Direction Finding Antennas and Accuracy

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About Alaris Antennas

From its roots in 1990, Alaris Antennas has grown to become a substantial supplier of advanced Electronic Warfare (EW) antennas.

For the global defense and security markets, Alaris Antennas' mission is to deliver high quality antenna Solutions, on time, through technical and service excellence.

We specialize in supplying innovative, customized antennas and related RF product solutions to global RF system integrators.

Alaris Antennas continues to be the trusted and innovative partner to its clients for over two decades.

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Part 1: Accuracy and Sensitivity

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It is sometimes said that: “If you can’t convince them, confuse them!”. Nowhere is this more apparent than the minefield which is antenna datasheets and brochures.

Direction finding antennas are meant to be instrumental in accurately determining the direction of an incoming signal, that much we all agree on. One would thus think that a graph of accuracy vs frequency would be very obvious and clear measure of how well an antenna will do its job, and you would be very wrong. Welcome to the world of specmanship.

Specmanship is the nefarious use of data to present to the customer what he wants or expects to see, rather than what is true. It is quite possible to present antenna performance figures, like ‘accuracy’ in this case, in a way that looks fantastic on paper, but will fail to live up to the customer expectations in real life applications. This blog post will attempt to delve into the world of DF antenna accuracy to explain how it should be interpreted in the context of real-world applications.

What is ‘accuracy’?

To generate the accuracy plot of a DF antenna, we generate a mathematical model of the antenna, and transmit a hypothetical signal to the antenna from a specific angle of incidence. The antenna (and its associated DF algorithm) will then receive this signal and calculate the angle from which it believes the signal is coming. If we do this for each direction while moving around the antenna, we can calculate an average (or RMS) error, taking into account incoming signals from all directions. This RMS error, plotted over frequency, is the typical ‘accuracy’ plot that you will find in many DF antenna datasheets. Simple enough, right?

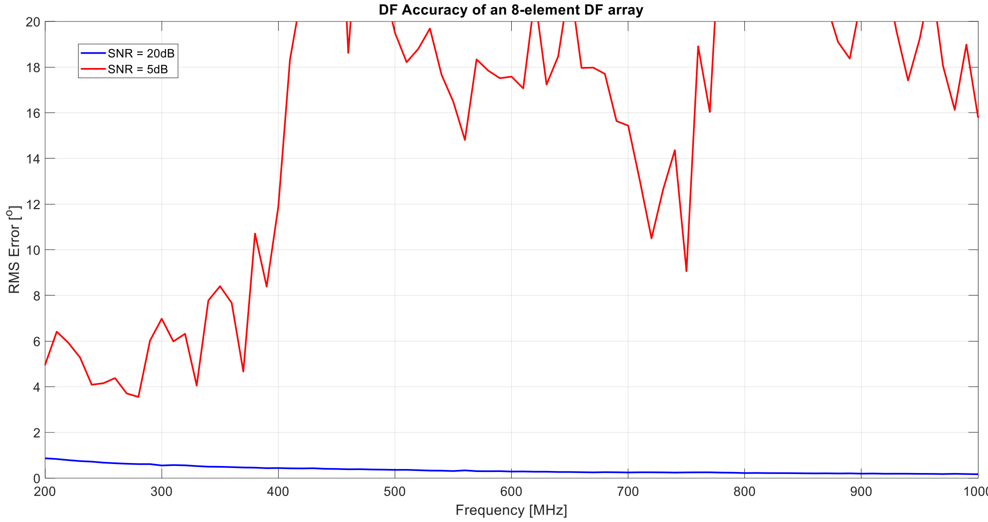
Well, not quite. The accuracy with which a DF antenna can estimate the direction of an incoming signal is dependent on a whole bunch of different factors. An accuracy plot without stating the underlying assumptions really provides very little information indeed. Let us consider a few factors that will influence the accuracy of a DF antenna.

Noise and signal level

The first, and most obvious parameter, is the signal level (or more accurately, the strength of the electric field) of the incoming signal. The incoming E-field needs to be large compared to the noise level, else the antenna/algorithm will have no way of extracting the signal of interest from the background noise.

As an analogy, suppose someone in the room is trying to get your attention at a dinner party. The person will need to shout louder than the average ‘noisiness’ created by all the other people at the party in order for you to differentiate that person’s voice above the others.

When trying to attract someone’s attention at a rock concert, however, you will have to shout much, much louder to get the same effect. Trying to determine your friend’s location by listening for his voice at a rock concert is much harder to do than at a dinner party. The same principle applies in DF systems.



In the example above, we used a hypothetical 8-element DF antenna and calculated the DF accuracy for incoming signals with a Signal-to-Noise ratio (SNR) of 5dB (loud rock concert) and 20dB (dinner party) respectively. As we suspected, when our signal of interest is barely stronger than the noise floor (SNR=5dB), the DF antenna/algorithm will make many estimation errors and will only be accurate to within about 20º or so. The very same antenna, given a nice strong signal (SNR=20dB), is however capable of achieving accuracies of way better than 1º.

Antenna manufacturers will sometimes publish accuracy plots like these labeled as "large-signal accuracy", indicating that the plot assumes zero (or very low) noise levels. This accuracy provides information about the array layout, size and a couple other more esoteric features of the antenna.

While this information is extremely useful for the antenna engineer during the design process, it really does not say much about how well the antenna will perform in the real world, mainly because of the following two factors that are cleverly (and sneakily) 'omitted'.

1.The accuracy calculated from the SNR excludes the gain of the antenna elements. SNR is a measurement taken at the radio interface, assuming the signal was already received on the antenna. You can achieve a good SNR on a poor antenna by blasting it with an extremely strong signal. Likewise, and desirably, a good antenna element should be able to provide a decent SNR given a relatively weak signal.

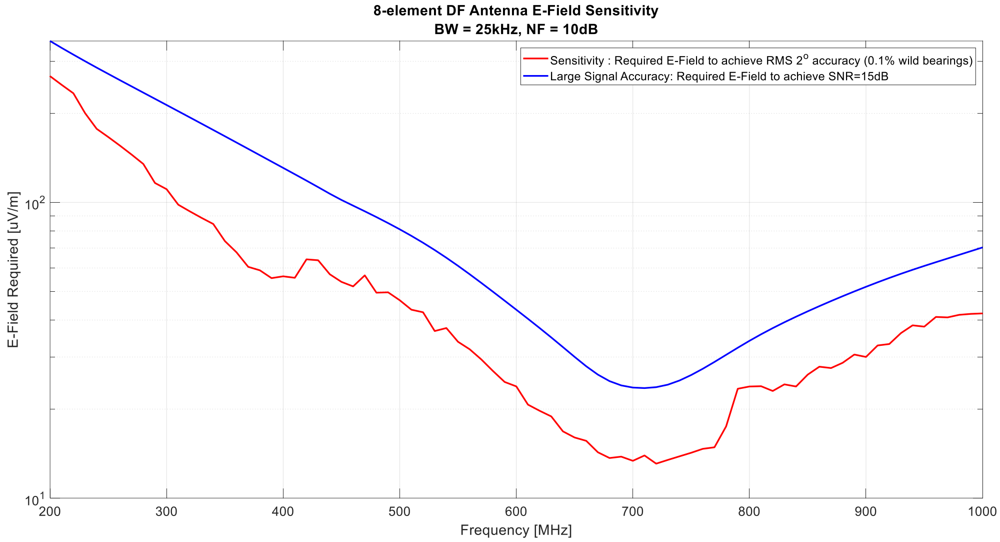
2.The accuracy is also dependent on the algorithm used for direction finding. Certain algorithms (like pure Watson-Watt or interferometry) can introduce 'bias' errors, which is caused by applying a mathematical model that assumes a perfect antenna pattern to a 'real-life' antenna which has patterns that may deviate from the ideal. The plots above make use of a correlative algorithm which has pre-knowledge of the antenna imperfections and can compensate for these during the estimation calculations. This topic will be explored in more detail in part 3 of this series. Accuracy plots should thus always be interpreted in the context of the algorithm used and should explicitly declare the algorithm used to generate the plot.

DF Antenna Sensitivity

To address problem 1 from the previous section, the performance of a DF antenna can be expressed in terms of its sensitivity to electric fields. Given that a typical DF antenna, using a correlative algorithm, is capable of sub-one-degree accuracy when the SNR is high, we can choose to calculate the incoming E-field strength that will generate a given SNR, or alternatively, the E-field strength that will produce a given RMS accuracy.

The advantage of using a sensitivity plot as a performance metric for a DF antenna is that it includes the gain of the antenna elements, and thus provides information about how good the individual antenna elements are, in addition to the overall layout of the array. Expressing the performance of a DF antenna in terms of its sensitivity also provides a much clearer indication of how well the antenna is expected to perform in real-life applications. With all other things being equal (same receiver system, same incoming signal), a DF antenna with better sensitivity will achieve better real-life accuracies than an antenna with lower sensitivity. The large-signal accuracy does not provide this straightforward equivalence to real-life performance without significant interpretation.

As an example, consider the calculated E-field sensitivity for the same antenna considered in the previous section.



This plot indicates the electric field strength required to achieve a SNR of 15dB (blue line) and the E-field strength required to achieve an RMS error of 2º or better. This plot allows the customer to directly evaluate whether this antenna is appropriate for the type of signals expected in their specific application. Notice however, that these plots also require several assumptions (like the channel bandwidth and noise figure of the system), and these should be stated explicitly.

As is the case for large-signal accuracy, this plot is only valid for correlative algorithms and will differ significantly when used with other types of algorithms.

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Given these obvious advantages in using the sensitivity plots as a metric of DF antenna performance, most Alaris Antenna brochures will publish sensitivity plots rather than accuracy plots.

Part 2 of this series will consider the factors that influence the accuracy and sensitivity of DF antennas, while part 3 will delve more deeply into the nuances of characterization measurements as it applies to correlative algorithms.

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