NOVATEUR PUBLICATIONS
International Journal of Research Publications in Engineering and Technology [IJRPET]
ISSN: 2454-7875
VOLUME 3, ISSUE 6, Jun.-2017

EFFECT OF AIR-GAP TECHNIQUE IN BANDWIDTH OF MICROSTRIP PATCH ARRAY ANTENNA

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ABSTRACT:

Study of sixteen elements microstrip array antenna of rectangular patches which is printed on the RT-duroid substrate, is presented in this paper. Air-Gap technique is used in this array configuration for the enhancement of Bandwidth. To study the bandwidth enhancement the radiation patterns have been plotted for E-plane, H-plane and array geometry. A precise comparison of radiation parameters of this array antenna are also performed with the same array antenna configuration without using Air-Gap technique. This Air-Gap bandwidth enhancement technique has provided around 62% enhancement. This technique is quite easy in implementation and make antenna structure very light weighted and handy essential for portable devices.

KEY WORDS: Rectangular patch microstrip antenna, 16 elements array configuration, RT-duroid, Air-Gap technique, Bandwidth enhancement.

INTRODUCTION:

One of the main limitations of microstrip antennas is narrow bandwidth. Hence, much effort has gone into broadening the bandwidth and search for new microstrip configuration with wider bandwidth has been a dominant feature of the research and much effort continues to be extended. Generally compact circuit designs are typically designed in high-index material but in contrast the low-index substrates facilitate high bandwidth antennas. To enhance the bandwidth there is a requirement to integrate the planer antenna on electrically thick low index region while the circuitry remains on the high index region. So without losing the advantages of low index materials, the patch antennas must integrate on high index substrates with housing of low index material. This can be achieved by using electromagnetic coupling, aperture coupling and by using micro-machining to eliminate a portion of the substrate material [1-4].

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 [5-6, 13]:

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

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 $T = R_o/Z_0$

The scope of this research is to improve the bandwidth of microstrip antenna. Many important wide band techniques are reposted in past [7-13]. All other techniques have their own merits and demerits. 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 Air Gap Technique.

ANTENNA STRUCTURE:

The Microstrip Antenna with Air-gap takes the advantage of the air gap which lowers the effective permittivity and increase the total thickness of the microstrip antenna which is an essential factor for bandwidth enhancement.

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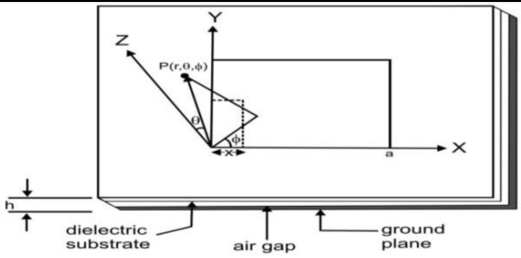

Figure 1: Geometry and coordinate system of rectangular patch microstrip antenna.

The geometry and coordinate system of Air-Gap RPMA is shown in figure 1. In this case Air-Gap RPMA is a two layer cavity. The upper layer is the dielectric substrate of thickness h_1 with relative permittivity ε_r and the lower layer is an air gap of thickness h_2 with relative permittivity equal to 1. Here we use an equivalent single layer structure of total height $h = h_1+h_2$ and an equivalent permittivity ε_{er} define by eqn.

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

The patch is considered as a TM cavity with leaky magnetic walls. This cavity will support quasi-discrete TM_{nm} modes transverse to z, where m and n are the modes numbers associated with y and x directions, respectively. The resonant frequency of the TM_{nm} mode of RPMA with an air gap is given by [13-15].

$$f_{nm} = \frac{f_{r0}\varepsilon_{re}}{\sqrt{\varepsilon_{eff}(a)\varepsilon_{eff}(b)(1+\delta)}} \qquad (5)$$

where f_{r0} is the 0^{th} order prediction of the resonant frequency defined as:

$$f_{r0} = \frac{c}{2a\sqrt{\varepsilon_{re}}}$$

$$\delta = \frac{h}{a}(0.882) + \left[\frac{0.164(\varepsilon_{re}-1)}{\varepsilon_{re}^2}\right] + \left[\frac{(\varepsilon_{re}+1)\left\{0.758 + \ln\left(\frac{h}{a} + 1.88\right)\right\}}{\pi\varepsilon_{re}}\right]$$

$$\varepsilon_{eff}(W) = \frac{(\varepsilon_{re}+1)}{2} + \frac{(\varepsilon_{re}-1)}{2}\left[1 + 10\frac{h}{W}\right]^{-1/2}$$

Here W is a variable and can be either of the patch dimensions 'b' or 'a' that can be easily calculated. The configuration and coordinate system of a planar array antenna considered are depicted in figure 2. It consist of 16 identical elements on a dielectric substrate of thickness 'h_1' and substrate permittivity ε_1 separated from ground plane by an air gap of thickness h_2 placed in x-y plane.

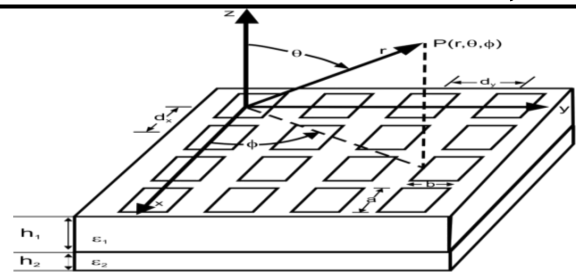

Figure 2: Geometry of 4 × 4 array microstrip rectangular patch antenna

The length and width of rectangular patch are 'a' and 'b' respectively. The array elements which are poisoned along x-axis are separated by d_x and array elements which are poisoned along y-axis are separated by d_y. The separation of array elements has been taken equal to wavelength of resonant frequency ($d_x = d_y = \lambda$ cm).

RESULTS:

The radiation patterns and radiation parameters have been plotted and calculated respectively.

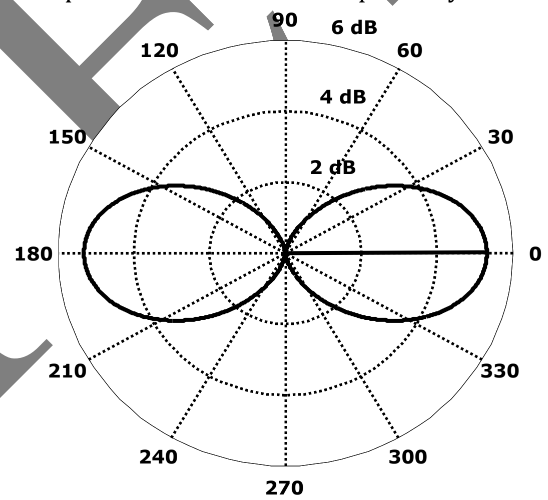

Figure 3: Radiation pattern of rectangular patch antenna in E-plane ($\varphi = 90^0$)

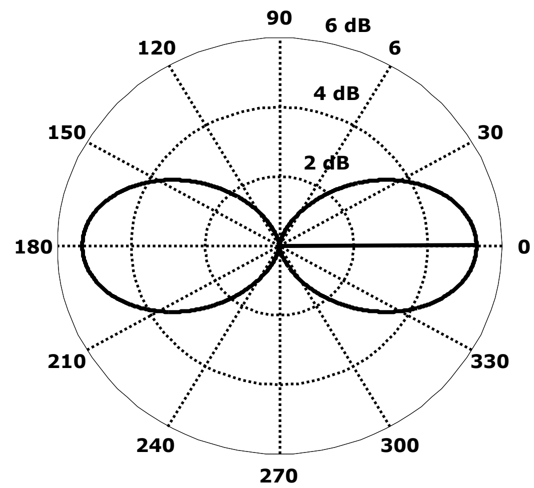

Figure 4: Radiation pattern of rectangular patch antenna in H-plane ($\varphi = 0^0$)

The planar array of sixteen rectangular patches of length b = 0.92 cm and width a = 1.84 cm, is printed with elements separation of 3 cm on RT-duroid substrate of ε_1 = 2.33 and height h_1 = 0.100 cm separated by h_2 = 0.065 cm of ε_2 = 1.

The far field radiation patterns are obtained for E plane ($\theta = 90^0$) and H plane ($\varphi = 0^0$). The total field 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 fig. 3, 4 & 5 respectively.

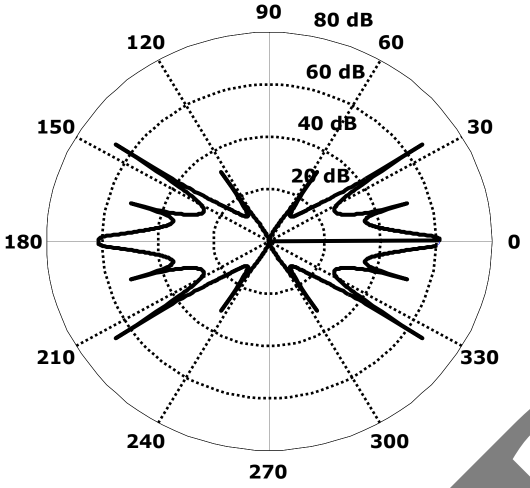

Figure 5: Variation of R(θ,φ) for 4×4 rectangular microstrip array configuration

Table 3.1: Comparison of characteristics of microstrip rectangular patch antenna on RT-duroid with and without Air-Gap technique to enhance bandwidth

S. No.	Radiation Parameters	Values	
		Without Technique	With Technique
1.	Length (b)	0.86 cm	0.94 cm
2.	Width (a)	1.64 cm	1.82 cm
3.	Bandwidth (BW)	6.14 %	9.96 %
4.	Directivity (D)	4.77 dB	4.77 dB
5.	Q. Factor (Q_F)	8.22	6.12
6.	Gain (G)	4.38 dB	4.87 dB
7.	Total Imped. (Z_{in})	255ohms	283ohms
8.	Half Power Beamwidth	E-82^0, H-156^0	E-60^0, H-164^0

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 4-5. The obtained results have been tabulated and compared with the results calculated for antenna printed on RT-duroid substrate without Air-Gap for the same frequency range.

CONCLUSION:

It has been established that using the technique of Air-Gap, 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 Air-Gap.

From the table 1 we can compare the values of bandwidth, directivity and gain for Microstrip Patch Antenna with and without Air-Gap. Results are favorable for the enhancement of Bandwidth by using Air-Gap Technique. Results also show a decrement in the value of quality factor. This decrement is only a compromise to the increment of bandwidth, directivity and gain.

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