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Understanding Antenna Gain, Beamwidth, And Directivity

Antenna gain is a performance indicator gauged in comparison to a reference source. In compliance engineering, antenna gain is measured in decibels over isotropic (dBi), referring to an isotropic antenna — an "ideal" antenna that transmits/receives energy uniformly in all directions, exhibiting a gain of 0 dBi (Fig. 1).

In a transmitting antenna, gain describes the antenna's ability to convert input power to radio waves sent in a specified direction. In a receiving antenna, gain describes the antenna's ability to convert radio waves (incoming from a specified direction) into electrical power.

This article explains antenna gain and dispels some of the misconceptions surrounding this valuable metric. It also discusses the gain typical of common antenna types and provides tools to calculate vital parameters relevant to antenna gain.

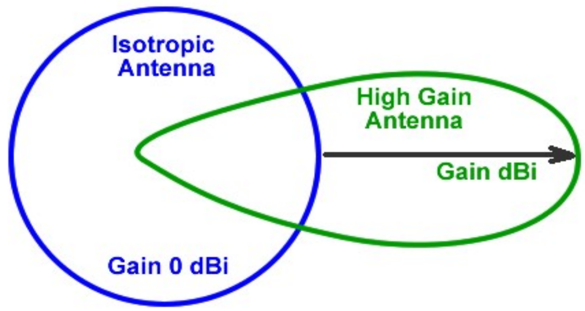

Figure 1 – Antenna Gain dBi

How Does Antenna Gain Work?

First, it warrants mention that in some industries — such as broadcast engineering — manufacturers may utilize dBd (gain relative to a dipole antenna) as a metric, rather than dBi. Note that dBd is inherently greater, defined as 2.15 dBi gain.

This disparity is due to the antennas' differing radiation patterns; picture an isotropic antenna's gain pattern as a sphere, and a dipole antenna's pattern as donut-shaped, resultant of the latter's more focused beam.

Similarly, when dealing with transmitting antennas, numeric gain may be used in lieu of dBi to calculate the field intensity an antenna is likely to produce. For purposes of this article, we will remain focused on receiving antennas whose gain is quantified in dBi.

Next, let's examine how gain functions: picture a perfectly symmetrical balloon representing an isotropic antenna. If you were to squeeze the balloon's sides, the ends would bulge. That analogy is the essence of gain; the pattern created by the theoretical balloon represents the gain of the antenna under test in this scenario — altering the gain "squeezes the balloon" and changes the antenna's radiation pattern.

Further, an antenna's gain can vary across its frequency range for a number of reasons.

For example, a broadband antenna is either tuned to one part of frequency range or another, or a multitude of antennas may be combined in an array, creating a ripple effect. Double ridge guide horn antennas may exhibit gain from zero up to 10 and back down again across their frequency ranges (they are intended to cover a broader frequency range).

Even "constant gain" antennas operate within a narrow gain range. Consider that open-ended wave guides or standard gain horn antennas (which cover a very narrow band) exhibit fairly constant gain. Such an antenna might be a 15 dBi gain antenna, but it actually fluctuates between 14 dBi and 16 dBi, averaging essentially 15 dBi and registering a flat response.

The frequency range trade-off comes in power; by creating an antenna to operate over a wider frequency range, you give up some of the antenna's performance. This reality directly counters the common misconception that antenna gain is analogous to amplifier gain: additional antenna gain does not create power, either in added field or voltage.

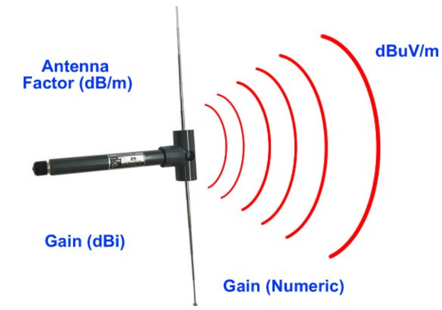

Figure 2 – Antenna and Gain calculator

This calculator can help you to determine gain (dBi or numeric) and antenna factor based on your antenna's frequency range and one other parameter.

Antenna gain also has a direct correlation to both antenna directivity and beamwidth. Higher gain antennas achieve extra power by focusing on a reduced area; thus, the greater the gain, the smaller the area covered (measured in degrees of beamwidth). Antenna gain and beamwidth always are inversely proportional.

Returning to the balloon analogy from above, the harder you squeeze, the further out other areas of the balloon will go as its energy is directed to a smaller area. This act of focusing directivity reduces the beamwidth; consequently, the coverage of the product under test is reduced. This scenario represents increasing gain.

This analogy can be related to all variances of gain. Gain may vary across the antenna's whole frequency range, which means your coverage is not consistent across that frequency range.

Thus, when designing test specifications or performing a test, ensure that you are properly applying appropriate beamwidth coverage to the antenna.

Say, for example, your directional antenna boresight (the axis of maximum gain/maximum radiated power) is 0. Then, if you vary left or right a certain degree, and your reading hits about 3 dB fewer, that's the point you're basically looking for. Typically, in compliance testing, a 30-degree beamwidth provides decent coverage at one meter away (Fig. 2).

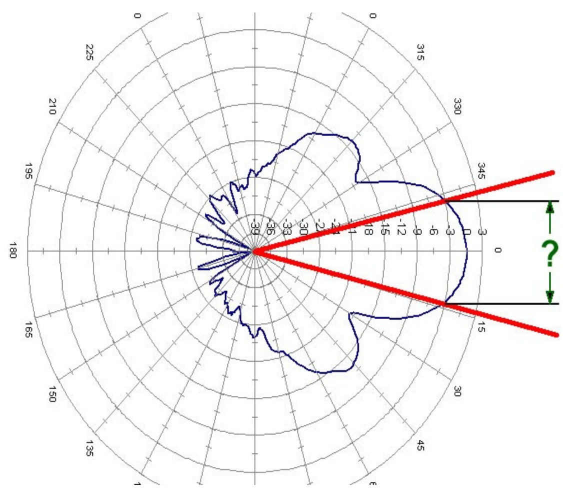

Figure 3 – Antenna beamwidth coverage

This tool can help you calculate an antenna's maximum (beamwidth) coverage from a specified distance, as well as its half-power beamwidth. Additionally, this tool can help you determine the actual field intensity or power density (in V/M) at a given distance with a known antenna gain.

Again, it bears stressing that higher antenna gain is not always advantageous. The advantages of lowering/raising gain depend on the application (though the inherent trade-offs remain the same).

For example, if you're testing a vehicle, you're going to have to sweep multiple times and you want a wider beamwidth, because it means fewer test setups. Conducting a similar test on a cell phone, meanwhile, doesn't call for a wide swath of beamwidth. Thus, ideally, higher gain is more advantageous in a smaller product.

That said, antennas all must abide by the laws of physics; you can only draw so much gain out of certain antennas.

Typical Properties of Common Antenna Types

Figure 4 – Half-Wave Dipole Antenna

Figure 5 – Double Ridge Guide Horn Antenna

- **Small Loop Antennas**
  - Gain: 2dBi max
  - Half-power beamwidth: 80 deg x 80 deg
- **Monopole Antennas**
  - Gain: 6 dBi at best
  - Half-power beamwidth: 45 deg x 360 deg
- **Biconical Antennas**
  - Gain: up to 4 dBi
  - Half-power beamwidth: 20-100 deg x 360 deg
- **$\lambda/2$ Dipole (Half-Wave Dipole Antenna)**
  - Gain: 2.15 dBi
  - Half-power beamwidth: 80 deg x 360 deg
- **Log Periodic Antennas**
  - Gain: 6 to 10 dBi
  - Half-power beamwidth: 60 deg x 80 deg
- **Flared Horn Antennas**
  - Gain: 5 to 24 dBi
  - Half-power beamwidth: 40 deg x 40 deg (dependent on gain)
- **Double Ridge Guide Horn Antennas**
  - Gain: 0 to 18 dBi
  - Half-power beamwidth: 5 to 100 deg both polarities

Conclusion

Antenna gain is a fundamental aspect of both antenna design and test. Understanding how gain functions and how it affects other antenna parameters is vital to saving time and budget, as well as ensuring a resulting antenna that performs as expected.

About A. H. Systems

A.H. Systems is one of the world's leading manufacturers of compliance test antennas and accessories. Established in 1974, A.H. Systems manufactures affordable and reliable compliance test antennas, preamplifiers and current probes to satisfy many test standards including CISPR, MIL-STD, FCC, EN, VDE, IEC and SAE. Specializing in next-day, on-time delivery of their products, A.H. Systems also offers antenna calibration services. Manufacturing high-quality products at competitive prices with immediate shipment and precise calibration services plus prompt technical support are the foundation of A.H. Systems.

For help selecting a measurement antenna, calculating antenna gain or antenna calibration services, contact A.H. Systems.