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High Gain Conformal Super High Frequency Antenna

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Abstract-
A high gain conformal antenna is proposed having E-shaped patch to be used in SHF frequency range. A comprehensive parametric study has been carried out to understand the effects of various dielectric substrate effects and to optimize the performance of the antenna. For various substrate materials the effect of dielectric constant, loss tangent, mass density, bulk conductivity is observed .Results are compared in two simulation software and found in good agreement.
Key Words- Conformal antenna, tri-band ,high gain, E-shaped Patch.

I

Now a days SHF frequencies occupy a "sweet spot" in the radio spectrum which is currently being exploited by many new radio services. They are the lowest frequency band where radio waves can be directed in narrow beams by conveniently sized antennas so they do not interfere with nearby transmitters on the same frequency, allowing frequency reuse. On the other hand, they are the highest frequencies which can be used for long distance terrestrial communication. Conformal antenna attracting wide acceptability in field of antenna design due to its low profile, small size and ease of handling. **.** A characteristic phenomenon of patch antennas Conformal to curved platforms is the dependence of resonant input impedance on surface curvature [10]. Understanding how surface curvature affects the input impedance and resonant frequency is crucial for matching with the feed network and efficient radiation. In light of this, it is vital that conformal antenna models include surface curvature so that the effect of surface geometry on their performance can be predicted more accurately.

As wireless systems continue to enjoy increased application and gain wider acceptance, performance and cost constraints on the antennas employed by these systems become more difficult to meet. Antennas that are conformal or low profile and that exhibit ultra wideband operation are of particular interest for many of these new systems. Concomitant with increased performance levels is the need for antenna designs with the potential for low cost manufacturing. To address the requirements and the severe constraints imposed by commercial application of these antennas, new innovative antenna design methodologies are required. To date, most new wireless system antenna designs have been derived from existing canonical designs such as the monopole and wavelength patch antennas.

Various feeding mechanism has been studied this far such as micro-strip line ,coaxial probe, aperture coupling and proximity coupling[1],[2],[3],[4],[5],[6][7].Here in this paper a cylindrically conformed version of E-shaped patch antenna[20] is proposed which is the extended work of previously proposed E-shaped planar antenna[9] Waveguide feeding is proposed in this paper. The advantages of an antenna that resembles the shape of the object to which it is attached are obvious. Some thinner varieties of microstrip that are commercially available today can change from their planar shape to represent some part of a cylinder [2].

The antenna proposed in this work is derived from a previously designed E-shaped planar antenna and being conformal it is having bandwidth better than the previous one. Different dielectric constant are examined to obtain desired characteristics and result are compared in HFSS and CST Microwave studio. The results are in good agreement the role of dielectric constant is to shift of resonant frequency.

The paper is organized as follow. Section II deals with designing of patch and the antenna.III deals with study of different dielectric materials. IV is for results and discussion and V deals with conclusion.

II

In [9] designing of a patch antenna includes first taking a rectangular patch according to the formula of length and width of a rectangular patch:

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{v_0}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad \ldots\ldots\ldots(1)$$

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{reff}} \sqrt{\mu_0 \varepsilon_0}} - 2\Delta L \quad \ldots\ldots\ldots\ldots(2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad \ldots\ldots\ldots\ldots\ldots(3)$$

Where the dimensions of the patch along its length have been extended on each end by a distance *ΔL*, which is a function of the effective dielectric constant ε_{reff} and the width to height ratio (*W/h*), and the normalized extension of the length, is

$$\Delta L = 0.412\, h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Here ε_r is relative permittivity, μ_r is relative permeability and v_0 is free space velocity of light. After defining patch dimension parallel slots are incorporated to exite second resonant frequency the dimension of the patch in this work is the same instead the outer U-shaped structure[] is removed only inner E-shaped patch is left.

This paper deals with conforming the same patch on a cylinder of 60mm diameter and inner radius 58mm providing an SHF antenna. This structure provides high gain and good directivity as compared to the previous design.

III

In this work effects of dielectric materials and loss tangent are examined and discussed as in the obtained results we can see how the increased permittivity leads to shifting of the resonant frequency to a lower side.

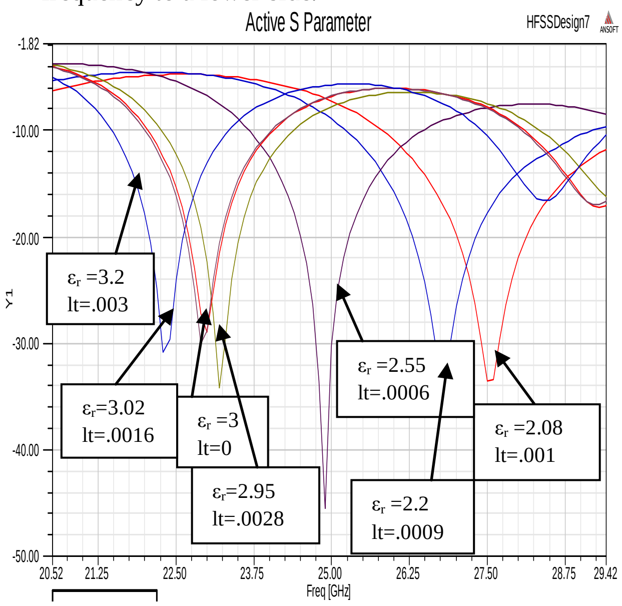

Fig 1: Return loss S_{11} for various dielectric materials and loss tangent from HFSS

The above result for various permittivity and loss tangent is seen and with the increment in the permittivity the frequency shift could also be seen. Loss tangent also plays a significant role as it adds to better the return loss. As could be seen from the equation (1) resonant frequency is inversely proportional to the permittivity so as the permittivity increases the resonant frequency decreases and shifts to lower frequency in SHF range. At the same time loss tangent is also considerable with the increase in loss tangent return loss increases so to reduce it, loss tangent should be less.

The results obtained are also analyzed in CST STUDIO and good agreement between the two is obtained.

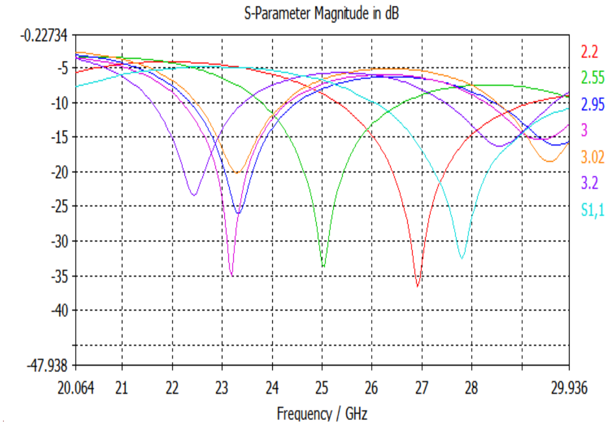

Fig 2.S_{11} Plots for different dielectric constant in CST STUDIO

IV. Results and discussion

The results obtained in this work for various dielectric constant are according to the needed specification. The radiation pattern shown in figure 1(HFSS) and in figure 2(CST STUDIO) shows that with the effect of increasing dielectric constant the resonant frequency shifts to a lower frequency band . Obviously if operation in a lower band is needed than the substrate of higher dielectric constant should be used at the same time if loss tangent is less return loss would be low and so gain improves.

One more thing to be considered is if the substrate has good conductivity and mass density it leads to enhance the gain as compared to other low loss tangent substrate. In this work the substrate rubber is having bulk conductivity as $1e^{-015}$ siemens/m and mass density as 1190 so is having better gain as compared to the low loss tangent material Taconic TLY which is having loss tangent as 0.0009 .

The table showing gain for all the used substrates are given below:

Table 1

S. N .	Substrat Material	Bulk conducti-vity	Mass Densi ty	permitti vity	Gain
1.	Teflon	0	0	2.08	10.301
2.	Taconic	0	0	2.2	10.136
3.	Taconic	0	0	2.55	9.89
4.	Taconic	0	0	2.95	8.98
5.	Rubber	$1\ e^{-015}$	1190	3	9.13
6.	Roger	0	0	3.02	8.86
7.	Taconic	0	0	3.2	7.28

The same effect could be seen in case of efficiency also as it also improves with low loss tangent and significantly for mass density and conductivity as shown below:

Table 2

S. N	Substra -te Materia l	Bulk conducti vity	Mass Dens ity	permitti vity	Efficie ncy
1.	Teflon	0	0	2.08	.8585
2.	Taconic	0	0	2.2	.84
3.	Taconic	0	0	2.55	.82
4.	Taconic	0	0	2.95	.746
5.	Rubber	$1 e^{-015}$	1190	3	.6803
6.	Roger	0	0	3.02	.7715
7.	Taconic	0	0	3.2	.7486

V. Conclusion

The above discussion of work concludes that the proposed antenna is good in terms of its structure in providing high gain antenna. Due to its compact size and conformability it is convenient to handle. In this work various aspects of different substrate are discussed and found good to provide desired specification. This structure is studied in terms of dielectric constant, loss tangent, mass density and bulk conductivity to obtain better gain reduced return loss and directivity.

The maximum directivity obtained is shown in the figure below:

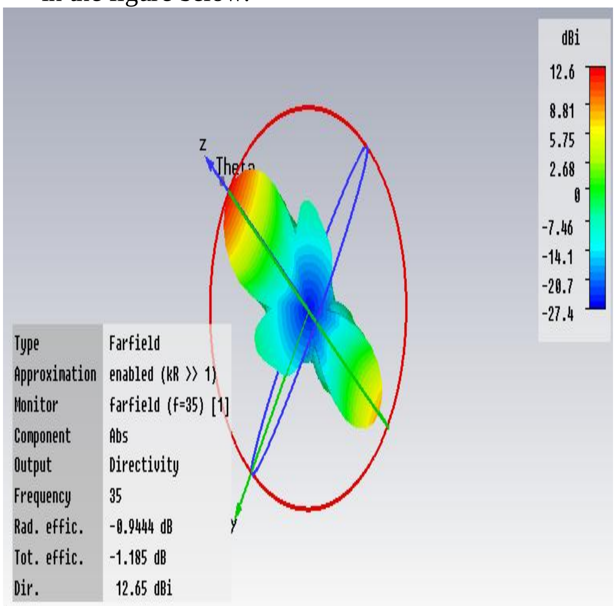

Fig.3 radiation pattern maximum directivity in z direction

It is concluded that to provide low return loss dielectric loss tangent should be low and at the same time good gain is possible for same patch dimension with reducing dielectric constant. With the invent of mass density and conductivity gain could be improved also with improved efficiency. This patch after conforming provides good gain and efficiency though no mazor improvement in bandwidth. For lower band operation the dielectric permittivity should be large.

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