DESCRIPTION OF THE CALCULABLE PRIMARY STANDARD FOR ANTENNA GAIN MEASUREMENTS FROM 1 GHz TO 18 GHz AT CENAM

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Abstract: The purpose of this paper is to describe the main characteristics of the Primary Standard for Antenna Gain used at CENAM and its applications.

1. INTRODUCTION

Antenna Gain (G) is a parameter for an antenna that relates actual radiated power density to a theoretical power density for an isotropic antenna at a given distance. Testing laboratories use this parameter to obtain values of electric field in radiated-emission testing and immunity testing as well in electromagnetic compatibility applications. Telecommunication industry uses antenna gain for applications like wireless communications coverage prediction from a Base Station. CENAM establishment of a Calculable Primary Standard for Antenna Gain (PNGA) concluded in March 2015. This paper shows the main characteristics of this standard.

2. PHYSICAL REALIZATION OF ANTENNA GAIN

Antenna Gain is a derived quantity whose realization depends on the frequency range. Antenna Gain is measured in the Far-Field zone of the antenna, that is, where the value is independent from distance. Far-Field zone is a function of frequency and antenna dimensions, so, the electrically larger is an antenna, the greater distance to reach the Far-Field zone. Given these size limitations, antenna standards are physically different depending on the frequency ranges: from 1 kHz to 30 MHz loop antennas or monopole antennas are used, from 30 MHz to 1 GHz, resonant dipoles, meanwhile from 1 GHz to 110 GHz pyramidal horn antennas are used as calculable standards.

Pyramidal horn antennas have some attributes that make them suitable for standards: they can be easily manufactured and its gain value can be accurately calculated and reproduced. The accuracy of the standard can be transferred to other antennas by means of some high accuracy methods like the Standard Antenna Method (STA) or the Three Antenna Method (TAM). A previous publication on the Primary Standard for Antenna Gain shows details about antenna parameters calculation [1]. Figure 1 shows the set of seven pairs of standard gain horn antennas (SGHA) available at CENAM.

Fig. 1. *Standard Gain Horn Antenna set.*

3. RESULTS

The Calculable Primary Standard for Antenna Gain covers the frequency range from 1 GHz to 18 GHz, with gain values ranging from 13.79 dB to 22.71 dB. The amplitude range does not necessarily means that other values cannot be measured. In fact, when using the STA or TAM, any antenna gain value is possible. The more directive the radiation pattern is, the higher the antenna gain value. Having high antenna gain values leads to better uncertainties in antenna calibration. Uncertainty levels goes from ± 0.21 dB to ± 0.68 dB (with k = 2 for a confidence level of about 95%) dependant on frequency. Details about results can be found in [2].

4. UNCERTAINTY ESTIMATION

As reported previously [1], mathematical model for antenna gain measurement is given by:

$$G = -13.78 + 10\log_{10}[R] + 10\log_{10}[f] + \frac{1}{2}[P_A - P_{Dir} + M_{21}] + E_{cc} \quad (1)$$

Where R [m] is the distance between antenna apertures, f [MHz] is frequency, P_A [dB] is the insertion loss when antennas are inserted, P_{Dir} [dB] is the direct connection insertion loss with no antennas present, M_{21} [dB] is the matching error correction and E_{cc} [dB] is the correction factor of the near field error. Table 1 shows the calculated uncertainty budget.

***Table 1**. Uncertainty Budget for 1 700 MHz.*

G at 1 700 MHz		Model: $G=-13.78+10\log_{10}[R]+10\log_{10}[f]+\frac{1}{2}[P_A-P_{Dir}+M_{21}]+E_{cc}$					
VI	VE	FI	PDF	$u(x)$	c. s.	$u(y)$ [dB]	ν
R	10 m	Mastil oscillation	uniform	0.05 m	$\frac{10\log e}{R}$	0.01	60
f	1 700 MHz	VNA frequency stability	uniform	0.21 MHz	$\frac{10\log e}{f}$	0.00	120
P_A	-31.32 dB	Standard deviation	normal	0.02 dB	0.5	0.00	4
		VNA uncertainty in transmission	uniform	0.16 dB		0.05	60
		Site imperfections	uniform	0.15 dB		0.04	80
		Antenna alignment	uniform	0.51		0.18	40
P_{Dir}	-7.87 dB	Standard deviation	normal	0.11 dB	0.5	0.03	4
		VNA uncertainty in transmission	uniform	0.05 dB		0.01	60
M_{21}	-0.02 dB	Mismatch uncertainty	uniform	0.00 dB	0.5	0.00	160
E_{cc}	0.19 dB	Chart resolution from [3]	uniform	0.05 dB	1	0.03	100
G	16.98 dB				u_c [dB]	0.20	
					ν_{eff}	55	
					k	2.0	
					U [dB]	0.40	

Among all uncertainty sources, antenna alignment and site imperfections are of special interest because of their contribution to U.

4.1. Antenna alignment

Calculation for antenna gain is based on theoretical power received in the direction of maximum radiation. This maximum power is received when the antenna pair has its axis aligned in that direction. Otherwise, received power will decay as a function of radiation pattern. The more directive the radiation pattern is, the more uncertainty due to antenna misalignment. The contribution is calculated using:

$$u_{alignment}=10\log\left[1+G_E(\theta)\right] \quad (2)$$

where $G_E(\theta)$) is the radiation pattern in θ direction, which is defined in [2] as the maximum tolerable misalignment. The value of θ depends on the capabilities of alignment for each laboratory.

4.2. Site imperfections

Antenna gain is also based on the direct-path received measured power. In order to avoid multipath in antenna calibration, antennas were placed at a height of 5 m over ground plane at CALTS-CENAM. This distance is sufficiently high to avoid such multipath interference. However, there is a slight response in the direct path due to radiation pattern. Therefore, estimation for uncertainty should estimated using:

$$u_{site}=10\log\left[1+G_E(\theta)\frac{R}{R'}\right] \quad (3)$$

which, in the worst case, adds (in-phase addition) or subtracts (out-of-phase addition) power from direct-path due to radiation pattern in the direction of specular reflection.

4.3. Other uncertainty sources

Table 1 shows other uncertainty sources, but its contribution to U can be negligible. Characterization of the VNA in both transmission and reflection can improve U. Using phase-matched cable can improve contribution due to P_{Dir} and P_A.

5. CONCLUSIONS

A Calculable Primary Standard for Antenna Gain was established in Mexico by using a calculable set of Standard Gain Horn Antennas in the frequency range from 1 GHz to 18 GHz. The Primary Standard of the Antenna Gain is the local realization of this derived quantity, which allows to establish domestic traceability to the SI Units by transferring its value and accuracy to other kind of antennas such as those used for EMC testing and for telecommunication services. by means of different calibration services available at CENAM.. Detailed information about this standard is published in an internal technical report and can be requested any time.

REFERENCES

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