Intermod: Getting the upper hand (Part 1)

By Harold Kinley

For those who haven't yet been initiated into the world of intermodulation interference, this will serve as a quick introduction, or it will simply serve as a basic review for the "old salts" who have been around for a while.

Intermodulation interference has always been a problem for those who work in the land mobile radio industry. In *channelized* communications systems, *odd-order* intermod products (resulting from *in-band* signals) will fall back into the same band.

Intermod can be predicted and calculated mathematically. There are many software applications ranging from commercial software to *shareware* and even *freeware,* that can be used to study the intermod phenomenon through mathematical analysis.

The requirements for the formation of an intermod signal are a non-linear mixing point and at least two signals (of different frequencies) applied to the non-linear mixer. The non-linear mixer can be the Class C RF amplifier output stage of a transmitter, an overloaded receiver input stage, a rusty point of a tower or a bad RF connector. In short, almost anything can become a non-linear mixer.

When dealing with large signal levels the mixer doesn't have to be highly efficient to produce an intermod signal of sufficient intensity to cause serious interference to an on-site receiver.

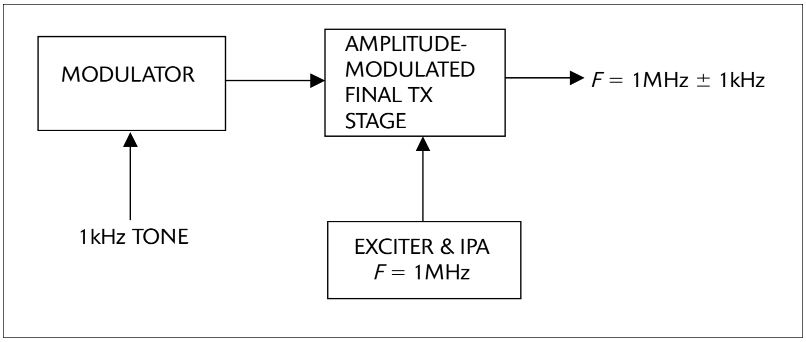

Figure 1. The intermodulation process in the modulated final stage of this AM transmitter from three signals at the output—the 1MHz carrier (F_c), F_c + 1kHz and F_c − 1kHz.

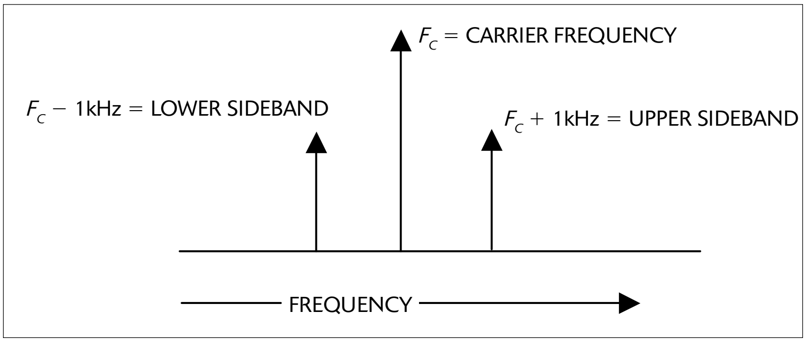

Figure 2. The process of amplitude modulating a carrier is produced by intermodulation. Here, the lower sideband is displaced below the carrier by a frequency separation equal to the frequency of the modulating tone. The upper sideband is displaced above the carrier by a frequency separation equal to the frequency of the modulating tone.

Figure 1 is a simple diagram of a plate-modulated AM transmitter. When a 1kHz sine-wave audio tone is applied to the input of the modulator, the signal is mixed with the RF carrier in the modulated stage to produce a sum and difference frequency of $F_c - F_a$ and $F_c + F_a$. If the carrier frequency is 1MHz (1,000kHz), then the difference frequency will be 999kHz and the sum frequency will be 1,001kHz.

Thus, the output from the transmitter will be the carrier frequency of 1,000kHz and the sum and difference frequencies (sidebands) would be spaced 1kHz above and below the carrier frequency. (See Figure 2.) These sidebands contain the *intelligence* of the signal and are the result of an intermodulation process.

Intermodulation occurs in a superheterodyne receiver where the local oscillator and RF signal are mixed to form an intermediate frequency. So, intermodulation isn't always a bad thing. Without intermodulation, our communications equipment wouldn't work. Yet, when *undesired* intermodulation occurs, it can cause our communications equipment to *not* work.

Odd-order intermod

Let's look at a channelized land mobile radio band where the channel spacing is 30kHz. (See Figure 3.) Here, seven frequencies are listed from a mobile radio band. Let's plug a couple of these frequencies into the third-order model: $2A - B$.

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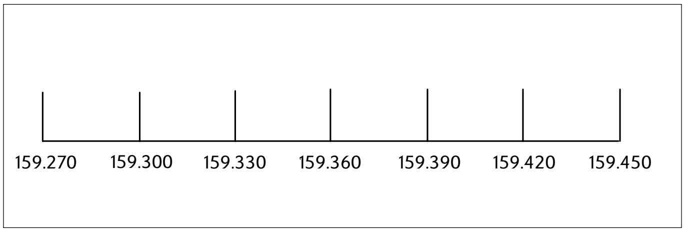

Figure 3. A few frequencies from a land mobile radio band are shown here. Odd-order intermod signals formed from any of these frequencies will fall back into the band. Even-order intermod signals formed from frequencies within this band will fall out of this band.

If we let A = 159.390MHz and B = 159.360MHz, then the resulting intermod frequency will be 159.420MHz. So, it falls right back into the band and will cause interference to a receiver on this frequency and near this site. This is called third-order intermod because the sum of the coefficients of the *mixed* frequencies is equal to 3.

Let's try a fifth-order product in the form of $3A - 2B$ where A is 159.330MHz and B is 159.300MHz. Then, 3(159.330) − 2(159.300) = 159.390. Again, the odd-order intermod falls back into the same band where it was generated. The odd-order intermod products are the most troublesome in land mobile radio—especially those of the third order.

Even-order intermod

Even-order intermod caused by *in-band* frequencies will fall out of band. Referring again to Figure 3, let's plug a couple of these frequencies into the even-order model $A - B$—a second-order intermod signal. In this example, let A =159.450 and B = 159.300. The resulting intermod signal is 150kHz and falls far out of band. This results in no interference to any of the in-band channels.

The rule

The rule that says odd-order intermod products fall in-band while even-order intermod products fall out of band is true as long as the frequencies forming the intermod are in-band frequencies. If the frequencies are from different bands, this statement no longer holds true.

Next month we will look at practical examples of intermod and how they can be resolved by taking advantage of the "leverage" factor. Until next time—*stay tuned!* ■