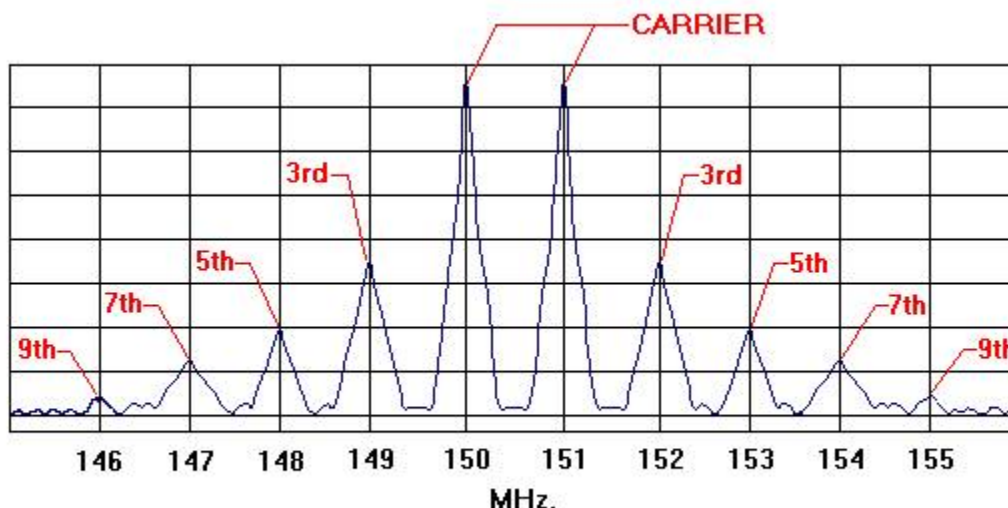


## What is Intermodulation Interference?

Intermodulation interference is the undesired combining of several signals in a nonlinear device, producing new, unwanted frequencies, which can cause interference in adjacent receivers located at repeater sites. Not all interference is a result of intermodulation distortion. It can come from co-channel interference, atmospheric conditions as well as man-made noise generated by medical, welding and heating equipment.

Most intermodulation occurs in a transmitter's nonlinear power amplifier (PA). The next most common mixing point is in the front end of a receiver. Usually it occurs in the unprotected first mixer of older model radios or in some cases an overdriven RF front-end amp. Intermodulation can also be produced in rusty or corroded tower joints, guy wires, turnbuckles and anchor rods or any nearby metallic object, which can act as a nonlinear "mixer/rectifier" device.

In the case of "transmitter" intermodulation, interference can only occur when both transmitters are on the air simultaneously. Suppose that transmitter "A" and transmitter "B" located nearby each other were on the air at the same instant on 150.00 MHz. and 151.00 MHz., respectively. If their antennas are close together it would be possible for the signal from transmitter "A" to be received by the antenna of transmitter "B" and coupled into it's final PA if no isolator, hybrid combiner or cavity filter protection devices are installed. The opposite case can also occur where B radiates into A. In either case mixing can occur in one or both of the transmitter's PA's generating several new frequencies at intervals of 1.0 MHz. (the difference between transmitter "A" and "B", 150.00 - 151.00). Spurious signals will occur at frequency intervals of  $\pm 1.0$  MHz. away from each transmit frequency. Examples are: 146.00 MHz., 147.00 MHz., 148.00 MHz., 149.00 MHz., 150.00 MHz., 151.00 MHz., 152.00 MHz., 153.00 MHz., 154.00 MHz., 155.00 MHz. The carrier frequencies are 150.00 MHz. and 151.00 MHz. The third order products are 149.00 MHz. and 152.00 MHz. The fifth order products are 148.00 MHz. and 153.00 MHz. The seventh orders are 147.00 MHz. and 154.00 MHz. The ninth orders are 146.00 MHz. and 155.00 MHz. Please notice how the signal level diminishes as the odd order increases. Generally the 7<sup>th</sup> and 9<sup>th</sup> orders are too weak to cause intermodulation interference. See the spectrum analyzer drawing below.



**Spectrual Display of Carriers and 3rd, 5th, 7th and 9th Odd Order Products**

Receiver intermodulation occurs as the results of two or more high-level off-channel signals overloading the receiver's RF amplifier causing it to operate in it's nonlinear region thus acting as

a mixer. Older radios may not employ an RF amp and go straight into the first mixer.

It may be difficult to determine where intermodulation is occurring because the new frequencies being generated are precisely the same whether they are generated in the receiver front end, transmitter PA or some other non-linearity. Inserting a 6 db. attenuator in the receiver front-end will attenuate "transmitter" intermod by 6 db. "Receiver" intermod will be attenuated more rapidly because both signals A & B are simultaneously reduced by 6 db each.

Intermodulation products are classified by their order ( $2^{\text{nd}}$ ,  $3^{\text{rd}}$ ,  $4^{\text{th}}$ ,  $5^{\text{th}}$ , ...,  $N^{\text{th}}$ ). The frequencies which give rise to the products are designated by capital letters (A, B, C, etc.). These terms may include harmonics which can be treated in the following manner: the  $2^{\text{nd}}$  harmonic of frequency A is designated "2A", and, therefore, contributes 2 terms; the  $3^{\text{rd}}$  harmonic of frequency B is designated "3B" and contributes 3 terms, and so on. The general equation for the intermodulation product is written:

$$\mathbf{I.M. = n_1A \pm n_2B \pm n_3C \pm \dots}$$

Where A, B, C, etc. are the mixing frequencies and  $n_1$ ,  $n_2$ ,  $n_3$ , etc. are the harmonics, or multiples, of the mixing frequencies. The order of the intermodulation product is equal to the sum of the harmonics ( $n_1$ ,  $n_2$ ,  $n_3$ , etc.). For instance,  $A + 2B + 2C$  generates a  $5^{\text{th}}$  order intermodulation term ( $1 + 2 + 2$ ).

Additional examples of product order: the frequency obtained by adding or subtracting the fundamental frequencies A and B, that is,  $A + B$  or  $A - B$ , are even  $2^{\text{nd}}$  order products; likewise,  $2A - B$  and  $A + B - C$  are odd  $3^{\text{rd}}$  order products while  $3A - 2B$  is a odd  $5^{\text{th}}$  order product while,  $A + B + C + D - E - F - G$  generates a odd  $7^{\text{th}}$  order intermodulation term ( $1 + 1 + 1 + 1 + 1 + 1 + 1$ ).

There is no limit to the number of products, but only a few are of any practical concern. Even order products ( $2^{\text{nd}}$ ,  $4^{\text{th}}$ ,  $6^{\text{th}}$ , etc.) can generally, but not always, be dismissed since they usually fall outside the frequency "band" of interest. The InterMod Calculator provides a checkbox to enable "Odd Order Only" calculations. By not checking the checkbox, both odd and even orders are tested which increases the number of calculations and time required for processing.

The "Low Order" and "High Order" entry fields are normally set to "Low Order" of 3 and the "High Order" of 5. If nothing is found, try incrementing the "High Order" to 7 or 9 or higher if necessary.

For example, an even second order product of 155.00 MHz. and 154.00 MHz. when mixed produces a difference frequency of 1.00 MHz. and a summation frequency of 309.00 MHz., both of which are far removed from the 150.00 MHz. "band" of interest. However, if there was a 309.00 MHz. military channel near this site it could be affected by a mix occurring in a rusty tower joint or the receivers front-end. "Transmitter" intermod at 309.00 MHz. is unlikely because it would be attenuated by the low pass filter in either the 155.00 MHz. or 154.00 MHz. transmitters.

Intermodulation interference most often concerns odd-order products. The most common interference are the  $3^{\text{rd}}$  and  $5^{\text{th}}$  orders. Higher order products are potential sources of intermod which cannot be ignored, because they also fall on in-band frequencies. However, their practical importance is minimized due to the fact that they are formed at lower power levels than the  $3^{\text{rd}}$  and  $5^{\text{th}}$  order products and are usually too weak to cause interference. The number of calculations increase exponentially as the order number goes up.

Even if an intermodulation product falls outside the receiver passband, the deviation (especially of the higher order products) may swing across the receiver passband, causing interference. The deviation of the intermodulation product is equal to the sum of each individual's signal deviation, multiplied by the coefficient for that signal indicated in the above formulas. If signal "A" has a  $\pm 5$  KHz. swing and signal "B" has a  $\pm 5$  KHz. swing, the fifth-order intermodulation product

represented by "2A + 3B" will have a peak deviation of  $(2 \times 5) + (3 \times 5) = \pm 25$  KHz.

For example, two transmitter frequencies: 155.00 MHz. and 154.00 MHz. gives us a 5<sup>th</sup> order  $(3A - 2B) = (465 - 308) = 157.00$  MHz. Suppose your receiver frequency that is being interfered with is 157.025 MHz. It would appear that this calculation would not produce a hit on your receiver. However, if tone signaling or voice modulation is present on each channel at the legal maximum of 5 KHz, then because of the 5<sup>th</sup> order calculation we would experience a peak deviation of  $(2*5) + (3*5) = 25$  KHz. which will now sweep across the channel causing interference and possible falsing of CTCSS/DCS/Burst Tone/Touch Tone/Two Tone/Five Tone decoders. The "Near Hit Window" feature of the InterMod Calculator allows you to check for this type of problem by selecting how many  $\pm$  KHz. off of the direct-hit frequency you wish to test for.

The Receive First High IF, on rare occasions, may be susceptible to strong signals and thus contribute to the potential of Intermodulation. This is why the "Receiver (IF)" field has been included but is rarely if ever used with modern day receivers. Furthermore, any "transmitter" intermod on a receiver's high IF would again be attenuated by the transmitter's PA final tank circuit.

One way to test for Intermodulation on rusty tower joints, rusty or corroded guy wire turnbuckles is to use an ultrasonic sniffer. You can actually hear the interference. Try installing a heavy copper gauge wire around the turnbuckle with clamps on each side. The most important thing of course is to utilize good site maintenance procedures such as isolators, combiners, cavity filters and vertical/horizontal antenna separation. There are several companies that can help you with these products such as EMR Corporation, Telewave, Decibel Products, TX RX Systems, Remec/Waycom.