IMPACT OF MICROWAVE TECHNOLOGY DEVELOPMENTS ON CATV SYSTEM DESIGN

T. M. Straus, R. T. Hsu, and L. A. Kaufman
Hughes Aircraft Company

Abstract

Recent microwave circuit developments have led to the realization of a third order intercept point of +62 dBm in a broadband block conversion type 13 GHz solid state transmitter. The 5 dB increased power output that this latest development allows adds to previous CARS band microwave block conversion transmitters, which in total now span a power capability ratio in excess of 200: 1. A summary explanation of the steps culminating in the dual-feedforward circuit utilized in this highest power transmitter is provided. The impact of improved third order intercept on noise and distortion in LDS microwave operation is reviewed. The resultant range capability is examined for various geographical areas. Comparison with fiber optic transportation systems is made and the advantages of CATV architectures employing parallel fiber and microwave paths is explored.

AML® TRANSMITTER DEVELOPMENTS

Seven years ago, CATV systems which utilized AML transmitters in microwave local distribution systems operated either with what was known as "high power" AML or " low power" AML. The former employed one klystron per channel and the latter had one klystron per eight channels, but both transmitters were based on a channelized design. These 13 GHz transmitters which were developed in the early 1970s were vastly superior to an even earlier 18 GHz design which was based on a high power broadband traveling wave tube (TWT) carrying the then standard 12 TV channels. The essential difference between these two approaches is that in the channelized approach the power output is limited only by the video-audio intermodulation product (which falls in the lower adjacent channel), while in the broadband transmitter the limiting third order distortion is the far more demanding composite triple beat (CTB) between video carriers. In the case of the TWT this severe distortion limitation is further aggravated by the large amount of noise generated within the TWT. With even a modest number of multiple carriers, the power capability of the TWT comes to naught because of the large amount of backoff in power dictated by CTB considerations, while the output noise floor looms ever larger. The squeeze between carrier-to-noise ratio (C/N) and C/CTB is all too familiar to CATV system designers.

The key microwave technology advance which permitted the development of reasonably well performing broadband transmitters was the advent of the high power field effect transistor (FET) amplifier. These early solid state devices, while not able to match the power output capability of the TWT, had a huge advantage in terms of noise performance which is critical to system performance. Nevertheless, the first solid state broadband transmitters were not even in the same performance ballpark as even the "low power" channelized equipment. However, in one critical respect, namely cost, the broadband transmitters were very attractive. Many applications, for which classical channelized AML could not be economically justified, were suitable for broadband microwave utilization.

High power FET technology has improved significantly during the past seven years. Saturated power output capability has increased from 1 watt to as high as 10 watts. Reliability has been proven by hundreds of 5 watt amplifiers which have been performing flawlessly for several years. However, this in itself could not close the 18 dB performance gap between the initial broadband transmitters and a single output of the channelized transmitter. A second microwave technology advance had to occur to bridge the gap. This was achieved in 1989 through the application of feedforward linearization.[1]

It must, of course, be noted that the comparison between the transmitters does not take into account that the channelized transmitter has multiple outputs, each of which have the same power per channel and the full complement of channels. Thus, while the IBBT-116 transmitter, operating at a level corresponding to 65 dB C/CTB, matches the power capability of the channelized MTX-132 transmitter (the comparison is reasonably accurate over a wide range of channel loading), the comparison is made in terms of the power available at the output port, which for the channelized transmitter is by no means the total output. Indeed, for a 64-channel system the standard multiplexing arrangement leads to 16 outputs. Often, however, these outputs are not all utilized. Moreover, some of the receive sites may be located relatively close to the transmitter so that the full output of that transmitter port, which feeds the close-in receiver, is not required. On the other hand, the broadband transmitter can easily incorporate a customized power splitting network which matches the needs of the application. Thus, in a typical application, the *total* power comparison gap is more like a factor of three than a factor of 16. This gap now has been closed by the latest broadband development.

AML-HIBT-118 TRANSMITTER

The performance of the HIBT-118 is summarized in Table 1. If one were to compare this capability to the IBBT-116, it would be seen

TABLE 1
HIBT POWER OUTPUT AND C/N FOR 65 dB C/CTB AND C/CSO

Number of Channels	P_o (dBm)	C/N (dBm)
12	20	66
21	18	64
35	15	61
60	12	58
80	11	57

that the output is 5 dB greater. Thus, the HIBT-118 output is also 5 dB greater than any one port of the MTX-132 and only 5 dB less than the output port of a high power STX-141 array. To describe the performance in yet another way, it would be accurate to say that, if it were to exist, a typical 200-watt FET amplifier, with 62 dBm third order intercept point, operated at the same output power and the same channel loading, would yield the same C/CTB.

The technological innovation utilized to achieve this performance is illustrated in Figure 1. The circuit consists of a feedforward amplifier imbedded within a feedforward correction loop. Although the concept is not entirely new[2], we believe this to be the first instance of application of this concept to a commercial product. In any case, the resultant performance breakthrough can have important consequences in CATV microwave Local Distribution Service (LDS) design. Figure 2 shows a photograph of the HIBT-118 transmitter. One aspect is immediately evident from this photo: the space required to house an 80-channel reasonably high-powered transmitter in the headend is now quite minimal. A close inspection of the photo shows the four heatsinks corresponding to the four 5-watt FET amplifiers included in Figure 1. These

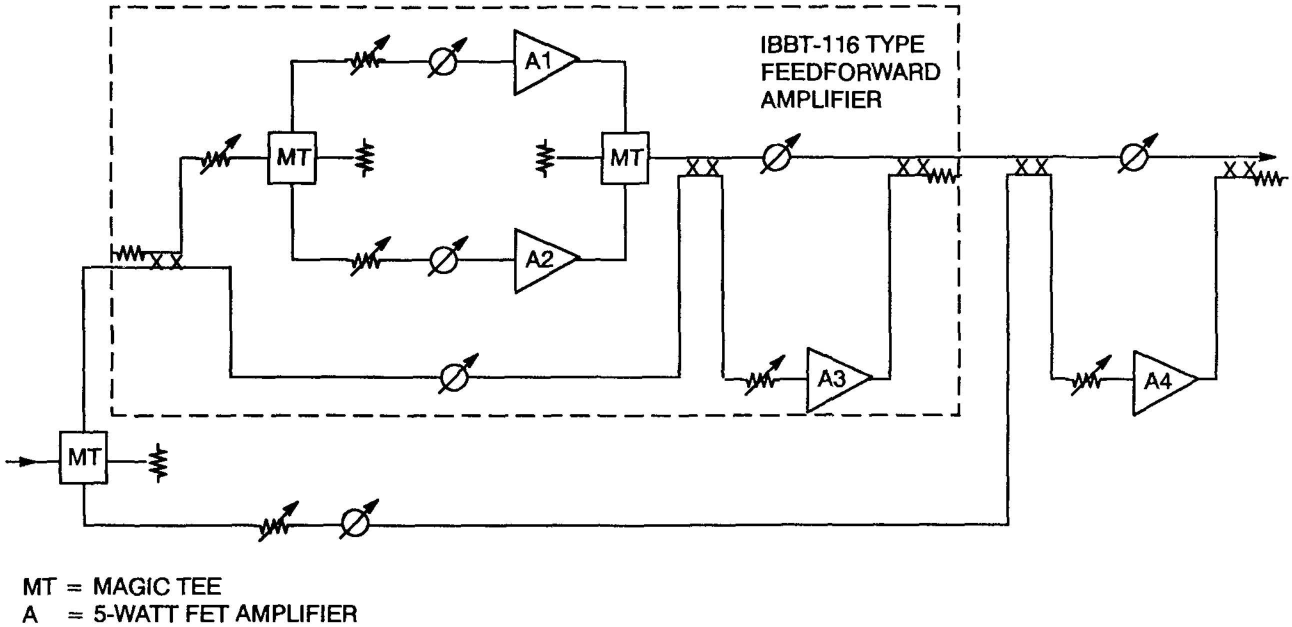

Figure 1 HIBT-118 double-feedforward output amplifier.

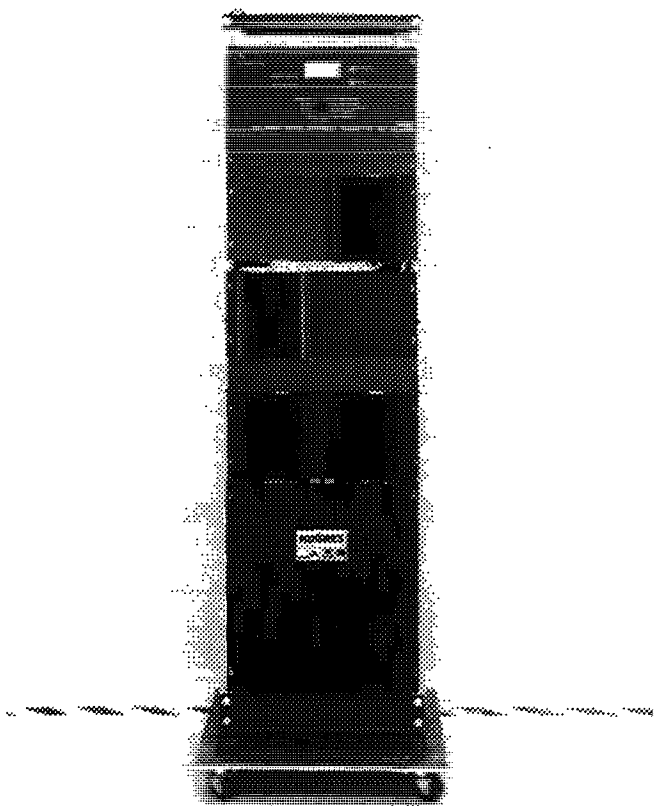

Figure 2 High power indoor broadband transmitter.

heatsinks operate only slightly above room temperature, the total transmitter power dissipation being less than 380 watts. Needless to say, the transmitter cost is also much less than a channelized system.

LDS SYSTEM DESIGN IMPLICATIONS

It may be of interest to consider the relative cost trend that the increase in broadband power output has followed. Certainly the higher power transmitters cost more, but the cost per unit of *total* power declines rapidly as power increases. Interestingly enough, the channelized transmitters are still the most cost effective choice if their full total output power capability is required. Such is the case in major metropolitan areas where up to 30 or more AML receive sites may serve as CATV distribution hubs. However, more typically there are only about four hubs, and then the HIBT-118 is far more cost effective while at the same time having the capability of servicing an intermediate size area. Even large metropolitan areas with multiple receive sites could be serviced through an array of HIBTs as shown in Figure 3.

The question of the range over which the HIBT can operate is certainly of interest. It is, however, very much complicated by all the associated parameters which may vary greatly. To illustrate the effect of just one variable, the location of the LDS system, consider a single microwave link with 10-ft antennas at each end. Assume further that a clear weather C/N of 56 dB and a C/CTB of 65 dB is required for 40-channel loading. Finally, assume that there are a total 4 dB of miscellaneous waveguide losses at transmitter output and receiver input. Table 2 summarizes the path distance for various multipath conditions and CCIR rain zones if only 1 hr/yr of fading below 35 dB C/N is permitted. The low and high distance extremes could for instance represent locations in Florida and Idaho.

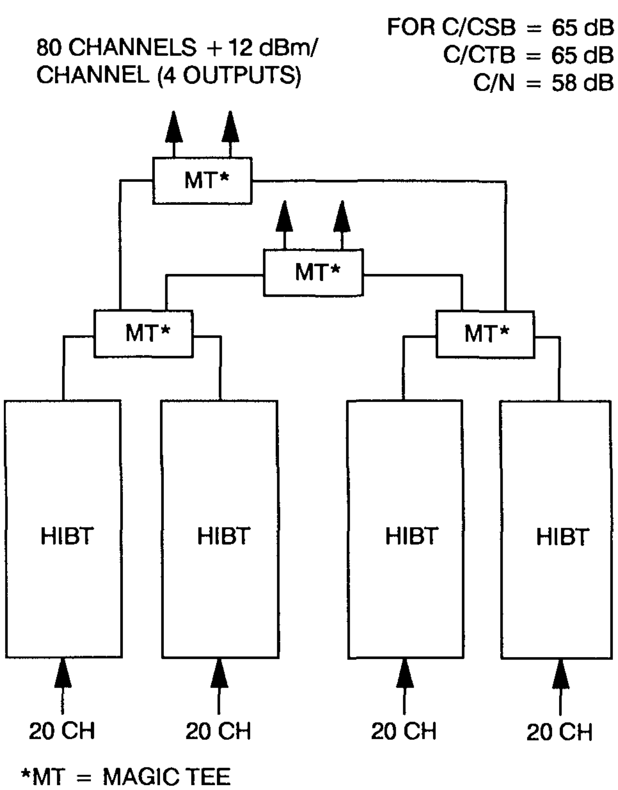

Figure 3 Multiple HIBT redundancy configuration.

Another aspect of the HIBT which could be of considerable interest to cable operators is illustrated by Figure 4. Here it is assumed that an existing 32-channel MTX-132 transmitter services four communities and that a channel expansion to 67 channels is desired. Referring to Table 1, the 35 additional channels can all be accommodated with the HIBT at an output level of +15 dBm. This closely matches the capability of a MTX-132 transmitter, having six channels in a circulator string, after the first level of magic tee splitting and combining. Therefore, the desired channel expansion can be accomplished with only 1 dB reduction in power out due to rearrangement, as indicated by Figure 4, of the original circulator channel multiplexing arrangement, and only one rack of equipment (the HIBT) is added. This compares with a 3 dB reduction and five additional MTX-132 racks at considerably greater cost if the channel expansion were implemented in the traditional manner.

Figures 3 and 4 are only two of almost innumerable combinations taking advantage of the flexibility of the high power broadband transmitter characteristics. If desired, an extra decibel of power output can be traded against a 3 dB reduction in C/CTB. In some circumstances, the HIBT, either alone or in combination with an IBBT, could entirely replace an old MTX-132 installation with

TABLE 2
RANGE OF 40-CHANNEL HIGH QUALITY
HIBT-118 LINK*

Multipath	CCIR Rain Zone	Distance (km)
Worst	E	12.1
Average	E	12.1
Average	D2	24.9
Average	B1	31.7
Best	B1	45.4

*See text for further definition.

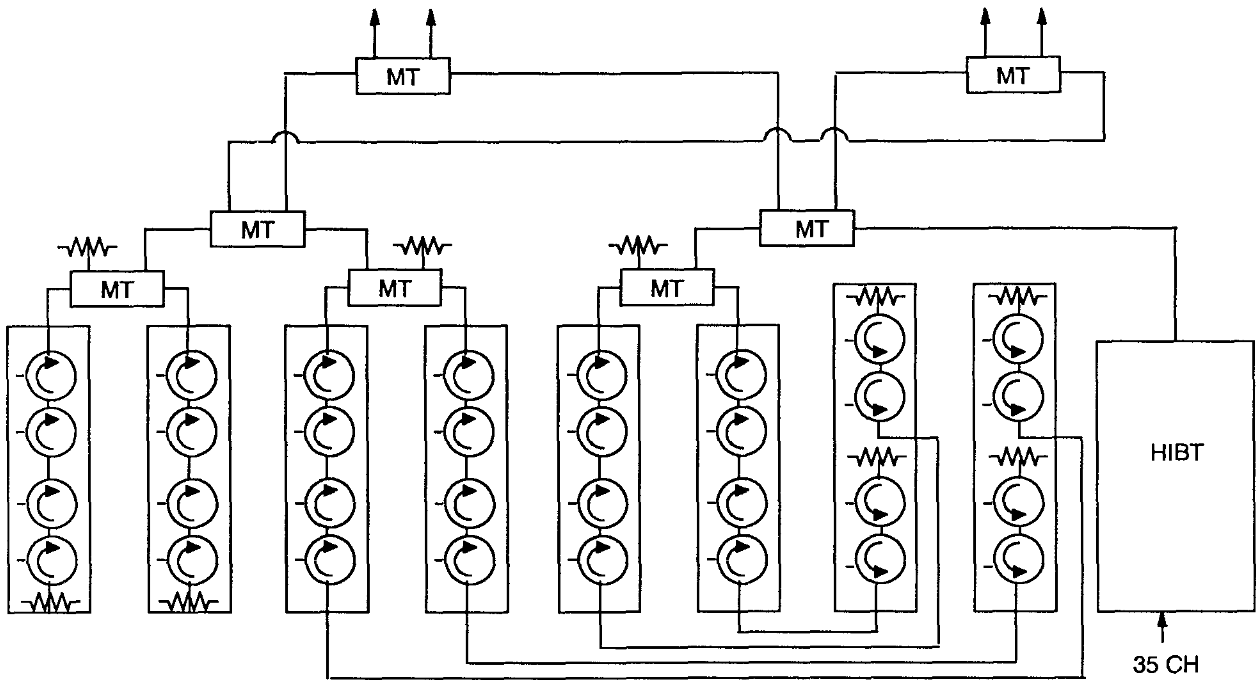

Figure 4 MTX-132 channel expansion using HIBT.

benefits to performance and additional headend space. Other rearrangements involving STX-141 arrays are also conceivable.

CATV SYSTEM DESIGN CONSIDERATIONS

Broadband microwave technology developments have enabled performance improvements which maintain a substantial edge over state-of-the-art AM fiber optic systems.[3] More importantly, the technologies can often complement rather than compete with one another. An obvious example is the case of a redundant supertrunk arrangement in which the microwave is backed up in case of rain fades and the fiber is insured against a cut. At the same time both are backed up in the case of equipment failure. For such applications a wide range of microwave broadband transmitters, summarized in Figure 5, are now available to fit the needs of the application.

One other aspect of broadband systems is worth mentioning. With the advent of digital compression techniques which potentially allow for even better spectrum conservation than traditional VSBAM, CARS band microwave will be able to carry many more channels than is presently possible. In addition, very large fade margin improvements would accrue if the system carried only digitally formatted signals. Although channelized systems would also benefit in both regards, the broadband systems can accommodate any carrier spacing without any modifications of existing filters.

SUMMARY

Advances in microwave technology have resulted in a wide array of products with which CATV system designs may be optimized. The highest power transmitter in this category is capable of exceeding by 5 dB the per port output of traditional "low power" channelized AML. This breakthrough in performance capability enables a wide variety of economical

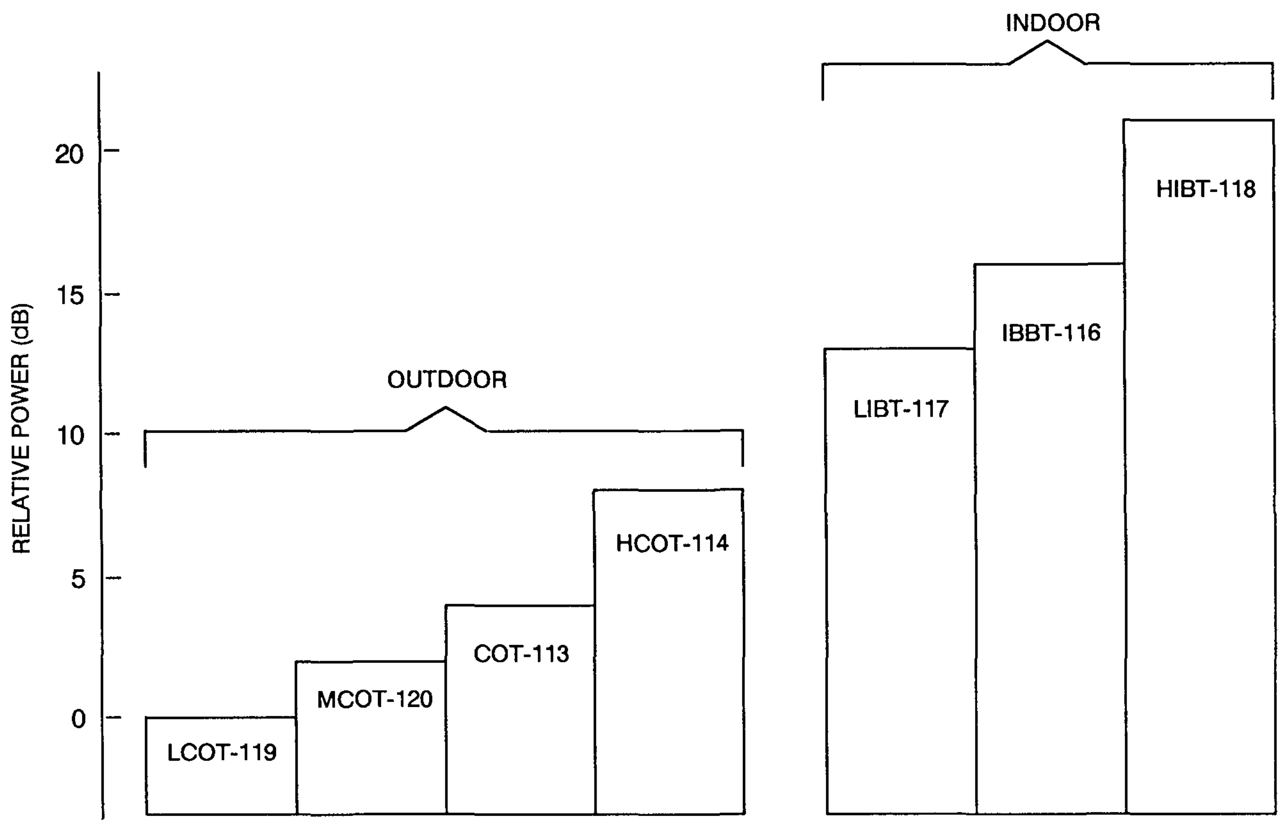

Figure 5 Broadband transmitter comparison.

LDS microwave configurations which heretofore have not been possible. The implications of this and future developments for system rebuilds could be of major benefit to CATV systems.

REFERENCES

1. T.M. Straus and R.T. Hsu, "New Higher Power Microwave Broadband Transmitter Design and System Application", *CCTA Technical Record*, 1989 (Toronto)

2. H. Seidel, "A Microwave Feedforward Experiment", *BSTJ 50*, No.9, November 1971.

3. J. Lipson, C.B. Roxlo, and C.J. McGrath, "AM Fiber Links: Performance Limits and Reliability", *CED*, November 1990.