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Are you experiencing self-generated interference in your RF systems?

Are you struggling to maintain link margins?

Are you interested in learning how to control cosite interference?

Pole/Zero Corporation is the authority in resolving interference issues.

The following tutorial reprinted from Microwave Product Digest (MPD) provides an introduction to the mechanisms creating cosite interference and the methods used to mitigate its effects.

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Mitigating Self-Generated Communications Interference

by Timothy A. Harrington, Business Development Engineer, Pole/Zero

When selecting a radio for a communications application, coverage bandwidth, modulation and frequency hopping capability, transmit output power and receive sensitivity are critical parameters to consider. Maximizing the latter two parameters in this list serves to maximize communications range, which is a key performance parameter for any communications network. If the candidate radio will be operated in close proximity to additional radios, other, previously unconsidered, parameters rise to critical importance due to the likelihood of self-generated or cosite interference. In this cosite environment, the maximum transmit power and receiver sensitivity, while maximizing range, exacerbates the cosite interference situation. Often, no moderate level of transmit power or receive sensitivity can be applied that results in both acceptable levels of cosite interference and communications range.

Inadequate isolation between a transmitter and a receiver in a cosite environment results in the receiver's diminished ability to process a weak desired signal- a condition termed "desensitization". This condition exists due to the great disparity between the cosite transmitter output power level and the weak desired receive signal level. For example, with a transmit power of 100 Watts or 50 dBm and a modern receiver in a cosite environment operating at a sensitivity level of -110 dBm, an isolation on the order of 160 dB is required to preclude interference. This isolation is commonly available through a combination of transmit and receive antenna isolation and system selectivity. With typical cosite transmit to receive antenna isolation of 20-40 dB, considerable system selectivity is required to prevent desensitization. Fortunately, with proper design, techniques exist to accommodate this challenging goal. This paper will discuss the issues involved in cosite interference mitigation from the perspective of both the transmitter and the receiver and introduce techniques to allow simultaneous long-range communications in a local environment of multiple communicators.

The Transmitter's Contribution

The transmitter creates the modulated energy at the frequency and within the channel of interest with the necessary output power to accomplish the desired communications range. As an undesirable byproduct of this process, the transmitter also creates low-level broadband noise that extends over many tens of megahertz from the carrier. **Figure 1** shows a typical spectrum of a transmitted signal evaluated at the cosite receiver input location over the receive bandwidth under two conditions of cosite transmit to receive antenna isolation, 30 dB and 40 dB. Superimposed on the chart is the sensitivity of the receiver representing the minimum signal required to obtain acceptable demodulation in the receiver. As can be seen, antenna isolation of 30 dB yields a broadband noise level that exceeds the sensitivity level of the receiver over the entire band. Hence, weak or distant signals that the receiver is inherently capable of receiving would be "lost" in the noise created by the cosite transmitter. Further, since this noise spectrum extends over many 10's of megahertz, the transmitter effectively limits the useful bandwidth of the receiver to an area beyond this region. Increasing antenna isolation yields an acceptable level of transmit noise at the receiver without desensitizing the receiver. Unfortunately, increased antenna isolation is often not easily achieved as the physical separation required for greater isolation is not available due to platform physical constraints.

Greater isolation can effectively be achieved through the use of selective filtering at the transmitter to minimize broadband noise. This selective filtering is applied following the primary noise sources in the transmit signal chain and has the overall effect of lowering the broadband noise without necessitating an increase in antenna isolation.

To meet these cosite applications, Pole/Zero Corporation produces four different families of electronically tunable filters intended for precluding cosite interference from 1.5 MHz to 2 GHz. These filters are the Micro-Pole®, Mini-Pole®, Maxi-Pole®, and Power-Pole™ with coverage bandwidths for a given filter of greater than an octave in frequency. Each of these filters is a two-pole design with a Butterworth (maximally flat) filter response. Like the gain-bandwidth product of a semiconductor device, the insertion loss-instantaneous 3 dB bandwidth product (expressed as a percentage of tune frequency) of a filter within a given family is fixed and, generally, decreases as the filter becomes physically larger. Performance data for these filter families is shown in **Table 1**.

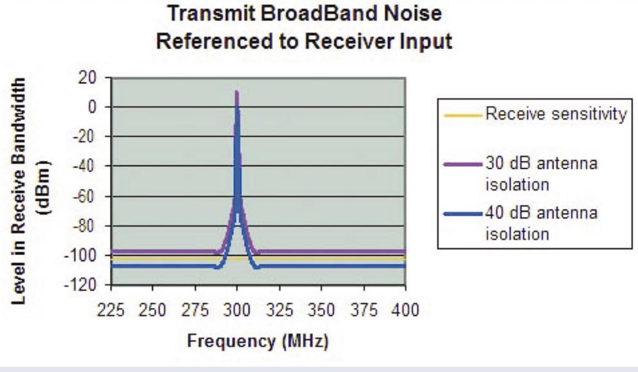

Figure 1

Filter Family	Insertion Loss-Bandwidth (3 dB) Product	In-Band Power Handling
Micro-Pole®	16	0 dBm
Mini-Pole®	20	26 to 30 dBm
Maxi-Pole®	10	30 dBm
Power-Pole™	8.5	43 dBm

Table 1: Performance Data

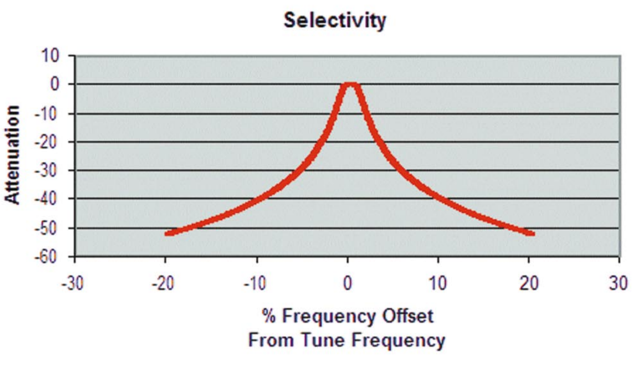

Figure 2: Basic Maxi-Pole® Filter Selectivity

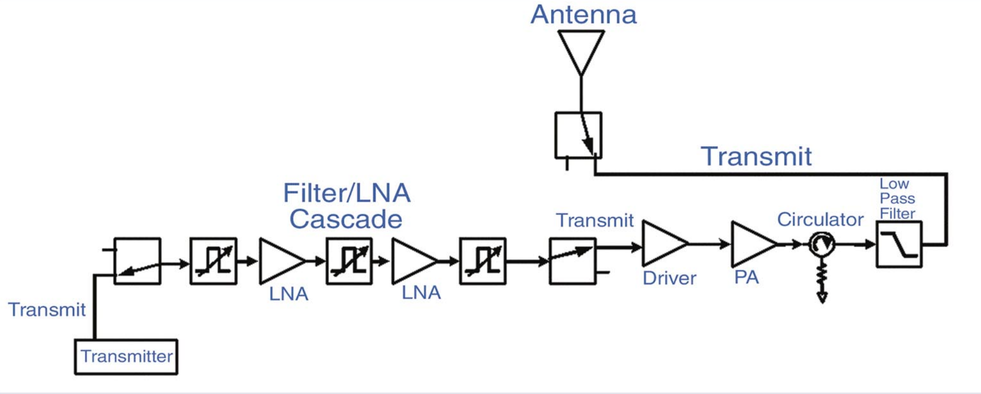

Figure 3: Transmit Filtering Block Diagram

Hence, a 2% instantaneous 3 dB bandwidth Maxi-Pole® filter with the tuning range of 90 to 200 MHz band, would have an insertion loss of approximately 5 dB (4.8 dB actual). A curve showing this selectivity characteristic is shown in **Figure 2**.

In the event that greater selectivity is warranted, multiple filters can be placed in cascade with low noise amplifiers (LNAs) for inter-filter isolation and filter loss recovery purposes. Additionally, in the event that greater output power is desired, the transmit cascade can be followed by a power amplifier suitably designed for efficient operation and low noise output. **Figure 3,** shows three filters in a cascade arrangement with LNAs and a power amplifier forming what Pole/Zero terms an Integrated Cosite Equipment (ICE) for enhanced broadband noise performance. The noise performance of this arrangement is 20-40 dB superior to the transmitter for measurements taken greater than 4 MHZ from the transmit carrier. This performance level further increases the effective isolation from cosite receivers and renders the vast percentage of the band available for reception by cosite receivers.

At this juncture, one might ask "Why not just design the transmitter with an acceptable level of broadband noise to suit cosite communications?" The answer lies in the fact that this level of performance increases the cost of the basic transceiver- a cost that is not justified for those applications where cosite conditions do not exist. However, often transceivers that were never designed for cosite applications become proliferated throughout their life cycle to the point that they are commonly used in cosite applications. **Figure 3** shows how to accommodate this common eventuality and, if desired, simultaneously decrease transmitter spurious output and increase the output power available from the transmitter. **Figure 4** shows the additional selectivity obtained from such an arrangement.

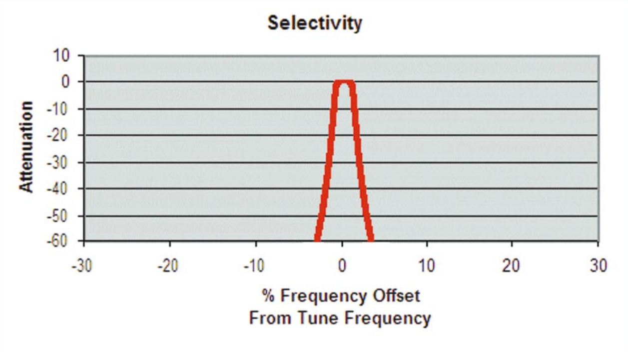

Figure 4: Selectivity Characteristic of a Transmit Filter/LNA Cascade

Cosite interference can also result from nonlinear mechanisms. Multiple transmitters coupled to antennas in close proximity create a condition called reverse or back intermodulation. In this situation, energy is coupled from one transmitter into the antenna of another creating a simultaneous flow of reverse energy and forward energy. The coupled energy mixes in the nonlinearities in the output network of the transmitter to create an infinite number of intermodulation products with amplitudes that are a function of the transmitted forward wave and coupled reverse wave and the nature of the nonlinearity. The products are then re-propagated to the collocated receivers creating products of sufficient level to preclude reception at those frequencies.

The use of circulators as isolators and electronically tuned high level filters in the transmit output network can minimize the mixing signals and, therefore, the magnitude of products created. Further, the power amplifier used in this application is designed to optimize its reverse intermodulation characteristic.

The Receiver's Contribution

Assuming that the cosite transmitter broadband noise is minimized through methods discussed above, the effect of the cosite transmitter's output carrier signal, although off-channel to the receiver, can significantly degrade the performance of the receiver. This off-channel energy would be isolated from the receiver only through the isolation of their

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respective antennas and, therefore, would potentially be available at the receiver at very high levels. To understand the effects of this off-channel energy in a cosite situation, one needs to expand the concept of amplifier compression. Classical amplifier theory would dictate that the 1 dB compression point of an amplifier is the actual output power where the small signal gain extrapolation of an amplifier exceeds the actual gain by 1 dB. For the purposes of cosite communications analysis, this concept is modified to accommodate the variation in this parameter due to the presence of selectivity in the system and the effect of multiple inputs to the receiver.

To develop this concept, the compression characteristics of a receiver are evaluated prior to detection with a desired signal one dB above sensitivity level. An interfering signal at various displacements from tune frequency is increased in amplitude until the desired signal degrades to the sensitivity level. This level is termed the one dB desensitization point and is representative of the debilitating effect the interferer has on the desired signal. The curve shown in red in **Figure 5** shows a representative curve of this characteristic for a typical receiver.

While one could conclude that a 1 dB drop in system gain is subtle, empirical evidence has shown that as the interferer increases above the one dB desensitization point, it is common to observe the desired signal level dropping as much as 4 db for every increase of one dB in interferer! Under these conditions, the desired signal level is clearly a function of the interfering signal amplitude, consequently Amplitude Modulation (AM) on the interfering signal will be impressed on the desired signal causing crossmodulation. Further, the receiver's compression is indicative of greater nonlinearity in the system potentially creating larger system intermodulation. These situations highlight the need to ensure that the receiver is operated below its one dB desensitization point. A prudent system designer would use this condition as a desirable goal in the design of a successful cosite communications system.

The use of a receive filter or filter/LNA cascade such as that introduced in the transmit chain can create "preselection" of the energy from the receive antenna and reduce the relative level of the cosite interferer to the desired signal. For transceiver applications, the filter/LNA cascade used in the transmit path can do "double duty" in receive filtering applications. With proper design of the filters and LNAs used in the early stages of the cascade, the receive system noise figure will not be degraded from the level of the basic receiver through the low noise figure/high gain character of the preselector. **Figure 6** shows the filter/LNA cascade from **Figure 3** configured for both transmit and receive functions.

The net effect of this level of preselection is shown graphically as the blue curve in **Figure 5**. Under this condition, the debilitating effect of cosite interference is mitigated by the selectivity of the preselector. Hence, 10-100 dB of additional isolation is achieved depending upon transmit carrier frequency displacement from receive frequency.

As in the transmit environment, nonlinear effects in the receive chain can be the source of additional cosite interference. Multiple, relatively large interfering signals coupled from cosite transmitters, can mix in the local environment or any receive nonlinearity and create distortion products at many locations within the band of interest. The preselection filter serves to minimize the level of the interfering signals prior to the receive nonlinearity, thereby minimizing any resulting products created within the receiver. Obviously, the preselection filter must, itself, be designed for accommodating these large interferers in a linear fashion. For this reason, Pole/Zero designs and tests the filters and LNAs that comprise the cascade filter to ensure acceptable levels of distortion occur under these conditions.

Figure 7 shows several Pole/Zero products from the basic Micro-Pole®, Mini-Pole®, Maxi-Pole®, and Power-Pole™ filters to several of the Integrated Cosite Equipments that incorporate the approaches outlined in this paper.

Conclusion

The radio parameters that predict successful communications network interoperability are different than those that predict successful cosite communications performance. Unfortunately, it is a common occurrence to find radios that were not designed for cosite performance applied to severe cosite environments. While this eventuality poses significant challenges, Pole/Zero has developed families of filter and Integrated Cosite Equipments to achieve nonrestrictive, multi-channel communications in this challenging scenario.

For over a decade, Pole/Zero has developed and fielded products to expand the linear dynamic range of communications products from 1.5 MHz to 3 GHz. This paper has discussed the cosite interference mechanisms and the use of a dual function (Transmit/Receive) filter/LNA cascade to mitigate these debilitating effects. For more details on this and other approaches to cosite mitigation, visit the Pole/Zero website at www.polezero.com, e-mail the author at tharrington@polezero.com or call at 513-870-9060, extension 130. Pole/Zero has extensive cosite communications analytical capability and will be happy to help analyze your cosite environment and develop solutions.

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Figure 7: Pole/Zero Products Covering 1.5 MHz to 3 GHz

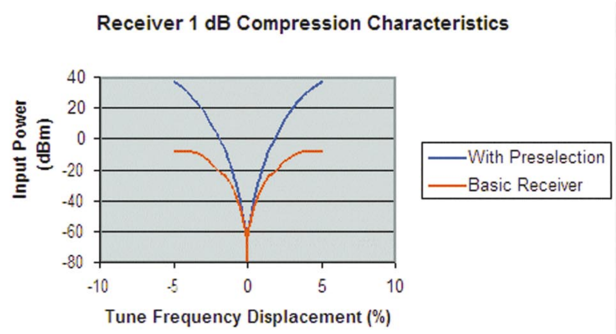

Figure 5: Representative Curve of a Receiver 1 dB Compression

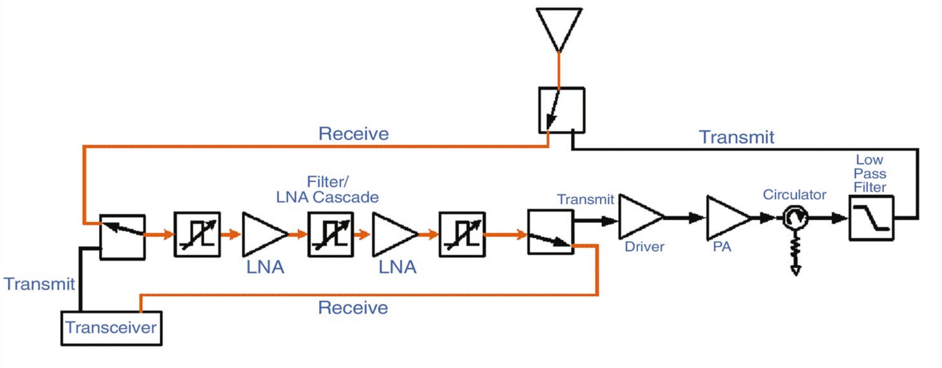

Figure 6: Dual Function Integrated Cosite Equipment