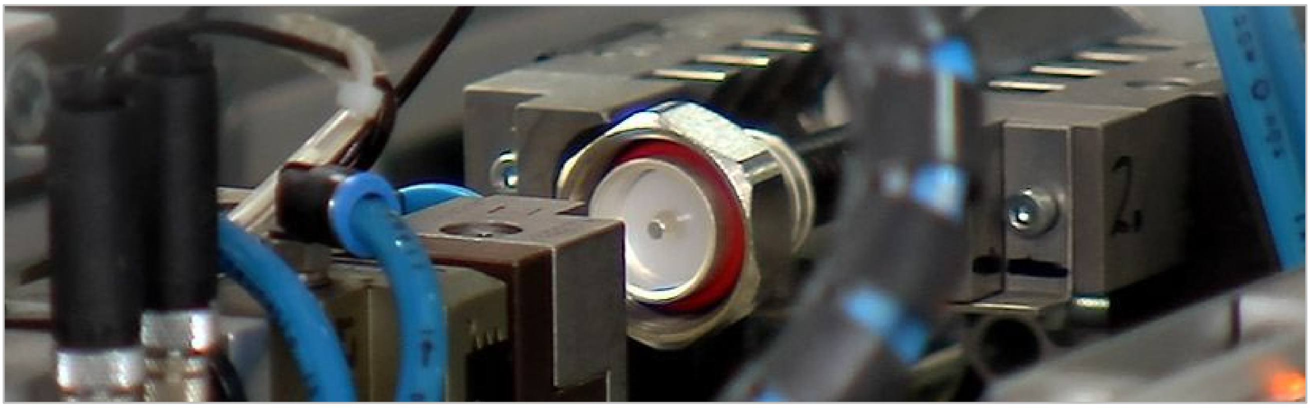
Passive Intermodulation - PIM

1. PIM at SPINNER

SPINNER was the first vendor to recognize passive intermodulation (PIM) as a potential risk to the performance of mobile communications systems. Already in 1994 we introduced the world's first automated jumper production line that automatically solders and assembles jumper cable assemblies, resulting in superior electrical and mechanical properties and considerably better passive intermodulation values than those of manually assembled connectors.



As PIM testers at that time were not commercially available, we developed our own PIM test setup to be able to prove the outstanding PIM performance of our products.

Additionally SPINNER took a leading role in drawing up the first international standard IEC 62037-1 which defines the intermodulation measurement of passive RF devices.

Nowadays mobile networks with different technologies use up to 8 frequency bands at the same time. Low PIM products are therefore more important than ever, and network operators around the world are aware of PIM's impact on the overall performance of their RF network. Understanding the growth in mobile networks based on additional frequency bands makes one decision very clear at SPINNER: a strong focus on developing a comprehensive low PIM portfolio – and has been doing so for more than thirty years!

Videos:
- Tests mit 4.3-10 und 7-16 low PIM Jumperkabel (https://youtu.be/ystqqkPB-lA)
- Tests mit 4.3-10 und 7-16 low PIM Messkabel (https://youtu.be/x2pZ_j5nvB0)

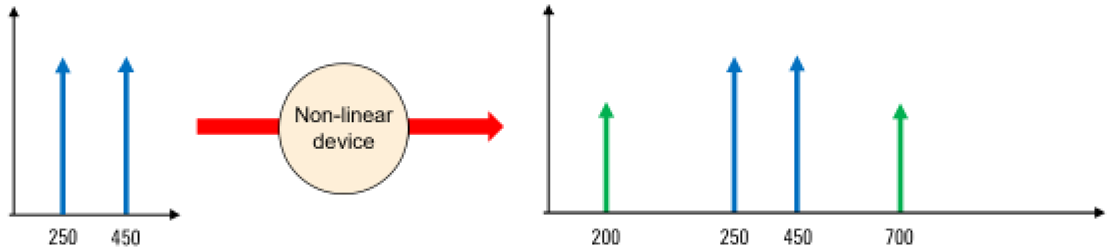
2. PIM – General Information

2.0 Intermodulation Products

PIM is a form of distortion that occurs when at least two different frequencies are transmitted by a passive component - normally thought of as linear - such as a connector or a jumper. Non-linearities of the component, e.g. due to poor design, imprecise manufacturing, poor material or improperly processed surfaces, cause an interference signal at the sum and difference frequencies.

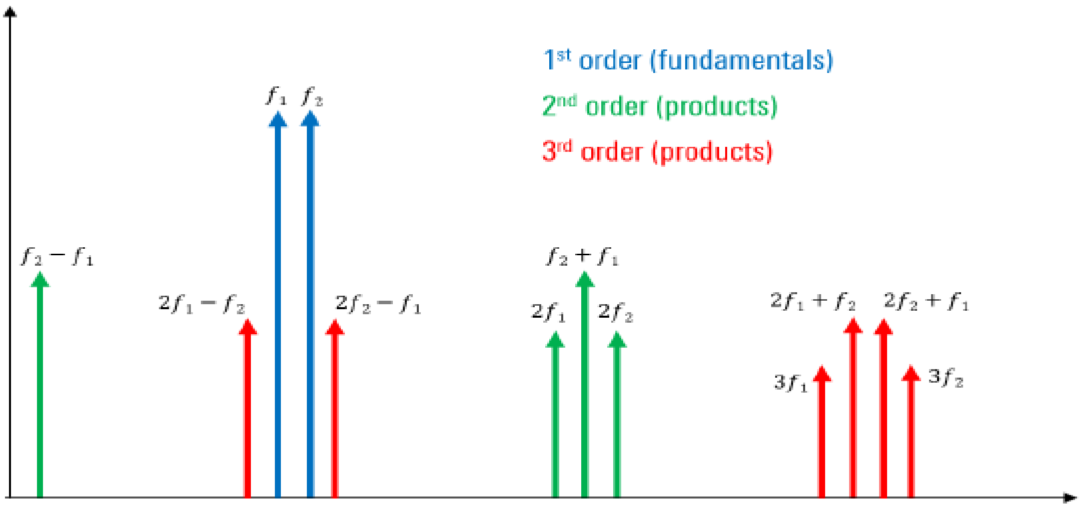
Template TD-00003A

For example, two signals, one at 250 MHz and one at 450, are input to a non-linear device. The output will contain both the original input tones, as well as tones at 700 MHz (the sum of 250 MHz and 450 MHz) and 200 MHz (the difference between 450 MHz and 250 MHz). The amplitude of these intermodulation products is always lower than the amplitude of the fundamental signals.



2.1 Higher Order of Intermodulation Products

In the example above, the mixing only occurrs between the two fundamental tones. However, it's also possible that mixing occurs between fundamentals and harmonics. This means that not only the two fundamental tones, f1 and f2, mix with each other, but they will also mix with the second harmonics, 2f1 and 2f2. This in turn produces additional intermodulation products at 2f1 + f2 , 2f1 – f2, 2f2 + f1, 2f2 – f1, etc.



The “order” of intermodulation products refers to the sum of the coefficients. For example, 2f1, the second harmonic of f1, is "second" order. Also the sum of the two fundamentals, f1 + f2 is second order (1 + 1). The third harmonic of f1, 3f1 is third order. And 2f2 – f1 or 2f2 + f1 are also third order products. These third order intermodulation products are particularly important when it comes to understanding passive intermodulation.

2.2 Width of Intermodulation Products

An additional important aspect of intermodulation products is that as the order of intermodulation products increase, the width of these intermodulation products increases. For example, if the fundamentals are 1 kHz wide, the 3rd order products will be 3 kHz wide, the 5th order products will be 5 kHz wide, etc. Depending on the frequency and spacing of the fundamentals, this widening of the signals may be hard to see in spectrum, especially when testing using narrowband or CW tones. However, this becomes much more noticeable if the fundamentals are wider. Cellular downlink signals may be several MHz wide (3G), tens of MHz wide (4G) or even hundreds (5G) of MHz wide.

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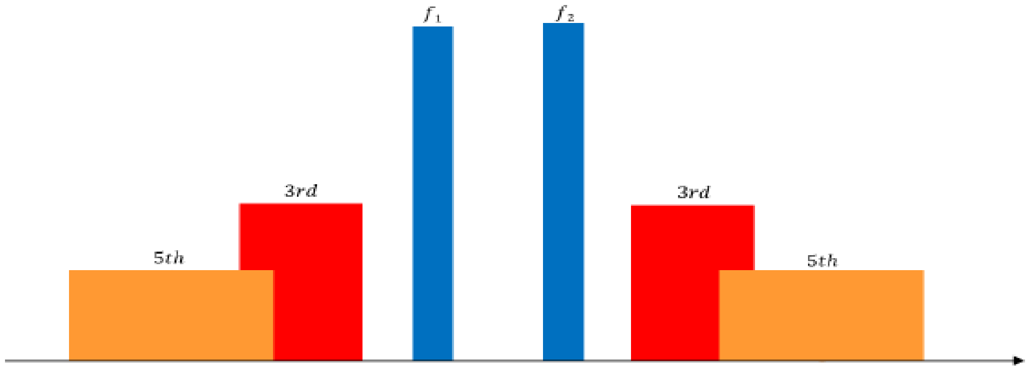

2.4 Common PIM sources

The junction of dissimilar materials or metals is the most common source of PIM, and these junctions can be created in various ways. Corrosion or rust is a very common culprit, as are defects during manufacturing or installation. Loose or overtightened connectors are another common source of PIM, and even passive components such as directional couplers can lead to PIM issues.

2.5 PIM vs. Power

In theory, third order intermodulation products decrease by 3dB for every 1dB in carrier power. That means that for each 3dB decrease in carrier power the 3rd order PIM power level decreases by 9dB. As intermodulation products are specified in dBc (decibel relative to the carrier), the relative power level decreases by 2dB for every 1dB in carrier power.
In reality third order PIM products will barely be measurable at 2x10W and they will be below the noise floor of the PIM test equipment at 2x5W. However, some equipment cannot be tested at 2x20W due to the power input limits. This is confusing though and makes it difficult to compare parts with different power ratings from different vendors. To be consistent in definitions, PIM can in such cases be specified in absolute level of dBm:

CW Power Rating	Test	PIM = -118dBm	PIM = -110dBm
40W	2 x 20W (+43dBm)	-161dBc (reference)	-153dBc (reference)
20W	2 x 10W (+40dBm)	-158dBc	-150dBc
10W	2 x 5W (+37dBm)	-155dBc	-147dBc
5W	2 x 2.5W (+34dBm)	-152dBc	-144dBc

2.6 Problems caused by PIM

PIM products are almost always undesired signals, especially when it comes to cellular networks. These products can fall into other channels or bands, creating noise, distortion, etc., which in turn can have a strong negative impact on the key performance indications in wireless networks, such as throughput, retainability (or call drops), etc.

In particular, the third order intermodulation products are the most troubling, since they both fall closer to the fundamental signals in frequency and they have greater amplitude than the higher order products. Note however that although these higher order intermodulation products are lower in peak amplitude, they can be very wide, raising the noise floor over a broad spectral range. This higher noise floor is a more serious problem for newer generations of cellular which tend to require a “cleaner” RF environment and lower noise floor due to their higher order modulation schemes. In addition, as spectrum becomes more crowded, there is an increased probability of intermodulation products falling onto occupied frequencies. Intermodulation products generated from the mixing of two cellular downlink carriers is particularly troublesome for several reasons: the carriers are typically very broad (especially in 4G and 5G networks), they have relatively high power, and these signals are "always on."

2.7 Internal vs. External PIM

There is another important distinction that should be made when discussing PIM: namely, the difference between internal and external PIM. In the case of internal PIM, the source of the PIM is between the transmitter and antenna. For example, if PIM is being caused by metal flakes inside of the base station cables or connectors, this would be a case of internal PIM. On the other hand, if a rusty fence near the antenna is creating PIM, this is an external PIM source – PIM is being generated outside of the base station components. Generally speaking, external PIM sources are much harder to physically locate and remedy than internal PIM sources.

2.8 Low PIM Measurement Equipment

Before network components can be tested for low PIM, a suitable measurement environment must be in place that meets even more stringent PIM requirements. This is due to the intermodulation that occurs within the test system, but also to the intermodulation of other components involved in the test, such as measuring cables, absorbers or attenuators. The applicable IEC standard requires their inherent PIM to be 10 dB better than the devices under test. At SPINNER, we support our customers worldwide in setting up professional and reliable measurement environments with low PIM testing components such as EasyDock Testing Adaptor, Coaxial Cables, Loads, Rotary Joints, Switch Matrices, Adapters, Port Saver and IM Reference Standards.