



Identification of External PIM Sources with Kaelus PIM Finder

Application Note

Introduction

Passive intermodulation (PIM) is a well-known issue in cellular systems. Downlink signals at the cell site mix at passive, non-linear junctions in the RF path, creating new signals at different frequencies to the original downlink signals. If the new signals fall in an operator's uplink band, they can elevate the noise floor and degrade system performance.

A challenging category of PIM to remedy is external PIM. This refers to PIM generated not in the cell site's antenna infrastructure but rather in objects in the surrounding environment. Examples include loose mounting brackets, roof flashing and structural steel beams. In such cases, downlink signals from the base station's antenna illuminate the external PIM source, causing a PIM signal to be excited in the object. The PIM signal is then re-radiated back towards the antenna and into the receiver of the BTS.

Identifying the location of external PIM sources has historically been a complicated problem for mobile operators worldwide. To address this measurement challenge, Kaelus offers a solution: the Kaelus PIM Finder.

Kaelus PIM Finder solutions include a software option available through the Kaelus Unify app, used in combination with the iVA Cable & Antenna analyzer and iPA/iXA Portable PIM analyzer.

The PIM Finder offers two solutions:

- The **PIM Finder 1-port solution**, as illustrated in Figure 1, is the base model and is available for all frequencies. An iPA (1) generates two CW tones and applies them to the antenna system. Thus, a simple PIM test can be performed, and the iPA can measure the reflected PIM. However, the only information provided to the user is the reflected PIM amplitude. The location of the PIM source is still unknown. Using the Range-to-Fault module (RTF) (2), the user can determine the distance from the iPA to the PIM source. He can also differentiate if the PIM source is located internally or externally to the system. The PIM sources internal to the system are somehow easy to locate, the RF system being a "close" system. However, for the external PIM sources, the only information provided to the user is the approximate radial distance to the antenna. Using the iVA (5), BPA (4) and Probe (3), the user scans the neighbouring environment with the Low-PIM probe while monitoring the received PIM level with the iVA using the PIM Finder mode. The iPA and iVA are controlled from one tablet (6) using the Kaelus unify application.
- The **PIM Finder 2-port solution**, as illustrated in Figure 2, is an advanced solution designed to detect external PIM generated when two or more radio units are collocated. This solution allows the PIM measurement to be performed in a situation as close as possible to the site configuration. The iXA (1) generates two CW tones and applies one tone on each antenna. With this approach, the PIM sources internal to the antenna systems cannot produce intermodulation products since they are only energized with a single tone. The rest of the method of operation is similar to the 1-port solution. Still, with some significant advantages: the iXA offers two different measurement modes which can be selected and configured remotely by software. First, the user can perform a standard two tones test and verify the internal PIM level of each system, then can switch seamlessly to the 2-port mode to focus on external PIM finding. Second, the iXA contains two RTF, one on each port. It, therefore, allows the user to perform four sets of RTF measurements: 2 tones on each feeder and one tone on each feeder (high band and low band). Consequently, the user now has four times the information compared to the 1-port solution to locate the external PIM source. Once the external PIM source has been identified, a variety of PIM mitigation techniques can be employed to reduce the PIM level and improve system performance.

The Kaelus PIM Finder solutions are suitable for all types of cell sites, including macro, small cells, rooftop and in-building for DAS systems.

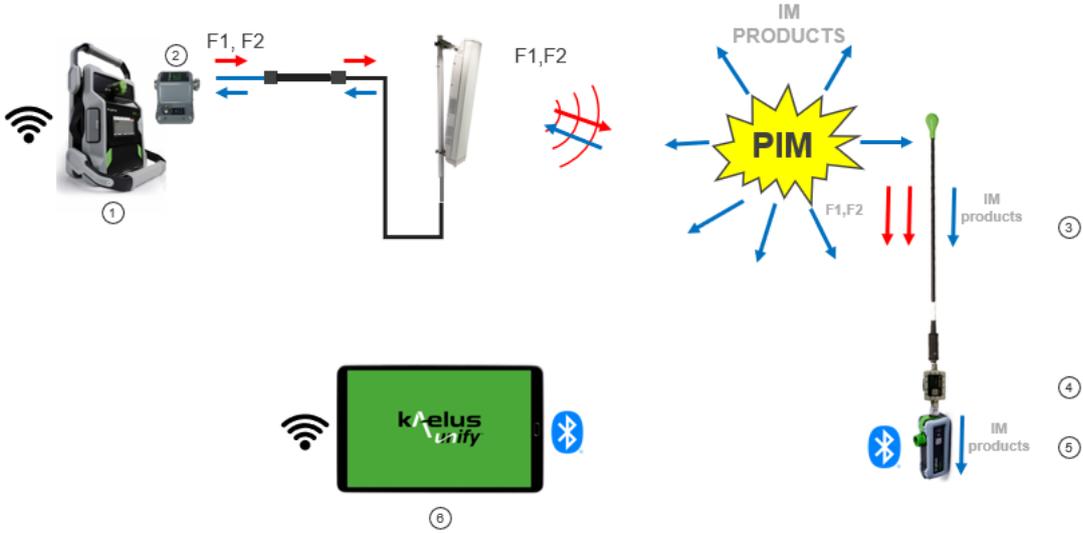


Figure 1. Diagram illustrating Kaelus PIM Finder (1-port solution) principle of operation.

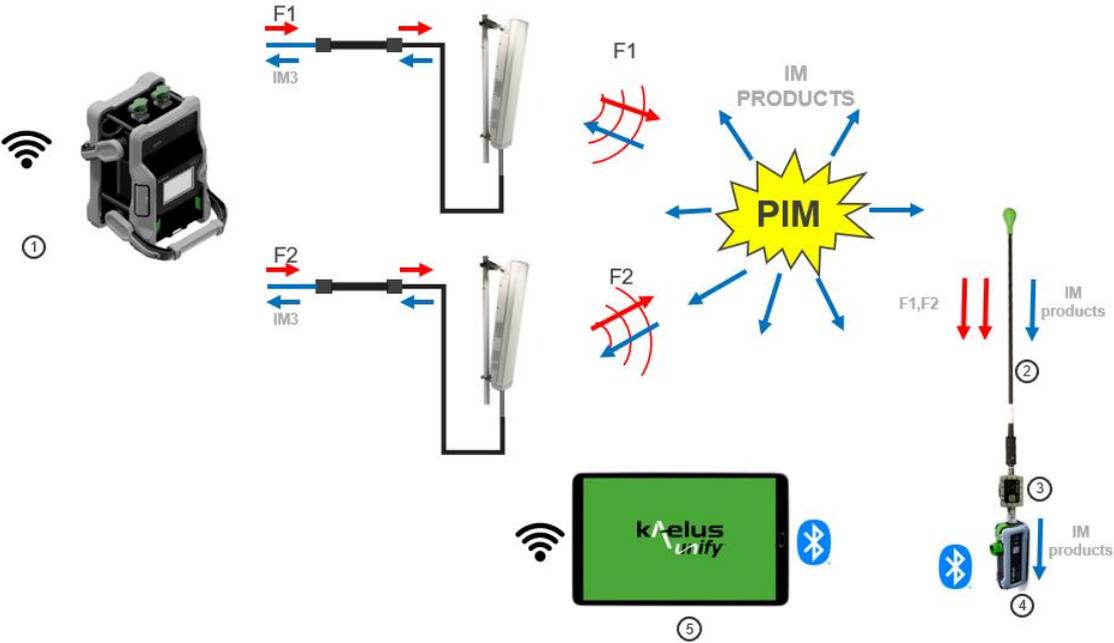


Figure 2. Diagram illustrating Kaelus PIM Finder (2-port solution) principle of operation.

Before going on site

For the site activities to be as efficient as possible, Kaelus advise to perform some preliminary investigations to get a better idea of the root cause of the interference issues:

- By turning off the radio transmitter, check if the radio receiver interference level reduces. If it does, there is a good chance that the interference is related to intermodulation products.
- Review the transmitter allocated frequencies used at that particular site and identify potential cross band PIM issues. Typically 2nd, 3rd, 4th, and 5th order PIM are the most likely root cause of noise floor rise. Refer to the White Paper: [Cross-Band PIM Generation in Collocated Cellular Base Stations.](#)
- Review site pictures to understand the configuration and equip yourself with the right PIM mitigation hardware.

Preparing for a PIM Finder Measurement

The equipment requirements for PIM Finder are as follows:

- iPA or iXA Portable PIM Analyzer¹
- iVA Cable & Antenna Analyzer
- Low-PIM Probe
- BPA, Bandpass Amplifier Filter (pass and amplify iPA/iXA receive band, reject iPA/iXA transmit band)
- Tablet computer with Kaelus Unify app installed



Figure 3. Equipment required for PIM Finder mode.

The first step in preparing for a PIM Finder measurement is to open the Kaelus Unify app, go to the Devices menu and establish wireless connections between the tablet and the iPA/iXA and iVA.

¹ If the user does not have access to an iPA/iXA PIM analyzer, or if the iPA/iXA is out of range of the tablet, it is possible to run PIM Finder in “standalone” mode. Note that this will require the user to perform additional manual steps when configuring and initiating a PIM Finder measurement. Refer to the PIM Finder Quick Start Guide for details.

The second step is to choose the Traces menu and select “PIM Finder” from the list of measurement modes. Kaelus Unify will automatically configure the iPA for a fixed-tone IM3 test, using the instrument’s default carrier frequencies and power levels. It will also tune the iVA’s receiver to the corresponding IM3 frequency. You will also need to set up the band pass amplifier gain level, refer to BPA PIM Finder Quick Start Guide.

As an optional third step, the user may define a PIM limit line and an (optional) audible alarm that will sound if the measured PIM level goes above the limit line.

The final step is to connect the iVA, Band Pass Amplifier (BPA) and low-PIM probe together as shown in Figure 3. Note that the use of the BPA is strongly recommended, as it prevents spurious PIM from being generated in the front end of the iVA by the test tones from the PIM analyzer. Refer to the [BPA quick start guide](#) for set up.

The PIM Finder system is now ready for use.

Process for Identifying an External PIM Source

The external PIM troubleshooting process begins with a traditional field PIM test on the cell site’s antenna infrastructure. The iXA portable PIM tester makes this measurement easy as the switching between 1 port and 2 port measurement is seamless.

If the PIM level is higher than the maximum permissible limit, the next step is to determine whether the fault is internal or external to the cell site. This can be achieved by performing a distance-to-PIM measurement using the Kaelus RTF module, and determining whether the fault lies before or after the antenna.

If the RTF module shows the PIM source lies beyond the antenna, it is often helpful to place a strong PIM source like a steel wool pad on the antenna aperture. This allows you to measure the relative distance between the antenna and the external PIM source.

Equipped with this information, you have an approximate starting distance to begin your search for the external PIM source.

Set up the PIM Finder system as described in the previous section, and trigger a measurement. The PIM Tester automatically turns on and performs a fixed-tone PIM test. At the same time, the iVA starts measuring the received PIM level, while the tablet plots PIM vs Time continuously on screen.

Now begin to physically search for the external PIM source by moving the low-PIM probe slowly across objects that are located the expected distance from the antenna, as shown in Figure 4.



Figure 4. Troubleshooting an external PIM source on a rooftop site using the Kaelus PIM Finder.

During the search process, be conscious of where you are standing. The body is a good attenuator by standing between the antenna and the external PIM source. As shown in Figure 5, the PIM level may drop dramatically.



WARNING! The radio frequency fields near cellular antennas may exceed safe levels for human exposure. Personnel engaged in troubleshooting external PIM sources should be trained for work in radio frequency environments and use a personal RF monitor if working near active antennas.

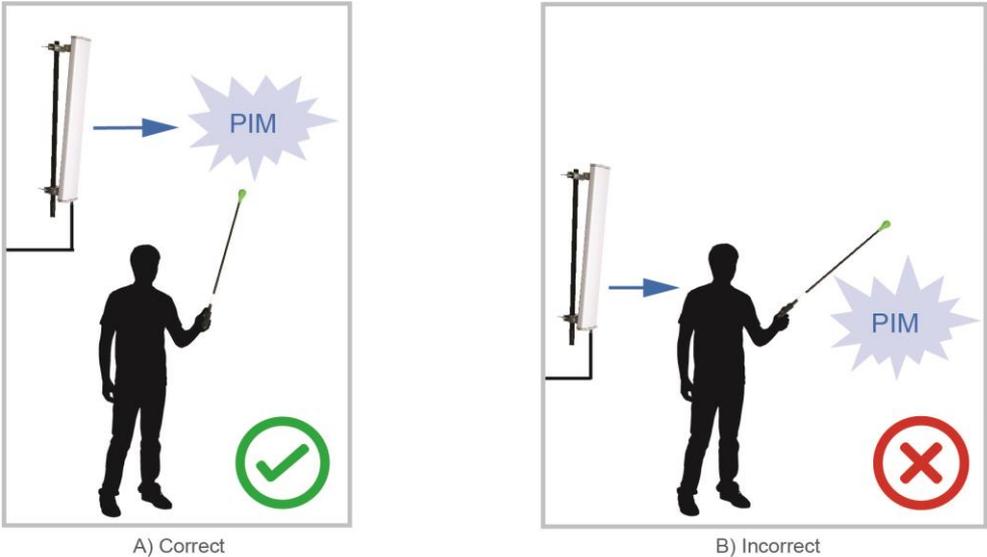
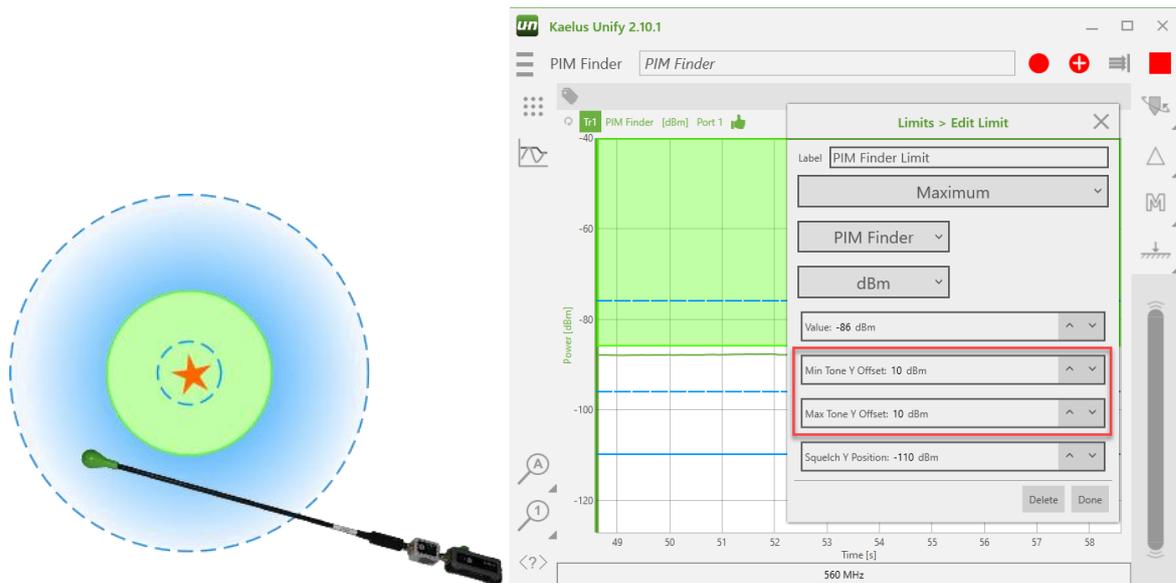


Figure 5. Illustration of correct and incorrect positions to stand in when searching for external PIM sources.

Moving closer to the external PIM source will cause the measured PIM level to rise. Using the audio and visual feedback developed based on experts advice, the PIM sources are much easier to find: the three controls; *Min Tone Y Offset*, *Max Tone Y Offset*, and *Squelch Y Position* work together to give you an amazing experience when searching for PIM. Read on to find out how...

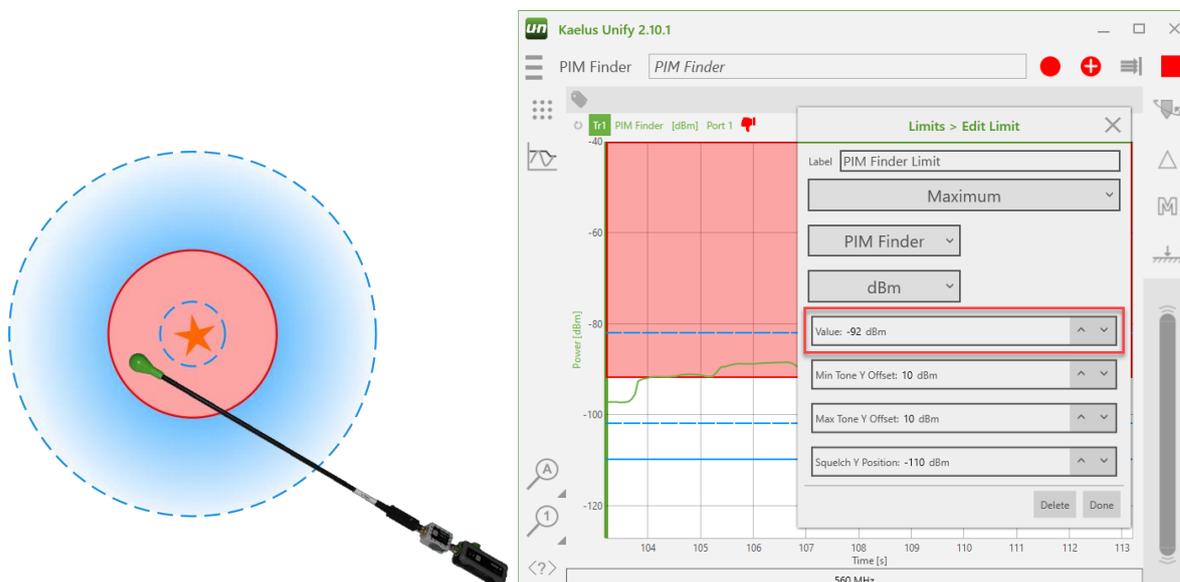
Create a circle-of-concern

The *Min* and *Max Tone Y Offset* values are represented by blue dashed lines relative to your limit threshold. These offsets control the lowest and highest comfortable audio tone values. Any signal received between these will provide a smooth audio feedback, and anything below will be silent. By being defined as offsets, these values move with your limit, meaning no adjustments are required as you scroll your threshold to target a differently sized PIM source... your circle-of-concern will always be ready for your next challenge.



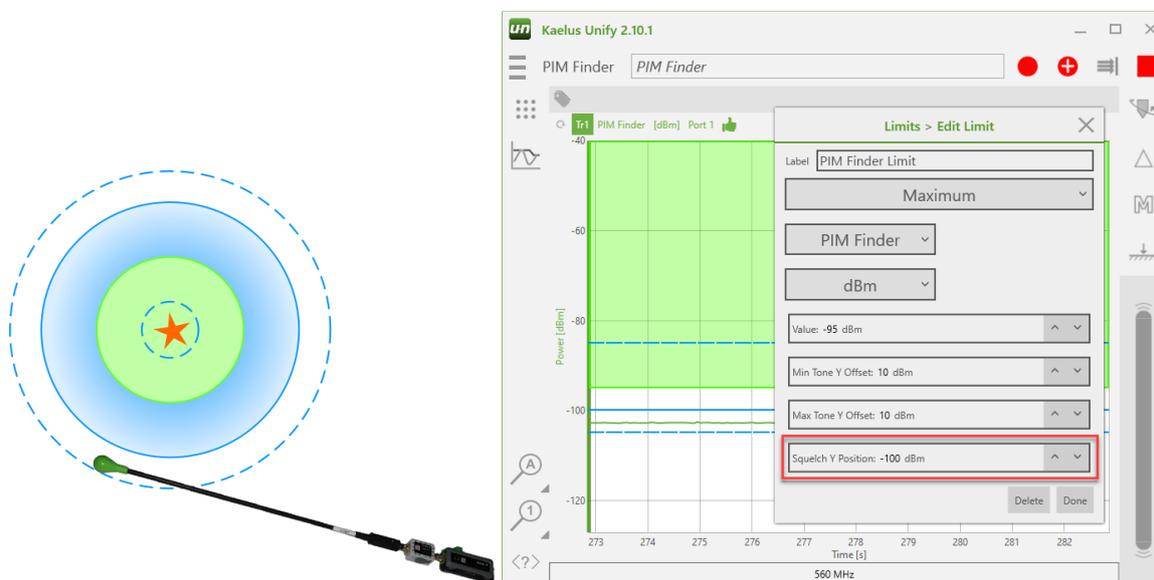
Finding the center

Your screen turns red *only* when your trace crosses the threshold set by your PIM Finder Limit. A short beep gets your attention without distracting from the continuous audio.



Avoid the noise floor

Often you must search for PIM right down to the noise floor of your spectrum analyzer. If the lower audio threshold happens to go below the noise floor, you'll always hear a tone and you lose your circle-of-concern. Set the *Squelch Y Position* just above your noise floor to automatically trim your circle-of-concern when getting down this low and save the pain of having to adjust your audio offset settings.



Once the external PIM source has been identified, a variety of PIM mitigation techniques can be employed to eliminate the fault.

As is the case for all measurements performed using Kaelus Unify, PIM Finder results can be tagged and saved if desired, in order to be included in the final site report.

Conclusion

External PIM sources have historically been very difficult to diagnose and isolate. With the introduction of Kaelus PIM Finder into the PIM testing arena, operators now have a tool set that allows them to rapidly and precisely determine the location of this type of fault.

The tight integration of PIM Finder with the Kaelus Unify software platform facilitates a high degree of automation in the measurement process, as well as allowing users to take advantage of the sophisticated reporting features of Kaelus Unify.

Contact Kaelus at www.Kaelus.com for additional information or to request a quote.