NEW MICROWAVE AND FIBER OPTIC SUPERTRUNKING SYSTEM CONFIGURATIONS

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ABSTRACT

Rapidly changing fiber optic and AML microwave technologies have opened up a new range of possibilities in implementing CATV supertrunks. These considerations apply not only to new builds, but also to many existing AML microwave systems whose reach could be extended. The same technologies can be applied to improve system reliability either through redundancy configurations or by dividing overly long microwave paths into smaller segments. Combinations of the two technologies are explored. System performance improvements possible with higher power transmitters and on-frequency repeaters are delineated. Advantages of configurations employing fiber to AML, AML to fiber, "low power" channelized AML with high power microwave repeaters, and fiber in parallel with AML are set forth.

INTRODUCTION

Within the last few years, extraordinary changes have occurred in both fiber optic and microwave technologies which are applicable to CATV transportation systems. At a time when there is increased concern with the quality and reliability of TV pictures available to the customer, these changes have tended, at least in the near term, to strengthen the hand of the advocates of delivery of multiple VSBAM signals all the way from the head-end to the home. Thus, although FM has been used in supertrunking applications, whether by cable, microwave, or fiber, this paper will restrict itself to AM systems which are not encumbered by the need to reprocess each channel with the attendant complexity, cost, and maintainability considerations.

The advances in fiber technology have been well publicized. Starting with the demonstration of a 40 channel, 6.5 km, AM fiber link at the 1987 Western Cable TV Convention, the spotlight of interest and attention both in the trade press and at the shows has been firmly on fiber. Deservedly so! The achievement of close to 50 dB C/N through direct modulation of Fabry-Perot diode lasers with a standard 40-channel VHF TV format(1) was an important milestone. It further stimulated development of the fiber backbone concept(2) and was followed within a year by the introduction of Distributed Feedback (DFB) lasers with 40-channel C/N capability of 52 dB at distances of 12 or more kilometers(3). Improvements in power output, Relative Intensity Noise (RIN), and linearity of DFB lasers have most recently led to reports of 56 dB C/N with 6 dB optical loss(4). These are indeed spectacular accomplishments.

The recent advances in microwave technology are in some respects equally significant to the cable industry even though the publicity spotlight has not been focussed on them. One could hardly expect that it would be otherwise since AML Microwave® is a technology which has been widely applied within the industry for almost 20 years. For many, the familiar and ubiquitous "high power" and "low power" channelized AML systems were the only yardsticks against which fiber system cost and performance could be measured. Although recent technology development has led to an all solid state high power channelized AML transmitter (5), with which 60 dB C/N microwave links can be supported, the greater part of recent microwave technology advances have been evidenced by low-cost broadband block conversion types of transmitters and active on-frequency repeaters. These latter equipment categories are similar to AM fiber transmitters in that power output, at given channel loading, is limited by CTB and CSO performance. The first generation of such transmitters was capable of only -9 dBm/channel output for 40-channel loading and 65 dB C/CTB.(6) However, within four years, a more than sixty-fold increase in power was made possible through the application of microwave feedforward technology(7) and the introduction of a higher power FET amplifier and power doubling within the feedforward loop(8). The combined noise and distortion performance is equivalent to that of a 60 watt low noise FET power amplifier if such a device were to exist at 13 GHz. Rigorous CATV system requirements are indeed conducive to the development of state-of-the-art microwave and fiber performance.

AM FIBER LINK PARAMETERS

Table 1 updates a similar summary published in 1989[9]. The changes reflect the increased laser output power, the lower RIN, and a higher per-channel modulation index, m, due to improved laser linearity. The net effect is that quantum (shot) noise dominates as before for optical loss in excess of 6 dB, but the overall link C/N is now much closer to the objectives established for fiber backbone systems. Significant additional improvement may be possible with still greater optical power output (7 dBm has been mentioned) and better RIN and linearity, but even the parameters assumed in the table have yet to be verified in production quantities.

The higher the modulation index, the greater the need for stable input level since the laser performance will degrade rapidly if the voltage swings below the laser threshold voltage. Another factor to consider is that DFB laser linearity typically degrades as the modulation frequency increases.[10] For 2-laser 80-channel systems, this is counterbalanced by avoidance of in-band second order distortion in the upper 40-channel grouping. Indeed, the second order distortion has typically dominated to such a degree that asymmetric frequency plans which minimize in-band second order are common in multi-laser systems. As with distortion, DFB laser RIN degrades with frequency so that 40-channel test C/N results are not necessarily indicative of what can be achieved between 300 and 550 MHz. Another factor which can play a limiting role at such excellent laser RIN is multiple reflection on the fiber link resulting in conversion of laser phase noise to AM noise[11]. The lower frequency channels could be affected most strongly when this phenomenon is present.

Recent advances in external modulation type fiber optic links[12,13] have renewed interest in this form of optical communication. A high power solid state Nd:YAG laser provides the optical carrier, which is then intensity modulated by a $LiNbO_3$ Mach-Zehnder interferometer. The modulator transfer characteristic is of the form

$$I = I_o/2\ [1 - \cos(\theta_o + \frac{\pi}{V_\pi} v(t))]$$

where V_π is the half-wave switching voltage and θ_o is set to $\pi/2$ by the dc bias voltage so as to avoid second order distortion. Since the transfer function is clearly not linear, some form of linearity correction circuit is required to avoid excessive third order distortion at even a modest modulation index. Moreover, in addition to the 3 dB loss intrinsic to the bias condition, the $Ti{:}LiNbO_3$ waveguide material is lossy and the match between the optical field pattern in the fiber and the modulator is imperfect. Finally, there are losses associated with focussing the available laser power into the fiber so that the overall optical power available to the fiber link is typically

TABLE 1

ASSUMED 40-CHANNEL DFB LASER LINK PARAMETERS

Optical Loss (dB)	C/N Source (dB)	C/N Quantum (dB)	C/N Receiver (dB)	C/N Link (dB)
2	59.9	63.2	77.6	58.2
4	59.9	61.2	73.6	57.4
6	59.9	59.2	69.6	56.3
8	59.9	57.2	65.6	54.9
10	59.9	55.2	61.6	53.2

Transmitter:

- m = 5%
- RIN = -155 dBc/Hz
- P_{Laser} = 4 mW (into fiber after isolater)

Receiver:

- Responsivity, R = 0.85 A/W
- Noise equivalent current, i_N = 5 pA/ $\sqrt{Hz}$

attenuated by 12-13 dB relative to the laser output. This may still be improved by 2-3 dB.

Table 2 models a 40-channel fiber link based on 15 dB cancellation of third order distortion and a requirement for 65 dB C/CTB. The transmitter output power is consistent with reference (12). We have also confirmed that laser RIN is on the order of -170 dBc/Hz. The measurement was made by plotting total link noise output versus receiver photo current. At high receiver input level, shot noise dominates and one can, therefore, clearly establish the RIN from the deviation of the total noise from pure shot noise.

One advantage of the Nd:YAG laser is that its line width is much narrower than that of a DFB diode laser. Consequently, the effect of optical reflections on link C/N should be much less. On the other hand, there remain serious questions related to the laser life. The Nd:YAG laser is "pumped" by an array of semiconductor lasers operating at high current. It is the long-term reliability of this optical pump source which still needs to be established. A secondary issue relates to power limitation due to the narrow spectral linewidth which could result in Brillouin scattering in the glass fiber at higher optical powers. A further property of the YAG laser is a low-level relaxation oscillation which modulates its output. In our measurements, we found this to result in 175 kHz sidebands at -62 dBc on either side of the VHF TV carrier. Although this does not effect the C/N, it can limit the achievable baseband S/N at high optical receiver input levels.

Another key issue relating to external modulation is long-term stability. Drift in the properties of the $LiNbO_3$ material could result in serious degradation of both second and third order distortion. At the very least, some form of active control must be established to maintain the modulator at its optimum bias point.

Comparison of Tables 1 and 2, for which both CTB and CSO are assumed to be 65 dB, shows that if the external modulation approach can overcome the above problems, it will offer slightly better C/N for optical loss under 10 dB. It must show a bigger advantage to overcome the cost burden of its more complicated transmitter. The most promising avenue would be increase of the modulation index made possible by further linearization of the transmitter.

AML MICROWAVE LINK PARAMETERS

For maximum link distance and optimum C/N, a high power solid-state channelized transmitter is

TABLE 2

ASSUMED 40-CHANNEL EXTERNAL MODULATION FIBER LINK

Optical Loss (dB)	C/N Source (dB)	C/N Quantum (dB)	C/N Receiver (dB)	C/N Link (dB)
4	69.9	59.8	76.5	59.3
6	69.9	57.8	72.5	57.4
8	69.9	55.8	68.5	55.4
10	69.9	53.8	64.5	53.3

Transmitter:

m = 2.8%

RIN = -170 dBc/Hz

P_{Trans} = 10 mW (into fiber after modulator)

Receiver:

R = 0.85 A/W

i_N = 5 pA/$\sqrt{Hz}$

currently utilized. The output power capabilities of these transmitter arrays are only 1 to 4 dB less than high power klystron-based units. The overwhelming advantages of greatly reduced power consumption and size of solid-state units when combined with the by now proven high reliability of the 5-watt FET amplifiers has, for the most part, turned the design choice for the highest power systems in their favor. A 40-channel system can span more than 32 km in each of 8 directions while providing 60 dB C/N and better than 65 dB CSO and CTB. The performance advantage of such microwave systems over AM fiber is further compounded by the fact that the 32 km is a line-of-sight distance which for a typical suburban fiber run might stretch to over 40 km.

A closer challenge to microwave system capability occurs if the system is restricted to low-cost block conversion transmitters. With this constraint, a 56 dB C/N can be obtained at a line-of-sight distance of 19.2 km. This still represents a sizable advantage over the best fiber system.

Recent developments in broadband microwave power output capability can best be summarized by Figure 1 which shows the relative capabilities of three microwave active on-frequency repeaters(14). The initial 10 dB jump in power capability was due to the introduction of feedforward technology. While widely used within the cable industry, this technology had not previously been applied at such high frequency (13 GHz). The further 8 dB increase was due to utilization of higher power (5W) FET amplifiers as well as power doubling within the feedforward loop. Overall performance of the IBBR-124 is summarized in Table 3. Note that the combined noise figure and gain imply a noise power output of -51.5 dBm/4 MHz, which in turn results in a 61 dB C/N contribution from the repeater for 40 channel loading at 65 dB C/CTB. Comparison to the two earlier repeaters shows that the IBBR-124 has respectively 3 and 7 dB better C/N, and 5 and 10 dB higher gain, than the FFR-123 and the MWB-122 for the same channel loading and C/CTB. Thus, in addition to the very large increase in power output capability, the latest microwave repeater technology offers substantial improvement in C/N and gain. These parameters are critical to achieving significantly better overall microwave link performance on extended supertrunk paths.

SUPERTRUNK CONSIDERATIONS

As with any other portion of the CATV system, cost, performance, and reliability are the considerations which determine the design of the supertrunking system. The choice of optimum design is a complex problem, not only because these three parameters are closely interrelated, but also because trade-offs can be made in allocating distortion budgets between the supertrunk and the other parts of the CATV system. In particular, it has been

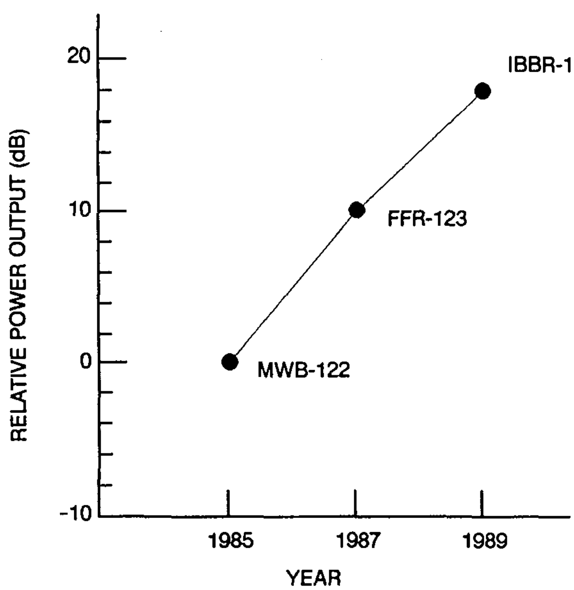

Figure 1 Microwave Repeater Development.

TABLE 3
IBBR-124 PERFORMANCE SUMMARY

Noise Figure	6.5 dB
Gain	50 dB
Capability at 65 dB C/CTB	
Channel Loading	Output Power/Channel (dBm)
12	15.5
21	13.5
35	10.5
60	7.5
80	5.5

pointed out[15] that in some smaller system designs it is more cost effective to allocate a larger portion of the distortion budget to the supertrunk than the traditional approach of demanding that it be essentially "transparent". In addition, there is the question of how the distortion on the supertrunk will add to the distortion in the cable trunk and distribution. The fact that composite triple beat need not add on a voltage basis is now documented[16],[17] and discussed further below.

In any case, the supertrunk services all or a very large portion of the cable system customers. For customer satisfaction, extended or repeated outages cannot be tolerated. With the increased emphasis on quality of service, it is mandatory to closely consider all aspects which affect service reliability. If the system is one that already exists, substantial cost saving may be possible with an upgrade which takes advantage of the latest technology without sacrificing improved reliability and performance goals. Extensions to the reach of the supertrunk should also, in many cases, be possible using either fiber, microwave repeaters, or a combination of the two.

Cost

Any discussion of cost comparisons is tremendously complicated by the large variability of this parameter. Microwave transmitter costs can vary from less than thirty thousand dollars for the lowest power broadband equipment, to over a million dollars for an 80-channel high power channelized transmitter. Other cost factors affecting microwave systems include questions relating to the necessity for towers, transmit and receive site property rentals, if required, and variations in antenna size and receiver noise figure. In terms of potential coverage area, and therefore, the number of customers who are serviced through the supertrunking system, the most cost effective systems are the large ones. On the other hand, the lower cost broadband systems lend themselves to greater flexibility in matching capability to limited numbers of receive sites at various distances from the transmitter.

With fiber, the greatest cost variability arises not from the electronics cost but from the cable length and installation costs. Pole attachment or duct utilization fees must also be included in the calculation, if applicable. Overlash onto existing plant and new underground construction in urban areas represent the extremes of installation costs. In any case, the longer the total cable length the less favorable the cost will be relative to microwave. The variability in the cost factors is so great that each case must be separately analyzed. However, even for the lowest construction cost situation, a microwave alternative will generally be more cost effective if the sum of cable lengths (i.e. supertrunk paths) exceeds 10 miles.

Performance

As previously stated, FM is excluded from consideration in this discussion because of the increased cost and complexity of reprocessing each channel at each of the hub sites. However, a special case exists when the satellite receive antennas are located at a considerable distance from the principal headend. In such instances it is possible to transport the FM signals via a fiber optic link after they have been downconverted to the 950-1450 MHz band, but before the second conversion and demodulation. If the system utilizes AML microwave after reprocessing the signals at the headend, one has, in effect, an FM fiber supertrunk feeding a VSBAM microwave supertrunk. As an alternate to the fiber, it is also possible that these FM signals could be transmitted via AML microwave. The FM portion of the supertrunk should, in such cases, be essentially transparent to the S/N established by the satellite down-link.

The performance of several microwave/fiber systems is summarized in Table 4. Although the combination of microwave and fiber is most probable in the context of an integrated AML/fiber backbone system, this need not necessarily be the case. It is possible that the fiber serves only to extend the reach of the supertrunk. Generally the link performance would be better if a direct line-of-sight were possible between the microwave transmitter and ultimate hub site, but in severe climate zones such as Central Florida this may not be the case. In other cases, the desired hub site is simply not compatible with a clear path, but an alternate microwave receiver site is available at some modest distance from the preferred site. In such cases, addition of the fiber supertrunk extension makes possible the addition of a receive site which might otherwise be

TABLE 4
40-CHANNEL INTEGRATED MICROWAVE/FIBER SYSTEMS

	AML Transmitter Type			
System Parameters	SSTX-145	MTX-132	IBBT-116	IBBT-116/ IBBR-124
Power Out, P_0/Channel, dBm	16	9	8.4	9
Number of Outputs at P_0	8	8	1	1
Path Length, km(1)	30.4	21.6	19.2	34.4
C/N, dB	58	58	56	55
C/CTB, dB	71	71	65	61
Fiber Tail Length, km	18	18	16	10
Supertrunk C/N	52	52	52	52
C/CTB	64	64	62	60
Effective Reach, km(2)	58	46	41	55

(1) Path calculations assume 10-foot antennas, 4-dB total transmit and receive waveguide loss, average multipath and rain (CCIR, Zone D2, and 1 hour/year fade below 35 dB C/N, except for the last column which is based on 1.5 hours/year.

(2) Microwave line-of-sight length x 1.3 plus maximum fiber backbone length.

burdened by the appendage of an excessively long coax cable trunk run.

With increased channel loading, the performance will, of course, degrade. However, in a recent laboratory experiment designed to investigate addition of CTB between dissimilar devices it was found that with 80-channel loading the combination of an IBBT-116 transmitter and an IBBR-124 repeater, each operating at +7 dBm/channel output, with a COR-299 receiver adjusted for -44 dBm AGC threshold, resulted in the expected 53 dB C/N but with C/CTB ranging between 59.2 and 64.2 dB across the frequency band. To partially explain these rather good results, it should be noted that a 3 dB CTB margin relative to published specifications is required in factory test of the IBBT and IBBR to allow for some drift in performance with temperature. Even so, to explain the measured CTB one cannot stick with voltage addition.

More particularly, when a standard CATV hybrid amplifier was added to the chain at the microwave receiver output and its output level adjusted so as to generate 61 dB C/CTB at the highest channel (547.25 MHz), the combined microwave plus CATV hybrid C/CTB was 60.9 dB. The microwave system by itself also measured 61 dB C/CTB on this channel. Therefore, at this frequency, for this particular pair of subsystems (i.e. the complete microwave system and the hybrid), the CTB added with an effective phase angle of 119°. "Normal" voltage addition is based on 0°. As frequency decreased, the phase angle gradually dropped below 90°. At the lowest frequency channels where the worst system CTB of 58.5 dB was measured, the hybrid CTB was so good that experimental error made it difficult to determine an exact phase angle, although it was clearly smallest (closer to voltage addition) at this end of the spectrum. On average, a 90° phase angle (power addition) was most descriptive of the CTB addition.

That this should be the case with dissimilar devices, particularly distortion cancellation devices such as the feed forward circuits within the IBBT and IBBR, should not be surprising. In this particular case, no attempt was made to pretune these circuits beyond the standard factory procedure. However, in a separate experiment[16] it was shown that tuning of the feedforward circuit does effect the phase angle. One point which remains to be investigated is the possibility of deliberately tuning the circuit for best overall C/CTB while simulating the rest of the cable system with an overdriven hybrid. The key question to be answered is that of long term stability. If it turns out that this is a successful technique, significant benefit would accrue to the microwave feedforward system since signal levels could be increased for better C/N and path reliability.

The above-described CTB addition measurement system was next modified by the substitution of an experimental 12-km fiber optic link for the CATV hybrid. The experimental arrangement is shown in Figure 2. With 40-channel loading, the IBBT and IBBR output levels were raised to + 10 dBm and the receiver AGC threshold set for -43 dBm. The microwave and fiber systems were separately characterized and then combined for the system measurement. Results are tabulated in Table 5. The system C/N was better than 52 dB. The point to be made is not that this represents the best that can be achieved - the optical link parameters were not as good as in Table 1 and its composite second order distortion was only 58 dB - but rather that the microwave and fiber CTB addition was even more favorable than power addition. The overall favorable addition is generally similar to that reported[16] with a totally different pair of microwave and fiber systems.

Supertrunk performance can be improved by reducing channel loading. In particular, many fiber optic systems utilize this technique to avoid the generation of otherwise limiting second order products. Similar techniques can be applied at microwave. For instance, in a 60-channel system, the channels could be equally divided among 3 block conversion transmitters so that the output power can be raised by 5 dB. Each transmitter is then connected to a separate antenna but all three antennas are aimed at the receive site where all 60

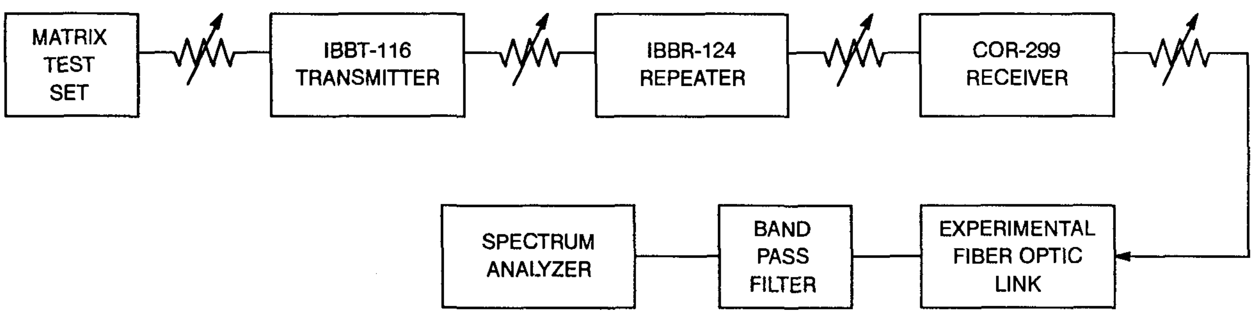

Figure 2 CTB Addition Experimental Setup.

TABLE 5

CTB ADDITION OF MICROWAVE AND EXPERIMENTAL FIBER LINK

Frequency (MHz)	Microwave CTB (dB)	Fiber CTB (dB)	System CTB (dB)	Effective Phase Angle (degrees)
61.25	64.7	67.3	63.5	99
193.25	65.4	66.0	64.9	114
307.25	63.5	66.5	63.9	115

channels are extracted from a single receiver. In the fiber system, 3 separate optical receivers would be required, and unless wavelength division multiplexing is used, 3 glass fibers are utilized. The only other difference is that the microwave transmitters must be locked to the same reference oscillator.

When multiple receive sites are involved, the technique of paralleling transmitters lends itself naturally to the addition of a combining network which simultaneously acts as a splitting network. Figure 3 shows such an IBBT-116 transmitter array. Here each of the 9 outputs carry all 60 channels, and thus each of the 9 transmit antennas would be trained at a separate receive site. Directional couplers are utilized to tap off power to the shorter paths. The transmitter contribution to both C/N and C/CTB is not any different than with the above described space combination mode, but with the multiple receive sites, transmit antennas need not be duplicated to obtain the benefit of improved output power. A further advantage is that this configuration lends itself to a graceful degradation redundancy mode. In the event one of the transmitters should fail, the VHF input to that transmitter is redistributed to the remaining two units such that each would operate at 30-channel loading. This feature would not be available in fiber systems which rely on filters to remove out-of-band distortion and noise at the output of each optical receiver.

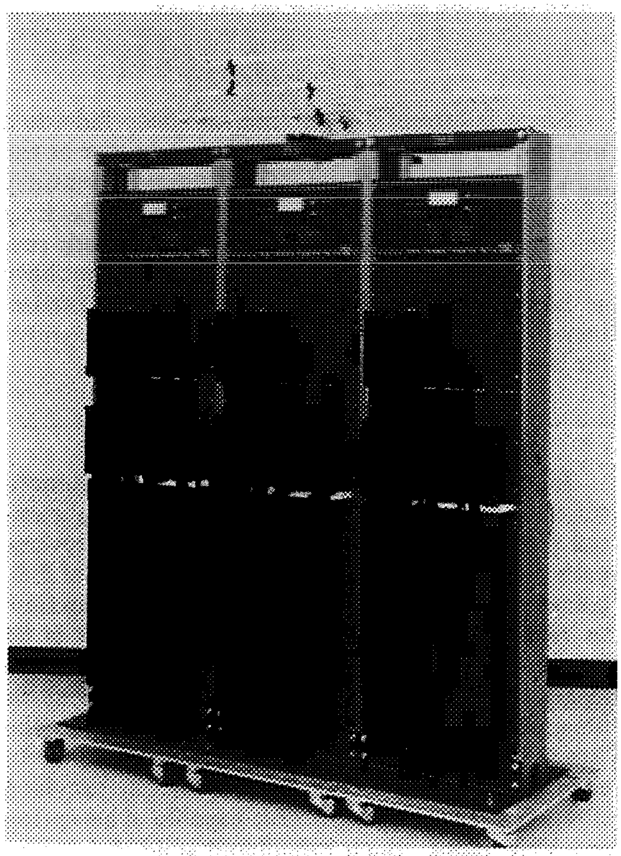

Figure 3 Fail-soft redundant IBBT-116 Transmitter Array.

Performance of existing microwave supertrunks can often be upgraded at relatively low cost. In klystron-based high power AML systems, replacement of the solid state source with a higher power source allows 3 dB increase in output power and consequent improvement in both C/N and path reliability. Regardless of the transmitter type, if the received signal is weak, addition of a tower-mounted LNA can substantially improve both C/N and path reliability. However, there is nothing new in either of these options.

What is new is that installation of a broadband repeater can now substantially improve performance of a MTX-132 transmitter link. Consider the example given in Table 6. Many older systems have expanded by adding receive sites which in some cases were more distant than originally intended. An LNA was then added to the receive site to obtain the best possible noise figure. Even so, predicted path reliability is only 99.88% for the 25-mile example. As before, an average multipath and rain condition is assumed. The table shows the result of interposing an IBBR-124 repeater at an intermediate distance. The repeater must be located such that the direct ray from the transmitter to the distant receiver is attenuated at least 45 dB through antenna angle discrimination. In this example, path reliability is improved to 99.97% and the normal C/N can be raised to 55 dB.

Microwave repeaters are particularly attractive as extenders of supertrunk reach when the supertrunk can be allocated a large share of the total CATV noise and distortion budget. In one such lightly populated region located in a benevolent B1 rain zone, a 4-hop 36-channel microwave system spans a total distance of 78 miles. Predicted end of line performance is only 49.7 dB C/N and 54 dB C/CTB (cw) with 99.83% path reliability. However, the broadband system which includes lesser length branches and a total of 15 receive sites at various intermediate points was the most economic solution for providing CATV service to the extended community.

TABLE 6
25-MILE MICROWAVE PATH UPGRADE

	Without Repeater	With IBBR-124
MTX-132 Output 40 Channels (dBm/ch)	9	9
First Hop Distance, Miles	25	10.8
Repeater Output in AGC (dBm/ch)	N.A.	8.1
Second Hop Distance, Miles	N.A.	14.2
LNA Input, dBm	-45.7	-40.7
System C/N, dB	53	55
System C/CTB, dB	77	65
Hours/Year Below 35 dB C/N	10.3	2.3

Reliability

Overall communication link availability depends on both the electronics equipment and on the intervening path. In the case of fiber, rain and multipath fades are not a problem, but the cable connection can nevertheless fail. The failure can be due to either natural causes or man-made. The latter category includes both accident and intentional sabotage. Whatever the cause, and however seldom a break occurs, the time to restore service can be quite lengthy. The news has provided numerous examples of horrendous outage situations in the communications industry. For this reason ring fiber architectures have been proposed and in some cases are being implemented. The primary drawback is one of cost.

In contrast to path failures in fiber links, CARS band microwave fading is a relatively common occurence, especially in areas of high rainfall rates. Path availability predictions are generally based on fading to a 35 dB C/N, at which point the pictures are noticeably noisy but still watchable. Deep fades beyond this point are generally of quite short duration and the link usually restores itself within a few minutes.

The only way to protect against such fading is to provide additional link margin through higher transmitter power, lower receiver noise figure, and reduced waveguide loss. The use of active repeaters to increase link availability has also been illustrated in the preceding section. The efficacy of such measures depends on a number of factors including whether the fade is due to rain or multipath. In many cases a mere 3 dB greater fade margin will halve the time spent below 35 dB C/N.

Since failure of a fiber link and deep fade on a microwave path are highly unlikely to occur at the same time, one method of providing essentially 100% reliability would be to use the one to back up the other. Such a solution could be particularly cost effective since the temporary back-up need not have as high a quality as the primary link. A further benefit of this solution is that protection is provided for both the path and the electronics.

In situations where parallel paths are not practical, redundant electronics can still make a substantial difference in overall reliability. A microwave path designed to have less than 1 hour/year of fade below 35 dB C/N makes little sense if the mean time to repair an unprotected electronic failure is 24 hours. As a minimum, adequate spares should be locally available. Fail-soft configurations such as illustrated by Figure 3 are attractive since the "spare" is fully utilized during normal operation. In channelized transmitters, back up can be provided through a frequency agile unit capable of accepting any VHF input. Such broadband solid state units have recently been developed for both "low" and "high" power AML.

Duplication of electronics to protect against broadband equipment failure is possible with both fiber and microwave systems. Automatic switching in the event of a failure, such as provided in the microwave receiver redundancy unit (RRU), is also possible.

CONCLUSION

Recent advances in both fiber and microwave technology have enlarged the design choices available to CATV supertrunk designers. While the highest performance systems still require channelized microwave, utilization of broadband fiber and microwave links in various combinations can provide attractive, cost effective solutions with good performance and reliability. The development of high power, low noise broadband microwave repeaters provides the means for extending supertrunk reach and improving path reliability in some existing systems.

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