TESTING OF A MULTICHANNEL SATELLITE TRANSPONDER USING AUTOMATIC TESTING EQUIPMENT (ATE)

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Abstract

This paper deals with the complex problem of testing the performance of a multichannel satellite transponder using automatic test equipment. The paper includes a summary of the factors which determine the use of an automatic test facility and the important considerations in fixing hardware and software requirements. Some of the peculiarities and possible sources of error using automatic test equipment for R.F. Microwave measurements are discussed and typical measurement results are presented.

Introduction

As the number of channels in communications satellites is increased, the number of pre-launch performance tests increases proportionally. When this is coupled with tighter schedules and the need for accurate, repeatable tests an attractive solution is to use automatic test equipment. The evaluation of both hardware and software requirements is a very critical factor when considering the tests to be conducted, the measurement method to be adopted, and the interface equipment required. A clear awareness of the limitations and sources of error must be understood to get maximum utility for an Automatic Test Equipment Facility (ATEF).

The Transponder and its Test Requirements

Multichannel Satellite Transponders.

The main element of a satellite communication system is a transponder. The transponder is essentially a space borne microwave repeater, receiving signals at uplink frequency from earth and retransmitting at downlink frequencies after filtering, down converting and amplifying. Figure 1 shows a block diagram of a typical multi-channel satellite transponder. The receiver is connected to the antenna subsystem via an orthoplexer, which enables the same antenna to be used for both receiving and transmitting signals at different frequencies and polarizations. The receiver is usually a single hetrodyne design with a wide band filter followed by a low noise preamplification stage (typically a FETA, Transistor Amplifier or driver TWTA). The rest of the transponder consists of channel by channel filtering input multiplexer, individual channel travelling wave tube amplifiers and channel combining output multiplexer. The connections to the transmitting antenna are through a wide band output filter assembly and the same orthoplexer as at the receiver

Test Requirements

Unlike production testing of a single component, a multi-channel transponder requires a great variety of tests, each with its own Test Setup. Table 1 shows a typical test matrix where the transponder performance tests are listed along with the environmental conditions, test methods and comments on test equipment used. For a typical twenty-four (24) channel transponder there are well over 2000 RF measurements to be conducted. The tests fall into different catagories. There are tests which involve one RF input signal ard they are done on a per channel basis; these include small signal gain, noise figure, saturated gain, phase shift and power output. There are a second series of tests which involve more than one input signal and these include: Intermodulation, crosstalk and spurious tests. In addition, some measurements results require the knowledge of both phase and amplitude information (e.g., phase shift) while most other tests only require amplitude information (e.g., small signal gain). The former test requires the use of a network analyzer while the results for the latter can be obtained by using the power meter or spectrum analyzer The selection of the test equipment and test procedure is determined by accuracy, speed and repeatability considerations. The environmental conditions essentially require repetition of a particular parameter measurement test over variations of temperature, operating voltage and applied R.F. level.

Hardware/Software Requirements

Hardware Requirements

Figure 2 shows the ATEF installation; included in the picture is the test equipment used both for interface and measurement purposes. Each of these units can be operated in a manual or automatic mode. There are many manual operations which are faster than automatic procedures. For instance, the human eye can scan a screen much faster than a computer controlled program. Therefore, before any test procedure is finalized, a careful evaluation of the steps involved in each test must be made to decide which operations are to be computer controlled, which are to be manual and which are to be semi-automatic. For example, the tests for saturated gain and output power group delay can be done in a semi-automatic manner more efficiently than using a completely automated method.

Computer Requirements

The assorted automatic test equipment is compatible for control by a mini-computer. For illustration purposes, the computer used in this presentation is an HP 2100S model which has an available core of 32K bits. The I/O peripherals include: Magnetic tape, cassette read/write deck, paper tape read/write unit, CRT screen with cursar, thermal printer, disc unit, and Versetek printer and plotter.

Software Requirements

Figure 3 shows a flow chart with the decisions which should be made when evaluating the software requirements for ATEF testing.

Some software guidelines are:

- Make sure the number of interacting modules does not become excessive.
- Choose most efficient programming language based on compiler and storage limitations.
- Design programs so they can be easily modified or re-programmed.
- Design program modules so they can be tested separately.
- Keep good documentation on program development and revisions.
- Use common subroutines as often as possible.
- Make allowance for debugging programs while measuring actual device under test (DUT)

Typical Test Results

Some typical transponder test results using a selection of the automatic test equipment are presented. Figure 4 shows the test results obtained by using the automatic network analyzer (ANA) coupled with the frequency translation unit (FTU) to measure input power versus phase. Figure 5 shows the results of a small signal gain measurement over one channel of a communications transponder. This test was done using the automatic spectrum analyzer (ASA). Finally, Figure 6 shows an amplifier saturation curve of input power versus output power which was obtained using the automatic power meter as the measuring device (APM). Environmental and status information present on these results is necessary for recording the multitude of test conducted.

Measurement Limitations, Peculiarities and Sources of Error

All measurement equipment has limitations, peculiarities and error sources which can and should be corrected for, and an ATEF is no exception. Some of the typical hardware/software error sources are:

- Tracking errors.
- Crosstalk between test equipment.
- Errors in interface mismatches.
- Errors in component directivity
- Voltage and frequency drift in equipment.
- Noise Sources - thermal, impulse, spurious signals.
- Quantization errors due to A/D conversion.
- Measurement resolution.
- Repeatability of switches and connectors.
- Calibration and stability of standards.
- Detector non-linear operation.

Some of the above errors are hardware dependent, some are time dependent. Many can easily be corrected by using calibration tables or by using a model to compensate for performance.

There are some peculiarities of automatic test equipment which can be mentioned. Since an ATEF is computer controlled, test results can be printed to almost any number of significant figures. Care should be used in printing only meaningful digits. Many times, graphs may appear to be jagged because of small quantization errors or too few points plotted. These graphs should be smoothed and certain measurements should be repeated and averaged to eliminate errors due to noise.

Conclusion

An overview of some of the aspects of automatic testing for measuring multi-channel transponders has been discussed and some sample test results have been presented. With proper maintenance, organization and planning, the many measurements that are required can be done accurately and efficiently by following the above guidelines.

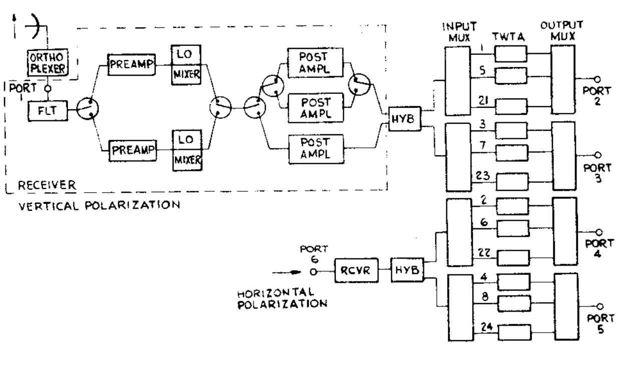

Figure 1. Satellite Transponder Block Diagram

TEST	ENVIRONMENTAL CONDITIONS	NUMBER ** OF MEASUREMENTS	DESIRED ACCURACY	COMMENTS
INPUT VSWR	AMBIENT TEMPERATURE & VOLTAGE	2	± .05	USING GENERAL PURPOSE PROGRAM PACKAGE
OUTPUT VSWR	AMBIENT TEMPERATURE & VOLTAGE	4	± .05	USING GENERAL PURPOSE PROGRAM PACKAGE
NOISE FIGURE	TEMPERATURE & VOLTAGE EXTREMES	288	± .5 dB	MANUAL CORRECTION FOR NOISE SOURCE ENR
SATURATED GAIN AND POWER OUTPUT	TEMPERATURE & VOLTAGE EXTREMES	288 96	± .1 dB ± .1 dB	MANUAL OR AUTOMATIC CORRECTION FOR TIU LOSSES
PHASE SHIFT	TEMPERATURE EXTREMES	288	± .2 dB	USING A.N.A.
SMALL SIGNAL GAIN	AMBIENT TEMPERATURE & VOLTAGE EXTREMES	288	± .1 dB	USING A.S.A. & AUTOMATIC POWER METER
GROUP DELAY	AMBIENT TEMPERATURE & VOLTAGE EXTREMES	96	± 1 ns	SPECIAL CALIBRATION REQUIRED FOR FAR FIELD TRANSPONDER MEASUREMENTS
SPURIOUS OUTPUTS	AMBIENT & TEMPERATURE EXTREMES	100	70 dB	USING A.S.A. WITH 110 dB DYNAMIC RANGE.
AMPLITUDE LINEARITY (Third Order Intermod)	AMBIENT & TEMPERATURE EXTREMES	288	± .5 dB	USING A.S.A. FOR THREE DIFFERENT INPUT CONDITIONS
FREQUENCY STABILITY	AMBIENT & TEMPERATURE EXTREMES	4	1 ppm	USING A.S.A.
CROSSTALK	AMBIENT & TEMPERATURE EXTREMES	576	± .5 dB	USING A.S.A. & SPECIAL TEST EQUIPMENT FOR CROSSTALK MEASUREMENTS

** FOR A TYPICAL TWENTY-FOUR (24) CHANNEL TRANSPONDER.

Table 1. Transponder Performance Test Matrix

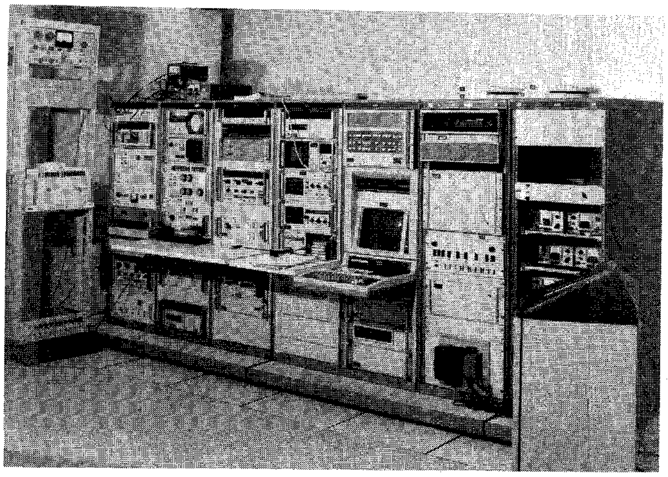

Figure 2. Automatic Test Equipment Facility.

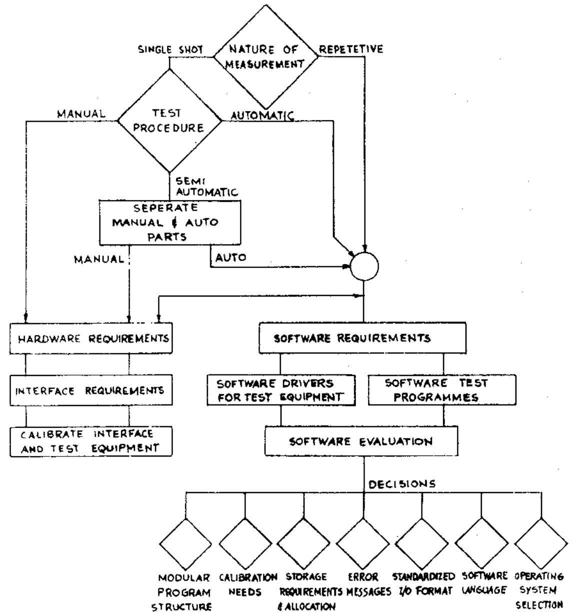

Figure 3. Testing Program Development Flow Chart;

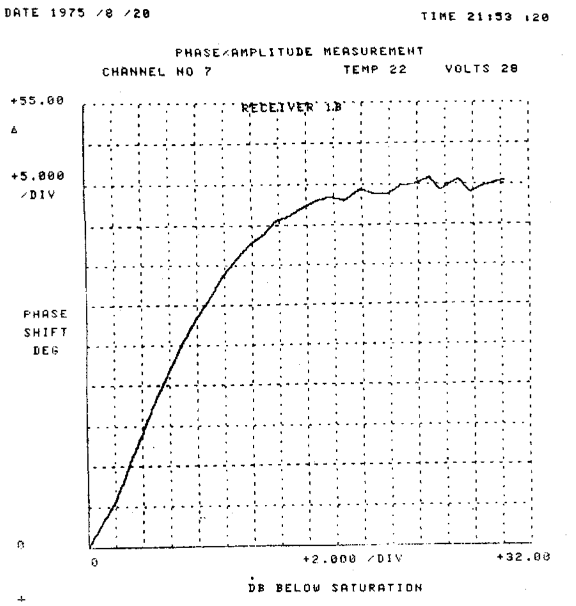

Figure 4. Input Power versus Phase.

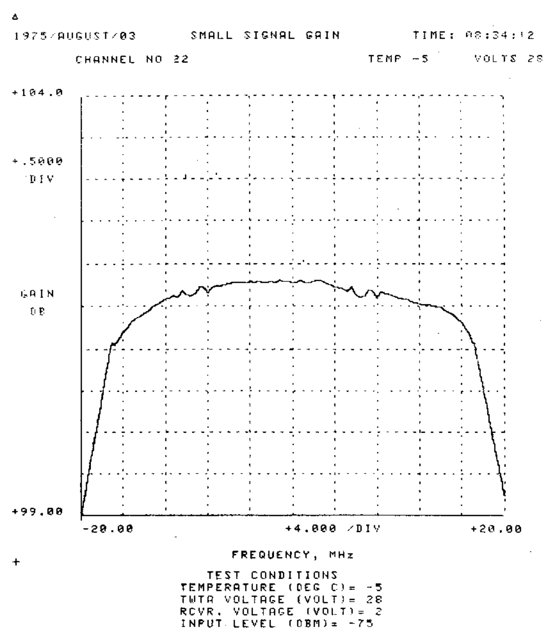

Figure 5. Small Signal Gain versus Frequency.

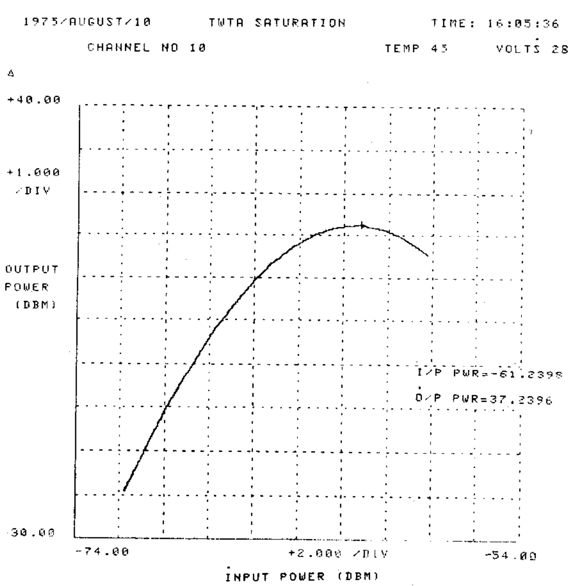

Figure 6. Input Power versus Output Power.