WINLAND ELECTRONICS, INC.

Application Note 00101

Wireless Sensor Test Results / Installation Guidelines

Sensor Placement Recommendations

1. Place the sensors as close as possible to the EA800-ip base unit
    a. Actual range depends greatly on the construction of walls/floors and other environmental factors. The table below contains reasonable expectations of wireless range with all devices located on the same level of the building:

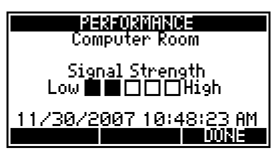
Environment	RF Path - Description	Typical Range (2 bars)
Outdoor – Flat Ground	Line of Sight	1000’
Indoor – Open Factory	No walls	100’
Indoor – Convenience Store	1 wall	75’
Indoor – Home	2 walls	45’

2. Whenever possible, place sensors such that there is a direct signal path to the EA800-ip
    a. Do not place sensors directly between large objects and a wall
    b. Do not place large metal objects between the sensors and the EA800-ip base unit

3. Avoid placing the sensors or the EA800-ip base unit directly on the floor

4. Multi-level environment considerations
    a. If the sensors and EA800-ip base unit are placed on the same level of the building:
        i. Place both the sensors and the EA800-ip approximately 4.5’ – 6.5’ off of the floor. In general, the sensors and EA800-ip base unit should be higher then the majority of objects but lower then the tops of doors that are between them
        ii. When mounting the sensor, position the antenna perpendicular to the floor
    b. If the sensors and EA800-ip base unit are placed on different levels of the building:
        i. The typical wireless range will be less then normal.
        ii. Devices on the lowest level should be placed at least 4.5’ off of the floor.
        iii. Do not mount sensors more then 1 level away from the EA800-ip base unit. For 3 levels of coverage – place the EA800-ip base unit in the middle level

5. After all above criteria are met, check the wireless performance of each sensor (consult the EA800-ip manual if you are unsure of how to do this). Ensure that at least 2 bars are displayed on the screen for each sensor as shown below:

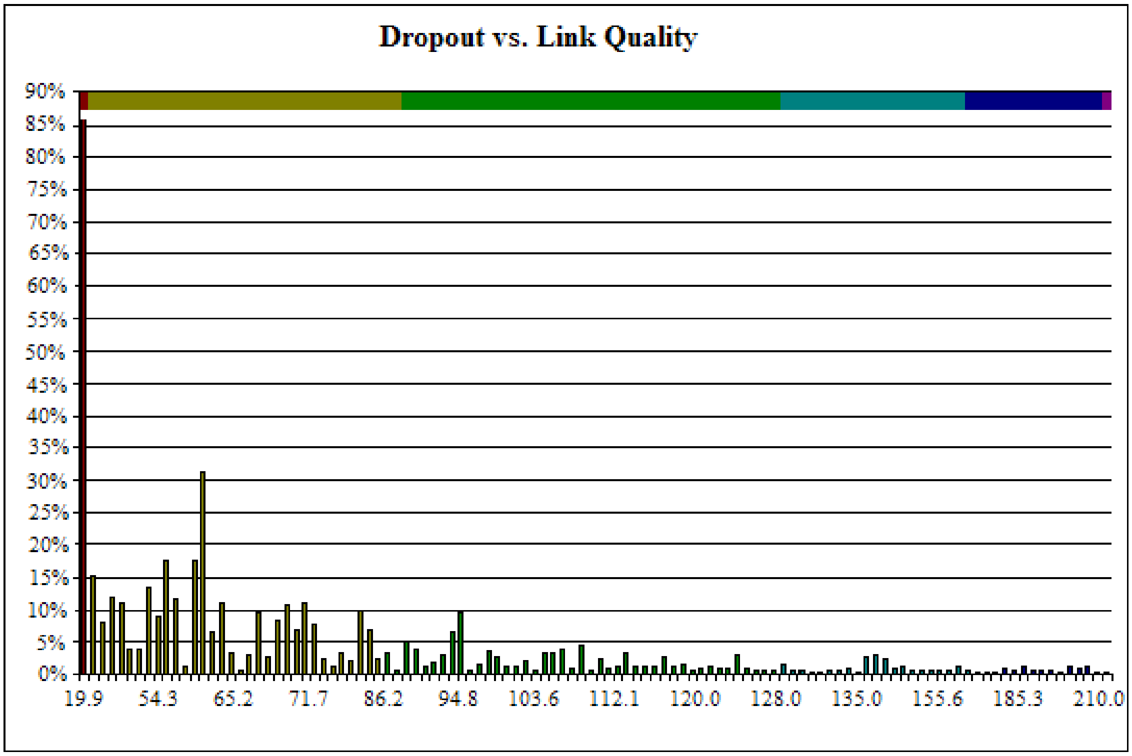


Due to the antenna algorithm and other environmental conditions, it is normal for the signal strength to vary as you are viewing it. If there are not at least 2 bars for the majority of the time, move the sensor to a new location (following the above recommendations) and try again. Placing sensors in locations that result in low signal strength will:

a. Increase sensor alarm latency
b. Increase likelihood of a wireless communication alarm
c. Decrease battery life

Dropout Rate Correlated to Wireless Performance Bars

A graph of Dropout vs. Link Quality is shown below.



The link quality is a decimal number from 0 – 255; 0 representing low signal quality/strength and 255 representing high signal quality/strength. From the graph, the following observations were made:

Link Quality Range	Max Drop Out	Bars on EA800-ip Screen
< 40	Unpredictable	0
40 – 84	< 35%	1
85 – 129	< 10%	2
130 – 174	< 5%	3
175 – 219	< 2%	4
220 – 255	< 1%	5

Summary of Testing

The location recommendations and dropout correlation to wireless performance bar information listed above was based on several tests. Winland Electronics conducted these tests in multiple use case environments at residential, commercial and industrial sites. A summary of these sites is listed in the table below:

Start Date	City, State	Location	Use Case	Unit Hours
6-15-07	Mankato, MN	Industrial Site	Server Room	1,144
6-29-07	Madison Lake, MN	Commercial Site A	Portable Floor Cooler	1,177
6-29-07	Madison Lake, MN	Commercial Site B	Walk-in Cooler	1,373
7-18-07	North Mankato, MN	Residential Site A	Water Heater	1,067
7-18-07	North Mankato, MN	Residential Site B	Laundry Room	1,371
8-29-07	Mankato, MN	Industrial Site	Server Room	1,272
			Total Unit Hours	**7,404**

Testing consisted of placing a single head unit in a location where an EA800-ip would be typically installed. Then, four wireless sensors were placed to surround the particular use case in a star topology.

The sensors would transmit once approximately every 4 seconds. A pseudorandom offset delay was placed in between transmissions (same as production units) so that if two sensors were to communicate at the same time (causing collisions and dropped packets), the next transmission from each sensor would have less then a 2% chance of overlapping again.

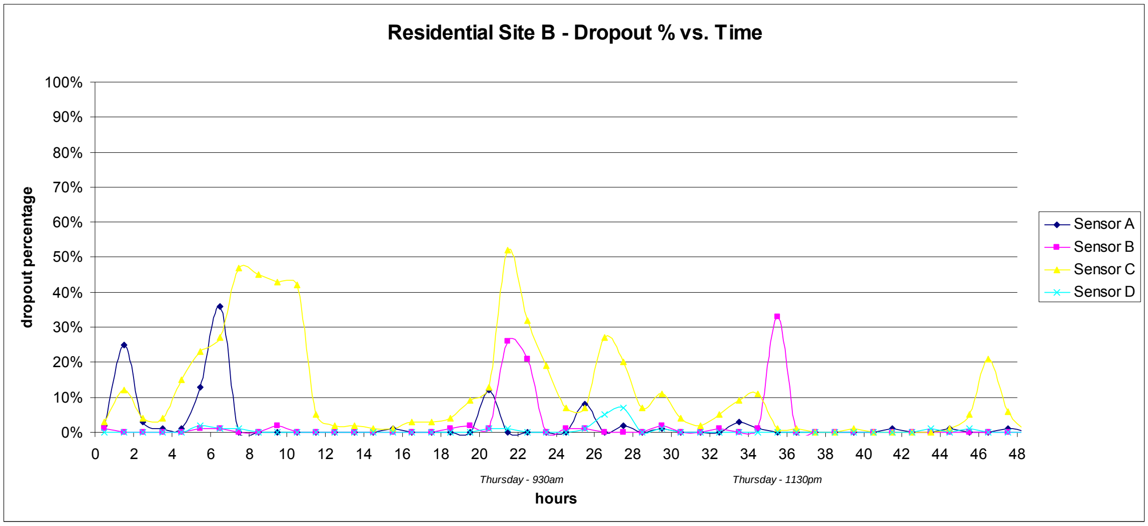
Each use case was visited 4 – 6 times during testing. During these visits, sensor and/or the head unit locations were changed. Typically, a use case would consist of 8 – 12 different sensor locations and 2 different head unit locations.

The purpose of this testing was to determine ideal mounting locations, if any, and to determine a value of the link quality that should be deemed acceptable. An acceptable link quality is one that produces an average of less then 1 nuisance (loss of communication) alarm per year.

Residential Data Obtained

Limited data was selected at random for this section of the document. Presenting all collected residential data would be outside the scope of this document.

Shown below is a 2 day graph of the “laundry room” use case.



The table below summarizes the test setup and results from the graph above:

Name	Distance from Head Unit	Level of Home	Comm Alarms (10 minute loss)	Average Link Quality
Head Unit	-	Main	-	-
Sensor A	46 feet	Basement (1 below main)	0	82.5
Sensor B	45 feet	Basement (1 below main)	0	101.6
Sensor C	45 feet	Basement (1 below main)	1	57.7
Sensor D	45 feet	Basement (1 below main)	0	93.9

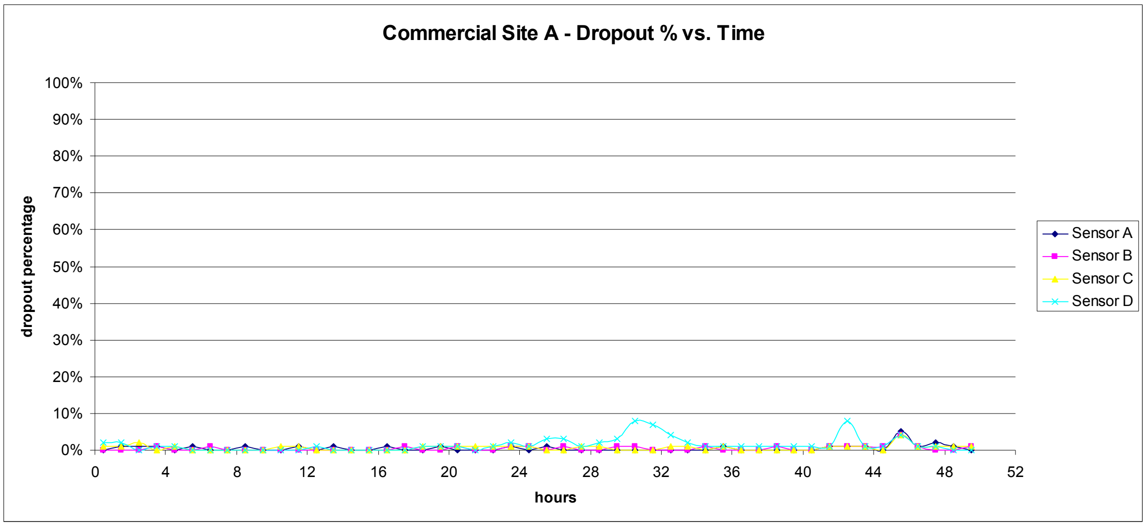
It can be seen from the table that two of the sensors had an average link quality below 85 (2 bars) and therefore their locations wouldn’t be recommended for a permanent installation.

It should be noted that additional testing was done in a “water heater” use case which had sensors at a total distance of approximately 15 feet, also traveling through a floor. These sensors had average link quality values of 115 to 209 (2 – 4 bars) and therefore, would be recommended for permanent installation.

Commercial Data Obtained

Limited data was selected at random for this section of the document. Presenting all collected commercial data would be outside the scope of this document.

Shown below is a 2 day graph of the “portable floor cooler” use case.



The table below summarizes the test setup and results from the graph above:

Name	Distance from Head Unit	Level of Commercial Building	Comm Alarms (10 minute loss)	Average Link Quality
Head Unit	-	Main	-	-
Sensor A	45 feet	Main	0	133.2
Sensor B	45 feet	Main	0	155.3
Sensor C	49 feet	Main	0	103.3
Sensor D	49 feet	Main	0	88.3

It can be seen from the table that every sensor had an average link quality above 85 (2 bars) and therefore their locations are recommended for permanent installation.

It should be noted that additional testing was done in a “walk-in cooler” use case which had sensors at a total distance of approximately 80 feet traveling through 2 walls. These sensors had average link quality values of 65 - 115 (1 – 2 bars) and therefore, would not be recommended for permanent installation.

Glossary

Bars – Referring to the bars displayed on the EA800-ip for a particular sensor in the performance screen.

Dropout Percentage – Percentage of missed packets sent to the head unit.

Head Unit – For testing purposes, this was a self powered RX Card. In the final product, the head unit will be the EA800-ip, which contains an identical radio layout to the RX Card.

Link Quality – Characterization of both the quality and signal strength of a received packet. “0” represents the poorest quality and signal strength whereas “255” represents the best.

Microcontroller – Small computer on a chip which is the “brains” of the electronics.

Pseudorandom Offset Delay – A delay varying between 0 and 2 seconds in increments of 1/32s (total of 64 different possible delays), randomly chosen by the microcontroller.

RF Path – The physical path between the sensor and the Head Unit where the wireless signals travel.

RX Card – Electronic device used to communicate with sensors. The RX Card contains an identical radio layout to both the wireless sensors and the EA800-ip.

Star Topology – All wireless sensors can only talk to the head unit, not with each other

Use Case – Typical scenario/objects that would require monitoring such as server rooms, coolers, water heaters and laundry rooms.