Articles

Brainstorm: RF Signal Interference

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by WDD Staff

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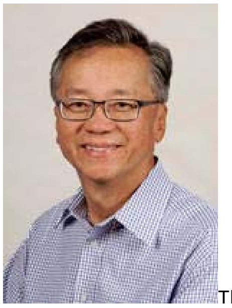
What are the most effective methods to prevent RF signal interference?

James Wong, Product Marketing Manager, Linear Technology

The cellular basestation industry has dealt rather successfully in mitigating RF signal interference through thoughtful radio system knowledge, cell planning, and appropriately applied standards specifications. Interference -- in-band or out-of-band -- can impair radio functionality if not properly protected. The deployment experience gained is beneficial for various types of new wireless systems, especially with the increase of high-density small- or microcell sites.

The most effective means of preventing interference is to design robustness into the radio electronics. This is accomplished by boosting the input linearity, and hence the dynamic range of the radio receiver front-end. Basestation receivers routinely handle close-in callers with strong signals as, well as distant callers with very weak signals, while in the presence of high-power interference signals from nearby cellular towers, broadcast radios, or emergency vehicle radios. All of these can overwhelm the receivers. Hence, front-end LNA (low noise amplifiers) and mixers, which are subject to the massive interference, must have extraordinarily high IIP3 capability to handle the high interference safely without inducing excessive distortion that can corrupt receive signals.

The second, and more subtle, problem with high-level interference signals is that they can desensitize the receivers by significantly raising the noise figure (therefore noise floor). This is caused by the front-end mixer's reciprocal mixing of the high level input signal with the LO phase noise, resulting in a higher noise level at the mixer output. If it is severe enough, it can prevent the distant callers' already weak signals from being clearly received.

Linear Technology's mixer products are designed to have exceptionally high-input IP3 performance, assuring their ability to handle high-input signal levels without excessive distortion. These mixers demonstrate superior noise figure in the presence of high blocker signals. This combination assures more robust receivers for heavy interference environments.

Gerald Stranford, Engineering Manager, CTS Electronic Components

EMI filters effectively reduce RF interference on signal or power lines. Such filters may be based on a single capacitor or inductor, but combinations of multiple components will increase the attenuation of RF interference.

An inductive reactance increases with increasing inductance and frequency. Therefore, an inductor in series with the signal path allows low frequencies to pass while the high frequencies are attenuated. On the other hand, the impedance of a capacitor decreases with increasing capacitance and frequency. Therefore, a capacitor connected between the signal line and ground provides a shunt to ground for the high-frequency interference.

Each inductive or capacitive component in the filter will reduce the RF interference by 20 dB per decade of frequency. Therefore, a two component filter will reduce the RF interference by 40 dB per decade, and a three component filter will reduce the RF interference by 60 dB per decade. Commonly available configurations are single inductor, single capacitor (C-filter), combination of one inductor and one capacitor (L-filter), one inductor and two capacitors (pi-filter), and two inductors and one capacitor (T-filter).

Pi and C- filters are used when the source and load impedances are high, while a T-filter is used when the source and load impedances are low. Filter performance is defined by insertion loss (IL), voltage rating, and current rating. IL represents the signal attenuation by the filter. Specifications are typically for room temperature and 50 Ohms load impedance.

Dr. Darcy Poulin, Chief Engineer and Wireless Systems Architect, Microsemi

Today's smartphones are extremely sophisticated RF devices supporting multiple RF bands. Users will routinely be operating multiple radios simultaneously; for example, when using the devices as a hotspot and for navigating, the LTE radio will be transmitting at 23 dBm, WiFi will be on, and the GPS radio will need to detect signals at -130 dBm. Clearly, RF signal interference mitigation is critical.

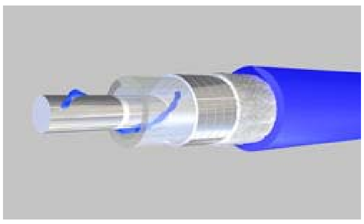
Preventing RF signal interference often comes down to filtering. Filters need to be placed around all RF blocks that need to be protected. In cases where bands are close to one another, steep-skirted BAW or SAW filters are used. In FDD radios used for many cellular networks, BAW or SAW duplex filters are often used to allow simultaneous transmission and reception.

These filters can also prevent interference from other radios. However, BAW and SAW filters are fairly large, lossy, and expensive. In addition, one filter is required for each radio since they are precisely tuned to the desired frequency range. Therefore, it is often advantageous to try and eliminate BAW or SAW filters.

There are other ways to mitigate effects of interference. WiFi, Bluetooth, and GSM have adopted a TDD-based approach, where the user transmits at one time, and listens at another time. TDD radios eliminate interference between the receiver and transmitter for one particular radio, and this offers significant advantages. However, there is still interference in between.

The solution to this is often filtering. If the bands are not close together, lower cost, smaller filters can be employed. One technique to eliminate the interference between WiFi and cellular is to simply use the 5 GHz WiFi band. Since the 5 GHz band is far from all other bands, filtering is straightforward and can often be incorporated into on-die matching circuits.

Ken Plourde, New Business Development Engineer, Temp-Flex



Coaxial cables with a high shielding effectiveness (SE) in excess of 100 dB

In many applications, to assure low RF emissions to the external environment and low susceptibility to external radiating RF sources, it is essential to use coaxial cables with a high shielding effectiveness (SE) in excess of 100 dB. An ideal shield would be highly conductive with 100% coverage, and have no holes or gaps; but such a shield would be stiff, heavy, and expensive. A typical braided shield only offers about -50 dB shielding effectiveness, and a double braid offers about -75 dB shielding effectiveness. In order to improve the SE of a coaxial shield and have it remain flexible, the shield should be configured as follows:

- Apply a helically wrapped and overlapped highly conductive, silver-plated copper strip around the insulated core. This tightly applied strip closely approximates the solid copper tube of a semi-rigid cable, and is the key to reduced RF leakage and susceptibility.
- Apply a highly conductive, silver-plated copper braid in intimate contact with the inner shield to hold it in place and keep it from unwrapping.
- Apply a tight jacket to hold the braid shield in place.

This shield configuration effectively minimizes RFI and EMI with the combination of shield layers. The shielding effectiveness, or RF leakage, of a cable can be tested per MIL_PRF-39012 utilizing a 50 Ohm airline tri-axial cavity. The cable under test is terminated into a 50 Ohm load and connected internally to the cavity. A network analyzer connected to the input and output ports of the cavity measures the tri- axial leakage. Test data for frequencies from 500 to 18 GHz show a shielding effectiveness >100 dB for the shield configuration described above.

**Teppo Lukkarila, global product line manager for base station antennas, RFS**

Passive Intermodulation (PIM) - the unwanted mixing of multiple signals in non-linear junctions within a system resulting in undesirable harmonic signals - is a leading cause of significant quality and performance problems at communications sites. RF interference problems arise when downlink signals create PIM in uplink frequencies.

These signals are frequently on the same level as those that the site would be receiving from a mobile unit, thus the radio receiver may not be able to differentiate between the unwanted PIM-generated signals and the appropriate uplink signals. In other words, PIM can raise the site's noise floor by several dB, causing a decrease in receiver sensitivity.

These issues can drastically degrade the performance of a site, causing a loss of capacity, an increase in the number of dropped calls, and increased data errors.

Fortunately, good site design, installation practices and site maintenance can keep PIM from becoming a major problem.

Before every product launch or product re-design, the following processes should be considered:

- ***Product or System Design*** – Simplified designs limit possible PIM generators.
- ***Careful selection of materials***, such as avoiding any alloys containing iron, is a primary concern, as are the circuit layouts themselves.
- ***Manufacturing Process*** – Maintaining a clean production environment is a key contributor to producing products with good PIM performance. Manufacturing processes should keep both raw materials and equipment as clean as possible to avoid adding any contaminants, which could cause PIM.
- ***Testing Prior to Shipment*** – While test processes differ from product to product, it is ideal to test 100% of antennas, diplexers, amplifiers, jumpers, feeders, and filters for PIM. No adjustments or assembly steps should be performed after PIM test.

By selecting proper materials and following strategic procedures throughout the complete design and construction of a site, PIM can be controlled and eliminated as a contributor to poor performance.

**Leonard Pelletier, Application Support, Freescale Technologies**

Electromagnetic interference (EMI) is broadly defined as a disturbance of an electrical circuit due to the proximity of a strong electromagnetic field created by rapidly changing electrical currents. The sources of these disruptive fields can be naturally occurring, such as lightening, sun spots or northern lights, or they can be man-made, such as radio or TV broadcast transmissions, electrical power lines or electrical motors.

In the very specific world of RF power amplifiers for cellular infrastructure networking systems, radio frequency interference (RFI) takes on a very specific problem and there is a common method for solving the created issues. The RF interference issue inside of power amplifiers in self-inducted RF feedback and cross induction between the low power baseband, driver stages and error correction control signals, and those of the higher power, fully modulated output broadcast signals.

Several types of both low and high power RF signals co-exist inside of a metal enclosure that is intentionally shielded to prevent the internally generated RF energy from escaping to the outside world, except thru the intended filtered output transmission port.

The disparity between these low and high power signals is on the order of 60 dB or greater, so the most common method to prevent internal RFI is to shield each individual amplifier active stage within its own Faraday cage to block in and out both the electrical and magnetic components of the interference signals.

When the electrical field component of EMI hits the electrically conductive surface of the copper shield, it induces an electrical current in that conductor. And since the shield is made of a highly conductive metal material, the energy of that field gets shunted around the enclosure. RF energy created inside the shield stays inside, external RF energy stays external.

Most shielded enclosures are made out of bright nickel plated copper with a solid fence structure around the active RF amplifier devices, directly soldered down to the RF backplane ground and with “mouse holes” in the walls to allow for RF microstrip egress. A vented lid with an overlapping seam is then press fit in place and all DC feed and control lines entering the chamber are RF filtered.

The shield need not have 100 percent totally seamless coverage and as long as the maximum size of any one aperture is 1/10 the size of the highest shielding frequency wavelength. With this prerequisite, the shielding effectiveness can be on the order of 90 dB or greater.

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