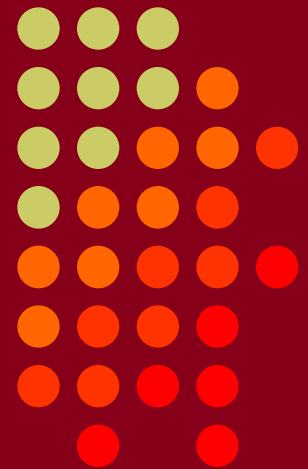


CTU Presents

*Coax Connectors, a Deep
Look at What Can Go Wrong*

by

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Topics to Cover



1. Let's Step Outside for a Moment.
2. What is **PIM**? (Passive Intermodulation)
3. Examples From the Field.
4. Techniques to Find the Problem.
5. Techniques to Avoid/Fix the Problem.
6. Acknowledgements.
7. References, Further Information.

Let's Step Outside for a Moment

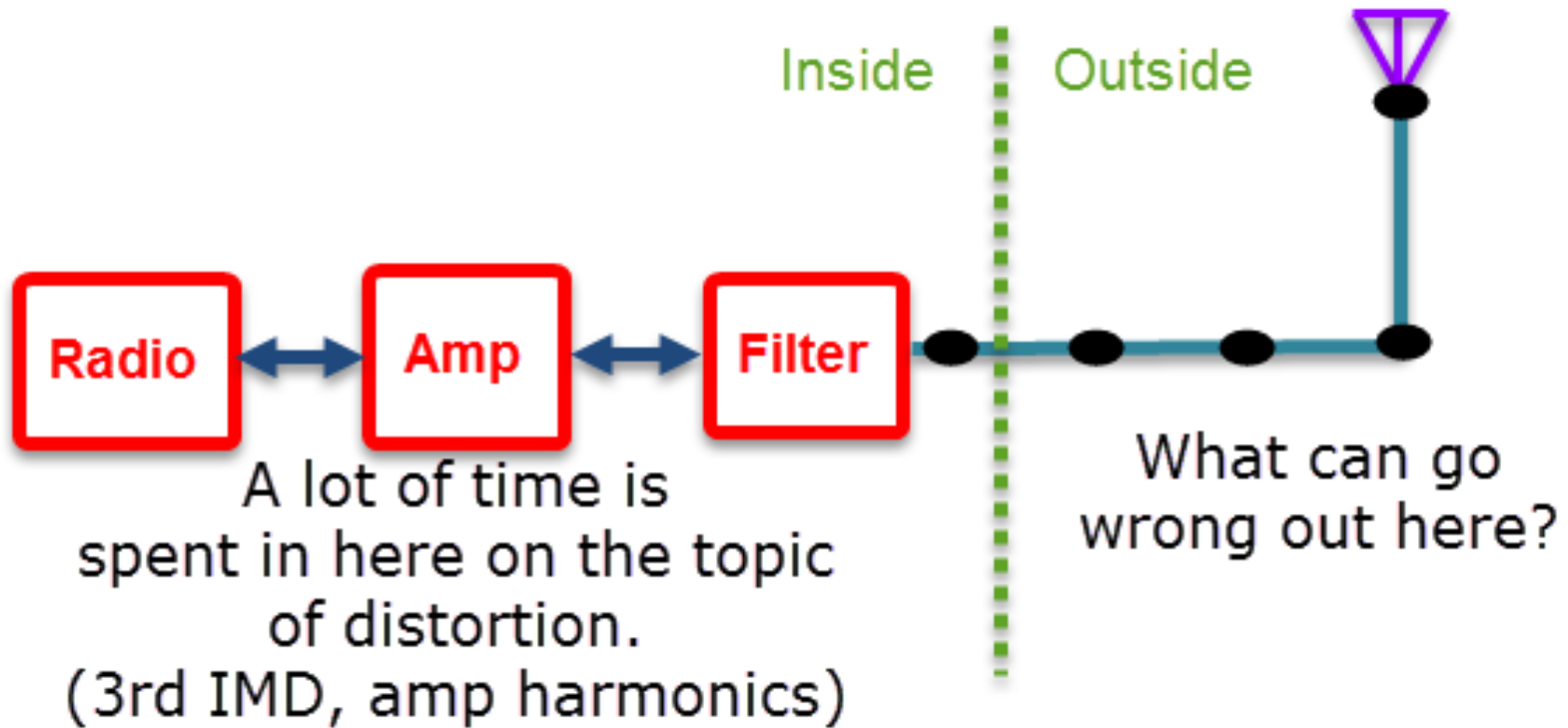


- It seems like the opportunities for something to go wrong around the old ham station are endless...
- In this session the focus will be on problems with normally passive and linear devices, usually located outside, and usually taken for granted.
- The session title names the *coax connector*, but the problems and solutions can be generalized to most any metal to metal connection.
- Another title might be: *How to Avoid Accidental Diodes*.
- RF + Diodes = Crud (and we want to avoid crud)



Let's Step Outside for a Moment (2)

- Simple station block diagram:





Let's Step Outside for a Moment (3)

- Of course a lot can go wrong outside!
 - Towers can collapse, antennas can fall, etc.
- Beyond those obvious problems, **distortion**, the creation of spurious signals that interfere with desired signals, can be generated by innocent looking passive devices, like coax connectors.
- One manifestation of the distortion is called **PIM** – *passive intermodulation distortion*.



What is PIM?

- “**PIM** is a form of intermodulation distortion that occurs in components normally thought of as linear, such as cables, connectors, antennas, and towers. When subject to high RF power, these devices can generate spurious signals. PIM shows up as a set of unwanted signals created by the mixing of two or more strong RF signals in a non-linear device, such as in a loose or corroded connector, or in nearby rust. Other names for PIM include the *diode effect* and the *rusty bolt effect*.” (Nicholas Cannon, Anritsu)



What is PIM? (2)

- PIM is a hot topic at the cellular/mobile service level.
- They have multiple transmitters/receivers/antennas jammed onto a single tower, and, the many added challenges inherent in GHz operation (usually due to short wavelengths).
- The problem can occur at HF, however.
- The contest station with multiple transmitters/receivers/antennas and even nearby commercial broadcast stations has a similar *RF rich* environment and lots of connectors and connections.
- The causes, culprits, and solutions are largely the same. (meaning we can learn from them!)

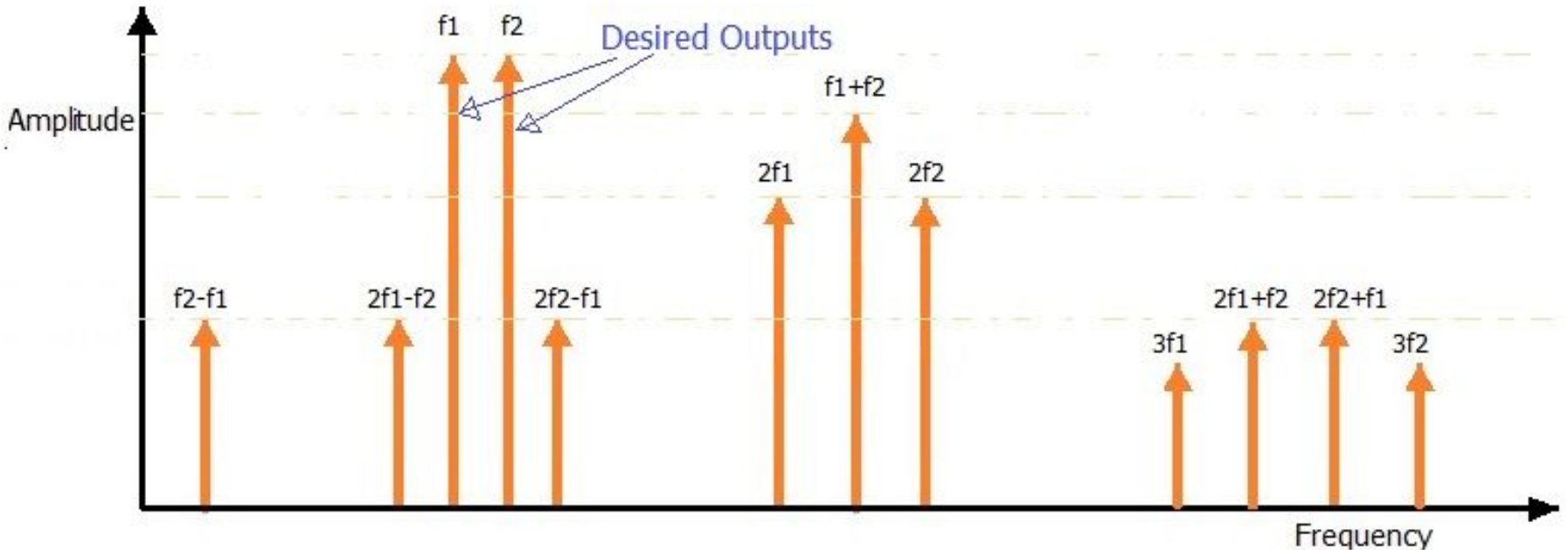
What is PIM? (3)



- PIM gets more discussion than simple harmonic generation because in the odd order cases you can generate spurious signals in the operating band – so they are right up in your grill.
 - You are forced to deal with your own pollution.
- But, there are many amateur bands with harmonic relationships and the opportunities to be negatively impacted by spurious signals goes far beyond PIM if PIM implies two signals.
- It's all the same underlying problem – diodes where you don't want diodes. Passive becomes active. Linear becomes non-linear.



What is PIM? (4)



- Fundamental, second order, third order products.
- Talk about crud!



What is PIM? (5)

- Common causes of PIM (thanks to Ian Poole):
 - (how to make a diode without really trying....)
- Dirty, oxidized, rusty, loose, corroded connections.
- Irregular contact areas.
- Use of ferromagnetic metals: e.g. iron, nickel, steel.
- Deterioration due to moisture entry (salt spray).
- Deterioration due to spark discharges creating craters/voids that then accumulate dirt/oxidation.
- Metal flakes/shavings/whiskers crossing over RF conductors.



What is PIM? (6)

- Joints where dissimilar metals meet.
- Coaxial connectors: joints with dissimilar metal in contact and exposure to the atmosphere and weather.
- Coaxial cable (the outer braid is nothing but an endless number of overlapping mechanical connections). A foil layer can help.
- The proverbial rusty fence, metal roof, loose and dirty gutter, or broken insulator (and on and on).
- Obviously Mother Nature invented diodes long before we noticed or needed them!
- Point Contact Diode discovery: Ferdinand Braun, 1874. He is better known for his invention of the CRT oscilloscope, 1897. He shared the 1909 Nobel Prize with Marconi for his "*Contributions to Wireless Telegraphy*".

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What is PIM? (7)

- Does a non-linear diode-like junction cause trouble if it falls over by itself in the woods?
- Not really – we also need to deliver energy into it (the signals), and conduct the undesired IMD products away from it and eventually to a receiver.
- Connectors and transmission lines are perfect for this since they carry radio RF as part of their job.
- Anything else that can act like an antenna can also contribute to energy flowing in or out.
 - And if a resonant conductor, then even more so.
 - With a direct or parasitic connection.

Examples From the Field



- Check updated presentation.

Techniques to Find the Problem



- It can be hard to find PIM problems.
- It is probably easier, therefore, to work a little harder to prevent them rather than have one show up and then try to find it.
- In other words, be *proactive* and not *reactive*.



Techniques to Find the Problem (2)

- Inspection/Cleaning of Connections
- Spectrum Analyzer
- TDR Time Domain Reflectometer
- Listen to identify AM station ID
- Consult list of nearby AM stations (FCC)
- Antenna Orientation, Resonant Lengths
- Chokes can break up common mode antennas.
- Portable receiver with Directional Antenna.
- Check Harmonic frequencies.
- Everything gets worse with time.

Techniques to Avoid/Fix the Problem



- From the Electro Rent Europe (they rent commercial PIM test equipment (cellular/mobile)) web site:
- **Q:** What are the most common causes of PIM?
- **A:** From testing over 2000 feeder lines, 75% of problems are found in poor quality, poorly assembled, dirty connectors. Other contributors are poor component plating, ferromagnetic materials, low contact pressure (connectors not torque correctly). [this is at UHF]

Techniques to Avoid/Fix the Problem (2)



- Periodic inspection, especially if a problem is suspected.
 - Return everything to shiny, bright, tight, dry, and taped.
- NCJ Article on PL-259's
- Solid friction fit.
- Clean with brass brush, remove flux/dirt, leave no residue (steel wool)
- Remove rust.
- Various Tape strategies.
- Chokes can deny common mode antenna energy.
- Bond metal around moving joints (ring rotators).

Many Thanks go to.....



- This presentation could not have been prepared without the help and input of many, including:
- Check updated presentation.....

References and Further Information



- How to reach me: ordy@seed-solutions.com
- The ARRL RFI Book
- <http://www.radio-electronics.com/info/rf-technology-design/passive-intermodulation-pim/basics-tutorial.php>
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