OPERATION OF SOLID STATE TRANSCEIVERS IN AN L-BAND ARRAY*

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Abstract

Solid state transceivers have been utilized in an L-Band array. The experience associated with the acquisition of over 300,000 total transceiver operating hours obtained with 97 transceivers will be described.

Summary

This paper describes the results of an experiment utilizing solid state transceivers in an L-Band array. The array was constructed to demonstrate the feasibility of a solid state phased array and was designed as a representative segment of a large array. An array testing program was carried out on an antenna range resulting in good agreement between calculated and measured performance. In addition, the equipment was designed for unattended operation enabling the acquisition of a significant number of transceiver operating hours on 97 transceivers as tabulated in Table I is reported.

The testing was conducted on the array shown in Fig. 1 with one transceiver used for each array element. The electrical specifications of the transceivers are shown in Table II. Figure 2 is a block diagram of the transceiver indicating the major components. The output power of four microwave transistors was combined in each transceiver to produce a nominal 50 watt output. The power transistors are aluminum metalized devices, without internal matching or ballasting. A maximum transient junction temperature of 140°C was specified for the transistors, but not confirmed for the sealed units. A logic level input switches the transceiver from transmit to receive. Row and column phase shift commands are sequentially added, stored in a register and subsequently transferred to a latching, biasing, circuit by a separate logic command. Figure 3 shows the hybrid microwave integrated circuit construction of a transceiver. Two manufacturers have built 100 transceivers each on "pilot production" lines and both designs have been used in the array. Untrimmed differences in electrical length between the two designs prohibited simultaneous use. The testing experience to date has been primarily with one design and the results of that testing only are being reported in this paper.

Two transceiver deficiencies were detected early in the array testing program. Initially, transceivers were being incorrectly phased and it was necessary to correct the line length phase trimmer to compensate for a unit to unit variation characterized by a frequency insensitive phase term. Incomplete testing of the logic functions resulted in detection of "built-in" logic malfunctions during array operation. In addition, spurious output signal levels were found to be a function of the mismatch into which the transceiver was operated.

The array was designed with fail safe circuits to protect the transceivers from voltage surges, cooling system failure and excessively high RF duty factor or long pulse length. During unattended operation the transmitters were exercised with an 18% duty factor and a 50 μsec pulse length. The condition of each unit was tested daily by an automated checkout and monitoring system that measured relative power output, receiver gain, and phase shifter operation. Data on the performance of each transceiver was accumulated and when failures were detected the unit was removed and tested.

Of the 97 transceivers of one design being reported on, 40 were found to have problems, 18 of which are believed to be chargeable failures. Table III provides a summary of the 18 transceiver failures by the function in which failures were found. All of the failed units were opened and, where possible, the failed component and the cause of failure determined. Nine transceivers were found with failures that specific corrective action could prevent. Five failed incoming inspection and were used only for specific tests. Seven transceivers had logic functions that did not work when first tested. One transceiver was believed to have been damaged accidentally. Examples of failures due to workmanship, defective components, and those believed due to random defects or environmental factors were found.

While not designed as a transceiver reliability test, this array field testing program has provided data on the performance of solid state transceivers in a phased array environment. The "a priori" assumption that the microwave power transistor represent the largest potential reliability problem is difficult to assess. For the proposition to be valid that an all solid-state radar is inherently more reliable than a conventional radar, it is evident that questions of component reliability, testing and quality control of the total transceiver must be answered.

With the test conditions described above and the assumption of an expotential failure distribution, mean-time to failure (MTTF) predictions can be made. The maximum number of operational hours on any transceiver was approximately 8,000 and no "wear-out" mechanism limiting transceiver life was observed.

Of the many people who contributed to this program, special acknowledgment is made to W. Beck of RCA, P. Noel of TI, R. McMillan of RADC, and E. Hakim of ECOM.

*This work was sponsored by the Department of the Army (Advanced Ballistic Missile Defense Agency) and was monitored by Rome Air Development Center, Griffiss Air Force Base, New York.

Contract F30602-73-C-0179.

TRANSCEIVER OPERATING HOURS

Number of Units	Operating Hours
1	0 – 1000
10	1 – 2000
18	2 – 3000
25	3 – 4000
22	4 – 5000
14	5 – 6000
4	6 – 7000
3	7 – 8000
Total Transceivers 97	Total Hours > 300,000

Table I

TRANSCEIVER MODULE SPECIFICATIONS

Frequency Band (instantaneous 1-dB BW)	1.259 to 1.391 GHz
RF Peak Output Power	38 W to 60 W
Input Power Requirement	0.1 W ± 1 dB
Pulse Length	1500 μsec maximum
Efficiency (RF out/DC + RF in)	30%
Duty Cycle	30%
Receiver Gain	25 to 28 dB
Receiver Gain Compression	1 dB at > −25 dBm input
Receiver Noise Figure	4.5 dB maximum
Phase Shifter Type	Diode-switched line
Phase Shifter Bits (at 1.259 GHz)	22.5°, 45°, 90°, 180°
Phase Shift and T/R Commands	Transistor Transistor Logic
Power Supply Voltages (DC)	+28 V, −15 V and +5 V

Table 2

TRANSCEIVER FAILURES

Function	Number
Transmitter	4
Receiver	8
Phase Shifter/Logic	2
Other	4
Total	18

Table III

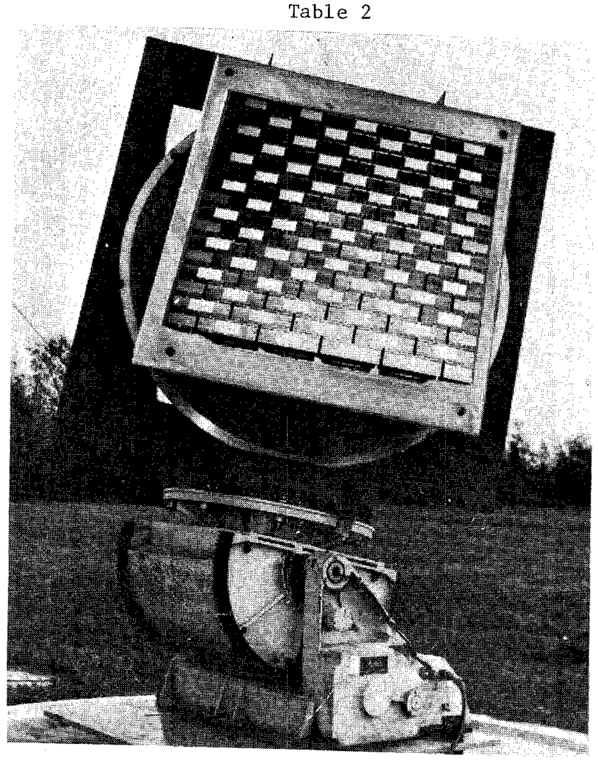


Figure 1. Experimental L-Band Array

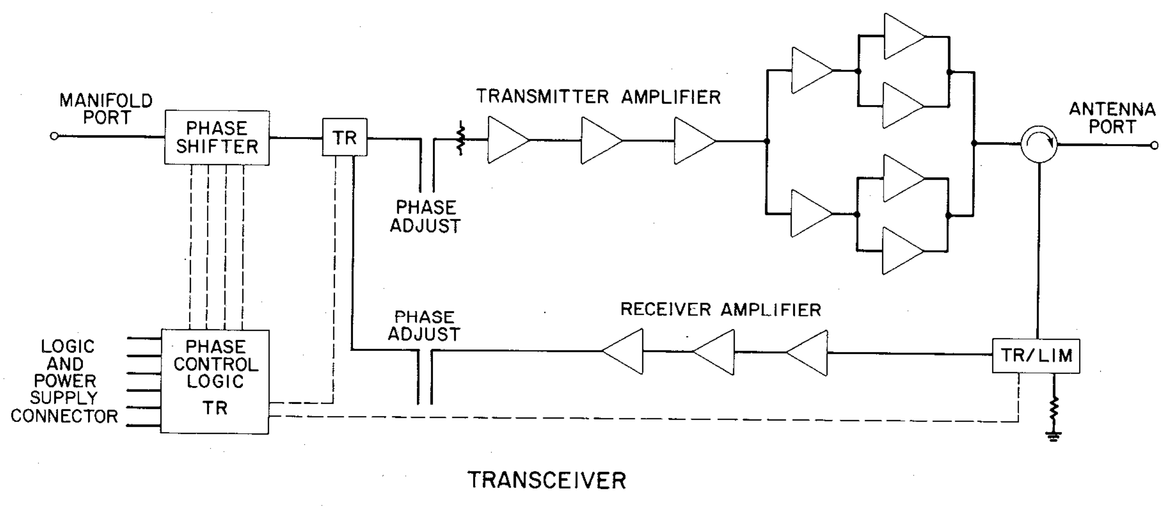
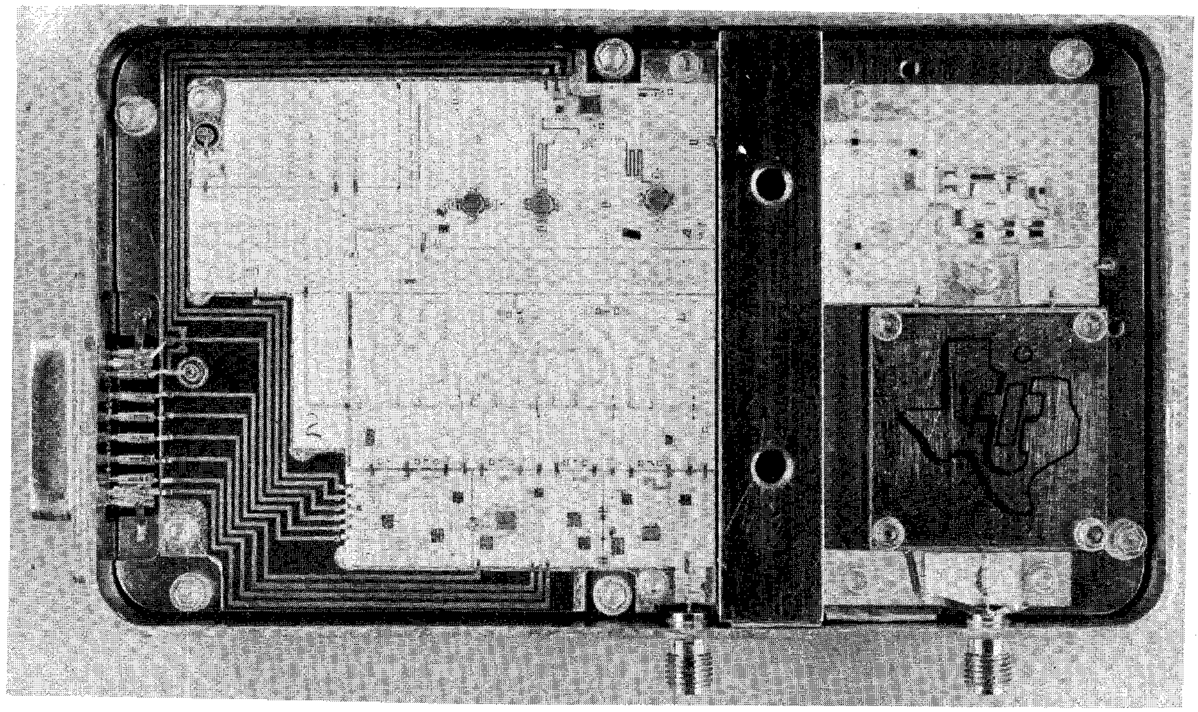
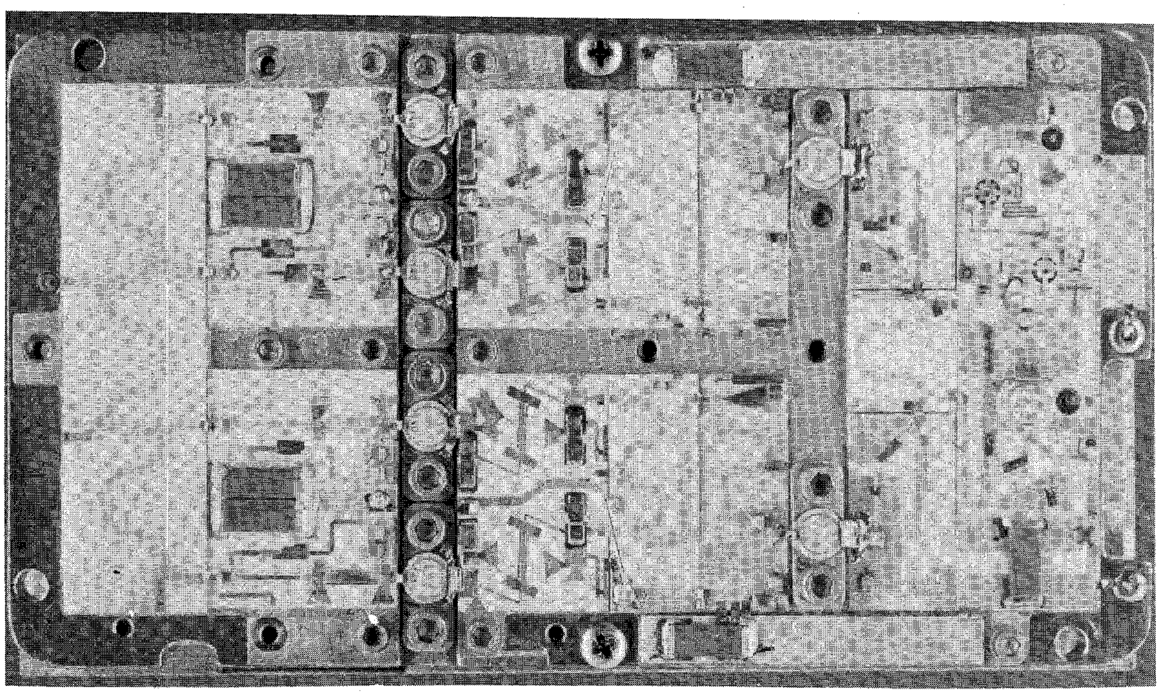


Figure 2. Transceiver Block Diagram



Low Level Stages
(a)



Power Amplifier
(b)

Figure 3. Transceiver Construction