ARIANNA antenna model into AraSim

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1 Antennas

1.1 Important quantities

Measured in meters, the effective height of an antenna h_e multiplied by the incident field E gives the voltage induced. Thus, in vector form

$$V = \mathbf{h_e} \cdot \mathbf{E} = h_e E \cos\theta,$$

where $\cos\theta$ is the angle between polarizations on the Poincaré sphere.

Another way of defining the effective height is

$$h_e = \frac{1}{I_0}\int_0^{h_p} I(z)dz,$$

where h_p is the physical height.

For an antenna of radiation resistance R_r, matched to its load, the power delivered to the load is equal to

$$P = \frac{1}{4}\frac{V^2}{R_r} = \frac{h_e^2 E^2}{4R_r} \tag{1}$$

In terms of the effective aperture, the same power is given by

$$P = SA_e = \frac{E^2 A_e}{Z_0},$$

where $Z_0 = 377\,\Omega$ is the intrinsic impedance of space.

From those two equations, one can easily get

$$h_E = 2\sqrt{\frac{R_r A_e}{Z_0}}.$$

Note that h_e is given in meters, so A_e should have units of area (m^2). Rewriting this expression yields,

$$A_e = \frac{h_e^2 Z_0}{4R_r} \tag{2}$$

$$= \frac{h_e^2 Z_0}{4\,\mathrm{Re}\{Z\}} \tag{3}$$

Another useful quantity is the antenna gain (G). It can be calculated as follows

$$G = \frac{4\pi A_e}{\lambda^2}$$

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2 Integrating the ARIANNA antenna model into AraSim

2.1 Goals

We want to use the antenna model used in the ARIANNA experiment. To do so, we built a script that can take the ARIANNA antenna model and produce an output file that can be read by AraSim.

2.2 Methods

The ARIANNA antenna model was obtained from `arianna.ps.uci.edu/~arianna/data/WIPLD_antennamodel_air_v2.root`. This ROOT file contains two trees, and each of them has data of relevance such as frequencies, voltages, gains, impedances, etc.

A ROOT script that generates and input file that can be read by AraSim was made, and is stored in GitHub `https://github.com/toej93/AraSim`. The standard output file has Hpol configuration, but it can be modified to produce a Vpol file by substracting 180° from the phase when writing the datafile (should read p-180 in the code).

2.3 Benchmark

Besides producing an output file, the code can reproduce several of the plots in [1] for comparison. As a benchmark check, we plotted the calculated gain, and compared it with the gain stored in the root file. As can be seen in Figure 1, the agreement is evident.

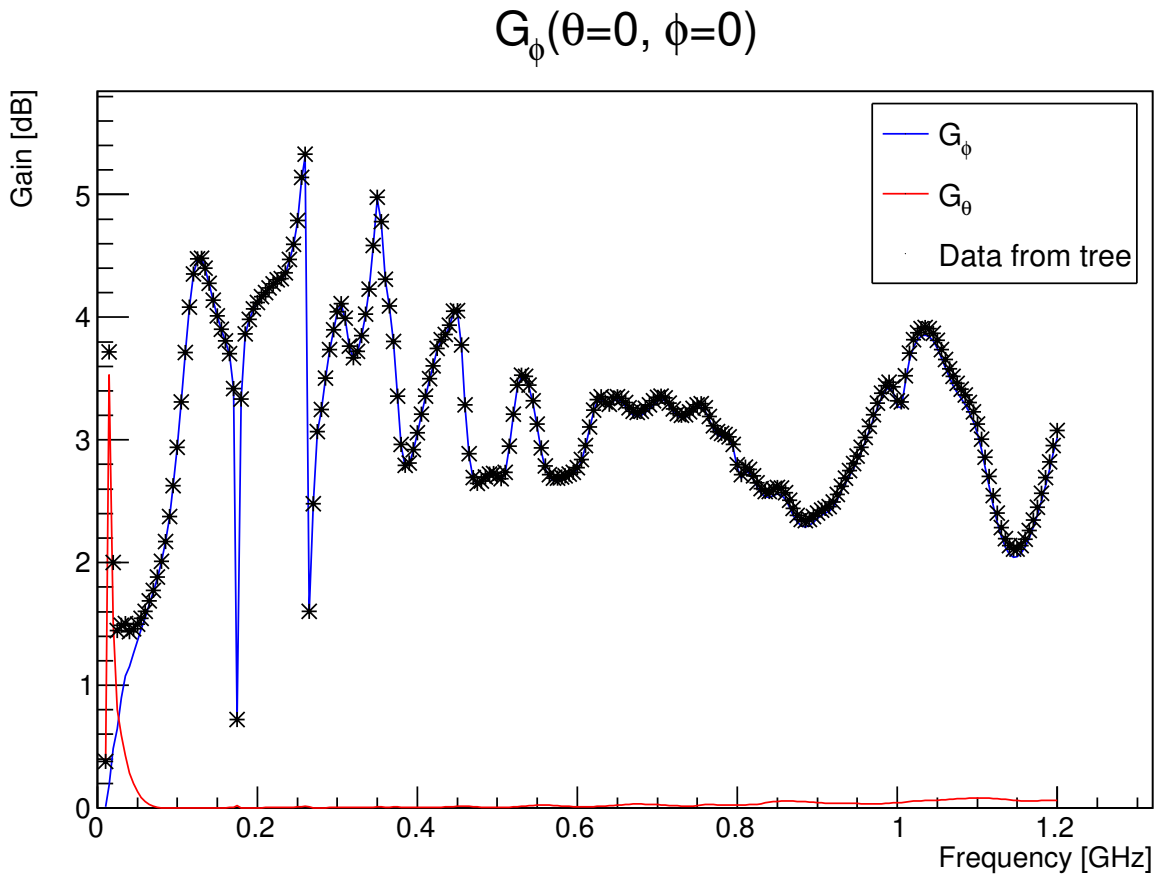

Figure 1: Gain vs. frequency for the ARIANNA antenna model. G_ϕ and G_θ are the components along $\phi = 0$ and $\theta = 0$ of gain in the on-sky coordinate system.

References

[1] S. W. Barwick et al. Radio detection of air showers with the ARIANNA experiment on the Ross Ice Shelf. *Astropart. Phys.*, 90:50–68, 2017.

[2] J.D. Kraus and R.J. Marhefka. *Antennas for all applications.* McGraw-Hill series in electrical engineering. McGraw-Hill, 2002.