ADVANCED HYBRIDS FOR CATV AMPLIFIERS

Jay G. Staiger

Magnavox CATV Systems, Inc.
100 Fairgrounds Drive, Manlius, NY 13104

Improvements in hybrid I.C. amplifiers from applications of superior impedence matching and thermal design techniques result in a cost effective means to achieve better noise and distortion performance for a CATV Distribution System. When implemented in a CATV design, several benefits can be realized:

1. Longer trunk cascades.
2. Higher trunk gains.
3. Expand existing bandwidth - 270-450 MHz.
4. Eliminate expensive hub architectures.
5. Eliminate expensive distortion cancelling techniques.

The CATV Industry has been demanding higher levels of performance from CATV distribution systems. Increased channel loading requirements to cover large areas, competition from a large number of high quality, local, off-air signals, and the economics of system architectures are reasons for the need to increase performance from a CATV amplifier.

As bandwidths expanded and were loaded in excess of 58 television channels, the tolerable trunk cascades were shortened. The trunk system which was designed to be typically transparent, became less transparent, and contributed significantly to the total system distortions. To compensate for the decreased transparency of the trunk, the bridger and line extender levels, along with the higher cable attenuation, significantly increased the initial and ongoing costs of the CATV distribution system.

Techniques such as harmonically related headends were applied to off-set some of the reductions in system trunk reach and lower feeder levels. However, these systems had to deal with the different problems. The trend now is to avoid harmonically related systems and stay with standard channel assignments, if at all possible.

The most demanding force for the higher CATV distribution system performance is the specifications required by the franchiser.

There is another technology which is available, and most importantly, is cost effective. It is cost effective because it can be used to do one or more of the following:

1. Eliminate multiple hub requirements.
   a. No duplicate headend processors.
   b. No duplicate tower antennas.
   c. Reduced microwave interconnect expense.
2. Eliminate HRC requirements.
3. Can be applied in place of feedforward techniques.
4. Reduce the number of amplifiers of the CATV distribution system Bill-of-Materials.
5. Reduce bandwidth expansion costs in existing plant.

This technology can be used to realize one or a combination of the above savings depending on the franchise requirement specifications, and system topology when a high performance amplifier is applied.

The Objective- The initial goal was to develop a technology that improves distortion and noise performance within the confines of the existing amplifier packages and to maintain the standard size of the hybrid amplifier. The paramount criteria is that it should be cost effective.

After months of careful documented research, Magnavox CATV Systems, together with its North American Philips' sister company, Amperex, has developed a significant technological breakthrough that met our goal. This breakthrough is called Power Doubling.

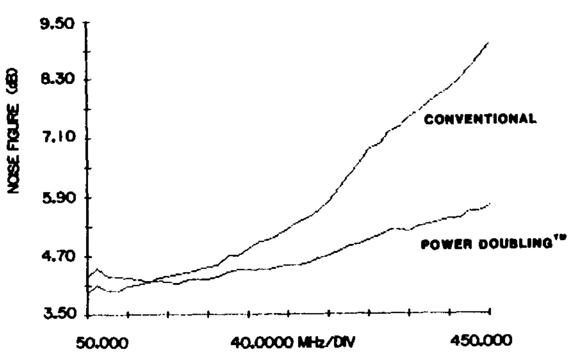
The heart of the Power Doubling system is the postamplifier with improved distortion parameters. The system utilizes precise impedence matching, optimized frequency response flatness, and superior thermal design that permits a much higher output from the single hybrid package. All these factors combined, provide a minimum of a 6 dB improvement in composite triple beat and cross mod specifications when compared to a conventional hybrid system

In addition, a low noise preamplifier has been introduced to the system so that excellent noise performance can be realized. This preamplifier allows the Magnavox Power Doubling product to have at least a 2 dB better noise figure than that available with other hybrids.

The above stated improvements will be the minimum achievable. Some of the data accumulated indicated that, typically, we can expect greater improvements. The subsequent text and illustrations will show greater than 3 dB improvement in noise figure and approximately 6.5 dB improvement in distortion. The two components which make-up the Power Doubling system, the low noise preamplifier and the power doubler postamplifier are configured so that it is packaged for use with Magnavox's present product line. This makes it extremely cost effective and provides the operator with equipment for an advanced system architecture at an affordable price.

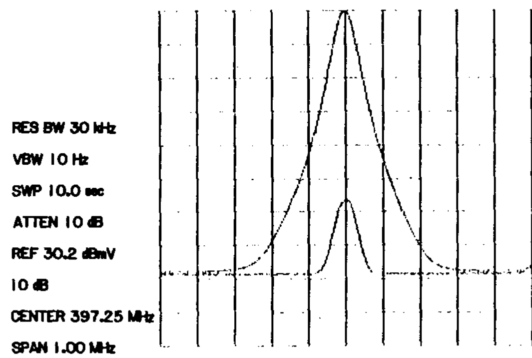
Test Results- Testing completed on the initial product proves the performance is as expected. Figure #1 is a graph of noise figure vs frequency, and is plotted from 50 MHz to 450 MHz. It indicates an improvement in the worst case noise figure at 450 MHz of 3.3 dB.

FIGURE 1
UNIT NOISE FIGURE
CONV. VS P.D.



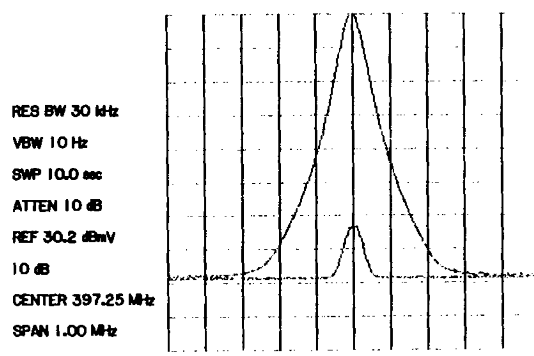
Test results for composite triple beat also show the expected results. Comparing Figure #2a with Figure #2b shows a 6.5 dB improvement in composite triple beat. Figure #2a is the conventional hybrid and measures -55.6 dB carrier-to-composite triple beat ratio. This figure illustrates a spectrum analyzer display with a CW carrier superimposed over the composite triple beat distortion. Figure #2b is a display of the carrier -to-composite triple beat ratio of the power doubling amplifier and measures a 63.1 dB carrier-to-composite triple beat ratio. Take note that the CW carrier levels for both Figure #'s 2a & 2b are equal, but the distortion is 6.5 dB lower in the power doubling case.

FIGURE 2a
UNIT C/CTB - CONVENTIONAL



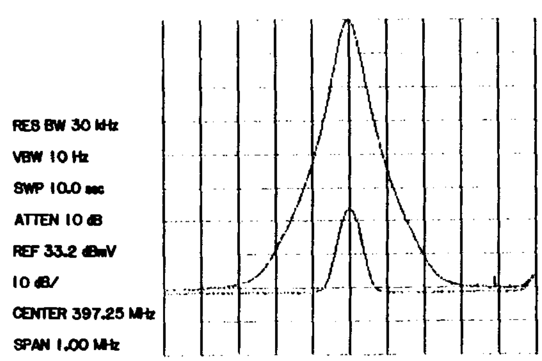
CONVENTIONAL 5-T440 W/58 CH. AT 46 dBmV (-55.6 dB)

FIGURE 2b
UNIT C/CTB - POWER DOUBLING™



POWER DOUBLER 5-T440 W/58 CH. AT 46 dBmV (-63.1 dB)

FIGURE 2c
UNIT C/CTB - POWER DOUBLING™
AT 3dB HIGHER OUTPUT



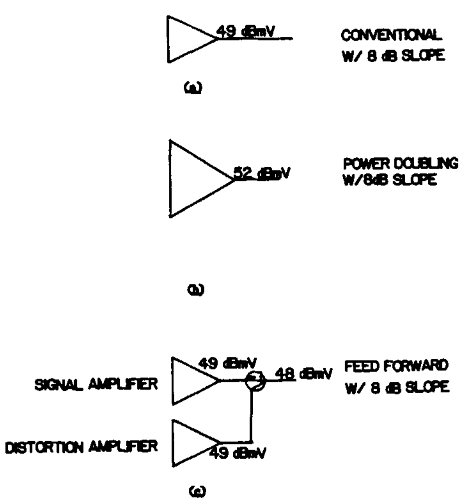
POWER DOUBLER 5-T440 W/58 CH. AT 49 dBmV (-56.1 dB)

To confirm this measurement, and also to prove that the third order peformance is behaving as expected on a 2 dB of distortion for 1 dB of output level change, the output level of the power doubling amplifier has been increased by 3 dB and is shown in Figure #2c. Take note that the carrier-to composite triple beat ratio measures -56.1 dB and is still .5 dB better than the conventional hybrid amplifier.

Summarizing the distortion test results, we can say that the amplifier has double the power output (a 3 dB increase is equal to twice the power) when compared to the conventional hybrid for approximately the same level of distortion.

Compression Point- For the purpose of the discussion in this paper, I am defining the compression point as the output level of the CATV amplifier where the change in distortion (take note that I do not say composite triple beat distortion) deviates from a 2 dB in composite beat for 1 dB of output level change, to a 3 dB of composite beat for 1 dB of output level change. Refer to Figure #3 for a comparison of the compression points for conventional, power doubling and feedforward amplifiers. Figure #3a is the conventional hybrid and shows a compression point of 49 dBmV. Figure #3b shows a Power Doubling amplifier having a 52 dBmV compression point or a 3 dB improvement over the conventional hybrid compression point.

FIGURE 3



Comparing feedforward technology to power doubling technology you will note that there is a 4 dB better compression point for the power doubler; the feedforward having 48 dBmV vs 52 dBmV of power doubler. Also note that a standard conventional hybrid has a 1 dB better compression point. The reason for the lower compression point of the feedforward amplifier is the fact that the signal output from the hybrid I.C. amplifier must pass through the combiner where the distortion cancellation takes place. This output combiner, for this illustration, is assummed to have 1 dB of insertion loss and results in a 1 dB degradation in the compression point.

During the system design planning process, when the engineer calculates the amplifier operating levels and the resulting system performance, he must consider the compression point of the amplifier. For a standard CATV hybrid loaded to 450 MHz, the output level should not exceed 50 dBmV. Likewise, I have noted system designs utilizing feedforward technology which are limited to 49 dBmV maximum operational output level. The power doubling amplifier, however, since it does have the improved compression point, can operate up to approximately 53 dBmV. In CATV systems with up to approximately 20 amplifiers in cascade, the power doubling, bridger amplifier and line extender amplifiers will be able to operate at higher levels, thus reducing the number of amplifiers required when compared to feedforward technology. A lower number of amplifiers means less initial expense, and less ongoing operational expense.

Longer Cascades and Extended Trunk Reach- At this point, I would like to restate the increase of performance for the power doubler in terms of dynamic range. The increase in dynamic range of the amplifier is 5 dB. That is the combination of the improvement in noise figure and the improvement in output levels:

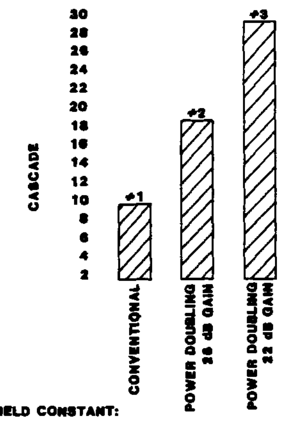
$$\text{Improved Dynamic Range} = \Delta\,\text{Noise Figure} + \Delta\,\text{CTB}/2$$

$$5\ \text{dB} = \Delta 2 + \Delta 6$$

This 5 dB increase in Dynamic Range will yield the improvements in cascadability that is shown in Figure #4. Three columns are shown. Column #1 indicates a conventional system at approximately 10 amplifier maximum cascade; the second column shows a power doubling amplifier at 26 dB gain and results in an approximate 20 amplifier maximum cascade; the third column depicts a power doubling amplifier at 22 dB gain and indicates an approximate 30 amplifier cascade. At the end of each of these cascades, the resulting system performance, in terms of carrier-to-noise and carrier-to-composite triple beat, are identical. This is to say, the power doubling column at 22 dB gain, will meet a 47 dB carrier-to-noise and 53 dB carrier-to-composite triple beat at the end of 30 trunk amplifiers, plus 1 bridger, plus 2 line extenders in cascade. This is an improvement of three times the system reach over the conventional system.

FIGURE 4

TECHNOLOGY VS. CASCADE COMPARISON



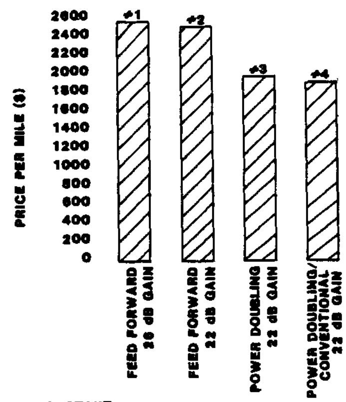
HELD CONSTANT:

FREQUENCY	440 MHz
CHANNEL LOADING	58
TRUNK SPACING	22 dB
BRIDGER OUT	46 dBmV
LINE EXTENDERS (2 IN CASCADE) OUT	42 dBmV
SYSTEM C/N	47 dB
SYSTEM C/CTB	-53 dB

FIGURE 5

PRICE PER MILE COMPARISON

(ACTIVE ELECTRONICS)



HELD CONSTANT:

FREQUENCY	440 MHz
CHANNEL LOADING	58 CHANNELS
DESIRED SYSTEM C/N	47
DESIRED SYSTEM C/CTB	-53
LONGEST CASCADE	29 at 22 dB trunkspacing 25 at 26 dB trunkspacing

As a result of the improved cascadability with power doubling, the cable TV operator can take advantage by reducing the number of hubs necessary to build a given CATV system; or, where critical specifications need to be met, power doubling can be used in lieu of feedforward technology. For example, if the specifications in Figure #4 were to be met at 29 amplifiers in cascade, a conventional system could not be used. Therefore, the choice would be either feedforward or power doubling to meet these specs.

Cost Effectiveness- In order to prove the cost effectiveness in systems where conventional amplifiers could not fulfill the specification requirements, a series of study designs were performed. A sample area was selected and consisted of approximately 25 miles of CATV distribution system. The performance specs. given in Figure #5 are held constant in each of the designs. The results of the study designs are plotted in Figure #5. Take note that the feedforward technology, shown by columns 1 and 2, priced out at approximately $2500.00 per mile. Comparing that to columns 3 and 4, which is the power doubling design, it priced out at approximately $1900.00 per mile, or approximately $600.00 less for power doubling.

To reiterate, it was determined that this system required approximately 29 amplifiers in cascade at 22 dB trunk spacing. It was determined by Figure #4 that the conventional technology can only meet those specifications up to 10 amplifiers in cascade. Therefore, it was concluded that either feedforward or power doubling need to be used. Now the judgment would be purely economic because the specifications could be met by both power doubling and feedforward. Based on economics of the study designs, the choice would obviously be for power doubling at $600.00 less per mile. Futhermore, I would like to put this savings into perspective. State-of-the-art CATV distribution systems now being proposed are usually a minimum of a dual subscriber system. In a dual cable subscriber system, this $600.00 a mile savings would have to be doubled for a total of $1200.00 a mile savings. If this was a 1000 mile system, the total initial cost savings would be $1.2 million dollars.

A cost savings can be illustrated in a different manner. For example, if the same system requiring a total of 30 amplifier cascades could be designed with conventional equipment and 2 hubs, the additional cost would result from the addition of 1 hub and all the associated equipment. If power doubling could be used to eliminate 1 of those hubs, the expense of an additional 58 channel headend, tower and antennas, earth station equipment, real estate, two-way microwave connection between hubs, and the associated ongoing operating costs could be eliminated.

Eliminate The Harmonically Related Signal Requirement- Harmonically related carrier systems (HRC) have been applied in expanded bandwidth systems to improve the subjective picture quality of the TV signals. Some people believe that there are sufficient technical reasons why HRC headends should not be used. Other people believe that the problems created through the use of HRC are outweighed by the subjective improvements. In a situation where the technical disadvantages are perceived the power doubling amplifier can be used to make up for the HRC benefit. In either case, the HRC headend is somewhat more expensive than headends applying standard frequency assignments. In these situations, the Power Doubling concept can be used to save the additional cost for the HRC headend.

It is felt that the general consensus for an HRC improvement is approximately equivalent to 6 dB of carrier-to-composite triple beat. For example, if a system was designed for a 53 dB carrier-to-composite triple beat ratio with standard frequency assignments, that same system with HRC could be designed for a 47 dB carrier-to-composite triple beat ratio, or a 6 dB reduction in the spec. This would yield the same picture quality for both the standard channel assignments and the HRC channel assignments.

Since the power doubling amplifier improves the distortion of a conventional amplifier by 6 dB, this improvement can be directly applied and compared to the 6 dB improvement of the HRC system. Therefore, a standard headend could be installed, along with power doubling amplifier systems, resulting in the same distribution system design architecture and bill-of-materials, but eliminating the need for harmonically related signals.

Drop-In Bandwidth Expansion- Another major benefit of a power doubling product is its ability to be applied for existing system bandwidth upgrades. Because of the significantly increased dynamic range of the product and, because it will be available with operational gains up to 27 dB, a 270 MHz distribution system can be upgraded to 450 MHz with 60 channel loading. This can be accomplished by directly dropping in the power doubling modules at existing trunk amplifier locations. There will be no need to move trunk amplifier locations. As indicated previously, the goal for this product was that it be housed identically to the Magnavox existing product. This means that existing Magnavox systems only need to swap out trunk modules and bridger modules. Housings, connector chassis and return modules can remain unchanged (if 270 MHz is to be expanded to 440 MHz, the model series 5-MC-2 chassis must be installed in the existing equipment).

With the conventional equipment, an upgrade from 270 to 450 MHz would require the complete redesign and respacing of the entire CATV distribution network. This would be more costly than the original initial build. The drop-in capability of power doubling provides a significant cost

SUMMARY

A net 5 dB improvement in dynamic range, as a result of a minimum of 2 dB better noise figure and 6 dB better distortion performance, is provided. Savings in CATV distribution systems design can be realized by reduction in actives, reduction in the number of hubs and elimination of the need for feedforward technology. Improved technical performance can be realized by eliminating the need for harmonically related carrier systems or by just applying the increased dynamic range for purposes of having sufficient head room on the subjective performance of the TV picture signal.

It should be noted that every CATV distribution system has its own unique features and design requirements. The examples presented here were based on certain assumptions. Magnavox's Systems Engineering Department can provide an analysis of your specific case to determine the benefits as they may apply.

Please stop by Booth #1502 at the 1983 NCTA, or write Magnavox CATV Systems, Inc., 100 Fairgrounds Drive, Manlius, NY 13104