Telewave.io Passive Intermodulation

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This paper will explore how the radio environment has changed, and why suddenly there is a new urgency to deal with our old enemy intermodulation, now renamed Passive Intermodulation (PIM).

Introduction

Intermodulation is a term that everyone in the LMR (Land Mobile Radio) industry has known for many years. We all have seen and/or used some sort of intermodulation tool that is used to pick system transmit and receive frequencies so that the sums and differences of the transmit frequencies will not equal any of the receive frequencies. We do this just in case, there is some non-linear item in the local transmitter or receiver environment that might take the transmitter energy and re-radiate it as a mix, landing on one of the receive frequencies.

Sometimes a strong on frequency mix happens; thus causing the receiver to not be able to hear the weaker signal from the legitimate user. This on frequency noise can only be fixed by eliminating one of the signals that contribute to the mix; or by removing or fixing the nonlinear item that is radiating the mix.

Some History

Intermodulation was noticed and identified early in the days of LMR. Many options to effectively combat the problem were adopted and for many years were sufficient to keep rogue carriers from stepping on the front of most receivers. Some of these tools were:

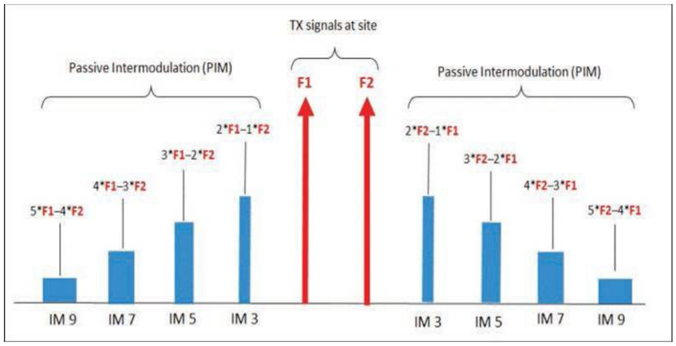
- Careful choosing of transmit and receive frequencies for all the co-located radios; having antennas on the same tower, or on towers within a few hundred feet of each other
- Selection of “compatible” non-reactive materials for fencing, guy wires and other site hardware
- Proper grounding of the tower, fencing, building, cables, radios and power distribution
- Periodic maintenance to make sure that local screws and bolts remain properly tightened
- Use of single or dual stage isolators on the output of all transmitter power amplifiers

As we noted above, careful selection of transmit and receive frequencies so that we know that all of the frequencies are mathematically compatible is a great first step, however:

- The calculation is only fool proof if you know ALL transmit and receive frequencies in use at the site; missing one transmit frequency can mean that a new receiver may not properly function.
- The calculation can become more and more cumbersome as additional frequencies are added to the scenario (modern algorithms & computers are better at resolving these complex problems)

Good construction and maintenance procedures at the site may take care of most external mix points.

The isolators placed on the output of the transmitter amplifiers do a good job of keeping any energy from other transmitters, from getting into the power amplifier circuitry; and mixing with the primary signal to produce intermodulation carriers.



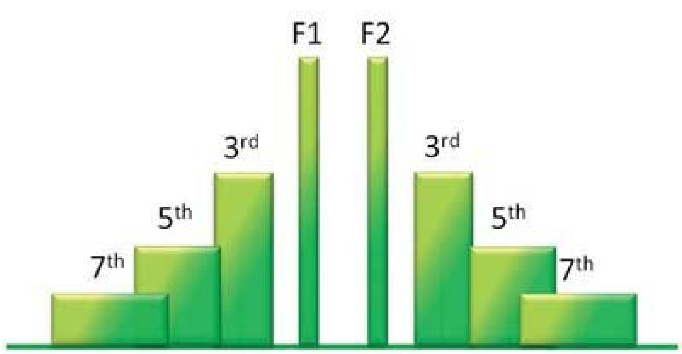
2-Tone IM products from two narrow bandwidth signals; with each order away from the primary the signal has less Amplitude but occupies more bandwidth.

What Changed?

For many years the use of software to find mathematically compatible frequencies, good construction and good installation practices sufficed. Then two things happened:

- Digital Modulation
- Wide bandwidth carriers for data (in addition to narrow bandwidth carriers used for voice only)

Suddenly the 2-tone algorithms no longer sufficed for predicting what signals would be compatible and which could create an intermodulation signal. In the cellular world a 200 KHz wide GSM signal creates a third order intermodulation sums and differences that are both 400 KHz wide! Now couple this wider bandwidth carrier with multiple carriers running at the same time, and the possible result is wide swaths of noise is generated across the entire RF spectrum.



Wider bandwidth carriers mean wider bandwidth intermodulation products when they occur.

How does this affect my narrow band LMR receiver?

Now where we used to think of 2F1 - F2 = 3rd order hit, we now have to think like this:

- (Bandwidth (lowest to highest frequency) of Carrier 1 times 2) minus

- Bandwidth (lowest to highest frequency) of Carrier 2 =
- 3^{rd} order hit of (2 * Bandwidth) of the widest carrier in the mix

With real numbers this time:

- (F1 = 824.2 MHz (BW of 200K = 824.1 to 824.3 MHz) times 2 = 1648.2 to 1648.6 MHz) minus
- F2 = 848.8 MHz (BW of 200K = 848.7 to 848.9 MHz)
- 3^{rd} order hit from 799.4 to 799.8 (400 KHz wide) Channel 65 - 128 / 1025 – 1088 all 6.25 KHz

As you can see in the example above; 400 KHz of the repeater/base receive bandwidth could be rendered useless, if there is sufficient energy present in a 3^{rd} order carrier produced by the mix of just two cellular transmitters. In this example several state and general use public safety channels are affected, as well as; 7MED66, 7AG60 (air ground), 7TAC52 and 7TAC55 interoperability channels.

The same bandwidth hit is true when a single LMR carrier is mixed with a 200 KHz wide GSM carrier; or a 100 KHz wide FM Broadcast carrier, or a 200 KHz wide FM-HD carrier, or a 6 MHz wide Digital TV Carrier. The 3^{rd} order IM hit will be 200 KHz, 400 KHz, or 12 MHz wide and could have a substantial power level.

How can Telewave.io help mitigate the Passive Intermodulation problem?

For many years Telewave.io has manufactured single and dual stage isolators. These isolators can be sold separately or as part of a combiner system. The isolators provide two functions:

- Safety valve to absorb energy reflected from a failed filter, cable or antenna component.
- Keep any energy from other transmitters from reaching the local transmitter power amplifier.

Keeping any external energy out of the power amplifier is important. This energy can mix within the circuitry and the intermodulation products amplified and radiated out the antenna along with the fundamental carrier. This is a waste of transmitter power and potential cause of receiver problems.

Telewave.io recently introduced new PIM-rated antennas to our product portfolio.

Along with the other high quality Telewave.io components in a LMR combiner or duplexer system, the PIM rated antenna will not be a source of significant intermodulation mixing no matter the transmitter power levels or the power level and frequencies of any other carriers in the environment.

When mixing and interference does occur, the Telewave.io components in the transmission system need not be considered a suspect during troubleshooting.

All Telewave.io antennas and other components are constructed in Fremont, CA. to exacting quality standards, and are individually tested before they are carefully packed and shipped to our customers.