IMPLICATIONS OF TELEPHONY SERVICE ON BROADBAND RF CABLE PLANT DESIGN

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Abstract

Recent events in the telephone and cable industry have included plans for the distribution of telephone services on broadband RF cable plants. This paper will discuss the effects that this service will have on new and existing plant designs. Implications on such things as system architecture, fiber node sizes, system powering, return bandwidth, drop integrity, and plant distortion requirements will be reviewed.

TELEPHONY REQUIREMENTS

System Components

A cable telephony system consists of headend interface units (HIU) and customer interface units (CIU). (See Figure 1) The HIU must interface with a telephony switch, transmit signals in the downstream path, and receive signals in the upstream path. In addition, this is where the control system, used to provision and monitor the system, would reside. The CIU must receive and process the downstream signals, transmit in the upstream path, provide a standard 2 wire telephone interface to the customers in house wiring, and provide ringing voltage.

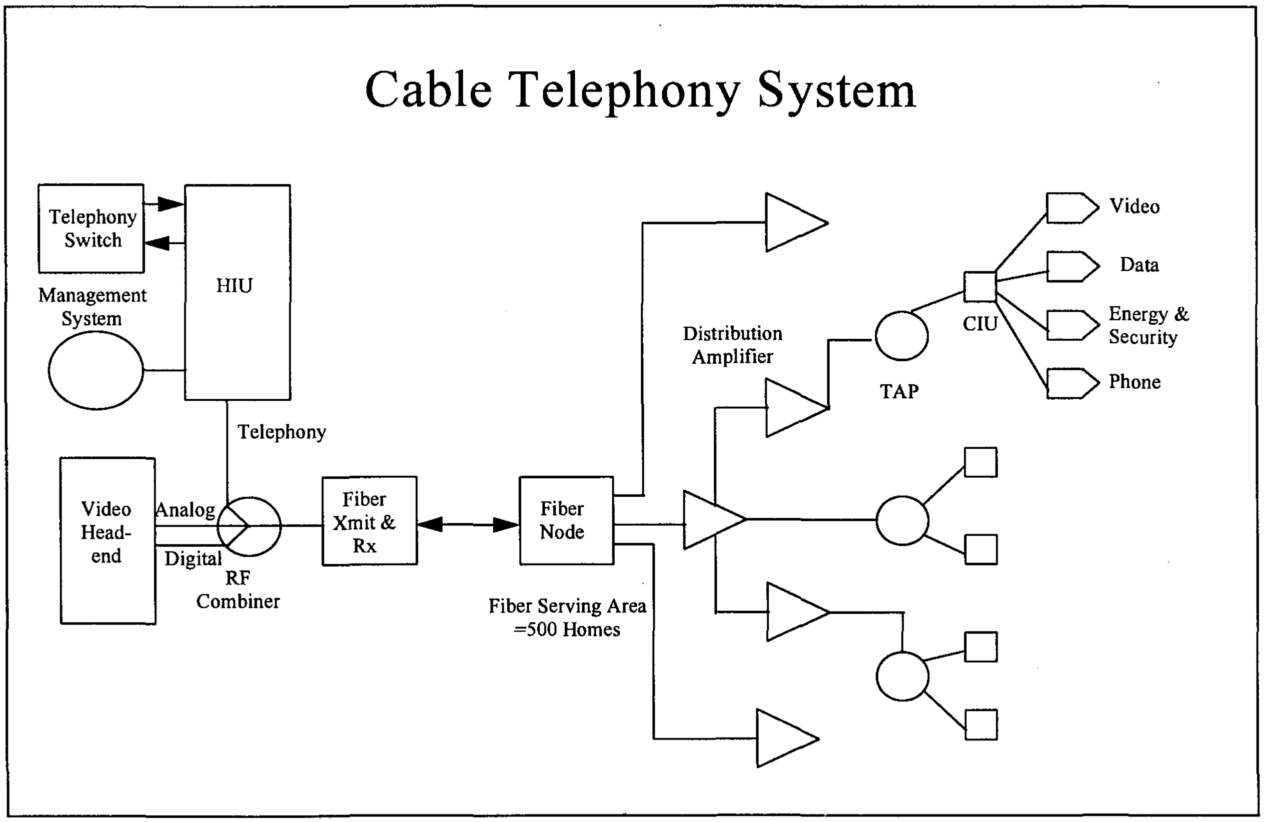

Figure 1

In between these two components is a Fiber to the Serving Area (FSA) distribution system. Since the reverse band of each fiber node can be processed separately at the headend, this architecture allows for the required amount of reverse bandwidth per subscriber.

Type of Service

Before deciding on cable plant requirements, the first question that must be answered is what level of telephony service is required. The Regional Bell Operating Companies have strict requirements in the areas of service downtime and line concentration, among others. A cable operator who desire's to offer the primary phone service may or may not have to meet these requirements. Teen lines, Fax lines, and modem lines could be offered, which might not fall under the same restrictions as the primary phone service due to the implications of emergency services. These requirements will also vary from country to country. Another possibility is T1 service for business applications. The integration of a cable telephone system with utility management functions would also be a natural fit. This paper will assume that the operator desires to offer a level of service equal to the current phone service in the United States.

Some of the main requirements placed on the carriage of Plain Old Telephone service (POTS) are in the area of downtime. Today's twisted pair local loops have extensive backup networks and typically maintain phone service for 4 hours or more after the power is first interrupted. This would require an extensive investment in backup power supplies to achieve this in a broadband plant.

SYSTEM REQUIREMENTS

Architecture

Of the recent technological advances in broadband RF plant designs, the switch from tree and branch style architecture to FSA is the one most responsible for making two way communications possible. This is because it brings with it the ability to separate the reverse paths by fiber nodes and reduce the amount of noise funneling that occurs in trunked systems. Another advantage of this type of system is the increased reliability brought about by decreased cascade lengths. Recent studies have shown that FSA architectures have achieved downtimes of less than 25 minutes per year per subscriber.[1]

Downstream Path

The additional requirements on the downstream path are minimal compared with the upstream path. Cable systems have been transmitting signals in this direction for many years and advances in equipment bandwidth and video compression are allowing more and more data to be carried in this direction. In a cable telephony system, each fiber node will carry only the calls for that node. Since the downstream path does not have inherent problems with ingress and interference, a higher order modulation type can be used in order to get a higher bits-per-Hertz ratio. An approach using QPR modulation could fit 480 DS0's in 18 MHz. (A DS0 is a standard single call, 64 kB/sec, signal format.) This 18 MHz would not have to be contiguous but could be split into 3 MHz bands so that two could fit in any available video channel. The effect on the distortions of the downstream path is minimal since these signals can be carried 7 dB below the level of video carriers.

Upstream Path

The reverse path frequency bandwidth will be the limiting factor in determining the fiber serving area node size. Due to the harsh realities of the return band, it is desirable and necessary to use a robust modulation scheme such as QPSK. As you can see from Table 1, this type of modulation does not offer the bits-per-Hertz performance of some higher order modulation schemes, however it does offer excellent performance with minimal carrier to noise (C/N). Also, since certain portions of the reverse band may not be useable at all times, it is desirable to use many relatively small bandwidth carriers. This will minimize the impact of any interference on the total number of carriers available for use at any one time. These carriers should also be agile in nature in order to deal with the variable nature of the reverse band ingress. Assuming all these things to be true, the reverse path then consists of agile QPSK modulated carriers, each dedicated to one customer call in progress, that are spread across the available reverse bandwidth. The amount of available reverse bandwidth is then directly proportional to the number of calls on the system at one time.

Modulation Type	**Required E_b/N_0***	**Bits per Hertz**
QPSK	15.7 dB	2
16 QAM	22.6 dB	4
64 QAM	28.8 dB	6

* E_b/N_0 is defined as bit energy to noise power spectral density and is proportional to C/N based on the noise BW and bit rate of a given system. [2]

Table 1

Recently cable distribution equipment manufacturers have announced plans to offer amplifiers with an increased amount of reverse bandwidth. The standard subsplit offered 25 MHz of bandwidth from 5-30 MHz. The expanded subsplit will offer 32 MHz of bandwidth from 5-42 MHz, a 48% increase. This does not come without tradeoffs. Decreasing the filter crossover region will require higher order filters which will cause increased channel 2 rolloff and increased group delay. But, since the FSA designs have short cascades of amplifiers this should be a manageable problem. Any other options that require reverse bandwidth also need to be considered. Services such as Status Monitoring, Impulse-Pay-Per-View, and any of the expanding number of

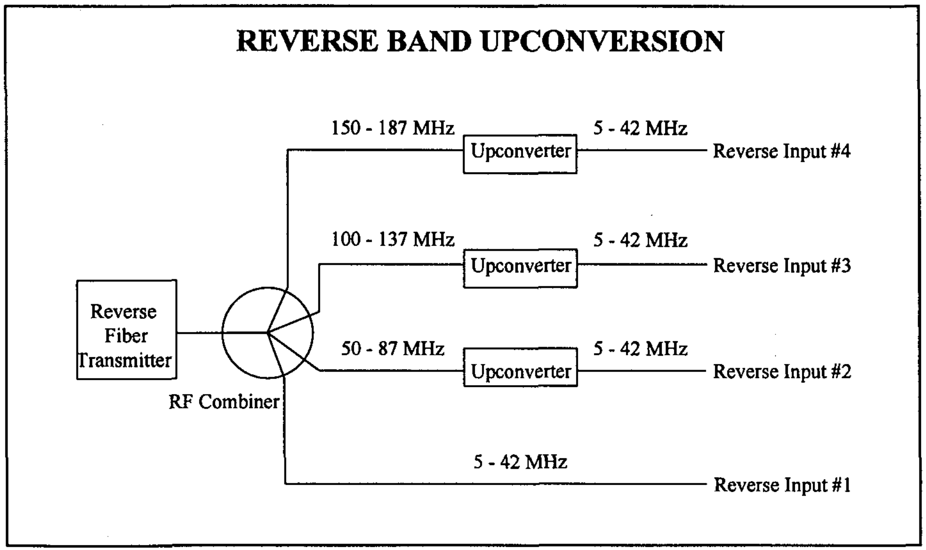

Figure 2

interactive services will affect the available bandwidth, and, therefore, the available number of calls.

Reverse Band Upconversion

One possible way of increasing the available return bandwidth per fiber node, is to separate the return bands that are being fed into the return laser and to block convert them up in frequency (see figure 2). This would allow a 2000 home node to be able to utilize its return band in 500 home pockets. The return bands at the headend would then have to be downconverted before being processed. This would require extra hardware at the fiber node and the headend, but this equipment could be less costly than a fiber link. The required downstream bandwidth in this scenario would increase four times, from 18 MHz, to 72 MHz per node.

Noise Funneling

As was stated earlier, the reverse path is a harsh environment. This has as much to do with interfering carriers as it has to do with noise funneling. The noise funneling that occurs is governed by the following equation:

$$\text{Noise} = 10\log N + C/N$$

where N = number of amplifiers per node and C/N = the carrier to noise of each amplifier (assuming they are all the same type of amplifier set up in the same configuration). For a typical 500 home node, the number of amplifiers = 4.5. This yields 6.5 dB of additional noise due to just noise funneling of the upstream coaxial plant.

Return Lasers

Due to the high cost of DFB lasers, Fabry-Perot lasers are currently being used in the return path. This type of laser has shortcomings in the area of noise and distortions. The C/N of a typical upstream system is set by the Fabry Perot laser. The C/N could be improved with the use of a DFB laser but this would cost approximately twice as much. However, if reverse band upconversion, as described earlier, is used, this may be required due to the increased number of carriers transmitted. In the future an intermediate grade of laser may be required with performance and cost between that of a DFB and Fabry-Perot laser.

Drop Integrity

Another source of noise in the return path is the customer premise drop. To minimize ingress in the reverse band, special care will need to be taken to ensure that the drops are of good integrity. This means the use of adequately shielded cable with tightly installed connectors. Recent studies have shown that by placing reverse band stop filters on the areas of the customer premise drop that do not require reverse transmission capability, the average noise returned to the headend was decreased by greater than 7 dB.[3] While this may not be feasible due to the increasing use of the reverse band in the home, it does show that if care is taken to limit undesirable ingress from the home, significant gains could be made.

POWERING

System powering will be a very important issue to any cable telephony system. The system could be customer powered or network powered, with or without backup capability. A strong case can be made for a battery backed up network powered solution for any system that is truly going to offer the type of service expected by consumers in the United States. Home powering will be resisted by consumers because it means a box in their home and because they do not need it with the present telephone service. Home powering is unacceptable without battery backup because it fails to offer lifeline service. The first time someone is unable to call 911 when the power is out will be the beginning of the end of that type of system. Home powering with battery backup would provide an unimaginable nightmare in replacement and disposal of rechargeable batteries. A network powered solution would require the same type of backup systems that are currently offered for cable systems today. Network power also would require the device to reside outside the home in order to meet the National Electric Code.

To get the power to the box located on the side of the home a twisted pair/coaxial cable combination could be used. (See figure 3) This would eliminate the contact corrosion that can occur when power is carried on the coax drop cable. While this would require the replacement of the drop cables, or the addition of a twisted pair cable in current systems, it would allow for the operators to ensure the integrity of these drops. This would also require the addition of a power converting device at the tap locations or a replacement of the RF only taps with taps that pass RF and Power.

To estimate the increased power demands for a cable telephony system, we will assume the following power requirements for the Customer Premise Equipment.

Ringing	7 Watts
Talking	5 Watts
Sleep Mode	2 Watts

A system with 500 home nodes, 100% penetration, and all subscribers off hook at

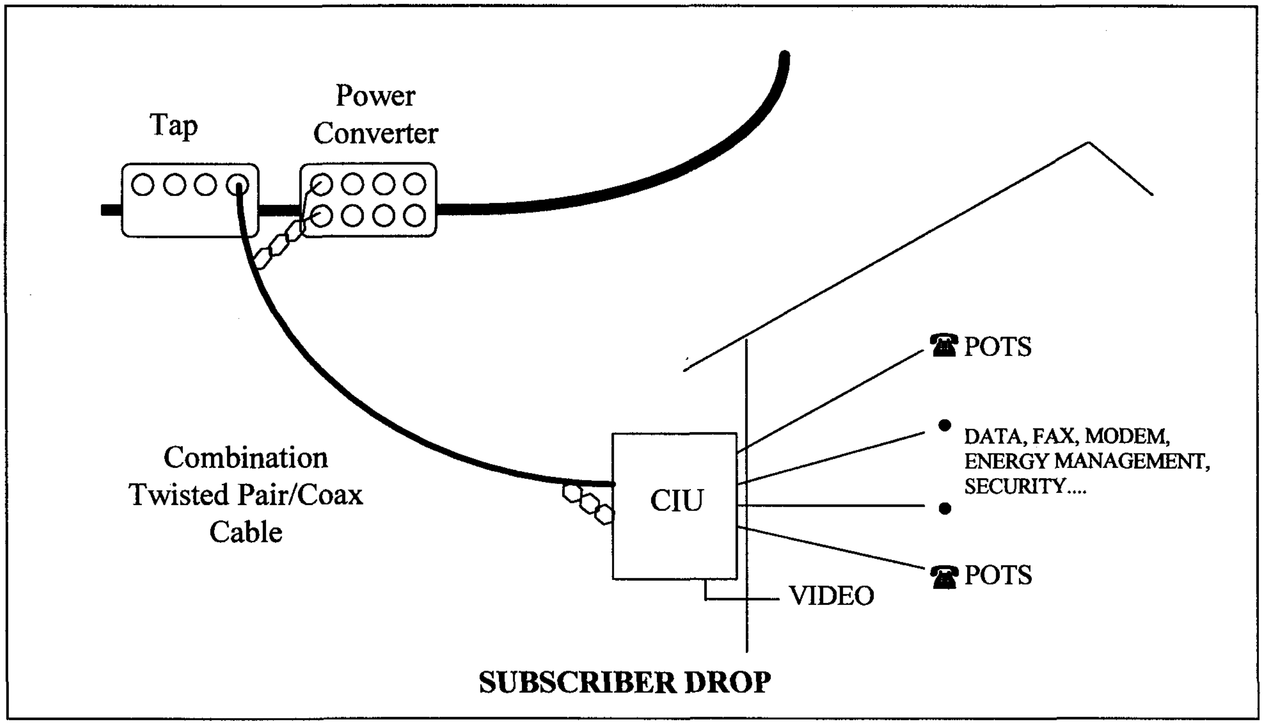

Figure 3

once, would then require 2500 more watts per node. This would require three additional 15 Amp backup power supplies.

CONCLUSION

There are several requirements placed on the design of a broadband RF cable system in order for it to be able to carry telephone signals. The primary requirement is the use of a Fiber to the Serving Area distribution system. Other requirements include:

- Available bandwidth in the forward and reverse paths
- An upstream band with sufficient integrity
- A power system capable of powering the customers premise equipment with battery backup

All of these requirements have feasible solutions and their implementation will result in a quality service that will be accepted by the consumer.

REFERENCES

[1] R. Pinkham, "Combining apples and oranges: The modern fiber/coax network", Telephony, pp. 28-32, February 7, 1994.

[2] B. Sklar, "Digital Communications Fundamentals and Applications", 1988, Prentice Hall, Englewood Cliffs, New Jersey 07632

[3] M. Dzuban, AT&T Return Path Study, CableLabs Return Path Conference, February 15, 1994.