Summary of Zigbee Board Range Testing

Prepared for SoftBaugh, Inc.

By Cincinnati Technologies, Ltd.

http://www.cincinnatitechnologies.com

December 27, 2005

Testing Goal

The goal of this effort is to evaluate the RF range performance of the Softbaugh DZ1612 2.4 GHz Zigbee boards. The testing included direct connect transmit power measurements, radiated power measurements, line-of-sight range testing and office environment testing.

General Setup

Testing was performed using the Airbee Zigbee evaluation software. The network consists of 4 boards. The boards are physically identical. Each board was loaded with unique software provided by Airbee. The Airbee application links the boards as shown in Figure 1 Zigbee Network Configuration. There are two kinds of connections between the boards, RF paths and control links. The RF paths, indicated with solid lines, are the actual radio communications paths between the physical units. The control links, indicated with dotted lines, are logical connections of a switch on one board controlling an LED on another board. The application links a switch on one board to an LED on another board. In order for a logical command, i.e. turn on the LED, to reach a unit at the end of the control link, a command must traverse through two radio paths. The COR is the network coordinator. R1, R2 and R3 are Zigbee routers. All testing was performed with a switching circuit connected to the switch of one of the boards. The circuit performed electronic equivalent switch presses at a 4 Hz rate. This provided regular transmissions between the boards. The regular transmissions caused the LED at the end of the control link to flash at a regular rate. Deviations from the regular flash rate indicate a loss of link.

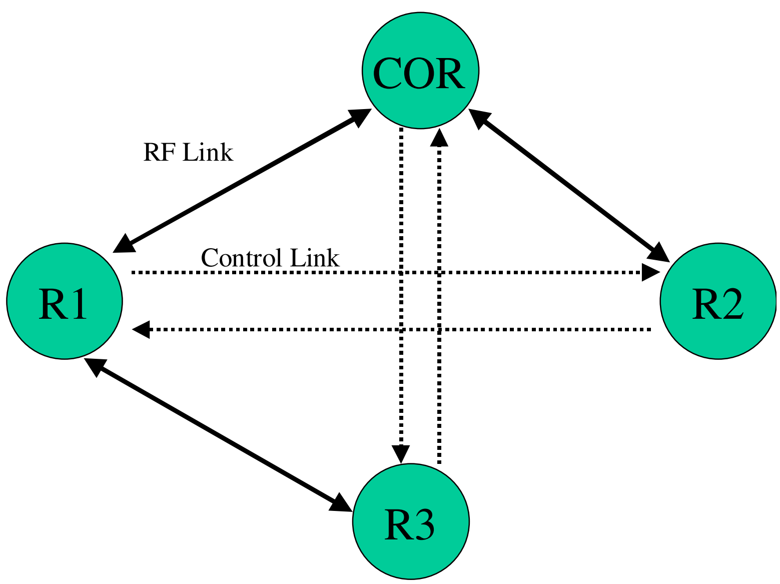


Figure 1 Zigbee Network Configuration

Transmitter Power

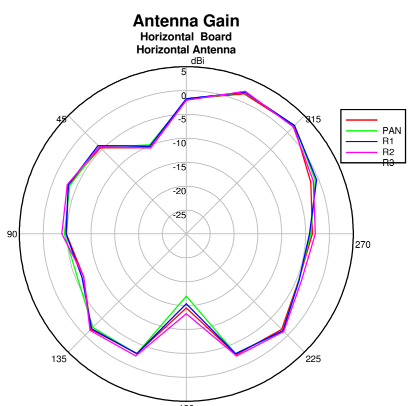
The transmit power of each board was measured using the channel power measurement on a spectrum analyzer that was diretly connected to the board under test. The results shown below indicate that the transmit power is consistent within 1dB between the boards. The CC2420 on the DZ1612 specified to have a minimum output power of –3 dBm with a nominal 0 dBm output power. All boards meet the CC2420 data sheet specification for transmit power.

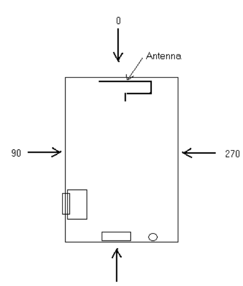
Unit	Power	
CON	-1.9	dBm
R3	-0.94	dBm
R2	-1.02	dBm
R1	-1.01	dBm

Antenna Gain

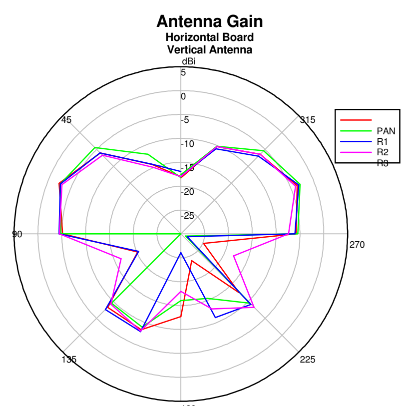
The radiated power of each board was measured. The measurement was performed over a 360 degree board rotation for two different board orientations. The horizontal orientation places the board surface parallel to the ground. The vertical orientation places the board surface perpendicular to the floor. In all cases the boards were 32 inches above the floor. For each board orientation, the horizontally and vertically polarized radiated emissions were measured as a function of polar angle.

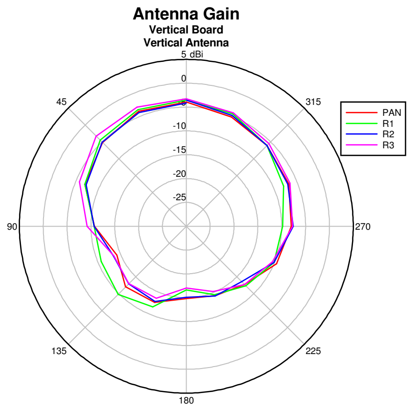
The antenna gain was calculated using the measured transmit power of the board, the measured receive power and the characteristics of the receive antenna and cables. The results are shown below. All views are looking down at the board from directly overhead. The results show that the primary radiation polarization is parallel to the board as is expected. The gain of the antenna ranges from –5 to +2 dBi depending on the polar angle. The gain excludes the nulls. The nominal gain of the antenna is 0 dBi. The antenna gain in the expected polarization is fairly smooth with only a few nulls. The expected polarization of the antenna is parallel to the board. The best results are obtained when the board is horizontal to the ground plane. They also show that the radiation from the side of the board away from the antenna is much lower than from the side with the antenna. Furthermore, the measurements of the gain cross polarized to the plane of the board are very peaky. The smooth curve with only a few nulls makes the board antenna effective.

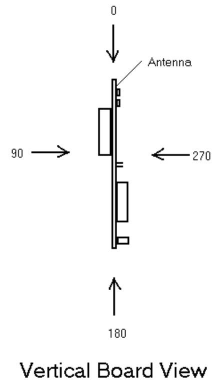


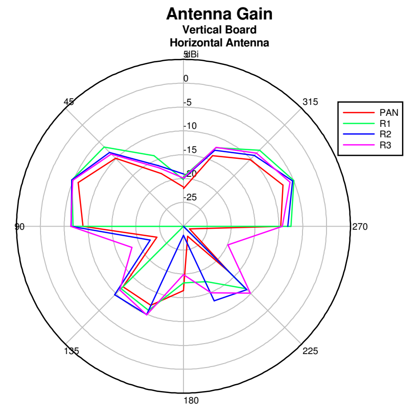


Horizontal Board View









Line of Sight Measurement

Two pairs of boards were evaluated for line-of-sight range over unobstructed level ground. The measurement was performed in an open parking lot with both boards 32 inches above the ground.

The CON to R3 RF path was measured. The line-of-sight range was 350 feet in the best orientation, 150 feet for most orientations and a minimum of 85 feet for almost any combination of board directions and orientations. The R1 to R2 RF path was measured. The line-of-sight range was 250 feet for the best case and a minimum of 90 feet for almost any combination of orientations.

Based on the measured transmit powers, expected receiver sensitivities of –94 dBm and measured antenna gains, the predicted line-of-sight range is 425 feet for the units 32 inches above ground. The 250 foot measurement corresponds to a 9 dB signal loss as compared to the 425 foot range. The 350 foot range corresponds to a 3 dB signal loss. Likely reasons for the discrepancy include tolerances in the measurement of the antenna gain, non-flatness of the test site, and the inherent variability in range measurements of this type. Also, the receive sensitivity of the units was not measured. The R1 and R2 combination was performed on a different day that was much colder than the day the CON and R3 combination was measured, so temperature may also have been a factor.

The line of sight range is 300 feet for the best case antenna orientation combination and 85 feet for almost any antenna orientation combination.

Office Evaluation

For the office evaluation the Cincinnati Technologies Mason office was used. The facility is approximately 3200 square feet as shown in Figure 2. The actual range test was between units R1 and R3. Since R2 and the CON must be linked for the network to operate, they were placed in a shielded box to drastically reduce their range and ensure that the link was between R1 and R3. R1 was placed near one end of the building. The flashing light hardware was connected to the CON in order to operate the CON to R3 control link. R3 was walked around the facility while it was turned and rotated. As long as the light flashed at the regular rate, the link was still complete. The link was generally complete over the lab except for a couple of small zones at the farthest distances from the fixed transmitter. The maximum distance between the boards was less than 100 feet.

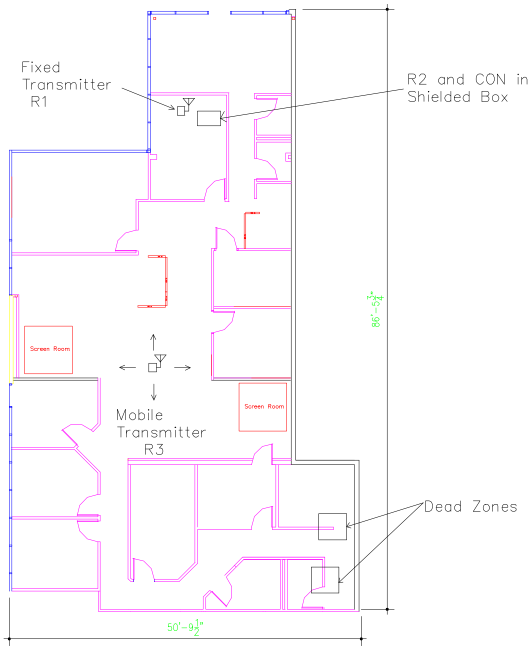


Figure 2 Office Range Test Location

Summary

The DZ1612 transmit power is consistent within 1 dB and meets the datasheet specification for the CC2420 radio transceiver on the board.

The antenna gain is nominally 0 dBi. The patterns are fairly uniform with a few nulls in the pattern attributable to the antenna being coplanar with the circuit board ground plane. More consistent range performance could be attained by use of an antenna design with a more uniform, vertically polarized, radial pattern.

The DZ1612 range performance is about what would be expected in both a line-of-sight and office environment. The line-of-sight range was 350 feet for one pair of boards and 250 feet for the other. 300 feet of range was expected based on Zigbee claims. This shows that a 300-foot best case range is a reasonable expectation, but it should not be expected in all cases of orientation. If orientation of the antennas is not controlled, or is consistently in an unfavorable orientation, a different antenna design with a more favorable pattern may be needed.

A pair of boards was shown to cover a small office where the maximum distance between boards is less than 100 feet. Pattern and polarization are frequently less of a factor in a high-reflection environment such as this, resulting in more consistent short-range performance but significantly shorter maximum range.