Measurement of Antenna Pattern of a Lens Focused Corrugated Horn using Modulated Scatterers

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Abstract

A lens focused corrugated horn antenna has been designed and manufactured for use in a radar to detect land mines. A corrugated horn and a bifocal lens were designed so that it provides an appropriate beam spot size at a certain standoff distance from the antenna. Then, the antenna patterns were measured using the technique of modulated scatterers. An experimental model was developed to validate the antenna performances and the measurement technique. The measured patterns were in good agreement with the theoretically computed patterns.

Keywords : Lens Focused Corrugated Horn Antenna Pattern Modulated Scatterer

1. Introduction

This work is part of project in which a land mine detection system is being investigated that simultaneously uses both electromagnetic and elastic waves. The development of an appropriate antenna for use in the land mine detection system is one of the biggest technical challenges. In general, an open-ended waveguide or a small horn is used as the antenna for the radar system. However, in order to maintain a sufficient spatial resolution (small beam spot size) for the radar, the antenna must be placed within a few centimetres of the target surface. This might cause radar system performance degradation by ground cover such as grass or rocks and the risk to the operator. In this work, a focused lens corrugated horn antenna is studied to obtain a sufficient small beam spot size at a standoff distance. A prototype of the antenna was designed and built. Then a series of measurements was conducted for validation of the antenna performance. In those measurements, the technique of modulated scatterers is introduced to measure antenna patterns. In the middle of 20’s century, Cullen and Parr and Richmond showed that field distributions can be measured by coherently detecting the back scattered signal from a modulated dipole, and by using the reciprocity principle, they showed that the back scattered signal is proportional to the square of the incident electric field at the dipole. Later, the analysis of modulated scatterers was extended by Harrington’s work. Since then, modulated scatterers have been extensively used to measure electromagnetic fields, including antenna patterns.

A lens focused corrugated horn is introduced in section 2. This antenna patterns were measured using the method of modulated scatterers. In section 3, the method of modulated scatterers and the experimental model are presented. A series of measurements is performed to validate the antenna performance and the experimental model. The measurement results are shown in section 4.

2. Lens Focused Corrugated Horn Antenna

For a practical focused antenna, a lens focused conical corrugated horn has been developed for use in the mine detection radar system. A diagram of this antenna is shown in Fig. 1. It consists of a waveguide tuner, a waveguide transformer, conical corrugated horn and a dielectric bifocal lens. The corrugated horn was carefully designed according to a common design with predetermined design parameters. The diameter of the horn aperture is 20 cm, and the design frequency is 8 GHz. The bifocal lens was designed and manufacture with a reflection index of 2.53 and a diameter of 20 cm. The lens has two focal lengths: an inner focal length of 20 cm and an outer focal length of 30 cm. In order to match the impedance between the free space and the surface of the lens, a quarter wavelength matching layer was designed and implemented on both surfaces of the lens. Several techniques of simulating a quarter wave matching have been reported. For this work, corrugated surface with horizontal corrugations were chosen. The lens is then assembled together with the corrugated horn and the waveguide transformer. The antenna is fed from a standard rectangular waveguide, and a waveguide transformer is used to transform the rectangular waveguide to the circular waveguide. The cross section of the transformer changes gradually from a rectangular shape to a circular one. Also, a waveguide-type tuner is used in order to match the antenna by achieving the standing wave ratio (SWR) of the antenna desired for the measurement. The waveguide-type tuner consists of a standard rectangular waveguide and three screws inserted into the waveguide. By rotating these screws, a match can be obtained. This antenna is monostatic so that this antenna functions as both a transmitter and a receiver.

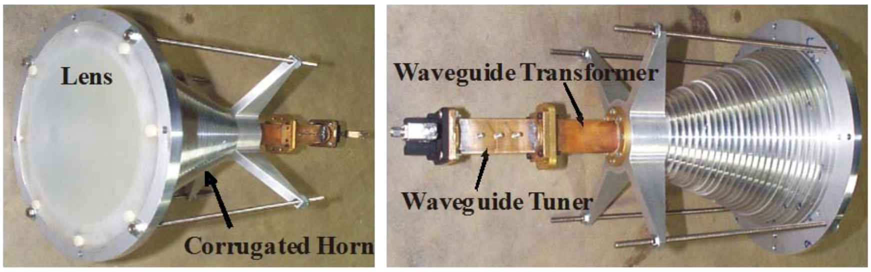

Figure 1: A photograph of the lens focused corrugated horn.

3. Antenna Pattern Measurement using Modulated Scatterers

In general, the antenna patterns represent the radiated patterns (one-way patterns) from the antenna under test (AUT). However, rather than the one-way pattern of the antenna, it is the two-way pattern involving the reflection from a scatterer back to the antenna when the antenna pattern is measured using modulated scatterers. This is because the antenna functions as both the transmitting and the receiving antenna. The two-way pattern can be easily obtained by introducing a scatterer in the presence of the antenna. Let $\vec{E}(\vec{R})$ be the fields at the position $\vec{R}$ radiated by the antenna without the scatterer. When the scatterer exists, the antenna receives the fields scattered back from the scatterer. The two-way pattern can be approximated as $\alpha\left|\vec{E}(\vec{R})\right|^2$, where α is a constant that depends on the size of the scatterer and the details of how the antenna is fed.

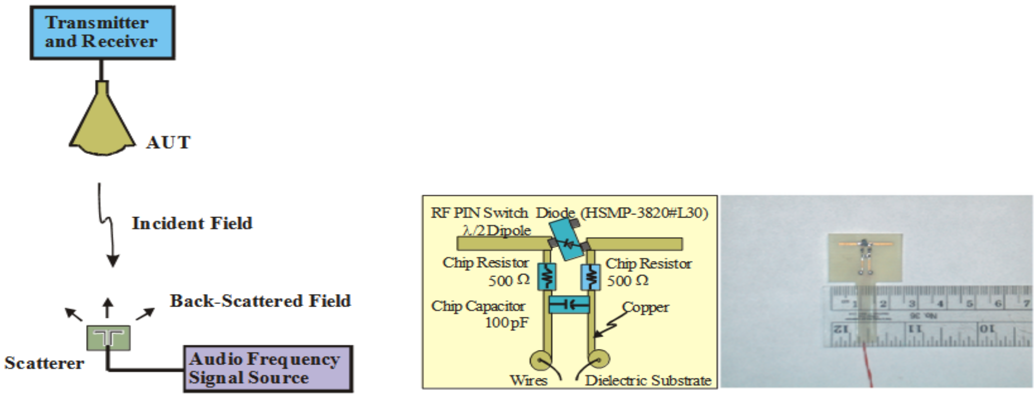

Figure 2: (a) A schematic diagram of the field measurement using a modulated scatterer and (b) Dipole scatterer: schematic and photograph.

Figure 2(a) shows an example of the measurement setup to measure the two way antenna pattern. The setup consists of an antenna under test (AUT), a transmitter and a receiver, a modulated scatterer, and an audio frequency signal source. The scatterer is independently modulated using an audio frequency generated by a modulated source signal. The field incident on a small scatterer is then modulated and back scattered. This back scattered signal is then picked up by the AUT and coherently detected by the receiver. This received signal represents the two way pattern of the AUT because the modulated and back scattered signal depends on transmission from the transmitter to the scatterer, and then from the scatterer to the receiver.

The choice of a scatterer is mainly dependent on the field distribution to be measured and the required sensitivity. The scatterers are normally relatively small in size compared to a wavelength. The commonly used scatterers are short electric dipoles or small loops. In this work, a half wave length dipole has been designed and built as the scatterer. A schematic and a photo graph of the dipole scatterer are shown in Fig. 2(b). It consists of a printed dipole on a dielectric substrate, a diode switch, and a feeding/decoupling circuit. A microwave PIN switch diode is bridged between the arms of the dipole. Chip resistors are used to limit the current driving the diode and as part of a filter. The two resistors are connected to a chip capacitor forming a low pass filter. The filter provides microwave frequency isolation between the dipole and the feed lines. This scatterer is then implemented to measure the two way pattern of the AUT. A schematic diagram and a photo graph of the measurement system are illustrated in Fig. 3. The measurement was conducted by placing the small dipole in the center of a large anechoic surface. The dipole was driven by an audio frequency of 1 KHz with a peak to peak amplitude of 20 volts. The receiver output was recorded at this frequency using two second integration time to build dynamic range above the noise floor. The antenna is placed 20 cm above the modulated dipole scatterer. The AUT was then scanned linearly across the surface. The anechoic treatment assured that the measurement could not be contaminated by a signal or by multiple reflected signals from the ground or from the scatterer. Using the modulated scatterer method, two way patterns of the antenna were measured in a laboratory at the Georgia Institute of Technology.

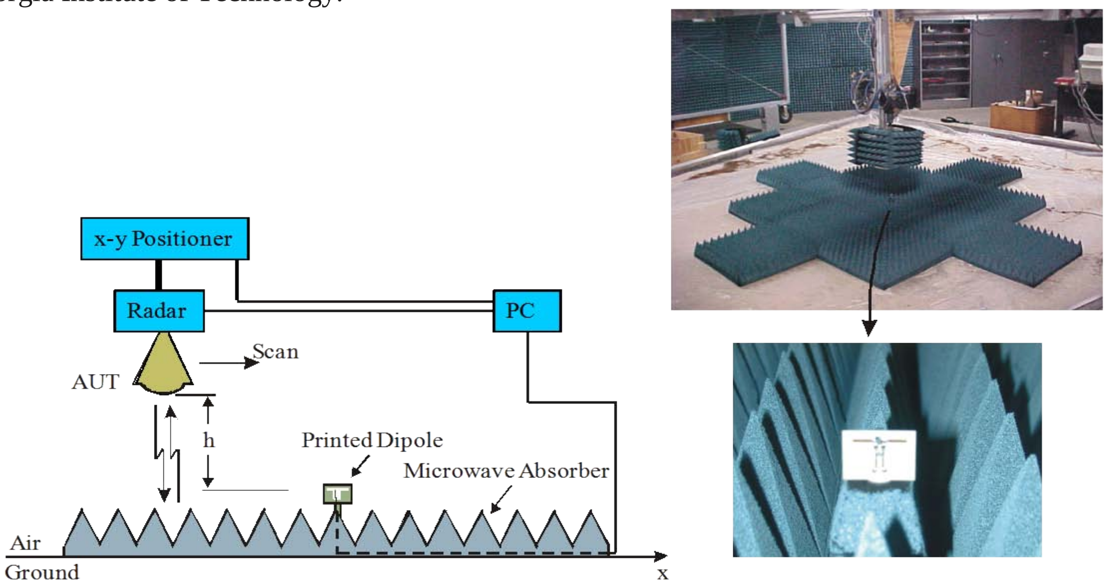

Figure 3: A schematic diagram and a photograph of the measurement setup.

4. Measurement Results

The prototype of the lens focused corrugated horn was tested with a series of experiments. These experiments include the measurement of the two-way pattern of the antenna using modulated scatterers. In order to verify the performance of the antenna and the measurement method using modulated scatterers, the antenna was also theoretically analyzed based on the integral method. The calculated patterns were calculated ignoring the reflections from the lens surfaces. For comparisons, the measured and calculated patterns are plotted together in Fig. 4. The patterns are the two way patterns when the antenna is placed 20 cm above the scatterer. The measurement and calculation for the patterns were performed at the frequency of 8 GHz. In general, the agreement is seen to be good for both E- and H-plane; the first sidelobe levels and the overall shapes of the patterns are in good agreement.

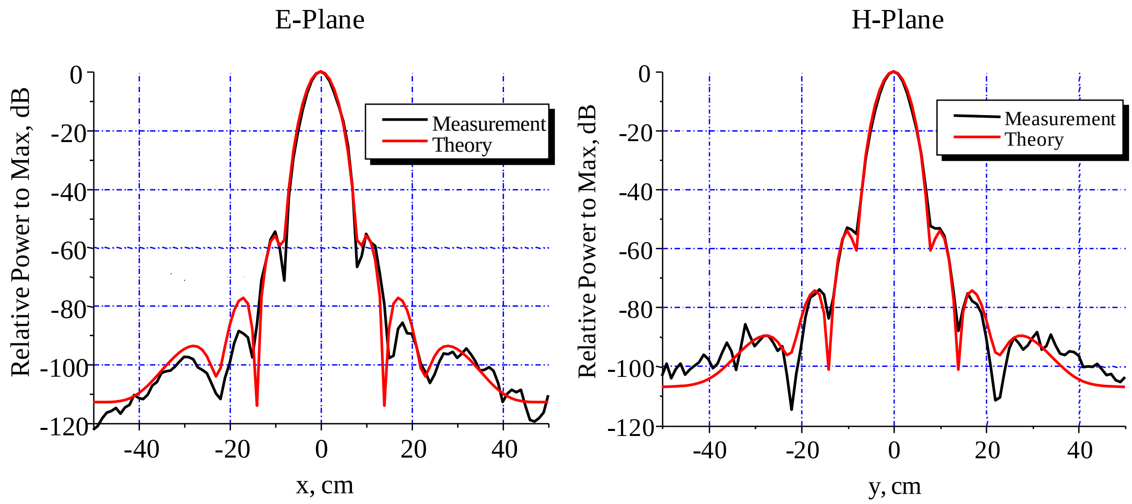

Figure 4: Comparisons between the calculated and measured patterns of the AUT at 8 GHz.

5. Conclusions

A lens-corrugated horn antenna was designed and built. The performance of this antenna was verified by measuring the patterns. For this measurement, a technique of modulated scatterers was used. An appropriate measurement setup was established using a proper scatterer. The results show that the antenna patterns measured using modulated scatterers are in good agreement with the patterns theoretically calculated.

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