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Quantitatave Estimation of Symmetrical Radiation Beam with Suspended Rectangular Microstrip Antenna

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Abstract: *A novel suspended rectangular microstrip antenna for symmetrical radiation beam performance is theoretically investigated. The conventional patch antenna on common substrates always produces broader E plane pattern compared to its H plane. In the present investigation, the same microstrip antenna is suspended over its ground plane and may be thought of as it is on air substrate, which shows an excellent radiation pattern with symmetrical 3 dB beam widths at its both E and H plane. The present antenna has been compared with the conventional structure and is presented in the paper. The complete quantitative analysis to explore such radiation beam characteristics for the proposed structure is also presented in this paper. The proposed idea has been verified through a commercial software package for X band.*

Keywords: *Conventional Antenna, Suspended Rectangular Microstrip Antenna, Symmetrical Beam widths.*

1. INTRODUCTION

The rectangular microstrip antenna is the most common and popular antenna for its well known striking features, such as low profile, light weight, and compatibility with monolithic microwave integrated circuits and thus it finds growing number of new applications day by day [1]. This microstrip antenna is etched on conventional substrates with dielectric constant ε_r = 2.2 to 10.2 [2]. But that microstrip antenna is suspended over ground plane is a least investigated configuration in any open literature, though it shows some interesting features particularly in its radiation characteristics. Rectangular microstrip normally radiates linearly polarized wave with about 4-5 dBi gain. These patches radiate along the broadside direction with broader E-plane pattern than H-plane [1]. As the microstrip antenna is inherently a low gain antenna, larger gain is always a positive requirement and can be achieved by increasing its width-to-length ratio as is reported in [3]. But, as soon as the conventional substrate is replaced by air, *i.e* the antenna becomes a suspended rectangular patch, gain of the antenna increases satisfactorily.

Some researchers had employed different configurations like, wedge-shaped air dielectric [4] or air cavities within the substrate [5] for different applications. Improved gain for microstrip antenna is always desirable but along with this symmetrical or uniform radiation beam pattern in both the E and H plane is also requisite to cover a wide area, particularly for wireless communications.

This can be achieved using the proposed suspended rectangular microstrip antenna and is presented in comparison with the conventional structure. One very recently reported article [6] shows an antenna fabricated on dielectric strips with appreciable gain and symmetrical beam pattern. But still it suffers from complex manufacturing process and there is no quantitative guide lines reported in [6] in support of their results. But here, the feature of high gain and symmetrical beam radiation is obtained from simpler structure and hence this proposed antenna do not suffers from the disadvantage of complex manufacturing process. A concrete quantitative analysis is presented to explain such behavior of the antenna. An easy and handful relationship between the length of patch antenna and its fringing length for the proposed antenna is established following the aperture antenna concept as reported in [7]. The theory is successfully utilized to evaluate the causes for uniform 3 dB beam widths which is verified using [8] and close agreement is revealed.

2. ANTENNA STRUCTURE

A rectangular microstrip antenna with length *L*= 11.8 mm and width *W*= 17.56 mm is shown in Fig. 1 (top-view of the patch and side view of whole antenna structure). A dielectric substrate of thickness *h* =1.58 mm of relative permittivity of ε_r = 2.33 is sandwiched between the patch and ground plane to develop the conventional patch antenna. On the other hand, the copper plate (patch) of same dimension is simply suspended over the ground plane keeping the finite gap of *h* =1.575 mm between ground plane and the copper plate (patch) for our proposed structure. For both the cases, the dimensions of ground plane are kept 1.6 λ_0 X 1.6 λ_0.

3. RESULTS AND DISCUSSIONS

Simulated results obtained using [8] for suspended rectangular microstrip antenna and the same with conventional substrate operating around X band is presented.

Fig. 2 shows the complete return loss profile of the proposed antenna which shows that the proper excitation has been achieved by accurately choosing the feed point. The proposed antenna resonates at 10.2 GHz with an impedance bandwidth of nearly 6%.

The next step is to examine the radiation pattern for two identical antennas; one with conventional PTFE substrate and the other with suspended rectangular microstrip antenna. Hence, the radiation patterns are compared between the antennas separately at E and H plane as shown in Fig. 3.

It is revealed that, 3dB beam width in E plane is quite broader than H plane beam width for conventional antenna while, those for proposed antenna show no changes in beam widths between its E and H planes. Commonly available literature shows that the beam width of any antenna in a particular plane typically depends on its dimension at that plane. In fact, the air below the patch modifies the fringing lengths and widths in such a way that the effective length and width acquire particular values such that beam widths remain same in each plane. The case is different when the region below the patch is filled up with conventional dielectric material which results unequal beam widths in different planes. It may also be noted that along with the symmetrical radiation beam, the gain of this present antenna is greater than conventional structure as also evident from Fig. 3. This may be due to the loosely bound electric fields below the patch, which contributes for the radiation fields for the present antenna. This is expected because the dielectric constant of the material below the patch is smaller *i.e* 1 compared to that (2.33) at conventional patch. The total results are summarized in Table-I.

TABLE I: Gain and Beam width of Rectangular Microstrip Antennas (conventional and proposed one)
Parameters as in Fig. 2

Antenna configuration	Peak Gain (dBi)	3 dB Beam width (degree)	
		E Plane	***H Plane***
Conventional antenna	6.0	77	40
Proposed antenna	8.2	56	56

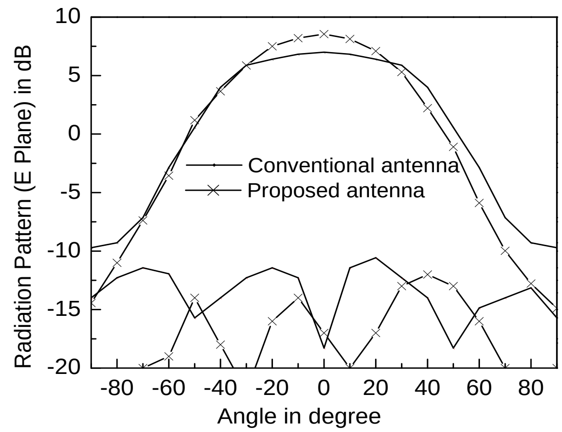

Fig. 2. Return loss characteristics of a suspended rectangular patch antenna. *L* = 11.8 mm, *W*= 17.56 mm, *h*= 1.58 mm, ρ = 2.6 mm; Substrate: uniform air: ε_r= 1.

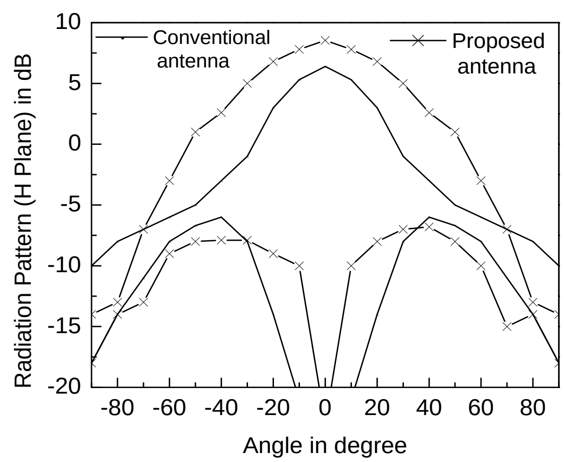

Fig 3. Radiation pattern of present antenna operating at 10.35 GHz compared with a conventional antenna using a PTFE (ε_r=2.33) substrate operating at 7.9 GHz.

4. QUANTITATIVE ANALYSIS

Any rectangular patch antenna radiates along its broadside direction and its field patterns at both E and H planes are given by [3]. This is equally valid for our proposed antenna as this suspended rectangular microstrip antenna may be thought of as it is on air substrate. Now if we follow the concept developed in [7] by one of the present authors, where the radiation from the patch has been considered as the radiation from rectangular aperture then following [10],[11] we may write the 3 dB E plane and H plane beam widths as

$$\theta_E = \frac{51^0}{L + 2\Delta L/\lambda} \quad (1)$$

and

$$\theta_H = \frac{67^0}{W + 2\Delta W/\lambda} \quad (2)$$

Now for beam widths to be equal in both the planes,

$$\theta_E = \theta_H \quad (3)$$

$$\frac{51^0}{L + 2\Delta L/\lambda} = \frac{67^0}{W + 2\Delta W/\lambda} \quad (4)$$

Thus,

$$\frac{W + 2\Delta W/\lambda}{L + 2\Delta L/\lambda} = \frac{67^0}{51^0} = 1.31 \quad (5)$$

$$\Rightarrow W + 2\Delta W = 1.31L + 2.62\Delta L \quad (6)$$

Again for most commonly used aspect ratio W/L=1.5; following [9] we may write,

$$\Delta W = \Delta L\left(1.5 - W/2L\right) = 0.75\Delta L \quad (7)$$

Thus equation (6) may be rewritten as

$$1.5L + 1.5\Delta L = 1.31L + 2.62\Delta L \quad (8)$$

Hence

$$L \cong 5.9\Delta L \quad (9)$$

Following the design guidelines [8]; the fringing lengths and widths (ΔL and ΔW), have been calculated and it is seen that, fringing length ΔL for the present antenna is 1.99 mm, where as that for antenna with conventional substrate is only 1.27 mm. Again if we keep our eyes on the length of the antenna it is 11.8 mm, which confirms that equation (9) is satisfied and this result in fact creates a theoretical background for such symmetrical 3 dB beam width characteristics for proposed suspended rectangular microstrip antenna.

5. CONCLUSIONS

A simple suspended rectangular microstrip antenna has been proposed for symmetrical 3 dB beam width characteristics and the proposed idea has been verified thoroughly using quantitative analysis in the perspective of half power beam widths of rectangular aperture antenna. A simple handful relationship between the length of patch antenna and its fringing length is established. The proposed antenna is very helpful for the researchers and in search of such low profile antenna with symmetrical beam radiation pattern.

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