Passive Intermodulation (PIM): What You Need To Know

Electronic Design
Lou Frenzel
Communications Editor
Mon, 2013-03-04 16:55

Q: What is passive intermodulation (PIM)?

A: PIM is the generation of interfering signals caused by nonlinearities in the mechanical components of a wireless system. Two signals mix together (amplitude modulation) to produce sum and difference signals and products within the same band, causing interference.

Q: Where does most PIM occur?

A: PIM is a problem in almost any wireless system but is most noticeable in cellular basestation antennas, transmission lines, and related components.

Q: What actually causes PIM?

A: The interaction of mechanical components generally causes the nonlinear elements, especially anywhere that two different metals come together. Junctions of dissimilar materials are a prime cause. PIM occurs in antenna elements, coax connectors, coax cable, and grounds. It is caused by rust, corrosion, loose connections, dirt, oxidation, and any contamination of these factors. Even nearby metal objects such as guy wires and anchors, roof flashings, and pipes can cause PIM. The result is a diode-like nonlinearity that makes an excellent mixer. As nonlinearity increases, so does the amplitude of the PIM signals.

Q: What conditions are necessary to cause PIM?

A: Typically, two relatively strong RF signals relatively close in frequency are required to trigger PIM effects. The outputs from two or more high-power (20 W or so) transmitters are enough to create the PIM effects. The higher the power used, the greater the PIM signals generated.

Q: What other conditions affect PIM?

A: PIM tends to increase as components age. Older systems are particularly susceptible. Environments where there are wide temperature variations, salt air or polluted air, or excessive vibrations exacerbate PIM.

Q: How are the various signals are formed?

A: Mixing generally produces the sum and difference frequencies of the two transmit signals f1 and f2. These signals are f1 + f2 and f1 – f2. Sum and difference signals are also formed with the harmonics of the transmitter signals.

Q: For example?

A: Consider the two cellular frequencies of f_1 = 869 MHz and f_2 = 894 MHz. Mixing these two signals together produces 894 – 869 = 25 MHz and 894 + 869 = 1763 MHz. These two signals are way out of the cellular bands of interest, so typically they won't cause PIM interference. However, the signals that mix with the second harmonic and higher harmonics are the problem. For instance, the second harmonics mixed with the base frequencies produce what we call third-order intermodulation products $2f_1 - f_2$ and $2f_2 - f_1$. These would be 844 MHz and 919 MHz, respectively, both in the same cellular band. These third-order PIM products are known as IM3 or IP3. Other harmful signals are the smaller fifth-order signals $3f_1 - 2f_2$ and $3f_2 - 2f_1$ called IM5. The signals to worry about are $mf_1 \pm nf_2$ where m and n are the harmonic numbers. The figure shows the spectrum generated by PIM.

Q: Besides interfering signals, what are the other negative effects on the wireless system?

A: The main effect is on the receiver with its high sensitivity. Interfering signals can raise the noise floor and block desired signals. Interfering signals can also reduce receiver sensitivity. End effects include dropped calls, decreased system capacity, and decreased data rates.

Q: What wireless systems are most affected?

A: Cellular systems using broadband methods like CDMA, HSPA, and LTE are the most vulnerable.

Q: How do I know if I have a PIM problem?

A: If its effect is minor, you may not know at all. If the problems of receiver sensitivity or interference seem to be present, you may have PIM. To know for sure, you have to test for it.

Q: What is the test procedure for PIM?

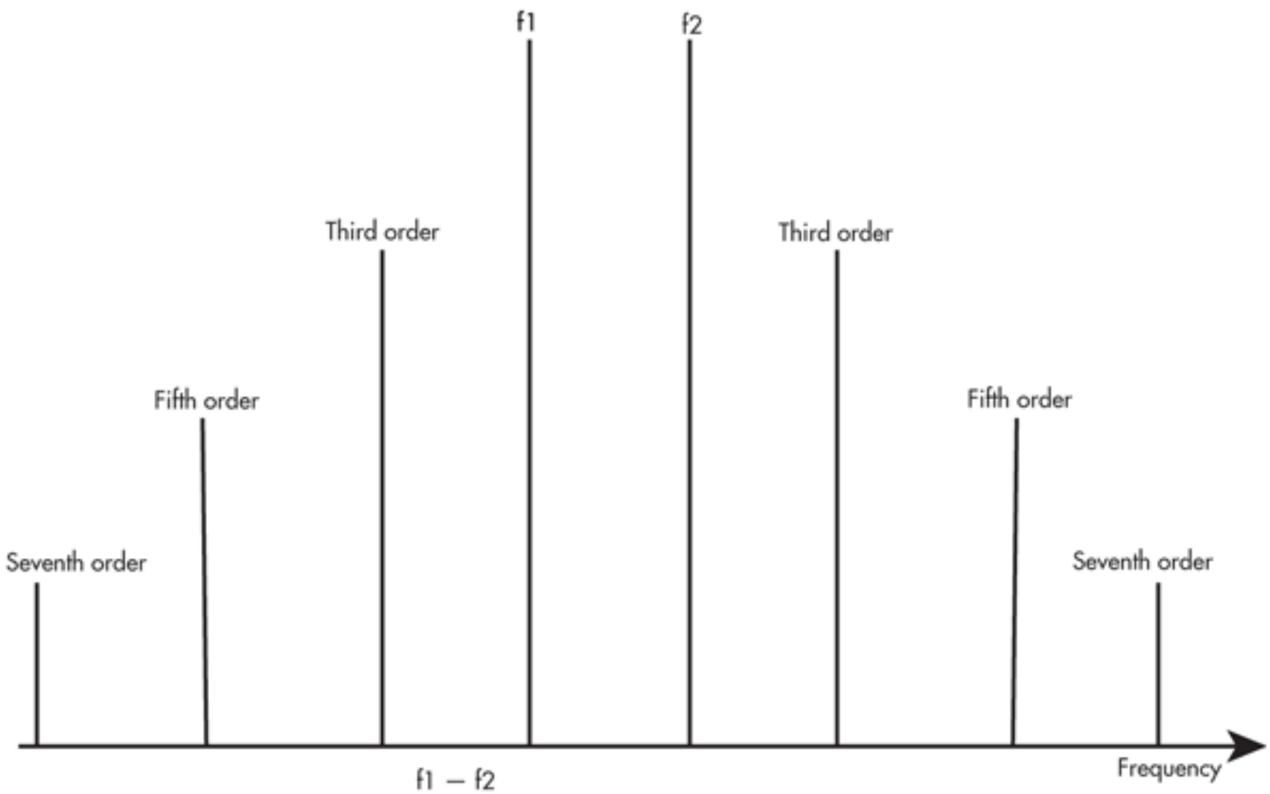
A: The basic process is to generate two high-power (typically 20 W or 43 dBm) RF signals similar to the ones used in the system and apply them to the cable, antenna, or other objects to be tested. If nonlinearity is encountered, PIM will be generated. The PIM signals travel from the cable to the antenna. They also propagate back to the PIM signal source where the test receiver will pick them up and display them. You will need a spectrum analyzer to see the signals. The most problematic signals are the IM3 signals. The best approach is to use test instruments especially made for PIM testing.

Q: How is the test procedure conducted?

A: One approach is to try to stress the suspected components involved. For example, you may want to tap on connectors or other components. Flex any suspected cables. You should do this while monitoring the PIM output on the test equipment. Some PIM testers have a feature that can measure and determine the distance to the nonlinear fault.

Q: Which companies make PIM test equipment?

A: Multiple companies make PIM test gear, including Agilent, Anritsu, Boonton, Kaelus, Rosenberger, Summitek, and Tessco.



PIM nonlinearities produce a specific frequency spectrum. The third-, fifth, and seventh-order signals are caused by f1 and f2 harmonics. The spacing between signals is f1 – f2.

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