Accuracy of Series 7000 (MPT) DF

A Technical Application Note from Doppler Systems

04 Aug 2014

1.0 Introduction

Accuracy refers to the precision of angle of arrival measurement under specified conditions. It is influenced by mechanical and electrical errors within the direction finder itself and my environmental conditions such as reflections, polarization mismatch, interfering signals, frequency errors, etc. These latter factors are beyond the control of the DF manufacturer, but they may be dominant. For this reason, it is very important when selecting a DF site and installing a DF system that reflections, interference, etc. be considered.

The manufacturing and calibration errors that affect DF accuracy can be measured, but only if the measurement setup is carefully arranged to minimize the environmental errors as well. For many years, we conducted these tests in an anechoic chamber, but with the 7000 system we found that even there, reflections were dominating the low system errors we were attempting to measure.

DF errors can be estimated using analytical models for the antenna, RF summing electronics, receiver and processor. The error sources produce angular errors that are cyclical. For an 8 element antenna, the bearing errors occur at 1, 2, 4 and 8 cycles per revolution of the antenna. The largest error source is the gain mismatch between the preamplifiers connected to the even and odd numbered antenna elements. This error is corrected by individual calibration of the RF summing electronics in each antenna. The calibration also corrects the error due to mismatch of the insertion loss through the switching circuitry associated with each element. Other error sources such as phase mismatch, pattern distortion due to the presence of the RF currents in the supporting masts and cables, etc. are not corrected by calibration but are controlled by the design (low tolerance components, precision cable lengths, ferrite decoupling, etc.)

2.0 Measurement Method

Since the bearing error varies with the angle of arrival, the accuracy measurement must include all angles of arrivals. This can be accomplished by keeping the DF antenna fixed and moving the transmitter to known positions around it, or by keeping the location of both DF antenna and transmitter fixed and rotating the DF antenna. We have used both methods, but the second one is more accurate and much more convenient. A precision computer controlled indexing fixture is used to rotate the DF antenna. The step size is adjustable, but we have found that taking measurements every 6 degrees provides an adequate characterization of the error curve.

Two test sites are used - Dugas and Cave Creek. Both locations are relatively clear of vegetation and no large reflecting objects including power lines are present for at least ¼ mile in all directions. There are no transmitters (cell towers, etc.) for at least 1 mile in all directions. The DF antenna is mounted on a mast which puts it about 14 feet above ground level. The transmitting source is a signal generator located about 75 feet distant from the DF antenna. The transmitting antenna is a short whip centered on a large (4x4 ft) aluminum ground plane. This antenna is close to the ground to minimize the multipath reflection from the ground itself. Data logging and control is located about 50 feet behind the DF antenna (away from the transmitter).

Dugas has a sloping topography such that the elevation angle between DF and transmit antennas is nearly zero. Cave Creek is flat, so the elevation angle of the received signal is arctan (14/75) or about 11 degrees downward.

Testing is performed at or near the center, the lowest and the highest frequencies of each antenna. The frequency is monitored to be sure that no on-air signals are present, and if so the channel frequency is changed slightly to a frequency that is unoccupied. The signal generator output is adjusted to produce a strong signal (S9) in the receiver.

All tests used an ICOM R8500 receiver with 12 KHz bandwidth. The MPT processor uses the default sweep rate of 1000 Hz. Default averaging of two ½ second samples is also used so the resulting bearing angles include both CW and CCW measurements. The software allows the system to dwell for about 2 seconds at each angle for settling and data collection before taking another 6 degree step.

The only post processing of the data is the recalculation of the zero bearing angle. We calculate the mean bearing angle of the center frequency data and use it to offset all of the data for that antenna. So the mean bearing angle error will by definition be zero at the center frequency, but the mean angle at the low and high frequencies will include any shift over the bandwidth of the antenna. Excel is used to calculate the means and standard deviations and to plot the bearing angle vs. the true LOS angle.

3.0 Measurement Results at Dugas

The 8 element VHF and UHF antennas were characterized at Dugas on 6/9/11. These are models DDF7091 and DDF7092 respectively.

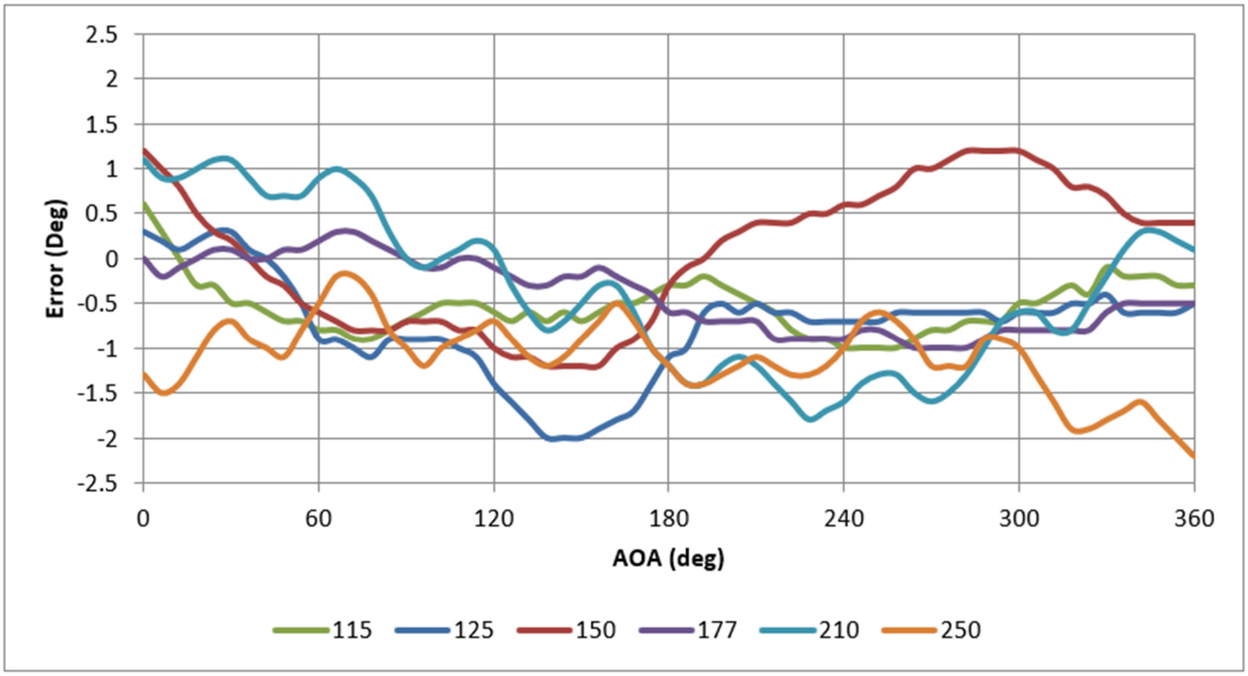

Figure 1 - Bearing Accuracy of DDF7091 (8VHF) Antenna

Frequency	Mean	Std Dev
115	-0.1	0.31
125	-0.4	0.57
150	0.5	0.79
177	0	0.4
210	0	0.9
250	-0.7	0.42

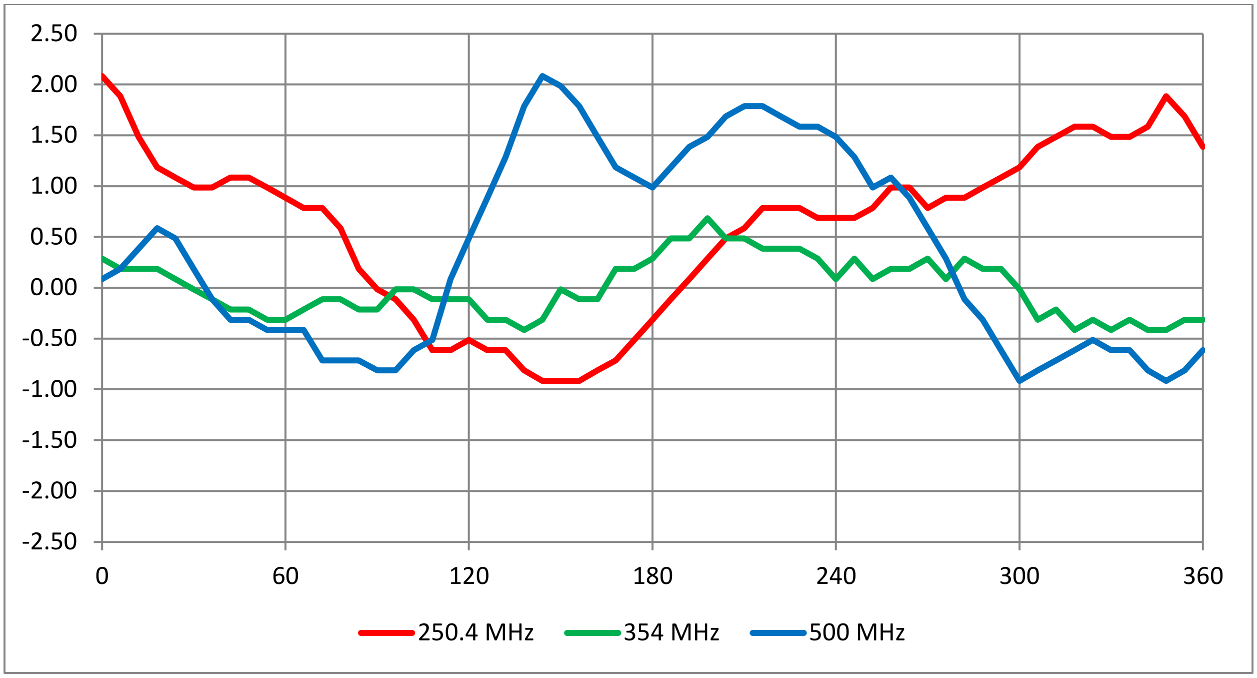

Figure 2 - Bearing Accuracy of DDF7092 (8UHF) Antenna

Frequency	Mean	Std Dev
250.4	0.60	0.83
354	0.00	0.29
500	0.36	0.97

4.0 Measurement Results at Cave Creek

The 8 element THF and 4 element VHF antennas were characterized at Cave Creek on 4/6/12. These are models DDF7093 and DDF7097 respectively.

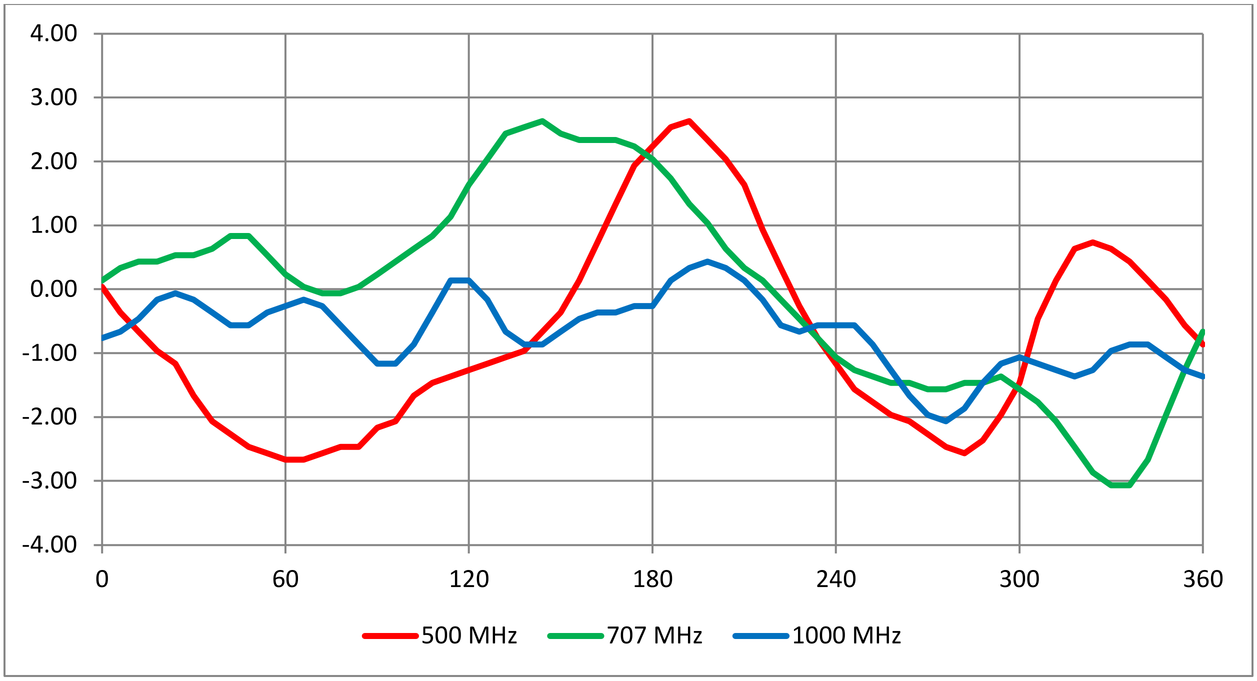

Figure 3 - Bearing Accuracy for DDF7093 (8THF) Antenna

Frequency	Mean	Std Dev
500	-0.73	1.50
707	0.00	1.56
1000	-0.67	0.57

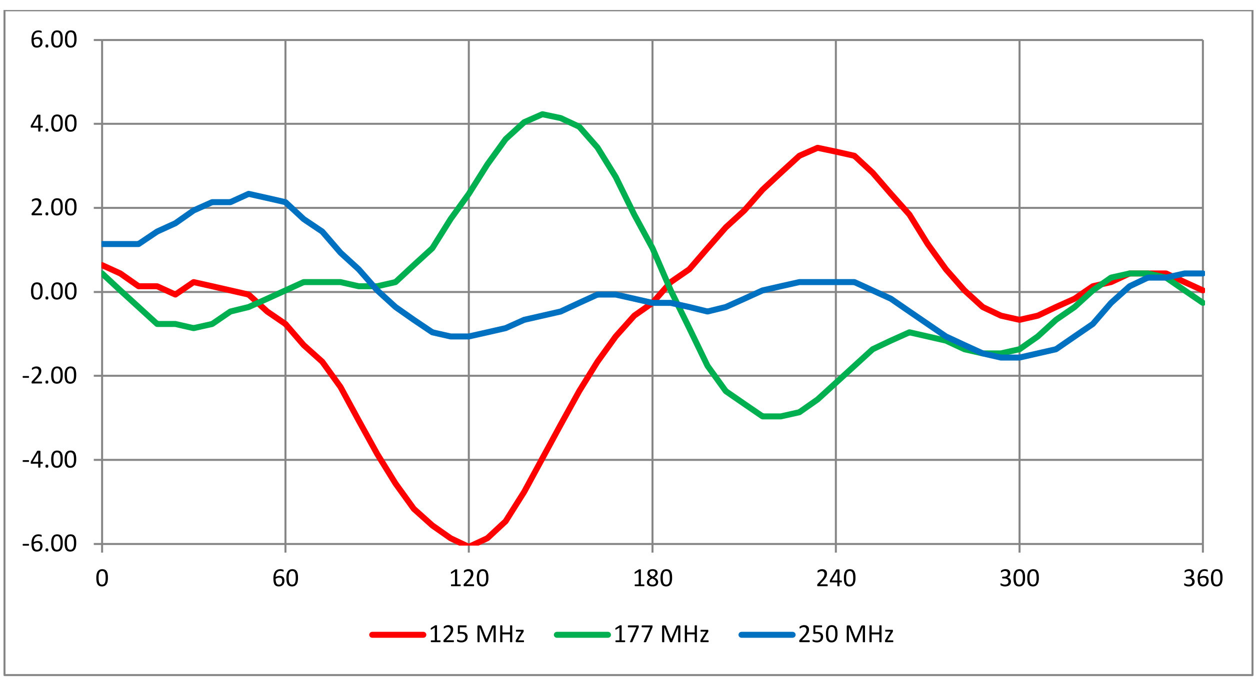

Figure 4 - Bearing Accuracy for DDF7097 (4VHF) Antenna

Frequency	Mean	Std Dev
125	-0.60	2.49
177	0.00	1.83
250	0.06	1.06

5.0 Summary of Results

The error for the 8 element VHF and UHF antennas is better than 1.0 degrees RMS. The RMS error of the 8 element THF antenna is better than 1.6 degrees. A 4 element VHF antenna has an RMS error better than 2.5 degrees.

All antennas have a mean shift of less than +/-1 degree over their operating bandwidth.