MEASUREMENT OF ANTENNA BORE-SIGHT GAIN

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Abstract

The absolute or free-field gain of a simple antenna can be approximated using standard antenna theory formulae or for a more accurate prediction, numerical methods may be employed to solve for antenna parameters including gain. Both of these methods will result in relatively reasonable estimates but in practice antenna gain is usually verified and documented via measurements and calibration. In this paper, a relatively simple and low-cost, yet effective means of determining the bore-sight free-field gain of a VHF/UHF antenna is proposed by using the Brewster angle relationship.

1. Introduction

- Determining antenna gain can be cost and schedule prohibitive especially when evaluating iterative designs
- Measurements in the VHF/UHF range are especially challenging
- By utilizing the Brewster's Angle optics principle, the free field gain of an antenna can be measured and approximated without the need for a costly antenna range

2. Background

- Early on in design, a "Rough Order of Magnitude" antenna gain can be invaluable to assess the viability of a design
- Measurements such as VSWR / Return Loss, while important in design, do not necessarily give an indication of radiation efficiency
- Methods to mitigate or fully understand the effects of multipath is crucial in determining free field antenna gain but can be very costly:
  - Anechoic Facility
  - Precise Ground Plane Construction
  - Antenna Range Calibration

3. Multipath Mitigation Using Brewster's Angle

- Free Space gain of an antenna, G_t, can be measured and calculated as follows
- $G_t = \frac{\left(\frac{ER}{5.47}\right)^2}{P_t}$
  - R = distance from transmit to receive antenna (m)
  - P_t = Power delivered to the transmit antenna (W)
  - E = RMS Electric field (V/m)
  - Only valid when calculating the electric field in free space with no reflections / multipath
- For a vertically polarized plane wave the reflection coefficient, Γ_v, at the dielectric interface of nonmagnetic media can be written as:
- $\Gamma_v = \frac{\frac{1}{\sqrt{\varepsilon_t}}\cos(\theta_t)-\frac{1}{\sqrt{\varepsilon_i}}\cos(\theta_i)}{\frac{1}{\sqrt{\varepsilon_t}}\cos(\theta_t)+\frac{1}{\sqrt{\varepsilon_i}}\cos(\theta_i)}$
- Assuming lossless nonmagnetic media, the Brewster Angle ($\Gamma_v = 0$) is:
- $\theta_B = sin^{-1}\sqrt{\frac{\varepsilon_t}{\varepsilon_i+\varepsilon_t}} = 67.8^\circ$

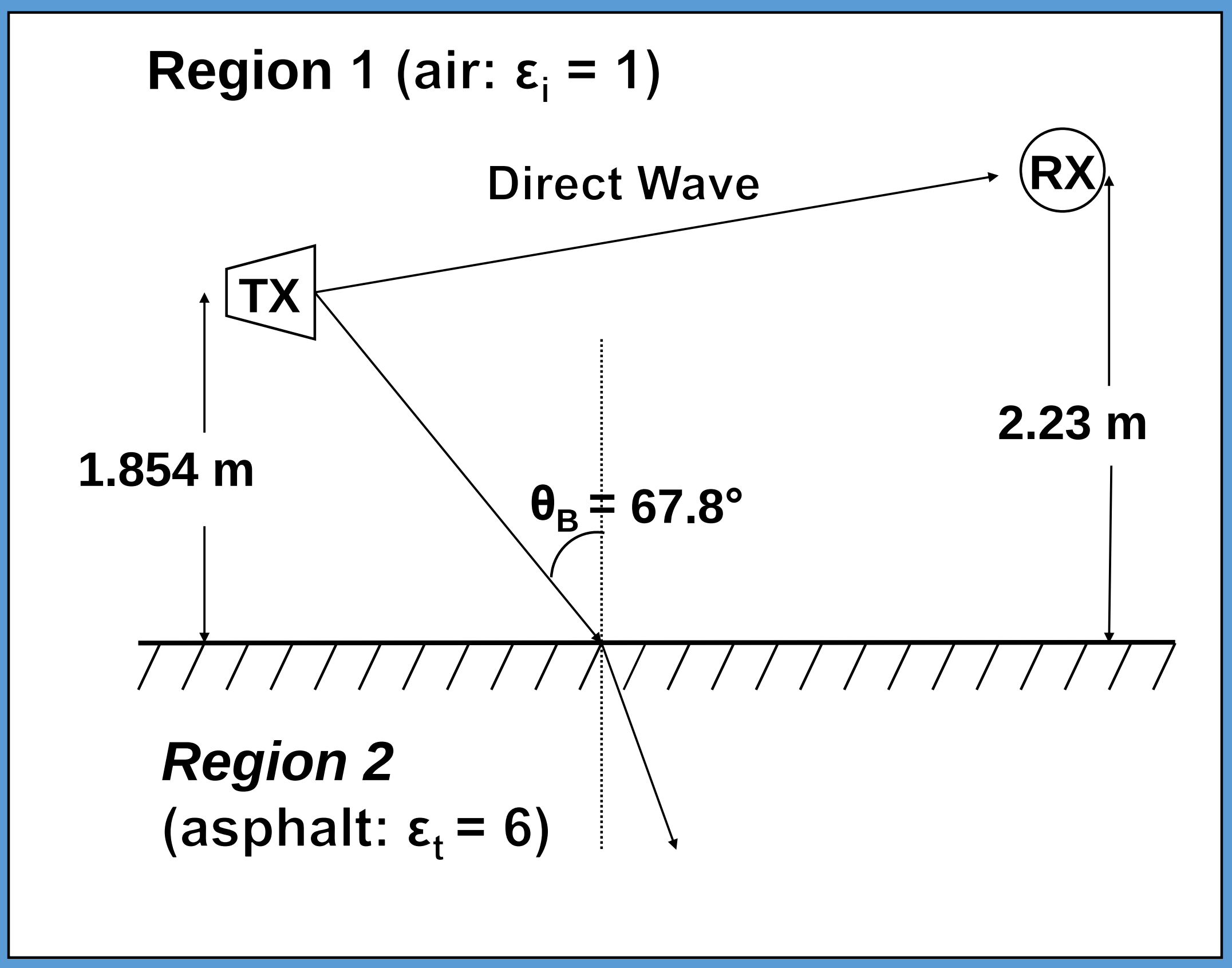


Figure 1. Brewster Angle Measurement Setup

4. Measurement Setup

- Electric Field Measurements taken at an Outdoor Area Test Site over an asphalt substrate ($\varepsilon_t = 6$) with all other obstructions > 200 meters from setup
- Transmit Antenna – Quadruple Ridged Horn Antenna with 1.524 m^2 aperture
- Receiver – Battery-powered E-field probe connected via fiber optic cable to monitor
- E-Field measurements taken using setup shown in Figures 1 and 2. Since only the direct wave reaches the receiver in this setup ($\Gamma_v = 0$) gain shown in Table 1 is calculated using the free space gain equation.

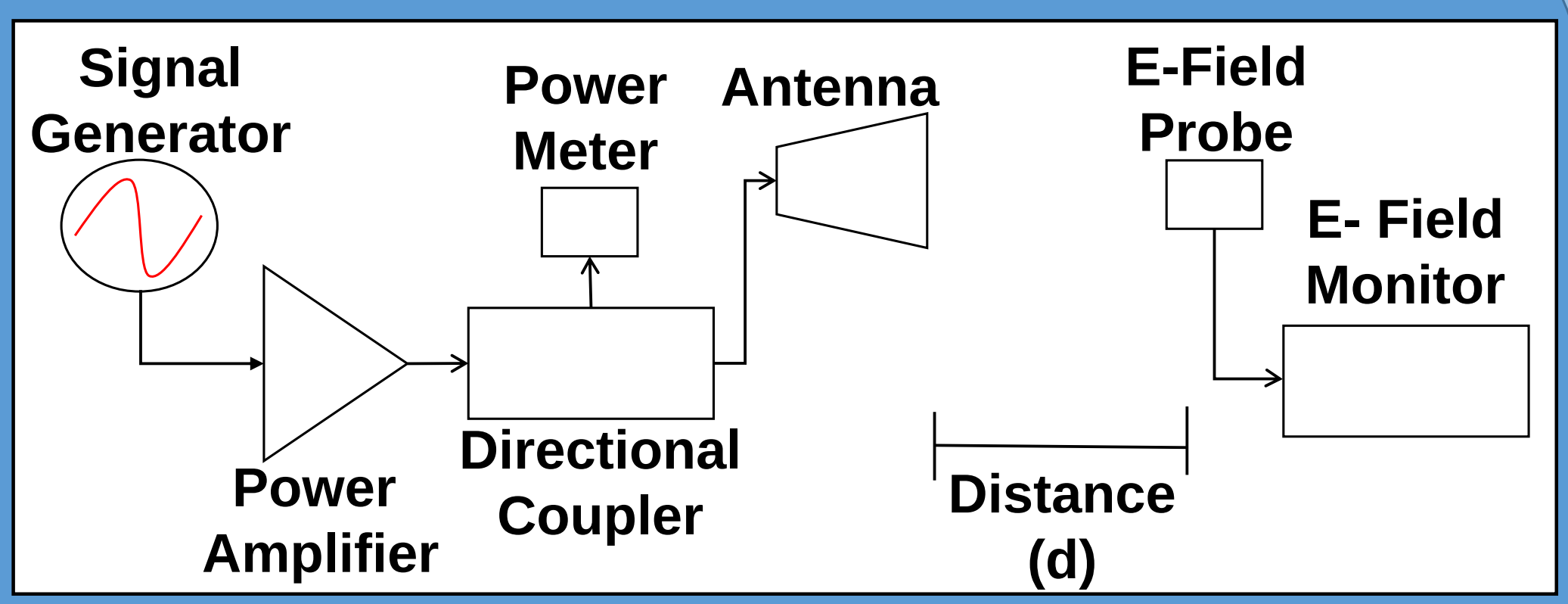


Figure 2. Measurement Setup Block Diagram

Table 1. Free Space Gain

Frequency (MHz)	Gain, G_t, (dBi)
150	6.43
250	6.54
350	9.53

5. Empirical Model Development

- *For a Vertically Polarized Plane Wave:*
- $E_V = Re\left[\left(\frac{5.47}{d_d}\sqrt{P_tG_t cos^n(\alpha 1)}\right)e^{-j\frac{2\pi f d_d}{c}} - \Gamma_v\left(\frac{5.47}{d_d}\sqrt{P_tG_t cos^n(\alpha 2)}\right)e^{-j\frac{2\pi f d_r}{c}}\right]$

Direct Path (d_d)

Gain Correction Factor for off Bore-Sight TX and RX

Reflected Path (d_r)

- Figure 3 shows E-Field Measurement setup:
  - Height of receiver, hrx: 2 – 5.5 m
  - Distance between TX and RX, d: 3 & 10 m
- Gain, G_t, from Table 1 used as model input. Section 6 shows a comparison of the measurement data and the model results.

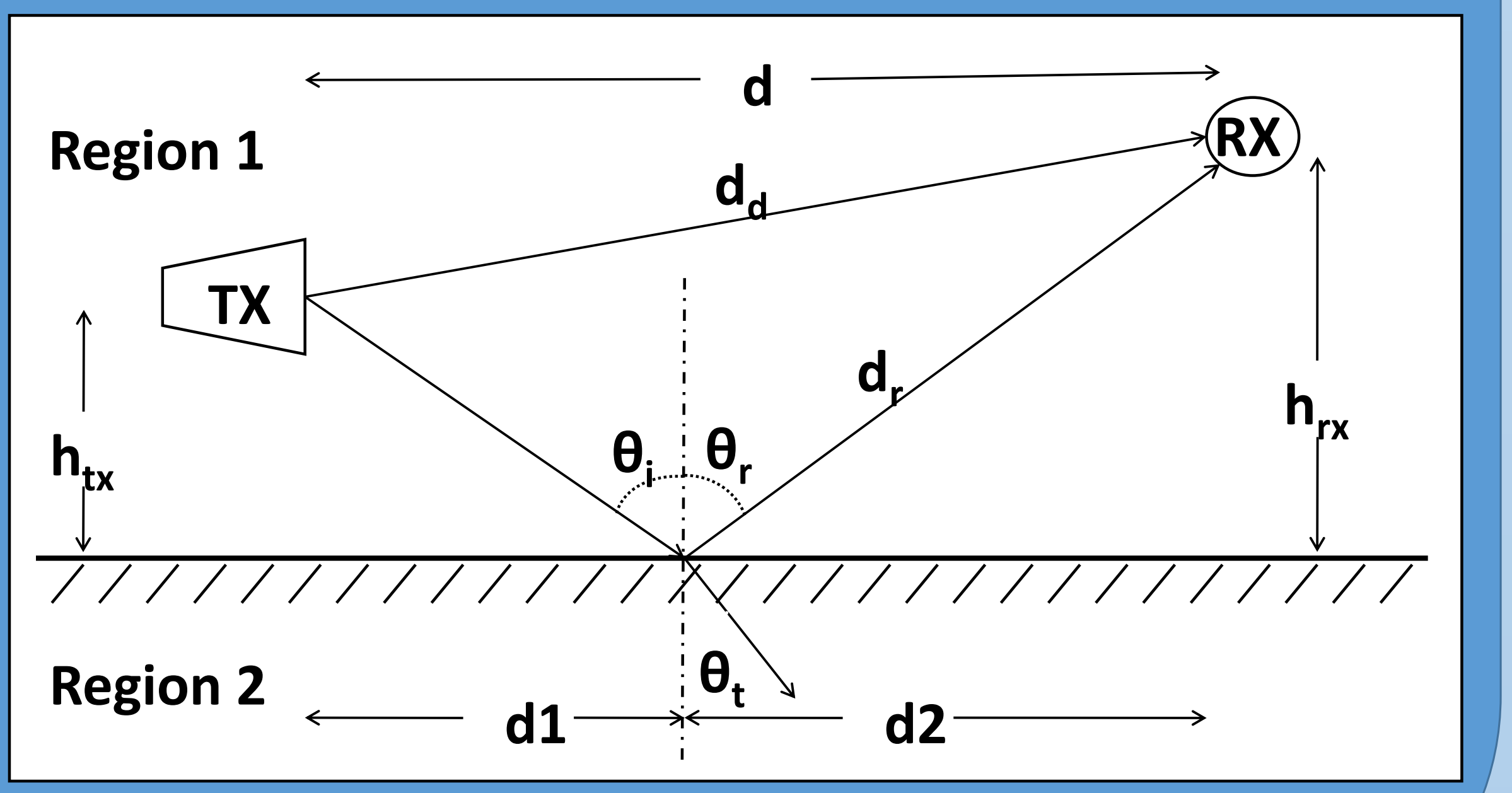
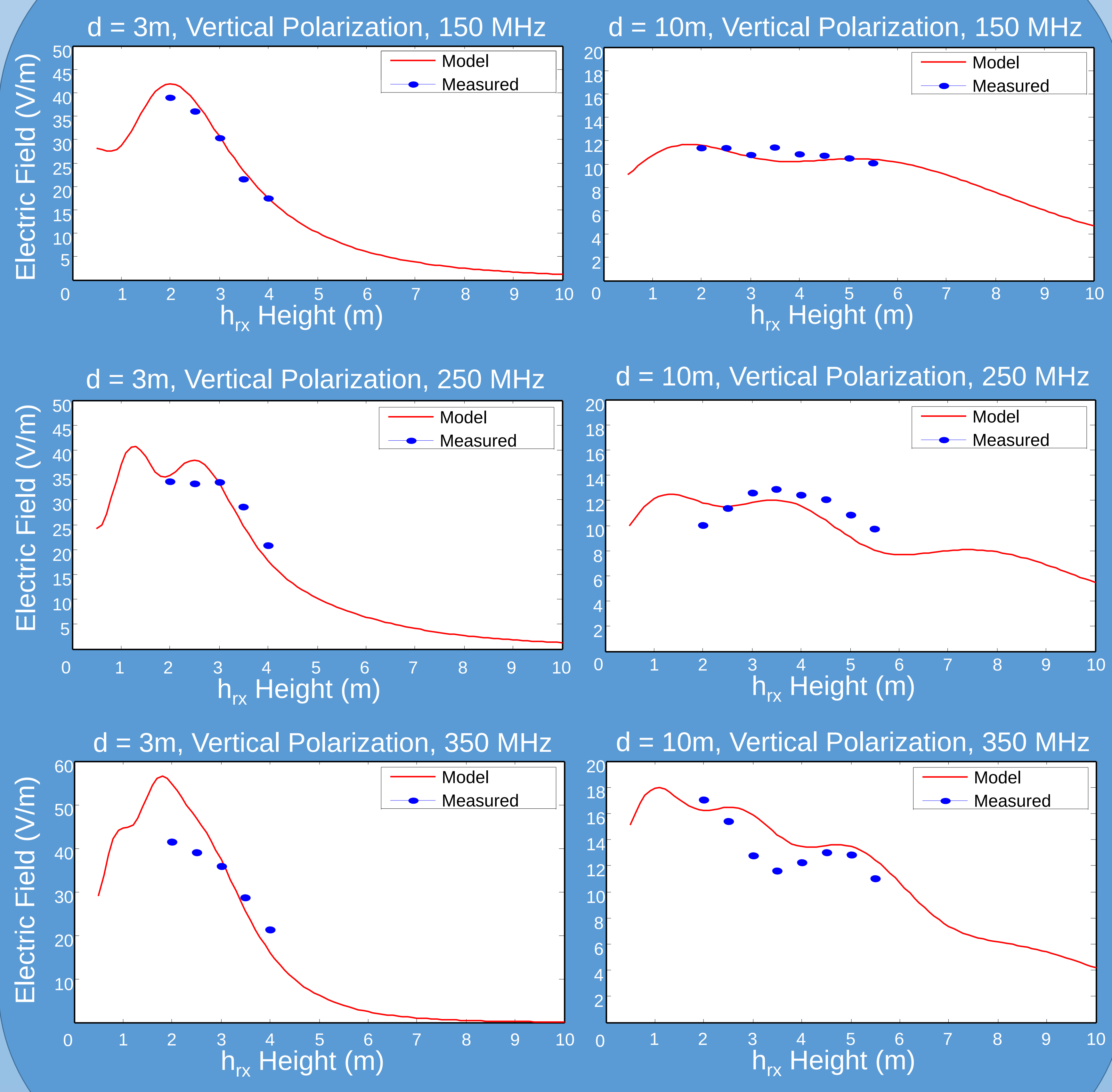


Figure 3. Generic E-Field Measurement Setup

6. Results



7. Conclusions

- The free field antenna gain of a ridged horn was found using the Brewster's angle method to mitigate multipath. The measured electric field results were compared with the calculated results from an empirical model.
- Although the measurements were performed in the VHF/UHF range, this technique could easily be extended into the GHz range using the same principles presented.
- Limitations and Improvements:
  - Only 1 source of multipath can easily be negated using this technique
  - Phase center compensation could improve accuracy. It was assumed that the phase center was at the front edge of the antenna over the entire frequency range.
  - Accuracy could be improved with a better understanding of the ground properties, particularly the dielectric constant as a function of frequency.