TV CABLE TRANSMISSION UP TO 900MHz

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ABSTRACT

Increased system bandwidth has been a technological trend for a number of years. Present-day amplifiers can handle full channel loading up to 550MHz.

There exist a number of requirements and possibilities which make an even wider frequency range desirable. Direct UHF distribution, as practiced and contemplated in Europe (and the U.S.) is one case. The thought of placing reverse transmissions into the higher frequency range has also been entertained. Obviously there are applications in MATV and similiar systems.

Hybrids suitable for the range from 40 through 900MHz have become available. This paper relates these devices to specific applications. Conventional performance characteristics are given and compared to "Noise-in-the-Slot" behaviour, which is a most revealing criterion for ultra wideband systems.

The feasibility of feedforward realizations based on these hybrids is discussed.

INTRODUCTION

The CATV industry seems to have an insatiable appetite for additional channel space. While in the past the justification for this has been the need to transmit more TV programs, other considerations have been voiced lately. The main theme is that the bulk of the UHF frequency range, which has been exclusively assigned to television signal transmission, is not available for CATV. Instead, cable transmissions have to share frequencies which are used by other services, resulting in the well-known problems of ingress and radition.

The reasons for the present situation are, of course, technical. Nothing ever seems to become easier as the frequency of operation is increased; losses are up, distortion rises, components become more critical. But it is also true that the same problems have existed in electronic communications since the beginning. Take transistors, for instance: The F_t of early devices was barely good enough for AM radios, now we operate at X-band.

Encouraged by progressive members of the CATV community, we felt the need to present our findings. To remain realistic, the maximum frequency of interest was limited to 900MHz. Hybrids with various output capabilities reading up or close to this frequency are available off-the-shelf. They are: VHF-UHF amplifiers used mainly for MATV, general purpose hybrids in TO-8 cans, and at least one specific CATV-type hybrid, appropriately called CA900.

The latter two types may be combined to form a high-gain circuit, which in turn becomes a candidate for a feedforward block.

In the following, the performance of these devices in 900MHz applications is discussed in detail.

900MHz CIRCUITS

The CA900

This hybrid consists of two cascaded common-emitter push-pull stages in a regular CATV package. It has a nominal gain of 17dB. The device has a CTB performance of -58.5dB measured with 85 channels, flat, 40dBmV.

It is a characteristic of the common emitter configuration that CTB remains rather flat vs. frequency. Therefore, one may predict with some confidence a CTB performance of -53.6dB for full channel loading over the enitre 900MHz band-width. This condition was simulated by broad-band noise loading, described later. Operation or testing with 150 channels (≈900/6) at 46dBmV is an unrealistic proposition. As seen from the following test results, 85 channels at 46dBmV constitute substantial overloading.

```
Part       Lot        Unit  Level  Slope   V     I    No   Chan  CTB
Name       Name             dBmV   dB    Volts Amps  Chan Name   dB
========== ========== ===== ====== ====== ===== ===== ==== ==== ======
CA4800     SAMPLE      4532  46.0    0.0  24.0 0.229   85  H47  -41.8

Part       Lot        Unit  Level  Slope   V     I    No   Chan  CTB
Name       Name             dBmV   dB    Volts Amps  Chan Name   dB
========== ========== ===== ====== ====== ===== ===== ==== ==== ======
CA4800     SAMPLE      4532  40.0    0.0  24.0 0.230   85  H47  -58.5
```

FIGURE 1, CTB Readings of 900MHz Hybrid

Feedforward

For extra performance or when running against technological stops, the feedforward circuit has become an effective remedy.

The feasibility of a 900MHz feedforward gain block was studied. No prototypes exist at this time. However, all the necessary ingredients are there, so that, if called upon, a device could be realized.

As a matter of fact, it appears that all circuitry can be housed in the same package that is presently used for 500MHz feedforwards. For comparison this package is shown next to a 900MHz hybrid. (CA4800 is a 50 ohm version).

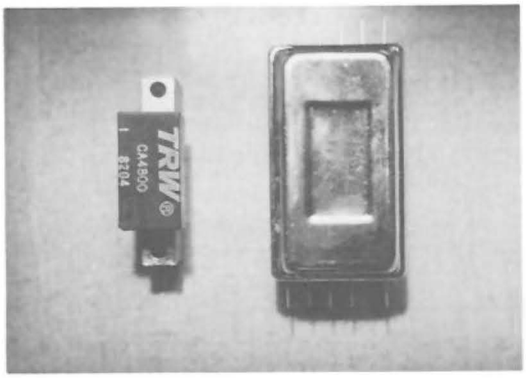

FIGURE 2, Feedforward Gain Block

The most important component is the gain block. A combination of the basic 900MHz circuit and a 15dB low-noise single ended pre-amp was breadboarded yielding a suitable 32dB block. One of the attractive properties of this arrangement is its excellent phase-linearity, brought about by the absence of transformers in the preamp and the use of transmission-line types in the final stages. This characteristic mates well with printed delay lines, which have an essentially linear phase. Delay-lines and directional couplers used in 550MHz feedforwards hold up remarkably up to 1000MHz; the main observed deteriorations being a few tenths of a dB increase in through-loss for the coupler and transmission loss for the delay line.

Based on measurements of the individual components, one may project a 21dB feedforward circuit with 20dB distortion improvement over that of the plain 17dB gain block.

900MHz TRUNK ANALYSIS

A program was written to determine the performance of the 900MHz circuits discussed in a trunk application. The extreme case of 150 channels and that of partial loading with 60 channels are analized. The following input data decks are self-explanatory with the exception of the value of interstage flat loss: The program automatically increases the number entered by 12% of station spacing to consider the necessary increase in range for tilt and gain controls. Further, the value of CTB is based on 46dBmV flat. Since the amplifier treated here are already in compression at this level, the number entered is measured data at 40dBmV plus 12dB.

```
TRUNK CTB                    -57.
TRUNK CNR                    43.
GAIN,BLOCK #1                17.5
GAIN-SLOPE,BLOCK #1          0.
NOISE FIG. BLOCK #1          9.
NF CHANGE, BLOCK #1          1.5
CTB BLOCK #1                 -41.47
CTB CHANGE,BLOCK #1          0.
GAIN, BLOCK #2               17.5
GAIN-SLOPE BLOCK #2          0.
NOISE FIG. BLOCK #2          9.
NF CHANGE, BLOCK #2          1.5
CTB BLOCK #2                 -41.47
CTB CHANGE BLOCK #2          0.
INPUT CKT FLAT LOSS          -1.5
INTERSTAGE FLAT LOSS         -10.
OUTPUT FLAT LOSS             -1.5
```

FIGURE 3, Input Data 2 X CA900

Because both CTB and Noise Figure vary very little vs. frequency, the performance cannot be improved by operating with a tilted spectrum. The summary of performance

STATION 2 X CA900
SPACING 19.6dB
NO. OF STATIONS 10
STATION OUTPUT 25.4dBmV
LOADING 150 Channels

Next the input data for a station consisting of two feedforward amplifiers:

TRUNK CTB	-57.
TRUNK CNR	43.
GAIN,BLOCK #1	21.
GAIN-SLOPE,BLOCK #1	0.
NOISE FIG. BLOCK #1	8.2
NF CHANGE, BLOCK #1	1.5
CTB BLOCK #1	-61.07
CTB CHANGE,BLOCK #1	0.
GAIN, BLOCK #2	21.
GAIN-SLOPE BLOCK #2	0.
NOISE FIG. BLOCK #2	8.2
NF CHANGE, BLOCK #2	1.5
CTB BLOCK #2	-61.07
CTB CHANGE BLOCK #2	0.
INPUT CKT FLAT LOSS	-1.5
INTERSTAGE FLAT LOSS	-10.
OUTPUT FLAT LOSS	-1.5

FIGURE 4, Input Data 2 X FF900

The results are:

STATION	2 X FF900
SPACING	25.9dB
NO. OF STATIONS	19
STATION OUTPUT	33.1dB
LOADING	150 Channels

This performance is similar to that obtainable with conventional hybrids at frequencies up to 400-500MHz.

The effect of partial loading of the amplifiers may be simulated by an improvement in amplifier CTB by approx. 20 * log (channels/150). Because of the insensitivity to frequency of operation mentioned before, the loading may be at any segment of the total available 900MHz. Following are the computer analysis results for 60 channels:

STATION	2 X CA900
SPACING	19.6dB
NO. OF STATIONS	16
STATION OUTPUT	27.5dBmV
LOADING	60 Channels

STATION	2 X FF900
SPACING	25.9dB
NO. OF STATIONS	30
STATION OUTPUT	35.1dBmV
LOADING	60 Channels

NOISE-IN-THE-SLOT

As the number of channels is increased, test equipment and test procedures become more cumbersome and expensive. As a possible alternative, or perhaps a complement to conventional distortion testing, a test method was investigated which has been applied successfully in the areas of microwave and telephone transmissions. Its popular identification is that of the "Noise-in-the-Slot method".

The principle is to drive an amplifier (or system) with a spectrum of white noise, such that the total output noise power corresponds to the summation of all the signal powers delivered by the amplifier under normal test conditions. A sharp notch filter is inserted before the amplifier, thus creating an empty slot in the drive spectrum. At the output of the amplifier inter-modulation noise will cause a partial filling of the slot. The exact distortion level can be measured with a selective meter such as a spectrum analyzer. Although equipment to perform such tests is commercially available, a noise source and notch filter were built in order to gain more "hands-on" experience.

Noise Source

A suitable source was obtained by cascading four general purpose 1GHz amplifiers type 1006 with a combined gain of 76 dB. This chain was driven by an HP Noise Source with a Noise Figure of 15dB. The expensive Noise Source could be replaced by another GPA which would be equivalent to a Noise Source with an approximate Noise Figure of 23.5dB. Figure 5 shows the four-amplifier cascade.

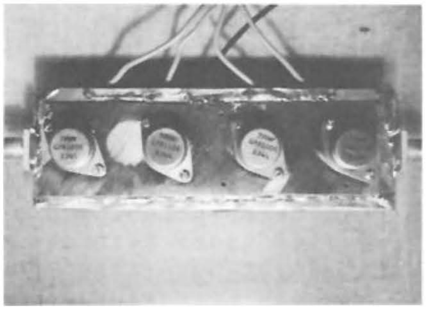

FIGURE 5, Noise Amplifier

Notch Filter

Somewhat arbitrarily the slot was placed at 750MHz. The filter used consisted of two quarter-wave sections of semi-rigid coax and three identical series traps, as shown

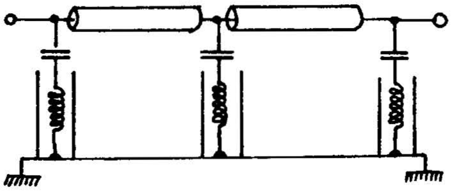

FIGURE 6, 750MHZ Band-stop Filter

The responses of the filter, S_{21} and S_{11}, are shown on the following photograph. Horizontal sweep is 5MHz/division, vertical resolution is 10dB/division.

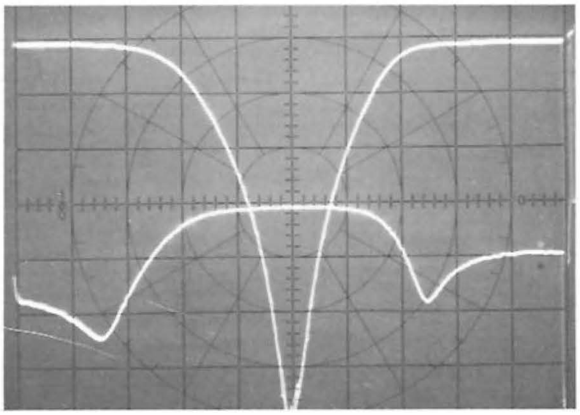

FIGURE 7,Response of Notch Filter

Noise Test

Following is a block diagram of the entire test set-up.

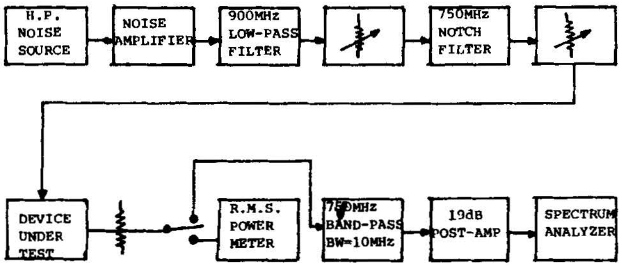

FIGURE 8, Test Set-up Block Diagram

The input noise spectrum was limited from 900MHz on by a three-pole low-pass filter. The amplifier under test was buffered by loss-pads at both input and output to avoid changes in performance due to the VSWR of adjacent filters.

The test procedure was as follows: Over a range of 20dB the input noise power was varied in steps of 1dB. The total 900 MHz Noise power was measured with a true RMS power meter and recorded for each attenuator setting. The range of output powers was from about one to one-hundred milliwatts. The next photo shows the output displayed on a spectrum analyzer.

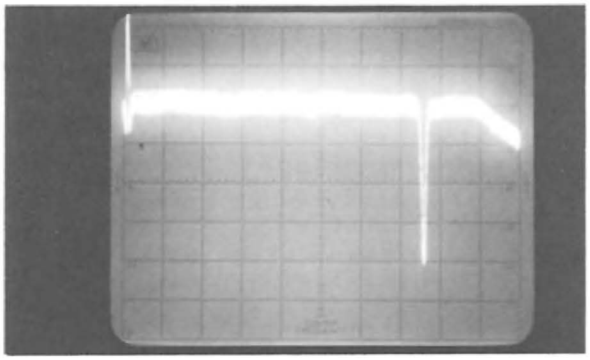

FIGURE 9, Output Noise Spectrum

The notch depth is not as deep as on Figure 6, because intermodulation is generated in the amplifier and spectrum analyzer.

Subsequently the distortion products were measured for each attenuator setting by tuning the spectrum analyzer carefully to the deepest point of the slot. Settings were: Zero-span, 1MHz BW, Video Filter 100Hz. The spectrum analyzer was calibrated in dBm (HP Model 8565A). By making the proper bandwidth and impedance conversions and taking into consideration the gain of the post-amp circuitry, dBm readings were converted to dBmV, RMS in a 6MHz segment, in a 75 ohm system.

Following are two plots, one in dBmV, the other one in millivolts, of the signal-to-intermodulation relationship.

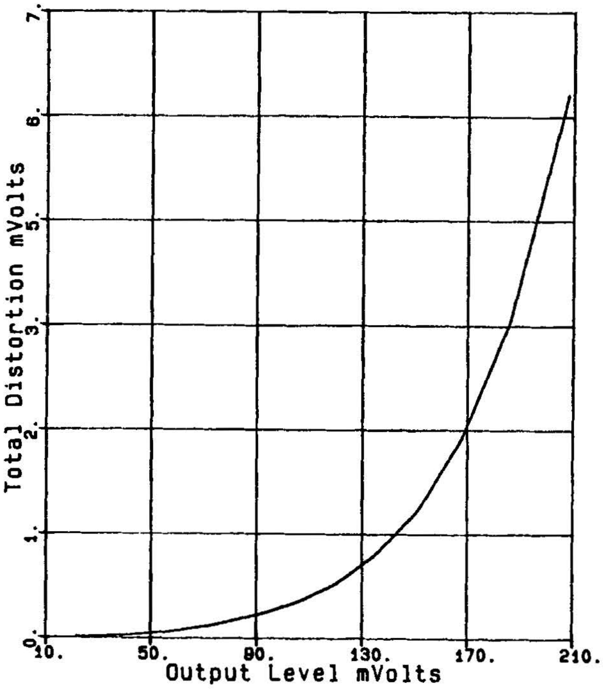

FIGURE 10, Intermodulation Noise - mV

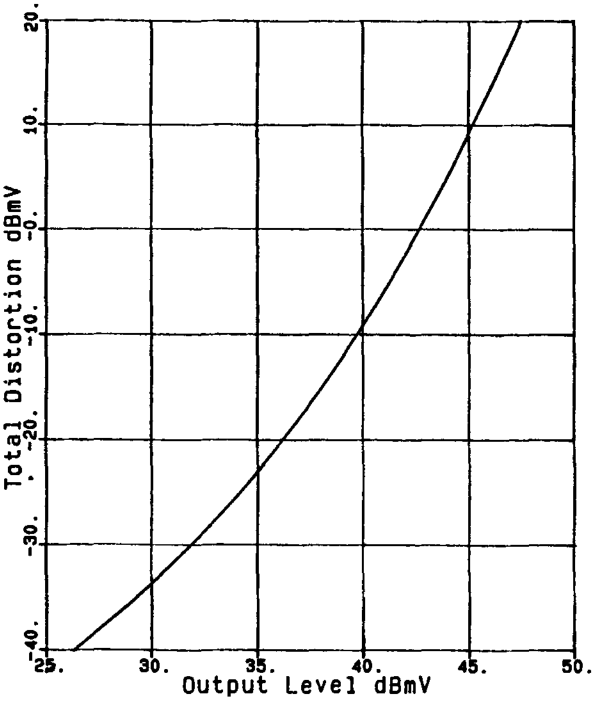

FIGURE 11, Intermodulation Noise-dBmV

Figure 11 reveals the increase in slope from 2:1 at low levels to more than twice that at high levels. This indicates primarily second-order distortion at low levels, with increasing amounts of higher-order components, possibly up to fifth order, as the output rises. For HRC Systems, which are likely candidates for high capacity installations, total composite distortion is a good quality indicator, since all distortion products, regardless of order, show up as "apparent cross-modulation". On the other hand, for conventional systems, and to predict distortion build-up in trunks, it is of interest to know the individual components of the total intermodulation noise. The data which went into Figure 10, may be used as a base for a mathematical analysis, which yields just that type of information.

Following is a computer print-out which lists the values of composite N-th order distortion, in dB, relative to carrier-equivalent noise. At 26dBmV the dominant distortion is of second order, while @ 46dBmV 4-th and 5-th order magnitudes indicate heavy overload.

Output	Distortions			
Level dBmV	2nd Order	3rd Order	4th Order	5th Order
26.80	-67.43	-79.17	-96.24	-116.00
27.80	-66.43	-77.17	-93.24	-112.00
28.80	-65.43	-75.17	-90.24	-108.00
29.80	-64.43	-73.17	-87.24	-104.00
30.80	-63.43	-71.17	-84.24	-100.00
31.70	-62.53	-69.37	-81.54	-96.40
32.70	-61.53	-67.37	-78.54	-92.40
33.70	-60.53	-65.37	-75.54	-88.40
34.60	-59.63	-63.57	-72.84	-84.80
35.60	-58.63	-61.57	-69.84	-80.80
36.60	-57.63	-59.57	-66.84	-76.80
37.60	-56.63	-57.57	-63.84	-72.80
38.60	-55.63	-55.57	-60.84	-68.80
39.60	-54.63	-53.57	-57.84	-64.80
40.60	-53.63	-51.57	-54.84	-60.80
41.60	-52.63	-49.57	-51.84	-56.80
42.60	-51.63	-47.57	-48.84	-52.80
43.60	-50.63	-45.57	-45.84	-48.80
44.50	-49.73	-43.77	-43.14	-45.20
45.40	-48.83	-41.97	-40.44	-41.60
46.40	-47.83	-39.97	-37.44	-37.60

FIGURE 12, Intermodulation by Order

The third order distortion at 40dBmV can be interpolated to be be 52.8dB. It must be pointed out at this time that all levels quoted and used in calculations are true RMS values. When calibrating the spectrum analyzer, it was (once again) observed that the spectrum analyzer noise reading was about 2.5dB below the power meter reading. Since the industry has become accustomed to quoting CTB in terms of spectrum analyzer indication, without applying a correction factor, -52.8dB corresponds to -55.3 db in customary terms. Applying further a a correction of -4.9dB to relate 150 channel performance to 85 channels, finally yields -60.2dB, which is within about 1.5 dB of the value of the convential 85-CH CTB for this device. This remarkable correlation is encouraging, but may have to be substantiated by further testing and method refinement.

CONCLUSION

The data shown and the projections made, indicate that technology has reached a level, where operation up to 900MHz is feasible.

A practical noise-loading test for very high capacity systems has been demonstrated, which yields new and interesting insight into the distortion behavior of CATV circuits.