BROADBAND SWEEPING: A NEW APPROACH

William Gregory Kostka

Engineering Manager
Gillcable TV
234 East Gish Road
San Jose, CA 95112

ABSTRACT

An active CATV system frequency response is typically measured by using either a high-level or a low-level sweep--but both of these methods have inherent limitations. Gillcable's on-going gated mid-level sweep project is developing a new method which can improve resolution and readability, while simultaneously minimizing system interference.

High-level sweeps provide good signal to noise ratios and are easy to detect, but they significantly interfere with existing cable signals. Because of this interference, the sweep repetition rate is usually low, thus impairing readability. While low-level sweep is relatively non-interfering, its low level reduces the signal to noise ratio thus impairing resolution. Furthermore, any higher level cable signal will mask the sweep and also impair readability.

Gillcable's gated mid-level sweep project is based on selective spectrum sampling; it is not an analog sweep, but a series of samples at arbitrary frequencies. The sample points can be set to avoid any critical cable frequencies. But beyond just that, to avoid interfering with television pictures, the signal source will only generate signals on an occupied channel during video blanking intervals.

Since the gated signals only minimally interfere with existing signals, sweep level can be set high enough to deliver good signal to noise ratios for a high-resolution display.

METHODS FOR MEASURING FREQUENCY RESPONSE

Frequency response, gain variation at different frequencies, is a critical CATV distribution system parameter. Several methods exist for measuring this response. Some, like noise insertion or standard broadband sweeping, require the cable signals be removed; others, like slow sweeping, require technicians in constant communication at both the head-end and in the field; while others, like simultaneous high-level sweep or low-level sweep can be continuously and automatically combined with regular cable signals.

The two former cases are not applicable in large active cable systems. The first method would require removing 24 hour premium services for extended periods, an act certain to provoke customer complaints, while the second method would require far too much time to sweep an 1800 mile plant like Gillcable. The latter method avoids those deficiencies. The sweeps run concurrently with cable programming, so no program interruptions are required. Furthermore, since they are continually available, many sweep receivers can be in use simultaneously, so a large plant can be swept in reasonable time.

The high-level sweep is typically run 15 to 20 dB above video carrier level. This relatively high level delivers a clear display because of its high signal to noise ratio. Also, its level makes it easy to recover, so sweep receivers are relatively uncomplicated and hence inexpensive. High-level sweep, however, does have a significant drawback--it interferes with the existing cable signals. As the sweep passes through an occupied TV channel, it can

- create visible distortions in the picture,
- prematurely trigger the vertical sync circuits in the TV causing the picture to roll,
- cause VCR servos to lose lock while recording, or
- fool AFC'd set-top decoders into "following" the sweep up and then locking onto the next channel.

The exact symptoms depend on subscriber terminal equipment, sweep level, and sweep speed. High-level sweeps also affect in-band and out-of-band telemetry and system pilots. The sweep can be trapped at these critical frequencies, but in a loaded system the sweep display soon begins to have as many holes in it as a golf course. One other distortion that can occur is loss of accuracy caused by too high a sweep level driving amplifiers into compression. Basically, as long as the amplifiers are operating in their linear regions high-level sweep provides a clear accurate display, but the interference is significant.

The interference can be minimized by reducing the time the sweep is actually present on the system. The repetition rate for high-level sweep is typically one sweep every 5 to 20 seconds. This low "rep" rate can be accommodated by using storage oscilloscopes or patient technicians. Incidentally, to further minimize the effects of the high-level sweep used at Gill, we have installed timers that prevent sweep from occuring during prime-time hours and have installed radio-controlled switches that enable sweep for 10 minutes at a time. That is enough time for a technician to adjust a station, then the sweep automatically turns off while he is in route to the next station.

Low-level sweep systems typically run 20 to 40 dB below video carriers. This prevents it from being as interfering as high-level sweep. Low-level sweep can be set far enough below video carriers so as to be virtually non-interfering. This reduction in level, however, makes the sweep signal more difficult to recover, so the receivers are correspondingly more complex and expensive. They are narrow-band spectrum analyzers that track the transmitter by locking to a pilot carrier. The reduction in level has also had an effect on display resolution. Since the sweep signal is below the level of cable signals, the sweep is masked by the cable signals and some of their side-bands. In a fully loaded cable system, much of the sweep is simply not visible. Also, the corresponding signal to noise ratio of the recovered sweep signal suffers from the reduced sweep level; the display is often an ambiguous 2 dB wide trace. This effect is accentuated by amplifier cascade length, but then so are system frequency response problems. So in long cascades where the most careful adjustments are needed, low-level sweep provides the least resolution.

In short, both high- and low-level sweep methods leave room for improvements.

MID-LEVEL SWEEP PROJECT

The purpose of this paper is to describe an on-going research and development project at Gillcable. We had as our goal, an improved CATV sweep system. We wanted a sweep system that was non-interfering, yet was continually present, and of course, required no technicians at the head-end. The sweep level was to reflect the typical video carrier levels on the cable: low enough to avoid non-linearities from the amplifiers, yet high enough to provide a clear, unambiguous sweep display. The receivers had to be easy-to-use, accurate, reliable, and inexpensive. Since they were field equipment, they also had to be compact, lightweight, rugged, and battery operated.

With these goals in mind, we proposed a sweep system uniquely suited to our CATV environment. We refer to it as the "Mid-level Sweep System." Mid-level refers to the RF carrier level, which is set at video carrier level. This puts it midway between high- and low-level sweep; 15 to 20 dB below high-level and 20 to 40 dB above low-level. This RF level will provide a clear display even in long cascades while avoiding any non-linear amplifier distortions from using too high a level. The term "sweep", however, is a misnomer. Instead of using an analog sweep that would pass through all possible frequencies, this proposed system would instead, use a switched carrier at discrete frequencies. The frequencies could be selected somewhat arbitrarily as long as they were sufficiently closely spaced to provide enough resolution to assure response anomalies were not missed. But more importantly, critical frequencies, like system pilots and telemetry carriers could be bypassed entirely. Interference at those critical frequencies, then, would not be a problem.

Obviously, we couldn't bypass all occupied TV channels, and interference caused by inserting an additional carrier into an occupied video channel is a major problem. There is simply no way to do it without creating some beat in the picture. However, during the horizontal and vertical blanking intervals in an NTSC television signal, the TV receiver is blanked; the picture tube is cut off, and the screen is black. We proposed to use these blanked intervals to hide any interfering beats our additional carrier created. Additionally, video side-band energy should be minimal during those intervals, so we would have a relatively clean spectrum in which to insert our signals.

The transmitter and receivers would be synchronized by an auxiliary data channel. Both timing and frequency data would insure the receivers could find these very short pulses as they are moved through the cable spectrum.

TRANSMITTER DESIGN CONSIDERATIONS

The transmitter control section needs to be intelligent enough to decide when a channel is occupied, even when the video is scrambled. It also needs some form of memory wherein to store the critical frequencies to be skipped. For these reasons, a microprocessor will be used to implement the programmable control section. Figure 1 shows a simplified block diagram of the transmitter.

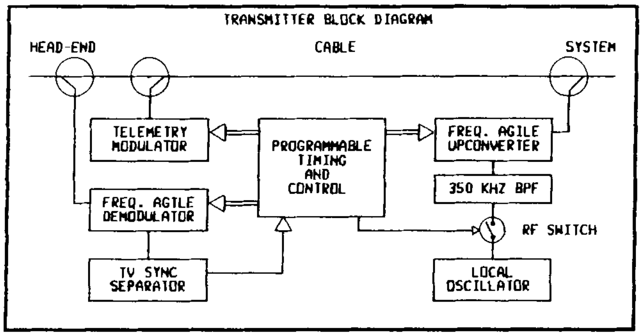

Figure 1. Simplified block diagram of transmitter.

One of the unique parts of the transmitter is the "look-ahead" frequency agile video demodulator. This demod is steered to the channel to be sampled next. The video is detected and the sync information stripped off. The sync is used for timing of the inserted carriers; no energy will be added to an occupied channel until either horizontal or vertical blanking is occuring.

The carriers are created by steering a synthesized upconverter to the proper location, then at the proper time, adding the local oscillator to its input. Pulse rise- and fall-times are restricted to one microsecond by the 350 KHz band-pass filters. This is derived from the approximation:

Bandwidth = 0.35 / rise-time.

Without the filter, the effective bandwidth caused by switching the carrier on and off at microsecond rates, would extend beyond the channel being tested.

Synchronizing signals are continually sent downstream on the auxiliary data channel. This data stream contains the necessary frequency and timing information for the receivers. The carrier frequency of the FSK telemetry modulator is considered one of the critical frequencies.

RECEIVER DESIGN CONSIDERATIONS

The receiver uses a microprocessor for coordinating received telemetry with synthesizer control, as well as for interpreting and preparing the received RF data information for the display. A simplified block diagram of the receiver is shown in figure 2.

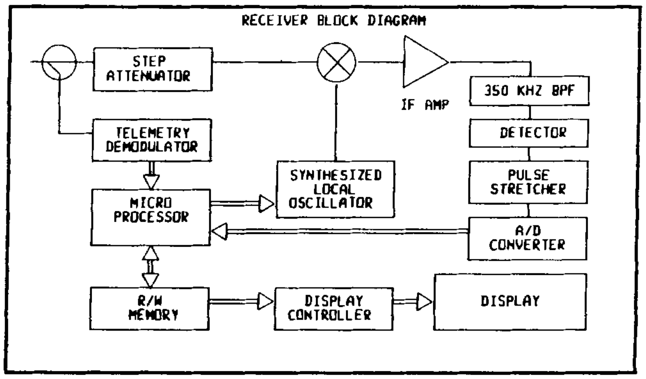

Figure 2. Simplified block diagram of receiver.

The auxiliary data channel is demodulated and the frequency and timing information made available to the microprocessor. Using this information, the local oscillator is steered to the proper frequency, then at the proper time, the pulse is detected. Its level is captured and converted to a digital value. These digital values are then decoded and used to generate the display.

The digitization of the RF signal provides the means to great flexibility in receiver design. Individual receiver flatness can be compensated for digitally. By connecting the receiver directly to the transmitter, any frequency response anomalies can be recorded and stored in non-volatile RAM. Then by compensating the readings by those factors, the displayed response will reflect only cable system response, not receiver response. Other techniques like digital averaging can be used to help readability in long cascades.

Incidentally, bypassing critical frequencies with this system will not cause the display to have holes in it. The points in between the sampled points will be approximated by using a quadratic approximation generated by the nearest three sampled points.

INITIAL TESTING PHASE

Our early days were spent trying to discover how much we could abuse an NTSC video signal and not cause perceptible interference. We wanted to use the horizontal sync pulses for timing because they were contained in the horizontal blanking interval, see figure 3[1], and their high frequency, if completely utilized, would allow the entire spectrum to be scanned in a very short time. If we were to sample a 50 to 300 MHz cable spectrum every megahertz it would take 251 samples. The horizontal line rate for NTSC is about 15750 Hz. If we could manage to use every line for one sample then we could scan the entire band in less than a sixtieth of a second. We could then have a display refresh rate of better than 60 Hz as indicated by table 1.

HORIZONTAL RATE

BAND	SAMPLE FREQ.	TOTAL SAMPLES	SAMPLE RATE	DISPLAY REFRESH RATE
50-300 MHZ	1 MHZ	251	15750 HZ	62.8 HZ
50-300 MHZ	2 MHZ	126	15750 HZ	125.0 HZ

VERTICAL RATE

BAND	SAMPLE FREQ.	TOTAL SAMPLES	SAMPLE RATE	DISPLAY REFRESH RATE
50-300 MHZ	1 MHZ	251	60 HZ	4.2 SECS.
50-300 MHZ	2 MHZ	126	60 HZ	2.1 SECS.

Table 1. Minimum screen refresh rates for typical frequency intervals during either vertical or horizontal blanking.

Actual display refresh rates would be higher, as there is spectrum where there are no video signals to wait for, some critical frequencies would be bypassed, and adjacent video channels' horizontal sync phase relationships would tend to reduce the effective horizontal rate when moving from channel to channel.

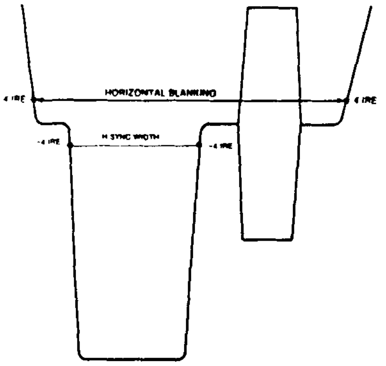

Figure 3. Diagram showing horizontal blanking and sync relationship.

Keeping up with these rates was going to be difficult. Synthesizers had to be able to slew to a new frequency and lock within one horizontal line, about 63 microseconds, and the auxiliary data channel had to have a very-high data rate. This turned out to be impractical, not because of equipment limitations, but because of television receiver complications.

TV receivers suffered from three types of visible interference, even though the beats were invisible. The exact symptoms varied from model to model depending on what type of video AGC was used; what type of horizontal AFC was used; and what type of detector was used. Video AGC's were of two varieties:

- Sync peak detectors with low-pass filters, and
- Sync gated circuits.

By adding extra energy during the horizontal sync period, that sync pulse had a higher amplitude than adjacent sync pulses. This extra amplitude had no visible affect on the AGC circuits that used sync peak detectors and low-pass filtering. But the gated AGC circuits behaved differently. These gated circuits derived AGC voltage on a line by line basis, so the AGC voltage applied to the following line of video was almost entirely determined by the preceeding sync pulse's amplitude. By artifically increasing one sync pulse's amplitude, the gain was reduced for the entire following line of video. This reduced the contrast for that line and, depending on program video content, the effect varied from nearly imperceptible to very obvious.

Horizontal AFC circuits were also affected by the timing of these pulses. When inserting these pulses in the horizontal sync period, we had some discretion in pulse position relative to sync. Some types of set AFC's ignored the extra energy when the pulse was started coincident with the start of sync, while others ignored it when it was exactly centered in the horizontal sync. The visible effect of not being properly timed was a slight pulling of the horizontal oscillator which was visible as a discontinuity in vertical lines, followed by a curved line as the oscillator regained its original phase. No matter where we chose to start the pulse, we were guaranteed to visibly affect some of the TV sets.

TV sets with product detectors also exhibited one other sensitivity to these additional carriers that diode detector sets did not. When the additional carrier was removed, the detector started oscillating. The duration of these oscillations were both frequency and level sensitive. At our chosen levels, the oscillation lasted through color burst, back-porch, and into active video, about 8 to 10 microseconds. This was visible as disturbance in one line at the left margin of the picture.

Short of reducing the RF level to 20 dB below video carriers or less, there was no way to insert these pulses into the horizontal blanking interval undetected. Since we had set out to have a higher level than that for improved resolution, we then focused our attention on the vertical interval (see figure 4[1]).

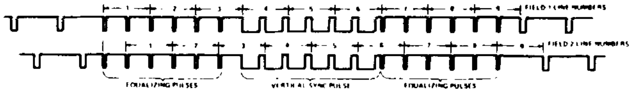

Figure 4. Vertical sync intervals for fields 1 and 2.

By using the vertical interval, we effectively hid all of the above mentioned video artifacts. Single line AGC affects in gated sync circuits occured during the time the entire line was blanked, hence the effect was invisible. By restricting ourselves to lines 4 through 9, any affect we had on the horizontal oscillator has until line 21, where active video starts, to recover. This was long enough for all the sets tested. Lastly, since the screen is blanked the detector oscillations are not visible as video disturbances. This is not to say that any of these problems quit occuring, I only indicate that their effects cannot be viewed on a normal TV set when they occur in the vertical interval. We have in fact inserted additional carriers into the vertical interval at RF levels 20 dB higher than the video carrier with no visible interference.

The relatively slow 60 Hz rate of the vertical interval had concommitant simplifications. Synthesizer design was much simpler; we no longer had to slew and lock in less than 63 microseconds. Also, the auxiliary data channel could now carry much more data between samples at a lower data rate for better synchronization. The lower throughput also permitted the use of common, inexpensive microprocessors to reduce cost. But as Table 1 indicated, the display refresh rate had fallen to one sweep every four seconds. The display requirements had become slightly more complicated, screen refresh had to be independent of incoming data.

CONCLUSION

Tests are still in progress to determine if there are any unforseen and as yet undiscovered complications that would prevent this from being a viable method. All the evidence so far indicates that signals carefully inserted into the vertical interval are ignored by normally operating television receivers and VCR's. Nevertheless, we are trying to find if any combinations of timing, level or frequency can cause a VCR to break servo lock or cause interference to a TV receiver.

Further tests are needed to clarify just how close the samples need to be in order to assure we will not skip typical cable frequency response problems. Certainly, one megahertz is close enough as experience indicates that response anomalies seldom affect less than six megahertz. But six megahertz is probably not close enough for the occasional problem that affects only a small portion of the cable spectrum. Sampling at two megahertz intervals now seems to be the optimum compromise between speed, synthesizer design, and resolution.

Still to be decided is the final form of the receiver display. Among the options are flat panel displays, especially the electro-luminescent types. But the lowest cost display is still an X-Y display using portable oscilloscopes like the Tektronix 323's or Leader LBO-308'S.

As a work-in-progress report, I can say that the initial concepts and designs have been worked out and patents applied for. Continuing work will certainly bring the new sweep system out of the lab and into the field by the end of the fiscal year. Initial results are encouraging and indicate that we will be able to have a non-interfering, high-resolution CATV sweep system in use at Gillcable then.

ACKNOWLEDGEMENTS

I would like to acknowledge those at Gillcable who have helped this project along. In particular, David Large was responsible for the initial concepts, and Rich Wayman was responsible for much of the data gathering and transmitter design. There was also the sweep crew who continually reminded us of what real cable problems were like outside of the lab.

REFERENCE

1. Figures 3 and 4 were adapted from "TELEVISION OPERATIONAL MEASUREMENTS, Video and RF for NTSC Systems", Tektronix, 1984, p. 9, 11, 12.