Coupling Enhancement of Rectangular Waveguide fed Hemispherical DRA

Jasmine P. M.[1], Dr. Abdulla P.[2], Raphika P. M.[1], Anu A. R.[3], Rekha T. K.[3], Ami Iqubal[3]

[1]*Associate Professor, M.E.S. College Marampally, Aluva, Kerala*

[2]*Professor, School of Engineering, Cochin University of Science and Technology, Kochi, Kerala*

[3]*Research Scholar, Cochin University of Science and Technology, Kochi, Kerala*

***Abstract* – A novel technique for the coupling enhancement of rectangular waveguide fed hemispherical dielectric resonator antenna is presented in this paper. The increased coupling in the proposed technique is due to the steps inserted between the rectangular waveguide and ground plane that acts as an impedance transformer. The cross-polarized signals are at least 20 dB below the corresponding co-polarized signals in the direction of maximum radiation. The antenna maintains a high gain of 5 dBi and above over the entire 10 dB impedance bandwidth. Symmetrical broadside radiation patterns with low cross-polarization levels are obtained.**

Keywords: dielectric resonator antenna, impedance matching, radiation pattern, rectangular waveguide.

I. INTRODUCTION

Dielectric resonator antenna (DRA) is very much suitable for high frequency applications especially in the microwave range due to the absence of conductor loss. In addition to this, DRA offers a number of advantages like small size, light weight, high radiation efficiency and easy integration with active circuitry [1]. Dielectric resonator antenna can be constructed in different shapes like rectangular, cylindrical, conical, split cylindrical and hemispherical. DRAs can be excited with different techniques like coaxial probe, direct microstrip, aperture coupled microstrip, coplanar waveguide and metallic waveguide. However all the coupling mechanisms except metallic waveguide suffer from feed line losses at high frequencies. The metallic walls of the waveguide offer excellent shielding between the interior and exterior regions avoiding radiation loss even at millimeter wave frequencies.

Although a high permittivity DRA can be efficiently excited by an empty waveguide, coupling is very poor with DRAs of low dielectric constant [2]. The poor coupling of direct coupled waveguide fed DRA is due to the inductive susceptance offered by the DRA loaded slot [3]. Therefore different coupling enhancement techniques are to be developed. A second dielectric resonator placed inside the rectangular waveguide close to the slot provides increased coupling [4]. But the overall cost of the system increases due to the additional DRA required and keeping the dielectric resonator inside the waveguide seems to be very difficult. Increased coupling can also be obtained by the use of multi-layer DRA [5]. Even though this technique does not require any extra matching elements, fabrication of multi-layer is difficult. In [6], the narrow wall dimension of the waveguide is reduced by inserting steps at both broad walls in order to enhance the coupling.

In this paper a new technique is suggested to enhance the coupling of direct coupled waveguide fed hemispherical DRA. The inductive susceptance of the DRA loaded slot in direct coupling is overcome by introducing two steps with reduced narrow wall dimension at one of the broad walls. The total number of steps is four in [6], while in the proposed design the total number of steps is only two. The measured resonant frequency is 9.37 GHz with a 10 dB bandwidth of 5.76%. The antenna has a high gain of more than 5 dBi over the entire 10 dB impedance bandwidth. The fabrication complexity of the proposed technique is less compared with other coupling enhancement techniques reported in the literature.

II. ANTENNA CONFIGURATION

Configuration of the proposed rectangular waveguide fed hemispherical dielectric resonator antenna (HDRA) with steps is shown in Fig. 1. The narrow wall dimension at the end of the rectangular waveguide is reduced in two steps. Width and thickness of step1 and step2 are denoted by w_1, t_1 and w_2, t_2 respectively.

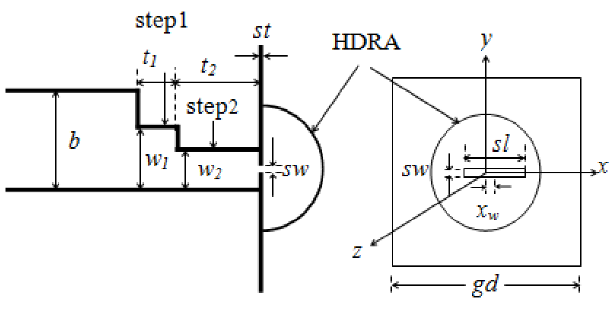

Fig. 1 Configuration of the rectangular waveguide fed HDRA using waveguide steps

The waveguide with steps is terminated by a thick square ground plane, on which a rectangular slot of dimension *sl* x *sw* is cut for exciting the DRA. The proposed technique can implement single, dual and wideband operations without using additional structures. The DRA is placed at the centre of the ground plane for single, dual and wideband operations. The slot is placed at the centre of the ground plane for single band operation and an offset is introduced along the length of the slot to provide dual and wide band operations.

III. SIMULATED AND MEASURED RESULTS

The proposed antenna consists of two resonant structures: DRA and slot. Resonant frequency of a hemispherical DRA is determined by its radius and dielectric constant [7]. In this paper, hemispherical DRA of radius 7.5 mm with dielectric constant 9.8 at 8.74 GHz is used. Since the slot itself acts as a resonant structure, its dimension is to be adjusted to resonate the entire structure at 8.74 GHz. Dimension of the steps plays an important role in matching, while it alters the resonant frequency slightly. WR90 waveguide is used for exciting the DRA in X band. A thorough parametric study has been conducted to find out the optimum value of various parameters.

A prototype of the rectangular waveguide fed hemispherical DRA with steps is fabricated for implementing single band operation using the optimized parameters. The optimum value of various parameters of the proposed structure is: gd = 100 mm, sl = 10.1 mm, sw = 0.8 mm, st = 1.3 mm, w_1 = 7.0 mm, t_1 = 5.5 mm, w_2 = 4.3 mm, and t_2 = 9.2 mm. Photograph of the prototype of the fabricated rectangular waveguide fed HDRA with waveguide steps is shown in Fig. 2. Due to limited fabrication facilities available in our laboratory, the

Fig. 2 Photograph of the fabricated rectangular waveguide fed hemispherical DRA using waveguide steps with gd = 100 mm, sl = 10.1 mm, sw = 0.8 mm, st = 1.3 mm, w_1 = 7.0 mm, t_1 = 5.5 mm, w_2 = 4.3 mm, and t_2 = 9.2 mm

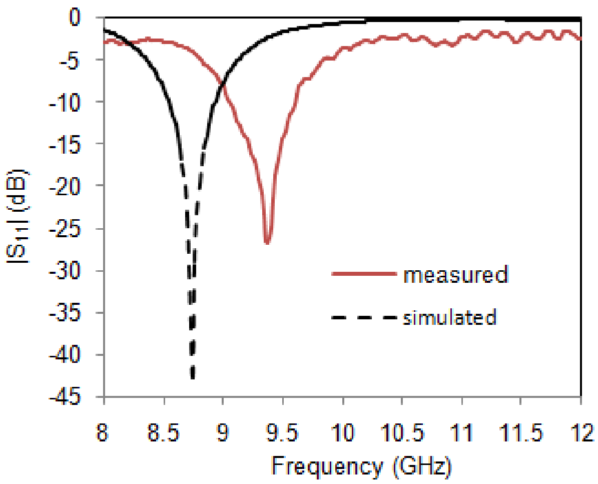

Fig. 3. Reflection characteristics of the rectangular waveguide fed HDRA using waveguide steps

fabricated structure shows uneven air gaps between the ground plane and DRA. The air gap causes the equivalent permittivity of the DRA to decrease, which causes the resonant frequency to increase and the matching to decrease [8]. The measured and simulated reflection coefficient is shown in Fig. 3. The measured resonant frequency of the proposed antenna is 9.37 GHz. with a 10 dB impedance bandwidth 5.76%. Figure 4 shows the measured gain of the antenna. The antenna has a maximum gain of 7.2 dBi at 9.3 GHz with a 3 dB gain bandwidth of 17%. The antenna maintains a high gain of 5 dBi and above over the entire 10 dB impedance bandwidth.

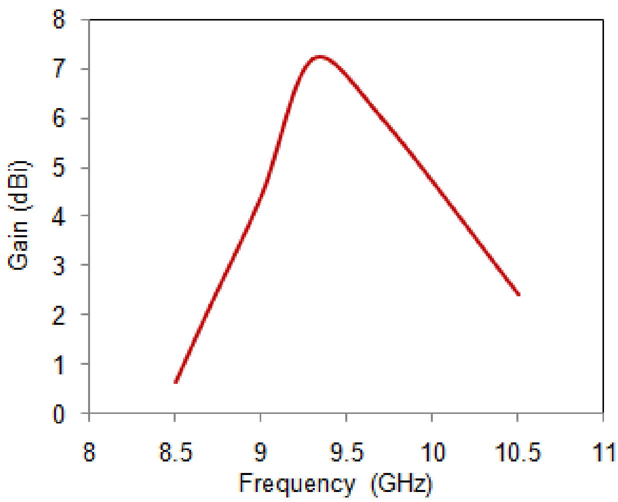

Fig. 4. Measured gain of the rectangular waveguide fed HDRA using waveguide steps

Figure 5 illustrates the measured radiation patterns in the E and H planes at 9.38 GHz. Lower cross-polarization levels are obtained, since the slot is centered under the DRA, which would mitigate the excitation of higher order modes that contribute to cross-polarization levels [9]. Symmetrical broadside radiation patterns with cross-polarization signals at least 20 dB below the corresponding co-polarization signals in the broad side direction are obtained.

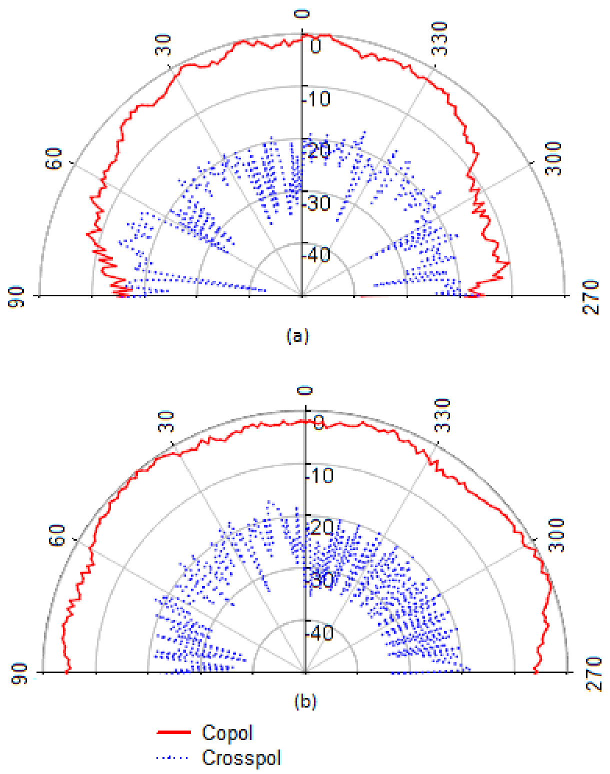

Fig. 5 Measured radiation patterns of waveguide fed HDRA with steps at 9.38 GHz (a) in H plane (b) in E plane

IV. CONCLUSION

A novel coupling enhancement technique of direct coupled waveguide fed hemispherical DRA using steps is presented. Very good coupling is ensured by the proposed technique with reduced fabrication complexity. The rectangular waveguide fed hemispherical DRA with steps has a 10 dB impedance bandwidth of 5.76% measured at the resonant frequency of 9.37 GHz and has a maximum gain of 7.2 dBi. The co-polarized signals are at least 20 dB stronger than the cross-polarized signals in the broadside direction. The proposed technique can be easily extended for millimeter wave range of frequencies.

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