XBee & XBee-PRO OEM RF Module Antenna Considerations

Contents

Application Note

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Abstract

This document presents practical information regarding the performance of the XBee and XBee-PRO RF Modules. The focus will be on the attributes of the different antenna options that are available to the modules. This information is intended to assist the designer in selecting the most appropriate module/antenna combination for their application. Indoor and outdoor systems will be covered.

XBee and XBee-PRO Product Comparison

XBee and XBee-PRO OEM RF Modules are small, high-performance, low-cost, wireless data transceivers. Both operate in the 2.4 GHz ISM band and because they have agency approvals (FCC, ETSI approvals pending), both can be operated without a station license. The XBee and XBee-PRO are pin-compatible with one another, though the XBee-PRO is slightly longer than the XBee. Both modules are available with a whip antenna, a PCB antenna, a RPSMA connector, or a U.FL connector (to which an external antenna can be connected). The XBee transmits up to 1 mW of power, while the XBee-PRO transmits up to 60 mW of power. In addition to transmitting more power, the XBee-PRO is capable of receiving weaker signals than is the XBee; which means the XBee-PRO has better receiver sensitivity. Because the XBee-PRO is both more sensitive and transmits more power, it can send and receive data over longer distances than the XBee.

Link Quality Evaluation

In an effort to provide some practical information to the reader, as it relates to the distance of various XBee/XBee-PRO wireless links, a series of range tests (both indoor and outdoor) were performed. The indoor range tests were carried out in an office building and in a large warehouse (containing aisles of storage shelving). The outdoor range tests were completed near a business park (interspersed with multilevel buildings, young trees, parking areas and bordering a residential area).

Link distance, or range, was determined by measuring packet delivery from a transmitter to a receiver. The transmitter resided in a fixed location, while the receiver was moved to a number of different locations. Receiver locations were chosen such that the distance between the transmitter and receiver could be gradually increased until the link quality began to suffer. Most of the outdoor receiver locations were within visual line-of-sight of the transmitter (refer to the "Maximizing Range" application note for more information regarding line-of-sight conditions). Some of the outdoor receiver locations were not within RF line-of-sight of the transmitter; however, they were within visual line-of-sight of the transmitter.

The transmitter was programmed to transmit packets containing a number that was incremented from one packet to the next (1, 2, 3 and so on…). The receiver (and associated lap-top PC) was configured to quantify successful packet delivery as a percentage of the total number of packets sent. The transmitter and receiver were alike, meaning that the module-type and antenna-type were identical. The modules were mounted to host interface boards. 99% successful packet delivery was chosen as a benchmark for comparison purposes. The receiver did not acknowledge to the transmitter when a packet arrived successfully. Furthermore, the transmitter sent each packet only once.

The table below summarizes the results of the evaluation. The distances presented in Table 1 represent what a user might expect to achieve in his application*. Activation of retries on the modules will improve packet delivery reliability in the presence of interference at the expense of overall data throughput (effective data rate).

Figure 1. Wireless link performance for various module/antenna/environment scenarios [Benchmark of 99% Packet Throughput]

Module	Antenna Type	Outdoor Distance (Visual Line-of-Sight)	Indoor Distance (Office Building)	Indoor Distance (Warehouse)
XBee	Chip	470 ft. (143 m)	80 ft. (24 m)	-
	Whip	845 ft. (258 m)	80 ft. (24 m)	84 ft. (26 m)
XBee-PRO	Chip	1690 ft. (515 m)	140 ft. (43 m)	-
	Whip	4382 ft. (1335 m)	140 ft. (43 m)	355 ft. (108 m)

A dipole antenna was also tested. The dipole and whip antennas perform similarly. Also, the PCB antenna will perform within 5% of the whip antenna.

The radiation pattern for the whip antenna is similar to that of a dipole. That is to say, it is shaped like a donut. Thus, the performance of a module using a whip antenna is relatively insensitive to its orientation in the plane that is perpendicular to the whip antenna. On the other hand, the radiation pattern of the chip antenna is not as uniform as that of the whip antenna. Therefore, certain orientations will achieve better performance than others. As our evaluation was performed, the orientation was selected to achieve the best performance. Because the radiation pattern will be affected by the antenna's immediate surroundings, Digi recommends range testing with the modules installed in their final assembly.

Observations

After reviewing Table 1, we can make several important observations.

- The whip antenna has a range advantage over the chip antenna, but only outdoors.
- The PCB antenna will perform within 5% of the whip antenna, therefore outperforming the chip antenna.
- The XBee-PRO can achieve more range than the XBee.
- The XBee-PRO and XBee both achieve more range outdoors than they do indoors.

** Actual performance depends on many factors in the environment. Consequently, individual results may vary. Factors include: antenna orientation; antenna height, proximity of antenna to other objects such as an enclosure, PCB, or other mounting structures; trees; rain; snow; sleet; hail; bushes; shrubbery; flocks of birds; swarms of bees; moving vans; parked cars, trucks and vans; cars, trucks and vans in motion; intentional or unintentional interferers; etc. Longer distances may be possible with reduced throughput. Obstructions in the propagation path will affect performance. Other wireless networks or systems may affect performance.*

Discussion

The whip antenna on the XBee module affords additional range in outdoor applications. However, it also occupies more space. If more range is required, and space is a constraint, then the XBee-PRO with a PCB antenna may be more appropriate. On the other hand, if more range is a requirement, and space is not the constraint, then the XBee with a whip or dipole antenna may be the best choice.

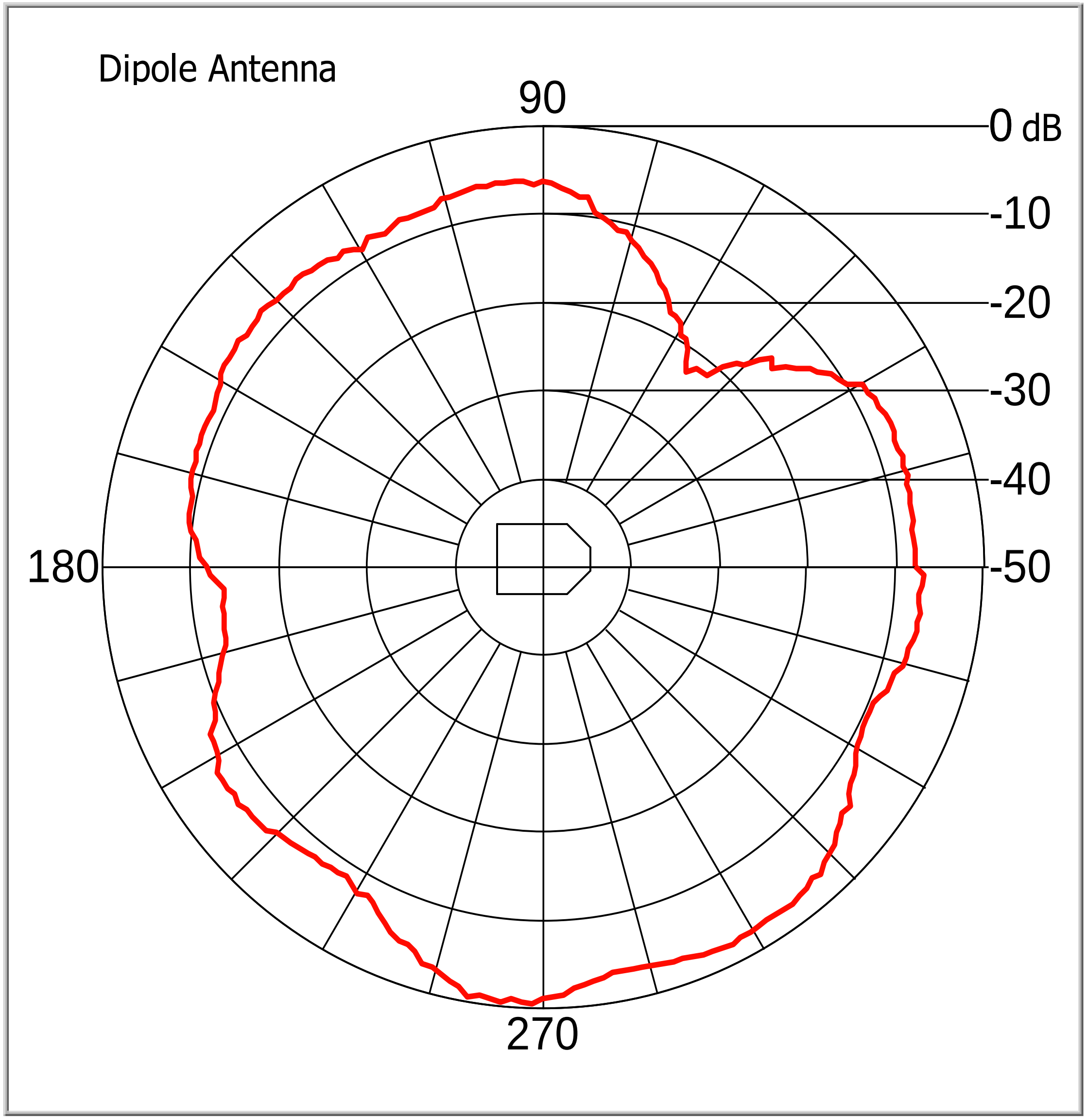
It should also be clear that the XBee-PRO can achieve superior range when compared to the XBee. Thus, if the application requires more range than the XBee can provide, then the XBee-PRO with a whip, a dipole, or a PCB antenna could be used. Again, the PCB antenna is best for tight spaces, while the whip and dipole antennas achieve more range.

More Information

The information presented above has been given to help the reader understand the basic performance of the XBee and XBee-PRO wireless transceiver modules under various operating conditions. More information and resources are available by visiting www.digi.com. Antenna radiation patterns for the dipole, chip, and whip antennas can be found in Appendix A. More detailed information associated with the link quality evaluation is also available. Thank you for considering Digi for your wireless data needs.

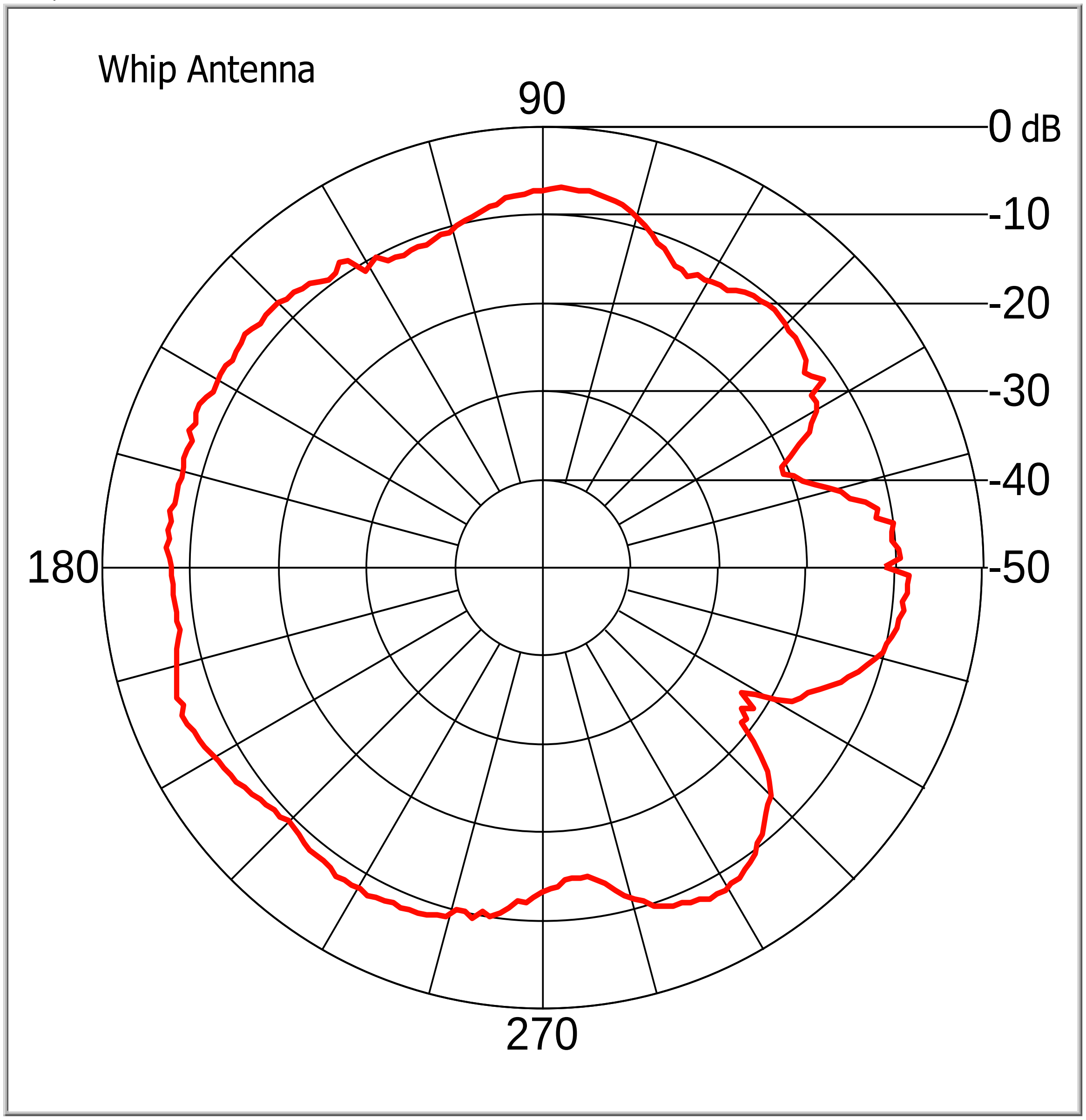
Appendix A

new picture



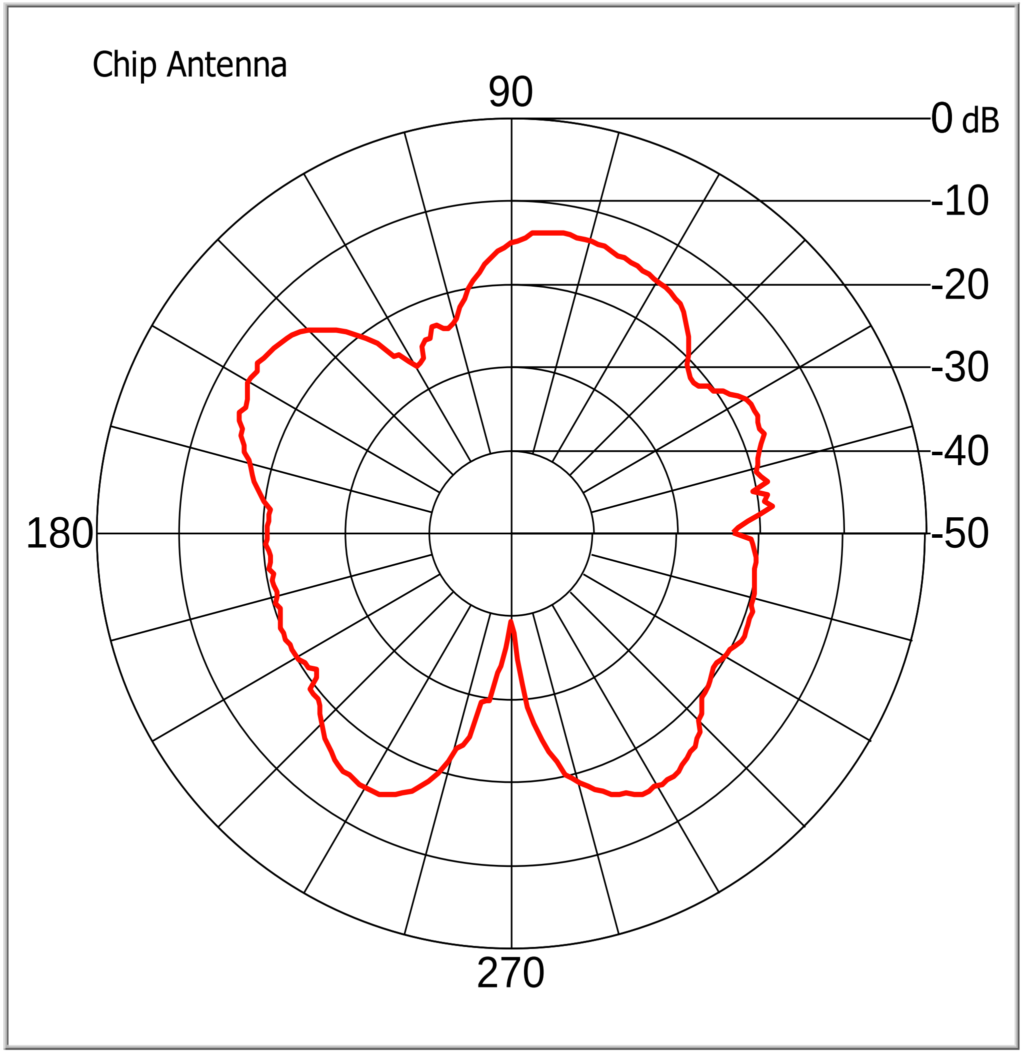
Radiation pattern of a dipole antenna connected to an XBee-PRO. The pattern is normalized to its peak. The chamfered end of the XBee-PRO points toward zero degrees as shown in the figure.

new picture



Radiation pattern of a whip antenna connected to an XBee-PRO. The pattern is normalized to the peak of the dipole antenna on the preceding page, permitting an easy comparison.

new picture



Radiation pattern of a chip antenna connected to an XBee-PRO. The pattern is normalized to the peak of the dipole antenna on the first page of this appendix, again, permitting an easy comparison.

*The PCB antenna has ~0.6 dB gain over most of a sphere, and the chip antenna is ~4.5 dB with larger gain variations; this gives the PCB antenna greater range.