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Study of electromagnetic coupled microstrip patch array antenna for bandwidth enhancement

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Abstract

In this communication a sixteen elements microstrip array antenna of rectangular patches is presented which is feed by source of 10 GHz with electromagnetic coupled feeding technique for the study of enhancement of Bandwidth. The patches are printed on the RT-duroid substrate. The radiation patterns for E-plane, H-plane and array geometry has been plotted and presented here. The radiation parameters of this array antenna are also compared with the same array antenna configuration without using electromagnet coupled technique. Comparison shows that the electromagnetic coupling has provided around 41% enhancement in bandwidth compare to simple patch antenna.

Keywords: rectangular patch microstrip array antenna, RT-duroid, electromagnetic coupling, bandwidth enhancement

1. Introduction

Broadening the bandwidth and search for new microstrip configuration with wider bandwidth has been a dominant feature of today's research and much effort continues to be extended. Compact circuit designs are typically achieved in high-index material which is in direct contrast to the low-index substrates imposes by high bandwidth antennas. The solution requires the capability to integrate the planer antenna on electrically thick low index region while the circuitry remains on the high index region. Thus, to integrate patch antennas into circuit designs on high index substrates without losing the advantages of low index materials, the regions in the substrate which will house the redacting element must have low index of reflection. This can be achieved by using electromagnetic coupling, aperture coupling and by using micro-machining to eliminate a portion of the substrate material (Chew, 1982; Sabban, 1983; Palanisamy and Gart, 1985; Papapolymerus *et al.*, 1988) [4, 11, 7, 8].

2.1 Materials and Methods

2.1 Theory

The bandwidth of an antenna in a practical system depends upon how severe an effect the variation of the antenna characteristic with frequency has upon the overall system performance (Pues and Van de Capelle, 1989; Bahl and Bhartia, 1990; Wong and Hsu, 1997) [10, 2, 14].

$$BW = \frac{f_2 - f_1}{f_r} \qquad (1)$$

Where, f_r is the resonant frequency

At resonance, the patch input impedance is real. Let its value be R_0. When it is connected to a transmission line with characteristic impedance, Z_0, the bandwidth can be expressed as

$$BW = \frac{1}{Q}\sqrt{\frac{(TS-1)(S-T)}{S}} \qquad (2)$$

Where $T = R_o/Z_0$ For the antenna fed with microstrip line and uses a quarter wave transformer connected to the patch edg and for the probe fed patches, the above expression in Equation 2 reduces to

$$BW = \frac{1}{Q}\frac{(S-1)}{\sqrt{S}} \qquad (3)$$

The scope of this research is to improve the bandwidth of microstrip antenna, thus, some of the important wide band techniques are listed below (Hall *et al.*, 1979; Derneryd, 1981; Pues, 1989; Bahl and Bhartia, 1990; Sze and Wong, 1999; Sze and Wong, 2000; Mann, 2004) [6, 5, 9, 2, 12, 13, 7].

- Using low dielectric thick substrate
- Using non regular shaped antennas
- Using Impedance matching network
- Using Multilayered configuration
- Using air gap configuration
- Using micromachining technique
- Using electromagnetic coupling
- Using aperture coupling

All of these techniques have their own merits and demerits, for example, using thick substrate, does increase the bandwidth linearly, but also results in the excitation of the surface wave adding to losses other than radiation, thereby reducing the radiation efficiency of the patch. On the other hand realizing microstrip antenna with active component is a tedious improves the impedance bandwidth but degrade the pattern bandwidth. Therefore, a judicious approach should be employed for selection of these techniques. Here, in the present work we have enhanced the bandwidth by considering the Micromachined Technique.

2.2 Antenna Structure

In the electromagnetically coupled MSA, one or more patches at the different dielectric layers are electromagnetically coupled to the feed line located at the bottom dielectric layer. The patches can be fabricated on different substrates, and accordingly the patch dimensions are to be optimized so that the resonance frequencies of the patches are close to each other to yield broad BW. These two layers may be separated by either air-gap or foam yielding BW of 15-30% (Balanis, 1982; Bahl and Bhartia, 1990) [3, 2].

The basic geometry of EMC patch antenna is given in figure 1. EMC patch antennas consist of two substrates. The patch is etched on the top one. The ground plane for this substrate is completely removed. The feed line is etched on the lower substrate, which's has its ground plane left intact. The two substrates may have different thicknesses and relative dielectric constraints. The feed line is run underneath the patch and left open circuited. The distance c from the patch edge to the line edge is referred to as the overlap. The fringing fields from the open-circuited end provide the main coupling mechanism to the antenna. The patch is considered to be electromagnetically coupled (EMC) to the feed and is often called an EMC patch.

When two different substrates are used an effective dielectric constant which permits the two layer cavity to be treated as a homogeneously filled single layer structure, may be defined by a simple expression (Bahl, 1982; Balanis, 1982; Bahl and Bhartia, 1990) [1, 3, 2].

$$\varepsilon_{re} = \frac{\varepsilon_1 \varepsilon_2 (h_1 + h_2)}{(\varepsilon_1 h_1 + \varepsilon_2 h_2)} \qquad (4)$$

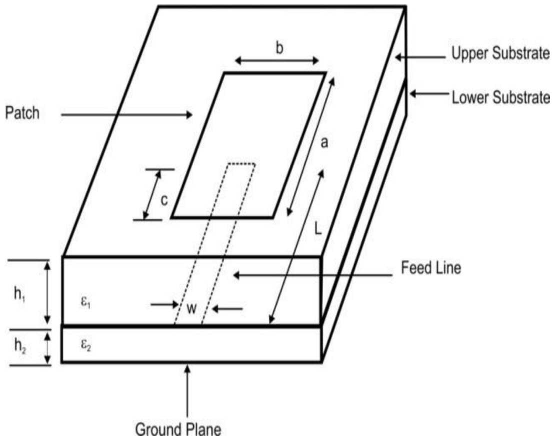

Fig 1: The two-layer EMC patch configuration

For different dielectric constant substrates, the lower one generally has the higher value. This reduces the size of the feed network. Normally using a high dielectric constant substrate degrades patch performance. With two substrates, the overall effective dielectric seen by the patch will be lower because of the upper substrate. Patch performance is thus improved over using a single substrate with the higher dielectric constant. Surface wave excitation is reduced. Using different dielectric constant substrates offers a way to minimize circuit size while maintaining good antenna performance.

The configuration and coordinate system of a planar array antenna considered are depicted in figure 2. it consist of 16 identical elements. The array is etched on the upper dielectric substrate of thickness 'h_1' and substrate permittivity ε_1.

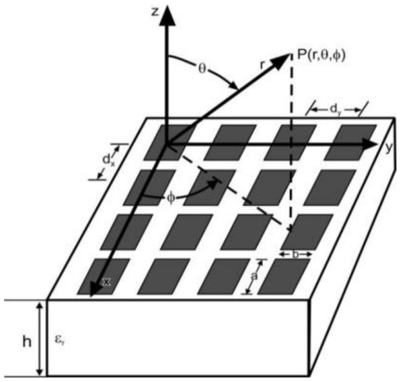

Fig 2: Geometry of 4 x 4 array microstrip rectangular patch antenna

The ground plane for this substrate is completely removed. The feed line is etched on the lower substrate of thickness 'h_2' and substrate permittivity ε_2. The length and width of rectangular patch are 'a' and 'b' respectively.

3. Results and Discussion

The planar array of rectangular patches having length b = 0.81 cm and width a = 1.64 cm respectively, is printed with elements separation $d_x = d_y = 3$ cm on RT-duroid upper substrate of $\varepsilon_1 = 2.33$ and height $h_1 = 0.100$ cm. The upper substrate placed on lower substrate of thickness $h_2 = 0.065$ cm and substrate permittivity $\varepsilon_2 = 2.2$.

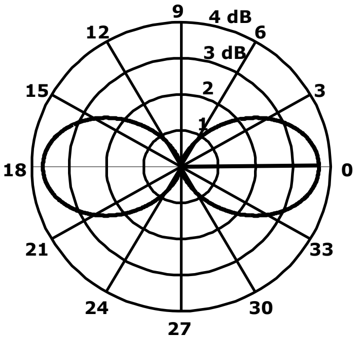

Fig 3: Radiation pattern of rectangular patch antenna in E-plane ($\varphi = \pi/2$)

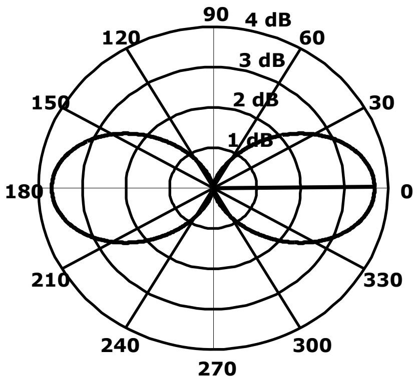

Fig 4: Radiation pattern of rectangular patch antenna in H-plane ($\varphi = 0^0$)

The radiation patterns and radiation parameters have been plotted and calculated respectively. The far field radiation patterns are obtained for E plane ($\theta = 90^0$) and H plane ($\varphi = 0^0$). The total field pattern $R(\theta,\varphi)$ is generally obtained by the relation: $R(\theta,\varphi) = |E_\theta|^2 + |E_\varphi|^2$. The planar array pattern is computed for source frequency f_r = 10 GHz with progressive phase excitation $b_x = b_y = 0$. The patterns of E plane, H plane and planar array are shown in figure 3, 4, 5 respectively.

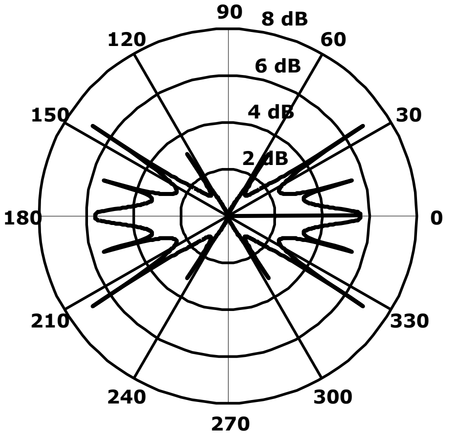

Fig 5: Variation of $R(\theta,\varphi)$ for 4×4 rectangular microstrip array configuration

All important parameters like bandwidth, directivity, gain, half power beamwidth (HPBW), total impedance and quality factor of rectangular microstrip patch array antenna has been calculated on the basis of equations 4.

Table 1: Comparison of characteristics of microstrip rectangular patch antenna on RT-duroid with and without EMC technique to enhance bandwidth

S. No.	**Parameter's Formula**	**Values**	
		Patch Antenna	**EMC Patch Antenna**
1.	Length (b)	0.86 cm	0.81 cm
2.	Width (a)	1.64 cm	1.64 cm
3.	Bandwidth (BW)	6.14 %	8.64 %
4.	Directivity (D)	4.77 dB	4.77 dB
5.	Quality Factor (Q_F)	8.22	6.74
6.	Gain (G)	4.38 dB	4.38 dB
7.	Total Imped. (Z_{in})	255ohms	336ohms
8.	Half Power Beamwidth (HPBW)	E-82^0, H-156^0	E-82^0, H-151^0

4. Conclusion

The obtained results have been tabulated in table 1 and compared with the results calculated for antenna printed on RT-duroid substrate ($\varepsilon_r = 2.33$, h = 1.65mm, $\tan\delta = 0.00066$) without electromagnetic coupling for the same frequency range. From the table 1 we can compare the values of bandwidth, directivity and gain for Electromagnetic Coupled Patch Antenna which is better than the antenna on RT-duroid substrate without electromagnetic coupling. Here if we consider only quality factor, it shows a decrement in value compare to antenna on RT-duroid which compromise the increment of bandwidth, directivity and gain. It has been established that using the technique of electromagnetic coupling, it alters the overall radiation performance of antenna system with a little bit increase in the patch size, about 15% compare to antenna printed on RT-duroid substrate without electromagnetic coupling.

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