SOLID STATE TRANSMIT/RECEIVE MODULE FOR THE PAVE PAWS (AN/FPS-115) PHASED ARRAY RADAR

DONALD J. HOFT
RAYTHEON COMPANY, EQUIPMENT DIVISION
WAYLAND, MASS.

ABSTRACT

The PAVE PAWS phased array radar (AN/FPS-115) utilized for long range detection and tracking of SLBM's is presently under construction at two sites in the U.S.A. The system utilizes a solid state transmitter and receiver. This paper will discuss the transmit-receive configuration and the transmit/receive module developed for this application. The (sub) system configuration, module requirements and description, RF power transistors and performance to date will be presented.

BACKGROUND/INTRODUCTION

The PAVE PAWS phased array radar (AN/FPS-115) presently under construction at two sites in the U.S.A., is capable of long range detection and tracking of SLBM's. Figure 1 shows the Otis AFB, Mass. site during construction in early 1978. The radar(s), which are hi-rel systems meant to operate continuously, utilize 3584 active solid state modules per site (7168 total) to (1) develop the transmitted R.F. Power with approximately 50,000 power transistors, (2) provide low-noise receiver preamplification, and (3) provide (4-bit) phase shift capability for (transmit and receive) beam steering. This paper will discuss all aspects of the module which is now in production.

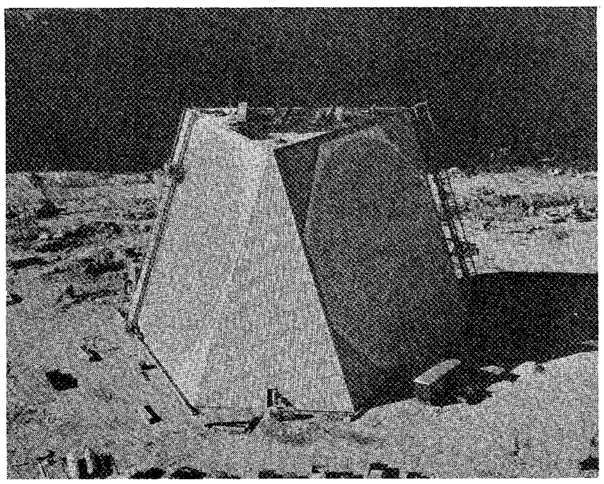

Figure 1.

SYSTEM CONFIGURATION

Figure 2 is a basic block diagram showing the transmitter and receiver-beam former (RBF) configuration for each face (2 per site). As shown, a single "array" predriver power amplifier (P.A.) drives 56 "sub-array" driver P.A.'s: these (each) in turn provide the drive power to 32 output modules (one sub-array). On receive the signal, following preamplification and phase-shifting within the T/R module, is combined in a sub-array and routed through the circulator to the RBF. The array driver is redundant to enhance system reliability. The sub-array drivers and output modules are "defacto" redundant and do not require "real" redundancy. System performance is maintained with as many as 200 modules per face inoperative. Since the system transmitted signal is circularly polarized each module output is made up of 2 signals in quadrature. Figure 3 shows a complete T/R output module. The unit plugs directly into the array antenna element thereby eliminating the need for a coaxial line between the module and element. Thus the insertion loss, mismatch, and most importantly the reliability are not negatively effected by this cable. The module's close proximity to the antenna is a major advantage of a solid state vs a tube type system where the losses between the amplifier and element are typically greater than 3 dB. The coaxial fittings (shown) were developed for the program. It is mechanically flexible in all three planes to eliminate tolerance buildups in the array mechanical structure.

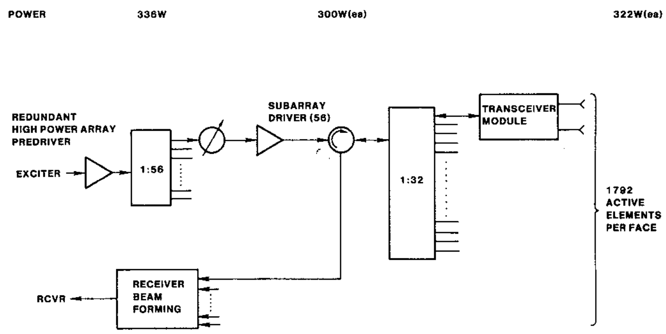

Figure 2. PAVE PAWS Transmitter/RBF Configuration

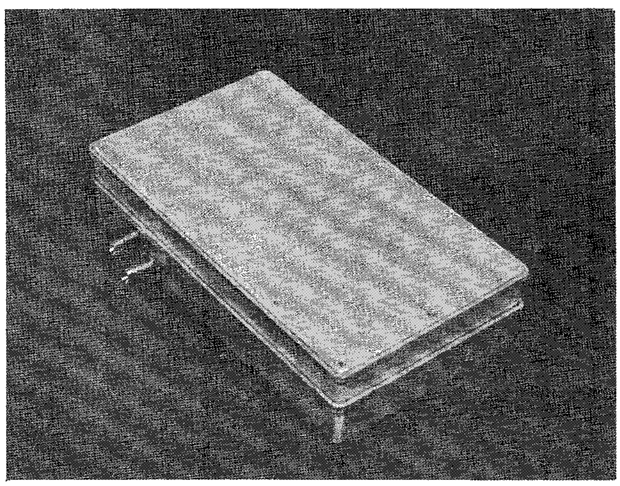

Figure 3.

MODULE REQUIREMENT/DESCRIPTION

Figures 4 and 5 are block diagrams of the module and power amplifier including levels, N.F.'s, etc. Table 1 lists the key electrical requirements. What might not be evident from Table 1 is that the *major* difficulty in building S.S. modules for transmitters is the high

CH1355-7/78/0000-0239$00.75

importance and difficulty of making all (and extensive) performance parameters repeat — in this case 7200 times. Major considerations in approach to the transmitter/module development were (in addition to cost);

- Conservative (reliable) design for long life
- Manufacturability
- Maintainability: field repairable
- Of less significance was size and weight

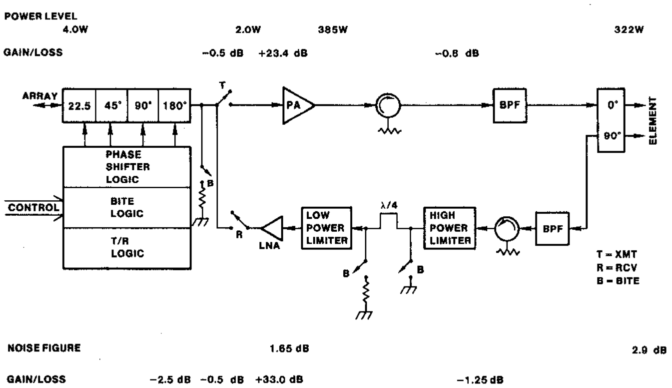

Figure 4. SSM Block Diagram

Table 1. Transceiver Module Electrical Specifications

TRANSMIT	SPECIFICATIONS LIMITS
Frequency	420-450 MHz
RF Peak Power Output	284-440 Watts 322 Watts Avg
Pulse Width	0.250 to 16 msec
Duty Cycle	0 to 30%
Efficiency	36% Ave (Min)
Antenna Port Tracking (Circularity)	
Amplitude	0.25 dB
Phase	3 Deg
Phase Tracking Error	14 Deg RMS
Phase Settling	25 Deg PK
Pulse Droop	1.0 dB Max
Harmonics	−90 dBc
RECEIVE	
Gain	30 dB Min ± 1 dB
Noise Figure	2.9 dB RMS Max
Limiter Power Handling	440 Watts, 16 msec, 25% D.F.
Phase Tracking	10 Deg RMS
Dynamic Range	KTBF to −28 dBm 1 dB CPRSN)
No. Phase Shifter Bits	4
Phase Shifter Error	4.6 Deg RMS

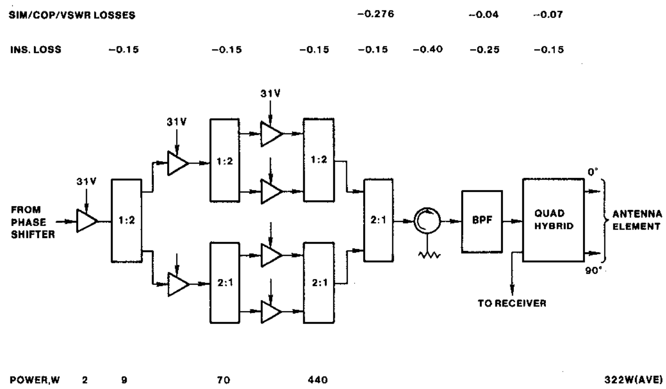

Figure 5. Transmitter Module Configuration

Figures 6 and 7 are views of the transmitter and receiver (sub) modules. To achieve these objectives the following features were implemented;

- Power transistor low junction temperatures; typically 80-120°C, 140°C max
- A 4 parallel transistor output stage in a 1-2-4 amplifier line-up
- Die cast, dual RCVR and transmitter chassis
- Conventional PCB's/Techniques
- PCB's (7) separately testable/replaceable/repairable
- Automated manufacturing line, including RF test station
- Interchangeable dual power transistor supplies
- Semi-automated, on-site, RF test stations

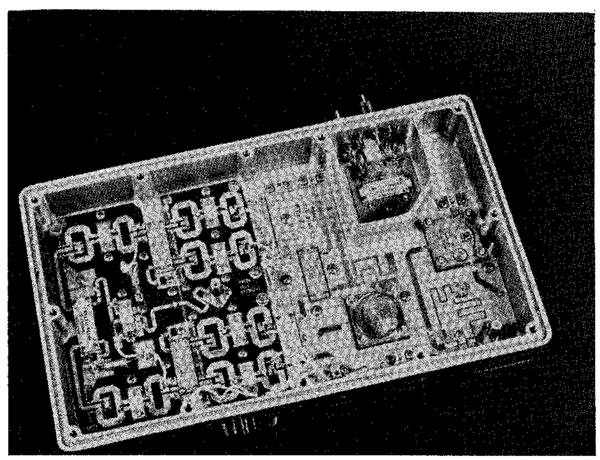

Figure 6.

With the operating junction temperatures as indicated, the MTBF (calculated) is approximately 250K and 220K hours for the receiver and transmitter (sub) modules. Each module undergoes 168 hours of RF operation after assembly and (pre) test. This is followed by final module acceptance test. Over 600 detailed measurements are made on each module in less than 7 minutes at the RF test station. One percent (1%) of all modules have their power transistors infrared (I.R.) scanned through clear sapphire windows (caps) to assure acceptable junction temperatures.

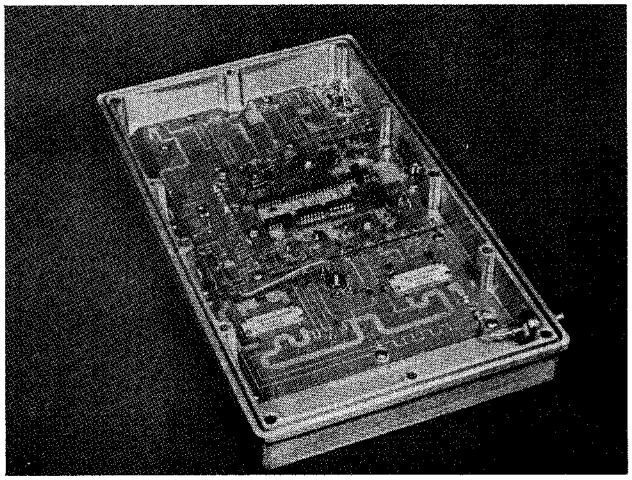

Figure 7.

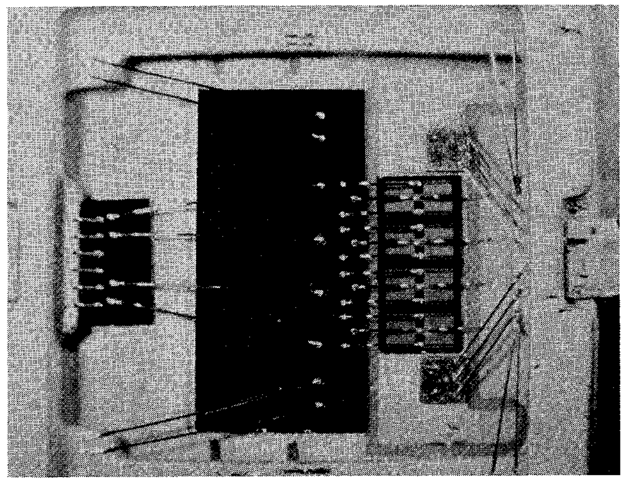

Figure 8.

POWER TRANSISTORS

Two sources of power transistors are utilized, e.g., see Figure 8, to supply the 50,000 transistors needed for 2 sites. Table 2 lists the major characteristics. Each transistor (source) has its own PCB design; these are interchangeable within the module. Similarly modules are interchangeable within the radar. While the basic transistor "die" design existed, each was tailored and optimized for the PAVE PAWS application. All transistors undergo high-rel screening including 168-hr D.C. burn-in. Samples of every wafer lot undergo 1000-hr RF testing to qualify the wafer lot. Acceptance RF testing is done utilizing the actual module circuit; to assure tolerance to circuit and device variations, performance testing includes operation under load mismatch conditions.

Table 2. PAVE PAWS Power Transistor Characteristics

Sources of Supply:	Power Hybrids Inc (PHI) Communications Transistor Corp. (CTC)
Power Output (16W Pin):	110-120 Watts PK (Ave) 130 Watts PK (Max) 100 Watts PK (Min)
Duty Factor:	30% Max
Pulsewidth:	16 Millisec Max
Configuration:	PHI; Single Ended, Internally Matched In/Out CTC; Balanced, Internally Matched In/Out
Metalization	PHI; Gold CTC; Aluminum
Junction Temperature (1.6:1.0 VSWR)	PHI (Au); 140°C Max CTC (Al); 120°C (Ave) Max: 10% Max May Fall Between 120-140°C
Ballast Resistors	PHI; Diffused CTC; Nichrome
Collector Efficiency	65% Ave, 60% Min
Sapphire Lids	5%
Quality	Jantxv Equivalent

PERFORMANCE

Production of the transmit/receive modules started in late 1977 and will build-up to an 800 monthly rate. Over 2 million power transistor hours have been accumulated, results to date are excellent. Table 3 lists electrical performance based on the first 300 modules. Over 1400 modules have been produced at date of submission.

Table 3. Module Performance (300 Modules)

	Performance	Spec
Power Output	330 Watts (Ave)	322 Watts (Ave)
Output Power Tracking	0.24 dB RMS	0.58 dB Max (Ave)
Insertion Phase Tracking, Transmit	6.7 Degrees (RMS)	14 Degrees Max (RMS)
Phase Shifter Error		
• Transmit	2.52 Degrees RMS	4.6 Degrees RMS Max
• Receive	2.30 Degrees RMS	4.6 Degrees RMS Max
Efficiency	37.88% Avg	36% Avg Min
Receiver Gain	34 dB Avg	27 dB Min
Receiver Gain Tracking	0.57 dB (RMS)	0.81 dB RMS Max
Insertion Phase Tracking, Receive	5.56 Degrees RMS	10 Degrees Max RMS
Noise Figure	2.71 dB (RMS)	2.9 dB RMS Max

ACKNOWLEDGMENT

Some of the material presented in this paper was developed under contract to the Air Force System Command's Electronic Systems Division (ESD), Hanscom Air Force Base, Bedford, Massachusetts.