German Army Wireless Equipment

A CRITICAL SURVEY OF THE MECHANICAL AND ELECTRICAL FEATURES

By W. Farrar, B.Sc., Signals Research and Development Establishment, Ministry of Supply

THE remarks and conclusions presented in this article are based on the results of the examination of German wireless equipment captured by the Allied Forces during the war, and on reports issued by British and American authorities in the European theatres of operations.

The nomenclature employed for German army wireless equipment gave some idea of the use for which it was intended. Transmitters were labelled with the nominal radio frequency power output and, in some cases, a distinguishing letter " 1 KW.S.b1 " indicated " 1-kilowatt sender, type b, mark 1." Receivers had an indication of the waveband covered, being classified into long, medium, short and ultra-short wave types, with type letter and number as for transmitters. Tuning scales, however, were marked in frequency or channel numbers, and never in wavelength. Special equipment, such as direction finders and intercept receivers, were described (in abbreviated form) on the nameplate, as were ultra-high frequency (decimetre-wave) equipment. This system of nomenclature, which applied to valves, vibrators, power units and the like, would appear to be better in many ways than the British number method.

Some of the German army frequency bands were different from the functionally corresponding bands used in the British army. For long-range working, with both fixed and mobile stations, low and medium frequencies up to about 7 Mc/s were used. Artillery units used 3-7.5 Mc/s for communication and 25-27 Mc/s for gun sound ranging. Tank-to-tank communications were carried out between 27 and 33 Mc/s while equipment, in armoured cars and self-propelled guns, varied between 20 and 25 Mc/s. Infantry in support of armoured units used pack sets with corresponding frequencies, but infantry in the front line used frequencies around 100 Mc/s and 150 Mc/s. 42-48 Mc/s was used for ground-to-air co-operation. As a general rule frequencies increased as the front line was approached, reliance being then placed on the limited ranges at high frequencies to make interception by the enemy difficult. That the Germans were intercept-conscious is shown by the large number of intercept receivers used, covering frequency ranges from 10 Kc/s up to 305 Mc/s.

For long-range multi-channel beam working, a chain of decimetre-wave relay stations was employed, these being the only production equipments employing frequency modulation. The capture late in the war of a development model of a small high-frequency transceiver with both amplitude and frequency modulation facilities showed that the Germans were considering the use of frequency modulation for normal short-range communication purposes.

The outstanding feature of German army wireless sets was the almost universal use of lightweight alloy in their construction. This was Elektron metal, approximately 90 per cent. magnesium, 8 per cent. aluminium, and 2 per cent. of other metals. Main frameworks used thick and often quite intricate castings, while screens and cover plates used sheet alloy cut and pressed as required, the whole assembly being bolted together. This system of construction made the equipment very rigid, rather more so than the pressed steel fabrication used in British sets, although, due to the thicker sections used, it was no lighter in weight. Towards the end of the war, probably due to scarcity of materials, castings of ferrous alloys and steel cover-plates came to be used in some instances. Since these were of the same dimensions as the formerly used Elektron metal pieces, this necessarily resulted in a considerable increase in the weight of the equipment. In the case of the 10-watt transmitter for tanks, use of these heavier metals increased the weight from 20 lb. to 30 lb., while an armoured car " house telephone " had its weight doubled to 30 lb. It is interesting to note that light alloy casting was being introduced into British Military equipment at about the same time as the Germans began to abandon it, probably for reasons of material shortage.

Instead of using a single chassis with components mounted above and below, the Germans mainly used a system of unit construction. The various stages or sections of an equipment were assembled separately and these sub-units bolted on to the main cast framework. Final inter-unit wiring connections were made by solder tags, lugs and screws, or plugs and sockets. Thus in the case of serious electrical or mechanical defects arising, a whole unit could be replaced and the equipment put back into service with a minimum of delay. While this method of construction simplified maintenance and gave additional mechanical rigidity, it also made the design much less flexible, with the result that very little modification occurred throughout the war. The 10-watt tank transmitter was for all practical purposes the same in 1945 as in 1937.

Ceramics were used extensively in various ways: moulded plates for mounting components, tubes as coil formers and rods as control spindles, particularly for variable tuning condensers. The latter were mostly made from solid Elektron castings, with slots machined in to form the plates. The stator sections of multi-gang units were fashioned from one block, and each rotor section was mounted on a common ceramic spindle, which served also to insulate the rotors from each other. While this type of construction produced a larger assembly than the conventional bolted plate system, the finished article was very rigid mechanically and sound electrically, due to the reduction in the number of joints.

Components were all of good quality. Although some of them were usable over a wide range of temperatures and probably capable of withstanding tropical conditions, complete equipments were made only for operation in temperate zones. Sealing against atmospheric effects was not good, there being merely a rubber gasket around the inside periphery of the cover of the case, and occasionally also between the front panel and the case. These precautions prevented damage only from showers or spray. Equipment captured during the North African campaign had quantities of fine desert sand inside it, in spite of efforts in the field to seal the equipment by painting around meters, dial escutcheons, fixing screws and other joints. White corrosion was formed on the Elektron metal when exposed to wet and left unattended.

In general, components had their values marked on them (relay coils and chokes had winding data printed on) and were numbered. Wiring, too, was numbered and both these sets of numbers were marked on the circuit diagram. This greatly facilitated servicing. Colour coding as on British condensers and resistors was not used in German equipment. Some ceramic condensers, however, appeared in various colours, depending on the type of ceramic used, to indicate different temperature coefficients.

All multi-band receivers specifically built for the German army had a well-constructed turret system for changing the frequency bands, a feature not generally incorporated into British equipment until fairly recently. These German turrets, from which individual tuning units could be easily removed, were driven from a handle on the panel through a train of gears, and in some cases levers also ; and were in general very positive in action. In some instances the fixed contacts were lifted off the turret before this rotated, and dropped down again only after it had come to rest, thus avoiding rubbing contacts. This is contrary to usual practice, and was probably done to avoid wearing off the contact material which was only very thinly deposited.

Precision gearing was also used in tuning drives. To obviate backlash, conventional spring-loaded split gears were employed. The absence of backlash and the use of large circular tuning scales (the largest examined was 11½ inches in diameter) extending up to 270 degrees of arc made accurate calibration of the equipment possible. The two-position flick mechanisms used on certain equipments were well designed, easy to adjust and positive in action, resulting in an average resetting accuracy of the order of 1 part in 10 thousands, a very satisfactory figure for mass-produced equipment.

Where an equipment had more than one frequency band it was customary to paint the sections of the tuning scale or of the movable escutcheon with different colours, to correspond with similar colours on the various positions of the band switch or indicator. Colouring was used in certain other instances : for example, H.T. and L.T. points on a voltmeter scale were picked out in blue and red respectively, and on some sets corresponding controls had the same colours marked on them. The idea behind this scheme was to simplify operation. Another form of simplification of operation was found in the range of intercept receivers. Here the tuning control (coaxial fast and slow-motion) was positioned to the left of the centre-line of the panel ; near the bottom, and adjacent to it on the centre-line, were edgewise controls for bandwidth and volume, and an A.F. tone filter switch. The operator, using only his left hand could, while listening to a signal, vary the tuning with his fingers, and the bandwidth, volume and tone-filter with his thumb, thus leaving his right hand free to take down the signal on paper.

The circuits employed in German army wireless equipment were, except for old sets, well designed and efficient, but by British wartime standards not up to date. The reason for this is that designs were frozen at or before the outbreak of war, as mentioned above, and subsequent modifications not possible due to the constructional system. New designs of some equipments, mainly man-pack sets, were brought out during the war, but were not outstanding electrically.

Wireless receivers in general use were, with one exception, all conventional super-heterodyne types, containing the usual features associated with a communications set. The exception, which was manufactured at least up to 1942, was an eight-band low and medium frequency straight receiver with two R.F. stages, detector, and A.F. output, which nevertheless performed quite well. Sensitivity of all superhet receivers, even those dating from 1936, was good, being of the order of 1-5 μV R.F. input for 10 mW output, and compared well with similar British equipments. Signal/noise ratio was also good. A 1945 model of the receiver for tanks (the design dating back to 1937) had so little background noise that, when it was switched on during tests, it was thought to be out of order. Selectivity was adequate, and in the case of most low and medium frequency superhets and in all intercept receivers, bandwidth was adjustable either continuously or, in some cases, in steps ; and a crystal filter was fitted in some instances.

Except in one or two equipments where suppressor-grid modulation was used, transmitters employed control-grid modulation. On old types of transmitters, which used triode amplifiers, R/T performance was poor, the modulation never exceeding 20 per cent. without severe distortion. In the later types (after 1937) fairly full modulation with reasonable quality was obtained. A feature of all German army transmitters was the complete absence of quartz crystal-controlled oscillator stages. Instead, use of good quality components, including lavish use of temperature compensated condensers, combined with the very rigid construction methods, produced very stable, continuously tunable, oscillator circuits.

In order that both transmitters and receivers could be set accurately to any required frequency, crystal calibrators were extensively used. These were of two types, quartz crystal oscillators and glow-crystals (*Leuchtquartz*). The former were of standard pattern, using the fundamental or a suitable harmonic of the crystal frequency, and were either incorporated in the equipment or used as external units fed by current from the set under test. The frequency of an equipment could be correctly set up at one or two points in the band and, due to the accurate construction of the tuning drive and scale, the calibration held within close limits over the whole frequency range. The glow-crystal consisted of a small bar of quartz supported between two electrodes in a glass envelope containing neon. This was connected, in series with a blocking capacitor, across the transmitter power amplifier stage (or an earlier stage in high-power equipment). When the transmitter was tuned to the resonant frequency of the quartz bar, a potential difference was developed between the supports which was of sufficient magnitude to strike the neon between the electrodes. This glow could be observed through an aperture in the front panel or screening of the set.

The stability of the sender and receiver oscillators, combined with crystal calibration and the large-sized tuning scales, made netting procedure very simple. The method employed was merely to set the main tuning controls to the frequency or channel number specified. Subsequent adjustments comprised matching of the transmitter aerial system, and perhaps adjusting the receiver fine tuning control, if fitted. Netting was then complete.

Valves used in transmitters were triode or pentode types used in a conventional manner. Receivers, however, almost always used general purpose pentodes and in almost every set the same type of valve served throughout, except at frequencies over 200 Mc/s, where special U.H.F. types were fitted. For use as triodes and diodes the anode and grids were strapped together and in one medium frequency superhet, a pentode was employed quite successfully as a double-diode triode, the anode and suppressor grid acting as the diode anodes, and the screen-grid as the triode anode. This system greatly simplified both valve manufacture and provision of spares, and appeared to have no adverse effect on the performance of the receiver.

Power supplies were of various types, depending on the use to which equipment was put. Most sets were, however, designed for battery supply, which took the general form of a dry H.T. battery and a 2- or 2.4-volt non-spillable accumulator for man-pack and portable equipments. Mobile transmitters and receivers worked from the 12-volt vehicle battery, an external vibrator pack or rotary converter being used to obtain the H.T. voltage. The converters were housed in cast-iron cases and were big and heavy compared with equivalent British models. This was somewhat compensated for by their increased reliability in operation. On fixed sites or with large mobile installations, A.C. rectifier units, working from the mains, or an auxiliary generator was used. An alternative for the 1- and 1.5-kilowatt transmitters was a large rotary converter. These units delivered well-smoothed L.T. as well as H.T. voltages to avoid modifications to equipment designed for battery operation. Decimetre-wave equipment employed built-in A.C. power packs.

The points of German army wireless equipment can be briefly summarised as follows. From the mechanical viewpoint, German equipment was very well built, due to the rigid light-alloy castings, anti-backlash gearing and accurate construction methods ; Electrically, the equipment was good and efficient, but not modern when judged by British war-time standards, although it was in some cases quite ingenious.