Design of H-slot Dielectric Resonator Antenna using two different dielectric materials for Wideband applications

Madhuri G R
Asst Professor, Dept of Electronics, Kuvempu University, Shimoga

***Abstract* - In this paper, a Dielectric resonator antenna (DRA) consist of H-slot in a rectangular patch is designed and achieved a better performance and operation when the dielectric resonator (DR) of εr1 =11.9 is replaced by DR of εr2 = 37.7. Both H-slot and the dielectric resonator act as resonant structures. The present antenna design technique gives an efficient method for enhancing the bandwidth and gain of the antenna. Antenna parameters such as; radiation pattern and return loss is measured and presented. The proposed DRA provides high gain and large bandwidth for wideband applications.**

***Index Terms* - Dielectric resonator antenna, slot fed, wideband, dielectric resonator, microstrip line**

I.INTRODUCTION

Dielectric resonator antenna is an excellent radiator as it has negligible metallic loss. It offers advantages such as, small size, wide bandwidth and low cost with the exciting feeding techniques. Some common feeding mechanism such as probe feed, aperture slot, microstrip line and coplanar line can be used with DRAs [1]. Bandwidth enhancement methods such as thick substrate, special Dielectric resonator (DR) geometry, slot-fed and stacked DR are used by various researchers [2-3]. Dielectric resonator of any shape can be used for antennas such as cylindrical, hemispherical, rectangular etc [4-7]. Dielectric resonator antennas could be made smaller than their microstrip patch counterparts through the use of high permittivity materials, since the guide wavelength is inversely proportional to the permittivity of the dielectric material,

$\lambda_{dielectric} = \lambda_0 / (\epsilon_r)^{1/2}$ (1)

The microstrip coupling excites the magnetic fields inside the dielectric resonator antenna and produces a horizontal magnetic dipole mode. The degree of coupling depends on the distance of the DRA from the microstrip line as well as its dielectric permittivity [8]. The microstrip stub length, the aperture shape and size as well as its relative position with respect to the dielectric resonator antenna are some of the parameters that can be varied to provide efficient coupling. Finally, an important advantage of the aperture coupling is the previously mentioned possibility to enhance the impedance bandwidth of the antenna by combining the dielectric resonator antenna resonances with the aperture resonances.

A. DIELECTRIC RESONATOR DIMENSIONS

With the understanding of the principle of antennas and its parameters, dielectric resonator antenna can be easily designed. The resonant frequency for the fundamental mode of the rectangular dielectric resonator structure can be roughly estimated from its,

- Dielectric constant (ϵ_r) of dielectric resonator.
- Size of the dielectric resonator (i.e., length, width & height). Increasing the size of the resonator it will resonate at low frequency.
- Structure of conducting walls, which can determine the radiation of the antenna.
- Position, length and the width of the microstripline.

The initial size of the dielectric resonator is calculated using the formulas

$K_x = \frac{\pi}{a}$; $K_y = \frac{\pi}{2h}$ (2)

$K_z \tan\left(\frac{K_z d}{2}\right) = \sqrt{(\epsilon r - 1)K_0{}^2 - K_z{}^2}$ (3)

$K_x{}^2 + K_y{}^2 + K_z{}^2 = \epsilon_r K_0{}^2$ (4)

where a is the length of the resonator, h is the height and d is the width, which are adapted from [9].

In this proposed work, high permittivity DR is used with a suitable feed arrangement to achieve wide bandwidth. The DR centered over a H-slot, which represent the coupling mechanism between resonator and microstrip-line. The shape and size of the slot has significant impact on the strength of coupling between feedline and DR. The study is carried out by using two

DRs of permittivity (ε_{r1} =11.9 and ε_{r2} = 37.7) proving enhancement in gain and bandwidth. The return loss and radiation patterns are measured and presented.

II.DESIGN CONSIDERATION

The proposed antenna geometry of H-slot dielectric resonator antenna is shown in fig.1. The DR fed by the H-slot etched on the ground plane of low cost glass epoxy substrate material. The slot dimensions are calculated in terms of λ_0, where λ_0 is free space wavelength in cm. A 50Ω microstrip feedline with stub obtained in terms of $\lambda_0/6$ is used for impedance matching. At the tip of microstrip feed line a 50Ω coaxial SMA connector is connected for feeding microwave power.

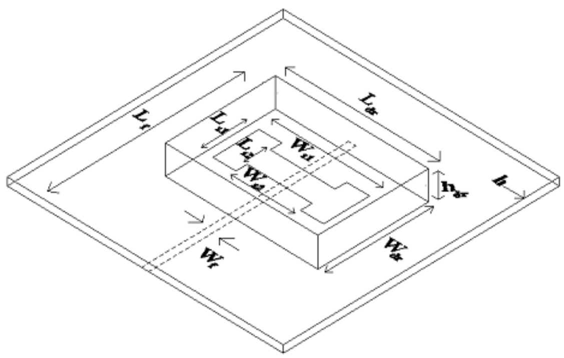

Fig.1. Geometry of H-slot DRA

Fig.1. shows the geometry of H-slot DRA. A rectangular DR of dimension h_{dr} = 3.12cm, w_{dr}= 2.44cm, h_{dr}= 0.6cm, and dielectric constant ε_{dr1} = 11.9 and ε_{dr2} =37.7, is fed by a slot of dimension L_{s1} = 1cm, L_{s2} = 0.5cm, w_{s1} 2.4cm w_{s2} = 1.4cm, which is etched on the ground plane of low cost glass epoxy substrate material having dielectric constant ε_r = 4.2 and thickness h = 0.16cm. The microstrip feedline with L_f = 3cm and W_f = 0.157cm is used for impedance matching.

III.EXPERIMENTAL RESULTS

The comparative study is made between two different antennas, first $HDRA_1$ with ε_{dr1} = 11.9 and $HDRA_2$ with ε_{dr2} =37.7. The DR is placed at the center of the antenna over the H-slot to achieve more impedance matching and control of resonance frequency. The impedance bandwidth over return loss less than -10dB for the proposed antennas is measured. The measurements are taken using Vector Network Analyzer (Rohde & Schwarz, German make ZVK model 1127.8651). Fig.2 shows the return loss verses frequency graph of $HDRA_1$ with ε_{dr1} = 11.9. It is seen from the figure that; antenna resonates for three bands of frequencies (BW_1 to BW_3). The magnitude of each band of frequency is 31.3 %, 5.76 %, and 16.91 % at 8.41 GHz, 12.37 GHz and 15.46 GHz respectively. The overall impedance bandwidth is 53.97 %.

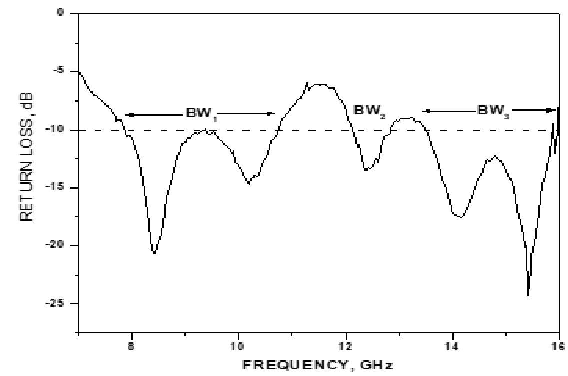

Fig.2: Variation of return loss versus frequency of $HDRA_1$(ε_{dr1} = 11.9)

Below Fig.3 shows the graph of variation of return loss versus frequency of $HDRA_2$ (ε_{dr2} =37.7).

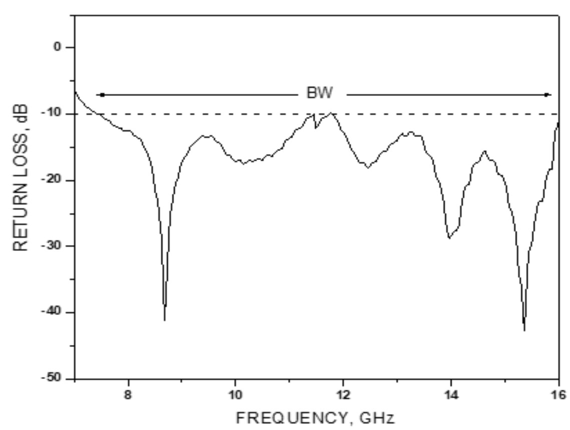

Fig.3: Variation of return loss versus frequency of $HDRA_2$ (ε_{dr2} = 37.7).

It is observed from this figure that, the antenna resonates for single band of frequency (BW) having maximum return loss of -43dB. The magnitude of operating band is 90.04% resonating between 7.39 GHz to 13.88 GHz.

It is clear that the multiple bands of $HDRA_1$ (ε_{dr1} = 11.9) is combined to single wideband by increasing the dielectric permittivity (ε_{dr2} = 37.7) of the dielectric resonator. The X-Y plane co-polar and cross-polar radiation patterns of both antennas are measured at their resonating frequencies.

The radiation patterns of $HDRA_1$ are measured for different resonating frequencies such as 8.41 GHz, 12.37 GHz and 15.46 GHz. The typical radiation pattern of this antenna is shown in Fig.4 (a), Fig.4(b) and Fig.4(c). It is observed that, the pattern is broad sided and linearly polarized and the HPBW is found to be 30^0, dual beam and 25^0 for each frequency respectively. But Fig.4(b) shows the dual beam, which is useful for many communication applications such as satellites etc.

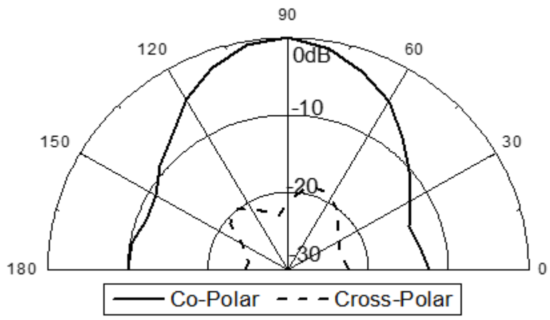

Fig.4 (a) Radiation Pattern of HDRA1at 8.41 GHz

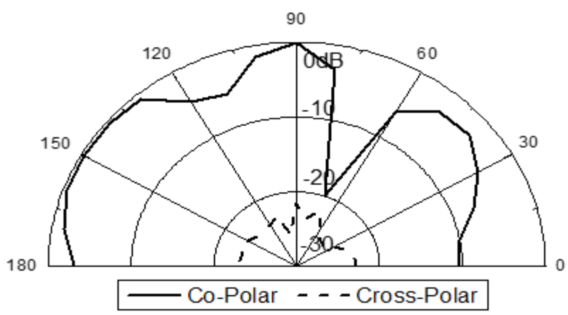

Fig.4(b) Radiation Pattern of HDRA1at 12.37 GHz

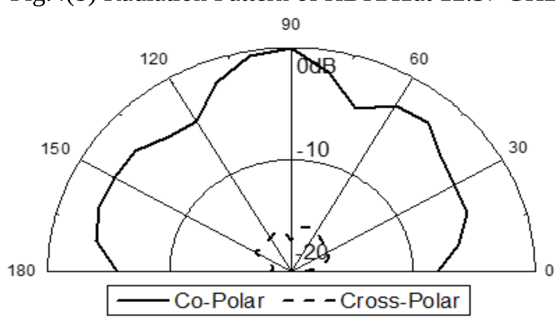

Fig.4(c) Radiation Pattern of $HDRA_1$at 15.46 GHz

The radiation pattern of $HDRA_2$ is measured for its operating frequency such as 15.37 GHz. The typical radiation pattern of this antenna is shown in Fig.5. It is observed from the figure that; the pattern is broad sided and linearly polarized and the HPBW is found to be 83^0.

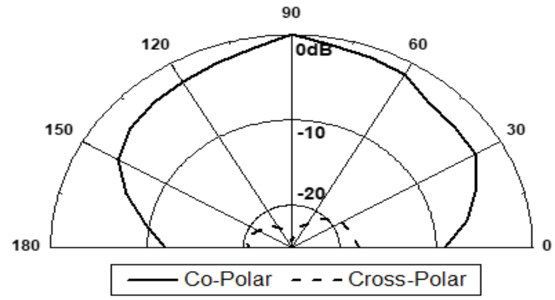

Fig.5:Radiation Pattern of $HDRA_2$ at 15.37 GHz

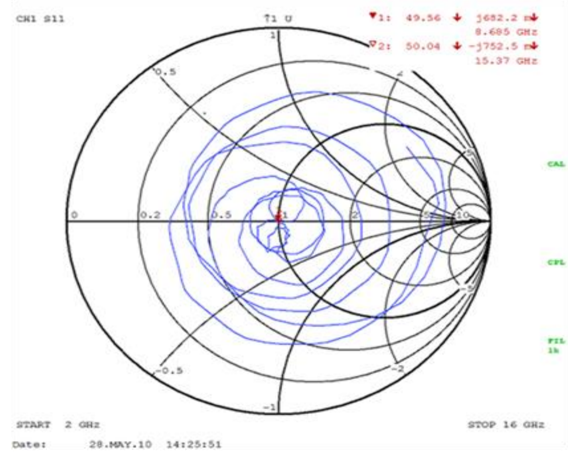

Fig. 6 Smith Chart of $HDRA_2$

IV.CONCLUSION

From the detailed experimental study, it is clear that, the impedance bandwidth and broadside radiation characteristics of HDRA2 are better compared to HDRA1. Hence high permittivity dielectric resonator results in increased gain and bandwidth. Since these antennas are capable of operating at different frequencies, they find applications in frequency agile systems and wideband wireless communication system.

Table: Comparison of Antenna Parameter of $HDRA_1$ and $HDRA_2$

Antennas	Parameters					
	Min return loss in dB	VSWR	HPBW in Deg.	Gain in dB	BW in %	Nature of impedance bandwidth
$HDRA_1$	-20.63 -13.47 -21.99	1.197 1.54 1.194	30 Split 25	4.83 - 1.4	7.66	Dual band
$HDRA_2$	-43	1.017	83	5.02	90.04	Single band

REFERENCES

[1] Petosa A., A.Ittipiboon, Y.M.M.Antar, D.Roscoe and M.Cuhaci, "Recent advances in dielectric resonator antenna technology," IEEE Antennas &PropagMagz, 40, (1998) 35.

[2] Madhuri R G, "A wideband stacked rectangular dielectric resonator antenna", Microwave and optical technology letters, Vol.52, No.11, Nov 2010.

[3] Madhuri R G, "Bandwidth enhancement of slot-fed dielectric resonator antenna", Microwave and optical technology letters, Vol.52, No.2, Feb 2010.

[4] Madhuri R G, "Design of high permittivity rectangular dielectric resonator antenna", microwave optical technology letters, Vol. 53, No.5, May 2011.

[5] Kishk A. A., "Applications of rotated sequential feeding for circular polarization bandwidth enhancement for planar arrays with single-fed dielectric resonator antenna element," IEEE Antennas &Propag Society. Int. Symp., 4, (2003) 664.

[6] Qinjang Rao, T. A. Denidmi and A. R. Sebak, "Study of broadband dielectric resonator antennas," Progress in Electromag. Research Symp., China, 2005.

[7] Praveen kumar A. V., V. Hamasakutty, J. Yohannan and K. T. Mathew, "Microstrip fed cylindrical dielectric resonator antenna with a coplanar parasitic strip," PIER 60, (2006) 143.

[8] R. K. Momgia & P. Bhartia, "A review and general design relations for resonant frequency and bandwidth", Int. Journal of Microwave and Millimeter-Wave Computer Aided Engineering, Vol. 4, No.3, pp. 230-247, 1994.

[9] G. Drosses, Z. Wu and L. E. Davis, "Theoretical and experimental investigations on a microstrip-coupled cylindrical dielectric resonator antenna", Microwave and Optical Technology Letters, Vol. 21, No. 1, pp. 18-25, April 1999.

[10] Leung K. W and H. K. Ng, " The slot-coupled hemispherical dielectric resonator antenna with a parasitic patch: Applications to the circularly polarized antenna and wide-band antenna," IEEE Antennas and PropagMagz., 53, (2005)1762.

[11] Luk K. M. and K. W. Leung, Editors, Dielectric resonator antennas, (Research Studies Press Ltd, Hertfordshir, England, UK), 2003.

[12] Rezaei. P, M. Hakkak and K. Foreoraghi, " Design of wideband dielectric resonator antenna with a two-segment structure," PIER 66, (2006) 111.

[13] Chair R., A. A. Kishk and K. F. Lee, " Wideband simple cylindrical dielectric resonator antennas," IEEE Microwave and wireless comp. Lett., 15, (2005) 241.

[14] Petosa A., N.Simons, R. Sinshansion, A. Ittipiboon and M.Cuhaci "Design and analysis of multisegment dielectric resonator antenna," IEEE Trans. Antennas Prop., 48, (2000) 738.

[15] Clent M and L.shafi, "Wideband single layer microstrip antenna for arrayapplications," Electron lett., 25, (1999)1292.

[16] Kishk A. A., Y.Yin and A.W.Glisson "Conical dielectric resonator antennas for wideband applications," IEEE Trans Antennas &Propag, 50, (2002) 469.

[17] Leung K. W.s, K. K. Tse, K. M. Luk and E. K. N. Yung, "Cross-polarization characteristics of a probe-fed hemispherical dielectric resonator antenna," IEEE Trans Antennas &Propag., 47, (1999) 1228.

[18] Amelia B, Kamal S and H. Mosallaei. "Compact slot and dielectric resonator antenna with dual-resonance, broadband characteristics" IEEE Tran .Antennas&Propag, 53, (2005)1020.

[19] K. Mongia, A. Ittibipoon and M. Cuchaci" Low profile dielectric resonator antennas using a very high permittivity material," Electron lett, 30, (1994) 1362.

[20] Makwana G. D and K. J. Vinoy, " A microstrip line fed rectangular dielectric resonator antenna for WLAN applications," IEEE Int. Symp on Microwave, ISM, Bangalore, 2008.

[21] Chaistopher. S. D. Y and S. A. Long, " Investigation of dual mode wide and rectangular and cylindrical dielectric resonator antennas," IEEE Antennas &Propog Society Int. Symp., 2005.