SLOPED-GAIN HYBRIDS

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ABSTRACT

All CATV hybrids currently on the market operate with flat gain. Recently an interest was shown in devices with an up-slope in gain from 14.5 to 18.5dB. Experimental circuits of this kind were assembled and measured. The performance in terms of trunk reach was calculated. Comparisons were made relative to flat-gain hybrids and a hypothetical device with 8dB gain slope. It was found that significant improvements in reach could be obtained, provided that tilt and interstage equalization were optimized.

DISCUSSION

Hybrids in CATV Trunks

The maximum length of a trunk depends primarily on two parameters: The noise figure and the composite triple-beat of the amplifiers used. The length or reach is often expressed in decibels which may be converted into miles once the cable losses/100 feet are known. Although the spacing of the amplifiers has a major influence on the reach (with the theoretical optimum being 1 Neper = 8.69dB), for a number of practical reasons a spacing of 25dB has become widely used practice. The following equation describes the relationships mentioned.

Reach = SP * 10exp (((-CTBB-CTB)/2-CNR-ENB+ET)/20) (1)

where:

SP = Amplifier spacing (dB)
CTBB = Composite triple-beat performance at the end of the trunk.
CTB = Amplifier CTB measured at a level of ET dBmV.
CNR = Carrier-to-noise ratio (dB) at the end of the trunk.
ENB = Noise voltage (dBmV) at the output of the amplifier.
ET = Output level (dBmV) at which CTB is measured.

In subsequent calculations trunk criteria are set to -63dB for CTBB and 43.5dB for CNR.

Since trunk amplifiers usually contain two hybrids, the amplifier performance is a function not only of the hybrid characteristics but also of the circuit employed and of the operating conditions. In the following analyses, an amplifier with these details is assumed:

- Frequency range 50 to 400 MHz
- Gain 25dB at 400 MHz
- Two identical hybrids with 18.5dB gain at 400 MHz
- Input equalizer with 2dB flat loss
- Interstage equalizer, gain and tilt control with 10dB flat loss

The cable slope is assumed to be:

Slope = 25 * (1-SQRT(F/400)) (2)
which results in about 16dB for F = 50 MHz.

The noise figure and the composite triple beat of the hybrid gain-blocks vary with frequency. The changes are approximated by:

X(F) = X(400) - DELTA * (400-F)/350 (3)

where:

X(F) = NF or CTB at frequency F
X(400) = NF or CTB at 400 MHz
DELTA = Difference in NF or CTB between 400 MHz and 50 MHz.

In this paper it is assumed:

NF(400) = 6dB, DELTA (NF) = 2dB
CTB(400) = -62dB, 52CH, flat, 46dBmV
DELTA (CTB) = 8dB

Another factor entering into the performance equation is the output spectrum tilt with which the hybrids are operated. While there is agreement that tilt improves composite triple beat, there is no consensus on the exact relationship. Theoretically one may argue, that tilting the output levels reduces the total output power and that therefore two dB in CTB should be gained for every dB drop in average power. Integrating the power for a 6dB tilted spectrum with 0dB 400 MHz reference, results in a value of -2.21dB for the average power. A theoretical CTB improvement of 4.42dB can therefore be predicted. The tilt was assumed to follow an inverse cable slope according to equation 2. The improvement differs somewhat for other degrees of tilt. It was calculated:

Tilt	CTB Improvement
1dB	0.82dB
6dB	4.42dB
10dB	6.74dB
16dB	9.34dB

In real life it is reasonable to expect less improvement. One reason for this lies in the fact that the higher frequencies contribute more to the overall CTB than the lower ones. In tilting the signal the higher frequencies remain fairly strong and maintain their influence.

In the literature one finds an empirical relationship, which states that a CTB improvement of 0.6dB is gained for every dB of tilt. This. value, which agrees fairly well with theory, was used in the calculations in this paper.

Flat-Gain Hybrids

It is the objective of this study to assess the influence of hybrids with substantial upslopes of gain on trunk performance. Before this case is analyzed, the base line, given by the performance of flat-gain hybrids, is established. Reference is made to Figure 1.

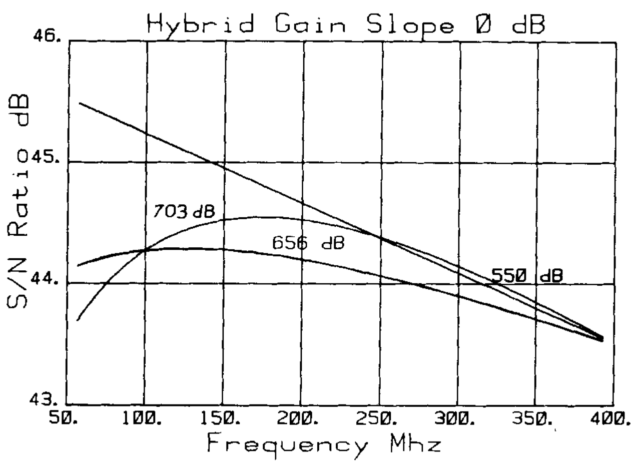

Figure 1. Trunk Reach for Flat-Gain Hybrids.

The top curve of Figure 1, labelled 550dB (trunk reach) relates the signal-to-noise ratio to frequency for an amplifier operating with flat spectra for both pre-amp and post-amp. It is seen that the C/N ratio at the low frequency end is unnecessarily good. Operating with 6dB tilt for the post-amp and 0dB for the pre-amp the reach is increased to 656dB. Finally, the computer was allowed to find optimum values of tilt for both input and output hybrids. A reach of 703dB was calculated for 9dB post-amp tilt and a down tilt of -3dB for the pre-amp. This somewhat puzzling result becomes understandable if one consideres the following: The tilt values obtained require an interstage equalizer of 11dB (and an input equalizer of 4dB for a total compensation of 16dB). The large value of interstage equalization loss at low frequencies reduces the noise contribution of the pre-amp. Therefore the low frequency output voltage levels may be reduced while still maintaining an acceptable CNR. As mentioned before the pre-amp operates with a down-tilt. This actually worsens its CTB performance relative to the flat output condition. It is apparent that increasing the amount of interstage equalization reduces the overall amplifier noise output, but increases the combined hybrid distortion. There exists, for every condition of post-amp output tilt, an optimum value of interstage equalization, resulting in maximum trunk reach.

Application of some of the operating conditions calculated may pose difficulties in practice. It is beyond the scope of this paper to ponder the practicality of all study results.

4dB Gain-Slope Hybrid

Industry inquiries seemed to show interest in a gain-block with a 4dB inverse cable equivalent slope. Experimental versions of such chips were constructed and measured. It was found that CTB and noise figure values were essentially equal to those obtained from equivalent flat-gain parts. Tilted output CTB performance agreed with the impirical relationship mentioned earlier.

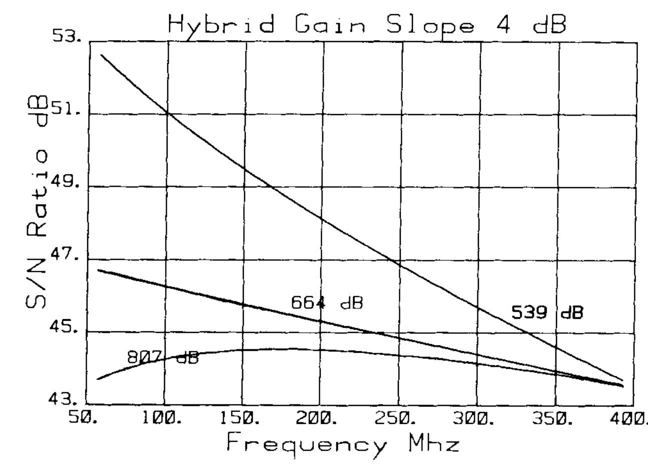

Figure 2. Trunk Reach for Hybrids with 4dB Gain Slope.

The operating conditions are summarized below:

Reach	Tilt	Interstage Equalization
539dB	0dB	0dB
664dB	6dB	0dB
807dB	13dB	7dB

The maximum trunk reach has increased 104dB over the best value obtained from the flat-gain parts. This is due to the fact that the noise output of the sloped-gain devices is 4dB lower at the low-frequency end. Therefore better distortion performance can be achieved by increasing the output tilt. Note however that there is practically no difference in reach between sloped and flat hybrids, if both are operated at 0 or 6dB tilt. CNR at low frequencies is better for the sloped-gain device, as one would expect.

8dB Gain-Slope Hybrid

To further investigate the subject, a hypothetical hybrid with 8dB gain-slope was examined.

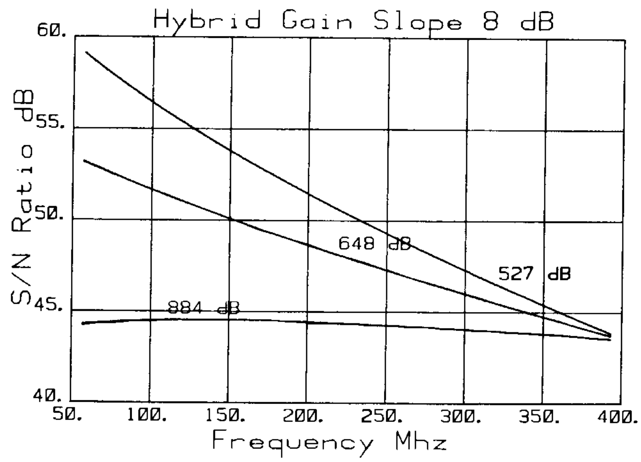

Figure 3. Trunk Reach for Hybrids with 8dB Gain Slope.

Reach	Tilt	Interstage Equalization
527dB	0dB	0dB
648dB	6dB	0dB
884dB	15dB	0dB

The reach improvement is now 181dB over the best performance of the flat-gain devices. It is up to the equipment designer to decide whether such a hybrid would be desirable.

METHOD OF ANALYSIS

A printout of a small computer program used to make the calculations for this study is shown at the end of this paper. The language is FORTRAN as used for a PR1ME computer. The example analyses one specific condition of tilt and equalization. By changing

```
DO 500 KTILT     0,20

DO 600 KEQNT     0,K
```

the program will scan a range of conditions for tilt and equalization.

CONCLUSION

It was shown that considerable improvements in trunk reach can be obtained by sloped-gain hybrids. In order to realize the theoretically possible performance, it is necessary to operate with appreciable output tilts.

```
.NULL.
      TRACE TILT,EQUAL,REACH,CNR
      REAL FSLOPE(67),AGAIN(67),ATT1(67),ATT2(67)
      REAL TB(67),RNF(67)
      REAL CTB1(67),CTB2(67),CTBB(67),ENB(67)
      REAL E2(67),E1(67)
      REAL CTB1T(67),CTB2T(67),CTBBT(67),RNFT(67)
      REAL FREQ(67)
      GAIN=18.5
      GSLP=4.
      TOTSLP=25.*(1.-SQRT(9./67.))
      K=INT(AINT(TOTSLP-2.*GSLP+.5))
      RNFHI=6.
      RNFLOW=4.
      CTBHI=-62.
      CTBLOW=-70.
      AFIX1=-2.
      AFIX2=-10.
      TILTFA=.6
      DO 500 KTILT=13,13
      DO 600 KEQNT=7,7
      EQFR=TOTSLP-2.*GSLP-FLOAT(KEQNT)
      DO 100 J=9,67
      I=76-J
      FREQ(I)=6.*FLOAT(I)
      FSLOPE(I)=(1.-SQRT(FLOAT(I)/67.))*25./TOTSLP
      AGAIN(I)=GAIN-GSLP*FSLOPE(I)
      ATT1(I)=-EQFR*FSLOPE(I)+AFIX1
      ATT2(I)=-FLOAT(KEQNT)*FSLOPE(I)+AFIX2
      TB(I)=CTBHI-(CTBHI-CTBLOW)*
     +(67.-FLOAT(I))/58.
      RNF(I)=RNFHI-(RNFHI-RNFLOW)*
     +(67.-FLOAT(I))/58.
      CTB2(I)=TB(I)-TILTFA*FLOAT(KTILT)
      CTB1(I)=TB(I)-(GAIN+AFIX2)*2.-TILTFA*(FLOAT
     +(KTILT)-GSLP-FLOAT(KEQNT))
      CTBB(I)=20.*ALOG10(10.**(CTB1(I)/20.)+10.**
     +(CTB2(I)/20.))
      ENB(I)=20.*ALOG10(SQRT((10.**((-59.+AGAIN(I)*
     +2.+RNF(I)+ATT2(I))/20.))**2.+(10.**((-59+RNF(I)+
     +AGAIN(I))/20.))**2.))
      DBS=(-63.-CTBB(67))/2.-43.5-ENB(67)+46.
      E0=43.5+ENB(67)+DBS/2.
      E2(I)=E0-FLOAT(KTILT)*FSLOPE(I)
      E1(I)=E2(I)-AGAIN(I)-ATT2(I)
      CTB2T(I)=CTB2(I)+2.*(E2(67)-46.)
      CTB1T(I)=CTB1(I)+2.*(E1(67)-46.)
      CTBBT(I)=CTBB(I)+2.*(E2(67)-46.)+DBS
      RNFT(I)=E2(I)-(ENB(I)+DBS/2.)
      IF(I.EQ.67) GO TO 100
      IF(CTBBT(I).GT.CTBBT(67)) GO TO 600
      IF(RNFT(I).LT.RNFT(67)) GO TO 600
100   CONTINUE
      REACH=10.**(DBS/20.)*25.
      CNR=RNFT(9)
      TILT=FLOAT(KTILT)
      EQUAL=FLOAT(KEQNT)
600   CONTINUE
500   CONTINUE
900   CALL EXIT
      END
BOTTOM


QUIT

OK, SEG #TILTAMP
 REACH=        807.1316
 CNR=         43.63605
 TILT=         13.00000
 EQUAL=         7.000000

OK,
```

Reference

The Future of CATV Hybrids
G. Luettgenau and J. Powell, "SCTE Spring Engineering Conference" Boston, 1982.