CABLE REPEATER STATION DESIGN
USING FIXED GAIN BLOCK PREAMPLIFIER AND POWERAMPLIFIER

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1.0 Introduction

A cable repeater trunk amplifier station design in common use today consists of a flat (or nearly flat) frequency response, fixed gain preamplifier and poweramplifier, separated from each other and from the station input and output connectors by various loss networks. Refer to the block diagram in Figure 1.

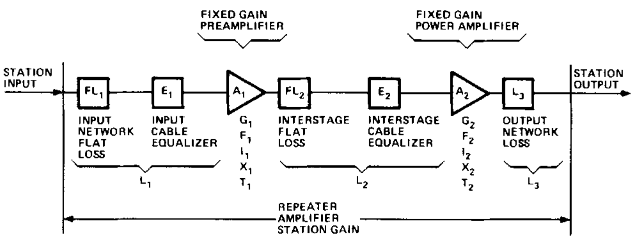

Figure 1. Repeater Station Block Diagram

The networks introducing loss provide the functions of cable equalization, gain and slope controls, bridging and AGC amplifier and power takeoff, and frequency division multiplex filters, all of which are necessary for cable repeater amplifier station performance. Apportioning the magnitude of loss in these networks in the station design should be done in a manner which, in the limit, allows the ultimate station noise figure to approach the value of the preamplifier (A_1) noise figure and the station distortion values to approach the values of the poweramplifier (A_2) distortion. Fixed gain amplifiers A_1 and A_2 will be referred to as IC (hybrid integrated circuit) amplifiers throughout the paper, although the analysis is general and applies to discrete component amplifiers as well.

The IC amplifier (A_1 and A_2) distortion (crossmodulation, second order intermodulation distortion, and triple beat) is usually specified by IC vendors for signal carriers at equal signal levels. Equal signal levels are used for convenience in measurement and also provide a convenient reference.

The signal levels at the inputs and outputs of A_1 and A_2 in the repeater amplifier are normally not flat because of the cable attenuation frequency response and the cable system block tilt many times used. The magnitude and frequency response of the input, interstage, and output loss networks L_1, L_2 and L_3 have very significant effects on the station noise and distortion performance. It is, therefore, difficult to predict and compare repeater amplifier station performance on the basis of various IC amplifier specifications based on flat level specifications. To solve this problem, a fast, simple means of predicting ultimate station performance from the known performance of IC amplifiers A_1 and A_2, system block tilts, and station equalizer and loss network values has been developed by deriving a number of normalized performance degradation factors. This paper will define and explain the use of these degradation factors, and show the advantages to be gained by their use. The degradation factors, when added to the flat level IC specifications at a given station operating level, provide the station distortion and signal-to-noise ratio specifications. A list of symbols and definitions of terms used in the paper is listed on page 13.

Three amplifier design problems which inspired the derivation and use of the degradation factors are summarized in Table I. The derivation and use of the Degradation Factors provides a simple, quick means of solving the three problems listed below and summarized in Table I.

1. Determine *station design* from fixed gain *IC amplifier specs* to *maximize station specs.*
2. Determine fixed gain *IC amplifier specs* and *station design* to *meet* required *station specs.*
3. *Determine station specs* for a *given station design* and *given fixed gain IC amplifier specs.*

Table I. Problems Solved with D-Factors

GIVEN	DETERMINE
1. IC Amplifier Specs	Station Design to Maximize Station Performance Specs
2. Station Performance Specs	IC Specs and Station Design to Meet Station Performance Specs
3. Station Design, and IC Amplifier Specs	Station Performance Specs

Ultimate station performance would be attained if the station noise figure were equal to the preamplifier noise figure F_1, and the station distortion were equal to or less than the poweramplifier distortion specifications I_2, T_2 and X_2. The D-Factor derivation assumes that any distortion contributed by the preamplifier is additive on a voltage basis (20 log). The station distortion could be less than the poweramplifier (A_2) distortion by the use of interstage distortion cancellation networks, particularly second order distortion. However, the distortion cancellation design approach is not in common use in present generation trunk station amplifier designs, and is not considered in this paper. Five D-Factor sets are derived for each particular trunk station design and level tilt. Each D-Factor is the number of dB that the trunk station performance deviates from the fixed gain IC amplifier specification measured at any flat level within the applicable dynamic range of the IC. This relationship is shown schematically in Figure 2.

The D-Factors (D_F and $D_{S/N}$) are precisely accurate at each frequency calculated for station noise figure and signal-to-noise figure. The D-Factors (D_I and D_T) are also accurate for the second order distortion product of each pair of frequencies calculated and each set of third order (triple beat) products calculated individually. The magnitude of the combination of second

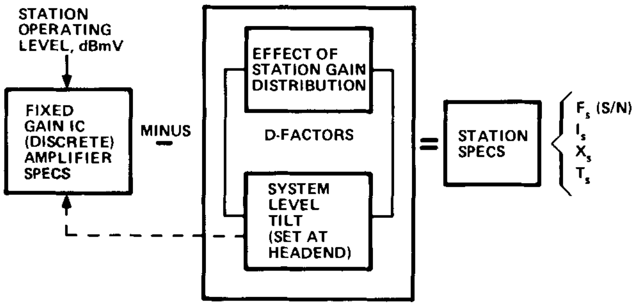

Figure 2. Relationship of IC Specs to Station Specs by D-Factors

and third order beats which occur at any single frequency for a given number of channels in the amplifier passband cannot be calculated in a practical way (Reference 6). The D-Factor (D_x) for crossmodulation in each channel calculated using the rule that "crossmodulation with n channels is [n-1] times that of a two channel measurement" is normally not accurate (Reference 9, 7) for broadband VHF amplifiers. A more precise answer for D_x can be obtained by measuring the actual fixed gain amplifiers with various block tilts and using these measured results as they apply to the calculation of D_x.

2.0 IC Amplifier Characteristics

Fixed Gain IC amplifier parameters are summarized in Table II below. The numbers used are those listed in the published TRW data sheet for the CA100 (preamplifier) and CA200 (poweramplifier) IC amplifiers.

Table II. Summary of IC Amplifier Specifications

PARAMETER	IC SPECIFICATION A_1 (preamp)	IC SPECIFICATION A_2 (poweramp)	STATION SPECIFICATION CATV MANUFACTURER
Gain (Fixed)	G_1 = 16.3 dB	G_2 = 16.3 dB	G_s = 22 dB (@ 300 MHz)
Frequency Response	Flat	Flat	Shaped to Equalize Cable Loss
Noise Figure	F_1 = 7.5 dB	F_2 = 10 dB	$F_s = F_1 + D_F$
Distortion, Flat Levels @ +50 dBmV			
Intermodulation (2nd) Order)(CH 2, 13, R)	I_1 = -68 dB	I_2 = -70 dB	$I_s = I_2 = D_I$
Crossmodulation (32 Channels)	X_1 = -52 dB	X_2 = -57 dB	$X_s = X_2 + D_x$
Triple Beat (3rd order)(CH 3 + CH 4 + CH A on 245 MHz)	T_1 = -73 dB	T_2 = -78 dB	$T_s = T_2 + D_T$

To attain bandwidth, input and output match, repeatability, gain stability and minimum cost, an IC amplifier with the devices available today must have more than one stage. At this time, it is difficult to design IC amplifiers with responses which equalize the various types of cables in use. It is for these reasons that the IC preamplifiers and poweramplifiers available today have a flat frequency response and approximately 16 dB of gain.

2.1 Fixed Gain Preamplifier

The preamplifier is designed for minimum attainable noise figure. The gain G_1 is fixed at approximately 16 dB. Preamplifier IM (I_1) distortion, crossmodulation distortion (X_1), and triple beat (T_1) is usually minimized by increasing the bias (which means more power consumption). An increase in bias tends to increase the preamplifier noise figure. Therefore, the trunk station designer should determine what preamplifier I_1, T_1 and X_1 he must have so that both power consumption and preamplifier noise figure can be minimized.

The station noise figure (F_s) design goal is to achieve an F_s which is limited only by the noise figure F_1 of the preamplifier. The station F_s is increased above F_1 by the loss networks in the station and also by the poweramplifier noise figure F_2.

2.2 Fixed Gain Poweramplifier

The station distortion design goal is to achieve station distortion (I_s, T_s and X_s) which is limited only by the distortion of the fixed gain poweramplifier (I_2, T_2 and X_2). The gain G_2 is fixed at approximately 16 dB. The IC poweramplifier is designed for minimum distortion (I_2, T_2 and X_2) and its noise figure F_2 is allowed to be higher than F_1. The minimum distortion is ultimately limited by the transistors (or active devices) used. The contribution of preamplifier distortion to the station distortion should be minimized by careful apportionment of the required loss networks in the station.

The station design challenge is to select the best compromise between conflicting requirements for the amount of loss apportioned to each loss network in the station (figure 1.0). Ultimate station noise figure should be limited by preamplifier noise figure and station distortion limited by poweramplifier distortion.

3.0 Relating Station Performance Parameters to Fixed Gain Preamplifier and Poweramplifier Parameters by D-Factors

Even though the fixed gain amplifier specifications such as those listed in Table II for A_1 and A_2 are known, the station specifications obtainable are not immediately obvious. The various loss networks required in the station, as shown in Figure 1, make it impossible to attain station specifications which are as good as the A_1 and A_2 specifications. To further complicate the prediction of the station specifications from the known specifications of A_1 and A_2, the station output level of each channel in the passband is normally not flat, but is tilted (block-tilted or linear-tilted).

A set of D-Factors[1] will be derived for a given set of station design requirements and system level tilts. The D-Factors are normalized such that they are independent of signal level. The fourth column of Table II lists the relationship between station and A_1, A_2 specifications by D-Factors. An outline of the station performance analysis leading to the D-Factors derivation and their use is shown in Figure 3. A station design example follows to show the type of results expected from the analysis. The numbers used are obtained from the analysis which follows later in the paper.

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[1]Because of the various functions required in a repeater amplifier station design, the station specifications will be worse than (or Degraded from) the Fixed gain A_1 and A_2 specifications; hence, the term D-Factor.

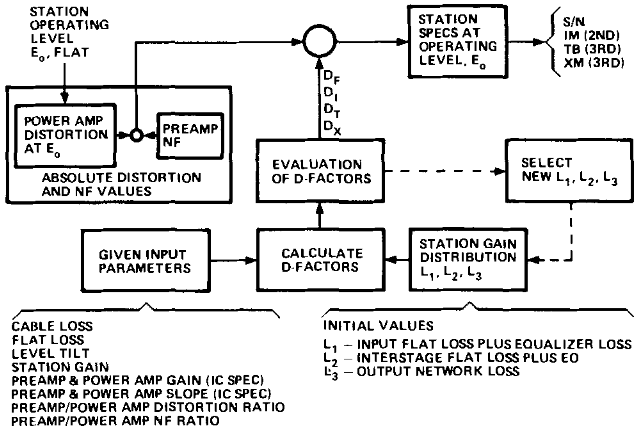


Figure 3. Station Performance Analysis Flow Diagram Using D-Factor Analysis

3.1 Design Example

GIVEN PARAMETERS

STATION	FIXED GAIN IC AMPLIFIERS (See Table II)
Cable Loss = 22 dB @ 300 MHz	G_1 = 16.3
G_s (Station Gain) = 22 dB @ 300 MHz	G_2 = 16.3
FL_1 = -1.5 dB	$F_2 - F_1$ = 2.5 dB
FL_2 = -3 dB	$I_1 - I_2$ = 2 dB
FL_3 = -1.5 dB	$X_1 - X_2$ = 5 dB
E_1 (input Equalizer) = 14 dB	$T_1 - T_2$ = 5 dB
Station Output Level = 31 dBmV	
Level Tilt[1] 4/2/0/0	

The D-Factors are calculated from the given parameters and the analysis procedures outlined in Figure 3 and derived in the following sections of this paper. The IC specs at +31 dBmV are summarized in the following table[2]. The D-Factors are added to the IC specifications to give the station specifications.

Note that the D-Factors are a function of frequency, so that D-Factors for a sufficient number of sets of frequencies are necessary to characterize the station performance across the passband of the amplifier. Note the difference of the station specs of column 4 versus the IC specs of column 2 in Table III.

The signal level of each channel applied to a station must be known in addition to the station noise figure F_s in order to determine the station signal-to-noise ratio (S/N). Since it is S/N and not N (noise) alone which is a measure of signal quality, an S/N degradation factor $D_{S/N}$ is also derived. The operating signal levels in a system requiring a cascade of a number of repeater stations assume considerable importance. The relationship between channel levels, which will be defined by a number of level tilt settings, effect not only station S/N, but also the station distortion. The significance of level (block) tilts will be discussed in Section 6.0. Since the D-Factor $D_{S/N}$ includes D_F, the D_F factor will be derived first, followed by the derivation of $D_{S/N}$ in Section 5.0.

Table III. Station Design Example Summary

Parameter	IC Specs (in dB) @ +31 dBmV, Flat Levels	D-FACTOR (in dB) Calculated from given Parameters Listed Above	Station Specs (in dB) @ +31 dBmV & 4/2/0/0 Block Tilt
NF	F_1 (300 MHz) = 7.5 F_1 (Chan 2) = 6.5	D_F (300 MHz) = 2.8 D_F (Chan 2) = 12.8	F_s (300 MHz) = 10.3 F_s (Chan 2) = 19.3
S/N	Input Level at 300 MHz is +9 dBmV	$D_{S/N}$ (300) = -2.7 $D_{S/N}$ (Chan 2) = -2.0	S/N (300 MHz) = +57.8 S/N (Chan 2) = +58.5
IM	I_2 (CH 2 + 13 R) = -89	D_I (CH 2 + 13 in R) = 3.4	I_s (CH 2 + 13 in R) = -85.6
TB	T_2 (CH 3 + 4 + A in Ch 0) = -116	D_T (CH 3 + 4 + A) = -3.8	T_s (CH 3 + 4 + A) = -119.8
XM	X_2 (CH 2, 32 Channels) = -95	D_x (CH 2) = 4.1	X_s (CH 2) = -90.9

4.0 Normalized Preamplifier Noise Figure Degradation, D_F

It has been previously stated that the ideal station noise figure (F_s) would be equal to the fixed gain preamplifier noise figure (F_1). In other words, D_F would be equal to zero in equation 4.1.

$$(4.1) \quad F_s = F_1 + D_F$$

The magnitude of D_F is a function of the following:

1. Input network loss (flat and sloped).
2. Interstage network loss (flat and sloped).
3. Poweramplifier to preamplifier noise figure ratio.

The input and interstage network losses are in part determined by G_1, G_2, and the station gain G_s. The magnitude of D_F will be different at maximum G_s compared to operating G_s. The noise figure F_1 of A_1 and F_2 of A_2 is normally a smooth function of frequency with today's devices, and is about 1.2 dB higher at 300 MHz compared to its value at 55 MHz. Also, L_1 and L_2 are functions of frequency, so that D_F is a function of frequency.

The noise figure at the IC preamplifier input terminals will be calculated first. The effect of input loss networks on the station noise figure will then be added to this result. Lower case symbols indicate numeric values and capital letters indicate dB values. The noise figure is independent of signal level and block tilt.

Referring to Figure 4, the expression for f_1' is

$$(4.2) \quad f_1' = f_1 + \frac{f_2' - 1}{g_1}$$

[1] Level Tilt notation defined in Section 6.0.

[2] This example assumes an IC distortion characteristic for which relative third order distortion (Crossmodulation and triple beat) decreases 2 dB for every 1 dB of level reduction and relative second order distortion decreases 1 dB for every 1 dB of level reduction. Note that the A_1 and A_2 distortion versus level characteristic must be defined in order to obtain a valid I_s, T_s and X_s.

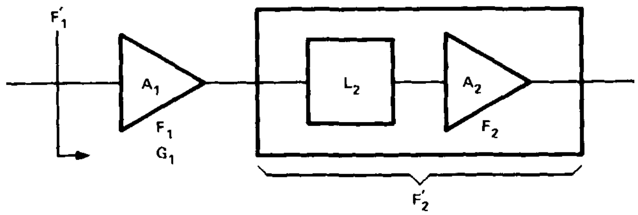


Figure 4. Block Diagram of Amplifiers Cascaded & Separated by Loss

The value of interstage loss L_2 is determined by G_s, G_1, and G_2 and the apportionment of loss between L_1, L_2 and L_3. L_2 adds to the noise figure F_2 on a dB for dB basis so that

$$(4.3) \quad F_2' = F_2 + L_2 \qquad \text{in dB}$$

The quantity l_2 is the numeric gain (loss) of the interstage network and is less than 1.0. Equation 4.2 becomes

$$(4.4) \quad f_1' = f_1 + \frac{(f_2/l_2) - 1}{g_1}$$

By factoring out f_1, the effect of f_2 and l_2 on f_1', the total noise factor, can be shown

$$(4.5) \quad f_1' = f_1 \left[1 - \frac{1}{f_1 g_1} + \frac{f_2}{f_1 g_1 l_2}\right] \qquad \text{Numeric}$$

$$(4.6) \quad f_1' = f_1 \left[\frac{f_1 g_1 - 1}{f_1 g_1} + \frac{k}{g_1 l_2}\right] \qquad \text{Numeric}$$

The ratio of f_2/f_1, denoted k, is normally greater than one, which means that the power amplifier noise factor has the effect of increasing f_1 as shown in equation 4.6. It is assumed here, without loss of generality, that F_1 versus frequency and F_2 versus frequency have the same relative values versus frequency.

Since $f_1 g_1 >> 1$ for most practical cases, equation 4.6 can be written

$$(4.7) \quad f_1' = f_1 \left[1 + \frac{k}{g_1 l_2}\right] \qquad \text{Numeric}$$

Equation 4.7 is a very important result. The interstage loss l_2 is a number less than one. The higher the interstage loss, the smaller l_2 and the larger f_1 becomes. Written in dB

$$(4.8) \quad F_1' = 10 \log f_1 + 10 \log \left[1 + \frac{k}{g_1 l_2}\right]$$

The factor D_F' is defined as the degradation of the preamplifier noise figure looking into the preamplifier (A_1) input terminals. It is a function of preamp gain, interstage loss; and the f_2/f_1 ratio.

$$(4.9) \quad D_F' = 10 \log \left[1 + \frac{k}{g_1 l_2}\right]$$

Preamplifier noise figure degradation as a function of interstage loss and A_2 to A_1 noise figure ratio is summarized in Table IV. Note that each dB of A_2 noise figure increase relative to F_1 is equivalent to a dB increase in interstage loss. Also note that the quantity l_2 is a function of frequency.

Table IV. Noise Figure Degradation for Diagram Shown in Figure 4.0 (Calculated Using G_1 = 15.5 dB)

INTERSTAGE LOSS L_2 in dB (at a Specific Frequency)	PREAMPLIFIER NOISE FIGURE DEGRADATION, D_F' ($K=F_2 - F_1$ in dB)			
	K=0	K=2	K=4	K=6
2	.17	.28	.44	.69
4	.28	.44	.69	1.06
6	.44	.69	1.06	1.59
8	.69	1.06	1.59	2.31
10	1.06	1.59	2.31	3.26
12	1.59	2.31	3.26	4.43
14	2.31	3.26	4.43	5.81
16	3.26	4.43	5.81	7.37

The noise figure degradation factor D_F' for k = 0, 2, and 4 is plotted in Figure 5 versus interstage attenuation.

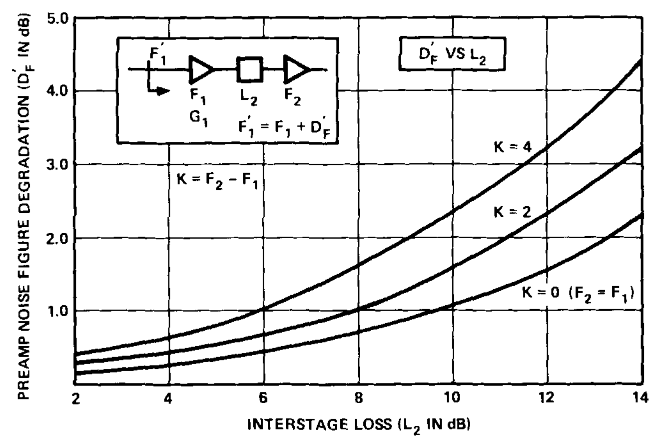


Figure 5. D_F vs L_2 (Interstage Loss) for G_1 = 15.5 dB

The station noise figure F_s is equal to F_1 in dB increased by the amount of loss of the input network (input equalizer loss plus flat loss).

$$(4.10) \quad F_s = F_1 + 10 \log \left[1 + \frac{k}{g_1 l_2}\right] + L_1 \qquad \text{in dB}$$

The normalized preamplifier noise figure degradation factor D_F, for the station, is therefore

$$(4.11) \quad D_F = 10 \log \left[1 + \frac{k}{g_1 l_2}\right] + L_1 \qquad \text{in dB}$$

The preamplifier noise figure degradation factor D_F is plotted in Figure 6 versus frequency for two different input equalizers, at operating station gain, and at maximum gain for an E_1 of 14 dB.

5.0 S/N Degradation Factor Derivation ($D_{S/N}$)

In an amplifier cascade design in which the amplifier gain at each frequency offsets the loss of the cable at each frequency — i.e., a unity gain system, the repeater station noise figure, input signal level (function of frequency), and the number of amplifiers in cascade define the cascade signal-to-noise (S/N) ratios.

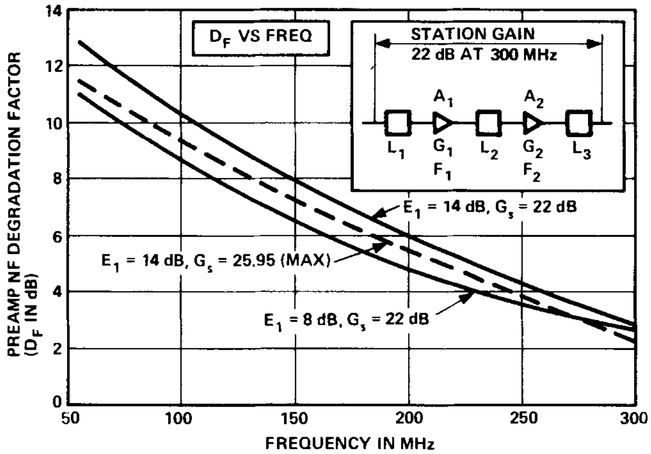
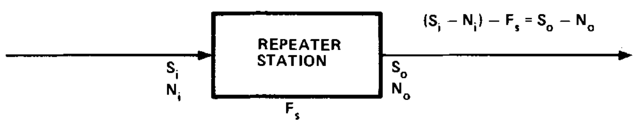


Figure 6. D_F versus Frequency using Design Example Parameters



F_s IS STATION NOISE FIGURE AND IS FREQUENCY DEPENDENT.
S_i IS THE INPUT LEVEL TO THE STATION AND IS FREQUENCY DEPENDENT.

Figure 7. Station S/N

The signal to noise ratio of an N amplifier cascade, assuming identical amplifiers, is:

$$S_i - N_i = S_i - \left[-59 + F_s + 10 \log_{10} N\right] \quad \text{in dB}$$

$$(5.1) \quad S_i - N_i = 59 + S_i - F_s - 10 \log_{10} N \quad \text{in dB}$$

-59 dBmV is the thermal noise threshold for a 4 MHz bandwidth in a 75 ohm system at 20°C.

For convenience, the S/N of a single station is analyzed and the results presented for a single station only. The 10 log N factor can be added later for specific system cascade lengths. The single station S/N is:

$$(S_i - N_i) = 59 + S_i - F_s$$

An S/N degradation factor is derived which serves a number of purposes. It is used to calculate station S/N as a function of station gain distribution and IC amplifier (A_1) noise figure. It normalizes the noise figure F_1 versus frequency characteristics of preamplifier A_1 to the highest frequency channel value. It normalizes the input signal S_i to the highest channel frequency signal level so that system analysis for all channels uses only this one signal level. The signal level normalization accounts for the cable loss versus frequency response and for the block tilt used.

The S/N degradation factor is denoted as $D_{S/N}$ and is a function of the following:

1. frequency
2. cable loss and cable system flat loss
3. F_1 versus frequency variation
4. poweramplifier to preamplifier noise figure ratio
5. interstage loss (flat and sloped)
6. input network loss (flat and sloped)
7. output network loss
8. block tilt
9. preamplifier and poweramplifier gain
10. station gain

The single repeater station S/N equation using the S/N degradation factor has the form:

$$(5.2) \quad S_i - N_i = 59 + S_i \text{ (at 300 MHz)} - F_1 \text{ (300 MHz)} + D_{S/N} \quad \text{in dB}$$

S_i is the input signal level in dBmV at the highest frequency, which for this analysis is 300 MHz.
F_1 is the noise figure of the IC preamplifier at 300 MHz.
$D_{S/N}$ is the signal to noise ratio degradation factor and is equal to D_F plus a level normalization factor, a noise figure normalization factor and a block tilt factor, B_F.

Figure 8 shows the general shape that input levels to a repeater station will have for flat level (solid curve) operation and block tilted level (dashed curve) operation. Reducing levels of lower frequency channels by block tilting levels lowers the S/N of these channels, but it will be shown in the sections on station distortion analysis that station distortion performance is improved. Block tilting levels provides a compromise between station S/N ratio on all channels and station distortion performance. Equation (5.3) defines $D_{S/N}$:

$$(5.3) \quad D_{S/N} = -10 \log \left[1 + \frac{k}{g_1 l_2}\right] - L_1 + \Delta A + B_F$$

Where ΔA is the difference in level in dB for each carrier frequency station input level compared to the station input level at 300 MHz.
B_F is the number of dB which must be subtracted from each channel for a given block tilt, compared to flat level operation.

The last two terms added to the expression for $D_{S/N}$, ΔA and B_F, could have been omitted since the effect they produce is taken into account in the S_i term of equation (5.1). However, by including them in the $D_{S/N}$ factor, the S_i term becomes a constant defined at one frequency. Since the $D_{S/N}$ factor contains other terms which vary with frequency, it is convenient to combine the ΔA and B_F terms with the D_F term. The term ΔA is positive and thereby increases the S/N. The term B_F will either be negative or zero at channel frequencies across the band. The cable system S/N will be highest when $D_{S/N}$ is most positive.

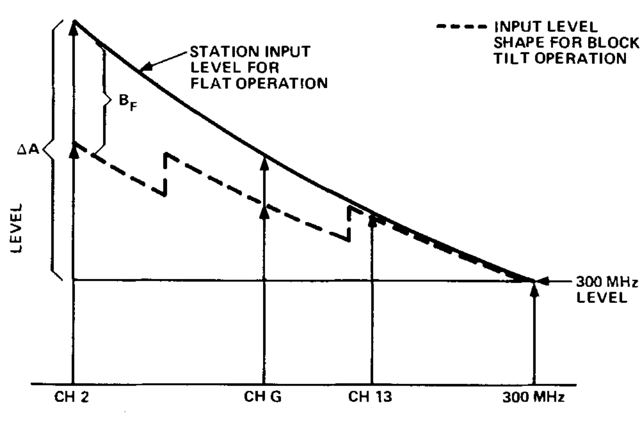


Figure 8. Station Input Level Relationships

5.1 Example of $D_{S/N}$ Application

The values of $D_{S/N}$ plotted in Figure 9 were calculated using the design parameters given in Section 3.0. The $D_{S/N}$ for flat level (0/0/0/0/) operation is plotted in Figure 9a, and a block tilt level (4/2/0/0) condition in Figure 9b. A set of $D_{S/N}$ values for input equalizer values of 8 dB and 14 dB is shown in each figure. Values of $D_{S/N}$ for Channels 2, 6, and 13 for two level tilt conditions and two input equalizer values are taken from the curves shown in Figure 9 (a & b) and listed in the table below. Also listed in the table are station S/N for an A_1 noise figure of 7.5 dB (300 MHz) and S_i (input level @ 300 MHz) of +9 dBmV. The S/N is evaluated from equation 5.2.

5.2 $S_i - N_i = 59 - F_1\ (300\ \text{MHz}) + S_i\ (300\ \text{MHz}) + D_{S/N}$

CHANNEL	Level Tilt 0/0/0/0 Input EQU=14 dB		Level Tilt 4/2/0/0 Input EQU=8 dB	
	$D_{S/N}$	S/N	$D_{S/N}$	S/N
2	1.98	62.5	-.14	60.4
6	1.38	61.9	-.83	59.7
13	1.09	59.4	-.14	60.4

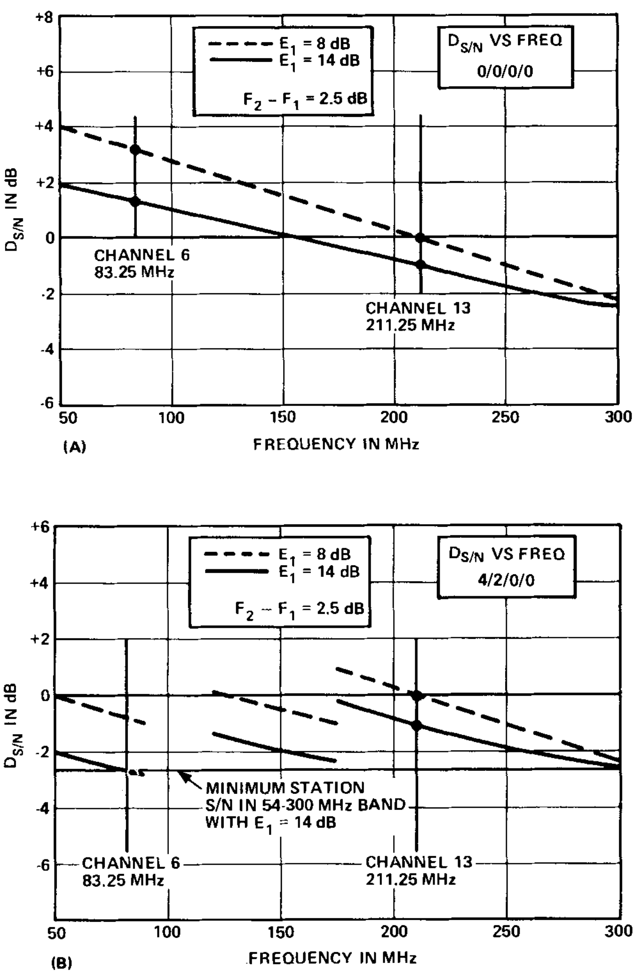


Figure 9. Comparison of $D_{S/N}$ versus Frequency For Two Level Tilts and Two Different Input Equalizers

The station design with a 14 dB input equalizer and operation with flat levels results in a better S/N (62.5 versus 60.4) at Channel 2 and worse S/N (59.4 versus 60.4) at Channel 13 than the station design with an 8 dB input equalizer and block tilted 4/2/0/0 levels. Choice of level tilt obviously has a significant effect on station S/N.

The system operator has some leeway in selecting a trunk station level tilt, but before deviating from the station manufacturer's recommended level tilt values, he must understand the consequences on the station S/N and distortion parameters.

6.0 Signal Level Relationships (Block Tilts)

The amplifier cascade design is a unity gain design. The gain of each repeater amplifier station at each frequency in its passband is set to exactly offset the loss which precedes it. Therefore, the relationship between levels at each frequency in the passband at the output of each repeater station will be identical to the level relationship set at the headend, modified only by the response flatness of the amplifier cascade. An example is shown in Figure 10.

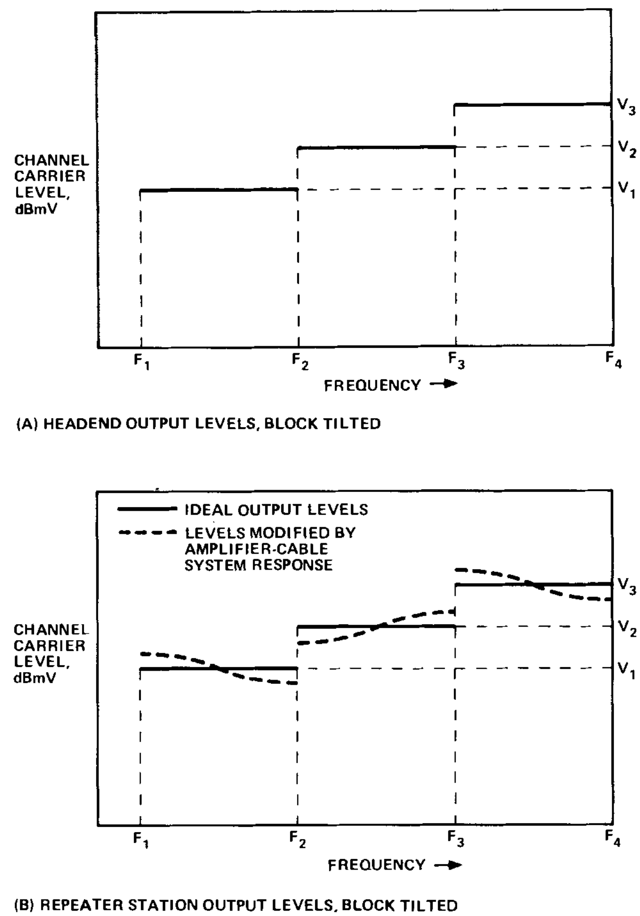


Figure 10.

The level at the repeater station output normally refers to the levels of the channel carriers in the highest frequency band block. In Figure 10, the level V_3 for channel carriers between frequencies f_3 and f_4 is referred to as the operating level of the station. The passband of the amplifier of Figure 10 is $f_4 - f_1$ and is divided into three frequency bands of blocks, $f_4 - f_3$, $f_3 - f_2$, and $f_2 - f_1$. When the level of each of the bands or blocks of carrier frequencies is set to a constant level, the levels are described as "block-tilted". Choice of the magnitude of difference in levels between frequency blocks ($V_3 - V_2$ and $V_2 - V_1$) and number of blocks is based on obtaining the result which gives the best compromise to maximize system S/N and minimize system distortion. A given repeater amplifier design may dictate the use of a specific block tilt to be used in order to optimize system performance. However, many times enough station performance margin is available so that the choice of a number of different "block tilts" can be used with a given repeater station design without sacrificing system performance.

The most important reason for selecting and operating with amplifier station output levels which are *not equal* at each frequency in the passband is that the amount of signal power at the station output can be reduced. Less signal power results in many lower magnitude distortion products, although some distortion product magnitudes will increase. Offsetting the advantage of reduced level of distortion products by use of a level tilt is a decrease in signal-to-noise ratio on those channels at reduced levels. However, consider that the level of channel 2 carrier frequency is attenuated by the cable approximately 13 dB less than a carrier frequency at 300 MHz for 22 dB spacing at 300 MHz. Therefore, reducing the levels of the low frequency channels can be down without reducing the S/N of low frequency channels relative to higher frequency channels. Also, the noise figure of the active amplifying devices have somewhat lower noise figures at lower frequencies relative to higher frequencies.

6.1 Shorthand Notation for Block Tilts in Use

The frequency band from 54 to 300 MHz is commonly divided into four bands.

Low band	54-88 MHz	CH 2-6	5 channels
Mid band	120-174 MHz	CH A-I	9 channels
High band	174-216 MHz	CH 7-13	7 channels
Super band	216-300 MHz	CH J-CH W	14 channels

Using the superband block of frequencies for the reference level, the block tilt (shorthand) notation takes the form:

4 / 2 / 0 / 0

Low Band — Mid Band — High Band — Super Band

The high band levels are the same as the super-band levels, mid-band levels are 2 dB below the super-band levels, and low-band levels are 4 dB below super-band levels. A summary of block tilts specified for trunk stations taken from a number of manufacturers' data sheets in the past year are summarized in Table V.

Table V. Examples of Block Tilts Published in Manufacturer's Data Sheets

COMPANY	BLOCK TILT
Anaconda	4/2/0/0
Jerrold	3/3/0/0
Theta-Com	7/4/2/0
Scientific Atlanta	4/2/2/0
Magnavox	0/0/0/0 (No block tilt)

6.2 General Comments on Distortion Product Accumulation in Broadband VHF Amplifiers.

Care must be exercised in attempting to analytically predict second order intermodulation product, triple beat (third order) product, and crossmodulation product accumulation in a single channel in a broadband VHF amplifier as a function of channels and amplitudes of individual channels. The only practical way to evaluate the cumulative distortion products of an amplifier station is by measurement. However, calculation of the magnitude of single second and third (triple beat) order beat products can be done precisely, and thereby provide considerable insight into the station design.

For reasons pointed out in both references 6 and 7, broadband VHF amplifiers used in CATV repeater stations have transfer characteristics which in general, invalidate the rule that "n channel crossmodulation distortion is n-1 times the 2 channel crossmodulation value". However, because measurement on a fixed gain amplifier in common use today does follow the "n-1 rule" for crossmodulation accumulation in channel 2 for trunk station application, a B_x factor for channel 2 is analytically derived. Obtaining a B_x factor must normally be done by measurement first, followed by analysis. Table VI contains a summary of the methods of analysis for these types of distortion products.

Table VI. Amplifier Distortion Characteristics Analysis Methods

DISTORTION PRODUCT AS FUNCTION OF LEVEL (Flat, Block, Linear) TILT	METHOD OF ANALYSIS
2nd Order → 2-Channel (Single Beat) 2nd Order → Accumulation (n-channel)	Analytical Measurement in Each Channel
Triple Beat → 3-Channel (Single Beat) Triple Beat → Accumulation (n-channel)	Analytical Measurement in Each Channel
Crossmodulation → Accumulation (n-channel) Crossmodulation → Accumulation (n-1 times 2-channel)	Measurement in Each Channel Analytical

6.3 Second Order IM (A ± B) Block Tilt Factor, B_I

A flat gain amplifier operated with a pair of equal level signals produces second order beats (A + B and A – B) which, if in the passband of the amplifier, interfere with a third signal. The ratio of second order beat to the signal for flat output levels is different than the ratio obtained when the amplifier is operated with linear or block tilted levels. The difference in second order IM ratio (in dB) resulting for tilted level operation versus flat level operation for the same amplifier is defined by a block tilt factor B_I. Values of B_I for six pairs of channel carrier frequencies and three level tilts are summarized in Table VI.

As an example, for the numbers listed in Table VII, the 2nd order IM product of Channel 13 minus (—) Channel G producing a beat which interferes with Channel 2 is 2 dB worse when operating with a 4/2/0/0 block tilt than with no block tilt (0/0/0/0) or flat levels. However, the IM ratio for the Channel 2 plus (+) Channel G beat in Channel 13 provides a 6 dB improvement for the 4/2/0/0 block tilt condition.

The magnitude of the combination of total number of second order beats occurring at a specific frequency for a specific system application and given number of channels can practically be determined by measurement only. Second order product addition depends on magnitude *and phase* of each product.

Table VII. Block Tilt Factor B_I For Six Pairs of Channel Carrier Frequencies and Three Block Tilts.

RELATIVE IM DISTORTION PRODUCT (TV CHANNELS)	BLOCK TILT FACTORS B_I IN dB		
	4/2/0/0	3/3/0/0	0/0/0/0
R – 13 (in Ch 2)	+4	+3	0
13 – G (in Ch 2)	+2	0	0
13 – 2 (in Ch G)	–2	0	0
2 + G (in Ch 13)	–6	–6	0
13 + 2 (in Ch R)	–4	–3	0
R – 2 (in Ch 13)	–4	-3	0

6.4 Third Order [Triple Beat (A ± B ± C)] Block Tilt Factor, B_T

The B_I factor is calculated considering the level difference of two frequencies and the level difference between that of the beat frequency and that of the frequency with which it interfaces. The B_T factor is calculated in a similar manner, except that the level difference of three frequencies rather than two frequencies is accounted for. A third order IM (2A ± B) factor could also be calculated, but is not included in this paper.

Triple beat products are considered to be a limiting parameter in 30+ channel systems with today's amplifiers. One complication of the triple beat problem is the sheer number of possible products for 30+ channel operation. It is therefore naive to assume that the calculation of a few triple products define an amplifier station's triple performance. However, calculation of the triple beat product amplitude for a few products for a given level tilt relative to flat level operation will indicate a trend, indicating whether triple beat magnitude reduction is possible by the use of level tilts. A more useful and detailed analysis of this problem must be reserved for another paper.

B_T factors for a few triple combinations and level tilt conditions are summarized in Table VIII.

Table VIII. Triple Beat Block Tilt Factors as Function of Block Tilt

TRIPLE BEAT PRODUCTS LISTED BY CHANNEL COMBINATIONS	TRIPLE BEAT BLOCK TILT FACTOR B_T IN dB		
	4/2/0/0	0/0/0/0	3/3/0/0
3 + 4 + A in 0	-10	0	-9
A – J + Q in 5	+2	0	0
G + S – J in 13	-2	0	-3
13 + R – J in Q	0	0	0
7 – 13 + L in G	+2	0	+3

A negative number in the table indicates a lower amplitude beat at the station output compared to flat level operation and a positive number indicates that the triple beat product for that specific three channel beat product is higher (or worse) than that resulting with flat level operation.

6.5 Crossmodulation Block Tilt Factor, B_x

The effect of tilted levels and fixed gain preamplifier crossmodulation distortion contribution for a given number of channels must be known in order to determine station XM from the given flat level XM specification of the fixed gain preamplifier and poweramplifier. Remembering the precautionary comments of Section 6.2, and applying the "n-1 XM accumulation" rule, a B_x factor for channel 2 is derived. The station level tilt factor, B_x, defines the difference between the XM produced with flat levels, compared to the XM expected with tilted levels for a given number of channels in a given channel. The B_x term is then included in the XM D-factor, D_x, for a given station design.

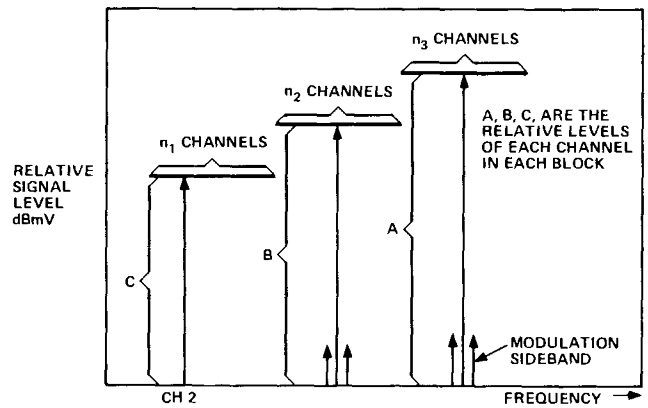


Figure 11. Block Tilted Levels Versus Frequency

The crossmodulation at the level of channel 2 for block tilted levels compared to flat levels is given by equation 6.5.1 (assuming equal modulation percentage on each modulated channel.)

$$(6.5.1)\quad m_2 = \frac{(n_1 - 1) + n_2\,(b/c)^2 + n_3\,(a/c)^2}{n - 1} \qquad \text{Numeric}$$

where $n_1 + n_2 + n_3 = n$ (total number of channels)

To obtain the B_x factor for channel 2 compared to flat level operation at level A (which would be the flat level condition):

$$(6.5.2)\quad B_x\ (\text{Channel } 2) = 20 \log (m_2) - (A\text{-}C)$$

As an example of the use of equation 6.5.2, consider the following:

Seven high band channels at level A, 5 dB above five (5) low band channels at level C.

$n_1 = 5$, $n_3 = 7$, A/C = 10 exp (5/20) = 1.79

Substituting these values in (6.5.1)

$$m_2 = \frac{(5-1) + 7\,(1.79)^2}{(12-1)} = \frac{4 + 22.4}{11} = 2.4$$

Evaluating equation 6.5.2

B_x (Channel 2) = 20 log (2.4) – 2 (5) = -2.4 dB

Operating with 12 channels, 5 of the channels 5 dB below level A, results in channel 2 XM 2.4 dB below the XM value of channel 2 when all 12 channels are at level A.

Using equations 6.5.1 and 6.5.2, the B_x factor for channel 2 is calculated and summarized in the table for a number of block tilt and number of channel conditions:

Table IX. XM Block Tilt Factor B_x
(Calculated using n-1 rule.)

					B_x CH 2
	12 CHANNELS				
	LOW		HIGH		
No. Chan.	5		7		
Relative Lev.	-3 dB		0 dB		-1.7 dB
	-5 dB		0 dB		-2.5
	21 CHANNELS				
	LOW	MID	HIGH		
No. Chan.	5	9	7		
Relative Lev.	-3	-3	0		-3.4
	-5	-2	0		-3.1
	35 CHANNELS				
	LOW	MID	HIGH	SUPER	
No. Chan.	5	9	7	14	
Relative Lev.	-3	-3	0	0	-1.8
	-4	-2	0	0	-1.6

7.0 Normalized Poweramplifier Second Order IM Distortion Degradation Factor, D_I

The quantity D_I is derived so that repeater station 2nd order IM distortion as a function of station gain distribution and block tilt can be easily related to the flat level IC preamplifier and poweramplifier IM distortion specifications. One D_I is calculated for each A + B and/or A – B product considered necessary to define the station IM performance across the passband.

(7.1) $I_s = I_2 + D_I$ in dB

The quantity I_s is the relative 2nd order IM for a pair of frequencies interfering with a third frequency at the station output. The quantity I_2 is the relative 2nd order IM ratio in dB for the same pair of frequencies at equal levels at the poweramplifier output.

D_I, the degradation factor, is independent of the absolute station output signal levels and is a function of the following:

1.0 Preamplifier IM distortion relative to poweramplifier distortion.
2.0 Preamplifier gain and poweramplifier gain.
3.0 Interstage network loss (flat and sloped), a function of station gain
4.0 Block tilt.

Two assumptions are made in the derivation of D_I which do not affect the result in general. First, the IM distortion specification for each pair of frequencies of the flat preamplifier is assumed to be related to the IM distortion specification for the same pair of frequencies of the flat poweramplifier by a constant number of dB. Second, the IM distortion of the preamplifier is assumed to add in phase with the IM distortion of the poweramplifier. This represents a worst case condition for the total IM distortion of the repeater station. Second order IM addition is phase and amplitude sensitive so that in the actual hardware design, some degree of cancellation will occur, either by accident or by design.

In the following analysis, lower case letters indicate numeric, and upper case letters indicate dB. The total repeater station IM distortion for a given pair of signals is the sum of the IM distortions generated by all sections of the amplifier. Assuming that the only sources of IM distortion products are the preamplifier and poweramplifier, then the station distortion is:

(7.2) $20 \log_{10} (i_1 + i_2) = 20 \log_{10} [i_2 (1 + i_1/i_2)]$

$i_1 = 10 \exp (I_1/20)$ Preamplifier IM distortion

$i_2 = 10 \exp (I_2/20)$ Poweramplifier IM distortion

The terms I_1 and I_2 represent the second order distortion ratio in dB for a given pair of frequencies as measured for the preamplifier and poweramplifier with flat output levels. Modification to the IM ratios for block tilt operation compared to flat level will be added later.

(7.3) The station second order IM distortion can be written as:

$$I_s = \underbrace{20 \log (i_2)}_{\text{Poweramplifier IM Distortion}} + \underbrace{20 \log (1 + i_1/i_2)}_{\text{IM Distortion Contributed by Preamplifier}}$$

The numeric ratio (i_1/i_2) may be solved by working with the amplifier constants in dB, since the numeric ratio can be written:

(7.4) $i_1/i_2 = 10 \exp \quad (I_1 - I_2)/20$

where I_1 and I_2 are in dB.

The difference between preamplifier and poweramplifier IM as measured with flat levels at the same level, is assumed equal to a constant D.

(7.5) $D = I_1 - I_2$ in dB (a positive number).

The quantity D is usually positive, since the preamplifier IM distortion is normally worse (less negative) than the poweramplifier IM distortion. If D = 0 dB, the preamplifier IM distortion is equal to the poweramplifier IM distortion.

Relative second order IM distortion is proportional to signal level, i.e., two signals whose levels are each changed by 1 dB produce a relative IM product change of 1 dB. As an example and to prepare for the analysis which follows, consider a poweramplifier with flat output levels preceded by a flat loss network and a flat output preamplifier, as shown in Figure 12.

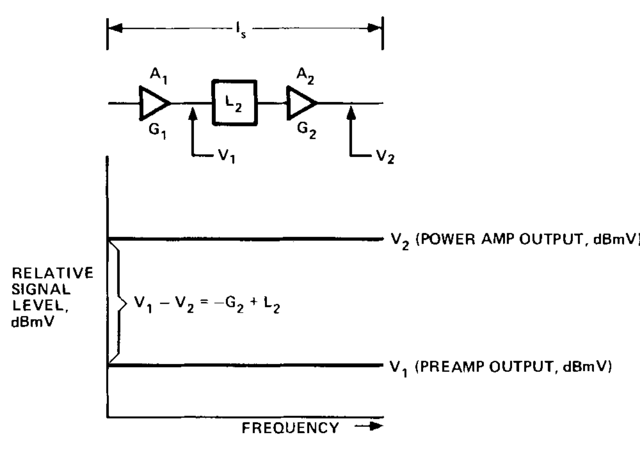


Figure 12. Flat Output Preamplifier and Poweramplifier

The ratio of preamp (A_1) to poweramp (A_2) distortion can be written:

$$(7.6)\quad (I_1 - I_2) = \underbrace{(V_1 - V_2)}_{\substack{\text{Due to level}\\ \text{difference of}\\ A_1 \text{ and } A_2}} + \underbrace{D}_{\substack{\text{Due to IM}\\ \text{difference of}\\ A_1 \text{ and } A_2}}$$

The preamp (A_1) output level V_1 is G_2 dB below the poweramp (A_2) output level V_2 increased by the interstage loss L_2. Equation 7.6 can then be written as:

$$(7.7)\quad (I_1 - I_2) = -G_2 + L_2 + D \qquad \text{in dB}$$

The station distortion I_s shown in Figure 12 can then be written:

$$(7.8)\quad I_s = I_2 + \underbrace{20\log\left[1 + 10\exp\left[(I_1 - I_2)/20\right]\right]}_{\text{Degradation of Poweramp IM Distortion Spec}}$$

In a cable repeater station, neither amplifier A_1 or A_2 may operate with flat levels. The poweramp (A_2) may operate with a level tilt, which has been set at the cable system headend, and the preamp (A_1) levels will be sloped as a result of cable equalization in the station.

It has been instructive to solve the flat level A_1, A_2, and L_2 problem described by equation (7.7). Using this equation as a building block, the final solution is obtained by the following procedure:

Step 1: Solve for the station ($I_1 - I_2$) ratio by considering the actual frequency response of the preamp A_1 output levels. The amount of cable loss, and cable equalization placed before the preamp A_1 will define this level relationship, which is sketched in Figure 13. The term L_2 in equation (7.7) must be modified to account for the sloped levels at preamp A_1 output. If the term L_2 in equation (7.7) is the interstage insertion loss at the frequency which is interfered with by the IM product, then a term ΔL must be added to the equation to account for the level differences of the frequencies at the preamp output.

Equation 7.7 now becomes:

$$(7.9)\quad (I_1 - I_2) = -G_2 + L_2 + \Delta L + D \qquad \text{in dB}$$

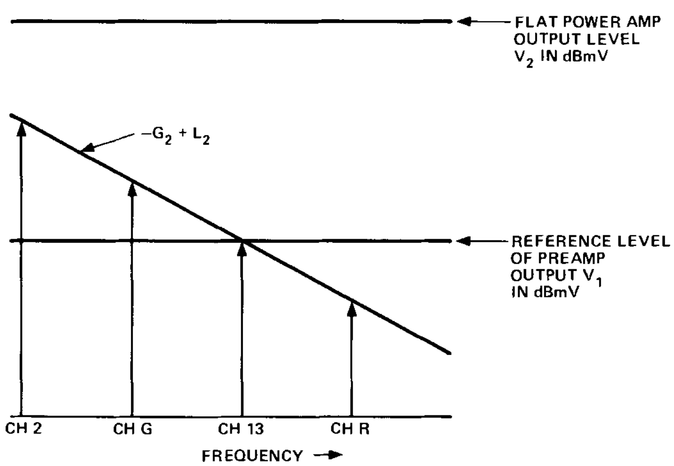


Figure 13. Sloped A_1 Output Levels When A_2 Output Levels are Flat

Step 2: Substitute the value of ($I_1 - I_2$) defined by equation (7.9) in 7.8, add the system block tilt factor B_I, and add L_3 which is any loss between A_2 output and station output terminals (connector).

The station IM ratio for a given pair of frequencies is then

$$(7.10)\quad I_s = I_2 + \underbrace{20\log\left[1 + 10\exp\left(\frac{(I_1 - I_2)}{20}\right)\right] + B_I + L_3}_{D_I}$$

The difference between station IM distortion and A_2 IM distortion for a given pair of frequencies is then:

$$(7.11)\quad D_I = 20\log\left[1 + 10\exp\left(\frac{(I_1 - I_2)}{20}\right)\right] + B_I + L_3 \quad \text{in dB}$$

where ($I_1 - I_2$) is determined by evaluating equation (7.9) for a given set of station design parameters.

Using A_1 and A_2 specifications and station design parameters given in Section 3.0, equation (7.11) was evaluated and the results plotted in Figure 14 for a flat level system and Figure 15 for a block tilt (4/2/0/0) system. The $D_{S/N}$ factor for channels 2, G, and 13 are also included in Figures 14 and 15 to show the relationship between D_I and $D_{S/N}$ as a function of input equalizer value. Specific values will be taken from these curves and used in the summary (Section 9.0).

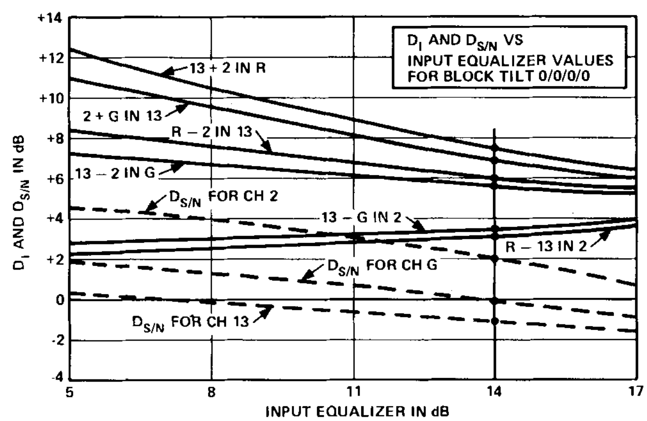


Figure 14. D_I and $D_{S/N}$ versus Input Equalizer Values for Block Tilt 0/0/0/0

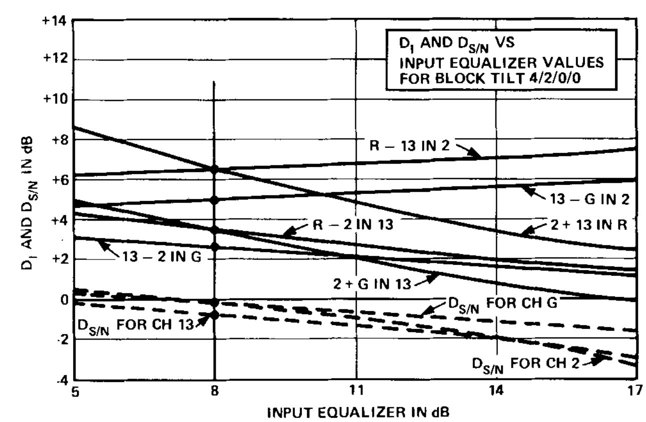


Figure 15. D_I and $D_{S/N}$ versus Input Equalizer Values for Block Tilt 4/2/0/0

8.0 **Normalized Poweramplifier Triple Beat (A ± B ± C) Distortion Degradation Factor, D_T**

A D_T factor for a few sets of A ± B ± C beats are calculated for the A_1 and A_2 specifications and station design parameters given in Section 3.0. The equations used for the D_T factor calculation are similar to those used for the D_I factor, with the exception that the relative levels of three frequencies causing a beat interfering with a fourth frequency are determined compared to relative levels of two frequencies causing a beat interfering with a third frequency. The station triple beat product in dB for three frequencies is:

(8.1) $T_s = T_2 + D_T$

Assuming that the only sources of triple beat distortion are A_1 and A_2:

(8.2) $20 \log (t_1 + t_2) = 20 \log [t_2 (1 + t_1/t_2)]$

$t_1 = 10 \exp (T_1/20)$ A_1 distortion

$t_2 = 10 \exp (T_2/20)$ A_2 distortion

The station triple beat distortion can be written as:

(8.3) $T_s = \underbrace{20 \log (t_2)}_{\text{A}_2\text{ TB Distortion}} + \underbrace{20 \log (1 + t_1/t_2)}_{\text{TB Distortion Contributed by A}_1}$

The ratio of A_1 to A_2 triple beat distortion in dB is:

(8.4) $T_1 - T_2 = (2) (-G_2 + L_2) + \Delta L + T$

where: T is the difference between A_1 and A_2 triple beat product amplitude specification measured at the same flat levels

ΔL is a factor which accounts for the effect of sloped A_1 output levels on T_1

L_2 is the interstage network attenuation at the channel frequency interfered with by the triple beat frequencies

The station triple beat ratio for a set of three frequencies then becomes, using the value of $(T_1 - T_2)$ evaluated in (8.4).

(8.5) $$T_s = T_2 + 20 \log \left[1 + 10 \exp \left(\frac{(T_1 - T_2)}{20}\right)\right] + B_T + 2L_3$$

The factor B_T accounts for the effect of any level block tilt at the station output. The factor (2) appears in both equations (8.4) and (8.5) because of the assumption that the triple beat product changes 2 dB for every 1 dB of level change of the three beat producing frequencies. The D_T factor is:

(8.6) $$D_T = 20 \log \left[1 + 10 \exp \left(\frac{(T_1 - T_2)}{20}\right)\right] + B_T + 2L_3$$

Values of D_T for the beat products listed in Table VIII are calculated and listed in Table X in Section 10.

9.0 **Normalized Poweramplifier Crossmodulation Distortion Degradation Factor, D_X**

The D_I and D_T factors for a given set of channel frequencies are easily calculated, becoming cumbersome only by the number of sets required to describe station performance over its entire passband. These factors do not consider the accumulation effect of beats at a given frequency. The D_X factor, however, must include the accumulation of crossmodulation from each channel onto a given channel carrier to be of any use. For the reasons discussed in Section 6.2, the method of calculating n-channel XM by assuming that n-channel XM is (n-1) times two channel XM may not be accurate. However, this calculation method does result in the maximum value of XM distortion for n-channel XM accumulation, if the two channel XM is pure AM (Ref. 6). As has been previously stated, channel 2 XM for one type of IC amplifier (A_1 and A_2) in common use today, can be analyzed fairly accurately by using the n-1 accumulation rule. Just remember that the following analysis must be applied with good judgment and only after the A_1 and A_2 XM characteristics have been adequately defined by XM measurements.

The D_X factor for channel 2 is calculated using equations similar to those used for calculation of D_T (equations 8.1 thru 8.6).

(9.1) $X_s = X_2 + D_X$ (One for each channel.)

Assuming that the only sources of XM distortion are A_1 and A_2.

(9.2) $20 \log (x_1 + x_2) = 20 \log x_2 (1 + x_1/x_2)$

$x_1 = 10 \exp (X_1/20)$

$x_2 = 10 \exp (X_2/20)$

The station XM distortion can be written as:

(9.3) $X_s = 20 \log (x_2) + 20 \log (1 + x_1/x_2)$

The ratio of A_1 to A_2 XM distortion is:

(9.4) $X_1 - X_2 = 2 (-G_2 + L_2) + B_x' + D_x'$

D_x' is the ratio of A_1 to A_2 XM measured at the same flat level

B_x' is a factor accounting for the sloped preamp (A_1) output levels. The magnitude of this factor varies as a function of input equalizer value and number of channels.

L_2 is the relative level of the channel for which D_x is being calculated.

A simplifying assumption is made to reduce the complexity of the B_x' factor by dividing the sloped A_1 output levels into average level flat blocks as sketched in Figure 16. Calculated

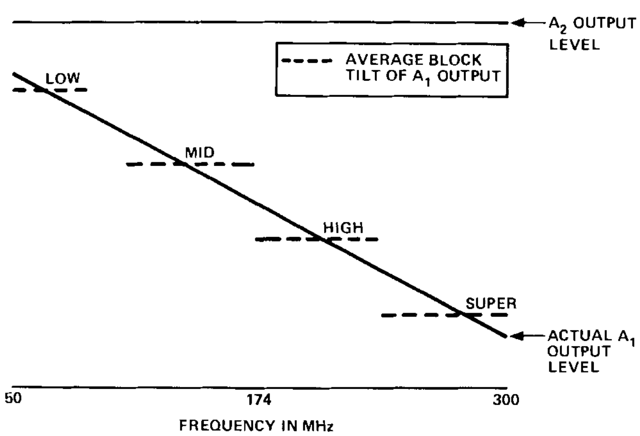


Figure 16. Approximation of Sloped A_1 Output Level by Flat Level Blocks

relative preamp output levels for two input equalizer and block tilt values and the design parameters of Section 3.0 are shown in Figure 17.

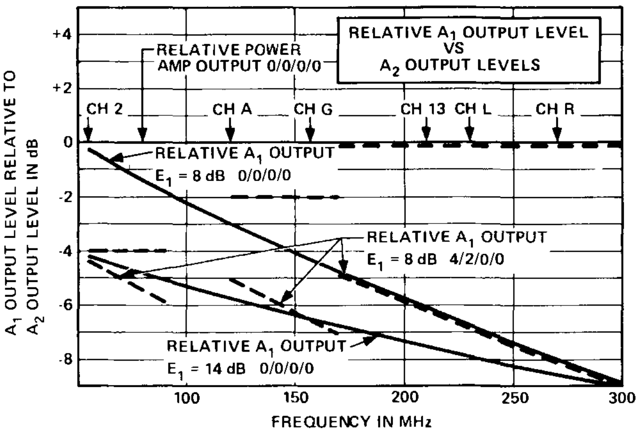


Figure 17. Relative Preamp Output Level versus Frequency

The station XM is now described by:

$$(9.5)\quad X_s = X_2 + 20 \log \left[1 + 10 \exp\left(\frac{(X_1 - X_2)}{20}\right)\right] + B_X + 2L_3$$

The B_X factor accounts for the effect of any level block tilt at the station output. The factor (2) appears in both equations (9.4) and (9.5) because of the assumption that the XM ratio changes 2 dB for every 1 dB level change of every channel. The D_X factor is:

$$(9.6)\quad D_X = 20 \log \left[1 + 10 \exp\left(\frac{X_1 - X_2}{20}\right)\right] + B_T + 2L_3$$

D_X factor is evaluated for channel 2 using design parameters in Section 3 and listed in Table X of Section 10.

10.0 SUMMARY

The D-factors calculated for two station designs, differing only by the values of input and interstage equalizers and two block tilts are summarized in Table X. The station, A_1, and A_2 parameters used in the calculations are those given in Section 3.0. Note that both station gain distribution (input, interstage and output loss networks) and system block tilt are interrelated and have a very significant effect on the station S/N and distortion.

The station specifications for the design parameters listed in Section 3 and in Table X can now be easily calculated by adding the D-factors listed in Table X to the IC amplifier specifications at the station operating level selected.

Comparison of the two columns of D-factor numbers in Table X, indicates that each design has its strengths and weaknesses. The final design selection requires more extensive analysis of the D_T factors and also inclusion of measured weighting factors in the analysis to account for the distortion product versus frequency characteristic of the IC amplifiers.

Table X. Summary of D-Factors Calculated for Parameters Given in Section 3.0

D-FACTOR PARAMETERS	INPUT EQU. 14 dB BLOCK TILT 0/0/0/0	INPUT EQU. 8 dB BLOCK TILT 4/2/0/0
D_F		
2	12.8	10.9
G	7.7	6.3
13	5.7	4.7
W	2.8	2.6
$D_{S/N}$		
2	2.0	-.1
G	-.1	-.7
13	-1.1	-.1
W	-2.7	-2.5
D_I		
R - 13 in 2	3.2	6.5
13 - G in 2	3.6	5.0
13 - 2 in G	5.7	2.6
2 + G in 13	7.0	3.4
2 + 13 in R	7.4	6.5
R - 2 in 13	6.0	3.5
D_T		
3 + 4 + A in 0	8.3	-3.8
A - J + Q in 5	4.9	7.1
G + S - J in 13	5.3	3.9
13 + R - J in Q	5.3	5.9
7 - 13 + L in G	5.2	8.7
D_X		
Chan 2	5.9	5.5

11.0 CONCLUSION

An analysis method using normalized D-factors for relating the noise and distortion parameters of a fixed gain preamplifier and poweramplifier to the cable repeater trunk station amplifier has been developed. The station design configuration and level tilt limit the noise and distortion performance obtainable from any given fixed gain IC amplifier. Use of the D-factors by the equipment manufacturer, IC manufacturer, and end user provides an aid in analyzing the relationships between IC amplifier performance specifications and trunk amplifier station performance specification. It must be noted that the final station design is determined by combining both measured and analytical results.

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SYMBOLS DEFINITIONS

A_1 Fixed gain preamplifier, could be IC or Discrete component design.

A_2 Fixed gain power amplifier, could be IC or Discrete component design.

G_1 Gain of A_1 in dB

G_2 Gain of A_2 in dB

G_s Station Gain

F_1 Noise Figure of A_1 in dB

f_1 Noise factor of A_1, numeric

F_2 Noise Figure of A_2 in dB

f_2 Noise factor of A_2, numeric

F_s Noise Figure of Station in dB

I_1 Carrier to second order intermodulation product ($A \pm B$) ratio of A_1 in dB

I_2 Carrier to second order intermodulation product ($A \pm B$) ratio of A_2 in dB

I_s Carrier to second order intermodulation product ($A \pm B$) ratio of station in dB for given I_1, I_2, station design, and block tilt

X_1 Carrier to crossmodulation distortion ratio of A_1 in dB, measured with equal channel levels for given number of channels.

X_2 Carrier to crossmodulation distortion ratio of A_2 in dB, measured with equal channel levels for given number of channels.

X_s Carrier to crossmodulation distortion ratio of station for given X_1, X_2 and station design and block tilt.

T_1 Carrier to triple beat product ($A \pm B \pm C$) ratio of A_1 in dB

T_2 Carrier to triple beat product ($A \pm B \pm C$) ratio of A_2 in dB

T_s Carrier to triple beat product ($A \pm B \pm C$) ratio of station in dB for given T_1, T_2, station design, and block tilt.

E_1 dB value of cable loss at reference frequency for which input equalizer equalizes.

E_2 dB value of cable loss at reference frequency for which interstage equalizer equalizes.

FL_1 Flat loss in dB proceding preamplifier A_1.

FL_2 Flat loss in dB in interstage network between A_1 output and A_2 input terminals.

L_3 Flat loss in dB between A_2 (poweramplifier) output and station output.

L_1 Total loss of input networks, flat loss plus equalizer loss.

L_2 Total interstage loss in dB equal to sum of interstage equalizer loss and flat loss.

D_F A_1 noise figure F_1 degradation factor for given station design $F_s = F_1 + D_F$ in dB.

$D_{S/N}$ Signal to noise ratio degradation factor for given station design. $S_i - N_i = 59 + S_i$ (ref. frq) $- F_1$ (ref. frq) $+ D_{S/N}$

$D_{S/N}$ includes D_F, block tilt factor, signal level variation and noise figure variation across frequency passband.

D_I A_2 second order IM degradation factor for given station design and I_2.

$I_s = I_2 + D_I$ (One D_I required for each $A + B$ and $A - B$ product).

D_T A_2 third order (triple beat) degradation factor for given station design and T_2.

$T_s = T_2 + D_T$ (One D_T required for each $A \pm B \pm C$ product).

D_x A_2 crossmodulation degradation factor for given station design and channel.

$X_s = X_2 + D_x$

B_I Block tilt factor relating difference, in dB, of second order IM product magnitude measured at block tilted levels compared to the magnitude measured at flat levels. Each $A \pm B$ product has a B_I.

B_T Block tilt factor relating difference, in dB, of third order (triple beat) product magnitude measured at block tilted levels compared to the magnitude measured at flat levels. Each $A \pm B \pm C$ product has a B_T.