# Antenna Primer

Technically savvy users are familiar with 2.4 GHz as the Wi-Fi connection in homes and offices. It would be incorrect to assume that 2.4 GHz isn't a strong and viable transmission signal for other applications. A common misconception is that while Wi-Fi is 2.4 GHz, 2.4 GHz is not exclusive to Wi-Fi. 2.4 GHz is in a very robust and powerful system.

When using the Tempest or Tempest/Channel D Solutions combination, keep in mind that often less is more. The following are common problems we encounter in attempting to optimize the capabilities of the system:

- Too many antennas and/or wrong antenna choice on a system
- Antennas spaced closely together
- Incorrect placement of antenna for maximum signal in high density venues.
- Judging the quality of the system when BeltStations are clumped together.

## How to Optimize the Capabilities of the Tempest/Channel D/Antenna combination

When starting to deploy any of these combinations, it is best to start with ONE antenna and add more as needed for proper coverage. The most common complaint of poor performance has been due primarily to data packet corruption by having too many antennas focused into an area. You may not need multiple antennas but rather one well placed and correctly chosen antenna.

When the customer purchased the Channel D Solutions distribution amplifier, it was engineered to meet their requirements using a specific antenna and antenna cable type combination.

A high gain antenna and a long piece of LMR-400 are perfectly acceptable. However, taking that same antenna and placing it at the end of a 5 foot length of LMR-200 will probably exceed the maximum allowable EIRP dictated by the FCC or other local regulations. It is the end user's responsibility to be sure that the correct antenna and cable type as specified by Channel D Solutions is properly deployed.

Users who are transitioning from a UHF communications system to a 2.4 GHz communications system need to understand that what worked with UHF may not work with a 2.4 GHz system.

Won't Wi-Fi Hotspots interfere with the Tempest 2400 system? The Tempest 2400 system has a very sophisticated method of data transmission. Please note that it is DATA transmission. Unlike UHF systems which are analog, the Tempest is digital. Even in a Wi-Fi rich environment, Tempest will be immune to interference from Wi-Fi Hot Spots. With redundant data transmission and frequency hopping at the rate of 200 times per second, the Tempest 2400 RF transmission is a moving target to normal Wi-Fi communications equipment.

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Know and understand your environment: When demoing a system, be aware of the physical structure of the building, area, obstacles, and other RF reflectors or blockers. There is a lot of steel reinforcement in a concrete structure. Take particular care in placing antennas in an empty venue. You may have excellent signal when the facility is empty but as it fills with people, BMI (body mass interference) begins to have detrimental effects. Generally speaking, for stadium coverage, the antenna should be placed high and focused down as in the case of a BeltStation moving throughout a football stadium. In the case of Tempest deployment for a concert event for the production staff, antennas will probably be located backstage. Placement of the antennas 7 to 8 feet off the floor may be sufficient for the stage area. Full coverage of the arena might not be necessary. Be sure to inquire as to where production staff will be during the performance.

## The Language of Antennas and Antenna Selection

Omni directional or Omni: An antenna that radiates the signal equally in all directions.

Directional: An antenna that concentrates the signal in a particular direction.

Vertical, Horizontal, and Circular Polarization: A vertical antenna radiates its signal in the horizontal plane and is mounted vertically. Horizontal is just the opposite. Both of these types are susceptible to multipath interference (signals being reflected from multiple surfaces and arriving at the receive location at different times and at different levels). Circular polarization means that the signal is sent in either a right-hand or left-hand rotation (imagine a slinky being outstretched). Any reflected signals reverse their rotation and tend to help reduce multipath interference, since any reflections are weaker than the main signal and of opposite polarization.

Sectorized: An antenna that has a radiation pattern engineered to cover a particular angle of area. These are the types of antennas you see on cell towers. Common patterns are $90^0$, $120^0$, and $180^0$ .

The “dBi” specification: What is it and how do I use it? – dB stands for decibel, which is an easy way of stating numbers in respect to each other. The “I” stands for isotropic, a theoretical antenna that radiates its signal equally well in all possible directions. The term dB, by itself, has no meaning (more on this later), It must have a reference. For antennas used in the Wi-Fi band, the reference is the isotropic antenna. For power levels, the reference is the milliwatt (1/1000 of a watt). An antenna that has 3 dBi gain means that it effectively radiates twice the power put into it as compared to the isotropic antenna. A 3dB increase doubles the output while a 3dB decrease reduces the power by half. Since we live in a real world and don’t get something from nothing, the gain actually comes from compressing the pattern into a narrower area. Imagine placing a balloon on a table (representing the isotropic antenna) and then taking your hand and pressing down on the top of the balloon. The height of the balloon decreases, but the circumference increases. This is how you get gain out of an antenna. The down side is that you reduce the radiated signal above and below the main signal.

The “dBm” specification,: As seen above, dB is a ratio of numbers. When applied to power levels, it makes it very easy to calculate coax losses and different antenna combinations. It also helps you decide whether the Effective Isotropic Radiated Power (EIRP) is within legal limits or not. The Tempest 2400 typically has an output power of around +16dBm. When used with the 2.5 dBi gain omni antennas that ship with the Tempest, (or on the Remote Transceiver), you can calculate that the EIRP is around 18.5 dBm, well within the legal limits worldwide. With the exception of Canada, the United States, Australia, and perhaps a few more

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countries, the maximum EIRP is +20 dBm. Some countries also limit the actual power output at the antenna connector in combination with the EIRP. In the U.S., maximum output power at the antenna connector is +30 dBm, and maximum EIRP is +36 dBm. Regulations vary between countries. Make certain your installation meets local laws! In France, there are different limits, depending on whether the device is used indoors or outdoors!

Connector types: Not all connectors are created equal. They must be able to function efficiently at the frequencies being utilized. The typical connector used on CB radios is only efficient up to about 300 Megahertz (MHz), or 0.3 Gigahertz (GHz). While the BNC, TNC, and N type connector share the same electrical architecture, the way they behave varies. The 50 ohm impedance BNC is rated to 4 GHz, while the TNC is typically rated to 11 GHz, as is the typical N connector. Also, because the Tempest operates in the license-free band, regulations state that the input and/or output connectors must be of a non-standard, or specialized, type. Meaning, the average consumer cannot walk into a Best Buy, Radio Shack, or other consumer type retail outlet and purchase one. The RP-TNC (Reverse Polarity TNC) has the same electrical characteristics as the standard connector and meets this requirement. This is why the RP-TNC is used on the Tempest Base output and on the Channel D input. In addition to the RP-TNC input connection, the output of the DB series features RP-N connectors.

Cable types and cable loss: The coaxial cable that connects the Tempest (or the Channel D box) to the antenna is much more than just a piece of wire that goes from point A to point B. It is a vital link that will determine the success or failure of your deployment. Each particular type and size has a specific loss in dB/foot that has to be factored in. At 2.5 GHz, LMR400 cable has a loss of 6.8 dB per 100 feet, LMR-200 has a loss of 16.9 dB per 100 feet, and LMR 100 has a loss of 40 dB per hundred feet.

Here's where we tie it all together:

As stated earlier, dB means nothing by itself, even though it was stated above that the cable loss was "X" dB. Using VERY simple math, we can determine whether or not the cable and antenna choice will make it or break it. Take the output power in dBm, add the antenna gain, and SUBTRACT the cable loss, in dB. This will give the EIRP, and help determine not only how well the signal will radiate, but whether you are LEGAL as well. +16dBm (Tempest output) plus a 9 dBi gain directional antenna, minus 100 feet of LMR-400 ( 6.8 dB @ 2.5 GHz) equals an EIRP of 18.2 dBm, legal and acceptable.

Why not use all high gain antennas? You can "over cover" an area, resulting in unacceptable performance.

What's the trade off of high gain vs. radiation dispersion? High gain works well when the BeltStation is roughly in the same plane (or height) as the antenna. However, if the BeltStation is above or below this area (remember, the pattern becomes more narrow the higher the gain) you can actually overshoot or undershoot the BeltStation!

The receive gain of the Channel D Solutions box is the key for BeltStation to BaseStation performance. We are limited as to maximum output power and EIRP of both the BaseStation and the BeltStation. While we cannot control the type of antenna used in the BeltStation, we CAN add receive amplification within the Channel D box. This has close to the same effect as using a higher gain antenna or higher output power from the BeltStation.

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