A Migration Strategy to High Capacity Return on HFC Networks

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Abstract

This paper explores the potential for the cable industry to use the high end of the RF spectrum for in-bound signals. Experience with such a system is documented, and its performance examined. Approaches to migrating from today's sub-low (5-40 MHz) return systems to the use of high-end return are explored, and a specific proposal, which would minimize or eliminate interruption of existing services during such a transition, is discussed. The conclusion is drawn that this technology is feasible, and has the potential to offer significant benefit as the need arises for high-capacity return in the context of more symmetrical telecommunications and data services over hybrid fiber/coax systems.

INTRODUCTION

The use of cable television transmission systems for two-way communications has been discussed, and occasionally implemented, for at least 25 years. Occasional uses have included return transmission of analog video material originated at schools and other locations remote from the headend, system telemetry, limited data communications, and customer response information in innovative systems such as Warner's QUBE network in the late '70s. More recently, there has been relatively widespread deployment of impulse pay-per-view capability in set-top boxes with non-real-time store-and-forward return transmission capability.

The cable industry has before it today, however, a much wider variety of potentially profitable two-way digital service opportunities, spanning telephony, high speed data communications between residences, businesses, and the Internet, and interactive television. Implementation of these services will require coming to grips with a host of new challenges, notably in the areas of capacity and reliability. Time Warner and other cable companies are shouldering these challenges. This paper will explore a unique approach which Time Warner has pioneered in its Orlando, Florida, interactive television system, which holds significant potential for high volume, highly reliable transmissions over the incoming portion of two-way cable systems.

Historically, cable systems have used the spectrum below channel 2, typically a band from 5 to 30 MHz or, more recently, 5 to 40 MHz, for inbound transmissions – those returning from the subscriber to the headend (Figure 1).

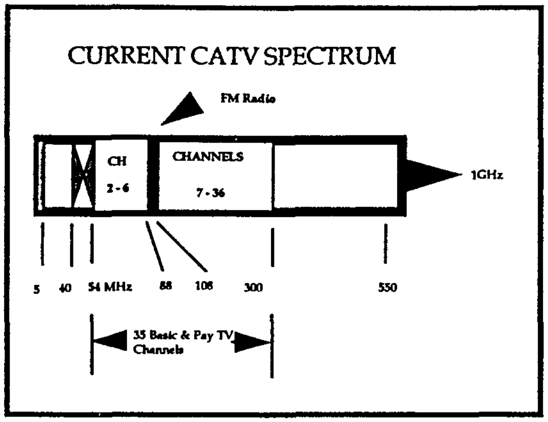

Figure 1

While cable system shielding integrity has improved dramatically in recent years, due in part to the implementation of FCC-mandated leakage monitoring requirements, the physical realities of coaxial plant, both in the distribution system in public rights-of-way and within subscribers' homes, dictate that shielding integrity will never be perfect. This gives rise to ingress of signals from a variety of interfering sources, including discrete carriers from radio sources ranging from short-wave broadcasts to CB and amateur radio transmissions, and from broadband impulse radio sources such as leaking electrical insulators, electric motors, and noisy electrical contacts. These sources are particularly plentiful and strong at low frequencies such as those in the 5 to 40 MHz band.

A second challenge with regard to traditional implementations of return transmission in cable networks arises from tree-and-branch cable architecture (Figure 2).

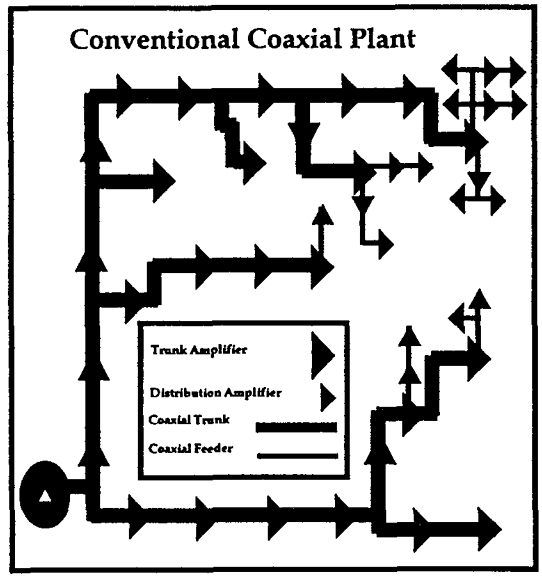

Figure 2

This architecture is a highly cost-effective means of distributing outgoing RF signals, which appear at all end points of the tree-and-branch system, but provides a highly undesirable additive funneling of ingress signals and thermal noise, along with the return transmissions from all points in the network. These factors have forced the adoption of extremely robust, and sometimes complex, schemes for reliable return transmission. Digital modulation schemes used in such systems, for example, generally trade throughput, in terms of bits per hertz, for robustness, using approaches such as QPSK (Quadrature Phase Shift Keying).

Bridger switching, a means of sequentially turning on and then off each distribution leg in the cable plant, and high pass filters on subscriber drops have been tried at various times as a means of making sub-low return transmissions more reliable and manageable. These approaches are, however, expensive and add considerable complexity to the operation of the cable system. Polled "store-and-forward" return schemes are in wide use for non-time-sensitive traffic, and derive robustness from their ability to ask for retransmission of missed data until it finally gets through.

The industry's rapid migration to hybrid fiber/coax ("HFC") architectures mitigates the challenges of utilizing sub-low return frequencies to a large extent by greatly reducing the size of the tree-and-branch sub-network which is funneling ingress, noise, and valid return signals together (Figure 3). In systems utilizing

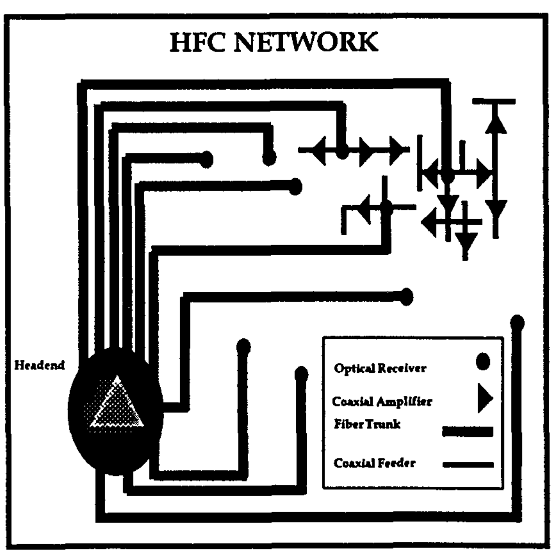

Figure 3

HFC architectures, return digital transmissions in the sub-low band can work quite well. Time Warner has implemented HFC telephony to a large number of customers in Rochester, New York, and has achieved a very high level of reliability. Early trials with cable modems also support this point.

Such systems make use of forward error correction and frequency agility, in addition to robust modulation schemes, to reach a high level of reliability. Nevertheless, HFC systems which utilize sub-low frequencies for the return have limited capacity. Future digital services which require a more symmetrical outbound and inbound transmission may, as penetrations grow, run up against capacity constraints. Such services include extensions of the HFC telephony, cable modem, and interactive television services which are in their early phase at present. The evolution of desktop video conferencing and video telephony, work-at-home applications, and web sites in homes and small businesses may bring about an increase in symmetry and demand for return bandwidth.

In addition to sub-segmenting HFC neighborhoods, the cable industry has available to it a source of a great deal of high-quality return bandwidth. This was demonstrated by Time Warner in its Orlando interactive television system, which has been connected to more than 4,000 homes and involves the use of the highest frequencies in the coaxial spectrum rather than the lowest. The results of the Orlando experience have been very promising, and the high-end return scheme has worked well. There is, however, a challenging migration problem, if and when the industry needs to take advantage of this additional spectrum. The industry has a rapidly growing base of deployed equipment in subscribers' homes which makes use of the sub-low frequencies. Obsoleting this equipment by switching to the high end of the spectrum for return transmissions is unlikely to be economically feasible. It will therefore be necessary, in order to tap the benefits of high-end return, to maintain sub-low transmissions at the same time. This paper will outline ways in which this can be accomplished.

Orlando System UHF Return

A UHF return system is used in the Full Service Network interactive television system in Orlando. There are 20 fiber nodes, serving approximately 100 miles of system configured with the high-return amplifiers. The forward system uses an HFC architecture that consists of a node receiver and up to 6 active devices in cascade. The forward bandwidth is from 54 to 735 MHz and the return bandwidth is from 900 MHz to 1 GHz, with the diplex filter crossover between 735 and 900 MHz. There is no sub-low return path (Figure 4).

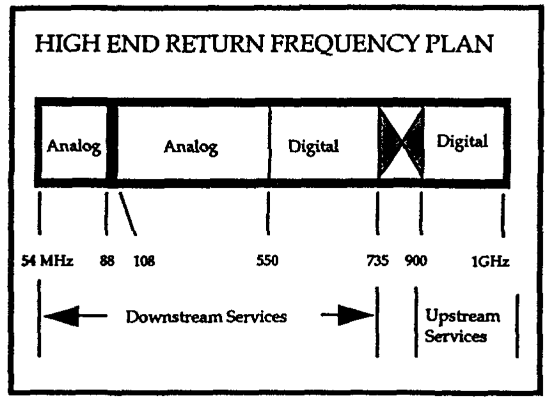

Figure 4

The high-return amplifier module has an operational gain of 36 dB, a third-order intercept point of 24 dBM, and a noise figure of 11.5. System specifications call for setting the lowest return-channel input level to a given amplifier at +1 dBmv. This fixes the system carrier-to-noise ratio ("C/N") at between 32 and 34 dB. This is sufficient to support high-level modulation techniques. Unlike sub-low return, the UHF bandwidth is very clean with respect to ingress and other interference sources.

The current version of the Home Communications Terminal ("HCT") used in Orlando has a frequency-agile transmitter utilizing QPSK modulation, carrying a DS1 (1.544 Mb/s) data signal with a variable RF output of 30 to 55 dBmv. Each HCT is assigned a frequency and a time slot when it is initialized. Current channel loading for the high return is 15 DS1 carriers between 906 and 937

MHz. This yields a peak loading of 375 HCTs per node. Expansion plans call for up to 24 DS1 circuits per node, or up to 600 terminals per node. All planned usage would occupy only slightly more than half the available return bandwidth for interactive TV, leaving the remainder for other services.

Diplex Filter and Gain Considerations

The diplex filter in the current high-return amplifier has a crossover bandwidth of 165 MHz. This was done as a matter of expediency for a prototype product and can be improved upon; significantly better crossover efficiencies should be readily achievable. A UHF return module selected at random and swept for frequency response had 1 dB roll-off at 750 MHz in the forward direction and 860 MHz in the reverse (Figure 5).

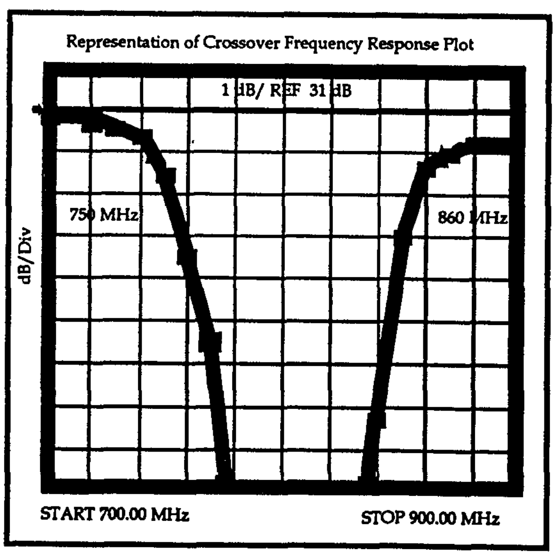

Figure 5

In the Orlando test there is 36 dB operational gain in the active devices (i.e., trunk and line extenders). This capability more than compensates for the losses between amplifiers.

The input to the first active device is set to +1 dBmv. This fixes the maximum loss between the home and amplifier at 54 dB (Figure 6).

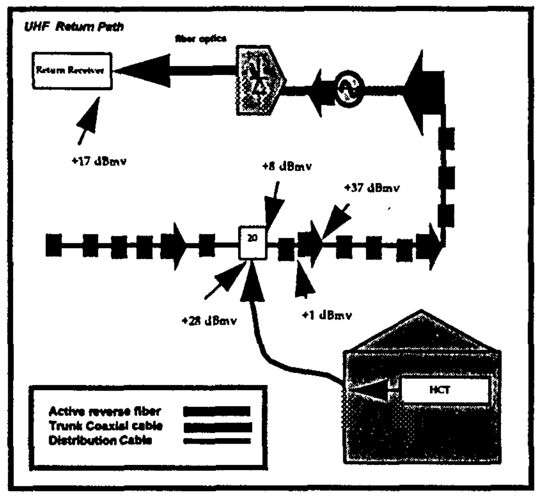

Figure 6

To achieve this maximum loss number, the system has to overcome the drop, coaxial, and passive losses. This can be a problem when a long drop and multiple splitters have been installed, but could be eliminated by giving the HCT a somewhat higher output. Another device that would be helpful for the longer drops and more-than-average number of outlets would be a house amp with gain in the reverse (UHF) direction.

The overall system C/N is between 32 and 34 dB with proper alignment. The return system currently carries 15 DS1 channels that occupy approximately 1 MHz of bandwidth each and can operate without error correction down to a C/N of 25 dB, leaving a margin of 7 to 9 dB. In a more widely deployed system, a somewhat greater margin would be desirable.

The UHF frequency band has so few problems with ingress and all the carriers fall within one octave, interference from ingress and distortions is almost nonexistent.

METHODS OF IMPLEMENTATION FOR NEW AND EXISTING PLANT

In new HFC plant, the implementation of high-end return or of both high and low-end return is relatively straightforward. Amplifiers may be developed by industry suppliers with built-in triplex filtering (Figure 7).

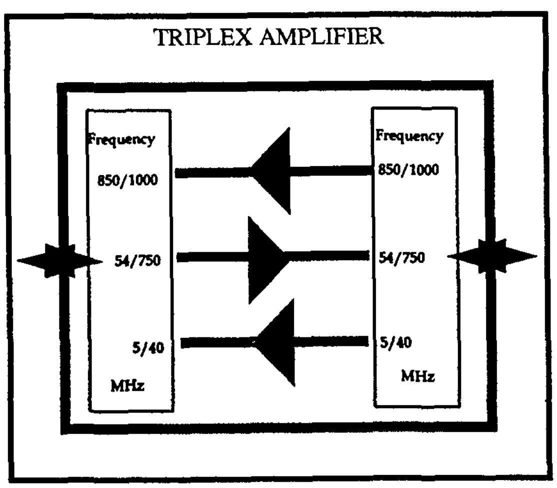

Figure 7

Within a single station, filtering would route sub-low and high-end return signals to their respective return amplifiers, while routing downstream signals, probably in the 50 to 750 MHz band, through a forward amplifier. This approach does include some engineering challenges, as a high degree of isolation must be maintained between these 3 signal paths in order to avoid the establishment of positive loop gain at certain frequencies, with resulting parasitic oscillations. This is a matter of filter isolation, as well as shielding isolation within the amplifier, but may well be achievable with careful design. Such amplifiers, when installed in new or rebuilt plant, would allow the use of customer premises equipment with either a sub-low or a high-end return transmitter.

A more difficult challenge arises in a system which has already been upgraded to 750 MHz downstream capacity, with a sub-low return, where it is desired to add high-end return as well.

Changing out all amplifiers in such a system is economically unattractive, but there are approaches which would allow the addition of high-end return equipment without necessitating the removal of existing active devices. One method is shown in Figure 8. In this approach, outboard high-split filters have been spliced into the cable at the input and output of each amplifier.

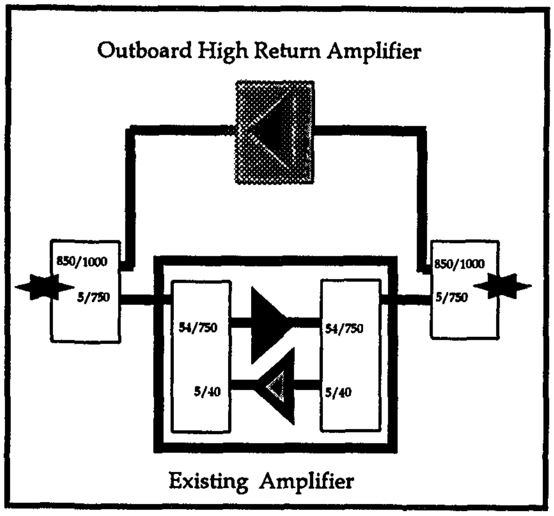

Figure 8

The sub-low diplex filters within the amplifier have been modified to accomplish a low-pass roll-off at 750 MHz, and an outboard housing with a new high-end return amplifier has been added. This approach preserves the investment in active equipment, and also eliminates the need for the high degree of shielding which would be required in the triplex amplifier outlined above. The only factor affecting isolation, and preventing loop-gain oscillation problems, lies in the directivity and isolation of the filters being added to the system. In this approach, there is also an opportunity to couple power from the center conductor of the coaxial cable to the new high-end return amplifier through the new filter.

There is, however, a significant drawback to this approach. It requires interruption of the system while new devices are cut into the cable at the input and output of every active device. This is of particular concern in systems which have implemented HFC telephony, with its need for a high level of reliability and continuity in order to maintain customer satisfaction in a competitive market. There is another approach to adding high-end return to an existing plant which avoids this problem.

Bypass Tap

The bypass tap is designed to route specific RF signals around existing working hardware (e.g., amplifiers) while causing no service interruptions (Figure 9). The bypass tap is modular and consists of 3 pieces: the clampshell, the tap, and the tap insert module. The tap provides an efficient means to clamp onto common coaxial cable sizes while at the same time providing an environmental seal and RF shielding. To install the bypass tap, a special cordless tool attaches to the clampshell

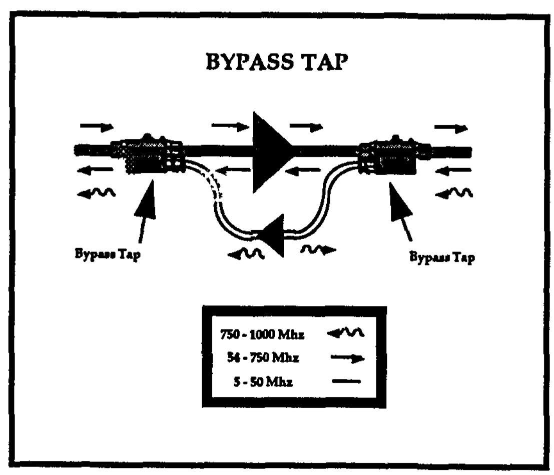

Figure 9

allowing access to the center core of the coax by cutting away part of the coax sheath and dielectric material.

The method used for the RF signal extraction from the distribution coaxial cable is innovative and unlike the traditional tap methods. Signals are extracted from the center conductor without physical contact, through capacitive and inductive coupling. Each tap has isolation of approximately 35 dB. Pairing two of the bypass taps allows the routing of specific RF signals around existing hardware without interrupting service. If power is required, it can be provided by changing to a power-passing insert. In the power-passing path, an RF choke is used to control return loss to avoid a second RF path interference (Figure 10). In both power passing and non-power passing versions, the existing signals and electrical power in the coax are not interrupted during installation.

FEATURES	SPECIFICATION
Frequency Response	.7 to 1.0 GHZ ± 1.0 dB
Tap Values	10 to 30 dB
Insertion Loss	≤ 1.2 dB
Return Loss	≥ 18.0 dB
Isolation	≥ 35 dB
Hum Modulation	≤ -80 dB
Bypass Power Capacity	2.0 Amps
RF Shielding	≥ 100 dB
Cable Connector	Bypass Port Only
Signal Interruption - Installation	NO

Figure 10

<u>Relative Costs</u>

In 1994 Time Warner completed an informal survey concerning the relative costs of manufacturing amplifiers with either a UHF return or a tri-band device that used both the sub-low and a UHF return. The cost premium for a high-return amplifier over a standard sub-low split was approximately $100. This cost differential would diminish with volume. The triplex filter version is technically more challenging and would require complete redesign of the majority of vendors' product lines. It would also, in many cases, be incompatible with existing amplifier housings.

An interesting alternative may be the bypass tap concept referenced earlier in this paper. This method could be retrofitted into existing plant without replacing existing equipment. The high-return amplifier would be mounted externally to the existing amplifier. Any additional isolation not furnished by the bypass taps could be added by modifying the diplexers in the sub-low split station. The estimated cost of the bypass tap approach described is about $50.

CONCLUSIONS

We have explored the nature of the return transmission challenge: the need for return capacity, and the need to find an evolutionary approach to increasing that capacity. We have explored a means of implementing a transition with minimal disruption of existing services and capital investment. The economics of this transition are probably attractive in the context of the kind of revenues which the need for the additional capacity implies.

In summary, high-end return is an excellent approach to high-capacity return transmission in cable systems. Like all technology introductions, however, its implementation is much more practical if it can be effected in an incremental fashion. We have described such an approach, and believe that it will prove to be practical and cost-effective. As the provision of two-way services over cable television plant grows in importance, the cable industry can rest assured that an increasing need for two-way capacity can be met with practical, evolutionary approaches such as those outlined in this paper.