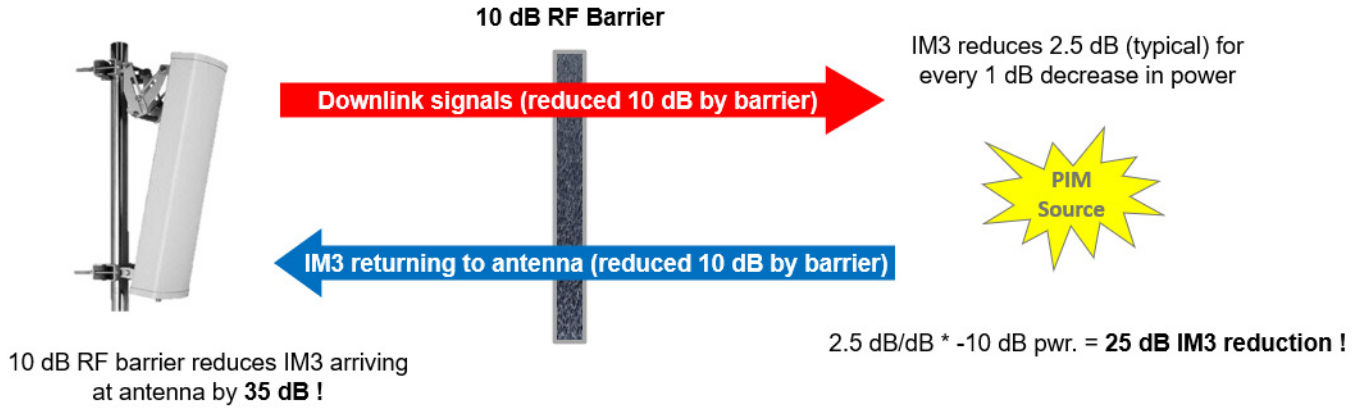
PIM Shield® Paint & PIM Seal™ Caulk

BACKGROUND:

Installing a RF barrier material between an antenna and an external PIM source is a proven method for reducing PIM interference at cell sites. If the downlink signals from the antenna are absorbed or reflected away before reaching a PIM source, the PIM generated by that source is greatly reduced. A RF barrier material that reduces the signal arriving at a PIM source by 10 dB can in theory reduce the IM3 seen at the system receiver by 35 dB, as shown below.



ConcealFab has developed a family of low PIM, RF barrier solutions to help reduce external PIM at cell sites. PIM blankets and PIM foil are temporary solutions that can be used during the test & measurement process to determine the level of improvement that could be achieved with a permanent repair. ConcealFab's patented PIM Shield® Roofing Membrane and PIM Shield® Tape are permanent RF barrier solutions that can be installed at sites to reduce PIM. These tough and reliable materials were developed in partnership with Johns Manville, a leading manufacturer with over 100 years of experience developing roofing products.

CONCEALFAB LIQUID RF BARRIER SOLUTIONS:

The newest additions to ConcealFab's portfolio of permanent RF barrier products are PIM Shield® Paint & PIM Seal™ Caulk. These new liquid solutions form effective and reliable RF barriers to reduce RF energy arriving at covered PIM sources. Unlike ConcealFab's previous barrier products that utilize a continuous layer of metal to block signals, these new liquid solutions use proprietary fillers and additives in an acrylic matrix to form a conductive barrier. Once cured, these new solutions form a flexible RF barrier with greater than 10 dB one-way signal reduction.

Conductive paints from other manufacturers have been tried in the past to mitigate external PIM with limited success. Existing conductive paints are designed for interior applications that see limited temperature variation. Due to the high loading of conductive fillers, existing paints are often brittle and can easily crack when subjected to temperature extremes. When cracks form, the paint itself becomes a PIM source. ConcealFab's liquid barrier products were formulated specifically to remain flexible and resist cracking due to environmental stresses. Extensive testing has been conducted by ConcealFab to verify the RF as well as mechanical performance of these new materials.

ENVIRONMENTAL/MECHANICAL TESTS:

Thermal Cycling test:

- 5 test samples prepared
- Bead of PIM Seal™ caulk applied to both sides of a U-bolt
- Caulk allowed to cure for 7 days before testing
- Visual inspection for cracks
- Pre-thermal cycling Radiated PIM test (Near Field test, 2x20W, 700 MHz & 1900 MHz)
- Thermal cycling (15 cycles, +70^{0}C to -40^{0}C)
- Visual inspection for cracks
- Post-Thermal cycling Radiated PIM test (Near Field test, 2x20W, 700 MHz & 1900 MHz)
- Results – **PASS**
  - *No cracks observed*
  - *IM3 <-100 dBm for all tests*

Salt spray test:

- Thermal cycle samples subjected to 96 hr. salt spray in accordance with ASTM B117
- Visual inspection for unexpected corrosion products
- Post-Salt spray Radiated PIM test (Near Field test, 2x20W, 700 MHz & 1900 MHz)
- Results – **PASS**
  - *No unexpected corrosion*
  - *IM3 <-100 dBm for all samples*

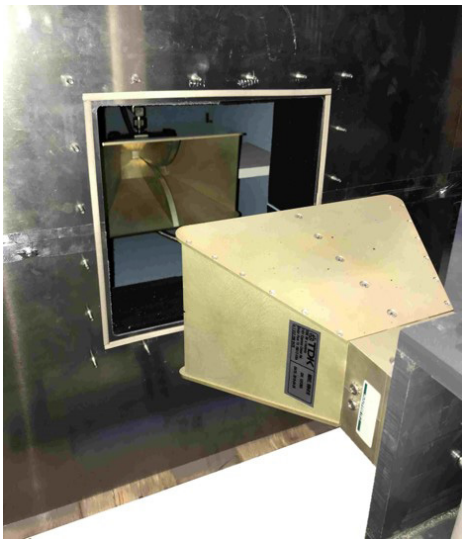
Bend test:

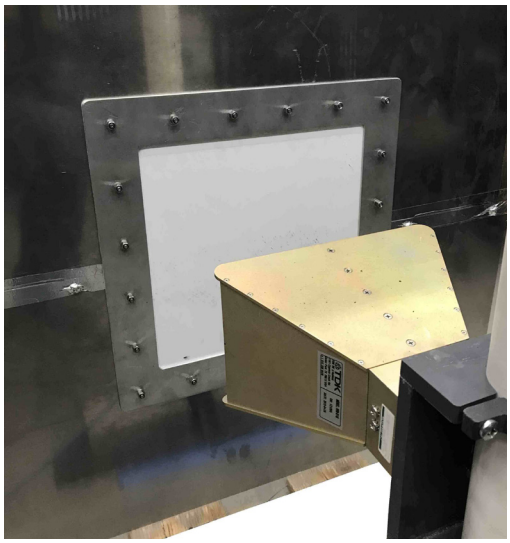
- PIM Shield® Paint applied to .025" thick steel test panels
- Paint allowed to cure 7 days before testing
- Samples bent 180 degrees over ¼" diameter mandrel
- Bend area inspected for cracks and delamination
- Results – **PASS**
  - *No cracks or delamination observed*

RF PERFORMANCE TESTS:

Transmission loss test:

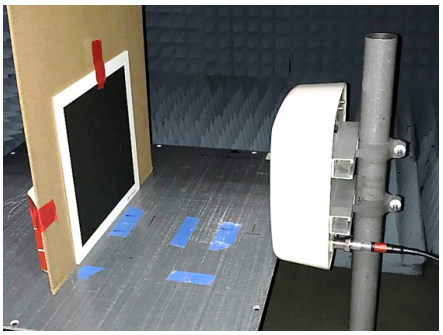
- Anechoic test chamber constructed with removeable window on one side
- Broadband horn antenna placed inside the chamber
- Broadband horn antenna placed outside the chamber
- RF transparent test panels produced using ConcealFab ClearWave® material
- Test panels coated with PIM Shield® Paint or PIM Seal™ caulk
- Test samples allowed to cure 7 days before testing
- Path calibrated with no test panel installed, 1 GHz to 10 GHz
- Test panel installed and loss vs. frequency measured, 1 GHz to 10 GHz
- Typical results over frequency range:
  - *10 mil paint provided >10 dB RF loss*
  - *20 mil paint provided >17 dB RF loss*
  - *15 mil caulk provided >15 dB RF loss*





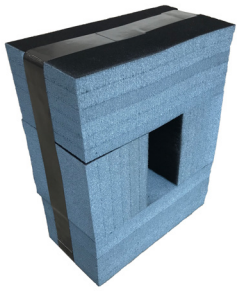
Radiated PIM test:

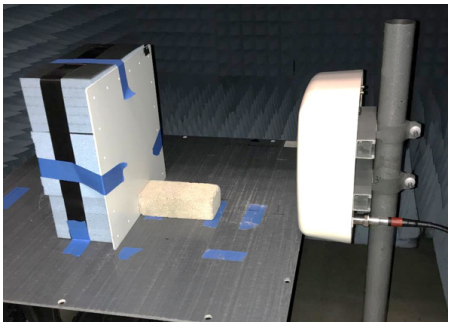
- Test panels used for transmission loss test placed 1 wavelength in front of 10 dBi panel antenna
- Radiated PIM test performed (Near Field test, static, 2x20W, 700 MHz & 1900 MHz)
- Results - **PASS**
  - *IM3 performance <-100 dBm for all samples*



PIM Reduction Test 1:

- RF absorber shroud created with opening on one side
- Diode PIM source placed inside opening
- Radiated PIM test performed (Near Field test, static, 2x20W, 700 MHz & 1900 MHz) without painted panel installed
- Test panel installed between PIM source and antenna (painted side of panel held in contact with RF absorber)
- Radiated PIM test repeated
- Change in IM3 level recorded
- Results:
  - *10 mil paint reduced IM3 by >28 dB*
  - *20 mil paint reduced IM3 by >47 dB*
  - *15 mil caulk reduced IM3 by >30 dB*



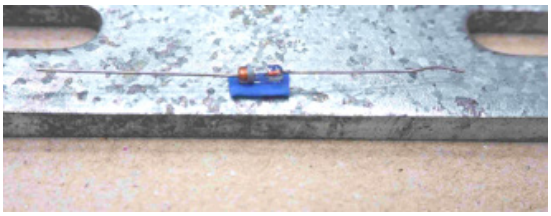


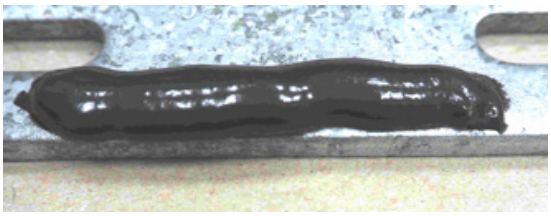
Note: This test does a fair job of demonstrating the concept but typically shows lower PIM reduction than predicted by theory. Curvature of the test panels results in an imperfect seal against the RF absorber shroud, allowing indirect RF paths to exist between the PIM source and the antenna.

PIM Reduction Test 2:

- Germanium diode taped to metal bracket
- Radiated PIM test performed (Near Field test, static, 2x20W, 1900 MHz)
- Bead of PIM Seal™ caulk applied over diode
- Radiated PIM test repeated with caulk still wet
- Radiated PIM test repeated after 1-, 4- and 7-days cure
- Change in IM3 level recorded
- Results:

Condition	IM3(dBm)	IM3 Reduction (dB)
Diode only	-79.9	n/a
Caulk applied (wet)	-96.5	16.6
1 day cure	-100.8	20.9
4 days cure	-113.3	33.4
7 days cure	-116.1	36.2





LAB TESTING SUMMARY:

The environmental and mechanical tests conducted confirm that ConcealFab's PIM Shield® Paint & PIM Seal™ Caulk are highly elastic and did not form cracks when subjected to bending or thermal cycling. It is important to note that in these experiments the material was applied to bolted connections that were not loose. ConcealFab's liquid barrier materials are highly elastic but will form cracks (and eventually generate PIM) if the surfaces where the material is applied are able to move with respect to each other.

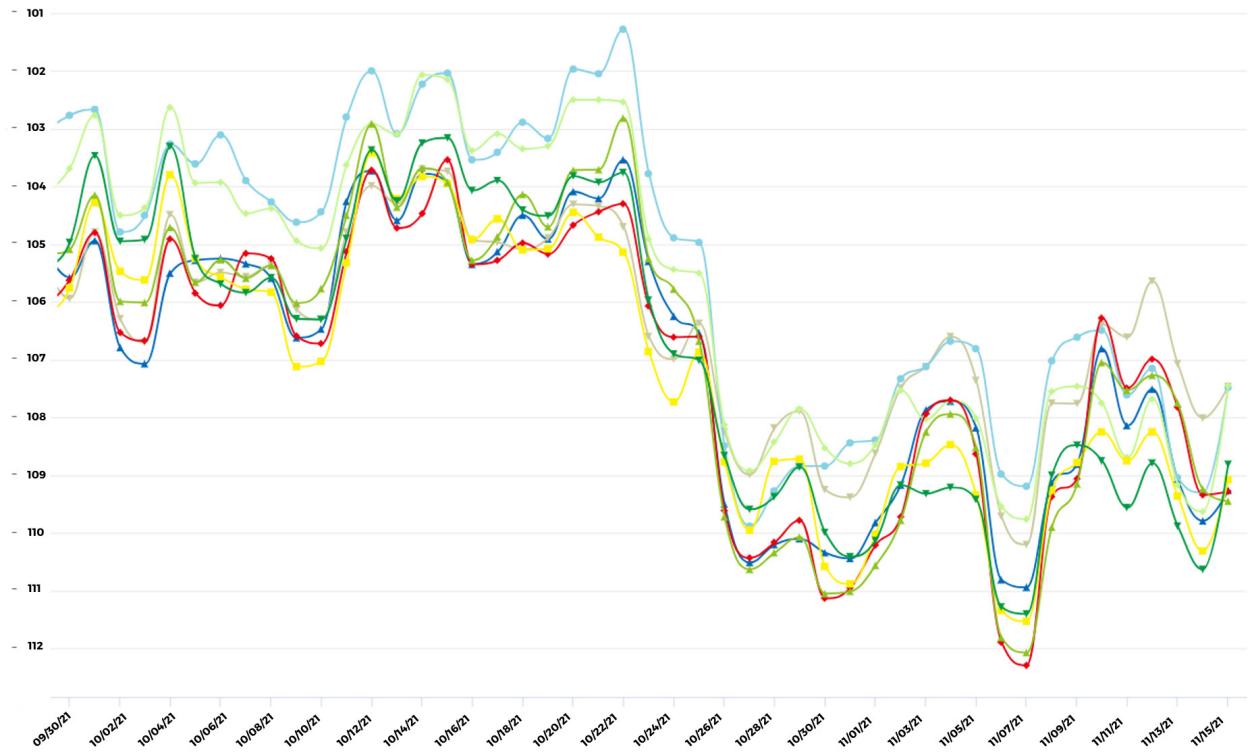
From an RF perspective, ConcealFab's PIM Shield® Paint & PIM Seal™ Caulk were both able to create effective barriers to block RF radiation. As predicted by theory, installing these RF barriers between an antenna and a PIM source significantly lowered the IM3 generated. PIM Reduction Test #1 confirmed that a thicker application of these materials provides greater benefit than a thinner application. When using PIM Shield® paint, ConcealFab recommends applying 2 coats at 10 mil wet thickness per coat for maximum benefit. PIM Reduction Test #2 shows that shielding effectiveness improves as the material cures. ConcealFab's PIM Shield® Paint & PIM Seal™ Caulk are water-based, and their conductivity increase as the water evaporates during cure. While significant site improvement should be expected immediately after application, maximum benefit will not occur until the paint or caulk has fully cured (7 days).

FIRST FIELD INSTALLATION:

A US operator invited ConcealFab to install PIM paint on one of their rooftop sectors to evaluate the material's ability to mitigate PIM. A PIM hunting crew had previously visited the site and reported that the stucco parapet wall directly in front of the antennas was generating PIM. The contractor proved this by placing a PIM blanket over the wall and showing that the average noise level reduced with the PIM blanket in place. The operator contacted the building owner and received approval to paint the parapet wall with PIM Shield® Paint prior to ConcealFab arriving on site.

Once on site, ConcealFab verified the contractor's results by temporarily installing PIM Foil over the areas where PIM Paint was planned to be applied. Additional PIM hunting showed that the largest remaining PIM source was a section of exterior stucco wall in front of the antennas. Unfortunately, we did not have permission (or the equipment) to apply paint to the exterior of the building, so two coats of PIM Paint were applied by roller to the areas we did have permission to cover.

Measured data showed that applying the PIM Paint to the parapet wall improved the average noise level by >4 dB in the two frequency bands impacted. To achieve additional benefit, the operator will need to either re-position the antennas to avoid illumination of the exterior wall area or work with the building owner to gain permission to apply PIM Shield® Paint to the exterior surface.



Average uplink noise vs. time on sector where PIM Paint was installed

CONCLUSION:

ConcealFab's new PIM Shield® Paint & PIM Seal™ Caulk form reliable RF barriers able to reduce external PIM interference at cell sites. Environmental and mechanical tests performed by ConcealFab show the material's ability to withstand harsh conditions without cracking, delaminating or generating unwanted corrosion products. Lab RF tests demonstrate the signal attenuation as well as PIM mitigation performance of these new liquid solutions. Finally, the first field application of PIM Shield® Paint demonstrates the real-world benefit to mobile operators impacted by external PIM. By applying 1-gallon of PIM Shield® Paint to the parapet wall on a rooftop sector, the operator was able to immediately achieve >4 dB reduction in average uplink noise. While additional improvement can certainly be achieved by further mitigation, PIM Shield® Paint provided a quick and simple gain in sector performance that will undoubtedly result in improved customer satisfaction by those served by this busy sector.