

Improving Data Speeds for EV-DO Rev. A Networks

Abhijit Karandikar: Sr. Product Manager - June 2007

Executive Summary

Over the past two years, the rapid growth of wireless data services allows customers the flexibility to do more than just talk on a wireless mobile phone. The capability to send or receive large e-mail files in Microsoft® Outlook®, to view graphic-intensive Microsoft® PowerPoint® presentations, high resolution pictures, and video clips, and to participate in two-way video conferencing and online gaming is now a reality. As evidence of this, the U.S. Wireless data market generated more than \$5 billion in revenue during the first quarter of 2007¹.

Accommodating the growth of wireless data services, telecommunications companies such as Sprint and Verizon have major initiatives to deploy and improve their EV-DO and EV-DO Rev. A networks.

As the surge of high speed data users continues, the need to improve and enhance wireless networks becomes increasingly important. A user's overall wireless mobile phone experience can be strongly affected by two key factors—interference and basestation (BTS) sensitivity. Out-of-band interfering signals produce intermodulation distortion (IMD) products, which degrade Quality of Service (QoS) and reduce data rates. STI has two product solutions to address these problems: SuperLink® eliminates interference and improves base station sensitivity and AmpLink™ improves sensitivity in the absence of interference. As a result, data speeds can improve by as much as 2X while improving capacity utilization by 55% and coverage of voice networks by as much as 20%. Higher receiver sensitivity also results in better in-building coverage and increased handset battery life.

Improving Base Station Sensitivity

Receiver noise in a base station (BTS) is caused by the following:

1. Intermodulation Distortion (IMD) noise is caused by out-of-band interfering signals acting on non-linear components in the BTS. **Brick wall filtering** eliminates IMD noise.
2. Electronic noise is caused by BTS electronics such as cable, filters, low noise amplifiers (LNAs), and mixers. The Gain and Noise Figure (NF) of the first components in the receiver chain have a big effect on how this noise disturbs the signal. Adding a **low noise gain component** improves the receiver NF.
3. Environmental noise enters through the antenna in the band of interest. It is caused by thermal noise, atmospheric noise, co-channel noise, and “rusty-nail” type mixing. These factors will not be discussed in this paper.

¹ RCR Wireless News

Brick Wall Filtering

The presence and strength of out of band interfering signals can adversely affect an operator's receive band. An example is Special Mobile Radio (SMR) signals (851-869 MHz) in proximity to cellular B receive band (835-849 MHz), and cellular B-band transmitters (881-894 MHz) in proximity to Sprint/Nextel's 896-901 MHz receive band. These out of band interfering signals, due to non-linearities in BTS components such as LNAs and mixers (Figure 1), produce in-band noise which degrades the signal-to-noise ratio (SNR) of the in-band channels, which in turn, degrades Quality of Service (QoS). This is commonly known as IMD. Insidious in nature, IMD is not readily detected or measured. The measure of a components' ability to minimize IMD products is the Input Intercept Point (IIP3).

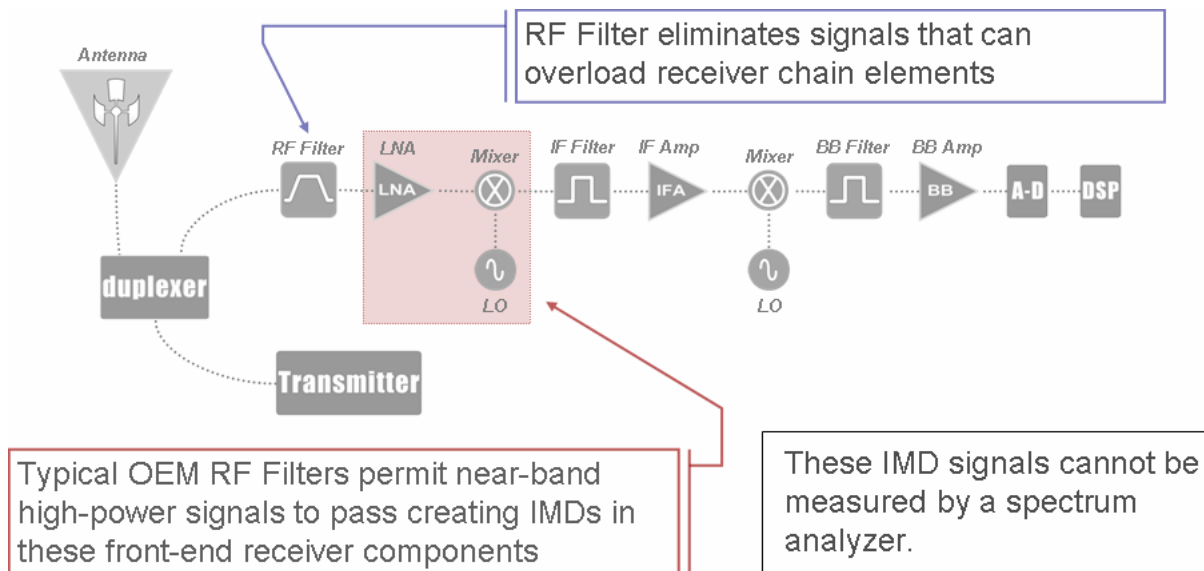


Figure 1. Block diagram of a BTS receiver.

When the power level of out-of-band interfering signals is high enough, it will cause the receiver components to saturate, causing all signals passing through that component to degrade significantly, including the signal of interest. This effect is called blocking, saturation, or desensitization. When blocking occurs, it reduces the QoS, limits coverage, lowers data throughput for EV-DO and EV-DO Rev. A, and decreases capacity utilization.

STI's SuperLink solves this problem by simultaneously eliminating the production of IMD signals by using its brick wall filter so that they no longer affect network performance and improving receiver sensitivity by using its proprietary LNA. The improvement in NF averages 4 dB, but is sometimes as much as 8 dB (Figure 2).

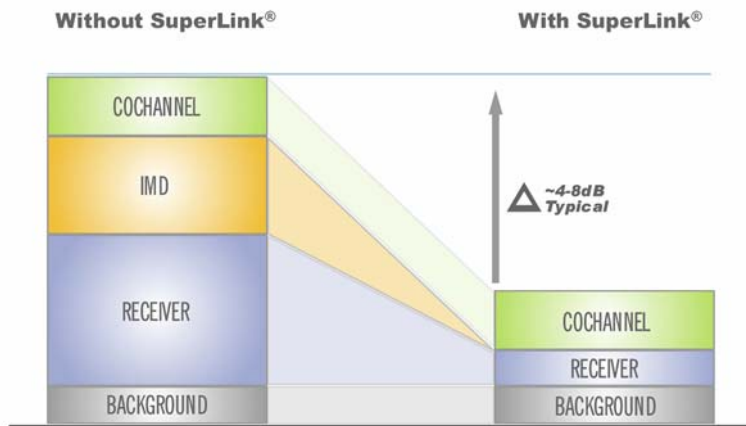


Figure 2. The performance improvement provided by SuperLink is unmatched. Note that the IMD products are completely eliminated.

The location of the brick wall filter in networks with interference is critical. The optimal location to place the filter (as SuperLink does) is in front of the first stage LNA. Filters placed after the first stage LNA are common to tower mount amplifier (TMA) solutions that tout SMR protection. In this case, the LNA may saturate in the presence of interfering signals, generating in-band signals that are amplified and passed directly through any SMR filter downstream (Figure 3). This will further degrade data rates and voice quality.

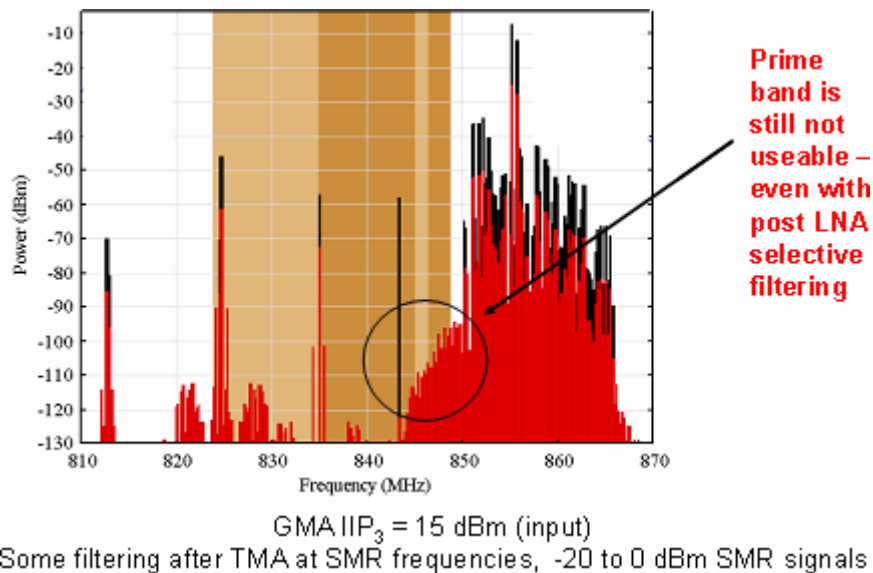


Figure 3. Filter location is critical in eliminating interference. Figure shows the effect of IMD's generated when the LNA does not have sufficient filtering at its input and saturates.

Low Noise Gain Component

For cases where near-band signals are absent, STI has a product solution. The addition of AmpLink, a low noise gain component (without brick wall filtering) between the antenna and BTS, improves receiver sensitivity by adding 13 dB of gain with a NF of 0.9 dB to the receiver. The Friis equation demonstrates how a BTS NF improves by adding gain with a very low noise device such as AmpLink:

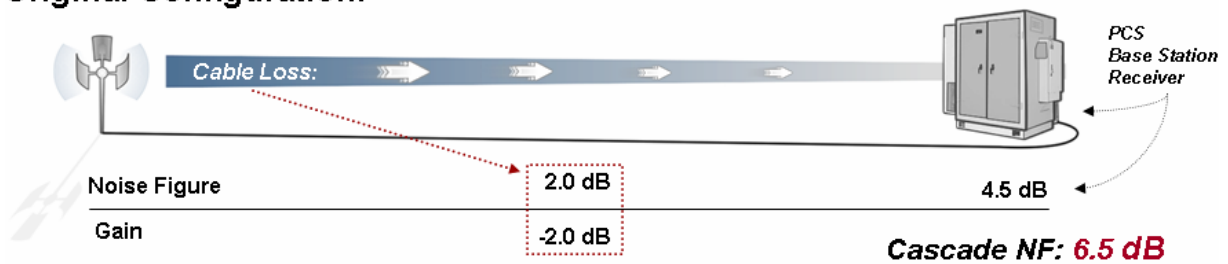
$$F_{sys} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \dots + \frac{F_n - 1}{G_1 G_2 \dots G_{n-1}}$$

where *NF* and Gain (*G*) for component *x* are illustrated as follows:

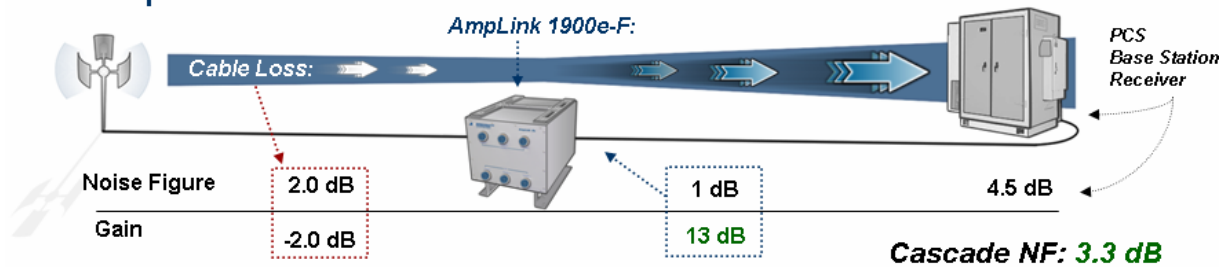
$$NF_x \equiv 10 \log_{10}(F_x); \quad G_{x,dB} \equiv 10 \log_{10}(G_x) \tag{1}$$

Applying the Friis equation for a BTS with a NF of 4.5 dB and an antenna feeder line loss of 2 dB, results in a cascaded NF of 6.5 dB. However, adding a device such as AmpLink (NF of 0.9 dB and 13 dB gain) between the antenna feeder line and BTS results in a cascaded NF of only 3.3 dB. Receiver sensitivity improvement results in 3.2 dB (Figure 4).

Original Configuration:



With AmpLink 1900e-F:



Improvement = 3.2 dB

Figure 4. Comparison of “before and after” AmpLink installation shows improvement in receiver sensitivity.

Advantages of Uplink Enhancement

Improving uplink receiver sensitivity allows mobile handsets to be further away from a BTS while maintaining the same QoS. This benefit can improve both BTS range and in-building coverage. Higher receiver sensitivity also allows the BTS to power down the handset, which translates to increased battery life. Numerous STI cluster trials over the past few years have consistently shown mobile transmit power reductions of 3-5 dB.

For CDMA-based networks, sensitivity improvement can also increase the use of existing capacity of a BTS. Illustrated in Figure 5, the trade-off between coverage and capacity utilization is shown. With a 3 dB improvement in uplink sensitivity, capacity utilization increases by 55% or cell radius (coverage) improves by 44%.

A 3 dB difference in system Noise Figure can result in a 55% increase in capacity utilization or a 44% increase in coverage area

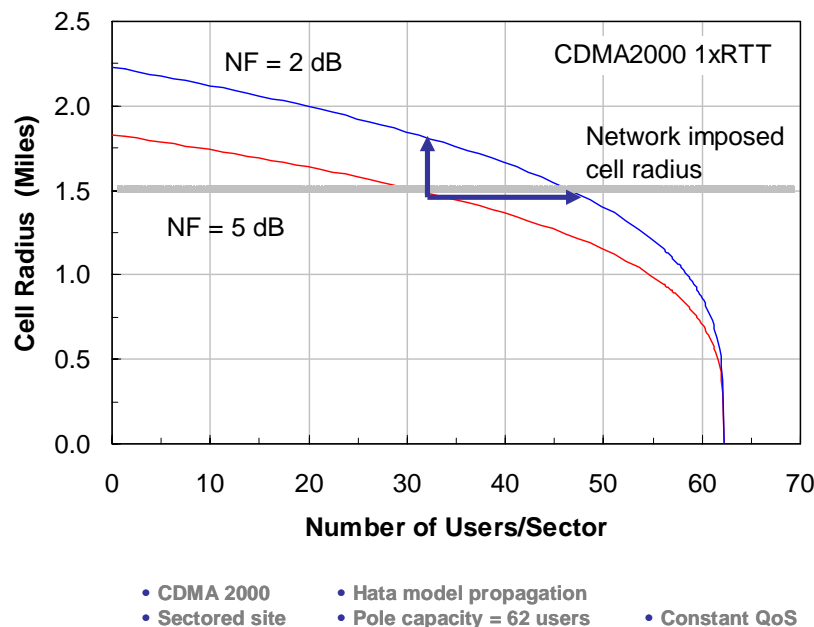


Figure 5. Base station noise figure improvement increases capacity utilization.

For EV-DO and EV-DO Rev. A networks, higher receiver sensitivity results in upload throughput improvements in addition to broader coverage, so users can maintain higher data rates over larger distances. Illustrated in Figure 6, the blue line represents the native BTS NF and the red line represents a BTS with a NF improvement of 3 dB. This figure shows that one can attain a 2X data speed over the same coverage distance when uplink sensitivity is improved by 3 dB. For this example, a BTS separation of 4 km, a propagation exponent of 3.5, and a cell loading of 50% were assumed.

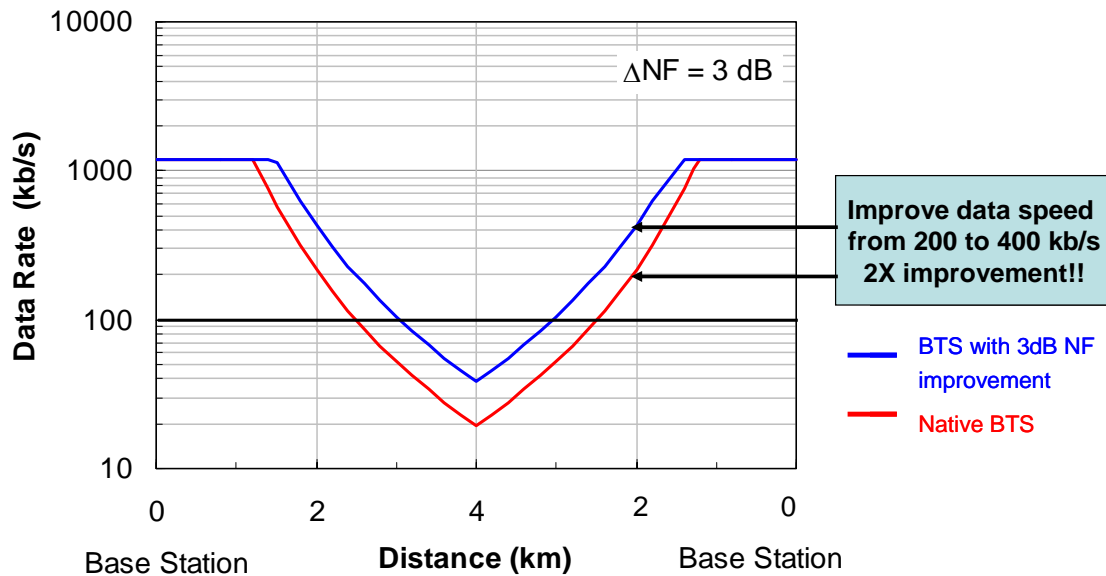


Figure 6. Noise figure improvement of 3 dB results in a 2X data speed improvement.

The basis for Figure 6 is the following: Available data rates are determined by the reverse-link traffic bit energy-to-noise spectral density ratio E_b/N_0 . For data networks, co-channel interference is frequently less than the thermal noise, so the expression for E_b/N_0 can be expressed in terms of the SNR in the following form:

$$\frac{E_b}{N_0} = \left(\frac{S}{FN} \right) \left(\frac{W}{R} \right) \quad (2)$$

where S is the received signal strength, F is a BTS NF given by Eq. (1), N is the thermal noise power at the receiver input, R is the data rate, and W is the spread-spectrum bandwidth. This equation can then be manipulated to solve for R :

$$R = \left(\frac{W}{F} \right) \left(\frac{S}{N} \right) \left(\frac{E_b}{N_0} \right)^{-1} \quad (3)$$

The data rate is maximized when the mobile user transmits at full power. Under this condition, the expression $(S/N) \cdot (E_b/N_0)^{-1}$ becomes a factor that essentially does not change. Therefore, the maximum available data rate is inversely proportional to a BTS Noise Figure (F) as shown in (4).

$$R \propto W/F \quad (4)$$

STI's Ground Mount Amplifier Solutions

STI offers a variety of uplink enhancement solutions for Cellular, PCS, and AWS frequencies. For wireless networks with interference issues, such as a Cellular network at 850 MHz, SuperLink provides the best solution by using STI's proprietary cryogenically cooled, superconducting filters with LNAs. This solution provides unmatched brick wall filtering and the lowest NF possible (0.5 dB including filter and LNA). For networks with non-interference issues, such as PCS 1900 MHz or AWS 1700 MHz, AmpLink improves receiver sensitivity through STI's proprietary LNAs with class-leading STI duplexers for a "plug and play" product.

In addition to the performance benefits highlighted earlier, STI's ground mount amplifier (GMA) solutions—SuperLink and AmpLink—provide exceptional operational and economic benefits. Operational factors include unmatched reliability, superior lightning protection, visible installation quality, and quick and easy installation and response time. Financial benefits include no tower climbs that require multiple specialized resources for installation and maintenance of equipment, no recurring lease costs, and no tower loading. These benefits translate into thousands of dollars in savings over the life of the product.

Summary

As the number of high speed data users continues to rapidly increase, the need for telecommunications companies to deploy, maintain, and enhance EV-DO and EV-DO Rev. A in their wireless networks is on the rise. Of increasing importance, the QoS of EV-DO and EV-DO Rev. A networks will be challenged. Key factors such as interference and BTS sensitivity—with the presence and strength of out-of-band interfering signals that produce IMD products—limit wireless network performance and ultimately data speeds.

With SuperLink's brick wall filtering or AmpLink's addition of a low noise gain component, BTS improvement in EV-DO and EV-DO Rev. A data speeds can be improved as much as 100% when STI GMA solutions are deployed. Interference and BTS sensitivity become non-issues when SuperLink or AmpLink are used in wireless networks. STI GMA benefits include:

- Improved reverse-link data coverage and throughput for high speed data (EV-DO Rev. A)
- Better Coverage (including in-building)
- Higher capacity utilization
- Improved Quality of Service

STI's ground-based solutions provide substantial operational and maintenance costs savings when compared to tower-based solutions, while providing exceptional improvements in interference protection and BTS sensitivity.