Explanation of "Pre Emphasis, & De Emphasis"

By Kevin K. Custer W3KKC

The concept of Pre-emphasis and De emphasis is a broad subject, however I will try to give you the basic concept behind the advantages, and necessities of using it in FM.

In common narrowband two way fm communications, Pre-emphasis follows a 6 dB per octave rate. This means that as the frequency doubles, the amplitude increases 6 dB. This is usually done between 300 - 3000 cycles. Pre-emphasis is needed in FM to maintain good signal to noise ratio. Why is it necessary? Common voice characteristics emit low frequencies higher in amplitude than high frequencies. The limiter circuits that clip the voice to allow protection of over deviation are usually not frequency sensitive, and are fixed in level, so they will clip or limit the lows before the highs. This results in added distortion because of the lows overdriving the limiter. Pre-emphasis is used to shape the voice signals to create a more equal amplitude of lows and highs before their application to the limiter. The result is that the signal received is perceived louder due to more equal clipping or limiting of the signal, but probably more important is the increased level of the higher frequencies being applied to the modulator results in a better transmitted audio signal to noise ratio due to the highs being above the noise as much or more than the lows. So what is the original reason for Pre-Emphasis?

Reasoning behind Pre-Emphasis in NBFM

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The FM broadcasting industry uses pre-emphasis and de-emphasis techniques to improve their signal-to-noise ratios. It's been correctly pointed out that audio frequencies below the breakpoint are transmitted flat, and audio frequencies above the breakpoint are transmitted pre-emphasized. (There have been other such "curves" used to tailor response, such as the RIAA curve in phonograph records, and the NAB curve in tape recording.)

But that isn't the original reason pre-emphasis and de-emphasis were used in narrow-band radio. The early transmitters were PM (phase modulated), not FM, so they naturally had a 6 dB/octave pre-emphasis. PM became the standard modulation method. When FM transmitters came along, their audio had to be intentionally pre-emphasized to maintain compatibility with the PM transmitters already in service. In very early narrow-band literature, you won't even find the terms "pre-emphasis" and "de-emphasis". Engineers simply "rolled off" the audio in the receiver with a single pole filter because they had to defeat the PM transmitter's characteristic "roll-up". The pre-emph and de-emph terms came from the broadcast people. (I wish the narrow-band radio industry had better terms for these characteristics. Unlike the broadcasters with their middle-of-the-band breakpoint, in narrow-band radio the breakpoints are outside the voice bandwidth.) So, de-emphasis has little to do with signal-to-noise radio and everything to do with making the response correct. If FM had always been used, there never would have been pre-emph or de-emph in narrow-band radio.

We must recognize that early narrow-band radio was intended for one transmitter, one receiver applications. This business of linking repeaters came much later. We pre-emph the audio to the

> FM transmitter to simulate PM, but must maintain a narrow bandwidth to be a good neighbor. So, we roll off the audio at, let's say, -3 dB at 3 kHz. If we hop through another similar system, the resulting audio is then down another 3 dB at 3 kHz, or a total of -6 dB at 3 kHz. This narrowing of the audio bandwidth is what everybody complains about in linked systems.
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> So, the popular answer is to eliminate de-emph and pre-emph in the repeater. Just feed the user's pre-emph'd audio from the repeater receiver's discriminator to the repeater transmitter after the pre-emp stage, thus bypassing the repeater's de-emp and pre-emp circuits, resulting in a "flat" repeater, right?. (Of course, you still have all those controller mods to make.) Everyone then assumes de-emph and pre-emph are evil!!! They must be, since the audio sounds better without them!
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> But from an engineering perspective, there is nothing inherently evil in pre-emph or de-emph. The transmitter still rolls off at 3 kHz. By feeding pre-emph'd audio to the transmitter, you are artificially increasing the amount of high-freq audio fed to it. You are "peaking" the transmitter so that it rolls up. You are effectively widening the bandwidth.
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> My response? First, let's at least admit that we are attempting to make narrow-band systems wide band. No bones about it. You want a nice, high-fidelity linked system? Go after the transmitters. Replace their audio filters with high order, brick wall audio filters that allow wider bandwidth signals (at the expense of smaller guard bands between channels). Or use wide-band links on higher bands. But if you want to continue defeating de-emph and pre-emph, at least admit that it's similar to putting an audio equalizer in line.
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> One last thing - FM'ing crystals is really hard (they're nonlinear). FM'ing in a synthesized transmitter is easy. So, if someone tells you he FM'ed his crystal-controlled repeater transmitter with a few wiring changes and a capacitor, make him prove it. What audio signal generator did he use to sweep the transmitter? What receiver was used to produce the measured audio? Remember, the proof is in the pudding (lab grade test equipment). If its really an FM transmitter, the received audio will be at a constant amplitude regardless of frequency. Anything else is modified PM.

Transmitters that employ a true FM modulator require a pre-emphasis circuit before the modulator fore the true FM modulator doesn't automatically pre-emphasize the audio like a transmitter that uses a phase modulator. A separate circuit is not necessary for pre-emphasis in a transmitter that has a phase modulator because the phase modulator applies pre-emphasis to the transmitted audio as a function of the phase modulator.

The receivers De emphasis circuitry takes the unnatural sounding pre emphasized audio and turns it back into its original response. Pre-emphasized (discriminator) audio is however available directly from the audio demodulation (discriminator) circuitry.

In linking systems, many choose to eliminate the emphasis circuitry to allow better representation of retransmitted signals. Since the signal has already been pre-emphasized (by the user that is transmitting,) and since the receiver you are listening to takes care of the de emphasis.... it doesn't need to be done over and over again.

Some loss of quality does exist, but quality is better maintained by a flat system. A flat audio response system is one which has equal output deviation for the same input deviation, no matter what the applied audio frequency is within reason. Reasonable audio frequency response would be from 50 cycles to about 3500 to 5000 cycles in a system not filtering PL. Audio response in a system filtering PL would be around 250 to about 3500 to 5000 cycles. Upper cut off frequency would be determined mainly on acceptable use of available bandwidth.

Injecting discriminator audio back into an FM modulator without any limiting or low pass filtering is bad news, plain and simple. On UHF, you've probably been able to get away with it without excessively bothering either of your adjacent channel neighbors, but on 2m, especially with 15 kHz spacing, you'd be asking for a lynching.

Without low pass filtering, all of the high frequency energy (hiss) that comes from the discriminator from a noisy user, if not low pass filtered, will deviate your transmitter in excess of 5 kHz, in addition to pushing the sidebands out further than they would be if the AF was cut off at/about 3 kHz. Do this to see what I mean. Set your repeater up for 1:1 input to output ratio (like, put in a signal that is deviated 3 kHz by a 1 kHz tone, and set your Tx audio gain to get 3 kHz out of the transmitter). Now open your repeater receiver squelch wide open. You should see your transmitter is now deviating somewhere around 8 or 9 kHz (presuming you have enough audio headroom through the controller). Under this test condition, the combination of the excessive deviation and the lack of high frequency filtering will make your signal somewhere around 30 kHz wide instead of 16 as it should be. The only thing "limiting" the occupied bandwidth at that point is the dynamic range of the audio circuits and the natural high frequency rolloff of the discriminator's output noise. Look at it on a spectrum analyzer if you don't believe me.

Obviously that's a worst case scenario, but the fact remains that you should have brick wall limiting at 5 kHz (a little lower at 15 kHz channel spacing), and low pass filtering at 3 kHz (a little higher if you want on 25 kHz channels).

A repeater can be built to utilize a flat audio response to maintain quality through the system. This is fairly easy in a system using a true FM modulator. Usually modification to the controller is necessary to allow it, especially ones that have speech or a phone patch. Systems using a phase modulator require de emphasis before the modulator because of the automatic pre-emphasis of the phase modulator, and for this reason... it is easier to utilize flat audio modifications and maintain quality audio in a system employing a true FM modulator in the transmitter.

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