Effect of shape of Parasitic Patches on MSA fed High Gain Antenna

Reena M. Nemade and Dr. R. K. Gupta

Abstract: In this paper the effect of 1x1 and 3x3 square and circular parasitic patches are placed on the FR4 layer and there effect on the various parameters of the antenna are compared. A microstrip antenna fed high gain antenna using array of parasitic patches on a FR4 superstrate layer is proposed. The suspended microstrip antenna is fabricated on FR4 substrate and placed at 1mm from ground. This suspended MSA feeds array of square as well as circular parasitic patches which are fabricated on a 1.59mm thick FR4 layer. This layer is suspended in air at λo/2. The printed MSA is fed by a 50 Ω coaxial probe. Here the The antenna provides 17.8 dB gain with gain variation of < 1.5 dB over 5.725-5.875 GHz. The antenna structure also provides more than 80 % efficiency, SLL < -18 dB and front to back lobe ratio > 22 dB. The VSWR is less than 2 over 5.725 – 5.875 GHz, frequency band. The proposed structure can be used for terrestrial and satellite communications.

Keyword: **Fabry Perot Cavity antenna, Multilayer, High gain, MSA, PRS, Directive antenna**.

I. INTRODUCTION

High directivity or high gain antennas are usually realized by using parabolic reflectors. The parabolic reflector antenna is bulky and occupies large space and therefore not suitable in mobile and space applications. Microstrip antennas (MSA) are planar, however, they have the disadvantages of low gain, low efficiency, low power handling capability and narrow bandwidth. Line-fed microstrip antenna arrays structure offers high gain, but suffers from low efficiency due to line and dielectric losses and higher cross-polar radiation due to feed-line network.[1-2].

High Gain antennas are realized by reflectarrays [2-4]. Reflectarrays avoid the feed-line network and can be made flat or conformal. But, reflectarrays suffer from aperture blockage as feed antenna is located in its radiation aperture. Also, its efficiency is low due to dielectric losses.

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Gain enhancement techniques based on Fabry-Perot Cavity (FPC) have been considered to increase broad side directivity. FPC consists of a partially reflecting surface (PRS) formed by single or multiple dielectric layers or a periodic screen which is placed at integral multiple of λ/2 above a ground plane. The gain improvement of FPC antenna depends on the reflection coefficient of PRS [5-9].

High gain microstrip array using a superstrate layer is proposed but it has the disadvantage of large inter-element spacing and significant side lobe level (SLL) [10].Three dimensional efficient directive antenna arrays fed in space using a single feed patch is proposed in [11]. The resulting array is planar and since the feed antenna is located behind the array, there is no aperture blockage but the structure has large dimensions and significant SLL for small size arrays.

Metal plated MSA fed high gain antennas using parasitic patches on a superstrate have been reported. These antennas do not require feed network and provides high efficiency and low SLL but these antennas have to be fabricated mechanically [12-13].

Here gain improvement using printed MSA feed and an array of parasitic patches is proposed. Here the parasitic patches are square and circular and the effect of this PP is seen on the various parameters of the antenna. The proposed antenna consists of a microstrip antenna fabricated on FR4 substrate and placed at 1 mm from ground. This MSA feeds an array of square parasitic patches printed on a FR4 superstrate and positioned at $\lambda_0/2$ from the microstrip antenna. The antenna with 5 X 5 square parasitic patch on finite ground provides more than 80 % efficiency, side lobe level <-18 dB and front to back lobe ratio of more than 22 dB with gain of 17.8 dB. The VSWR is < 2 over 5.725 – 5.875 GHz, Industrial, Scientific and Medical (ISM) frequency band.

The following sections deal with the antenna geometry, design theory and simulation results. Radiation pattern and impedance variation of antenna structures on infinite and finite ground plane are also described

II. ANTENNA GEOMETRY AND DESIGN THEORY

A broadside directive radiation pattern results when the distance between the ground plane and PRS causes the waves emanating from PRS in phase in normal direction. If reflection coefficient of the PRS is $\rho e^{j\psi}$ and f (α) is the normalized field pattern of feed antenna, then normalized electric field E and power S at an angle α to the normal are given by [2]

$$|E| = \sqrt{\frac{1-\rho^2}{1+\rho^2-2\rho\cos\phi}}\, f(\alpha) \qquad (1)$$

$$S = \frac{1-\rho^2}{1+\rho^2-2\rho\cos\phi}\, f^2(\alpha) \qquad (2)$$

Where, ϕ is the phase difference between waves emanating from PRS. For the waves emanating from PRS to be in phase in broadside direction, resonant distance L_r between ground plane and PRS is given by [2]

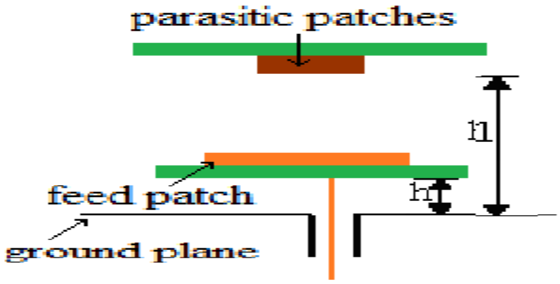
$$L_r = \left(\frac{\psi_0}{360} - 0.5\right)\frac{\lambda}{2} + N\frac{\lambda}{2} \qquad (3)$$

Here ψ_0 is PRS reflection coefficient phase angle in degree and N=0, 1, 2, 3 etc.

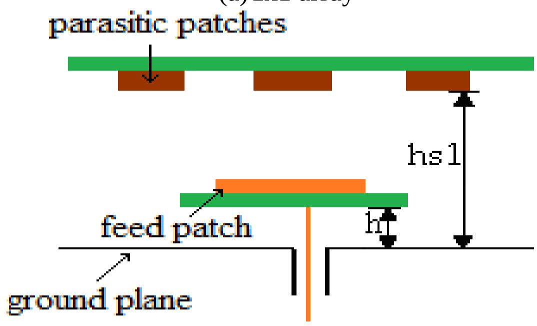
Gain can be increased by using array of parasitic elements on a superstrate layer. High gain broadside radiation can be achieved if the elements are fed in phase. The parasitic elements in an array are fed from the radiating field of microstrip antenna [12-13]. The parasitic patches are at different distance from feed patch. Hence feed to each element involves amplitude tapering as well as phase delay. Amplitude tapering in feed to parasitic patches is also due to the radiation pattern of microstrip antenna. The amplitude tapering improves side lobe level, but decreases gain of antenna.

The phase delay in feed to different elements located at different position is compensated by decreasing its length corresponding to the feed delay so that parasitic elements radiate in phase resulting in directive broadside radiation pattern. However, as the distance of parasitic patches increases from feed patch, it receives less feed amplitude. As a result, mutual coupling effect of these elements decreases and they contribute less in radiation. Therefore, gain improvement decreases with increase in array size.

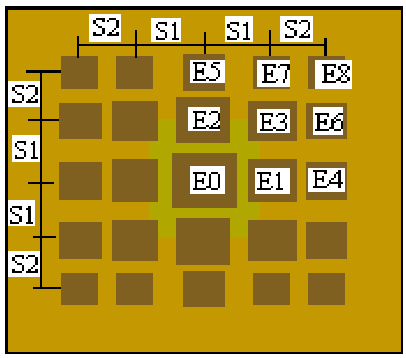
Here the square and circular parasitic patches are placed on the FR4 layer. The geometry of the proposed antenna structure is shown in Fig. 1(a) and (b) both for 1x1 and 3x3 array. The top view of both 3x3 array for square and parasitic patches has been shown in Fig 1. (c) and (d). The MSA is fabricated on FR4 and placed at 1 mm from ground. The square parasitic patches are located at a height 'hs' from the feed patch and fabricated on the bottom side of FR4 superstrate of thickness 1.59 mm. Relative permittivity and loss tangent of FR4 is 4.4 and 0.02 respectively. The FR4 layer also acts as a radome to the antenna. Air is used as a dielectric medium between superstrate and feed patch to achieve high efficiency. MSA is fed through a coaxial probe of 50 Ω. The structure is designed to operate over 5.725 – 5.875 GHz band. The structures have symmetry about the centre and parasitic patches at same distance from the centre have same dimension in E or H plane. The antenna design and optimization have been carried out using commercial IE3D software [18]. All dimensions mentioned here are in mm only.



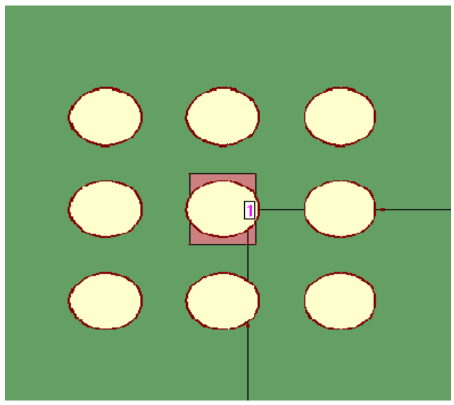
(a) 1x1 array



(b) 3x3 array



(c) Top view of square patches for 3x3 array



(d)Top view of circular patches for 3x3 array

Fig 1. Geometry of antenna structure

III. ANTENNA DESIGN ON INFINITE GROUND

Initially, a MSA on infinite ground plane with spacing h=1 mm to operate over 5.725-5.875 GHz, ISM band is designed. MSA provides gain of 6.5 dB. Then a FR4 superstrate layer is placed at a distance of λo/2 above it. Gain improves to 8.8 dB.

The structure is termed as MSA0. Now a square parasitic patch is placed on the superstrate layer and the dimensions of the patch is optimised. Maximum gain of 10.5 dB is obtained when the patch dimension is λ/2 where λ is the wavelength in the dielectric medium at central operating frequency. Similarly instead of square, circular patch for 1x1 array is designed. The maximum gain obtained for it is 10.1 dB. 3x3 square parasitic patch array (SPPA) are placed on a superstrate layer. The structure is optimized. The optimum dimensions are, hs=28.0, E1=16 and S1=25.9. VSWR< 2 over 5.725-5.875 GHz and 14.5 dB gain are obtained. Now 3x3 circular parasitic patches having radius of 8mm are placed on the superstrate layer and the structure is optimized. VSWR< 2 over 5.7-5.875 GHz and antenna gain of 12.8 dB is obtained. The optimum dimensions are h=2, hs=25.9, E0=E1=16, E2= E5=19, E3 =17, E4=12, E6 =E7=E8=16, S1= S2= S3=25.9. Impedance variation and gain variation of 1x1 and 3x3 for square and circular parasitic patches are shown in Fig. 2 and Fig. 3 respectively.

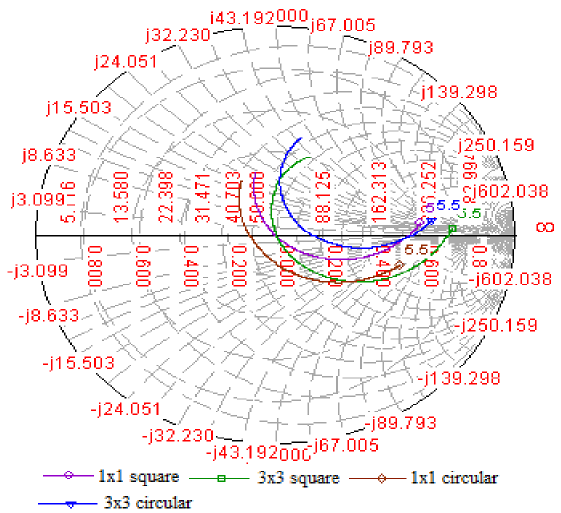


Fig 2. Impedance variations vs. frequency

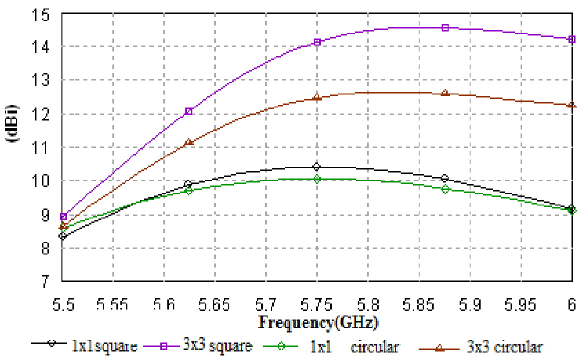


Fig 3. Gain variations vs. frequency

Fig. 4 shows VSWR vs frequency graphs for all 1x1 and 3x3 square as well as circular parasitic patches.From this it is seen that VSWR is less than 2 for all. But the VSWR for array of square parasitic parches is more less than 2 than the circular parasitic patches. Fig. 5. Shows antenne efficiency vs frequency graph for all. Here more or less about 61% is obtained for 3x3 array of square PP. For the other the efficiency is below than that for the 3x3 square. So as compared to circular PP the square PP has more efficiency.

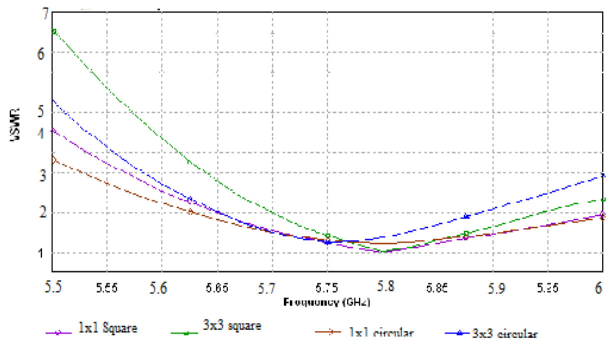


Fig 4. VSWR vs. frequency

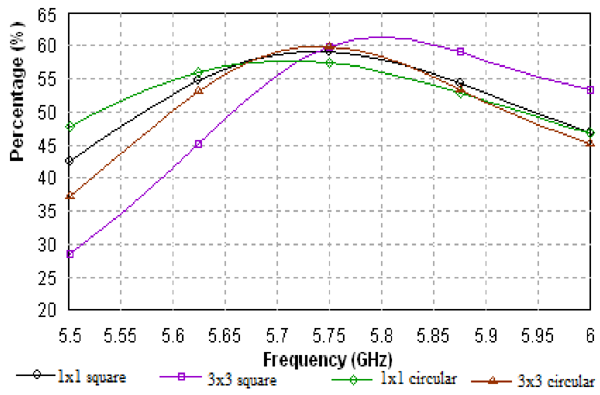
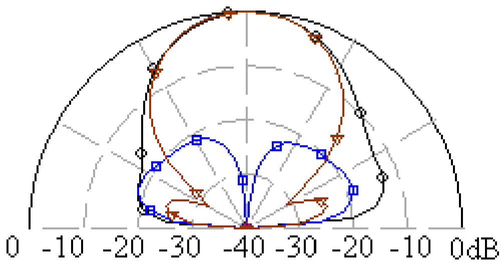
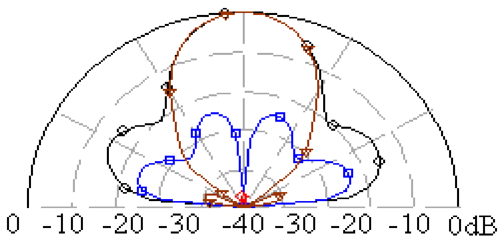


Fig 5. Antenna efficiency vs. frequency

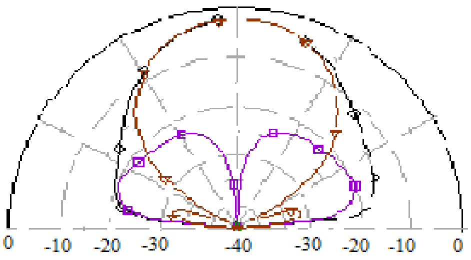
Figure 6. Shows the radiation pattern for 1x1 and 3x3 square as well as circular PP.



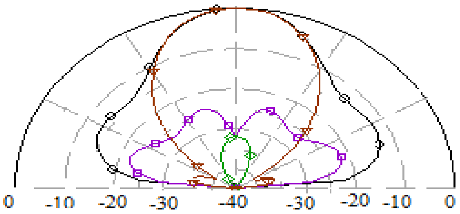
(i) 1x1 square



(ii) 3x3 square



(iii) 1x1 circular



(iv) 3x3 circular

Fig 6. Radiation pattern at Infinite ground plane at 5.8 GHz

IV. CONCLISION

An efficient, high gain, easy-to-fabricate printed MSA fed antenna having low SLL and high gain is proposed. MSA antenna is placed in a FPC to enhance gain. The MSA dimension, parasitic patch dimensions and spacing between parasitic patches, MSA height and FPC height are the determining factor in improving gain of antenna. Here the effect of square and circular parasitic patches on MSA fed high gain antenna is seen. It shows that as compared to circular the square parasitic patches provides more gain, low SLL and less cross polarization. The proposed structure is suitable for satellite as well as terrestrial communications and can be embedded into the host vehicle.

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