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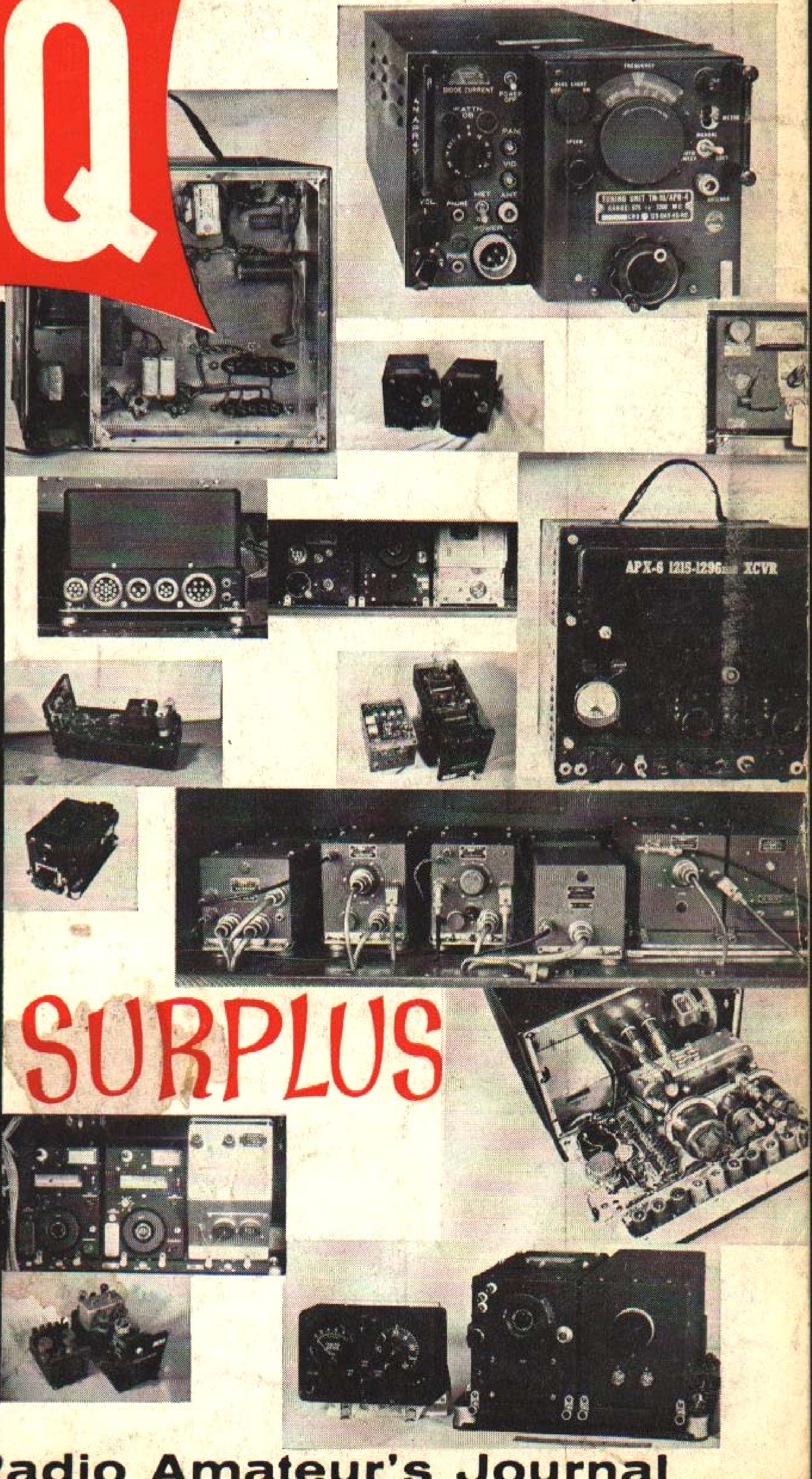

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COMMAND SETS

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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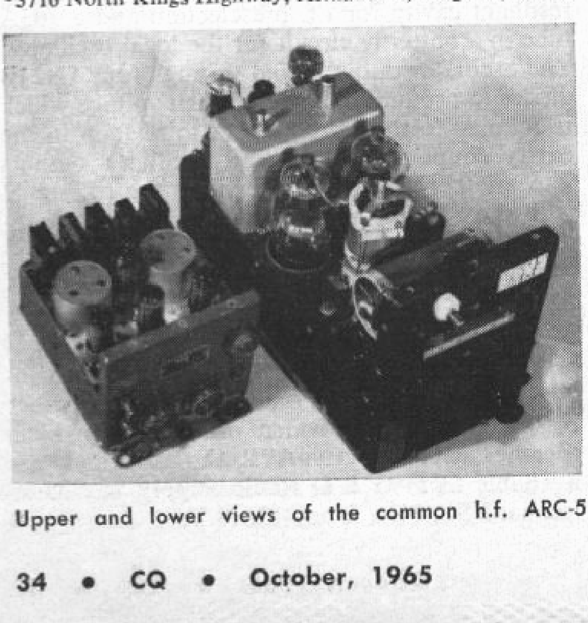
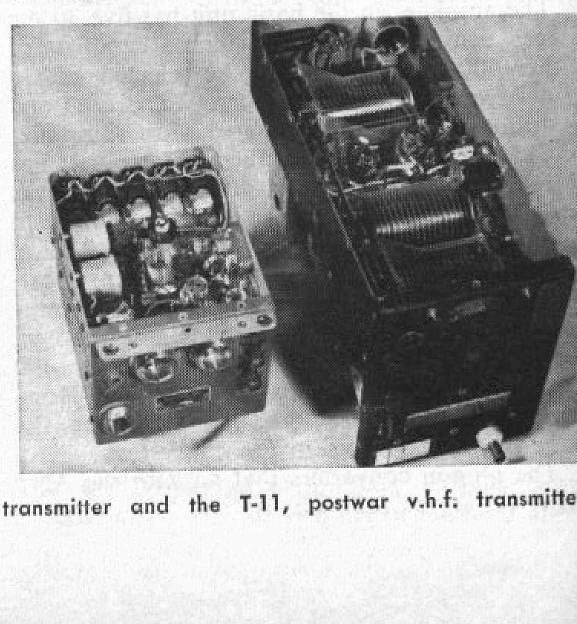




Upper and lower views of the common h.f. ARC-5 transmitter and the T-11, postwar v.h.f. transmitter.

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.

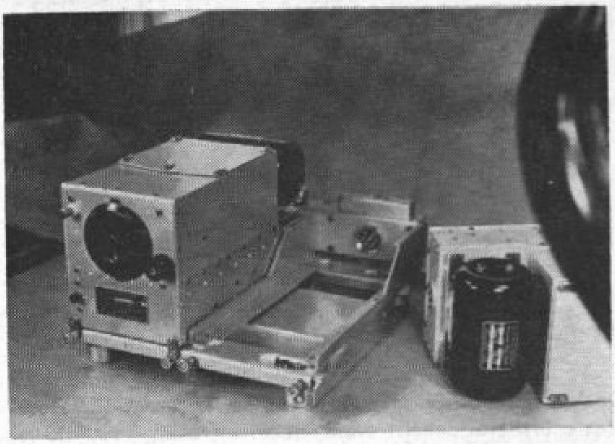
The Navy, in 1943, modified 300 Command receivers, and 450 transmitters, for optional crystal control. The program, undertaken by the Navy Research Lab, was dropped when the more stable AN/ARC-5 equipment came out. Although the modification was successful, it still required manual tuning to the vicinity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

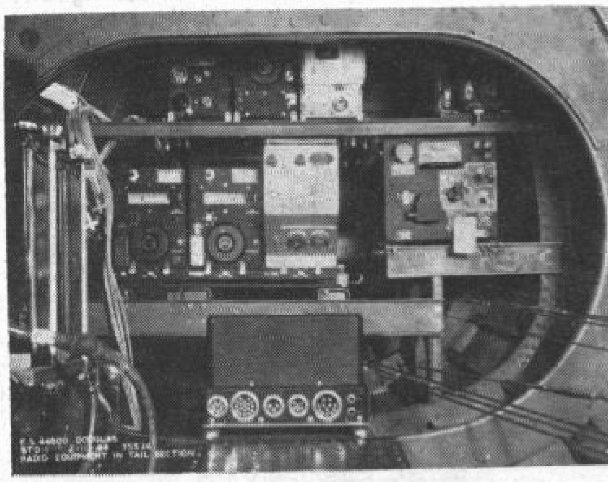
About 1,000 sets of these units were built for the Army before the Navy took over the contract, re-naming the units R-28/ARC-5 and T-23/ARC-5. The latter was modified to work with the MD-7/ARC-5 modulator, but both units resembled the SCR-274-N sets in most details. A T-126/ARC-5 transmitter was later 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-

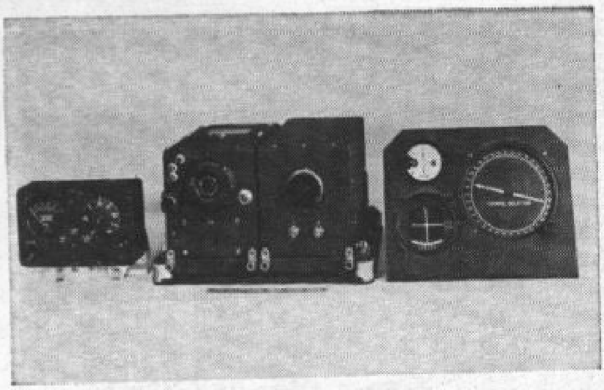


This photo shows the original SCR-274 prototype of 1939. The receiver on the left is the 200-580 kc unit; the receiver at right was 3.5-7 mc. Note the difference between this and the SCR-274-N units brought out two years later.

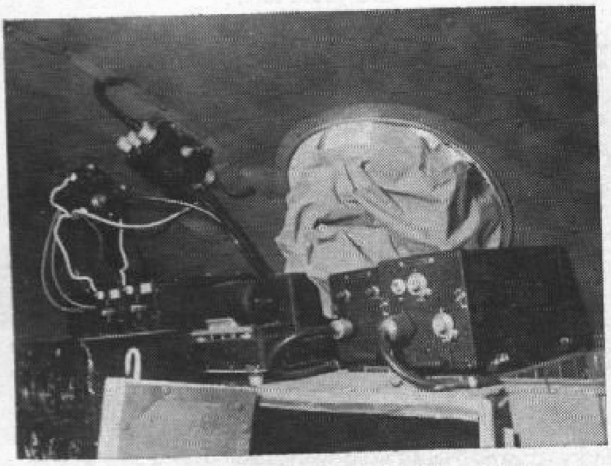
This T-90/ARC-5 was the last of the WW II command transmitter designs, covering 125-156 mc.



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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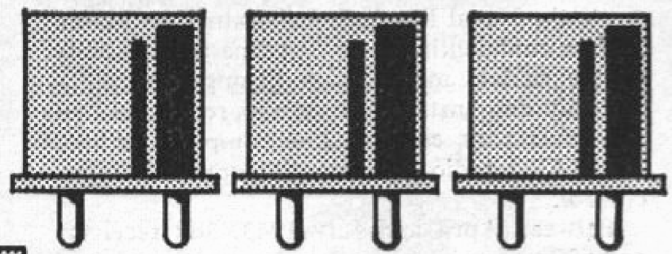
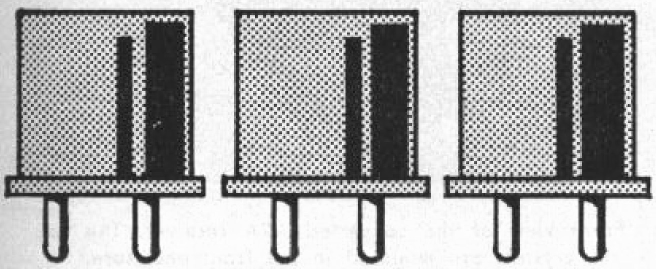
Crystal Controlled Command Sets





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.

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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

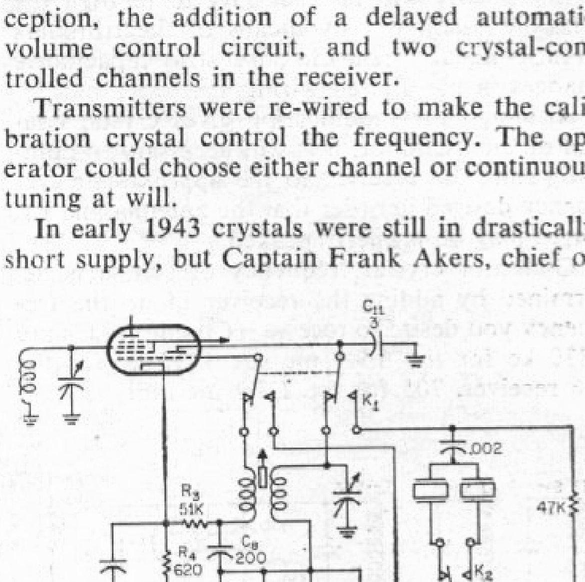


Fig. 1—The 12K8 mixer circuit with NRL modifications for 2 channel crystal control operation. Relay contacts, K_1, selects crystal or variable frequency control and relay contacts K_2 selects the desired crystal. The 28 volt relay coils are not shown.

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.

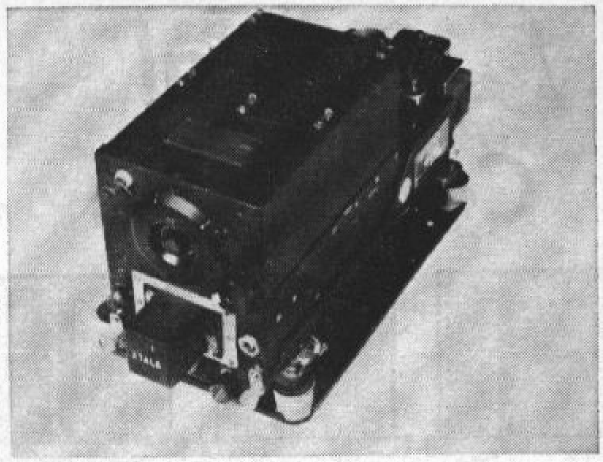
The NRL crystal modification however, remains of interest to radio amateurs who have adapted so many command sets to their peacetime use. Fairly simple to build into the receiver, the NRL modification permits ease of operation on nets, or other frequencies requiring accurate setting, possibly beyond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

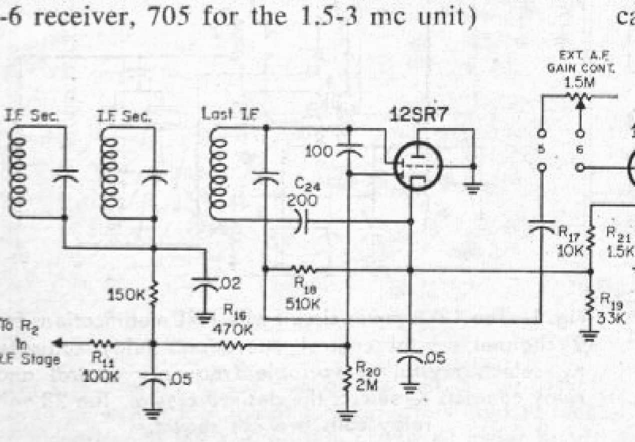


Fig. 2—The delayed a.v.c. circuit as installed by N.R.L.