MeshNetics®

ZigBit™

ZigBit™ OEM Module 1.1

Application Note

Comparative Study of ZigBit™ Range Performance

Document Overview

This application note describes a comparative study of receiver sensitivity and range performance of ZigBit™ (ZDM-A1281-B0 and ZDM-A1281-A2) modules and two other leading module vendors. The note outlines a working test setup and gives detailed account of the environmental conditions during test. In the end, conclusions are drawn on the basis of link quality and dropped packet rate for each of the receiver modules under test.

Executive Summary

In the course of this study, it was determined that ZigBit™ demonstrates superior or competitive outdoor range performance in comparison to devices of two other module vendors.

Qualitative performance results are as follows:

vs	Vendor 1	Vendor 2 (chip antenna)	Vendor 2 (dipole antenna)
ZigBit™ PCB antenna	ZigBit™	ZigBit™	ZigBit™
ZigBit™ chip antenna	even	ZigBit™	ZigBit™

Related documents:

[1] Range Measurement Tool User's Guide. MeshNetics Doc. P-ZBN-451

[2] ZigBit™ Development Kit 2.0 User's Guide. MeshNetics Doc. S-ZDK-451

Open Space Range Measurement

Many module vendors measure range performance in open space, but definitions of open space differ across vendors and there is no standard specifying what constitutes such a space. One common simplification is to define open space as a visual line of sight between transmitter and receiver. Unfortunately, this definition does not work well for the 2.4 GHz band. Due to physical properties of waves at these frequencies, stationary and moving objects far away from the direct radio path can drastically change interference picture and affect range performance.

Fresnel Zone is a football-shaped space between the transmitter and receiver and is a conceptual equivalent of visual line of sight for RF signals (see Figure 1). In order to increase range performance in open space, not only the line of sight but also the whole of Fresnel Zone must be free of obstacles. For instance, for ranges up to 300 meters (980 ft), the diameter of Fresnel Zone must be at least 5.4 meters. Clearly, free line of sight environment alone is insufficient to measure range performance in open space.

Figure 1. Approximate shape of Fresnel Zone between transmitter and receiver

Besides presence of physical obstacles in Fresnel Zone, each vendor's results can be affected by other environmental factors, most notably temperature and humidity. Comparative studies of range performance, i.e. studies where each device is subject to the same environmental conditions and is placed into the same open space environment, allow an unbiased result across many different vendors. One of the goals of this application note is to describe a setup in which range performance of multiple vendors can be compared side-by-side. The results presented are thus normalized with respect to critical environmental factors.

Outdoor Space and Environmental Conditions

Open space range measurement requires a sufficient area of leveled open space with line of sight, sufficiently wide radio path between transmitter and receiver and no above ground obstacles. Likewise, one must be certain that there is no interference from propagating signals other than signals from the radios under test. Properties of the physical medium (humidity, temperature, etc.), background noise and multi-path propagation can also affect radio performance and must be considered. Because antenna orientation and position can be experimentally controlled, they are discussed in "Equipment Inventory and Test Setup" section of the document.

For this particular range test, a public park northwest of Moscow, Russia was chosen (Google Maps). The park offers couple of 300-400 meters (980-1310 ft) line of sight radio paths with few or no obstacles. One of the two radio paths crosses a small pond. The satellite picture, with marker points in red and radio paths highlighted in light blue, is shown below. Distances between reference points are listed in Table 2.

Figure 2. Satellite map of range test location w/ reference points labeled

As seen from Figure 2, the pond is surrounded by dense vegetation, and there are several smaller shrubs on the radio paths. Figure 3 shows the view from point A toward point E.

Figure 3. Ground-level view from point A toward point E

The following weather conditions were observed on the day of test:

Temperature	0 ºC (32 ºF)
Relative humidity	75%
Atmospheric pressure	745 mm Hg (.98 atm)
Wind	SW at 7-8 m/s (15-18 mph)
Other parameters	Cloudy and overcast with no precipitation

Equipment Inventory and Test Setup

The following equipment was used in the tests:

- Dell laptop
- 2 Aluminum tripods set to a height of 1.4 m (4.6 ft)
- ZigBit™ module w/ chip antenna (ZDM-A1281-A2) mounted on MeshBean development board (receiver)
- ZigBit™ module (ZDM-A1281-B0) mounted on MeshBean development board with PCB antenna (receiver)
- Vendor 1 board w/ amplifier (receiver)
- Vendor 2 board w/ chip antenna (receiver)
- Vendor 2 board w/ dipole antenna (receiver)
- ZigBit™ module (ZDM-A1281-B0) mounted on MeshBean development board with PCB antenna (transmitter)
- Compass
- Laser distance meter

Additional equipment included:

- 35 A·hr battery
- 12/220V inverter
- 9V power supply
- D-Link USB hub
- Connecting cables

Receiver boards were positioned vertically on a leveled plastic board mounted on top of the tripod (see Figure 4). Prior to each test run, the plastic board was rotated so that the receiver antennas are pointed toward the transmitter. Likewise, transmitter antenna was pointed toward the receiver. Antenna alignment was checked visually.

Referring back to Figure 1, the receiver set was placed at points A and J' (point J' being in close proximity to reference point J). For point A, range measurements were recorded with transmitter located at points P1, P2, X1, X2, and X3. For point J', range measurements were recorded with transmitter located at A1, A2, A3, A4, and A5.

Location of reference points (e.g. A and J) was determined with a GSM receiver. The rest of locations and distances were computed with hand compass and laser distance meter in reference to these reference points.

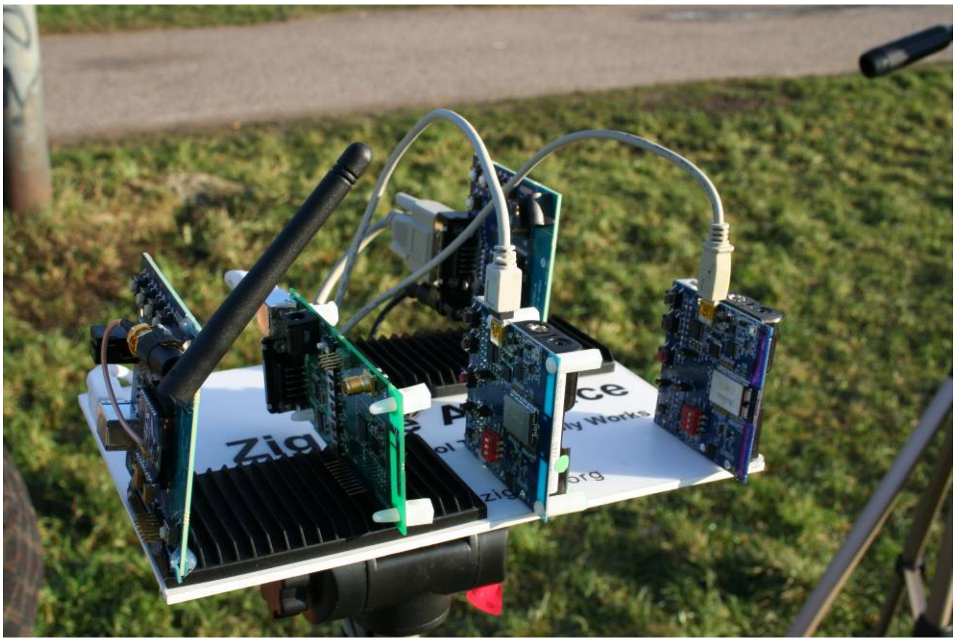

Figure 4. Receiver boards on top of tripod

For each pairing of points a test run consisted of the transmitter generating 10,000 data packets, and receiver recording information about the number of packets received, packets dropped, and packets containing bit errors. Each receiver device was in turn hooked up to the laptop (via USB and serial connections) with terminal software logging the data.

Table 1 below specifies the software installed on all devices prior to test. Receiving and transmitting ZigBits are programmed with the corresponding images from the Range Measurement Tool [1] available within MeshNetics ZigBit Development Kit [2].

Table 1. Software installed

Device	Software
ZigBit™ (transmitter)	`transmitter.hex`, transmitter image
ZigBit™ (receiver)	`receiver.hex`, receiver image
Vendor 1	receiver image for Vendor 1 platform (see [1])
Vendor 2 w/ chip antenna	receiver image for Vendor 2 platform (see [1])
Vendor 2 w/ dipole antenna	receiver image for Vendor 2 platform (see [1])
PC	ZOC 5.05 terminal software (1 instance for every receiver)

Setup Notes

Vendor 2 modules were disqualified from further testing due to poor performance of the chip antenna version and a USB conflict of the dipole antenna version and Vendor 1 board. Specifically, Vendor 2 chip antenna did not achieve ranges above 50 m (164 ft). After visual examination of link quality on Vendor 3 module with a dipole antenna, it was concluded that its performance did exceed that of Vendor 1. In the end, qualitative measurements were obtained for three types of boards:

- ZigBit™ module w/ chip antenna (ZDM-A1281-A2) mounted on MeshBean development board (receiver)
- ZigBit™ module (ZDM-A1281-B0) mounted on MeshBean development board with PCB antenna (receiver)
- Vendor 1 board w/ amplifier (receiver)

Range Performance Results

Although the radio path from point A was visually clear (see Figure 2), it was determined that trees and vegetations located within 5-10 m (16-33 ft) of the line of sight can already have a significant effect on link quality. With transmitter at point P1 and P2, another team of engineers was spotted performing what appeared to be a similar range test on unknown type of device (!). This might have accounted for the relatively small maximum range recorded at those points (86 and 129 m, respectively).

After determining the best performer on each of the radio paths, connection was attempted beyond the best performer's top range. Both ZigBit™ modules showed maximum ranges at least 25 m higher than Vendor 1. Furthermore, the chip antenna version of ZigBit™ module exhibited better performance than the PCB antenna version. One possible explanation for this behavior is higher degree of scattering and cross-polarization with signal reflected off the earth and surrounding vegetation. For an antenna with a wider radiation pattern, the kind of radiation pattern the chip antenna has, the wider radiation pattern could account for better performance.

With the receiver set at point J' (located immediately on the water's edge), the radio path appeared clearer than the one with the receiver set at point A. This resulted in considerably longer measured range (200 m (650 ft) and above). However, with the transmitter at point A1, which is closest to the water's edge, the link quality was somewhat poorer than expected. Signal reflected off the water's surface may be one explanation.

During the tests on the J' radio path, all modules indicated RSSI's lower than the lowest reportable value. While Vendor 1 received very little traffic under these conditions, both MeshBean boards enjoyed relatively error-free operation. Moving away from the pond along the radio path, signal strength dropped lower still, but the link quality remained satisfactory. The best on this radio path was ZigBit™ module with PCB antenna, the worst—ZigBit™ with chip antenna.

Table 2. Range test summary

Point	Distance (m)	ZigBit™ chip			ZigBit™ PCB			Vendor 1		
		FC	PER	BER	FC	PER	BER	FC	PER	BER
P1	86	9708	7.3e-3	1.2e-4	9721	1.3e-2	3.6e-5	9638	2.6e-1	3.4e-3
P2	129	9456	9.6e-1	1.3e-2	1464	1.0	8.0e-2	9204	9.9e-1	1.5e-2
X1	160	9549	2.7e-1	4.3e-3	9532	2.1e-1	3.6e-3	9285	7.6e-1	1.2e-2
X2	147	9680	6.0e-2	7.0e-4	9746	7.7e-3	7.6e-5	9583	4.0e-1	6.1e-3
X3	135	9694	1.5e-2	2.5e-4	9727	1.7e-3	5.6e-5	9576	2.8e-1	5.3e-3
A1	113	9754	7.3e-3	2.5e-4	9457	5.5e-2	1.3e-3	5017	5.6e-1	4.1e-2
A2	133	9757	0.0	0.0	9299	4.9e-2	1.4e-3	9783	4.1e-4	1.3e-4
A3	153	9765	0.0	0.0	9758	1.1e-3	5.2e-6	9778	5.1e-4	1.2e-4
A4	180	9758	0.0	0.0	9762	3.2e-3	1.6e-4	9774	1.2e-2	1.8e-4
A5	200	9764	2.0e-4	4.0e-7	8813	1.2e-1	2.9e-3	9780	5.1e-4	1.1e-4
	FC: frame count									
	PER: packet error rate									
	BER: bit error rate									
	winner									
	loser									

Table 2 presents a summary of test results. Note that the table shows that for comparative study it is insufficient to count error packets alone, maximum number of packets received by any module on the test run must also be considered. Table 3 normalizes the measured number of packets received by the difference between packets received and maximum number of packets received by any of the modules in a test run.

Table 3. Frame totals for entire duration of tests

Module	Measured # of received frames	Measured # of received erroneous frames	Total # of erroneous frames
ZigBit™ PCB	294647	85131	85131
ZigBit™ chip	252151	64644	107140
Vendor 1	287392	99939	107194

In particular, Table 3 shows that the overall range performance and reception quality of ZigBit™ module with chip antenna is comparable with Vendor 1 module.

All modules appeared quite sensitive to movement (both of the modules themselves and of the surrounding objects), hence it can be concluded that accurate range measurements are possible only in highly static environments.

Conclusions

This study has clearly shown that in receiver mode ZigBit™ module with PCB antenna shows range performance superior to that of Vendor 1 with amplifier enabled. Likewise ZigBit™ module with PCB antenna shows superior range performance in comparison with Vendor 2 module with dipole antenna.

Although on open radio paths Vendor 1 module delivers better range performance in comparison with ZigBit™ module w/ chip antenna, under circumstances where reflection off ground and water is significant, ZigBit™ module w/ chip antenna prevails.

Qualitative performance summary is provided below.

vs	Vendor 1	Vendor 2 (chip antenna)	Vendor 2 (dipole antenna)
ZigBit™ PCB antenna	ZigBit™	ZigBit™	ZigBit™
ZigBit™ chip antenna	even	ZigBit™	ZigBit™