Frequency modulation the amplitude

INTRODUCTION

In frequency modulation the amplitude is kept constant and the frequency is modulated by the amplitude of the modulating signal. The modulation index for fm is

m = maximum frequency deviation/modulating frequency.

FM signal can be represented as:-

v = ac sin(wct + m sin wmt)

ABSTRACT

Frequency modulation is a type of modulation where the frequency of the carrier is varied in accordance with the modulating signal. The amplitude of the carrier remains constant.

The information-bearing signal (the modulating signal) changes the instantaneous frequency of the carrier. Since the amplitude is kept constant, FM modulation is a low-noise process and provides a high quality modulation technique which is used for music and speech in hi-fidelity broadcasts.

In addition to hi-fidelity radio transmission, FM techniques are used for other important consumer applications such as audio

synthesis and recording the luminance portion of a video signal with less distortion.

There are several devices that are capable of generating FM signals, such as a VCO or a reactance modulator.

Frequency Modulation is abbreviated FM.

Definitions

An important concept in the understanding of FM is that of frequency deviation. The amount of frequency deviation a signal experiences is a measure of the change in transmitter output frequency from the rest frequency of the transmitter. The rest frequency of a transmitter is defined as the output frequency with no modulating signal applied. For a transmitter

with linear modulation characteristics, the frequency deviation of the carrier is directly proportional to the amplitude of the applied modulating signal.

Mathematical Analysis of FM

As was done with AM, a mathematical analysis of a high-frequency sine wave, modulated by a single tone or frequency, will be used to yield information about the frequency components in an FM wave, FM power relations, and the bandwidth of an FM signal. From the definition of frequency deviation, an equation can be written for the signal frequency of an FM wave as a function of time:

fsignal = fC + kf eM(t) = fC + kf EM sin? Mt

And substitution of d = kf – EM yields:

fsignal = fC + d sin? Mt

But what does this equation indicate? It seems to be saying that the frequency of the transmitter is varying with time. This brings up the same type of problem that was observed when we looked at a time display of AM and then performed a mathematical analysis in an attempt to determine its frequency content. With AM, the signal appeared to be a sine wave that's amplitude was changing with time. At the time, it was pointed out that a sine wave, by definition, has a constant peak amplitude, and thus cannot have a peak amplitude that varies with time. What about the sine wave's frequency? It also must be a constant and cannot be varying with time.

As was the case with AM, where it turned out that our modulated wave was actually the vector sum of three sine waves, a similar situation is true for FM. An FM wave will consist of three or more frequency components vectorially added together to give the appearance of a sine wave that's frequency is varying with time when displayed in the time domain. A somewhat complex mathematical analysis will yield an equation for the instantaneous voltage of an FM wave of the form shown here:

eFM(t) = EC sin(? Ct + mf sin? Mt)

where EC is the rest-frequency peak amplitude, ? C and ? M represent the rest and modulating frequencies, and mf is the index of modulation. This equation represents a single low-frequency sine wave, fM, frequency modulating another high-frequency sine wave, fC. Note that this

equation indicates that the argument of the sine wave is itself a sine wave.

The Index of Modulation

The index of modulation, mf, is given by the following relationship:

A few more comments about the index of modulation, mf, are appropriate. As can be seen from the equation, mf is equal to the peak deviation caused when the signal is modulated by the frequency of the modulating signal;

therefore, mf is a function of both the modulating signal amplitude and frequency. Furthermore, mf can take on any value from 0 to infinity. Its range

is not limited as it is for AM.

FM Power Relations

Recall that for an FM wave the amplitude of the signal, and hence the power, remains constant. This means that the power in the individual frequency components of the wave must add up to the transmitter output power. Furthermore, if the modulation index changes, the total power must

redistribute itself over the resulting frequency components. If there is no modulation, then mf = 0 and J0 = 1. 0. Mathematically, this can be shown by the following:

Prest freq = J0 power 2 – Ptrans

or

Prest freq = Ptrans

for mf = 0. 0.

To determine the power for any individual frequency component, we

can use the following relation:

Pn = Jn

2(mf) – Ptrans 4. 11

Furthermore, the total signal power will be given by:

Ptotal = (J0power2 + 2J1power2 + 2J2power2 + 2J3power2 + …) – Ptrans.

The Effect of Noise on FM

Recall AM and the effect of noise on it. Random electrical variations added to the AM signal altered the original modulation of the signal. For FM, noise still adds to the signal, but because the information resides in frequency changes instead of amplitude changes, the noise tends to have less of an effect. Expanding upon this idea a bit, one notes that the random electrical

variations encountered by the FM signal will indeed cause distortion by " jittering" the frequency of the FM signal. However, the change in frequency modulation caused by the jittering usually turns out to be less than the change in the amplitude modulation caused by the same relative

amplitude noise variations on an AM signal. Also unlike AM, the effect of the frequency jittering becomes progressively worse as the modulating frequency increases. In other words, the effect of noise increases with modulation frequency. Pre-Emphasis and De-Emphasis

To compensate for this last effect, FM communication systems have incorporated a noise-combating system of pre-emphasis and de-emphasis

FM Generation Techniques

FM signals can be generated using either direct or indirect frequency modulation.

- Direct FM modulation can be achieved by directly feeding the message into the input of a VCO.

- For indirect FM modulation, the message signal is integrated to generate a phase modulated signal. This is used to modulate a crystal controlled oscillator, and the result is passed through a frequency multiplier to give an FM signal

DIRECT FM GENERATION

The simplest method for generating FM directly is to vary the frequency of an oscillator. A capacitance microphone or a varactor diode may be used as part of the oscillator's frequency determining network. The capacitor microphone's capacitance varies in response to the intensity of the sound waves striking it, making the oscillator's frequency vary as the amplitude of the sound varies. The varactor diode's capacitance depends on the voltage across it. Audio signals placed across the diode cause its capacitance to change, which in turn, causes the frequency of the oscillator to vary.

INDIRECT FM GENERATION

While it is not possible to vary the frequency of a crystal oscillator directly, it is possible to vary its phase. The resulting PM signal can be used to create FM. This is the basis of the Armstrong modulator. The mathematics required to analyze the Armstrong modulator completely are complex, so we will discuss only the basic circuit operation. An audio signal is passed through a preemphasis network and then an integrator, a special network whose output is the time integral of the input signal.. In this way an FM signal is generated. The Armstrong modulator cannot produce much deviation, so combination of multipliers and mixers are used to raise the carrier frequency and the deviation. The multipliers are used to multiply the carrier and the deviation. The mixers are used to decrease the carrier, while keeping the deviation constant so that additional multiplier stages can be used to obtain more deviation.

FM Performance

FM Spectrum

A spectrum represents the relative amounts of different frequency components in any signal. Its like the display on the graphic-equalizer in your stereo which has leds showing the relative amounts of bass, midrange and treble. These correspond directly to increasing frequencies (treble being the high frequency components). It is a well-know fact of mathematics, that any function (signal) can be decomposed into purely sinusoidal components (with a few pathological exceptions) . In technical terms, the sines and cosines form a complete set of functions, also known as a basis in the infinite-dimensional vector space of real-valued functions (gag reflex). Given that any signal can be thought to be made up of sinusoidal signals, the spectrum then represents the " recipe card" of how to make the signal from sinusoids. Like: 1 part of 50 Hz and 2 parts of 200 Hz. Pure sinusoids have the simplest spectrum of all, just one component:

In this example, the carrier has 8 Hz and so the spectrum has a single component with value 1. 0 at 8 Hz . The FM spectrum is considerably more complicated. The spectrum of a simple FM signal looks like:

The carrier is now 65 Hz, the modulating signal is a pure 5 Hz tone, and the modulation index is 2. What we see are multiple side-bands (spikes at other than the carrier frequency) separated by the modulating frequency, 5 Hz.

There are roughly 3 side-bands on either side of the carrier. The shape of the spectrum may be explained using a simple heterodyne argument: when you mix the three frequencies (fc, fm and Df) together you get the sum and difference frequencies.

The largest combination is fc + fm + Df, and the smallest is fc – fm – Df. Since Df = b fm, the frequency varies (b + 1) fm above and below the carrier. A more realistic example is to use an audio spectrum to provide the modulation:

In this example, the information signal varies between 1 and 11 Hz. The carrier is at 65 Hz and the modulation index is 2. The individual side-band spikes are replaced by a more-or-less continuous spectrum. However, the extent of the side-bands is limited (approximately) to (b + 1) fm above and below. Here, that would be 33 Hz above and below, making the bandwidth about 66 Hz. We see the side-bands extend from 35 to 90 Hz, so out observed bandwidth is 65 Hz.

You may have wondered why we ignored the smooth humps at the extreme ends of the spectrum. The truth is that they are in fact a by-product of frequency modulation (there is no random noise in this example). However, they may be safely ignored because they are have only a minute fraction of the total power. In practice, the random noise would obscure them anyway.

Frequency Response

Frequency response is a specification used in amplifiers, pre-amplifiers, CD players, tape decks and other audio components to measure how uniformly it reproduces sounds from the lowest tones to the highest. An amplifier or other component should preserve the loudness relationship between various instruments and voices and should not over or under-emphasize any frequency or tone. This is known as flat frequency response.

Bandwidth

As we have already shown, the bandwidth of a FM signal may be predicted using:

BW = 2 (b + 1) fm

where b is the modulation index and

fm is the maximum modulating frequency used.

FM radio has a significantly larger bandwidth than AM radio, but the FM radio band is also larger. The combination keeps the number of available channels about the same.

The bandwidth of an FM signal has a more complicated dependency than in the AM case (recall, the bandwidth of AM signals depend only on the maximum modulation frequency). In FM, both the modulation index and the modulating frequency affect the bandwidth. As the information is made stronger, the bandwidth also grows.

Applications of frequency modulation:

Broadcasting:

FM is commonly used at VHF radio frequencies for high-fidelity broadcasts of music and speech . Normal (analog) TV sound is also broadcast using FM. A narrow band form is used for voice communications in commercial and amateur radio settings. The type of FM used in broadcast is generally called wide-FM, or W-FM. In two-way radio, narrowband narrow-fm (N-FM) is used to conserve bandwidth. In addition, it is used to send signals into space.

Sound:

FM is also used at audio frequencies to synthesize sound. This technique, known as FM synthesis, was popularized by early digital synthesizers and became a standard feature for several generations of personal computer sound cards.

Radio:

An example of frequency modulation. This diagram shows the modulating, or message, signal, xm(t), superimposed on the carrier wave, xc(t)

The modulated signal, y(t), produced from frequency-modulating xc(t) with xm(t).

A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation called radio FM.

As , wideband FM (W-FM) requires a wider signal bandwidth than amplitude modulation by an equivalent modulating signal, but this also makes the signal more robust against noise and interference. Frequency modulation is also more robust against simple signal amplitude fading phenomena. As a result, FM was chosen as the modulation standard for high frequency, high fidelity radio transmission: hence the term “ FM radio” (although for many years the BBC called it “ VHF radio”, because commercial FM broadcasting uses a well-known part of the VHF band; in certain countries, expressions referencing the more familiar wavelength notion are still used in place of the more abstract modulation technique name). A high-efficiency radio-frequency switching amplifier can be used to transmit FM signals (and other constant-amplitude signals). For a given signal strength (measured at the receiver antenna), switching amplifiers use less battery power and typically cost less than a linear amplifier. This gives FM another advantage over other modulation schemes that require linear amplifiers, such as AM and QAM.

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