Telematic Antenna Testing

Today’s automobiles have a wide variety of RF systems with antennas on them for Sirius and XM radio, collision avoidance radars, the Global Positioning System (GPS) and other systems. Conventional test facilities can only perform terrestrial directed pattern measurements of the antenna on the automobile. Special test facilities are required when the automobile must communicate with a satellite as well as other ground systems. Table 1 provides a partial list of satellite-based wireless systems below 2.5 GHz in frequency. This paper discusses a system specially designed for making antenna measurements from the zenith to the horizon. In addition, some of the issues involved in making satellite band measurements such as Sirius/XM and GPS and terrestrial band measurements such as CELL800 and CELL1800 are reviewed.

Table 1: Common satellite-based wireless systems below 2500.0 MHz.

	Satellite-Based RF System	Test Band (MHz)	Polarization (Unitless)	Elevation1 (Degrees)
1.	Inmarsat	1525.0 – 1600.0	RHCP2	0-80
2.	GPS	L1: 1575.42 L2: 1227.9	RHCP	0-80
3.	Globalstar – Transmit Band	1610 – 1626.5	LHCP3	0-80
4.	Iridium	1616.0-1626.5	RHCP	0-80
5.	Sirius Satellite Radio	2320.0 – 2332.5	LHCP VLP	0-75 75-90
6.	XM Satellite Radio	2332.5-2345.0	LHCP VLP	30-70 70-90
7.	Globalstar – Receive Band	2483.5 – 2500.0	LHCP	0-80

1 – Elevation angles referenced with respect to antenna zenith (i.e. +z-axis.) 2 – right hand circular polarization (RHCP) 3 – left hand circular polarization (LHCP)

Test System

A telematics measurement system must be able to measure the antenna pattern

over the upper hemisphere when the antenna is installed on the vehicle since the vehicle can deteriorate the pattern if the antenna is installed in the wrong location [1]. A typical system for performing these measurements is shown in Figure 1. A turntable mounted flush with the ground rotates the vehicle 360° in azimuth while a gantry arm positions the measurement probe from 0° to 90°. This turntable-gantry arm combination allows the probe to measure the antenna pattern over the entire upper hemisphere.

Figure 1. Outdoor MI Technologies telematics test system at Oakland University.

The installed antenna can induce currents to flow on the vehicle and these currents can corrupt the desired pattern from the antenna. A theoretically exact pattern from the installed antenna is obtained the using the spherical near-field measurement technique [2]. This method uses the probe to sample the near-field on the measurement hemisphere at uniformly spaced azimuth and elevation angles. The measured near-field data is then processed using the near-field algorithm, the effects of the probe are removed and the data converted to a far-field pattern. Alternately, the far-field pattern can be measured directly without near-field processing if the interaction of the antenna with the vehicle is fairly localized. This latter approach is commonly used since it allows rapid pattern measurements. The instrumentation for the measurements consists of a measurement system, here a MI-3000, which automatically positions the turntable and gantry to the required locations as well as controlling a vector network analyzer that make the RF measurements at specified frequencies. The data is automatically collected,

processed and displayed.

Illustration of GPS Antenna Pattern Measurements

An example of the radiation pattern performance for a GPS antenna mounted on a vehicle’s roof at a single frequency is presented in Figures 2-4. The measurement setup collected data spatially over the hemisphere from 0°to 80°in zenith angle in 10°increments and from 0°to 359°in azimuth angle in 1°increments resulting in 3240 spatial points. The spatial data were collected at 3 distinct frequencies. Figure 2 shows the three-dimensional RHCP gain pattern for the roofmounted GPS antenna. The peak RHCP gain is maximum at zenith (i.e. ?=0°) and minimum and the antenna horizon (i.e. ?=80°).

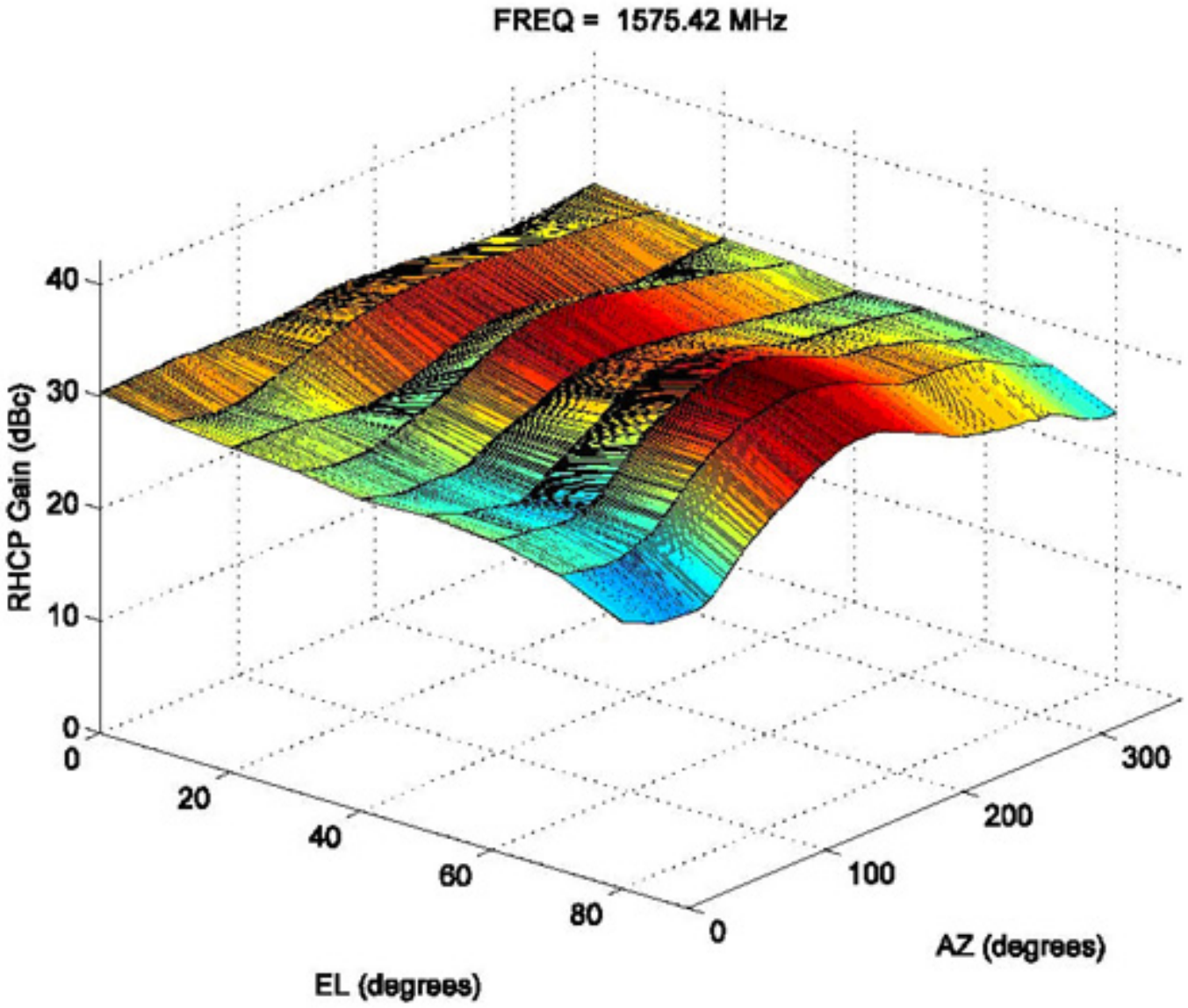

Figure 2. Three-dimensional RHCP gain pattern of a GPS antenna mounted on the roof of a vehicle at a single frequency. It is useful to quantify the statistical behavior of the RHCP gain pattern as in Figure 3. The linear average gain, average gain, minimum gain, maximum gain and standard deviation of the RHCP gain are calculated for the 360 azimuth points within a particular elevation band. All of the aforementioned statistics of the RHCP gain decrease as the elevation angle deviates from antenna zenith (Θ=0°) to antenna horizon (Θ=90°) with the exception of the standard deviation. The standard deviation of the RHCP gain increases near the antenna horizon because reflections from the vehicle and ground are more prevalent.

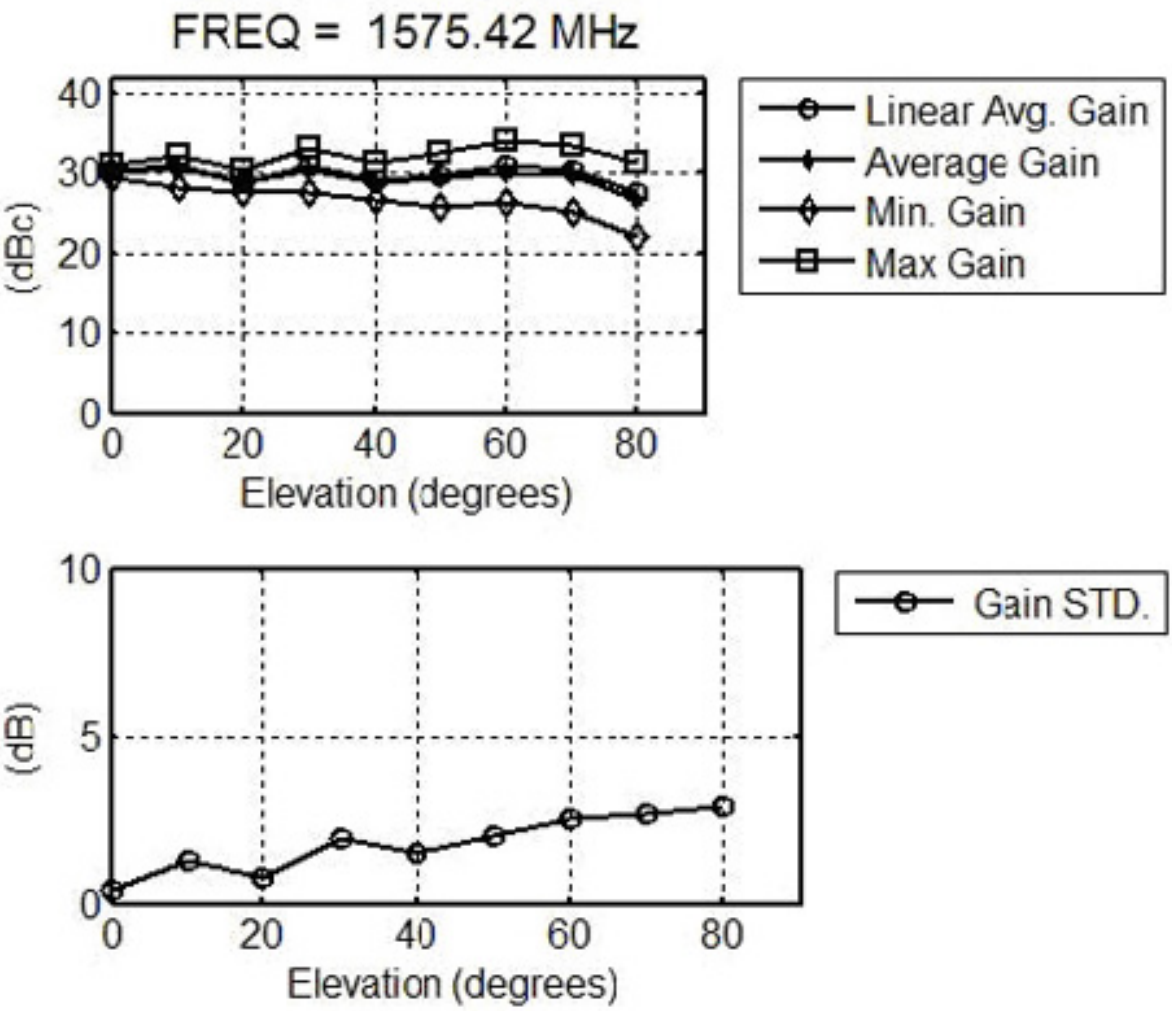

Figure 3. Statistical summary per elevation angle of the RCHP gain of a GPS antenna mounted on the roof of a sedan at a single frequency.

Range Performance Issues:
Many factors impact the accuracy and repeatability performance of antenna range. A few of these issues are briefly mentioned. Transmit antenna characteristics such as the half-power beamwidth and the polarization purity are important traits that will impact range performance when out of tolerance. The short term stability of the radio frequency power link is important as typical gain calculations are typically specified relative to the absolute gain of reference antenna such as a dipole or horn antenna. The measurement instrumentation that transmits and receives the radio frequency signals should possess adequate dynamic range so that the received power levels have adequate margin above the noise floor. The purity of the radio frequency environment for outdoor antenna ranges is important as interference increases the noise level in the gain calculation measurement. Also, the antenna range operating procedures for aligning test antennas and post-processing the collected data can impact range performance if done with little attention to detail.

References
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2 J. E. Hansen, editor, "Spherical Near-Field Antenna Measurements," Peter Peregrinus, 1988.

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