Radar Altimeter

TRANS / REC (RADAR)
5826 - 99 - 954 - 2879
APN-117 ?

Made by STC (UK) in 1966

Reverse engineered 1 July 2014
What is it

This radar transmitter/receiver is a distance meter or altimeter, based on the FM-CW principle. I don't have an instrument to measure the frequency and power, but I guess it is in the 4.2-4.4 GHz range. The transmitter is a temperature controlled box, probably with a microwave transistor as power oscillator, tuned with a varactor. The oscillator supply is -30Vdc at 250mA, so the RF output might be approx. 500mW.

The transmitter is frequency-modulated with a 300Hz triangle in one of 3 modes:

1. Maximum amplitude is selected for low altitude,
2. Controlled amplitude at higher altitude (above 200 feet?)
3. Dithering superimposes a 37.5Hz sinewave-like signal on the 300Hz triangle

The receiver has a mixer with a part of the transmitter signal as LO. The "IF" amplifier has a bandwidth of 1 ... 100 kHz. The output of the unit is a DC voltage, proportional to the range.

The unit is built in 1965 by STC in the United Kingdom.

Technology of 1965

Typical is the use of the very first integrated circuits in original flatpak:

-- first opamps from Texas Instruments (SN523A and SN524A)
-- first opamps from Fairchild (uA702 in flatpak)
-- first digital IC's from Texas Instruments (SN511B)
-- first digital IC's from Motorola (MC253G)
-- 4.3GHz oscillator with transistor? (just possible in 1965)

Strange: - The power supply has a missing diode in each diodebridge

Modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar R/T</td>
<td>5826 - 99 - 954 - 2879</td>
</tr>
<tr>
<td>Transmitter</td>
<td>IMP-5024 Western Microwave Inc.</td>
</tr>
<tr>
<td>Receiver</td>
<td>IMP-5023 Western Microwave Inc.</td>
</tr>
<tr>
<td>Chassis</td>
<td>5826 - 99 - 954 - 2870</td>
</tr>
<tr>
<td>Electronics</td>
<td>5826 - 99 - 954 - 2875</td>
</tr>
<tr>
<td>Amplifier</td>
<td>5826 - 99 - 954 - 2884</td>
</tr>
<tr>
<td>Sweep &amp; control</td>
<td>5826 - 99 - 954 - 2871</td>
</tr>
<tr>
<td>DeGlitcher</td>
<td>5826 - 99 - 954 - 2871</td>
</tr>
<tr>
<td>Relay module</td>
<td>5826 - 99 - 954 - 2877</td>
</tr>
<tr>
<td>Power Supply</td>
<td>6130 - 99 - 854 - 2869</td>
</tr>
</tbody>
</table>

Also from STC in pressurized case:

30-LRU-20J-1 TRANS/REC
Theory

Radar altimeters with the CW-FM principle have a small transmitter which transmits a continuous, frequency modulated wave. The modulation is a symmetrical triangular wave with a peak-to-peak deviation (BW) of approx. 150MHz, and a frequency of 300Hz (T=1.667 ms).

The receiver receives the ground echo with a second antenna. The echo has the transmitted frequency a few microseconds ago, and is mixed with the actual transmitted signal. The frequency difference is proportional with the altitude.

\[
BW = \text{peak-to-peak frequency deviation (100 MHz)}
\]
\[
T = \text{min to max frequency deviation time, (1.667 ms)}
\]
\[
dF = \text{frequency difference between received and transmitted signal;}
\]
\[
c = \text{speed of light (3.10} {\uparrow} 8 \text{ m/s = 983 feet/µs)}
\]

Gives

\[
2 \times \text{altitude} = \frac{c \times dF \times T}{BW}
\]

Twice the height of the antenna's above the ground plus the length of the cables to the antenna's should be subtracted from this value. Say this is Ho [feet], and with dF in kHz and BW in MHz, this formula reduces to

\[
\text{Altitude [feet]} = \frac{820 \times dF}{BW} - Ho
\]

This set has a fixed triangle amplitude (=BW) up to \(dF=32\text{kHz}\) from the receiver, then the bandwidth is gradually reduced down to a factor 5 at \(dF=63\text{kHz}\). The relation of the output voltage to altitude becomes non-linear. The beat frequency amplifier has a bandwidth of 3-100 kHz.

When I assume Ho= 60 feet (20 meters) and the initial BW is 100 MHz, then
- The lowest frequency is 7.3 kHz at 0 feet
- The altitude at 32 kHz is 202 feet
- The altitude at 63 kHz and BW=100/5 is 2520 feet

The "valid" relay output is active from \(dF=5\) to 70 kHz, with 5mV input to the amplifier, or from 8 to 100 kHz with 2 mV input.

Radar altimeters operate in the 4200 - 4400 MHz "C" band.

Doppler shift

If the altitude increases, the echo frequency rises both in the up, and downward part of the triangle, so the difference frequency is smaller in the upward part, and higher in the downward part of the triangle. If the modulating wave is symmetrical, and perfectly linear, these effects average out, and true altitude is measured, independent of doppler shift when the altitude changes.

When the altitude changes with 10m/sec, the doppler shift is \(10\text{m/s} \times 4.2\text{GHz/c}=140\text{ Hz}\).

Typical altimeters

Radar altimeters exist with maximum altitude 2,500 or 5,000 ft. The circular display is linear up to 500 feet and logarithmic from 500 - 2,500 (or 5,000) feet, making the lower range of heights easier to read.

All radio altimeter displays have a setting control for a decision height, at which point a warning will be given. The height can be set by positioning an outside cursor against the required height on the scale. The setting control will normally double as a PTT (press-to-test) facility which, when engaged, drives the display to a predetermined value - normally 100 feet.
Measuring results

The beat frequency amplifier has a relatively flat gain from 5 to 100 kHz. With open P and E inputs, a square wave of 3mVpp on the SMA connector is sufficient for a stable, symmetrical square wave to the deglitcher.

The output at pin R of the main connector is proportional with the beat frequency at 80 mV/kHz without load. With a 270 deg, 1mA meter with 5k total resistance, full scale is at 10 V. The "zero" position of the pointer is masked. The pointer appears at 0 feet when dF=7 kHz. Up to 32 kHz, the bandwidth is 100 MHz, and the altitude is proportional with the beat frequency. Above 32 kHz, the BW is reduced (pin M of main connector), and the altitude scale becomes non-linear. The Valid relays K3-4-5 are on from 5 to 75 kHz. With only 2mV signal (5mV below 10kHz) to SMA connector.

Below 32 kHz, a 37.5Hz sinewave is superimposed on the frequency modulating 300Hz triangle to give some dithering. The occupied bandwidth is 150MHz (100MHz without dithering).
**Testpoints**
The Radar Transmitter/Receiver has a 32 pin main plug and a 26-pin testplug.

The 26 pin test connector has the following signals.
Pins A,B,C,D, G , N and R are supply voltages

A + 70V pwr supply varactor diode  
B + 12V pwr supply opamps  
C - 12V pwr supply opamps  
D - 30V pwr supply transmitter (gunn diode?)  
E gnd  
F + 21V AGC signal  
G -0.4 V adj offset output  
H - selftest module  
J - selftest module  
K df/dt slope  
L + 3.5V Valid relay K3-4-5 coil --> +3V=VALID  
M Pwr ON when connected to 115Vac LO  
N + 32V pwr supply totempoles  
P + 3.9V varactor drive signal (a 300Hz triangle)  
R + 25V pwr supply for relays  
S 115V ac LO  
T 115V ac HI  
U 115Vac on transformer  
V no pin  
W 0..10V main output  
X no pin  
Y disable dithering  
Z to main connector pin S  
a no pin  
b 28Vac from transformer  
c to main connector pin F

**Frequency measurement 24 aug 2014**
It was not possible to measure the altimeter frequency directly, I have no equipment at 4 GHz.
However, I could use my Tek2712 spectrum analyser with 10cm whip, coupled to altimeter transmitter output, terminated with 50 ohm and also short whip, which revealed a signal at 1610 MHz, swept over a 24 MHz bandwidth. This is with open tx module.

The real frequency of the altimeter is either:
- The mirror of the SA: 1.61 GHz + 2 x 2.11 GHz = 5.83 GHz, the SA's first IF is 2110 MHz, or
- The altimeter tx has an oscillator at 1610 MHz, followed by a tripler to 4.83 GHz.
Expected 1433 MHz x 3 = 4.3 GHz center freq?
IF AMPLIFIER

IF Front-end

CONTROL

H,N,R

Self test module

*1kHz square wave on SMA input, other inputs open

blue opamp uA702 flatpak
yellow opamp SN524A or N92
Inside the transmitter box
situated inside a thermostaat.

The active element is probably a bipolar transistor. The type number is nearly unreadable, ending on ..617.

What is the emitter, base, or collector?
Wire numbers in blue

Voltages (ac / dc) in red at 81V/400Hz on P-T primary when all regulators have stabilized output.

- 30V
+ 70V
+ 35V
+ 25V
+12V
+35V unstab

not used