circumstances, and you have your receiving antenna on the proper connection. In the "L" POSITION you may use a LOOP (to be described later) which is connected to the binding posts marked L. The ANTENNA, incidentally, is connected to the ANTENNA BINDING POST. While your LOOP BINDING POSTS (all two of them) permit the use of a LOOP ANTENNA when such an installation is called for. (You'll run across loop antenna in direction finding.)

Now the ALINE INPUT CONTROL. In operation it tunes the antenna to the desired frequency. You haven't heard much about antenna tuning, but they're tuned. And in most cases you adjust the aline input control when there has been a shift in receiver frequency over a comparatively large range.

The VOLUME CONTROL should be RETARDED before this adjustment is made. You place the VOLUME CONTROL AT MANUAL, and continue the adjustment of the aline input control until the signal is at maximum strength in the headphones.

Finally you have your ICS (intercommunication system) JACK, and your REMOTE TUNING CONTROL. You'll have to do with your ICS JACK when you catch up with the "inter-com" system. Briefly, it permits the insertion of telephones in the grid circuit of the AUDIO AMPLIFIER for ICS use.

As for the REMOTE TUNING CONTROL (you've heard of remote control) it may be used by a pilot or radioman in "second position" for remote tuning of RU receivers. Its dial is calibrated from 0 to 100. The reading of its indicator will conform to the dial-setting on the receiver proper.

There, in brief, you have the controls you'll operate with your RU receiver. Now for the lowdown on receiver tuning.

HOW TO TUNE THE RU

Go through these maneuvers as outlined and in this order, and you won't go wrong.

FIRST—Select the proper coil for the desired frequency, and INSERT IT into the receiver.

SECOND—Apply power to the equipment by turning the AUTO-OFF-MANUAL SWITCH to MANUAL. (In this position the switch applies direct-current power to the DYNAMOTOR, which in turn supplies voltage to your receiver and LM crystal frequency indicator.)

THIRD—Determine the APPROXIMATE DIAL READING for the desired frequency by consulting your

TUNING CHART. You will find the chart on the top of your receiver. Make interpolations if necessary. (The term "interpolations" will be explained to you later.)

FOURTH—Adjust the CFI to the desired frequency. Throw the modulation switch of the CFI to ON. Insert the telephone jack into the receiver switch-box.

FIFTH—COUPLE THE LEAD from the CFI loosely around the ANTENNA POST.

SIXTH—Throw your CW-MCW SWITCH on the receiver switch box to MCW position.

SEVENTH—Rotate the RECEIVER TUNING CONTROL for a maximum signal in the headphones.

EIGHTH—Adjust the ALINE-INPUT KNOB until you reach a maximum signal in the headphones. DECREASE the signal strength and READJUST the aline-input knob.

Score these eight, and you've gained your objective. The receiver is NOW TUNED to the approximate frequency desired.

Then suppose you want an ABSOLUTE determination of frequency. All you have to do is TURN OFF the CFI MODULATION SWITCH and throw the CW SWITCH on the receiver switch-box to CW. Then adjust your receiver until an absolute ZERO BEAT is attained in the headphones.

In this respect, here's a point to remember. If your receiver is tuned to an absolute zero beat AND the distant transmitter happens to be tuned to that same frequency NO SIGNAL WOULD BE HEARD in your headphones. Therefore, the receiver should be tuned slightly off zero beat so you can hear the signal from the transmitting station. The trick here while searching for the transmitted signal, is to vary (a veteran would say "rock") the tuning control across the zero-beat "spot" on the dial.

Here's some more inside dope on the insides of your RU. The RU receiver has a tuned radio-frequency circuit composed of three radio-frequency amplifiers. It has one AGC (automatic gain circuit). It has a detector, a beat frequency oscillator, and an audio amplifier. One section of a dual triode vacuum tube is used as the beat frequency oscillator and the other section is used as the audio amplifier.

These circuits are not hard to follow. The radio frequency amplifier stages are of the conventional type. The detector employs plate rectification to make the signal audible. The signal of audio frequency is developed in the plate circuit of the detector tube and is impressed upon the grid of the audio amplifier tube.

The AGC circuit goes into action when the switch on the receiver switch-box is thrown to AUTO. In operation, the AGC tube rectifies a portion of the signal voltage developed in the antenna, and applies it as a negative d-c bias voltage to the grids of the r-f amplifier tubes. By this means the signal is kept at almost constant level in the headphones.

The beat frequency oscillator is designed to permit reception of CW signals. When the CW switch is thrown to CW, the oscillator section of the combination oscillator and audio-amplifying tube begins to oscillate at one-half the frequency of the incoming signal. The SECOND HARMONIC of this oscillation is fed into the CATHODE CIRCUIT of the detector tube. There it mixes with the incoming signal to produce the BEAT FREQUENCY (the difference between the two frequencies).

This beat frequency is fed to the audio-amplifying section of the beat frequency oscillator, and amplified. Because of the BROAD SELECTIVITY of the radio-frequency amplifiers, the difference between the SIGNAL SELECTED and the OSCILLATOR FREQUENCY may be varied by the main TUNING CONTROL of the receiver. This permits an AUDIBLE frequency to be heard. The range of the frequency is from zero to 15,000 cycles.

MODEL ARA RECEIVER

The model ARA aircraft radio receiver, in which five separate units cover the frequency range of 190 to 9100 kilocycles is a complete "multichannel" receiver. Multichannel means capable of operating on two or more frequency bands simultaneously.

In figure 47 you have a front panel view of the receiver with its control boxes.

Any two or three units of the receiver may be installed and operated individually or simultaneously by REMOTE CONTROL from the control-box of the receiver. The particular units supplied or installed will depend upon service requirements.

Primary power is obtained from a 22 to 30-volt direct-current supply. The power is controlled by a CW–OFF–MCW switch. When the switch is OFF, as you might suspect, no power flows to the receiver.

Continuous wave (CW) or modulated (MCW or VOICE) radio signals may be received by this equipment. MANUAL CONTROL of the signal-strength is employed, aided by a built-in HIGH LEVEL AUTOMATIC GAIN CONTROL circuit which prevents strong signals from blocking the receiver.

The outputs of two (or three) receivers may be connected in a parallel line to a single head-set. Or they may be separated into two lines for reception by more than one operator.

A single antenna is used for all receivers except that of the 190 to 550 kilocycles unit. If such a

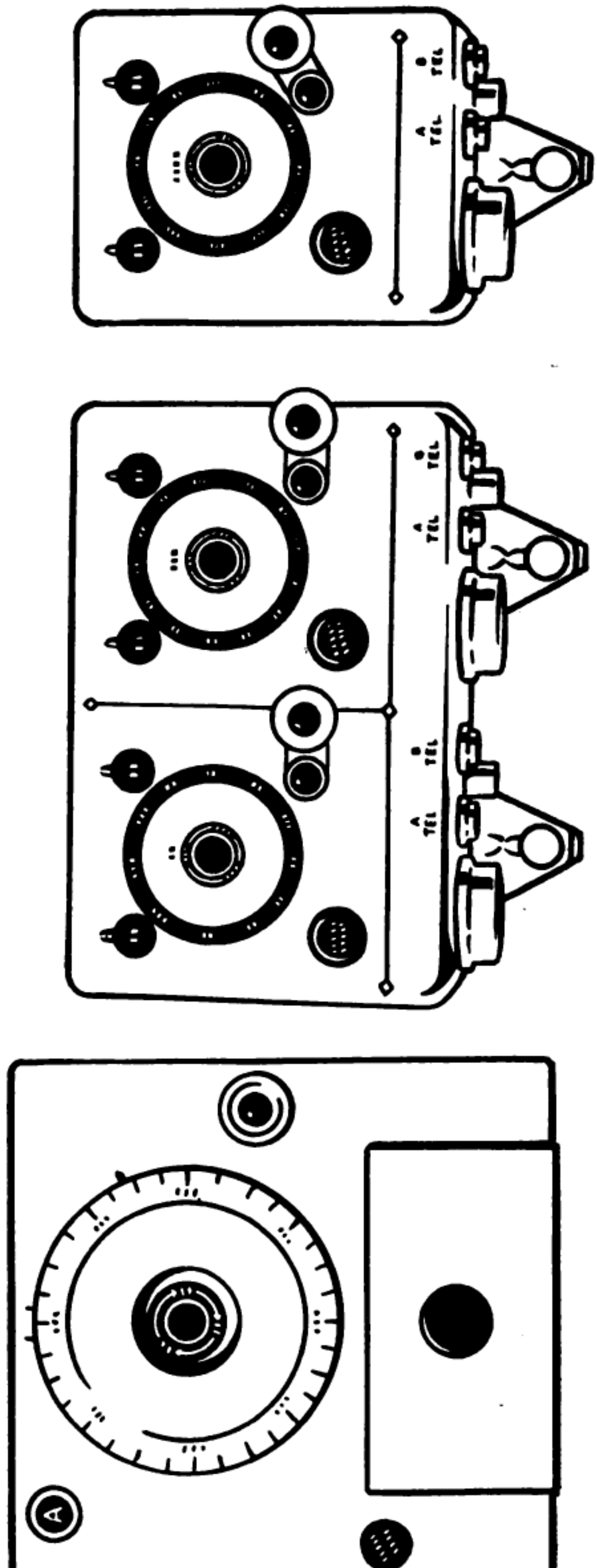


Figure 47.—Front panel ARA receiver and control boxes.

unit is employed for the reception of airway radio range signals, a suitable antenna to use is a 2 or 3-foot vertical mast or a nearly vertical wire.

All tuning dials are calibrated directly in kilocycles or megacycles (mcs). The accuracy is better than 0.3 percent and that's really accurate. In fact you won't have to check the frequency of this equipment with a CFI. •

As for the electrical equipment circuit of your ARA, the receiver is a "super-het" employing six metal 12-volt tubes. A block diagram would show your radio-frequency amplifier, your mixer and local oscillator, two intermediate frequency amplifiers, a diode detector, a CW heterodyne oscillator and an audio-amplifier.

The receiver units are interchangeable with those of corresponding frequency ranges in the MODEL RAV equipment. Except that the model RAV receiver units, which cover the 190–555, and 520–1500 kilocycles bands, are equipped with loop binding posts and an antenna-loop switch.

The receiver units of the RAT–1 equipment are operated in the receiver racks of the MODEL ARA equipment, or vice versa. The receiver units of the RAT series were designed for 12-volt operation, and therefore are not used in the receiver racks of the 24-volt model ARA equipment.

You'll be interested in a description of Model ARA CONTROLS.

The 1, 2, and 3-unit receiver control boxes maintain complete REMOTE CONTROL over any of the receivers. Means for local control of the receivers are not supplied.

Each control box is equipped with a group of controls. Here they are in brief review.

There's the CW-OFF-MCW SWITCH. It allows selection of the type of wave to be received, and in the OFF position primary power to the equipment is broken.

Next you have the TUNING CONTROL. This permits REMOTE TUNING of the receivers.

Then the INCREASE-OUTPUT CONTROL allows manually-operated receiver gain. You don't leave it in a retarded position, by the way, or weak signals will be lost. On the other hand, if left in the maximum gain position, strong signals will become ear-splitting. So the increase-output control should be adjusted to make signals easy on the ear. In the reception of AIRWAYS RADIO RANGE SIGNALS, the increase-output control must always be kept RETARDED to a point well below the level of maximum audio output in order to prevent distortion.

Finally you have the TEL LINE SELECTOR SWITCH. This is one of the most intricate controls in your ARA receiver. Don't let that worry you, for its workings are fairly easy to understand.

When the TEL selector switch is in the center position, it acts as a "stand-by" switch for receivers to which it is connected. At such a position, the output from the receiver is eliminated without the necessity of turning off power, detuning, or retarding the gain control.

There are other uses for the TEL. It transfers output from a receiver to the A or B line telephone jacks, and any receiver can be switched to these lines in any form desired. The gain control may be used to "fade" the output of one receiver with respect to others. The output from the receiver of radio range signals, for example, may be "faded" down to bare audibility or the nearest whisper without affecting the output from any of the other receivers.

BENDIX RECEIVER RA–1B

Another Navy aircraft receiver of the "superhet" type is the Bendix RA–1B. This receiver covers a frequency range in six bands of 150 to 15,000 kilocycles. It is designed to operate from a 24–28 volt d-c source of power.

The power supplies the filament voltage for the tubes and also operates a dynamotor which supplies high voltage direct current for the plates of the tubes. A BAND SELECTOR CONTROL is used to select any desired frequency band. Plug-in coils aren't needed.

The BENDIX RA–1B receives CW, MCW or VOICE signals. It is provided with external jacks so that filament voltage, plate voltage, and signal voltage may be measured by appropriate meters.

Here are the steps you'll follow in operating a Bendix RA–1B receiver.

> Check to see that the LOCAL REMOTE SWITCH is in the LOCAL position. This switch provides local and remote tuning for the receiver.
>
> Connect the ANTENNA to the position marked A and the antenna switch to TA.
>
> Plug phones into the PHONE JACK. Each local unit has a phone jack located in the lower left corner of a receiver.
>
> TURN POWER SWITCH ON.
>
> Turn BAND SELECTOR to the desired band.
>
> Turn TUNING KNOB to the desired frequency. In the lower window you will see the full coverage of frequencies of each band. These frequencies change as the band selector is changed from one frequency to another.
>
> To receive CODE SIGNALS turn the A. V. C. (automatic volume control) switch OFF and the CW switch ON. To receive VOICE Signals first tune in the CARRIER WAVE by having the A. V. C. and the CW switches ON.
>
> When you find the station you want, turn the VOLUME CONTROL all the way down, and

turn the CW switch OFF. Slowly increase the volume control until you hear the VOICE signals.

You will find four single JACK PLUGS on the right side of the face of the receiver. They are labeled BT, AT, AUDIO and G. By using a direct current voltmeter with the NEGATIVE test lead plugged into the jack marked B, and the positive test lead plugged into the jack marked BT, you can determine whether or not the receiver dynamotor is delivering the desired plate voltage. Should you have NO voltage, you must inspect the PLATE SUPPLY FUSE on the dynamotor assembly.

To determine whether or not filament voltage is present on the tubes of a receiver, use a direct current voltmeter with a NEGATIVE lead plugged into the G jack and the POSITIVE lead plugged into the AT. Now if you have no filament voltage, you know something is wrong with the FUSES at the filament or motor on the dynamotor unit.

By using an alternating current meter, or an OUTPUT meter, with one test lead plugged into the G jack, and the other plugged into the jack marked AUDIO, you can determine the amount of output VOLTAGE across the TERMINALS OF THE HEADPHONES.

The Bendix Receiver RA–1B may be the last in this chapter, but it is by no means the least of the Navy receivers.

CHAPTER 7

NAVAL AVIATION RADIO DIRECTION FINDER

WHAT IT IS

What are the workings of a RADIO DIRECTION FINDER? How does an operator take a bearing? What types are used in Navy aircraft, and how do you make corrections for error?

The RADIO DIRECTION FINDER is all that its name implies. By locating the source of a transmitted signal, come nightfall, dog-fight or ceiling zero, it shows you the way to go home.

Consider Old Man Noah making a landfall after 40 days and nights of bad weather. Or Columbus sailing toward the sunset, expecting any evening to go "over the edge." Such hardy mariners, charting their course b'guess and b'God, navigated almost wholly by dead reckoning. It was an ominous-sounding term, and allowed little correction for error.

Today the ship's captain is relieved of such chance-taking, while the aircraft pilot, over unknown territory with perhaps 40 minutes gas supply, might well UNDERLINE THE ADJECTIVE in that salty term were his course left to luck.

Mothered largely by the necessities of commercial aviation, the RADIO DIRECTION FINDER has almost eliminated the hazards of dead reckoning and blind flying. How was this fine instrument developed?

Back home you may have built your own set and rigged up an aerial. As you know, a radio wave passing across an aerial starts a flow of electrons in the aerial ground system. You say an electrical PRESSURE was set up in the aerial, and that electrons flow because of a DIFFERENCE of pressure at two points. Electrons flow from the point of high pressure to the point of low pressure (or from negative to positive). Were the pressure equal throughout, there would be no electron flow.

Now assume you set up a simple straight wire aerial parallel to a flat roof. If you lived in an apartment house, you may have done so, and if so you might have noticed that your aerial, after various adjustments, gave better reception pointing in one direction than in another. Why?

Well, if all parts of the antenna were at exactly the same distance from the transmitting station across town, a radio wave would pass across all parts simultaneously. There would be little or no difference of emf. Therefore little or no electron flow.

Suppose, then, at first rigging, your aerial was in that position. Reception was poor, or very weak. Then, when you shifted it around, reception vastly improved. That was because one end of the aerial was pointing TOWARD the transmitting station, and the radio wave, striking that end of the aerial wire first, created a difference of electrical pressure between that end and the far end, resulting in a flow of electrons along the wire.

So you deduced that reception was better—in other words, louder—when your aerial pointed into the on-coming radio wave. And you ob-

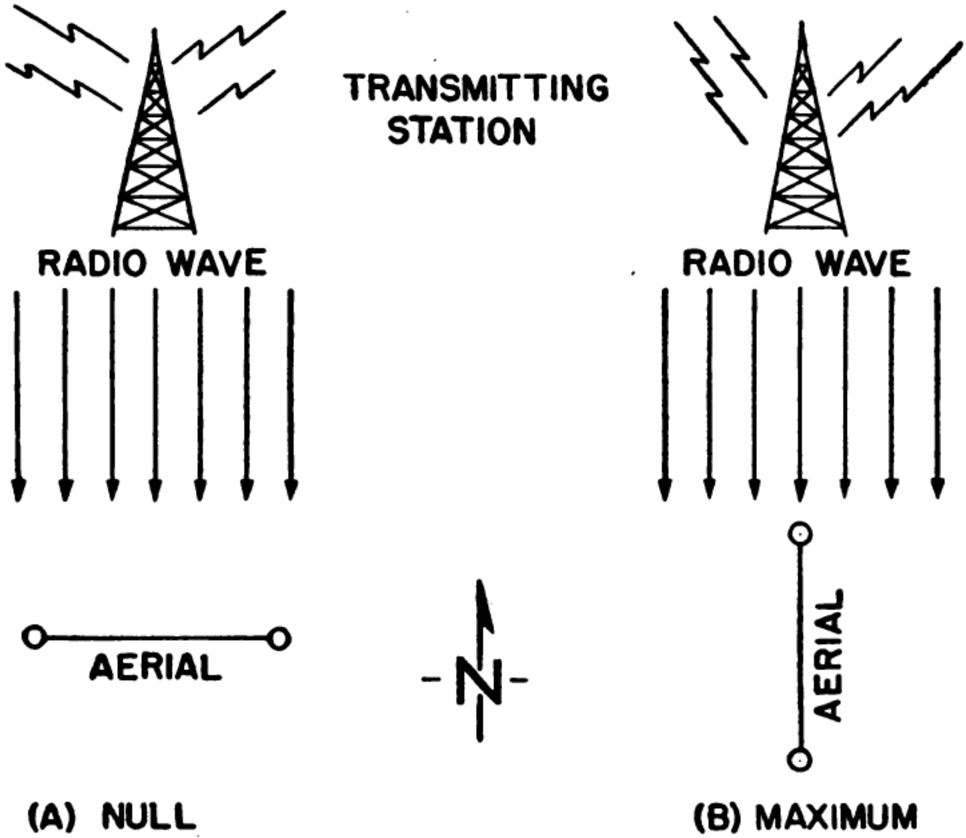


Figure 48.—Null and maximum positions of simple antenna.

A—Illustrating aerial at right angles to transmitted wave (minimum reception).

B—Aerial pointing into oncoming radio wave, and signal loudest (due to difference in emf in N and S end of aerial wire).

tained maximum reception when your aerial was aimed directly at the transmitting station, at which point, had you been shifting your wire around like a weather vane, the signal would have come in loudest. Incidentally, and accidentally, you would have found the LINE OF DIRECTION of the transmitting station. Also you would have demonstrated the basic principle behind the RADIO DIRECTION FINDER. You see this illustrated in figure 48.

However, such a means of direction finding would have its limitations. To begin with, LINE OF DIRECTION does not determine the location of the transmitter, for your wire, after all, has two ends.

Assume the signal came in loudest when your aerial pointed due north and south. You would know the LINE OF DIRECTION of the transmitter, but

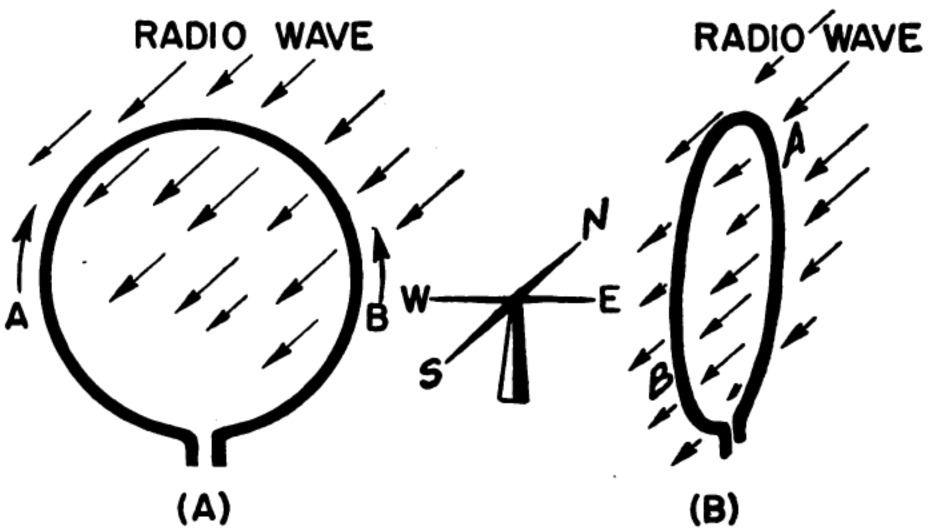


Figure 49.—Null and maximum positions of loop antenna.

maximum reception may come from EITHER direction. Does the sending station lie in the south or north? The radio wave—does it come from Detroit or Dixie?

And when is the signal at its loudest? Obviously it would take a hard boiled, if not keen, ear to determine the peak in volume.

It is also obvious that maneuvering an aerial-wire, weathervane-fashion on a roof, takes a good bit of juggling. Aboard an airplane there is little time for such hit-or-miss acrobatics.

Someone thought up the loop aerial.

The small loop antenna, developed to serve the superheterodyne receiver, solves the problem.

Imagine a loop of wire as illustrated in figure 49. Say it's about the circumference of a lady's hand mirror, and assume you're on the roof where you formerly juggled your lengthy aerial wire. Note how much easier it is to rotate this handy loop. Anyone can manage it without getting all fouled up.

Now assume you're seeking maximum reception, listening for the loudest signal. Holding the loop as though it were a mirror in front of your handsome countenance you are facing north. You hear little or no signal and are getting minimum reception.

The right and left sides of the loop, corresponding to the sides of a mirror-frame (or represented in diagram as two vertical lines) are presented to the oncoming radio wave in such manner that they are bathed by the wave simultaneously.

The flow of electrons in the two vertical sides (illustrated by arrows marked *A* and *B* at sides of loop (A)) will be of equal strength and opposite direction, and therefore cancel out.

Now you rotate the loop 90° so that one edge points into the oncoming radio wave (as in fig. 49B.) You can see how the horizontal lines of the diagram are now in the transmitter's LINE OF DIRECTION. The oncoming wave strikes point *A* of the loop a fraction of an instant before it strikes point *B*. Also think of the radio wave as undulant—to put it simply, a crest may strike point *A* and a trough may reach point *B*. The vertical sides of the loop are bathed at different points and not simultaneously. This creates difference of pressure, and emf creates electron-flow. Although the electron streams are in opposite direction, the pressure at point *A* is greater than that at point *B* (because point *A* is nearer the transmitter) and the greater pressure overcoming the lesser, current is set flowing in a counterclockwise direction.

Connect a receiver to the loop, and the electron flow will become audible as a signal.

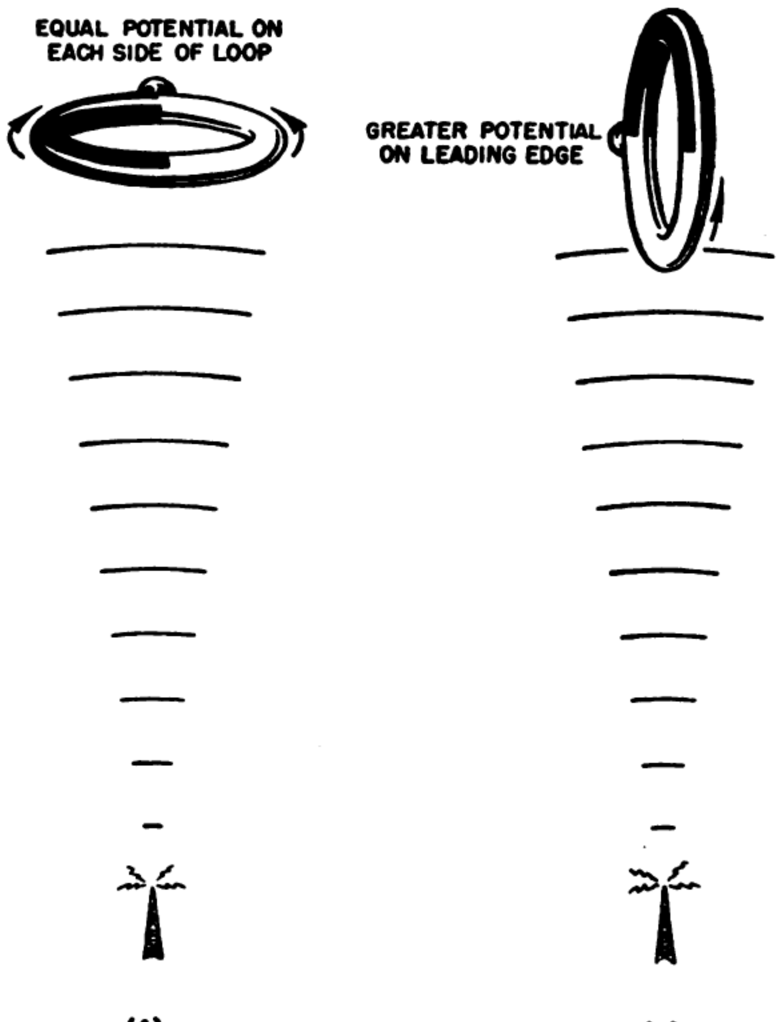


Figure 50.—Loop positions for maximum and minimum signals.

BUT SAY WHEN!

A glance at figure 50 will clarify the idea of the loop at minimum and maximum reception.

All clear? Rotate the loop antenna until the signal comes in loudest and the edges will be along the transmitter's line of direction.

WHEN is the signal at its loudest? There are fine shades to loudness, and they are hard for your ear-drum to measure. Given average hearing, it is easier to detect silence than measure degrees of sound.

So, in effect, the direction-finder operator reverses the operation. He rotates the loop until it faces the oncoming radio wave, the point at which reception is at minimum and the signal WEAKEST.

Were conditions perfect, a loop-position should be reached where no sound at all would be heard—zero signal—that point known as NULL POSITION.

And when are conditions perfect? You said it. Perfect NULL POSITIONS are practically nil. You're always liable to hear something. But it is easier to distinguish between a very faint, almost inaudible signal and one a little louder, than between two ear-splitters. So weak signals are employed in direction finding.

The loop antenna is tuned to the frequency of the incoming wave by means of a variable condenser. A condenser, similar to the trimmers of a t. r. f. receiver, is employed to attain exact balance in the arms of the loop before reception is attempted. Once the loop is tuned and balanced, it may be connected across the input of the first radio frequency amplifier tube, and the signal is amplified as usual.

SHOWS YOU THE WAY TO GO HOME!

But where's that transmitting station? You've found the LINE OF DIRECTION—say, north and south—now for what you'll refer to technically as the SENSE OF DIRECTION.

You've got two directions to pick from, but up in the air that's one too many. It's time to TAKE A BEARING.

For a ship at sea the problem is comparatively simple.

Picture night. Fog. A tanker, approximately 100 miles off shore, wishes to know its position.

Sparks sends out a radio signal. It is picked up simultaneously by stations along the coast. Assume one in Jacksonville, Fla., another in St. Augustine. Both stations immediately determine LINE OF DIRECTION of the ship, and establish same on a map. Then one station reports its findings to the other. Jacksonville plots St. Augustine's line, and vice versa, and where the two seagoing lines converge on the map, there lies the ship. Latitude and longitude are radioed to the tanker, and Sparks knows his ship's position.

The procedure is known as TAKING A BEARING.

But you're upstairs in a bomber, and your problem is a little more critical. You can't drop anchor and wait in a fixed position for your answer. Neither are you carrying 500,000 gallons of gas.

And a Navy plane, trying to find its way back home to a carrier, has other problems. There is only one transmitting station—in this case, the carrier. Furthermore, the carrier's location continually changes. It may be under way at forced draught, altering its course to dodge submarines.

A loop may locate its LINE OF DIRECTION—north and south—but you can't fly in two directions, and you can't leave it up to heads or tails. How does your direction finder handle this situation?

SHAKE HANDS WITH THE SENSE AERIAL!

The answer is a vertical antenna working in conjunction with your loop. The idea is simple. (Puzzles always are, after they're solved.)

Picture in your mind a single-wire vertical aerial coupled to your receiving set. Equidistant from this antenna, at points north, south, east and west, are four transmitting stations. Of equal power, they are sending with equal strength. Get the picture?

Were you to diagram this with drawing compass, your antenna at center-point, the circumference of your circle would pass through the four transmitting stations. Plot in the lines of direction and you have four radii. The vertical antenna is centered as the hub in a wheel, and the radii represent spokes.

You now have the PATTERN of the DIRECTIONAL CHARACTERISTICS of a vertical antenna. You call a vertical antenna NONDIRECTIONAL.

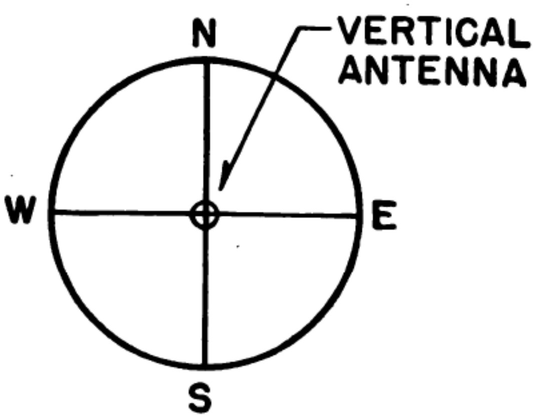


Figure 51.—Pattern of directional characteristics of a vertical antenna.

The why is obvious.

As you see in figure 51, the radii (which indicates maximum reception from the transmitters at which they point) are of equal length. The vertical antenna can receive four signals of equal strength from four (or more) equidistant points. As the signals may come simultaneously from all directions, there is no distinguishing the individual transmitter. Therefore a vertical antenna is NONDIRECTIONAL.

And now for the SENSE AERIAL.

Put spectacles on your imagination and visualize a vertical antenna erected at the exact center of the patterned loop antenna's "figure-8."

The stations located due north and south will come in at zero signal, while those due east and west will be heard at maximum reception.

Then, as in figure 53*A*, combine the pattern

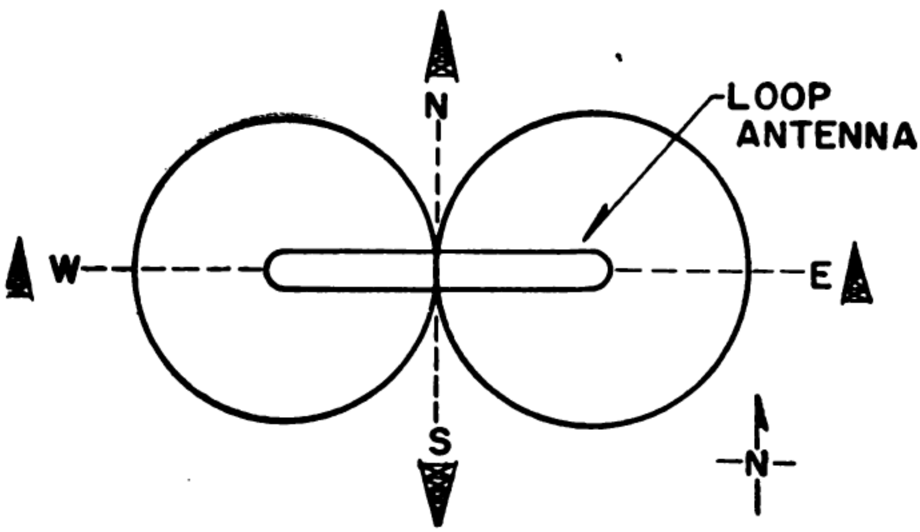


Figure 52.—Pattern of the directional characteristics of a loop antenna.

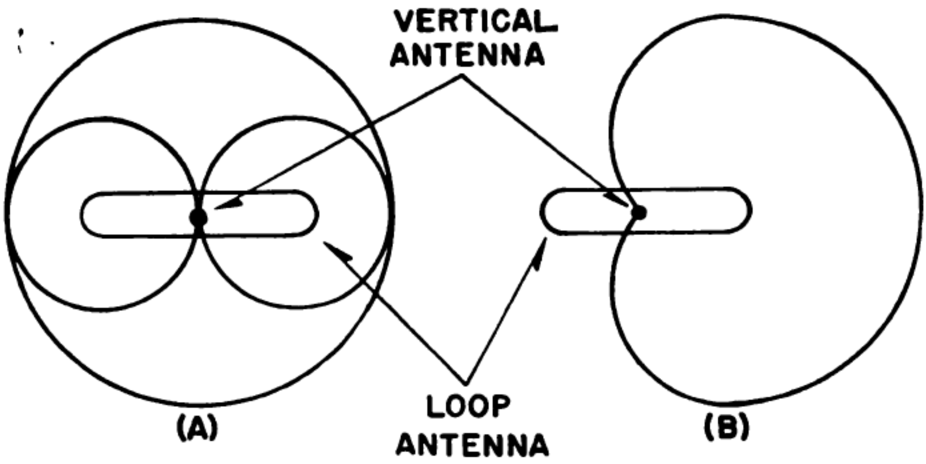


Figure 53–*A*.—Combined patterns of directional characteristics of vertical and loop aerials.

B.—Combined pattern of both in operation.

of the directional characteristics of the vertical and loop antenna.

Imagine the vertical aerial as coupled to the loop by a transformer. Electrons set flowing in the vertical aerial would start a second stream flowing in the loop, and this electron flow induced in the loop would lopside the pattern as shown in figure 53*B*.

From which direction is the radio wave coming in the above imaginative instance? Quick, Watson, the needle! You don't need a compass needle to suspect your line of direction lies east and west, and the transmitting station lies due east.

In other words, our new invention (the vertical and loop aerials combined) can receive better from one direction than another. You have SENSE OF DIRECTION as well as LINE OF DIRECTION.

As introduced, the vertical antenna is known as the SENSE AERIAL.

And here you have your direction finder!

ONE FLIES EAST, AND ONE FLIES WEST

Say you're out in the Pacific returning from a bombing mission. You're a little overdue, having paused on the way home to knock out a couple of enemy toughs, and the sun is two down, and you're hungry. The bean-rag will be flying, but the carrier isn't going to be where it was. Navigator, trot out that direction finder!

You're the navigator. You open the switch and take a null bearing with the loop to locate the carrier's line of direction (she's signalling for you, of course).

Then you work the switch that connects the sense aerial into the circuit. After which you rotate the loop until the signal seems to come in at its loudest. A pointer connected to the loop antenna indicates the direction of the incoming signal.

Now that you're pretty well checked, you can fix your loop aerial in null position (which would be at right angles to the incoming radio wave from the carrier) and as long as the pilot flies you along this line, you will hear no signal. If the plane goes off course, the balance of the loop is promptly upset, the electrons start flowing, and the warning signal comes through. You pass this advice on to the pilot who, as hungry as you are, hustles the plane back into the groove.

This procedure is known as HOMING. The term has a pleasanter sound than dead reckoning, and has been found to have pleasanter results.

You may be aided in your navigation by a RADIO COMPASS or HOMING DEVICE.

Simply, this is an electric meter connected to your loop antenna. At null, or zero signal, the indicator points to a marker on its scale which reads "on course." Should the plane deviate in flight to port or starboard, the needle would swing to left or right, indicating on the scale the degree of deviation. You inform the pilot, and he comes back in "on the beam."

And the next you know you're in your flat-top's mess room finishing your third cup of Joe.

BUT WAIT A MINUTE!

You don't want your bomber in there with you. With all that high octane and other explosives aboard, there WOULD be a mess. A bomber that far below decks is dangerous, and you'd never live to tell your grandchildren about course deviations and CORRECTIONS FOR ERROR.

No human being is infallible. Neither are the devices invented and installed by human beings. And to err is human, even when it's done by a direction finder.

One source of error in a direction finder is unbalance in the loop circuit. The loop is calibrated to compensate for possible deviations, and unbalance must be corrected by means of the condenser for that purpose.

Wires and other metallic objects located near the loop antenna may affect balance and the loop must be tested and shielded against interfering magnetic fields.

Atmospheric disturbances such as those caused by "sun spots" create electric fields in the stratosphere. Your loop antenna must be checked against such phenomena.

Greatest offender, perhaps, is NIGHT ERROR.

Cause of this troublesome phenomenon is that layer of electrified air which encompasses the earth. Studied by two scientists, Kennelly and Heaviside, this stratospheric layer of electrified air is often responsible for FADING in radio reception, and other fascinating electronic tricks.

A WORD ABOUT THE HEAVISIDE LAYER

Referred to by scientists as the HEAVISIDE LAYER, this stratum of electrified atmosphere, composed of ionized gases, might be thought of as an overhead, aerial dome.

Another name for this electrified stratum is the IONOSPHERE. Scientists presume that cosmic stellar rays and ultraviolet rays from the sun are the controlling agents of this gaseous layer.

By day it remains suspended about 60 miles above the earth's surface and by night it rises to an altitude of some 200 miles.

This difference in elevation has a decidedly noticeable effect on radio waves.

You might easily imagine the SKY WAVE as leaving a transmitter and traveling on forever out into skyward space. No; before it can get to Mars, it hits the Heaviside layer and is ricochetted back to earth like a sunbeam reflected from a mirror.

Carom shot off the right-hand cushion, it bounces back to the Heaviside layer and is again deflected to earth. The distance between the transmitter and the point where the sky wave comes back to earth in first rebound is called t SKIP DISTANCE.

So the sky wave caroms between earth ai IONOSPHERE in a series of skips around the worl In daytime, then, when the ionosphere is coı paratively low to the earth's surface, the sk distance is shortened.

But at night, the increase in altitude increas the skip distance, and the beam comes back earth at a point much farther from the tran mitting antenna.

This variation in SKIP DISTANCE, tends to u balance the loop aerial. Why? Because due the earth's curvature the reflected wave will stril the earth at varying angles. And the angle which an incoming wave strikes the horizont arms of your loop affects the emf, remembeı Any difference at the point of interception r sults in a difference of electrical pressure whi in turn affects the signal.

The resulting error in determination of dire tion is called NIGHT ERROR. Blame it on the shift IONOSPHERE.

One means of correction is the ADCOCK LO AERIAL which, in diagram, resembles the letter H There are two horizontal lines which cross i mid-H, however, breaking the letter into tw segments.

As these horizontal lines, or arms, are in clo proximity, the radio wave strikes them almo simultaneously. Thus they cancel out. The ele trical pressure in both arms is so nearly equa there will be no electron flow. The vertical wav or sky wave, is thereby eliminated. The loo direction finder will now pick up the horizont GROUND WAVE as usual, and night error is ove come.

Have a look at the direction finder in figure 54. As you know, the process of using a direction ıder is called "taking a bearing," or just "a ·aring." A bearing here means how the trans-itting station lies or bears with respect to your ›sition and heading.

There are several ways of determining your ›aring by radio, by the way. One of them is to

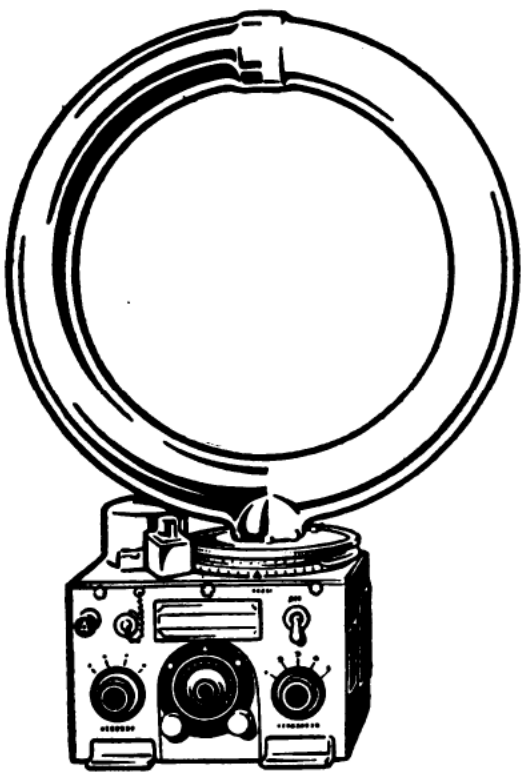


Figure 54.—DU direction finder.

ıeasure your bearing in degrees, in a clockwise irection from 0° to 360°, or to measure the angle ›rmed by the junction of a line from the station rith the center line of the plane. The bearing ıken is called a RELATIVE BEARING.

Figure 55 illustrates this method.

A VISUAL BEARING is a relative bearing taken by ctually sighting an object through an angle-ıeasuring device called a PELORUS. The pelorus

measures the angle between a line from the obje
and the center line of your ship.

Your bearing with respect to true north is call
a TRUE BEARING.

Now assume you're cruising over the briny ar
you want to take a true bearing. The pilot, wl
is in communication with you through the inte
com system, will read the true magnetic headin

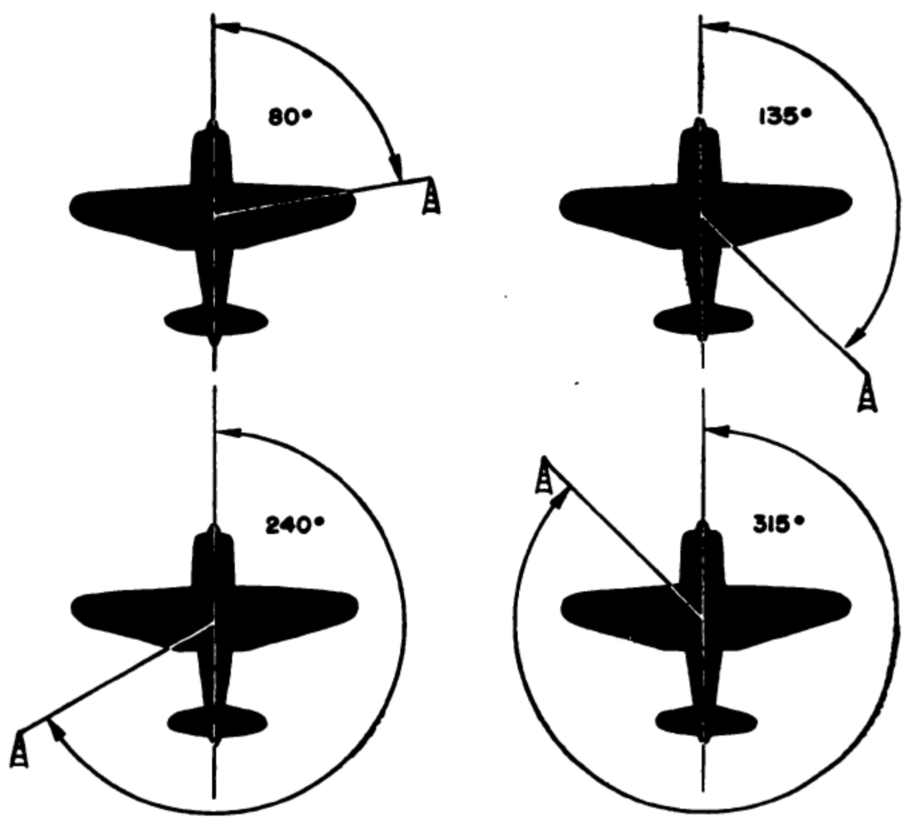


Figure 55.—Relative bearings. Angle formed by interception of line fro transmitter with center line of plane.

from his compass. At the same time, you tak
a RELATIVE BEARING of the station.

The bearing, after correction for deviation, i
added to the magnetic heading, and the sum give
you the true bearing of the station. Right? Th
true bearing is the corrected relative bearing plu
the plane's heading.

Essentially the radio direction finder (RDF
is a radio receiver with loop antenna, as previ

sly described. The loop, consisting of a coil a few turns of wire, is usually circular or tangular in shape, and is placed inside a metal se or electrostatic shield. Reason for the elecstatic shield? Radio waves are made up of th electrostatic and electromagnetic waves. It desirable in direction finding to use only elec-

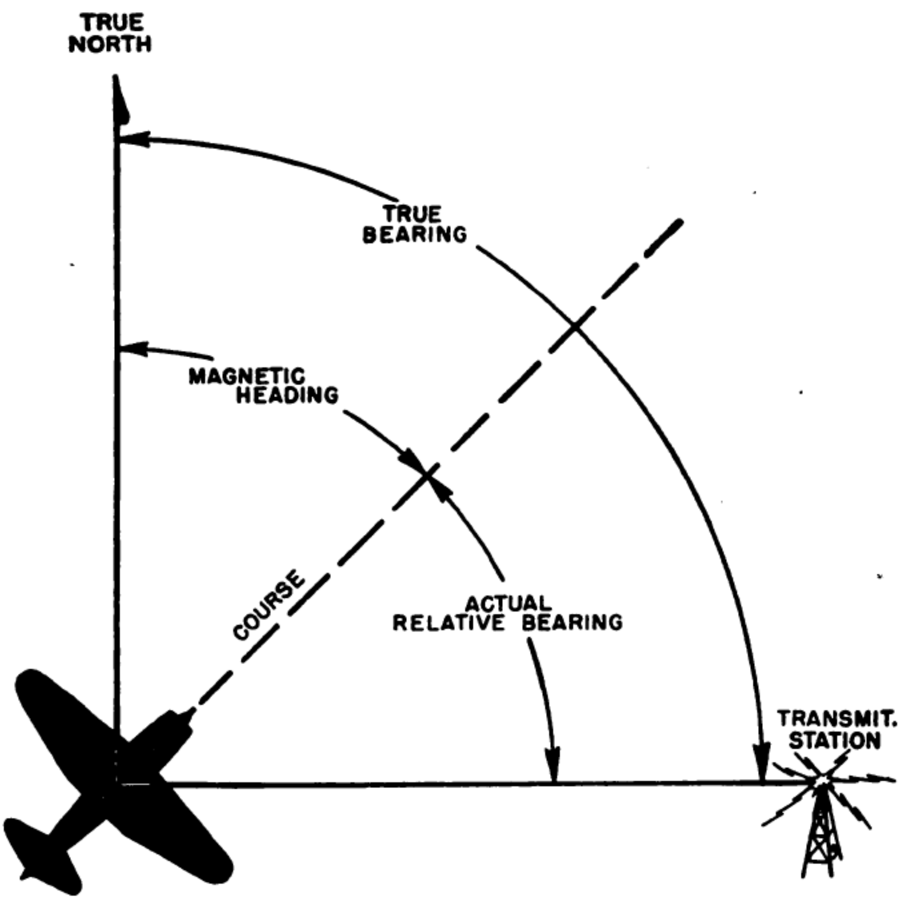


Figure 56.—True bearing.

omagnetic waves. Therefore the electrostatic ield.

Still in use is the RDF which does not have the nse antenna. You call this a BILATERAL DIRECON FINDER. In operation you rotate the loop 0° through four positions, each 90° apart. ius you obtain two maximum signals 180° apart, d two minimum signals 180° apart. By this means, your maximum, or minimum (null) pos tions may be determined.

You already know that this direction find can determine line of direction, but it cann determine from which side of the loop the rad wave comes. You can determine this yoursel however, by means of the angle your loop forn with the center line of the ship.

To your aid comes the AZIMUTH SCALE as pi tured in figure 57.

Here you see the loop mounted on a disk ba

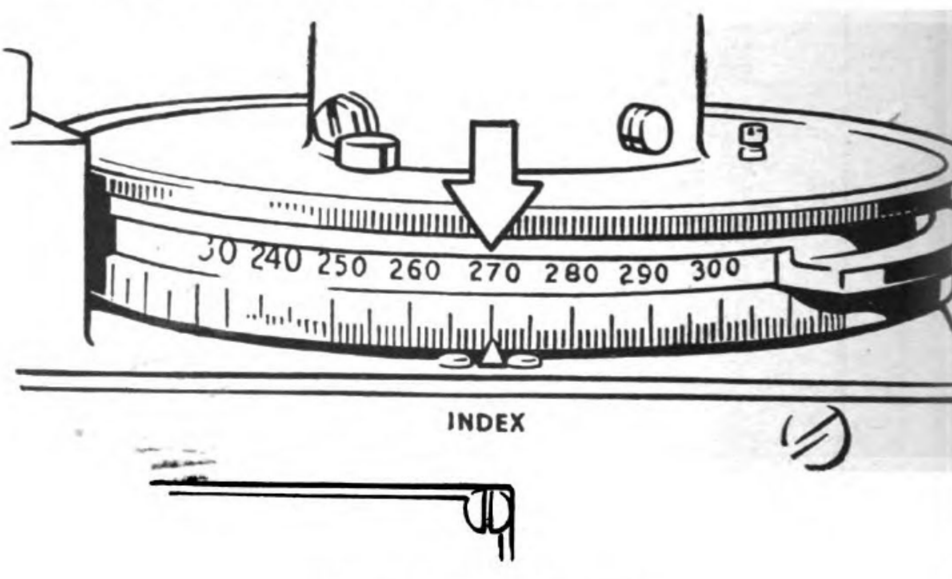


Figure 57.—Azimuth scale.

so that loop and base rotate together. The dis is calibrated in degrees from 0 to 360. Note tl pointer under the scale to indicate how far yc turn the loop.

To get the angle between the loop and the cent line of the plane, turn the loop until it lines u with the center line of the plane. Now read tl index and it will give you your bearing.

When the loop is turned at a right angle the plane's center line the azimuth scale will sho 0° or 180°. These are the minimum or null sign positions of the loop on which bearings are take n the scale. As you may suspect, when your lane is flying directly toward a transmitting sta- ion with your loop in a null position, you will ee zero degrees on the azimuth scale. You're n the beam!

Now consider another angle of your direction nder.

The radio waves from the transmitting station re bent or deflected by the fuselage of your

AZIMUTH SCALE RDG	CORRECT REL. BEARING	AZIMUTH SCALE RDG	CORRECT REL. BEARING
70	77	275	280
71	77	276	282
72	78	277	284
73	79	278	285
74	80	279	285
75	80	280	286

Figure 58.—Calibration chart.

lane. Like a sunbeam slanting from a bit of right-work, the wave may hit your direction inder at a tangent which would give you an in- ccurate bearing, or what is called an OBSERVED ADIO BEARING.

If you deviate too far off a course of study you nay end up at the bottom of a class, but if you leviate even a little in a course at sea you may end up at the bottom of "Davy Jones' locker."

With a happier landing in mind, you want to

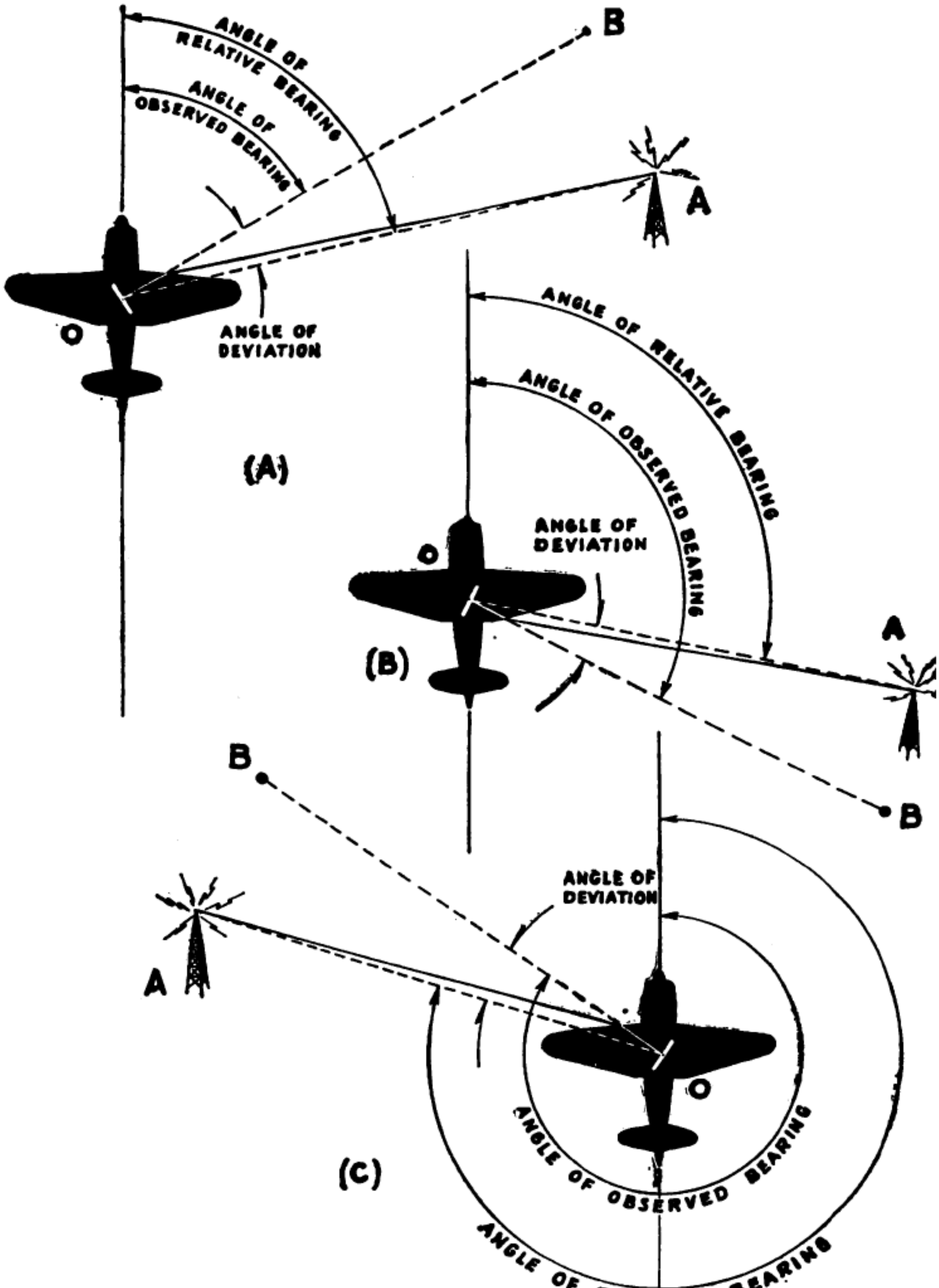


Figure 59.—Illustrating deviation.

correct the deviations of an OBSERVED RADIO BEARING and come out with a REAL OR ACTUAL RELATIVE BEARING. The method is fairly simple.

Accompanying your RDF will be a handy chart, a section of which is shown in figure 58. This gives you the correct reading for every position of your loop.

You take a bearing, and then refer to the chart which shows you the correct relative bearing. Your RDF readings are in black type, and the correct relative bearings will be indicated in red.

Suppose your direction finder reading is 72°. You will find by a glance at the chart (see figure 58) that the correct relative bearing is 78°. Figure 59 illustrates the subject.

From this figure you can understand another problem—whether the deviation is positive or negative. If the radio wave deviates in the direction in which your plane is going, as in figure 59*A*, the deviation is said to be positive. In views *B* and *C* the observed radio bearing is greater than the actual bearing—because the wave has been deflected in the opposite direction—therefore, the deviation is minus, and is subtracted from the observed radio bearing.

AND NOW TO INSURE A HAPPY LANDING

Remember—in operating the direction finder, you first use the maximum signal to establish the correct line of direction. Then, you rotate the loop to minimum signal position to obtain the correct bearing.

Aside from giving your ear a break, the minimum signal will prove the more accurate. Examine figure 60.

The idea is that when the loop is in maximum position, as illustrated, a variation of three or four degrees on either side of the center line will create but a small change in signal intensity.

At null position, however, small rotations of the loop produce large changes in signal intensity which are easily discerned by your ear. Thus your readings will be more accurate if you go home with your RDF at null position.

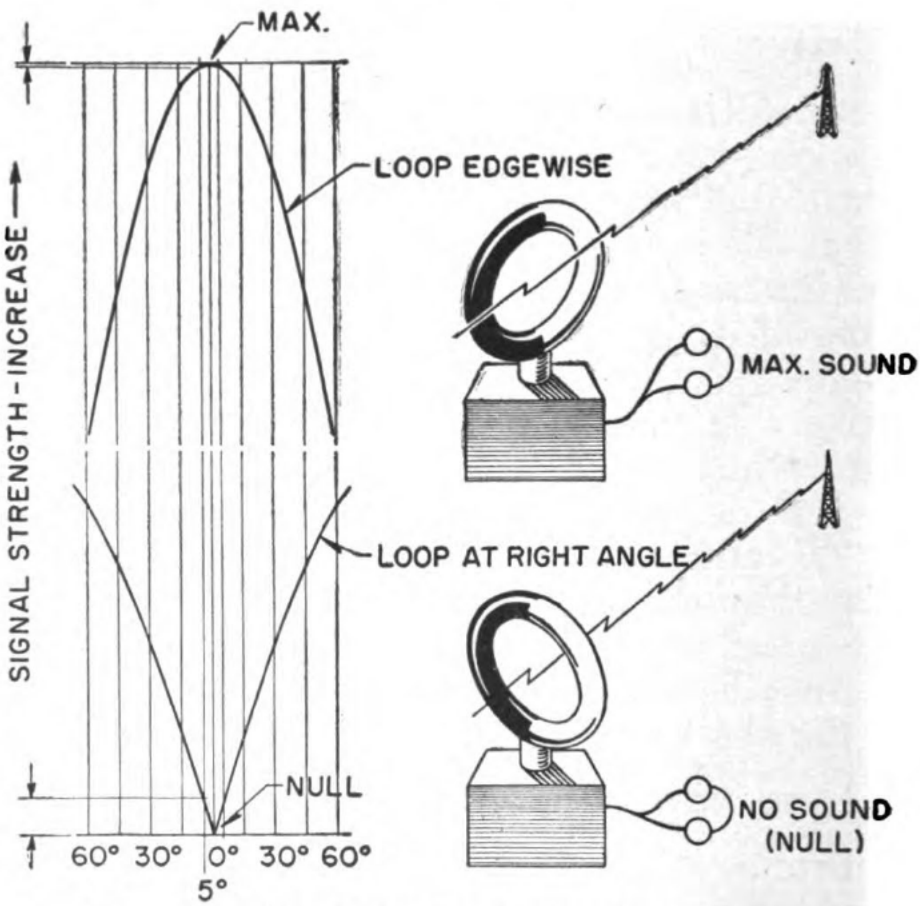


Figure 60.—Illustrating relative changes of signal intensity.

WITHOUT A SENSE AERIAL?

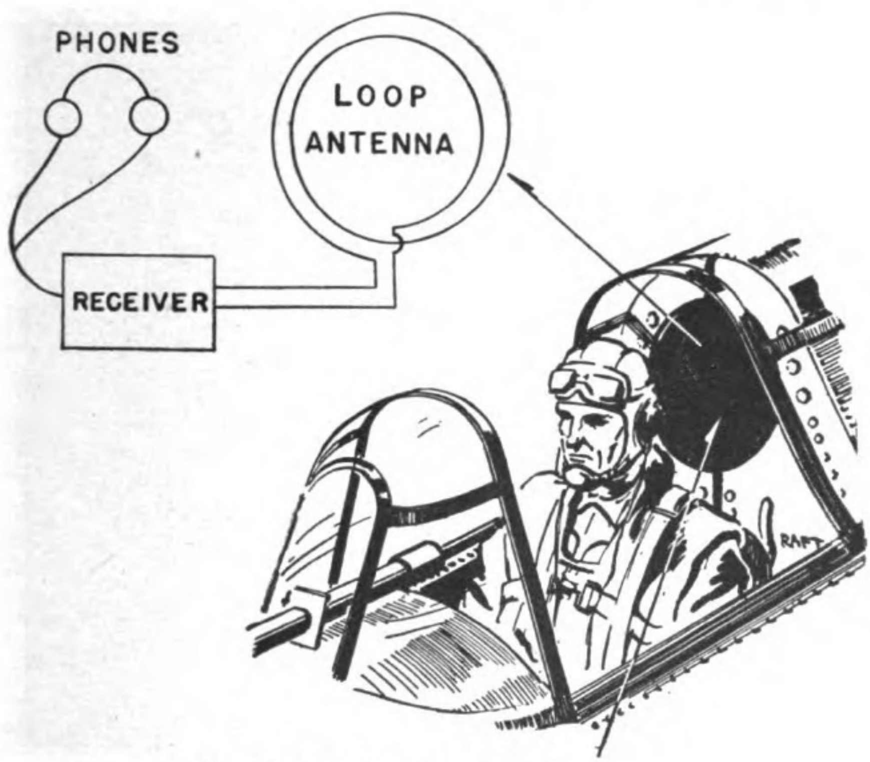
Yes, you can get home with a BILATERAL DIRECTION FINDER.

Consider a fighter plane with a fixed loop antenna installed in the pilot's head rest, as illustrated in figure 61.

The plane, having completed a mission, is on its way back to an aircraft carrier, and the flat-top having altered an earlier course, is sending out its call sign on a continuous radio signal.

The pilot picks up the call sign which identifies the distant aircraft carrier. He then switches his receiver to the loop antenna circuit and tunes to the transmitter-frequency of the aircraft carrier.

Now he maneuvers the plane until he hears a maximum signal in his headphones. The edges of



FIXED LOOP AND PILOT'S HEAD REST

Figure 61.—Fixed loop in pilot's head rest.

the loop will be in line of direction of the transmitting station, and the plane is flying at right-angles to the flat-top as illustrated in figure 62, line *A–B*.

The pilot now changes his course approximately 90° to port, and swings the plane until he is flying on null signal, as shown by line *B* and *C*. As yet, he doesn't know whether he's flying toward or away from the carrier. He marks his course on

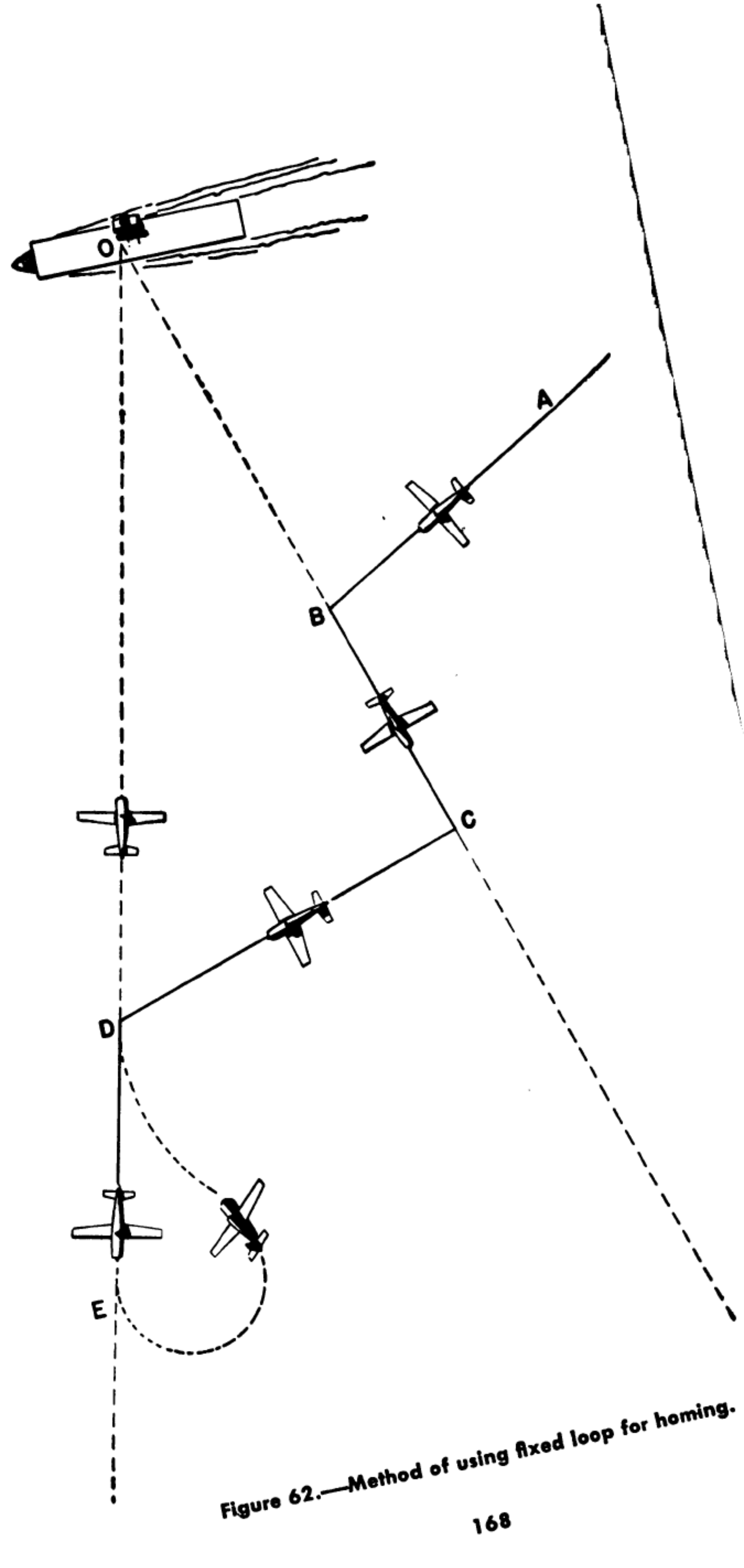


Figure 62.—Method of using fixed loop for homing.

the chart board at this point, and veers off on an abrupt tack 90° to starboard (see line *C–D*).

You'll note he's back on the maximum signal, and he flies this course for perhaps 10 minutes, charting it as he goes, and then swings again to port. Again he picks up the line of null signal.

Charting this line (*D* to *E*) and then extending the lines of the two null courses, he is able to plot a triangle (the line of his second maximum course as base) as shown in figure 62.

At the apex or focal point (*O*) of such a triangle he will always find his transmitting station.

Assuming then, as in the case illustrated, that he is flying in the opposite direction, he has but to do a smart about-face and check his course for the null signal, along which he hightails home.

However, the disadvantages of such a homing procedure are obvious. Gas and oil may be running short. And by the time the pilot completes the necessary maneuvers, a flock of enemy pilots may be hightailing along home with him.

You'll be glad to recall, then, that little matter of the sense aerial, and turn to your—

UNILATERAL DIRECTION FINDER

That is the technical name of your RDF which has loop antenna and sense aerial combined.

The vertical aerial, as you recall, makes the signal much stronger and increases the directional pattern on the side of your loop, which is turned toward a transmitting station. This gives you sense of direction as well as line of direction.

As an aid to the operator, the side of the loop which gives a maximum signal when pointed at the station is painted aluminum color, and the "weak" or minimum side of the loop is painted black. You will also find on top of the azimuth scale two arrows which will point in the direction of the incoming wave (see fig. 63). By these means you can easily determine in which direction the sending station lies.

Now take off with your UNILATERAL DIRECTION FINDER.

You rotate the loop for maximum signal to find the direction of the transmitting station.

Then, for easier and more accurate readings, you cut out the sense antenna and turn the loop 90° to the right (so that the flat side is toward

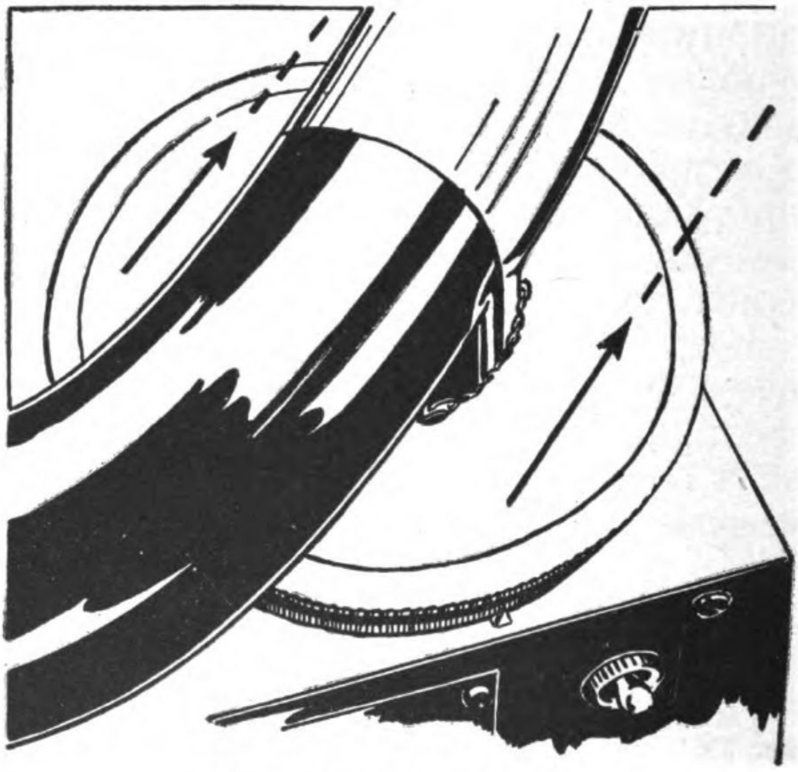


Figure 63.—Azimuth arrows.

the sending station) and you obtain a null signal. By using this null position, you can take an accurate bearing.

This calls for reference to your azimuth scale. There is a fixed pointer on the front of the scale which indicates your bearing in degrees of null position, and another pointer at the right which indicates degrees of bearing in the maximum position.

When the "aluminum" side of your loop antenna is pointing forward along the center-line of your plane, the azimuth scale will read 270° at the front pointer and 0° at the right-hand pointer.

Rotate the loop in right-hand direction to null position, and the reading at the front pointer will be 0°.

Another device to your aid is the masking piece on the azimuth scale. In case you're unfamiliar with the term, a masking piece is a disk or metal plate which slides or rotates over a scale to reveal only a sector of the scale.

You set the masking piece over the front pointer after the maximum signal position of the loop has been established. A marker may also be adjusted to indicate the position. Now you'll have no trouble remembering which way to turn the loop.

MEET THE DU–1 DIRECTION FINDER

Having familiarized yourself with direction finders in general, meet some of the more important members of the family. Like the members of any family they have their individual quirks and characteristics. Better know them. You can depend on them as ace guides when the time comes—they'll stand by you in a fix. But you have to meet them half way. The better you understand them, the more they'll stand by you.

Here in figure 64 is one from the family album to remember—the DU–1 direction finder. It's a sensitive number, designed to take accurate unilateral and bilateral bearings when used in conjunction with Navy radio receiving equipment of the model RU series.

You'll find it in open-cockpit types of naval aircraft, such as scouting and observation planes, where all operating controls must be accessible to pilot or observer. It operates over a frequency range of from 200 to 1600 kilocycles. Said range is covered by three manually switched bands which measure off 200 to 400 kilocycles, 400 to 800 kilocycles, and 800 to 1600 kilocycles.

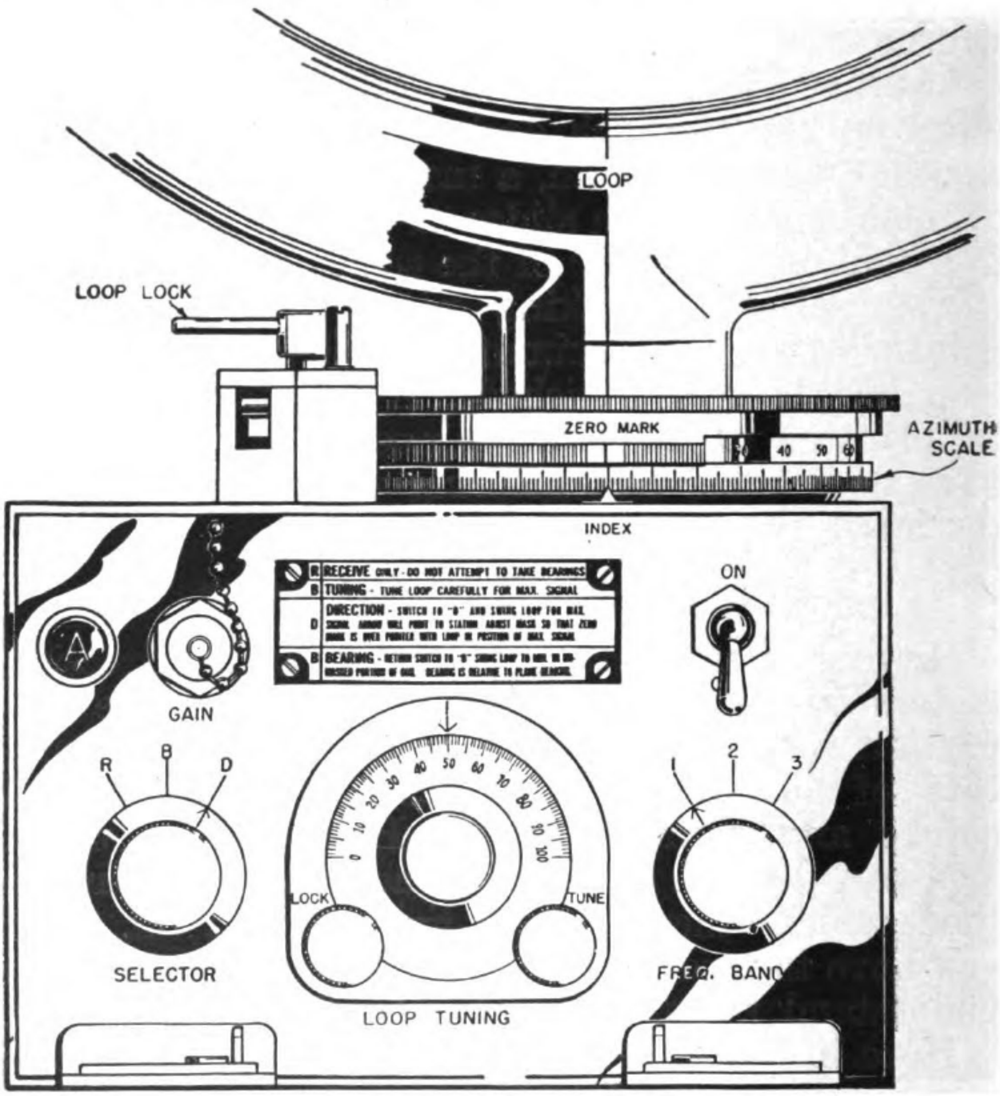


Figure 64.—Front view—model DU-1 direction finder.

Look at the portrait view (front panel) as shown. You see a coupler unit which contains a power switch, frequency selector, loop tuning dial, selector switch, gain control, vertical antenna connection, index pointer, and instruction plate.

Observe also the loop antenna, the azimuth scale, the locking device for the loop, and the adjustable masking piece on the azimuth scale—all mounted on top of the coupler unit and forming the LOOP ASSEMBLY.

Power for the DU coupler unit is usually supplied through a shielded cable from an RU receiver junction box; the connection, and that of the RU receiver antenna, on the back panel of the unit.

The DU is mounted in the plane either at the factory or by the installation crew. It is held in its base by snap-slide fasteners. All adjustments such as alinement of the azimuth scale with the center line of the plane, and phasing adjustments, are taken care of at installation.

Recalling the human element, however, you should always check for error.

Now you're ready to operate the DU. But be sure you are able afterwards to—

TELL ABOUT YOUR OPERATION!

Go easy until you're well acquainted. KEEP AN EYE ON YOUR SAFETY REGULATIONS. The DU, like all sensitive apparatus, is high strung. You don't fool with hot-tempered individuals on short acquaintance. Neither do you play around with high-voltage direction finders.

Respect the DU's voltage. After all, operations are no good unless you live to tell about them.

DIRECTION FINDING

So examine the SELECTOR SWITCH as pictured in figure 64. You see the letter *R*.

This indicates the first, or *R* position, at which the fixed antenna on the plane feeds through the coupler unit to give you nondirectional reception. Your receiver is now tuned as for ordinary antenna reception.

Meantime the loop should have been DE-TUNED. Otherwise, through stray couplings, it may produce slight variations of output.

For this operation only, the coupler unit power switch (if desired) may be left in the "off" position.

The next step is *B* for LOOP TUNING.

In this position you should note the setting of the receiver switch box. It should always be set on the MANUAL CONTROL position, and the "CW-MCW" switch should be on "CW."

The COUPLER UNIT POWER SWITCH should be ON.

In preparation for direction indications, the loop must be tuned to resonance in order to match the output of the fixed antenna. Tuning the loop gives a large increase in sensitivity and prevents error.

Should the loop be improperly tuned, you will be unable to obtain correct phase relationship with the fixed antenna, and directional indications will not come through. In this event, rotate the loop by means of the thumb wheel to EITHER maximum signal position, and tune for a maximum signal. This will facilitate proper adjustment of the loop tuning control.

Now tune for a maximum signal at this position—

D IS FOR DIRECTION

At *R* position you tuned your receiver.

At *B* you tuned your loop and obtained your maximum signal.

D position will give you your approximate direction.

Rotate the loop for a maximum signal output. The arrows on the azimuth scale thumb-wheel will point toward the transmitting station when the maximum signal is being received. Now you have the approximate bearing of the station—you know whether it lies to port or starboard, astern or somewhere ahead.

When the loop and antenna components are properly matched, this indication of direction will be clearly discernable.

Hold the loop in this maximum signal position and rotate the masking piece on the azimuth scale so that the zero mark coincides with the position of the index pointer.

Then turn the selector switch back to *B* position to obtain your bearing.

BACK ON B FOR BEARING

You rotate the loop, without moving the masking piece, until the signal minimum is at the point where the exposed sector of the azimuth scale and the index pointer come together.

When the signal is at a minimum, the observed reading gives you the indicated radio bearing of the transmitting station with respect to the heading of your plane.

You now refer to the correction chart. (See fig. 58.) Pick off the corrected relative bearing that corresponds to the observed bearing you just obtained.

In most cases the minimum signal, as observed on a meter, will be less than a degree in width. Your ear would have to be sharp as a piano tuner's to make so accurate an estimate. Leave it up to your loop.

Pick a definite signal level. From this level rotate the loop through the minimum to an equal level on the opposite side of the minima. Note the amount of rotation, and the center of that arc is the CORRECT INDICATED BEARING.

ADVICE!

Under no condition should the masking piece be moved from the time it is set on the *D* position to the time the bearing is taken on *B* position. When the proper procedure is followed, as outlined, there is no chance reversal of bearing. Bearings taken in daytime over the intermediate frequency range (200 to 1600 kilocycles) are reliable.

But at night, and particularly at dawn and dusk, beware night effect. Scientifically speaking, distortion of the minimum signal in a loop direction finder occurs as a result of a reflection horizontally of polarized components of the radio wave.

Call it night error and blame it on the mysterious Heaviside Layer.

Other errors may be invited by quirks of installation which interfere with good unilateral direction finding. Bugs may sometimes be ironed out and operation improved by a very slight readjustment of the loop tuning dial. Delicacy is called for. Treat the dial with heavy hand, and no direction at all will be indicated. The loop will not respond properly if too much change is made.

Remember, your RDF is a sensitive instrument. Treat it with friendly respect, and handle with care.

APPROXIMATE BEARINGS

It may be necessary at times to obtain approximate bearings without interrupting the reception of communications.

In such a case, you may operate your equipment with the selector switch on *D,* the loop adjusted to the center of the maximum signal zone where reception compares favorably with that obtained at *R* position. Your approximate bearing, relative to the plane heading, is then obtained by reading the azimuth scale from the pointer at the right-hand end of the coupler unit.

An even more rapid, but less accurate, indication is given by the arrows on top of the azimuth scale. Or simply note that the light-colored side of the loop always points toward the transmitting station when the loop is rotated to maximum signal on the *D* position.

Incidentally, if broadcasting stations should be your signal source, your selections must be made with care. Two stations operating on the same frequency may tend to indicate more than one direction, or fail to give any directional indication whatever. Those stations operating on clear channels will give best results. You will note, too, that broadcast transmitting stations are often situated some distance from the outskirts of the cities controlling them. (You don't want to aim for Australia and come down in Cy Jones' cow pasture).

Automatic volume control (A. V. C.) in a receiver is generally undesirable for direction finding. Reason is, it prevents normal change in signal strength with loop direction.

Manual volume control should always be used. Ordinarily your receiver should be in its CW position. However, if the incoming signal is strong, with a steady tone modulation, you may obtain better results with the receiver nonoscillating on MCW.

An OUTPUT METER can be used to get a very accurate observation of minimum reception. Using such a meter, you should listen carefully to be sure you correctly identify the signal.

So far you have operated your DU as a rotating-loop direction finder. You may also operate it as a fixed-loop homing device.

For this purpose you adjust the rotating loop and set the SELECTOR switch at *D*.

A maximum-signal reading of 270° on your azimuth scale denotes the plane's heading in the direction of the transmitting station.

All right, rotate the loop to 0 degrees, lock the thumb-wheel clamp, and see that your selector switch is on point *B*, while the plane continues to fly in the direction of minimum signal strength. Now check the direction from time to time. You do this (while your loop is locked athwartships) by throwing the selector switch to *D* while the plane veers 90° to the right. You return the selector switch to point *B* as the pilot swings back in the direction which gives you your minimum signal.

You'll find this method of homing (your DU employed as a bilateral direction finder) becomes increasingly tedious as you approach your target station. The receiver output and the sharpness of the minimum signal both increase rapidly as you near the transmitter. You may also fly through the "no minimum" zone over a station without knowing it.

You avoid this by shifting the selector switch to *D* and completing the flight on the CARDIOID MAXIMUM, with your loop locked at 270°. You can use an output voltmeter to advantage in defining the cardioid maximum.

Cardioid—in case you've forgotten the term—means heart-shaped. And the cardioid maximum, as defined by your dictionary on radio, means that lopsided directional pattern obtained by your sense aerial and loop antenna combined—

remember? It was lopsided (heart-shaped) in the direction of the incoming radio wave.

To define the cardioid maximum with your VOLTMETER, you use the 1.5 or 6-volt scale, and continue to reduce the receiver volume control (by manual operation) as necessary to prevent overload.

The signal level will drop to low value when passing over the target station, and it will not ascend to its former value after passing, unless the loop is rotated 180°. Why? Because the station then lies in the position of the CARDIOID MINIMUM.

Planes flying blind at an altitude of 6,000 feet have, by this method of homing, located stations to within 500 feet.

The method is also good for distant homing when excessive fading blurs your signal, and when simultaneous reception of communication is desired.

INSTALLATION NOTE—In types of aircraft where the loop is located in a particularly strong airstream—say near the propellors—there are certain angular positions at which the loop may vibrate and whip. Such areas should be determined at installation, and the loop should not be locked in these areas during flight.

OPERATION NOTE—During all fixed-loop homing maneuvers you should secure the LOOP TUNING DIAL at resonance by means of the LOCK-KNOB located on the left of the tune control.

This will prevent frequency shift caused by vibration—a gremlin which would otherwise give you phoney directions and false bearings.

MEET BENDIX MN–26C

This is a new type of RDF, and you'll be interested in striking up an acquaintance while you're on the subject.

The Bendix MN–26C boasts a superheterodyne receiver circuit, a VISUAL "ON COURSE" INDICATOR, and a calibrated dial which permits correction of radio bearings to true bearings and shows the relation of magnetic bearings to an aircraft's magnetic heading.

By means of the "on course" indicator, the

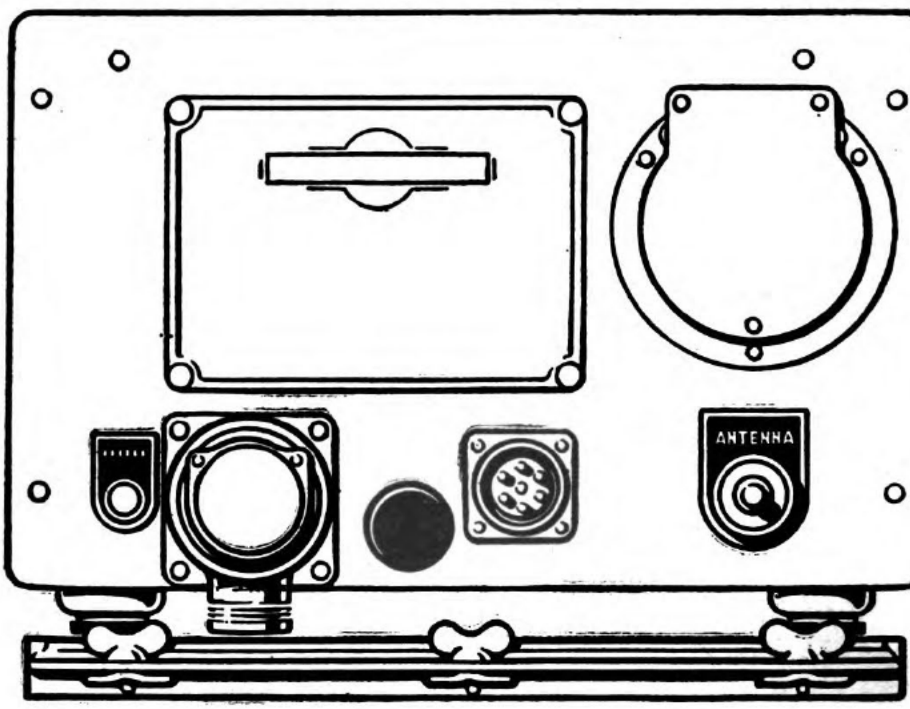


Figure 65.—The Bendix MN–26C direction finder (front panel view).

Bendix MN–26C (see fig. 65) may be operated to give the usual sound bearings and visual indications. Frequency range is from 150 kcs. to 1500 kcs. in three bands. Each may be selected as desired by a BAND CONTROL SWITCH.

How does it work?

Briefly, the sense-antenna output is fed into two matching tubes which operate the visual "on course" indicator. Tube outputs are balanced, so the voltage across the visual indicator is negligible, and the meter shows no deflection.

The voltage developed in the loop antenna is fed to the visual indicator in combination with the voltage developed by the sense antenna. Result—the visual indicator needle is deflected to either right or left, depending on which side of the loop is cut by the radio wave.

If the loop is cut equally on both sides? The voltage is then balanced, and the visual-indicator needle remains in upright position. You know your loop antenna is at right angles to the incoming wave. Deduction? By means of the visual indicator your plane can keep on its course.

Now suppose you want to take unilateral bearings. You rotate the loop to left or right, watching the needle on the visual indicator. If it swings to the right then the loop bearing being taken is ahead of the plane. If it swings in the SAME DIRECTION as the loop (for example, rightward when you rotate the loop to the right) the bearing is RECIPROCAL. In such a case, it is necessary to rotate the loop 180°. When homing by means of the visual indicator, the plane must be turned 180°.

Bilateral bearings alone may be taken by means of AURAL SENSE.

Aural, of course, referring to ear, you secure a minimum signal in your headphones. Bearings are then read from the compass under the indicator.

To find your MAGNETIC BEARING in relation to the plane's course, you adjust the inner movable dial so that the course is exactly opposite zero on the first dial. In relation to the transmitting station, the ship's magnetic bearing is read under the pointer.

To obtain a TRUE BEARING of the ship's magnetic course, you adjust the inner movable dial to the necessary east or west variation as indicated on the upper half of the compass face. The ship's magnetic course, placed against the east or west variation, and the bearing read under the pointer, will give you your corrected, or true bearing.

CHAPTER 8

NAVAL AVIATION TRANSMITTERS

GF SERIES

Modern radio transmitters, as you know, send out radio waves which may be of two types—CONTINUOUS (unmodulated) or MODULATED. You are acquainted with the designations, CW (continuous wave), VOICE (voice modulated) and MCW (modulated continuous wave). Their study involved the "theory" of transmission.

Now you will take up the construction and operation of several modern aircraft transmitters.

First consider a light and compact type of transmitter, ideal for small aircraft on which space and weight are at a premium. More than fitting the requirement is this GF TRANSMITTER, herewith pictured, front-panel view, in figure 66.

GF's are generally installed in fighter, observation, and patrol planes for VOICE communications. And they pack a real punch.

Power is derived from a 12- or 24-volt battery.

A dynamotor furnishes proper voltages for the tubes in the transmitter. The heater, relay and microphone voltages are taken directly from the battery supply or through dropping resistors. The transmitter has a power output of from 12 to 14 watts.

Like other transmitters, the GF has four major circuits. Here they are in brief review.

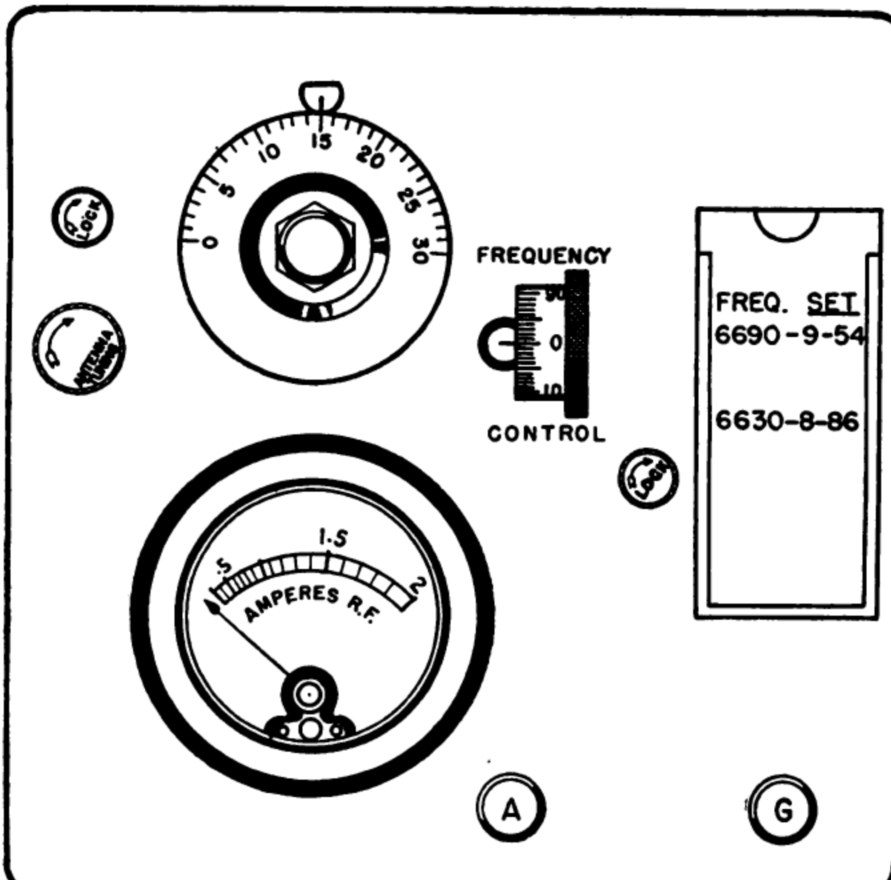


Figure 66.—Front panel view—GF transmitter.

THE MASTER OSCILLATOR, which generates the signal and determines its frequency.

THE POWER AMPLIFIER—as the name implies, increases, or amplifies in power the signal from the master oscillator.

THE MODULATION OUTPUT CIRCUIT, whose business is to modulate an outgoing signal with an audio voltage of voice frequencies when the VOICE SWITCH is on, and with an audio voltage of constant frequency when the MCW SWITCH is on. The test meter is a direct-current milliameter with a scale from 0 to 35 milliamperes. It is used to read the modulator current or the amplifier current in the transmitter.

THE ANTENNA CIRCUIT radiates the signal into space to be picked up by distant receiving stations. You adjust the taps on the antenna coil to the right number of turns. Then vary the antenna tuning condenser until all circuits are matched. This is indicated by maximum reading on the r-f ammeter, which is in the antenna circuit.

There in a nutshell are your four circuits, and now a word in brief about FREQUENCY CONTROL.

By means of frequency control you may tune the MASTER OSCILLATOR to any frequency selected within the limits of the GF frequency. The frequency control has two moving parts—a main dial, which is calibrated from 0 to 30, and a vernier dial which is calibrated in degrees from 0 to 100.

One complete revolution of the vernier dial advances the main dial 1°. If a dial setting of 1500 is required, the vernier dial is rotated until the main dial indicates 15, and the vernier dial 0.

For another example, if a dial setting of 580 is required, the vernier dial will be rotated until the main dial reads 5. After the vernier dial is advanced to 80 you get 580.

On the left-hand side of the transmitter, you'll find a CALIBRATED DIAL which is marked off from 0–35. It is connected to the shaft of the antenna tuning condenser. Keep a record of the dial readings for each frequency when the meter indicates maximum amperes r-f. You'll save time and trouble when you want to use the same frequency again.

The r-f ammeter will always indicate when you've tuned the circuits properly. It indicates a maximum reading when the antenna tuning condenser is correctly set. BEAR IN MIND that the antenna circuit must ALWAYS be tuned for MAXIMUM indication, regardless of the frequency being used.

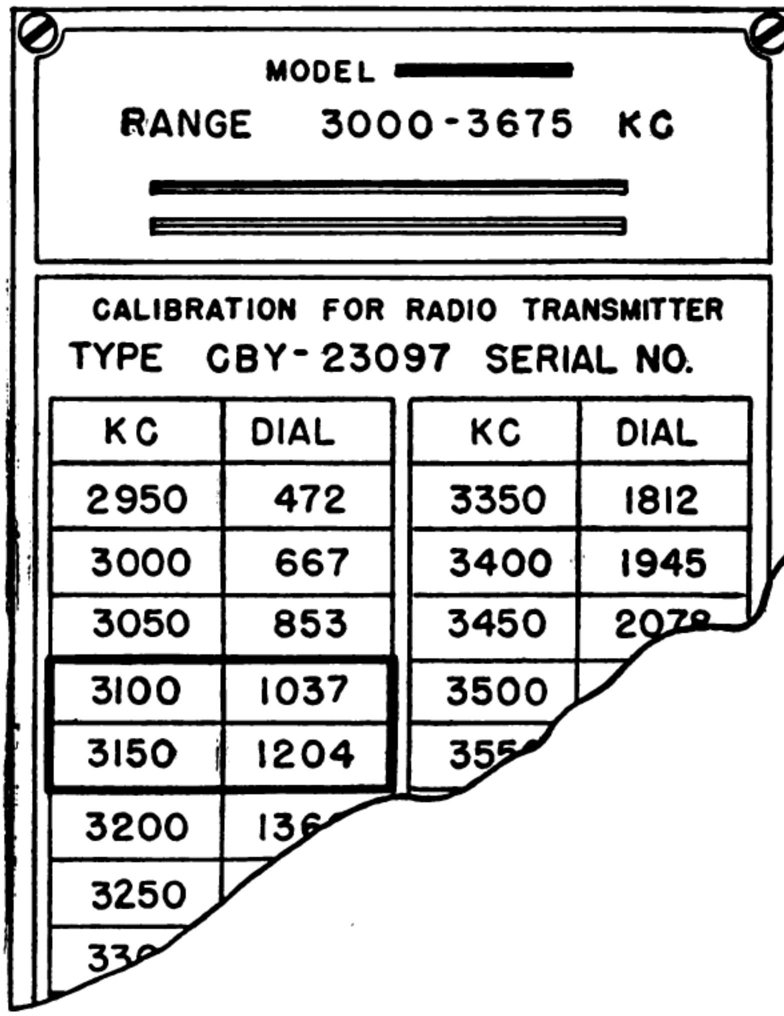


Figure 67.—Calibration chart, GF transmitter.

At this point, there are four more parts in a GF transmitter worth your attention—

The ANTENNA POST, by means of which energy from the transmitter is carried to the antenna of a plane. The GROUND POST, and the TWO LOCKS which prevent the master oscillator and the antenna tuning selection from being jarred by vibration.

Now for your TUNING CHART and the subject of INTERPOLATION. The latter is a method of finding an APPROXIMATE FREQUENCY in any instance where a tuning chart is available with a radio transmitter or receiver.

Glance at figure 67 which illustrates a portion of a FREQUENCY-DIAL CALIBRATION employed with a GF transmitter.

You'll find a chart of this kind located on each coil unit. As you can see, it's comparatively simple to set the transmitter on any frequency listed.

Since the chart divides the kilocycle scale by 50, you have to do a little easy and painless arithmetic if, for example, you want to operate your transmitter on 3115 kilocycles. Here's the procedure.

Find the number of degrees on the dial that corresponds to 1 kilocycle. Multiply this figure by 15 to find the dial-change for 15 kilocycles. Add this to 3100 kilocycles. Here's what it looks like on paper.

KILOCYCLES	DIAL READING
3150 kc.	1204°
−3100 kc.	−1037°
50 kc.	167°

1 kc. = 167 ÷ 50 = 3.30°
15 kc. = 15(3.3°) = 49.50°
3100 kc. = 1037°
3115 kc. = 1037° + 49.5° = 1086.5°

Bingo! You've not only avoided a lot of guessing. You have also an approximate dial setting.

HOW TO TUNE YOUR GF

Learn these steps to follow, and you'll know how to tune your GF transmitter. Easy does it.

First, turn the switch on the transmitter control box to CW.

Throw TOGGLE SWITCH or transmitter control box to RADIO.

Your transmitter is ready now for frequency calibration and there are three main adjustments. Let's go! SET THE FREQUENCY CONTROL (which operates the variable condenser of the master oscillator) at the desired transmission frequency by means of the chart found on the transmitter coil unit. In most cases you'll have to make interpolations. If you require an accurate frequency use the CFI.

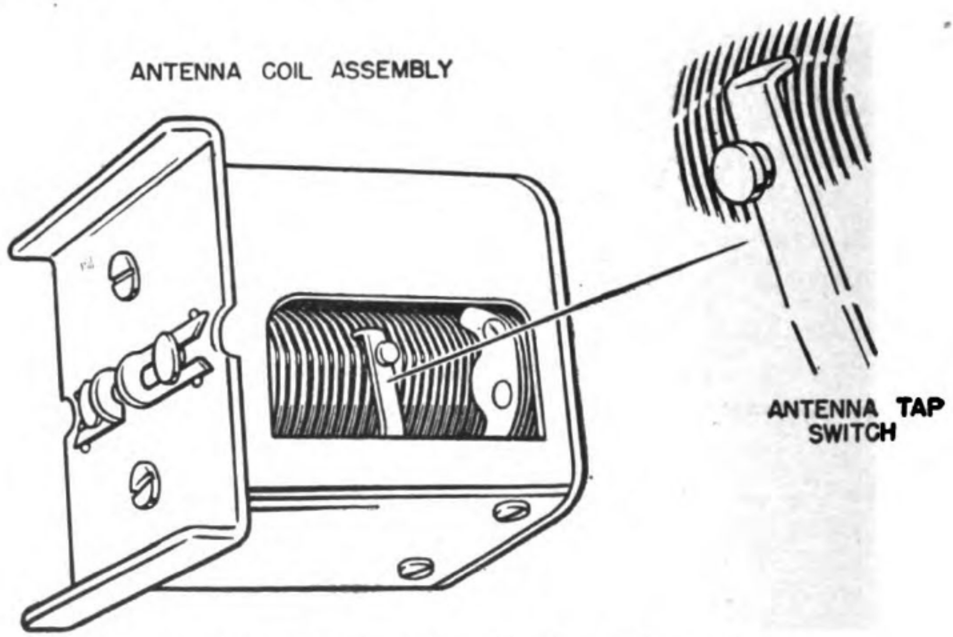


Figure 68.—Adjustment antenna coil, GF transmitter.

Now adjust the ANTENNA COIL TAP SWITCH in the coil set (illustrated in fig. 68). You'll probably have to try several different settings before you find the proper setting of the tap switch for a given frequency. This tap switch varies the inductance. Only one position of this tap will give an absolute maximum of current and power output. A higher frequency requires fewer turns of the antenna coil.

Now press the key and turn the antenna tuning knob until maximum antenna current is indicated on the meter. If you get no meter reading, or if the current is still increasing when you reach the limit of the antenna tuning knob, release the key and change the ANTENNA TAP SWITCH one turn in either direction.

Key the transmitter again and try tuning. If you still obtain no result at this setting, move the antenna tap back one turn in the OPPOSITE DIRECTION from your original maneuver. Continue trying different settings of the antenna tap switch until you obtain maximum current. This reading should not occur at either end of the antenna tuning condenser range. You get the best results when maximum antenna current is obtained with a midscale reading of the antenna tuning condenser dial.

On all types of aviation transmitters there are small locks on the dials to prevent any change of the settings which might otherwise occur from vibrations in the aircraft. Make sure all your dials are LOCKED.

That's the low-down on your GF transmitter. Among aircraft radio transmitters, it's in there fighting. The rest is up to you. KEEP SENDING!

GP TRANSMITTER

Now take a look at a larger type of transmitter, the GP. Heavier and more powerful than the GF type, the GP transmitter is generally installed in SCOUT and TORPEDO BOMBERS. The GP has an output of 85 to 125 watts when emitting CW and MCW over a frequency range of 350 to 9050 kilocycles, and an output of from 30 to 40 watts when using VOICE. Here's the front-panel view (fig. 69).

You'll use PLUG-IN TUNING UNITS to obtain the frequency range. Normally the frequencies you'll employ are predetermined and only one extra tuning unit is carried.

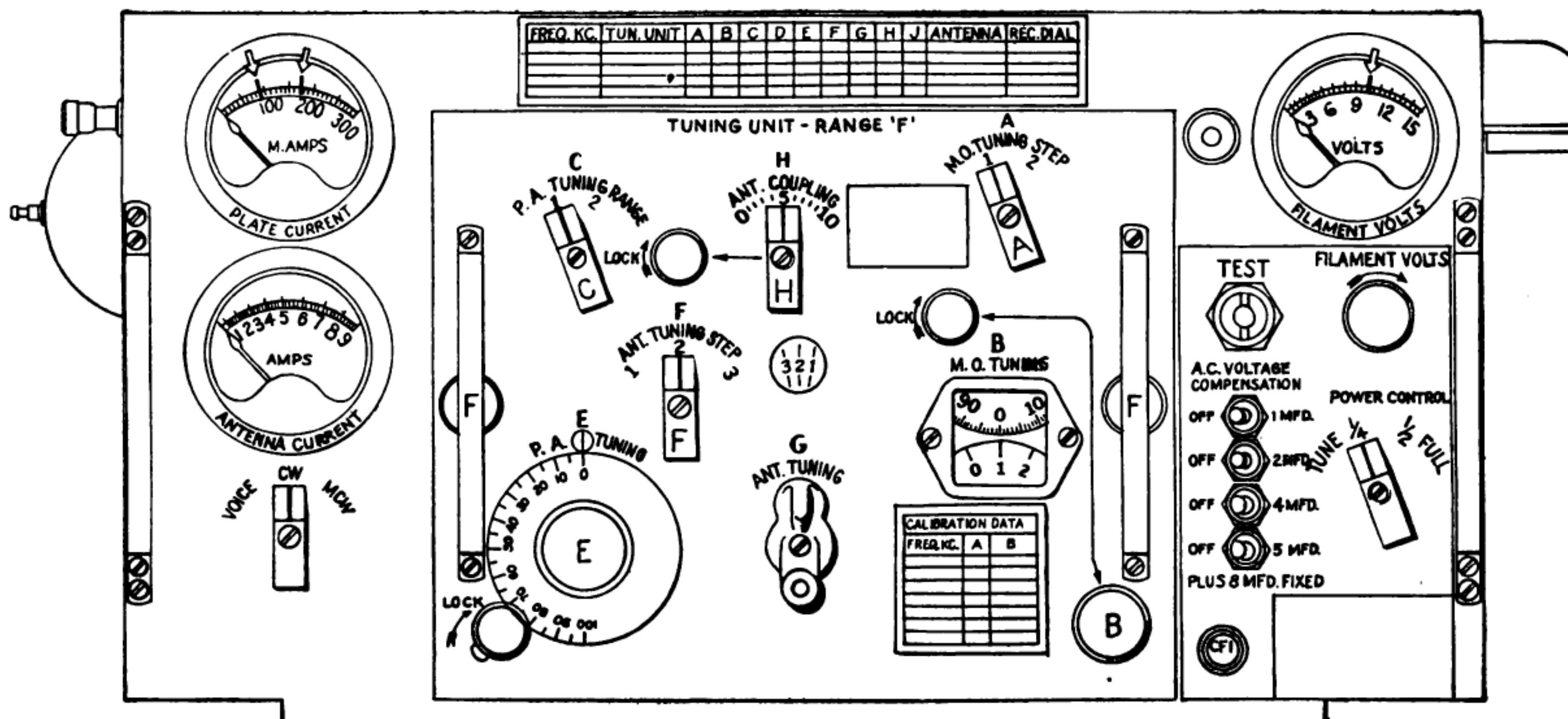


Figure 69.—Front panel view, GP transmitter.

The POWER REQUIREMENTS differ among later nodels. However, it is only the direct-current upply that differs. 120 volts alternating current 800 cycles) and a 12- to 14-volt direct curent were supplied to the earlier models by a enerator driven by the aircraft engine. Later nodels with modern-type generators are supplied 120-volt (800 cycle) alternating current and 4–28 volts direct current.

The rectifier unit in the transmitter will operate rom these voltage supplies. To obtain these oltages it is necessary to run the airplane engine t a speed that will cut in the generator which vill be indicated by a charging current showing n the battery ammeter.

As all transmitters are tuned in much the same vay, you should, if thoroughly familiar with the uning procedure of a GP, be able to tune another ransmitter with little or no extra instruction. f you examine a close-up of each transmitter ircuit, then, you'll get a mental picture of the roper tuning procedure.

As in the GF series there are four major cir-uits in the GP transmitter. You'll want to re-all the two methods of TUNING the MASTER OSCIL-ATOR. In one you use the DIAL SETTING of a fre-uency that has been used before and RECORDED. n the other you BEAT the signal generated by the naster oscillator against a KNOWN and DEFINITE ignal as determined by the CFI.

In the GP transmitter, the POWER AMPLIFIER is unable, and this tuning operation is performed y varying the P. A. TUNING CONTROL. The only way you can determine when the power amplifier s correctly tuned to the oscillator frequency is by noting the MINIMUM INDICATION on the P. A. LATE-CURRENT METER. When this minimum is btained, you know the signal has reached the

power amplifier and is ready for transference t
the ANTENNA CIRCUIT.

As in the GF transmitter, the MODULATOR CII
CUIT of the GP places on the signal an AUDI
VOLTAGE of constant frequency (MCW) when th

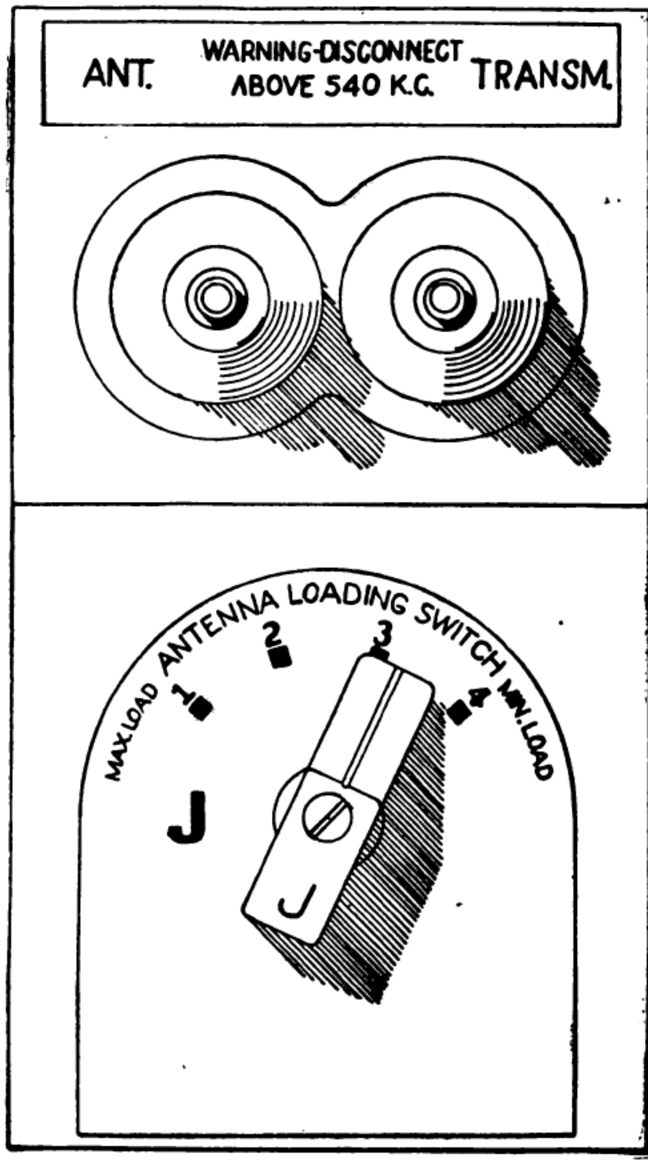


Figure 70.—External antenna loading unit.

selector switch is thrown to MCW. And an audi
voltage at VOICE frequencies when the selecto
switch is thrown to VOICE. This circuit is no
tuned.

The ANTENNA CIRCUIT is tuned until the anenna-current meter (radio frequency output) egisters maximum. Then you know that the ntenna circuit is receiving MAXIMUM RADIO NERGY from the POWER AMPLIFIER, and is on the ob, SENDING.

For frequencies below 500 kc., the antenna cir-uit has an EXTERNAL ANTENNA LOADING UNIT. You see this represented in figure 70.

As you are warned by the instructions on the panel, this unit must be DISCONNECTED from the circuit when transmitting above 540 kc.

Now for a step by step demonstration of HOW TO TUNE YOUR GP TRANSMITTER.

First, CHECK THE INSTALLATION. Make sure that all plugs and cables are secure, and that the antenna is properly connected.

Then place the POWER CONTROL SWITCH (see fig. 69) in "TUNE" POSITION.

TURN ON THE four MFD and two MFD TOGGLE SWITCHES located under "A. C. Voltage Compensation."

Place the VOICE-CW-MCW SWITCH (at left-hand corner of panel) in CW position.

Now select the PROPER TUNING UNIT for the desired frequency and insert it into the transmitter. This is a delicate operation, and you don't want to injure the equipment. Easy does it.

Next adjust the MASTER OSCILLATOR TUNING CONTROLS (marked *"A"* and *"B"*) to the approximate setting given by the TUNING CHART for this coil.

Then turn the ANTENNA COUPLING CONTROL (marked *"H"*) to zero (O) position.

Assuming now that your power supply is functioning, you check the controls you've just set, and then—

MOVE THE MASTER CONTROL SWITCH to ON position. Insert KEY or MICROPHONE in their proper JACKS.

The TRANSMITTER-CONTROL SWITCH on the pilot or operator's control box should be moved to on side or the other, whichever CLOSES the alternatin current power circuit.

Adjust the FILAMENT RHEOSTAT on the front o the RECTIFIER POWER UNIT until the needle on th FILAMENT VOLTMETER coincides with the RED MAR ON THE VOLTMETER SCALE. Warning! Neve above or below! The needle must toe the mark

Now go back and turn the POWER CONTRO SWITCH to "one-fourth" power.

Set the POWER AMPLIFIER TUNING RANGE SWITC to the position as indicated on the chart.

Then adjust the POWER AMPLIFIER CONTRO (marked *"E"*) while KEYING the transmitter a FIVE-SECOND INTERVALS until a MINIMUM READIN is obtained on the PLATE CURRENT MILLIAMMETE

All right. You've finished keying, and you'v got the minimum reading. Now ADVANCE TH ANTENNA COUPLING CONTROL (marked "*H*") fron zero (0) to approximately 3 divisions on the scale

Note the position of the ANTENNA TUNING STE control. It should be at the No. 2 position, a indicated on the chart.

Again KEY THE TRANMITTER at 5- or 10-secon intervals and vary the ANTENNA TUNING CONTRO marked *G* until MAXIMUM INDICATION is observe on the ANTENNA CURRENT METER.

Now you have three readjustments to make.

You readjust the ANTENNA COUPLING CONTRO ("*H*") until the PLATE CURRENT MILLIAMMETE reads approximately 80 milliamperes. That wil be the FIRST RED LINE on the meter.

Next you readjust the ANTENNA TUNING CONTRO ("*G*") for MAXIMUM INDICATION on the ANTENN CURRENT METER.

Then you readjust the POWER AMPLIFIER TUNIN CONTROL ("*E*") for MINIMUM READING on the

PLATE CURRENT MILLIAMMETER. NOW LOCK ALL CONTROLS.

When the TRANSMITTER POWER SWITCH is switched to FULL POWER, the plate milliammeter should NOT EXCEED a reading of 175 milliamperes.

And SO YOU'RE SENDING! Use the MINIMUM POWER that will enable you to successfully carry on the communication. You're "on the air." You're the ace magician of your time—getting off a message that goes seven times around the world in an eyewink—and your radio transmitter beats the oriental rope trick a mile.

All through? Then sign off, and secure.

To secure the transmitter, reverse the action of the TOGGLE SWITCH on the operator's switch box, and SHUT OFF THE MASTER CONTROL SWITCH.

Done? Okay. At ease.

GP TRANSMITTER CONTROLS

Now if you can stamp those step by step operations on your memory so they won't wash out like Rommel's footprints on the Libyan sands, you'll know how to work your transmitter.

Some information on the inside workings of your transmitter-controls will help to cement those tuning-operation steps in your mind. Although the controls of Navy transmitters are fundamentally the same, they differ somewhat in various models of the GP series.

One of the more intricate of these controls is found on the GP–5.

As you know, before power is applied to the transmitter, the power control is set at TUNE position. The control has four positions. TUNE, ONE-QUARTER, ONE-HALF, and FULL. In the TUNE position, PLATE VOLTAGES are applied to the MASTER OSCILLATOR, but not to the rest of the transmitter. This allows the operator to tune the master oscillator to a desired frequency without radiating any energy from the transmitter.

In the ONE-HALF, ONE-QUARTER, and FULL positions, plate voltages are applied to the master oscillator and power amplifier in varying amounts, as indicated by the markings above the power control.

You'll find FUSES for the GP inside the transmitter if you remove the PLUG-IN UNIT on the left-hand side of the panel.

How about the FILAMENT VOLTS CONTROL? The filament volts control takes care of the amount of voltage reaching the filaments of the tubes. A RED LINE on the meter just above the control indicates 10 volts, the correct voltage for your GP transmitter.

Those four TOGGLE SWITCHES you see under the designation, "A. C. Voltage Compensation," serve to eliminate fluctuations in the filament voltage caused by keying. Meantime, before power is applied to the transmitter, the switches marked "2 MFD" and "4 MFD" should be thrown to "ON" position.

In some transmitter models you will have a TEST KEY. This allows you to key the transmitter from the front panel. The key should not be held down for long periods of time when power is applied to the P. A. (power amplifier). Otherwise the transmitter may be damaged.

At the bottom of the panel you'll find the CFI BINDING POST by which the r-f coupling lead of the CFI is connected. This lead should be wrapped loosely around the post, and NOT metallically connected.

Since oscillation is an important feature of your radio transmitter, consider the MASTER OSCILLATOR SECTION of your GP. First you have the M. O. TUNING STEP, marked *"A."* This control operates a tapped switch, and selects a given tuning range.

Assume, for example, that the over-all frequency range of the particular coil in your GP is 300 to 900 kilocycles. Then, with the M. O. tuning step control in the No. 1 position, a tuning range of 300 to 600 kilocycles is selected; and if the M. O. tuning step control is in the No. 2 position, the latter half of the frequency range is selected—that is, 600 to 900 kilocycles.

Now for the M. O. tuning device labelled *"B."* This is a variable device designed to permit a finer selection of frequency within the band already selected by the *"A"* tuning step.

Say you wanted a frequency of 400 kilocycles. The over-all frequency range of the coil in the GP at this particular moment is, as previously assumed, 300 to 900 kilocycles. Therefore you must set the M. O. TUNING STEP control to "1" since the frequency you're after falls within the first half of the tuning range.

Now assume that the dial setting for 400 kilocycles, as determined by a previous recording, is 278. You adjust the M. O. tuning control (*"B"*) until a reading of "2" appears on the LOWER half of the movable dial in the window. Then you slowly turn the knob until a reading of 78 appears on the UPPER half of the movable dial. This gives you a reading of 278, which corresponds to 400 kilocycles.

(P. S. The UPPER half of the movable dial is calibrated from 0 to 100, and one complete revolution of this dial would advance the lower half by 1°.)

So much for the MASTER OSCILLATOR SECTION, now go on to the POWER AMPLIFIER (P. A.) SECTION.

The P. A. TUNING RANGE marked *"C"* is a control quite similar in operation to the M. O. tuning step. And ordinarily if the M. O. tuning step is in No. 1 position, the P. A. TUNING RANGE CONTROL will be at "1." The control selects a given frequency range for the power amplifier.

The P. A. TUNING CONTROL marked *"E"* is manipulated to obtain a fine selection of frequency within the band selected on the P. A. tuning range. When this point of desired frequency is reached, the P. A. PLATE CURRENT METER will register MINIMUM, which indicates that the power amplifier has been tuned to the OSCILLATOR FREQUENCY.

Now have a look at the ANTENNA TUNING SECTION. There's the ANTENNA TUNING STEP, marked *"F."* The switch is similar in operation to the P. A. tuning range switch and the M. O. tuning step switch, in that it selects a given frequency range for the antenna circuit. Ordinarily, if the P. A. tuning range is set at "1," and the M. O. tuning step is set at "1," the antenna tuning step switch will also be brought to "1." In some cases this may not occur, but in general you'll observe it.

The ANTENNA TUNING, marked *"G,"* tunes the antenna circuit to the desired frequency of the transmitter. When this is accomplished, the ANTENNA CURRENT METER will register MAXIMUM, indicating that maximum radio energy is being received from the power amplifier and radiated into space.

The ANTENNA COUPLING, marked *"H,"* is adjusted to increase or decrease the coupling between the antenna circuit and the power amplifier. On one-quarter power this control should be adjusted after the stages are tuned. The adjustment should cause the PLATE CURRENT METER to register on the FIRST RED MARK.

You'll notice there are three meters on the GP transmitter. The FILAMENT VOLTMETER indicates the amount of voltage applied to the tube filaments. The P. A. PLATE CURRENT METER indicates whether the power amplifier is tuned to the oscillator frequency. The meter will register at MINIMUM when this condition is obtained. Finally, the ANTENNA CURRENT METER, indicating that your antenna circuit has been properly tuned, will register a MAXIMUM.

The EMISSION SWITCH, as you already know, is always tuned on CW. After which you select the type of radio signal to be used in message-transmission, and go ahead. If voice is called for, you turn the switch to VOICE and use the mike. If you want CW or MCW, instead, you turn the switch to the positions so designated.

And don't forget to LOCK the controls.

FOOTNOTE TO TUNING YOUR GP

Like all champions of blue-ribbon pedigree, your GP transmitter (affectionately called "The Jeep") has some special quirks of temperament.

In tuning, you have to be careful not to tune the P. A. to a harmonic of the M. O.

A harmonic, as you know, is a multiple of the fundamental frequency. Suppose your fundamental is 400 kilocycles. It would be possible, in tuning the P. A., to obtain a dip in the plate circuit meter at the second harmonic (800 kilocycles), the third (1200 kilocycles), the fourth (1600 kilocycles), and so on. The degree of dip, however, would be less for each harmonic successively removed from the fundamental. A little care in adjusting the controls will safeguard against this difficulty.

First, make sure the TAP SWITCH for the band to be used is in the proper position. Then, by noting whether the frequency you wish to use lies in the upper or lower part of the band, you will be able to determine the direction in which you'll start rotating the TUNING CONTROL. For example—If the frequency you wish to tune is 650 kilocycles and the band in use is 600 to 900 kilocycles, you would start with maximum capacity in your tuning condenser, and gradually decrease it until resonance was indicated. The first indication of resonance will be 650 kilocycles.

GO–9 TRANSMITTER

In most naval patrolling land or seaplanes you'll find the GO–9 transmitter. The GO–9 is comprised of three units, namely the LOW FREQUENCY TRANSMITTER (I. F.) which operates on a frequency band of 300 to 500 kilocycles, the HIGH FREQUENCY TRANSMITTER (H. F.) which covers the band from 3000 to 18,000 kilocycles, and the rectifier power supply unit.

The transmitter has a power output of 70 to 125 watts when operating into a trailing antenna, and a little less with a fixed antenna. The rectifier or power supply unit, is essentially the same as that of the GP transmitter.

Operation of the GO–9 is similar to your GP. You have a chart to find the dial setting of each frequency, and a CFI to check an unknown frequency.

Figure 71 gives you a full panel view of the GO–9 transmitter, showing you the three units of the type discussed. Examine the figure. The I. F. section (*A*) is familiar to you, but the H. F. section (*C*) has a somewhat different line-up of circuits.

First you have your MASTER OSCILLATOR to generate signals at a given fundamental frequency. To double or triple this frequency you have an INTERMEDIATE AMPLIFIER which amplifies the HARMONIC of the signal.

A POWER AMPLIFIER increases the signal strength and your antenna, as usual, wings it on its way.

For a better understanding of the INTERMEDIATE AMPLIFIER, assume a frequency of 9000 kilocycles

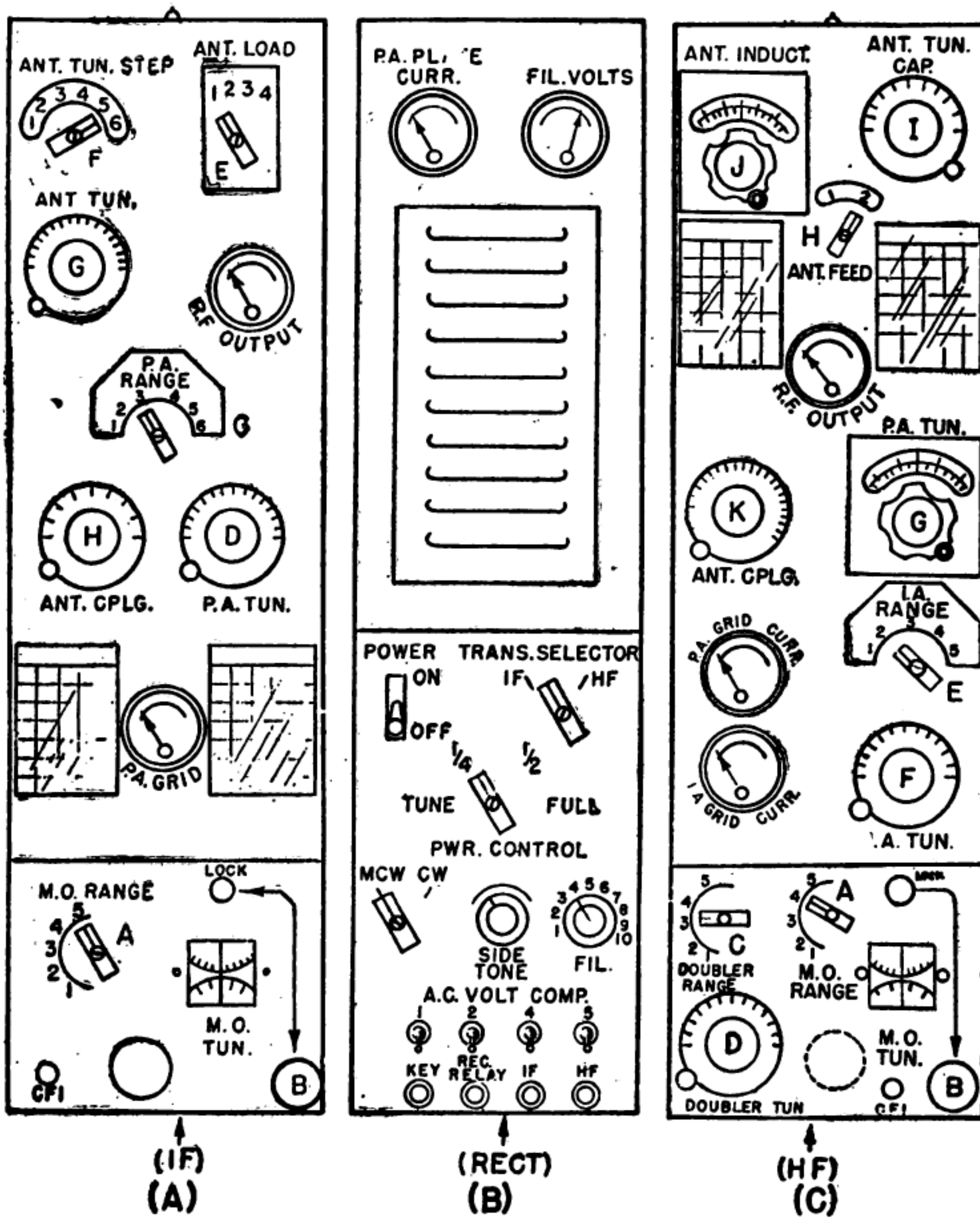


Figure 71.—Full panel view GO–9 transmitter.

is desired. The OSCILLATOR in a GO–9 will not produce that frequency as a fundamental. The master oscillator only covers a frequency of 1500 to 3050 kicycles. So if you want 9000 kilocycles as an output frequency, you must adjust the master oscillator to generate a fundamental frequency of 300 kilocycles and its associated harmonics.

The third harmonic of a 3000 kcs. signal is 9000 kc., and you employ it by tuning the GRID CIRCUIT of your INTERMEDIATE AMPLIFIER to 9000 kcs. This frequency is then amplified in the intermediate and power amplifiers, and the frequency of the current in the antenna accordingly becomes 9000 kcs.

Now take a good look at the POWER SECTION of your GO–9 (fig. 71 *B*). Upper left, you find the ON and OFF SWITCH by means of which you control the filament voltage of both sections of the GO–9, and start the action of the rectifier section.

Alongside, you see the TRANS-SELECTOR SWITCH which permits you to select either the IF of HF sections of the transmitter.

Below the trans-selector you have your POWER CONTROL SWITCH which operates similarly to those in other-type transmitters, and then, marked "FIL", a FILAMENT RHEOSTAT which permits adjustment of the filament voltage to 10 volts on the filament voltmeter.

To the left below the power control is the MCW/CW SWITCH which selects the type of emission desired.

The P. A. PLATE CURRENT METER (at top of the panel) indicates the plate current being drawn by the power amplifier. It should be adjusted to MINIMUM by means of the P. A. TUNING CONTROL marked "*G*" on the HF section, and the P. A. control marked "*D*" on the IF section. The meter is common to either the HF or IF section of the transmitter, depending on the one you have selected.

So much for the power section of the GO–9. It is rather less intricate than the HF section, the latter being a self-contained unit with some features like those in other transmitters.

Examine the HF SECTION represented in figure 71*C*. Bottom of the panel, marked *"A"*, you have the MO RANGE CONTROL by means of which you select the desired range of your master oscillator. The switch is calibrated in five steps, and since the fundamental range of the oscillator is 1500 to 3050 kilocycles, this over-all frequency may be divided by five to give an approximate, accumulative range of each step.

Alongside, you find the MO TUNING CONTROL. This control, marked *"B"*, gives you a fine selection of frequency over the range you determined by your setting of the MO range switch.

The DOUBLER RANGE CONTROL, marked *"C"*, is adjusted to the desired harmonic as indicated. For example, you desire an output frequency of 9000 kilocycles. The DOUBLER RANGE SWITCH is adjusted for a frequency of 9000 kilocycles.

Then the DOUBLER TUNING CONTROL, marked *"D"*, affords a fine selection of frequency over the frequency band you've selected by means of the DOUBLER RANGE SWITCH. (You tune the DOUBLER TUNING CONTROL until a MAXIMUM "IA" grid current is indicated.)

The "IA" RANGE CONTROL SWITCH, marked *"E"*, is adjusted to the output frequency desired, and gives you a rough "step—selection" of frequency. Look for it in midpanel.

The "IA" TUNING CONTROL, marked *"F"*, affords fine tuning over the frequency range as selected by the "IA" RANGE SWITCH. This control should be tuned until the P. A. GRID CURRENT METER registers MAXIMUM.

At the top of the panel, the ANTENNA FEED CONTROL, marked *"H"*, is a device by means of which you select the antenna best suited for a particular installation.

Above the ANTENNA-FEED SWITCH you find the ANTENNA TUNING CAPACITOR. This control permits tuning by means of a capacitor in the transmitter's antenna circuit. At its left, you see the ANTENNA INDUCTANCE CONTROL by means of which you select the correct inductance for a desired frequency.

The ANTENNA COUPLING CONTROL, marked *"K"*, should be set at MINIMUM.

Turning now to the IF SECTION of your GO–9 transmitter (fig. 71*A*), you note several differences between this and the HF section. The MO range switch and MO tuning control in both sections are identical. But in the IF section you have, for instance, the BINDING POST, marked "CFI."

As you suspect, the CFI BINDING POST is designed to permit coupling of the master oscillator to the CFI for frequency checking.

Another feature is the P. A. GRID CURRENT METER which gives an indication of the signal energy being delivered by the master oscillator into the grid of the power amplifier.

The P. A. RANGE SWITCH, marked *"C"*, allows a rough selection of frequency to be determined on the power amplifier. While the P. A. TUNING CONTROL, marked *"D"*, permits a fine selection of the frequency over the range selected by means of the P. A. range switch.

The ANTENNA LOAD SWITCH (top right) is set at 1. The ANTENNA TUNING STEP CONTROL, marked *"F"*, will in most cases correspond to the setting of the P. A. RANGE CONTROL, marked *"C"*.

The ANTENNA TUNING CONTROL, marked *"G"*, is a device similar in operation to the P. A. TUNING CONTROL, in that it allows you to obtain a fine selection of frequency for the antenna. This control should be rotated until a MAXIMUM indication is registered on the R. F. OUTPUT METER which you see at its right. (In some cases you may find it necessary to adjust the ANTENNA LOAD SWITCH again before this maximum indication is obtained.)

The ANTENNA COUPLING CONTROL, marked *"H"*, should be set at zero to obtain MINIMUM COUPLING before a MAXIMUM indication is secured on the R. F. output meter. Should the P. A. PLATE CURRENT METER fail to indicate the FULL VALUE allowed for the power being used, the antenna coupling control may be adjusted to secure this allowed maximum reading on the P. A. current meter.

Now for the step by step adjustment of the HF TRANSMITTER of your GO–9. Here's the routine.

TUNING THE HF SECTION OF THE GO–9

First, turn all voltage compensators OFF.

Set POWER CONTROL SWITCH to TUNE position.

Set TRANS. SELECTOR SWITCH to HF.

Set EMISSION SWITCH to CW.

Use the TUNING CHART found on the right hand panel of the GO–9, and set all controls to approximate setting for the frequency desired.

Turn POWER SWITCH ON, allowing at least 40 seconds for tubes to reach proper filament operating temperature before pressing key.

Adjust filament voltage to 10 volts (RED LINE) using FILAMENT RHEOSTAT.

Throw in A-C VOLTAGE COMPENSATOR SWITCHES, one by one, until fluctuation in FILAMENT VOLTMETER, caused by keying, is removed.

Press TELEGRAPH KEY and tune MO to the desired frequency as indicated by the CFI.

Press telegraph key and tune the DOUBLER TUNING CIRCUIT for MAXIMUM GRID CURRENT as indicated on the P. A. GRID METER.

Set POWER CONTROL SWITCH to ¼ power.

Press key and tune POWER AMPLIFIER. This will be indicated by a MINIMUM READING on the P. A. PLATE METER, or the lowest dip in plate current reading.

Set ANTENNA TUNING CAPACITOR at 50.

Rotate ANTENNA INDUCTANCE CONTROL, watching P. A. PLATE CURRENT METER and R. F. OUTPUT METER. Adjust the control until a MAXIMUM indication is registered on the R. F. OUTPUT METER. The P. A. PLATE CURRENT METER should not indicate over 80. It should toe the mark at the FIRST RED LINE when the R. F. OUTPUT METER registers maximum. If the P. A. meter registers ABOVE the line, re-adjust the ANTENNA COUPLING until the reading falls to the red line.

The transmitter is NOW TUNED, and the power necessary for communication may be selected by means of the POWER CONTROL SWITCH.

A few words of caution—

After you throw the power control switch to ¼ power, do NOT key the transmitter any longer than at 10-SECOND INTERVALS, until you are sure the transmitter is completely IN RESONANCE.

And remember, the operation of a GO–9 involves the use of HIGH VOLTAGE. High voltages are DANGEROUS. Treat them with respect. Criminals who play around with electric chairs learn a lesson they don't soon forget. Your high voltage transmitter is not intended for such operations. Don't expose yourself to unnecessary lessons.

HOW TO TUNE "IF" SECTION OF GO–9

The tuning operation of your GO–9 transmitter's IF SECTION is very similar to that of your GP series. Here are the steps to follow.

Turn all A-C VOLTAGE COMPENSATORS to OFF position.

Set POWER CONTROL SWITCH to TUNE position.

Set TRANS-SELECTOR SWITCH to IF.

Set EMISSION SWITCH for CW operation.

Use the CALIBRATION CHART on the left-hand side of the panel and set all controls to approximate settings for the frequency desired.

Turn POWER SWITCH to ON position, allowing at least 40 seconds for the tubes to reach proper operating temperature before pressing the key.

Adjust FILAMENT VOLTAGE to 10 volts (RED LINE) using the FILAMENT RHEOSTAT.

Throw in A-C COMPENSATOR SWITCHES, one by one, until fluctuations in the filament volt meter caused by keying are removed.

Press TELEGRAPH KEY and tune MO to the desired frequency as indicated by the CFI.

Set POWER CONTROL SWITCH on ¼ power.

Set ANTENNA COUPLING CONTROL to MINIMUM reading.

Press TELEGRAPH KEY and tune the P. A. CIRCUIT until a MINIMUM reading, or lowest dip in PLATE CURRENT is indicated on the P. A. PLATE CURRENT METER.

Tune ANTENNA TUNING CIRCUIT until a MAXIMUM indication is reached on the R. F. OUTPUT METER. The P. A. PLATE CURRENT METER should indicate a reading of exactly 80, or the needle at the FIRST RED LINE on the meter. Failing to obtain this condition, you employ the ANTENNA COUPLING CONTROL to bring the plate current reading to exactly 80, or the first red line.

The IF SECTION of your GO–9 transmitter is NOW TUNED, and the power necessary for communication may be selected by means of your POWER CONTROL SWITCH.

Having made good friends of your GF, GP and GO–9 series transmitters, shake hands with another ace Navy transmitter, model ATA. Figure 72 is a reasonable likeness.

In this sturdy model you have a complete, multichannel radio transmitting set which may be used to transmit voice, tone-modulated, or continuous wave signals. It may be installed in any type of aircraft in which a 22- to 30-volt direct-current power supply is available.

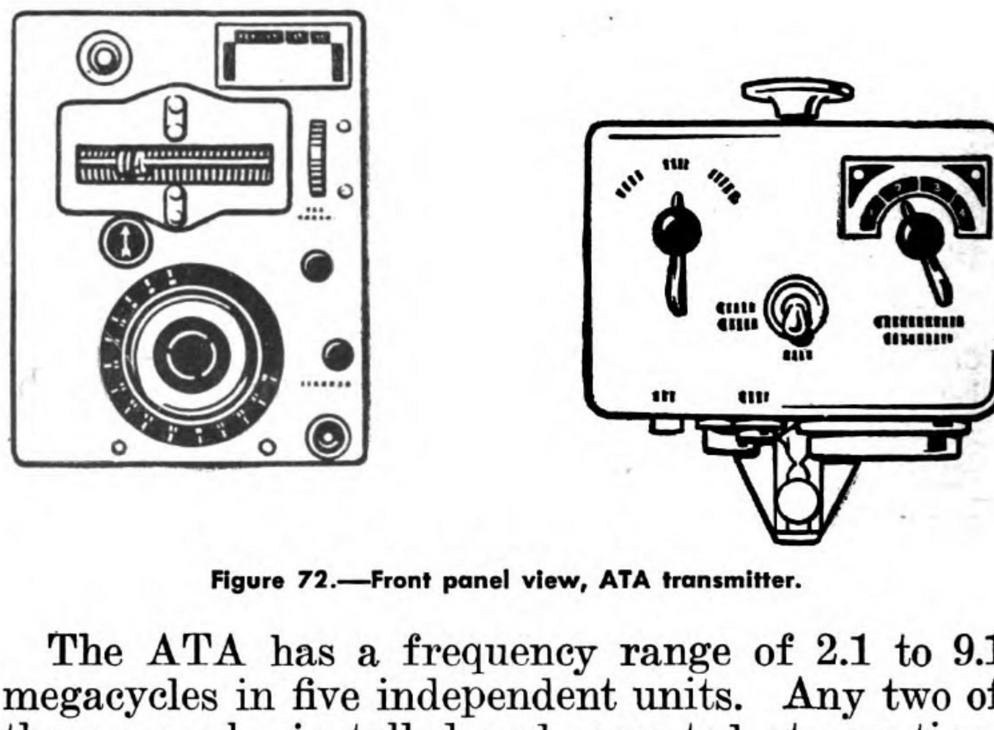


Figure 72.—Front panel view, ATA transmitter.

The ATA has a frequency range of 2.1 to 9.1 megacycles in five independent units. Any two of these may be installed and operated at one time, depending on the requirements. The bands are—2.1 to 3 mc., 3 to 4 mc., 4 to 5.3 mc., 5.3 to 7 mc., and 7 to 9.1 mc. The dials are accordingly calibrated in megacycles.

The power output of each individual transmitter, under the best antenna loading-conditions, exceeds 40 watts CW, and 15 watts voice carrier.

The position of the TUNE-CW-VOICE SWITCH on the transmitter control box determines the type of emission, and the four-position switch on the same box selects a pretuned transmitter. Four positions are provided so that an additional two transmitters may be controlled by the same box when occasion demands.

A single antenna may be used by all transmitters, providing it has the characteristics to cover the operating frequencies of the transmitters.

One of the excellent features of the Model ATA is a RESONANCE INDICATING CIRCUIT which eliminates the CFI in frequency determination. This built-in RESONANCE INDICATOR has a MAGIC-EYE TUBE and a CRYSTAL whose frequency lies between the outer limits of the transmitter frequency range.

The crystal is connected into the grid circuit of the magic-eye tube. A lead from the master oscillator circuit is also connected through a series isolating resistance into the grid circuit of the resonance indicator tube.

How does it work? Well, as resonance is reached between the crystal and master oscillator circuits of the transmitter, the shadow in the magic eye increases. And as absolute resonance is obtained between the two circuits, the shadow in the magic eye will be at its greatest width. Thus frequency alinement is indicated between the master oscillator and the crystal.

Note that the crystal in no way controls the frequency of the master oscillator. It merely gives an indication of when the frequency of the transmitter reaches its own (the crystal) frequency. The degree of departure from frequency (as the transmitter is tuned away from the central checking frequency of the crystal) is so small as to make the error in frequency negligible.

Now glance over the transmitter control-box. First, you have the TUNE SELECTOR SWITCH by means of which you select the type of emission.

You have also a transmitter POWER CONTROL SWITCH, which places primary voltage on the transmitter, and a MICROPHONE RECEPTACLE, and a KEY PLUG.

For TRANSMITTER CONTROLS you have a FREQUENCY TUNING KNOB, a FREQUENCY CALIBRATION DIAL, an ANTENNA INDUCTANCE CONTROL, and an ANTENNA COUPLING CONTROL.

These are similar in operation to the controls of transmitters you've already studied, and you don't need a review of their ways and means.

However, you may be uncertain about the tuning procedure of the ATA, so another step by step demonstration won't hurt. When you can run through this routine as easily as you go through the motions at the wheel of a car, you'll be budding into a real radioman. Here's the pattern.

ATA TUNING PROCEDURE

Throw TOGGLE SWITCH on ANTENNA RELAY UNIT to LOCK.

Set the EMISSION SWITCH on the transmitter control box to CW.

Set the TRANS-SELECTOR SWITCH on the transmitter control box to "1" or "2", depending on whether the right or left transmitter is being tuned.

Make sure that neither the MICROPHONE BUTTON nor the KEY is closed. Then throw the POWER SWITCH to ON, starting the transmitter dynamotor.

Allow 15 seconds for the tubes to heat up.

Then open the HINGE COVER (top rear of your transmitter) to such an angle that the reflection of the entire RESONANCE INDICATOR SCREEN may be seen.

The BUILT-IN KEY on top of the transmitter control box may be LOCKED at this point. You're going strong, and half way through the tuning procedure.

Now resonate the antenna circuit by adjusting your ANTENNA INDUCTANCE to MAXIMUM antenna current. This adjustment should be made with the ANTENNA COUPLING CONTROL at MINIMUM position.

Vary the ANTENNA COUPLING CONTROL until MAXIMUM current is indicated on the meter of the ANTENNA RELAY UNIT. And don't rush the job. THIS SETTING MUST BE MADE VERY CAREFULLY.

The second transmitter should now be tuned up, following the same routine as for the first. After you've done this, the two transmitter's dial calibrations will be accurate over their given frequency ranges.

And now LOCK the THREE CONTROLS of each transmitter by ROTATING the LOCK KNOB ONE-HALF TURN CLOCKWISE to a stop.

Leave the TOGGLE SWITCH on the ANTENNA RELAY UNIT on LOCK.

And finally, if you want a little check, jot down the frequency to which each transmitter has been tuned. Use a soft pencil, and make your notations in the blank space on the plate above the TRANS-SELECTOR SWITCH.

Now you've got it. Your ATA is tuned. Not as hard as it looks, once you learn the ropes. But be sure to LEARN the ropes, otherwise you may get fouled up in some pretty uncomfortable knots.

There's one knot you particularly want to avoid, and you'll avoid it by remembering this—TRANSMITTERS MUST ALWAYS BE TUNED WITH THE EMISSION SWITCH OF YOUR TRANSMITTER CONTROL-BOX IN "CW" POSITION. AND THEY MUST NOT BE READJUSTED IN ANY WAY AFTER SWITCHING TO "TONE" OR "VOICE." Such retrimming (as it's called) would result in greater antenna current in this position, and as a result, the transmitter could not be modulated properly.

Tattoo it on your memory.

TUNE TRANSMITTER WITH CONTROL-BOX EMISSION SWITCH AT "CW."

NO RE-ADJUSTMENT AFTER SWITCHING TO "TONE" OR "VOICE."

MODEL ATC

Another fine aircraft radio transmitter is the MODEL ATC. Specifically designed for installation in aircraft, this equipment is built to withstand all such vibration and shock as are common to normal aircraft service. Wherever possible, corrosion-resistant materials are used in the construction of the ATC. Here, then, is stout equipment that will take a lot of weather and gremlin-pounding.

The ATC is also so constructed that various component parts may be removed without a major disassembly of the whole unit. The MCW-CFI, the AUDIO AMPLIFIER, and the LF OSCILLATOR UNITS are connected by multi-terminal plugs which make for easy removal and servicing. Components that may require replacement have been made easily accessible.

Incorporated in the model ATC to permit rapid frequency change, you have the COLLINS AUTOTUNE SYSTEM. This is an electrically controlled apparatus which mechanically manipulates such adjustable devices as switches, variable inductors, and variable capacitors. The accuracy of this repositioning is of a very high order, and it will not be seriously affected by wear, humidity or temperature-changes. No tools are necessary to change the position of any control. ELEVEN autotune positions are available, permitting transmission on any one of eleven present frequencies.

Ten of the frequencies are in the range of 200 to 1500 kilocycles.

With your model ATC three types of transmission are available—CW, MCW and VOICE MODULATED. The audio system is capable of modulating the carrier at least 90 percent for MCW or voice emission. Keying speeds, up to 30 words per minute, may be used when operating with CW and MCW emission, and you won't have any objectionable chirp, or distortion of the length of keyed characters. It's a top transmitter, your ATC.

The AUTOTUNE frequency change system is a marvelous invention. The electricity controlled positioning elements, which automatically move the switches and other adjustables, are driven by a single motor. In normal room temperature with normal battery voltage, the system will operate to change the frequency of transmission in less than 25 seconds. What's more, MANUAL frequency change and tuning adjustments may be made without disturbing the autotune "stop-ring" adjustments, if the CHANNEL SELECTOR SWITCH is placed in the MANUAL position.

How about the POWER OUTPUT of your ATC? The power delivered to the antenna varies with frequency and antenna characteristics. Two power levels are available. The power is automatically reduced to half the full power by a PRESSURE OPERATED RELAY when an altitude of 25,000 feet is reached by your aircraft. The transmitter will operate without "flash-over" at full power output up to altitudes of 25,000 feet above sea level.

By automatically reducing the maximum plate voltage of 1150 volts to 750 volts, approximately one-half of full power will be obtained, and the transmitter will operate without "flash-over" up to altitudes of 40,000 feet above sea level. That's high-flying, and your ATC is an ace in its own right.

It is also designed to operate from a 28-volt direct current power source. Direct current as low as 24 volts may be used, with, of course, reduced output and slower autotune operation.

The 400-volt output circuit of the dynamotor supply is protected from short circuit by a fuse. Two THERMAL OPERATED RELAYS in the 28-volt supply leads protect the primary circuits. These relays are located in the power control unit, and are of the single circuit "reset" type.

Two types of MICROPHONES may be used with your ATC, the input circuit permitting the employment of either a CARBON type or DYNAMIC type. When the CARBON mike is used, an audio input of 1.45 volts is required for 90 percent modulation. When the DYNAMIC microphone is used, an audio input of 16 millivolts to the microphone jack is required for 90 percent modulation.

Concerning FREQUENCY RANGE, two bands of transmission frequencies are available with the ATC. Output may be obtained in the low frequency range of 200 to 1500 kilocycles, and in the high frequency range of 2000 to 18,100 kilocycles.

Your low frequency range may be from 200 to 600 kilocycles, or from 600 to 1500 kilocycles, depending on the type of LOADING COIL used. Two LOADING COILS are supplied. The first type is designed for operation in the frequency range from 200 to 600 kilocycles. With it you have a 200-foot TRAILING WIRE ANTENNA. The second type LOADING COIL is designed for operation in a frequency range of 500 to 1100 kilocycles, with the 200-foot trailing-wire antenna. And you also employ it in the frequency range of 1100 to 1500 kilocycles, using a 150-foot trailing wire antenna. No modification of the transmitter adjustment is necessary when you change from one loading coil to another. Just remember to shorten your trailing antenna wire to 150-foot length when you employ the second type loading coil for the 1100 to 1500 kilocycles frequency range.

A FIXED ANTENNA of the usual aircraft type, from 17 to 60 feet in length, may be used when operating your transmitter in the HIGH FREQUENCY band. However, this type of antenna may lack sufficient CAPACITY to match the IMPEDANCE of the transmitter output NETWORK in a range from 2000 to 3000 kilocycles. (Impedance meaning the total opposition of a circuit to the passage of a-c current.) To overcome this lack, an ANTENNA SHUNT CAPACITOR is supplied to permit antenna matching when you operate within the 2000 to 3000 kilocycles frequency range.

The AUTOTUNE SYSTEM, the PRESSURE OPERATED RELAY giving you two power levels, your CARBON and DYNAMIC MICROPHONES, and two types of LOADING COILS are the big features to remember in your Model ATC TRANSMITTER.

BENDIX TRANSMITTER TA–2J

If the fighting GF and GP series, the punch-packing GO–9, the powerful ATA and wizard ATC transmitters made your fingers itch to go, here's an ultra-modern Navy ace to thrill any radioman. As new as tomorrow, featuring a CRYSTAL OSCILLATOR, and IPA STAGE, a POWER AMPLIFIER and an ANTENNA CIRCUIT, it is CRYSTAL CONTROLLED. Primary power comes from a 24-volt bank of batteries. Frequency ranges are from 300 to 600 kilocycles and from 2000 to 18,000 kilocycles. It is especially designed for eight channels of frequency operation, and each channel is selected by a CRYSTAL SELECTOR on the CONTROL UNIT.

Shake hands with the BENDIX TRANSMITTER TA-2J.

The IPA is the INTERMEDIATE AMPLIFYING stage in which frequency may be doubled. The OSCILLATOR COIL, IPA COILS, and the POWER AMPLIFIER COILS are maintained on a ROTABLE UNIT which is powered by a small a-c reversible motor. When the CRYSTAL SELECTOR is set to a desired frequency, the motor goes into operation. The ROTABLE UNIT is turned until the proper coils have come to rest under a set of finger contacts.

Frequency may be doubled by installing in the IPA circuit a COIL which is RESONANT to the desired harmonic of the crystal. Since the coil is resonant over the desired frequency range, the IPA is not tunable. A meter is used in the different circuits.

The ONLY TUNING REQUIRED is in the POWER AMPLIFIER. You plug the meter into AMP, and throw the switch to AMP-2. Through a panel-hole in the door of the power amplifier compartment, you insert a screwdriver. A turn of the screw, and you tune the POWER AMPLIFIER for a MINIMUM plate current reading. Nothing to it!

An ANTENNA LOADING UNIT is readily fitted into place for use in frequencies below 2000 kilocycles. When the CRYSTAL SELECTOR SWITCH is thrown to frequencies below 2000 kilocycles, an AUTOMATIC RELAY goes into operation. This automatic relay connects the unit to the transmitter. When the transmitter is being used on frequencies below 2000 kilocycles, it is not necessary to tune the POWER AMPLIFIER. In such instance, the CHANNEL TUNING arrangement on the ANTENNA LOADING UNIT is used to resonate the loading unit to the desired frequency.

Here's the entire TUNING PROCEDURE for your BENDIX TRANSMITTER TA–2J.

Set the WAVE SELECTOR SWITCH (at the right hand side of the control box) on CW position.

Insert the METER PLUG into the GRID JACK, and throw the METER SELECTOR SWITCH to OSC position. (You'll find these units on the main transmitter just below the channel indicator box.)

Make sure the KEY IS NOT CLOSED.

Turn the POWER SWITCH to ON. (You'll find it in the center of the transmitter remote control box.)

Turn the FREQUENCY SELECTOR SWITCH to the desired frequency. Crystal-controlled, the transmitter contains a separate crystal for each frequency. The first four crystals, numbered 1 to 4, are ground to low frequencies (below 2000 kilocycles.) The second four crystals, numbered 5 to 8, are ground to high frequencies (above 2000 kilocycles.) The FREQUENCY SELECTOR SWITCH gives you your choice.

Now CLOSE THE TRANSMITTING KEY. Note the CURRENT READING on the meter. This gives you your indication of OSCILLATOR GRID CURRENT. If no current is registered, you know the crystal is not oscillating.

If the crystal is oscillating, LET UP the key, and PLUG THE METER into AMP position, then turn METER SELECTION SWITCH to AMP–2.

CLOSE the transmitting key, and with a screwdriver rotate the P. A. COIL until a MAXIMUM dip is secured on the direct-current milliameter. (You'll find the P. A. coil on the top center of the transmitter.)

For frequencies below 2000 kilocycles, remember, no adjustment is necessary on the transmitter. When using these frequencies, a LOADING

COIL INDUCTANCE in the ANTENNA LOADING UNIT is tuned by varying the CHANNEL SCREWS.

If the dip on the milliameter does not drop below 150, RELEASE THE KEY and TURN THE POWER SWITCH OFF. Readjust the SLIDE CONTACTS on the P. A. COIL. You do this by opening the P. A. coil door, and, with a screwdriver, raising one of the slide contacts to slip it forward or backward one or two notches at a time. Repeat the tuning process until a MAXIMUM DIP is obtained.

REPEAT THIS PROCESS FOR ALL EIGHT CHANNELS.

When the ANTENNA CURRENT METER is at a MAXIMUM, and the direct-current milliameter indicates 150 MILLIAMPERES, your BENDIX TRANSMITTER TA-2J is TUNED.

HOW ABOUT YOU?

Can you go through these tuning procedures—from the GF series, through your Model ATC to the crystal-controlled TA-2J? Remember, ALL transmitters are tuned primarily in the same manner—the GF's and GP's are BASIC—learn the ropes for those models, and you'll have the working background for them all.

CHAPTER 9

NAVAL INTERPHONE COMMUNICATION SYSTEM

HELLO, HAWAII, HOW-ARE-YA?

The Signal Corps operated the telephones when the first American Expeditionary Force went to France. The folks back home sang, "Hello, Central, Give Me No Man's Land." Phones at the front were quite a novelty.

Telephones in aircraft? Not in the Lafayette Escadrille, or Rickenbacker's "Hat-in-the-Ring" crowd. For that matter, aircraft was quite a novelty, and as for Navy aircraft, you could count them under a hundred.

In general, these latter were two- or three-place flying boats, a few of which were equipped with radio that could send as far as 200 miles. They (the planes) took off with a shattering roar, and what for the din of engine and propellers, the creak of straining struts and the wind-howl of the slipstream, you could hardly hear yourself think.

Communication with the ground was difficult enough. Communication BETWEEN PILOT AND CREW was another problem. If the pilot wanted the airman in the rear seat to take over, it was a matter of shouting, or frantic pantomine, or signalling with the fingers. If the man astern had stopped an unlucky bullet, or passed out from the altitude, it might be hazardous minutes before the pilot was warned.

An observer might spy an objective and have to crawl forward with the news. Messages were sometimes painfully written out and passed by hand. As for the rear-gunner, he was Tail-End Charley for fair, as lonely as an eagle in a nest, and as far astern as Idaho. He might see a dozen enemies coming down out of a cloud, yet be unable to warn the pilot at the controls. Uh huh, he was in a spot!

But inventions, mothered by necessity, were on the way. Already another song was popular in sheet music, featuring a long-distance call by wireless telephone. Folks sang, "Hello, Hawaii, how-are-ya!" Maybe you remember it.

Today, the wireless telephone to Hawaii is busy all along the line. And with the whole tempo of aerial warfare stepped up to hurricane pitch, with flying, itself, gone streamlined, a reliable means of communication between the crew members of an aircraft is of utmost importance.

Every man aboard a plane (and you can count Navy planes by the thousand) is a player in a fast-moving team. The successful accomplishment of a patrol bomber's mission is absolutely dependent upon PERFECT TEAMWORK and COORDINATION between the crew members. The rear-gunner no longer rides in lonely solitude. He's on the party-line. And the pilots direct and coordinate the activities of the entire plane crew.

To this end, a telephone system throughout the airplane was developed. This is your INTERPHONE COMMUNICATION SYSTEM (ICS), known among airmen as the Inter-Com.

MODEL RL–24A SERIES

The Model RL–24A is particularly arranged for use in communication between nine members of a crew in a patrol plane. In addition, it permits INTER-SWITCHING and mixing of radio receiving

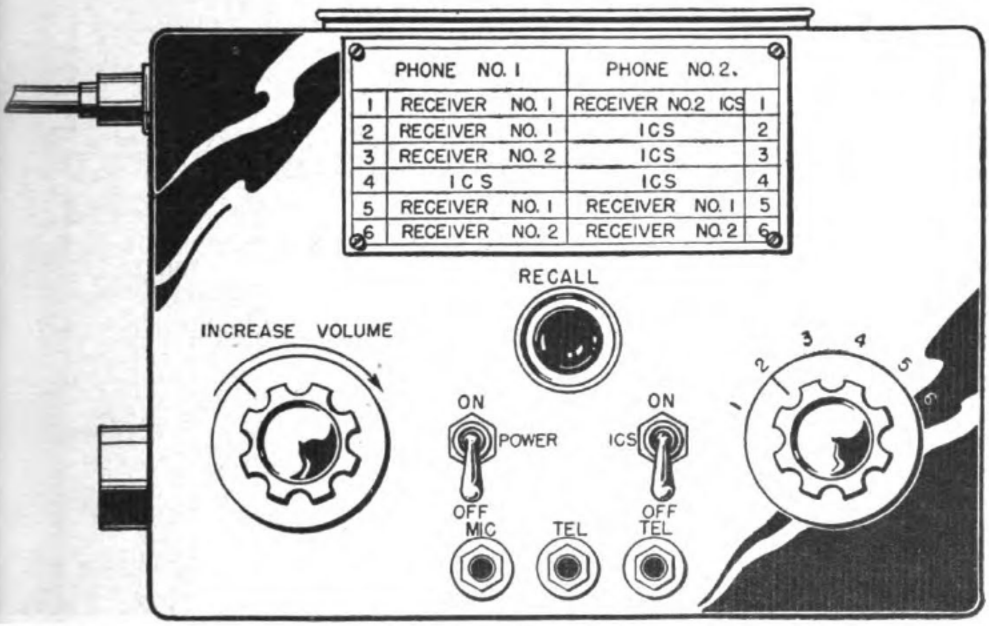


Figure 73.—Interphone control unit.

apparatus. Figure 73 shows you the INTERPHONE CONTROL UNIT of your RL–24A.

Along with this interphone control unit, the RL–24A has a PILOT'S CONTROL BOX, DYNAMOTOR, PILOT'S STATION BOX, INTERPHONE JUNCTION BOX, SIX CREW-STATION BOXES. Operation of this model takes 24 volts from a junction box on the plane's distribution system.

The interphone control unit comes up first for examination. What are its components? How do they function? How does the pilot, in one system, talk between the members of his plane crew?

Presented with the front panel of this unit (figure 73) the pilot sees a POWER SWITCH, a RADIOMAN'S SELECTOR SWITCH, an ICS SWITCH, a RECALL SIGNAL LIGHT, a MICROPHONE JACK and TWO TELEPHONE JACKS for split headphones. At the top of the panel there is a chart.

The pilot must concentrate on flying, and he needs a rapid and well-trained radioman to operate the plane's radio equipment. The intercom is part of your job.

All right, you're ready to connect TWO RECEIVERS to the SELECTOR SWITCH, and plug your headphones into the OUTGOING TELEPHONE JACK. You also plug a MICROPHONE into the CONTROL UNIT in order to reach all stations in the plane over the intercommunication system. To make yourself heard, you have an AMPLIFIER CIRCUIT to amplify your voice.

Now, comparing your movements to the CHART on the control unit—

With the SELECTOR SWITCH on 1 (that's the switch, lower right on the panel) you have Nos. 1 and 2 RECEIVER SIGNALS in the headphones. The ICS is now open for the microphone.

You move the SELECTOR to 2, and No. 1 RECEIVER SIGNAL is in one headphone, and the ICS is in the other. The MICROPHONE is still on ICS.

Move the SELECTOR to 3, and No. 2 RECEIVER SIGNAL is in one headphone, ICS is in the other, and microphone is on ICS.

Both headphones are capable of receiving ICS signals only in POSITION 4, with the microphone on ICS.

In the remaining two positions, there is only a slight change. While on POSITION 5, the No. 1 RECEIVER SIGNAL is in BOTH headphones and the microphone is on ICS. And with the selector on POSITION 6, the No. 2 RECEIVER SIGNAL is in BOTH headphones, while the microphone is on ICS.

Having selected whatever position is required, you, the radioman, may now disconnect yourself from the intercom by TURNING OFF the ICS TOGGLE SWITCH. This allows the pilot to use the same headsets and mike for speaking to his crew.

The pilot has a SWITCHBOARD which enables him to change from one method of operation to another. This is called the PILOT'S CONTROL BOX. You'll see it conveniently located for use by two

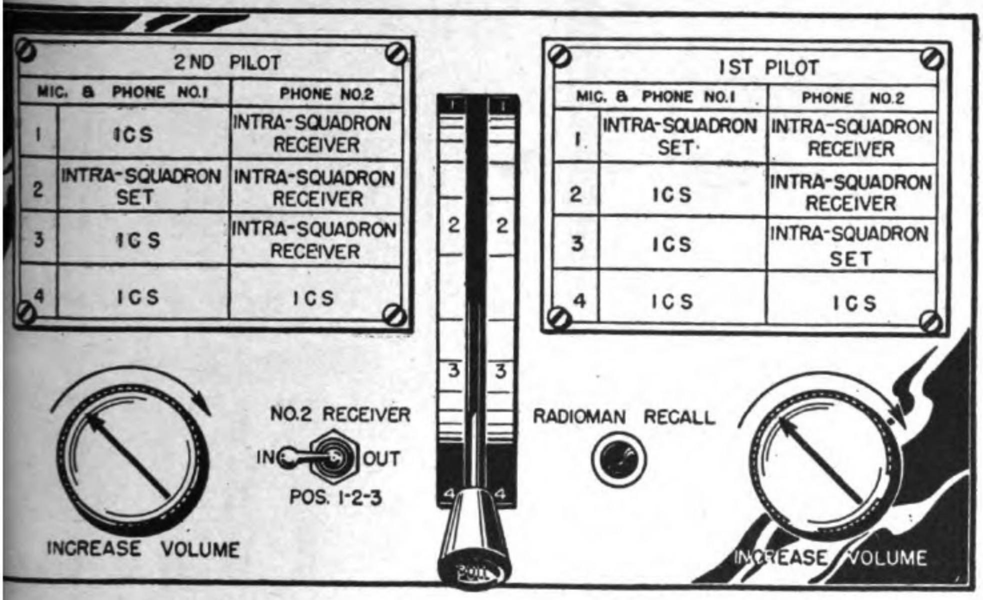


Figure 74.—Pilot's control box.

pilots in an aircraft. In figure 74 you have the illustration.

Examine the pilot's control box. The SELECTOR SWITCH differs somewhat from the radioman's, having four positions instead of six. It has, however, a TOGGLE SWITCH to match the radioman's No. 2 RECEIVER by obtaining positions 1, 2, or 3 on the SELECTOR SWITCH. Also the pilot's control box has a LEVER instead of a DIAL selector

Now compare the pilot's selector movement with the chart. Assume he is "first pilot."

With the lever on No. 1, he has his HEADPHONE and MICROPHONE on the INTRA-SQUADRON receive and transmitter. The second pilot has ONE phon on the intra-squadron receiver, and the othe phone and microphone on the ICS.

In POSITION 2 both headphones and microphon of the SECOND PILOT are on the INTRA-SQUADRON

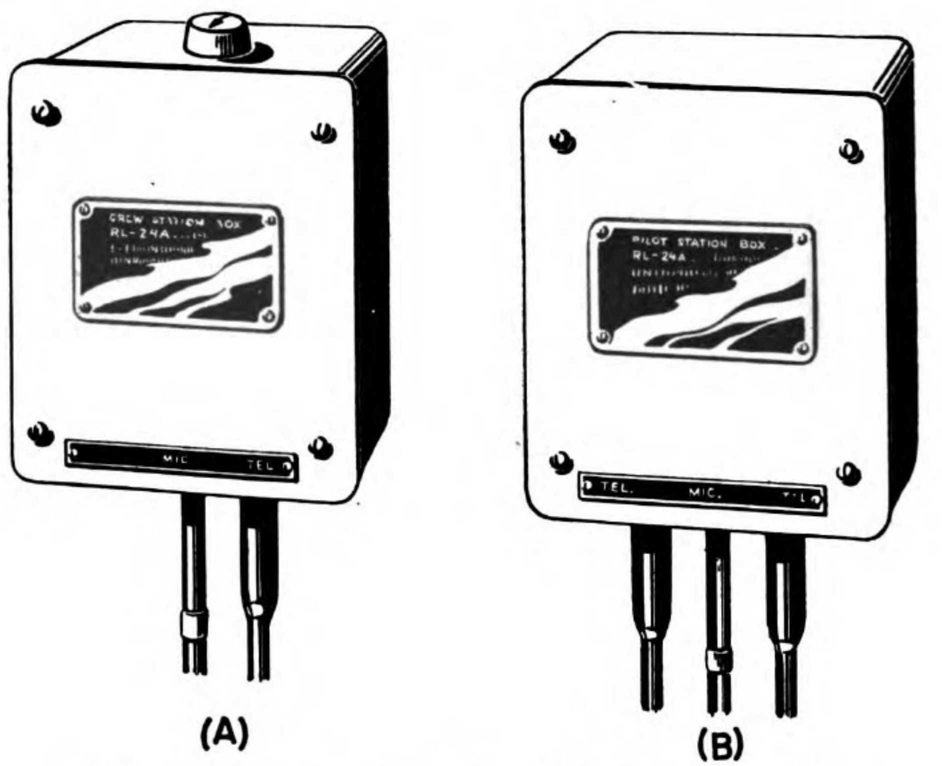


Figure 75—(A)—Crew station box. (B)—Pilot's station box.

receiver and transmitter, while the FIRST PILOT's one headphone is on the intra-squadron receiver and the other headphone and the mike are on ICS

In POSITION 3, the first pilot's one headphone is on ICS; the other headphone and the mike are on the intra-squadron receiver and transmitter. The second pilot's one headphone is on the intra-squadron receiver, and the other headphone and the mike are on ICS.

In POSITION 4, both headphones and microphone of the first and second pilot are on ICS.

Now for the JUNCTION BOX of your ICS. The junction box connects various circuits and has a LOAD RESISTOR which INCREASES PROGRESSIVELY—the number of stations beginning with 9 to 20. The STATION DISTRIBUTION JUNCTION BOX is a secondary distribution point for INTERPHONE CIRCUITS between CREW STATION BOXES and the INTERPHONE JUNCTION BOX.

The pilot plugs his "split type" headphones and microphone into the PILOT'S STATION BOX, which is similar to a CREW STATION BOX. You see both boxes pictured in figure 75.

There are SIX CREW STATION BOXES. Each has a MICROPHONE and a TELEPHONE JACK, along with a VOLUME CONTROL which can be adjusted from whisper-level to full volume. One wire in this circuit (as illustrated in fig. 75*B*) is carefully SHIELDED to prevent "cross-talk."

Your INTERPHONE CONTROL is finally complete when the HIGH VOLTAGE LINE to the AMPLIFIER is connected by a PLUG AND CABLE ASSEMBLY, in which a FILTER has been installed, from the DYNAMOTOR to the CONTROL UNIT.

And that takes care of your INTERPHONE COMMUNICATION SYSTEM.

CHAPTER 10

AIRCRAFT RADIO INSTALLATIONS

GADGET MAN

Back in the old days when planes were called flying machines and pilots were called daredevils the radioman was known as gadgets. Gadgets was a busy man. Generally he had more troubles than a one-armed paper hanger. Installing an aircraft radio was a particularly tough job. The plane had bicycle wheels, or pontoons about as light as canal boats, and the old crystal set with its storage batteries and audions didn't lighten the load, or fit in very well.

If your flying machine didn't fly to pieces in midair, the radio generally did, resulting in some unhappy landings for gadgets. For that matter, a bumpy take-off on land or water was liable to jar the set loose from its moorings at the start, and scatter the contents through the cockpit like a lady's handbag.

All sorts of devices were invented to hold the equipment in place, but these added weight to the already burdened camel's back, besides creating electrostatic fields that resulted in operational interference—and when the chances looked bad, the radio was often the first thing to go overboard.

In recent years, radio equipment has become as important as any item aboard a plane. Its installation in aircraft has also been greatly simplified.

When a certain type of airplane is put into production for the Navy, the kind of radio equipment to be installed and the positions of this equipment are carefully predetermined.

The MOUNTING BRACKETS are marked properly. Usually they are drilled to accommodate each piece of apparatus. All necessary BONDING and SHIELDING are installed at the factory. In some instances, the radio equipment, itself, is installed by aircraft delivery units. The planes are delivered ready for operation to a unit or squadron.

However, occasion often arises when it becomes necessary to make an initial installation, or to replace old radio equipment with new and more modern equipment. As a Naval Aviation Radio Technician, or Aviation Radioman you should be familiar with installation procedure.

INSTALLATION NOTES

Upon receipt of the radio equipment to be installed, it is removed from its crates or cases, and THOROUGHLY CHECKED against the MANUFACTURER'S INSTRUCTION BOOK for assurance that all UNITS, CABLES, FITTINGS, VACUUM TUBES, LOOSE SCREWS AND MINOR PARTS are COMPLETE.

When you are SURE that each set of equipment is complete, the radio units should be BENCH-TESTED for actual operation. If power facilities are not available for operating on the test bench, the equipment should be checked over thoroughly in a non-operating condition.

ALL NUTS, BOLTS, FITTINGS, AND CONNECTIONS should be examined for LOOSENESS. When the bench check is completed satisfactorily, CALIBRATION of the equipment may be done, so that the most commonly used frequencies on which the equipment is required to operate may be recorded.

Such MAIN UNITS as TRANSMITTER, RECEIVER, DYNAMOTORS, JUNCTION and CONTROL BOXES may now be mounted in the brackets provided.

The INTER-CONNECTING CABLES are next installed between units, and securely fastened to bulkheads, brackets or cross-pieces by means of BONDING CLIPS. Such procedure effectively grounds the OUTER SHIELDING of the cables to the fuselage. (In late types of equipment the cables are rubber-covered and are grounded to the MAIN UNITS of the equipment at the PLUG ENDS.)

GROUND LEADS for receivers and transmitters should be installed as SHORT as possible, allowing only enough length so that SHOCK-MOUNTS can vibrate freely. If the ground leads are too short, however, they may loosen or break.

The equipment can now be connected to the ANTENNA of the PLANE.

ALL POWER SWITCHES SHOULD BE CHECKED TO DETERMINE THAT THEY ARE IN "OFF" POSITION.

POWER LEADS may now be connected to the BINDING POSTS provided in the POWER JUNCTION BOXES.

POLARITY OF THE DIRECT CURRENT CONNECTIONS MUST BE PROPERLY OBSERVED.

The airplane engine may now be tuned up and the equipment-group TESTED FOR OPERATION with the power supplied by the AIRCRAFT GENERATOR. Upon completion of this check, ALL UNITS SHOULD BE SAFETY-WIRED to their respective brackets or mountings. A TEST FLIGHT should be made for final checkup of this equipment's operation under flight conditions.

FINAL NOTE

Remember. For the efficient operation of aircraft radio equipment, and for a minimum of noise and interference, ALL GROUND LEADS, BONDING WIRES and CLIPS must be FASTENED SECURELY so that they make good METALLIC CONTACT.

Equipment should never be reported ready for operation before ground leads and bonding wires are checked for metallic connections.

SECURITY. That's the word on aircraft radio installations. And when you're certain of that, you, yourself, will be squared away.

SECURE!

How Well Do You Know—

AIRCRAFT RADIO EQUIPMENT

(QUIZ)

CHAPTER 1

INTRODUCTION TO RADIO

1. Give an example of—
   (*a*) Transverse waves.
   (*b*) Longitudinal waves.
2. Define the following—
   (*a*) Wave length.
   (*b*) Frequency.
   (*c*) Cycle.
   (*d*) Amplitude.
3. What is the approximate speed of radio waves?
4. What is an oscillator?
5. What are the four essential parts of a receiver?
6. (*a*) What name is given to the relation between two circuits or radio waves when they are tuned to the same frequency?
   (*b*) What name is given to the inherent property of a COIL by which it stores up electrical energy? In what units is this property measured?
   (*c*) What name is given to the inherent property of a CONDENSER by which it stores up electrical energy? In what units is this property measured?
7. What is the function of a detector?

CHAPTER 2

VACUUM TUBE

1. What is a space charge?
2. What is meant by plate current saturation of a tube?

3. What is the function of—
   (*a*) A battery?
   (*b*) B battery?
   (*c*) C battery?
4. What effect does an increase in grid bias have on plate current?
5. What is "regeneration"?
6. How does grid current result in a distorted output?
7. Why is it preferable to use a cathode sleeve rather than a filament in a vacuum tube operating on alternating current?
8. Explain the development of cathode bias.
9. Draw a full wave power supply, complete with single-section filter and bleeder. Indicate direction of current flow on both positive and negative alternations.
10. How many grids are there in a—
   (*a*) Pentode tube?
   (*b*) Tetrode tube?
   (*c*) Pentagrid converter?
   (*d*) Diode tube?

CHAPTER 3

ELEMENTARY TRANSMITTER

1. Is an antenna system a series or parallel circuit?
2. What device would you place in series with an antenna circuit if you wished to shorten the electrical length of the antenna?
3. What is meant by "modulation"?
4. What are the major differences betwen the carrier wave as transmitted in radio telegraphy (CW) and radiotelephony?
5. What is the function of a microphone?
6. (*a*) How is radiotelegraphy accomplished by MCW transmission?
   (*b*) What is the disadvantage of this type of transmission?
   (*c*) What are two advantages?
7. What does "M. O. P. A." stand for?

8. What is the relation between the frequencies of a fundamental and of its harmonics?
9. If you were required to construct an oscillator intended to operate on a FIXED frequency, what type would you build?
10. Describe the "piezo-electric" effect.
11. What three characteristics determine the natural frequency of a quartz crystal?
12. Describe a Marconi antenna.
13. Describe a Hertz antenna.
14. Draw a schematic diagram of a crystal oscillator.

CHAPTER 4

ELEMENTARY RECEIVER

1. What is meant by the following characteristics of a receiver?
   (*a*) Sensitivity.
   (*b*) Selectivity.
   (*c*) Fidelity.
2. What is the chief requirement for a high fidelity audio amplifier?
3. What determines the frequency to which a circuit will be resonant?
4. What is the purpose of the screen grid in a tetrode tube?
5. What is the principle difference between a t. r. f. and a superheterodyne receiver?
6. What must be added to the t. r. f. receiver to adapt it for receiving CW telegraphic signals?
7. Draw a block diagram of a superheterodyne receiver capable of receiving CW signals. Include one stage of preselection, two IF's and two audio stages. Name each block.
8. Label each block of the diagram (drawn for question 7 above) with suitable frequencies. Assume that the receiver is tuned to 2,000 kilocycles per second. Use a standard IF of 465; make all others bear the proper relation to this frequency. CW signals are being received.

9. Is the Navy RU receiver of t. r. f. or superheterodyne design?
10. What advantages are obtained by amplification at an intermediate frequency (superheterodyne) rather than at the signal frequency (t. r. f.)?
11. What is meant by "alining" a receiver?
12. What are three ways of controlling the volume of a superheterodyne receiver (manually)?
13. How does an A. V. C. system operate?

CHAPTER 5

FREQUENCY MEASUREMENT

1. The LM frequency meter covers a wide range of frequencies within two bands. What are the limits of each range?
2. Draw a block diagram of a CFI and label all parts.
3. What sound will be heard in the phones when a condition of zero beat exists?
4. What is "heterodyne action"?
5. What is the crystal oscillator used for in the LM?
6. Calibration markers are obtained every ______ kilocycles, because the fundamental frequency of the crystal oscillator is ______ kilocycles per second.
7. What part of the dial of the heterodyne oscillator is checked for accurate calibration?
8. After zero beat is obtained how do you know what the frequency is?
9. Outline the steps you would take to set a receiver on a given frequency by using the CFI.
10. On the LM—type CFI—
    (*a*) What is the "corrector control" used for?
    (*b*) What does the "R-F Coupling Control Switch" do?
11. What would be the result of making a metallic connection between the CFI R-F Coupling lead and the antenna binding post of the receiver?
12. What is the minimum time that the LM should be permitted to warm up before being placed into operation? Why?

CHAPTER 6

NAVAL AVIATION RECEIVERS

1. What are the limits of the frequency range of the RU receiver?
2. What circuits are contained in the RU?
3. What is the power source from which the RU operates?
4. What current is measured when a meter is inserted in the meter jack of the RU?
5. What device is employed in changing the RU from one frequency band to another?
6. The beat frequency oscillator of the RU oscillates at a frequency that is what percent of the incoming signal frequency?
7. What is a multichannel receiver?
8. How accurate are the dial calibrations on the ARA receiver?
9. (*a*) What is the frequency range of the ARA?
   (*b*) How many units are required to cover this range?
10. Draw a block diagram of the ARA, naming each block.
11. How many tubes are incorporated in the ARA?
12. (*a*) What is the frequency range of the Bendix RA–1B receiver?
    (*b*) How many bands are required to cover this range?
13. Describe the filament and plate power supplies for the RA–1B.
14. Why are all receivers designed so that the A. V. C. is OFF when receiving CW signals?

CHAPTER 7

NAVAL AVIATION RADIO DIRECTION FINDERS

1. Does a loop antenna have the greatest pick-up when it is at right angles to the direction the radio wave is travelling?
2. In adjusting a RDF, why do we use the null position of the antenna rather than the maximum signal strength?

3. Why must a sense antenna be erected vertically?
4. Why is a RDF without a sense antenna termed a bilateral device?
5. How can you tell, by using the sense antenna, whether you are travelling in the right direction?
6. (*a*) What causes "night error"?
   (*b*) What is the effect of night error?
7. What is a "pelorus"?
8. What is the difference between relative and true bearing?
9. How is the calibration chart of the RDF employed?
10. Why is one side of a RDF loop painted black and the other side aluminum?
11. (*a*) What is a "masking piece"?
    (*b*) With what part of the RDF is a masking piece used?
12. Why shouldn't A. V. C. be used in conjunction with radio direction finding?
13. What precaution must be exercised when using an output meter for null indications?
14. What is a "cardioid pattern"?

CHAPTER 8

NAVAL AVIATION TRANSMITTERS

1. What are the four major circuits of the GF transmitter?
2. A calibration chart gives a frequency of 2000 kilocycles per second a dial setting of 190, and a frequency of 2050 kilocycles a dial setting of 205. What is the setting for approximately 2019 kilocycles?
3. In tuning the GP antenna circuit, if no antenna current is indicated or if the current is still increasing when you reach the limit of the antenna tuning control, what corrective measure is indicated?
4. What are the power outputs for various types of transmission, using the GP transmitter?
5. What is the frequency range of the GP?
6. What is the source of power for the GP?
7. What is the essential difference between the procedures for tuning a PA plate circuit and an antenna circuit?

8. What is the essential difference between the PA circuit of the GF and the GP?
9. How is the proper filament voltage indicated on the filament voltmeter?
10. What type of emission is employed while tuning the GP transmitter?
11. What precaution is necessary to prevent the PA plate current meter from indicating above the red line during the tuning process?
12. (*a*) Name the two principal units of the GO–9 transmitter and the frequency capabilities of each.
    (*b*) What is the power output of the GO–9?
13. (*a*) What difference is there, in the stage line-up, between the high and low frequency sections of the GO–9?
    (*b*) What is the frequency range of the oscillator in the high frequency unit?
14. If the "PA" meter of the GO–9 reads above the line, when all circuits are properly tuned, on full power, what should you do to reduce it to a safe level?
15. (*a*) What is the total frequency range of the ATA?
    (*b*) How many units are required to cover this range?
16. What are the approximate power outputs on voice and CW transmissions of the ATA?
17. What is the purpose of the "magic eye" tube in the ATA transmitter?
18. In the ATC transmitter, what is the function of the "Collins Autotune System"?
19. What frequency ranges are possible with the ATC?
20. How are "flashovers" prevented in the ATC, at the higher altitudes?
21. How many crystals are used in the TA–2J transmitter?
22. What are the frequency ranges of the TA–2J?
23. Outline the steps to follow in setting a transmitter to a desired frequency.

CHAPTER 9

NAVAL INTERPHONE COMMUNICATION SYSTEM

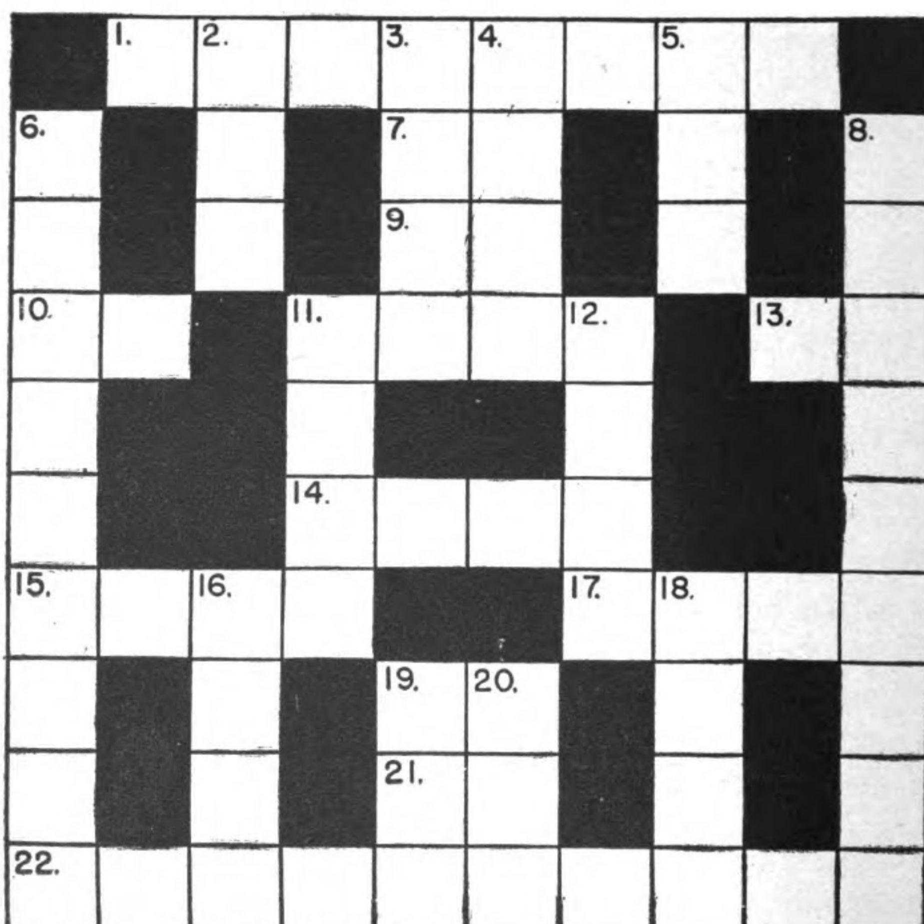
1. How many members of the crew can be accommodated by the RL–24A intercommunication system?
2. (*a*) Where does the power to operate the RL–24A come from?

   (*b*) How much power does it require?

CHAPTER 10

AIRCRAFT RADIO INSTALLATIONS

1. What is meant by "bonding"?
2. Why is it necessary to have complete bonding of aircraft radio equipment?
3. Can you do this crossword puzzle?



DOWN

2. Particle formed by gas in Heaviside Layer.
3. The center of a transformer.
4. Section of a transmitter or receiver.
5. A type of receiver (abbreviation).
6. A crystal under varying pressure will __________.
8. Multiunit tube often used as a full wave rectifier.
11. A good radio operator will always __________.
12. A type of curve well known in radio.
16. If you came home on maximum instead of null signals, you wouldn't get ahead but you would get a head _____.
18. Wire from your antenna (usually followed by the word "in").
19. Rating for radio technician.
20. Good name for a Nazi.

ACROSS

1. Your receiver has numerous __________.
7. In homing with a DF your A. V. C. should not be __________.
9. There's a big Navy base in this State (abbreviation).
10. A type of wave (abbreviation).
11. Radio equipment comes in __________.
13. Do you need tetrodes as R-F amplifiers?
14. Theoretically, the time at which ionosphere is nearest earth.
15. A resistor across the output of a circuit.
17. Will the Japs win the war? (This is a tough one, but give it a British accent.)
19. Type of current.
21. Navy type of receiver.
22. Elements of a vacuum tube.

ANSWERS TO QUIZ

CHAPTER 1

INTRODUCTION TO RADIO

1. (*a*) Waves in water.
   (*b*) Sound waves.
2. (a) The distance from crest to crest (or trough to trough).
   (*b*) The number of cycles occurring within a given unit of time.
   (*c*) The path a wave travels in going one wave length.
   (*d*) The height or depth of the wave.
3. 186,000 miles per second.
4. A generator of high frequency currents.
5. Aerial-ground system.
   Tuner.
   Detector.
   Reproducer.
6. (*a*) Resonance.
   (*b*) Inductance.—Henry.
   (*c*) Capacitance.—Farad.
7. To rectify alternating radio frequency current.

CHAPTER 2

VACUUM TUBE

1. Cloud of electrons which forms around the filament (cathode) of a tube.
2. The condition wherein all electrons emitted by the filament (cathode) are consumed as plate current.
3. (*a*) Supply filament voltage.
   (*b*) Supply plate voltage.
   (*c*) Supply grid voltage.

4. It causes plate current to decrease.
5. The process of feeding part of the signal back into the grid circuit to reinforce (louden) the original signal.
6. A bias is developed across the transformer secondary during positive alternations. This bias is nonexistent on negative alternations; therefore their respective amplifications are not equal.
7. Temperature variations in a filament heated directly by alternating current will result in fluctuating electron emission; whereas the cathode sleeve, because of its mass and material, is not subject to such variations.
8. Plate current is equal to cathode current. The IR drop across the resistor is in series with the grid-cathode circuit and is therefore utilized as bias.
9. Check your answer against figures 17 and 15 for diagram and current direction, respectively.
10. (*a*) Three.
    (*b*) Two.
    (*c*) Five.
    (*d*) None.

CHAPTER 3

ELEMENTARY TRANSMITTER

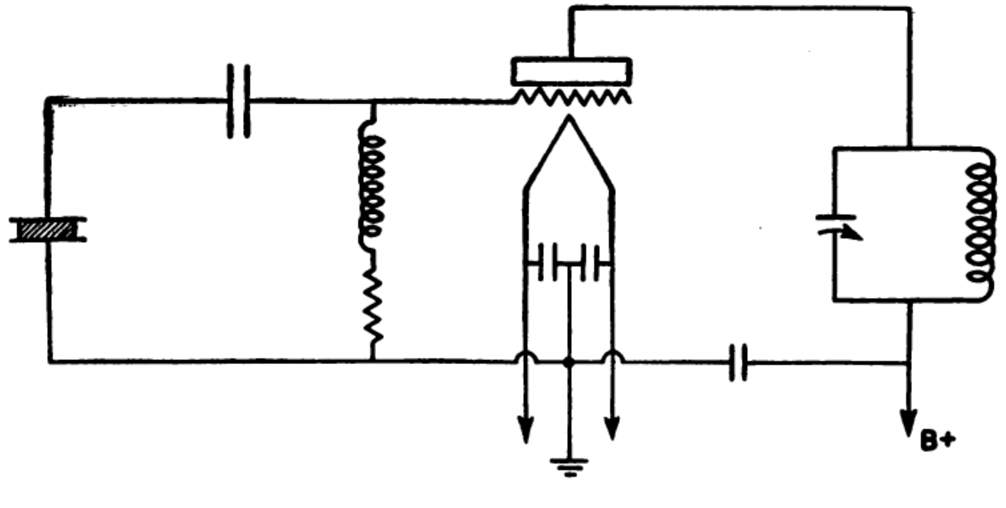
1. Series.
2. A condenser.
3. The process of varying the frequency or amplitude of a continuous carrier current so that the carrier wave can convey intelligence from a transmitter.
4. In radiotelegraphy the amplitude and frequency of the carrier wave are constant but the wave is interrupted in accordance with the intelligence to be transmitted. In radiotelephony, the carrier wave is not interrupted but its amplitude (or frequency) is varied.
5. To convert sound impulses into electrical impulses.
6. (*a*) By applying a steady tone to a carrier wave and interrupting the tone (modulating the carrier wave by pressing the key down) in accordance with the intelligence to be transmitted.

(*b*) The sending range of an MCW transmitter is less than that of a straight CW transmitter of equal power output.

(*c*) It furnishes a broader signal, which is more easily picked up.

(*d*) It may be received on an ordinary broadcast receiver.

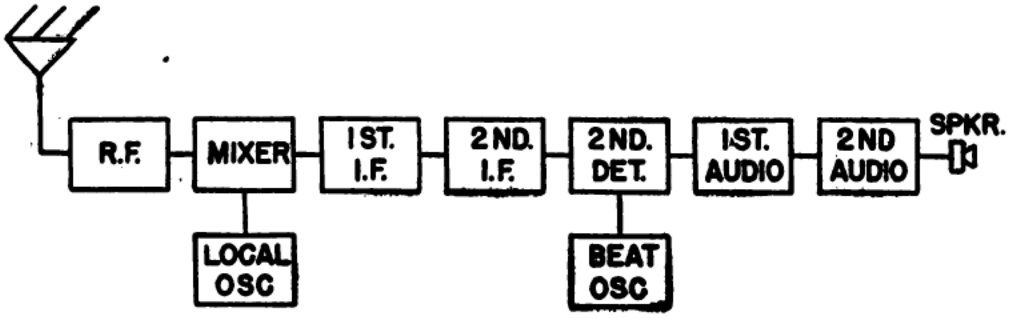
7. Master oscillator-power amplifier.
8. A harmonic will be some multiple of the fundamental.
9. Crystal oscillator.
10. Certain crystalline substances, when distorted (compressed and suddenly released), generate small a-c voltages. Conversely, if an a-c voltage at the natural frequency of the crystal is applied to a crystal, the crystal will be distorted and will generate an oscillating current.
11. Shape.
    Size.
    Quality.
12. Usually one-quarter of the wave length of the fundamental frequency; grounded; vertically or partially horizontally polarized; used on long waves.
13. Half the wave length of the fundamental frequency; suspended free from the earth; used on short waves.



CHAPTER 4

ELEMENTARY RECEIVER

1. (*a*) Ability to pick up weak signals.
   (*b*) Ability to select the desired radio signal from a number of incoming signals.
   (*c*) Faithful reproduction of the transmitted signals.
2. It must have uniform amplification over the whole audio frequency band. (30 to 10,000 cycles per second.)
3. The product of L (Inductance) and C (Capacitance) in the circuit.
4. To serve as an electrostatic shield between plate and control grid, thereby reducing the internal capacitance of the tube and eliminating the need for neutralization in radio frequency amplifiers.
5. In a T. R. F. the signal is amplified at the signal frequency; whereas in a super-het the signal is amplified at a fixed intermediate frequency.
6. A regenerative detector, or a separate oscillator tuned approximately 1000 cycles different from the signal frequency.
7.



8. Osc=2465 kc.
   Beat Osc=466 kc.
   1st Audio=1000 cycles.
   2nd Audio=1000 cycles.
9. T. R. F.

10. Low frequency tuned circuits are highly selective. Higher gain and uniform amplification are more easily obtained with low frequency circuits.
11. Tuning each individual stage for maximum performance at a fixed frequency.
12. (*1*) Controlling the strength of the incoming signal as it is applied to the input circuit of the amplifier.
    (*2*) Changing the audio-voltage impressed on the audio amplifier (by varying the screen-grid voltage in IF amplifiers or the plate voltage in audio amplifiers).
    (*3*) Varying the over-all amplification or "gain" of the receiver (by varying the control grid bias of the tubes in all amplifier stages).
13. A portion of the signal voltage is rectified and fed to the grid returns of the RF amplifying tubes as a negative bias which varies directly as the intensity of the signal. Thus the sensitivity of the receiver is automatically controlled by the signal intensity, and the receiver's output is held to a constant level.

CHAPTER 5

FREQUENCY MEASUREMENT

1. 195 to 2000 kcs. per second. 2000 to 20,000 kcs. per second.
2. Check your answer against figure 41.
3. No sound.
4. The procedure of mixing two signals in a detector circuit to procedure a beat frequency.
5. To check the accuracy and dial calibration of the heterodyne oscillator.
6. 1000.
   1000.
7. The check point that is nearest to the frequency to be measured.
8. Check the dial reading against the calibration chart.
9. *1.* Set receiver on approximate frequency by receiver dial.

2. Set HETERODYNE OSCILLATOR of CFI at the crystal check point nearest to the desired frequency.
3. Couple the output of the CFI to receiver antenna.
4. Adjust receiver dial until CFI signal is tuned in.
5. Receiver is now set to predetermined frequency.

NOTE:—MCW output of CFI may be used to pick up the signal. The output is then changed to CW for fine adjustment.

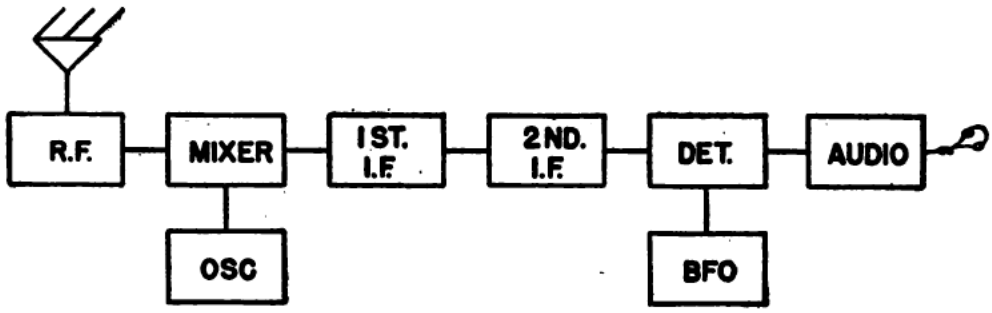
10. (*a*) To adjust the heterodyne oscillator in order to obtain a zero beat between the heterodyne and crystal oscillator when checking the dial calibration against the crystal check point.
    (*b*) Varies the strength of the signals coming in from the transmitter oscillator and going from the CFI to the receiver.
11. The signal from the CFI would be too strong and would create a broad expanse of zero beat on the receiver dial, thus increasing the chance of error in frequency calibration.
12. Ten minutes. To minimize frequency creeping or shifting as the CFI approaches operating temperature.

CHAPTER 6

NAVAL AVIATION RECEIVERS

1. 195 to 13,575 kcs per second.
2. 3 stages of RF.
   Automatic gain control circuit.
   Detector.
   Combination audio amplifier and CW heterodyne oscillator.
3. Dynamotor driven by 12–15 volt direct current sources such as aircraft batteries.
4. Cathode current in the receiving tubes.
5. Plug-in coil assembly.
6. 50 percent.
7. A receiver capable of operating on two or more frequency bands simultaneously.

8. Better than 0.3 percent accurate.
9. (*a*) 190 to 9100 kcs per second.
(*b*) Five units.
10.



11. Six.
12. (*a*) 150 to 15,000 kcs per second.
(*b*) Six bands.
13. 24-28 volt direct current furnishes filament voltage and operates a dynamotor which supplies the high voltage for the plates (and screens) of the tubes.
14. With no signal, receiver sensitivity is maximum and background noise high. Therefore spaces between dots, dashes and words would be filled in by a high background noise.

CHAPTER 7

NAVAL AVIATION RADIO DIRECTION FINDERS

1. No.
2. Because with average hearing, it is easier to detect silence than to distinguish degree of loudness.
3. So that its pickup will be non-directional.
4. It can determine the line of direction only, not which side of the loop the radio waves come from.
5. When the loop is rotated, the signal will be the loudest when arrow of indicator is pointing toward transmitting station.
6. (*a*) Shifting of the layer of electrified air (heaviside layer or ionosphere) encompassing the earth.

(*b*) Fading signals; error in RDF readings.

7. An optical angle-measuring instrument used for taking visual bearings.
8. True bearing defines position in relation to true north. Relative bearing defines position in relation to the airplane's nose.
9. RDF bearing is referred to the calibration chart and correct relative bearing is read in the adjacent column.
10. As an aid to the operator. The black will indicate weakest signal and aluminum the strongest signal when pointed at the station.
11. (*a*) A disk or metal plate which slides or rotates over a scale to reveal only a sector of the scale.

    (*b*) Azimuth scale.
12. Because it prevents normal changes in signal strength with loop rotation.
13. The operator must listen carefully to the signal to be sure he correctly identifies it, particularly during maneuvering, and does not follow the wrong beam.
14. A heart-shaped directional pattern obtained by the sense antenna and loop antenna combined.

CHAPTER 8

NAVAL AVIATION TRANSMITTERS

1. Master oscillator.

   Power amplifier.

   Modulation output circuit.

   Antenna circuit.
2. 195.7.
3. Change the antenna tap switch one turn in either direction until maximum current is obtained.
4. 85 to 125 watts for CW and MCW.

   30 to 40 watts on voice.
5. 350 to 9050 kcs. per sceond.
6. Aircraft-engine-driven generator which supplies 120 volt (800 cycle) a. c. and 24 to 28 volt d. c.
7. P. A. is tuned for minimum plate current, whereas an antenna circuit is tuned for maximum current.

8. GF is untuned. GP is tunable.
9. By a red line.
10. CW.
11. Always tune transmitter on reduced power.
12. (*a*) Low frequency transmitter (I. F.) 300 to 500 kcs. per second.
    High frequency transmitter (H. F.) 3000 to 18,000 kcs. per second.
    (*b*) Approximately 70 to 125 watts.
13. (*a*) The high frequency unit has an intermediate amplifier which serves as a frequency multiplier.
    (*b*) 1500 to 3050 kcs. per second.
14. Loosen the antenna coupling.
15. (*a*) 2.1 to 9.1 mc.
    (*b*) Five units.
16. 40 watts CW.
    15 watts voice.
17. To indicate resonance when the frequency of the transmitter master oscillator is the same as the crystal frequency.
18. To tune automatically, by mechanical manipulation, adjustable devices such as switches, variable inductors and capacitors.
19. 200 to 1500 kcs. per second and 200 to 18,100 kcs. per second.
20. By a pressure operated relay which automatically reduces the power to one-half its normal value when the aircraft reaches an altitude of 25,000 feet.
21. Eight.
22. 300 to 600 and 2000 to 18,000 kcs. per second.
23. *1.* Set heterodyne oscillator to nearest crystal check point.
    2. Set heterodyne oscillator dial on exact dial reading for desired frequency as determined from the calibration chart.
    3. Turn off crystal and modulator switches.
    4. Loosely couple transmitter oscillator to detector of CFI.

5. Tune transmitter oscillator until its frequency zero beats with that of the heterodyne oscillator in the CFI.

CHAPTER 9

NAVAL INTERPHONE COMMUNICATION SYSTEM

1. Nine.
2. (*a*) A junction box on the plane's distribution system.
   (*b*) 24 volts.

CHAPTER 10

AIRCRAFT RADIO INSTALLATIONS

1. Connecting all units or metal objects to some common terminal.
2. Difference in potential between metallic objects might result in arcing. This might cause radio interference, or even explosion of hi-test gas fumes.

	1. C	2. I	R	3. C	4. U	I	5. T	S	
6. O		O		7. O	N		R		8. D
S		N		9. R	I		F		U
10. C	W		11. S	E	T	12. S		13. N	O
I			E			I			D
L			14. N	O	O	N			I
15. L	O	16. A	D			17. E	18. L	N	O
A		C		19. A	20. C		E		D
T		H		21. R	U		A		E
22. E	L	E	C	T	R	O	D	E	S