

Stacked Arrangement of Convexo-Concave Antenna and Simple Rectangular Patch Antenna for Modern Communication Systems

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Abstract: In the present communication, we have proposed stacked arrangement of two planar antennas. The lower patch has convexo-concave structure and acts as driver element and the upper stacked patch is a simple rectangular patch which acts as parasitically coupled to lower patch. The size of upper patch is marginally higher than that of driver element. The two patches are separated by a thin foam substrate. This proposed antenna resonates at two frequencies which lie in the medium band (3.25 to 3.85 GHz) and upper band (5.2 to 5.85 GHz) of Wi-Max application. The impedance bandwidths in these two bands are 19.89% and 14.42% with respect to center frequency. In addition, antenna also provides circularly polarized radiations. The axial ratio bandwidth, gain, directivity and radiation efficiency are improved than a single layer convexo-concave antenna. The radiation patterns of proposed antenna in the entire frequency range are identical in shape and directed normal to patch geometry.

Keywords: Microstrip Patch, Stacked Arrangement, Circularly polarized, Broadband, Radiation patterns

1. Introduction

Microstrip antennas are one of the most widely studied antenna structures perhaps due to their inherent properties like compact size, light weight and their capability to get integrated with other circuit components¹⁻². However their narrow bandwidth and low gain performance restrict their possible applications in modern communication systems. Broadband antennas are generally preferred in modern wireless communication systems while circularly polarized antennas are preferred in space communication systems. Looking inherent limitations of conventional patch antennas, several alterations in patch geometries were proposed in recent times to achieve circularly polarized broadband antennas³⁻⁴.

A Broadband Circularly Polarized Corner-truncated Square Patch Array Antenna has been described by Choi et al. ⁵ whose impedance and axial ratio bandwidths were remarkably improved by using the stacked patches, thin film, thick foam and sequential rotation feed. The axial-ratio bandwidth and gain of circularly polarized stacked microstrip antenna has been improved by Nasimuddin et al. ⁶, by optimizing the location of the feed and a few other parameters and by using a quasi-planar short horn and a new C-type single feed. In the present communication, we have investigated the radiation performance of a single feed circularly polarized stacked patch antenna designed on glass epoxy FR-4 substrate and its performance is compared with that of a single layer convexo-concave patch antenna. After extensive optimizations, a dual frequency circularly polarized broadband antenna for application in modern communication systems is achieved.

2. Antenna Design and Results

A. Conventional square patch antenna

In this communication, first a single layered conventional square patch antenna is considered as shown in figure -1 and its radiation performance is simulated by applying IE3D simulator [7]. The patch has dimensions ' a ' = 20mm and it designed on glass epoxy FR-4 substrate ($\epsilon_r = 4.4$, $\tan\delta = 0.025$, substrate thickness ' h ' = 0.159cm). Single inset feed arrangement using

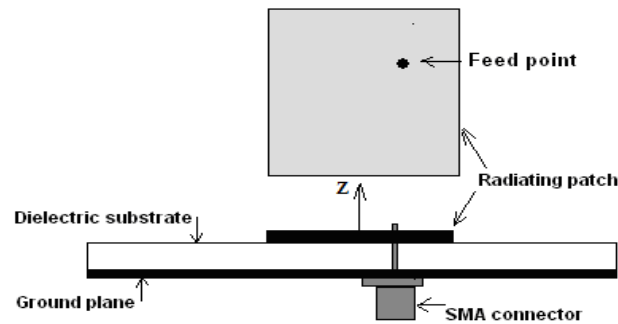


Fig. 1 Geometry of conventional square patch antenna

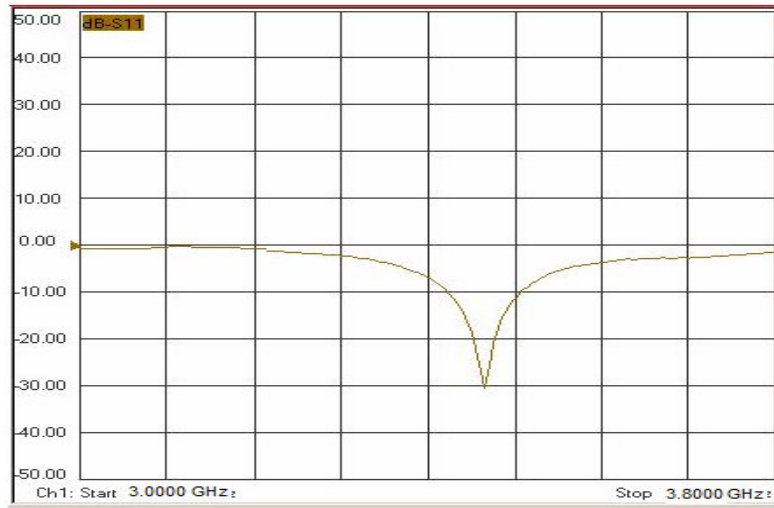


Fig. 2 Variation of S_{11} parameter as a function of frequency

SMA connector at (1.36cm, 1.15cm) is applied to excite this antenna. The measured S_{11} parameter variation of this antenna as a function of frequency is shown in figure 2 which indicates that antenna resonates at 3.42GHz corresponding to its dominant TE_{10} mode and the impedance bandwidth of this antenna is 2.54%. The band width, gain and efficiency of antenna are very low and hence this antenna in its present form is not suitable for application in modern communication systems.

B. Convexo-concave Microstrip patch antenna

The square patch antenna is modified by applying a circular arc at its one edge with radius of curvature R_1 while another circular arc parallel to the previous arc with radius of curvature R_2 is applied in the opposite arm as shown in figure 3. The radius of curvature is optimized to achieve best performance and it is realised that on making $R_1 = 53.5\text{mm}$, best performance with this structure may be achieved. The rectangular patch antenna is modified further by applying another circular arc parallel to the previous arc with radius of curvature R_2 as shown in figure 3a. The radius of curvature is again optimized to achieve best performance and it is realised that on making $R_2 = 15\text{mm}$, best performance with this structure may be achieved. The proto type structure prepared for the present work is shown in figure 3b. With inset feed arrangement from feed location (0.63cm, 0.63cm), measured S_{11} parameter as a function of frequency of this convexo-concave antenna is shown in figure 4. Antenna is now resonating at two closely spaced frequencies 3.502 GHz and 3.69 GHz. This suggests that with this

modifications in patch geometry, an additional mode in addition to dominant mode is excited. The measured impedance bandwidth is 0.317GHz or 8.77% corresponding to central frequency.

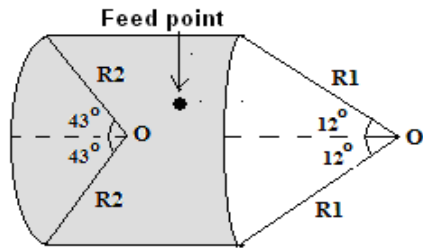


Fig. 3a Geometry of convexo-concave patch antenna

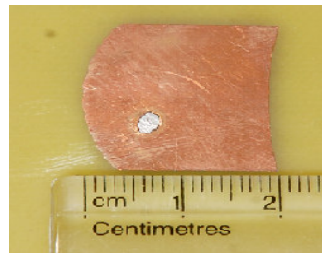


Fig. 3b Fabricated convexo-concave patch antenna

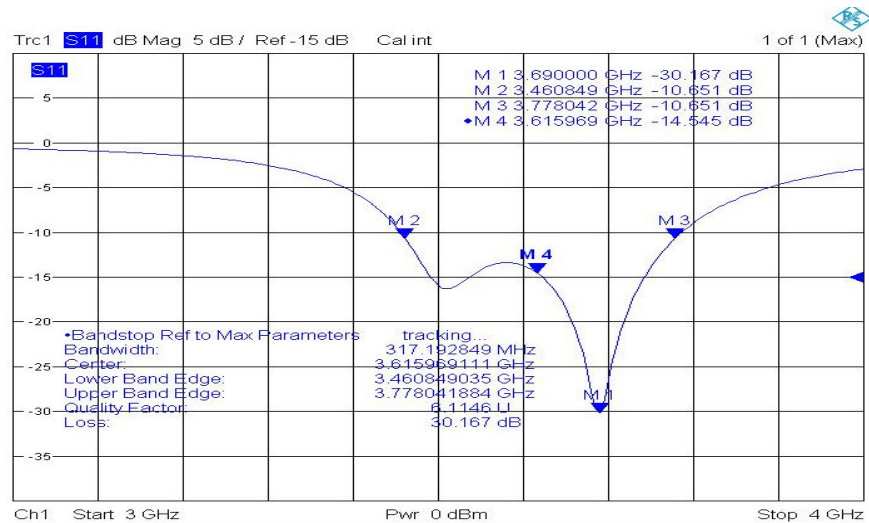


Fig. 4 Measured S_{11} parameter of convexo-concave patch antenna

The modified antenna is right circularly polarized antenna and the minimum axial ratio presented by antenna is 2.142dB at 3.599GHz as shown

in figure 5. The axial ratio bandwidth is also marginally improved and attained a value 1.24%. The gain and efficiency of antenna are still low. Though the performance of this antenna is improved, we decided to modify it further to obtain better performance.

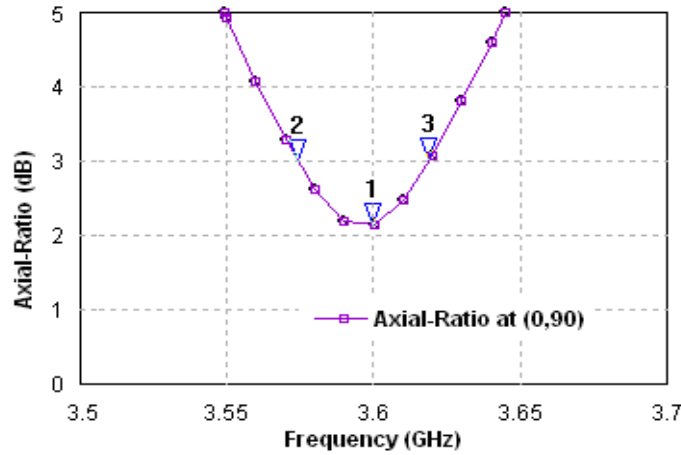


Fig. 5 Variation of axial ratio of convexo-concave patch antenna as a function of frequency

C. Stacked Arrangement of Convexo-Concave Antenna and Simple Rectangular Patch Antenna

The further improvements are difficult to achieve with single layer structure and hence in this section we have considered the stacked arrangement of convexo-concave patch antenna with a rectangular patch antenna. The lower patch has convexo-concave structure and acts as driver element while the upper stacked patch is a simple rectangular patch which acts as parasitically coupled patch. The size of upper patch is marginally higher than that of driver element. The two patches are separated by a thin foam substrate ($\epsilon_r = 1.02$, $\tan\delta = 0.0002$) as shown in figure-6. The performance of antenna is optimized by varying the foam thickness, dimensions of stacked patch and feed location of the driver patch. The optimum performance is achieved on considering the dimensions of stacked patch as $L = 20\text{mm}$ and $W = 24\text{mm}$ and by retaining the dimensions of driver patch identical to those considered in the previous section. The thickness of foam substrate is taken equal to 5mm.

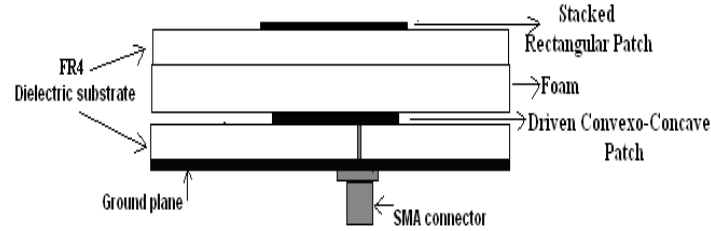
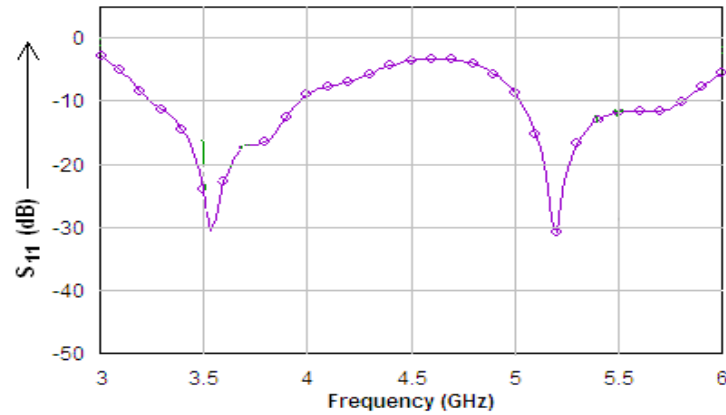


Fig. 6 Geometry of proposed stacked patch antenna

Fig. 7 Variation of S_{11} parameter as the function of frequency

The simulated variation of reflection coefficient (S_{11}) with frequency as shown in figure 7 indicates that structure is resonating at two frequencies namely 3.54GHz and 5.2GHz and presents two distinct bands in the medium band (3.25 to 3.85 GHz) and upper band (5.2 to 5.85 GHz) of Wi-Max application. The impedance bandwidths in these two bands are 0.717GHz (19.89%) with respect to center frequency 3.605GHz and 0.782GHz (14.42%) at center frequency 5.416GHz. The simulation analysis for input impedance suggests that the input impedances at two resonant frequencies are $(48.16 + j 2.2) \Omega$ and $(51.60 - j 2.42) \Omega$ respectively which are close to 50 ohm impedance of the feed line. It shows good matching between prepared antenna geometry and the feed line.

The elevation plane E and H-plane radiation patterns of antenna at different frequencies covering both bandwidth regions are shown in figure 8(a) & 8(b). It can be seen that patterns in both bandwidth regions are

symmetrical in nature. In the median band, the direction of maximum radiations in normal to patch geometry while in upper band maximum radiations are inclined in $\theta = 60^\circ$. The patterns in upper band are more directive in nature.

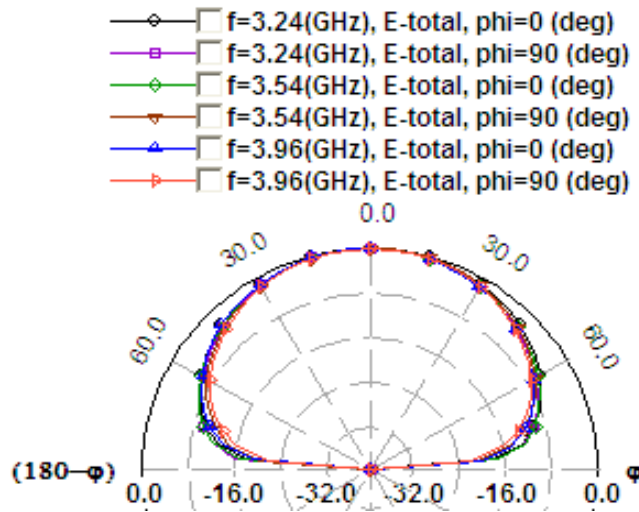


Fig. 8a E and H plane elevation patterns at different frequency in median band

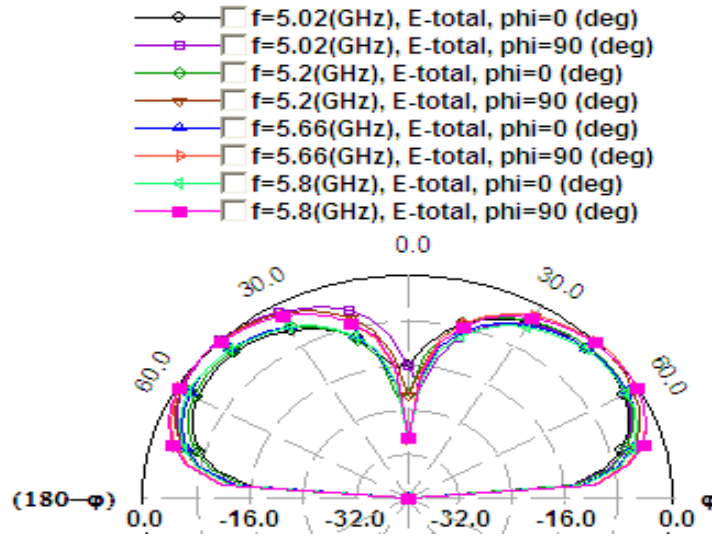


Fig. 8b E and H plane elevation patterns at different frequency in upper band

Figure 9 presents the simulated variation of axial ratio as a function of frequency. It shows that proposed antenna presents minimum axial ratio 2.39dB at 3.36GHz, 1.77dB at 3.96GHz, 1.79dB at 5.159GHz and 2.76dB at

5.88GHz. out of them, first and third axial ratio values lie in two impedance bandwidth range respectively, whereas second is on margin and fourth is out of range. The axial ratio bandwidth values at the two resonance frequencies lying in impedance bandwidth range are 2.36% & 2.62% respectively.

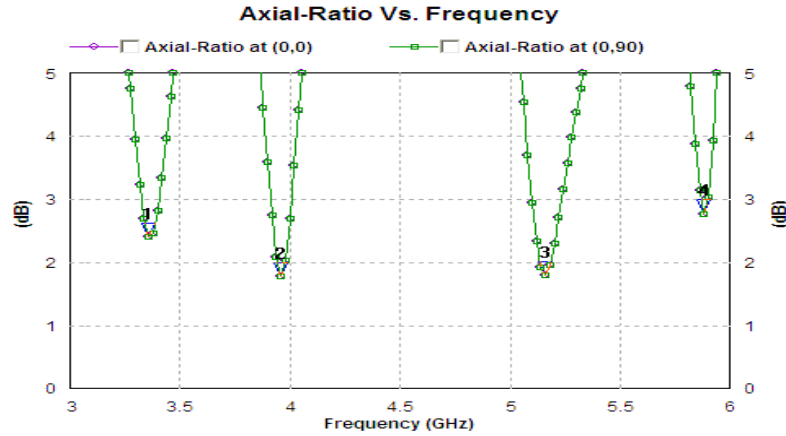


Fig. 9 Variation of axial ratio as a function of frequency

A comparison of total field gain of antenna as a function of frequency of single layer patch antenna and stacked antenna is shown in figures 10. It reveals that gain of stacked antenna is improved by nearly 4dBi in both frequency bands. The gain variation is almost unchanged in the entire both bandwidths range and the value of total gain of stacked antenna is 6.489dBi at 3.54GHz and 4.263dBi at 5.2GHz.

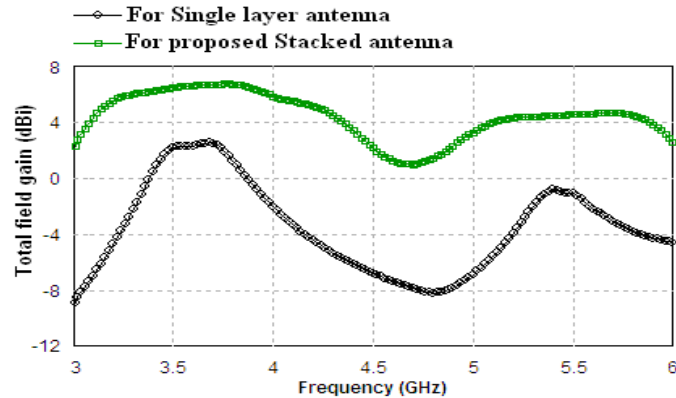


Fig. 10 Comparison of gain of proposed stacked patch antenna and single layer antenna as a function of frequency

3. Conclusions

In this paper, the performance of a stacked arrangement of patch antennas is investigated and all results are systematically presented. This stacked arrangement has two planar antennas. The lower patch is convexo-concave structure (driver element) and the upper stacked patch is a simple rectangular patch (parasitically coupled). This stacked arrangement presents two improved bandwidths 0.717GHz (19.89%) at center frequency 3.605GHz and 0.782GHz (14.42%) at center frequency 5.416GHz which are applicable for medium band (3.25 to 3.85 GHz) and upper band (5.2 to 5.85 GHz) of Wi-Max application. The gain is also improved approximately by 4dBi than single layer patch antenna in entire frequency range. The stacked antenna is again circularly-polarized in nature and the axial ratio bandwidth is marginally improved.

4. Acknowledgement

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