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Design & Implementation of ATE for Line Replaceable Units of Active Phased Array Radar

R. Karthik*, K. Jyothi* and T. Vijetha, T. Pardhu****

ABSTRACT

A Radar system consists of various components/subsystems such as transmitter, receiver, and antenna to operate. For Radar to operate, all these components have to be first tested in the laboratory and then integrated to the system. Also, these components need to be maintained during the lifetime of the radar system. To test the various subsystems, a facility called ATE (Automatic Test Equipment) is used. The ATE is the main element in the Maintenance Shelter. It enables the testing of various LRUs on ATE and trouble shooting and fault isolation down to Shop Replaceable Unit (SRU) levels for the LRUs. ATE is the application that is used to check the status of the radar modules like TRM (Transmit receive Module), TRC (transmit receive Controller), CU (central Unit) and GC (Group Controller). ATE software compares the received data with the default data depending upon result of comparison; it will send the status of all the sub-modules to the LabVIEW Software. The whole software is built in the LabVIEW environment. All test parameters are automatically compared to unit-specification limits as well as reference-standard (unit-to-unit) limits. The system errors are measured periodically through use of calibration standards, stored in memory, and applied as corrections to the measured data on the module under test. All test data are recorded on magnetic tape and available to the operator by means of a line printer when desired.

Keywords: c Automatic Test Equipment (ATE), Transmit Receive Module (TRM), Transmit Receive Controller (TRC), Line Replaceable unit, Shop Replaceable unit.

1. INTRODUCTION

The ATE is the main element in the Maintenance shelter. It enables troubleshooting and fault isolation down to Shop Replaceable Unit (SRU) levels for the following Radar units: TRU, GU and TRM.

The ATE is comprised of the following main elements:

1. ATE Computer
2. Standard Test Equipment (STE)

The ATE tests includes stimulus, measurements, control switching and display capabilities for functional and performance tests of the Unit under Test (UUT). The ATE is operator-controlled via terminal and keyboard. Self-tests are performed in order to check the ATE own operational status.

All ATE test equipment is based on COTS standard commercial test equipment, and is controlled by the ATE computer via GPIB (General Purpose Interface Bus) / LAN (Local Area Network). The ATE test results are provided in either hard-copy report format or magnetic media files.

The ATE is physically comprised of three 19" ventilated racks bolted together and installed on rubber-rimmed wheels, to provide one rigid unit. Fig. 1 shows the general view of an ATE [1]. A table is installed to the right-hand side of the racks. The ATE installation is physically divided into two functional groups:

* Dept. of Electronics and Communication Engineering MLR Institute of Technology Hyderabad, India, *Email: karthik.r@mlrinstitutions.ac.in*

** Dept. of Electronics and Communication Engineering MLR Institute of Technology Hyderabad, India.

Figure 1: ATE General View

Interface Group: It enables signal and control paths between the standard test equipment (STE) and the UUT. It comprises RF switching drawers, module drawer, test cables and adapters.

Support Group: It provides cooling and power supply to the UUT. This group comprises Liquid-to-Air cooling unit, electrical power distribution system, and DC power source unit.

The STE is permanently installed on front of rack, and can be removed by opening the respective bolts[4]. The UUT interface drawer is slide-mounted and can be extended without interrupting the test procedure process. Fixed signals and control paths are provided between the STE, the ATE computer, and the UUT interface [6]. Cables ending on interface drawer's rear panel permit side extension, if necessary. Each rack has a rear door permitting easy access to the inside. AC power is fed to the equipment through power manager UPS.

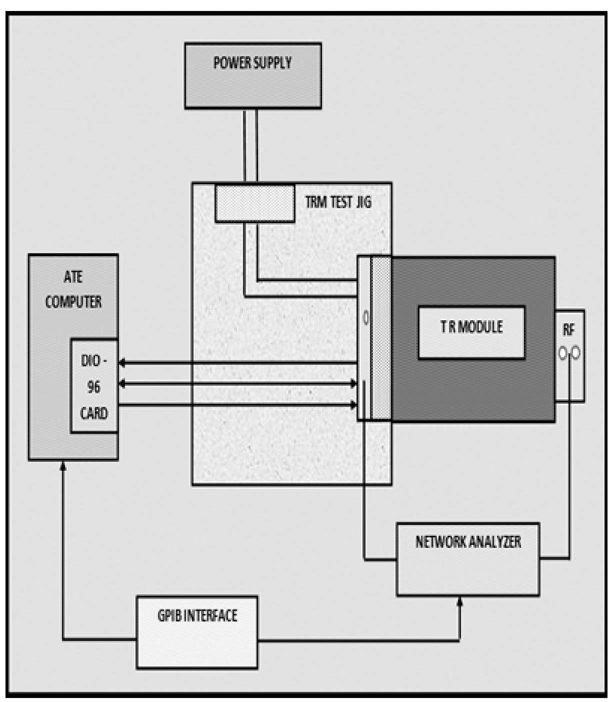

Figure 2: ATE Block diagram

2. DESCRIPTION

Fig. 2 is a Block Diagram of the ATE. The ATE (Automated Test equipment) software is used for the fault tolerant systems. The main application of the ATE software is to check whether all the modules of the RADAR system are working properly or not. The ATE software is developed in LabVIEW environment.

LabVIEW software is connected to the ATE software. ATE software contains GPIB card and DIO-96 card. Through GPIB card, Network Analyzer is connected to the transmit section of the unit under test (UUT). Port 2 is connected to the receive section. Communication is established between ATE software and unit under test (UUT) through DIO-96 card.

The GPIB or General Purpose Interface Bus is one of the more popular and versatile interface standards available today. GPIB is widely used for enabling test instruments to be controlled remotely. The GPIB is a very flexible system allowing data to flow between any of the instruments on the bus, at a speed suitable for the slowest active instrument. Upto Fifteen instruments may be connected together with a maximum bus length not exceeding 20m. Measurement and automation explorer (MAX) provides access to National Instruments products. Use Measurement & Automation Explorer (MAX) to do the following:

- Configure National Instruments hardware and software
- MAX is used to manage devices and interfaces.
- Back up or replicate configuration data
- Create and edit channels, tasks, interfaces, scales, and virtual instruments
- Execute system diagnostics
- View devices and instruments connected to system.

Network analyzer instrument is connected to the ATE computer via GPIB cable. In the ATE computer MAX software is installed. In the Measurement & Automation Explorer software under the device and interface window if we click the scan for device button, it will automatically scan for the devices that are connected to ATE software via GPIB cable, and provide us the primary address of the instruments.

With NI DIO 96 CARD, the computer can be used as digital I/O system controller for laboratory testing, production testing, and industrial process monitoring and control. Main purpose of the DIO 96 card is to communicate b/w the ATE software and TR module. It is having 96 bidirectional I/O lines divided as 12 ports. Each port supports 8 I/O lines. Here ports 0, 1 and 2 are used. Ports 0 and 1 are used as data ports. Port2 is used as control port.

Hardware Requirements for ATE.

- NI DIO-96 card
- GPIB 488.2 card, GPIB cable
- Network Analyzer Agilent E8362B.

Software Requirements for ATE.

- LabVIEW 8.6 version.
- Measurement and automation explorer 4.5 version.
- Instrument Driver for Agilent e8362b network analyzer.

2.1. ATE Functions and Interface

The ATE supplies the required operation voltages, control signals and RF signals to the UUTs and performs the following functions:

• Supply of operation voltages, communication and excitation to the UUT.

• Supply of the cooling required by the UUT.

• Performing serviceability checks to the UUT.

• Analysing test results.

The ATE comprises all the power supplies and RF signal source required for operating the UUTs. During test, the ATE supplies the input signals and control signals to the UUT. The ATE tests the UUT response via the measuring instruments installed on the ATE racks.

All RF signals from/to the UUTs pass through the dedicated drawers that route the RF signals from the UUT to the standard instruments and vice versa.

2.2. ATE Tests

An Acceptance Test Procedure (ATP) available for each unit tests all the functions pertaining to the UUT. The overall test of the unit is divided by appropriate test programs to sub-tests each pertaining exclusively to the UUT.

The user has the ability to run the sub-tests separately, to select part of the tests or select all the tests, i.e. to run a full ATP. The ATE software enables easy operation of the ATE, using a set of screens. Operator intervention is accomplished using a mouse and a keyboard.

3. TRM–A TYPICAL UUT

The T/R Module, which forms the basic building block of the radiating system, performs the following functions.

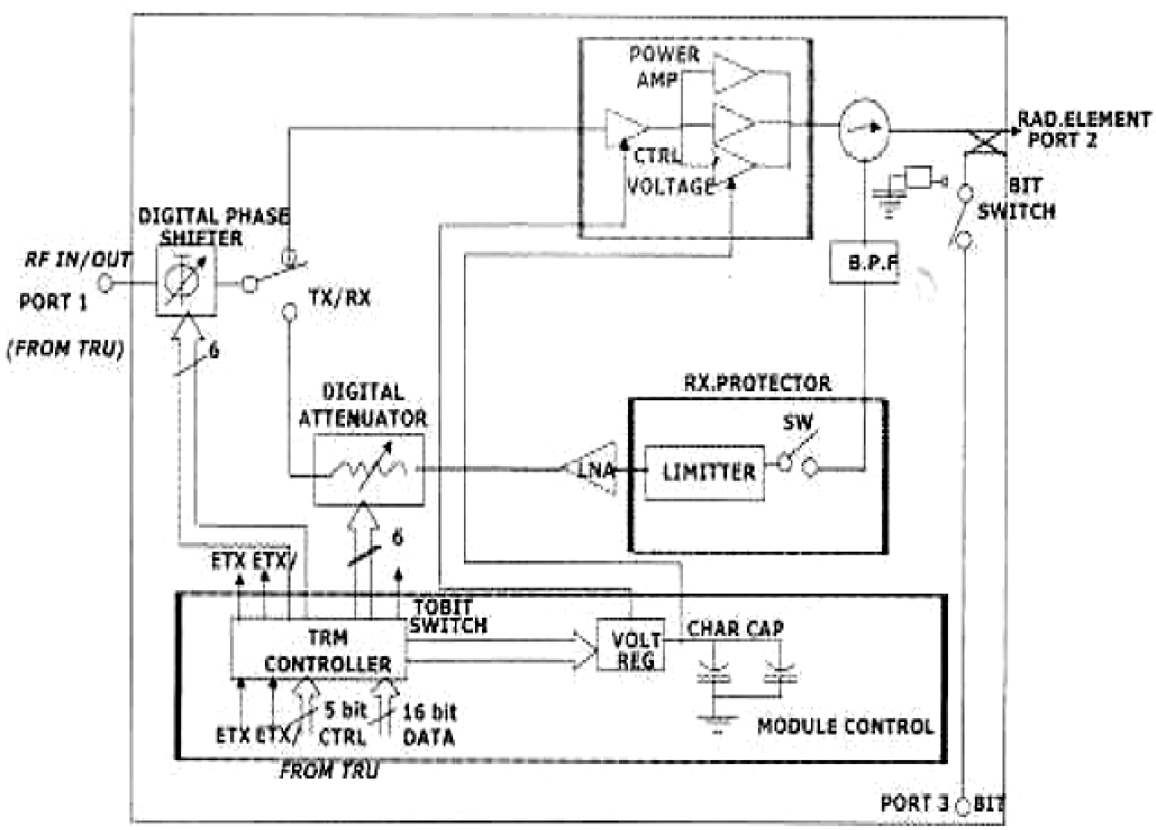

Figure 3: TRM Functional Block Diagram

- Power Amplification during Transmission.
- Phase Shift Control during Transmit & Receive.
- Low Noise Amplification during receive.
- Transmit/Receive Switching.

Each T/R module in the radiation system gives 100 watts of output power. The output powers of all the T/R modules are combined in space to get the required transmit power in the desired direction.

The T/R module consists of transmit and receive sections, of which some of the elements are common for both transmit and receive.

The TRM functional block diagram is shown in Fig. 3. The module is designed to be a shop replaceable unit inside the Transmit/Receive Controller [7].

The T/R module transmit section consists of

- 6 Bit phase shifter
- Tx/Rx switch
- Driver Amplifier
- Power Amplifier
- Circulator and
- BIT coupler

The Receive section includes

- Band Pass Filter
- Power Divider/Combiner
- Limiter
- Low Noise Amplifier and
- 6 Bit digitally controlled attenuator

The Phase shifter, Tx/Rx Switch, Circulator and BIT coupler are common for both Transmit and Receive sections.

The pulsed RF signals for transmission enters transmit section from the T/R controller. The phase shifter will shift the phase of the input signal. The driver amplifier drives the two succeeding amplifiers connected in parallel. The circulator will isolate the Rx channel from the high transmit power and will also stop the reflections back to the power amplifiers. The TRM output power is radiated through the radiating element.

The returned echo signal is received by the radiating element and the circulator will send the signal through the receiving channel. In the receive channel, the signal is first sent through a band pass filter to eliminate the unwanted RF signals. Then the signal is power divided in a quadrate power divider, to account for the limited power handling capacity of the following stages and separately amplified in two identical LNAs. The ATE is being designed and developed for testing the various functional blocks of TRM.

Active Phased Arrays use individual solid-state T/R microwave module element at each of its radiating element (antenna), thus avoiding the distribution and phase shifter losses encountered in the Passive Array design. For the same radiated power, Active Phased Array Systems have been found to be significantly efficient, smaller and lighter than the conventional Passive Array systems. Need to generate very large power to obtain large power aperture product for long-range surveillance can be satisfied only with Active Phased Array Systems utilizing Active Aperture Array techniques [9].

T/R modules set up system performance in a phased array. Their main three functions are to boost output power of the transmitted signal up to its final radiated power, establish system noise figure for receive, and provide beam steering control [10].

4. TRM TEST PROGRAM

The ATE (Automated Test equipment) software is used for the fault tolerant systems .The main application of the ATE software is to check whether all the modules of the RADAR system are working properly or not. The ATE software is developed in LabVIEW environment [5]. ATE software communicates with different software and hardware while knowing the status of the different RADAR modules.

Login page is used for the security purpose. Only authorized user has the access to the ATE software page. i.e. if both the username and password is correct then login page will lead you to the ATE software page. Fig. 4 is a picture showing the ATE login page. Here ATE Software is communicating with the LabVIEW software. For sending the data from ATE software to LabVIEW software UDP socket programming is used [3]. LabVIEW software is remotely located. First ATE sends the device Id for the TRM device to the LabVIEW software by clicking on the device that we need to test. LabVIEW software must be running before the ATE software is run. When LabVIEW software receives the device ID, it comes to know that ATE software is requesting the test packets for the specified device. If the device id sent from the ATE software is 0x8000, LabVIEW Software sends the five different TRM test packets in the duration of 1

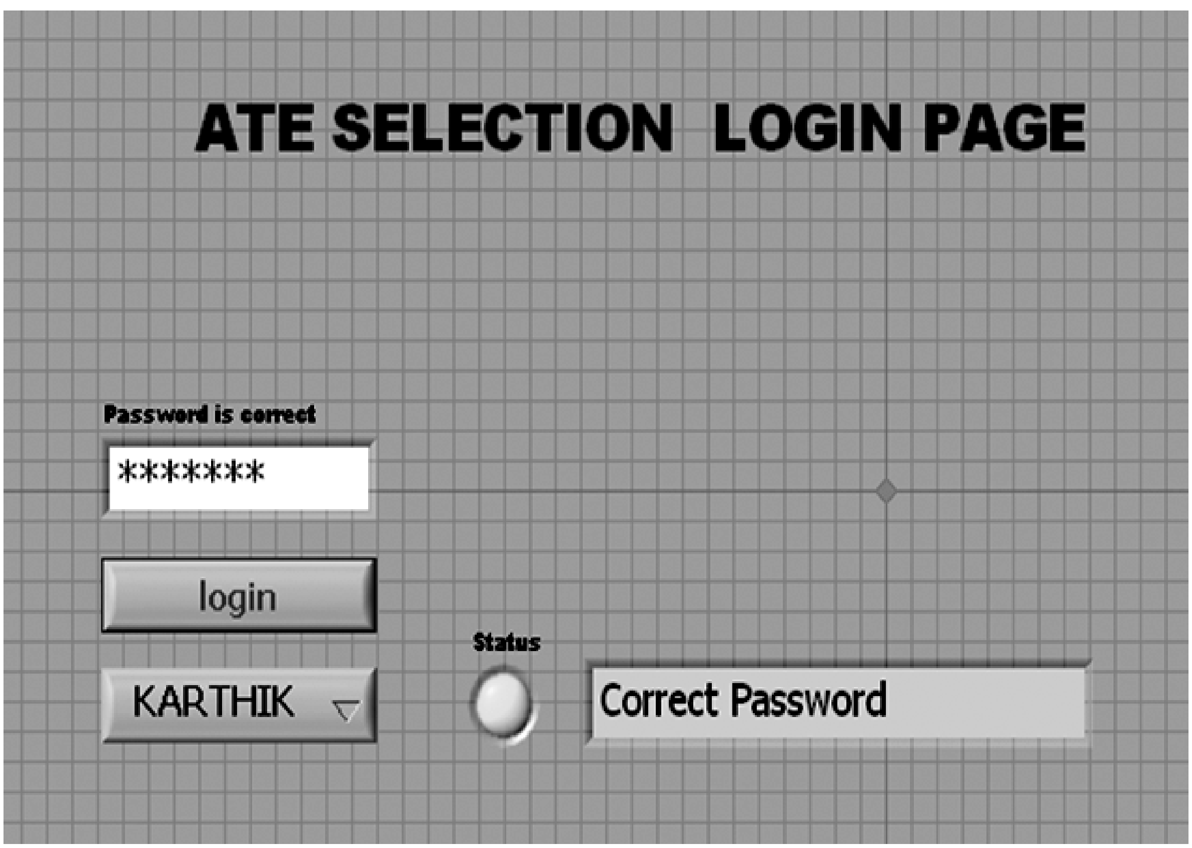

Figure 4: ATE Login Page

second. There is unique device id for the device. For TRM device, the unique id is 0x8000. The length of the data received in the ATE is 512 bytes.

Under TRM functionality test, the following tests are carried out.

- Gate Array Test
- Short Receiving Test
- Full Receiving Test
- Bit test

4.1. Gate Array Test

During the gate array test, the program will write 16 bit words to the TRM gate array ports, AB and CE and read back from those ports. Four different words are written to each port. If the written and read values are same, the gate array is qualified.

4.2. Short Receiving Test

Under short receiving test, two different measurements are performed at the centre frequency ("Fc" MHz) of the operating frequency band.

- Measurement of all phase step values (5.6, 11, 22 ……357°) @ 0 dB attenuation.
- Measurement of all attn. Step values (0.5, 1, 2 ……31.5 dB) @ 0° phase.
- Measurement of receive channel gain for minimum gain point, maximum gain point and at "Fc" MHz for 0 dB attenuation.

If these values are within the limits, the module is qualified in the short receiving test. Under the full receiving test, both the above tests will be performed at three different frequencies.

4.3. Full Receiving Test

In the full receiving test, the program performs the following measurements of the receive channel at three spot frequencies (F1 MHz, Fc MHz and F3 MHz).

- Measurement of all phase step values (5.6, 11, 22 ……357°) @ 0 dB attenuation.
- Measurement of all attn. Step values (0.5, 1, 2 ……31.5 dB) @ 0° phase.

4.4. Bit Test

In Bit Test, test is performed to monitor the sampled power received in the RX channel during the time of transmission. When the BIT Switch is in open position the Isolation is measured between the Transmit section and the Receive section and is 44 dB. When the BIT Switch is in closed position the coupling between the transmitted and the receiving section is measured and is between 19 +/- 3 dB. The ATE computer will indicate Pass/Fail based on the measured results obtained.

4.5. TRM Test Result

At the end of the test, the TRM status appears in a window as either PASS or FAIL and saves the test report before viewing. This enables the operator to view/print the report at a later stage by clicking on the history button. Before exiting the program, view/print the test results. Fig. 5 is a TRM Test report window.

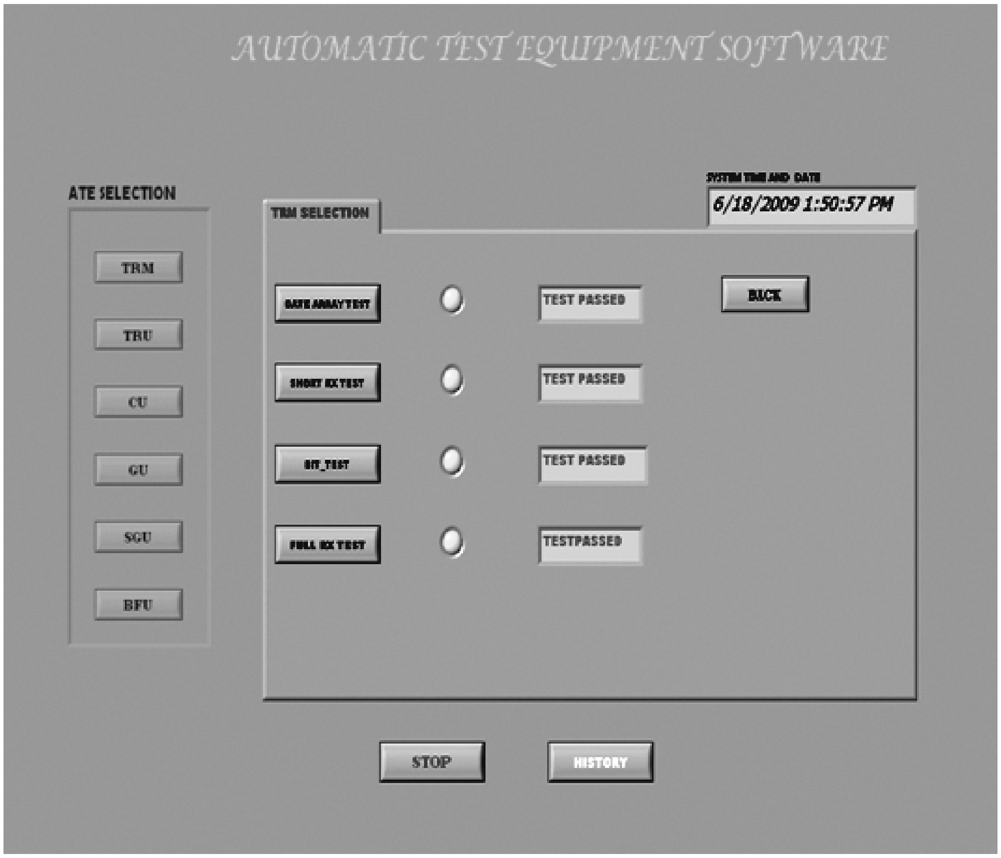

Figure 5: TRM Report Window

5. TEST RESULTS

5.1. Gate Array Test

Sl. No.	*Tested G.A.*	*Test 1*	*Test 2*	*Test 3*	*Test 4*	*Status*
	Expected Result	55AA	FF00	FF	AA55	
1.	TRM PORT AB CS1	55AA	FF00	FF	AA55	PASS
2	TRM PORT CE CS2	55AA	FF00	FF	AA55	PASS

5.2. Short Receiving Test

Phase Shifter Test (Deg.) Attenuators @ 0 dB

Phase shift in Deg		*Ref*	*5.6*	*11*	*22*	*45*	*90*	*180*	*Status*
Phase	Low Limit		4.2	10.00	21.0	46.0	93.0	186.0	
	@Fc MHz	N.A.	4.96	11.21	23.8	47.9	96.3	191.5	PASS
	High Limit		8.50	15.00	27.0	52.0	102	197.0	

Attenuators Test (dB.) Phase @ 0 Deg

Attenuation in dB		*Ref*	*0.5*	*1.0*	*2.0*	*4.0*	*8.0*	*16.0*	*Status*
Atten.	Low Limit		0.3	0.7	1.6	3.4	7.3	14.8	
	@ Fc MHz	N.A.	0.59	1.08	2.00	4.20	7.80	15.1	PASS
	High Limit		0.8	1.4	2.4	4.5	8.8	17.3	

5.3. Full Receiving Test

Phase Shifter Test (Deg.) Attenuators @ 0 dB

Phase shift in Deg	*Ref*	*5.6*	*11*	*22*	*45*	*90*	*180*	*Status*
Phase Low Limit		4.0	9.60	20.5	44.0	88.0	178.0	
@ F1 MHz	N.A.	6.26	12.05	24.9	48.5	96.8	185.6	PASS
High Limit		8.0	14.50	26.0	50.0	98.0	188.0	
Phase Low Limit		4.2	10.00	21.0	46.0	93.0	186.0	
@ Fc MHz	N.A.	6.52	12.50	25.9	50.3	100.7	192.7	PASS
High Limit		8.50	15.00	27.0	52.0	102	197.0	
Phase Low Limit		4.4	10.50	21.5	48.0	96.0	193.0	
@ F2 MHz	N.A.	6.93	13.00	27.0	52.3	104.5	199.8	PASS
High Limit		9.00	15.50	28.0	56.0	106	205.0	

Attenuators Test (dB.) Phase @ 0 Deg

Attenuation in dB	*Ref*	*0.5*	*1.0*	*2.0*	*4.0*	*8.0*	*16.0*	*Status*
Atten. Low Limit		0.3	0.7	1.6	3.4	7.3	14.8	
@ F1 MHz	N.A.	0.59	1.08	2.12	4.20	7.80	15.1	PASS
High Limit		0.8	1.4	2.4	4.5	8.8	17.3	
Atten. Low Limit		0.3	0.7	1.6	3.4	7.3	14.8	
@ Fc MHz	N.A.	0.65	1.28	2.24	4.19	7.9	15.7	PASS
High Limit		0.8	1.4	2.4	4.5	8.8	17.3	
Atten. Low Limit		0.3	0.7	1.6	3.4	7.3	14.8	
@ F2 MHz	N.A.	0.74	1.35	2.31	4.39	8.4	16.2	PASS
High Limit		0.8	1.4	2.4	4.5	8.8	17.3	

5.4. BitTest

Frequency [MHZ]	*F1*	*Fc*	*F2*	*Status*
Isolation Exp.>44 dB	53.3	54.9	59	PASS
Coupling Exp.19+/-3 dB	17.9	18.1	18.3	PASS

6. CONCLUSION

The test system described in this paper was designed for testing active solid-state microwave modules and circuit subassemblies used in the Active Phased Array Radar. The large number of measurements and limit comparisons required on each module to insure optimum system performance are made automatically in a minimum amount of time with standard laboratory accuracy. The test features of the system are summarized as follows.

1. Amplitude and phase is measured automatically.
2. System errors are measured periodically, stored, and applied as corrections to the measured data as and when required.
3. Test parameters are automatically compared to unit-specification limits, as well as reference standard (unit-to-unit) limits.

4. Input power is set automatically at the source using GPIB command prior to each test.

Many of the test system concepts developed and used on this program are being applied to other similar programs, and will be useful as well in future test systems.

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