

GHOST CANCELLING AND CABLE

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Abstract

This paper provides a pragmatic approach to ghost canceller applications in a cable television system. The experience of Rogers Cablesystems in the deployment of ghost cancellers in its Vancouver operation will be shared with other cable operators and a check list of what precautions to take when installing a Ghost Canceller is presented. Further field tests are planned to assess the Ghost Canceller's ability to further recuperate an echo contaminated signal at various depths into the cable network. The ultimate goal of this exercise is to deliver the best possible picture.

Introduction

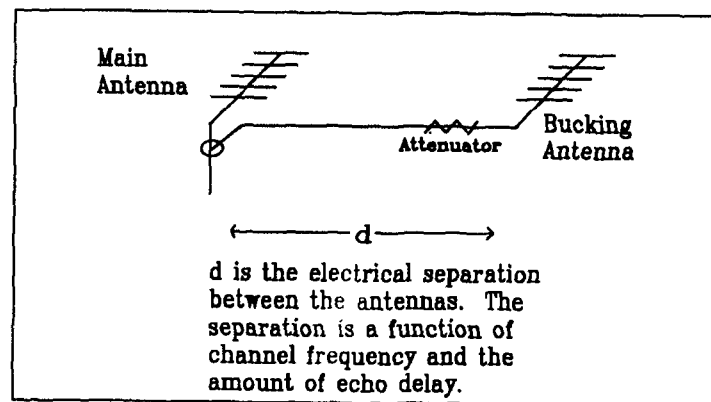
Signal reflections from terrain and large structures has plagued broadcast television reception since broadcasting's inception. TV set manufacturers have been studying ways to correct for the resulting "ghosts" for decades but the circuit complexities required to accomplish this have been very costly. More recently with the advent of high speed integrated circuits microprocessors and low cost memory, stand alone "ghost cancellers" have been made commercially available but these are still quite costly for most consumers. Eventually these circuits will be embedded within the TV receiver itself especially within receiver intended for the reception of advanced television formats.

Consumers are demanding better quality reception now. It's going to take many years before a

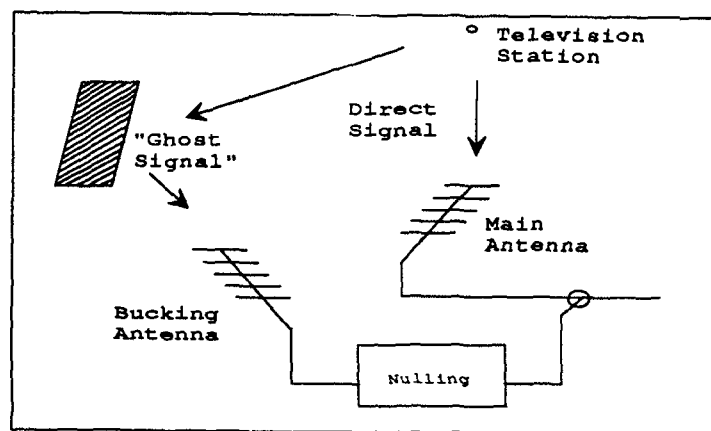
significant number of "ghost cancelling" receivers are in the market place. However, placing ghost cancelling equipment at cable television headends allows all television receivers connected to the cable television network to benefit from the resulting ghost free picture. With the rapidly increasing number of television sets obtaining their broadcast TV reception from cable there is little need to burden each television set with complex and costly echo cancelling circuits.

Pros and Cons about using antenna systems to eliminate "Ghosts"

Cable operators have long been battling the problem of multipath reflections contaminating their received headends signals. Historically, an RF technique (sometimes baseband technique) has been used to cancel the ghost (See Figure 1a, 1b and Figure 2). These techniques require a high degree of precision in trimming long lengths of cable to the appropriate delays or adjusting sensitive phasing devices and matching the amplitude of the reflections using active or passive devices. These techniques, although time consuming to set up, have been quite effective. Once they are set up, little maintenance is required. They usually don't achieve 100% cancellation. In particular, the colour burst signal is somewhat difficult to cancel precisely in phase. In addition, signal-to-noise ratios are sacrificed during signal recombination and any change in



(a)



(b)

Figure 1: RF Cancellation Technique

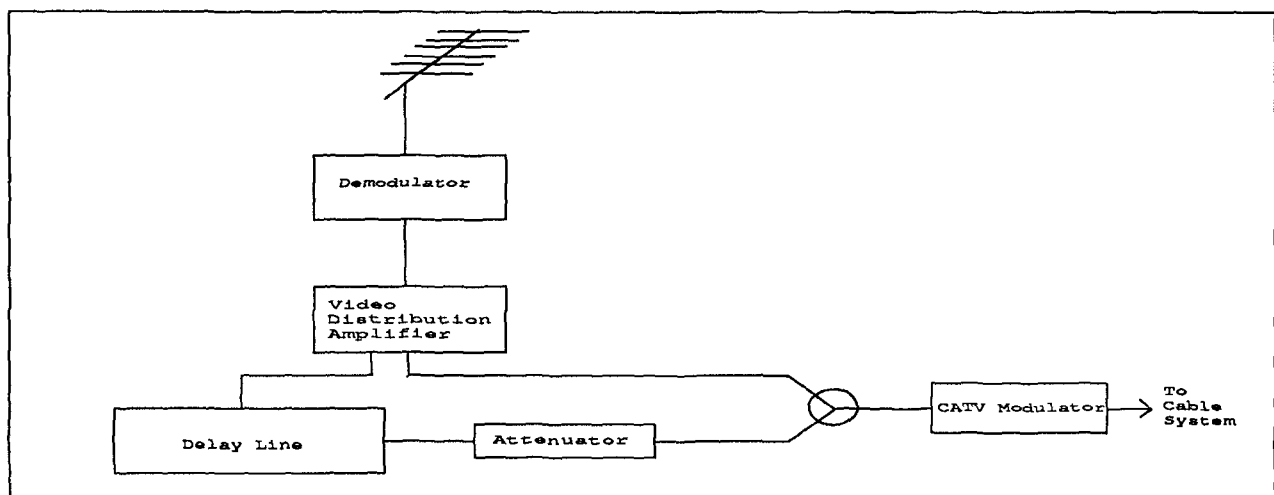


Figure 2: Baseband Cancellation Technique

propagation conditions affects cancellation performance.

Chronology of the Rogers Ghost Cancellor Project

In early January, 1990, Rogers Cablesystems embarked upon a project in Vancouver, B.C. to improve the reception quality of the three Seattle based television stations. The three transmitters are located near downtown Seattle. Thus, the signals received at a remote headend site on Salt Spring Island (see Figure 3) were severely impaired by several reflections created by the Seattle downtown core. The situation was deteriorating as developers built additional commercial office towers.

The objective of the exercise, was to improve picture quality through the application of Ghost Canceller Technology. In early 1990, Electronic Ghost Canceller equipment was not commercially available in North America. A few technical journals had published articles about the availability of Ghost Canceller technology and equipment in Japan but none of this equipment was yet available in North America. Rogers was able to obtain some of these units from these Japanese manufacturers. With the cooperation of one of the Seattle broadcast stations to insert special signal in the VBI and the loan of insertion equipment from equipment suppliers, the units were placed in test at Salt Spring Island immediately following the NAB convention. The Ghost Cancellers were put into full operation on the first channel May 11, 1990. Shortly thereafter, the second and third units were put into service.

Fundamentals of Electronic Ghost Cancelling

Two configurations of ghost cancellers are now commercially

available in Japan: a stand-alone set top unit and a version integrated within high-end television set. The set top unit 76 is essentially a television tuner demodulator and echo cancelling circuitry. The integrated version incorporates the ghost cancelling circuitry as part of a television sets own base band circuitry. They both use the same principle of operation relying on a reference signal in the vertical blanking interval. The Ghost Cancel Reference (GCR) signal was developed for this application by BTA of Japan. The format of the signal is a $\sin x/x$ bar signal (see Figure 4). The reference signal is inserted at the transmitter on lines 18 field 1 and 2 in the vertical blanking interval. It is transmitted in an eight-field sequence. The eight-field sequence is derived as a result of the four-field sequence of NTSC signal and the ease of extraction of the GCR signal by a simple subtraction. The GCR signal is able to cope with multiple reflections up to 44 microseconds of delay. Figure 5 is a generic block diagram illustrating the principle of operation of a ghost canceller. The echo is eliminated by the transversal filters. The tap coefficients of the filters are derived from the output signal and the reference signal. Based on the distorted GCR signal received, the microcomputer applies some mathematical manipulations to transform the distorted GCR to its original shape. The mathematical transform is then converted to the transversal filter tap coefficients.

There are two ways of calculating the tap coefficients of the transversal filters. The first method employs a Fast Fourier Transform with which all tap coefficients are calculated in one single shot. The second method is an iterative method

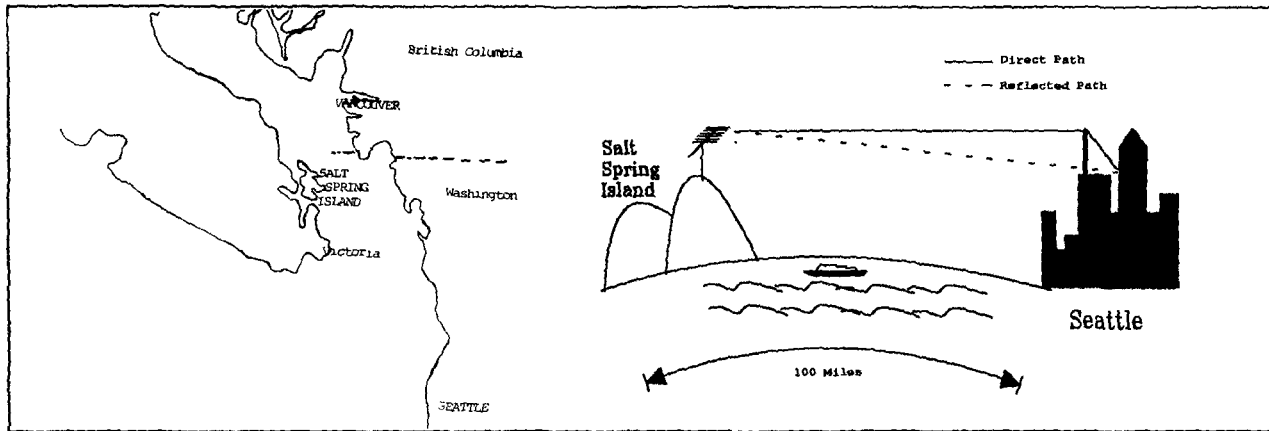


Figure 3: Transmitter and Headend Location

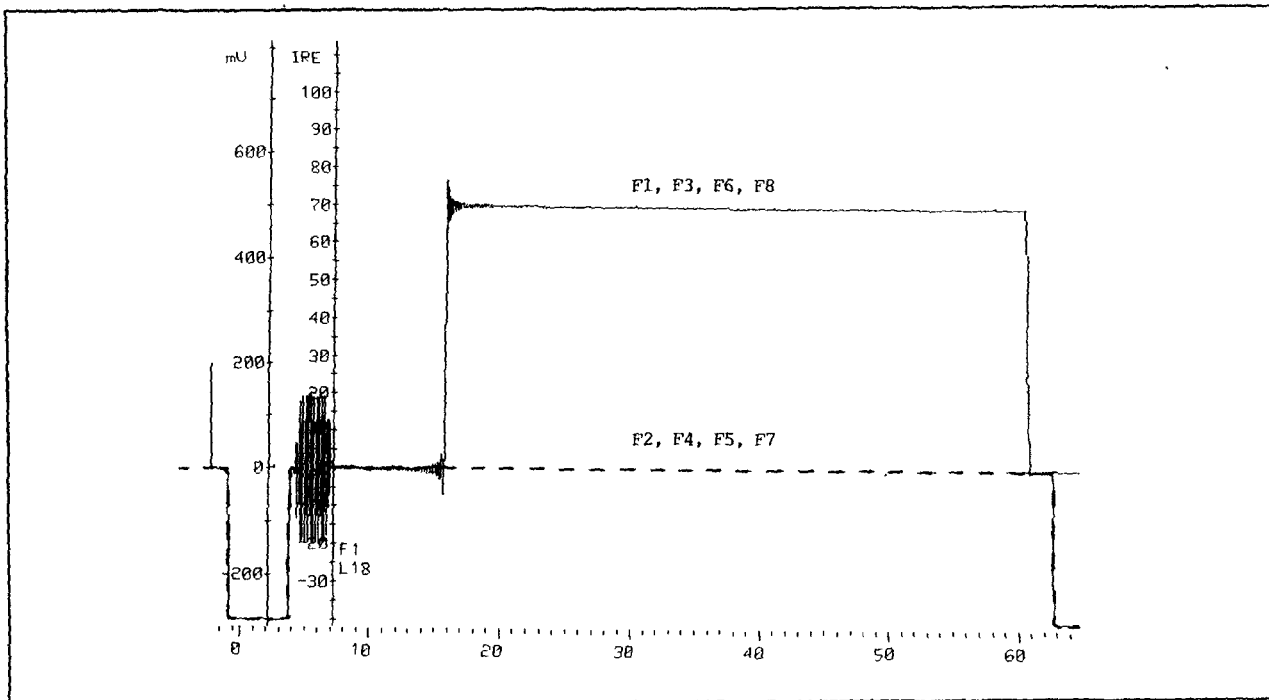


Figure 4: Format of a BTA Ghost Cancel Reference (GCR)

which requires less processing power but demands a longer calculation time. Most consumer grade Ghost Canceller units employ the iterative algorithm and an optimum number of taps for reduced cost while still being able to reproduce a relatively echo free picture. Some versions have differing training method to achieve a faster convergence time. Figure 6 shows a block diagram of a typical Electronic Ghost Canceller.

Installation of Ghost Canceller Equipment at the Headend

To most cable television technicians, installation of a television tuner is simple and considered straight forward. However, implementing Ghost canceller capabilities proved not to be a trivial matter. One first has to obtain cooperation from the broadcaster to insert the GCR signal on line 18 in the vertical blanking interval. One of the broadcast stations in Seattle was already using line 18 for automatic station monitoring. This had to be relocated.

Apart from freeing up line 18, attention must be given to the line preceding a GCR signal. Information on the line can be any test signal except it must be time invariant. Teletext, closed captioning and active video are examples of time varying signals. Such signals compounded with long delays may confuse the ghost cancelling iteration process and adversely affect the convergence.

Another complication with present equipment is channel tuning. Since existing Ghost Cancellers are made for the Japanese market, the tuners' frequency assignments are of the Japanese standard. The units will not tune any low band channels or the first four high band channels. This inconvenience may be overcome by modifying the units to accept input at video

baseband. Some manufacturers do provide a video baseband input feature as an option. A problem associated with using the video input is that the cable demodulator feeding the Ghost Canceller must operate in synchronous detection mode. Its' tuner/demodulator characteristic must also be very linear for the ghost cancellation to function properly. Demodulator non-linearity greatly affects the Ghost Canceller performance. Figure 7 outlines an acceptable level of demodulator performance. When AC powering these early Ghost Cancellers, it is handy to note they may have been configured to operate with 100 volts ac, the Japan powering standard. Using 120 volts may seem to be no problem initially but that running a device constantly with a 20 % higher rated voltage will have an adverse effect on its reliability and performance.

Another concern is the 4.5 MHz subcarrier. The Ghost Cancellation process occurs at baseband and the video signal is digitized and processed in the digital domain. The processed video will likely contain digitally generated spurious products which fall above 4.2 MHz. This spurious above 4.2 MHz is of little concern when the Ghost Canceller is used in its consumer application feeding directly into a television set. Cable transmission requires a clean 4.5 MHz aural subcarrier. The spurious outputs resulting from the digital to analog conversion, may create audio distortion described as "a mysterious crackling effect on the main audio" by the customers.

Operating Experience with Various Makes of Ghost Cancellers

A few problems were experienced at the Salt Spring Island antenna site. For example, one of the

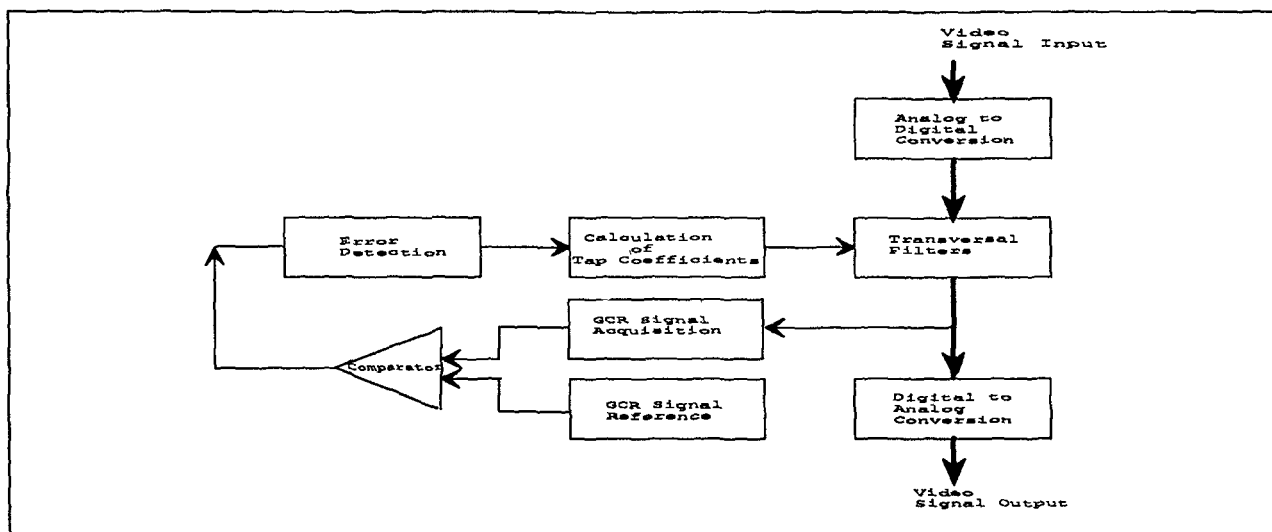


Figure 5: Diagram of Principle of Operation

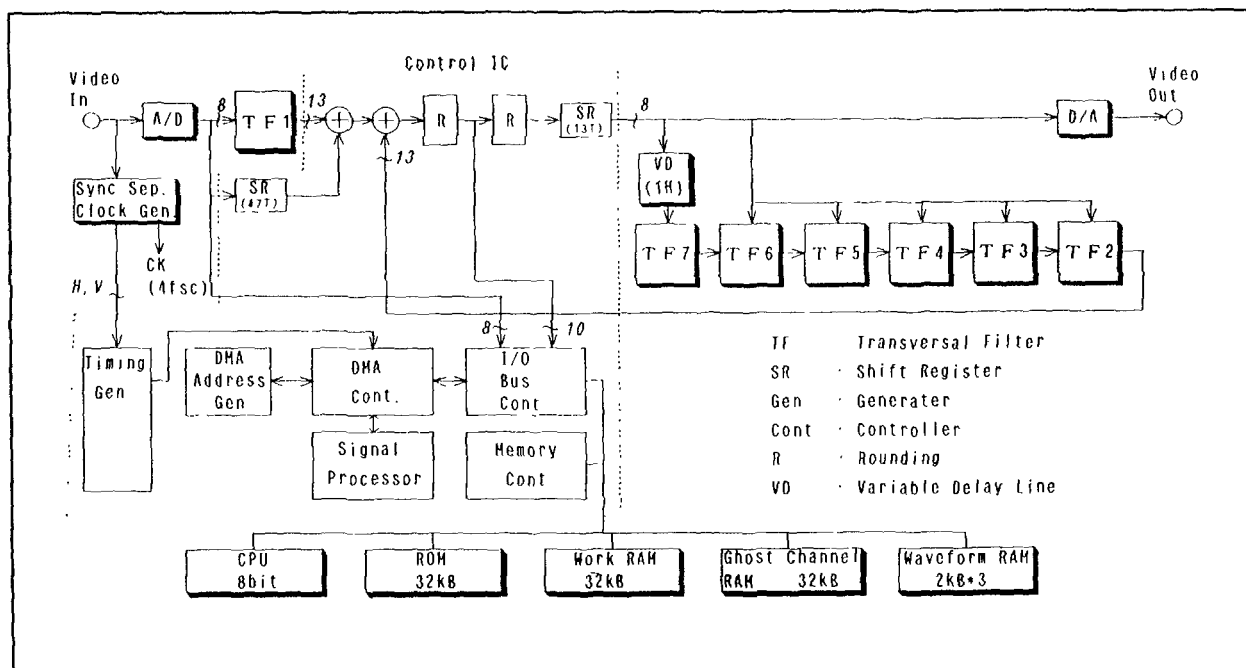


Figure 6: Block Diagram of a Typical Ghost Canceller

(Courtesy of Toshiba Audio Video Engineering Co.
 Ltd. --- IEEE Transaction on Consumer Electronics
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ghost canceller units would occasionally unlock causing a ghostly picture to appear for a few seconds then correct itself. Another example was that the ghost cancelling iterative process locks-up. Consequently, the unit fails to track the change in ghost condition when propagation condition vary. The latter problem was resolved, in the short term, by installing a remotely controlled switch that would reset the unit when dispatch noticed the condition. In the longer term it is anticipated the manufacturer will correct these defects.

Ongoing Research into Ghost Cancellers and their Application

Rogers Cablesystems and CableLabs are jointly conducting further field tests on a variety of ghost cancellers. Various manufacturers and the three Broadcasters continue to provide their support. In addition to the three ghost cancellers mentioned above, the performance of a more sophisticated Ghost Canceller is being evaluated. This particular unit, although an engineering prototype, is tailored for the professional market. Along with baseband input and output, this Ghost Canceller features interframe processing techniques to achieve received signal noise reduction.

Initially, all the Ghost Cancellers will be tested in a laboratory environment. Each unit will be carefully characterized for its video and/or RF performance. Subsequent to the laboratory testing, a series of over-the-air tests will be conducted at the antenna site in Salt Spring Island to assess each units reaction to varying propagation conditions. The findings will be presented in a report through Cable Television Laboratories, Inc. in Boulder, Colorado.

The second phase of the tests are aimed at assessing the benefits of ghost cancelling equipment in improving the quality of transmission in a cable television network. GCR signal insertion equipment will be installed at Rogers' Vancouver central headend. A full set of propagation tests over coaxial cable plant will be conducted. Two test channels will be chosen, one from the low band and one from the ultraband. Four test points from the trunk will be chosen and correspondingly, four test points from the feeder plant will be selected. Each test point will be monitored over four months of periodic testing. Further test bench analysis will then be made on each individual Ghost Canceller. Each unit will be subjected to a range of noise and non-linear distortion products to determine thresholds of inoperability in the presence of interference. This will assess the ruggedness of the GCR signal to cable system transmission impairments. A final report will be prepared detailing the various findings and results of the analysis. Again, the second part of the report will be presented through Cable Television Laboratories, Inc.

Too Early for Conclusions

Ghost Cancelling equipment available today is mostly aimed at the consumer marketplace for domestic TV off air reception. From a cable operators' perspective, a unit at the headend immediately allows all customers to benefit from improved reception. The most intriguing notion is whether further improvements are possible by migrating the location of the units further into the network. The additional reflections and noise induced by this part of the network would be removed if indeed the Ghost Canceller does

Synchronous Detection

Noise Figure	<7dB
Differential Gain	<2%
Differential Phase	<1°
Image Rejection	>60dB
Adjacent Channel Rejection	>60dB
Frequency Response	<0.5dB
Envelope Delay	<50 ns

Figure 7: Acceptable Demodulator Performance

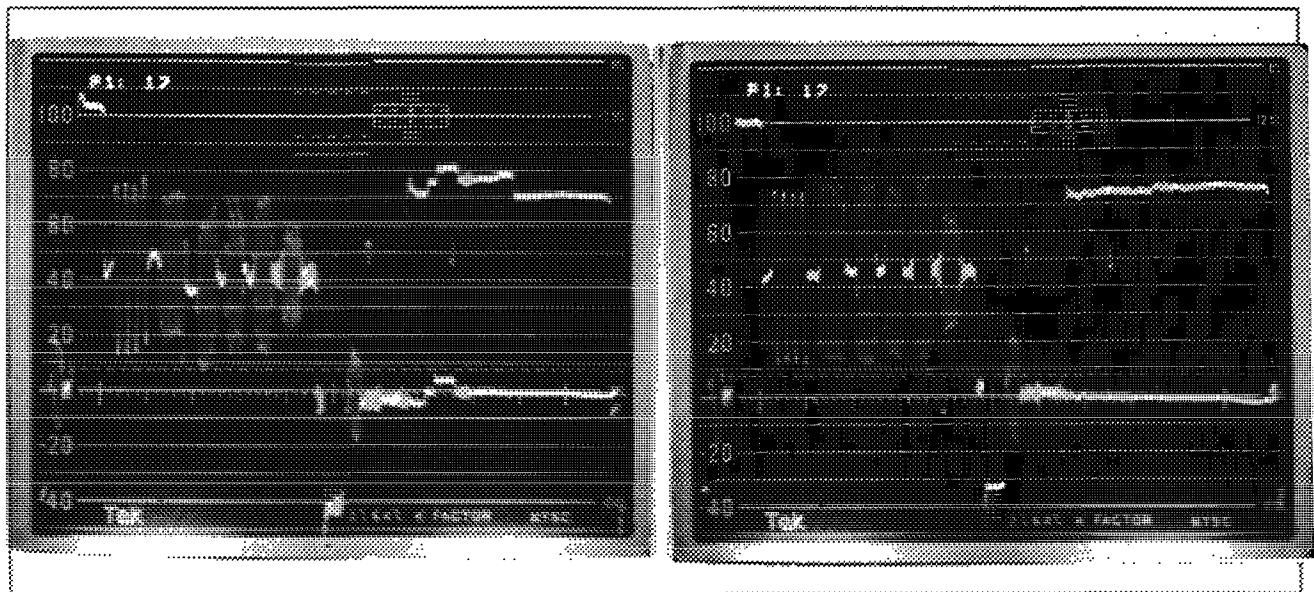


Figure 8a: Video Waveform without Ghost Cancellation

Figure 8b: Video Waveform after Ghost Cancellation

recuperate the original signal. However, with the inclusion of various active elements in the transmission path, will the performance of Ghost cancellation be sacrificed? What will be the tradeoffs?

Experience has already shown that the Ghost Cancellers do not work very well with a clamping amplifier in an FM microwave link. But, is the Ghost Canceller capable of eliminating multipath associated with FM or AM microwave or supertrunking systems?

Most existing ghost canceller equipment is a consumer electronic product and is not designed for the professional environment. How well will it stand up to the 24 hours a day and 7 days a week operating conditions of a headend application? What would it take to produce a unit having the professional quality suitable for broadcast and cable television applications?

What about the possibility of exploiting the Ghost Cancelling concept to tackle co-channel interference?

It is the intention of Rogers Cablesystems and CableLabs to assess the strength and weaknesses of the Ghost Canceller system and to study the full implication of this technology for the cable industry. It is hopeful that partial results of these Ghost Canceller studies will be available at the presentation of this paper.

Acknowledgement

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stations and the support of various Ghost Canceller manufacturers is vital to this ongoing project. Their help and support is most appreciated. Currently, Rogers Cable TV has four Ghost Reduction Devices (JVC, NEC, SONY and Toshiba) in daily headend operations at the Salt Spring Island antenna site.

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Biographies

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Nick Hamilton-Piercy is the Vice-President, Engineering and Technical Services for Rogers Cablesystems Limited, his duties include managing the corporate engineering group, Rogers Engineering, as well as being responsible for the engineering and capital programs within the Company operating systems. Nick has been with Rogers for 15 years.

Prior to this, Nick was with the Canadian Marconi Company where he managed an analogue and R. F. engineering department responsible for the design development and manufacture of a wide range of telecommunications equipment including microwave radio systems, multichannel UHF tactical relay systems and microwave R.F. hardware.

Nick graduated in Engineering from the Medway College of Technology in Chatham, England, during 1961 where he specialized in electrical engineering and qualified for full Chartered Engineering status. He is a member of the Institute of Electrical Engineers (IEE) U.K.; a member of the Association of Professional Engineers of Ontario (APEO); a Senior Member of the Institute of Electrical and Electronic Engineers (IEEE); a Senior Member of the Society of Cable Television Engineers (SCTE); Chairman - Futures Committee, Canadian Cable Television Association (CCTA); Chairman ATV Subcommittee of Cable Television Laboratories Technical Advisory Committee, and Chairman of the National Cable Television Association Engineering Committee - HDTV Subcommittee.



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Gary Chan is a Staff Engineer at Rogers Engineering, Toronto, Canada. He received his B.Sc.E.E. degree in 1980 from the University of Manitoba and Master of Engineering (Electrical) degree in 1986 from the University of Alberta. Since his graduation in 1980, he has engaged in CATV design, operation, maintenance, research and development of advanced cable television technologies. He is a member of the IEEE and a registered Professional Engineer of Ontario.

