Agilent PN 89440A-4

Characterization of Digital Communications Channels with the Agilent 89410A and 89440A

Product Note

Accurate measurements of channel imperfections are important to the designers and operators of digital communication systems. These measurements are especially critical because of our desire for greater information density. Conventional network analyzers cannot measure systems that span several miles. The Agilent Technologies 89410A (dc–10 MHz) and 89440A (dc–1.8 GHz) vector signal analyzers (VSA) define a new class of analyzers that can easily measure amplitude and group delay variations of existing communication channels.

This product note describes the VSA channel characterization measurement method and specific cable television (CATV) applications. Although examples from the CATV industry are used, the VSA method may be applied to other communication channels.

Introduction

Digital communication schemes are rapidly replacing older analog schemes in many applications. The desire for greater information density has increased the importance of understanding the imperfections of the communication channel. Deviations from constant amplitude or linear phase limit the complexity of the modulation scheme that a channel can support.

Limitations of traditional measurements

In older analog systems, precise channel characterization was not necessary. Crude methods were sufficient to "measure" amplitude response and group delay, such as observing the envelope of a frequency sweep or the base line of a two-tone burst on an oscilloscope display. These methods are clearly inadequate as digital modulation schemes are added to these older systems.

A conventional network analyzer is capable of measuring the characteristics of a communication channel if both ends are in the same location. However, in a typical cable television (CATV) system, the receiving location may be twenty miles or more from the cable head-end. With the exception of only a few systems, this spatial restriction limits the use of a network analyzer to laboratory simulations. While simulations may provide some valuable information, they can be costly and may not accurately represent the real system. For example, it is not practical to construct a simulated CATV network that exhibits the myriad of micro-reflections that plague real systems.

Advent of time-selective vector signal analyzers

The 89410A (dc-10 MHz) and 89440A (dc-1.8 GHz) vector signal analyzers represent a new class of measurement instrument. These analyzers calculate both frequency and modulation domain characteristics from a time-record. The time-record of the desired frequency span is produced by accurately digitizing the input waveform, mixing with a digital quadrature local oscillator, and band-limiting with digital filters.

Selectable trigger delay and time-record length control the portion of the time-domain waveform that is captured. In addition, time-gating allows a subset of the time-record to be selected for subsequent calculations.

This ability to easily measure time-variant signals is essential for measuring communication systems. With a VSA, it is easy to make accurate measurements of the amplitude and group delay variations of existing communication channels.

Channel characterization with a VSA

To understand channel characterization with a VSA, a baseband measurement is discussed first. Later, the technique is extended to RF.

Baseband measurement

Figure 1 shows a baseband measurement block diagram. A reference measurement of the test signal is taken without the network under test in the circuit. This measurement is made once, then stored in nonvolatile RAM or on disk. The subsequent measurements with the network under test will be normalized to this reference measurement.

The difficulty in measuring the network with a traditional network analyzer is that there is no common phase reference available at the ends of the network under test. The VSA overcomes this difficulty by using a test signal with known phase relationships among all its frequency components. The signal must also be frequency band-limited to avoid interference with adjacent channels. Although many signals, including a frequency chirp and a sin(x)/x pulse, have these attributes, the chirp is referred to in this paper because of its superior signal-to-noise ratio across the frequency band of interest.

The 89410A source is configured to send the test signal repetitively. The receiving 89410A is set to trigger on the test signal with negative trigger delay and a time-record length sufficient to capture the entire transmitted signal, as shown in Figure 2.

This captured time record is then converted to a vector spectrum in the frequency domain. The spectrum contains both amplitude and phase information for every frequency component of the test signal. Dividing this vector spectrum by the previously measured reference yields the transfer function of the network with an arbitrary delay term (phase ramp). The actual propagation delay cannot be measured with this technique; however, in most applications, the delay is irrelevant and only the deviation from linear phase is of interest. Amplitude and group delay variations across the frequency band are displayed as shown in Figure 3.

If necessary, improved signal to noise ratio is achieved by time averaging several measurements. Because the noise is not correlated with the repetitive test signal, the noise averages to zero over time.

The 89410A automates the entire process, from capturing the test signal to displaying the amplitude and group delay variations of the network under test.

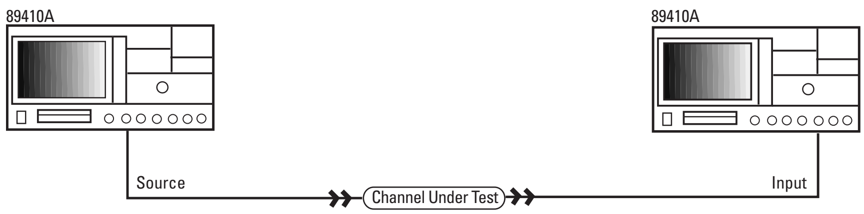

Figure 1. Baseband network characterization

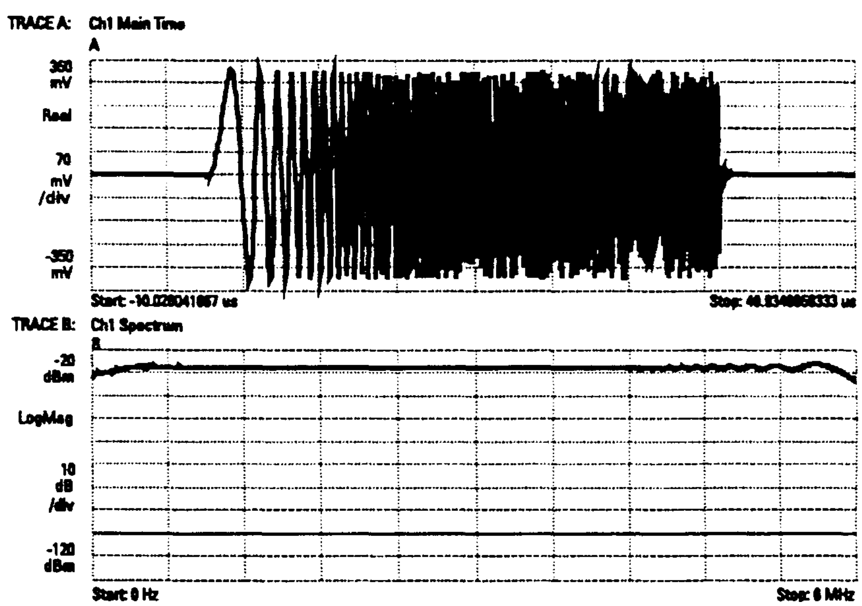

Figure 2. Frequency chirp test signal

RF Measurement
The baseband measurement may be extended to RF by providing external modulation and demodulation. You can insert the test signal between other information on an active communication channel, then use the time-gating feature to easily select just the test signal for analysis.

Two examples of RF measurements on a CATV network are described next.

Example 1: 4.5-MHz Active NTSC CATV Channel

Figure 4 shows the block diagram of a CATV channel characterization measurement.

With the 89410A, it is possible to characterize the 4.5-MHz video portion of any given NTSC channel on a CATV network, without taking the channel off the air. The test signal is inserted into a single video line in the vertical blanking interval, as shown in Figure 5.

The recently developed Philips Ghost Cancellation System uses a reference chirp on line 19 that may be used as the test signal for this measurement, simplifying the block diagram.

Example 2: 6-MHz digital CATV channel

To characterize the full 6-MHz bandwidth of a CATV channel, the modulator and demodulator must have a 6-MHz bandwidth and the channel must not be occupied. This measurement is discussed in more detail in a paper entitled "CATV Channel Characterization for Digital Data Transmission Applications" by Dehart et. al., presented at the National Cable Television Association (NCTA) convention in June 1993.

Direct RF Measurements
The 89440A 1.8-GHz vector signal analyzer allows you to directly measure the RF-channel characteristics within its 7-MHz information bandwidth without using external modulation and demodulation. An Instrument BASIC program is required to remove the phase of the RF downconverter.

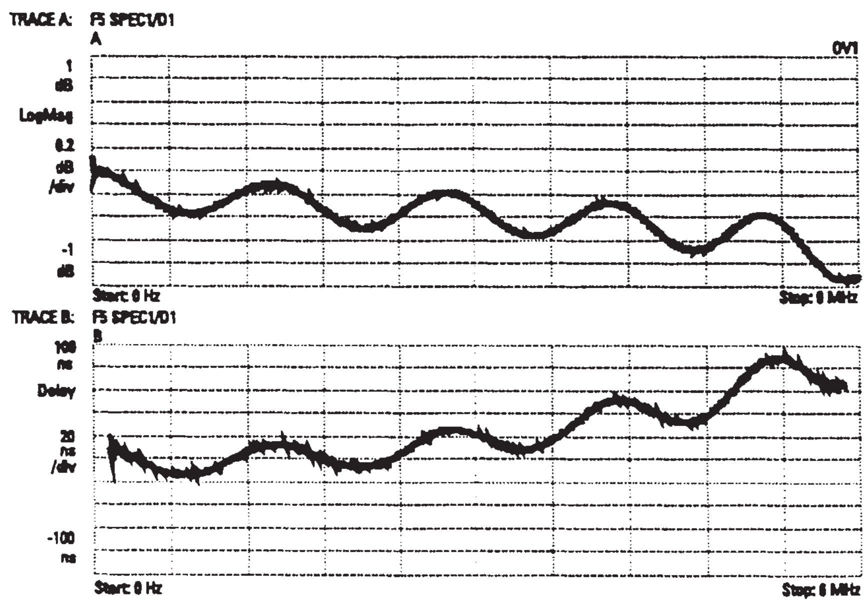

Figure 3. Network characteristics

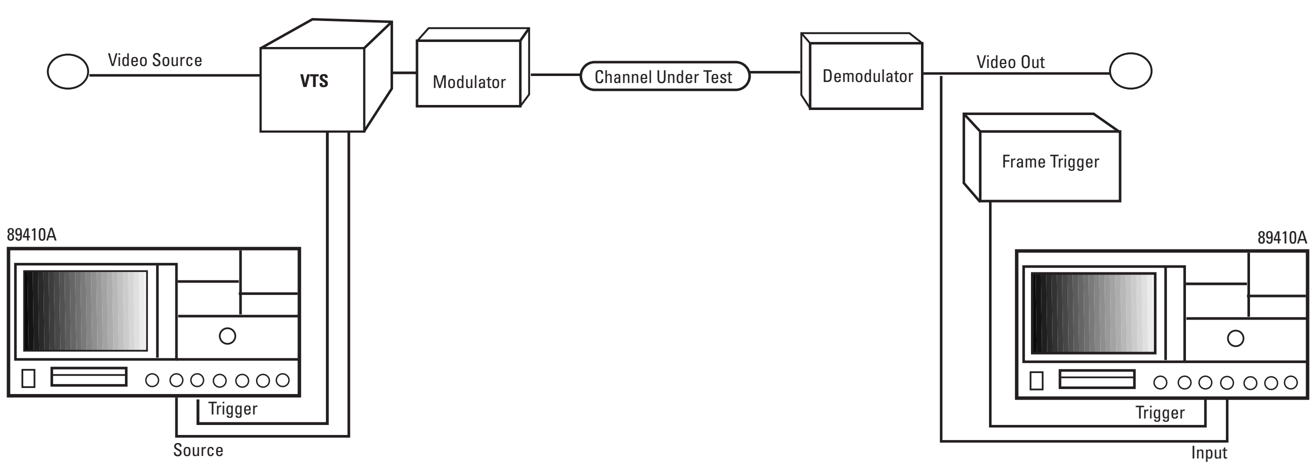

Figure 4. Measuring an active NTSC channel

Conclusion

Understanding communication channel amplitude and group delay variations is critical to the designers and operators of digital communications systems. While these imperfections have been historically difficult to measure, a new class of measurement device defined by the 89410A and 89440A vector signal analyzers make it easy.

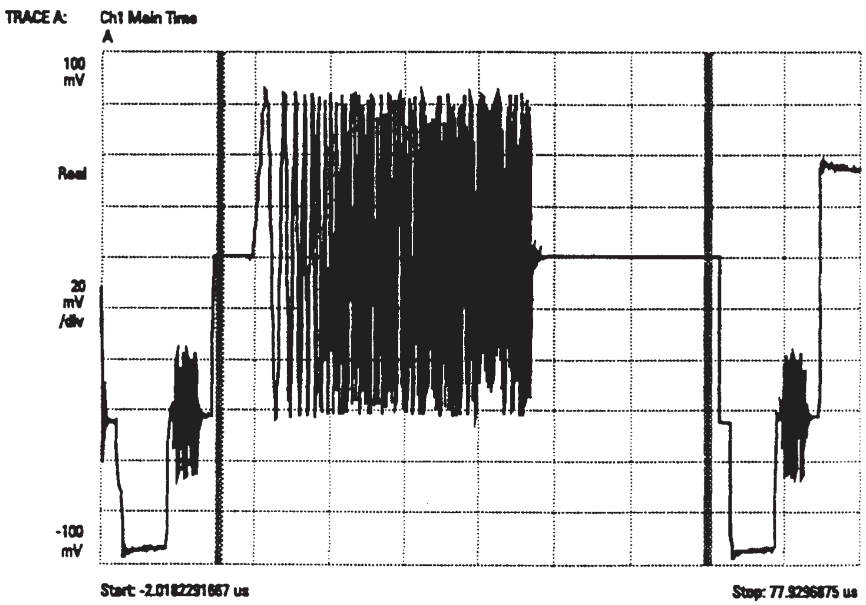

Figure 5. Test signal is inserted on a video line

Although examples from the CATV industry were described in this article, the VSA characterization method may be applied to other communication channels that are within the 10-MHz information bandwidth of the 89410A.

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