ZigBit™ Amp
OEM Modules

ZDM-A1281-PN

Application Note

Measuring Range Performance of ZigBit™ Amp

Document Overview

This application note describes a range performance test performed for ZigBit™ Amp wireless module. The note outlines a working test setup, giving the details on the field conditions during the test. The conclusions are based on link quality and dropped packet rate for the wireless module under test.

Executive Summary

This study reveals a superior outdoor range performance of ZigBit Amp module [1], compared to conventional ZigBit configurations [2] tested earlier [5].

It is determined that the ZigBit Amp range performance reaches up to 4000 m.

Related documents:

[1] ZigBit™ Amp OEM Modules. Product Datasheet. MeshNetics Doc. M-251~03

[2] ZigBit™ OEM Modules. Product Datasheet. MeshNetics Doc. M-251~01

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

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

[5] ZigBit™ OEM Module. Application Note. Comparative Study of ZigBit™ Receiver Range Performance. MeshNetics Doc. AN-481~02

Environment Factors Disturbing RF Connectivity

Due to physical properties of radio waves in 2.4 GHz frequency band, the effect of multi-path propagation is especially apparent in open space. Instead of considering visual line of sight as the only direction in which RF signal propagates, one should take into account the so-called Fresnel Zone, an elliptical propagation area between transmitter and receiver. In order to improve range performance in open space, not only the line of sight but the whole Fresnel Zone must be cleared of obstacles. As an example, for ranges up to 300 meters (980 ft), the diameter of Fresnel Zone must be at least 5.4 meters.

Landscape details obviously affect reception since the ground soil in Fresnel Zone is capable of decreasing signal power and changing polarization. Surrounding vegetation can also attenuate the signal. Water surface can generate reflections affecting reception as well. Thus range measurements in excess of 1km are best performed in cross-country environments with transmitter and receiver placed on hills separated by depressions.

Stationary and moving objects far away from the visual line can drastically interfere with the resulting pattern thus also affecting range performance. Large metal objects, power lines, vehicles as well as humans can also disturb RF propagation. Obviously, technogenic/human factors should be minimized, particularly the RF sources other than signals from the radios in question.

Beyond the presence of physical obstacles, testing results can be also affected by weather factors, most notably by temperature and humidity.

Outdoor Space and Environmental Conditions

For the range test of ZigBit Amp at long distances, the M7 highway (Gor'kovskoye shosse) area, 60 km eastward off Moscow, Russia, was considered among other options. This 20 m (66 ft) wide road offers straight paths which are long enough for expected distances, with few landscape obstacles. This whole area was found extremely flat, which appeared critical to selected target location. Having discovered the M7 highway bridge crossing a local railway, the receiver (RX) station was disposed there, for the downhill pass was found in eastward direction, up to 5 km long (see Google Earth general view in Figure 1). The highway bridge crossing the railroad was about at 8 m (26 ft) high.

Thus, the receivers' location was fixed at the established RX station on the 3 m wide shoulder. Using a car equipped with fine distance meter (see Figure 2) the transmitter was gradually moved eastward along the highway through locations distanced at 2000m, 3000m and 4000 m away from the station. To eliminate the influence of forest vegetation close to the roadway, the transmitter side was chosen across the road, thus admitting the measurements across some moving traffic.

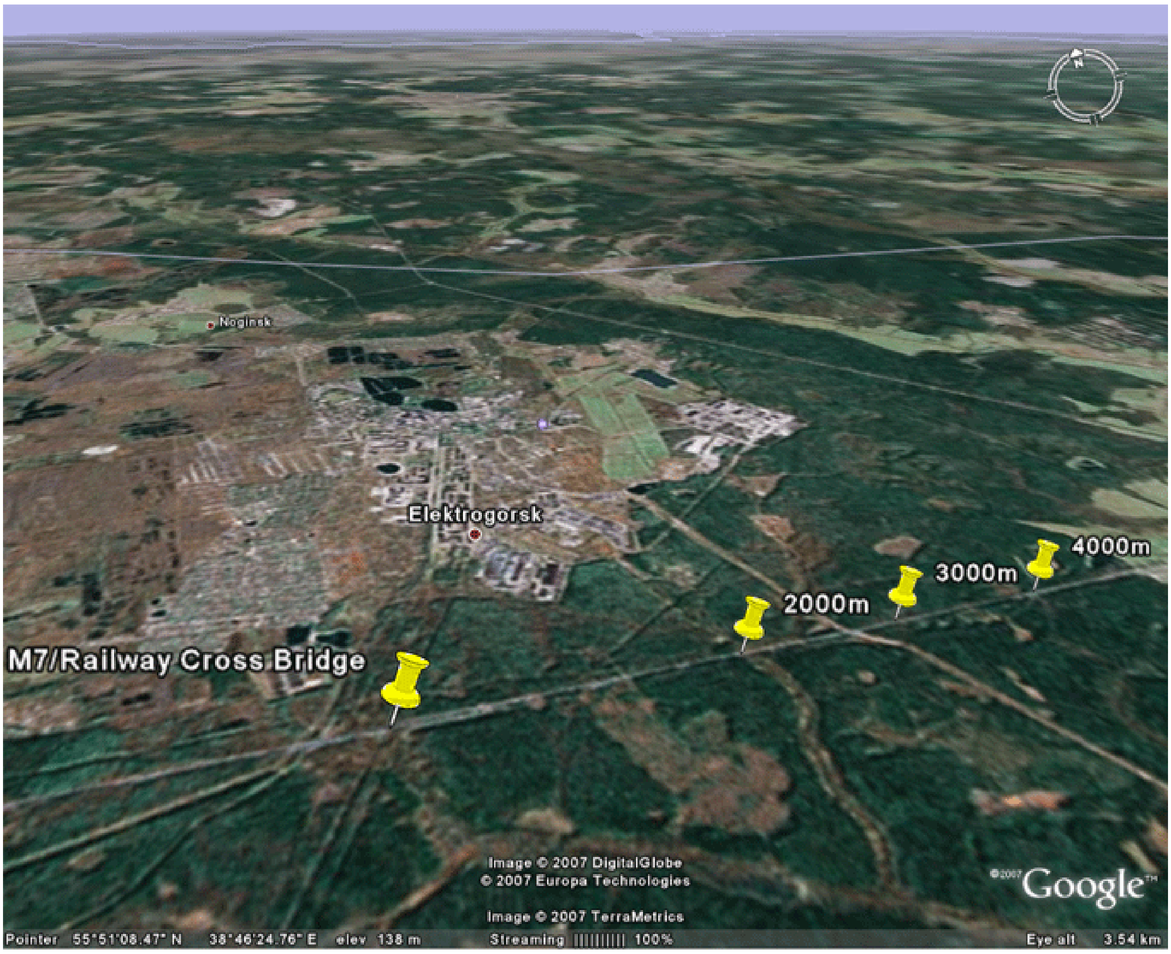

Figure 1. Range test location with reference points

To make the complete series of measurements for each distance both transmitter and receiver module were installed on top of 1.6 m tall tripods (see Figure 2 below).

The following weather conditions were observed on an early winter day of the test (see Table 1).

Table 1. Weather conditions during the test*

Date	November 8, 2007
Temperature	– 6 ºC (21.2 ºF)
Relative humidity	73%
Atmospheric pressure	744 mm Hg (0.98 atm)
Wind	Still

*Retrieved from Meteo archive, Moscow

Equipment Inventory and Test Setup

The following equipment was used in the test:

- 2 Aluminum tripods extended to a height of 1.6 m (5,3 ft)
- Dell laptop PC powered by external AC generator
- ZigBit™ Amp module (ZDM-A1281-PN rev.2.0) with the built-in output Power Amplifier and input Low-Noise Amplifier, which is mounted on MeshBean development board (set up as receiver) connected to laptop PC through RS232 interface
- external high performance 2.4 GHz Titanis swivel antenna attached to ZigBit Amp module through Hirose's U.FL to SMA connector (see Figure 2)
- the same ZigBit Amp module device with same antenna (set up as transmitter).

Figure 2. Receiver module with external antenna mounted on top of tripod

Auxiliary equipment included:

- Two pairs of 1.5 V high capacity D-type batteries to power the transmitter
- RS-232 cable to connect the receiver module with the laptop
- Distance meter, a part of driving system in the car which was employed to transport the transmitter module (see Figure 3).

Figure 3. Car distance meter

All tests were made under following conditions:

- Both MeshBean2 boards disposed on tripods horizontally with the antenna set up vertically
- RF signal transmitted on channel `0x14`
- TX output power enabled at maximum: 100 mW (+20 dBm).

Table 2 below specifies the software installed on each of the wireless devices and on PC prior to test. Receiving and transmitting ZigBits are programmed with the corresponding images from the Range Measurement Tool [3] available within MeshNetics ZigBit Development Kit [4].

Table 2. Software installed

Device	Software
ZigBit™ Amp (transmitter)	`transmitter.srec`, `transmitter.hex` – any of these image files can be optionally used to load transmitter with Range Measurement Tool
ZigBit™ Amp (receiver)	`receiver.srec`, `receiver.hex` – any of these image files can be optionally used to load receiver with Range Measurement Tool
PC	Hyper Terminal software

To load `srec` image files with Serial Bootloader utility we used fuse bits as `FF/9C/C0`, checking on the following options:

```
Brown-out detection disabled
JTAG interface enabled
Serial program downloading (SPI) enabled
Boot Flash section size=1024 words Boot start address=$FC00
Boot Reset vector Enabled (default address=$0000)
Ext.Clock; Start-up Time: 6 CK + 0ms.
```

To load `hex` image files with JTAG `FF/9D/C0` fuse bits should be set, checking on the options below:

```
Brown-out detection disabled
JTAG interface enabled
Serial program downloading (SPI) enabled
Boot Flash section size=1024 words Boot start address=$FC00
Ext.Clock; Start-up Time: 6 CK + 0ms.
```

To enable maximum output power for transmitter we set DIP-switch `SW4` in `ON/ON/ON` position and further we reset transmitter module by pressing the `RESET` button. To switch transmitter to channel `0x14` we pressed `SW2` button slowly 9 times, taking into account the starting channel as (`0xB` – 2405 MHz) default. Similarly, we set channel `0x14` for receiver module.

Before connection is established, all LEDs are blinking at receiver. Upon connection established, green LED stays ON while yellow and red LEDs are flashing periodically.

Starting Hyper Terminal software, we set the corresponding COM port with the following parameters (see Table 3).

Table 3. COM port settings

Parameter	Value
Data Rate	38400 bps
Data Bits	8
Parity	none
Stop Bits	1
Flow Control	none

In-Field Observations

To determine range performance for ZigBit Amp, the connection quality has been estimated depending on TX/RX distance. To observe transmission errors we ran the Hyper Terminal software at receiver's PC.

For each distance a test run consisted of the transmitter periodically sending data packets containing 1024 bits from specially generated pseudorandom sequence (polynomial, according to ITU-T O.151 recommendation), and receiver recording information about the number of packets (frames) received, packets dropped, and packets containing bit errors (see below).

The encountered connection status was monitored at receiver's PC in plain half-second statistics shown in screenshot example in Figure 4.

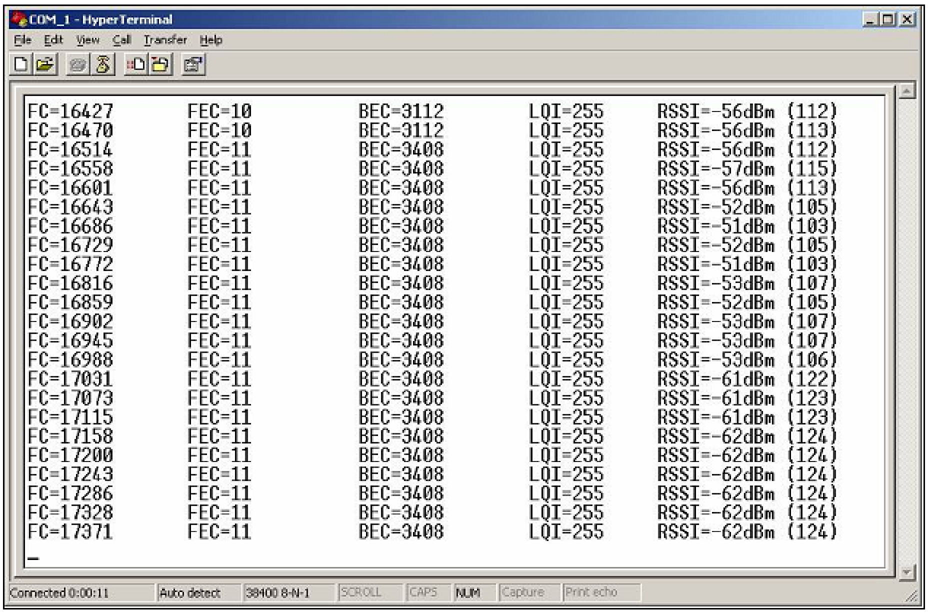

Figure 4. Hyper Terminal output from Range Measurement Application

The observed connection quality parameters are listed in Table 4.

The connection crash was evidenced by all LEDs blinking on the receiver board, whereas the FC counter stops. Complementing these crash observations, the connection stability was visually determined for each test run through visual estimations based on 'connected-time ratio' with the 'ON' connection indicated by LEDs.

Table 4. The observed connection quality parameters

Parameter	Description
FC	Frame Counter
BEC	Bit Error Counter
FEC	Frame Error Counter
LQI	Link Quality Indicator
RSSI	Received Signal Strength Indicator

The single Hyper Terminal session provides subsequent connection series. The test data series were saved into text log files, separately for each TX/RX distance.

Estimating the Connection Quality

The laboratory interpretation of each log data was based on calculation of rate statistics and it also involved the standard RSSI indicator. Rate statistics are listed below in Table 5. These rate statistics were visualized in format shown below in Figure 5.

Table 5. Rate statistics

Statistics	Description
FR	Frame Rate
BER_{short}	Bit Error Rate (short-term value)
BER_{cum}	Bit Error Rate (cumulated value)
FER_{short}	Frame Error Rate (short-term value)
FER_{cum}	Frame Error Rate (cumulated value)

Connection was considered stable if both of the following conditions are satisfied:

$$FER < 0.1$$
and
$$BER < 0.01.$$

Connection was considered crashed **when**: any of partial conditions above are broken in terms of FER_{cum} or BER_{cum} (cumulative) values **or** any of these partial conditions are broken in short term, while at least five of FER_{short} or BER_{short} peaks were observed at once exceeding the specified thresholds.

To estimate the module's range performance the measurement results are summarized in Table 6. Along with the averaged RSSI, the estimations of BER_{cum}, FER_{cum} are given for each measurement in terms of final levels achieved during the stabilization period (about 3 min). Following the discussed specifics, TX locations can be sorted with respect to the observed connection quality, which is represented by different shades of gray.

Table 6. Range Test Observation Summary

TX/RX distance, m	RSSI, dBm	FER	BER	Notes
2000	-72	0.02	0.0010	Connection stable
3000	-78	0.05	0.0015	Rare peaks in FER and BER, no drops, connection stable
4000	-83	0.10	0.0040	No BER crash, episodical peaks in FER, connection acceptable

The variations in connection stability for 4000 m TX/RX distance are shown on Figure 5.

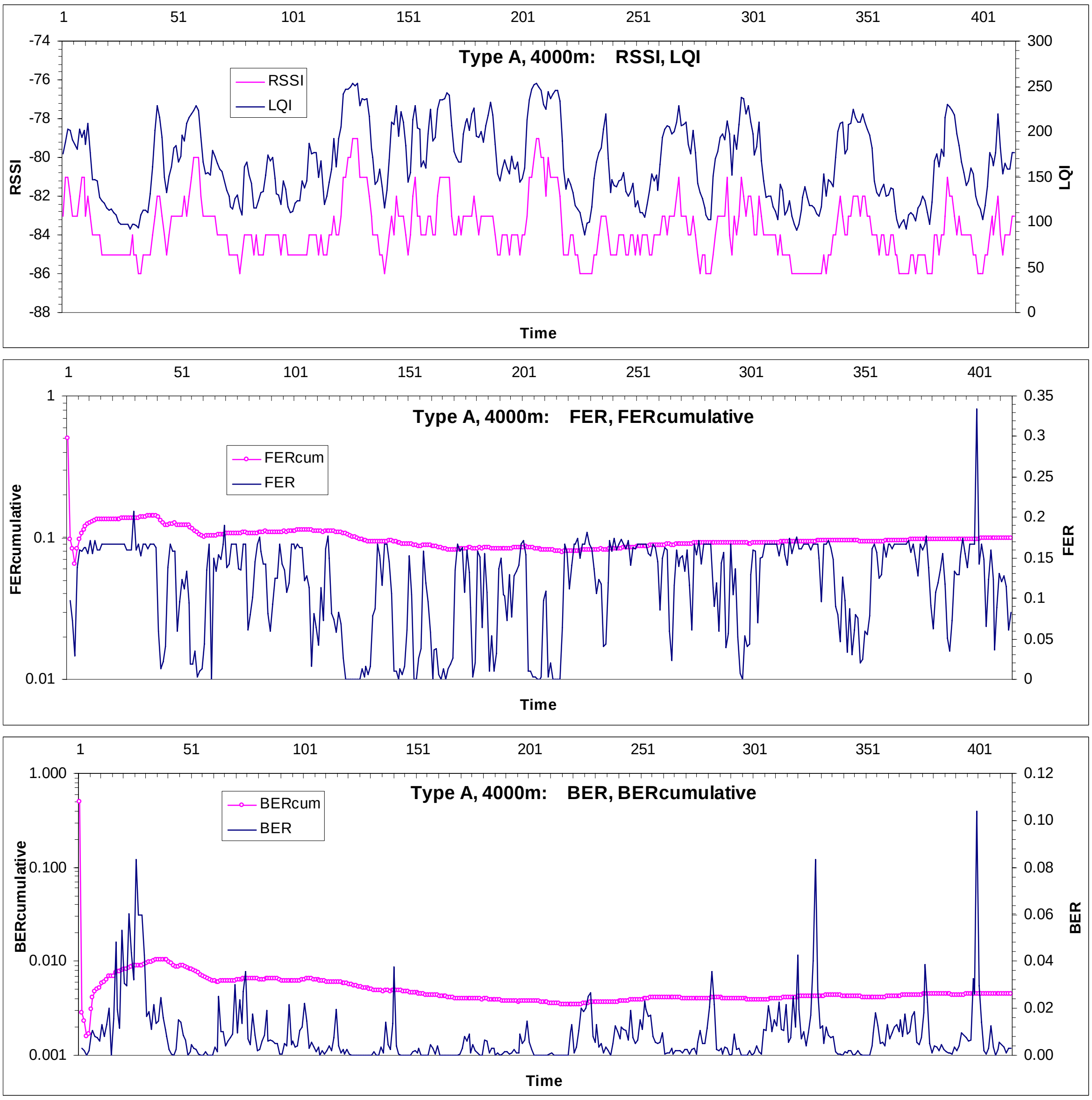

Figure 5. Connection quality in time domain for 4000 m distance

Conclusion

ZigBit™ Amp module enhanced with output power amplifier and input low-noise amplifier delivers acceptable range performance at the maximum distance of 4000m.