MICROWAVE RADIO RELAY LINK FOR MILITARY USE

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Radio set AN/TRC-29 is the nomenclature for a frequency-modulated microwave radio link equipment designed for military use. It transmits in the band from 1700 to 2400 megacycles and will accept input signals between 30 cycles and 4.5 megacycles. In most cases, it will probably be used in conjunction with Multiplexer Set AN/TCC-13. This latter unit, which will also be described, is a pulse-position-multiplex equipment providing 23 voice channels. Facilities are included so that two multiplexer sets can be combined to provide 46 voice channels for transmission over one radio set. In place of 46 voice channels, the radio set can be used for transmission of radar signals. It can also carry television signals, but direct-current reinsertion amplifiers would be necessary in approximately every third station. Various other types of signals whose bandwidth lies within the 30-cycle-to-4.5-megacycle range can also be carried.

1. Radio Set AN/TRC-29

1.1 Transmitter

The transmitter consists basically of a modulated klystron and a radio-frequency buffer-amplifier used to isolate the antenna system from the klystron. The incoming signals are amplified to a suitable level and modulate the klystron by varying its repeller voltage. To cover the entire range of 1700 to 2400 megacycles a family of three klystrons is required. These are similar in performance, but divide the 700-megacycle band into three approximately equal parts. The radio-frequency power output of the klystron is fed through a 6-decibel pad to a grounded-grid amplifier using a 2C39 tube. The final transmitter power output varies from 8 watts to 4 watts across the band. One-hundred-percent modulation corresponds to a deviation of $\pm$ 4.5 megacycles.

The frequency of the klystron is controlled by a comparison system. A quartz-crystal oscillator is provided at a frequency such that a suitable harmonic thereof differs from the desired output frequency by 120 megacycles. This harmonic output is compared to the klystron output frequency and the difference is fed to a 120-megacycle intermediate-frequency amplifier and a discriminator. The discriminator output feeds a direct-current amplifier driving a motor that controls the klystron frequency. In this way the final frequency is held to within 0.03 percent of the desired value. Various test signals and metering circuits are built into the equipment so that frequencies can be changed in the field.

1.2 Receiver

The receiver is a superheterodyne using a two-cavity preselector and a crystal mixer. The local oscillator employs a 6BM6 klystron with an external cavity. Its frequency, as in the transmitter, is compared to a harmonic of a crystal oscillator. The resulting difference frequency goes through a 34.5-megacycle intermediate-frequency amplifier and discriminator. The discriminator drives a direct-current amplifier with the klystron repeller at its output.

1.3 Order Wire

To permit maintenance of the system regardless of the type of information transmitted, an order-wire channel is provided. The order-wire system consists of a 6-megacycle frequency-modulation transmitter and receiver capable of carrying voice modulation and ringing or alarm signals. In other words, one may look at the radio set as a two-channel frequency-division system, wherein one channel extends from 30 cycles to 4.5 megacycles and carries the main intelligence and the other consists of a subcarrier located at 6 megacycles for order-wire purposes. The order-wire transmitter and receiver are designed according to conventional frequency-modulation techniques.

1.4 Antenna System and Diplexing Filter

The diplexing filter differs from conventional filters used heretofore in that no adjustments are required. Assume

for example that the transmitter works into a low-pass filter that passes all frequencies from 1700 to 2000 megacycles and attenuates by at least 50 decibels all frequencies above 2100 megacycles. Similarly, the receiver is fed from a high-pass filter that passes all frequencies above 2100 megacycles and attenuates by at least 50 decibels all frequencies below 2000 megacycles. These two filters are coupled through a suitable junction that connects to the radio-frequency transmission line going to the antenna. In this case, it will be seen that a useful system is obtained provided the transmitter stays in the band 1700 to 2000 megacycles and the receiver within the band 2100 to 2400 megacycles. This type of operation would not permit a transmitter to be at, say, 1700 megacycles and its receiver at, say, 1750 megacycles. However, it is felt that the loss in flexibility is far more than offset by the ease of operation when using this type of cross-band system. It will be noticed that there is an idle band in the example cited, from 2000 to 2100 megacycles. In actual practice, two sets of filters are provided such that their idle bands are adjacent, permitting operation of a transmitter or a receiver anywhere within its range.

The antenna consists of an 8-foot expanded-metal paraboloid with a waveguide horn feed. The horn includes a transition to coaxial line and provides a 50-ohm coaxial output fitting. The horn is designed to have a voltage standing-wave ratio no greater than 1.4 over the entire band.

A sectionalized tower built of tubing similar to that used on building scaffolds will be furnished with the radio set. This type of tower can be quickly installed in heights from about 80 to 200 feet.

The radio-frequency transmission line to be provided with this equipment is the G line, or surface-wave transmission line, consisting of a single number-10 copper wire coated with a thin film of dielectric. Suitable launcher units terminating in 50-ohm coaxial fittings are used at each end of the line.

1.5 Miscellaneous

As shown in Figure 1, an entire radio set (including transmitter, receiver, power supplies, diplexing filter, and order-wire equipment) is housed in two 5-foot carrying cases. These are designed to withstand rough field treatment. The power supplies will operate over the range of 115 volts ± 10-percent and frequencies from 47 to 63 cycles. In addition, an external 4-kilovolt-ampere autotransformer is supplied that will permit operation from 97 to 136 volts, and also from 195 to 270 volts. Altogether, 27 channel crystals are provided, giving a choice of operating frequency every 25 megacycles. A spare-parts chest is provided for tubes, fuses, etc.

2. Multiplexer Set AN/TCC-13

The multiplexer set is a time-division-multiplex terminal providing 23 two-way voice-frequency channels, including ringing. This unit plus an oscilloscope, transmission-measuring set, and an accessory compartment is housed in two 5-foot carrying cases, as shown in Figure 2.

2.1 Test-Equipment Rack

One of the cases contains the test-equipment rack, and includes the following chassis.

2.1.1 Oscilloscope. The oscilloscope includes a 5-inch cathode-ray tube and has a 6-megacycle response. In addition to various sweep speeds and an amplitude calibrator, it includes a continuous phase shifter to permit any one of the 23 channel pulses to be examined, and timing markers to permit adjustment of the 23 pulses to their exact positions in time. A self-contained power supply is incorporated so that the oscilloscope may be used with other equipments.

2.1.2 Transmission-Measuring Set. This unit includes a 1000-cycle oscillator whose output can be set in 1-decibel steps from -35 to +10 decibels referred to 1 milliwatt. It also includes a receiving amplifier so that measurements may be made on signals in the range of +10 to -80 decibels referred to 1 milliwatt with F1A noise weighting. Facilities are also built in so that the meter will measure total distortion. This set provides all the equipment necessary for adjusting the levels and measuring noise, cross-talk, and distortion on each channel. A self-contained power supply is incorporated so that it may be used with other equipments.

2.1.3 Test Panel. The third chassis on the rack permits the operator to listen, talk, and ring on any one of the 23 channels.

2.1.4 Accessory Case. A case is available to hold a spare telephone set, instruction books, tools, etc.

2.1.5 Power Supply. An unregulated 250-volt supply for the entire multiplexer set, using selenium rectifiers, is incorporated at the bottom of the test-equipment rack.

2.2 Multiplexer Rack

The second of the two cases contains the multiplexer rack and includes the following units.

2.2.1 Common Unit. The common unit includes two chassis mounted on one front panel. One chassis is for all circuits common to the sending, or multiplexer, part of the set, while the other is for the receiving, or demultiplexer, part. Tip jacks brought out to the front panel permit observation of important wave shapes. The unit is mounted on slides to permit removal from the rack without interruption of service.

2.2.2 Modems. Each of the 23 channels is provided with an identical modem. This unit contains all audio, pulse, and ringing circuits, and all test facilities peculiar to that particular channel. The modulator section of the modem accepts the incoming speech signal of a given channel and converts it into a time-modulated pulse. The demodulator section converts the incoming channel pulse back into a speech signal. All connections to each modem are made through a plug-and-socket arrangement that permits plug-in operation of the modems. A test extension is provided so that a channel may be physically withdrawn from the mounting rack and yet be electrically connected to permit trouble shooting.

Each modem has an internal plug-and-socket assembly in which the plug may be inserted in either of two ways, thus providing two- or four-wire operation at the option of the operator, without requiring tools or a soldering iron.

When a ringing voltage is received from the line of a particular channel, an alternating-current relay connected across the line is energized and its contacts operate to remove the pulse from that channel. At the far end of the link, failure to receive a pulse on a particular channel causes a locally generated 20-cycle ringing voltage to be connected to the outgoing line of that channel. Alarm circuits on the common demultiplexer unit are connected so that failure to receive an incoming pulse train disables the ringer to prevent outgoing ringing on all channels.

There are two controls per channel, one for output-level adjustment in the demodulator and one for pulse-position adjustment in the modulator. When the latter is set at room temperature, the ambient temperature may then be varied from -60 to +150 degrees farenheit without affecting performance.

All test facilities that would normally be provided by a jack field are obtained in this equipment through the use of a 5-position switch on each modem plus a 4-position switch on the test panel. These facilities, for any one of the channels are:

A. Disconnect line from radio.

B. Connect oscillator of transmission-measuring set to either line or radio.

C. Connect receiving-level meter of transmission-measuring set to either line or radio.

D. Connect operator's telephone set to channel.

E. Ring on channel.

A white plastic strip is attached to each modem for noting line allocations.

Two tip jacks are located on the front panel of each modem to permit observation of the channel-modulator output pulse, and of the channel-demodulator gate pulse.

2.2.3 Modem Mounting Rack. This rack holds the 24 modems, 23 in use and one spare. In the rear of the rack, centrally located and extending its full length, are both the modulator and demodulator delay lines. These act as commutators for the channels. Also on the back of the mounting rack and paralleling the delay lines, are the rows of binding posts and lightning arrestors for the channels.

2.2.4 Filament Supply. The bottom chassis of the multiplexer rack houses a blower, filament transformers, and fuses.

2.3 Miscellaneous

A spare-parts box is provided in addition to the two racks mentioned above. A power-line voltage regulator is also furnished, consisting of a servo-controlled variable transformer. The 5-foot transit cases for the multiplexer set are the same as those used with the radio set.

3. System Performance

A 30-mile distance between stations with typical tower heights provides a net

path loss of about 80 decibels. The multiplexer set in conjunction with the radio set will operate over losses of at least 110 decibels, thus giving a margin of 30 decibels. Over an 80-decibel path, the signal-to-noise ratio on each channel is 60 decibels with F1A weighting (this corresponds to a flat signal-to-noise ratio of 57 decibels). In a time-division-multiplex equipment, the most severe cross-talk is from a given channel into the channel next adjacent in a time sense, i.e., from channel x into x+1. In this sytem, this adjacent-channel cross-talk averages 55 decibels for the worst 45 cross-talk combinations; i.e., channel x into x+1, channel x+1 into x+2, etc. For the remainder of the 2000 possible cross-talk combinations using 46 channels, cross-talk averages 65 decibels.

The manner in which 46 channels are obtained in this system consists of connecting two multiplexer sets together so that the 8-kilocycle timing generator of one set is also used for the second. In this way, the pulse trains automatically have the same repetition frequency. Proper phasing of the two trains is accomplished by a delay line. The two trains are interleaved, using pulses of opposite polarity; i.e., one 23-channel system generates a train of 23 positive pulses (plus a marker) spaced 5.2 microseconds apart. The other 23-channel multiplex generates a similar train of negative pulses, spaced 2.6 microseconds from the first train. In the demultiplexer common chassis, polarity-sensitive gates are provided to separate the incoming 46-channel pulse train into two 23-channel pulse trains. All circuits past this gate are then identical for either 23- or 46-channel operation.

4. Channel Dropping and Pulse-Reshaping Equipment

4.1 AN/TRA-10

Another item of equipment used in conjunction with the foregoing equipments is the AN/TRA-10. This set has two functions: (A) to permit two of the 46 channels to be dropped at repeater stations for local traffic (these two channels are equipped not only for voice communication with the remote terminals but also have direct-current keying controls so that they may be connected to a push-to-talk very-high-frequency radio set, which can then be remotely controlled from the distant terminal); and (B), to slice the incoming pulse train and reshape the pulses so that they have the same width as when they were originally transmitted from the distant terminal. The AN/TRA-10 also includes a test oscilloscope similar to that used in the multiplexer set. The entire unit is mounted in a 5-foot transit case.

4.2 AN/TCA-1

The AN/TCA-1 is identical in function to the AN/TRA-10, except that it has provision for dropping 8 of the 46 channels at a repeater station for local- or branch-circuit traffic. This equipment is housed in two 5-foot transit cases. One of these two, a test-equipment rack, is identical to that used in the multiplexer set. The second rack is quite similar to the multiplexer rack of the multiplexer set, except that it has 16 modems (8 channels for 2 directions) and pulse-reshaper circuits.

Signal-to-noise and cross-talk figures for both the AN/TRA-10 and AN/TCA-1 are similar to those of the multiplexer set.

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Mr. J. H. Reynolds handled the enormous mass of detail concerning specifications and parts approvals.

The above list is by no means complete, but space does not permit listing all the engineers, draftsmen, technicians, and machinists who participated in this development.

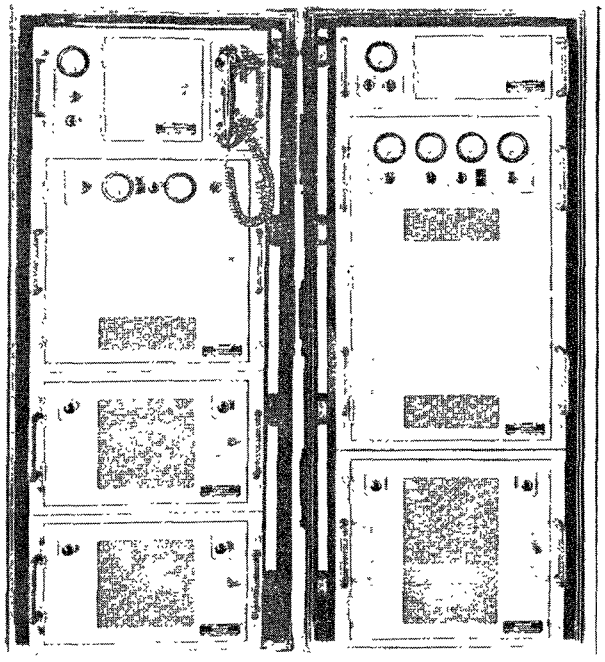

Fig. 1 - A complete Radio Set AN/TRC-29 is housed in two 5-foot carrying cases.

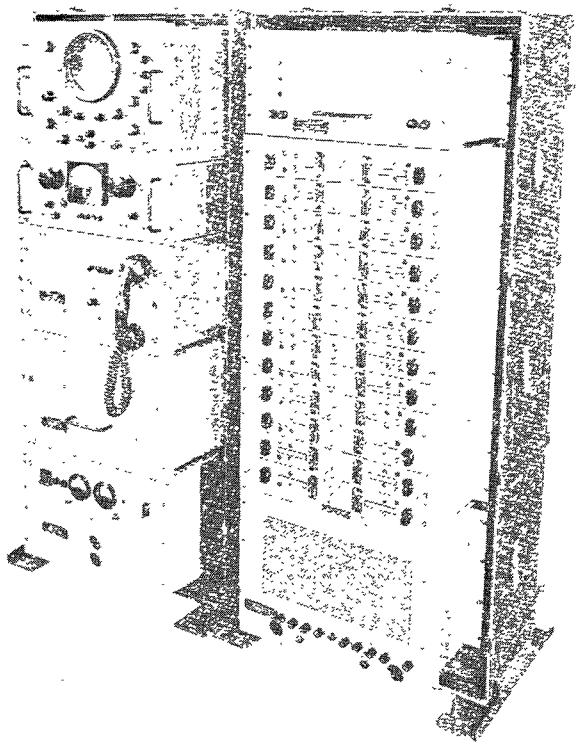

Fig. 2 - Multiplexer Set AN/TCC-13 provides 23 two-way voice-frequency channels by time-division multiplexing.