HDTV CABLE TESTS: METHOD OF MEASUREMENT

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ABSTRACT

A method of measurement was recently developed at CRC to evaluate amplitude and group delay responses of TV channels, broadcast or cable.

This method makes use of conventional test instruments or modified instruments when the channel being investigated has a bandwidth exceeding 4.2 MHz. It was adopted and used by the CABSC (Canadian Advanced Broadcast Systems Committee) during its cable TV field test program in November 1988, which was aimed at characterizing 12 MHz wide cable channels for transmission of HDTV signals. The test method has also been adopted by the ATTC (Advanced Television Test Center) for the characterization of wideband off-air channels in the VHF, 2.5 GHz and 12 GHz bands. Actual tests are underway in Washington DC. This paper describes in detail the concept of the measurement method and its implementation.

INTRODUCTION

The test method described in this paper was developed at the Communications Research Center (CRC) in the context of its contribution to the CABSC's field tests on Cable TV systems. In May 1988, the CABSC Working Group on Channel Characterization undertook to prepare a test plan to characterize 12 MHz cable TV channels. This knowledge would enable the W.G. members to establish the performance specifications of typical wideband cable TV channels. This in turn would allow a realistic assessment of the robustness of the various HDTV signal formats proposed to the FCC, when carried over modern cable TV systems. Although there are some indications[1] that the utilization of wideband channels for off-air HDTV broadcasting is unlikely, due to the major impact on the current frequency plan, there is the possibility that cable TV systems may elect to carry a signal format that is different from the one adopted by broadcast. Also it is believed that the results can be applied to bandwidths smaller than 12 MHz if necessary. Consequently, the test plan[2] was finalized and the tests carried out on three cable systems during Fall 1988.

THE CONCEPT

The objective of the test method is to characterize 12 MHz wide channels by measuring their response to an impulse and then calculating their amplitude, phase and group delay responses. This technique is referred to as the "Complex Impulse Response"[3].

As an example, a low-pass filter can be characterized by its impulse response h(t), (see Figure 1). The Fourier Transform of h(t) provides the mathematical expression of the filter's "transfer function" H(w) which characterizes its amplitude and phase response. The group delay response is simply the derivative of the phase response.

$$F\,[\underbrace{h(t)}_{\text{time domain}}] = \underbrace{H(w)}_{\text{frequency domain}} = \text{transfer function}$$

In the case of an unsymmetrical system[4] such as an rf channel amplitude modulated, with unsymmetrical sidebands (see Figure 2), the response to an impulse includes a carrier frequency w_o which is amplitude modulated by an in-phase term and a quadrature term (i.e. 90° phase from the first term). These two terms brought to baseband through synchronous demodulation constitute the "complex impulse response" of the channel:

$$h(t) = h_I(t) \cos w_o t + h_Q(t) \sin w_o t \qquad (1)$$

where w_o = carrier frequency
$h_I(t)$ = in-phase component
$h_Q(t)$ = quadrature component

When an rf channel is perfectly symmetrical about its centre frequency (eg. ideal AM-DSB), $h_Q(t)$ is equal to zero. Therefore, the magnitude of the quadrature term can be seen as a measure of the degree

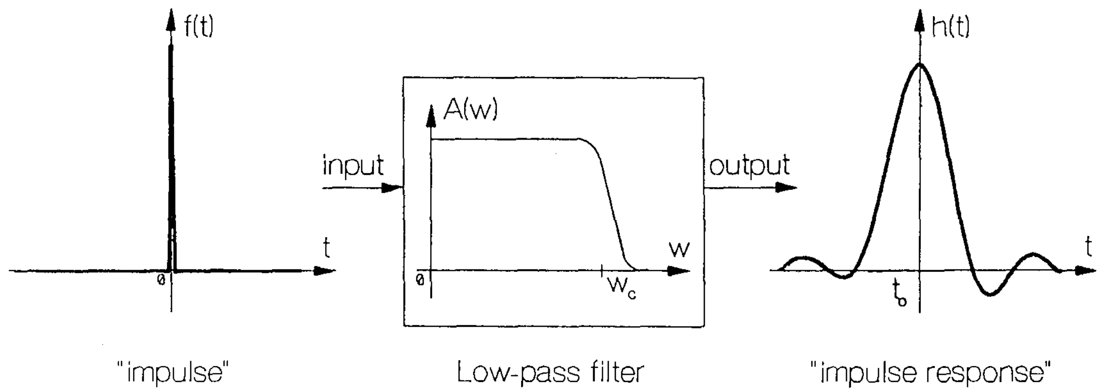

Figure 1a Impulse response

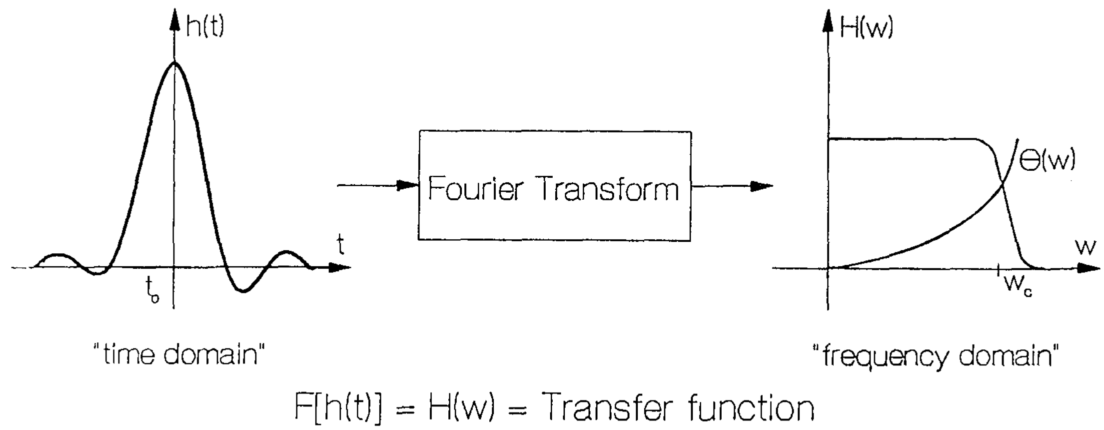

Figure 1b Transfer function

of asymmetry of the channel frequency response.

A synchronous detection process allows the recuperation of $h_I(t)$ and $h_Q(t)$. Then the transfer function H(w) defined over the whole channel bandwidth (12 MHz) can be derived from the expression:

$$H(w) = F[h(t)] = F[h_I(t) + jh_Q(t)] \qquad (2)$$

PHYSICAL IMPLEMENTATION

In a real application several simplifications to the theoretical concept are necessary to accommodate the various constraints and limitations of distribution systems and test equipment.

Sin x/x pulse

The impulse had to be traded for a truncated sin x/x pulse[5] whose spectrum has the interesting property of resembling that of the "ideal low-pass filter", which features flat amplitude response and linear phase response up to w_c, the cut-off frequency determined by the width of the pulse (see Figure 3).

The response to a sin x/x pulse is considered equivalent to the response of an ideal impulse since the basic requirement is that the spectrum of the probe signal be constant in the bandpass to be characterized[4].

DSB modulation

A sin x/x pulse with a cut-off frequency of 6 MHz in conjunction with Double-Sideband amplitude modulation was selected to uniformly spread energy in a 12 MHz wide frequency window (see Figure 3d).

By truncating the pulse duration to 24 usec, the pulse could be inserted twice (one positive and one inverted) in a VBI line of a regular NTSC signal (see Figure 6a). The truncation process induced a negligeable amount of ripple on the frequency spectrum of the test signal.

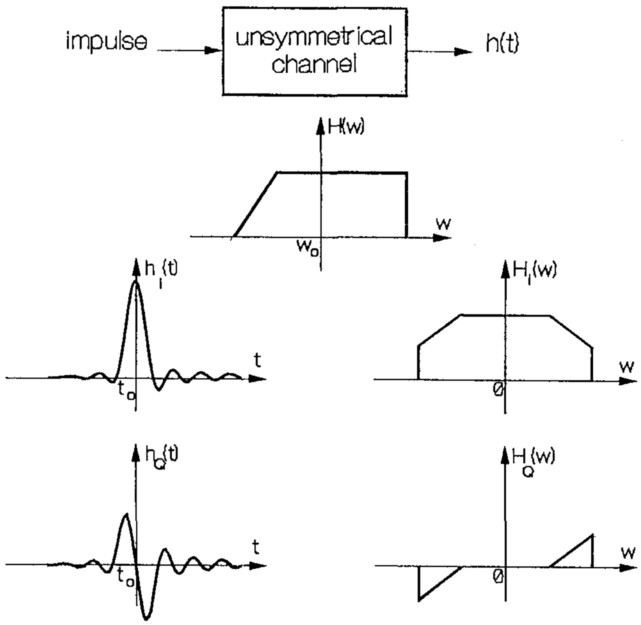

Figure 2 Response to an unsymmetrical channel

The NTSC video signal (Colour Bars) with the 6 MHz sin x/x pulse in its VBI is then fed to an AM-DSB TV modulator whose bandwidth exceeds 12 MHz, and tuned to the visual carrier frequency of the channel under investigation. At the receiving end, a synchronous AM-DSB demodulator also flat on the entire 12 MHz band, locks its phase to that of the incoming carrier and detects the modulating signals on both the I and Q components. The two baseband signals are then digitized to facilitate their processing and storage. This function is performed by a digital oscilloscope with two input channels. The two signals I & Q are tested separately by two 8 bit A/D converters operating at a sampling frequency of 100 MHz (see Figure 4).

Time averaging

The small amount of energy in a sin x/x pulse makes the technique proposed extremely sensitive to noise. Time averaging of video waveforms is a process by which random and time varying components (noise, transients, etc) can be discarded from time invariant components such as the transmitted test signal. In theory the signal-to-noise ratio can be improved by as much as 30 dB when the received test signal is averaged over 1024 transmissions. The theoretical improvement in SNR is expressed by:

$$\Delta\, SNR = 3 \log_2 n \text{ (dB)} \qquad (3)$$

where n is the number of times the signal is averaged. Repeated additions of the incoming sin x/x lines take place in the oscilloscope according to a formula that takes into consideration the relative weight of each line. These calculations are done in 16 bit registers, using the 8 bit input samples, (5,000 samples per line) to minimize quantization noise generated by the analog-to-digital conversion process.

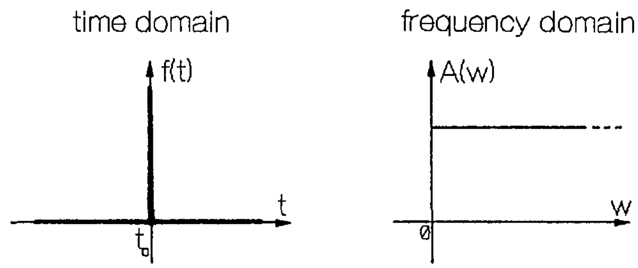

Figure 3a Impulse

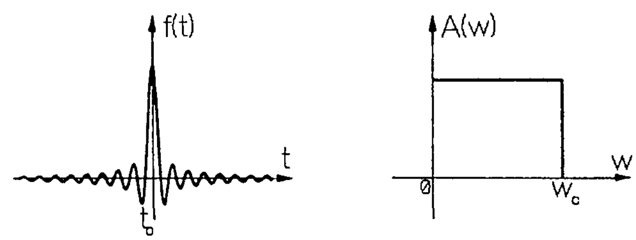

Figure 3b Sin x/x pulse

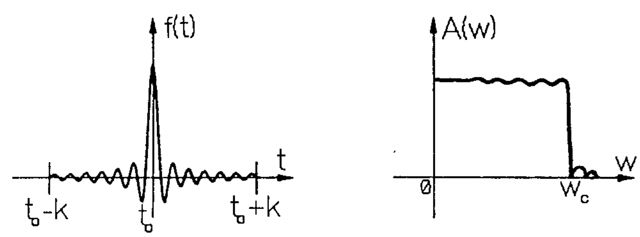

Figure 3c Truncated sin x/x pulse

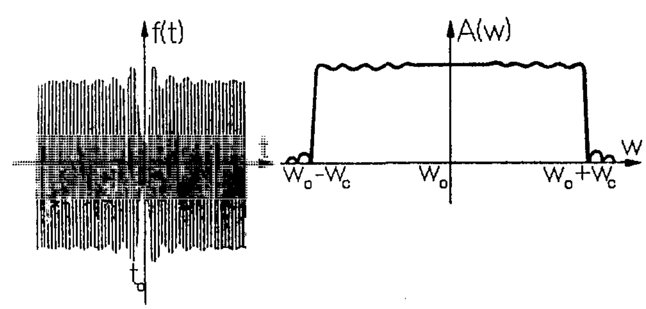

Figure 3d DSB-AM sin x/x pulse

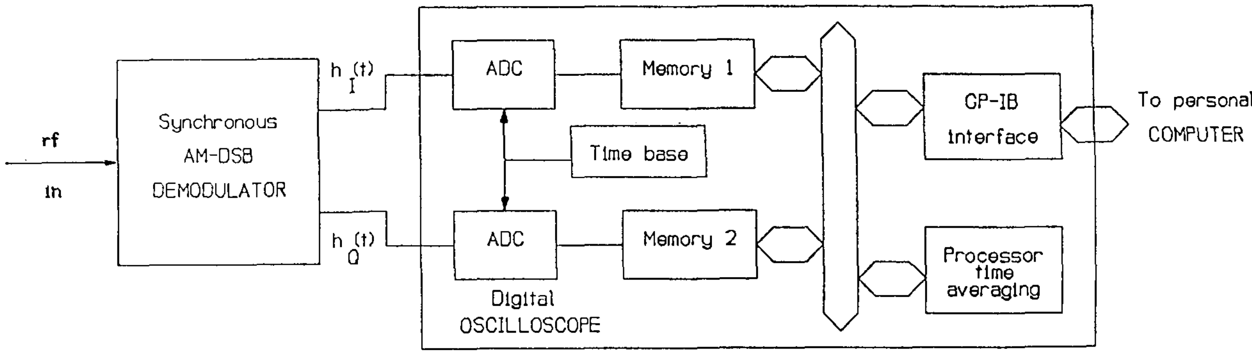

Figure 4 Digitization of impulse response

Triggering

The time averaging process requires that a given sample of the digitized sin x/x signal be averaged with samples corresponding to the same time slot in the test line. This raises the need for a very stable and reliable clock recovery system. The triggering of the oscilloscope must be tightly synchronized to the incoming signal as well as the sampling clock, otherwise a low-pass filtering effect would be observed on the averaged sin x/x pulse due to jitter on the recovered sampling clock. The presence of noise compounds the problem. A digital frame synchronizer which proved to be very reliable even in a 25 dB SNR environment was modified to provide a triggering pulse at the beginning of each 4th field. The oscilloscope could then acquire the sin x/x line after having waited a preset time period. The cadence of one field out of four was dictated by the need to conserve the colour burst of the test line, and the time taken by the processor to do the averaging. It follows that for 2000 averaging periods, each one taking 1/15 sec, the averaging process for one test signal requires a little over 2 minutes. When two signals (I on channel 1 and Q on channel 2) are processed, the time taken by the oscilloscope is doubled and the overall process lasts for 4 minutes.

Instruments Control

In order to automate the process it was decided to control the operation of the oscilloscope with a personal computer via a GPIB bus. A software program was developed to activate the appropriate functions during the acquisition process and to transfer the data from the oscilloscope to data files on the computer hard disk.

Data Processing

Once stored on the computer hard disk, the data files can be retrieved to be processed by a digital signal processing software. The digitized I and Q responses are combined in a Fast Fourier Transform algorithm which produces graphs showing the amplitude, the phase and the group delay responses of the channel measured (see Figure 5).

Later when the signature of the modulator-demodulator is known, it is subtracted from all the impulse responses collected to isolate the contribution of the cable system.

Additional Test Signals

Because a distorted sin x/x pulse does not lend itself to direct and easy interpretation, more "user friendly" tests signals were included in the video signal.

The first one is a special COMPOSITE test signal (see Figure 6b) which includes two $\sin^2$ pulses, one with a half amplitude duration(H.A.D.) of 250 nsec (4 MHz) and one with a H.A.D. of 167 nsec (6 MHz). The second test signal is the "6 MHz line sweep" (see Figure 6c). It consists of a sine wave with a period that decreases linearly from 1.67 usec (600 kHz) to 0.167 usec (6 MHz). This signal allows the field personnel to quickly assess the flatness of the channel amplitude response.

These two additional test signals were to be acquired, time averaged and stored for later comparison with the calculated response of the channel. By adding an X-Y plotter to the set-up, good quality plots of the received test signals can be obtained right at the test site.

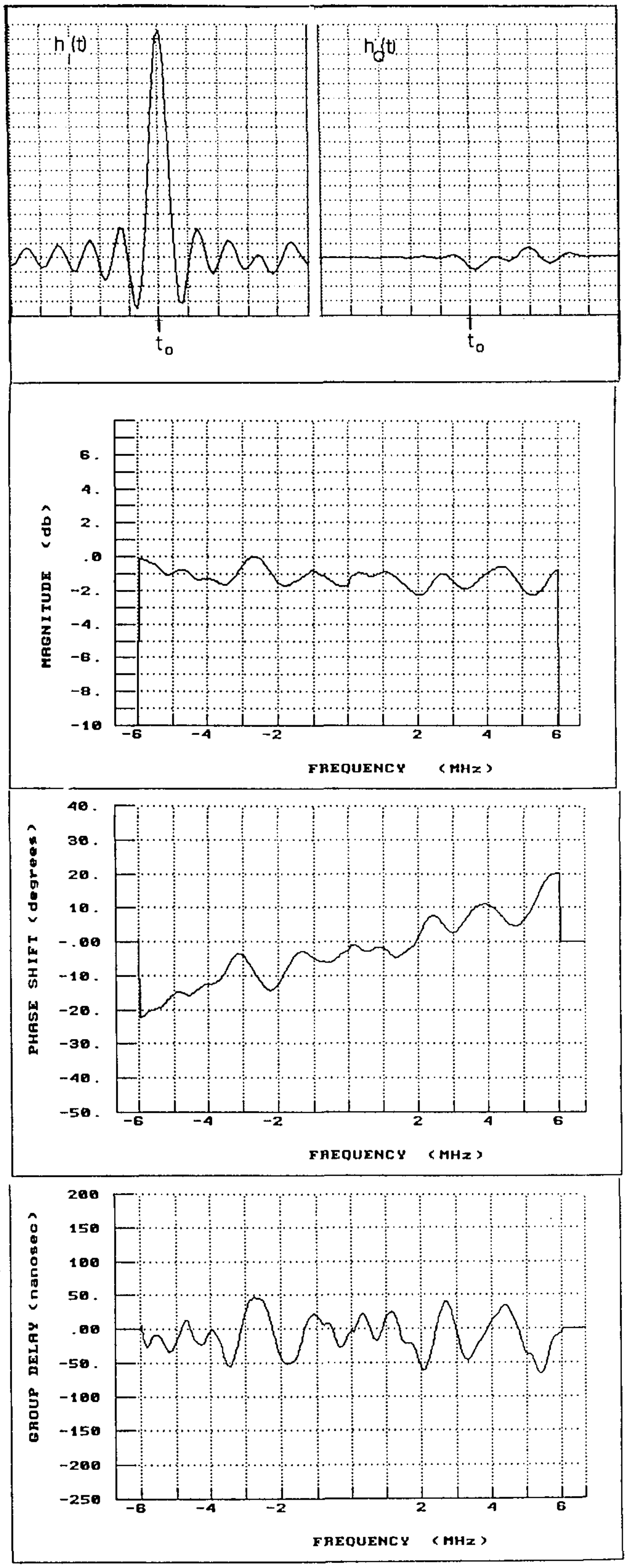

Figure 5 Typical results

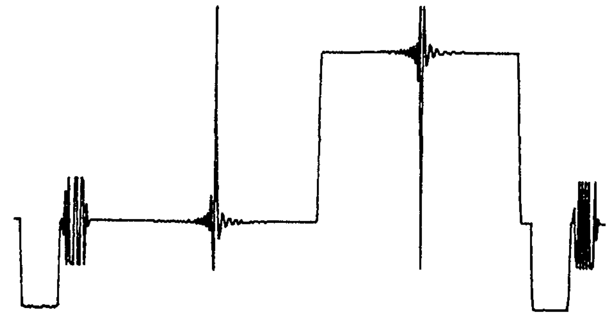

Figure 6a "6 MHz sin x/x" test line

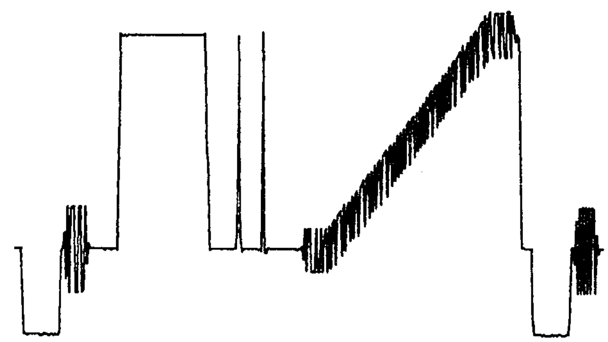

Figure 6b "6 MHz composite" test line

Figure 6c "6 MHz line sweep" test line

CHANNEL TESTS

For the actual tests conducted on cable TV systems, the signal generation equipment was installed at the system headend according to a set-up illustrated in Figure 7. The receive equipment was mounted in a test vehicle which could be driven to any test point of the distribution system (see Figure 8). The "channel" consisted of all the cable equipment and hardware (amplifiers, cable, AML system, taps, etc) comprised between the headend combiner and the subscriber's

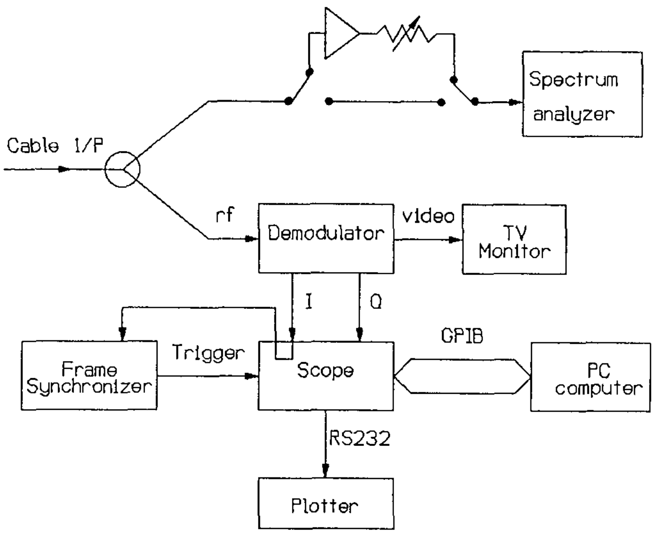

Figure 7 Equipment set-up in the test mobile

drop to which the receive set-up was connected. The carrier frequency was above 400 MHz. Approximately 25 points per system were visited providing results on a good variety of configurations. Also for each system, a "system sweep" was performed by repeating several times the test, at a fixed site, each time using a new carrier frequency to investigate the full CATV spectrum.

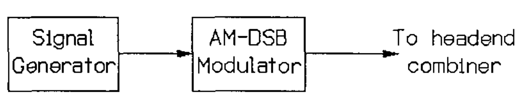

Figure 8 Headend set-up

TESTS RESULTS

At the time of writing this paper, the data collected was being processed and analysed at CRC. Actual results should be available and be presented at the NCTA convention.

CONCLUSION

The concept of the Complex Impulse Response was implemented and used for the characterization of 12 MHz wide cable TV channels. The analysis of the data collected should provide accurate information on certain aspects of modern cable TV systems' performance such as in-band amplitude and group-delay responses, micro-reflections, system group-delay and other parameters that will have an impact on the quality of an HDTV service.

REFERENCES

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