INCREASED PERFORMANCE AND REPEATABILITY
FOR PORTABLE CATV MEASUREMENT SYSTEMS

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ABSTRACT

Microprocessors and large scale integrated circuits as major elements in test instruments provide significant benefits. The speed and packaging density allows the designer to set up, control and display the results for a variety of measurement requirements.

While most of these measurements for CATV are analog functions, converters (A to D and D to A) allow easy access to the power of digital processing.

Digital support circuits which utilize large scale integration are used by the computer industry in very large quantities, consequently the designer finds the cost performance ratio to be excellent.

Designing portable measurement systems utilizing these advantages may provide a combination of functions which would normally require several instruments and a skilled operator. An user friendly integrated instrument will allow good repeatability results, even with a less experienced operator.

INTRODUCTION

At the 1979 NCTA Convention Marv Milholland and myself, introduced the concept of microprocessor control for CATV instruments. This period marked the departure from general purpose and arrival of application engineered measurement systems for CATV. The technical growth of our industry created a challenge to both the system operator (find enough skilled people) and the instrument designer (keep up with trends without gambling large capital investments too early). It became clear that the availability of skilled people would lag demand, operators would need to make more efficient use of their key people.

It was suggested that an instrument designer must focus on the goal to provide test equipment which will allow the operator to gain the most useful information about the condition of the system under test, in the time spent making tests and measurements.

We are looking at return on investment and with a limited human resource, the performance of the equipment could justify its cost. Human engineering and built-in intelligence would enhance the efficiency of the "man and his machine" while in some cases allowing complicated measurements to be performed with a less skilled operator.

PERFORMANCE

As defined by Webster, performance is the execution of the functions required of one.

An instrument has many dimensions to its performance, the most important of which is the ability to make the desired measurement, the environmental insensitivities, the package compatibility.

The instrument must be cost effective which is how the price performance ratio is evaluated.

A good rule is avoid "the ultimate machine", put in what is required, consider the human interface and provide an instrument that will give the user the most for his money.

THE MEASUREMENTS

In order to achieve an optimum price performance ratio it is necessary to analyze the requirements for a series of related tests and establish an algorithm. An example might be measurement of crossmodulation in an amplifier. This measurement could be done by analyzing the sideband components on a CW carrier, which are the result of intermodulation distortion. If this measurement were made with a conventional Spectrum Analyzer one would select span, center frequency, resolution bandwidth, scan rate, and video filter bandwidth.

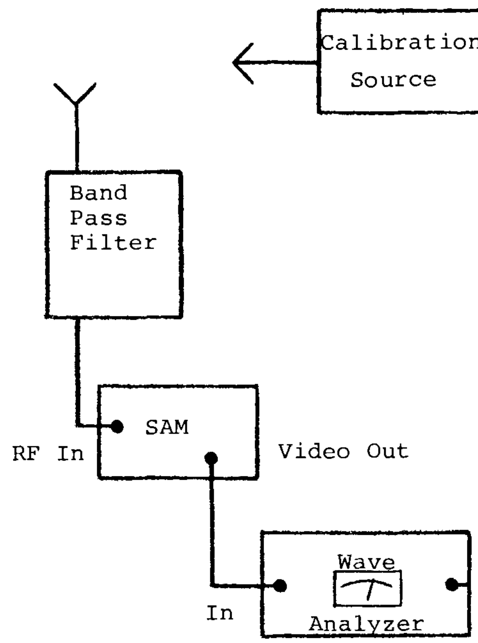
On a general purpose instrument some of these selections are uniquely related by ganged controls but because of the flexibility, a skilled operator is required to achieve optimum performance.

An alternate method is the combination of a signal level meter and a wave analyzer.

This method shown in Fig. 1 is more

cost effective but has the disadvantage of requiring interconnection of instruments and a calibration procedure to insure that the combination is being properly utilized.

Fig. 1



Wave Analyzer method to measure crossmodulation to point under test.

Performance of this measurement in a microprocessor controlled System Analyzer can be reduced to a hardware/software algorithm. Processing the RF input like a signal level meter the video detector output is internally presented to a calibrated tuned amplifier, who's output is detected and processed by an analog to digital converter. The digital output is compared to a precalibrated table or program in memory to establish the readout for the CRT display. The indication will be an alphanumeric presentation o the equivalent crossmodulation in dB down from the carrier. This method will minimize the operator interface and eliminate much of the setup decisions. This should allow a less skilled operator to achieve repeatable, accurate results.

UNIQUE SYSTEM FUNCTIONS

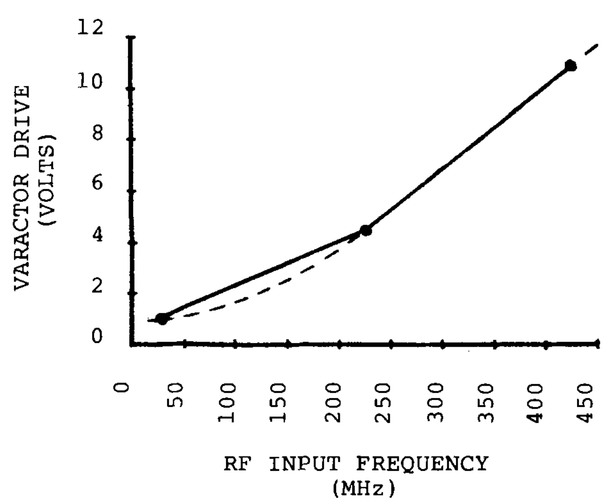
The previous cross-modulation measurement was one of many algorithms implemented in a new System Analyzer designed to provide the objective advocated by the writer. If we examine some of these algorithms, which comprise thousands of bytes of code; we will gain some insight into the power of the modern components and design techniques. There are many similarities between the System Analyzer and a conventional Spectrum Analyzer.

The most obvious is the requirement to set span, scan rate and center frequency. A digital to analog converter (DAC) is set up to have ≈ 27 KHz/bit resolution.

Entering a center frequency via the keyboard activates a binary search which compares the first Lo frequency (VCO) to a calculated value (CF=VCO-1st IF) and connects the DAC output as required. The selected span can then be established by selecting the optimum slope for that span at the selected center frequency. Since the center frequency is controlled it is possible to optimize the slope for the span on both sides of the center thus eliminating the need for noisy and temperature dependent sweep linearity controls. In Fig. 2 the setup from memory is shown superimposed over the curve for the typical varactor drive voltage to the first Lo for a given input frequency.

The table values for the different center frequencies and spans for 2A, 2B, and 2C show how independent selection of slope for left and right of center frequency can significantly improve the span accuracy. Linearity improves as span is reduced, however, with a marker system which actually counts the first Lo frequency to establish its value the need for absolute linearity is not a primary requirement.

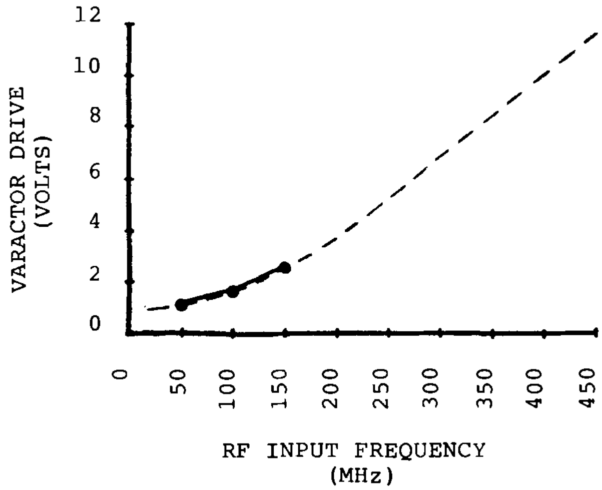
Fig. 2A



From A Table in Memory

C.F. (MHz)	Span (MHz)	Slope volts/MHz Left	Right
225	400	.021	.029

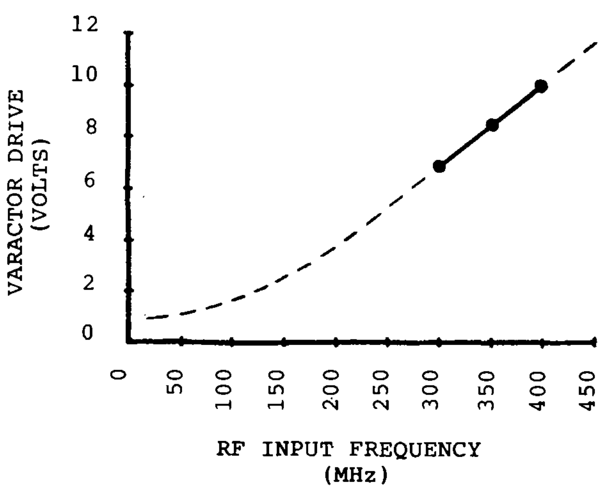
Fig. 2B



From A Table in Memory

C.F. (MHz)	Span (MHz)	Slope volts/MHz Left	Right
100	100	.015	.019

Fig. 2C



From A Table in Memory

C.F. (MHz)	Span (MHz)	Slope volts/MHz Left	Right
350	100	.029	.029

SYSTEM ANALYZER BACKGROUND SWEEP

Using the entered center frequency and span to determine the Δ DAC increment value, a binary search method is used to find out the DAC value of entered center frequency. The DAC value for center frequency is multiplied by 2^8 to make it as a 24 bit value. There are 125 points between left hand side CRT and center of CRT so the DAC value of starting frequency = DAC value of center frequency - 125* Δ DAC increment. All three values are 24 bits in length. We use the following formula to paint the screen.
DAC value of Nth point =
(DAC) value of starting frequency + N* Δ DAC increment) ÷ 2^8.

N can be any number from Ø to 124. Dividing by 2^8 is necessary because we only have a 14 bit DAC in our frequency control system.

AMPLITUDE MEASUREMENT

The traditional Spectrum Analyzer must be set up with care when correlating carrier and carrier to beat ratios with signal level meter readings. The reason is that the signal level meter uses a peak detector. The peak detector allows the signal level meter to be calibrated at the RMS of the carrier during peak sync.

There are many settings for a conventional Spectrum Analyzer which will mask this peak response.

The System Analyzer displays amplitude of carriers using the peak detection concept described for signal level meters.

The concept becomes unique when we consider the system is to measure a series of levels as it scans the frequencies determined by the span settings.

The measurement becomes further complicated by the fact that due to cost and power considerations the system will only display 250 frequency cells with ± .25 dB amplitude resolution. When spans are large the microprocessor divides the total number of available increments by 250 and steps through that number of increments (N) with the peak detector activated. At the end of N increments the peak detector will contain the largest amplitude of the previous N increments. The value in the peak detector at this time is converted by a high resolution (12 bit) analog to digital converter and stored into memory as one of the 250 display frequency cells. The microprocessor then clears the peak detector, increments the pointer and repeats the previous process for the next frequency cell. In the 10 dB/division mode the 256 point vertical display (8 bit) represents ± .25 dB of resolution of the displayed data.
Note: It is interesting that with a 60 dB dynamic range the human operator can just perceive this magnitude of variance even on an analog scale with infinite resolution.

Since the number converted by the analog to digital converter has 4096 point resolution (12 bit) the use of a special marker system will allow the alphanumeric presentation of the amplitude value at a frequency cell to a higher degree of accuracy than the graphical display.

Scan loss is under control of the microprocessor, if the span is large the scan time is at a maximum (.7 sec) if the span is small the scan time is reduced proportionally.

This adaptive scan rate concept is applied when the measurement algorithm calls for narrow IF filter resolution bandwidth or heavy video filtering. Additional factors which effect the amplitude measurement accuracy are; the attenuation versus frequency (slope) due to cables, attenuators, input filters and converters. Also the incremental linearity of the log amplifier and the temperature variation of the entire measurement system.

To address the first area (slope), the microprocessor was programmed to modify the detected level value at any frequency to compensate for the slope at that frequency. The consideration for linearity and temperature variation are somewhat independent but the implementation of an internal calibration source, which is exceptionally temperature stable, can be activated at any vertical position to establish a desired reference. The entire vertical scale is modified to make that position calibrated.

With the feature of alphanumeric readout, the marker system becomes a valuable performance contributor. The microprocessor allows the operator to manually position the marker to any area of the screen and the readout will display amplitude and frequency for that point. Two such markers can be activated and will be used more extensively for some of the unique measurements.

The marker can be sent to the peak in an area via keyboard entry and in a similar manner that marker and carrier can be moved to the center of the display.

A zoom function takes the present span and reduces it by a maximum of 5 and a minimum of 3 to expand the resolution in the area of interest.

A useful performance enhancement is the programming of narrow span around the various channels. There is a table in memory with these center frequencies along with a program to activate the 10 MHz span around the table value when the operator selects a particular channel. A split screen mode can be activated to look at two channels at once or look at one channel on the left and a large area of the spectrum on the right of center.

ADDITIONAL MEASUREMENTS

Frequency deviation below 200 KHz peak to peak can be measured by placing the marker to the peak of the carrier to be tested.

The selection of Δ F from the keyboard sets up an algorithm where the instrument goes into a zero span mode around the marker frequency, an AFC circuit is activated in the final IF and a calibrated discriminator output is compared against a table in memory.

The results are peak averaged and displayed with updating of graphic data every sample and updating of alphanumerical display with the largest of every 5 samples.

Composite beats and carrier to noise measurements are made with similar algorithms.

It is necessary to turn the carrier off at the head end to make the composite beat measurement. Only a single marker is required.

The marker is positioned to the peak of the reference carrier and amplitude measurement is performed by the instrument. Pressing a 2nd/3rd order key activates the composite beat measurement. The instrument changes resolution bandwidth to 30 KHz, selects an averaged output with a 10 Hz video bandwidth and reduces the scan rate to account for the slower response for this measurement.

Since the noise floor for this condition is significantly lower an offset in display and readout is effected thus extending the beat measurement range to greater than 70 dB. The difference between the measured amplitude before and after selection of this function is displayed and the marker remains active to give the operator a means to position it on the exact peak of the composite beat

Carrier to noise is measured by taking the difference between two markers, one of which is placed on the peak of the carrier while the other is placed on the noise floor. A correction factor is applied to the readout, compensating for the difference in bandwidth and the relationship between peak and RMS noise.

Hum modulation is measured by activating a calibrated low pass video amplifier/filter and comparing the detector output to a reference table in memory. Again the display of results is effected in a like manner to measurements previously reviewed. Some of the additional measurements which enhance the performance of such an instrument are temperature measurement, internal automatic calibration, peak hold, A B memories for comparison of measurements, built-in diagnostics, and flexibility for future expansion.

A simple matrix key pad which is utilized as an extension of the instruments memory allows a human interface which can effect complex measurements with one or two key strokes. The results of stacking these functions and their straight forward access, assures maximum performance and repeatablity of results.