modulation standards

for

vhf fm

A discussion of modulation circuits and techniques to improve the performance of fm systems

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It is not widely realized that there are certain variables in frequency modulation or fm that must be defined and standardized before full compatibility is obtained between transmitting and receiving equipment. In this article I will attempt to identify these variables, point out current standard practice and discuss how these standards affect transmitter and receiver circuitry.

modulation level

In amplitude modulation systems the modulation limit is related to carrier level. This limit is called 100 percent modulation. There is no such inherent limitation for fm systems. Any modulation level, or deviation, may be transmitted as long as the receiver bandwidth will accept it.

Two standard receiver bandwidths are currently found in amateur practice. These bandwidths, as well as most of the other standards which we will discuss, stem from commercial practice—and the large amount of commercial fm equipment used by amateurs. The most common bandwidth permits a deviation of ±15 kHz; this referred to as wideband. Newer commercial equipment permits a deviation of only ±5 kHz; this referred to as narrowband. (Narrowband should not be confused with the nbfm permitted on the amateur bands below 30 MHz; nbfm is limited by regulation to ±3 kHz.)

Narrowband may be copied on a wideband receiver with only a slight loss of audio, but wideband is not copyable on a narrowband receiver because of modulation excursions out of the receiver passband. When both types of equipment are in use, modulation levels are set for the narrower receivers.

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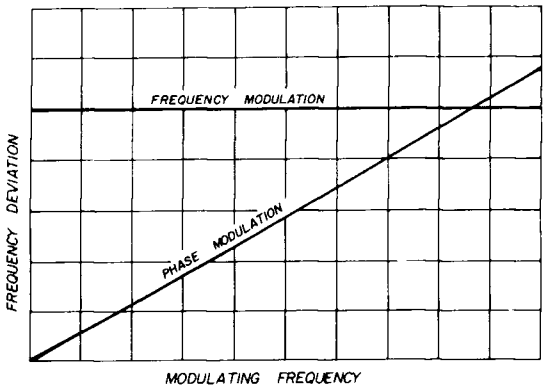

fig. 1. Modulating frequency dependence of fm and pm with constant audio input level.

audio response characteristics

Through use, "frequency modulation" has come to refer to any angular modulation system, either true fm or pm (phase modulation). Although the difference between an fm and a pm modulator is known, it is not widely realized that the two systems result in an inherent difference in audio-response characteristics.

A constant audio level applied to a frequency modulator will result in a certain frequency deviation which does not change with the modulating frequency. However, a constant audio level applied to a phase modulator will only result in a constant peak phase shift. The frequency deviation depends on how rapidly the phase shifts. Since the phase shift becomes more rapid as the modulating frequency is increased, the frequency deviation of a phase-modulated transmitter is directly proportional to the modulating frequency as shown in **fig. 1**.

The result is that a pm signal detected in an fm discriminator will have a 6 dB per octave rising audio characteristic. This can be overcome in one of two ways. If an RC network that will cause a 6-dB-per-octave *rolloff* across the entire audio range is placed in the transmitter audio (before the phase modulator) the transmitted signal will be identical to a true fm signal **(fig. 2B)**. The alternative is to place the same RC circuit after the fm discriminator in the receiver **(fig. 3A)**. In this case

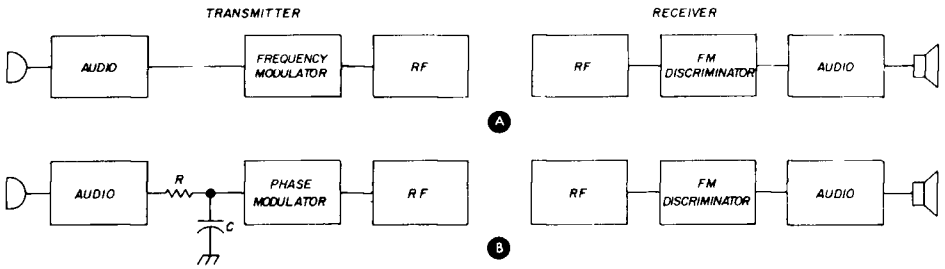

fig. 2. Frequency modulation and fm-equivalent systems.

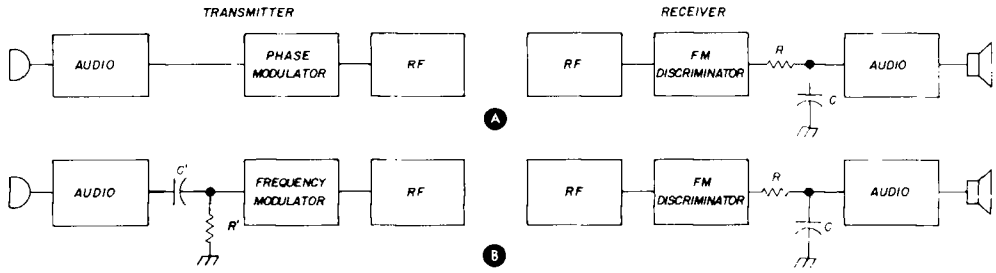

fig. 3. Phase modulation and pm-equivalent system.

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the system audio will still have a net flat response but the transmitted signal will be pm.

It is pm which is standard for commercial[1,2] and amateur use. For this reason, when a frequency modulator is used an RC network with a 6-dB-per-octave *rising* characteristic is placed in the transmit audio circuit prior to the modulator **(fig. 3B)**. If steps are not taken to assure standardized audio response different equipment combinations can result in either high- or low-pitched received audio with accompanying loss in intelligibility.

The RC rolloff network used in the above examples should have a time constant of RC=530 microseconds for a low-frequency limit of 300 Hz. The rising

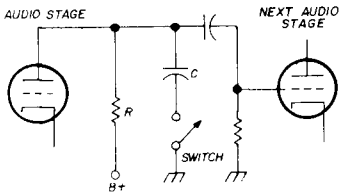

fig. 4. Modifying an a-m receiver to slope detect pm. Capacitor C and switch are added. Shunt circuit impedances are assumed to be high relative to R and are ignored in computing RC.

response RC network for use with a frequency modulator should have a time constant of R'C'=53 microseconds for a high-frequency limit of 3 kHz (R in ohms, C in farads). The closest standard component values may be used.

An improvement in reception may be gained when slope detecting pm on an a-m receiver if audio rolloff is added as with the fm discriminator. Not only will the unnatural high pitched quality be eliminated, some noise reduction will result. A shunt capacitor may be selected for the proper time constant (530 microseconds may be used) in conjunction with an existing plate load resistor (see **fig. 4**).

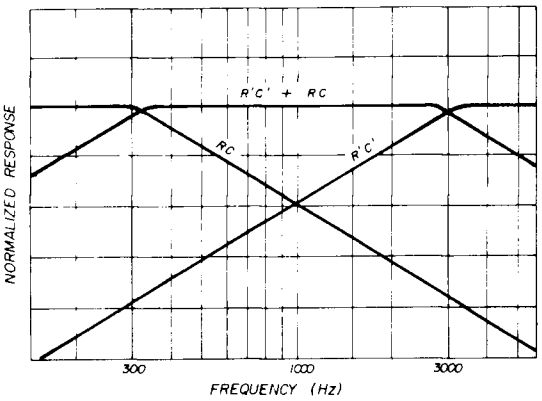

fig. 6. Normalized response of the circuit of fig. 5.

Provision should be made to switch the capacitor out for a-m reception. This arrangement is recommended for monitoring purposes only because of the inferior reception provided by slope detection. Also, tunable receivers are discouraged for fm communications because they encourage poor operating practices.

speech clipping

Speech clipping is a useful method of maintaining high average deviation levels without going beyond the receiver bandpass. It has previously been established that the system in use is phase modulation; since pm exhibits a different deviation level for each modulating frequency it's obvious that fixed amplitude clipping by itself will not work unless it is made

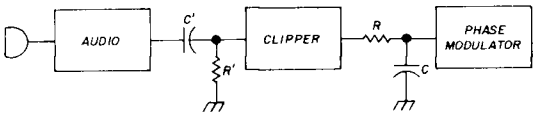

fig. 5. Speech clipping for constant maximum frequency deviation with phase modulation. R'C' = 53 microseconds and RC = 530 microseconds for 3-dB points at 300 and 3000 Hz.

frequency dependent. This is normally done as shown in **fig. 5** by preceding the clipper with a network with a 6-dB-per-octave *rising* characteristic. This enables

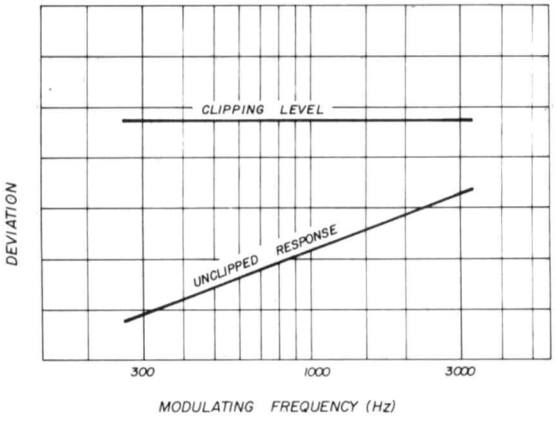

fig. 7. Deviation characteristics of the circuit of fig. 5.

the clipper to take a bigger bite of the higher frequencies. The clipper is followed by a 6-db-per-octave *rolloff* network that restores the unclipped audio to a flat response as shown in **fig. 6**. The net result is a pm signal clipped to a constant maximum frequency deviation.

When the audio clipper is used with a frequency modulator rather than a phase modulator, network RC is left out but R'C' is left in. The resulting signal is the same as pm limited to a constant maximum frequency deviation.

It should be noted that excessive clipping with this method will cause a noticeable loss of high audio frequencies. However, at normal clipping levels the spectral distribution of speech is such that little high-frequency clipping takes place, and the highs appear normal. This loss effect has been noted on many improperly adjusted repeaters around the country where the receiver is overdriving the clipper. Not only is excessive distortion created by too much clipping, but further degradation of intelligibility is caused by the muffled highs.

summary

Despite the fact that fm is the general term applied to angular-modulated vhf and uhf work, the truth is that pm is the system in use from the point of view of system audio response. Audio compensation must be used with fm modulators and detectors to maintain correct audio recovery for maximum intelligibility.

Modulation levels are restricted only by receiver bandwidths (except on those lower frequencies where the FCC specifies maximum bandwidths). Speech clipping is almost universally used but special audio frequency processing is necessary in the transmitter to limit a pm signal to a constant maximum frequency deviation. Standard modulation levels are wideband (15-kHz deviation) and narrowband (5-kHz deviation).

reference

1. EIA Standard RS-152A, "Minimum Standard for Land-Mobile Communications FM or PM Transmitters 25-470 Mc.," Electronic Industries Association, 1959, Section 6.
2. EIA Standard RS-204, "Minimum Standards for Land-Mobile Communications FM or PM Receivers," Electronic Industries Association, 1958, Section 11.

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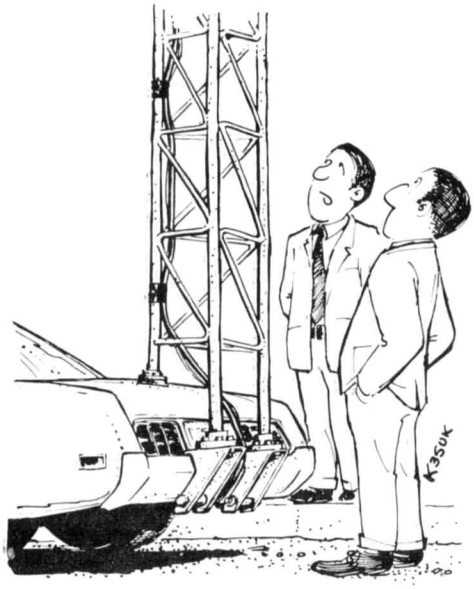

"I'll betcha a steak dinner that he's not married."