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# Multilayer Printed MSA fed High Gain Antenna

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**Abstract**— A multilayer printed 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 5 X 5 array of square parasitic patches which are fabricated on a 1.6mm thick FR4 layer. This layer is suspended in air at λo/2. The printed MSA is fed by a 50 Ω coaxial probe. 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.

**Index Terms**— Wireless Communication, Radiating Systems, Antennas, Fabry Perot Cavity antenna, Multilayer, High gain, MSA, PRS, Directive antenna.

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## 1 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],[3],[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.

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. 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 λ0/2 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

## 2 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 ρejψ 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]

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

$$S = \frac{1-\rho^2}{1+\rho^2 - 2\rho\cos\phi}\, f^2(\alpha)$$
(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 Lr between ground plane and PRS is given by [2]

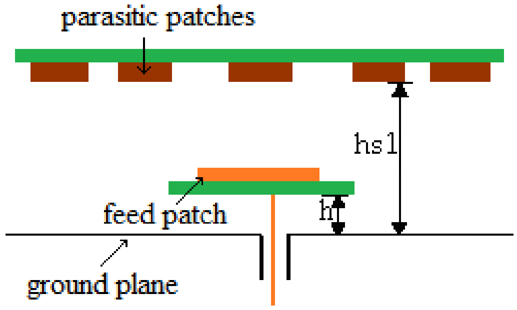
$$L_r = \left(\frac{\psi_0}{360} - 0.5\right)\frac{\lambda}{2} + N\frac{\lambda}{2} \qquad (3)$$

Here ψ0 is PRS reflection coefficient phase angle in degree and N=0, 1, 2, 3 etc.

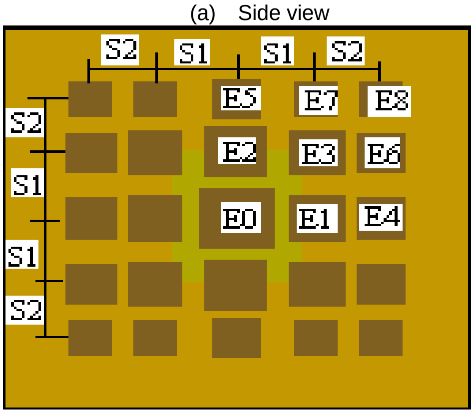
Gain can be increased by using array of parasitic elements on a superstrate layer. High gain broadside radiation can be achieved if the elements are fed in phase. The parasitic elements in an array are fed from the radiating field of microstrip antenna [12-13]. The parasitic patches are at different 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.

The geometry of the proposed antenna structure is shown in Fig. 1. 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 1.6 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) Side view




(b) Top view

Fig. 1. Geometry of antenna structure

## 3 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. 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 5x5 square parasitic patches are placed on the superstrate layer and the structure is optimized. VSWR< 2 over 5.7-5.875 GHz and antenna gain of 16.0 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, 3x3 and 5x5 SPPA are shown in Fig. 2 and Fig. 3 respectively.

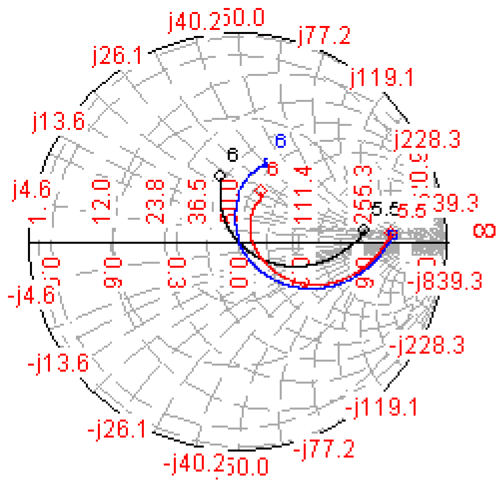



Fig. 2. Impedance variations vs. frequency (—◆—1x1, —□—3x3, —◇— 5x5)

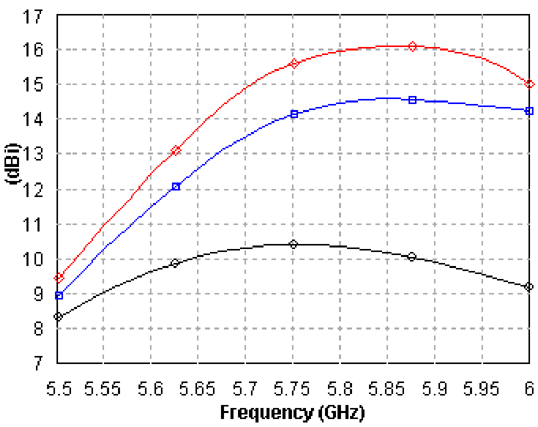



Fig. 3. Gain variations vs. frequency (—◆—1x1, —□—3x3, —◇— 5x5)

Fig. 4. shows average and vector current distribution at the feed and parasitic patches at 5.8 GHz. The current distribution shows that the amplitude of current induced in parasitic patches are nearly in phase and decrease as its distance from feed element increases. The superstrate affects the phase and amplitude distribution of fields. The phase distributions of the fields with a superstrate are observed to be more uniform than one without the superstrate. The superstrate has a focusing or phase smoothening effect and thus increases the effective aperture area, resulting in gain improvement [12], [13].

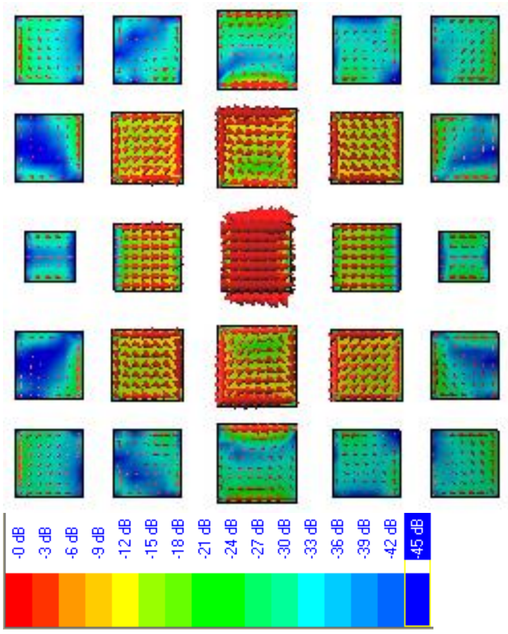



Fig. 4. Current distribution of 5x5 SPPA at 5.8 GHz

## 4 Antenna Design on Finite Ground

The MSA fed 5x5 SPPA structure is redesigned on finite ground plane of size 180mm x 180 mm. The VSWR is < 2 over 5.725 – 5.875 GHz frequency band as shown in Fig. 5 The antenna provides 17.8 dB gain with < 1.5 dB gain variation over 5.725-5.875 GHz, WLAN band. There is little radiation pattern variation over band. Gain variations of structures on finite and infinite ground are shown in Fig. 6. It is observed that gain increases slightly with finite ground and HPBW decreases. It is due to constructive interference between radiated and reflected waves at particular dimensions of finite ground. The antenna offer more than 80% antenna efficiency as shown in Fig. 7. Radiation patterns of 1x1, 3x3 and 5x5 SPPA on infinite and 5x5 SPPA on finite ground are shown in Fig. 8. Broadside Radiation patterns are symmetrical with < -18 dB SLL, < -25 dB cross polarization and F/B of about 22 dB.

## 5 Conclusion

An efficient, high gain, easy-to-fabricate printed MSA fed antenna having low SLL and high F/B 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. The proposed structure is suitable for satellite as well as terrestrial communications and can be embedded into the host vehicle.

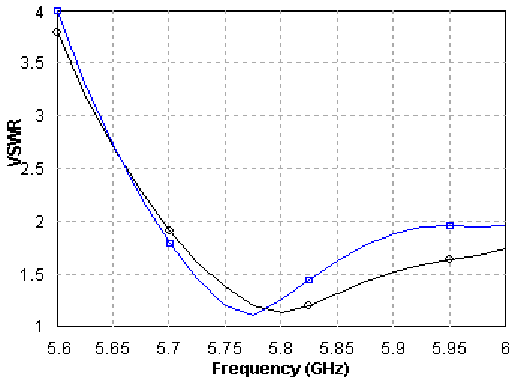



Fig. 5. VSWR vs. frequency (—◇— Infinite, —□—Finite Ground)

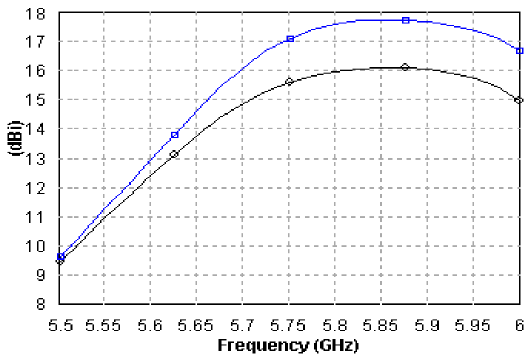



Fig. 6. Gain vs. frequency of 5x5 SPPA (—◇— Infinite, —□—Finite)

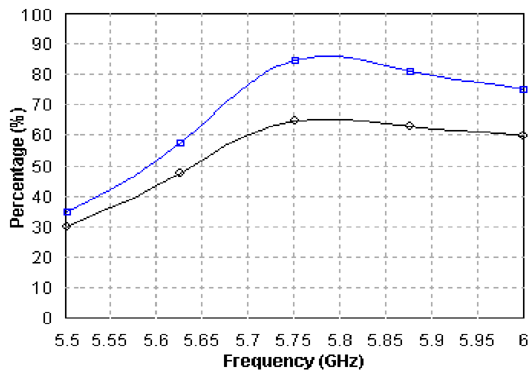
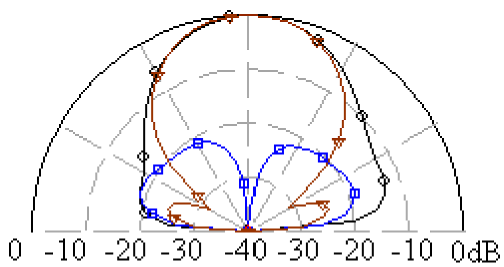
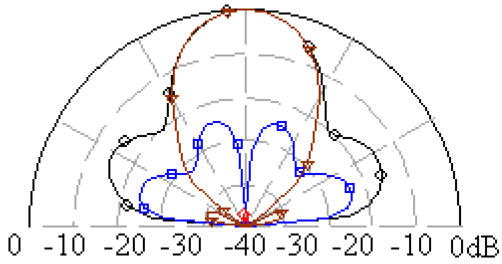


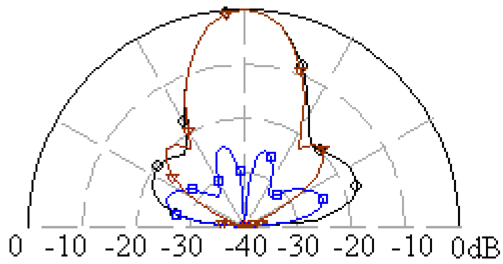

Fig. 7. Antenna efficiency vs. frequency of 5x5 SPPA (—◇— Infinite, —□—Finite)




(i) 1x1

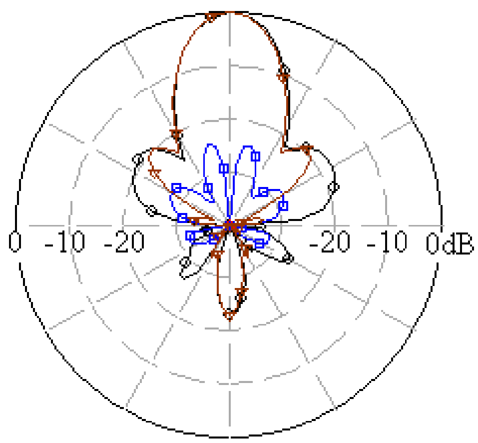



(ii) 3x3




(iii) 5x5

(a) Radiation pattern at Infinite ground plane




5x5 SPPA

(a) Finite ground plane

(b) (—◇— Eθ —◇— EΦ at Φ = 0° ,—□—Eθ —▽— EΦ at Φ = 90°)

(c) Fig. 8: Radiation patterns at 5.8 GHz

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## REFERENCES

[1] G. Kumar and K P. Ray, Broadband Microstrip Antennas, Norwood, MA Artech house, 2003.

[2] D.M. Pozar, S.D.Targonski, and H. Syrigos, Design of millimeter wave microstrip reflectarrays", IEEE Trans. Antennas Propagat., vol. AP-45, no.2, pp.287-295, Feb. 1997.

[3] R. D. Javor, X.D. Wu, and K. Chang, "Design and performance of a microstrip reflect array antenna", IEEE Trans. Antennas Propagat., vol. AP- 43, no.9, pp.932-939, Sept. 1995.

[4] J. Huang, and R. J. Pogorzelski, "A Ka band microstrip reflectarray with elements having variable rotation angles", IEEE Trans. Antennas Propagat., vol. AP46, no.5, pp.650-656, May 1998.

[5] G. V. Trentini, Partially reflecting sheet arrays, IRE Trans. Antennas Propag. 4, 1956, pp. 666–671.

[6] A. P. Feresidis and J. C. Vardaxoglou, High gain planar antenna using optimized partially reflective surfaces, IEE Proc. Microw. Antennas Propag 148, 2001, pp. 345–350.

[7] Renato Gardelli, Matteo Albani, and Filippo Capolino, Array thinning by using antennas in a Fabry–Perot Cavity for gain enhancement, IEEE Trans. Antennas Propag AP- 54, 2006, pp. 1979–1990.

[8] Antonije R. Djordjević and Alenka G. Zajić, Optimization of resonant cavity antenna, European Conference on Antennas and Propagation, 2006.

[9] E.A. Parker, "The gentleman's guide to frequency selective surfaces", 17th Q.M.W. Antenna Symposium, London, April 1991.

[10] W. Choi, Y.H. Cho, C. Pyo and J. Choi, High Gain Microstrip Patch Array Antenna using a Superstrate Layer, ETRI journal,Vol. 25, no.5, Oct. 2003.

[11] P.N.Chine and Girish Kumar, "Three Dimensional, Efficient, Directive Microstrip Antenna Arrays," IEEE Int. Symposium Antenna and Propagation. Washington DC., July 2005.

[12] R. K. Gupta and J. Mukherjee, Low cost efficient high gain antenna using array of parasitic patches on a superstrate layer, Microw. Opt. Technol. Lett. 51, 2009, pp. 733– 739.

[13] R. K. Gupta and J. Mukherjee, Effect of superstrate material on a high gain antenna using array of parasitic patches, Microw. Opt. Technol. Lett. 52, 2010, pp. 82– 88.

[14] Zhi-Chen Ge, Wen-Xun Zhang, Zhen-Guo Liu,Ying-Ying Gu, Broadband and High gain printed antennas constructed from Fabry- Perot resonator structure using EBG or FSS cover, Microw. Opt. Technol. Lett., 48, 2006, pp. 1272–1274.

[15] H. Legay and L. Shafai, A new stacked microstrip antenna with large bandwidth and high gain, Proc. IEEE AP-S Int. Symp., 1993, pp. 948–951.

[16] Egashira S., Nishiyama E., Stacked microstrip antenna with wide bandwidth and high gain, IEEE Trans. Antennas Propag, 44, 1996, pp. 1533-1534.

[17] Lee R.Q., Lee K.F., Experimental study of two layer electromagnetically coupled rectangular patch antenna, IEEE Trans. Antennas Propag., 38, 1990, pp. 1298-1302.

[18] IE3D release 14.0, Zeland software Inc., Fremont, CA., USA, 2006.