MORE SPECTRUM, NEW CHALLENGES:

PIM in the age of 5G

EXFO

RCRWireless News
INTELLIGENCE ON ALL THINGS WIRELESS

MORE SPECTRUM, MORE PROBLEMS: PIM in the age of 5G

Radio frequency interference is the bane of good network performance, and the RF environment is only getting more complex with the deployment of 5G—meaning more opportunities for interference to rear its head. A variety of new spectrum bands, from low-band 600 MHz all the way up to millimeter-wave frequencies, are being deployed to meet 5G's needs for wider channels, additional bandwidth and capacity so that the newest "G" lives up to consumer and enterprise expectations. Carriers are building out these new networks as rapidly as possible, and RF interference issues gum up the works with the additional time and expense of location and mitigation, not to mention the potential customer ramifications of a less-than-stellar 5G experience.

One of the primary problems in 5G networks is passive intermodulation, or PIM. PIM isn't a new issue in cellular networks, but it is an increasingly common cause of interference because of the increasing density of cellular networks, the increased bandwidth and use of more sensitive, higher-order signal modulation and new, midband Time Division Duplex spectrum that is being deployed, particularly in the C-Band.

THE PIM PROBLEM IN 5G

Passive intermodulation is interference that is generated when two or more simultaneous signals interact in a nonlinear environment, where passive components (as opposed to transmitting ones) can cause new, unwanted signal noise to be generated that impacts the performance of the RF system.

Why is PIM taking on a new life in 5G? There are a number of reasons, explains Tom Bell. Bell is senior director of interference products at ConcealFab, which has been working since 2016 specifically on developing methods to identify and mitigate passive intermodulation.

These reasons include:

1. **New midband spectrum** that is designated for 5G deployments around the world is TDD spectrum, meaning that timing and synchronization is crucial to network performance. If neighboring (particularly co-located) cell transmissions are out of sync and "step on" one another, this results in intermodulation interference, says Bell. "If you don't synchronize properly, you are absolutely dropping a third-order intermod directly into the adjacent channel," said Bell. "So synchronization is absolutely crucial."

   Simply adding new spectrum bands—in this case, many spectrum bands, including low-, mid- and high-band airwaves—increases the chance of second- and third-order signals that will fall somewhere in spectrum actively being used at a site. In North America, Bell adds, there is also already PIM interference happening due to lower frequencies interacting and creating second- and third-order intermodulation products in the 3.7 GHz uplink. Every operator using midband spectrum for 5G will have to navigate these issues.

2. **Macro deployments** will generally see more PIM issues. With a new network technology deployment, carriers focus first on gaining as much coverage as possible. This means a focus on macro-site deployments at full power. PIM is highly correlated with power levels. While small cells may also have PIM problems, the issue is more significant at macro sites (the first and easiest sites that are sought for coverage) because of the higher power levels.

3. **New deployments can mean newly noticeable PIM.** There's a bit of an "if a tree falls in a forest" situation with PIM interference, where the severity of the problem isn't necessarily evident until a new network is up and operating. Noise may be generated in the band(s) at issue, but it may not be obvious and impact performance until there is a turned-up network with active devices—because another characteristic of PIM is that as traffic increases, so does the level of interference.

4. **Deployment activities themselves are likely to generate PIM.** Every time a human touches a tower, they may do something that increases the risk of PIM: Bumping or knocking something loose, adding new metal to the site, leaving behind metal trash that could generate PIM. With the scale and speed being demanded for 5G deployment, this increases both site activity and the possibility of installation mistakes that can result in PIM.

THE HUNT FOR PIM

When it comes to identifying, tracking down PIM sources and mitigating them, the process has some relatively new strategies as well as the advantage of knowledge built up over years of dealing with PIM issues.

Mobile network operators' internal systems are intelligent enough to flag when a key performance indicator is off—high Received Signal Strength Indicator (RSSI) or Received Total Wideband Power (RTWP) indicating elevated uplink noise that is impacting performance in a cell sector. At that point, there are several potential causes for the problem: PIM, external interference, or possibly something like incorrect set-up of the sector that could give a false RSSI reading. Bell says that now, operators will often try to narrow down the possibilities by taking advantage of remote network control and running artificial traffic at the site. "Does the RSSI increase as the traffic level increases? Is it consistent? If that's the case, that generally points them back to, it's a PIM problem," Bell says.

The traditional next step has been to send a team out with a PIM analyzer and a PIM probe to go hunting within the sector. But Bell says that an even easier place to start is with what he calls "PIM hygiene," which relies on the expertise that people within the industry have built up over years of dealing with PIM. ConcealFab and test equipment company EXFO have worked together to build a new solution for PIM source identification, one that uses a combination of RF over CPRI analysis (leveraging EXFO's 5GPro Spectrum Analyzer and iORF) to determine if interference at a cell sector is internal or external, plus a PIM-blocking "blanket" that can be used to cover suspected PIM sources in order to quickly isolate the problem and over-the-air spectrum analysis to get real-time confirmation and feedback on whether a given action mitigates the interference at the site.

A crew armed with those tools and hand-tools can go in and fix loose brackets or pick up metal trash from previous installations, then proceed with covering radios or adjacent materials to see if they are PIM sources. "A lot of time, they're able to get enough improvement by doing that, that you don't have to go any further," Bell added. With artificial traffic running, a crew can test to see if covering, say, the parapet wall in front of a rooftop antenna reduces the level of interference. "If you see a noise reduction, well, you've just found the PIM source," Bell says. "Sometimes [crews] are able to get 10, 12 db of reduction, just by using their intuition and covering obvious things."

The RF over CPRI and real-time spectrum analysis cut down on the need to wait for an off-site network technician to run commands on the radios themselves—lag time that adds to the cost of the endeavor. "While you're doing those tests, your feedback is immediate, and so it makes those crews much more effective," Bell explained. They can cover a potential PIM source or even wrap pads around the antenna itself, and get immediate confirmation of whether the noise in the uplink was reduced or not.

"There are a lot of changes in the workforce, and fewer and fewer RF experts," says Danny Sleiman, business development manager for EXFO, who said that the company's approach is meant to both reduce the time involved in PIM interference finding as well as make it easier for people with less expertise to successfully find and mitigate PIM sources. The combined analysis and RF absorber system that EXFO put together with ConcealFab helps identify quickly whether the interference at a site is external—originating beyond the antenna—or an internal issue, and whether it's PIM or external RF interference. Sleiman explained that with a PIM analyzer-based approach, multiple ports have to be tested, since PIM can have uneven effects across antenna ports; analyzing RF spectrum over CPRI with EXFO's iORF is able to allow viewing of effects on each of the "branches," or antenna ports, he says.

Figuring out if the interference at a site is internal or external is the basis for helping to determine who is responsible for fixing the issue, as well as mitigation tactics. "As simple of a thing as that is, it's actually very powerful" for determining whether a contractor needs to revisit a site or if a crew needs to address external PIM, Sleiman said.

Bell chimed in that in the event that PIM is external, the RF absorber kit also provides a target for a site's noise floor—the point at which mitigation is as good as it's going to get. He said that ConcealFab tells customers that they should look at RSSI levels when the antenna is completely enclosed and target within 3 db of that level, with the site at 100% loading. "You know, if you can get to within 3 dB of the theoretical best-case at 100% loading in real-world conditions, that means you're not going to see measurable interference in the network," he explained.

PROACTIVE PLANNING TO HEAD OFF PIM PROBLEMS

PIM often doesn't show up as a major issue until there is enough traffic, or perhaps when a popular new device adds new spectrum support—or when a new site suddenly takes on traffic. But it really shouldn't come as a surprise, according to Bell.

"I refer to dealing with PIM as equivalent to the seven stages of grieving—and it always starts with denial. 'How can this be?' " he says jokingly. He goes on to say that the industry has a process for site builds that it has been following, largely unchanged, for decades. "But what we're finding is that practices that were used to build sites historically, aren't good enough any more. And that means there's a lot of change required in the organizations to adapt," he said. Identifying PIM and its cause at any particular site is actually the easy part, Bell says, adding, "The hard part is affecting the change within the organization to say, let's proactively stop building sites the way that we've done historically."

He points out that PIM signals are predictable and calculable based on the originating frequencies, and there are multiple good, free PIM analysis tools available that will tell network planners whether, given current and new spectrum blocks, whether they should expect intermodulation products in their uplinks. But, Bell says, use of such tools is often an afterthought: Operators will turn up spectrum, find there is a major noise issue and then try to identify if it is PIM, rather then doing the analysis ahead of time to see if they should expect PIM to be present.

> **Every time an operator adds a new frequency band, the probability of getting a third-order intermod falling in your uplink increases dramatically. Quite honestly, it's only a matter of time.**
>
> **Tom Bell**
> Senior Director of Interference Products at ConcealFab

"Every time an operator adds a new frequency band, the probability of getting a third-order intermod falling in your uplink increases dramatically," Bell said. "Quite honestly, it's only a matter of time. … Spectrum is the most valuable asset an operator has, and so every time spectrum becomes available, operators are going to buy more—whether it's good spectrum for them or not.
"You always find a way to make it work," he acknowledges, but the turn-up of new spectrum—no matter how badly needed for capacity purposes—can result in abrupt PIM issues in the uplink that need to be remediated quickly.

In this context, then, network design processes that have stood the test of time in preceding generations of cellular technology may not stand the test of PIM now. Bell argues that, just as the telecom industry has adopted new standards for construction, connectors and PIM-tested components, it should also reexamine how its underlying system of network design and planning and prioritizing both deployment speed and lowest-cost contractors contribute to interference problems that then need to be fixed.

Bell gives a few examples: Not allowing antenna position to be skewed in relation to the frame, which ends up directing energy from the main beam into adjacent antennas and causing PIM; or skew with respect to the building edge for rooftop sites. When rooftop sites are placed far back from the building edge and illuminate yards and yards of rooftop, it increases the likelihood of PIM. These are site design issues, Bell says—and solving them (and the resulting PIM) means addressing some fundamental issues in the industry's historical approach and constant pressure to do more with less. For example, a four-sector rooftop site design with 90-degrees of coverage for each sector would provide a better match with building edges where antennas could be pushed closer to roof edges and minimize illumination—but it would also be more expensive to add that fourth antenna.

Still, he says, the industry has made big changes before in order to address RF problems. Operators have raised their standards on construction and installation quality when it became clear that sloppy work was causing site performance issues, and factory-tested components for reduced PIM have also become more widely available and required by operators. Those efforts have gone a long way toward reducing internal system issues. "The sheer number of internal problems is lower, but has not gone away," Bell says. "That last guy who tightens that connection with the wrench is still always going to be a human, and humans can make mistakes—so that's always going to be there."

That's also the reality going on now, with heightened build-out and densification activity that increases the risk of new PIM sources. "People going back to sites and touching the hardware is just terrible, because you know no matter what they do, they're going to bump things, they're going to add new equipment. Every time a human touches the site, you've got an opportunity to generate new PIM sources," Bell says ruefully. "You've got lots and lots of metal-to-metal connections and so having well-designed connections, to minimize the probability of them becoming loose, is important," he goes on. "But even if it's perfectly designed, you still have humans putting it together, and things are going to happen. And things are going to change over time, and temperature, and wind, and everything else," he concluded. "The best you can do is, use robust designs that are just less inherent to have the ability to come loose. That's important."

Another thing that he says ConcealFab includes in its training is that once the on-site work of PIM mitigation is complete, they encourage people to jump or shake the frame to see if new PIM problems pop up. The real-time component of being able to use EXFO's iORF to observe spectrum live and see if motion on-site has RF consequences is key, Bell says. "You can watch it in real time: You jump up and down, you can see if the spectrum is jumping up and down again. [If it does,], hey, you've got more work to do—you don't leave the site just barely passing. You need to make sure it's as robust as you can, and if you're doing that, then you should be good for a while."

"How much effort you put into it is going to have a direct impact on how good of a job you've done," he says.