Future Hybrid AM/Digital CATV Systems

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ABSTRACT

Digital video compression technology is being developed for NTSC and HDTV applications. In addition to the benefits to the subscriber in terms of picture quality, digital transmission has a number of implications for the distribution plant. This paper will detail some of the effects of digital signals on the CATV system.

INTRODUCTION

Digital video compression technology is being pursued by a number of R&D organizations around the world for a number of applications. Potential DBS operators are interested in increasing the number of program selections that they can offer with their limited transmission bandwidth. Compression ratios as high as 10 video channels per transponder are anticipated[1]. Bellcore is interested in developing the technology to allow the transmission of video programs over existing twisted pair telephone drop wires[2]. The computer industry is interested in integrating full motion video with audio and data (desktop video). The consumer electronics industry will likely be interested in offering digital video products for home use. In addition to all of the above activity on digital NTSC delivery, three of the current proposals for the U.S. HDTV transmission standard are all-digital. Because of all of this activity it seems inevitable that some video signals will be transmitted over cable systems in digital form in the 3 - 6 year timeframe. This paper will look at how this move toward digital transmission will affect the performance of CATV distribution systems.

APPLICATIONS

Basic services

Over the past several years, there has been an explosion in the number of basic services available to the system operator. A recent listing showed 61 satellite delivered basic services[3]. Add to that 5 - 10 local broadcast channels, regional basic services, local origination and text services and it is easy to envision a 550 MHz cable system that is completely filled by basic service in the not too distant future. While basic services could certainly be transmitted digitally, many operators will likely reject this option because of the costs associated with installing multiple converters in every home that receives basic service.

Premium and IPPV services

The use of digital compression for satellite transmission may help to fuel growth in the availability of IPPV programming because it will lower the programmer's costs. Some type of converter or on/off premise device is required to provide the IPPV functionality and signal security. A digital compression converter could provide signal security as well as offering the benefits of consistent signal quality and video program capacity expansion.

HDTV

A number of the candidates for the U.S. HDTV transmission standard are proposing all-digital systems. If one of these systems is chosen, then even if digital compression is not used for any NTSC services, cable systems will be required to transmit digital HDTV signals to their customers.

OBJECTIVE

The objective of this paper is to explore how a mix of AM and digital signals will affect distribution plant performance. As outlined above, future systems will probably require 80+ channels of basic service. When you add premium services, multi-channel IPPV and HDTV, system bandwidth requirements of 750 MHz, or higher, seem likely. Due to the limited availability of 750 MHz hybrids at the present time, the data presented in this paper is based on 550 MHz devices.

ASSUMPTIONS

All of the data presented in this paper is based on one simple assumption. The assumption is that medium speed (20 Mb/s) digital data can be transmitted through a 6 MHz channel and accurately recovered if the channel has a carrier to noise plus distortion ratio greater than roughly 25 dB. This is a dramatically different requirement than that of a VSB-AM video signal. For high quality pictures, a VSB-AM signal requires a carrier to noise ratio of 47 to 52 dB and carrier to distortion ratios of 53 to 57 dB. What this means is that the digital carriers can be transmitted through a cable system at lower levels than conventional VSB-AM channels. This reduces the loading on the RF and optical devices in the system and improves system distortion performance.

SYSTEM PERFORMANCE

The simplest case to analyze would be that of a system that transmits all channels digitally. In the case of an AM fiber trunk link, the C/N requirement might drop from 50 dB to 28 dB. This would increase the loss budget from 12 dB to roughly 26 dB. If the AM link served an average of 4 receivers from each transmitter, the digital link would serve roughly 64 receivers from each transmitter. This would obviously improve the system cost significantly. The effect on the RF distribution plant would be that far more taps could be served from each active device.

While the prior example was interesting, it does not really fit with most operator's strategies. As outlined above, most operators will likely prefer to transmit basic cable services using VSB-AM modulation. This means that when digital technology becomes available, the typical CATV system will have to carry a mix of AM and digital signals. The effects of this mixed signal environment on the CATV network are not as straightforward as the all-digital scenario, but they are still significant.

For this paper, a mix of actual measurements and computer simulations were used to quantify the effects of digital signals on RF amplifier performance. The performance of a typical push-pull CATV hybrid is shown in Figure 1. The data points show measured CTB at several frequencies when the amplifier is loaded with 77 channels at 44 dBmV per channel. The curve fit to the measurements describes the behavior of the amplifier over the frequency range of interest. Note that even though the number of beats is highest in the center of the band (roughly 2000 beats at 331.25 MHz), the amplifier CTB performance is worst at 547.25 MHz (roughly 1360 beats). This is because the amplitude of the individual triple beats increases with frequency.

Figure 2 shows the projected performance of this amplifier when operating with a tilted (cable equivalent slope) output. These data were calculated using a program that accounts for the amplitude of each of the individual triple beats that make up CTB at each frequency. The flat curve is the same as in Figure 1. In both tilted cases, the output level at 547.25 MHz is 44 dBmV. This graph shows that as the output tilt is increased, the amplifier's CTB performance improves significantly at high frequencies. There is not as much net improvement at low frequencies because the carrier levels are decreasing as well as the distortion levels.

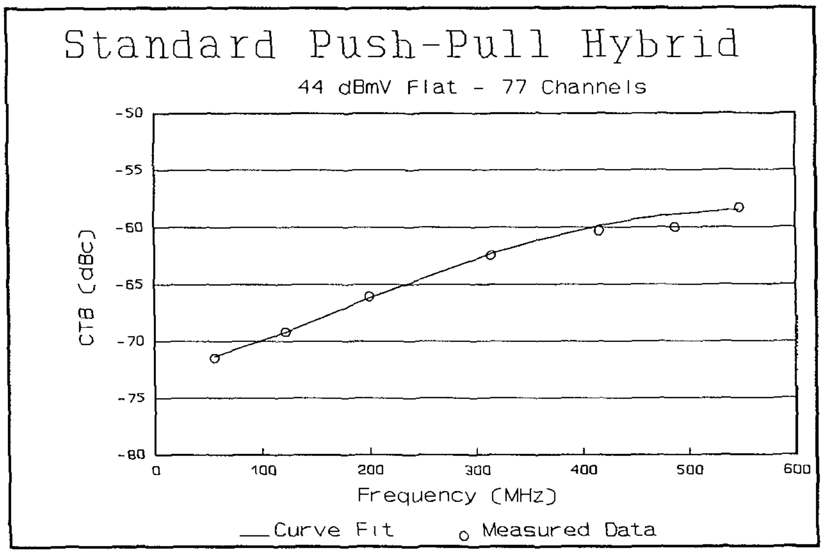

Figure 1

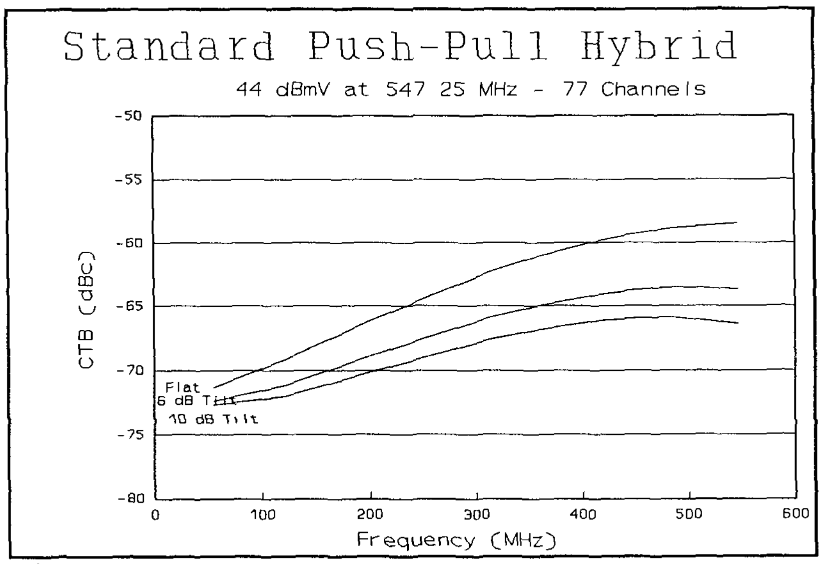

Figure 2

Because digital signals can tolerate higher levels of noise and distortion, it was assumed that the digital carriers would be transmitted through the system at a level 10 dB lower than for a conventional AM channel. It was also assumed that the digital channels would be located at the same frequencies (6 MHz spacing) as conventional AM signals. Two 550 MHz scenarios were investigated. The first assumed that standard AM channels would be transmitted in the band from 50 - 350 MHz, and digital carriers would be transmitted in the band from 350 - 550 MHz. This gives a total capacity of 44 AM channels and 33 digital channels. Each digital channel can support 1-5 video programs depending on the compression system employed. The second scenario is similar except the split point between AM and digital is located at 450 MHz, yielding 60 AM and 17 digital channels. Figure 3 shows the spectrum for the first scenario with no tilt. Figure 4 shows the predicted and measured amplifier CTB when loaded with the signal shown in Figure 3. The measured data points agree fairly well with the predicted performance. The predicted worst case CTB for an AM channel is -67.5 dBc at 349.25 MHz. This represents a 9 dB improvement in performance when compared to the worst case CTB for 77 AM channels. This is a dramatic improvement in device performance that can have a significant effect on system cost and performance. The performance improvement when using a tilted output is even more dramatic as shown in Figure 5 and Table I. Part of the reason that the distortion improvements are so dramatic is the fact that the hybrid distortion is worse at higher frequencies. For a device with a flat distortion vs. frequency characteristic, the improvement factors would be 5.0, 7.4 & 9.0 dB for 0, 6 & 10 dB of tilt, respectively. One example of a device with a flatter distortion characteristic is the Darlington hybrid. Another factor affecting the CTB improvement factor is that in a typical CATV amplifier the levels might be flat at the preamp output and tilted at the postamp output. To the extent that the input hybrid contributes to the overall amplifier CTB, the improvement factors will be decreased slightly. Because of these issues, the improvement factor for an amplifier or AM fiber product depends on the configuration and selection of components.

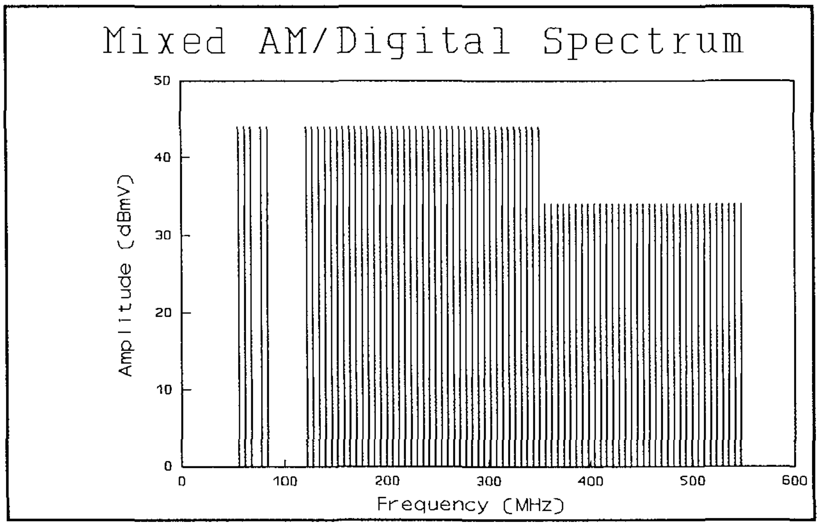

Figure 3

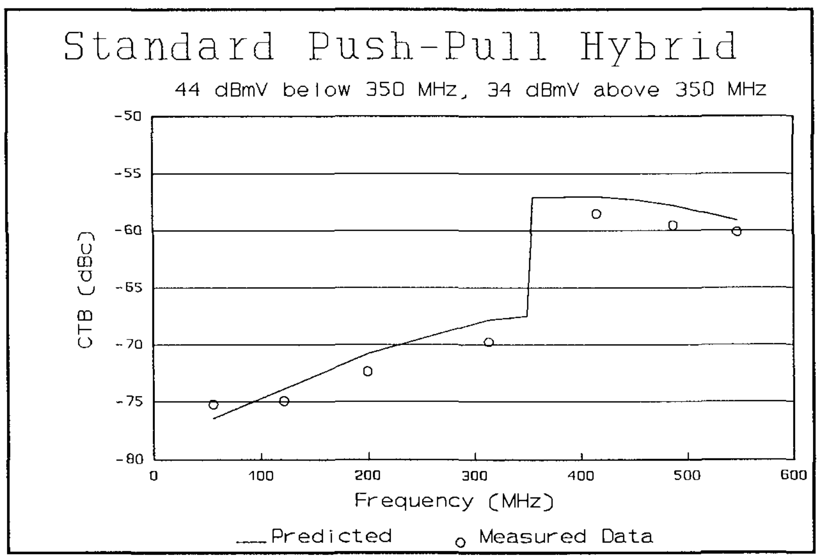

Figure 4

Figures 6 & 7 and Table II show measured data and projected performance for the same hybrid with AM video below 450 MHz and digital channels above 450 MHz.

Figures 5 & 7 also show that the worst case CTB for a digital channel is about 10 dB worse than the worst case AM channel. If a distribution system was designed with a target CTB spec of -53 dBc for the AM channels, the CTB for the digital channels would be on the order of -43 dBc. This should be well below the threshold of degradation for the digital channel.

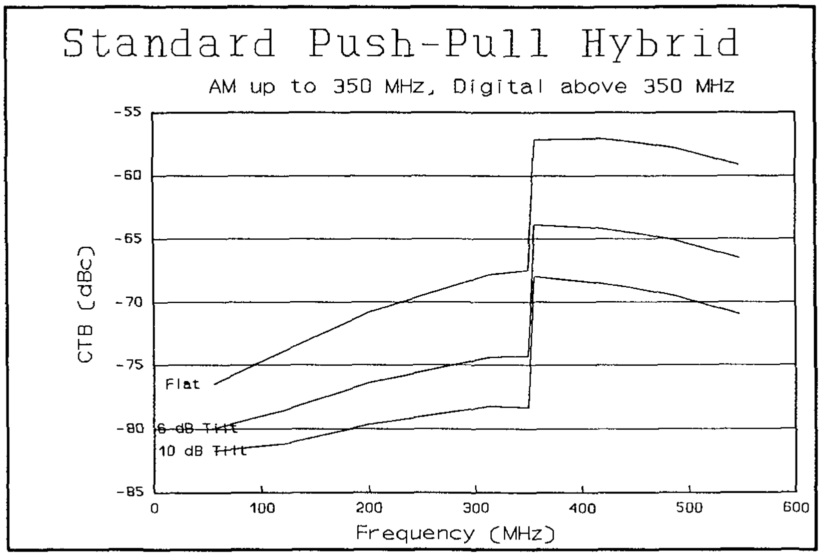

Figure 5

improvements outlined in Tables I & II. The designs assumed a new or rebuild situation and both conventional tree & branch and fiber to the feeder alternatives were investigated. The designs were done on a system with 100 homes per mile, with end of line performance (AM channels) of C/N = 47 dB, CTB = -53 dBc. The result of the study showed that the cost savings, mainly in RF and fiber equipment, are on the order of $50 - 100 per mile per dB of performance improvement. In other words, the equipment cost for a 350/550 MHz AM/Digital system is roughly $450 - $900 per mile less than a conventional 550 MHz AM system, assuming a 9 dB performance improvement factor. The savings works out to $4.50 to $9.00 per home passed or $7.50 to $15.00 per subscriber (60% penetration).

While these cost savings are significant in terms of total plant cost, they do not justify the installation of digital converters in every home for basic service in a new or rebuild scenario. The one exception would be operators who plan to scramble all channels, including basics, anyway. In their case the incremental cost of the digital converter

COST IMPLICATIONS

There are many ways that the effects of digital transmission on system performance can be exploited, depending on the individual system requirements. In a system upgrade, the use of digital transmission may make the upgrade more economical or allow a greater increase in performance or bandwidth. In a new build or rebuild digital transmission can make the system design more economical or allow higher performance levels for the same plant design.

A few small trial designs were performed to assess the value of the performance

Table I

Worst Case CTB for AM Channels
350/550 MHz Split
Push-Pull Cascode Hybrid

Tilt	All AM	AM/Dig	Improvement
0	-58.5	-67.5	9.0
6	-63.5	-74.3	10.8
10	-65.9	-78.3	12.4

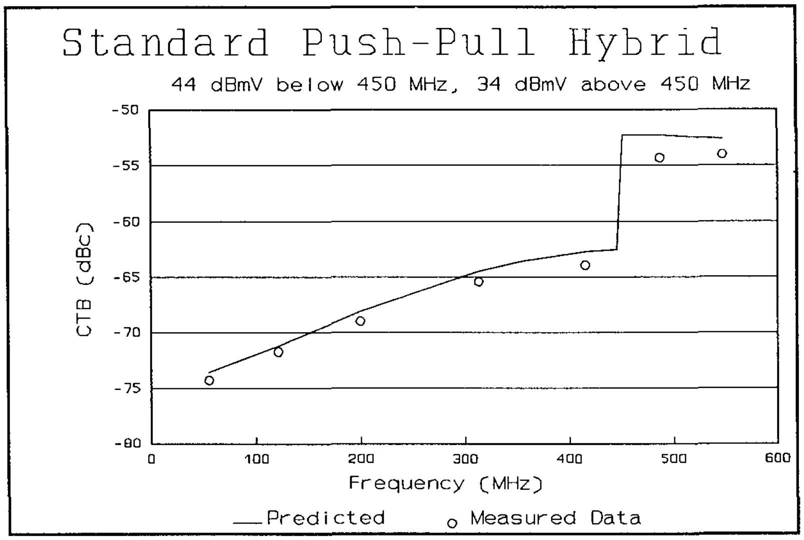

Figure 6

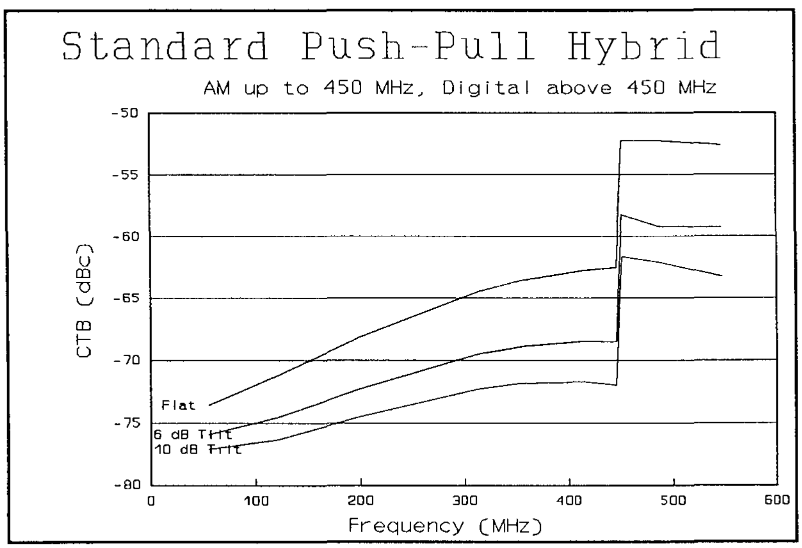

Figure 7

would have to be traded off against performance improvements and plant cost savings.

The prior analysis was for a new or rebuild or situation. In the case of a system upgrade, the tradeoffs will be different for each specific case. Digital transmission could be used to expand system program capacity without actually modifying the existing plant. For example, the top 5 channels of an existing system could be converted to digital channels. These 5 channels could then be used to provide 20 video programs (assuming 4 digital video programs per 6 MHz). If the additional program capacity is needed for premium or IPPV services, then this type of upgrade would probably be cost effective because the digital converters only go into homes buying premium services. However, if the system needs the additional capacity for basic services, it will likely be more cost effective to upgrade the distribution system.

Table II

Worst Case CTB for AM Channels
450/550 MHz Split
Push-Pull Cascode Hybrid

Tilt	All AM	AM/Dig	Improvement
0	-58.5	-62.5	4.0
6	-63.5	-68.5	5.0
10	-65.9	-71.7	5.8

EXPANDED BANDWIDTHS

Significant performance improvements are also expected for AM/Digital systems at higher bandwidths. The improvement factor will probably be in the range of 4 - 6 dB for a 550/750 MHz split system, compared to an all-AM 750 MHz system. The precise improvement factor will depend on the distortion characteristics of the devices used in these systems. Another important factor in the design of extended bandwidth systems is the high tap levels that will be required at 750 MHz for AM signals. The use of digital carriers above 550 MHz would ease high frequency tap level requirements because the digital signals can tolerate more noise.

CONCLUSIONS

When digital compression technology becomes economical, from a distribution plant perspective it will be beneficial to broadcast premium services in digital form. The digital technology can provide the desired signal security, and at the same time performance can be improved for the remaining AM video channels. Alternatively, the cost of the distribution plant can be reduced for a given desired performance level on the AM channels.

The use of digital transmission for signals above 550 MHz will enable more cost effective plant upgrades to higher bandwidths.

REFERENCES

1) "SkyPix cooks up home satellite dish for $700," EE Times, January 21, 1991, pp. 1-14.

2) "AT&T tests megabit data delivery over twisted-pair wiring," EE Times, December 3, 1991, p. 8.

3) Cablevision, December 17, 1990, p. 41.