Alleviating RF Transmit Signal Corruption in Wireless Data Systems

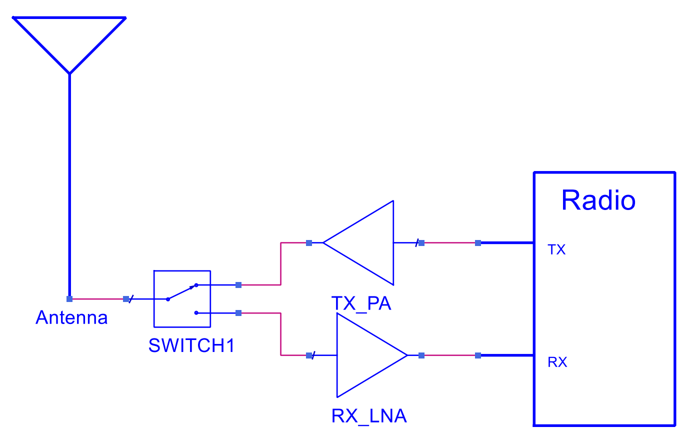
By Ryan Pratt

Introduction

In high speed wireless data systems, it is common to see RF Transmit signal corruption limit the power level that a wireless data device can put out at its antenna. While there can be many causes for this distortion, one of the most common causes is, surprisingly, the Low Noise Amplifier (LNA) in the receive portion of the wireless data device (see diagram below). This white paper will describe symptoms associated with this problem, currently used solutions to address it, and propose a better solution in the form of Guerrilla RF's patent pending Guerrilla Armor™ technology.

Background

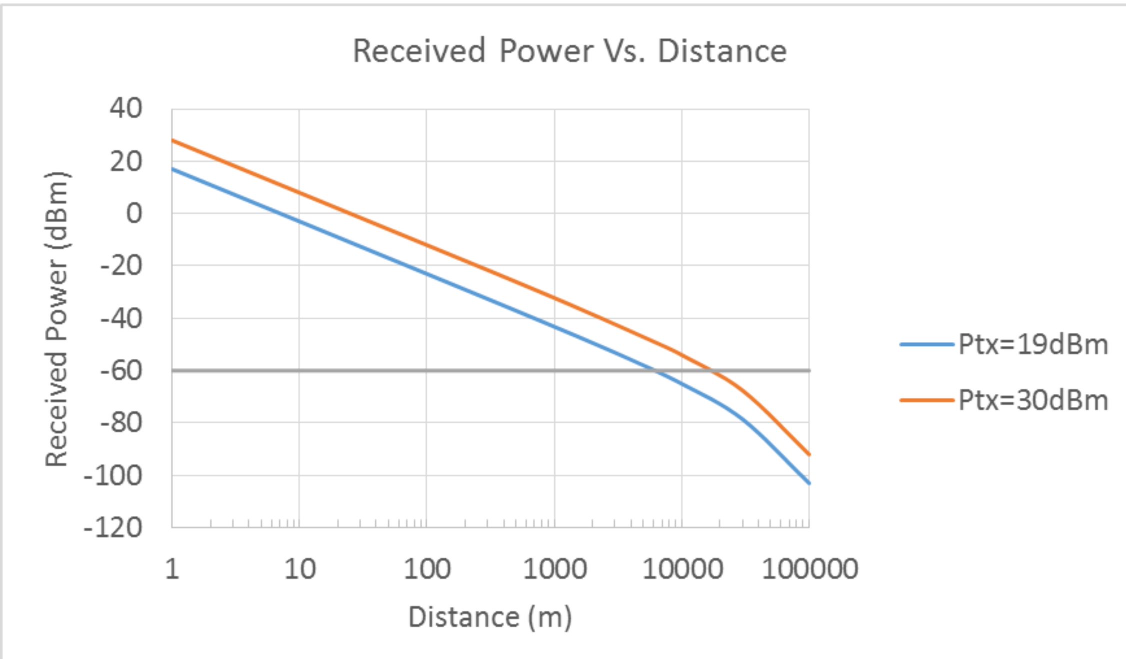
In any Time-Division Duplexing (TDD) wireless communication system, the terminal radio is either transmitting or receiving a signal. It never does both simultaneously. Some examples of high speed wireless data systems using TDD are Wi-Fi networks (802.11a/b/g/n/ac), TD-LTE 4G (used in China), and TD-SCDMA (used in China). In addition, there are numerous proprietary systems in wireless backhaul applications (point-to-point/point-to-multipoint fixed wireless links) that are TDD.



Typical Wireless System

In these TDD systems (or any wireless system for that matter), one must overcome path loss to maximize effective range and link quality (see graph below). The most obvious way to overcome path loss is to maximize both transmit power and receive sensitivity. This brute force method entails transmitting the highest power (biggest) signal allowed by governmental regulators while having a receiver sensitive enough to pick up an extremely attenuated (tiny) signal.

In the example shown below, two lines are drawn representing the range of a 6GHz transmitted signal at two different power levels (19dBm and 30dBm transmitted). By increasing the transmit power from 19dBm to 30dBm (US FCC max power limit), a 3X theoretical range improvement is realized.



3X range increase (6km vs. 18km) by increasing transmit power 11dB

Freq=6GHz, 23dBi antenna gain

With such clear benefits obtained, why not always use the maximum transmit power? A few reasons:

1. High cost/unavailability of active power devices (power amplifiers or PA's) for certain frequencies.

2. Applications not requiring large coverage area (indoor use for example).

3. Inherent system limitations (lack of adequate power control or spectral regrowth at high power). For the purposes of this white paper, we will concentrate on the last limitation, spectral regrowth.

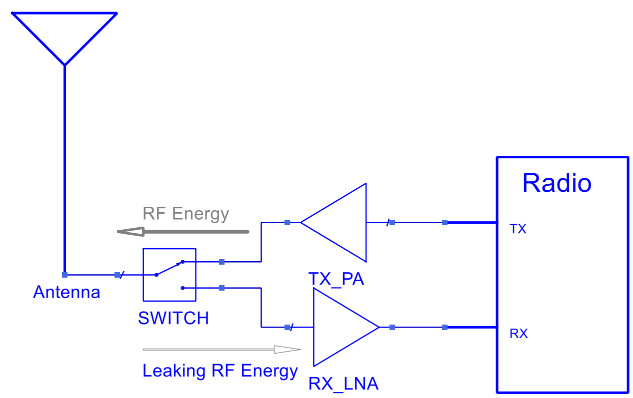
Causes of Spectral Regrowth

First, let's define spectral regrowth. Spectral regrowth occurs when undesired energy is present/transmitted along with the desired signal, often in very close frequency proximity. This poses an issue, as the undesired signal can interfere with other radios in the area. In addition, since the undesired energy is so close to the desired signal, it can't be filtered out easily. As a result, spectral regrowth limits for wireless systems are set by government regulators.

There are a few predominant causes of spectral regrowth. The first comes via inherent non-linearity in the active device. When amplified by a PA for example, an RF signal undergoes distortion resulting in spectral regrowth at offsets to the carrier frequency. To avoid this type of regrowth, the PA must be linear at its operating transmit power. Usually this requires it be capable of delivering much more RF power (5-10dB) than that desired for the application.

The second common cause of spectral regrowth is PA instability. When a PA is unstable, it can begin to oscillate and spontaneously generate RF energy with no relation to the applied input signal. These oscillations typically appear as very narrow spikes of energy all over the frequency spectrum, often in close proximity to the desired output signal. To prevent oscillatory behavior from occurring, the PA and its associated board layout must be tuned for stable operation (much easier said than done!).

A final common cause of spectral regrowth actually originates in the receive path. With the PA transmitting, power is incident at both the antenna (desired) and the input of the turned-off LNA through the antenna switch. At 5-6GHz, a typical SPDT antenna switch has about 25dB of isolation. With a transmitted power of +30dBm, then, +5dBm of RF power is leaking through the switch and hitting the input of the turned off LNA. Many LNA's on the market today begin to turn-on with -10dBm of RF power, so in this case the LNA would be sufficiently "on" so as to have very little isolation. Perhaps it would even see gain!



Transmitted RF Energy Hitting LNA Input

With the LNA now inadvertently turned on, a strong RF signal enters the RX port of the transceiver. Non-linearities of the LNA will re-modulate the signal and create RF energy at nearby frequency. This re-modulated energy will easily hop onto nearby PCB traces, possibly including the input trace to the PA. The re-modulated signal will now be amplified in addition to the intended signal, creating an output spectrum not unlike that of an oscillating PA. Output spur power levels will be proportional to the transmit output power of the PA, appearing similar to those of an oscillating amplifier. As such, this can be a very tricky issue from which to determine origin/cause.

Conventional Ways of Correcting Spectral Regrowth Caused by LNA Turn-on

As things stand in today's market, there are a few common techniques used to remedy this LNA turn-on issue. The first is to implement a pull-down on the LNA voltage supply line. This entails placing discrete transistors and arranging them to create an open circuit on the supply line leading to the LNA, along with shorting the LNA side of the supply line to GND. The resultant configuration ensures that the LNA will not turn-on in the presence of incident RF power, as it cannot "pull" required current to go active. The problem with this solution is that it requires several component placements to implement the pull-down and associated logic. Extra components mean higher costs due to the components themselves, their placements and a larger solution footprint on valuable PCB space.

A second solution would be to implement two or more LNA's in series. In this case the first LNA will turn-on with degraded but sufficient isolation to buffer the input of the second LNA, keeping it off. The two downsides here are:

1. Opportunity for re-modulation/coupling still exists with the first LNA turning on.

2. This approach doubles your LNA cost and footprint, since you have two LNA's instead of one.

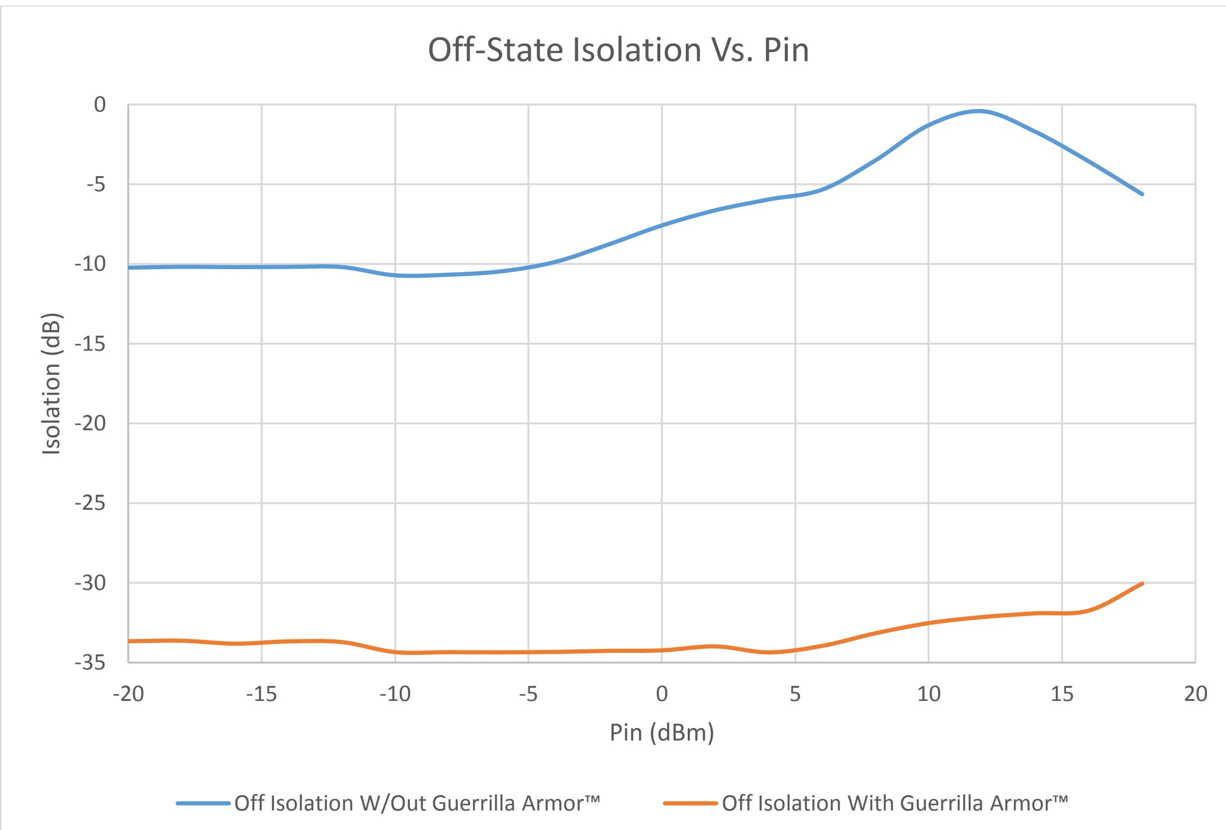
A third solution would be to simply reduce the transmit power until the spurs are sufficiently suppressed. With transmit power backed down 10dB to +20dBm, the LNA input would see -5dBm. While this would prompt turn-on, it would still greatly reduce negative effects. The problem with this approach is that it greatly reduces the coverage area/range of the wireless system as shown earlier (66% reduction in range).

A final common solution is to use a high isolation switch on the antenna. With a 40dB isolation switch, the input of the LNA would not be exposed to more than -10dBm with +30dBm being transmitted. While straightforward, this approach often requires the use of an expensive switch. Also, with greater isolation in the switch, the insertion loss of the transmit path is most certainly degraded (around 1dB). With higher insertion loss on the transmit path, the PA output power is correspondingly reduced and the transmit efficiency takes a proportional decrease as well. This results in reduced range and increased power consumption.

A New Way to Eliminate Spectral Regrowth Caused by LNA Turn-on

Given the shortcomings of existing solutions to this LNA turn-on issue, a better solution becomes imperative. We believe Guerrilla RF's technology, known as Guerrilla Armor™, provides the best possible solution to this problem. Guerrilla Armor™ is a patent pending circuit architecture that is implemented on several of our LNA products.

This circuit architecture prevents our LNA's, when turned off, from turning on in the presence of large RF input signals. With RF input power > +15dBm, our LNA's maintain >30dB off-state isolation (we define off-state isolation as S(2,1) when the amplifier is turned off). As can be seen in the graph below, our technology offers an exceptional improvement in isolation. In addition, this is achieved with almost no impact to the LNA's on-state performance. Specifically, our products achieve best in class noise figure and gain even with our Guerrilla Armor™ technology integrated. Finally, our technology fits in the exact same form factor as existing individual LNA's. This means zero additional component placements are necessary with our Guerrilla Armor™ LNA's, resulting in substantial cost and size savings.



Effectiveness of Guerrilla Armor™

Data taken at 5.5GHz, Vdd=3.3V, Venable=0V

Summary

To achieve the best possible range and coverage area in modern wireless systems, the simplest solution is to maximize RF transmit power. In doing so, several issues can arise. One would be spectral regrowth caused by inadvertent LNA turn on. The most efficient and effective way to correct spectral regrowth caused by LNA turn-on: Guerrilla RF's Guerrilla Armor™ technology, in that it is the only solution minimizing cost/solution footprint while maximizing allowable transmit power.

About The Author

Thanks to the Guerrilla RF team for their assistance in preparing this whitepaper!

Ryan Pratt is the Founder and CEO of Guerrilla RF. Previously he held RF design and engineering management positions at both RFMD and Skyworks Solutions. A named Inventor on 5 issued and multiple pending US patents, he holds a BSEE degree from North Carolina State University.

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