MRF24WB0M Indoor and Outdoor Antenna Range Testing

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INTRODUCTION

This application note discusses outdoor Line-of-Sight (LOS) and indoor antenna range for MRF24WB0MA and MRF24WB0MB modules with various modular certified antennas under specific infrastructure usage models. It also provides detailed information on the measured results and methodologies.

802.11 is the primary wireless protocol for devices to gain internet connection. The combination of ubiquitous Wi-Fi™ access and billions of end-points is paving the way for new products. The Microchip's Wi-Fi solution provides an easy-to-use and cost effective solution to bring new applications to the market. The Microchip's Wi-Fi parts MRF24WB0MA and MRF24WB0MB are in production, and are modularly certified for regulatory domains with various cost effective antenna solutions. The following are a few proposed applications for the Microchip's Wi-Fi module solutions:

- Utility and Smart Energy
  - Configure and control thermostat
  - Monitor and update storage conditions
  - Reconnect during power outage
  - Debug and analyze utility meters
- Consumer Electronics
  - Stream audio
  - Store and access media content
  - Access content from device-to-device
  - Control toys wirelessly
- Industrial Controls
  - Monitor traffic conditions with wireless cameras
  - Update digital messaging in real-time
  - Detect and alert of intrusions
- Remote Device Management
  - Update advertisements in real-time
  - Configure and update data to multiple locations
  - Track and manage assets
- Retail
  - Manage assets
  - Notify inventory shortage
  - Bill and delivery inventory automatically
- Medical, Health care and Fitness
  - Maintain and access medical devices
  - Collect and update health records
  - Notify patient's test results

Microchip's modules differ from other embedded WLAN modules by offering a variety of 13 regulatory and modularly certified external antennas along with onboard PCB antenna version.

The modularly certified external antennas include:

- Portable 2 dBi RFA-02-P05 (Wi-Fi enabled internet radio)
- 2 dBi RFA-02-D3 (portable Wi-Fi enabled medical electronic note pads) to 9 dBi AN2400-5901RS (Industrial wireless cameras)

For more information on modularly certified external antennas, see Table 1.

RANGE TESTING OVERVIEW

In telecommunication, the best range is the free-space path loss (FSPL), which is the loss in signal strength of an electromagnetic wave that results from a LOS path through the free space, with no obstacles nearby to cause reflection or diffraction. Path loss (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space.

Path loss is caused by free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, absorption. It is also influenced by the terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), distance between the transmitter and the receiver, and height and location of antennas. Path loss is unaffected by the factors such as gain of the antennas used at the transmitter and the receiver and the loss associated with hardware imperfections. Free space loss is dominant in an outdoor LOS environment where antenna is far from the ground, with 0 degrees contour and with no obstructions.

In an indoor environment, many obstructions may add constructively or destructively for the radio wave propagations. For example, part of the wave energy are transmitted or absorbed into the obstruction and the remaining wave energy will be reflected off of the medium's surface. Also, the transmitted and reflected wave energy is a function of the geometry and material properties of the obstruction and the amplitude, phase, and polarization of the incident wave. Diffraction occurs when the surface of the obstruction has sharp edges producing secondary waves that in effect bend around the obstruction. Like reflection, diffraction is affected by the physical properties of the obstruction and the incident wave characteristics. In a situation, where the receiver is heavily obstructed, the diffracted waves may have sufficient strength to produce a useful signal. Scattering occurs when the transmitted wave encounters a large quantity of small dimension objects such as lamp posts, bushes, and trees. The reflected energy in a scattering situation is spread in all directions.

Generally, the obstructed path loss is more difficult to predict, especially for the myriad of different indoor scenarios and materials. Therefore, different path loss models exist to describe a unique dominant indoor characteristics, such as multi-level buildings with windows and single level buildings without windows. The attenuation decreases per floor with the increase in the number of floors. This phenomenon is caused by diffraction of the radio waves along the side of a building as the radio waves penetrate the building's windows. Also, many different indoor configurations can be categorized for buildings with enclosed offices, or office spaces consisting of a mix of cubicles and enclosed rooms. The following are examples of 2.4 GHz signal attenuation through obstacles for various materials:

- Window brick wall – 2 dB
- Metal frameglass wall into building – 6 dB
- Office wall – 6 dB
- Metal door in office wall – 6 dB
- Cinder block wall – 4 dB
- Metal door in brick wall – 12 dB
- Brick wall next to metal door – 3 dB

When a transmitted radio wave undergoes transformation in the indoor environment it reaches the receiving antenna through many routes giving rise to multipath noise. Multipath introduces random variation in the received signal amplitude. Multipath effect varies and it depends on the location and the type of the antenna used. Variations as much as 40 dB occurs due to multipath fading (radio waves combining destructively or constructively). Fading can be rapid or slow depending on the moving source and the propagation effects manifested at the receiver antenna. Rapid variations over short distances are defined as small-scale fading. In indoor testing, fading effects are caused by human activities and they usually exhibit both slow and fast variations. Sometimes, oscillating metal blade fans can also cause rapid fading effects. Applications of the WLAN radio indoors can either be fixed or mobile. Therefore, small-scale fading effects can be described using multipath time delay spreading. The signals will experience different arrival times because the signals can take many paths before reaching the receiver antenna. Therefore, a spreading in time (frequency) can occur. Different arrival times ultimately create further degeneration of the signal.

 Preliminary

The directional properties of an antenna can be modified by the ground, because the earth acts as a reflector. If a dipole antenna is placed horizontally above the ground, most of the energy radiated downward from the dipole is reflected upward. The reflected waves combine with the direct waves (those radiated at angles above the horizontal) in various ways, depending on the height of the antenna, frequency, and electrical characteristics of the ground under and around the antenna.

At some vertical angles above the horizon, the direct and reflected waves may be exactly in phase where the maximum signal or field strengths of both waves are reached simultaneously at some distant point. In this case, the resultant field strength is equal to the sum of the two components. At other vertical angles the two waves may be completely out of phase at some distant point that is, the fields are maximized at the same instant but the phase directions are opposite. The resultant field strength in this case is the difference between the two. At some other angles the resultant field will have intermediate values. Therefore, the effect of the ground is to increase the intensity of radiation at some vertical angles and to decrease it at others.

The elevation angles at which the maxima and minima occur depend primarily on the antenna height above the ground (the electrical characteristics of the ground have some slight effect too). For indoor environments, different antenna heights were used, not because of ground effect but due to obstructions in an indoor office environment.

The increase in the number of different WLAN products leads to an increased demand for more indoor radio WLAN range metrics and benchmarks. Particularly, in comparison of Frequency Hopping (FH) and Direct Sequence (DS) radio systems. In addition to that, the usage of the WLAN radio dictates the performance of the radio in network applications. Therefore, the indoor range of a customer may vary from the stated results due to the difference in customer indoor environment.

All antennas have a gain factor expressed in decibels that is relative to an isotropic radiator. An isotropic radiator radiates uniformly in all directions like a point source of light. All the power that the transmitter produces ideally is radiated by the antenna. However, this is not generally true in practice as there are losses in both the antenna and its associated feedline. Also, antenna gain does not increase power, it only concentrates effective radiation pattern.

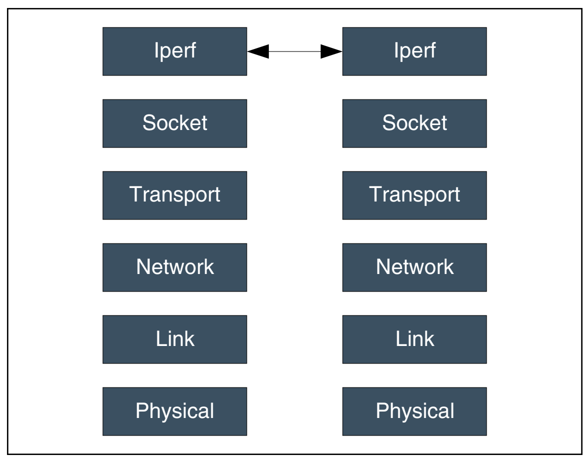
RANGE TESTING

Range testing is performed using the following usage range models:

- Establishing connectivity range, where Dynamic Host Configuration Protocol (DHCP) time out and does not assign Internet Protocol (IP) and address to the Device Under Test (DUT). After a hardware reset, this connectivity range was determined. In this test, only 802.11 hand shake was done and connection was established.
- Establishing User Datagram Protocol (UDP) throughput at the edge of IP assignment by the access points (APs) DHCP. The connection and subsequent IP assignment, and UDP throughput were tested at the determined distance from the access point.

All the tests were done in infrastructure mode with Linksys WRT54G AP antenna configuration (with security turned off) and all DUT certified antennas configured in free air (vertical polarization). Iperf was used in this analysis to create the wireless connections and transfer data. The Iperf hierarchy block diagram is illustrated in Figure 1.

FIGURE 1: IPERF HIERARCHY



RANGE TEST SETUP

This section provides details of the test setup and test environments as illustrated in Figure 2, Figure 3, Figure 7, Figure 8 and Figure 9.

FIGURE 2: OUTDOOR LINE-OF-SIGHT TEST SETUP

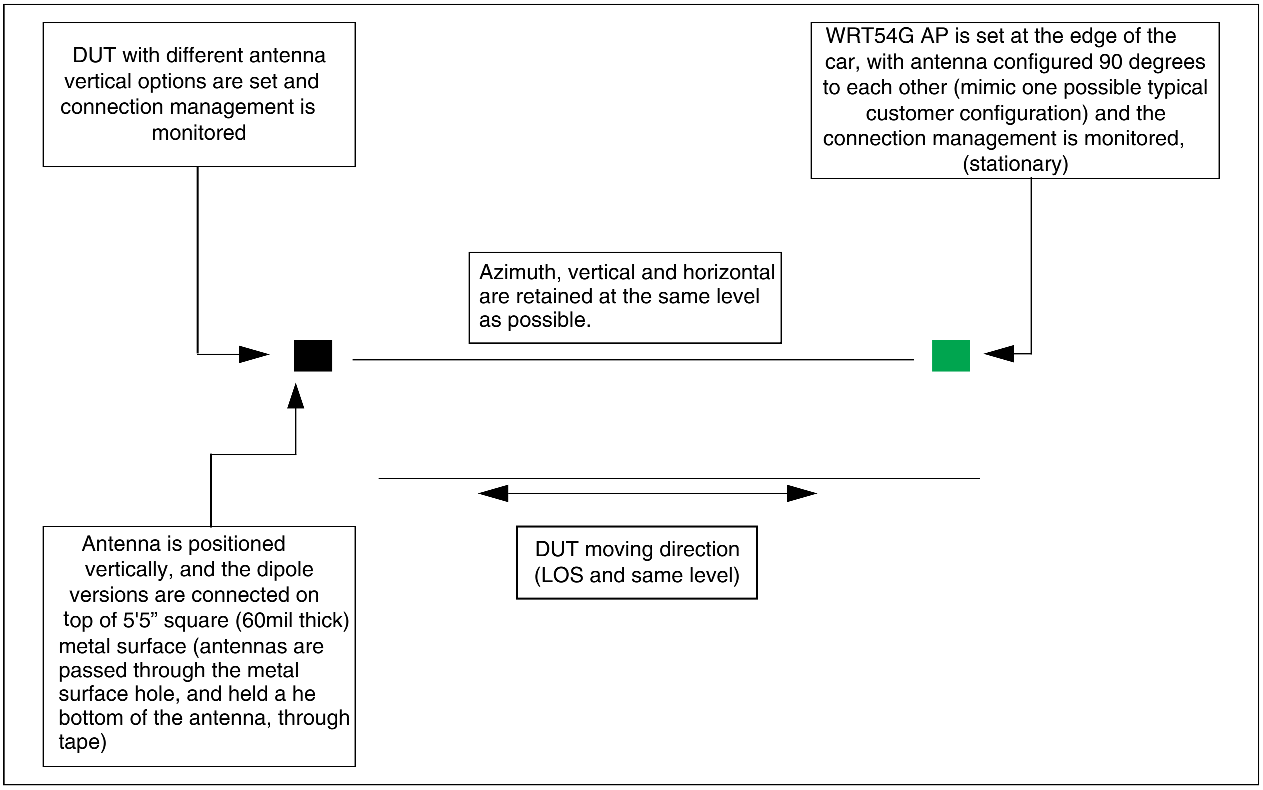


FIGURE 3: IPERF APPLICATION TEST SETUP OVERVIEW

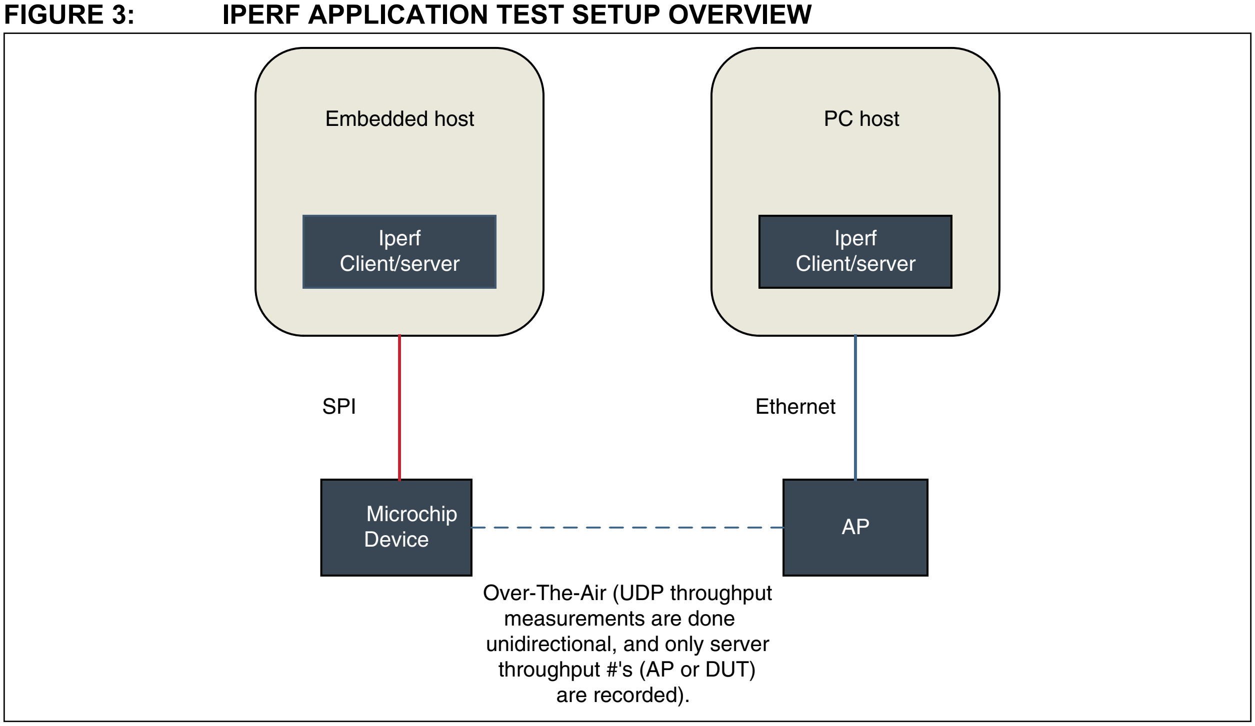


Figure 4 illustrates the steps needs to be performed by a client and server for the DHCP exchange process. It also illustrates where the process is interrupted for the first range usage model.

FIGURE 4: DHCP IP TO CLIENT ASSIGNMENT OVERVIEW

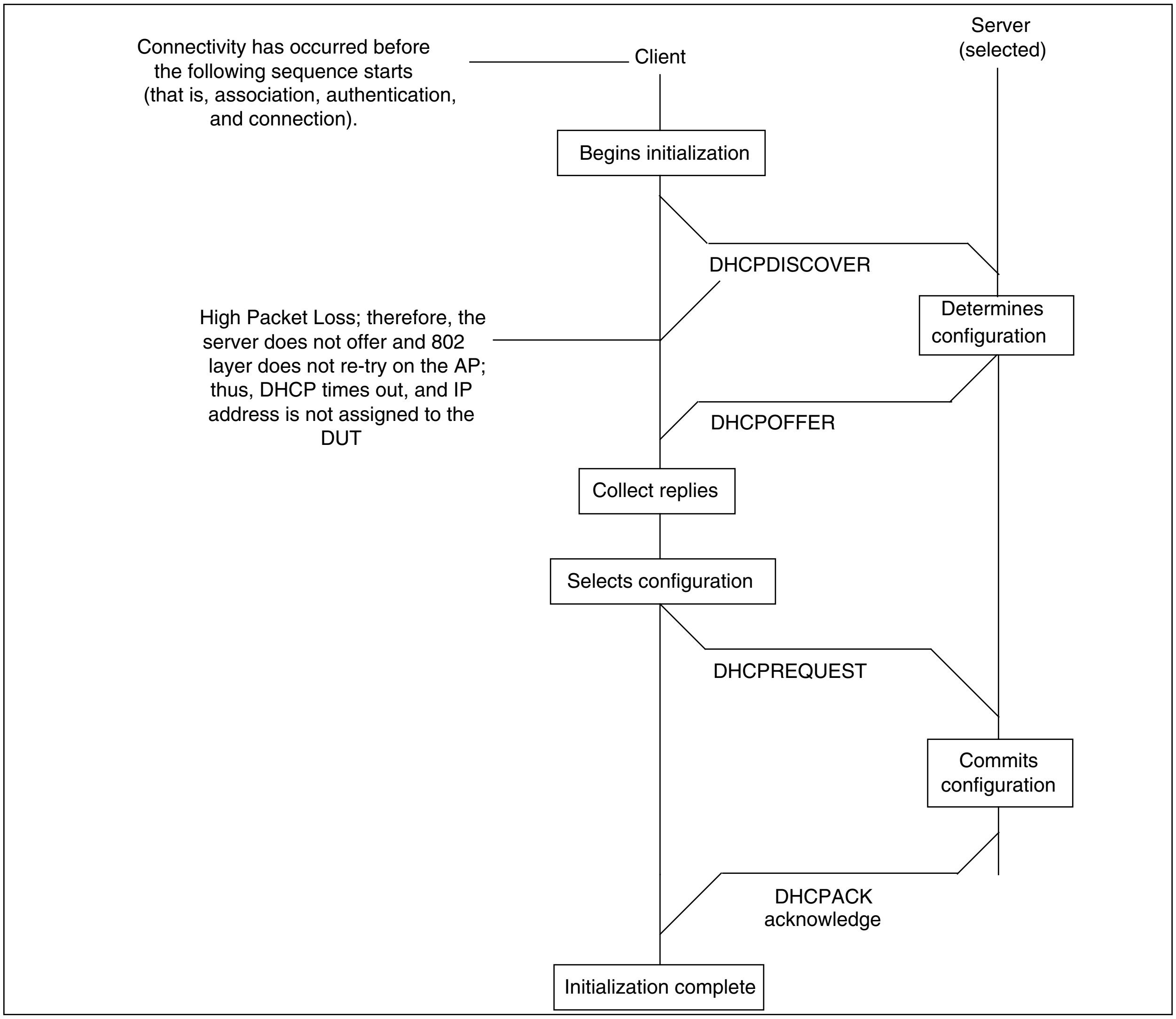
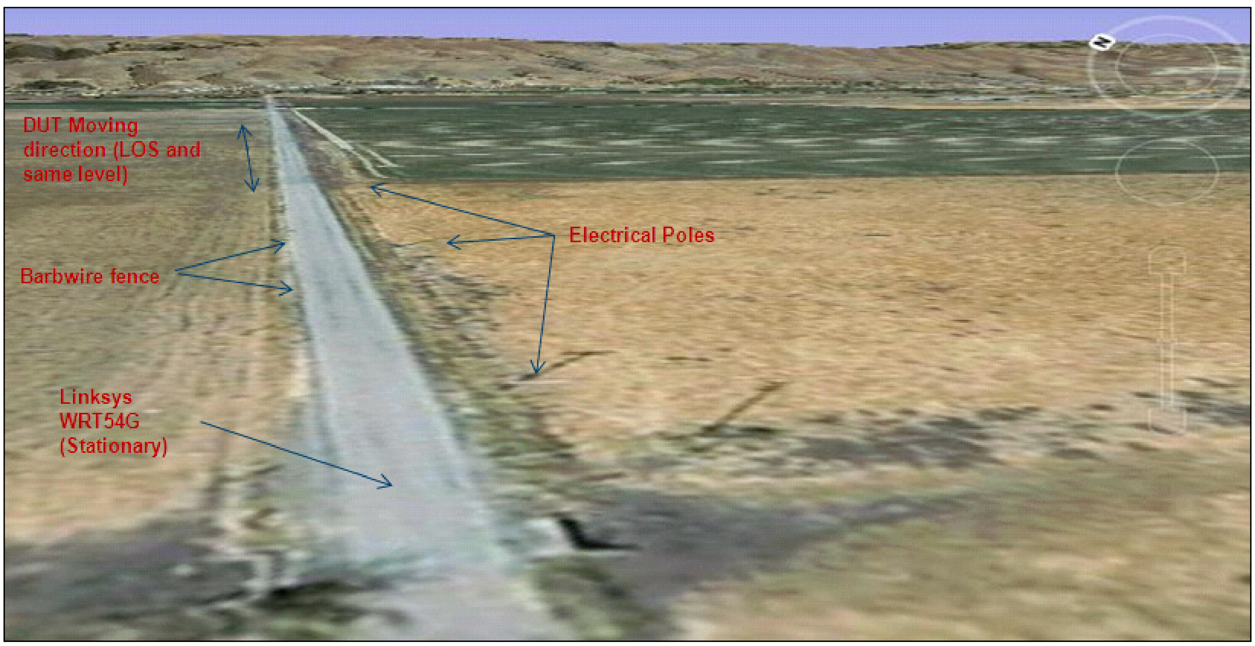


Figure 5 and Figure 6 illustrates the areas used for the LOS testing.

FIGURE 5: OUTDOOR LOS RANGE TESTING TERRAIN

FIGURE 6: STREET VIEW OF OUTDOOR LOS RANGE TESTING TERRAIN



 Preliminary

FIGURE 7: BARBED WIRE FENCE VIEW OF OUTDOOR LOS RANGE TESTING TERRAIN

Note:	The barbed wire fence height is approximate 3 ft. along the roadside. All the range testings are done on the road, either away from the fence or electric poles. The height of the AP and DUT with various antennas are kept at a stationary 5 ft away from the ground (GND).

FIGURE 8: STREET VIEW OF OUTDOOR LOS RANGE TESTING TERRAIN FOR 9 dBi ANTENNA OBSTRUCTION LIMITATIONS

FIGURE 9: ZG2101M AND ZG2100M OUTDOOR LOS RANGE TESTING TERRAIN 9 dBi ANTENNA OBSTRUCTION LIMITATIONS TOP VIEW

Figure 10 illustrates the interference of the frequency band that is the sum of all interferers (time multiplexed, frequency hopping interferes, constant jammers), measurements with 2.4 GHz. 2 dBi whip antenna (vertically polarized) is placed next to the WRT54G Linksys AP antenna.

FIGURE 10: INDOOR 2.4~2.5 GHZ IN BAND INTERFERENCE

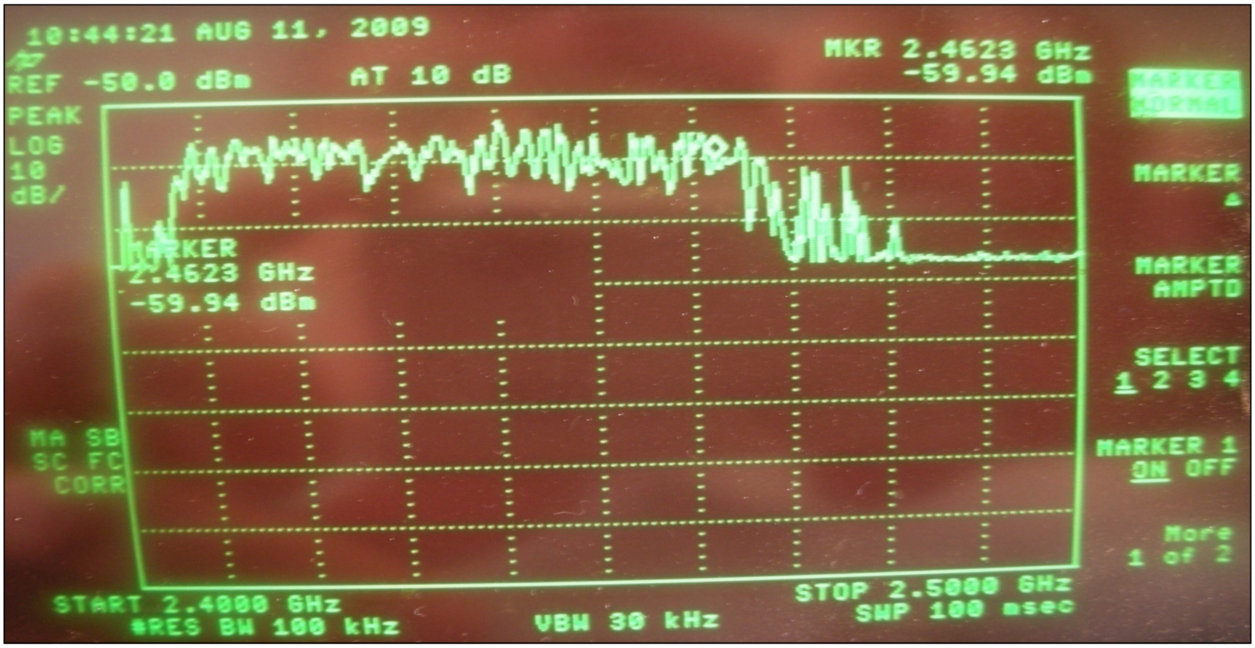


Figure 11 illustrates the interference of the frequency band that is the sum of all the interferers (time multiplexed, frequency hopping interferes, constant jammers), measurements with 2.4 GHz. 2 dBi whip antenna (vertically polarized) is placed next to the DUT antennas.

FIGURE 11: INDOOR 2.4~2.5 GHZ IN BAND INTERFERENCE

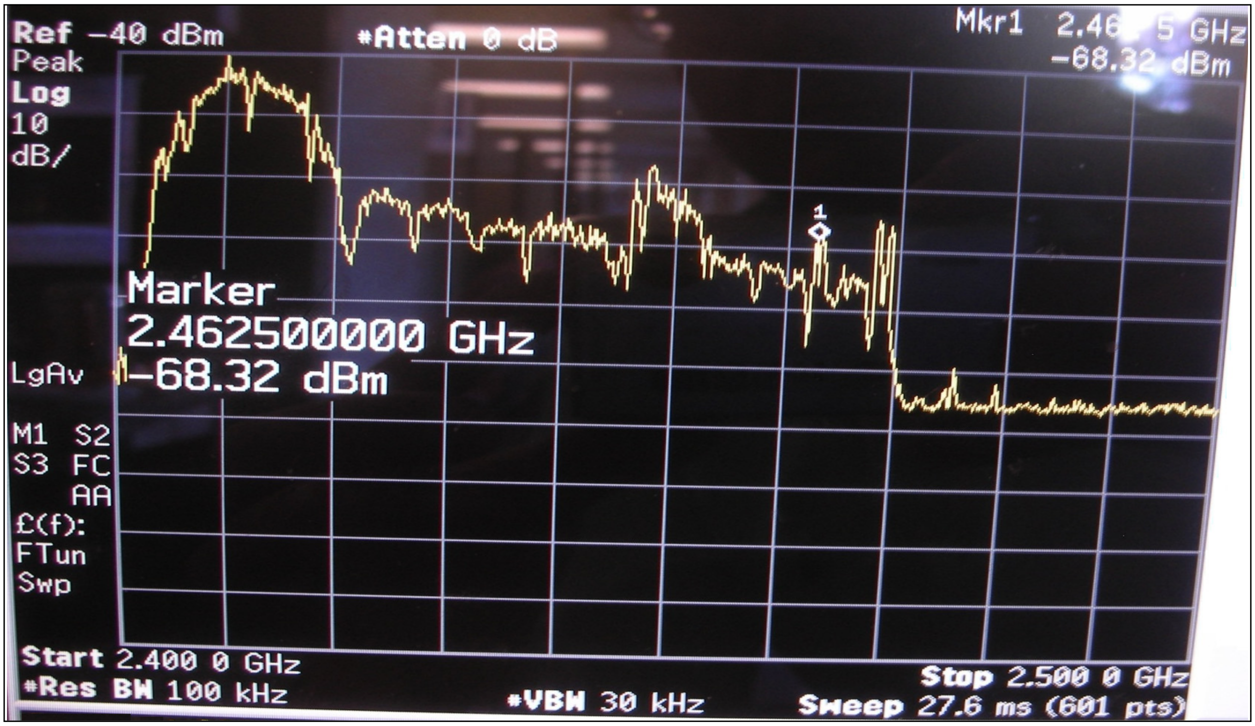
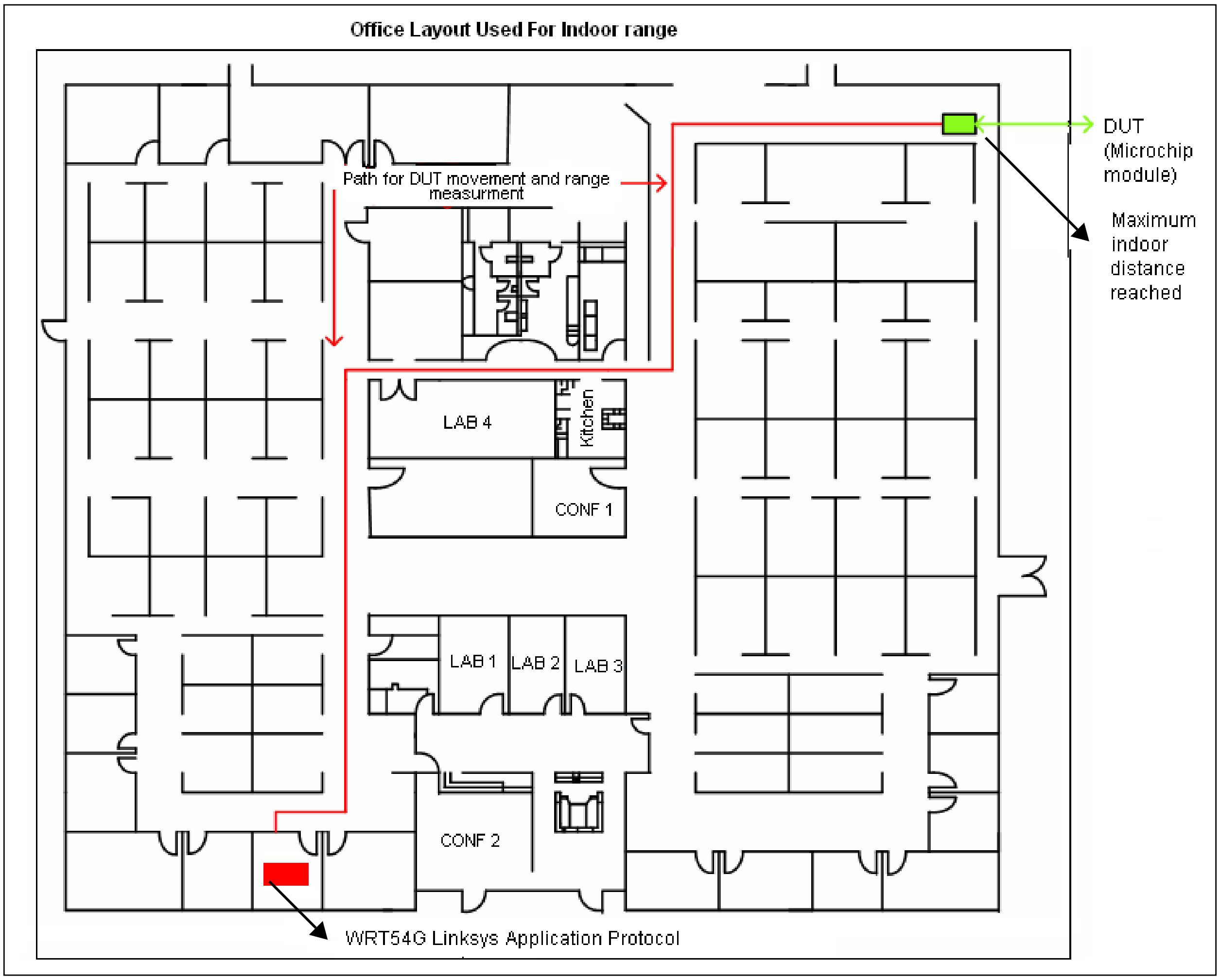


Figure 12 illustrates the indoor furniture configuration used for the range testing.

FIGURE 12: INDOOR FURNITURE CONFIGURATION FOR RANGE TESTING



CERTIFIED ANTENNA LIST

Table 1 provides details of the modularly certified antennas.

TABLE 1: MODULARLY CERTIFIED ANTENNAS

Part Number	Type	Frequency Range (MHz)	Gain	VSWR	Connector	Vendor & Website
RFA-02-P05	PCB	2400-2500	2 dBi	2.0 Max	IPEX	Aristotle
RFA-02-L6H1-70-35	Dipole	2400-2500	2 dBi	2.0 Max	IPEX	Aristotle
RFA-02-D3	Dipole	2400-2500	1.5 dBi	2.0 Max	IPEX	Aristotle
RFA-02-L2H1	Dipole	2400-2500	2 dBi	2.0 Max	IPEX	Aristotle
RFA-02-3-C5H1	Dipole	2400-2500	3 dBi	2.0 Max	IPEX	Aristotle
RFA-02-5-C7H1	Dipole	2400-2500	5 dBi	2.0 Max	IPEX	Aristotle
RFA-02-5-F7H1	Dipole	2400-2500	5 dBi	2.0 Max	IPEX	Aristotle
WF2400-15001A	Dipole	2400-2500	5 dBi	2.0 Max	IPEX	Saytec
WF2400-15001A	Dipole	2400-2500	5 dBi	2.0 Max	RF-IPEX	Saytec
WF2400-10001I	Dipole	2400-2500	2 dBi	2.0 Max	IPEX	Saytec
WF2400-10001R	Dipole	2400-2500	2 dBi	2.0 Max	RF-IPEX	Saytec
AN2400-5901RS, used with connector SMASFR8-3152H-00X00I	Omni	2400-2500	9 dBi	2.0 Max	IPEX	Saytec
AN2400-5901RS, used with connector SMASFR8-3152H-00X00IR	Omni	2400-2500	9 dBi	2.0 Max	RF-IPEX	Saytec
ANT-2.4-CW-RH, used with connector BTC013-1-70B-150	Helical	2370-2530	2 dBi	<1.9 typ	IPEX	Antenna Factor (ANT-2.4-CW-RH) Aristotle (BTC013-1-70B-150)
ANT-2.4-CW-RH-SMA, used with connector BTC013-1-70B-150	Helical	2370-2530	2 dBi	<1.9 typ	IPEX	Antenna Factor (ANT-2.4-CW-RH-SMA) Aristotle (BTC013-1-70B-150)

Figure 13 and Figure 14 graphically illustrates the results of the outdoor LOS range data per usage model. Table 2 describes the outdoor LOS range data results.

FIGURE 13: OUTDOOR LOS RANGE DATA PER USAGE MODEL

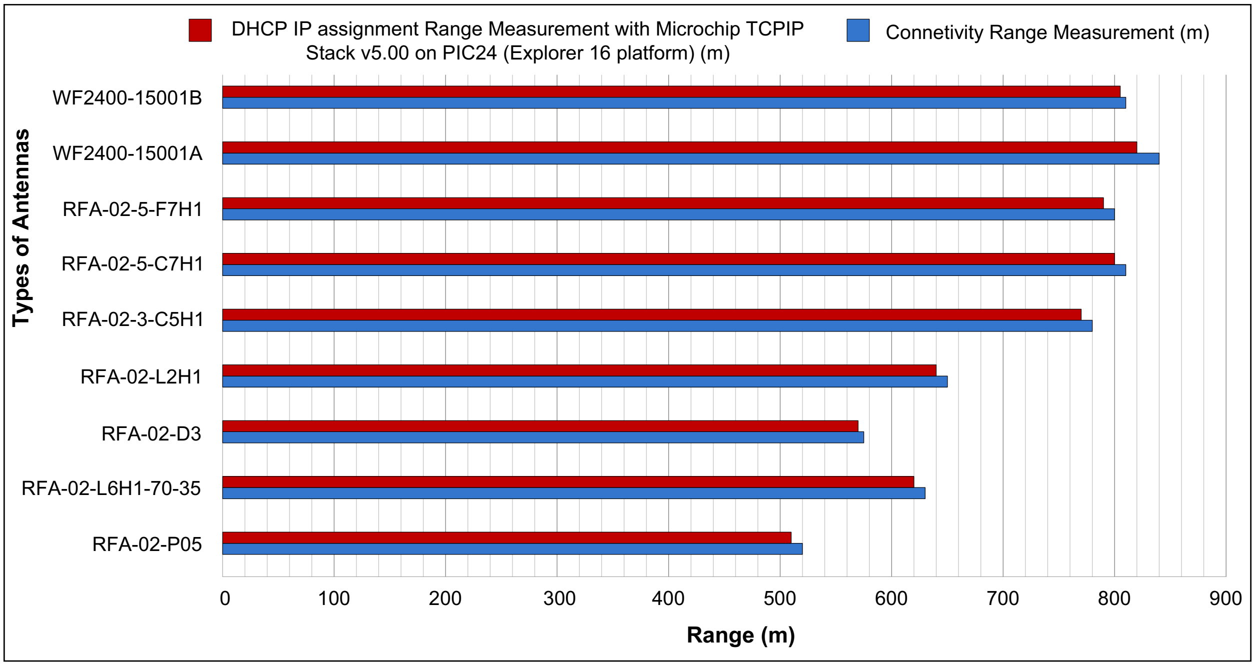


FIGURE 14: OUTDOOR LOS RANGE GRAPH PER USAGE MODEL

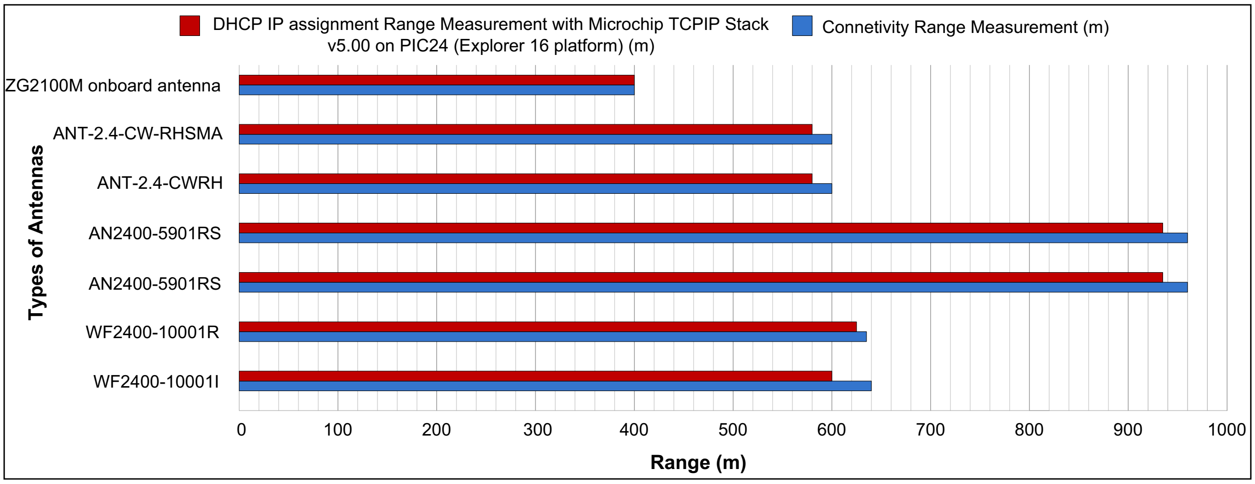


TABLE 2: OUTDOOR LOS DATA AND GRAPH PER USAGE MODEL RESULTS

Antenna Items	Connectivity Range Measurement (m)	DHCP IP assignment Range Measurement with Microchip TCPIP Stack v5.00 on PIC 24 (Explorer 16 platform) (m)
RFA-02-P05	520	509
RFA-02-L6H1-70-35	633	621
RFA-02-D3	577	572
RFA-02-L2H1	648	639
RFA-02-3-C5H1	782	758
RFA-02-5-C7H1	809	799
RFA-02-5-F7H1	799	795
WF2400-15001A	839	831
WF2400-15001B	809	782
WF2400-10001I	642	599
WF2400-10001R	639	626
AN2400-5901RS, used with connector SMASFR8-3152H-00X00I (Sample =7 dBi)	961	935
AN2400-5901RS, used with connector SMASFR8-3152H-00X00IR (Sample =7 dBi)	961	935
ANT-2.4-CWRH, used with connector BTC013-1-70B-150	600	581
ANT-2.4-CW-RHSMA, used with connector BTC013-1-70B-150	600	581
ZG2100MCC3 onboard antenna	401	401

Figure 15 graphically illustrates the results of the MRF24WB0MA and MRF24WB0MB Indoor LOS range data per usage model.

Table 3 describes the MRF24WB0MA and MRF24WB0MB Indoor range data results.

FIGURE 15: MRF24WB0MA AND MRF24WB0MB INDOOR RANGE GRAPH PER USAGE MODEL

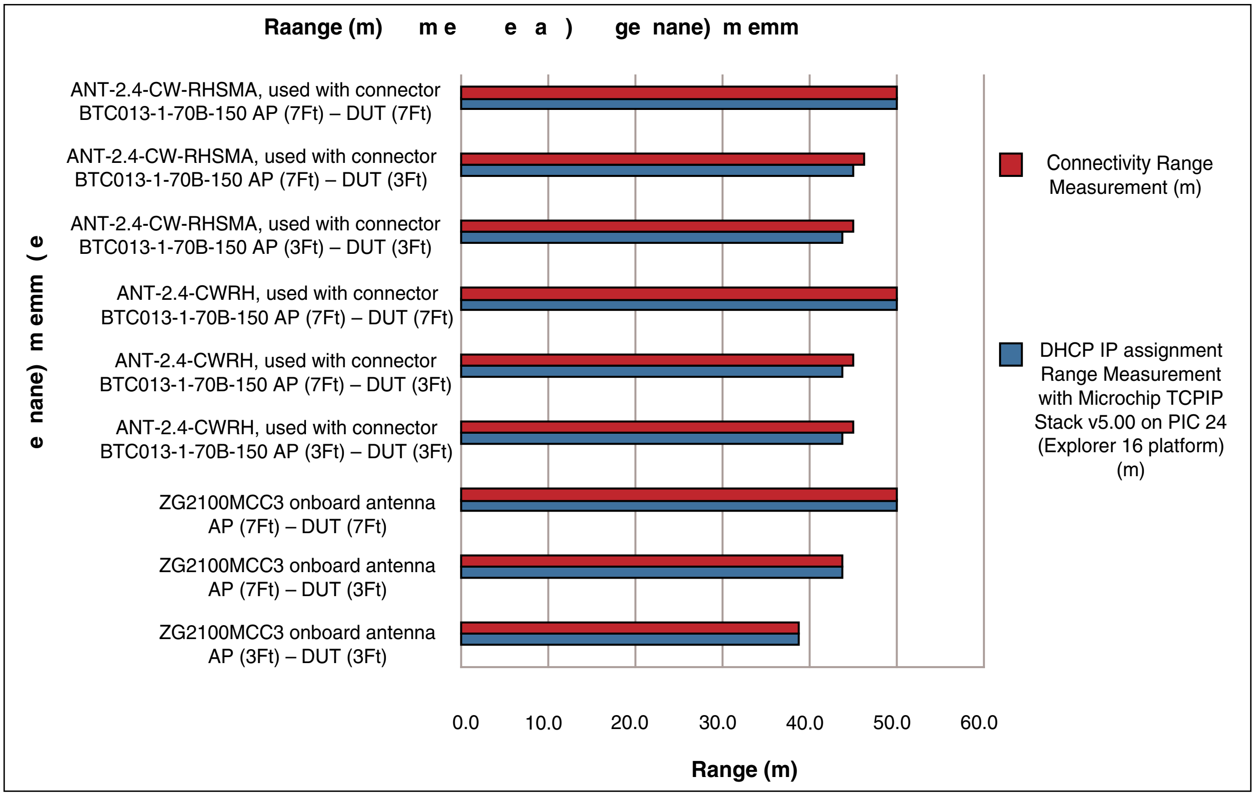


TABLE 3: MRF24WB0MA AND MRF24WB0MB INDOOR RANGE DATA PER USAGE MODEL

Certified Antenna Items	DHCP IP assignment Range Measurement with Microchip TCPIP Stack v5.00 on PIC 24 (Explorer 16 platform) (m)	Connectivity Range Measurement (m)
ZG2100MCC3 onboard antenna AP (3Ft) - DUT (3Ft)	39.0	39.0
ZG2100MCC3 onboard antenna AP (7Ft) - DUT (3Ft)	44.3	44.3
ZG2100MCC3 onboard antenna AP (7Ft) - DUT (7Ft)	50.2	50.2
ANT-2.4-CWRH, used with connector BTC013- 1-70B-150 AP (3Ft) - DUT (3Ft)	43.4	44.3
ANT-2.4-CWRH, used with connector BTC013- 1-70B-150 AP (7Ft) - DUT (3Ft)	44.3	45.4
ANT-2.4-CWRH, used with connector BTC013- 1-70B-150 AP (7Ft) - DUT (7Ft)	50.2	50.2
ANT-2.4-CW-RHSMA, used with connector BTC013- 1-70B-150 AP (3Ft) - DUT (3Ft)	43.4	44.3
ANT-2.4-CW-RHSMA, used with connector BTC013- 1-70B-150 AP (7Ft) - DUT (3Ft)	44.3	45.4
ANT-2.4-CW-RHSMA, used with connector BTC013- 1-70B-150 AP (7Ft) - DUT (7Ft)	50.2	50.2

Figure 16 graphically illustrates the MRF24WB0MB Indoor range data results per usage model.

Table 4 describes the MRF24WB0MB Indoor range data results per usage model.

FIGURE 16: MRF24WB0MB INDOOR RANGE GRAPH PER USAGE MODEL

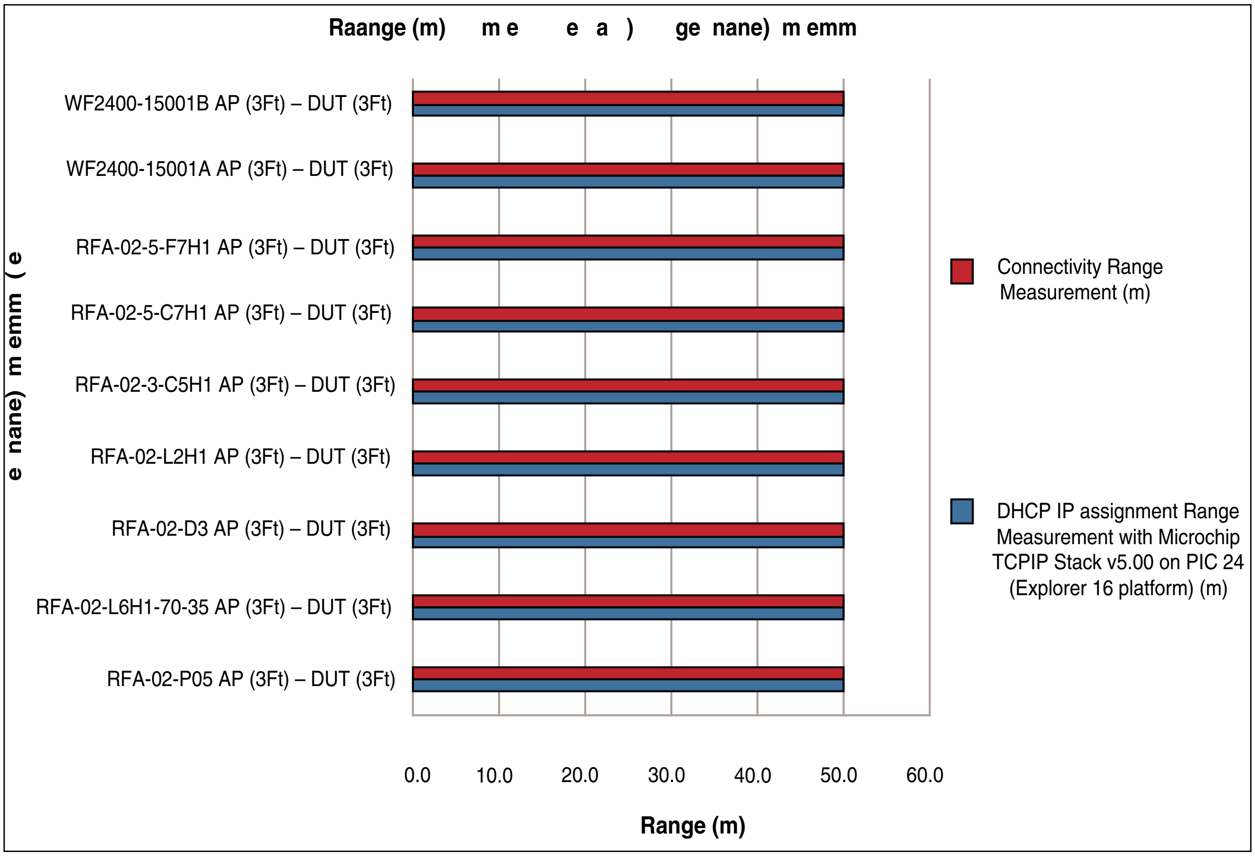


TABLE 4: MRF24WB0MB INDOOR RANGE DATA PER USAGE MODEL

Certified Antenna Items	DHCP IP assignment Range Measurement with Microchip TCPIP Stack v5.00 on PIC 24 (Explorer 16 platform) (m)	Connectivity Range Measurement (m)
RFA-02-P05 AP (3Ft) - DUT (3Ft)	50.2	50.2
RFA-02-L6H1-70-35 AP (3Ft) - DUT (3Ft)	50.2	50.2
RFA-02-D3 AP (3Ft) - DUT (3Ft)	50.2	50.2
RFA-02-L2H1 AP (3Ft) - DUT (3Ft)	50.2	50.2
RFA-02-3-C5H1 AP (3Ft) - DUT (3Ft)	50.2	50.2
RFA-02-5-C7H1 AP (3Ft) - DUT (3Ft)	50.2	50.2
RFA-02-5-F7H1 AP (3Ft) - DUT (3Ft)	50.2	50.2
WF2400-15001A AP (3Ft) - DUT (3Ft)	50.2	50.2
WF2400-15001B AP (3Ft) - DUT (3Ft)	50.2	50.2

Figure 17 graphically illustrates the MRF24WB0MB Indoor range data results per usage model.

Table 5 describes the MRF24WB0MB Indoor range data results per usage model.

FIGURE 17: MRF24WB0MB INDOOR RANGE GRAPH PER USAGE MODEL

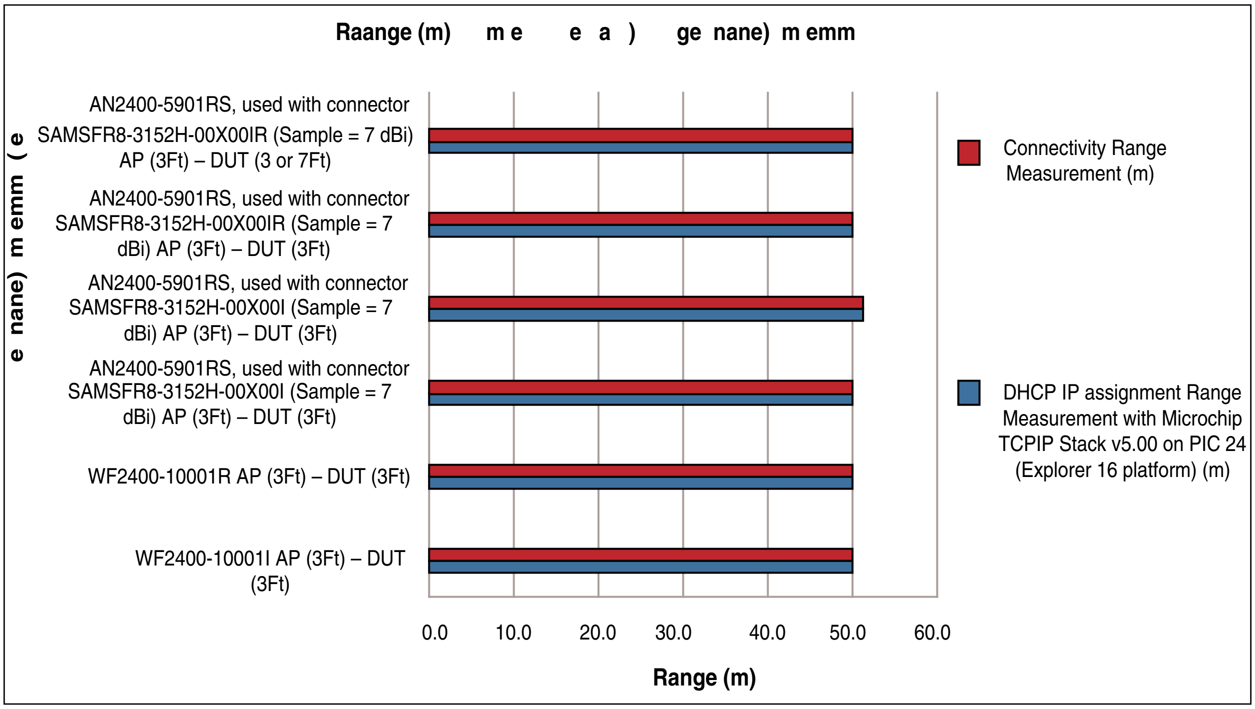


TABLE 5: MRF24WB0MB INDOOR RANGE DATA PER USAGE MODEL

Certified Antenna Items	DHCP IP assignment Range Measurement with Microchip TCPIP Stack v5.00 on PIC 24 (Explorer 16 platform) (m)	Connectivity Range Measurement (m)
WF2400-10001I AP (3Ft) - DUT (3Ft)	50.2	50.2
WF2400-10001R AP (3Ft) - DUT (3Ft)	50.2	50.2
AN2400- 5901RS, used with connector SMASFR8- 3152H-00X00I (Sample =7 dBi) AP (3Ft) - DUT (3Ft)	50.2	50.2
AN2400- 5901RS, used with connector SMASFR8- 3152H-00X00I (Sample =7 dBi) AP (7Ft) - DUT (3 or 7 Ft.)	52.2	52.2
AN2400- 5901RS, used with connector SMASFR8- 3152H-00X00IR (Sample =7 dBi) AP (3Ft) - DUT (3Ft)	50.2	50.2
AN2400- 5901RS, used with connector SMASFR8- 3152H-00X00IR (Sample =7 dBi) AP (7Ft) - DUT (3 or 7 Ft.)	52.2	52.2

Note: Outside of the office environment, range measurement was done only for 9 dBi antenna options. However, the rest of antenna MAX range was done only in indoors to emulate indoor customer usage environment. Therefore, antennas with 502 meter indoor range measurements limitations may be due to the test environment size limitation, and they can perform better in connectivity indoor environments.

REVISION HISTORY

Revision A (December 2010)

This is the initial release of the document.

NOTES:

Note the following details of the code protection feature on Microchip devices:

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