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DESIGN OF MODIFIED MICROSTRIP COMBLINE ARRAY ANTENNA FOR AVIONIC APPLICATION

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Abstract—A modified microstrip combline array antenna (MMCA) is designed to obtain wide beamwidth ($\approx 90^\circ$) in E-plane radiation pattern and therefore the better coverage for using in the radio controller systems for avionic application. Beside wide beamwidth, wide bandwidth can be obtained by designing of MMCA in travelling wave mode. Moreover, as will be seen in the paper, to achieve a better performance we need the low sidelobe level and tilted radiation pattern, which can be obtained by suitable tapering the amplitudes of array elements and adjustment the phase difference between them, respectively.

1. INTRODUCTION

The microstrip combline array is an array with series feeding structure, in which the radiating elements are open-circuited microstrip stubs [1]. Using this structure in travelling wave mode, it is possible to obtain wide bandwidth at the expense of dissipation of some power in the matched load [2, 3]. It must be noticed that the dissipated power in the matched load decreases with increasing the number of radiating elements. Therefore, this configuration is suitable for using in high gain and bandwidth applications. Also, this antenna is suitable to use in high frequency applications, especially in millimeter wave

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applications [2, 4]. This property is due to the possibility of using a thin substrate in designing of this antenna and hence eliminating the higher order surface waves excitation in high frequencies [4]. Another property of this antenna is its frequency scan radiation pattern which makes it possible to achieve a tilted radiation pattern in desired frequency [4].

Because of wide bandwidth, high gain, simple and low profile construction, this antenna has been used in various applications. One of the suitable applications of microstrip combline array antennas is using two or more of them on cylindrical structures such as rocket and UAV, for command, communications or Telemetry applications. To obtain the better coverage in these applications, it is necessary to broaden the E-plane radiation pattern of a conventional combline array antenna. To this end, in this paper a modified combline array antenna is proposed. In Section 2, the radiation characteristics of conventional microstrip combline array are studied, briefly. In Section 3, the radiation characteristics of the proposed modified microstrip combline array are studied and finally in Section 4, special application of this modified antenna with tilted main lobe and low sidelobe suitable for using in radio fuse application is introduced. All structures have been simulated using Ansoft-HFSS software [5] based on FEM and final design is verified by experimental results.

2. RADIATION CHARACTERISTICS OF CONVENTIONAL MICROSTRIP COMBLINE ARRAY ANTENNA

The combline microstrip array antennas have been studied widely in many literatures and books [1]. In this section, this structure is studied from array viewpoint and based on it the modified combline array is studied in the next section. Figure 1 shows the conventional microstrip combline array antenna.

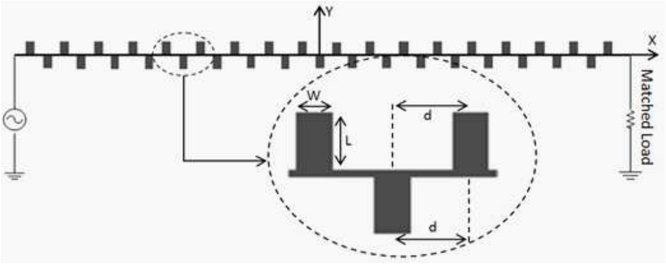

Figure 1. Conventional combline microstrip array antennas.

To achieve the broadside radiation pattern, the spacing and length of open stubs as radiating elements (d and L) are half of the wavelength (guided wavelength). All stubs in on side of microstrip line are equiphase and have 180° phase difference respect to the other side stubs.

It must be noticed that in the radiation mechanism of array, the 180° phase difference of upper and lower stubs is compensated by odd symmetry of them respect to microstrip line. Therefore, all stubs have the same sign in the array factor. In this case for odd number of stubs, the array factor is:

$$|AF| \propto \left| \cos\left[\beta L \sin\theta \sin\varphi - \frac{\beta d}{2}\sin\theta\cos\varphi\right] \times \frac{\sin\left[\frac{(N-1)}{2}\beta d \sin\theta\cos\varphi\right]}{\sin[\beta d \sin\theta \cos\varphi]} \right| \tag{1}$$

where d is the spacing of the stubs, L is the length of stubs and N is the number of stubs. The first term of the array factor is due to array elements in y direction and the second term is due to the array elements in x direction.

3. MODIFIED MICROSTRIP COMBLINE ARRAY ANTENNA AND ITS RADIATION CHARACTERISTICS

In the $\varphi = 90°$ plane (E-plane), the first term of AF in (1) is $\cos(\beta l \sin\theta)$ which provides the cosine function and therefore the narrower radiation beam in such plane. To solve this problem the array elements must be aligned in the same axis along x direction, or $L = 0$. To accomplish this requirement, it is necessary to vary the construction of conventional microstrip combline array. Figure 2 shows the modified microstrip combline array to broadening the radiation pattern in E-plane.

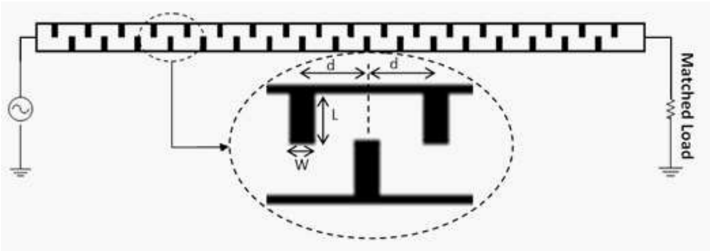

Figure 2. Modified combline microstrip array.

In this structure, choosing the geometrical parameters for broadside radiation pattern in operating frequency is the same as the conventional type. In this case, to have a suitable matching between the source and array structure the characteristics impedance of each microstrip transmission line section must be twice of the characteristics impedance of the line in the conventional one which is achieved by reducing the width of the microstrip transmission line [6].

In spite of the resonating behavior of microstrip patch antenna, the open circuited stubs are not resonating structures and act as shunt admittance Y where periodically inserted on the transmission line. The conductance of each stub $G = \mathrm{Re}(Y)$, which is result of the radiation from its open end, varies by its width (w) [2].

To reduce the effect of the stubs on the performance of microstrip transmission line, the length of each stub assumes about half of guided wavelength in operating frequency. In designing of combline microstrip array the effect of T-junction in connecting point of stubs and microstrip transmission line must be considered too [3]. Therefore, to achieve a suitable phase difference between radiating open ended stubs and good impedance matching between source and combline microstrip array, it is necessary to modify the values of d and L from their primary values. To obtain the optimum values of d and L the configuration shown in Figure 3 is studied.

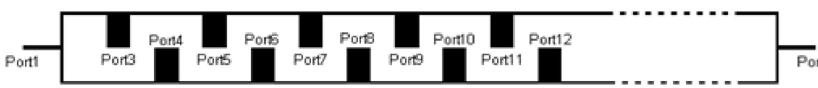

Figure 3. Structure to study the optimum values of the length and spacing of stubs.

In the operating frequency, to have the optimum values for broadside radiation pattern the phase difference of the ports of upper (lower) side respect to port 1 must be the same. Also the phase difference of upper side ports respect to lower side ports must be 180°.

In Figure 4, the phase difference of some of the ports respect to port 1 is seen. The structure is implemented on the PCB microwave board Rogers RT/duroid5880 with 0.381 mm thickness and $\varepsilon_{r=}2.2$. The optimum values of d, L and w for operating frequency (10 GHz) are 12.5 mm, 10.2 mm and 2 mm respectively.

The non zero phase difference in other frequencies leads to phase difference in array elements and therefore tilted radiation pattern. The E-plane ($\varphi = 90°$) and H-plane ($\varphi = 0$) directivity radiation pattern of antenna at $f = 10$ GHz is depicted in Figure 5.

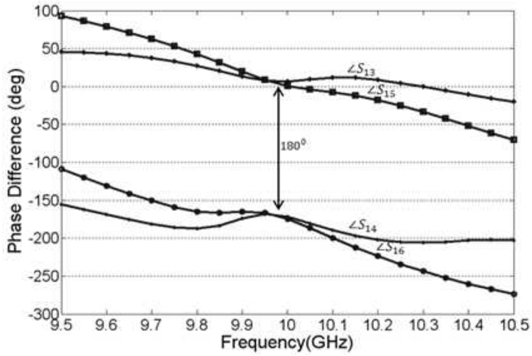

Figure 4. Phase difference of the ports 3, 4, 5 and 6 respect to 1.

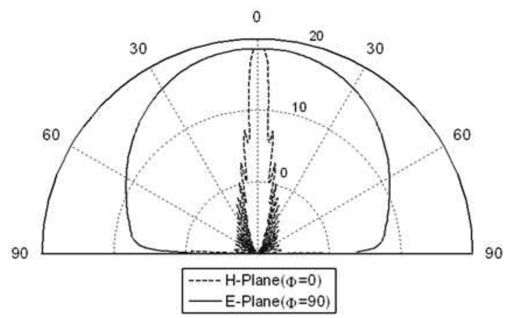

Figure 5. (E & H)-plane directivity radiation pattern of antenna (dB) at $f = 10\,\text{GHz}$.

The H-plane radiation pattern of antenna for different frequencies is depicted in Figure 6. As was mentioned before, because of phase difference between the array elements in other frequencies, the radiation pattern will be tilted in H-plane. This property is useful in design of radio controller systems in the next section.

To compare the performance of the modified combline microstrip array (Figure 2) with the conventional one (Figure 1), the E-plane ($\varphi = 90°$) directivity radiation pattern at operating frequency is shown in Figure 7. It is seen that in the modified structure the E-plane beamwidth, approximately has been increased from 700 to 900 ($\approx$ 30% BW enhancement). This characteristic leads to the better space coverage in E-plane.

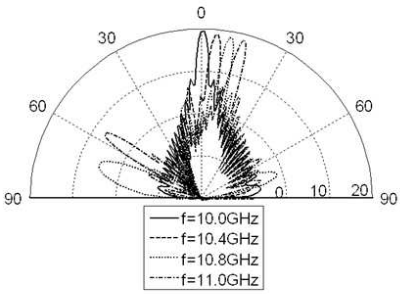

Figure 6. H-plane directivity radiation pattern of antenna for difference frequencies.

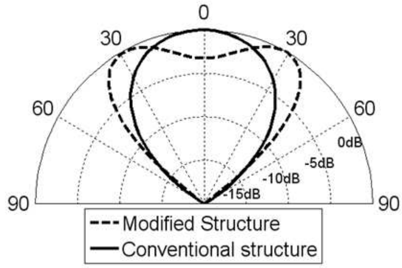

Figure 7. E-plane normalized radiation pattern of antenna for conventional and modified case.

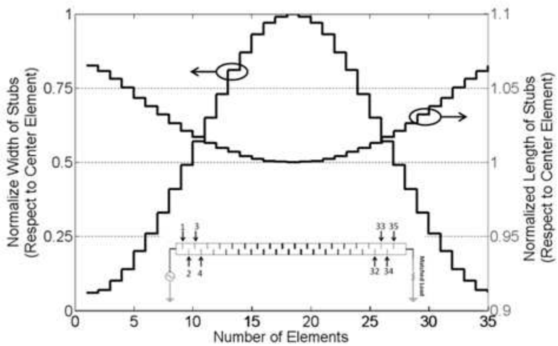

Figure 8. Tapered width and length of elements of non-uniform modified combline microstrip array antenna with 35 elements.

4. DESIGN OF NONUNIFORM MODIFIED COMBLINE MICROSTRIP ANTENNA

In this section the non-uniform modified combline microstrip antenna to obtain tilted beam in H-plane with low SLL is studied. To decrease the side lobe level (SLL), the non-uniform combline microstrip is studied. In the uniform distribution, the SLL of the radiation pattern in H-plane is about 13 dB. To reduce the SLL of antenna it is necessary to taper the amplitude distribution of array elements. This is done by tapering the width of the stubs as radiating elements of array (Figure 8).

To tapering the array we use the standard distribution of Taylor line source with SLL $= -25$ dB and $n = 5$, where n is the number of equal side lobe levels [7, 8]. Figure 9 shows the improvement of SLL of antenna respect to the uniform case.

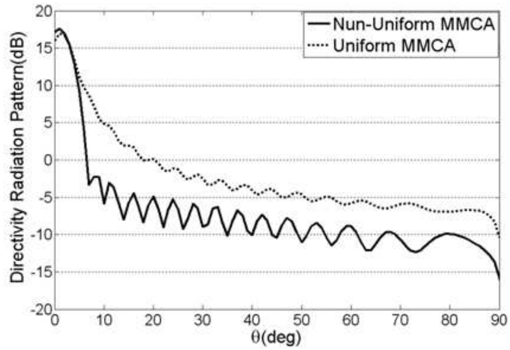

Figure 9. Comparison of SLL of uniform and non-uniform MMCA.

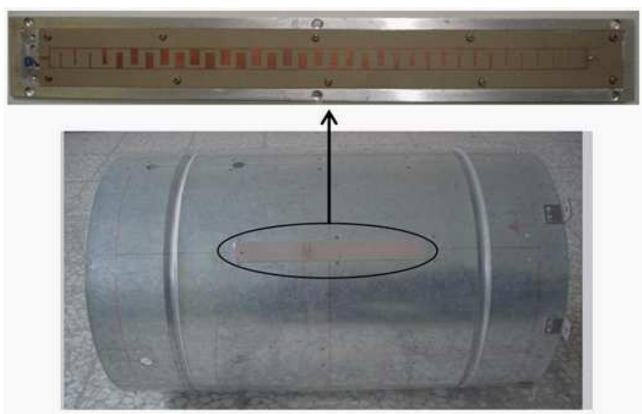

Figure 10. Antenna configuration installed on the PEC cylinder.

5. EXPERIMENTAL RESULTS

In this section based on the properties of MMCA antenna described in previous sections, we have design and fabricate the MMCA antenna which its SLL is about -20 dB and its radiation beam is tilted about 30° respect to the array broadside direction. To measurement the radiation pattern of this antenna we installed it on the PEC cylinder with 35 cm diameter (Figure 10).

The H-plane normalized radiation patterns of the fabricated antenna for different frequencies are shown in Figure 11.

Also, to comparing the MMCA and conventional one, the E-plane normalized radiation pattern at $f = 10.3$ GHz is depicted in Figure 12.

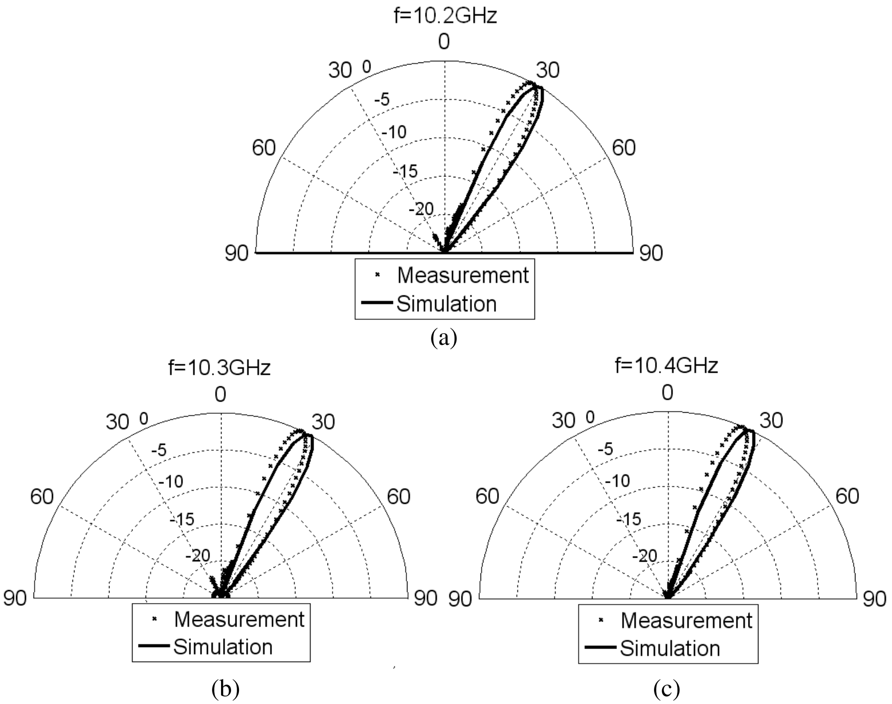

Figure 11. *H*-plane normalized radiation patterns of antenna (simulation and measurement).

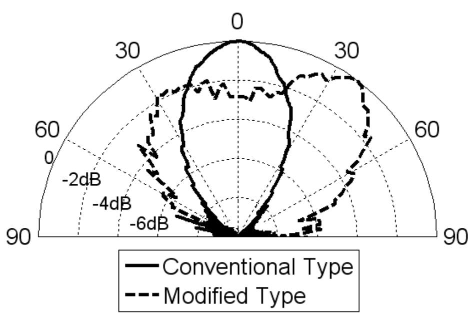

Figure 12. Measurement results of *E*-plane normalized radiation patterns of conventional and modified antenna.

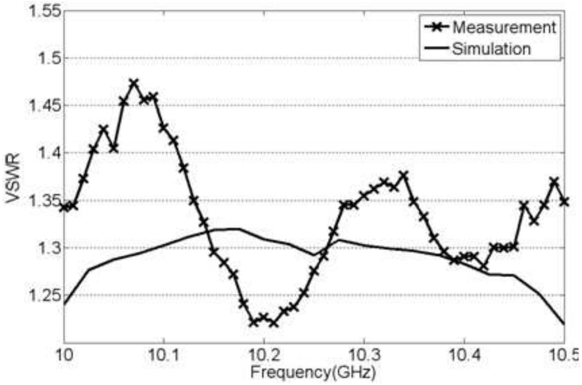

Figure 13. VSWR of antenna.

The return loss of the antenna is also depicted in Figure 13 which confirms the wide band operation of antenna.

6. CONCLUSION

In this paper the Modified Microstrip Combline Array Antenna to achieve broad beamwidth in its E-plane was studied. Our idea was verified by the simulation and measurement results. Also, Because of controllable side lobes and tilted radiation pattern in H-plane, as an application that was mentioned in the paper, this antenna can be used in design of radio fuse or other side looking radar (radio) systems.

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