

# Cellular Wireless Antennas

## A Technical Brief – GarrettCom Inc., November 2010

### Overview

The Cellular Wireless Antenna Technical brief is provided to assist with the design and deployment of the DX940 Cellular wireless interface from GarrettCom. It details some of the basic theories of Radio technologies and Antennas, including common issues such as signal distortion, different types of antennas, and their characteristics. This brief also lists the technical details of the antennas which have been tested and certified with the DX940 router Cellular wireless interface.

### Executive Summary

There are at least three alternatives for a cellular antenna that work with the DX cellular option. All three options are offered by GarrettCom Inc. These options are described and analyzed in this Technical Brief.

Choose the dipole antenna for regular use. This antenna is included with the cellular interface.

When the DX940 with the cellular option is used in a building, the cellular signal maybe weak. An external antenna is recommended for proper operation. The external antenna comes in two varieties. One of them is a low profile antenna which can be mounted on the side of a building. The other one is ideal for mounting on a pole. Both these antennas are described in this Technical Brief as well.

All antennas described here provide similar gain characteristics. For additional antennas or for system integrators in your area who specialize in providing solutions contact GarrettCom Inc.

### Antenna Background

An antenna is designed to provide a signal boost (or gain) to a radio transmitter and receiver. An antenna also pulls signals from outside a building to the interior where signals may be blocked due to walls or other obstacles. Such antennas are referred to as external antennas.

The gain of an antenna is usually dependent on three variables – direction, power, and polarization.

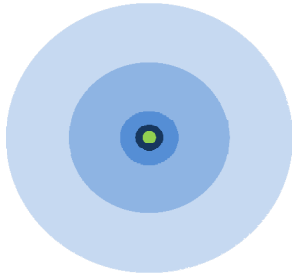
Directional gain is due to the shape of the transmission pattern. Not all antennas provide directional gain. These are called omni-directional antennas. Not all applications call for a directional gain antenna.

Power gain is the gain received due to additional RF signal collective capacity achieved by the antenna. A good analogy is a solar reflector or a parabolic mirror; for example, in flash lights or automobile lights. A solar reflector or a parabolic mirror collects the energy falling on the surface and concentrates it on a small area, referred to as the central spot or foci. The energy at the central spot is more than the energy elsewhere, thus providing a power gain. The power gain depends on the size and shape of the antenna.

Polarization defines how the signal travels in the air. It is usually measured by displaying the characteristics both in the horizontal and the vertical plane.

For cellular wireless networks an omni-directional antenna is commonly used. GarrettCom offers omni-directional antennas which are designed to work with the cellular interface in the DX routers, such as the DX940 router.

An omni-directional antenna is designed to provide a 360-degree radiation pattern as shown below.



*Figure 1 – Radiation pattern from an omni-directional antenna. The pattern is only an approximate visualization of the signal radiated from an omni-directional antenna.*

A dipole antenna is commonly used with wireless devices. An example of the dipole antenna (also called the “rubber duck” antenna) is shown below. The dipole antenna is an omni-directional antenna.



*Figure 2 – An example of a dipole or “rubber duck” antenna.*

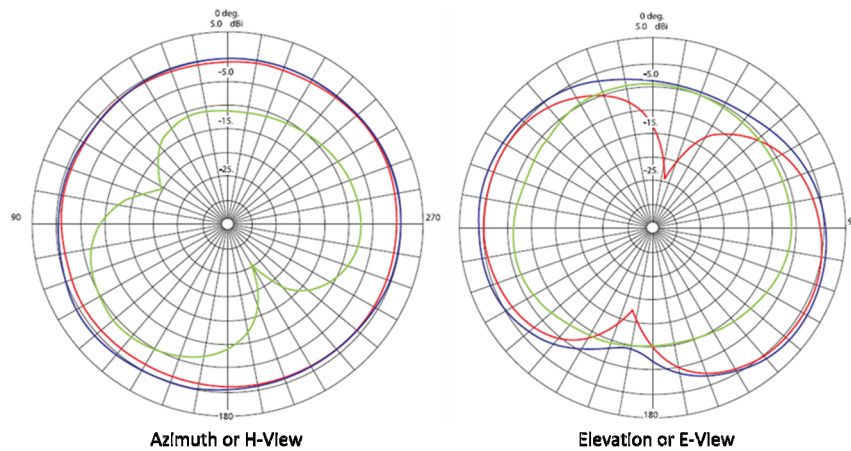
The dipole antenna from GarrettCom has operating frequencies of 824 - 894 MHz, 1850 - 1990 MHz and covers the spectrum commonly used by cellular carriers. This antenna is the ideal choice for many applications.

The DX940 cellular module has an interface for two antennas. Included with the DX940 cellular interface are two dipole antennas to leverage the diversity capability and improve the signal reliability. In the Magnum DX cellular wireless interface one antenna acts as a diversity antenna. MNS-DX software includes the capabilities to recover distorted signals using the diversity antennas. More details on diversity antenna are discussed later under “Signal Distortion”.

Each antenna is usually accompanied by the Antenna Pattern Polar Coordinate Graphs (usually plotted on a polar-radian chart as shown in Figure 3) to display the polarization characteristics of the antenna. The graphs show signal field strength from a "side view" (called the Elevation view or "E-Graph") – this view displays the field strength in the vertical plane. Now imagine that you are looking down at the antenna from the ceiling. This view is different than the side-view and is called the "top view" (called an Azimuth view or Horizontal view or H-Graph) – this view displays the field strength in the horizontal

plane. The vertical and horizontal plane graphs enable engineers to envision the working characteristics and placement of the antenna.

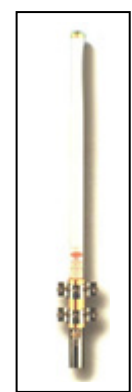
As an example, the dipole antennas offered with the Magnum DX cellular products, the H-View and E-View graphs are shown below.



*Figure 3 – Antenna Pattern Polar Coordinate graphs for wireless antennas.*

Besides the dipole antennas, the Magnum DX Cellular solutions offer two additional antennas for use as external antennas:

- Industrial Wall/Ceiling Mount 3G Cellular Omni Antenna. This antenna can be mounted externally on a roof or on the external side-wall of a building and has a low profile. This antenna can also be mounted on industrial or mining automobiles / trucks on a metal or fiber glass surface, making it ideal for use in transportation industries. Since this antenna can be mounted on metal or wooden surfaces, the DX940 makes an ideal choice for use where data needs to be transported from remote locations including telephone poles or traffic light corners.
- Fiberglass Omni-directional Wireless Antenna. This antenna is commonly installed on a mast or on a pole. The antenna has to be clear of reflecting surfaces and has to have a clear line of sight to function properly.



## Regulations

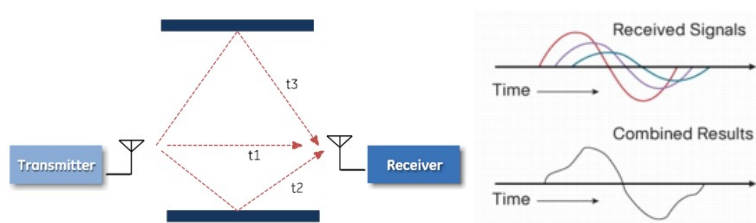
In all countries, the Cellular spectrum is regulated for use. GarrettCom works with the cellular operators in each specific country to certify the radios for proper compliance and use. Please contact GarrettCom to verify if the radio is certified to operate with a specific carrier in a country.

## Signal Distortion

Wireless signals get distorted for many reasons. This includes wireless technologies such as Wi-Fi, Cellular, WiMAX, UHF transmissions etc. Some common sources of distortion include construction materials (walls, fixtures etc.), buildings, trees, etc.

Multipath interference (distortion) occurs when an RF signal has more than one path between a receiver and a transmitter. This occurs at sites that have a large amount of metallic or other RF reflective surfaces. Just as light and sound bounce off objects, so do radio waves. There can be more than one path that RF takes when going from a TX to an RX antenna. These multiple signals combine in the RX antenna and receiver to cause distortion of the signal.

Multipath interference can cause the RF energy of an antenna to be very high, but the data would be unrecoverable. Changing the type and location of the antenna can reduce or eliminate multipath interference.



*Figure 4 – Multipath distortion. Note the signal can be corrupted due to distortion. Changing the location of the antenna or type of antenna could eliminate or reduce the distortion.*

Another source of distortion could be walls in a building – commercial grade building construction has more steel. Metal reflects radio waves. The density of the material used in construction limits the number of walls the radio signal can traverse through. Paper and vinyl walls have very little effect on signal penetration. Concrete floors, and solid or precast concrete walls can limit signal penetration. Concrete block walls may also limit signal penetration. Wood or drywall typically allow for adequate penetration. Stucco walls (with a chicken mesh cover) can also cause interference and limit penetration of signals. A thick metal wall reflects signals, resulting in poor penetration. In substations, a “shed” is typically used for storing networking and other operational equipment. Most of the time this shed is constructed using metal. The metal in the construction could cause signal interference. This is solved by using an external antenna.

In urban and indoor environments, a clear line-of-sight between the transmitter and receiver is usually not possible. The signal is reflected along multiple paths before finally being received. Each of these bounces can introduce phase shifts, time delays, attenuations, and even distortions which can destructively interfere with one another at the aperture of the receiving antenna. Antenna diversity is effective at reducing these multipath situations. Multiple antennas offer a receiver several observations of the same signal. Each antenna will experience a different interference environment. Thus, if one antenna is experiencing a deep fade, it is likely that another one has a sufficient signal. Smart algorithms can eliminate these distortions and collectively such a system can provide a robust link. While this is

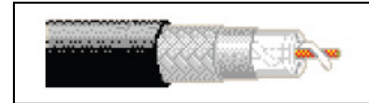
primarily seen in receiving systems (diversity reception), the same technique has also proven valuable for transmitting systems (transmit diversity).

Inherently, an antenna diversity scheme requires additional hardware and integration versus a single antenna system. In the DX940, a fair amount of circuitry is shared making the solution affordable. For industrial environments, signal reliability is paramount and using multiple antennas (or diversity antennas) is an effective way to decrease the number of drop-outs and lost connections. The GarrettCom Magnum DX940 Wireless solution uses antenna diversity to reduce signal distortion.

## Cabling

A coaxial cable connects the external antenna to the Magnum DX router. This cable can be purchased from several sources – including web e-commerce sites which sell cables and connectors. The cable has to have the proper connector for the antenna and the appropriate matching connector for the Magnum DX router. For example, most external antennas use an RG-58 connector. The DX router uses a SMA female connector. Special attention should be paid to the gender type of the cable connectors. The cabling and connectors can introduce signal losses. This loss can negate some of the gain introduced by an antenna. Low-Loss/Ultra-Low-Loss cables cause a lower loss than standard interconnect cables, and can be used when the antenna must be placed at some distance from the radio. While these are low-loss cables, they should still be kept to a minimum length and excessive cable coiling should be avoided. Typical distance is expected to be about 30 feet for most applications. Cable impedance should match the impedance of the antenna and the radio, and should be 50 Ohms.

A 50 Ohm braided Coax cable - for example, the 9913 Coax - RG-8/U Type cable from Belden - is an example of a low loss cable.



## Mounting Hardware

Each external antenna requires some type of mounting to withstand rain, wind, and other atmospheric conditions. Each situation is unique. In order to ensure that the proper hardware is used to mount the antenna, GarrettCom recommends that you work with solution providers who specialize in wireless technologies. Users who choose to mount their own antennas should ensure the proper support as well as other factors such as distance of cabling, lightning, RF reflection issues etc. Once the antenna is connected, verify the signal strength and other operational parameters from the MNS-DX interface. The details are covered in the MNS-DX User Guide.

## Lightning Arresters

When antennas are mounted outside, there is always a possibility of lightning strikes or other ESD related voltage surges. In stormy or cloudy conditions there is sufficient induced voltage on the external antenna. A lightning arrester is designed to protect the equipment from static electricity and lightning-induced voltage surges which travel on coaxial transmission lines. Installation of a lightning arrester between the antenna and the Magnum DX router is recommended. Ensure that all systems (the arrester as well as the Magnum DX device) are properly grounded. Most lightning arresters work on an electrical arc or gas discharge or voltage isolation principle and are rated for a specific voltage surge. Most lightning arresters do not prevent damage in the event of a direct lightning hit.

A lightning arrester introduces a loss on the cable. This can offset some of the gains an antenna provides. Along with the cables, it is a good idea to look at the loss values of a lightning arrester.


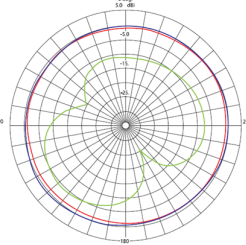
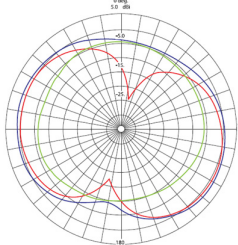

Finally, not all lightning arresters operate at all frequency ranges. Please ensure that the lightning arrester operates in the operating frequency range used with the radio.

## Antennas offered by GarrettCom

GarrettCom offers one internal antenna (a simple dipole) and two external antennas. The first is a low profile antenna ideally suited for mounting on sides of buildings. The second is ideal for mounting on a pole – both of which can be used with the Cellular Wireless Magnum DX products from GarrettCom.

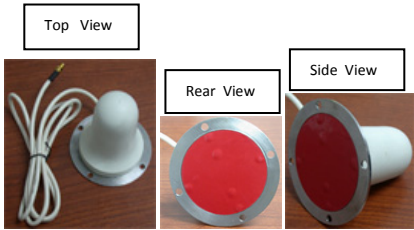
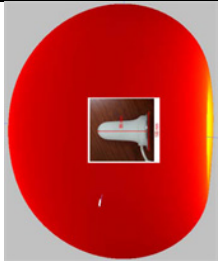
### Dipole Antenna

The dipole antenna is shown in the figure below. It does not need any special cables and can be connected to the DX Cellular interface directly for internal use applications. The details are as below.

Specifications	Information	
	 <b>Azimuth Plane Radiation Pattern</b>	 <b>Elevation Plane Radiation Pattern</b>
Frequency Range	824-960 MHz; 1710- 2170 MHz	
VSWR	≤ 3.5 @ 824 -960 MHz; ≤ 4.0 @ 1710- 2170 MHz	
Gain	2.0 ± 0.7dBi @ 824-960 MHz; 1.5 ± 0.7dBi @ 1710-2170 MHz	
Polarization	Linear	
Antenna Connector	SMA male, Copper Plated	
Cable Length	None – mounts directly	
Impedance	50 Ω	
Dimensions	0.51 inches x 7.72 inches(1.3 cm x 19.6 cm)	
Mounting	 SMA male connector on Antenna	
Environmental	Operational temperature:-30°C to +85°C; storage temperature -30°C to +85°C	


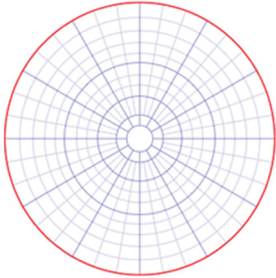
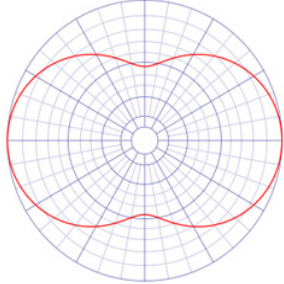
### Low Profile (Dome) External Antenna

The low profile external antenna is shown in the figure below. The antenna comes with a 5 ft RG58 low-loss cable and an SMA female connector. An additional low loss cable should be used to connect the antenna from the mounting point to the Magnum DX device. The antenna can be mounted to any surface – wood, metal, concrete, or other surfaces. The antenna will have the same characteristics, irrespective of the mounting surface. The details of the antenna are shown below.

Specifications	Information
 <p>Top View</p> <p>Rear View</p> <p>Side View</p>	 <p>Radiation pattern – shown as 3D image with antenna mounted as shown.</p>
Frequency Range	824 -960 MHz; 1710-2170 MHz
VSWR	≤ 3 @ 880 MHz; ≤ 2.5 @ 1710- 2170 MHz
Gain	2.0 ± 0.7dBi @ 824 ~ 960 MHz; 1.5 ± 0.7dBi @ 1710 ~ 2170 MHz
Polarization	Linear
Antenna Connector	SMA female
Antenna cable	RG-58 cable, 4.9 feet (1.5 m) with SMA female connector, Copper Plated. Use a low-loss cable with SMA Male connector on both ends (as described earlier).
Impedance	50 Ω
Dimensions	3.8 inches Height x 3.9 inches diameter of base plate (9.6 cm x 10 cm)
Mounting	Depends on surface. The mounting holes in the base provide guidance for mounting options. Lightning arresters are strongly recommended.
Environmental	Operational temperature:-40°C to +90°C; storage temperature -30°C to +85°C, meets standards for UL 94V-0, RoHS compliant

## Pole Mount External Antenna

The pole mount external antenna is shown in the figure below. The antenna does not include any cable. A low loss cable should be used to connect the antenna from the mounting pole to the Magnum DX device. It is recommended that this antenna be mounted on a pole, away from any reflective surfaces such as walls, ceilings etc. Since this antenna is mounted on a pole, special care should be taken to use proper harnessing and lightning arresters, as discussed earlier. The details of the antenna are shown below.

Specifications	Information	
	 <b>Azimuth Plane Radiation Pattern</b>	 <b>Elevation Plane Radiation Pattern</b>
Frequency Range	821-896 MHz; 1850-1990 MHz	
VSWR	≤ 3 @ 880 MHz; ≤ 2.5 @ 1710- 2170 MHz	
Gain	Unity; 3dB	
Polarization	Linear	
Antenna Connector	SMA female	
Antenna cable	None included. Use a low-loss cable with SMA Male connector on both ends.	
Impedance	50 Ω	
Dimensions	Length 14 inches x 1 inch (35.6 cm x 2.5 cm)	
Mounting	Special care should be taken for mounting on the pole, away from reflective surfaces. Lightning arresters are strongly recommended. No mounting brackets or hardware is included.	
Environmental	Operational temperature: -40°C to 90°C; storage temperature -30°C to 85°C, meets standards for UL 94V-0, RoHS compliant	

## Conclusion

There are many factors which come into play in choosing and installing antennas, especially external antennas. External antennas are useful when signals cannot reach the area where the Magnum DX router is installed. Antenna choices from GarrettCom make it easy to select the proper external antenna to work with the Magnum DX Cellular interface.



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