METHOD FOR CALCULATING THE PRE-EMPHASIS SCHEDULE FOR AN FM/FM TELEMETRY SYSTEM BASED ON OPTIMUM PERFORMANCE

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Summary. This paper will describe a system for calculating the pre-emphasis schedule and the required receiver IF bandwidth for FM/FM Telemetry Systems (Frequency Division Multiplexing.

An investigation of the procedures presently in use, disclose that system engineers calculate their system pre-emphasis based on the 3/2 Power Law, for proportional bandwidth systems and a 6 db per octave taper for constant bandwidth systems. Systems using both proportional and constant bandwidth channels are usually left to empirical methods. The total deviation and the receiver bandwidth is assumed using empirical values previously found successful. So far, an investigation has not shown any exact technical basis for the selection of the total deviation or the receiver bandwidth to be utilized in a system.

Introduction. The following lists the requirements that systems engineer should design for, in establishing the optimum pre-emphasis schedule:

1) The system shall perform as close to threshold of the receiver as possible with no loss of data.

2) At this point of receiver operation, the signal to noise ratio at the output of each subcarrier discriminator shall be a minimum of 40 db.

3) The bandwidth of the receiver shall be the minimum required to provide undistorted data. The considerations are the information bandwidth required, and the stabilities of the transmitter and receiver. The determination of the bandwidth is extremely important since it enters into the margin calculations. Using more bandwidth than required does not improve the performance of the system and has a detrimental effect on the margin calculations.

4) Modification of the lower frequency VCO channels to insure sufficient output from the receiver to limit the subcarrier discriminators. This variation from the

normal pre-emphasis schedules is what is commonly referred to as the modified pre-emphasis schedule.

This paper will define all of the requirements listed above. The method employed will be capable of defining a proportional bandwidth system, a constant bandwidth system or a combination of both. It takes into consideration the various frequency responses of the subcarrier oscillator (SCO), the various deviation ratios of the SCO, as well as any special SCO channels that may be used. It should be noted that there are no cases of FM/FM Systems that this procedure cannot define. It is also of great significance in the design of PAM/FM/FM and FM/FM/FM (triple FM) Systems where bandwidths and deviation of high frequency SCO’s must be calculated accurately, together with, the modulation requirements of the transmitter. The result will be reliable data transmission, with the least amount of transmitter deviation, and the narrowest receiver bandwidth requirements, which are the desired result. Before describing the procedure, an understanding of the parameters which describe the system performance must be presented.

The first parameter is the deviation of the RF carrier by each subcarrier oscillator. In a Telemetry System a number of SCO’s are multiplexed to modulate a transmitter. As the received signal level decreases in the receiver, the desired result is that each SCO channel is deviating the transmitter an exact amount, such that at threshold of the receiver, the signal to noise ratio of each channel shall be the same. In the standard language of the system designer, “All of the SCO channels will drop out simultaneously”. As previously stated the only modification to the pre-emphasis schedule which is not consistent with the recommended calculations is the lower frequency channels (i.e., below 5.4KHz). Due to the sensitivity of the subcarrier discriminators used in the demodulation phase, the lower frequency subcarrier oscillator must be adjusted to insure sufficient output voltage from the receiver to provide limiting or lock of the subcarrier discriminator.

The second important parameter which effects this “performance” of the system, is the receiver bandwidth. The receiver bandwidth requirements are a function of the deviation of the transmitter and the frequencies of the modulation signal. To best describe the requirements for bandwidth a frequency spectrum diagram can be used, Figure 1. This diagram shows three different modulating frequencies, modulating a transmitter at the same modulation index.

The diagram of Figure 1 is an indication of the deviation of the transmitter, but cannot be directly measured in the diagram. The deviation can be calculated by determining the Modulation Index (MI) from the spectrum display and applying it to the formula:
$fdc = M \bullet fs$.

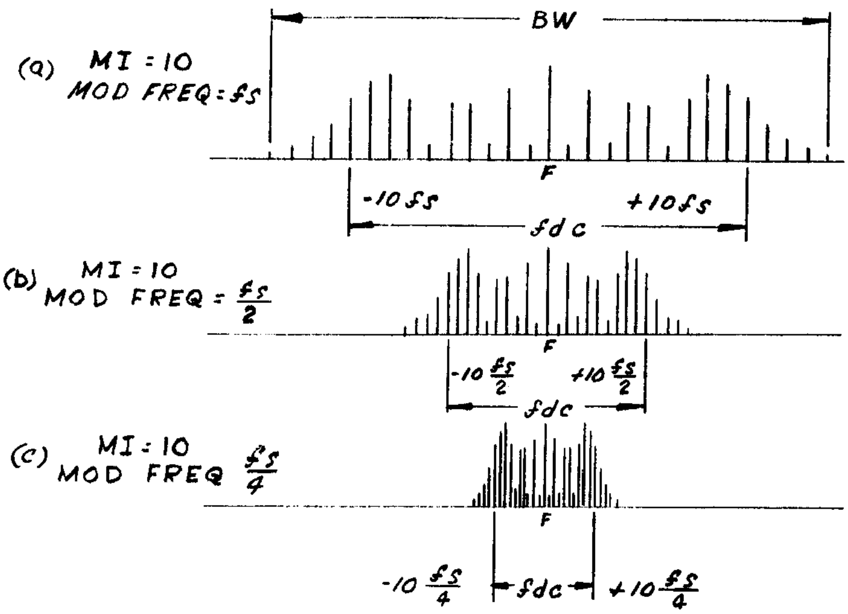

FIGURE 1

The bandwidth is directly apparent by counting the number of sidebands of any of the modulating frequencies. This is so because the sidebands are displaced as a function of the modulating frequency.

If we now take these three frequencies and linearly mix them and modulate the transmitter then we can superimpose the three spectrum displays. From this we can see that the deviation of the transmitter will increase, but the bandwidth requirements with respect to the modulating frequencies will remain the same. The sidebands generated by the two lower frequencies will fall within the bandwidth required by the highest modulation frequency.

The bandwidth requirements of the system are therefore a function of the highest modulation frequency and the total deviation of the transmitter. The only error which can occur in this analysis is when a lower frequency modulates the transmitter sufficiently to generate sidebands beyond the highest modulation frequency. In the standard FM/FM Telemetry Systems, this does not occur due to the nature of the frequency division multiplex system. In both the proportional and constant bandwidth subcarrier channels the higher the subcarrier frequency, the larger the deviation must be, to keep the signal to noise ratio constant. This fact will be established later in the analysis.

It has now been established that the highest frequency subcarrier and the total deviation describe the overall information bandwidth requirements of the system. There are two equations which are commonly used for calculating bandwidth. $Bc = 2\,(fdc + 2fs)$ - Found in ITT Handbook, pp 21-9. This is the rule of thumb equation used to determine the bandwidth requirements for the 1% sidebands components. Bc = 2 (fdc + fs) found in "Information Transmission, Modulation Noise" by Schwartz, pp 247. This again is the rule of thumb equation for determining the bandwidth required for the 10% sideband components. In order to determine the exact bandwidth required, the Bessel functions should be referred to for either the 10% or 1% values. Sidebands generated in all the systems that have so far been observed are such that either me of the approximate equations has been found adequate for bandwidth determination. Since the 10% sideband equation requires less bandwidth, it will be used in the procedure described in this paper.

Glossary.

SCO	=	Subcarrier Oscillator
$\left(\frac{S}{N}\right)_d$	=	Data or Discriminator output RE signal to noise ratio, expressed as a voltage ratio.
$\left(\frac{S}{N}\right)_c$	=	Receiver carrier to noise ratio, expressed as a voltage ratio.
Bc	=	Receiver IF bandwidth.
fdc	=	RF carrier peak deviation produced by the SCO.
fds	=	SCO peak deviation produced by data.
fs	=	SCO center frequency.
Fud	=	Maximum data frequency modulating an SCO or 3 db frequency of the subcarrier output low pass filter.
M	=	Modulation Index of SCO modulating the RF carrier.
N	=	Modulation Index of highest frequency data modulating an SCO.
Δf	=	Total peak deviation of RF carrier by all the SOO channels in the system.
C	=	Constant determine by the ratio of the subcarrier discriminator signal to noise ratio, divided by the quantity of the receiver signal to noise ratio, times the square root of 3/4.
A	=	The sum of the ratios of the SCO channels modulating a transmitter where the deviation of each SCO is normalized with respect to the deviation of the highest frequency SCO modulating an PF carrier.
K	=	Peak deviation of a SCO produced by data (i.e., narrow band channels are 7.5%).
fdc^1	=	Terms which is established from the equation for fdc for purposed of determining the value of A.

Description of Procedure. The following procedures will determine the optimum RF deviation for a group of subcarrier channels and the optimum receiver bandwidth. Equation 1 describes the thermal noise performance of an FM/FM channel above threshold.

Equation 1 $= \left(\frac{S}{N}\right)_d = \left(\frac{S}{N}\right)_c \bullet \left(\frac{3}{4}\right)^{\frac{1}{2}} \bullet \left(\frac{Bc}{Fud}\right)^{\frac{1}{2}} \bullet \frac{fdc}{fs} \bullet \frac{fds}{Fud}$ *

* Refer to Telemetry Standards IRIG 106-71, pp 85.

There have been many papers written on noise performance of an FM/FM channel, and the basic equations are similiar. This particular equation, and its nomenclatures were used, because it appears in the IRIG 106-71 Standards, pp 85. It is therefore the intent of this procedure to be an extention of this equation. From it the system engineer can determine the optimum bandwidth of the receiver required, the deviation of the transmitter by each subcarrier channel, and the total deviation. When the receiver bandwidth required does not correspond to the standard receiver bandwidths available, he can select the standard one which is greater than calculated and adjust the systems in accordance with the procedure which will be discussed.

It must be clearly understood that the above thermal noise equation can be used only to determine the optimum deviation and bandwidth. In most cases, the bandwidth selected will be different than the calculated value due to the availability of receivers and receiver IF plug in modules. It is obvious from studying the equation that to maintain a 40db S/N ratio at the output of the subcarrier discriminator the equation states that, as the receiver bandwidth is increased the transmitter deviation should be decreased. Obviously this is not consistent with the established theory of signal to noise performance of a system. The value of this equation and others like it, is that it provides a starting point. As will be described, the equation provides the ability to calculate the values of receiver BW and the transmitter deviation for optimum performance conditions. After these parameters are established and the receiver bandwidth selected is larger than the calculated value, (which will be the usual case) then the transmitter deviation must be increased to maintain the same signal to noise ratio. Optimum performance will be maintained in this fashion. This procedure will eliminate the over designing of systems which unnecessarily waste bandwidth and exceed power output requirement for adequate transmission range. It will eliminate using 3.3MHz bandwidth when 1MHz is more than adequate, and will eliminate deviating the transmitter 500KHz when 250KHz is adequate. These are the major contributions of this paper.

Optimum Performance is described as follows: The output of each subcarrier discriminator in the system shall have a minimum signal to noise ratio of 40db at 1db above receiver threshold, using the minimum receiver IF bandwidth which will provide undistorted data. Then referring to Equation 1, the following conditions are established.

$\left(\frac{S}{N}\right)_c$ 10db = 3.16 voltage ratio. This was selected because it is 1db above threshold which has been established over the years through analysis and actual tests. (Crosby FM Modulation Analysis).

$\left(\frac{S}{N}\right)_d$ 40db = 100 voltage ratio. This has been selected because the noise contribution will be limited to 1% of the data information.

For other performance requirements $\left(\frac{S}{N}\right)_c$ and $\left(\frac{S}{N}\right)_d$ are selected by the system engineer.

Referring to Equation 1 the following constants are established:

Constant 1

$$C = \frac{\left(\frac{S}{N}\right)_d}{\left(\frac{S}{N}\right)_c \left(\frac{3}{4}\right)^{\frac{1}{2}}} = \frac{100}{3.16} \times \left(\frac{3}{4}\right)^{\frac{1}{2}} = 36.54 \text{ (for optimum performance).}$$

Constant 2

$M = \frac{fdc}{fs}$ Modulation Index of SCO modulating the transmitter.

Constant 3

$N = \frac{fds}{Fud}$ Modulation Index of data modulating SCO for the highest modulation frequency.

$Bc = 2\ (\Delta f + fs)$ Receiver bandwidth as a function of the highest modulating frequency and the total deviation of the transmitter.

A further description of the bandwidth equation will be made so it can be used in this analysis. The total deviation Δf can be described in the terms of any one of the subcarrier frequencies in the system. To standardized for purposes of this paper the total deviation (Δf) will be described with respect to the highest modulating frequency in the system. If the ratio of the transmitter deviation of each subcarrier frequency is established with respect to the highest modulating frequency, then by adding up the ratios and multiplying it by the highest modulating frequency, the total deviation can be determined. The bandwidth equation can now be rewritten.

Constant 4

$$Bc = 2\ (A\ fdc + fs)$$

where

A = the sun of the ratios of the SCO channels in the system.

fdc = the transmitter deviation of the highest SCO channel.

fs = the frequency of the highest SCO channel.

Constant 5

fds = K fs — Peak deviation of subcarrier referred to subcarrier center frequency.

Substitute Constants 1 and 3 in Equation 1

$$C = \left(\frac{Bc}{\frac{fds}{N}}\right)^{\frac{1}{2}} \bullet \frac{fdc}{fs} \bullet N$$

Squaring the above

$$C^2 = \frac{Bc \bullet fdc^2 \bullet N^3}{fds \bullet fs^2}$$

Solve for fdc^2

$$fdc^2 = \frac{C^2 \bullet fds \bullet fs^2}{Bc \bullet N^3}$$

Substitute Constant 5 for fds.

Equation 2

$$fdc^2 = \frac{C^2 \bullet K \bullet fs^3}{Bc \bullet N^3} \qquad = \qquad fdc = \frac{C \bullet K^{\frac{1}{2}} \bullet fs^{\frac{3}{2}}}{Bc^{\frac{1}{2}} \bullet N^{\frac{3}{2}}}$$

Substitute Constant 4, into Equation.2 to reduce the equation to one unknown.

Equation 3

$$fdc^2 = \frac{C^2 \bullet K \bullet (fs)^3}{2\ (A\ fdc + fs) \bullet N^3}$$

Re-arrange the equation in terms of the unknown fdc.

Equation 4

$$A\ fdc^3 + fs \bullet fdc^2 = \frac{C^2 \bullet K \bullet (fs)^3}{2N^3}$$

The only unknown in Equation 4 is fdc. Equation 4 can be reduced in term of the modulation index (M) by dividing both sides of the equation by fs because

$$M = \frac{fdc}{fs} \quad \text{(constant 2)}$$

Then the only unknown will be the modulation index (M)

Equation 5

$$AM^3 + M^2 = \frac{C^2 \bullet K}{2N^3}$$

The value of M can be found by substituting the constants in the formula and using the general solution for a cubic equation.

Once the value of M is found,the system parameters can be established as follows: The transmitter deviation of the highest modulation channel is determined using the following equation: fdc = Mfs Constant 2

Since the value of A is known, the receiver bandwidth can be determined by the equation Bc = 2 (Afdc + fs) Constant 4.

The transmitter deviation of each subcarrier in the system can now be determined by solving

Equation 2 $$fdc = \frac{C \bullet K^{\frac{1}{2}} \bullet fs^{\frac{3}{2}}}{Bc^{\frac{1}{2}} \bullet N^{\frac{3}{2}}}$$

Another method of determining the transmitter deviation of each subcarrier channel will be established later when the step by step procedure is presented. As can be observed in Equation 2 the only variable in determining the deviations of each SCO channel is the modulating frequency fs. This value varies as a function of fs to the 3/2 Power, which is the mathematical justification for the 3/2 Power setting for the proportional bandwidth channel FM/FM Systems. In the constant bandwidth systems where fds is the subcarrier peak deviation produced by data $K = \frac{fds}{fs}$ then the Equation 2 will become

$$fdc = \frac{C \bullet fds^{\frac{1}{2}} \bullet fs}{Bc^{\frac{1}{2}} \bullet N^{\frac{3}{2}}}$$

The variable fs to the 1 Power establishes the 6 db octave settings for the constant bandwidth channel FM/FM Systems.

One other point must be established before a complete procedure can be presented for solving all of the parameters of the system and calculating all of the values. The value of A is determined by summing the normalized deviations with respect to the highest SCO frequency deviation. As discussed previously, the relationship between the deviations of each subcarrier channel is a function of Equation 2 or in the equivalent equation for constant B.W. channels.

These equations will now be used in determining the value of A

Equation 2

Proportional Channels

$$fdc = \frac{C \bullet K^{\frac{1}{2}} \bullet fs^{\frac{3}{2}}}{Bc^{\frac{1}{2}} \bullet N^{\frac{3}{2}}}$$

or

Constant Bandwidth Channels

$$fdc = \frac{C \bullet fds^{\frac{1}{2}} \bullet fs}{Bc^{\frac{1}{2}} \bullet N^{\frac{3}{2}}}$$

Once the bandwidth is determined (Bc), it will remain a constant for the system. In the standard proportional or constant bandwidth systems all of the terms of the equation are fixed such as, N = 5; K = .075 for narrow band channels and K = .15 for wideband channels or

$$K = \frac{2 \times 10^3}{fs}$$

$$K = \frac{4 \times 10^3}{fs}$$

$$K = \frac{8 \times 10^3}{fs}$$

for constant BW channels.

However, in many present day systems there are nonstandard frequency channels used, and many with variations as to the modulation index (N) and the peak deviation of the subcarrier oscillator. For these reasons the discipline of making the following calculations using the entire equation is urged.

To establish the value of A, Equation 2 will be used. Since the bandwidth (Bc) once established will be constant for the entire system, it will not enter in determining the normalized relationship between the SCO channel deviations. Therefore, it can be dropped from Equation 2 without affecting the relationship. Doing this we can establish a now term fdc^1. The equations for fdc^1 are as follows:

For proportional subcarrier channels

$$fdc^1 = \frac{C \bullet K^{\frac{1}{2}} \bullet fs^{\frac{3}{2}}}{N^{\frac{3}{2}}}$$

For constant bandwidth channels

$$fdc^1 = \frac{C \bullet fds^{\frac{1}{2}} \bullet fs}{N^{\frac{3}{2}}}$$

The values of fdc^1 of each subcarrier channel are used in the determination of the term (A).

The constants and equations which have been established will now be used in an 11 step procedure which will describe the setting up of an FM/FM System and determining the receiver bandwidth. Finally a table has been established which will require the posting of the results of the calculation of certain of the steps. The final column of this table will be the transmitter deviation of each subcarrier, and the required optimum receiver IF bandwidth will be determined in one of the steps of the procedure.

STEP 1 Calculate fdc^1 for each subcarrier channel.

Proportion

$$fdc^1 = \frac{C \bullet K^{\frac{1}{2}} \bullet fs^{\frac{3}{2}}}{N^{\frac{3}{2}}}$$

Constant Bandwidth

$$fdc^1 = \frac{C \bullet fds^{\frac{1}{2}} \bullet fs}{N^{\frac{3}{2}}}$$

Post in Table of Values

STEP 2

Normalize the values of fdc^1 in terms of the highest frequency SCO channel. Divide fdc^1 for the highest modulating SCO into the values of fdc^1 calculated for each SCO channel. The normalized value of the highest SCO channel will be 1 and all others will be proportionally lower. Post in Tables of Values.

STEP 3

Add the normalized values. This number = A

STEP 4

Substitute all of the known values for the highest SCO channel in equation

$$AM^3 + M^2 = \frac{C^2 \bullet K}{2N^3}$$

Solve for M, which is the modulation index for the transmitter deviation of the highest frequency subcarrier channel.

STEP 5

Substitute M in equation fdc = Mfs where fs is the highest subcarrier frequency. This will be the transmitter deviation of the highest SCO channel.

STEP 6

Calculate the receiver bandwidth required using the following equation

$$Bc = 2\,(Afdc + fs)$$

Both fdc and fs teruLs are with respect to the highest SCO channel. (A • fdc) is the total transmitter deviation (Δf).

STEP 7

Determine the transmitter deviation of each subcarrier channel by multiplying the normalized values established in Step 2 by the deviation fdc calculated in Step 5.

The complete system has now been determined. The optimum receiver bandwidth has been calculated in Step 6 and the required transmitter deviation for each subcarrier channel has been established to provide 40db S/N ratio at the output of the subcarrier discriminators at 1db above threshold of the receiver.

STEP 8

At this point the receiver bandwidth must be selected with respect to the availability of equipment. The receiver bandwidth selected should be equal to the calculated value of Step 6 or the closest larger bandwidth which is available.

STEP 9

Divide the bandwidth selected in Step 8 by the bandwidth calculated in Step 6. This will be a multiplier constant (B).

STEP 10

Using constant B calculated in Step 9, multiply each of the subcarrier SCO transmitter deviations calculated in Step 7 by constant B to determine their new deviations in terms of the new bandwidth. Post in table of values.

The justification for this step is as follows: As the receiver bandwidth is opened it allows more noise into the system. Since the noise bandwidth is flat, any increase in bandwidth will result in a linear increase in the amplitude of the noise. To keep the signal to noise ratio constant in the system, the deviations will have to be increased proportionately. The new total deviation resulting from this procedure will no longer satisfy the bandwidth equation $Bc = 2 (\Delta f + fs)$. If the total deviation (Δf) is determined using the selected Bc of Step 8 it will be larger than what is established by Step 11. However, it is not necessary to satisfy this equation at this point in the procedure. The system requirement is to provide sufficient deviation of the transmitter to maintain the desired signal to noise ratio, using the minimum IF bandwidth necessary to provide undistorted data.

STEP 11

Modify the deviations of the lower SCO channels wherever necessary to provide sufficient receiver output to limit or lock the subcarrier discriminators. Also round out the deviations of all channels. Post in Table of Values.

The system has sufficient tolerance so that the center frequency of the SCO channels can be used for the term fs instead of the upper bandedge. If the transmitter or receiver has excessive drift, for example non crystal controlled transmitter, then this drift in frequency must be added to the bandwidth (Bc) required before the final bandwidth selection. Then the usable information bandwidth is applied in Step 9 of the procedure.

The performance of the system will be degraded, but this cannot be helped in view of the available equipment. If in some cases the bandwidth available is less than the bandwidth calculated for optimm performance, the amount of degradation of system performance can be calculated.

The following is the Table of Value chart, the procedure steps in actual form, and a typical example.

CHANNEL	CHAN FREQ fs KHZ	fdc' STEP1	NORMALIZED fdc' VALUES	fdc:NORMALIZED VALUES x fdc (HIGHEST SCO) KHZ	NEW fdc B x fdc OF (STEP 7)	FINAL fdc LOW FREQUENCY SCO CHANNELS ADJUST
			STEP 2	STEP 7	STEP 10	STEP 11
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
			STEP 3 A = TOTAL	Δf = TOTAL TRANS. DEVIATION	Δf = TOTAL DEVIATION	Δf = TOTAL DEVIATION

STEP 4

$$AM + M = \frac{C^2 K}{2N}$$

STEP 5

fdc = Mfs (Highest SCO channel)

STEP 6

Bc = 2 (Afdc + fs) (Highest SCO channel)
Afdc = Total Deviation (Δf)

STEP 8

Selection of receiver IF BW to be used.

STEP 9

$$B = \frac{\text{Step 8}}{\text{Step 6}}$$

STEP 10

B x fdc

STEP 11

Adjust low frequency channels for sufficient deviation and round off deviations of all channels.

Typical Example

1) 5 SCO channels, standard narrow band proportional channels, with standard modulation index, frequency 22KHz, 30KHz, 40KHz, 52.5KHz, 70KHz. N = 5 K = .075.

2) Desired operation: 40db S/N ratio at output of subcarrier discriminator at 1db, above receiver threshold.

$$C = \frac{100}{3.16 \left(\frac{3}{4}\right)^{\frac{1}{2}}} = 36.54$$

STEP 1

For proportional channels

$$fdc^1 = \frac{C \cdot K^{\frac{1}{2}} \cdot f^{\frac{3}{2}}}{N^{\frac{3}{2}}} = \frac{36.54 \cdot (.075)^{\frac{1}{2}} \cdot fs^{\frac{3}{2}}}{(5)^{\frac{3}{2}}}$$

Calculate fdc^1 for each SCO channel
Post in Table of Values

STEP 2

$$\text{Normalized } fdc^1 \text{ values} = \frac{fdc^1}{fdc^1} \text{ (Highest mod channel)}$$

$$= \frac{fdc^1}{16.40 \times 10^6}$$

Post in Table of Values

STEP 3

Total of Normalized values A = 2.54
Post at bottom of Step 2 column in Table of Values

CHANNEL	CHAN FREQ fs KHZ	fdc^1 STEP1	NORMALIZED fdc^1 VALUES STEP 2	fdc: NORMALIZED VALUES x fdc (HIGHEST SCO) KHZ STEP 7	NEW fdc B x fdc OF (STEP 7) STEP 10	FINAL fdc LOW FREQUENCY SCO CHANNELS ADJUST STEP 11
1	70	16.4×10^6	1	30.52	51.7	52
2	52.5	10.65×10^6	.65	19.8	33.6	34
3	40	7.08×10^6	.43	13.2	22.4	23
4	30	4.60×10^6	.28	8.55	14.5	15
5	22	2.90×10^6	.18	5.5	9.3	10
			TOTAL A: 2.54 STEP 3	TOTAL DEVIATION (Δf) 77.57	TOTAL Δf 131.5 KHZ	TOTAL DEVIATION Δf 134 KHZ

STEP 4

$$AM^3 + M^2 = \frac{C^2 K}{2N^3} = \frac{(36.54)^2 (.075)}{2 (5)^3}$$

$$2.54M^3 + M^2 = .4 \qquad M = .436$$

STEP 5

$$fdc_{70KHz} = Mfs = .436 \times 70 \times 10^3$$
$$= 30.52KHz$$

STEP 6

$Bc = 2 (Afdc + fs) = 2 (2.54 \times 30.52 \times 10^3 + 70 \times 10^3$
Bc = 295KHz = Receiver IF bandwidth
$Afdc = 2.54 \times 30.52 \times 10^3 = 77.52 = \Delta f$ total deviation

STEP 7

fdc^1 = Normalized Values x Step 5
= Normalized Values x 30.52 = deviation of each SCO channel
Post in Table of Values

STEP 8

SelectedReceiver IF bandwidth = 500KHz

STEP 9

$$B = \frac{\text{Step 8}}{\text{Step 6}} = \frac{500}{295} = 1.68$$

STEP 10

B x fdc = 1.68 x fdc
Post in Table of Values

STEP 11

Modify deviation
Post in Table of Values

The system should have used a 300KHz receiver IF bandwidth for optimum conditions, and the design would have been completed by skipping from Step 7 to Step 11. But for the purposes of showing the procedure for the selection of another bandwidth, which might be the only one available, the example was continued by just such a selection.

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