THE GILLCABLE PRECISION NON-INTERFERING SWEEP SYSTEM

David Large

Gill Industries
San Jose, CA

ABSTRACT

At the 1985 NCTA Convention, Gill Cable described an ongoing project whose objective was the development of a dramatically improved system response test instrument. The report outlined the limitations of current high level and low level sweepers and proposed a new "smart" system which could overcome the limitations of the previous methods.[1]

Gill was motivated in this development by the lack of satisfactory options available to it in doing its own testing. An increasing number of complaints related to the use of high-level sweep made it imperative that less intrusive testing be done. A lack of accuracy available with other products on the market dictated a new approach to response measurement.

In the intervening three years, continued work at Gill has resulted in the development of a successful prototype sweeper with high resolution, fast refresh time and total absence of interference. In field trials it achieved noise-free displays at the maximum cascade of the Gill system (40 amplifiers), electronic error correction, and 0.05 dB of screen resolution. The transmitter generated no complaints of interference in over a month of continuous operation. A patent has been issued in recognition of the uniqueness of the Gill approach.[2]

Although there have been recent product announcements by several vendors in this field, it is felt that there are still serious limitations to all of the newly available approaches. Their dependence on the stability of video carriers at the headend severely limits their usefulness as precision alignment tools in Gill's view.

BACKGROUND

In order to deliver the highest possible quality television signals to consumers, operators must operate cable systems at carefully controlled levels: if carriers are too low pictures will be noisy; if they are too high, various distortion products will become visible. Operating at the ideal amplitudes requires careful level setting at the headend and maintaining the distribution system such that the frequency response is flat and so that the gain of each amplifier is just sufficient to overcome the loss preceding it. Sweep systems are the primary tools for distribution system monitoring and alignment.

Various methods have been developed over the years to allow system sweeping without requiring the removal of television carriers or unduly interfering with reception. Each involves compromises as outlined below.

High Level Sweep

The most common technique in use today is high level sweeping, patented in 1972. In this method a test carrier is inserted into the distribution system at a level approximately 20 dB above that of the television visual carriers (equivalent to adding 100 additional television carriers to the system loading!) The test carrier is rapidly swept from the lowest to highest frequencies of interest. The test receiver can sample this signal at any physical point in the plant.

Since the test signal is highly interfering, a low repetition rate (2-8 seconds) is employed along with a very fast sweep (1-5 milliseconds). Additionally, conscientious operators use communications radio systems to "trigger" the sweep on only when necessary and, further, disable it during prime viewing hours.

Recent changes in the industry have combined to make the high level sweep even less acceptable:

- o High VCR penetration, since VCR servo systems can be affected by the sweep signal more than TV sets.
- o Implementation of addressable systems whose data and channel tagging systems can be affected by the sweep signal.

o An increasing emphasis on PPV whose "one-shot" nature has raised quality expectations among consumers.

Aside from the problems with a properly operated high level system, it is subject to inadvertent abuse from inadequately trained technicians. If the test carrier is set too high, the amplifiers will begin to compress, making the system appear to have a flat frequency response and causing a higher degree of interference because of intermodulation products.

Low Level Sweep

In 1976 Avantek introduced a sweep system which allowed the test signal to be 30 dB below video carrier levels by use of a narrow-bandwidth tracking spectrum analyzer technique. While not truly non-interfering, it was a significant improvement in that respect compared with high level sweep. In addition to interference reduction, it offered simple spectrum analyzer functions.

On the negative side, it did not have the amplitude resolution of high level sweep and all response information was lost in the vicinity of each system carrier. The latter was not a problem in the lightly loaded systems of fifteen years ago, but has become one in recent years.

This product was withdrawn from the market in 1987 and is currently not available.

"No-Sweep" Sweep

A recent innovation requires no test carrier for response testing. In this technique, a spectrum analyzer is modified to measure and memorize the levels of all carriers in the system at the headend. This measurement is repeated at each test point and a smooth curve displayed showing the difference in decibels between the headend levels and the test point levels.

The limitations of this method are:

o Its accuracy depends on the amplitude stability of headend levels.

o Data is available only for those portions of the band in which signals are present.

o Only one or two data points are available for each channel, limiting frequency resolution.

The dependence on headend level stability is probably the most serious. Either high or low level sweep systems can achieve an amplitude resolution of a fraction of a dB, while individual headend signal levels can vary over much greater ranges because of:

o switching between standby carriers and live programming

o channel sharing between two services

o routine headend adjustments

o imperfect AGC circuits in processors

o aging and intermittent components

It is for precisely these reasons that sweep systems were developed in the first place: to allow system response testing to take place independent of system carriers.

Hybrid Systems

A recent entry into the sweeper market uses a hybrid technique to overcome some of the limitations of high level and "no-sweep" sweep methods. Its readout is based on carrier levels in the occupied portions of the band while a method akin to low level (but at much higher test signal levels) is used in the unoccupied portions of the band. It thereby achieves a complete response curve over the entire distribution system bandwidth.

Unfortunately, it has the same dependence on carrier levels as the "no-sweep" technique in the most critical frequencies.

THE GILL PRECISION NON-INTERFERING SWEEPER

Gill's technique differs substantially from existing technology in that it avoids interference by taking advantage of the unique characteristics of television signals. In this system, the test signal is generated by a frequency synthesizer and is inserted into the headend output at approximately the same level as video carriers. Interference is avoided by inserting the test carrier in each channel only during the first few lines of the vertical retrace interval when television sets are blanked.

Aside from the lack of subscriber interference, this portion of the vertical interval is uniquely suited to response testing for two other reasons (see Figure 1). First, it is the only time during the entire field that there is no chroma or burst, thereby clearing out that portion of the spectrum lying between luminance and aural carriers. Second, luminance modulation is limited to 25% downward modulation by equalizing/serration pulses.

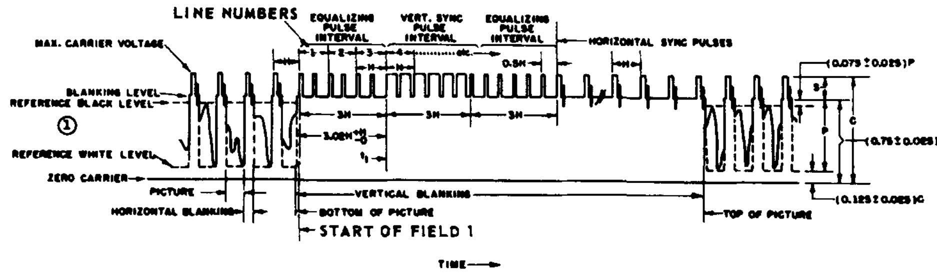

FIGURE 1. VIDEO WAVEFORM DIAGRAM

This level of luminance modulation is equivalent to 14.3% symmetrical amplitude modulation. If the modulation waveform were sinusoidal, this would result in a single sideband down 23 dB from the video carrier. Since the modulation is in the form of narrow pulses (8% duty cycle) however, the sideband energy is distributed among a series of sidebands spaced 31.5 kHz apart and extending to at least 1.38 MHz[3].

Given a test receiver bandwidth of approximately 27Ø kHz, only about 2Ø% of the sidebands would be received simultaneously, so that the received sideband energy would be reduced another 7 dB below the carrier level or a total of 3Ø dB. This corresponds to a detected power level of Ø.1% relative to the video-level test signal and produces a Ø.ØØ4 dB reading uncertainty, well below the Ø.Ø4 dB resolution of the instrument. Thus very accurate response measurements can be made almost anywhere between luminance and aural carriers.

In summary, advantages of the Gill system are:

- o Because the test signal level is comparable to normal video carrier levels, it avoids overloading of amplifiers which can easily occur with the high level system.
- o The relatively high test carrier level compared with the low-level system assures highly accurate response even at very high cascade numbers.
- o Carefully choosing test frequencies allows resolutions of approximately 2 MHz while avoiding loss of data near video and aural carriers. This resolution is sufficient to resolve "fine-grain" VSWR problems that can confound a lesser resolution system.
- o Taking full advantage of the on-board microprocessor allows for full error correction eliminating the need for "grease pencil lines and visual correction of data.
- o Since the system is totally non-interfering, the sweep rate can be much higher than high level systems. This translates directly into increased efficiency for sweep crews.
- o The receiver can be made in such a way that it also allows very accurate read-out of system carrier levels, eliminating the necessity for the sweep personnel to carry level meters to each amplifier location.

DESCRIPTION OF OPERATION

Figure 2 is a block diagram of the transmitter. Operation in each television channel is as follows. The receiver/sync separator first tunes to the channel and derives vertical synchronization timing (including scrambled channels). The transmit signal generator is tuned to the first test frequency within the channel and, via the telemetry signal, the receiver is tuned to the same frequency. During the first few lines of the vertical interval, the transmitter is gated on for approximately ten microseconds. The transmitter and receiver are then incremented to the next frequency and a test signal briefly inserted into the following vertical interval, and so on until that channel is completed. Then the receiver tunes to the next channel and the entire sequence is repeated.

The keypad on the transmitter allows initial setup for any given cable system: start and end frequencies, frequency plan and any critical frequencies to be avoided.

Telemetry may be transmitted on any convenient frequency as, unlike the low-level system, there is no critical

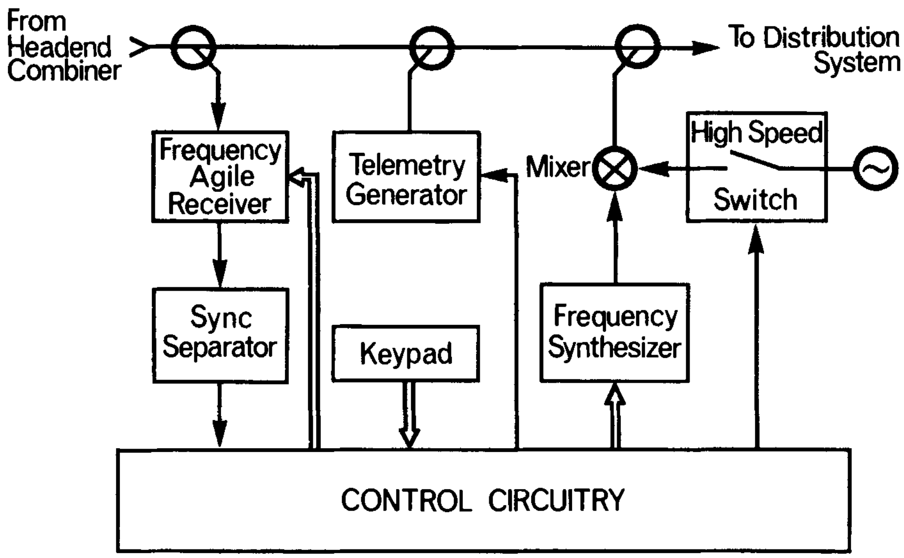

FIGURE 2. TEST SIGNAL GENERATOR

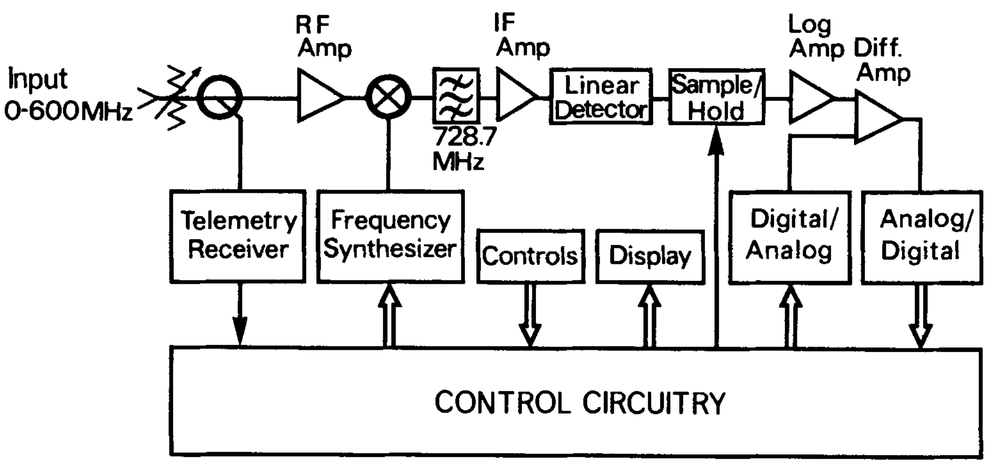

FIGURE 3. TEST SIGNAL RECEIVER

relationship between telemetry and test signals.

Figure 3 is a block diagram of the receiver. The telemetry receiver serves to keep the transmitter and receiver in synchronization and avoids having to specially program the receiver. The test signal receiver is synthesizer-controlled and uses a double conversion scheme to totally eliminate in-band images. This scheme allows a maximum frequency of 600 MHz (potentially up to 700 MHz). The detector uses active linearization to avoid temperature and linearity problems inherent with diode detectors.

A sample-and-hold circuit following the detector captures the brief test signal and a highly accurate log amplifier converts it to dB. Correction for the residual flatness of the transmitter and receiver is derived by making a back-to-back measurement at the headend. These errors are memorized in the receiver and subtracted out at each measured frequency before the data is stored.

The stored data is continuously displayed on the screen. The first prototypes have been built using flat panel electro-luminescent (EL) display screens for high readability under varying light conditions. This also eliminates the cost, size and weight associated with CRT systems. Given the rapid developments in back-lit super-twist LCD displays for computers, future products might well use this technology, allowing dramatic reductions in battery size and weight.

The microprocessor in the receiver also allows for several other features which enhance readability:

- o A vertical graticule directly calibrated in dB referenced to the headend is displayed.
- o The horizontal trace is adjusted to full screen, regardless of the range swept, for highest resolution. In the future, a calibrated horizontal frequency graticule will also be displayed.
- o A digital read-out of the peak-to-valley response in dB is also displayed.
- o The instrument can memorize several traces so that a tech can compare the output of a given amplifier with the output of previous amplifiers.
- o A smooth curve is presented using a quadratic approximation derived from the sampled data available.

Additionally, a calibrated attenuator will allow offsetting of the trace to allow direct observation of amplifier input levels and bridger or line extender output levels.

STATE OF DEVELOPMENT

The first prototype was field tested in the Gill system in September, 1987 and the patent issued in October. The prototype fully exhibited the expected resolution and lack of interference. The transmitter successfully synchronized to both clear and scrambled channels. Scrambling systems tested included both baseband sync-suppression/video inversion scrambling and RF sinewave sync-suppression scrambling.

Figure 4 shows the front panel and a typical trace display on the first version (which lacks horizontal graticule and frequency scale). Figure 5 shows the receiver packaging with the display on bottom, the microcomputer and control circuitry below that, the RF deck next, and the batteries and power supply on the top.

Figure 6 is a photograph of a waveform displayed on an oscilloscope showing the placement of the sweep signal in the vertical interval. The waveform was taken from the video output jack of a Sony television receiver connected to the cable system with the sweep transmitter operating. As can be seen, the sweep signal is not only at a non-intrusive level, but uses a portion of the vertical interval not used for any other test or data services, including addressing or channel tagging for addressable devices.

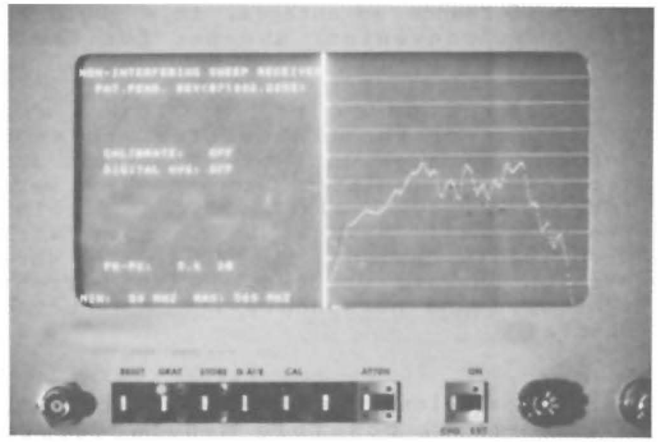

FIGURE 4. RECEIVER FRONT PANEL

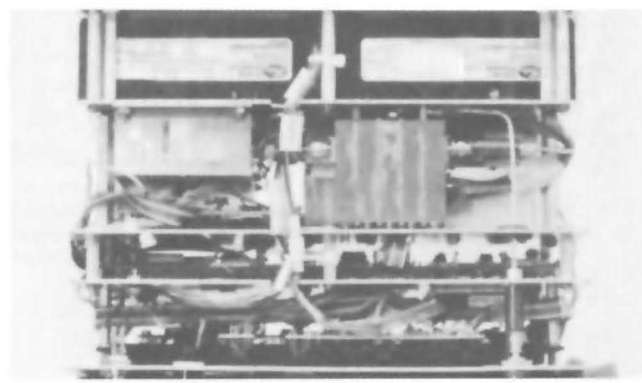

FIGURE 5. RECEIVER PACKAGING

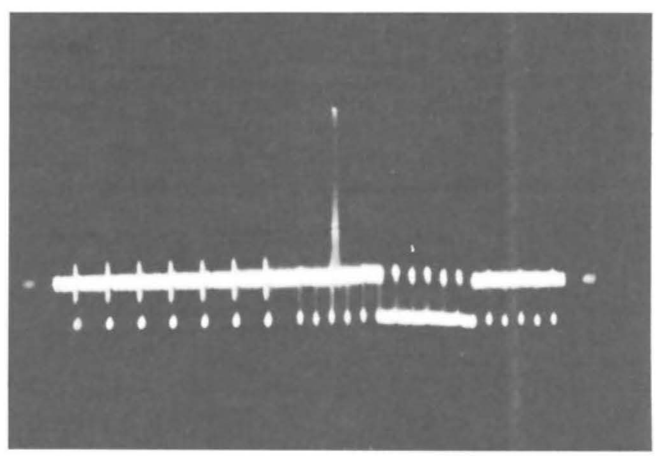

FIGURE 6. TEST SIGNAL PLACEMENT

Even with its relatively crude packaging, the receiver is smaller than any of the products currently on the market. Work is under way to take more than two additional inches off its depth. Additional tooling by a volume manufacturer should allow further substantial weight and size requirements so that, in addition to its performance advantages, this could be the most convenient sweeper for field personnel to use.

Remaining to be completed are packaging of the transmitter and some software features in both transmitter and receiver. Transmitter circuits which were temporarily synthesized using commercial products still have to be replaced with proprietary designs, but this is a very straightforward process. With current schedules and personnel, it is expected that a full prototype will be complete in July.

Negotiations are currently under way with several possible manufacturers regarding licensing of the technology for possible inclusion in commercial products.

CONCLUSION

The sweep system developed by Gill represents the next logical step in cable system frequency response testing. It overcomes the limitations of all the previous technologies and achieves the level of accuracy and non-interference that are needed to optimize cable system performance while not alienating customers. It is Gill's hope that commercial products using this technology will shortly be available to other operators.

ACKNOWLEDGMENTS

The Gill Cable Research and Development group (Bill Kostka, Rich Wayman, Mike Truppa and Jerry Sotirhos) have all spent many hours developing this product. It goes without saying, however, that without the enlightened support of Bob Hosfeldt, president of Gill Industries, the project would not have been possible. The illustrations and text preparation are the work of Gloria Cook.

REFERENCES

[1]Kostka: "Broadband Sweeping: A New Approach", 1985 NCTA Technical Papers, NCTA, Washington, D.C., 1985.

[2]U.S. Patent #4,700,222, issued in October, 1987.

[3]The Fourier transform of a series of narrow pulses into the frequency domain consists of a series of frequencies whose spacing is the repetition rate of the pulse train and whose upper frequency can be approximated by $F_{max} = 0.35/t_r$, where t_r is the rise time of an individual pulse, in this case 0.254 microseconds maximum.