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The First and the Last Q-5er

The ubiquitous command sets based on the Type K "channel" design were the most numerous single type of radio gear to come out of World War II, and the low frequency receiver, the "Q-5er" was the longest-lived component of that prolific breed.

That most durable command set covered 190-550 kc in its final design. It was the first to be put on the drawing boards in 1935 and its civilian version was manufactured by Aircraft Radio Corp. into the 1960's, a fantastic life span in a 25 year period of electronic advances which reached from the TRF receiver to satellite computers.

The last military-sponsored set in the Command line was a Navy project, designed in the waning days of the war as a modification of the command receiver. It incorporated modern automatic gain control and diode noise limiting while abandoning the CW oscillator and the outputs for the by-then defunct ZA instrument landing system.

Historically, Aircraft Radio Corp. had come into being in 1928 with a low frequency (200-400 kc) tuned-radio-frequency receiver for the fledgling air lines of that day. The original Radio Frequency Laboratory Model B was bought by the Signal Corps and the Bureau of Aeronautics in a military version which lasted to see action in the disastrous early days of World War II, 13 years later.

The fatal mishaps in the Army Air Mail flights of 1934 set the stage for a new radio type for the Air Corps, the superheterodyne. The Aircraft Radio Corp. "channel" receivers were designed to meet that need in 1935-37, at first for the Army, but finally for the Navy, which saw the value of the design when the Army could not.

The first "Command Set" was a 200-580 kc receiver, painstakingly hand-assembled at A.R.C.'s tiny Boonton, New Jersey, plant. It used double-ended tubes in RF and *if* stages, plus a new tetrode output stage using, during development, three tubes built for A.R.C., the RCA type 1278, the Raytheon CK-45, and the Sylvania S-392. The 1278 was later standardized as the 12A6.

Among advances in the set were small mica button capacitors, assembled of silvered-mica wafers on a stainless steel stud. They had accuracy and stability parameters significantly above the then-industry standard.

Small paper and electrolytic capacitors were designed for bypass and filter functions by A.R.C. and Cornell-Dublier, a nearby New Jersey firm.

Special switches, *if* transformers, chokes and output transformers were hand-built at A.R.C. along with specially-machined hardware and painstakingly formed chassis and other sheet metal components. Riveting was an art perfected by A.R.C. machinist John Johanson for what were, by 1936 standards, extremely miniature components.

Automatic volume control circuits had been worked out by A.R.C. engineers ten years earlier before the Corporation had sold the Radio Frequency Labs trademark and patents. The second hand-built channel receivers contained a wide-range AVC circuit, with front-panel AVC controls.

The new design went to both the Navy, at Bellevue, in Washington, D.C., and to the

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Army's Wright Field, Ohio, test facility. The Army did not buy it. The Navy did.

In the confusion of the 1940-41 buildup of U.S. air forces the Type K Command Set (including the familiar Command transmitters and other components) was bought by both the Army and the Navy. It was first made as Navy Type RAT and RAT-1, then, jointly, as SCR-274-N (for Navy), with agreements on specifications which included a rudimentary AVC. This design applied only enough control to the RF and *if* stage grids to prevent "course reversals" through RF overloading when flying the low frequency navigation ranges of the day.

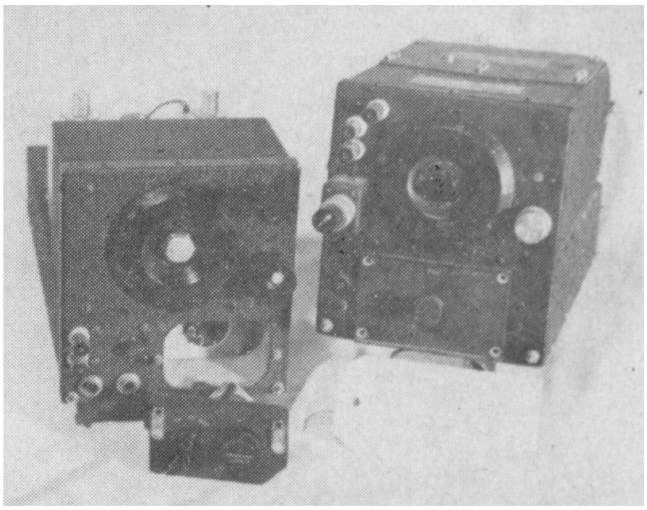
The AVC designed into the second series of Type K reeciver prototypes derived a bias voltage from the same diode detector leak used to furnish audio output, fed back to the control grids of the variable mu (remote cut off) 6K7 RF and *if* tubes. Manual gain control was achieved by grounding the AVC line and varying a resistance in the RF and *if* cathode circuits.

The SCR-274-N and Navy ARA AVC circuit derived bias voltage across a 100,000 ohm resistor, bypassed for audio, in the grid circuit of the last *if* tube. The voltage developed there at high RF levels was applied to the grids of preceding stages. The system preserves the modulation envelope pretty well for subsequent detection. (When the detector diode feeds a delayed AVC line, extraction of power from the *if* circuit by the AVC only at the top of the modulation envelope tends to distort the audio peaks. This drawback was overcome in the latter AN/ARC-5 sets by using undelayed AVC clamped by a shunt diode which provides the required "delay" in the AVC action) "blocking," which the SCR-274-N and ARA sets were designed to defeat would have given spurious navigation information by giving decreased output with increased input beyond a certain RF input level.

The RAT, RAV and ARA designs were virtually identical with the SCR-274-N (N for Navy) production through 1942, but changes were in the wind.

Crystal control had become practical. Stability was of the essence. Command sets were being used for fleet communications over much longer distances than the design basis of short-range plane-to-plane work. Combat pilots could not twist volume control knobs continually. Special instrument landing system equipment was used with teh Command system.

The author has already described the Naval Research Laboratory Crystal-controlled command set—with AVC—circa 1943. Official Naval correspondence reveals the problems



On the left is the Model 1, Serial 1 low frequency Command receiver, circa 1936. Note the slightly different front panel control panel, the phone jacks and different placement of the antenna and ground fittings. The dial was adapted from the Navy RU series receiver.

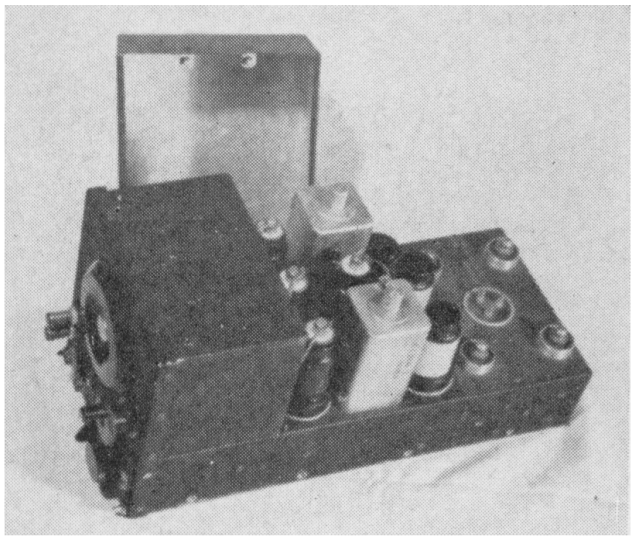
which cried desperately for improved gear to handle the new demand of the services. The Army itself sent A.R.C. President Dr. Lewis M. Hull to Europe with General Harold McClelland to see what could be done to improve communications in the Eighth Air Force.

Dr. Hull's highly-classified recommendations: remove all controls except volume from the pilots' panel; locktune or crystal-control the Command Set, and add AVC to make even the volume control unnecessary.

Back in Boonton A.R.C. engineers attacked both problems. Under a contract calling for receivers to operate with the ZA ILS system, with the assistance of Air Track Corporation engineers, the low frequency command receivers were overhauled. Delayed AVC of a more conventional type was applied to the 190-550 and 520-1,500 kc receivers and cathode follower outputs were provided to the ZA equipment in the aircraft.

The product was the R-20, R-21, R-22, R-23, R-24 receivers. The first three, covering 1.5-9.1 mc retained the SCR-274-N AVC, while the navigation sets were more drastically altered. All five bands were given new, redesigned, temperature-compensated front ends, additional use of ceramic dielectrics, and new external controls. A type 12SF7 *if* tube was specified in order to provide proper bias on the cathode of the AVC stage in the new design, and to avoid interaction between the AVC and the BFO circuits.

Before R-20, R-21 and R-22 production was put into high gear the Navy decided to put full AVC into all the command receivers. The



Top view of the first Q-5er. The set used only two 90 kc if circuits. Designer Paul O. Farnham said recently "the use of three tuned if coupling units on the two lower frequency bands was not deemed proper because two such tuned units appeared to give adequate gain and selectivity. We changed our minds later." Tube lineup in this set included 6K7 RF and if tubes, 6L7 mixer, and 6H6 detector. Audio and BFO tubes were experimental Raytheon CK-45 power pentodes with 6.3 volt heaters designed for A.R.C.

modified sets were labeled R-25, R-26 and R-27 in the AN/ARC-5 series.

The tuning capacitor in the ARC-5 series was a completely new component. It was so built—out of brass and invar (36% nickel) steel, as to have a slight (.000015 pf/pf/degree C.) negative coefficient, i.e., with normal warmup heating it would decrease in capacitance. (An un-compensated capacitor would be expected to increase markedly in capacitance with temperature.)

The warmup of the oscillator tube and the oscillator tank coil would tend to increase the circuit capacitance. The negative tuning capacitor behavior would thus tend to offset that change. Residual changes were absorbed by an additional small (3 pf) "padder" with a negative coefficient of 750 parts per million per degree centigrade.

Unfortunately the R-23 and its sister R-24 (520-1,500 kc) receiver suffered from low audio output problems. Back at the drawing boards the A.R.C. Engineers under designer Dr. Frederick Drake made more changes.

Output with the improved circuit was increased from 120 milliwatts for the standard input of 10 microvolts at 1000 cycles modulated to 30 percent to better than 400 milliwatts.

This new model—the R-23-A/ARC-5—was accepted by the Navy in 1945 despite the fact that the test aircraft at Anacostia Naval Air Station in Washington was equipped with a 14 volt electrical system. (The R-23-A was a 28 volt receiver.) Engineer Norman J. Anderson recalled recently that a planeload of Navy brass found the set highly improved despite the half-voltage on the tube heaters.

Shortly afterwards the Navy ordered the R-148/ARC-5x, a 14 volt model of the R-23-A.

By the end of the war the ZA ILS system had disappeared. The low-frequency command receiver became a standard item on all military aircraft for range nagivation even though the transmitters and receivers for other bands were abandoned and the CW oscillator joined the ZA in disuse.

Although the R-23-A was now standardized, low-frequency navigation was disappearing. By 1960 it was a relic in North America and obsolescent overseas. VHF Omni had replaced it. The R-23-A remained as a little-used standby in transport aircraft, a role it still plays, today, in 1966, thirty years after it was designed.

The final improvement in the receiver was noise-limiting, proposed by the Navy in 1946. The 12SR7 BFO tube and the BFO transformer, plus the ZA output circuits were dropped. In their places were added a 12H6 double diode and a noise-limiter control relay. The 12A6 output tetrode was replaced by a tetrode-diode tube under the RCA experimental number A-5023.

Noise limiting had first been applied to command receivers in the 1944 VHF receiver design, following techniques developed by the British in wartime research. It had been the subject of considerable research in both private and government labs in this country, with detailed work done by Maguire Industries under a Navy contract.

The R-112 and R-112/ARC-5 receivers used diode-connected triode noise limiting circuits, but the R-23-A was built with the 12H6 twin diode tube. AVC in the set was delayed by using the diode in the 12SF7 *if* tube as a clamp to prevent AVC voltage from appearing at the RF and *if* grids until enough AVC voltage had been generated to override the 30 volt cathode bias on the 12SF7 tube.

The modified R-23-A was examined at Wright Field and at NRL in 1945 and 1946. At the same time competitive bidding on R-23-A procurement brought in the Lewyt Corporation and Stromberg Carlson. The former failed to fulfil an 1,100 set contract according to specifications and the latter finally dropped command set production. A.R.C. officials were stung by the postwar military procurement depression and moved into the

civilian market. The Command Sets were finally demobilized and dressed in gray peacetime paint.

Engineer Paul O. Farnham, the designer of much of the command gear, told this writer he was disappointed to see the command design changed, the dial discarded, the plug-in RF and *if* feature abandoned, and cost made a higher consideration than maintenance convenience.

But in many ways the postwar gear was very good. The best materials were no longer scarce. New ceramics and modern finishes including better insulating varnish and other top-quality components were now available. Locktal tubes such as the 14A7 and the 14R7 were ready. They eliminated the moisture-holding tube base of octal tubes and offered improvements in reliability.

Early R-11 (civilian) receivers returned to the twin-triode NL circuit, but VHF gear was built with a double triode AVC-NL-detector designed by Farnham, using an unbypassed audio cathode resistance. Later (1958) a highly effective squelch was added to this circuit.

The dial-less, ceramic-insulated locktal-tube command set was basically designed in 1946 by Engineer Norman J. Anderson with only slight changes from the modified R-23-A to adapt the postwar tubes.

The last 15 years of command set production was devoted chiefly to these civilian versions, R-10, R-11, R-13, R-15 and R-19 which were bought in large numbers by the military for use in the Korean conflict in 1950-54. Aircraft Radio Corp. was rescued from the postwar aircraft equipment depression by the demand of the Army and Navy for lightweight radio gear to be used in helicopters and spotting planes like the L-17 Navion, the L-19, and aircraft as large as light twins and jet trainers such as the T-37.

Much of the business went into Cessna-built light planes, an association that culminated in 1957 in the purchase of A.R.C., by the Cessna Corporation. The transaction came at the time that crystal control was becoming mandatory in civil flying and transistors were revolutionizing electronic design.

Most of the old hands at A.R.C. have now left Boonton. President Lewis Hull, Field Engineer Al Parkes, Paul Farnham, Norman Anderson, John Johanson, and the father of the command sets, Dr. Fred Drake were all retired from A.R.C. by 1961 when the last Command receiver left the white clapboard plant in Boonton, N.J. The Command Sets, and an era, had ended.

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