SPECTRUM ANALYZER AS A COMPUTERIZED "PROOF OF PERFORMANCE" MACHINE

I. Switzer, P.Eng.,
Switzer Engineering Services Limited,
5840 Indian Line,
Mississauga, Ontario, L4V 1G2 Canada

ABSTRACT

The new Hewlett-Packard 8568A spectrum analyzer and associated computer controller and peripherals have been applied to the problem of automated field testing of cable television systems. The automated spectrum analyzer reduces testing time per test point from more than one hour to about 5 minutes. The test program emulates manual testing methods, but future development is expected to develop more optimum testing strategies. The system will be most valuable for testing new systems built under turn-key contracts and for technical audit of systems, particularly in cases of change of ownership. It is expected that automated video waveform testing will be introduced within a year.

The spectrum analyzer is now widely used and accepted as an important electronic instrument in cable television applications. Their principles of operation are now widely understood and various models are in use in the cable television industry in both field and laboratory application. They function as a form of "swept-display signal-level meter", presenting a comprehensive view of signal amplitude as a function of frequency. The first laboratory class instruments suitable for cable television work were introduced by Hewlett-Packard about 1970. This spectrum analyzer system was described, along with a number of cable television applications, in a paper which I presented at this convention in 1971. Similar laboratory class analyzers were introduced by Tektronix a few years later. Field type portable analyzers were later introduced by Texscan. Both laboratory and field type analyzers are now widely used in the cable television industry.

The versatility and precision of the laboratory type spectrum analyzers, particulaly the H-P and Tektronix models have made them popular for precision field television systems. Although I have referred to these analyzers as "laboratory" instruments, they can and are successfully used in the field, although their size, weight and power requirements means that they are somewhat restricted in their mobility. We have specially constructed, shock mounted cases for taking our laboratory type analyzers into the field - usually in a van with an engine driven AC generator system for power.

We have used laboratory class analyzers, both H-P and Tektronix, since they first became available. They made possible a class of measurement versatility and precision previously unavailable. A new generation of spectrum analyzer - exemplified by the HP 8568A system - is now available further expanding the utility, flexibility and precision of spectrum analyzers in cable television applications.

THE H-P 8568A SPECTRUM ANALYZER

The 8568A was made available by HP in 1978. It's principle distinguishing features include:

- use of digital processing and display of the video signal
- use of synthesizers for generation of local oscillators
- full programmability of all instrument control functions, using digital instrument keyboard, three internal microprocessors, and external HP-IB digital control bus
- compatibility with external computers, printers, plotters and other digital and analogue peripherals
- significant improvement in specifications over previous generation analyzers.

The 8568A tunes the 100 Hz to 1500 MHz range with synthesizer precision. It offers 10 Hz resolution throughout that tuning range. Tuning stability and phase noise are exceptional, and represent a considerable improvement over previous generation spectrum analyzers. It offers a spurious free dynamic display range of better than 85 dB with 100 dB displayed on the screen. It has a high quality flicker-free display with versatile alpha-numeric titling, further enhanced by the ability to reproduce the display on attached digital plotting and printing equipment. It has excellent internal self-calibrating features and above all is fully programmable. It is the programmable feature that appealed to us.

The 8568A functions can be programmed from a variety of external computer systems. The HP 9825A desk-top computer is most commonly used. H-P makes a variety of "library" programs available for using the 9825A as a controller for the 8568A and sells the complete system as the 8581A Automatic Spectrum Analyzer. We couldn't afford the 8568A as a "manual" spectrum analzyer, i.e. without the computer controller and preipherals. We feel that the cost of the analyzer is best justified when operated in an automatic mode.

APPLICATIONS OF AN AUTOMATED SPECTRUM ANALYZER

Automated test equipment has become very popular in manufacturing operations where an automated instrument set can be programmed and employed on a high volume production line with obvious economies. Such automated test sets perform complicated test routines automatically and accurately. We are not in the manufacturing business and we had other applications in mind when we bought our automatic spectrum analyzer system.

As a consulting firm providing support to several MSO's we have had extensive experience in proof-of-performance testing. We have two laboratory type spectrum analyzer systems (one each by H-P and Tektronix) that we employ nearly full time in such applications. We find that an experienced field engineer will take about one hour per test point to check a 20 channel system. It takes somewhat longer to check a system carrying more channels. Additional time is required in the office to interpret the field notes and 'scope photographs and to prepare the report sheets for each point tested. It takes a fair amount of experience and skill to run the instrumentation through all the tests required and to make sure that observations are accurately noted. We wanted to automate most of this process.

The easiest way to appreciate the degree of programmability of this analyzer is to study the manufacturer's operating manual or to participate in an actual demonstration. Center frequency, sweep width, reference level, etc. are all selected by digital keyboard. IF bandwidth, video bandwidth, and sweep time all adjust themselves automatically to maintain valid displays. All these parameters can also be individually controlled if desired. To put it briefly - control is provided, whether by keyboard or externally programmable, for virtually every operating parameter that the operator might wish. The analyzer also provides features not available on previous generation spectrum analyzers. There is a "max hold" mode in which the display updates only when the value is higher than previous sweeps. There is an automatic "video averaging" mode in which successive sweeps are arithmetically averaged and displayed. There is a "delta marker" mode in which the difference in both level and frequency between two markers is displayed. There are three digital memory storage arrays. Display data can be transferred between them and between analyzer and external computer.

These functions can be better appreciated by reviewing the digital video signal handling. The basic spectrum analyzer functions are performed in "analogue" mode. The analyzer is a triple conversion receiver, using synthesizers as local oscillators. After detection the video signal is converted to digital form by means of a digital/analogue converter. The display functions are then handled in digital form. The display consists of a 1000X1000 point array which is refreshed from memory at about 60 Hz rate. The 1000X1000 point memory array is managed by internal microprocessors which feed the video and sweep data into the array. These display arrays can then be "averaged", "added", " subtracted", printed out, plotted or handled in any other "digital" way that we may wish.

The digital video signal handling allows the instrument to perform such usefull functions as averaging and "max hold". It also provides fast "noise measurement" since it automatically performs the noise-bandwidth adjustments and calculations providing direct readouts in terms of level normalized to 1 Hz bandwidth. The computer controller then makes easy extrapolations to any other noise bandwidth, e.g. 4 MHz, that we wish.

Measurement units are also easily adjusted. Pushing a couple of buttons (or a simple computer command) changes readings instantly from dBm to dBmv to mv, and introduces the compensation for any external matching devices which are required. Vertical display scales are similarly changable from 10 db to 5 db to 2 db to 1 db per division.

Consideration of the specifications and operating manuals, and a bit of direct experience soon convinces one that this instrument under computer control can do anything a field engineer can do with a manually opoerated spectrum analyzer - better, more accurately and much faster.

Consideration of operating speed should be tempered by the fact that this is still an analogue instrument up to the video detector and it is subject to the same trade-offs of bandwidth, span and sweep time as are conventional spectrum analyzers. A sweep requiring narrow bandwidth and wide span still requires considerable time even when the sweep has been commanded digitally and the display is being read out and handled digitally. These sweep times become the limiting factor in system operating speed and are kept in mind when programming important consideration is that a complete display represents about 1 megabit of data and takes appreciable times to read in and out of the analyzer and occupies considerable external storage space.

With these advantages, and within the constraints we have briefly described, we have programmed our system to automatically perform a "proof-of-performance" test, printing and plotting the results automatically. We have generally emulated ther manual operation as a first generation approach top the required program. With some further field experience we expect to refine the program and technique, optimizing the procedure to take full advantage of this particular instrument system. The system first asks what tests and procedures are to be run, reads in external data such as names, date, location, etc. It then performs all the tests required, printing out directly, or storing information in digital form for later read-out. Sample displays and print-outs are appended to this presentation. We hope to provide an actual demonstration with the oral presentation of this paper at the convention.

ADVANTAGES OF AUTOMATIC TESTING

We believe that the main advantage of the automatic testing for cable television is speed. Added precision and clarity of data presentation is a valuable secondary feature.

The speed of operation (about 5 minutes per test point) is not necessarily a great advantage if there are few test points to be done and if there is a significant travel time between test points, as in the periodic testing to FCC or DOC requirements. These government requirements can be met by the testing of relatively few points and with a degree of precision adequately provided by less costly and complex instrumentation. Our principle interest in developing and applying this automated system is in proof of new turn-key contracts and in internal technical audit of operating systems.

Turn-key contracts are detailed technical contracts involving large sums of money and a complicated technical "product". Contractors are anxious to have their product accepted by the purchaser and receive their money. The purchaser is anxious to receive the system in the condition and to the specification contracted for so that he can begin business and startearning revenues just as soon as possible. An automated testing system allows a much larger number of test points to be checked to specification and at lower cost than is possible with the present manual testing techniques. The automated test system represents an investment of about $100,000. The presently used manually operated systems represent capital investments of about $35,000. By tripling the capital investment we increase the productivity about ten times. We think this is a worthwhile trade off, particularly in applications where productivity over sustained period of time is important.

We believe that automated testing will also be important in other cases where a comprehensive and accurate technical appraisal of a cable system is prequired, e.g. when a system is being sold or when management requires a "technical audit". We believe that it is important to be able to make a meaningfull number of measurements in a conveniently small period of time. We obviously cannot test every subscriber tap in a system. Testing and technical appraisal is therefore statistical in nature. We can significantly improve the reliability of the appraisal if we increase the number of points tested. It is expensive to wait for the manual testing of a statistically significant number of test points because a substantial amount of money is tied up during this time. The speed of automated testing is therefore a very attractive feature. The added precision and accuracy is a valuable bonus.

FUTURE ADVANCES IN AUTOMATED TESTING

We look forward to additional forms of automated test systems for cable television application. Our next automated system will no doubt be a computerized automatic video baseband testing system, probably the new Tektronix ANSWER II system. This system converts video waveforms to digital form for measurement and analysis. We are working on a programmable tuner for the Tektronix demodulator that will enable fully automated tuning and analysis of cable television video channels.

Although we operate RF cable distribution systems our subscribers look at video waveforms displayed on their television receivers. The ability to examine these waveforms in detail on an automated basis will be a valuable augmentation of the automated RF capability we are presently introducing. We expect to have this automated video baseband testing system in operation about one year from now.

8568A PERFORMANCE SUMMARY

FREQUENCY

MEASUREMENT RANGE
100 Hz to 1500 MHz dc coupled and 100 kHz to 1500 MHz ac coupled.

DISPLAYED RANGE
From 100 Hz full span to 1500 MHz full span.

RESOLUTION
3 dB bandwidths of 10 Hz to 3 MHz in a 1, 3, 10 sequence.

SPECTRAL PURITY
Noise sidebands > 80 dB below peak of CW signal at frequency offsets ≥ 30 × resolution bandwidth setting, for resolution bandwidths ≤ 1 kHz.

ACCURACY

Center Frequency
± (2% of frequency span + frequency reference error × tune frequency) using error correction.

Marker
Normal: Same as center frequency accuracy.
Freq Count: Frequency reference error × displayed frequency ± 2 counts (span ≤ 100 kHz).

Frequency Reference Error (aging rate)
$< 1 \times 10^{-9}$/Day (2×10^{-7}/Yr).

AMPLITUDE

MEASUREMENT RANGE
−137 dBm to +30 dBm or equivalent in dBmV, dBμV; 32 nV to 7 V.

DISPLAYED RANGE
10,5,2,1 dB/div and linear calibration; a 10 division vertical scale.

DYNAMIC RANGE

Spurious Responses
Second harmonic distortion and third order intermodulation distortion > 70 dB below signal levels ≤ −30 dBm at the input mixer.

Average Noise Level
< −137 dBm in 10 Hz resolution bandwidth.

ACCURACY
Measurement accuracy is a function of technique. The following sources of uncertainty can be summed to determine achievable accuracy: (at constant ambient temperature, assuming the error correction function is used and avoiding unnecessary control changes between calibration and measurement):

Calibrator Uncertainty
±0.2 dB.

Frequency Response Uncertainty
± 1.0 dB.

Comparison Uncertainty
(resulting from **one** of the following techniques for comparing the unknown signal with the calibration level)

Repositioning Signal to Calibration Level: ± 1.7 dB.

Using Marker: ± 1.7 dB.

SWEEP

TIME
20 msec full span to 1500 sec full span. Zero Frequency Span, 1 μsec full sweep to 1500 sec full sweep.

INPUT

RF INPUTS
100 Hz to 1500 MHz, 50 Ω dc coupled (BNC fused); and 100 kHz to 1500 MHz, 50 Ω ac coupled (type N).

MAX INPUT LEVEL
ac: +30 dBm (1 watt) continuous power; 100 watts, 10 μsec pulse into ≥ 50 dB attenuation.
dc: 0 volts dc coupled input and ±50 volts for ac coupled input.

ATTENUATOR
70 dB range in 10 dB steps.

OUTPUT

DISPLAY
X, Y, and Z outputs for auxiliary CRT display.

RECORDER
Horizontal sweep output (X), video output (Y), and penlift/blanking output (Z) to drive an X-Y recorder.

INSTRUMENT STATE STORAGE

Up to 6 sets of user defined control settings may be saved and recalled.

REMOTE OPERATION

All analyzer control settings (with the exception of video trigger level, focus, align, intensity, frequency zero, and amplitude cal) may be programmed via the Hewlett Packard Interface Bus (HP-IB).