400 MHz - A CHALLENGE FOR THE HYBRID AMPLIFIER

G. Luettgenau
A. Morawski
W. Inouye

TRW Semiconductors
14520 Aviation Blvd.,
Lawndale, CA 90260

The trend towards 400 MHz charges the hybrid manufacturer with the responsibility of providing increased performance without jeopardizing the high standards of quality and reliability required for profitable system operation. Thus, a prudent respone lies in the gradual implementation of the new generation of hybrids.

The availability of chips providing gain and match out to 400 MHz constitutes the first step. Advanced circuit techniques and tighter process control are applied. Subsequently, the dynamic range will be increased by phasing-in more sophisticated semiconductors.

This paper previews the upcoming technical changes. It is intended to provide a basis for the evaluation of the impact of hybrid technology on system cost and performance.

1.0 Introduction

Throughout its history, the CATV industry has seen an increasing demand for extended system bandwidth. The latest move raises the upper frequency limit to 400 MHz, thus providing space for 52 channels.

These changes in system parameters make new demands on the hybrid amplifier module. Compared to 300 MHz, module noise figures are on the average 2 dB higher at 400 MHz. Going from 35 to 52 channels, raises the number of worst-channel triple-beats by a factor of 2.63, thus lowering the CTB performance by 4.2 dB. Because of additional deterioration due to high-frequency effects, the degradation at channel H14 with 52 channel loading may be 12 dB worse than 35 channel performance measured at channel W.

Assuming typical amplifier design, these characteristics result in a reduction in trunk reach from 650 dB to 300 dB. A remedy from a system design point-of-view is closer spacing, or, if applicable, more hubs. Both measures are costly. Ideally the performance of the hybrids should be improved to handle the additional work load without deterioration.

In the following the options and possible choices for the hybrid manufacturer are discussed. Trunk station performance is calculated as a function of hybrid improvements.

2.0 Hybrid Improvements

2.1 Noise Figure

The noise figure of a bipolar junction transistor is determined primarily by the parameters: f_t, r_b', and β. Beta is made as high as possible in order to lower the noise and to increase the resistance of base-biasing networks. Practical values of 200 are presently achieved. Major increases are not likely, since other important device characteristics will have to be compromised.

In most general purpose high-frequency transistors, low noise is obtained by reducing r_b' to the lowest possible value. In the case of CATV transistors this technique is not applicable. Resistor noise is generated by all resistors in the base-emitter (= input) loop. The emitter resistance has the same effect as base resistance. Since all presently used CATV amplifier circuits use emitter resistors which are larger than r_b', little benefit arises from reducing base resistance.

The most promising remedy is an increase in f_t. In this area significant progress was made. New manufacturing techniques have resulted in an improvement of 2 dB in hybrid noise figure at 400 MHz. TRW plans to phase-in these new transistor chips during 1980, resulting in 400 MHz hybrid noise of 4.5 dB.

2.2 Output Capability

As evidenced from the illustrations in later paragraphs, an increase in output capability has the most dramatic effects. It is also the most difficult improvement to achieve. In high-performance transistors the distortion characteristics are the result of careful balancing of material and processing parameters. The last few years have brought about advances in material quality, fabrication control and sophistication, and, most significantly, computer-aided-design techniques. This progress puts a 3 dB output increase into the realm of possibility.

Earlier designs have been made which improve the output at the expense of ruggedness. The technique used consists of thinning the epitaxial collector layer and thereby, unfortunately, reducing the protective properties of this region. New designs avoid this shortcoming. The feasibility of reliable high-output devices has been demonstrated on an engineering level. Manufacturing methods are being developed. Incorporation of the 3 dB+ chip in 400 MHz hybrids is anticipated for 1981.

3.0 Trunk Station Analysis

In order to evaluate the behavior of existing and future CATV hybrids in a 400 MHz trunk, a typical station was modelled and subjected to a very detailed computer analysis. The objective was to determine optimum spacing and maximum reach, since these are major cost factors in a CATV system.

3.1 Station Layout

To allow comparison and to take into account industry practice, a previously(1) described layout is used. Refere to Figure #1, Block diagram of Trunk Station.

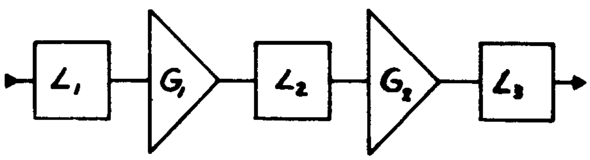

Figure 1. Block Diagram of Trunk Station

The input network, L_1, contains 0.5 dB of flat loss plus an equalizer with a minimum loss of 1 dB @ 400 MHz. For the purpose of analysis, the up-tilt of the equalizer may be changed from zero to full cable-slope compensation. The transfer function is slope-cable equivalent. The first hybrid, G1 is characterized by a flat gain, which may be varied in the analysis. Distortion is specified as 53-channel CTB measured @ H14 (off). Several different curves of noise figure vs. frequency, as measured on actual hybrids, are stored in the computer program, and may be called out as needed. The interstage network, L_2, contains a flat loss of 5.5 dB + 12% of spacing. It further equalizes that part of the station cable slope, which was not taken care of in L_2. Hybrid G2 has the same gain as G1, but may be specified to have different values of NF and CTB. The output circuitry, L_3, exhibits a flat loss of 1.5 dB.

3.2 Modes of Operation

Apart from using different amounts of cable equalization at the station input, two modes of output signal tilt were investigated. In one case a conventional tilt, as used in many systems, was assumed. The program automatically selects a tilt which results in as uniform a CNR as possible. In the other case it was postulated that the output levels were adjusted, (at the head-end) to maintain an exactly equal signal-to-noise ratio for all channels. The noise figure of present day 400 MHz hybrids varies considerably with frequency. An output level tilt which follows the contour of the noise level might, it was speculated, result in improved distortion characteristics. Figure 2 shows the noise output in dBmV for a normal hybrid combination, as a function of input equalization. EQ = 1 means all cable slope is equalized at the input of the station. EQ = 0. means all equalization takes place in L_2.

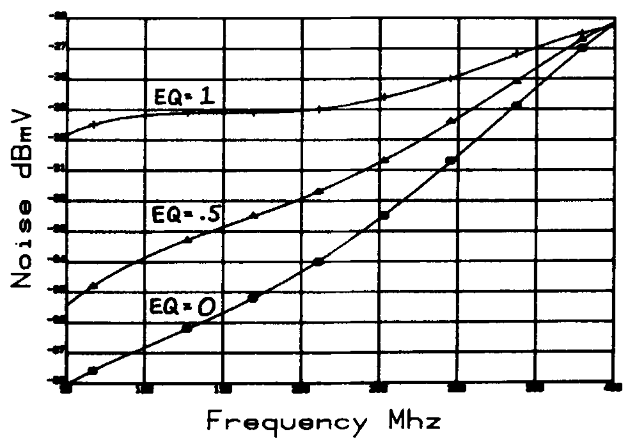

Figure 2. Station Noise, CA4101 and CA4201

Figure # 3 shows station noise using new, low-noise hybrids.

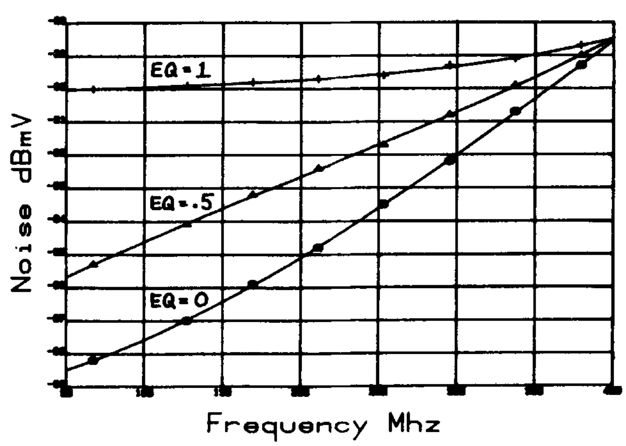

Figure 3. Station Noise, Low-Noise Hybrids

The effect of arbitary output voltage tilts was investigated by the following experiment: 53-channel CTB was measured on eight representative channels. While observing CTB on a particular channel, eight blocks of channels were varied in amplitude, one block at a time. Thus, the CTB sensitivity to amplitude variations throughout the frequency range was determined. After some manipulation, an 8x8 matrix was generated which allowed the computer to predict CTB improvements due to output tilts of various shapes. In the following figures, results obtained from conventional output tilt are identified by TILT-C, while constant CNR tilts are labelled TILT-N.

Figure 3 through 6 show maximum trunk reach for three types of amplifiers as a function of input equalization.

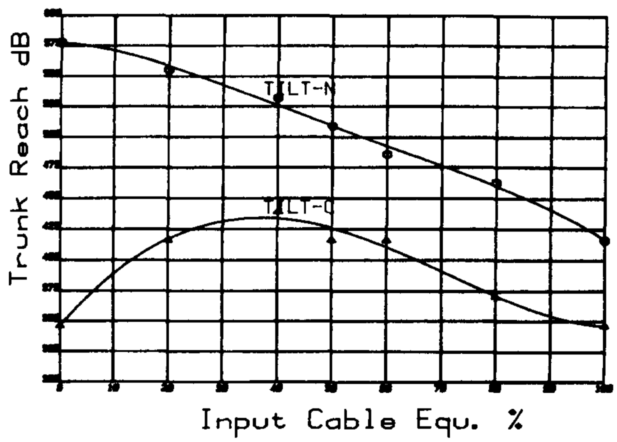

Figure 4. Reach of CA4101 + CA4102

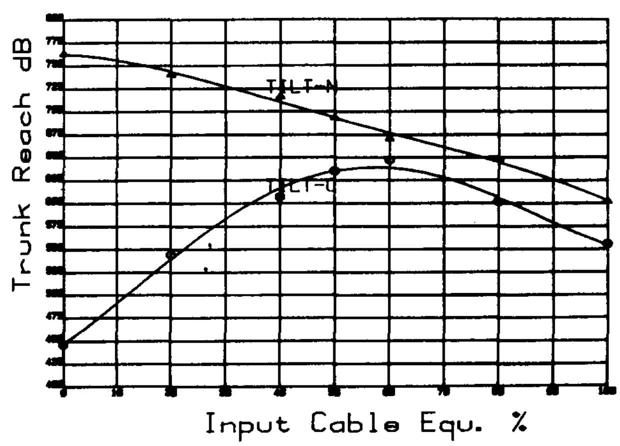

Figure 5. Reach of Low-Noise Hybrids

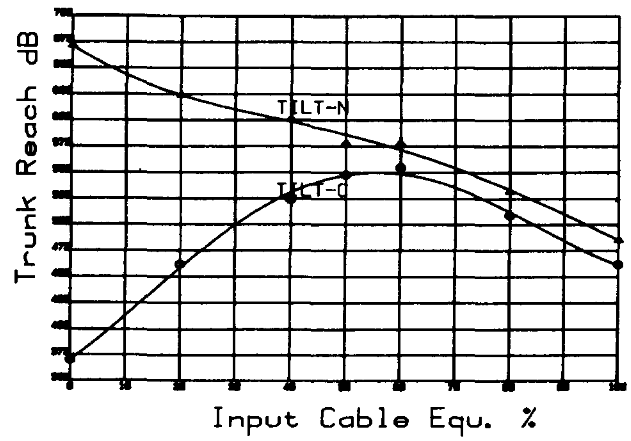

Figure 6. Reach of Low-Noise, Improved Output Hybrids

3.4 Optimum Hybrid Gain

400 MHz hybrids presently on the market are specified for a nominal gain of 17 dB at 50 MHz. The reason for this is that the first step towards 400 MHz consisted of improving existing 300 MHz trunk types with respect to match, gain flatness and second order distortion, so that performance up to 400 MHz could be obtained. As mentioned before, major improvements in semiconductor technology will soon bring up to 5 dB additional dynamic range. At that time the question of optimum hybrid gain may be raised again.

Shown in Figure 7 is reach as a function of hybrid gain for a compliment of future hybrids. Noise figures were 5.4 dB and 6.4 dB, H14 -46 dBmV CTB -56 and -62 dB respectively.

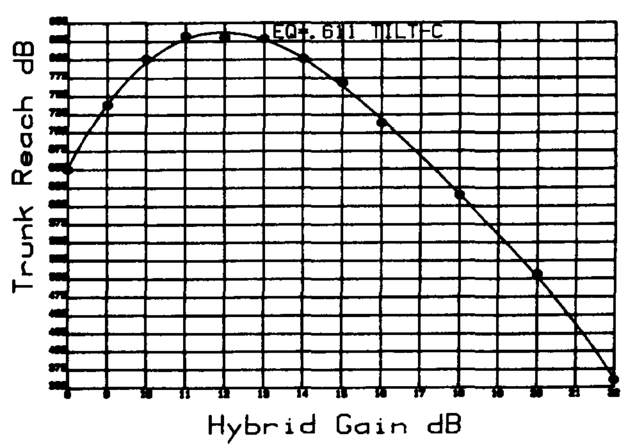

Figure 7. Reach vs. Hybrid Gain

For maximum trunk length, it is seen that 17 dB gain is not optimum. In order to evaluate the cost impact of decreased hybrid gain, the spacing needs to be known. This is shown in Figure 8.

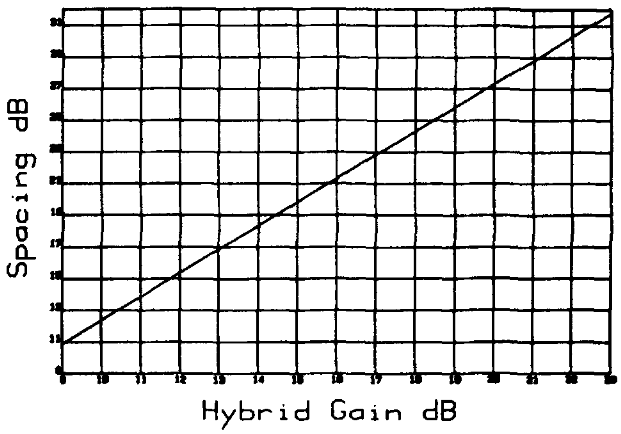

Figure 8. Spacing vs. Hybrid Gain

4.0 System Improvements

The increased work load imposed by 400 MHz operation has led to the use of other techniques to enhance picture quality.

4.1 HRC

The use of harmonically related carriers has long been known to result in improved transmission quality.(2)A computer-aided study predicts a distortion improvement of 6 dB on the worst channel, and more on other channels. (3). The remaining distortion has the appearance of cross-modulation which has led to the speculation that this parameter is of renewed importance. It can be shown, however, that the basic quality parameter is still composite triple-beat. The difference with HRC is that the many components of the "beat-noise" are now on one frequency and have a fixed phase-relationship to each other. HRC seeks to obtain a net zero amplitude by phase-cancellation. The starting point is still a vector resulting from the summation of all triple-beats.

4.2 Frame Synchronization

This technique, which requires complex and costly electronics, causes the sync-pulses of all TV signals to occur at the same time. Thus, maximum intermodulation happens, while no video information is transmitted. The net result is an improvement proportional to the ratio of peak-sync to average signal power.

5.0 Conclusion

The semiconductor industry is responding to 400 MHz according to a plan which will result in trunk characteristics comparable to present 300 MHz performance.

Further improvement may be obtained by head-end sophistication. Presently known schemes apply to TV-signal transmission only. The need to maintain system transparency, the importance of future non-TV services, and the cost of these improvements will be pondered in the time to come.

Reference List

(1) Preschutti, J.P. "Extended Bandwidth Broadband Communications Systems Performance Up To 400 MHz" IEEE Transactions on Cable Television, Volume CATV-4, No. 3, July 1979

(2) Switzer, I. "A Harmonically Related Carrier System for Cable Television" IEEE Transactions on Communications, Volume COM-23, No. 1, January 1975

(3) Krick, w. "Improvement of CATV Transmission using an Optimum Coherent Carrier System", 11th International TV Symposium, Montreux, Switzerland, May 1979 Heinrich-Hertz-Institut für Nachrichtentechnik, Berlin