CABLELABS' GHOST CANCELLER TESTING PROJECT

Tom Williams
Cable Television Laboratories, Inc.

Abstract

Digital technology has progressed to the point where it is possible to remove ghosts from television pictures by using baseband digital filters. However for the digital filters to work, they must be programmed with the correct set of coefficients. The best way to determine coefficients is to put a training signal in the vertical interval and analyze the received training signal. The Advanced Television Systems Committee (ATSC) is sponsoring an effort to select a voluntary standard training signal. The committee work is being carried out by the ATSC T3,S5 specialist group. The effort consists of off-air field tests by the National Association of Broadcasters (NAB), lab tests and computer simulation by the Canadian Research Center (CRC), and cable lab and field tests by CableLabs. The BTA ghost cancelling system is currently in use in Japan. This paper discusses the CableLabs tests and results.

The most generally agreed upon characteristics that determine a good training signal are highest possible energy within the time and power constraints of NTSC transmission, flat frequency spectrum, an impulsive autocorrelation function with near zero residual correlation for all time displacements, ease of extraction, immunity from non-linear impairments and small VBI usage. It is important to note that ghost cancellers are designed to fix linear distortions only.

The whole idea of testing hardware to pick a training signal is somewhat tenuous because the proponents' equipment was not all equal in terms of development, and it is possible for a better designed training signal to perform worse in the testing process because of hardware implementation. On the other hand, it is impossible for a system to deghost better than the training signal design allows. The CRC has performed computer simulations on three of the five proponents training signals, and their effort provides valuable information to the committee on the theoretical limits of the systems.

Proponent Description

Five proponents have proposed training signals and built hardware which was evaluated. The waveforms are illustrated in Fig. 1, and are incomplete samples. Typically the waveforms change in a multifield sequence to provide more functions such as DC level reconstruction and noise averaging. The proponents are:

1. ATT/Zenith (ATT) with a pseudo-noise (PN) sequence
2. BTA of Japan(BTA) with an integrated sinx/x pulse
3. Philips (PHI) with a modulated frequency sweep or chirp.
4. Samsung (SAM) with a PN sequence and
5. David Sarnoff Research Center (DSL), also with a PN sequence.

The ATT/Zenith unit was a prototype in the early stages of development. It occupied about of foot of rack space, and had a manual video AGC knob that needed to be adjusted. It produced a number of artifacts, which were presumably related to the development stage it was in. It did incorporate an interesting optional feature: The unit could put on line 12 the solution it had found for the impulse response of the channel. The BTA unit that we were supposed to test failed during the interface week, and a commercial Toshiba deghoster was substituted. This unit was a fully developed commercial product designed to sit on a TV, but had been modified to accept a baseband video input. The unit took a while to deghost, but included a front panel

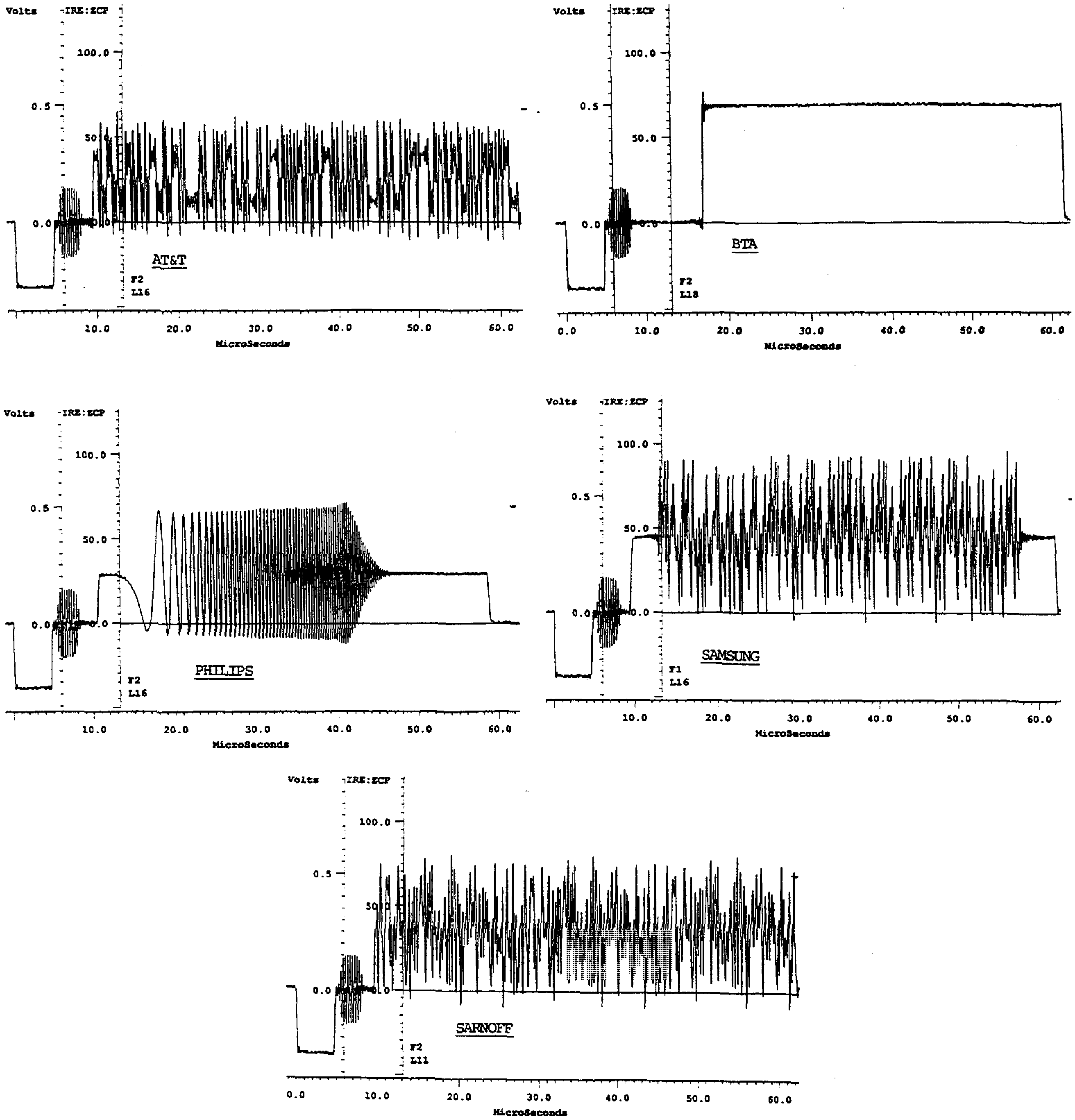


Figure 1. Proponent Training Signals for Ghost Cancellers

display to indicate when it was done. The Philips unit was a prototype in an advanced stage of development, and was also of a size and configuration to sit on a TV. In operation, it computed a whole new set of coefficients every few seconds, and did not appear to do a sliding average. The Samsung unit was another unit in the early stages of development. It stood in a rack about 5 feet high and included a DOS computer. It did not deghost the picture continually, but only when commanded by the computer. The David Sarnoff Research Center unit was a relative of their ACTV enhanced definition ATV system and stood in a rack about 3 feet tall. The unit deghosted continually and used a sliding average deghosting solution. The Sarnoff unit was unique in that it was the only one with no ability to freeze the correction (at lease during the CableLabs and NAB test periods), and it required a full bandwidth quadrature channel.

Testing

The testing that CableLabs did was performed in the Washington DC area by CableLabs personnel during November and December of 1991 in association with the ATSC and National Association of Broadcasters (NAB). We used the same van and some of the same equipment used by the NAB in their field test phase, which took place in September and October. CableLabs testing consisted of two phases, a laboratory phase and a field phase.

For both the lab phase and the field phase, the 5 ghost training signals were all programmed into the vertical intervals of three identical TEK1910 video generators. The video generators were used only for vertical interval insertion. For the cable field tests, two of the training signal

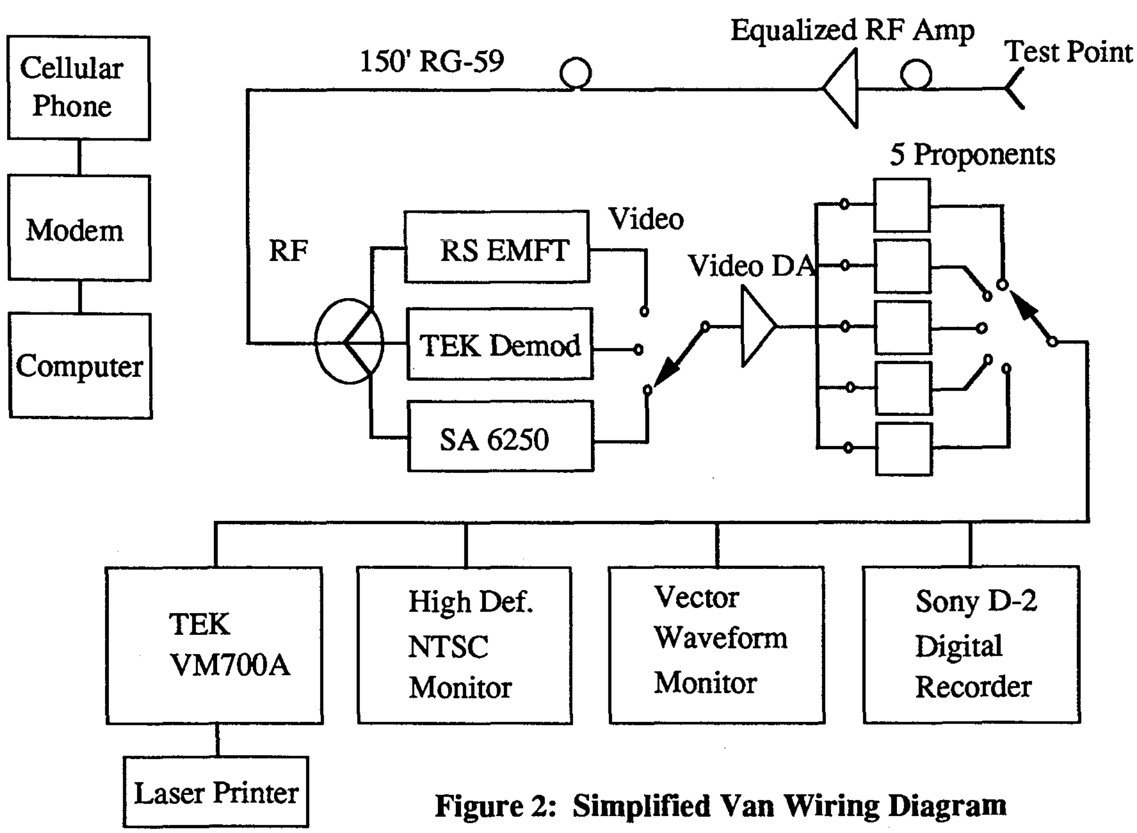


Figure 2: Simplified Van Wiring Diagram

generators were used on the off-air channels 4 and 20. The other training signal generator was located in the headend and put on an unused channel with a video pattern that allowed easy identification of ghosts and other impairments (such as loss of resolution).

In the test van, all 5 proponent's deghosting equipment was loaded along with our test gear. Figure 2 shows the wiring diagram of the van. A cellular phone was used with a modem to communicate between the mobile test van and the 1910 generators for purposes of changing proponents signals. The main demod used whenever possible was a TEK1450-1 because Sarnoff Labs needed a full bandwidth quadrature channel. The Rohde & Schwartz EMFT demod was used as a backup unit to the Tek demod for tests where phase instability was encountered, because it is more tolerant of phase noise. The synchronous SA6250 was used for one specific test because it represents cable gear typically used in headends. Various pieces of video analysis and recording gear were used to analyze and capture the data.

Digital recording was done on a Sony portable D2 composite video tape recorder and waveforms were recorded from and analyzed by a Tek VM700A waveform analyzer driving a laser printer.

The lab portion of the tests were performed by backing the test van up to the CableLabs test bed in Alexandria, Va., and running an impaired channel 12 carrier out to the van, as shown in Fig. 3. The lab tests lasted about a week and consisted of tests with ghosts, as well as ghosts with additional impairments such as Gaussian noise, composite triple beat and residual FM plus phase noise. Tests were also done with negative traps and with different demodulators and set top converters to check compatibility.

Figure 4 is a diagram of the Cable field tests. The field tests were performed on four different cable systems, Jones in Alexandria, District Cablevision in Washington DC, Cable TV Montgomery, and Media General of Fairfax. The general procedure was to install our equip-

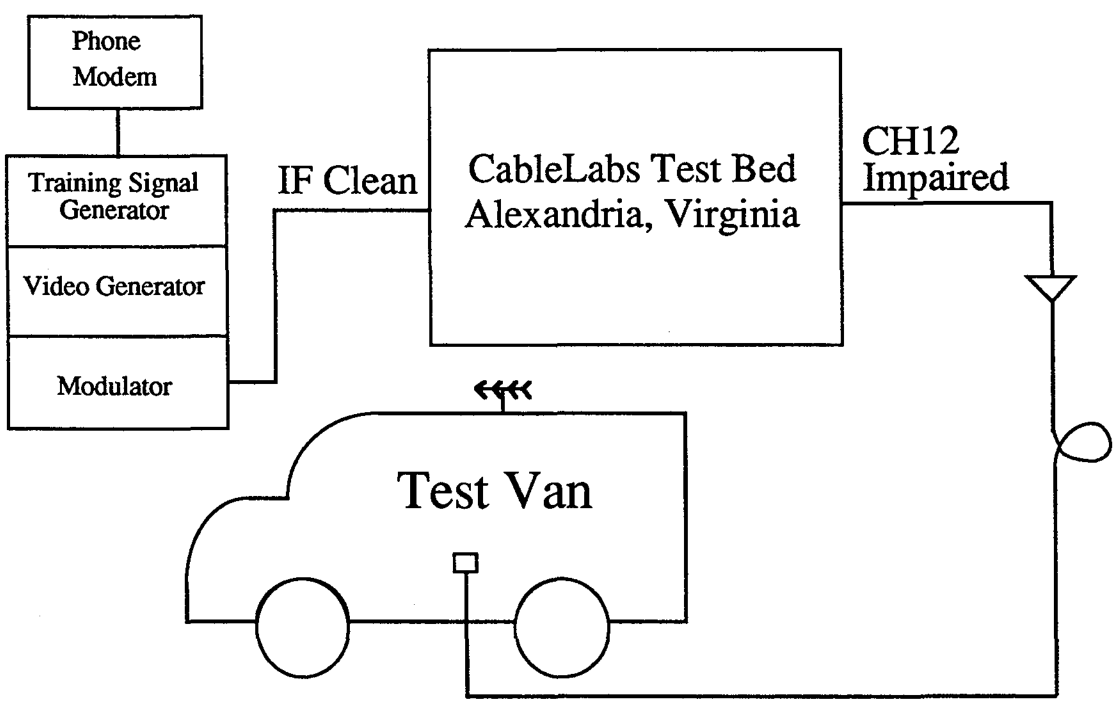


Figure 3: Lab Test Diagram

ment into the headend on an unused channel, characterize the location for both off air and the locally originated channel, and then test the proponent's equipment. Then the van was taken out into the field to 1 AML hub site, one fiber hub site, 12 taps, and 12 individual homes. Typically, the channels were characterized, and then each of the ghost cancellers were allowed to correct the channels one at a time. The tests that were actually performed at each location varied, and were chosen to reveal system compatibility problems as well as to identify performance differences between the proponents. The video and waveforms of the corrected video were digitally recorded.

Additionally, tests were done with each of the proponents on selected RF and baseband converters. The concern with the RF set top converters was that the phase noise and residual FM from the up-down converter would cause problems with the true synchronous demods that are necessary to demodulate video for ghost cancelling. The concern with the baseband converters is that they use non-synchronous demodulators, and these may cause poor deghoster performance. Although the handful of set tops tested did perform relatively well, more investigation of representative samples of the overall population converter boxes is merited.

Results

Figure 5 summarizes the results of the lab test using the magnitude frequency response ripple to 3.58MHz as the vertical axis. The baseband

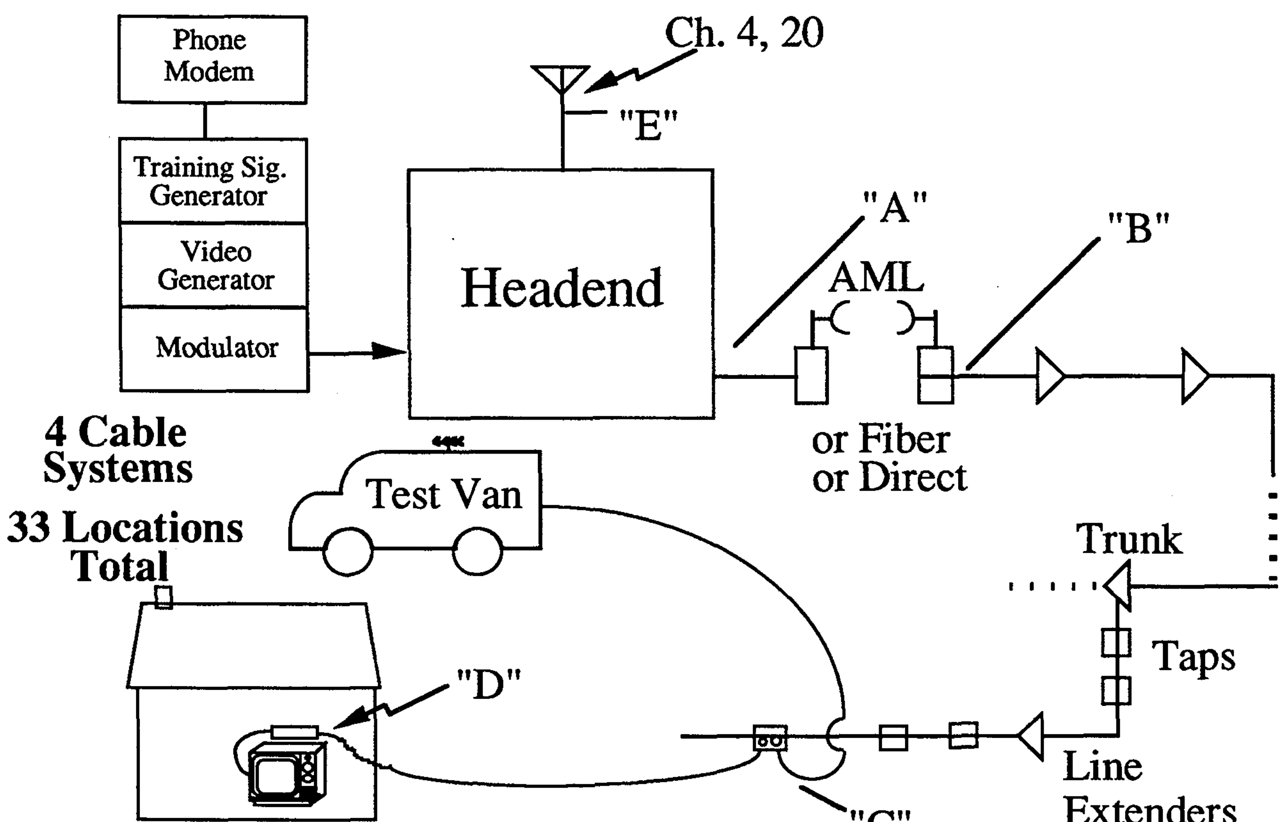
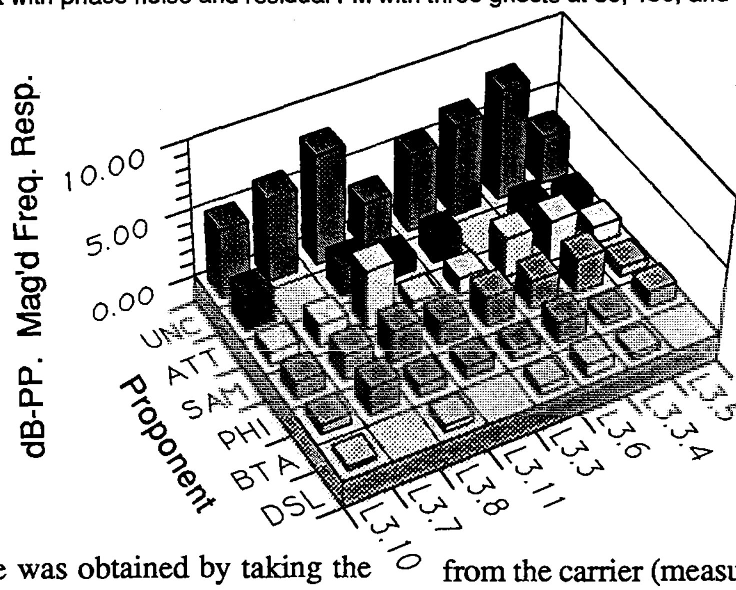


Figure 4: Field Test Diagram

Fig. 5 Peak-to-peak magnitude frequency response versus proponent versus lab test number.

L3.10	Test with traps at channels 11 and 13
L3.7	Test with SA8580 RF converter and ghosts at 150, 600, and 2500ns, each -15dBc.
L3.8	Test with -40dB CTB and three ghosts at 300, 600, and 1250ns.
L3.11	Test with SA6250 synchronous demod and three ghosts at 80, 150, and 1250ns.
L3.3	Test with three ghosts at 40, 150, and 2500ns.
L3.6	Test with SA8590 baseband converter and three ghosts at 150, 600, and 2500ns.
L3.3.4	Test with three ghosts at 300, 600, and 1250ns.
L3.5	Test with phase noise and residual FM with three ghosts at 80, 150, and 2500ns.



frequency response was obtained by taking the fast fourier transform (FFT) of the sinx/x waveform in the vertical interval. The corrected frequency response ripple does not take into account the fact that a long ghost is more noticeable than a short ghost, but it provides, along with K factor, a good indication of how the ghost canceller is functioning as both a ghost canceller and channel equalizer. The uncorrected data was labeled "UNC" and placed as the last set of bars in the graph. In the case of ATT the missing blocks are due the equipment being out of service. Most of the missing data on DSL is due to the fact that a demodulator with a broadband quadrature output, that would withstand large amounts of phase noise, was not available. Two test were done with ghosts only. One test used ghosts at 300, 600, and 1250ns. and the other used ghosts at 40, 150, and 2500ns. The levels of the ghosts were all 15dB below the carrier at random phases. The residual FM and phase noise tests were done with 120Hz. FM at 8kHz. deviation, combined with a phase noise of -82dB below the carrier at +/- 20kHz from the carrier (measured in a 1Hz bandwidth). Set top converter tests were done with a RF heterodyne converter and with a baseband unit borrowed from Jones Intercable. The Rohde & Schwartz EMFT demod had to be used to demodulate the signal from the RF set-top converter because of phase noise and residual FM. A test was also done with ghosts using the SA6250 demod. Again, the lack of a quadrature channel meant that Sarnoff could not be tested. The test with traps was done to see if the roll-off caused by adjacent traps could be corrected by the ghost cancellers.

Figure 6 shows the frequency response of the received off-air channels along with deghosted response. Most of the data was taken using headends, but location 16 data was taken using the van antenna. Although there were not any long, large prominent ghosts encountered in the headends we visited, we observed short ghosts and equalization problems as a result of ghosts.

Fig. 6 Peak-to-peak magnitude frequency response versus proponent versus location and off-air channel.

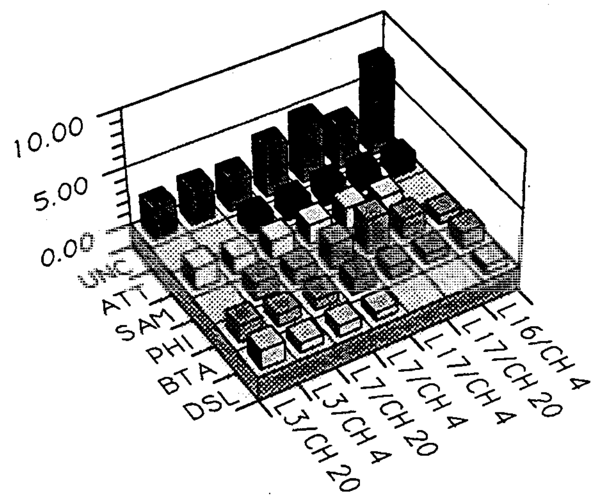


Table 1

Proponent	ATT	BTA	PHI	SAM	DSL
Carr. to Noise	35dB	40dB	30dB	35dB	25dB

Table 1 summarizes how the ghost cancellers performed with noise. The test was performed by increasing the noise level in 5dB increments and noting the last place that a proponent's equipment was seen working. The observation that should be made from this data is that the BTA system fails to cancel ghosts at a higher carrier to noise level, and this is expected because their differentiated training signal is a low energy one. The differences between the other proponents is more than can be explained away by a theoretical analysis of the energy in their waveforms, and was probably due to differences in the amount of averaging done to remove noise, and differences in the performance of individual sync separator circuits. The proponents have been nondescript of their system implementation technical details, so we can only surmise the reasons for some of the test results.

The tests indicate that these ghost cancelling devices work well and will produce dramatic improvements in the quality of the off-air broadcast signals. Cable systems should deghost off-air signals for their subscribers and can additionally flatten signals that only need equalization. Additionally, TV sets with built in deghosters should work without artifacts on cable. This means that the cable industry needs to work with the consumer electronics manufacturers to insure that the necessary features such as a phase noise tolerant demod, and an "OFF" switch are built in. Another unresolved issue is the ability to track ghosts that are time varying. In heavy wind loading conditions, transmit and receive towers sway, and this means that the ghost canceller must be very fast to track movement. The higher the UHF channel, the worse the problem will appear to be. Training signal acquisition time and computation time must both be figured evaluated.

Conclusions

It appears that ghost cancellers can soon be in the headend, and should provide us with a valuable tool to improve the quality of off-air channels. Many thanks to the systems that provided equipment, personnel, and time to our tests, and to the CableLabs technical people who supported the testing and analysis effort.