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Novel microstrip patch antenna to use in 2×2 sub arrays for DBS reception

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Abstract

Antennas for direct broadcast satellite (DBS) reception often consist of a parabolic reflector and a LNB are realized in different technologies (the feed in hollow waveguide technology and the signal-processing unit in planar waveguide technology) and are very heavy and bulky. Recently, to solve above problems, microstrip array antennas have been designed and developed for DBS reception. For this purpose, the design of microstrip array antenna has to be done in frequency range from 10.75 GHZ to 12.75 GHZ, simultaneous reception of horizontally and vertically polarized waves, with return loss less than -10 dB (VSWR<2) and gain more than 30 dB. In this paper, at first a 16×16 microstrip array has been designed with 31 dB gain and 250 MHZ bandwidth using 2× 2 Sub arrays. Secondly, Improved 2×2 Sub array has been proposed to use in array lead to enhancement in DBS antenna bandwidth until 10%. Finally, novel microstirp patch antenna has proposed to use in 2× 2 Sub array with 12% bandwidth that cover all DBS frequency range from 10.75 GHZ to 12.75 GHZ. Significance of this work lies in greater gain and VSWR bandwidth than those reported in the literatures and simultaneously reception of vertically and horizontally polarization while previous works didn't have such specification simultaneously. Therefore, this antenna is proposed to develop of microstrip array for DBS reception.

Keywords: Antenna, DBS, PBG, Microstrip Array

Introduction

Conventional reflector antennas are usually used for direct broadcast satellite (DBS) reception. Such antennas have high gain, simultaneous horizontally and vertically polarization and wide bandwidth of VSWR. These antennas often consist of a parabolic reflector and a LNB (Low Noise Block Converter) that can't easily be used due to curved bulky structure and being heavy. Also, the feed of such antennas is in hollow waveguide technology and the signal processing unit in planar waveguide technology, leading to increase the production cost. Recently, microstrip array antennas have been designed and developed (Schwenzfeier, 2001). Yagi Antenna Corporation of Japan has developed an array of 1024 elements, which has an aperture of 48×64 cm^2 and peek gain of about 33 dBi (Garg Ramesh, 2001). NHK Science and Technical Research Laboratories of Japan has also Developed a flat microstrip antenna array with 512 square patch elements, a size of 32 × 64 cm^2, and peak gain 32 dBi. However, the bandwidth of conventional microstrip antennas are about 3%-10% (Garg Ramesh, 2001), whereas for DBS reception, the design of microstrip antennas has to be done in frequency range for 10.75GHZ-12.75 GHZ, and for simultaneous reception of horizontally and vertically polarized wave.

In this paper, firstly, we have introduced previous work with an array consist 64 of 2× 2 Sub arrays, which has an aperture of 35×50 cm^2 and peak gain about 31 dBi, for using in DBS reception, hence getting the same gain but with fewer patch elements than those reported in the previous works. Secondly, Improved 2×2 Sub array has been proposed to use in array lead to enhancement in DBS antenna bandwidth until 10%. Finally, novel microstirp patch antenna using photonic band gap (PBG) structure has proposed to use in 2× 2 Sub array with about 13% bandwidth and circular polarization.

Design procedure and analysis

To design microstrip array, firstly, a single patch antenna should be designed in 11 GHZ frequency band. Impedance matching, maximum gain and maximum VSWR bandwidth are important design considerations (Garg Ramesh, 2001). In this work for impedance matching inset fed patch was used. The dielectric substrate, separating the ground plane and the antenna patches, has a dielectric constant ε_r of 2.33 and thickness, h, of 0.51 mm. The best dimensions (Length, L, Width, W) for a patch operating within such frequency band, has been achieved (Ghiyasvand & ForoORagh, 2005):

L= 9mm, W= 13mm

For each 2×2 subarray, the elements was separated by

Fig.1. 2×2 Sub arry inset feed

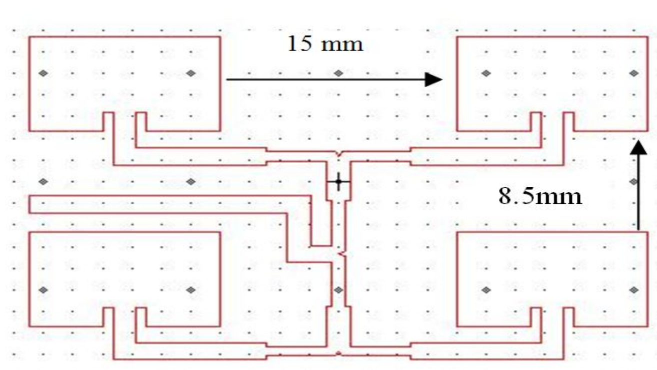

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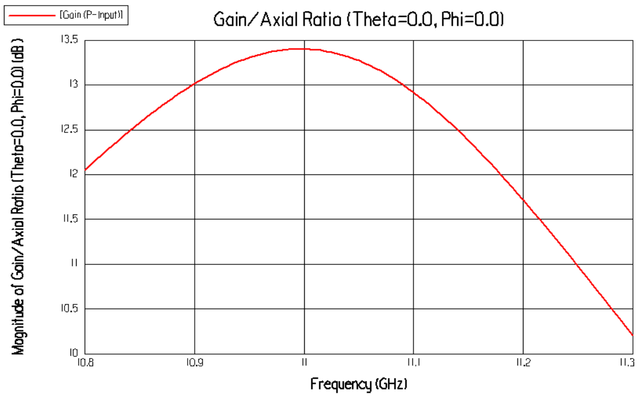
Fig. 2. Simulation Results of 2× 2 Sub Array
(a) Gain



(b) Return Loss

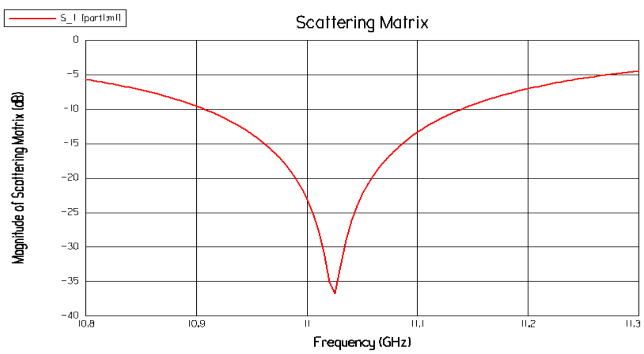


Fig. 3. 256 Elements Array Designed

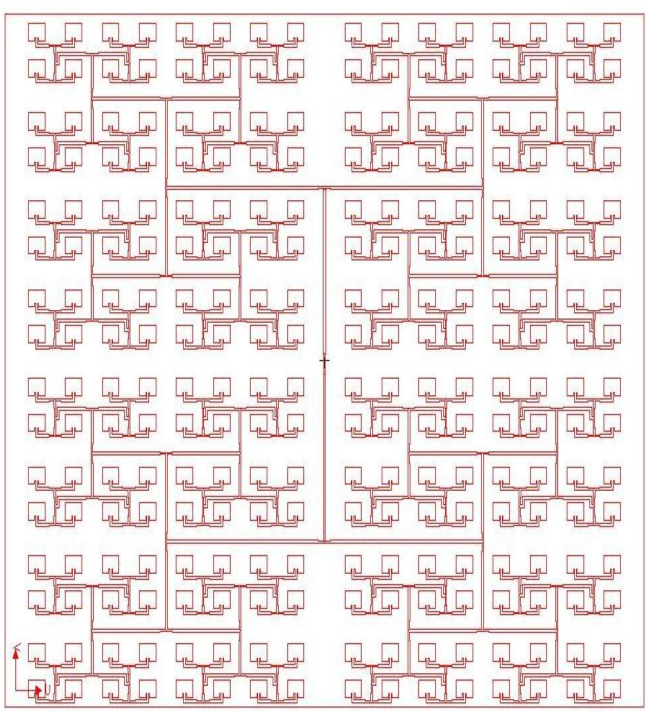
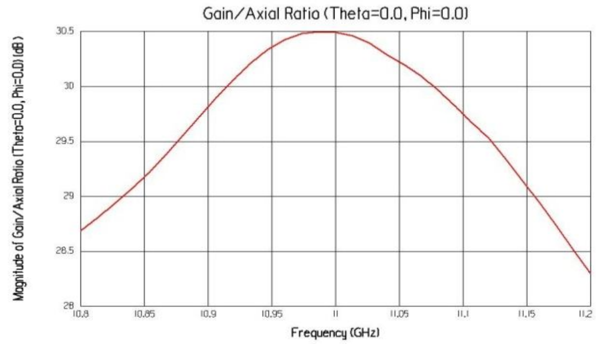
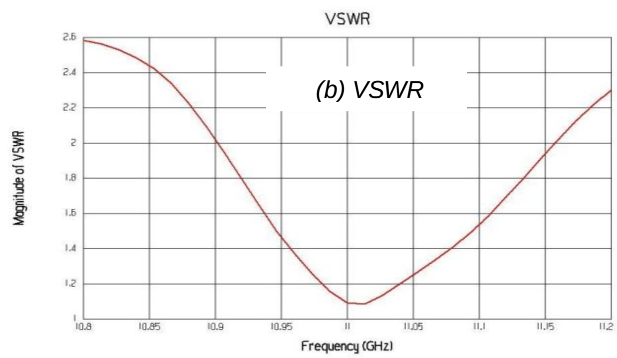
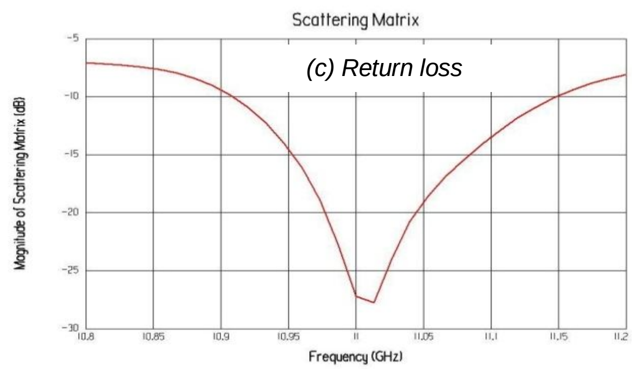


Fig.4. Simulation results of 16×16 Array
(a) Gain



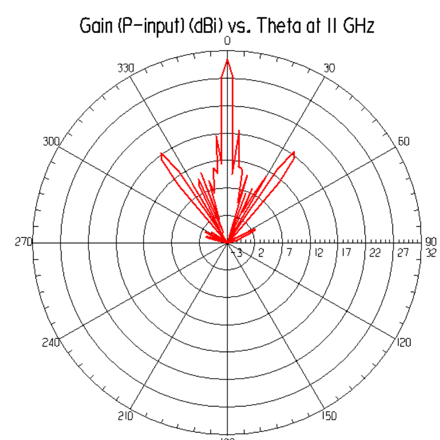


(b) VSWR



(c) Return loss

Fig.5. Radiation Pattern of 16×16



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distances of 15 mm and 8.5 mm in the x and y directions, respectively (Fig.1). This subarray has been simulated by Ansoft Ensemble (Ghiyasvand & Forooragh, 2005) and its result indicated in Fig. 2.

16×16 Array

To achieve more than 30 dBigain, using mentioned 2×2 sub array, only 64sub arrays required (Fig.3). The distances between sub arrays in the x and y directions has been optimized by using optimization tab of Ansoft Ensemble. Such array has been simulated and its result showed that designed 256 elements array has 31dBi gain and 250 MHZ bandwidth (Ghiyasvand & Forooragh, 2005) (Fig.4). Also, Radiation pattern of Array has been shown in Fig.5. Such array is proper for DBS reception. The advantage of this antenna for DBS reception is being lightweight, easily installed on a building wall, low cost manufacturing and being small in size.

Improved 2× 2 Sub array

The above microstrip array has an aperture of 35×50 cm^2 peak gain about 31 dBi and about 3% bandwidth and vertically polarized (Ghiyasvand & Forooragh, 2005). In this section we have proposed an improved 2× 2 Sub array to use for DBS reception.

Proximity coupled microstrip patch antennas (PCMA) have been investigated and found suitable for applications where bandwidths greater than those provided by other feeding techniques are needed (Amman Max, 1997). This simple configuration provided enhanced bandwidth without undesired radiation caused by the discontinuities and asymmetry of contacting feed method. Proximity-coupled antennas are known for the reception of one polarization only (Garg Ramesh, 2001). However, we concentrate on circular polarized PCMA. The configuration of antenna, have been shown in Fig.6. The design procedure of such antennas has been shown in previous work (Ghiyasvand et al., 2005a). The dielectric constants and height of selected substrates (RT5870) are as follows:

$$\varepsilon_{r2} = \varepsilon_{r2} = 2.33, h_1 = 0.03 inch, h_2 = 0.02 inch \quad (1)$$

It has been obtained that the Proper width of 50Ω microstrip feed line on the lower substrate is $0.132\lambda_g$.

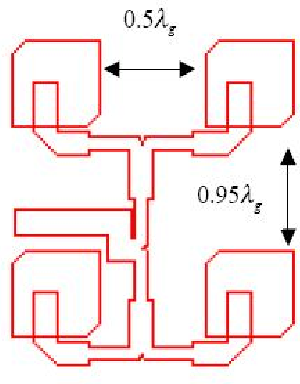
The length of the patch has been obtained $0.46\lambda_g$.We have observed for optimum design of circular polarized PCMA, patch's width should be equal to its length. We observed that the best impedance matching is happened when we select as follows (Ghiyasvand *et al.*, 2005):

$$l_1 = 0.24\lambda_g, p = 0.23\lambda_g \quad (4)$$

To achieve circular polarization, square patch with truncated corner structure have been used. Base on theory show in previous work, other parameters of PCMA has been given (Ghiyasvand *et al.*, 2005):

$$\Delta s = c^2, s = L^2, c = 0.023\lambda_g \quad (5)$$

Fig.7. 2× 2 Sub Array Circularly Polarized PCMA



For the best antenna operating in DBS reception radiation characteristics should be improved as follows:

1. Increasing VSWR bandwidth (RL<-10 dB).
2. Increasing gain and the gain bandwidth of PCMA.
3. Increasing bandwidth of axial- ratio (AR<6dB).

To achieve the above purpose PCMA can be used to make 2× 2 Sub array, but the distance between the each element is very important parameter to improve the radiation characteristics. For proposed configuration in this work the optimum distances has been shown in Fig.7.

Proposed Circularly Polarized PCMA 2×2 Sub array has been simulated by Ansoft Ensemble and its result indicated in Fig.8. Results show that bandwidth has been increased up to 10% which is much better than conventional 2×2 Sub array in previous works. Also one can see gain has remained constant through the bandwidth and AR bandwidth is increasing up to 4%. Therefore the Circularly Polarized PCMA 2×2 Sub array is proposed to use in DBS reception array antennas. Radiation characteristics of this sub array can be improved more, using some techniques such as photonic band gap structure (PBG).

Improved PCMA using PBG

Various types of PBG structures have been reported to use inmicrostrip antennas (Rahmanand Stuchly, 2001). The PBG structure is considered in this work is shown in Fig.9. This PBG is array of square metallic patches connected to the ground plane by metal wires (Rahman & Stuchly, 2001). The Rahman model is used for design the PBG structure in operating frequency of PCMA. This model is based on transmission line and periodic structure theory (Ghiyasvand et al., 2005b). Figure 10 shows the result (dispersion diagram) for the PBG structure with following dimensions (a=3.5 mm, g=0.5 mm, d=0.5 mm) (Ghiyasvand *et al.*, 2005b).

Fig. 6. Circularly Polarized PCMA

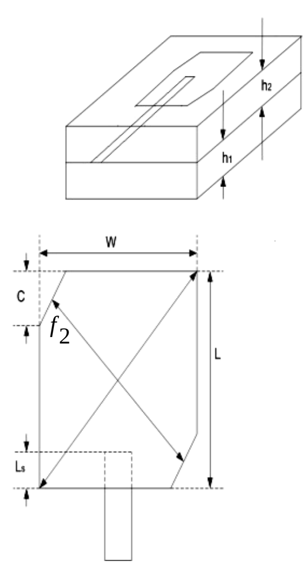


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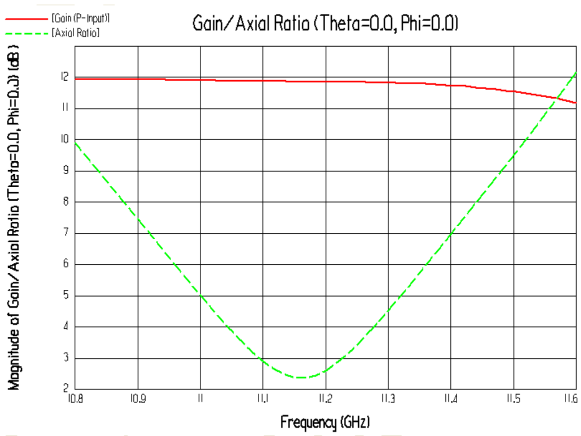
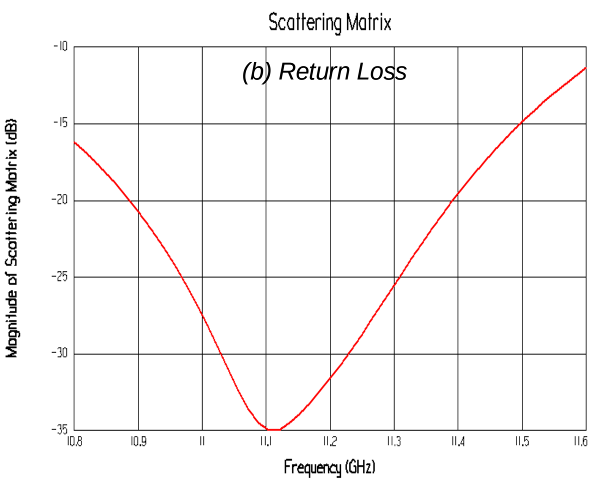
Fig. 8. Radiation Characteristics of 2× 2 Sub array C.P. PCMA (a) Gain





(b) Return Loss

(c) Radiation Pattern

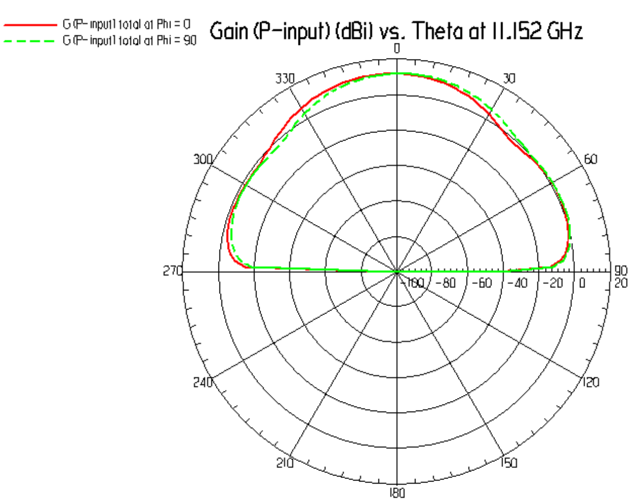


Fig. 9. PBG Structures With Via

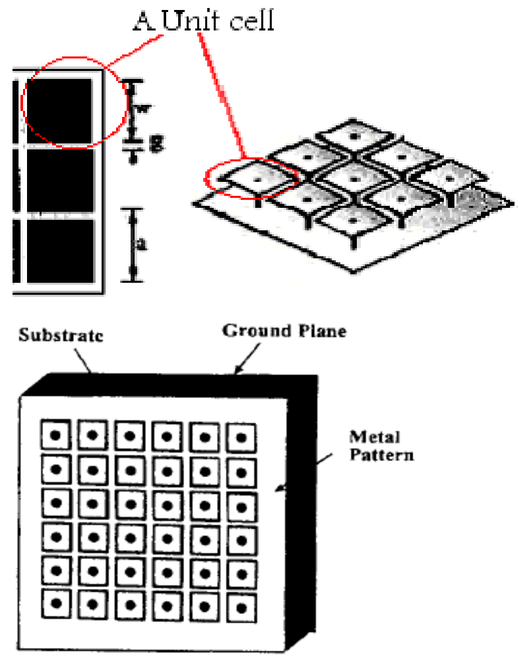


Fig.10. Dispersion diagram for the

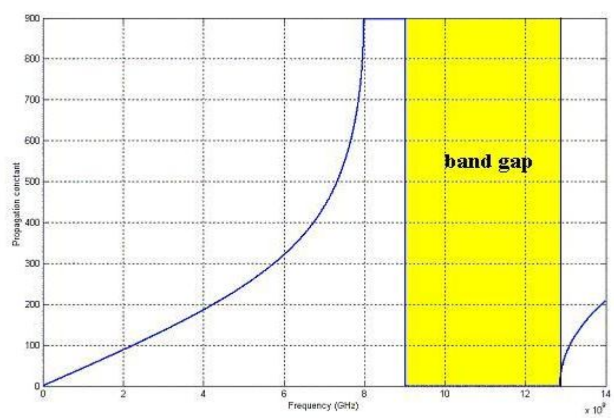


Fig. 11. PCMA Surrounded by PBG

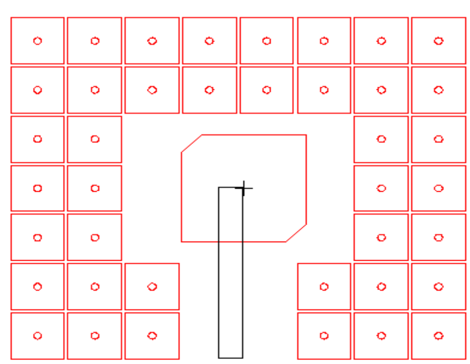
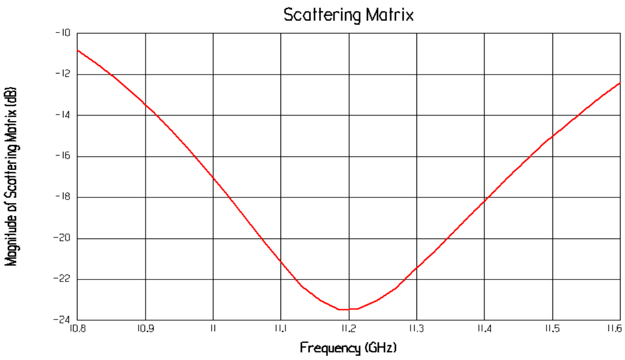
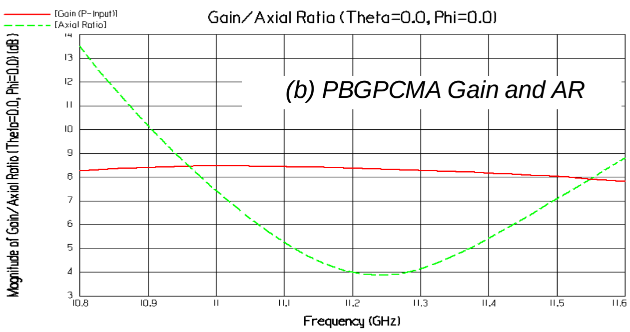
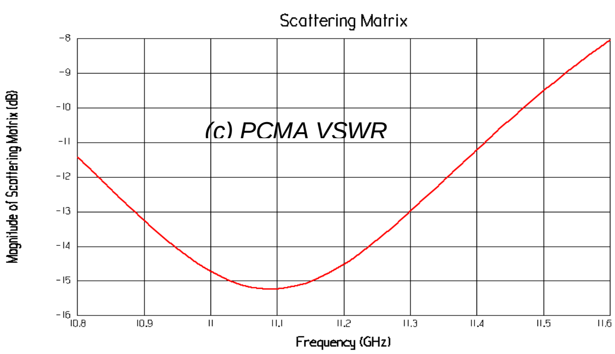


Fig.12. Radiation characteristics(a) PBGPCMA VSWR







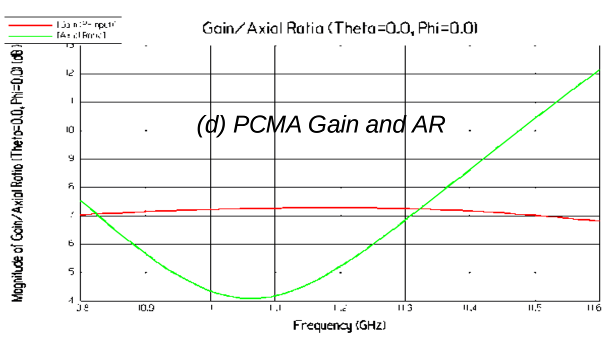


Fig.10 shows that band gap have happened in desired frequency band (9 GHZ -13 GHZ) (Ghiyasvand *et al*., 2005b). In the last pervious work a dual polarized PCMA has been surrounded using PBG structures. Simulation results showed the PBG PCMA radiation characteristic were improved significantly rather than PCMA without PBG (Ghiyasvand *et al*., 2005b). This is a good idea for improving the Circular polarized PCMA radiation characteristics. Fig.11 shows the schematic of the proposed circular polarized PCMA surrounded by PBG structure. Such configuration has been simulated by Ansoft Ensemble. The simulation results of PCMA surrounded by PBG structures have been indicated in Fig.12.

An increase in the gain from 7 dB for conventional PCMA to 8.5 dB for the PBG PCMA, and the gain bandwidth from 10.8 GHZ to 12 GHZ noticed in Fig.12. Also, Fig.12 shows an increase in the VSWR bandwidth from 9% for PCMA to 12% for PBG PCMA. It shows an improving in the axial ratio bandwidth up to 4%,too. Therefore, PBGPCMA can be used for developing Circularly Polarized PCMA 2×2 Sub array to use in DBS reception array antennas.

Conclusion

In this paper, at first a 16×16 microstrip array has been designed with 31 dB gain and 250 MHZ bandwidth using 2× 2 Sub arrays. Secondly, Improved 2×2 PCMA Sub array has been introduced to use in array lead to enhancement in DBS antenna bandwidth until 10%. Finally, novel microstirp patch antenna using PBG has proposed to use in 2× 2 Sub array with 12% bandwidth that cover almost of DBS frequency range from 10.75 GHZ to 12.75 GHZ. Significance of this work lies in greater gain and VSWR bandwidth than those reported earlier (Ghiyasvand *et al.*, 2005a, Ghiyasvand *et al*., 2005b, Badr, 2010) and simultaneously reception of vertically and horizontally polarization while previous works didn't have such specification simultaneously. Therefore, this antenna is proposed to develop of microstrip array for DBS reception.

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