ANTENNA RADIATION PATTERNS MEASUREMENTS USING THE MIRROR METHOD IN TIME DOMAIN

Hynek Bartik
Department of Electromagnetic Field, Czech Technical University in Prague
Technicka 2, 166 27 Prague 6, Czech Republic
bartikh@fel.cvut.cz

1. Introduction

Antenna radiation pattern is the spatial distribution of quantity (e.g. power density), which characterizes the electromagnetic field generated by an antenna [1]. Antenna test ranges can be divided into three categories: an indoor or outdoor far-field range, a compact range and near-field range. The far-field range requires a sufficient distance between transmitting and receiving antenna ($R \geq 2D^2/\lambda$, where D is an antenna aperture diameter and λ is a wavelength), which limits frequency of measurement and dimension of measurable antennas inside anechoic chambers. The compact range requires precise parabolic reflector and the near-field range requires high precision equipment for probe positioning.

On the results of previous study of a mirror method antenna gain measurement [4] the application of the mirror method with gating in time domain to antenna radiation pattern measurement seems to be promising. The mirror method of radiation pattern measurement twice reduces length of a test range (in comparison with the traditional far-field range) and this method needs only 1 antenna, simple flat reflector and equipment for time domain measurement.

2. Mirror Method of Gain and Antenna Radiation Pattern Measurement

This method issues from a frequency domain mirror method of gain measurement [2], see Figure 1. The antenna under test (AUT) is placed at a distance of R from the plane reflector and directed to the centre of the plane reflector, which reflects the transmitted energy back to the antenna. The gain of antenna is determined from transmitted power P_T, received power P_R, distance R and frequency. Problems involved with this method for precision gain measurements are numerous (e.g. finite isolation of P_T and P_R, diffractions on the edges of the reflecting plane, undesirable reflections from the neighbouring objects, multiple reflections, losses of reflector, reflector deviation). Gating in time domain measurement eliminates most of these problems. The experiment set-up of the mirror method of gain measurement with gating in time domain is depicted in Figure 2 [4]. If the AUT is placed on a turntable this system will be applicable to antenna radiation pattern measurement.

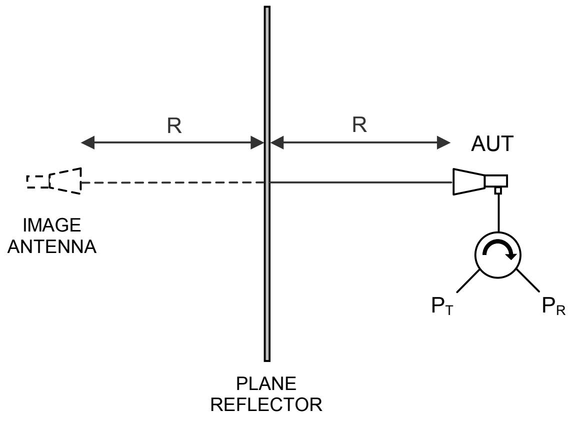

Figure 1. The test configuration for the mirror method of gain determination [2].

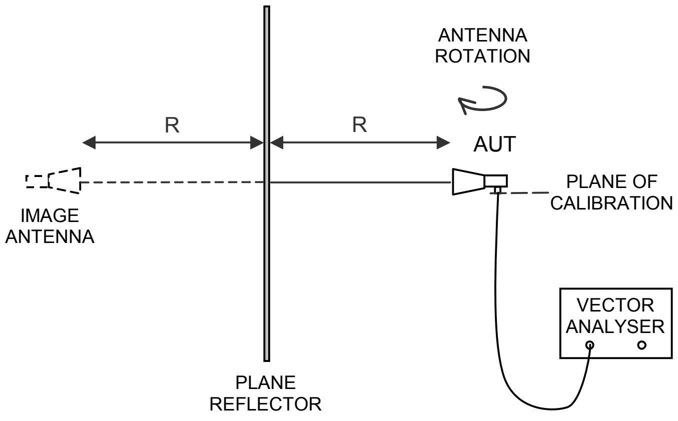

Figure 2. The test configuration for the mirror method of gain and radiation patterns determination with gating in time domain.

ISBN: 89-86522-79-9 94460©KEES

3. Mirror Method of Radiation pattern Measurement with Gating in Time Domain

Modern vector analysers with the Time Domain Option installed [3] allow the transformation of measurements from frequency domain into the time domain (inverse Fourier transformation), removing undesired delayed signals (gating) and the results transformation back to the frequency domain (Fourier transformation). Presented mirror method of the radiation patterns measurements with gating in time domain is based on the usage of the flat reflector and the gating function of a vector analyser (with Time Domain Option), which is set to the antenna reflection coefficient measurement. For every angle of measurement analyser filters out all responses except desired signal, which is returned from the flat reflector to the AUT.

In our experiment double-ridged waveguide horn DRH20 [5] was placed on a turntable at a distance of 5.35 m from the plane reflector with dimensions 2 x 2 m. Measurement of the AUT radiation patterns started when antenna main lobe was oriented backward to the reflector (angle 0°). Vector analyser E8364A was set to the antenna reflection coefficient S11 measurement in frequency band from 2 to 19 GHz. A calibration of vector analyser was performed at the plane of coaxial connector of the AUT to correct possible reflections in coaxial cable and to simply determine a time delay of the signal reflected from the plane reflector. For every angle of measurement the analyser filtered out all responses except desired signal, which was returned from the flat reflector to the AUT. Time domain data responses of double-ridged waveguide horn DRH20 for measurement without gating are depicted in Figure 3 and for measurement with gating from 35.5 to 37.5 ns in Figure 4. The time domain responses in these figures were recorded when the main lobe of the antenna DRH20 was directed perpendicular to the plane reflector surface. The time domain data response of double-ridged waveguide horn without gating contains a number of peaks caused by reflections inside the antenna or reflections from surrounding objects. Significant reflection peak at 36.4737 ns corresponds to the reflection from plane reflector. Corresponding distance 5.467 m includes antenna aperture to reflector surface distance and antenna connector to antenna aperture distance. A gating interval (2 ns) was chosen approximately 2 times wider than optimal set-up, which would suppress signals diffracted on the edges of plane reflector. Reason for this gating set-up was ignorance of position of the AUT phase centre and the effort to eliminate errors caused by changes of the distance between AUT phase centre and reflector during antenna rotation. Figure 5 shows magnitude of the reflection coefficient S11 of the antenna DRH20 obtained from the mirror method with gating in time domain. The determination of the antenna radiation pattern from reflecting coefficient S11 is shown in Equation 1:

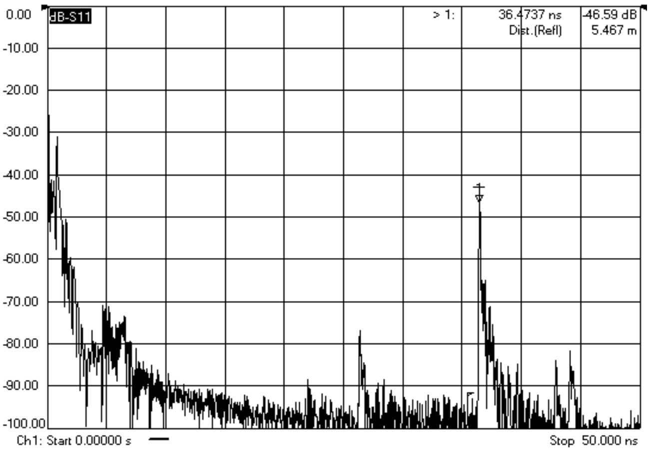

Figure 3. The time domain data responses of double-ridged waveguide horn DRH20 without gating.

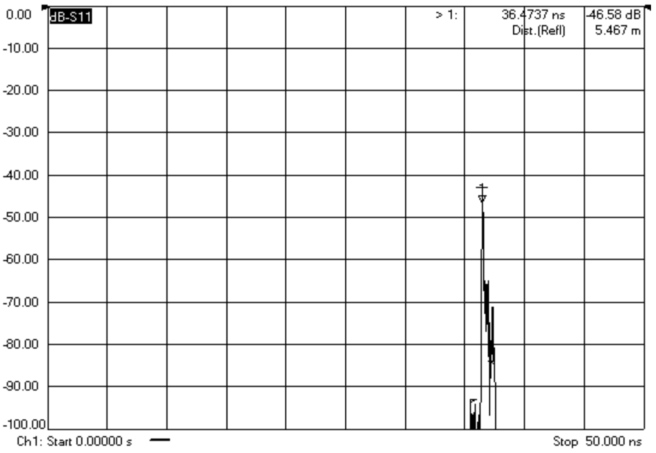

Figure 4. The time domain data responses of double-ridged waveguide horn DRH20 with gating from 35.5 to 37.5 ns.

$$PL_{dB} \approx 0.5 \cdot S11_{dB} \ , \qquad (1)$$

where

PL_{dB} = radiation pattern level of the AUT in dB,
$S11_{dB}$ = gated reflection coefficient of the AUT in dB.

A constant 0.5 represents the fact that a change of signal reflected from the plane reflector is double of the change of transmitted signal (change of the gain of the AUT and also of the image antenna).

Figures 6, 7 and 8 show comparisons of the double-ridged waveguide horn DRH20 radiation patterns measured by a far-field range (full lines) and the mirror method with gating in time domain (discrete points) for arrangement above mentioned.

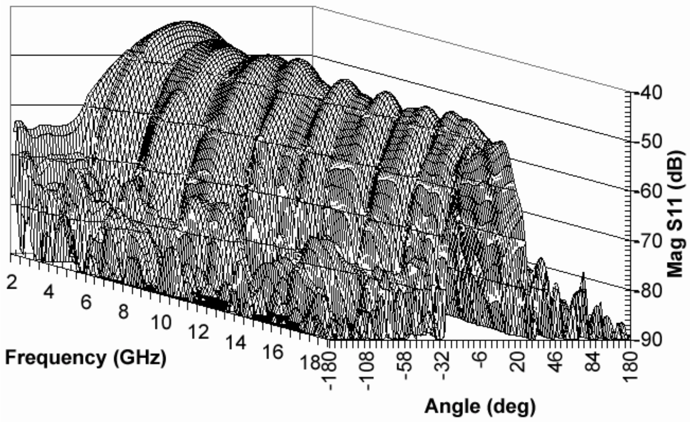

Figure 5. Magnitude of a reflection coefficient S11 of the antenna DRH20, measured using the mirror method with gating in time domain.

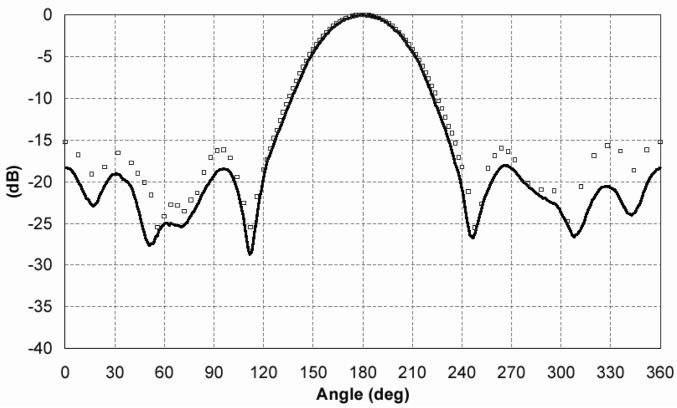

Figure 6. The radiation patterns of the antenna DRH20 at 4 GHz.

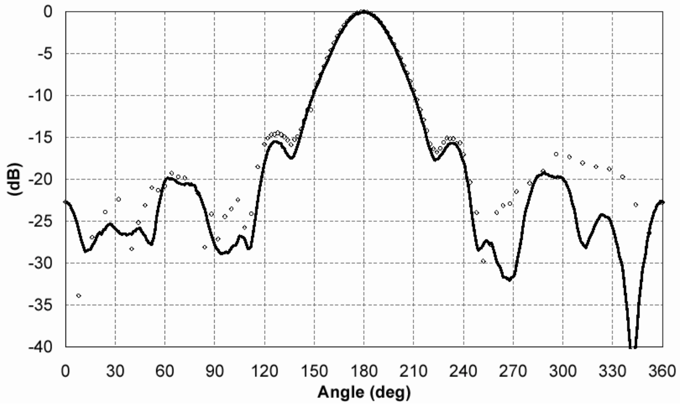

Figure 7. The radiation pattern of the antenna DRH20 at 8 GHz.

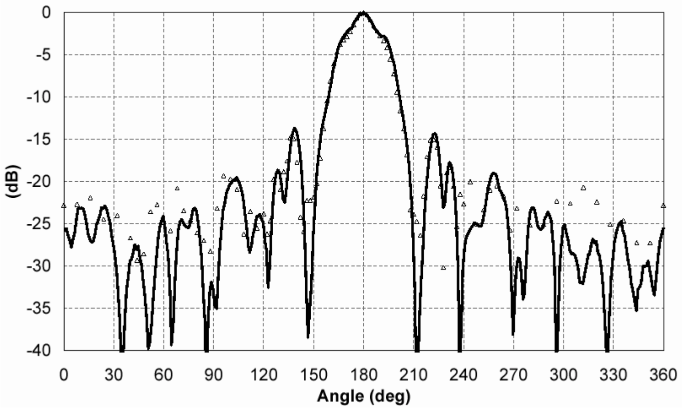

Figure 8. The radiation pattern of the antenna DRH20 at 18 GHz.

The results show good agreement for first 15 - 20 dB of the radiation patterns dynamic range. This limit is mostly caused by a principle of this method (constant 0.5 in Equation 1). The antenna DRH20 could be measured at a minimum distance of 1.1 m from the plane reflector, which would improve the radiation patterns dynamic range (by approximately 13 dB). Another factor limiting the measurable dynamic range is a maximum available suppression of the gated out signals by the vector analyser in a process of filtering in time domain [3].

The main advantages of the mirror method with gating in time domain are its simplicity (single-antenna method), less space requirement, measurement in a full antenna frequency band in a single antenna turn and an ability to filter out undesirable reflected signals (i.e. the measurement doesn't require an anechoic chamber). The disadvantages of this method are a necessity of the flat reflector and an equipment for time domain measurement, a limited dynamic range of obtained radiation patterns and a fact, that presented method is not suitable for the measurement of circularly-polarized (a reflection changes a sense of circular polarisation) and narrow-band antennas (a width of frequency band is proportional to a resolution in time domain).

4. Conclusion

A new method of the antenna radiation patterns measurements, which uses the mirror method in time domain, has been presented. The results show good agreement for low dynamic ranges of antenna radiation patterns. The mirror method with gating in time domain seems to be a promising method for measurements of radiation patterns of ultra-wideband linearly polarized antennas.

Acknowledgement:

This work has been supported by grant No.: GACR 102/02/D054/A “Research of radiating near field antenna measurement including probes correction and time domain measurements” of the Grant Agency of the Czech Republic. This research and publication have been also sponsored by the Czech Ministry of Education, Youth and Sports in the frame of the project Research in the Area of the Prospective Information and Navigation Technologies MSM 6840770014.

References:

[1] Evans, G. E.: Antenna Measurement Techniques, Artec House, London, 1990.
[2] *Microwave Antenna Measurements*, Scientific- Atlanta, Inc. Atlanta, Georgia, USA 1985.
[3] *PNA Series Network Analyser Help*, Agilent Technologies, 2003.
[4] Bartik, H.: Antenna Gain Measurement Using the Mirror Method in Time Domain, WSEAS Transactions on Computers, vol. 3, pp.1882-1883, December 2004.
[5] Double Ridged Waveguide Horn - Model DRH20, www.rfspin.cz, 2005.