Multi-Polarization Array for C-Band

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Abstract

This paper describes a novel microstrip planar array of 8 elements operating in the C-band from 3.7 to 4.2 GHz and giving a gain of 17 dB. It can produce many types of polarizations such as $E_?$, $E_?$, right and left circular. In all these polarizations, the cross-polar level is around 20 dB lower than the co-polar level (except for $E_?$, for which it is around 10 dB). It is constructed using parasitic patch and shorting pins. It gives wide bandwidth and multi-polarization due to parasitic patch and shorting pins respectively. The array is simulated using Agilent Technologies Advanced Design System (ADS) 2003A Momentum software.

1. INTRODUCTION

The C-band from 3.7 to 4.2 GHz is widely used for reception of TV signals via satellite. In order to receive the signals from the satellite, it requires high gain antenna (of around 32 dB). There are various types of antennas such as parabolic dish, planar arrays, etc. that can give the required gain of around 32 dB. The drawback of parabolic dish at C-band is its large size and can not be made conformal to the host surface.

In this paper, efforts have been made to design planar array. The planar array is formed using microstrip antennas (or patches). These microstrip antennas should provide sufficient bandwidth. Unfortunately the microstrip antennas have very narrow bandwidth due to the fact that they are very thin. If thickness is increased to increase the bandwidth, the cost of the patch will rise and the radiation efficiency will decrease. Therefore other techniques can be used to increase bandwidth. These are as follows:

A. *Planar Multiresonator Configuration [1]*

In this method, in addition to the main patch, parasitic patches are placed near and in the same plane as the main patch. This method gives 20% maximum bandwidth. The major drawback of this method is its large planner size.

B. *Impedance Matching Networks for Broadband Microstrip Antenna [2]*

Impedance matching networks such as stubs are used to increase the bandwidth. This method gives bandwidth around 10%. Hence it is clear that this method cannot give more bandwidth.

C. *Aperture-Coupled Stacked Multiresonators [3]*

Stacked multiresonators with a slot in the ground plane can give a maximum of 70% bandwidth. The drawbacks of this method is complex design and poor front-to-back ratio.

D. *Electromagnetically-Coupled Microstrip Antenna [4]*

In this antenna, stacked multiresonators or multilayers are used. The upper parasitic layer is electro magnetically coupled to obtain high bandwidth. The design is simple, gives high front-to-back ratio and enough bandwidth around (30%).

The planar array should be compact one. The array can be compact if number of patches in the array is less or minimum. In order to achieve this, the gain of the individual patch should be increased. The gain of the patch can be increased either by using superstrates or by using stacked patches. If superstrates are used to increase the gain, following difficulties are encountered at this frequency:

- Thicker superstrate is used which degrades efficiency.
- It affects bandwidth.
- By doubling number of patches, gain does not double.

The last two difficulties mentioned above are encountered in case of stacked patches [5].

Electromagnetically coupled microstrip antenna is used in this paper. The single patch gives gain of 8.2 dB and bandwidth of 500 MHz (at C-band from 3.7 to 4.2 GHz). In order to obtain high gain of 32 dB, it requires such 256 patches. These patches are to be properly spaced and inter connected using appropriate matching networks. The size of this antenna array is 1 metre^2.

2. DESIGN & SIMULATION RESULTS

A. *Design of Patch Antenna*

The patch antenna consists of a ground plane, a radiating patch and a parasitic patch as shown in fig. 1. The dielectric materials used to support the radiating patch and the parasitic patch are of same type. The dielectric material has thickness of 1.6 mm and dielectric constant of 2.2. The parasitic patch is suspended 4 mm above the radiating patch with the help of foam and non-conductive pins [4].

1) *Effect of distance between radiating and parasitic substrate:* The separation between the parasitic patch and radiating patch should be around 0.1λ for maximum bandwidth [6]. In this antenna, it is 4 mm (air) + 1.6 mm (dielectric) which is approximately 0.108λ [3]. If the distance between the radiating and parasitic patch is 4 mm, just sufficient bandwidth is bandwidth (at C-band from 3.7 to 4.2 GHz). The bandwidth and the VSWR goes on improving slowly for the distance from 4 to 8 mm. If the distance between the substrates is increased to 14 mm or more the bandwidth starts decreasing.

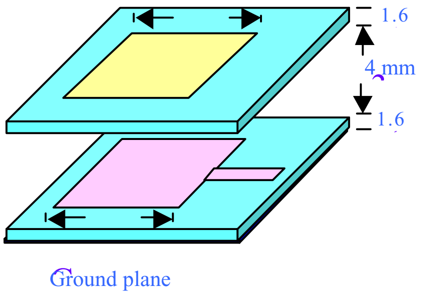


Fig.1: Structure of the antenna

2) *Shape and size of the patches:* In order to obtain all types of polarization and required bandwidth, the square patches (both radiating as well as parasitic) are used. The size of the parasitic patch is kept around 8% less than the size of the radiating patch. The optimized dimensions of the patches are shown in fig. 1.

B. Design of Shorting Pins

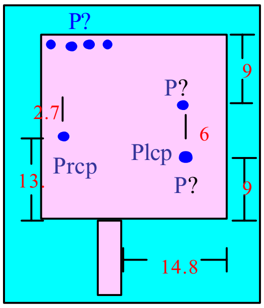
Shorting pins are used to obtain various types of polarizations [7]. Four shorting pins are used in this design. All the shorting pins are having diameters of 0.6 mm. Instead of shorting pins, PIN diodes can be used. The exact positions of the shorts on the patch are shown in fig. 2.

1) *$P_?$ shorting pins:* The group of four shorting pins placed at the left top corner of the radiating patch produces $E_?$ polarization when other three shorting pins P_{rcp}, P_{lcp} and $P_?$ are open.

2) $P_?$ *shorting pins:* The two $P_?$ shorting pins placed at the right side of the radiating patch produces $E_?$ polarization.

3) *P_{lcp} shorting pins*: If this shorting pin is placed and all other are open, it produces left circular polarization.

4) *P_{rcp} shorting pins*: If this shorting pin is placed and all other are open, it produces right circular polarization.



(All dimensions are in mm)

Fig. 2: Position of shorting pins

C. Results obtained using various shorting pins: Required polarization can be obtained using the corresponding pin(s) as follows.

1) *$E_?$ polarization:* In order to obtain $E_?$ polarization, the three shorting pins P_{rcp} , P_{lcp} and $E_?$ are removed. The $P_?$ shorting pins (four shorting pins at the top) should be placed as shown in fig. 2. Instead of shorting pin, if PIN diodes are used, the $P_?$ diodes should be forward-biased and remaining diodes should be reversed biased. In the entire band, the cross-polar level is around 10 dB lower than the co-polar polar level. The bandwidth obtained in this case is approximately 700 GHz (at C-band from 3.5 to 4.2 GHz). The variation in return loss (S_{11}) with respect to frequency and the polarization plots are shown in fig. 3 and fig. 4 respectively.

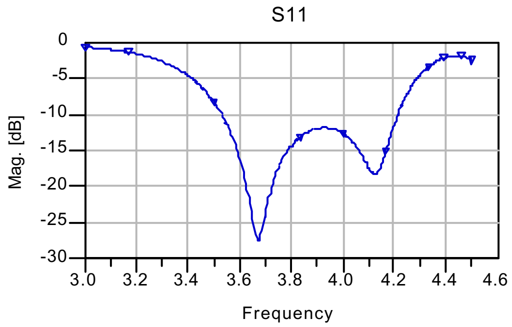


Fig. 3: Return loss for $E_?$ polarization

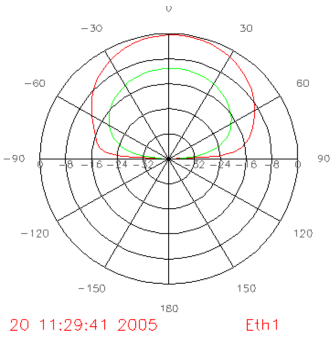


Fig. 4: Polarization plot for $E_?$
Red --- $E_?$ polarization
Green --- $E_?$ polarization

2) *$E_?$ Polarization:* In order to obtain $E_?$ polarization, the two shorting pins P_{rcp} and $E_?$ (the four shorting pins at the top) are removed. The $P_?$ and P_{lcp} shorting pin should be placed as shown in fig. 2. Instead of shorting pins, if PIN diodes are used, the $P_?$ and P_{lcp} diodes should be forward biased. In this case we get bandwidth around 500 GHz (at C-band from 3.7 to 4.2 GHz.). The $E_?$ level is higher than $E_?$ by around 20 dB. The variation in return loss (S_{11}) with respect to frequency and polarization plots are shown in fig. 5 and fig. 6 respectively.

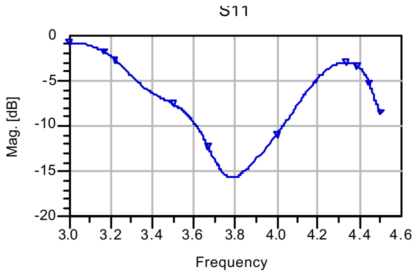


Fig.5:*Return loss for $E_?$ polarization*

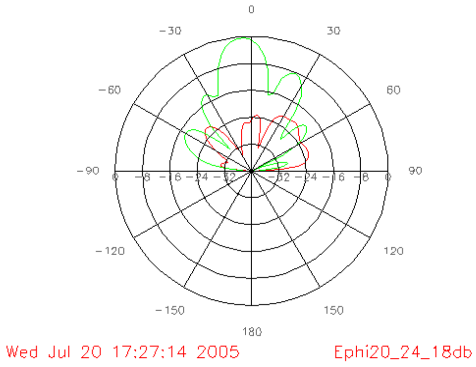


Fig. 6.: Polarization plot for $E_?$
Green --- $E_?$ Polarization
Red --- $E_?$ polarization

3) *Left Circular polarization:* This polarization is obtained by forward biasing the PIN diode at P_{lcp} position and open-circuiting the remaining diodes. In this case we get more bandwidth of around 700 MHz (at C-band from 3.7 to 4.2 GHz). In the entire band the difference between the left and right circular polarization is around 20 dB. The variation in return loss (S11) with respect to frequency and polarization plots are shown in fig. 7 and fig. 8 respectively.

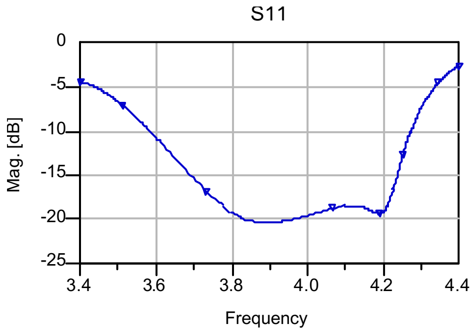


Fig.7: Return loss for lcp polarization

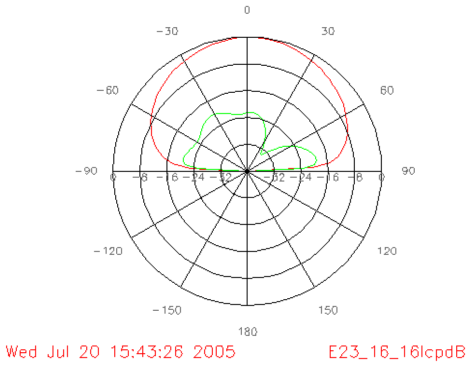


Fig. 8: Polarization plot for lcp
Red --- lcp polarization
Green --- rcp Polarization

4) *Right Circular polarization:* This polarization is obtained by forward biasing the diode at P_{rcp} position and open circuiting the remaining two diodes. In this case we get more bandwidth of around 700 GHz (at C-band 3.7 to 4.2 GHz). In the entire band the difference between the right and left circular polarization is more than 18 dB. The variation in return loss (S_{11}) with respect to frequency and polarization plots are shown in fig. 9 and fig. 10 respectively.

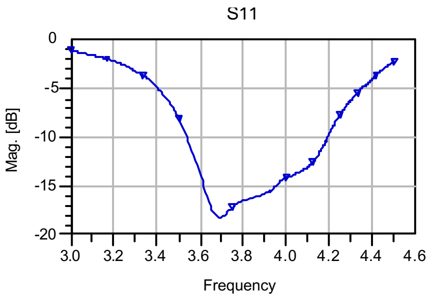


Fig. 9: Return loss for rcp polarization

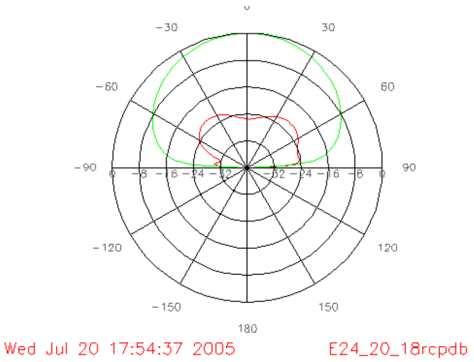


Fig. 10: Polarization plot for rcp
Green --- rcp Polarization
Red --- lcp polarization

C. Design of Feed

The patch is fed with the help of microstrip line having characteristic impedance of 50 ohms. In order to obtain proper impedance matching between the feed line and the patch, the feed is placed at an offset. The exact position of the feed is shown in fig. 2.

D. Design of Array

Using above patch an array is designed. The separation between the two adjacent patches is kept as 30 mm. (approximately $\lambda/2$). At this separation, better bandwidth, polarization and low mutual coupling are obtained.

E. Design of Feed Network

Corporate feed is used to feed the patches in same phases. This is useful to obtain maximum directivity in the broadside direction. Most of the feed lines are having 50 ohm characteristic impedance. Metering is done at the bends or corners to improve the frequency response. Quarter wave transformers are used to match the impedances at the points where power is divided from one branch to two branches. A 100 ohm line is used at the port so that it will see a 50 ohm impedance. The feed network feeding eight elements is shown in fig. 11.

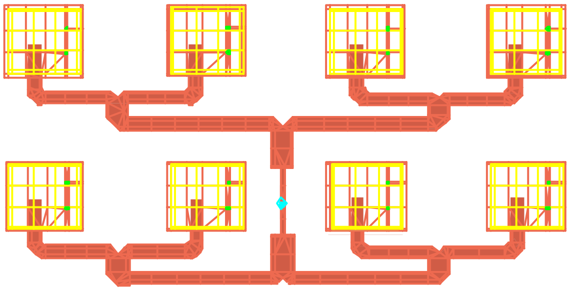


Fig. 11: Array of eight elements array of eight elements (E? polarization)

3. MEASERMENTS

Fig. 11 shows an array of 8 elements. It gives gain of 16.5 dB at 3.8 GHz and gain of 17.1 dB at 4.2 GHz. A single patch gives gain of 8.2 dB. Two patches give gain of 11.1 dB. Four patches produce gain of 14 dB. If we double the no of patches, the gain also doubles or increases by 3 dB. In order to obtain gain of around 30 dB, it requires 256 patches.

Fig. 12 shows the 3-dimensional radiation pattern for an array of eight elements. The variations in return loss (S_{11}) with frequency are plotted in fig. 13.

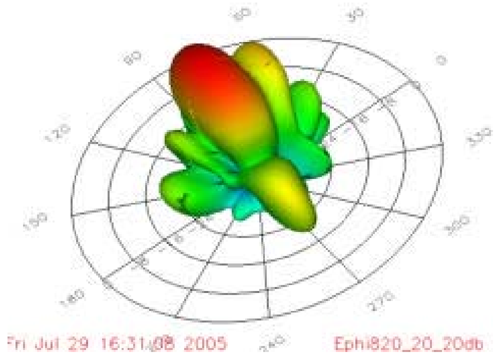


Fig. 12: Three dimensional radiation pattern for array of eight elements (E? polarization)

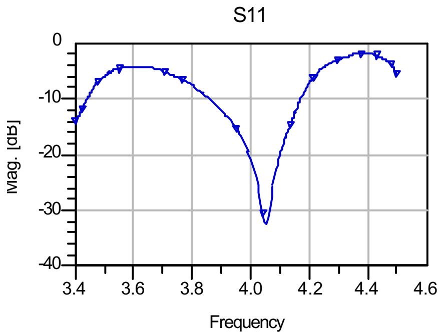


Fig. 13. Return loss of array of eight elements ($E_?$ polarization)

Fig. 14 shows the polarization levels. Red curve shows the levels of $E_?$. Green curve shows levels of $E_?$. The difference between the $E_?$ and $E_?$ circular polarization is 20, 24 and 18 dB at start, middle and at end of the band. Similar results are obtained for other types of polarizations using 8 patches. When an array is formed, the positions of shorting pins need to be slightly adjusted to get more polarization purity. Finally, an array is designed for 256 patches giving a gain of around 32 dB and occupying 1 m^2 area.

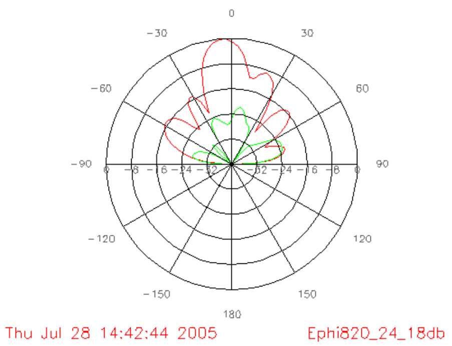


Fig. 14: Polarization plot of array of eight elements ($E_?$ polarization)

4. CONCLUSIONS

The electromagnetically coupled patch is compact and broadband. It can produce $E_?$, $E_?$ and right as well as left circular polarizations. The array of 256 patches gives gain of around 32 dB in the at C-band in the frequency range from 3.7 to 4.2 GHz making it useful for satellite TV reception applications.

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