COMPUTER ASSISTED RF PERFORMANCE TESTING

Jack Koscinski
Director of Product Engineering

Dan Earley
Staff Engineer

Warner Amex Cable Communications Inc
Plainfield, NJ

ABSTRACT

Evaluating the RF performance parameters of CATV products can be quite cumbersome. Some of the major performance parameters are: gain, flatness, return loss, noise figure and distortions. Certain distortion tests such as composite triple beat, cross-mod and second order are especially time consuming and require a high level of operator skill to interpret the desired data accurately.

The introduction of RF computer controlled test equipment has made it possible to perform all of the above RF performance tests automatically under the supervision of a controller. The test programs (software) can be written in a high level language such as "BASIC", thus enabling expedient program development.

This paper describes the equipment requirements and test methodology used in implementing such a test station at Warner Amex to facilitate RF product evlauations.

INTRODUCTION

Computer assisted RF proof of performance testing capability has been available for some time now. The advent of the Hp 8568A Spectrum Analyzer in 1978 was instrumental in providing this capability. I. Switzer described the merits of this spectrum analyzer in a previous NCTA paper "The Spectrum Analyzer As A Computerized Proof of Performance Machine" (1).

Magnavox's Mobile Training Center has incorporated an impressive computer controlled RF proof of performance test system utilizing the Hp 8568A Spectrum Analyzer, Matrix ASX-16 Signal Generator, and the Matrix AR-12 Distortion Receiver. This RF test system is controlled by an Hp Computer and performs system sweep response, carrier/noise, and composite triple beat measurements.

Warner Amex has recently established a Product Engineering department whose function is primarily concerned with product evaluations of all CATV products. To support this activity Warner has implemented a product evaluation facility that is equipped to perform comprehensive performance evaluations on most of the CATV products used in its systems.

Taking advantage of the availability of computer controlled test equipment, Warner Amex has developed an automated RF test system that performs many of the RF performance tests. Among the tests presently automated are gain, response, composite triple beat, cross-mod, second order and noise figure.

The objective of this paper is to describe this RF test system implementation and review some of the testing considerations that led to the selection of the specific equipment in this set-up.

RF PERFORMANCE TESTS: SELECTION AND CONSIDERATIONS

The initial step in the development of the RF test system was to establish the main RF testing objectives. Which RF tests should be performed? What degree of automation should be implemented?

The main application of this RF test system is to perform new product acceptance tests on CATV products. Amplifiers, set-top converters and CATV passives such as multi-taps, traps, etc. are the principle products to be evaluated.

A synopsis of the major RF tests and associated testing considerations are presented below. Conventional test problems are identified to highlight the areas that an automated system may alleviate.

Gain/Response

Gain and response measurements are key tests for most CATV products. These measurements are performed using conventional sweep techniques. An important consideration in gain/response testing is to anticipate the requirement for testing a converter type product. Converters translate the input frequencies to different output frequencies and thus require a broadband detector to accurately display the response. Unfortunately, dynamic range is sacrificed in using a broadband detector. A technique that provides excellent dynamic range utilizes a tracking generator and spectrum analyzer but this equipment cannot test converters because the generator and spectrum analyzer (receiver) track each other at the same frequency.

A solution is to utilize a signal generator to sweep thru the input frequency range and store the output response on a spectrum analyzer by using the storage mode. This technique provides good dynamic range and frequency translation compatibility.

Return Loss

Return loss measurements typically are performed using a bridge and reference termination. The 0dB return loss reference is established by applying a short or open to the test port on the bridge. Then the unit under test is connected and the difference between the reference and test response is the return loss.

Unfortunately the reference response is not normally flat and therefore interpretation of the return loss is tedious. An equipment/system feature that provides an (A-B) mode can cancel out the reference ripple and thus provide a flat reference for measurement ease and accuracy. This feature could be performed by the equipment directly or a controller can provide this mathemathical operation.

Composite Triple Beat (CTB)

Distortion measurements are cumbersome tests to perform manually. There are numerous channels and signal level combinations that could be tested. Automation of composite triple beat testing is one of the principle justifications for implementing a computer assisted RF test system.

A popular approach for measuring CTB utilizes a multi-channel signal generator and spectrum analyzer. The spectrum analyzer may also generate distortion and thus a filter must be used to eliminate all channels except the desired from reaching the spectrum analyzer full strength.

An alternative approach to CTB measurement utilizes the Matrix AR-12 Distortion Receiver. The AR-12 consists of a tuned receiver and AM detector that detects CTB components within ± 17.5KHz of the carrier.

A precaution should be understood when testing CATV converters. Converters commonly have some residual FM on the output frequency. This is especially true of converters that use LC oscillators. This residual FM may be converted to AM in the highly selective input filter of the AR-12. The CTB detector would interpret any AM within its bandwidth as a CTB component. A solution consists of bypassing the AR-12 filter and employing an external single channel SAW filter.

Cross-Modulation

Cross-modulation tests have been of less interest with the advent of equipment operating with greater than 36 channels. Nevertheless, it should be anticipated in a comprehensive test system. Several products such as CATV converters have been recognized to be distortion limited by cross-mod rather than CTB. This is probably due to the second mixer providing significant contribution to the total distortion.

A common error is sometimes made in cross-mod measurements. The cross-modulation is measured with a spectrum analyzer directly by comparing a 100% modulated signal (reference) to the resultant modulation (distortion) when the reference modulation is removed.

The spectrum analyzer display should not be used directly for the measurement because the display consists of all cross-modulation components (AM and PM). Since the TV receiver is an AM detector, only the AM components of cross-mod should be accounted for.

There are two popular approaches to perform this type of cross-mod measurement. First, the spectrum analyzer can be used as an AM receiver with the AM detected signal output supplied to a wave analyzer. A comparison can then be made between 100% reference modulation and resultant cross-mod. The second approach utilizes the Matrix AR-12 Distortion Receiver where the Matrix AR-12 incorporates a commutative filter processor that provides measurement capability of greater than 100dB.

Carrier/Noise

Carrier to noise measurements are important on their own but they can also be used to provide noise figure measurements. A reference calibrated noise source and a power measuring instrument such as a spectrum analyzer are required for the noise figure tests.

DESCRIPTION OF SYSTEM EQUIPMENT

Once the RF test objectives and considerations were identified an RF system design plan was developed. Most of the equipment required was off the shelf except for the Matrix Signal Generator and Distortion Receiver.

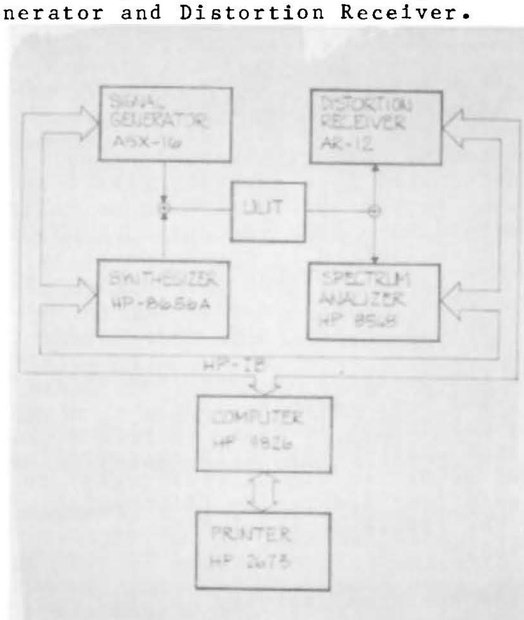

Fig. 1 RF Test System Block Diagram

Although Matrix has provided computer controlled versions of this equipment to several customers each of them tends to be somewhat custom. Warner developed a specification to define the required features and functions necessary for the RF product evaluation application.

The computer assisted RF test system block diagram and equipment are shown in Fig. 1 and 2. The major components are:

- Computer Hp 9826
- Signal Generator : Hp 8656 A
- Multi Channel : ASX-16 Signal Generator
- Distortion Receiver : AR-12
- Spectrum Analyzer : Hp 8568
- Printer Hp 2673

Communications to and from each piece of equipment is supervised by the Hp 9826 computer controller using the HP-IB interface bus. A functional description for each of the main equipment in this system is discussed below

Computer; Hp 9826

The Hp 9826 (Fig. 3) is a powerful tool for measurement automation. It is friendly, easy to use and offers uncomplicated program development. The Hp 9826 is an integrated package with built in CRT and a single floppy disk. A choice of three programming languages are available. There's Hp enhanced

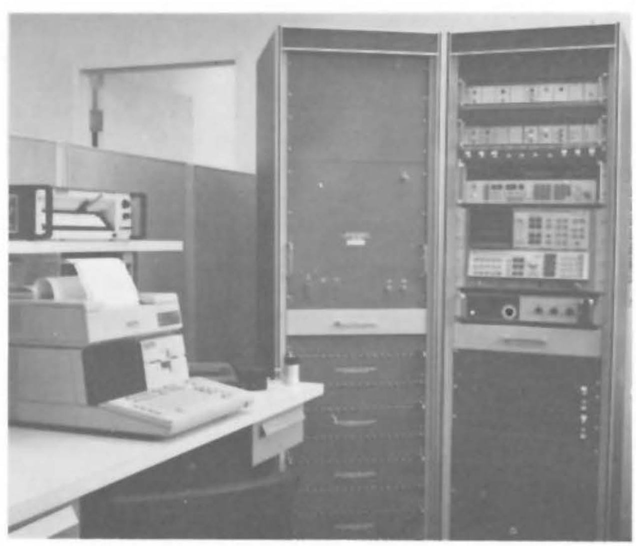

Fig. 2 RF Test System

Fig 3. Hp 9826 System Controller

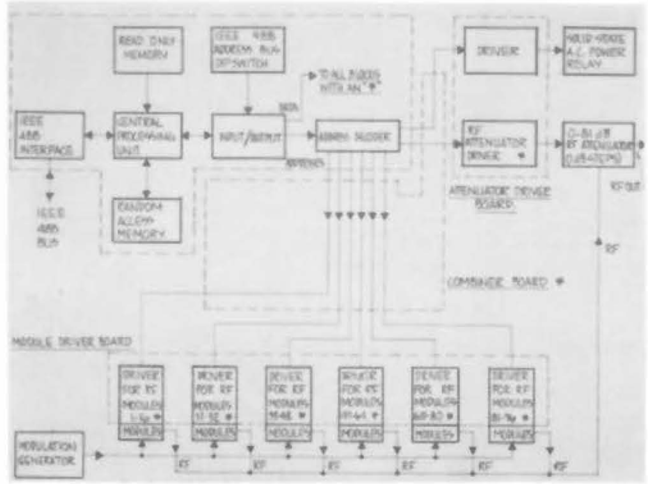

Fig. 4 ASX-16 Signal Generator

Basic, HPL, and Pascal so one can match needs and programming experience with the right language. A standard feature is the HP-IB interface card. The HP-IB is a well defined general purpose digital interface system which simplifies the design and integration of instruments and computers into systems. All of the equipment in this test system utilize the HP-IB interface for communications with the controller.

Signal Generator: Matrix ASX-16

The ASX-16 is a multiple frequency signal generator which can be equipped with up to (100) crystal controlled modules. Each module can be individually turned on or off, modulated with a 15.75 KHz signal, set for CW (no modulation), and output leveled over a $\pm$ 5dB range. A final RF output attenuator may vary the combined channels over a range of 0 to 81dB in 1dB steps. There are 64 channels in this test system which span the range from 5 thru 440 MHz. Additional channels may be retrofitted at a later time if required.

Output levels up to 50 dBmV are available with all harmonics and intermodulation products below 100dB. A block diagram of the ASX-16 is shown in Fig. 4.

Distortion Receiver: Matrix AR-12

The Matrix Distortion Receiver is a multi-purpose device designed to perform cross-modulation and composite triple beat measurements automatically for any channel in the 5 to 440MHz bandwidth (64 channels). Additional channels above 440MHz are available from the manufacturer and may be retrofitted into the basic equipment if required at a later time.

The AR-12 receiver (Fig. 5) contains two detectors. For cross-modulation measurements a commutative filter processor is employed which provides a measurement range greater than 100dB.

Commutative filtering provides detection results comparable to synchronous detection without the accurate phase tracking requirement between the reference and test signals. Phase tracking can be a problem when performing distortion tests of an amplifier cascade with 16 to 20 amplifiers.

In the commutative filter approach a distortion generator detects the modulation components and uses this resultant signal to synchronize a narrow band commutative filter and peak detector.

Composite triple beat measurements are made using a composite triple beat processor. The processor bandwidth is 17.5 KHz and the detector measures the RMS value of the distortion. A high

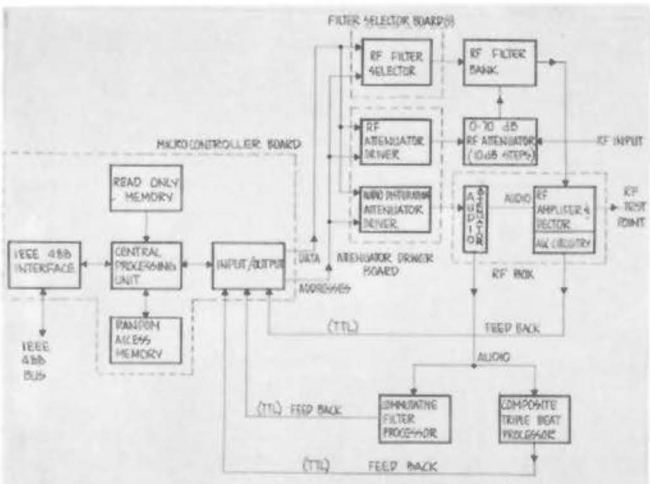

Fig 5. AR-12 Distortion Receiver

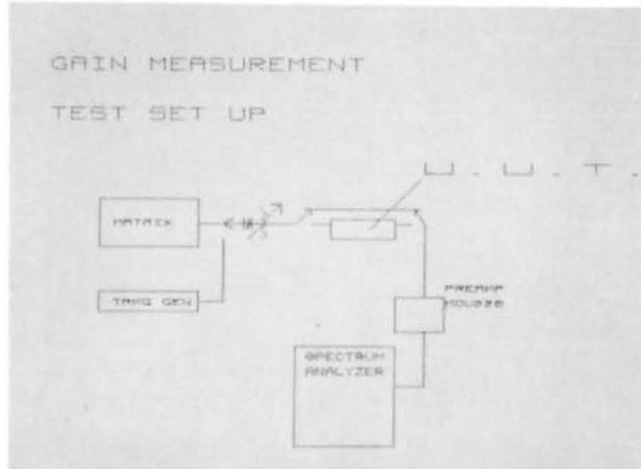

Fig. 6 Gain Test Block Diagram

pass filter near the low end of the band can be added if hum problems are masking the real CTB distortions.

Spectrum Analyzer; Hp-8568

The Hp 8568 Spectrum Analyzer provides unprecedented precision, range, and capability in RF spectrum analysis. All the essential front

panel control settings may be programmed via the HP-IB. Programming codes are powerful, very user friendly and provide for interactivity with the operator.

One of the most powerful features of the analyzer is the marker functions. A marker can be tuned to a particular signal with the amplitude and frequency automatically read out on the CRT screen. Additionally, a peak search can be activated that quickly places the marker on the peak signal of the display. Finally a delta marker mode is available that supplies two independent markers. The frequency and amplitude difference of the two markers is read-out on the CRT screen and may also be read-out onto the HP-IB bus.

User messages can be printed onto the spectrum analyzer screen from the computer thus providing titles for the data or prompts to the operator to perform a certain task. Equipment test set-ups may also be drawn on the CRT screen (Fig. 6).

Another very useful feature of the Hp 8568 is the trace storage (max hold) function. The largest amplitude occuring at each of 1001 horizontal points across the CRT screen can be stored and with a simple program this data can be dumped onto a printer. This feature is handy to use in conjunction with manual testing in that it provides a convenient hard copy without requiring photographs. Fig. 7 and 8 demonstrate this capability.

The Hp 8568 has proven to be a precious and valuable measurement resource. Even without using the bus programmability feature of the equipment, the performance and user features may justify the expense of this equipment over other non programmable analyzers. The front panel of the Hp 8568 is indeed a friendly face.

The performance of the Hp 8568 is unparalled. Some of the key performance specifications are listed below.

- 100 Hz to 1500 MHz Frequency Measurement Range
- 10 Hz to 3MHz Resolution Bandwidth in 1, 3, 10 sequence
- Noise Sidebands 80dB down 300Hz away (10 Hz bandwidth)
- 85dB Spurious Free Dynamic Range
- -85 dBmV to + 80 dBmV Amplitude Measurement Range

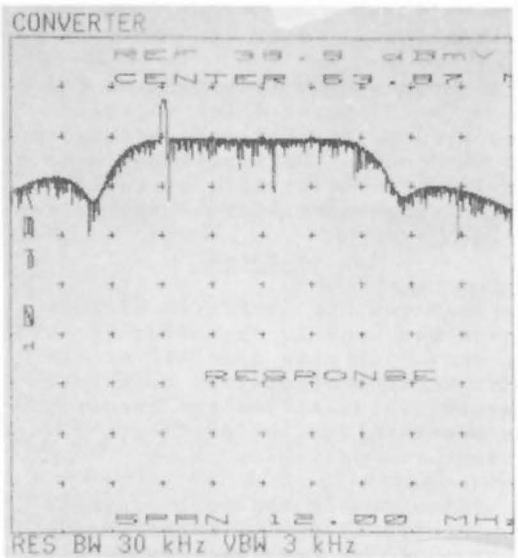

Fig. 7 Response Plot

- Counter Frequency Accuracy (1×10^{-9}/Day)
- Amplitude Accuracy ($\pm$ 1.5 dB)

SOFTWARE ASPECTS

The predecessor of the Hp 9826 computer was the Hp 9825 which utilized the HPL programming language. This language was quite efficient in producing fast test programs but was not as user friendly as "Basic". With the advent of the Hp 9826 computer, the "Basic" language is now available for developing effective computer test programs with the simplicity of a high level language.

Test programs are written in modular form which can be called out by a control program as required. All the test programs utilize a menu format and provide prompts and if, required, an explanation of how to set-up the equipment connections.

Operator interactivity is utilized whenever practical to avoid undue complication of hardware or software. For example, there may be a requirement to turn a unit off that is not normally bus controllable. The test program would pause and instruct the operator to perform this operation manually and then proceed with the measurement. Many items such as this arise once an automated system is implemented.

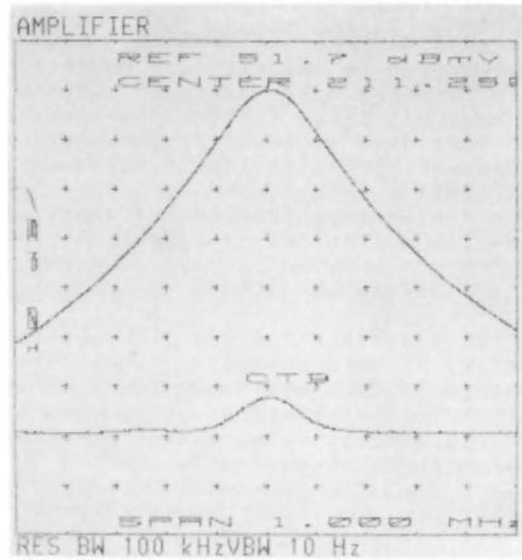

Fig. 8 CTB Distortion

Individual commands to the respective equipment are very simple and straight forward. The protocol consists only of an address (for the particular equipment) and a command (for the particular function).

BENEFITS OF THE COMPUTER ASSISTED RF TEST SYSTEM

This computer assisted RF test system has provided many advantages over conventional manual test methods.

Accuracy And Precision

Tests are performed accurately with the computer tirelessly providing the set-up conditions and taking the data. Precision is enhanced by the computer taking data with more significant figures. Computations may be performed in the computer prior to outputing the final answer thus eliminating data transfer errors.

Repeatability

Tests conducted using the computer enforce consistancy. The computer performs tests in the same sequence using the same set-up conditions as prescribed in the control program.

Operator Skill Level

Skill level of operator can be lowered once the test programs have been developed and debugged. Although test knowledge is important it is not as essential since the computer controls most of the testing. Operator interaction is desirable in certain circumstances. For example, a test program may pause and ask the operator to input data or identify the test parameter. Eliminating the operator interaction may require an extremely complicated test program and additional computer controlled equipment.

Data Analysis

An important feature of computer testing is data analysis. When large amounts of data are taken the computer can perform statistical operations to provide summary results such as worst case, range, average etc.

Speed

Obviously, the speed in testing improves tremendously. Consider the time required to set-up and perform CTB measurements manually for several channel loadings, several frequencies, and several different operating levels. Speed also promotes better characterization of a product. Prior to computer assisted testing, the CTB measurement would be sparsely sampled to confirm compliance. With a computer assisted test system a greater number of tests can be run in the same time, thus promoting better characterization of the product for CTB performance.

Documentation

The data from test results can be stored in computer files (disk), displayed on the CRT, and printed out for hard copy. Data printouts can be provided in easily interpretable form by the programmability of the system.

SUMMARY

This computer assisted RF test system has been in operation for about one year. At this time all of the major RF test objectives have been successfully realized and the system has been utilized to assist in several product evaluations.

Software for the test programs is continually being optimized and expanded to provide maximum versatility for testing the many different types of products required of the system. Program development has proven to be very friendly with the exceptional editing features and powerful commands of the system.

References

1. I. Switzer, "Spectrum Analyzer As A Computerized Proof of Performance Machine", NCTA Technical Papers, 1980.