Airborne Tacan Equipment AN/ARN-21

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THE TACAN SYSTEM provides distance and bearing information to an aircraft from a selected ground beacon or transpondor such as the *AN/URN-3*. In furnishing distance-measurement service, this beacon always transmits a constant number of pulses regardless of the number of interrogations. It is designed to reply simultaneously to 100 aircraft. The constant-duty-cycle pulses are amplitude modulated by a rotating antenna system at both 15 and 135 cycles per second, providing rough and fine bearing information in much the same way that the hands of a clock give rough and fine indications of time without ambiguity. It has the novelty of providing both distance and bearing on the same channel and the use of a 2-speed system for bearing information.

The fundamental components of an airborne tacan equipment such as the *AN/ARN-21* are shown in Figure 1.

The local oscillator offers a selection of 126 crystal-controlled frequencies at 1-megacycle intervals from 1025 to 1150 megacycles. These frequencies are used directly to control the airborne transmitter and also to beat against the incoming signal from the ground transpondor at 962 to 1024 and 1151 to 1213 megacycles. The receiver intermediate frequency is 63 megacycles. The output of the receiver operates the airborne bearing circuits that in turn operate the bearing display. The receiver in cooperation with the transmitter also operates the range circuit that drives the range display. The main equipment is housed in a single package 17½ by 10 by 7½ inches (44 by 25 by 19 centimeters) weighing 56 pounds (25.5 kilograms) and powered by 450 volt–amperes from a 115-volt 400-cycle supply. External to this equipment are the two displays, the channel-selection control box, and the shock mount. An over-all view appears in Figure 2.

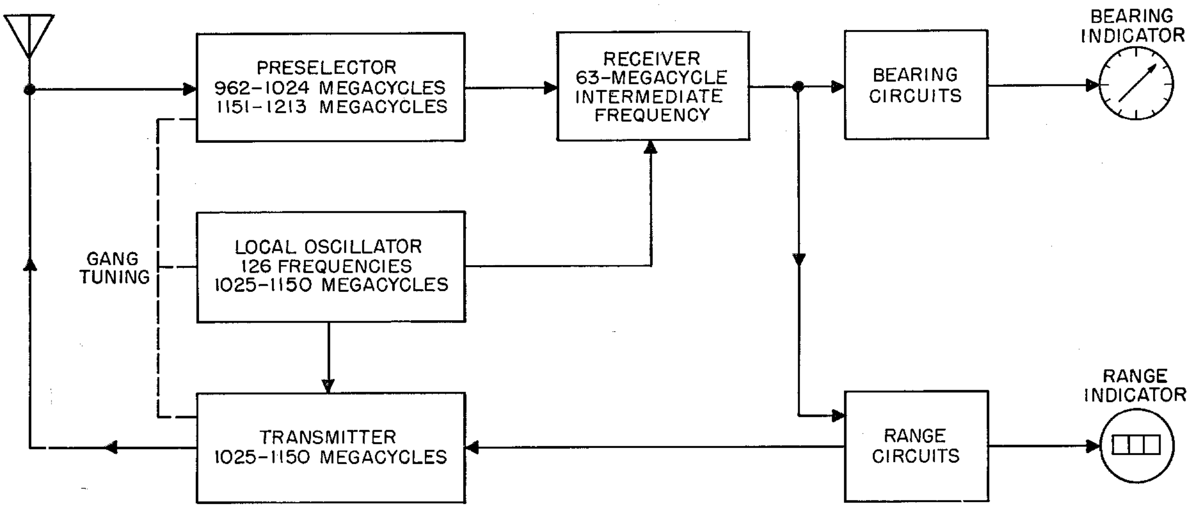

Figure 1—Block diagram of airborne equipment.

The signals received from the ground transpondor comprise pulses of 3.5-microsecond duration, in pairs spaced by 12 microseconds. Paired pulses are used to reduce the effect of pulse interference, mainly man-made. The constant-duty-cycle transpondor radiates 2700 pairs of pulses per second with random timing either in reply to range interrogations or as a

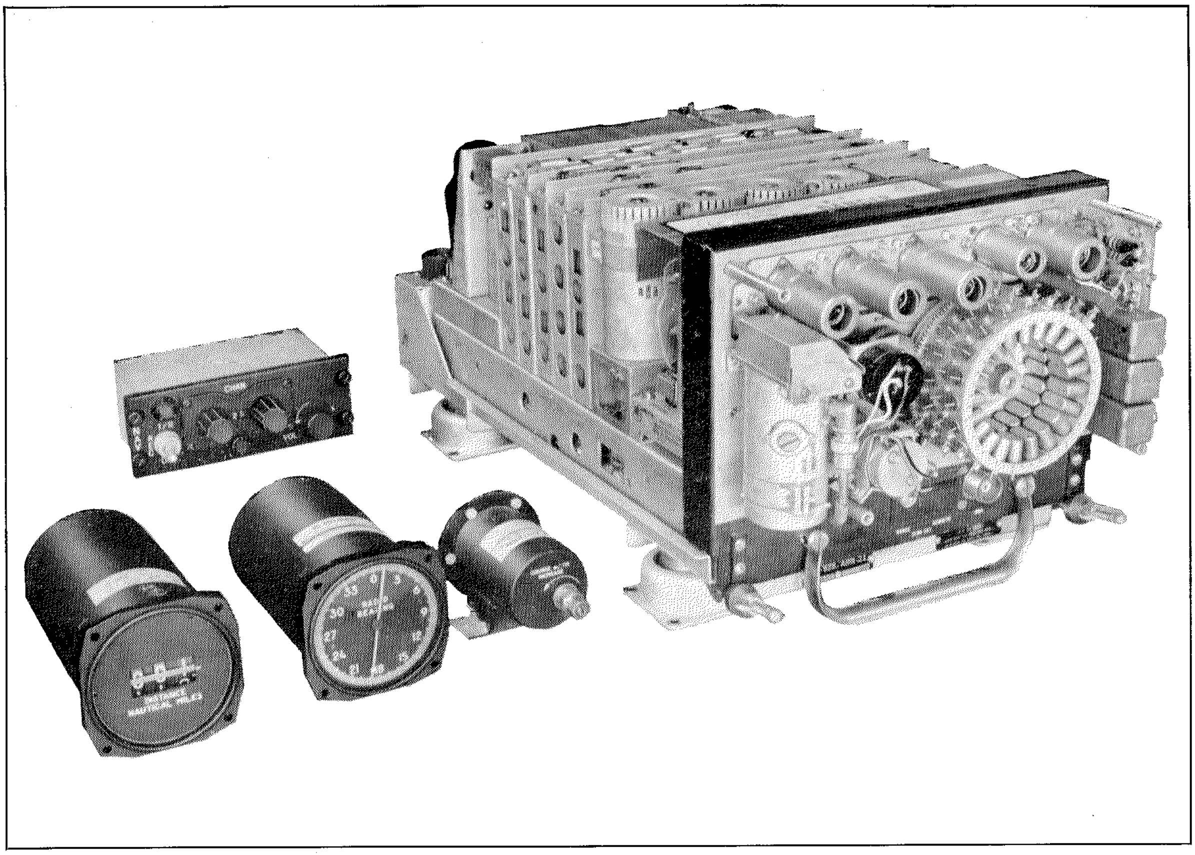

Figure 2—Airborne equipment.

substitute for such interrogations when fewer than 100 aircraft are being served. An additional 900 pairs per second are radiated by the transpondor to form 15- and 135-cycle reference bursts. The whole pulse train is amplitude modulated by the rotating transpondor antenna at 15 and 135 cycles.

Signals transmitted from the airborne equipment comprise range interrogation pulses of 3.5-microsecond duration in pairs spaced by 12 microseconds. They are of 1.5-kilowatt amplitude at a repetition rate of 27 pairs per second during range tracking and 130 pairs per second during range searching.

For bearing, the airborne equipment must display the phase difference between the amplitude-modulated sine waves and their corresponding reference bursts.

For range it must display in miles the time difference between interrogating pulses and reply pulses.

These problems, together with the channeling problem, would present little difficulty were unlimited space available. However, no electrical problem has been unaccompanied by space and power-consumption limitations. Therefore, it should be noted that many circuit choices were made not for performance alone but also because they represented the best over-all compromise.

1. Local Oscillator

Any one of 42 crystals that are mounted in a turret may be selected to provide a channel in the 1067-to-1109-megacycle band. A frequency multiplication of 27 is employed. Mixed with the output of this frequency multiplier is a fixed frequency of 42 megacycles, thus generating an additional 84 frequencies each either 42 megacycles above or below the output of the multiplier.

The local-oscillator chain is supplied with sufficient plate voltage to generate about 10 milliwatts for injection into the receiver mixer. The chain is also pulsed (exclusive of the first 2 stages) to generate about 5 watts peak for application to the final 3 transmitter stages.

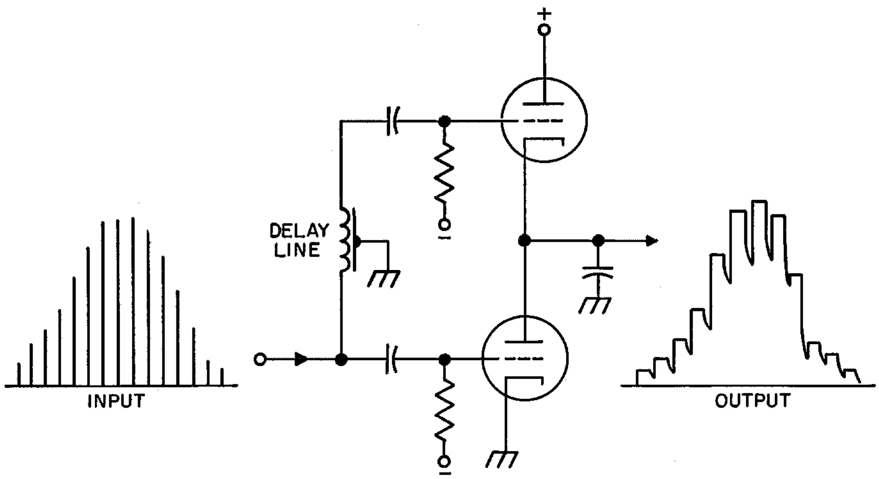

Figure 3—Typical peak-rider circuits.

2. *Transmitter*

The transmitter comprises 3 amplifier stages at the final local-oscillator frequency and employs *2C39A* grounded-grid triodes. They are anode pulsed at 2500 volts by a modulator using a *3D21A* vacuum tetrode driven by one *2D21* thyratron for each of the pulses in a 12-microsecond pair. The 3 stages are ganged to and track with the last stage of the local-oscillator chain, the preselector, and the crystal turret. The turret makes 3 revolutions as the frequency is varied over the 126 channels. The *2C39A* amplifier stages employ coaxial circuits, the anode–grid circuit being a quarter-wavelength long, resonated by a variable capacitor. The cathode–grid circuit is broad-banded over the necessary range. Above 30 000 feet, a barometric switch cuts the power to 800 watts, permitting unpressurized operation to 50 000 feet.

3. *Preselector*

The preselector protects the receiver mixer crystal from the transmitter and reduces spurious responses. Four quarter-wavelength circuits are used, a pair for the low band of 962 to 1024 megacycles and a pair for the high band of 1151 to 1213 megacycles. Both low-band and high-band pairs are permanently coupled to the antenna and to the receiver mixer, but the unused pair is short-circuited, raising its resonant frequency to the 2000-megacycle region. The preselector absorbs energy from the antenna only when resonant and therefore does not detract from the transmitter power output, which is 63 megacycles away.

Tuning is by varying the length of the quarter-wavelength sections, this resulting in the unusually high unloaded *Q* of about 2000 despite the cross-section of 1 square inch (6.5 square centimeters) per tuned circuit. Insertion loss with a 3-megacycle bandwidth is consequently less than 2 decibels.

4. *Receiver*

A *IN23B* silicon crystal is followed by an intermediate-frequency amplifier using a *2C51* twin-triode cascode input stage, followed by 5 conventional pentode stages using *6AK5* tubes. Automatic-gain-control voltage is applied to all grids except the second stage of the cascode and the last pentode.

5. *Bearing Circuits*

The received video pulses are decoded by conventional means employing a 12-microsecond inductance–capacitance delay circuit and a pentode tube with short suppressor-grid base. The signal is then split two ways: one portion retains its amplitude modulation and is supplied to the peak-rider and automatic-gain-control circuit. The other portion is amplitude-limited and goes to the range reply circuit, bearing reference-burst decoders, and identity-tone amplifier.

The peak-rider causes each decoded pulse to discharge a capacitor and then to charge it some 5 microseconds later. A "direct" voltage is thereby generated, proportional to the amplitude of the last-received pulse as shown in Figure 3. This direct current consequently closely follows the amplitude modulation imposed by the rotating transpondor antenna. After suitable filtering, it provides the 15- and 135-cycle bearing sine waves. Referring to Figure 4, these sine waves are phase-shifted by motor-driven goniometers in the bearing indicator and then compared with the reference

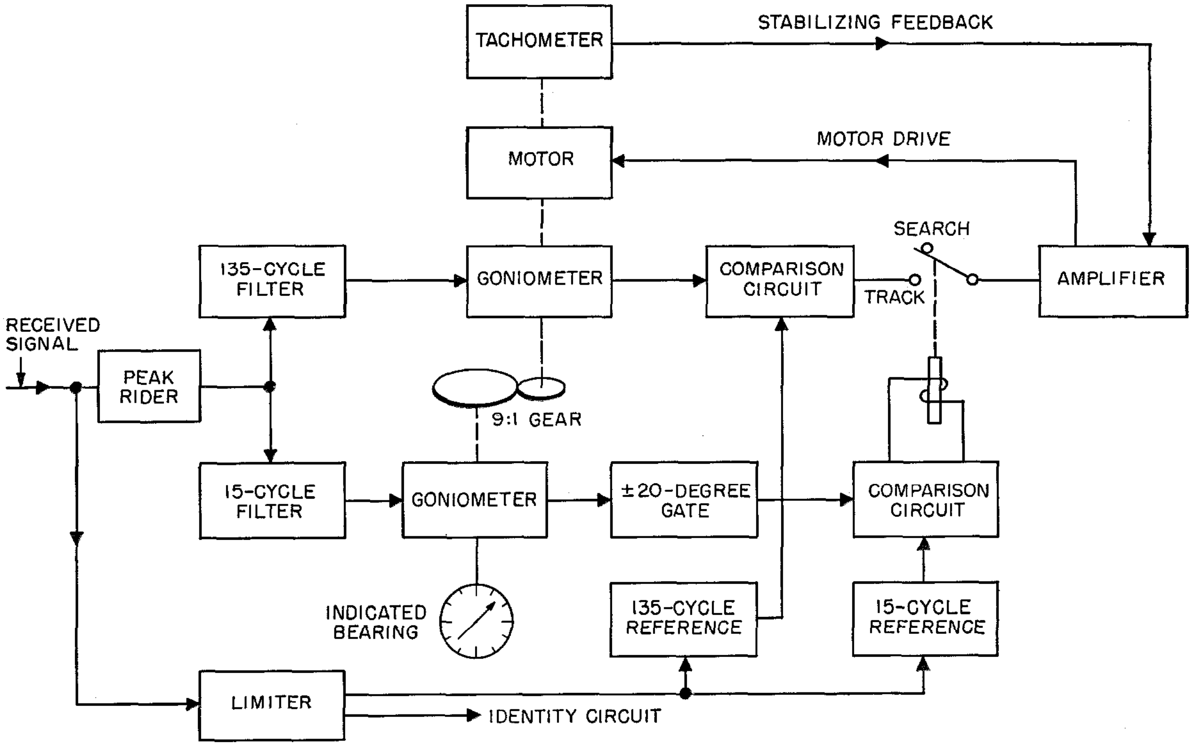

Figure 4—Airborne bearing circuits.

bursts. The resulting error voltage is amplified and used to drive the motor in the indicator towards minimum error, thus indicating true bearing.

Whenever the indicated bearing lies outside a range of ±20 degrees with respect to the receiver bearing, the 135-cycle information is removed and the indicator searches at 4 revolutions per minute. When it is within the ±20-degree sector, the indicator tracks the received bearing to within an accuracy of ±0.1 degree at rates up to 10 degrees per second.

Tachometer feedback is used to stabilize the servo system.

6. Range Circuit

The range circuit is fundamentally more complex than the bearing circuit since not only is the information rate somewhat less but this circuit must discriminate against the replies intended for up to 99 other aircraft. For this latter reason, the gate that determines the search-or-track operation covers a far smaller proportion of the range to be scanned, being 20 out of 2200 microseconds, compared with the 40 out of 360 degrees employed in the bearing circuits.

Aside from this major difference, many of the same principles will be noted. A 2-speed system is employed to gain accuracy and a similar motor-tachometer indicator drive is used.

Referring to Figure 5, fully half the circuit is taken up with the generation of a pair of 10-microsecond gates that during track straddle the received reply. This comprises the upper portion of the diagram. An oscillator having 1 cycle exactly equal to the round-trip time at a 20-nautical-mile (37-kilometer) range, generates accurately spaced pulses every 20 miles; these can be phase shifted by a goniometer driven by a motor, which also drives the Veeder counter-type display. To avoid ambiguity every 20 miles, a 200-nautical-mile (371-kilometer) phantastron provides a single broad pulse, phase-shifted by a variable resistor geared 10:1 to the goniometer. The coincident 20-mile and 200-mile pulses then generate a pair of gates that can be shifted smoothly by the motor from 0 to 200 miles but with an accuracy some 10-fold better than could be obtained with the phantastron alone.

These gates are compared with the received signal and, when coincident, drive the motor so as to follow the signal. Whenever the signal is missing from the gate for more than 10 seconds, the motor amplifier is connected to the search voltage, which drives the display at 10 nautical miles (19 kilometers) per second.

During track, the display follows the true slant range to an accuracy of 0.1 mile (0.19 kilometer) ±0.25 percent up to speeds of 1000 knots (1900 kilometers per hour).

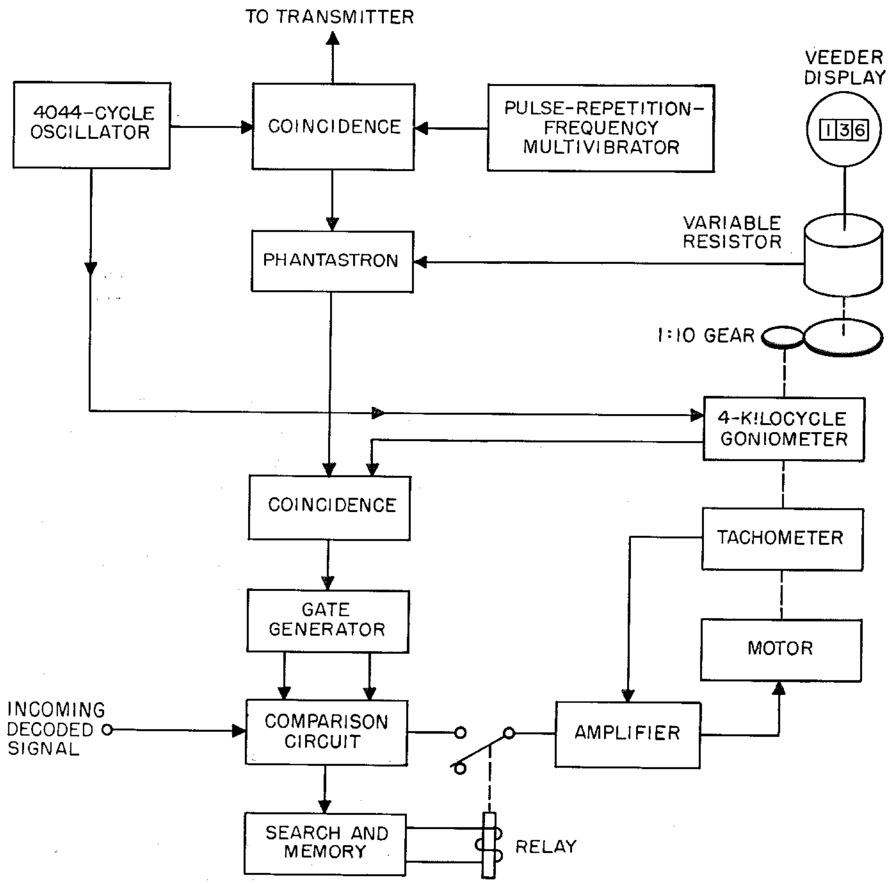

Figure 5—Range circuit.

7. *Packaging*

Of the 73 tubes used in all, 5 are disk-seal ultra-high-frequency triodes, 2 are octal-based units, 27 are miniatures, and the rest are subminiatures. Even with the use of subminiature tubes, the packaging problem would have been severe had it not been for the use of plug-in subunit construction. The equipment contains 10 such removable units, none of which has more than 9 tubes. Specifications of these units are held to close mechanical and electrical limits enabling the several manufacturers of the equipment to provide fully interchangeable units.