The Power of Sensitivity

Improving range with receiver sensitivity

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Figure 2. MaxStream's compact 9XStream™ 900 MHz Wireless OEM Module with –110 dBm sensitivity.

Whether designing with a wireless module, chipset, or stand-alone transceiver, it is important to understand the options and related costs for increasing range. Improving receiver sensitivity is presented as a viable solution to increase range while maintaining low cost in a wireless product or system.

To illustrate three viable options for increasing range, a typical spread-spectrum wireless module available in the 902 to 928 MHz ISM band is specified in Table 1 as the Current Transceiver Specification. To simplify the analysis, this article considers the specifications required to double the range.

The Options

In order to understand the options available, the Friis Transmission Formula was utilized to show quantitatively how a designer can effectively double the range of a wireless system.

$$R = \sqrt[N]{\frac{P_T G_T \lambda^2}{P_R F_M 16\pi^2}}$$

R = *Maximum range for communication link*
N = *Propagation Law (N=2 for line-of-sight, N=4 for urban environments)*
P_T = *Transmit power*
G_T = *Total antenna gain*
λ = *Wavelength*
P_R = *Receiver sensitivity*
F_M = *Fading margin*

The Propagation Law (N) is usually determined empirically and quantifies how far the waves will propagate based on the amount of obstruction between the transmitter and receiver. This analysis assumed a non line-of-sight environment and used a propagation law of N=4 to account for buildings, trees and other obstructions.

For this analysis, it was assumed the only parameters that could be changed were transmit power (**P_T**), total antenna gain (**G_T**), and receiver sensitivity (**P_R**). The Friis Transmission Formula was simplified three times, with each of these parameters listed as the only variable, and the remaining factors represented by a constant.

$$R = \sqrt[4]{P_T K_1} = \sqrt[4]{G_T K_2} = \sqrt[4]{P_R^{-1} K_3}$$

It becomes evident that in order to double the range, the transmit power, total antenna gain or receiver sensitivity must be improved by a factor of 16, or 12 dB.

$$R = 2 = \sqrt[4]{16}$$

A factor of 16 corresponds to 12 dB because $10\log_{10}(16) = 12$ dB.

Transmit Power

To double the range, the transmit power must increase 16 times (or 12 dB), from 100 milliwatts to 1600 milliwatts, or 1.6 Watts. According to the FCC Title 47 Part 15.247, the maximum allowable conducted output power is 1 Watt, rendering a 1.6 Watt solution non-compliant with US Government regulations. Despite non-compliance with government regulations, increasing transmit power from 100 milliwatts to 1.6 Watts increases current consumption an additional 750 milliamps (5 Volt system at 40% efficiency). Increasing current consumption to this magnitude could require larger and more expensive power supplies or batteries.

Increasing transmit power also raises the costs of RF components and heat sinking hardware, which are passed on to OEMs and their customers. These increased costs can be quite high, with many 1 Watt transceivers costing hundreds of dollars more per unit than many lower powered solutions.

The high costs involved with increasing transmit power often force designers to find a more economical long-range solution. High-gain antennas could be that solution.

High-Gain Antennas

To double the range, the total antenna gain for the current system must increase 16 times (or 12 dB). Assuming that both transceivers are already equipped with 2 dB antennas, the total antenna gain equals 4 db. To double the range, total antenna gain must increase to 16 dB. This can be achieved by removing one 2 dB antenna and installing a 14 dB high-gain directional antenna at one end of the wireless link.

A Yagi-style antenna is an effective solution for achieving 14 dB of gain when transmitting in the 902 to 928 MHz band. Though this option helps to effectively double the range, its large size (5'L x 6"W x 2"H) and cost of approximately $150 plus installation could make the solution too cumbersome and expensive for OEMs to impose upon their customers. The designer must also consider that high-gain antennas are not omni-directional, allowing the wireless link to operate effectively only in the direction of the Yagi antenna.

The remaining long-range option for designers to consider is finding or designing a solution with improved receiver sensitivity.

Receiver Sensitivity

Receiver sensitivity is a measure of how well the receiver performs and is defined as the power of the weakest signal the receiver can detect. The transmitted signal attenuates or becomes weaker as it propagates through the air and other physical obstructions. In order to double the range, the receiver must be able to detect signals that are 16 times (or 12 dB) smaller. Therefore, improving receiver sensitivity from -93 dBm to -105 dBm doubles the range.

Manufactures may avoid developing wireless solutions with improved receiver sensitivity because a potential exists for significantly increasing hardware costs and generating intolerable interference vulnerability. MaxStream (www.maxstream.net), a wireless transceiver manufacturer, was able to improve its receiver sensitivity from -90 dBm to -114 dBm by utilizing proprietary demodulation techniques, adding only three dollars in hardware costs and maintaining 70 dB of pager and cellular phone rejection. This example demonstrates how improving receiver sensitivity can be affordable without exposing the receiver to intolerable levels of interference.

Research performed by MaxStream has determined the average receive sensitivity in the transceiver market is –93 dBm. Designers can use this value as a benchmark to help locate transceivers with superior range. In an urban-cellular environment, a transceiver with receiver sensitivity at –105 dBm has twice the range of the industry's average transceiver, while a transceiver at –112 dBm has three times the range. Figure 1 shows graphically the exponential, long-range benefits acquired as receiver sensitivity is improved.

MaxStream provides its 9XStream™ 900 MHz 9600 Baud Wireless Transceiver (see Figure 2) with sensitivity at -110 dBm and recently introduced a 1200 baud module at –114 dBm with over three times the range of the industry's average.

Conclusion

Three methods were analyzed for improving range. Doubling the range by increasing transmit power brought significantly higher power supply and hardware costs. Doubling the range by using a high-gain antenna significantly increased hardware and installation costs. However, improving receiver sensitivity doubled the range with minimal hardware costs and without exposing the receiver to intolerable levels of interference. The true power of sensitivity lies in its ability to help designers effectively increase range while maintaining low cost in a wireless product or system.