Optimum Pre-Emphasis for Frequency Modulation Applications

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Introduction

Frequency modulated communication receiving systems that operate under varying RF input power conditions use a generalized pre-emphasis schedule that provides improved communication reception. In many instances, a receiving system operates with a stable RF input power. The optimization of FM systems, operating with a stable RF input power, requires the use of a particular pre-emphasis schedule.

Typical FM systems are not frequency modulated with a constant modulation index for all baseband frequencies. Instead, they use a signal pre-emphasis circuit at the transmitter and a complementary de-emphasis circuit at the receiver to optimize system operation. Pre-emphasis and de-emphasis are required whenever the noise amplitude varies significantly for different frequencies in the baseband (Figure la). FM pre-emphasis at the transmitter accentuates certain baseband frequencies with respect to other frequencies in the baseband (Figure lb). The complementary FM de-emphasis at the receiver de-accentuates those frequencies in the baseband that were originally pre-emphasized by the transmitter, and maintains a constant output signal to noise ratio density throughout the baseband (Figure 1c).

A typical pre-emphasis schedule assumes that the noise power amplitude (given in units of db) in the baseband is a logarithmic function of baseband frequency octaves and that this logarithmic relationship is independent of receiver RF input power. These assumptions, although not rigorous, provide acceptable results for generalized communication systems operating under varying receiving system RF input power conditions.

In many instances a receiving system operates with a stable RF input power. This is common in closed loop systems and certain "short haul" open loop systems. The optimization of operation of these specialized systems requires the utilization of a particular pre-emphasis schedule for the specific operating RF input power.

To accomplish this optimization of FM system operation, the following analysis was developed where the actual pre-emphasis required for the specialized system can be precisely determined.

The determination of the pre-emphasis required for optimization of FM system operation requires a precise knowledge of the spectral noise characteristics in the baseband of the receiver (without de-emphasis) as a function of RF input power. The noise, No, in an FM receiver baseband is a function of RF input power. The signal, So, understood to be the information portion of the wave which the receiver processed in latter stages, produces negligible additional noise. The carrier frequency signal can be used to determine the spectral noise characteristics in the baseband of the FM receiver, as a function of RF input power.

Test Setup

Figure 2 shows the test setup used to determine the spectral noise characteristics in the baseband of receiver (without de-emphasis) as a function of RF input power. A calibrated RF signal generator and precision RF attenuator are connected to a receiver and a wave analyzer (tunable voltmeter). The wave analyzer measures the noise in a small frequency slot centered at a specified baseband frequency. The RF generator and FM receiver are set to the operating carrier frequency. The wave analyzer is then tuned to a frequency near the low end of the baseband frequency spectrum. The RF signal generator output power is varied in discrete increments over the dynamic range of the FM receiver. The wave analyzer measures the noise in the selected baseband frequency slot for each discrete increment of RF input power. The results (Output Noise (db) vs RF Input Power (dbm) for the specific baseband center frequency) are then plotted on a graph (figure 3).

The wave analyzer is now tuned to a different frequency in the baseband and data for another curve is obtained and plotted on the same graph as previously described. The family of curves in Figure 3 is obtained by tuning the wave analyzer in discrete increments over the entire baseband spectrum.

Analysis

Figure 3 is a family of receiver quieting curves for a particular receiver. These curves are typical of all FM receivers, although the absolute magnitude of parameters will be different. An examination of the graph at the three power points (-95 dbm, -65 dbm and -20 dbm) shows that the relationships of the difference in noise amplitudes between the plotted baseband frequencies for each power point are not the same. In many instances, a receiving system operates with a fixed RF input power. This is common in closed loop systems and certain "short haul" open loop systems. A generalized pre-emphasis schedule for the FM receiver will not result in optimization of system operation for these specialized systems.

The noise amplitudes for discrete baseband frequencies at any RF input power value can readily be obtained from Figure 3. For a particular RF input power, the relative difference in noise amplitudes for different baseband frequencies, with respect to a reference noise level, determines the amount of pre-emphasis and complementary de-emphasis required for optimization of system operation.

An example is given to illustrate the application of this data to a specific FM communication system. Assume that the fixed RF input power to the receiving station is -65 dbm. This point, -65 dbm, is located on the horizontal axis of the graph (Figure 3), and a vertical line is drawn through this point parallel to the verical axis. The vertical distance values (in db) along this drawn line, from the thermal reference level to each baseband frequency curve plotted, are then obtained and listed as follows:

Baseband Frequency (KH_Z)	Relative Noise Amplitude From Thermal Reference Level (-db)
3.9	62.5
10.5	60.5
30.0	54.5
70.0	49.0
100.0	45.0

This data is then plotted on a graph (Figure 4). A smooth curve is drawn through these plotted points. The curve for pre-emphasis required at the transmitter is identical to the receiver noise curve in Figure 4. (Refer to Figures 1a and 1b). The difference in noise amplitude (in db) between any two frequencies on the curve is the amount of pre-emphasis required between these two frequencies. The de-emphasis restores the signal to its original frequency distribution, therefore the signal must be de-emphasized by an equal and opposite amount (in db) from that which is used for pre-emphasis. The precise curve has been established from which the required values may be obtained to design the exact transmitter pre-emphasis and complementary receiver de-emphasis networks for this specified operating RF input power. Figure 5 illustrates the receiver noise spectrum (without de-emphasis) for various RF input power values.

Conclusion

The signal attenuation (path loss) between the transmitting and receiving locations must first be determined. This is normally done by a combination of path loss measurements and empirical calculations. This path loss in conjunction with a knowledge of transmitter output power and receiver threshold establishes the receiver operating point.

This operating point (in receiver power units) is plotted on its respective RF input power curve in Figure 5. This curve represents the transfer function of the network that must be designed by employing the rules of conventional network synthesis.

The systems designer now has a precise and accurate knowledge of the pre and de-emphasis phenomena that affect his particular hardware requirement. When his RF input operating point is relatively stable he no longer must compromise performance with generalized pre and de-emphasis networks that provide barely acceptable results over the entire dynamic range of the receiver.

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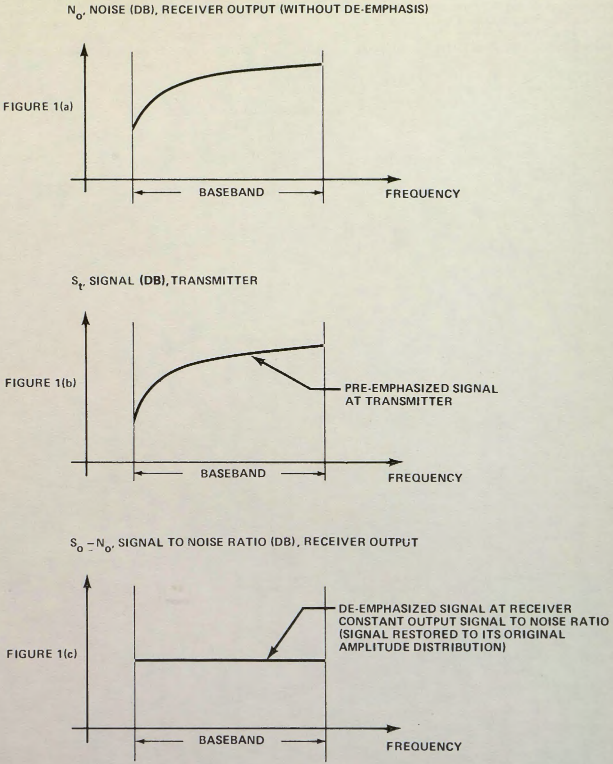

FIGURE 1
TYPICAL NOISE, PRE-EMPHASIS AND DE-EMPHASIS RESPONSE CHARACTERISTICS FOR AN FM COMMUNICATION SYSTEM

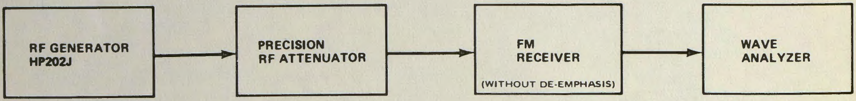

FIGURE 2
EQUIPMENT TEST SETUP

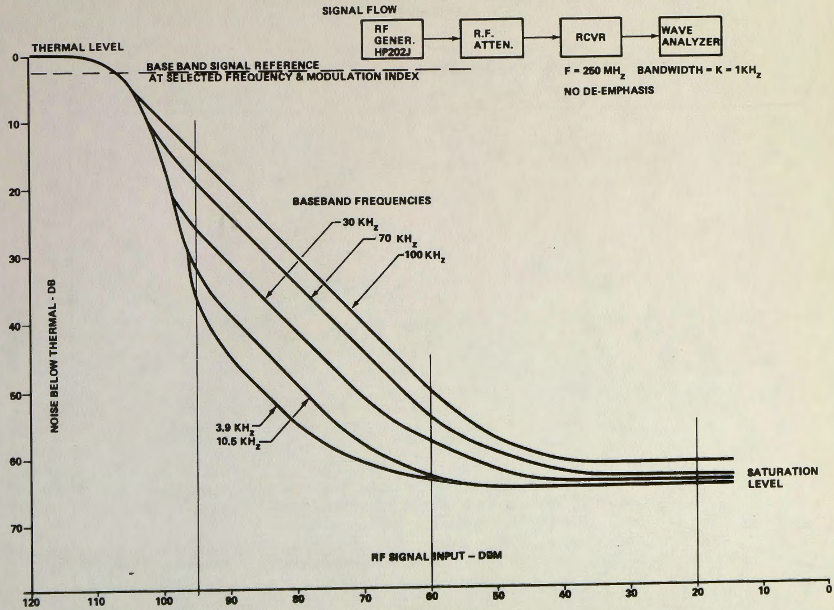

FIGURE 3
RECEIVER QUIETING CHARACTERISTICS VS BASEBAND FREQUENCY

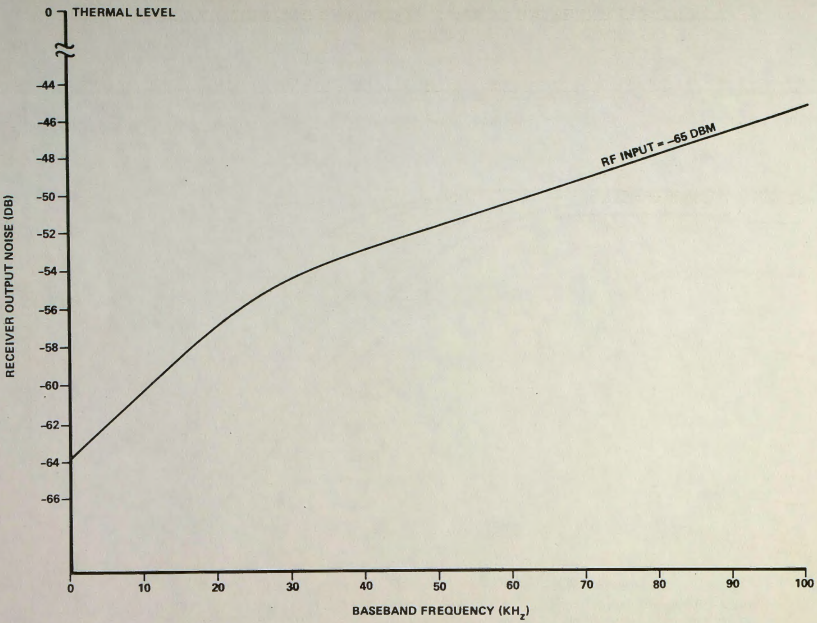

FIGURE 4
RELATIVE NOISE AMPLITUDE VS BASEBAND FREQUENCY FOR AN RF INPUT OF -65DBM WITHOUT DE-EMPHASIS (THERMAL NOISE LEVEL USED AS REFERENCE)

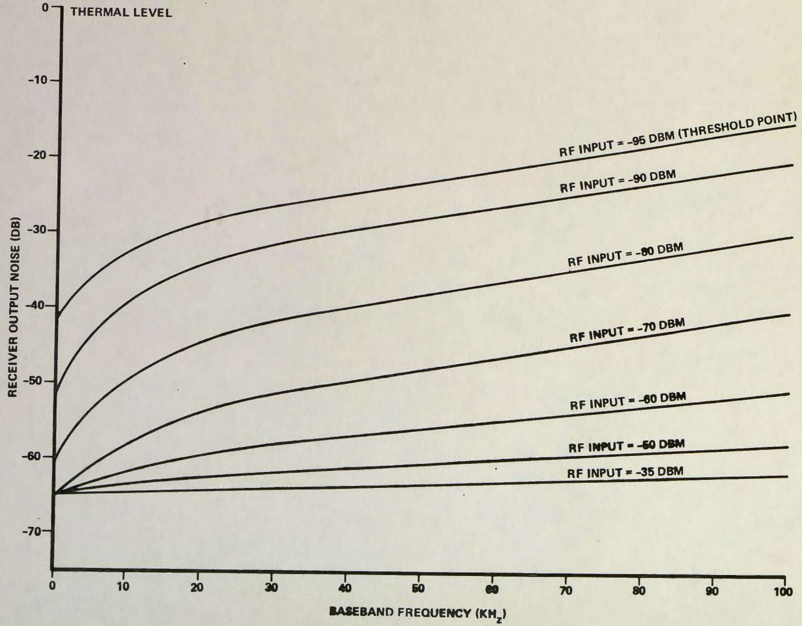

FIGURE 5
RELATIVE NOISE AMPLITUDE VS BASEBAND FREQUENCY FOR VARIOUS RF INPUTS WITHOUT DE-EMPHASIS (THERMAL NOISE LEVEL USED AS REFERENCE)