

COMMAND SETS

BY GORDON ELIOT WHITE*

The following discusses some of the lesser known accessory and auxiliary command set equipment that turns up from time to time to intrigue most amateurs.

WHEN the Type K Command sets were conceived in 1935, they were to be a complex of modular components which could be assembled in flexible arrangements to suit the requirements of a wide assortment of combat aircraft. Before World War II ended ten years later, that plan was realized with a proliferation of gear that even its designer, Dr. Frederick Drake, could not have foreseen.

Some of the less-ordinary parts to the command sets are truly rare, and seldom turn up in surplus. Others are common, but few hams have realized just what function they serve. A few are highly interesting, their design of possibly unrealized value today.

The purpose of this account is to list these lesser-known parts, outlining the wide scope of the command concept with an eye to providing information the author believes has not previously been available.

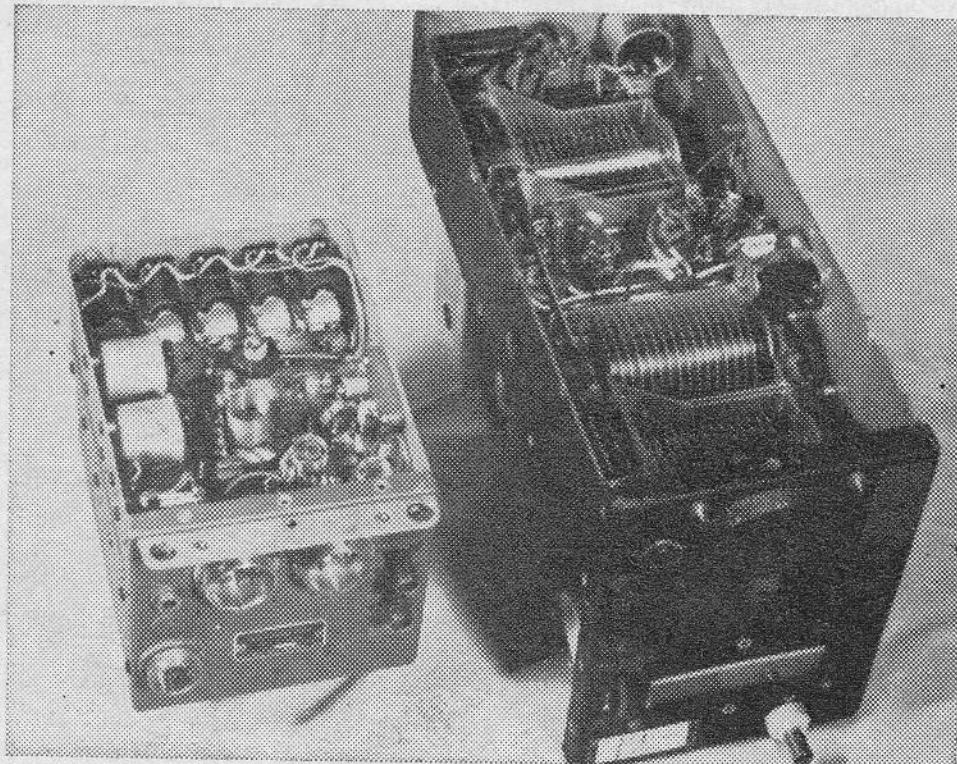
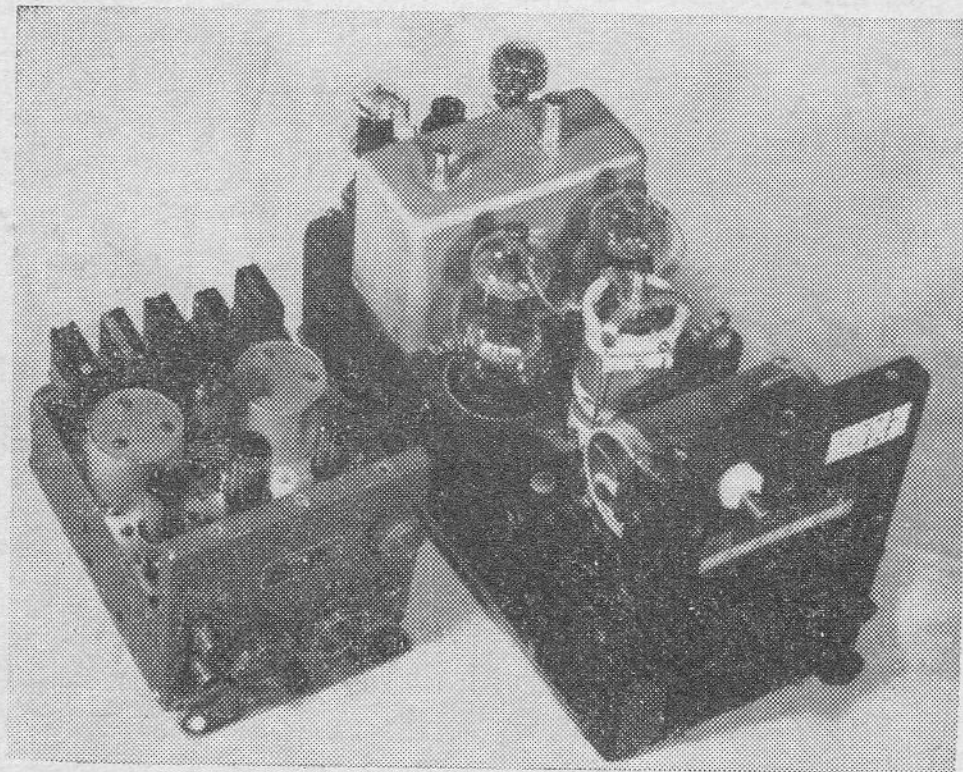
The spectrum of Command Receivers originally covered seven bands reaching from 200

kc to 20 mc. A 20-27 mc unit was designed on a 1939 Navy order, but the highest three bands were never bought in quantity. Reserved for relatively long-range liaison communications, the frequencies between 9 and 27 mc were covered by the more bulky RAX sets, used in heavy aircraft. The RAX of course had space for an additional r.f. stage, important at high frequencies.

Only an aggregate of about 350 command receivers were built in the ranges 9-13.5, 13.5-20 and 20-27 mc, with the 9-13.5 mc set seeing only production of 46 units in 1941-42, under RAV nomenclature.

Although this total seems small beside the million-set out-pouring of receivers in other bands from 1941 until 1945 and later, the author has seen these high-frequency sets in the surplus market from time to time. They are capable of the same excellent performance as the more common units, except for the upper end of the 20-27 mc area, where sensitivity with the original single 12SK7 r.f. stage is inadequate by present standards.

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Upper and lower views of the common h.f. ARC-5 transmitter and the T-11, postwar v.h.f. transmitter.

In another article the author will cover conversions of the common command receivers to the h.f. bands using original engineering data to provide accurate, tracked tuning and sensitivity.

There has been an impression that a 9-18 mc receiver was built in small quantities. Design records and military archives show only that the Signal Corps considered such a band for air-ground liaison, but that no design work was ever undertaken. It is possible that a 9-18 mc unit was put together at Wright Field for test use, but none were ever manufactured.

A 30-40 mc receiver was built in England from a BC-455 command set by Eighth Air Force radiomen. It was to receive the then-current British instrument landing signals, but a design proposal for such a receiver was killed in Washington.

A special keyer, built to work with early British equipment, was known as the "pipsqueak," BC-608. It keyed the command transmitter in a special code for identification-friend-or-foe by ground direction-finding stations. About 500 BC-608 units were built before radar transponders outmoded the system.

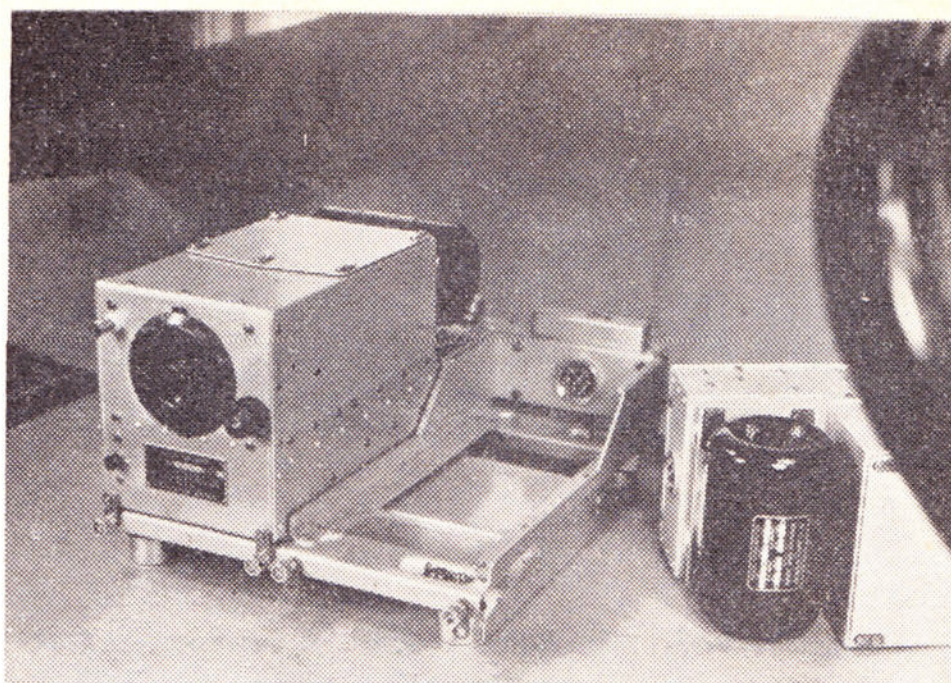
The Navy, in 1943, modified 300 Command receivers, and 450 transmitters, for optional crystal control. The program, undertaken by the Navy Research Lab, was dropped when the more stable AN/ARC-5 equipment came out. Although the modification was successful, it still required manual tuning to the vicinity of the desired signal.

Both 200-580 kc and 3.5-7 mc receivers were built during 1939 for the Air Corps, on a test basis, by Aircraft Radio Corporation; they were never manufactured in quantity.

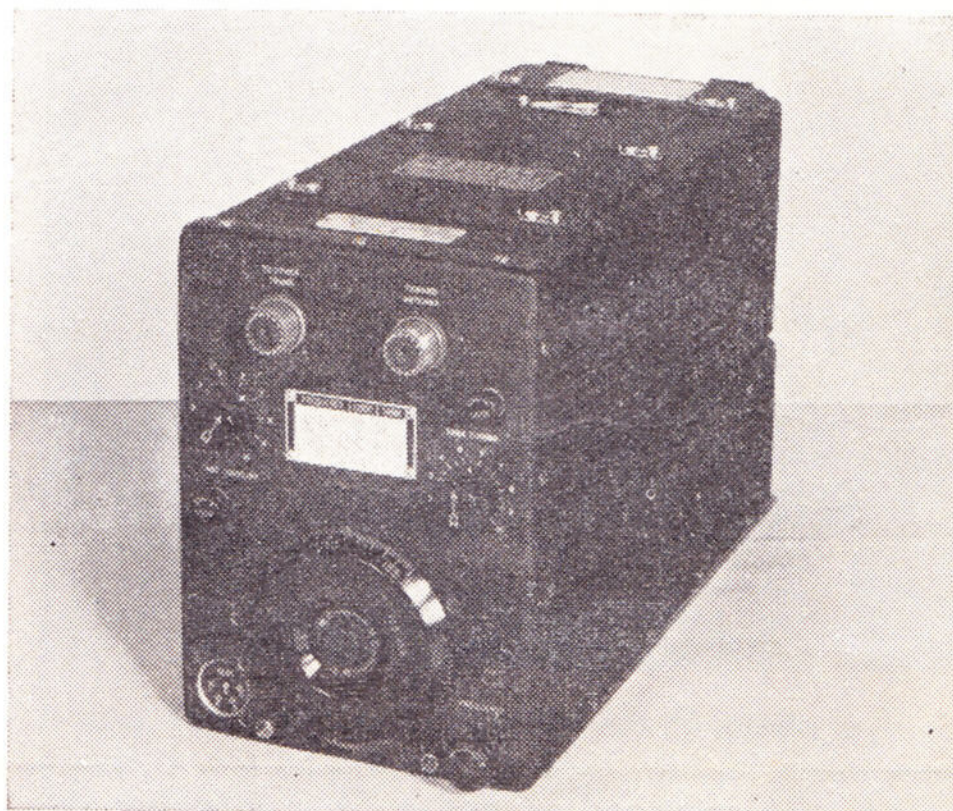
After the v.h.f. bands were opened to military use, the first American-designed set to operate above 100 mc was a Western Electric-built command prototype for the SCR-274-N system. The BC-695 receiver and the BC-699 transmitter were crystal-controlled, manually-tuned units in the 100-156 mc band. They were made only in test quantities. Motor tuning was added in 1943 and the crystal v.h.f. SCR-274-N sets were eventually built as BC-942 (receiver) and BC-950 (transmitter).

About 1,000 sets of these units were built for the Army before the Navy took over the contract, re-naming the units R-28/ARC-5 and T-23/ARC-5. The latter was modified to work with the MD-7/ARC-5 modulator, but both units resembled the SCR-274-N sets in most details. A T-126/ARC-5 transmitter was later built which covered any four channels between 100 and 146 mc. (The T-23 was restricted to certain segments of the 100-156 mc band.)

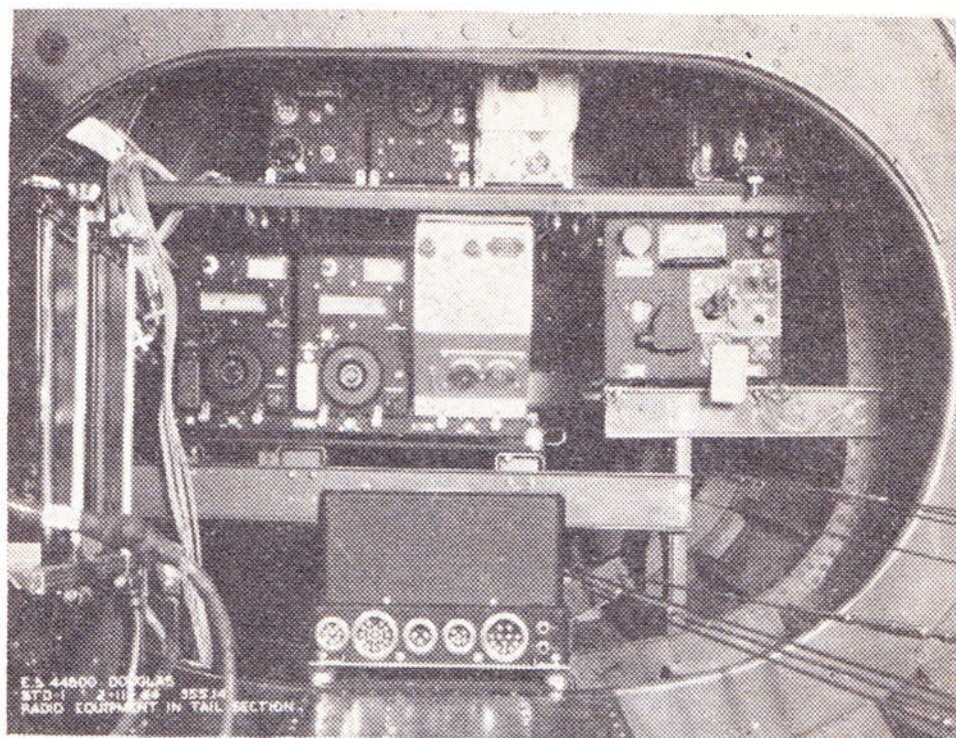
The Aircraft Radio Corporation tuneable v.h.f. sets were bought late in the war, and designated R-112 and R-113 and T-89 and T-90/ARC-5. No more than 200 were made. Many still lie in dusty corners of surplus dealers' shelves, by-passed in part because they are hard to identify as part of the more common equip-



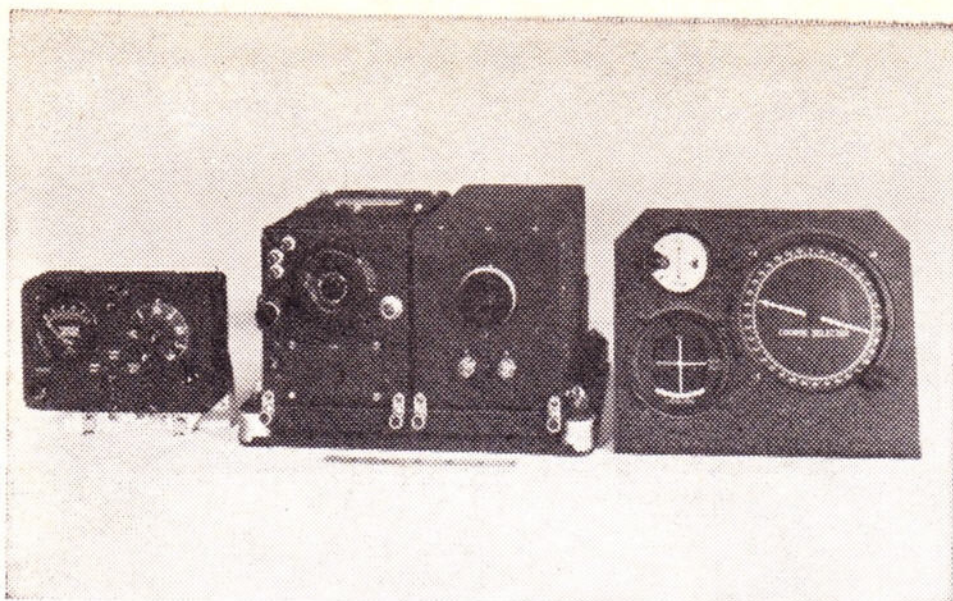
This photo shows the original SCR-274 prototype of 1939. The receiver on the left is the 200-580 kc unit; the receiver at right was 3.5-7 mc. Note the difference between this and the SCR-274-N units brought out two years later.



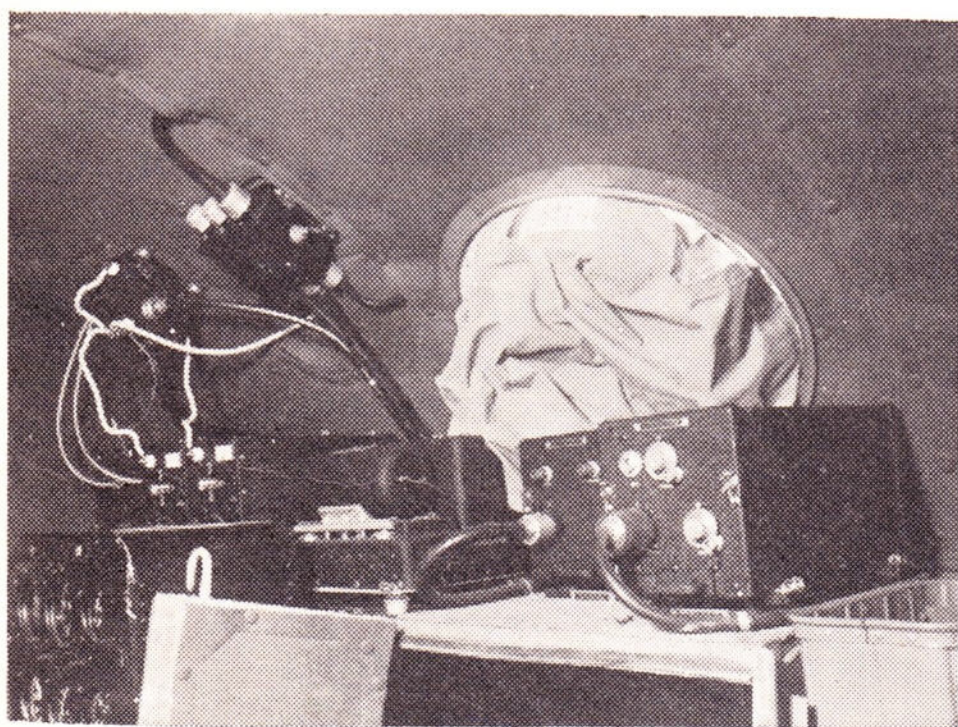
This T-90/ARC-5 was the last of the WW II command transmitter designs, covering 125-156 mc.



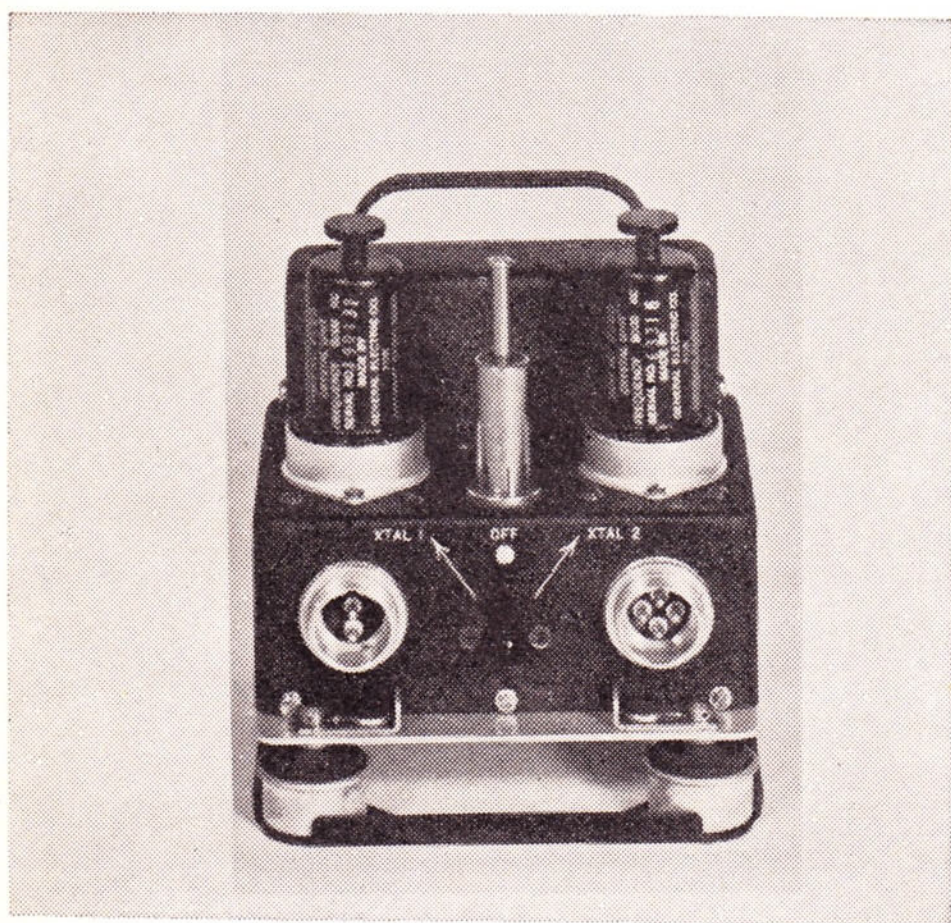
A typical command set system is shown in this photo of a 1944 Douglas Navy torpedo bomber. Top row l. to r. are an R-4/ARR-2 navigation receiver (234-258 mc), R-26/ARC-5 receiver (3-6 mc) and an R-28/ARC-5 v.h.f. receiver (100-156 mc) followed by an RE-2/ARC-5 antenna relay for the h.f. sets. In the middle row l. to r. are the transmitters, T-19/ARC-5 (3-4 mc), T-21/ARC-5 (5.3-7 mc), T-23/ARC-5 (100-156 mc) and an ARB liaison set, (190 kc to 9 mc). The bottom unit is a MD-7/ARC-5 modulator. Most of these are covered in the *Surplus Conversion Handbook*.



Designed in 1947, this A.R.C. type 17 navigation set was a low frequency "omni" receiver, using the R-23-A command receiver from the AN/ARC-5 command set. The converter on the right derived the navigation information from the audio signal of the R-23-A. A glideslope could be fed to the cross-pointer as well.



This is a photo of the interior of a Navy PBY patrol plane taken in July 1942 by the Martin Co. It shows an ATA/ARA command set and a ZA installation. The ZA "localizer" is on the left; it took the audio signal from the 190-550 kc command receiver and filtered the 90-150 cycle modulation to give course information. The 93 mc ZA glidescope receiver is on the right. A self-contained portion of the system, it provided information on the pilot's cross-pointer instrument.



Extremely stable AN/ARC-5 communications receivers were set and lock-tuned to tactical frequencies by this 28 volt crystal frequency meter, O-4/ARC-5.

ment. These sets covered the 100-156 mc band in two parts; 100-125 and 125-156 mc.

Another receiver, the ZB, was closely associated with the command sets. This was a homing unit for carrier planes which may have saved this country a year or more of fighting in the Pacific. Without it, the Battle of Midway and the other carrier fights could not have been won.

Even in peacetime, using radio direction finders, the Navy had been losing carrier planes which could not find their ships after over-the-horizon flights. In wartime, communications silence would have made carrier flying suicidal. The little ZB set picked up 246 mc signals, too high in frequency to be detected by the Japanese. Transmitted by a rotating, directional yagi antenna on the carrier, the signal was keyed in 15 degree segments to indicate homing azimuths.

To make the ZB system even more secure, the signals were double-modulated, the second frequency falling in the 540-1240 kc area. The ZB thus was a tuned radio frequency u.h.f. "tuner" which attached to the 520-1,500 kc band command receiver. So successful was the device that the old DU loop, designed to attach to the command receiver loop terminals was made obsolete before the war began.

The ZB became AN/ARR-1 under joint nomenclature, and was used by the Army to some extent with radiocompass receivers. It was superseded by the AN/ARR-2, a set which fit the command receiver rack and carried its own low-frequency and audio channels. It still used a t.r.f. u.h.f. front end.

The original ZB and AN/ARR-1 adapters had been powered through special plugs on the front of the appropriate command receivers. The Army Air Corps bought the BC-946, broadcast band receiver, strictly to work with the ZB, and original BC-946 receivers all carried the FT-310 adapter for this purpose.

The ZA was also used with the command sets. An instrument landing system, it was the first operational, all-weather landing aid, and it led the way to the current world standard ILS.

The ZA used a pair of transmitters for "localizer" information. One was modulated at 90 cycles, the other at 150 cycles. The centerline of the runway was marked by the point where the two signals were equalized. The carrier frequency fell in the 190-550 kc band of the command set. In the plane the ZA audio filter split the output from the receiver into left and right indications, shown on a cross-pointed instrument on the pilot's panel. At the same time a 93 mc glideslope fed height information through a separate receiver, controlling the second needle on the panel. The MX-19 adapter in the command receiver series was part of the ZA hookup.

The ZA was later outmoded by the SCS-151 ILS system, which had a 108 mc "localizer" and a straight-line 333 mc glideslope. Despite its demise during WW II, the ZA made its mark as the first successfully-tested aircraft carrier blind landing system (1935) and was an important

aid at fog-bound Navy patrol bases in 1940-42. Its development was chiefly Navy. Engineering and production was carried out by the Washington Institute of Technology and the Air Track Corporation, of College Park, Maryland.

A third navigation component was the BC-1159, a compass-modulator built under sub-contract to Stewart-Warner Corp., for the Air Corps. Also known as the AN/ARA-1, the set fit a receiver rack next to a low-frequency command receiver. Attached mechanically by a geared linkage through the tuning shaft, the AN/ARA-1 provided loop and compass circuits for automatic direction finding, a concept much cherished by the Army.

Only about 500 BC-1159's were made, according to Signal Corps records. Its small iron-core loop, a German invention, was designed here by Dr. Polydorff, of Chicago. The loop design later was adapted to the AN/ARN-6 and most subsequent RDF units used until quite recently in commercial aviation.

Although not a military design, the R-13 v.h.f. receiver was bought postwar by the military for navigation work as AN/ARN-30. Aircraft Radio Corp. engineers Paul Farnham, Norman Anderson and Dr. Paul King had redesigned the R-112/ARC-5 and added the B-10 converter, for reception of the new C.A.A. "omni," in 1946. Together the receiver and converter made up the Type 15, the first commercial omni set for v.h.f. air navigation.

The R-13 was an improved version of the wartime AN/ARC-5 receiver, with extensive use of ceramic dielectrics and loctal tubes. The 15 mc i.f. transformers were modified from the brass-wire wartime units to provide a higher Q, narrower bandpass. Equipped with a dial, the R-13 closely resembled AN/ARC-5 equipment, but was generally produced in a gray paint job. The R-13 was part of an "omni" navigation set; the companion R-15 was a communications version. Generally the only difference between the two involved care to avoid unwanted phase reversals in the navigation version. About 2,500 R-13 sets were made through 1949, when the design was radically overhauled and crystal control instituted.

A low-frequency omni, Type 17, was built in very small numbers in 1947, but suffered from phase-reversal due to night effect, and was dropped.

Briefly, both omnis provided multiple "tracks" inbound or outbound from the station in much the way a lighthouse gives azimuth indications. While the rotating beam of light turns, another flashes as the revolving beam passes through north. At one revolution per minute, an observer can find his compass bearing to the station by timing the delay between the flash and the arrival of the beam.

On the omnirange, the reference "flash" is a stable-phase signal and the "revolving beam" is a varying phase signal "rotating" at 30 cycles per second.

Aircraft Radio Corp. also built an R-19 receiver, covering 118-148 mc, much like the R-15 and R-13, but all three, in later versions, were made without dials, and designed to be tuned remotely. The T-11 and T-13 transmitters were part of this postwar equipment, and provided low-power v.h.f. communications in the 118-148 mc area.

The AN/ARC-60 set used the R-19 receiver and a "transverter," the TV-10, which transmitted in the 228-258 mc band and converted u.h.f. signals into the R-19. It was widely used in Army aircraft in the 1950's.

Although not strictly a part of the Type K command line, the AN/ARC-39, made in the early 1950's, used a great number of command components. It was a transceiver covering the 2-9 mc band in 12 crystal-controlled channels. About 400 were made. The set had an i.f. of 750 kc.

Aircraft Radio Corp. built several interesting items of test gear out of command equipment, including a 10-20 kc variable oscillator and a 6-13 mc oscillator in receiver cases. JAN units included a two-crystal frequency meter, O-4/ARC-5 used to set lock-tuned receivers. A receiver test set, #7869, was also built for field test work.

Other little-known components included the TN-6/ARC-5, a loading coil for the 500-2,100 kc transmitters, and the RE-16/ARC-5, a coax relay for the v.h.f. transmitters. (A.R.C. at first tried an iron-core loading coil in the LF transmitters, but went to the external unit to save weight.)

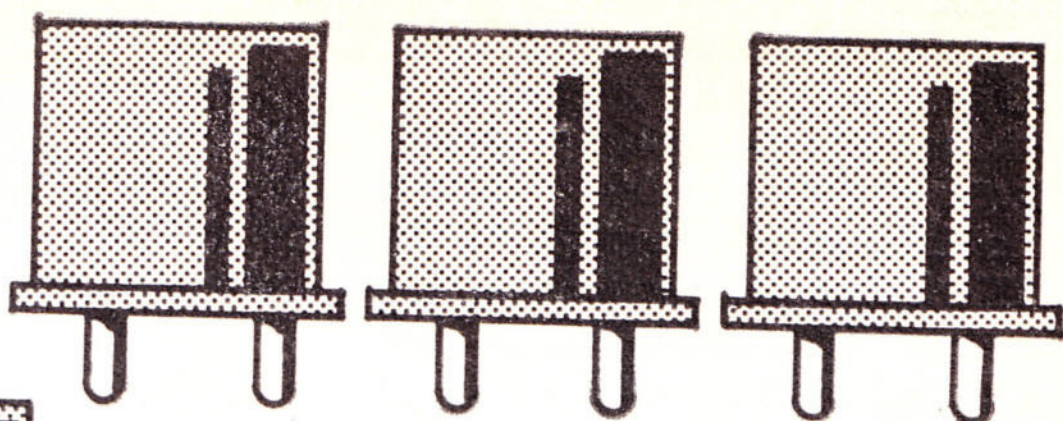
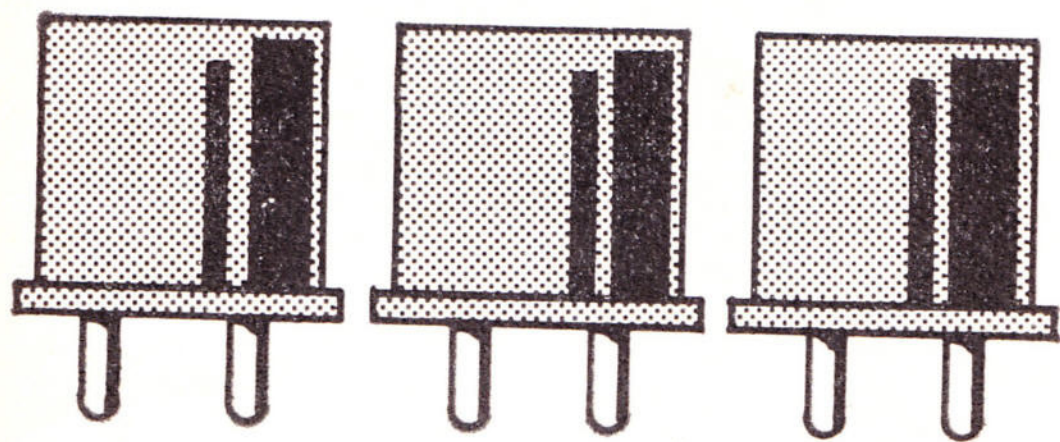
The rare T-89 and T-90 transmitters are still occasionally found. These use a v.f.o. plus multiplier stages with 832A tubes and the same sort of antenna coupling and final tank tuning as the h.f. sets. A crystal calibration arrangement was also used as in the more common units.

Of all of these accessories, the AN/ARR-2 probably represents the best surplus bargain. At prices ranging from 35¢ without tubes, to \$6 in excellent shape, this little set can be used as a broadcast band receiver, a fairly sharp 200 kc i.f. strip, or a v.h.f. double-conversion receiver. Ken Grayson wrote up one conversion in the August, 1959 *CQ*. The present author has additional conversion data on this set which he plans to put together in the near future for *CQ* readers.

The R-13, R-15, and R-19 v.h.f. receivers, tuning from 108 to 148 mc, represent the cream of the postwar command gear. Capable of sensitivity of less than 1 microvolt, stable, and with extreme tuning accuracy, these make top-quality 2-meter receivers at prices ranging around \$30. ■

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Crystal Controlled



Command Sets

BY GORDON ELIOT WHITE*

THE flagship of the mighty U.S. Atlantic Fleet rode gently on the calm surface of the tropical Caribbean, just off the Cuban coast. The warm summer morning, late in the nineteen twenties was peaceful. Dawn broke clear, with a light breeze.

As the chief communicators—lieutenants, commanders and a few four-striped captains from two-score ships, climbed the gangways of the flagship, they were grim-faced and quiet. Each was accompanied by a seaman carrying a small metal case holding tiny fractions of the problem which had immobilized the fleet.

For the mighty U.S. Navy had been brought near to chaos by quartz crystals.

Communications plans, painstakingly worked out ashore had broken down as radiomen tried to shift channels according to the intricate orders, avoiding "enemy" jamming, or to cover secret messages by frequency shifts, only to find that they lacked the correct crystal. Unforeseen tactics called for new, unplanned channels for which the crystals were not available.

Aboard the flagship, the problem of channel allocation finally brought the collected communicators to their knees beneath the 16 inch guns on the foredeck, shuffling crystals like dominoes. Shortages in one band vied with excesses in another to confound the Navy's best communications men. By sundown, senior Navy officers had a profound distrust of the "rock-bound" inflexibility of crystal control which was to last more than 14 years, until the luxury and instability of variable frequency transmitters and receivers was blasted by the Pacific war.

Its anti-crystal bias was a factor which helped lead the Navy to buy the Aircraft Radio Corporation Type K Command set in 1939, a non-crystal aircraft radio system. The design was excellent, but required manual tuning.

The Army had tried crystal control in its ill-fated SCR-240 set of 1937-38, apparently proving that crystal designs were not ready for use in combat radio equipment.

Although both services eventually bought vast numbers of the Type K command equipment, combat soon showed that pilots were too busy fighting to tune coffee-grinder radios. Push buttons were the answer.

The Army bought the British TR-1143, and had it built by Bendix as the SCR-522, a four-channel, v.h.f., push-button transmitter-receiver. A v.h.f. version of the Command Set was ordered.

The Navy, slower to see the advantages of the push-button, began to suspect in late 1942 that crystal control might be useful in a small way.

It can now be revealed that the first Navy crystal-controlled aircraft radios of WW II were modified command sets, rebuilt by the Naval Research Laboratory, at Bellevue, in Washington, D.C.

The NRL design worked out in early 1943 involved elimination of the b.f.o. for c.w. reception, the addition of a delayed automatic volume control circuit, and two crystal-controlled channels in the receiver.

Transmitters were re-wired to make the calibration crystal control the frequency. The operator could choose either channel or continuous tuning at will.

In early 1943 crystals were still in drastically short supply, but Captain Frank Akers, chief of

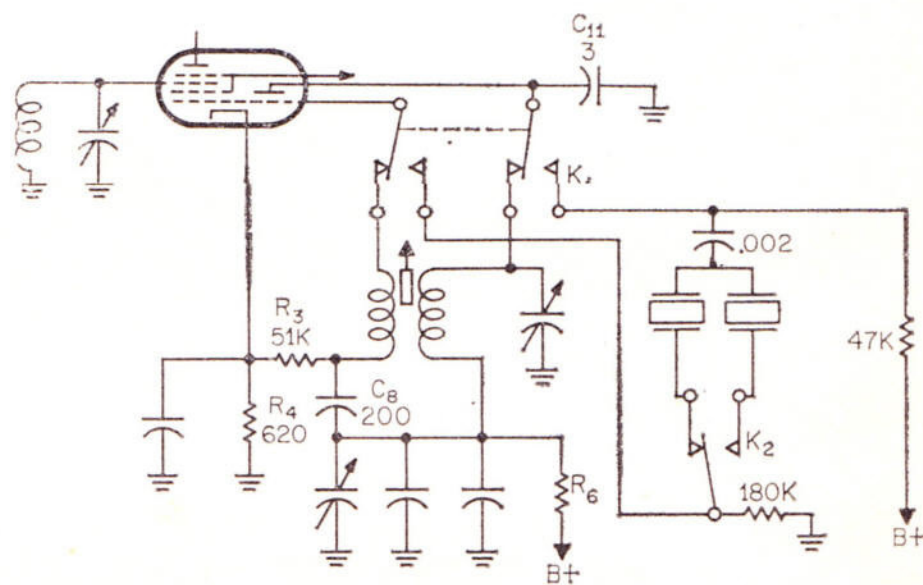


Fig. 1—The 12K8 mixer circuit with NRL modifications for 2 channel crystal control operation. Relay contacts, K_1 , selects crystal or variable frequency control and relay contacts K_2 selects the desired crystal. The 28 volt relay coils are not shown.

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the radio section of the Bureau of Aeronautics wrote the Naval Research Laboratory on March 23 in a confidential letter that "the practicability of the subject modification having been satisfactorily demonstrated, it is now requested that the laboratory convert 150 complete sets of ATA/ARA radio equipment to optional crystal control.

Between April and July 1943, 300 receivers and 600 transmitters were changed over, stamped "modified" in white ink; the rear connecting plugs were rotated 90 degrees to prevent their being used in unmodified racks.

Although the NRL design was tested by Aircraft Radio Corporation, it was never manufactured under contract. Instead, A.R.C. tightened up the frequency drift of their ATA/ARA sets, issuing them under the joint nomenclature AN/ARC-5, for lock-tuned operation. The frequencies were set on the ground and apparently stayed accurately on-frequency even during combat operations.

The Navy adapted a motor-driven tuner to about 5,000 3-6 mc receivers in another AN/ARC-5 configuration, the "Yardeny" spot-tuner C-131/AR, which was bolted to the front of the set.

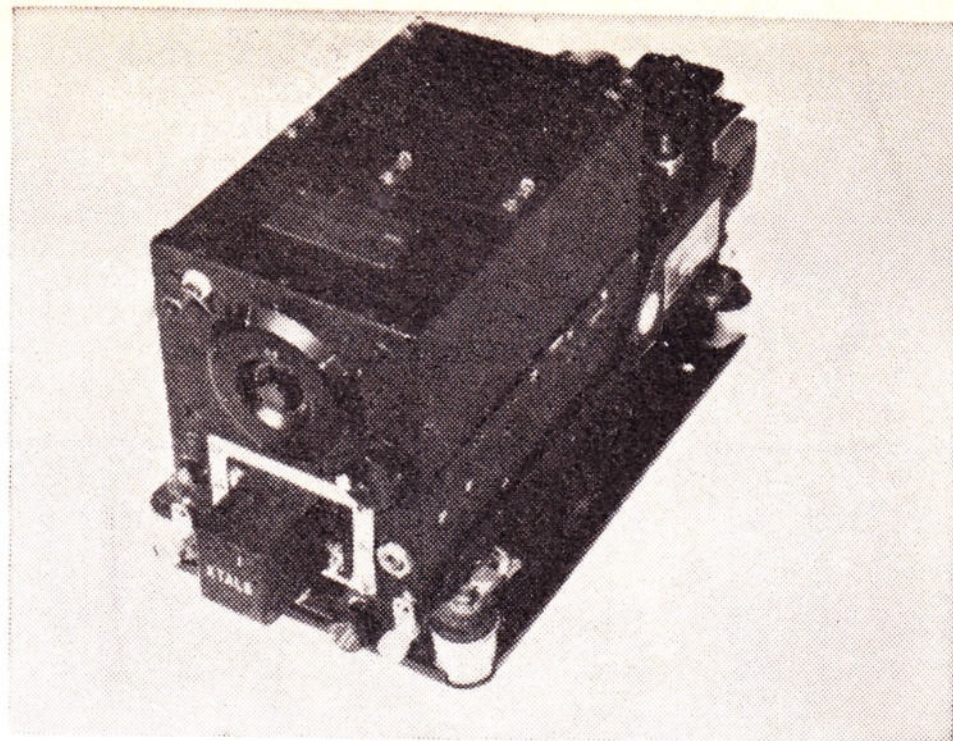
The NRL crystal modification however, remains of interest to radio amateurs who have adapted so many command sets to their peacetime use. Fairly simple to build into the receiver, the NRL modification permits ease of operation on nets, or other frequencies requiring accurate setting, possibly beyond the .04 percent tuning accuracy of the Command equipment dials.

The NRL circuit is reproduced in fig. 1. The crystals were plugged into sockets on the front of the receiver; their switching is done by a pair of 28 volt relays.

It probably will be necessary to re-align the tuneable oscillator (by means of the trimmers on the condenser gang) to offset stray capacitance changes in the altered wiring.

Although the modification gives crystal control of the oscillator, it is still necessary to manually tune the receiver to the approximate frequency desired in order that the antenna and r.f. stages may be properly peaked.

Oscillator crystal frequency of course is determined by adding the receiver i.f. to the frequency you desire to receive. (Common i.f.'s are 2830 kc for the 6-9.1 mc set, 1415 kc for the 3-6 receiver, 705 for the 1.5-3 mc unit)



Front view of the converted ARA receiver. The two crystals are mounted in the front enclosure.

The NRL circuit providing a.v.c. in the ARA receivers is shown in fig. 2. It increased useable receiver output as well, but eliminated the c.w. oscillator. Audio level was set by a pot on an external control panel.

A positive voltage is taken from the 12A6 cathode circuit and divided down to the required 2 or 3 volts by R_{17} and R_{19} and applied to the cathode of the 12SR7, the detector and a.v.c. rectifier. The detector diode (pin 4) is returned directly to the cathode so the applied d.c. voltage does not affect this circuit.

The a.v.c. diode (pin 5 of the 12SR7) returns to ground through the 2 megohm resistor, R_{20} so the plus d.c. voltage applied to the cathode is effective in this circuit. The small positive voltage on the cathode blocks the rectifier action of the a.v.c. diode until the signal exceeds this d.c. voltage. This delays the a.v.c. action for weak signals only and effects a desirable control action on the stronger signals.

For almost all amateur use, additional audio is not required if the output impedance is properly matched to the headset or speaker. All except the earliest Army -A model receivers had provisions for 600 ohm outputs. (The early Army equipment had 4000 ohm output, and later Army gear provided optional 4000 ohm taps. Late Army and all Navy receivers had low impedance audio circuits.) By using a cheap universal audio transformer between the receiver and a speaker voice coil, enough power is available to drive an 8" speaker with all the audio you can stand.

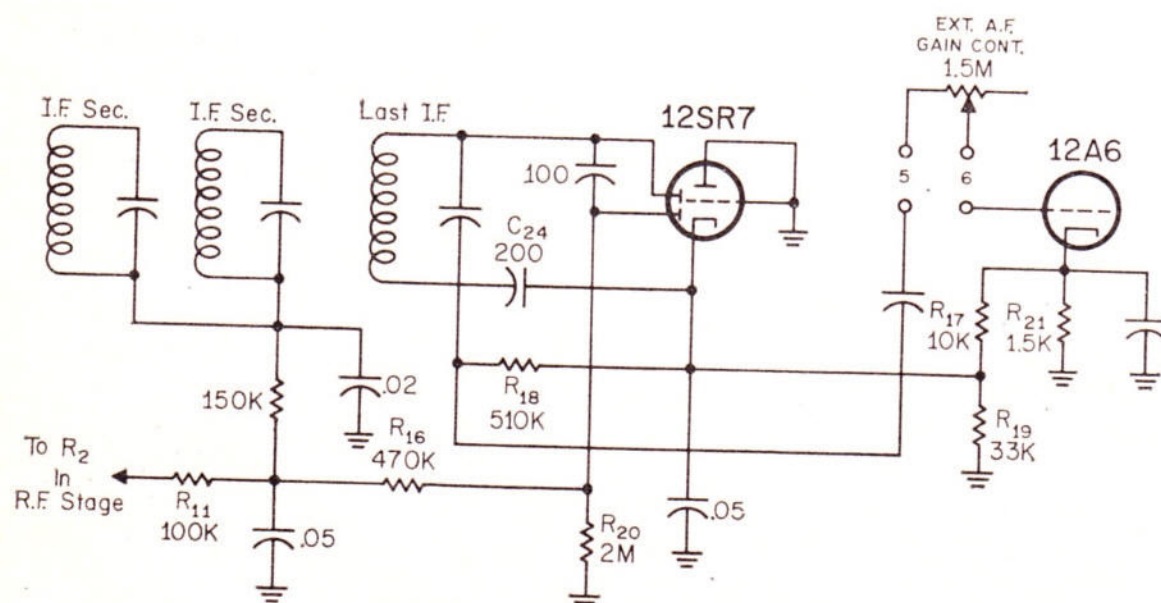


Fig. 2—The delayed a.v.c. circuit as installed by N.R.L.

Command Set Receivers for All Frequencies— The Easy Way

BY GORDON E. WHITE*

The most widely-used piece of surplus equipment ever to hit the amateur market is the famous Type-K Command Set receiver. Probably thousands have been mauled by the experimenting ham in an effort to change the frequency coverage of an available unit to something more suitable. Below is a wealth of practical, no-nonsense information direct from the manufacturer's files, bound to make the job an easy one.

THE command sets, based on the Type K design, were made in fabulous numbers during WW II. Korean War and civilian versions pushed the production record to about a million receivers alone during the 20 years they were manufactured.

Such a vast outpouring, plus the high inherent quality of the command design has made the sets the most popular items in the long postwar history of amateur use of former military gear.

Unfortunately, despite the larger numbers of command sets made, there was a wide disparity in the production rate of the receivers in the different bands. Although there were eight l.f.-m.f.-h.f. receivers designed, only five are still common, and only three saw really massive production. (The tuneable v.h.f. sets are a story to themselves, and the author hopes to deal with their excellent qualities and detailed specs in a subsequent article.)

While more than 450,000 "beacon" band command receivers were made, covering 190-550 kc, only 46 sets were built for the 9-13.5 mc band. Well over 200,000 sets were built in both the 3-6 mc and 6-9.1 mc bands, but fewer than 150 were manufactured for the 13.5-20 mc and 20-27 mc segments.

The Army bought the BC-946 broadcast band (520-1,500 kc) set chiefly to be used with the ZB homing adapter, and only 11,000 were made. The Navy procured another 18-20,000, making these

sets relatively scarce and costly today. There was no Army production, and fewer than 50,000 Navy sets in the 1.5-3 mc marine frequency band, also a rare unit now.

The above figures show the prudence of conversion of the more plentiful sets to cover the rare frequencies for amateurs who covet the simplicity, stability, and tuning accuracy of command receivers in other than 190-550 kc, 3-6 and 6-9.1 mc bands.

Conversion Data

The author has uncovered original design data on the entire line of command receivers, from the 1939 prototypes through the 1961 civilian production. The tables in this article cover the r.f. the i.f. and b.f.o. transformers.

These specifications will provide all the parameters necessary to build receivers in any of nine bands, including the 3.5-7 mc prototype of the original SCR-274, which was never built in quantity. Performance of these conversions should match the original receivers, with a great saving in trial and error labor.

In the past, conversion data has been published which attempted to achieve similar ends, but in most of these the writer has not had the time or test equipment to optimize the conversion. This set of tables comes directly from the meticulous designs of Dr. Frederick H. Drake, Paul O. Farnham, and Norman J. Anderson in the Boonton, N.J. laboratories of the Aircraft Radio Corporation.

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TABLE I—Similarities & Differences								
Range	190-550	520-1,500	1.5-3.0	3-6	6-9.1	9-13.5	13.5-20	20-27
Navy No.	46102	46103	46104	46105	46106	46107	46108	46109
C ₁ (mmf)	11	11	11	11	8.5	6.5	6.5	6.5
Loop Input	Yes, except ARA, SCR-274-N	Yes, except ARA, SCR-274-N	No	No	No	No	No	No
C ₄ No.	3936	3936	4601	4601	6558	6558	6558	4609
C ₄ Max. (mmf)	346	346	147	147	62	62	62	41
C _{4F/G} Cap.	min./ $\frac{1}{2}$	min./ $\frac{1}{2}$	$\frac{1}{2}$ / $\frac{1}{2}$	$\frac{1}{2}$ /max.	$\frac{1}{2}$ /max.	$\frac{1}{2}$ /max.	$\frac{1}{2}$ /max.	$\frac{1}{2}$ / $\frac{1}{2}$
C ₁₀ (mmf)	690	670	365	365	240	240	340	300
R ₆ (Meg.)	.51	.30	.20	.20	.15	.10	.10	.10
C ₃₉ across L ₂	120mmf	None	None	None	None	None	None	None
I.F. (kc)	85	239	705	1415	2830	4200	4200	4200
Tuned I.F. Ckts.	274-N	2 (var.)	2 (var.)	2 fixed	2 fixed	1	1	1
	ARC-5	2	2	2 fixed	2 fixed	2 fixed	2 fixed	2 fixed
Tapped I.F. Coils	L ₈ -L ₁₁	L ₈ -L ₁₁	L ₁₀ , L ₁₁	L ₁₀	None	None	None	None
Iron Core I.F.	274-N	No	No	Yes	Yes	No	No	No
	ARC-5	No	No	Yes	Yes	Yes	Yes	Yes
R ₁₂	510	510	510	510	510	390	390	390

Table I—Similarities and differences in the RAV series of command receivers covering 190 kc to 27 mc.

R.F. Problems

One or two cautions are in order. First, the 20-27 mc receiver was built with the same circuit and tubes as the lower frequency sets. It was satisfactory for short, direct, plane-to-plane work, but definitely lacks the sensitivity for long range reception. In fact, it was replaced by the General Electric RAX set in liaison use for Navy patrol aircraft early in the war. A single 12SK7 tube just cannot function as well above 20 mc as it does at six or nine megacycles.

The author has at least partially solved the sensitivity and noise problem in his own RAT-1 sets by substituting a 6AB7 for the r.f. tube. The filaments have been wired for 12 volt parallel

operation, with the exception of the r.f. and audio tubes. Wiring these in series allows the use of a 6V6 output tube which nicely matches the filament current of the 6AB7.

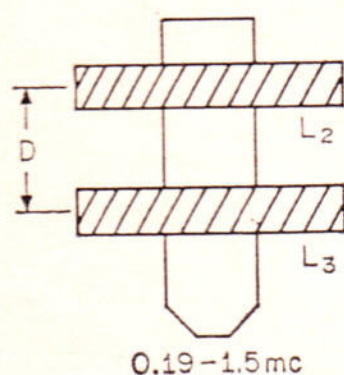
Running the heater wiring directly from the r.f. to the audio gave no trouble, but dress of wiring involved could in some causes cause feedback. This applies particularly to the plastic wiring in the later AN/ARC-5 sets.

The 6AB7 of course required a screen voltage boost to 200 volts from 85 in the original circuit. A 200 ohm cathode resistor should replace the standard 620 ohm unit.

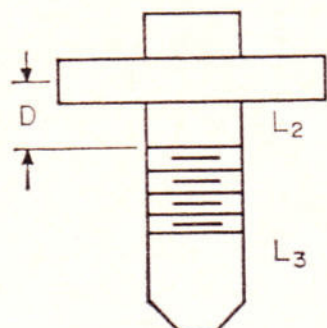
I.F. Changes

In the SCR-274-N and ARA sets, and the older

TABLE II—R.F. Coil Data									
Range (mc)	Antenna L ₁	Mixer L ₂	f (kc)	Mixer L ₃	Oscillator L ₄	Oscillator L ₅	Loop L ₆	D (Inches)	Winding Data L ₁ , L ₃ , L ₅
0.19-0.55	* 285 t. ① #36 SSE	* 720 t. ③ #38 SSE	147	* 255 t. 5-41 Litz	* 50 t. #36 SSE	* 235 t. 5-41 Litz	28 t. ④ #36 SSE	0.500	U.W.
0.52-1.5	* 102 t. ② 7-41 Litz	* 743 t. #38 SSE	394	* 104 t. 7-41 Litz	* 20 t. #36 SSE	* 83 t. 7-41 Litz	15 t. ④ #36 SSE	0.469	U.W.
1.5-3	* 61 t. 5-41 Litz	* 219 t. #36 SSE	1125	* 61 t. 5-41 Litz	7½ t. #36 e.	* 48 t. 5-41 Litz	N.A.	0.219	U.W.
3-6	31½ t. #30 e.	* 110 t. #34 SSE	2250	31½ t. #30 e.	6 t. #32 e.	26 t. #30 e.	N.A.	0.219	52 t.p.i.
3.5-7	22½ t. #26 e.	* 75 t. #34 SSE		23½ t. #30 e.	6 t. #32 e.	21 t. #30 e.	N.A.	0.219	52 t.p.i.
6-9.1	20½ t. #26 e.	* 50 t. #34 SSE	4550	20½ t. #26 e.	2½ t. #32 e.	17 t. #26 e.	N.A.	0.219	36 t.p.i.
9-13.5	13½ t. #24 Tin	* 33 t. #34 SSE	6665	13½ t. #24 Tin	2½ t. #32 e.	10½ t. #24 Tin	N.A.	0.219	24 t.p.i.
13.5-20	8½ t. #24 Tin	* 20 t. #34 SSE	9450	8½ t. #24 Tin	2½ t. #32 e.	7½ t. #24 Tin	N.A.	0.219	18 t.p.i.
20-27	6½ t. #24 Tin	* 14 t. #34 SSE	14,900	6½ t. #24 Tin	2½ t. #32 e.	5½ t. #24 Tin	N.A.	0.219	17 t.p.i.
27-40	← EXPERIMENTAL →						N.A.	0.219	14 t.p.i.



0.19-1.5 mc



1.5-27 mc

NOTES:

- ① RAV, ARA and AN/ARC-5 series, tapped at 198 t.
- ② RAV, ARA and AN/ARC-5 series, tapped at 71 t.
- ③ Paralleled with a 100mmf capacitor.
- ④ Wound on L₁ for low impedance loop antenna input.

f—Resonant frequency of L₂, cold, with tubes in place.

D—Coil spacing between L₂ and L₃.

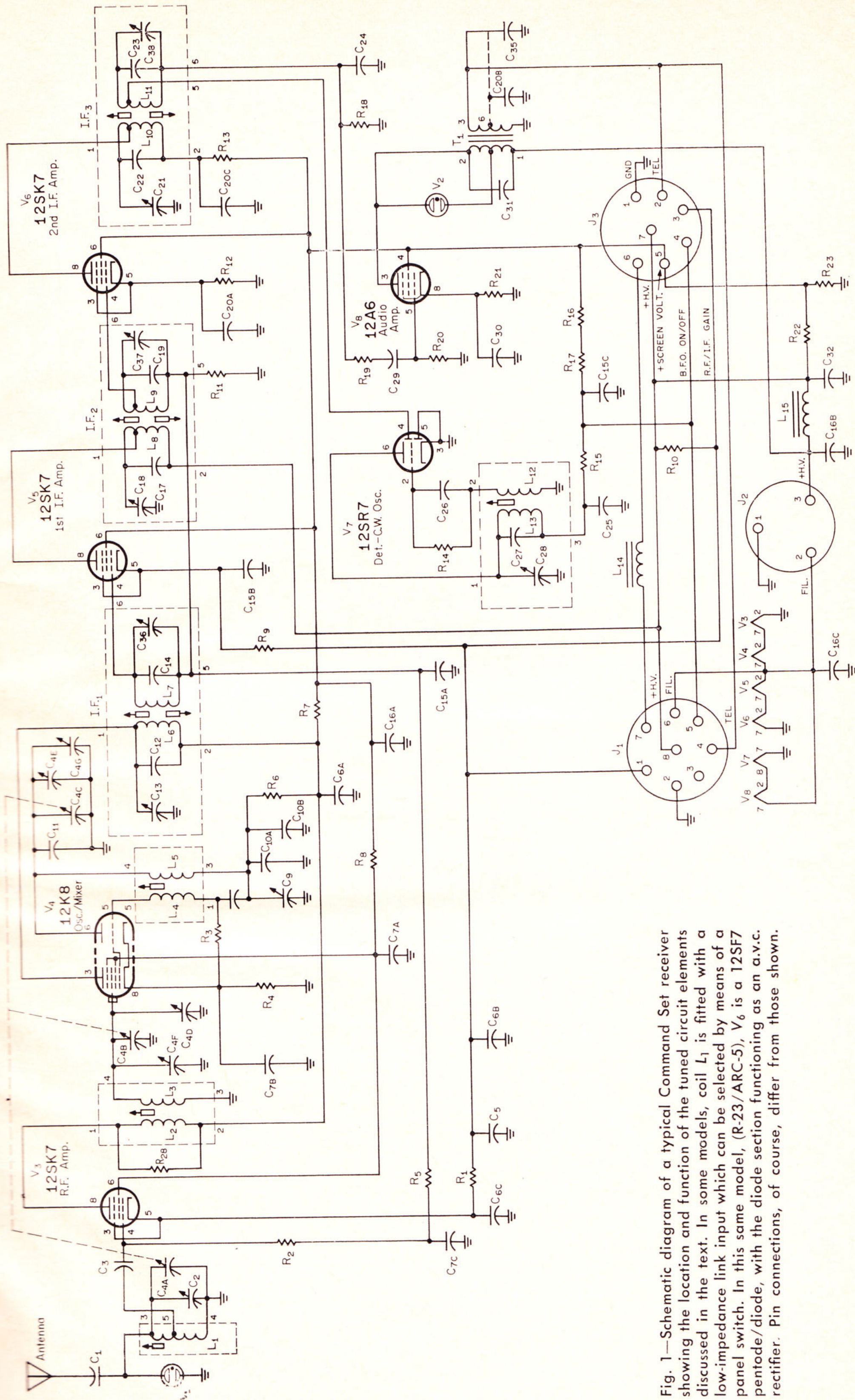
SSE—Single silk wound enameled wire.

U/W—Universal wound.

N/A—Not applicable.

e—enamel.

Table II—R.f. coil data necessary to convert the more available command sets to cover any desired frequency range. All windings marked with an asterisk are universal wound; the others are single layer windings. Chart term definitions are listed above.



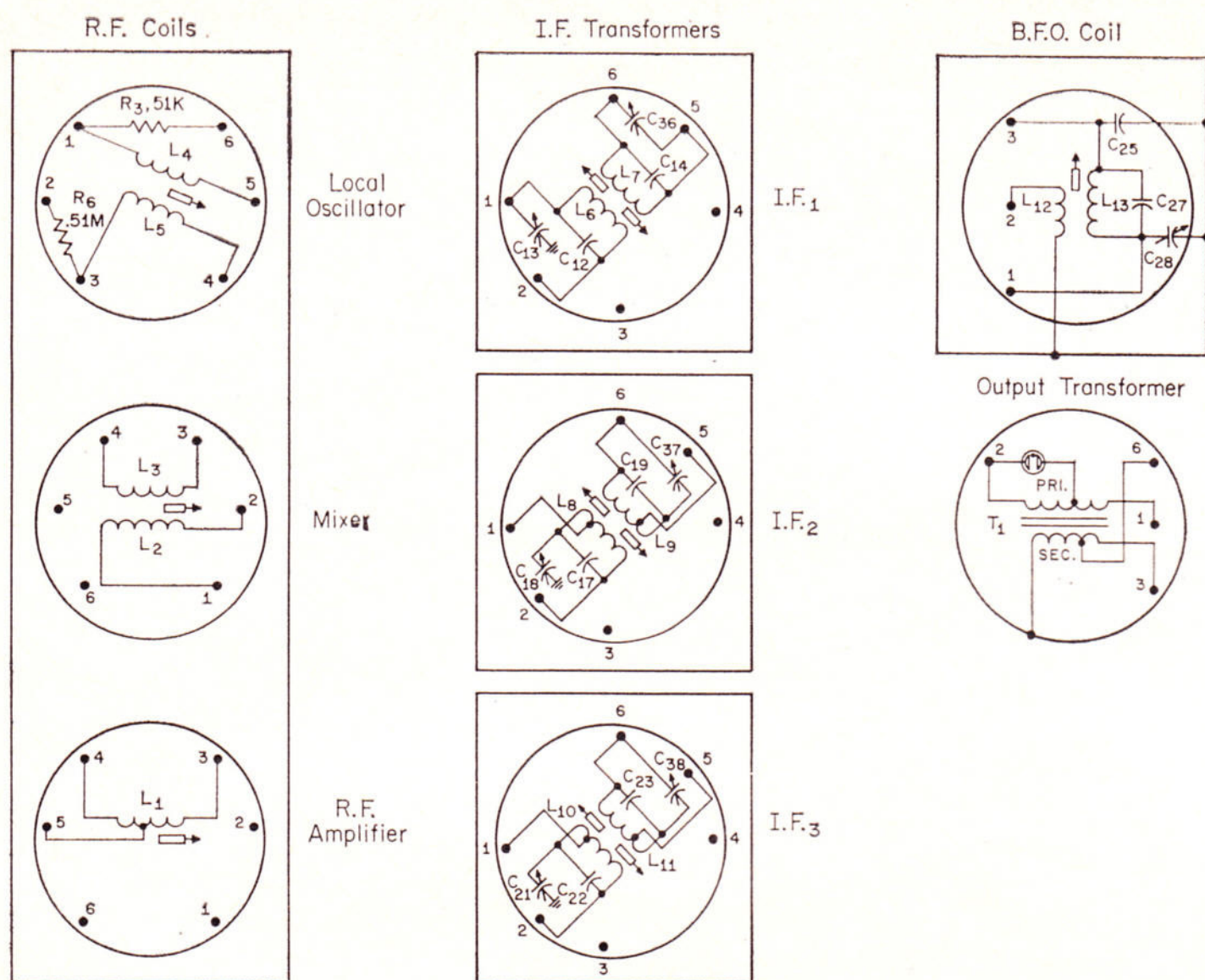


Fig. 2—Circuit data for the r.f. coils of the ARC-5.

RAT and RAV versions, 6AC7 tubes can be used in the i.f. versions, with appropriate filament changes and set realignment. The sharp cutoff characteristics of the 6AC7 does not harm the pseudo a.v.c. action in these receivers. It would *not* operate properly in the a.v.c.-equipped ARC-5 on postwar units.

The original bands will “track” accurately across the entire tuning range when properly aligned, when the correct i.f. is used and the correct part values installed.

The 3.5-7 mc receiver used an i.f. of 1660 kc, and the units covering the 9-27 mc bands used a 4,200 kc i.f. These are of course broad, but they eliminate most image response and most important, allow good tracking.

The I.F. Coils and the B.F.O.’s

Since the Type K-prototype Command Sets were the first superhetrodyne receivers used as standard quipment in the majority of U.S. combat aircraft, the design of the intermediate frequency circuits necessarily required thinking and solutions to problems that were, in 1935, new. Primarily, the receivers needed to combine light weight and small size with good sensitivity, and in the lower frequency sets, selectivity. Conversely, the high frequency receivers needed to be relatively broad because of the inherent drift limitations of airborne transmitters; remember, the command sets were designed for plane-to-plane communications in the 3—20 mc frequencies.

The engineers at Aircraft Radio Corporation had a solid background in commercial broadcast receivers, and had held patents on automatic volume control and “ganged,” tracked superhet circuits. In designing for civil aircraft use, cost was secondary to performance. In military aeronautical designs, cost was hardly a factor; thus

A.R.C. had great freedom to use the optimum in components and basic design.

Anyone who doubts this should look at an early command set coil: wound meticulously with enameled copper wire on a ceramic form, with all other dielectrics of clear ruby mica, even the small capacitors are specially-made. Such capacitors were, in 1935, unreliable, but Dr. F. H. Drake, at A.R.C. designed a stacked silver-mica capacitor, on a stainless steel screw, which could be adjusted to extremely fine tolerances. This was later converted to the silver-mica bell-shaped “button,” for manufacturing convenience.

Images

In order to avoid leak-through of “image” signals, a high intermediate frequency is often used. The Type K design criteria called for an i.f. just under half the lowest tuneable r.f. frequency, thus eliminating all but the strongest images in the final output.

At low r.f. frequencies (190-550 kc; 520-1,500 kc) this Type K criteria gives quite a low i.f. In the military design this was proper because the lower two receivers were used for navigation or homing on ground stations, which could have rigidly controlled frequency standards.

At higher frequencies, above 3 mc, broadness was indicated in order to work with other airborne equipment. This was met admirably by i.f.’s of 1415 kc in the 3-6 mc receiver; 2830 kc in the 6-9.1 set, and 4,200 kc in the remaining h.f. units.

For ground use by amateurs or SWL’s today, this broadness is undesirable, but may be eliminated by a variety of methods such as double-conversion into a “0-5er,” the lowest band command receiver. These devices however do not concern us at present.

TABLE III—I.F. and B.F.O. Coil Data						
INTERMED. FREQ. (KC)	I.F. PRI. L ₆ , L ₈ , L ₁₀	I.F. SEC. L ₇ , L ₉ , L ₁₁	SPACING D ₁	B.F.O. L ₁₂	B.F.O. L ₁₃	D ₀
85 (NOTE 1)	12001. * #38SSE	12101. * #38SSE	0.250"	1801. * #38SSE	6331. * #38SSE	0.172"
239 (NOTE 2)	4201. * 5-41 LITZ	4251. * 5-41 LITZ	0.875"	701. * 5-41 LITZ	2131. * 5-41 LITZ	0.172"
705 (NOTE 3)	1001. * 7-41 LITZ	1021. * 7-41 LITZ	0.875"	401. * 7-41 LITZ	981. * 7-41 LITZ	0.172"
1415 (NOTE 3)	471. * 7-41 LITZ	481. * 7-41 LITZ	0.875"	251. * 7-41 LITZ	451. * 7-41 LITZ	0.157"
1660	391. * 7-41 LITZ	401. * 7-41 LITZ	0.875"	221. * 7-41 LITZ	391. * 7-41 LITZ	$\frac{1}{32}$ "
2830	351. * 7-41 LITZ	361. * 7-41 LITZ	0.875"	15 $\frac{7}{8}$ 1. * #34 e.	26 $\frac{1}{8}$ 1. * #30 DSE	$\frac{1}{32}$ "
4200	241. * 7-41 LITZ	251. * 7-41 LITZ	0.875"	12 $\frac{7}{8}$ 1. * #32 e.	17 $\frac{1}{8}$ 1. * #30 e.	$\frac{1}{32}$ "
2830	411. * #28 e.	3001. * #38 SSE	FOR ARA, SCR-274-N	NOTES ON L ₈ -L ₁₁ : 1. TAPPED AT 4001. FROM START. 2. TAPPED AT 1801. FROM START. 3. TAPPED AT 301. FROM START.		
4200	28 $\frac{1}{2}$ 1. * #24	2001. * #36 SSE				

Table III—I.f. and b.f.o. coil data for the command set series. Those windings marked by an asterisk are single layer windings; all others are universal wound.

Tracking

In order to “track” a superhet receiver, the antenna, r.f., and oscillator stages must tune together very closely, with the oscillator frequency differing from the r.f. by the intermediate frequency, in a most constantly accurate fashion. The problems of attaining really good tracking require a combination of carefully taken data on the circuit with a grasp of some intricate mathematics; for most of us, tracking is a matter of luck in home brew superhets.

Since, however, the designers in Boonton worked out tracking solutions for nine bands of command receivers between 190 kc and 27 mc, we can filch their data to build excellent conversions from the more common command receivers.

It is necessary to keep in mind only that the tracking solution remains the same for a given receiving gang tuning capacitor so long as the ratio of the highest tuned i.f. frequency to the lowest tuned frequency remains constant with respect to the i.f.

For instance, using the same 21 gang in the 1.5-3 mc receiver, with its 705 kc i.f., the ratio remains quite close for the 3-6 mc set, with its 1415 kc i.f., and the 3.5-7 mc prototype, with a 1660 kc intermediate frequency. Thus all three should track approximately correctly using the same padders such as C₁₀ in the command cir-

cuit. This would hold true for any band you might choose, using the same tuning gang, so long as the ratios were about the same. The formula is this:

$$R = \frac{i.f.}{\frac{L + H}{2}}$$

where *R* is the ratio, *i.f.* is the intermediate frequency, *L* is the lowest tuned frequency, and *H* is the highest. Thus, for the 1.5-3 mc set:

$$R = \frac{705}{\frac{1.5 + 3}{2}} = 313$$

To obtain correct tracking for 3.5-7 mc coverage with the same gang and oscillator padders work it backwards:

$$313 = \frac{\text{unknown } i.f.}{\frac{3.5 + 7}{2}}$$

$$i.f. = 313 \times 5.25 \\ = 1643 \text{ kc}$$

This gives an i.f. of 1643 kc, very close to the 1660 “round number” actually used by A.R.C. engineers.

To work out tracking for a different i.f. would require considerably more math. Do it the easy way! Copy their data shown in Table III.

Coil strips for the r.f. section of the command receivers are available in surplus channels, generally in the 6-9.1 mc band, and are easily converted to higher frequencies. The author will supply the three section r.f. coils suitable for conversion at \$1.00 per set and 4,200 kc i.f. transformers at 3 for \$2, as long as his small supply lasts. Other sources include Rex Radio, 84 Cortland Street, Manhattan—(4,200 kc i.f. cans), Communications Equipment Corp., 343 Canal Street, Manhattan (i.f. and r.f. cans), Aircraft Radio Industries, 85 St. John Street, New Haven, Conn., Ritco Electronics, 7275-C Little River Tpk., Annandale, Va. ■

FLASH! 11,000 Miles Spanned On 144 Mc!

Occuring almost accidentally as an unscheduled shot-in-the-dark, a solid two-way contact was established between VK3ATN in Victoria, Australia and K2MWA of Homdel, New Jersey on November 28th on 144.90 mc which *has been confirmed*. Rendering obsolete the long-standing 5250-mile record between OH1NL and W6DNG, this feat comes very close to matching the 12,000-mile all-time v.h.f. record set achieved in 1956 on 50 mc between Japan and Argentina.

Regular moon bounce efforts between “T.R.” Naughton, VK3ATN and the famed WA6LET group came to a halt during the wee hours of November 28th when the Australian learned of an equipment breakdown at the California end. However, with prior knowledge of WA6LET’s schedule with the Crawford Hill Radio Club of Homdel, N.J., the 150-watt VK3ATN decided to “go all the way” for a long-haul direct contact with K2MWA. At approximately 5 A.M. EST, his signals were not only heard, but acknowledged, marking the beginning of a new era in long-distance moonbounce communications.

VK3ATN’s antenna system, consists of a 50-wavelength rhombic, while the Homdel group, headed by W2IMU, used a full kw into a 60-foot dish.

Formal presentation of statements, correspondence and tape recordings was made to ARRL approximately two weeks later for official documentation and endorsement. — K2ZSQ

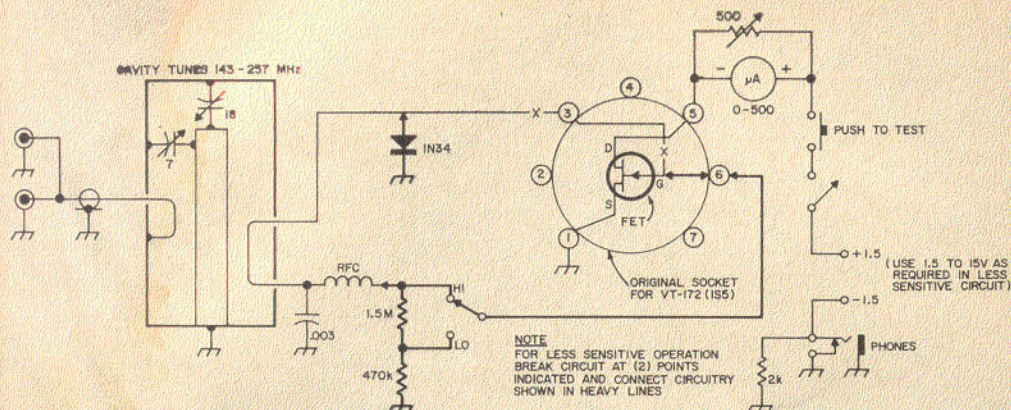


Fig. 2. Conversion of the BC-906 frequency meter to a field effect transistor. This frequency meter will detect rf signals down to a 100 microvolts or so and will tune through both the 2 and 1 1/4 meter bands.

tube to work at 2 1/2 meters! For the younger man the occasion might be similar to uncorking his first 807 on 10 meters. At any rate, the yield of good oscillators from the packet of 100 bargain items is surprising. Many were vigorous to 7.3MHz. How well they will work in other circuits remains to be learned. It may be safe to assume that some of them will perform as rf amplifiers; how noisy they are can be learned from trial and error unless one uses the more modern transistor testers which are available at much greater cost than the simple ones referred to in this work.

The field effect transistors are indeed fascinating. It boggles the mind to think what would have happened to the radio-radar-sonar systems had the solid state version of the tube arrived first. We'd probably be discovering the vacuum tube about now and that would be a blessing to those of us who need bi-focal glasses in order to work with these miniature components. Jim's FET Primer caused me to try the FET's offered by Poly-Paks. Again, the ones received are unmarked except that one is painted an ominous black. The advertisement seems to say that mine are low noise FET's made by Crystalonics. The package has a nice re-print from 73 and also some data which leads me to believe that one of the FET's is a C-610. Since my surplus BC-906E Frequency Meter had a 1S5 tube which went west, it was a logical choice to go FET. The original and modified circuits are shown in Fig. 2.

The FET can be plugged into the tube socket for experimentation, then later soldered in if you so desire. The schematics show the tube socket pin numbers in which to plug the FET leads. It is necessary to

remember that when looking at the bottom of the FET, the *base* lead is where the collector lead normally is located on a standard transistor. (Not on all FET's. Consult manufacturer's data sheet if in doubt. Ed.)

The absorption wave-meter with the FET performs much the same as the original tube version. One less battery is required and the battery voltage will depend upon the FET used. The FET which I assumed to be a C-610 works well with 1.5 volts. When the meter reads 500 micro-amperes full scale, the measured drain current is 1.5 milliamperes. As the cavity is tuned through a two meter rf field, the drain current will dip just as it did with the vacuum tube in the circuit.

The sensitivity may be improved by leaving out the 1N34 diode and disconnecting the 1.5 megohm resistor from the end of the radio frequency choke nearest the Hi-Lo switch. These modifications are indicated in Fig. 2 by the heavy lines. Then, with the rf lead from the cavity connected to the gate of the FET, the field effect transistor will act like an old-fashioned vacuum tube with a floating, leaky grid.

With this modification the frequency meter will respond to 100 microvolt signals fed into the cavity by way of the plug-in antenna. The fact that the FET will perform in this manner is a measure of compensation and a bit of solace to a hard vacuum tube man.

... W5SOT

1. WA6BSO, "Field Effect Transistor Primer," 73, December 1965.
2. W6AJF, "Two Transistor Testers," 73, September 1966.
3. M. S. Kiver, "Transistors," 3rd edition, 1962, McGraw-Hill Book Company, New York.

Using FET's in the Command Set Transmitter

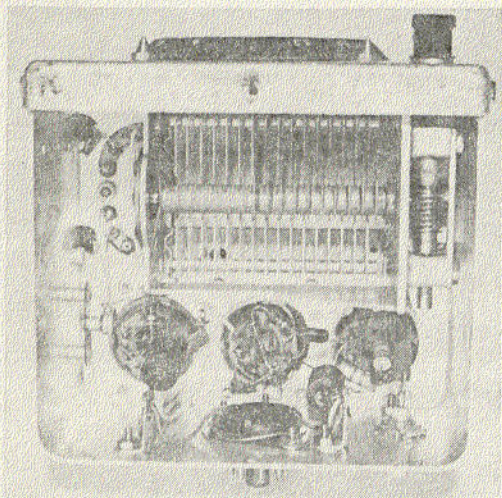
How to build a very stable VFO using a Command Set and three transistors—one FET and two conventional types.

Do you need a good stable VFO that's quite easy and inexpensive to build? Well I did, and after discarding many possibilities I came back to the old reliable Command

Set. Tubes were definitely out—after all, who needs them with so many types of semiconductors to choose from. Besides, the FET is supposed to behave like a tube, why not use it.

Hastily I attached an FET to the cathode, grid and plate pin of the oscillator tube. Boy, was I surprised—the oscillator took right off when voltage was applied without any component changes.

Enthusiastically, I began to remove everything from the chassis and decided to cut down its size as detailed in the *Command Set*® book. All parts except those associated with the oscillator were removed. The set was then rewired as shown in Fig. 1. The first transistor after the FET oscillator is operated as a class A buffer amplifier to isolate the oscillator from the output transistor and to build up the small signal to drive the next stage. The output stage is a broadband class C amplifier and only draws current when the oscillator is operating. No tuned circuits are used except the original circuit so the output is constant across



Bottom view of the transistORIZED Command Set. The oscillator section of the original Command Set is located on the rear of the chassis. In this conversion the chassis was cut in half and the rear part attached to the front panel.

*"Command Sets," Copyright 1957 by Cowan Publishing Co., Port Washington, L. I., N. Y.

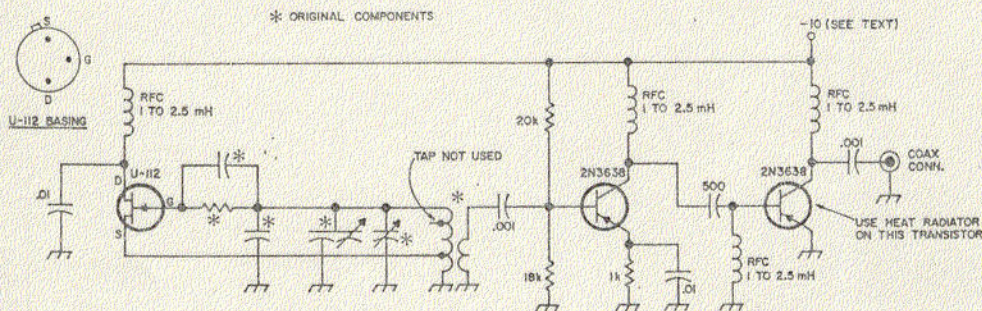
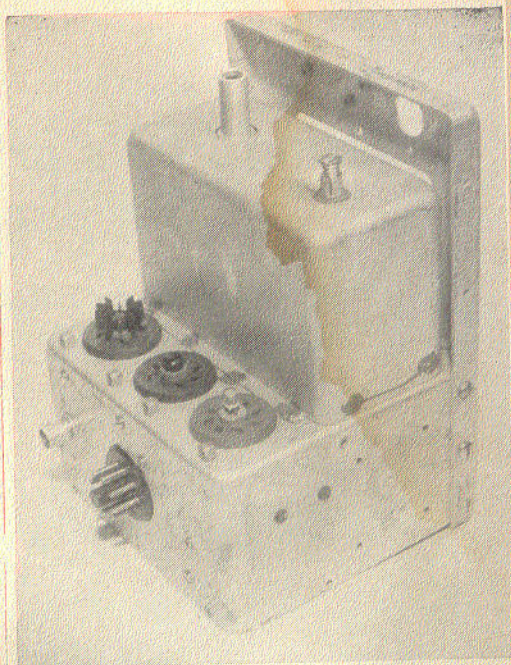


Fig. 1. Schematic of the transistORIZED Command Set transmitter. All components marked with an asterisk are original Command Set parts. The use of an FET in the oscillator circuit permits a simple and direct conversion from vacuum tube circuitry to semiconductors.



The shortie, transistorized Command Set. The transistor sockets are mounted in the center of the old octal tube sockets.

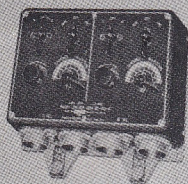
the band. With a 10 volt supply you get a full watt of input power to the final transistor. This is plenty enough to drive any crystal controlled transmitter.

All the HF Command sets were tried and the oscillator functioned perfectly. I won't attempt to give any of the basic data on converting the Command Sets. This information is quite readily available and would only bore most readers.

To keep the heat dissipation of the final transistor within safe limits, 10 volts is used for the supply voltage. Even with 10 volts a cap type heat radiator should be used. An increase of 2 volts more than doubles the power so be careful. When driving a Gonset Communicator III, for which this unit was designed, I find that dropping the supply voltage to 6 volts is more than ample to drive the transmitter to full output.

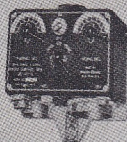
The transistors really carry a nice price tag, and should appeal to almost everybody. They are made by Fairchild Semiconductors and sell for about 62c apiece. The FET is a Siliconix unit. If another type is used it should have a transconductance of 1000 or better. If you really like pleasant surprises try this conversion.

... K3LCU



RADIO CONTROL
BOX BC-710-T1

MOUNTING
FT-240-A



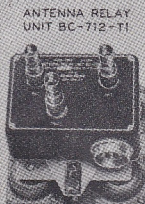
RADIO CONTROL
BOX BC-711-T1

MOUNTING
FT-228-A



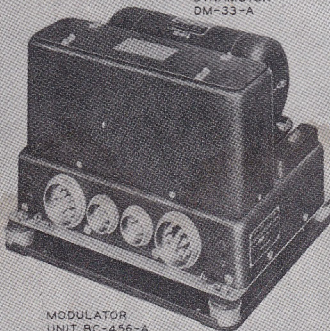
JUNCTION
BOX JB-50-T1

MOUNTING
FT-254-T1



ANTENNA RELAY
UNIT BC-712-T1

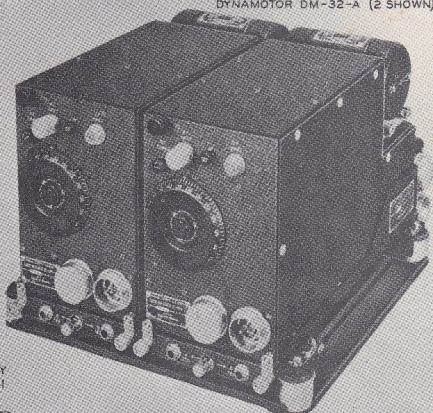
MOUNTING
E50-681967



DYNAMOTOR
DM-33-A

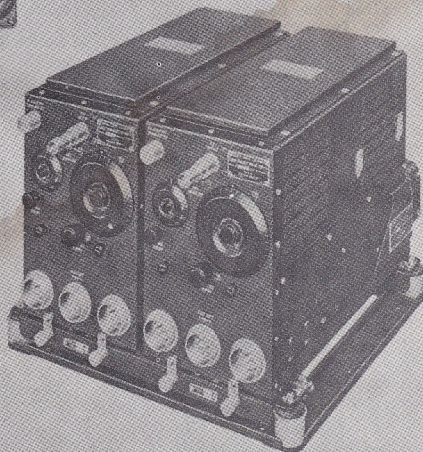
MODULATOR
UNIT BC-456-A

MOUNTING
FT-225-A



DYNAMOTOR DM-32-A (2 SHOWN)

RADIO RECEIVER BC-695-T1 (2 SHOWN)
RACK (2 RECEIVER) FT-277-T1
MOUNTING FT-279-T1



RADIO TRANSMITTER BC-699-T1 (2 SHOWN)
RACK (2 TRANSMITTER) FT-226-A
MOUNTING FT-227-A

Fig. 1—Major components for u.h.f operation of the SCR-274-N.

Solid-State BC-221 Frequency Meter

Modernize that fine old BC-221 of yours with FETs and a 9-volt battery! These complete instructions show you how.†

By R. S. N. Rau,* VU2CX

The tubes used in the BC-221 frequency meters long ago became obsolete and are now difficult to obtain — especially the older non-octal types — and as all models of the meter have excellent accuracy it would be a pity if the instruments have to be junked for want of tubes. However, with very little effort these instruments may be modernized with FETs, with no sacrifice of accuracy, by changing and adding a few components. In the author's model no recalibration was required, and the instrument now operates from a small 9-V battery.

Modifications

The only description of replacing tubes with FETs in the BC-221 known to the author is by Charles Landhal (73 *Magazine*, May, 1971, p. 61), and using this as a guide, he has modified his BC-221-1. The modifications given below specially concern this model, particularly regarding part numbers and base diagrams. However, all BC-221s and LM counterparts are basically similar and hence the modifications apply to most, if not all models.

The three tubes used are replaced by four N-channel JFETs, type 2N3819, but BFW10 or BFW11 may also be used. The only new components required in addition to the FETs are three octal plugs, five resistors, one capacitor and a 9-V transistor radio battery.

The tube used for the VFO is a VT116-B (6SJ7-Y), which is replaced by the N-channel JFET, Q1 (2N3819), mounted inside an octal plug as shown in Figs. 1A and B. Fig. 1C shows the modifications to the anode load resistor

of 56 k Ω (part no. 19). The value of R1 will depend on the particular sample of the FET used and ranges from 1 to 6800 Ω .

Mixer and Crystal Oscillator

The tube used for the mixer-oscillator is a VT167 (6K8), which is replaced by two 2N3819 JFETs, Q2 and Q3, one for the mixer and the other for the crystal oscillator. Fig. 2 shows the necessary connections. The two FETs, together with the associated components R2, R3 and C1, are mounted inside the octal plug. R2 and R3 may need some experimentation in the vicinity of the values given (6800 Ω and 3300 Ω , respectively).

It is important to note that the original leads going to pin numbers 2, 7 (heater) and 4 (screen grid) should be cut and insulated. The top-cap clip of the mixer valve should be connected to pin 4.

A short stiff wire of appropriate length is soldered to pin 4 and the other end of the wire is soldered to a small grid cap obtained from a defunct tube. The lead bearing the clip formerly going to the top cap of the mixer tube now goes to the new cap.

Beat-Frequency Amplifier

The tube for this is a VT116 (6SJ7), generally connected as a triode in all models using this tube. This again is replaced by a 2N3819 FET (Q4) mounted and connected inside an octal plug exactly as in the case of Q1 (Fig.

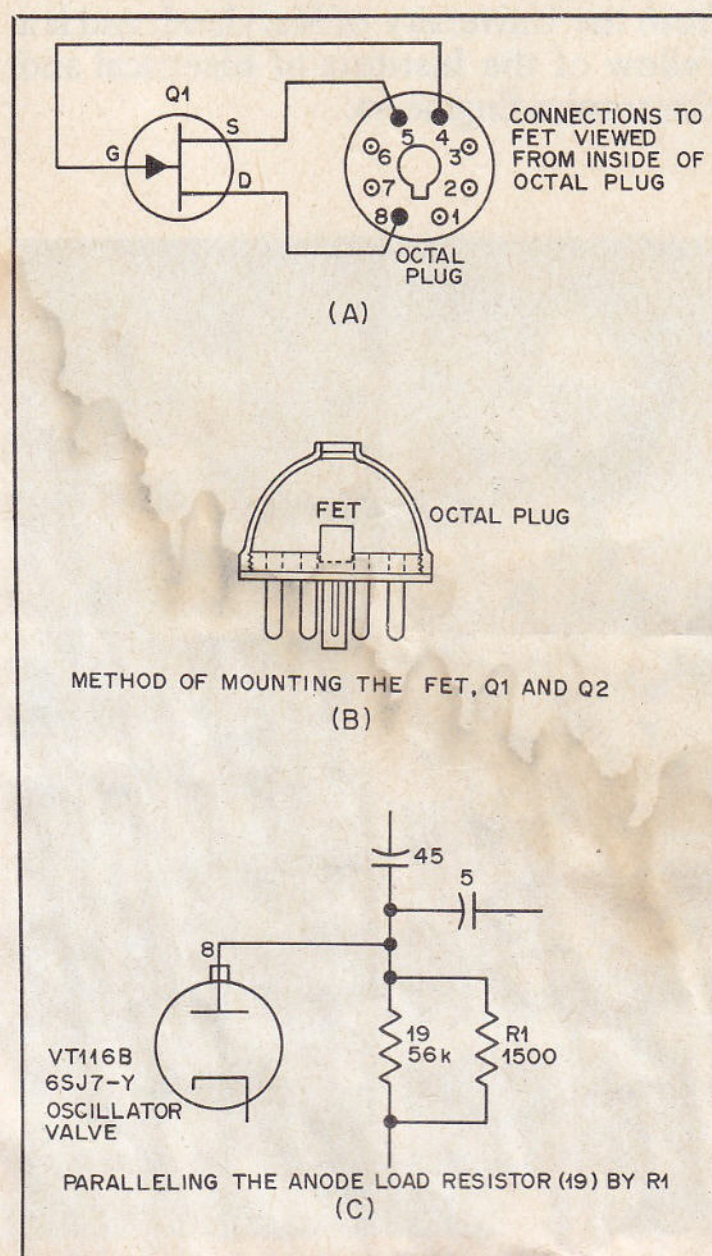


Fig. 1 — Modifications to the VFO circuit.

†Adapted from *Radio Comm.*, Aug., 1976.

*41/2 VI Main Road, Bangalore 560 003, India

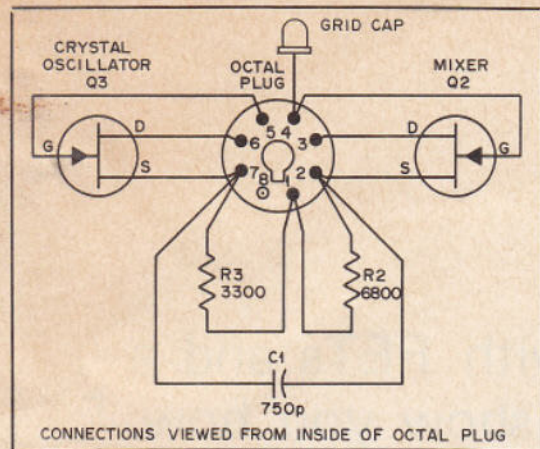


Fig. 2 — Modifications to the mixer and crystal-oscillator circuit.

1A and B). Parallel the 15-k Ω anode load resistor (part no. 24-2) by a 4.7- Ω , 1/4-watt resistor. Remove the original

300- Ω cathode resistor (part no. 41) and replace with one that gives a source current of approximately 1 mA; typically this is in the range 1000 Ω to 3300 Ω .

The power supply is shown in Fig. 3 and is self explanatory. A small 9-V transistor radio battery fastened by a clip to the side of the instrument now powers it. The total current drain is approximately 3 mA, which assures almost shelf life for the battery. The instrument can also be operated from the mains via a filtered low-voltage dc supply stabilized by a 9-V Zener diode.

Performance

All the checkpoints listed in the calibration book for low and high ranges could be clearly located and brought to settings noted in the book using the

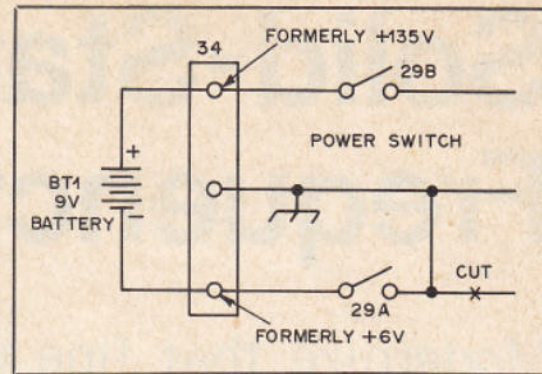


Fig. 3 — Battery connections.

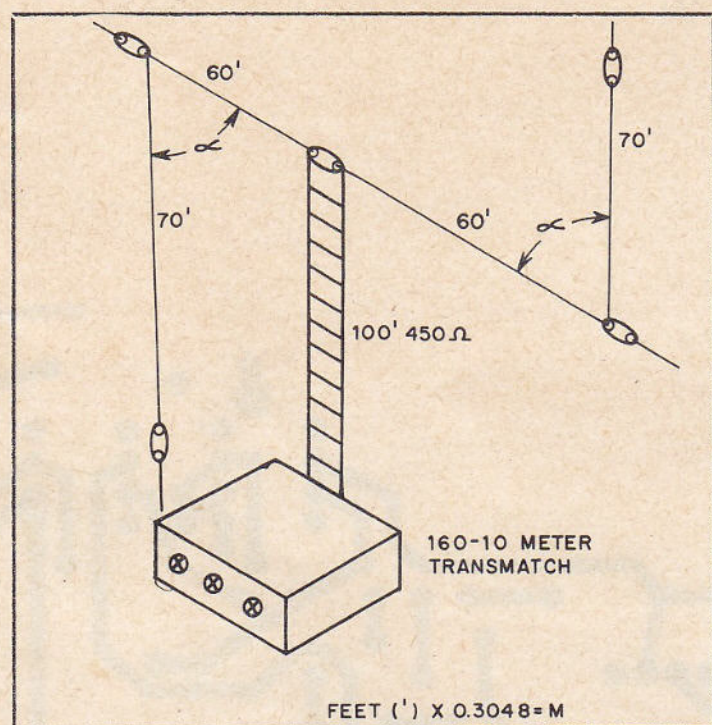
corrector. No recalibration was found to be necessary. The beats were sufficiently loud, although not as loud as the tube version. From the instant of switching on, there was practically no drift.

A "Z" ANTENNA FOR THE 10-160 METER BANDS

One of my interests in ham radio is designing and constructing antennas for both general amateur use and for the Army MARS system. For the amateur who has limited space, I have designed a "Z" antenna that covers the bands from 10 through 160 meters. It is easily constructed from wire. Spreaders for the transmission line are fabricated from Lucite strips or Plexiglas rods. (Refer to the yellow pages of telephone directories for the names of dealers who handle Plexiglas or the equivalent.) For two no. 14 wires, a 2-inch (51-mm) spacing is adequate.

Although a height of 100 feet (30 meters) is indeed desirable for this antenna, hams who settle for elevations between 30 and 50 feet (9 and 15 meters) will still obtain good results. The angles α between the wire segments will depend on individual situations such as the placement of trees or other supports. Generally, the wider the angle, the better the performance.

WINH, the New Hampshire SCM, who is really into antennas, says my design is "FB." My evaluation of the antenna is that the "aerial" is great. — *John N. MacInnes III, WB1FPD, ADN1JD, Hampton, NH*



A 10- to 160-meter horizontal Z antenna. Inexpensive no. 14 copper-clad (electric fence) wire may be used. For complete information on open-wire transmission lines, see *The ARRL Antenna Book*, any recent edition.

MORE ON SOLID-STATE CONVERSION OF BC-221/LM FREQUENCY METERS

Although I've converted several BC-221 frequency meters to solid state following the guidelines set by R. S. N. Rau's February 1977 *QST* article, I admit that finding octal plugs posed one problem. As an alternative, appropriate metal tubes were dismembered and conversion parts mounted in the tube shells.

Later, an LM-II with built-in modulation and 77, 6A7 and 78 tubes was encountered. In this case, some old 5, 6 and 7-pin tubes were broken from their bases and those bases employed to mount conversion parts. Bare, tinned hookup wire was soldered into the appropriate pins and cut off even with the top of each tube base. The JFET leads were then soldered (bug style) to the respective wires from the pins. To prevent microphonics, a small glob of clear silicone cement similar to that used for bathtub sealer, was placed between the top of the leads and the inside wall of the tube

base. This prevented any "guitar effect" from the rigid wires. An alternative is to saw off the tube-base cylinder and mount the components as close as possible to the tube pins in order to avoid mechanical movement.

Anyone attempting to convert a BC-221 or an LM frequency meter for the first time will do well to convert one stage at a time, isolating any problems if and when they occur. There may be a substandard FET or one could become overheated from soldering. Start with the audio stage first: It's the easiest!

Next, isolate the B+ from the stage. Temporarily connect the 9-V battery in its place. There should be almost as much audio from the solid-state stage as there was from the tube stage. Following this, modify the crystal oscillator and converter stages.

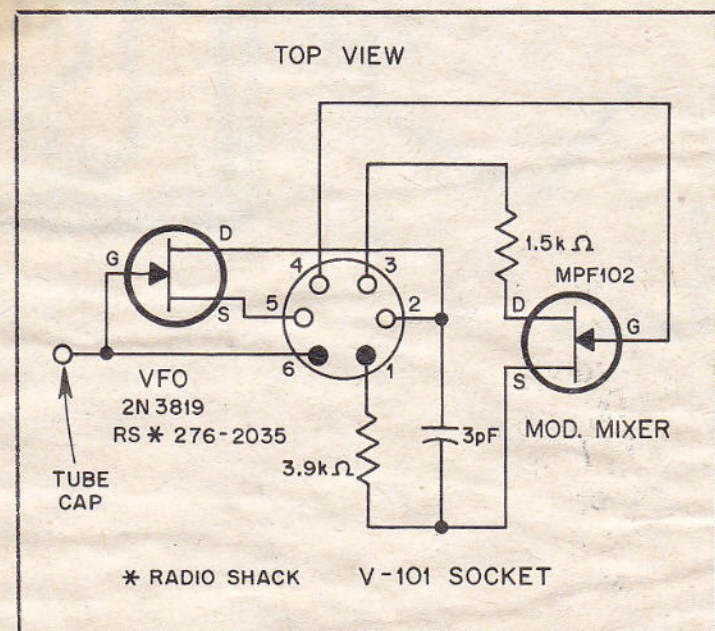
Once the VFO has been converted, check the calibration points. If some are too weak or missing, put a potentiometer in place of R2 and R3 and adjust for best output. (See Fig. 2 in Rau's article.) Install appropriate fixed-value resistors in place of the potentiometer. Keep in mind that not all FETs respond alike.

No method could be found for direct-coupling the modulator to the VFO stage. The tube version used suppressor-grid modulation. Therefore, I added a mixer or converter stage, using light coupling from the source lead of the mixer to the drain of the VFO JFET. If source-to-source coupling is used, the VFO stage is detuned to the extent that the corrector capacitor will not bring it back into calibration. With drain modulation, the error is small and easily corrected. The circuit for this state is shown in the accompanying illustration.

Disconnect the lead to pin 6 of V101. Pin 1 remains as is to provide the source return to ground. R105 in the mixer gate load should be shorted out. R114 provides proper loading for the gate return since it holds the modulation level to about 80 percent.

R115, in series with audio choke L104, should be shorted out and R103, the high-voltage regulator resistor also should be shorted when converting to the 9-V supply. This particular LM drew only 1.7 mA with all stages functioning. The rf output, however, was only about 25 percent of that normally produced by BC-221s. Still, that's an adequate signal for alignment work. The small physical size of the LM and the modulation feature provides advantages over the BC-221 instrument.

— *Floyd K. Peck, K6SNO, Hemet, CA* QST



K6SNO uses this arrangement for modifying the VFO/Mod. Mixer of an LM-II frequency meter. Q1 is a 2N3819 or Radio Shack 276-2035 JFET while Q2 is a Motorola MPF102 JFET. Connections are shown in relation to the V101 socket.