Sidelobe Level Reduction In Microstrip Patch antenna array

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Abstract— **The reduction in side lobe level (SLL) of a microstrip patch antenna array is discussed. For reducing the surface wave, air core within the substrate below each of the patch antennas is used and to reduce the mutual coupling between the array elements simple narrow strip fence between the elements are used. An array of 16 circular microstrip patch antennas fed through coaxial probes with appropriate Chebyshev amplitude distribution is considered. It is shown that application of the air cores and the narrow strips in the array results in an improvement of the SLL by 4.2 dB and 1.2 dB, respectively. Simulated return loss and pattern results obtained through two software packages of HFSS and CST are provided and results are discussed.**

I. INTRODUCTION

Microstrip antennas, due to features such as light weight, small size, planar structure and easy fabrication for mass production are very attractive for radar applications. One of the important parameters in radars is the side lobe level, SLL. To design a microtrip patch antenna array with SLL lower than -25 dB becomes difficult due to: mutual coupling between array elements, surface wave effects, reflections within the substrate and tolerances in fabrication [1]

To reduce the mutual coupling and surface wave effects in a printed antenna array several approaches have been proposed. In [1] a 16 element array fed through coaxial probes with appropriate phase shifters is used leading to a low SLL of -35 dB. In [2], to shield the feed network from the main radiating elements the feed network is placed behind the ground plane and connecting the feed to the patch antenna via pins, a non-planar structure in the shape of a corner reflector is proposed resulting in a SLL of -32 dB. Use of aperture coupled patch antennas [3, 4]; and waveguide-fed microstrip patch array at 76 GHz [5, 6] have also led to low SLL designs. To reduce the mutual coupling and surface wave effects, electromagnetic band gap structures, EBG, have also been employed, [7]. By extending the finite ground plane in between the Yagi-like antenna elements, [8], and the double dipole antenna elements, [9], low sidelobe, -32 dB, linear series-fed endfire arrays are proposed.

In [10], through reasoning, it is shown that by placing an air core below a single circular patch antenna which is coaxially fed, a reduction in surface wave can be achieved.

In this paper, a combination of air core under the patches and narrow fence strips in between the patch array elements to reduce the SLL is introduced. The design of a 16 element planar array of circular shaped microstrip patches fed via coaxial probes leading to an improvement of more than 5.4 dB is provided. The array antenna is simulated through the use of commercially available software packages Ansoft HFSS (a finite element method in the frequency domain) and CST (finite integral technique and analysis in time domain). These two results confirm the accuracy of the method.

II. ANTENNA DESIGN

The aim of this work is to design a planar microstrip antenna array with lower side lobe level (without effecting the other parameters of the antenna such as gain, bandwidth, etc.). It is already known that for reducing SLL, surface wave, mutual coupling and parasitic radiation from feeding network should be decreased. To reduce the parasitic radiation from the feeding network coaxial feed can be used, while to reduce the surface wave and mutual coupling one can choose a specific design for the antenna elements.

As mentioned in the previous section, one can introduce an air core under the patch in order to reduce the surface wave. This is implemented in this work to design an array of patch antennas each fed by coaxial probes. Initially, the single circular patch is designed, Fig. 1. With the full substrate being present, the position of the coaxial probe for the lowest reflection coefficient is obtained. Then the air core is introduced into the structure. It is noticed through simulation that the coaxial probe must be placed within the air-core to obtain a good radiation pattern as well as good impedance match. Through optimization, the position of the probe and the radius of the air-core can be obtained.

Fig. 2 shows the structure of the linear array of the circular microstrip patch antennas with air core under each patch. The array elements shown are placed in the H-plane. It will be shown in the next section that the mutual coupling between the array elements can be further reduced if a strip fence is introduced in between the elements. The length of the strip fence should not be of half wavelength. The dimension of the fence strip obtained through optimization to give the lowest SLL is: W_{fence} = 0.2 mm and L_{fence} = 70 mm. The array has 16 elements and in order to reduce the sidelobe level, a 40 dB Chebyshev amplitude distribution is employed. The antenna elements are spaced $\lambda_o/2$ from each other.

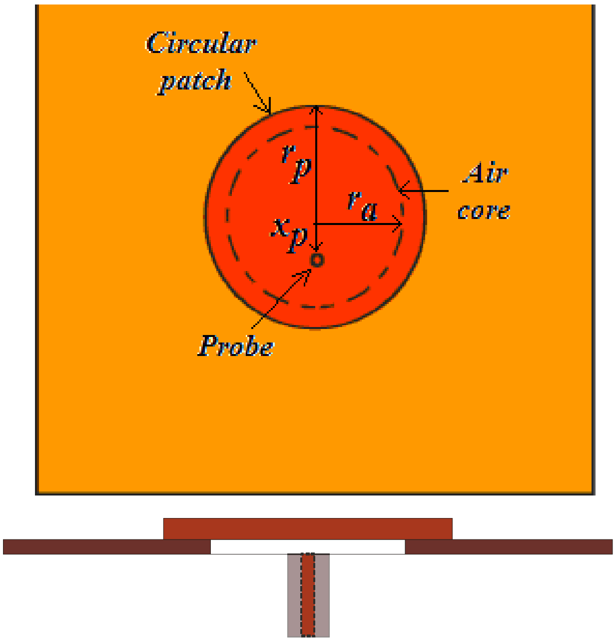


Fig. 1. Circular patch antenna with air core fed through a coaxial probe. r_p= 2.15 cm, d=1.651mm, ε_r = 2.2, L_{sub}=W_{sub} = 47 mm, r_a =15 mm. x_p = 7.27 mm.

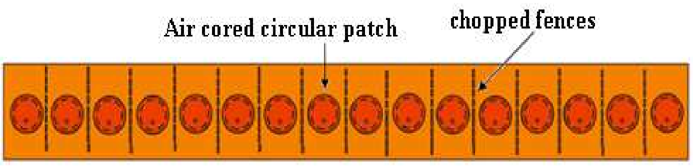


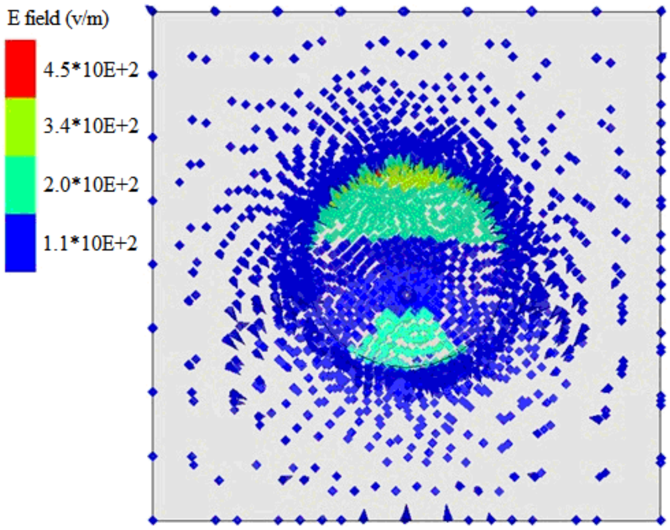
Fig. 2. H-plane array of circular patch antennas with air cores and strip fences, fed by coaxial probes. r_p= 21.5 mm, d = 1.651 mm, ε_r = 2.2, L_{sub} = 400 mm, W_{sub} = 47 mm, r_a = 1.5cm. x_p = 6.2mm, W_{fence} = 2 mm and L_{fence} = 70 mm.

III. RESULT

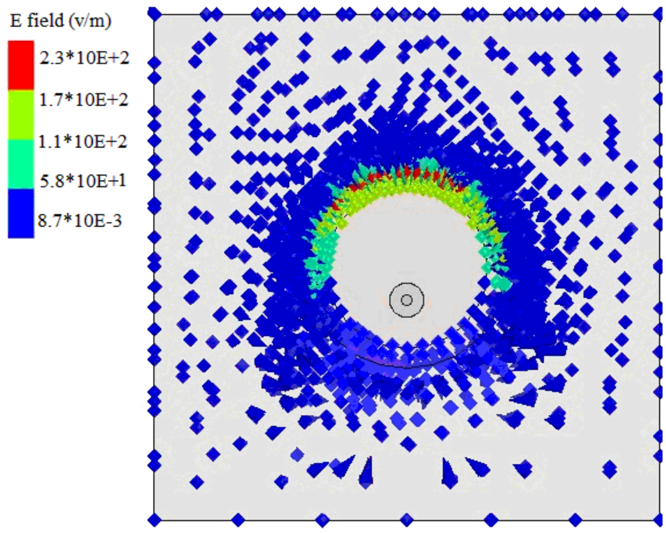
The electric field distribution around a single patch antenna with and without the air-core are shown in Fig. 3. From this figure it can be seen that the presence of the air-core has resulted in the electric field around the patch antenna to decay by more than 100 times. As such, it is obvious that the air-core can reduce the coupling between two such patches in an array environment.

A 16 element array of circular patches with air-cores, similar to the structure shown in Fig. 2 has been designed and the simulated results obtained through HFSS. To check and confirm the accuracy of the results, the antenna structure is also simulated through software package CST. Figure 4 shows the reflection coefficient results for the H-plane array antenna with the air-cores.

The E- and H-plane radiation patterns of the 16 element array antenna with and without the air-cores are shown in Figure 5.



(a)



(b)

Fig. 3. Field distribution around the single patch antenna (a) without the air-core and (b) with the air-core under the patch

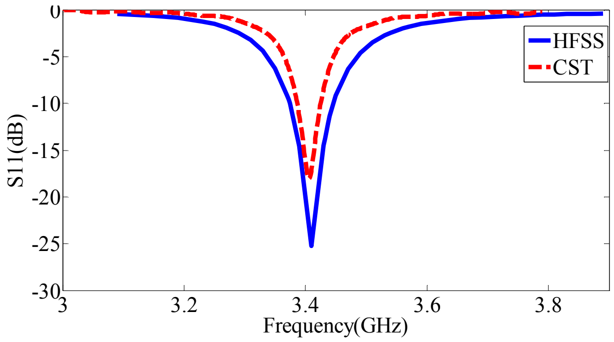
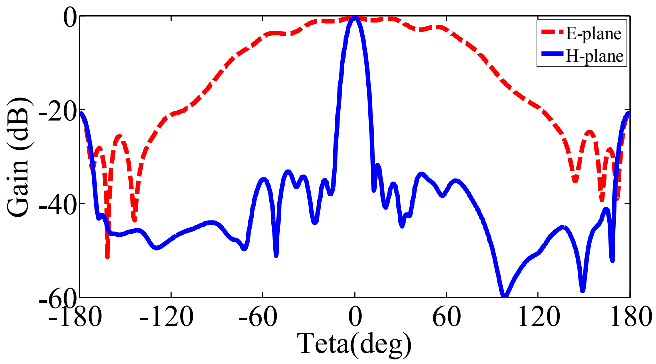
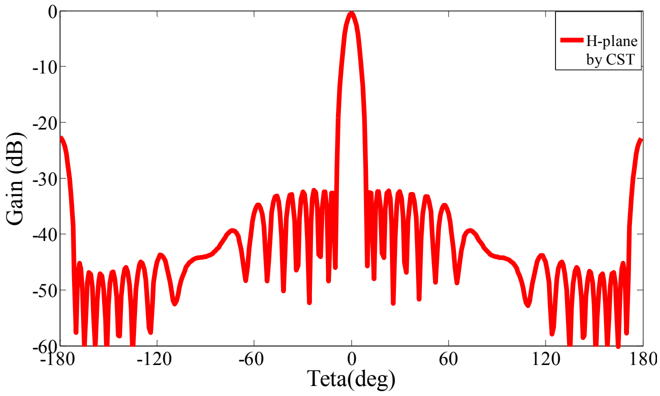
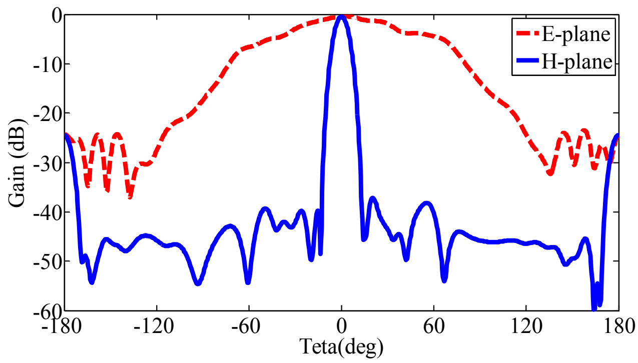


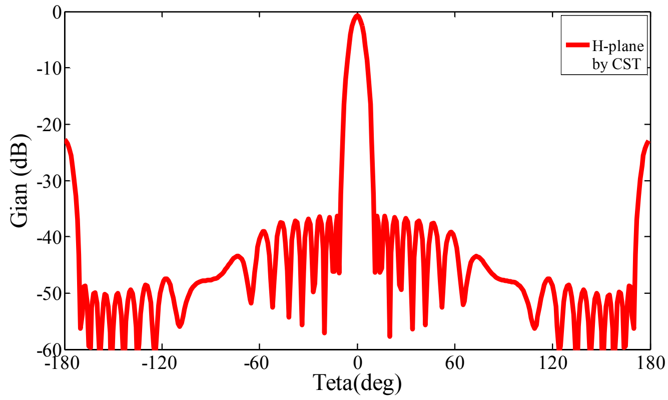
Fig. 4. The reflection coefficient of the H-plane circular patch array antenna with air-cores.





(a)





(b)

Fig. 5. The E- and H-plane radiation patterns of the 16 element circular patch antenna array (a) without the air-core and (b) with air-core

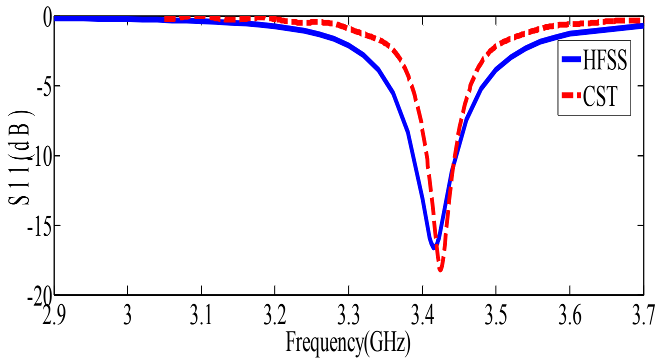
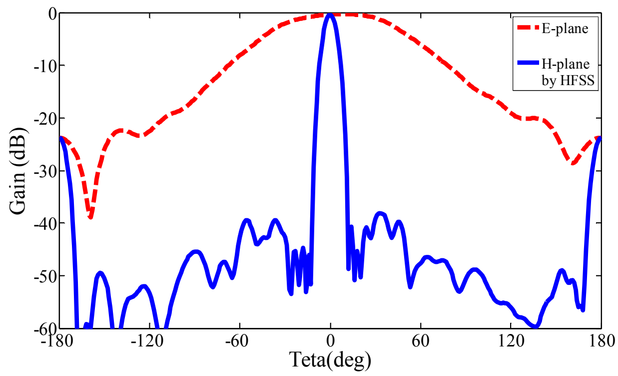


Fig. 6.The reflection coefficient of the 16 element H-plane array of circular patch antennas with air-cores and fence strips



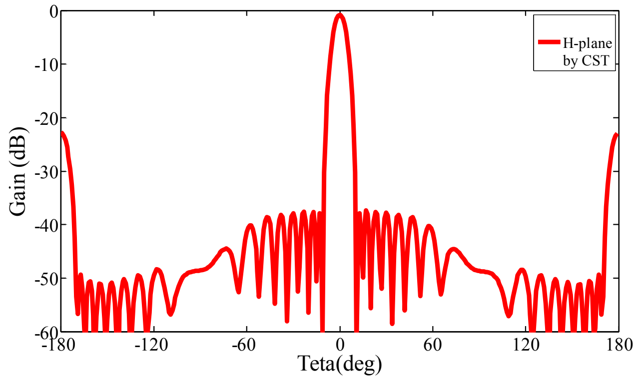


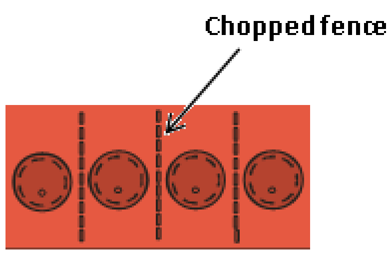
Fig. 7. The E- and H-plane radiation patterns of the 16 element circular patch antenna array with air-cores and fence strips

From the results it can be seen that the presence of the air-cores has reduced the sidelobe levels by as much as 4.5 dB in the H-plane array while the shape of the main beam has not changed. As expected an air core results in reduction of the surface wave in the substrate and reduction in the SLL.

As mentioned before, to reduce the mutual coupling even further one can place a narrow fence strip in between the two neighboring patches leading to the structure shown in Fig. 2. The reflection coefficient result of the 16 element array with both air-core and fence strips is shown in Fig. 6. Upon comparison with the result of Fig. 4 one can see that presence of such simple fences have almost no effects on the S11 value.

Figure 7 shows the E- and H-plane radiation patterns of the H-plane circular patch array with both air-cores and fence strips. As compared with the results of Fig. 5(b) that of array with air-cores only, one sees that the SLL has reduced by 1.2 dB.

Figure 8 shows the E- and H-plane radiation patterns of the 16 element H-plane array with air-cores and fence strips that have been chopped. Following the optimization of the chopped strips simulation results show that the overall gain of the antenna increases by 0.8 dB while the other parameters of the antenna such as S11 and SLL remain almost the same. The shape of the chopped strip and its dimension are also shown in Fig. 8.



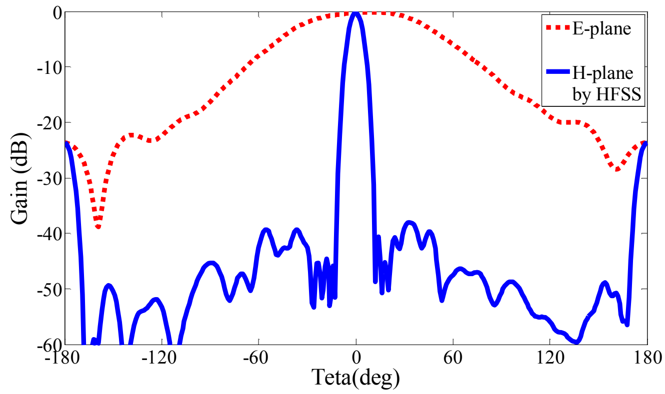


Fig. 8. The E- and H-plane radiation patterns of the 16 element circular patch antenna array with air-cores and chopped fence strips

IV. CONCLUSION

In an array of microstrip patch antennas fed by coaxial probes by placing air-cores in the substrate below each of the patch elements more than 4.2 dB improvement is SLL can be obtained. The SLL can further be reduced by 1.2 dB if narrow fence strips are placed in between each of the patch elements. For the 16 element proposed array the gain is 18.2dB. By chopping the fence strips, the gain of the array can be increase by 0.8 dB without affecting the other parameters of the array.

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