UPGRADING COAXIAL DISTRIBUTION NETWORKS WITH AMPLIFIED TAPS

Exploring a Reliable, Cost-Effective Approach to GigaHertz CATV Plant

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ABSTRACT

Substantial progress has been made in the last few years in improving approaches to the trunking portion of CATV plant, largely through innovations in broadband analog optical fiber transmission technology. While this provides a trunking system with essentially unlimited potential bandwidth and excellent performance specifications, it leaves the remaining coaxial distribution plant as the weak point in these networks. This paper presents an approach to distribution architecture, and to tap design, which addresses this issue. This approach greatly reduces or eliminates the use of in-line amplification in distribution plant, and introduces the use of "active taps." This means that the reach of the distribution plant is determined primarily by cable loss, as splitting loss is largely eliminated. Active devices are used to provide isolation and output levels sufficient to drive subscriber drops. The failure of any active device in such a system would affect only the very few subscribers fed by that individual tap.

In addition to an architectural and strategic overview, specific tap design possibilities are outlined, and the capital and operating economics of such a plant are reviewed. This paper is intended to contribute to a dialogue in the cable television industry which may lead to the development of a new family of coaxial distribution hardware.

INTRODUCTION

The cable industry today is in the process of making dramatic changes to its network architecture. Traditionally, cable plant has been designed with two primary elements, the first of which is trunk plant, providing branched coaxial distribution of high quality signals from the central headend (or regional hubs in very large communities) deep into the system, within one or two miles of every subscriber. The second element is the distribution plant, which consists of a branched and tapped coaxial network passing every possible subscriber in the service area, in sufficient proximity to provide for a service drop distance of no more than 200 to 300 feet.

Because of coaxial cable and branching losses, traditional trunk plant requires broadband amplifiers every 2,000 feet or less. The resulting cascades, or series, of trunk amplifiers, with their additive noise and intermodulation distortion, provide practical limits to the achievable bandwidth, reliability, and signal quality of today's CATV systems.[1] The replacement or reinforcement of the trunk plant with low loss optical fiber can dramatically improve the channel capacity, transmission quality, and reliability in this portion of the system. Advancements over the last several years in low noise, high bandwidth, highly linear lasers and detectors have made this replacement of coaxial trunk plant with fiber trunking cost-effective, and much of the new construction and system upgrades now underway take advantage of this technology.[2,3] It is quite feasible to construct high quality trunking plant with a useable bandwidth well in excess of 1 GHz today, using off-the-shelf lasers and detectors.

The evolution of coaxial distribution plant architecture as bandwidths increase has proven to be more challenging. As channel capacities increase, carrier loading and noise bandwidth increase, and coaxial cable loss increases as well. This means that the distribution amplifiers required for conventional distribution architectures in high capacity systems must have significantly greater performance capabilities than those available today. In addition, losses introduced by splitting and power-passing devices become more critical at higher frequencies.

On top of these challenges lies an opportunity. The cable industry as structured today is remarkably labor-intensive. The drop connection to each subscriber must be physically connected and then disconnected when that subscriber decides to receive or terminate service.

One interesting solution to the formidable problems of bandwidth expansion may be offered by the replacement of today's passive coaxial tapping devices with active devices. This could be realized by the provision of an amplifier for each subscriber or small group of subscribers, coupled to the distribution transmission cables either passively or actively. As will be seen, this may provide an opportunity to substantially extend the reach of coaxial cable without the use of distribution amplifiers, or, alternatively, allow the minimization of amplifier cascades. The introduction of active electronics at the tap means coming to grips with difficult issues of powering and reliability in an electrically and physically hostile environment. It also carries with it an opportunity to significantly improve operating efficiencies, however. Once there are active electronics at the tap, there should be little additional cost in providing on/off switching for each subscriber, eliminating a major source of cable industry labor.

In addition to these advantages, active taps, through the replacement of "lumped" gain blocks within the distribution plant by "distributed gain" in the subscriber leg of each tap-off device, should provide an opportunity to improve perceived plant reliability significantly. Even though a much larger number of active devices would exist in the plant, only one would exist between each subscriber and the fiber trunking system. This means that widespread outages would become much less frequent than in today's system architectures, since device failures would generally affect only one or a very small number of subscribers.

There have been several attempts in the past to realize active tap electronics. Each has met with frustration, but the advent of new types of electronics and new techniques to protect semiconductor devices from voltage transients and current surges, coupled with challenges facing the cable industry regarding channel capacity and customer service, may mean that the time has come to revisit this idea.

THE ACTIVE TAP CONCEPT

Current Tap Technology

The taps used in cable television systems today have one primary function, which is to tap off a percentage of the broadband RF signal power on the distribution line to distribute to the subscribers' homes. An additional requirement is that they allow 60 volt, 60 Hz powering to flow along the coaxial distribution line, while blocking voltage from the tap output ports which feed subscriber drops.

The conventional tap configuration, shown in Figure 1, is a simple transformer-wound directional coupler, feeding a four-output RF power splitter. In order to achieve AC power-passing capability, an RF choke is added in parallel to blocking capacitors which isolate the RF coupler. The "tap value" or coupling ratio of the transformer is selected based on the desired percentage of signal power to be tapped off.

Each tap installed in the distribution line attenuates the signal power passing along the line as it taps off signal. The amount of insertion loss varies with tap value. The total insertion loss caused by a tap can be characterized as the sum of: i) the reduction in signal power resulting from the power split of the directional coupler; ii) the power lost to inefficiencies of the directional coupler's ferrite transformer; and iii) the power lost as a result of the 60 Hz line power bypass, blocking network, and associated matching networks. The excess insertion loss, that is, loss in excess of the theoretical value for the power split, can equal or exceed 1 dB and is frequency dependent.

Tap insertion loss, when added to the signal attenuation due to the distribution cable, dictates the maximum distance between distribution amplifier locations. The cumulative insertion loss caused by the taps in the feeder line is proportional to the required signal level at the output of the taps which feed subscribers. As the bandwidths of cable television systems increase, the tap output level must also increase due to the added attenuation of the drop cable.

Figure 2 shows the effects of tap insertion loss when combined with cable attenuation in a sample feeder line. The diagram also shows how different cable sizes at different frequencies,

Conventional Tap Block Diagram

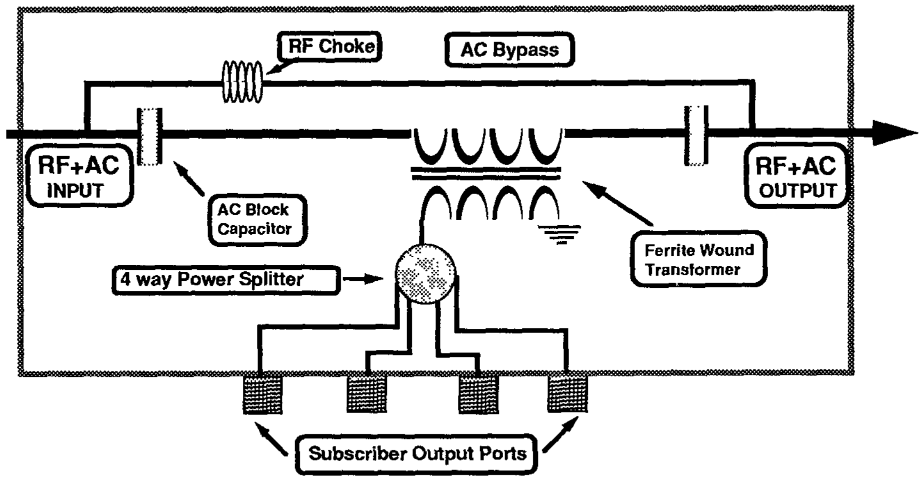

FIGURE 1

Feeder Line Reach Model

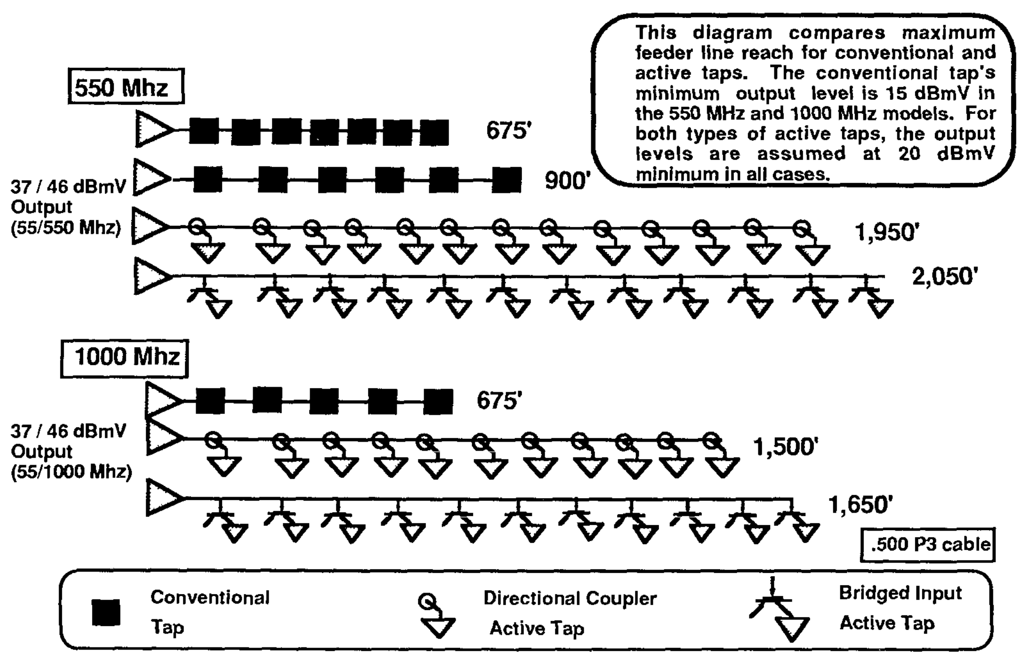

FIGURE 2

along with tap insertion loss, affect the maximum reach after an amplifier, for a given minimum tap output level. Also compared on this diagram are examples of feeder line reach when equipped with the two types of active taps that are discussed in the following sections of this document.

Directional Coupler Active Tap

A "directional coupler active tap" in a distribution line serves the same basic purpose as a conventional tap. Since the tap, as shown in Figure 3, represents distributed amplification, it allows distribution plant architecture which eliminates the use of amplifiers after the fiber optic node. Taps need not be capable of passing 60 Hz, 60 volt line power, assuming that the active tap device is powered directly from the subscribers' homes.

The interest in this type of active tap stems from its amplification ability. By having internal amplification, and by locating the RF power splitters after the gain stage, the active tap reduces the amount of signal power that must be tapped from the feeder line. Since less RF power is tapped, the tap's insertion loss is reduced. By reducing the tap insertion loss, the maximum reach of the feeder line is extended.

The directional coupler active tap shown in Figure 3 begins with a high value (low insertion loss) directional coupler feeding a plug-in attenuator pad. An optional diplex filter for low frequency return signals could be installed between the directional coupler and the plug-in pad if two-way operation were required. The purpose of the pad is to reduce the number of different values of directional couplers that would be required. Due to the discrete nature of the wound ferrite transformer, directional couplers are usually only available in three to four dB steps. In the reach model (Figure 2), ten of the thirteen directional coupled active taps used directional couplers with values of 16 dB or greater. The insertion loss of these couplers was assumed to be 0.8 dB. Since the theoretical insertion loss of a non-power passing 16 dB directional coupler is 0.1 dB, it would appear that improvements in efficiency could be expected. It is important to note that with a 0.3 dB improvement per directional coupler, there would be an additional three dB of signal after the tenth tap. This extra signal might allow an increase of 150 feet in the feeder line reach.

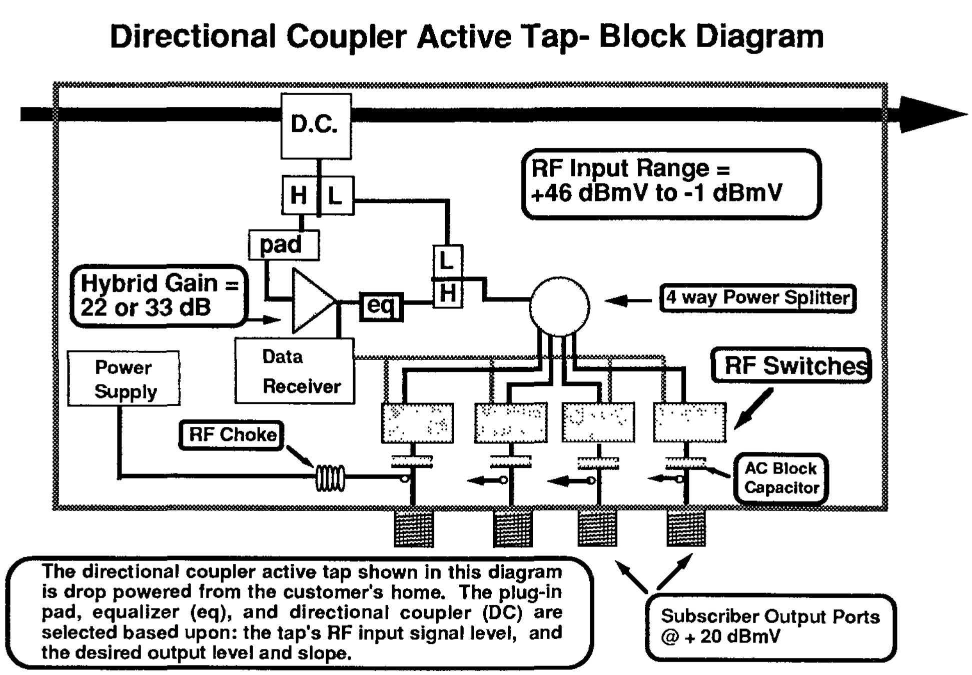

FIGURE 3

The plug-in pad is followed by the hybrid amplifier gain stage. This amplifier chip, for the 550 MHz version of the active tap, would be a push-pull type hybrid with a 5-6 dB noise figure and with 30-33 dB of gain or less depending upon carrier to noise ratio ("C/N"), number of tap output ports, and output level requirements. (The hybrid gain for seven of the thirteen directional coupler active taps shown in the 550 MHz feeder line in Figure 2 could have been 22 dB, while still providing a 20 dBmV output level on four ports.)

The nominal operating output level of the hybrid amplifier would be 30-36 dBmV. It would appear that the operating level could increase to 42 dBmV (with no tilt) before its contribution to overall system distortions would cause the end-of-line performance to degrade below established goals. Following the hybrid amplifier is a plug-in equalizer. The equalizer is selected based upon the active tap's location in the feeder line (or the degree to which the RF signals are tilted) and the amount of tilt that will be added by the average drop fed by that specific tap. Post-hybrid equalization was selected in order to protect the C/N ratio of the low band channels. Reduced C/N ratio for these channels is a common problem in single stage, high gain amplifiers with front-end equalization or slope control operating with significant output tilt.

Following the equalizer is a directional coupler or resistive tap that would feed signals to a data receiver. Past the directional coupler is a second (optional) diplex filter, which completes the upstream signal path around the amplifier. According to the number of tap output ports needed, a two, four, or eight way splitter would be installed after the diplex filter. Connected to each of the output ports would be a PIN diode switch, which is driven by an output of the data receiver, allowing the on/off switching of the signals at each tap port. The last component in the chain is a voltage blocking capacitor/powering extractor circuit that allows the tap to be powered from a subscriber's home.

The Bridged Input Active Tap

This device is similar to the previously described active tap except that the directional coupler is replaced with a field-effect transistor ("FET") with a high input impedance as a tap-off device. (See Figure 4.) As a result of its high impedance, the tap appears to have a zero dB insertion loss across the 75 ohm distribution line. This allows the placement of active taps, in unlimited quantity, along the distribution line until the distance is reached where the cable has attenuated the signals below the required threshold for the active tap.

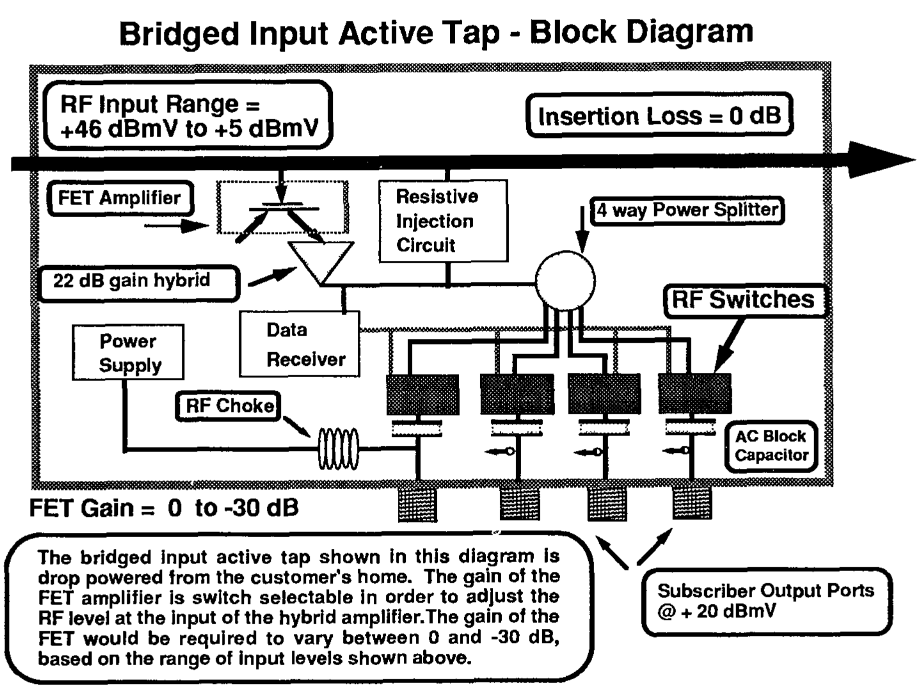

FIGURE 4

The fact that this technology allows any quantity of taps to be placed on a feeder line makes it density insensitive. The maximum feeder line reach from the optical node is therefore dependent only upon the cable type used and the cable system's bandwidth when assuming constant node output levels. The effect of density on the maximum reach of a conventionally tapped feeder line can be seen in Figure 2 (550 MHz case). By maximizing the feeder line reach, one assures that the fiber optic node will serve the largest number of homes possible.

The differences between this tap and the directional coupler active tap are found between the feeder cable center conductor and the input to the hybrid gain stage. As previously mentioned, the directional coupler in the preceding active tap is replaced with a high impedance, voltage sensitive, FET amplifier. This amplifier serves to isolate the 75 ohm hybrid from the feeder line. The gain of the FET could vary from 0 dB (unity gain) to -40 dB. The window of gain variation could be minimized, if necessary, by adding a plug-in pad located between the output of the FET and the input of the hybrid amplifier.

As compared with a directional coupler active tap, the hybrid's gain requirement for the bridged input active tap is significantly reduced. It would appear that a hybrid with 22 dB of gain would suffice in all cases. In fact, hybrid amplifier chips would not be required in the bridged input active taps that were installed within 900 feet of the node, assuming the unity gain FET could directly feed the power splitter.

The amount of gain might be controlled by selectable dip switches in the device. If the gain versus frequency response of the FET amplifier could also be controlled by switches, this might eliminate the requirement for post-hybrid equalization.

The diplex filter located between the directional coupler and the hybrid input in the earlier active tap would be replaced with a passive or active/passive "injection circuit" for return signals. This injection circuit would greatly resemble a 30-40 dB resistive tap. Some amount of gain, although less than the loss of the injector circuit, could be added in series. Since there would be minimal flat loss at the low frequencies used for upstream signals, between the active tap and the input to the fiber node, this would seem to represent a workable approach. As long as the negative gain of this circuit (when added to the gain (loss) of the FET amplifier) exceeds the positive gain of the hybrid, instability as a result of positive loop gain would be avoided.

The circuitry following the amplifier hybrid would be the same as that described for the directional coupled active tap.

Performance Requirements

The performance requirements for both types of active taps are listed in Figure 5. The C/N ratio specification for the directional coupled active tap assumes a distribution line level of +46 dBmV maximum and -1 dBmV minimum. In the case of the bridged active tap, the C/N ratio should be met with feeder line levels between +46 dBmV and +5 dBmV. These levels were selected given the expected noise performance of the bridged active tap product. Both types of active taps should provide a tap port output level of +20 dBmV minimum for two-port and four-port models. For an eight-output port active tap, the output level should be at least +18 dBmV. These output levels are specified at the active tap's maximum rated frequency. The tap should be able to introduce the range of positive slopes as specified in

RF Performance Requirements

	Optical Trunk	Optical Bridger	Active Tap	Total
C/N	50	67	51	47.5
CTB	65	64	59	53
CSO	65	70	55	53

The table indicates the assumed specifications for the optical trunk and the optical bridger. The "total" column indicates the desired minimum end of line system specifications. The column labeled "Active Tap" indicates the performance required of the active tap in order to meet total system specifications.

FIGURE 5

Drop Slope Table

Drop Length	550 MHz	1000 MHz
100'	4.1 dB	6.2 dB
125'	4.9	7.4
150'	5.8	8.6
175'	6.6	10.0
200'	7.4	11.1

The table indicates the amount of negative tilt that will be introduced by the length of RG-6 cable shown in the left column. The negative tilt, in dBs, is specified between 55 MHz and the frequency shown in the top row. Also included in the total negative tilt is the contribution of a two way splitter.

FIGURE 6

Figure 6. The CTB and CSO performance should be at least that shown in Figure 5, at the minimum tap output levels shown above, when operated with the output tilts shown in Figure 6.

On/Off Capability

In order to dramatically reduce connect/disconnect operating labor costs, the active tap should be capable of switching the downstream signal flow on and off at each of the tap output ports. This switching capability would be addressably controlled through the billing system via a data transmitter located at the headend. The data receiver, shown in the active tap diagrams, would command the switches (pin diode attenuators) to open or close depending on the instructions received from the billing system. This data receiver would be similar to that currently used in addressable converters. The frequency of its discrete data carrier could match that of the addressable converters used in the system.

TECHNICAL CHALLENGES

Powering

There are two logical means to power the active tap: from subscribers' homes and via the distribution line. There are advantages and drawbacks to each method. Distribution line powering, used today to power line amplifiers, is straightforward and relatively simple. Given the number of added active devices in relationship to the number of line amplifiers removed, additional power supply locations would be needed. The assumption has been made that, if line powered, this system would require 30% more power supplies. This is based on a power consumption for each active tap approximately equal to consumption of commercially available off-premise interdiction taps. Since the goal of the active tap is to have almost no distribution line insertion loss, the challenge would be to add the necessary AC power passing circuits without noticeably increasing insertion loss.

One solution to line powering active taps without incurring additional losses might be the use of DC powering, particularly for bridged input active taps. In this scenario, current would not be required to pass through a coupling transformer, since it would simply be carried on the transmission line through the tap. Since the gate of the bridging FET would be directly connected to the transmission line, the gate potential would be that of the DC voltage on the center conductor of the coaxial cable. Biasing would be accomplished through networks attached to the source and drain of the transistor. The amplifier hybrid and data receiver's power could be extracted from the transmission line through a carefully designed RF blocking network. With this direct connection to the coaxial cable, protection from power surges and spikes would be particularly critical.

By powering the unit via the drop from the subscriber's homes, the required number of line AC power supplies in the system would be greatly reduced. This would also eliminate the challenge of designing low insertion loss, AC power-passing circuitry. Powering from the home does, however, create its own problems. For example, if two customers are connected to the active tap, which drop (i.e., home) would actually power the tap? If only one drop actually powered the tap, and that customer disconnected his cable service, an outage for the other customer(s) fed from the tap would occur. When powering from the home, it would be useful to have power fed to the active tap on each drop. In that case, the active tap would automatically sense and use the drop with sufficient supply voltage to obtain its power. Two associated costs are the installation of the miniature power supply in the customer's home, and the long-term effects of electrolysis on the drop cable if direct current (DC) powering is used.

The RF signal level provided to the home using an active tap would insure adequate levels on more television sets than is currently provided with conventional architectures. Many cable television systems must use a drop amplifier in the home to provide adequate signal levels for more than two television sets. The active tap, both in terms of functionality and power consumption, is essentially a high quality drop amplifier mounted on the pole, followed by a splitter. The only added circuitry would be that of the data receiver and the drop on/off switches. Since the drop amplifier is often located close to the ground block (i.e., before any splitter) and may already be remotely powered from some other location in the home, one might view the drop powering issue in terms of relocating the drop amp further towards the tap.

Installation

In order to minimize installation costs, it would be useful if the active tap were packaged in an enclosure that could be mounted directly to the existing conventional tap base (for models of taps where the power-passing circuitry is part of the tap face plate). This laborsaving approach would eliminate the need to change the tap housing and associated connectors. The other primary aspect of the installation process would be to confirm, or install, the correct value of pad and equalizer (and directional coupler in the DC active tap). If drop powering is used, it would be necessary to install the small transformer and power inserter in the customer's home.

Maintenance and Reliability

An active tap must be essentially maintenance free. This implies that there should be no potentiometers to adjust output levels, etc. Long-term stability of gain, distortion, and frequency response should be engineered into the product. In the same vein, the reliability of the data receiver and its command of the on/off switches must be flawless over time and exposure to the elements. The product should be able to withstand significant electrical surges and transients as a result of lightning, power utility switching, sheath currents, etc., without damage to the hybrid amplifier, the data receiver, or the FET.

Overall reliability of an active tap product is critical. In a typical 100,000 customer cable system one would find 40,000 to 50,000 active taps. Unlike the addressable converters used today, it would not be possible for the customer to bring in a failed active tap for an over-the-counter exchange.

Dynamic Range

As previously mentioned in the section on performance requirements, the active tap must function over a wide range of input level conditions. The bridged input active tap should be able to accept at least +46 dBmV with up to 9 dB of slope. This tap should also accept input signal levels as low as +5 dBmV and 9 dB of reverse slope without degradation to the C/N performance. This requires a dynamic range of at least 41 dB. The dynamic range of the directional coupled active tap is somewhat less critical as a result of the directional coupler and selectable input pad. Nevertheless, this tap should meet target specifications with slopes from 9 dB positive to 9 dB negative, and with signal level variations of -2 to +5 dB.

ECONOMICS

Modeling Issues

There are many ways to imagine deploying active taps. The most likely would be as part of a system upgrade or rebuild. Another way might be as a result of a plant extension project. Plant modification projects, such as serving a new, unexpected apartment building, may be the case where the use of few active taps can save many thousands of capital dollars by eliminating trunk extensions that would otherwise be required.

Previous work analyzing the economics of off-premises addressable interdiction systems has provided examples of ways to deal with the economic analysis of the kinds of costs and savings represented by active tap technology.[4]

In the analysis that follows, the following factors were taken into account:

- Operational savings from the reduction of disconnect and reconnect labor
- Capital savings from the elimination of line extenders in an upgrade or rebuild
- Capital savings from the elimination of drop amplifiers

Pertinent issues that were not taken into account in the analysis include:

- Added costs to power the plant if line-powered active taps were used

- Added maintenance costs from having more active devices in the field

- Added installation costs when using drop powering from the home, which would require the installation of a power supply

- Cost savings from not having to power the plant, other than the optical trunk nodes, if drop powering were used

- Reduced service calls as a result of increased drop longevity through reduced physical disconnects and reconnects

- Marketing "lift" or increased revenue from "instant on/off" capabilities, e.g., weekend service, timely non-pay disconnects

- Reduction in future converter costs by eliminating the need for front-end pre-amps, since active taps would provide an additional 6 dB of signal at the set in most cases

- Capital cost savings by avoiding the need to replace the subscriber's drop or internal wiring as a part of system upgrade plans as a result of the high tap output level of an active tap

Economic Analysis

The starting base assumptions were as follows:

- Annual churn rate 30%
- Disconnect truck roll $16
- Reconnect truck roll $30
- Cost of capital/yr 10%
- Active tap unit cost $100

Other relevant assumptions:

- 1000 subscribers
- 100 homes per mile density
- 33 taps per mile
- 3 homes per tap

Case 1

Pay-back of capital (see example, Figure 7), only as a result of truck roll savings for reconnects and disconnects:

- w/60% penetration: 5-1/3 yrs

- w/80% penetration: 3-3/4 yrs

Sample Payback Calculation

-For 60 % penetration & 30% churn
-Case 1 analysis (no capital savings)

INVESTED CAPITAL = ACTIVE TAP COST LESS CAPITAL SAVINGS

(Capital savings present only in Cases 2 & 3)
(12 Month Interest Expense calculated on prior year end invested capital less prior year's cash flow savings)

CASH FLOW SAVINGS = REDUCTION IN ANNUAL TRUCK ROLLS

(In this case, 300 disconnects @ $ 16 & 300 reconnects @ $ 30)

For Case 1, 60% penetration:
Capital Investment = $ 55,000
Annual Cash Flow Savings = $ 13,800

Year	YE Capital Balance	Cash Flow Savings
Year 0	$ 55,000	$ 0
Year 1	$ 46,700	$ 13,800
Year 2	$ 37,750	$ 13,800
Year 3	$ 27,527	$ 13,800
Year 4	$ 16,480	$ 13,800
Year 5	$ 4,328	$ 13,800
Year 6	$ -9,039	$ 13,800

FIGURE 7

Case 2

Deployment of active taps as part of a Fiber-to-the-Feeder, or Fiber Backbone system upgrade, taking into account the elimination of capital costs for line extenders:

- Saved line extenders offset 34% of capital cost

  w/60% penetration: 2-1/2 yrs

Case 3

Expanding the previous scenario with the assumption that 20% of all subscribers would require a $67 drop amp to be installed if active taps were not used:

- Saved drop amps offset 24% of capital cost (collectively with LE's - 58%)

  w/60% penetration: 1-1/2 yrs

  w/80% penetration: < 1 yr

  w/80% penetration, but only 15% churn: 1-1/2 yrs

Price Goals

The price used for an active tap in the above analysis was $100. This price was derived by starting with a commercially available high quality drop amplifier. This drop amp features a 550 MHz push-pull hybrid, passive return capability (diplex filters), signal equalization, remote power supply, and power inserter. The circuitry missing for a DC active tap would be a data receiver, the pin diode switches, an output splitter, and an input directional coupler. Packaging the product for a pole-mounted environment would also add to the total cost.

The Market Potential

As the requirements to increase channel capacity cause more systems to be upgraded or rebuilt, system operators will find it necessary in most cases to replace their existing taps. With concurrent needs to increase signal level in the home as a result of higher extra outlet penetrations, increased drop cable attenuation at higher bandwidths, or desired improvements in terminal carrier to noise ratio, the active tap offers a powerful solution to respond to these challenges.

A complementary, lower gain active tap, with power-passing capabilities, would allow the device to be used in plant modifications, as well as in upgrade or rebuild scenarios with conventional trunk and feeder architectures. The lower gain would cause the active tap to have distortion performance similar to a single trunk amplifier.

The combined offering of these products may permit the active tap to be the tap of choice for tap replacement in all cases except routine plant maintenance. In this scenario, the market potential for an active tap is significant.

With 84,000,000 homes passed in the United States, and assuming three homes per tap, one would estimate that there are 28,000,000 taps. If one assumes that all U.S. cable systems will be upgraded using active taps by the year 2000, and that the cost of an active tap is $100, the potential market would be $2.8 billion over a nine year period.

Conclusion

As we have seen, there are a number of approaches to designing active taps which may be of interest. The simplest is an active device fed with a directional coupler. The addition of an active bridging element may provide additional benefit. It is hoped that this discussion will spark additional thinking and work in these areas. There is significant market potential available for vendors who are successful in developing reliable devices with these capabilities. In addition, this technology promises substantial benefit to the cable operator, as it has the potential to dramatically reduce operating costs, improve perceived customer service levels, and facilitate the development of expanded capacity systems.

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BIOGRAPHIES

James A. Chiddix is Senior Vice President, Engineering & Technology, with American Television and Communications. Mr. Chiddix is responsible for corporate engineering activities as well as research and development. ATC serves 4.5 million subscribers in 33 states and is 82% owned by Time Warner Inc.

Mr. Chiddix is a Senior Member and former Director of the Society of Cable Television Engineers and is a Senior Member of the IEEE. In 1983 he received the National Cable Television Association's Engineering Award for Outstanding Achievement in Operations, reflecting, in part, his role in introducing addressable converter technology.

Mr. Chiddix serves as a member of the Board of Directors of CableVision 21, a company which provides cable service in Fukuoka, Japan.

Jay A. Vaughan currently holds the position of Senior Project Engineer with American Television and Communications. In September 1990 Mr. Vaughan returned to the United States after a two year assignment in France where he was involved in the engineering and construction of 860 MHz cable system systems.

Prior to his overseas assignment he held the position of Project Engineer with ATC. Mr. Vaughan has also worked for Rogers Communications, Jerrold Electronics, and others during his 14 years in the cable television industry. He received his BSEE from the University of Texas in Austin in 1981.