HIGH DYNAMIC RANGE AIRBORNE TRACKING AND FIRE CONTROL RADAR SUBSYSTEMS

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ABSTRACT

Two high dynamic range receiver sub-systems for use in airborne radar fire control and tracking applications are described. A high performance X-band monopulse tracking receiver and a doppler fire control receiver are presented with performance data and design considerations to achieve high dynamic range.

INTRODUCTION

Radar receivers used for tracking and fire control in airborne applications require high amplitude dynamic range capability to linearly process the target returns from short ranges (500 ft.) as well as long distances, in the presence of clutter.

To achieve high dyanmic range a low noise preamplifier is used at the antenna output, preceded by a programmable digital or analog attenuator which reduces strong signal amplitudes, for linear operation. Additional IF programmable attenuation can be used to extend the dynamic range. In a monopulse system which which uses two channel RF reception, good gain and phase tracking over attenuation is required for accurate target tracking. For single channel pulsed doppler receivers a high dynamic range receiver is necessary to insure discriminating the desired target returns, from mainbeam and sidelobe clutter returns, and distortion products. A STC (sensitivity time control) circuit preceding the LNA reduces strong close in target returns to levels which can be processed with no distortion.

The radar subsystems to be described operate at X-band about 9.3 GHz and use magnetrons to produce the transmit pulses. An AFC circuit locks the internal local oscillators to the transmit frequency so as to produce a 60 MHz IF downconverted return. A detailed description of the two radar subsystems follows.

MONOPULSE TRACKING RADAR DESCRIPTION

A monopulse radar detector which utilizes identical rapid switching phase tracking programmable attenuators in the sum and difference receiver channels can produce a normalized difference channel output for target tracking. This type of monopulse processor relies on coherent amplitude detection of the difference channel using the sum signal as the phase reference. This approach requires extremely rapid attenuator switching and good tracking over the attenuator dynamic range.

The monopulse system described uses this fast AGC approach using 80 dB of programmable attenuation to achieve extremely high dynamic range.

A photograph of the complete X-Band monopulse receiver is given in Figure 1.

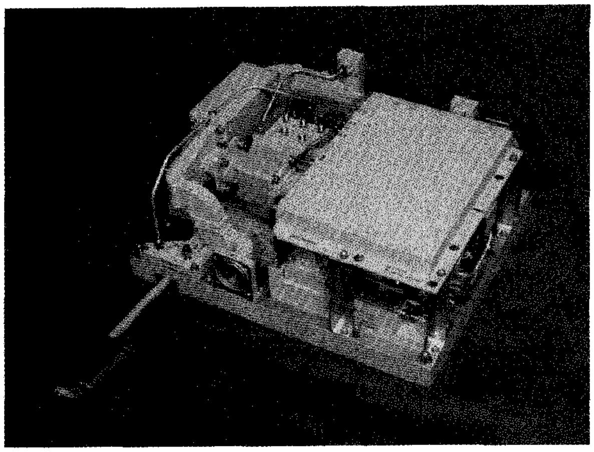

FIGURE 1
MONOPULSE RADAR RECEIVER

A block diagram of the monopulse receiver appears in Figure 2. The monopulse receiver assembly contains a high power circulator, two channel TRL tubes, downconverters, programmable RF and IF attenuators, coherent detectors, AFC circuitry and a log sum video channel with variable bandwidth. The receiver operates at 9.35 GHz, is frequency agile $\pm$ 60 MHz at a 50 Hz rate and operates over pulse widths of .3 to 4.0 μ sec. To achieve both a maximum sensitivity (<6 dB NF) and high operational dynamic range (+7) dBm max input), a LNA and programmable attenuator combination are used at the receiver front end. Up to 40 dB of attenuation in 10 dB steps is available at the receiver front end. A total max gain of 25 dB with 3.40 dB NF is achieved in the preamp assembly. It utilizes 3 FET amplifier stages cascaded with 3 PIN diode attenuation stages. The measured performance of the front end LNA/Attenuator gives less than ±7° of phase tracking and ±.75 dB of gain tracking over the full attenuation range.

MONOPULSE MEASURED PERFORMANCE

The measured performance of the integrated X-Band monopulse receiver is presented in Table I.

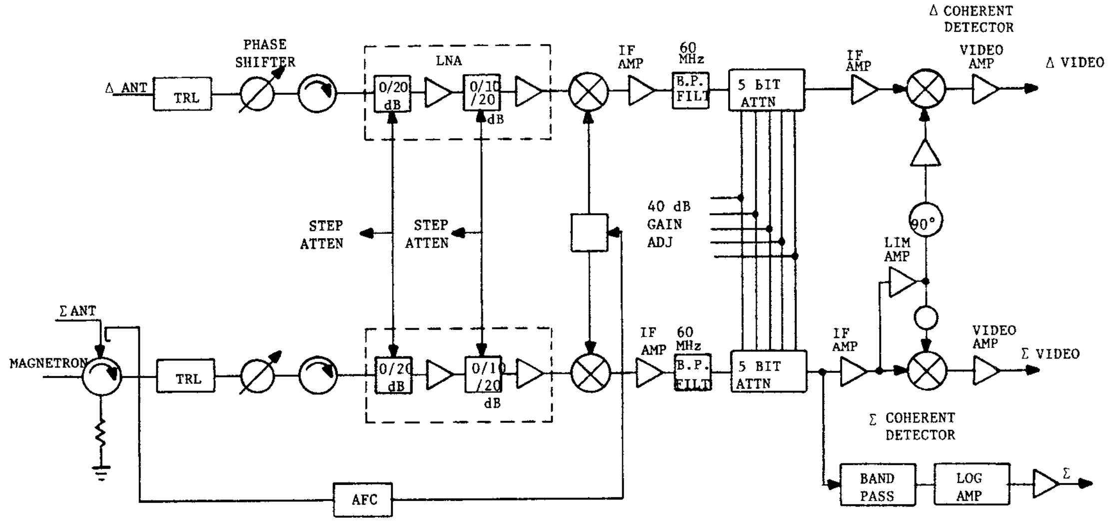

FIGURE 2

X-BAND MONOPULSE RADAR RECEIVER CONFIGURATION

An additional 40 dB of programmable attenuation is produced in the 60 MHz IF amplifiers following the bandpass filters. Since the outputs of the difference and sum videos are sampled during pulsewidths of as little as .3 μ sec, the programmable attenuators must settle in less than 50 nsec to prevent switching spikes from obscuring the true video signals. The programmable IF attenuator is a special design utilizing FET switches for each bit to minimize switching transients. The overall phase and amplitude tracking of the IF attenuator is better than 4° and .5 dB over the attenuation range and operating temperature range. A built in AFC circuit maintains the IF at 60 MHz within .5 MHz as the magnetron frequency slews ± 60 MHz at a 50 Hz rate. The AFC is designed so as to optimize the accuracy at the different system pulsewidths.

An overall system noise figure of 6 dB was obtained at 20° rising to 6.5 dB at 71°C. A linear instantaneous dynamic range of 42 dB with 80 dB of programmable gain was achieved with low two tone intermodulation products (-45 dBc) and spurious responses (-60 dBc). Total phase tracking between channels over all attenuation settings, over -54 to +71°C temperature, and over a 120 MHz frequency band was ± 15°. Total, amplitude tracking over the same conditions was ± 1 dB.

TABLE I

X-BAND MONOPULSE RECEIVER MEASURED PERFORMANCE

Operating Frequency	9.36 ± .290 GHz
Frequency Agility	± 60 MHz at 50 Hz Rate
Pulsewidth	.3 to 4.0 μsec
PRF	2000 PPS to 250 PPS
Single Sideband Noise Figure	6 dB at 20°C 6.5 dB at 71°C
Image Rejection	20 dB
Linear Instantaneous Dynamic Range (8 MHz IF BW)	42 dB
Log Channel Instantaneous Dynamic Range	80 dB
Gain Control	
Front End	40 dB in 10 dB Steps
IF	40 dB in 2 dB Steps
Phase Tracking Between Channels	± 15° Over -54 to +71°C & ± 60 MHz of Center Freq.
Amplitude Tracking Between Channels	± 1 dB over all Attenuation Ranges
Supurious Signals	-60 dBc
Two Tone, Third Order Responses (-30 dBm Input)	-45 dBc

DOPPLER RADAR DESCRIPTION

The elements of the X-Band Doppler Radar Subsystem are shown in the block diagram of Figure 3. They include a fast recovery multi-section TRL Tube and a precise STC circuit for range controlled attenuation. Other components are a High Power Low Loss Circulator, a Low Noise FET, an Image Rejection Mixer and an AFC for frequency lock of the LO onto the magnetron transmit pulse.

A photograph of the completed integrated subassembly appears in Figure 4.

The combination of the low noise GaAs FET amplifier preceding the image rejection mixer improves the Single Side-band (SSB) noise figure without degrading the overall receiver dynamic range. A time-sensitivity attenuator (STC) preceding the low noise amplifier attenuates strong, close in radar returns by a minimum of 18 dB. This prevents overloading of the receiver front end for target returns as close as 500 feet, and maintains an instantaneous dynamic range of 80 dB.

The receiver gain reduction curve (STC) vs. time is such that at 1 μ sec after pulse

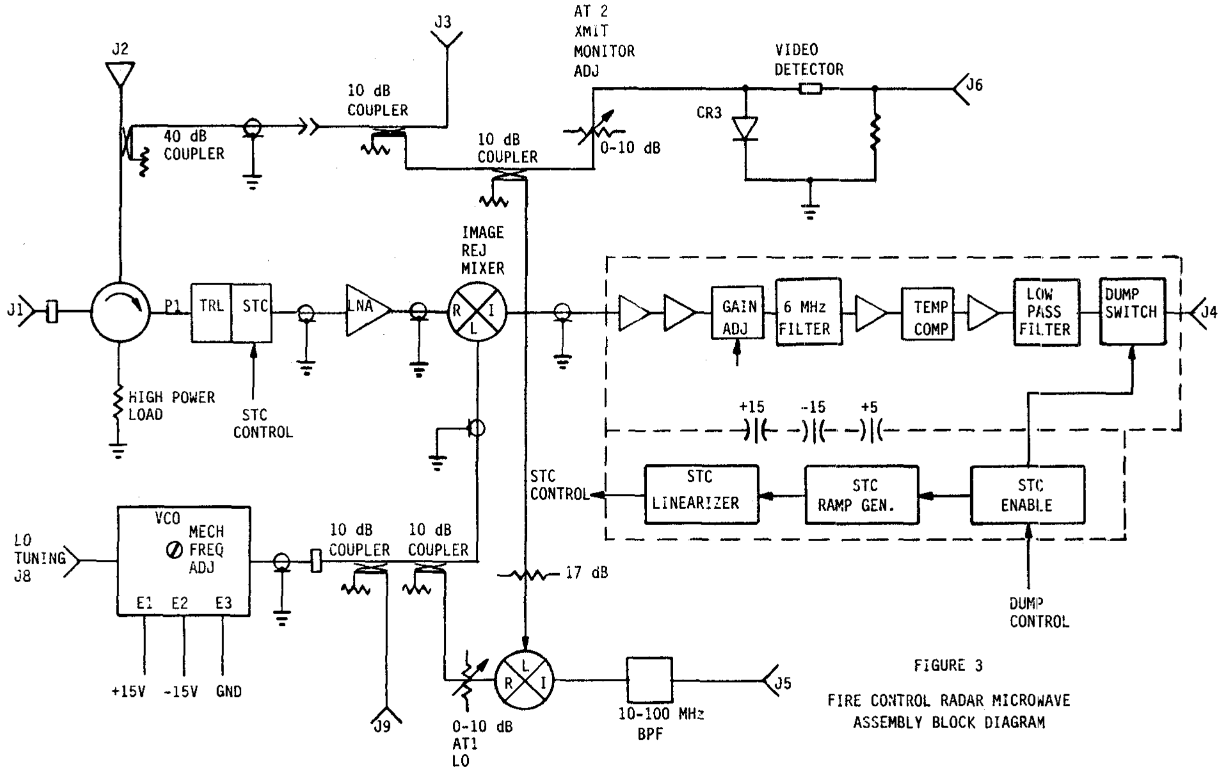

FIGURE 3
FIRE CONTROL RADAR MICROWAVE ASSEMBLY BLOCK DIAGRAM

transmission a minimum of 18 dB of attenuation is provided. It then slopes linearily with an accuracy of $\pm$ 3 dB to 14 dB attenuation at 3.0 μ sec, and to 0 dB attenuation at 5.0 μ sec.

A minimum of 60 dB of dump attenuation at the 60 MHz IF output is provided during the transmit pulse. This prevents any possible overloading by transmit transients of the radar's 80 dB dynamic range signal processor.

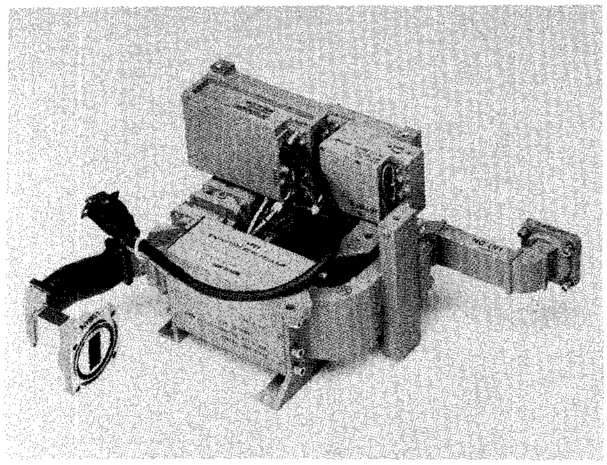

FIGURE 4
DOPPLER RADAR RECEIVER

DOPPLER MEASURED PERFORMANCE

The measured performance of the complete doppler radar receiver subsystems is presented in Table II.

At maximum gain (no STC) an overall system noise figure of 4.6 dB was met at 25°C.

80 dB of instantaneous dynamic range with -35 dBc maximum spurious level was measured. The fast STC and quick recovery of the TRL tube allows reception of received signals within 1 μ sec of the start of the transmitted pulse.

TABLE II

DOPPLER RADAR RECEIVER MEASURED PERFORMANCE

Operating Frequency	9.3 ± .15 GHz
Pulse Width	.4 ± .04 μ sec
PRF	2500 PPS 1500 PPS
Frequency Agility	± 50 MHz at 100 Hz Rate
Received Signal Levels	-103.7 dBm to -10 dBm
Noise Figure	4.6 dB at 25°c
Instantaneous Dynamic Range	≥ 80 dB
Spurious Signals	> 35 dBc
Image Rejection	15 dB Minimum
Gain	22 dB nominal
STC	18 dB 1 μ sec after transmit pulse; decreases linearily to 0 dB in 5.0 μ sec
Dump Attenuation	>60 dB Fast Recovery

CONCLUSION

For monopulse radar the fast AGC approach utilizing RF and IF programmable attenuators with coherent detectors can provide high dynamic range monopulse receiver performance. Careful design of the attenuators for rapid switching and tracking in phase and amplitude over all attenuation states and with temperature is essential for accurate system nulls.

For pulsed doppler radar close in target tracking was achieved using a fast recovery TRL and front end STC circuit. Accurate control of the time varying gain allows optimum performance of the radar in the presence of returns and over a high instantaneous dynamic range.

REFERENCES

1. Samuel M. Sherman, "Monopulse Principles and Techniques", Artech House, Inc., Dedham, MA.

2. Asad M. Madni and G. Stillwell, "Design Consideration in the Development of Monopulse Radar Receivers", 1987 IEEE Aerospace Application Conference