**RT220B – Range circuits**

The range circuits are

Z107 Modulator
Z106 Range gate
Z105 Range control

Tacan range measurement is based on the time-of-flight measurement of pulses that are sent from the airborne unit (interrogation) and responded by the ground beacon. The pulses are sent by the aircraft irregular intervals, and the airborne unit has to search in the great many pulses received from the beacon those that have a (near) fixed delay from its own interrogations.

**Z107 Modulator**

The modulator has a high power circuit, a pulse repetition frequency (PRF) generator, a double pulse former, and muting circuits.

The free running PRF generator operates at approx. 23 to 28 Hz in track mode (see later) or 150Hz in search mode. Start of a new cycle is triggered by a pulse from the 4kHz Xtal oscilator on the range gate module, so transmit pulses always coincide with a 4kHz pulse. The first transmit pulse starts with the breakdown of thyratron V2, which pulses the grid of the HV tetrode. The resulting 3us rounded-rectangular pulse is transformed and provides the anodevoltage for the RF transmitter triodes. A 9us delay line triggers the second thyratron V4, making a second transmitter pulse. The distance between the pulses is 12us. When the aircraft flies above 30000 ft, the air is too thin for 2.5kV pulses. In that case, a barometric switch and relay extends the primary winding of the modulator supply transformer, reducing the secondary voltage from +2.5kV to +1.7kV.

**Muting**

When the channel selection motor runs, thyratron V2 is cut-off by -100V on the grids. Transmitter action is blocked, mainly to protect the mixer diode when cavity pairs are switched.

On the cockpit control panel, either REC (receive only) or T/R (transmit/receive) can be selected. This switches the 400Hz supply voltage to the modulator. Without high voltage, both thyratrons are cut-off, so the “SUPPR” pulses on the BNC plug on the front of the ARN21 are gone as well.

**Early and late gates**

When triggered, the delay line in the anode of V9 is µpulses, the early and late gate, at a “fixed” time from width. This is the “early” gate. A second delay line delays this pulse by 10µs to form the “late” gate, testpoint E602. During these gate pulses, pentode V7 resp. V8 run conduct, and will pass any received pulse at that moment.

The glitch at the first division is the moment that the range gate passes the replies at full speed. At that moment, relay Ry1 drops off, the PRF is reduced, the motor voltage becomes low (lower trace), the inch-back process starts, and the red shutter is removed from the indicator display. The indicator comes to stand still after 1 sec, and inches back a fixed amount in the next half second. After this a damped oscillation converges to the stable track mode. Especially at short range, damping can take more than 10 cycles with the ID-310 instrument I have.

**Z106 Range gate**

The range gate circuit generates two adjacent, short pulses, the early and late gate, at a “fixed” time from each transmitted pulse. This fixed time is proportional with the count on the range indicator, as the time is made using a potmeter and resolver inside the range indicator.

*The potmeter*

Tube V4 is a phantastron circuit, a one shot that starts at each transmitted pulse, with a pulsewidth from 40 to 2500µs depending on the potmeter position in the indicator. The higher the voltage on the wiper, the longer the pulse. Triode V5 converts the end of the phantastron pulse into a 0.2 ms pulse, E603 in the oscillogram below. When the indicator motor runs, this pulse runs on the oscilloscope screen in 20 seconds from left to right and then repeats. The span of the indicator is 200 nautical miles, which corresponds to 50 + 200 x 12.36 = 2522 µs (time of flight plus beacon delay). The “hundred mile”wheel has alternating 0 and 1 on its circumference, and the potmeter allows multiple revolutions.

*The resolver*

The required 0.1% range accuracy is provided by the circuit around the resolver, a rotary phase shifter like the one in the bearing indicator. This resolver is fed from a very low (!) frequency Xtal oscilator at 4035 Hz. Each cycle of this frequency corresponds to 20 miles. The resolver is geared at 10 times the speed of the potmeter and phase shifts the 4kHz signal with the aid of a matched RC circuit. V6 converts the shifted sinewave to 4kHz pulses. When these were added to the oscillogram below, 10 pulses would be visible, shifting from left to right at the same speed as the single pulse at E603. In fact, V9 triggers on the one that coincides with the pulse on E603.

**Z105 Range control**

Range measurement is a two step process, search and then track.

*Search mode*

Initially, V3 is off. E502 is +280V, and V6 is on, so Ry1 is activated. In this mode, the system searches for replies and the range instrument motor runs at full speed, scanning the range gate from 0 to 2.5ms every 20 seconds.

During the search process, the ARN21B transmits at PRF = 150 (double) pulses per second, so 150 replies/s are received. The range gate passes a 10us wide window in 20 sec x 10/2500 = 80ms. If a reply coincides with the early gate, then V3 is driven a little more positive, and the voltage on E502 drops. When the range gate passes the moment that the replies arrive, then enough positive pulses arrive at the grid of V3 that V6 is turned off, and Ry1 is deactivated. This ends the hard drive of the motor, which brakes from 7000rpm to zero in approx. 1.5 s., which gives an overshoot of approx 1 mile on the display. The branch with 7M5 and 4M7 then inches the motor back by a fixed amount, hopefully equal to the overshoot. This should make the error near zero, so the track mode can take over.

**Track mode**

Once in track mode, the PRF is reduced to 20Hz, so every 50ms there is a received pulse, which more or less coincides with the early or late window. When the reply coincides with the early gate there is a 1V negative pulse on E501, when it coincides with the late gate there is a 1V positive pulse. This drives the motor a little forward or backward, so the reply pulse is maintained (“cradled”) exactly between the early and late gate pulse. As can be seen in the next oscillogram, the servo loop converges to track with a few oscillations of 0.3Hz, probably the bandwidth of the loop. The displayed value during these oscillations doesn’t change more than 0.2 miles.

**Range output**

The range output of the ARN21 tacan system is:

- Visible on the range indicator;
- The position of two floating potmeters in this range indicator.

In later tacan sets, one potmeter is used to decrease the modulator power pulse at short range to reduce interference with other aircraft near the same airfield.