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Double-Sided Microstrip Circular Antenna Array for Radar Applications

Angeline M. Flashy [1], Dr.T.Pearson [2], A.Vijaya Shanthi [3]
[1] *M.E. Communication System,* [2] *Professor, E.C.E. Department,* [3] *Asst. Professor, E.C.E. Department*

Abstract

The design and characteriztics of the double-sided microstrip circular antenna arrays are presented. The proposed array antenna are designed for single band at 5.25 -5.75 GHz for C band and dual bands at 6.05 – 7 GHz and 9 – 10 GHz to support C band and X band Weather Radar applications respectively. The single band antenna shows omnidirectional radiation pattern with the gain value of 6.2 dBi at 5.5 GHz and dual band at 3.12 dBi at 6.5 GHz and 3.8 dBi at 9.5 GHz. The single band antenna array is placed on the top layer and the dual band antenna array is placed on both the top and bottom layers to obtain the desired antenna characteristics. The proposed single-sided single band and double-sided dual band antenna provides omnidirectional radiation pattern with high gain.

***Index Terms*:** *Antenna Array; Circular Patch; Dual Band; Single Band; Omni-directional; Radar Applications*

1. Introduction

Microstrip circular antenna arrays are very popular due to their low profile, small size, light weight, low cost, high efficiency, relatively compact and possibility of dual frequency operation for Radar applications [1]. They are easy and less-expensive to manufacture are conformable for planar and non-planar planes [2]. It is quite common with dual coverage from the frequency of 4 – 12 GHz [3]. This makes C band radars suitable for short range weather observation. The objective of this work is to develop a low-cost, high gain, omnidirectional antenna operating in the C-band that enables eventual integration of electronics for radiation pattern control and operates on frequency ranging 4-8 GHz and X band radar, is more sensitive and it is highly efficient to detect smaller particles and operates on the frequency of 8-12 GHz[4]. These radars shall be used for studies on Airborne weather development because they can detect the tiny water particles and also used to detect light precipitation such as snow. Major Airplanes are equipped with an X band radar to pick up turbulence and other weather phenomenon [5]. The antenna array systems that operate in the C and X bands are normally designed using separate antennae for each band[6]. Since it is becomes more important to use such systems in one setting, it is desirable to design a single antenna that operates in both frequency bands. This, in turn, requires wideband antenna that covers the two bands [7].

The feed methods can be categorized as series and corporate feed architectures. Rectangular arrays are common type used for antenna arrays. Studies on dual band antennas employing rectangular arrays were reported [8]. Compared to rectangular patch antenna arrays, there are limited numbers of studies performed on circular patch antenna arrays due to difficulties in fabrication [9], but the advantages of circular antenna array include high gain [10].

In this paper, a new microstrip circular antenna arrays were designed and characterized to provide omnidirectional radiation pattern for C/X band Radar applications. Double-Sided antenna arrays were designed for dual bands at 6.05 – 7 GHz and 9 – 10 GHz. For dual band operation, circular patch array was placed on both top and bottom layers of the microstrip with larger rectangular patch placed on the bottom layer. Dual band (double-sided) microstrip antenna arrays provide desirable antenna characteristics for the intended application.

2. Performance of the proposed system

The configuration of the proposed single band antenna array at 5.5 GHz for C band Weather Radar applications is shown in Table (1). It consists of three circular patches which are placed only on the top layer. The small rectangular patch is placed on the bottom layer for ground connection.

The proposed dual microstrip antenna has circular arrays both on the top and bottom layers. It consists of three

circular patches on each layer for the operational frequencies of 6.5 GHz and 9.5 GHz of C band and X band Weather Radar Applications.

The Gain of the Circular patch antenna was calculated using,

Gain= Antenna Efficiency x Directivity (D_0)

Where the Antenna Efficiency is calculated using.

$$\text{Antenna Efficiency} = \frac{\text{Total Efficiency}}{\text{Reflection Efficiency}} \quad \text{------- (1)}$$

The Directivity is calculated as

$$D_0 = \frac{(k_0 a_e)^2}{120 G_{rad}} \quad \text{------- (2)}$$

3. Dimension of single-sided and double-sided circular antenna array

The design of the Single- Sided antenna array and Double- Sided antenna array as shown in Fig(1). For the design of Single-sided antenna array, single layer is used and for the design of Double-sided antenna array, both top and bottom layer is used with the FR-4 substrate of dielectric constant 4.4.

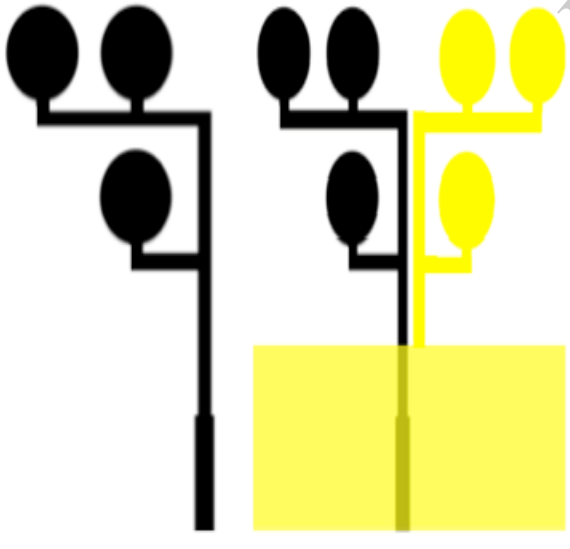

Fig. 1. Design of the proposed antenna for single and dual band

The configurations of the single-sided antenna array and double-sided antenna array are as shown in Fig (2).

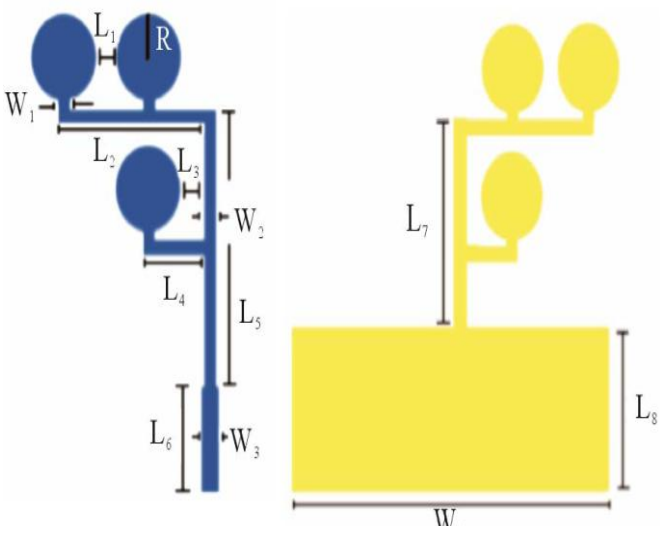

Fig. 2. Dimensions for the proposed single and dual band antenna

The dimensions for the proposed single-sided antenna array and double-sided antenna array are given in Table (1).

Table 1: Dimensions of the proposed single-sided and double-sided antenna array

Variables	Values(mm)
L1	1.20
L2	15.6
L3	1.00
L4	6.70
L5	22.0
L6	8.00
L7	19.2
L8	10.9
W1	1.00
W2	1.20
W3	2.00
W4	41.4
R	4

The simulation was performed using ADS for the above configurations.

4. Simulation Results

4.1 Layout design of the single-sided and double-sided antenna array

The Layout design of the Single-sided antenna array is shown as Fig(3)

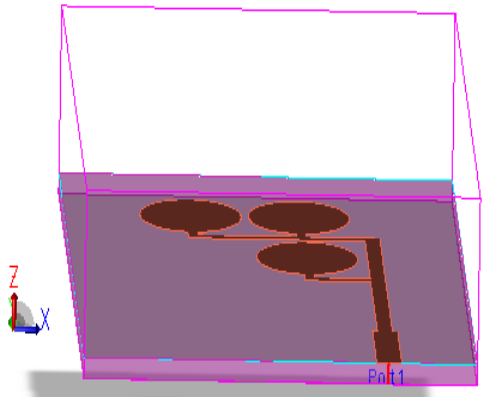

Fig.3 Layout design of single-sided antenna array

The Layout design of the Double-sided antenna array is shown as Fig (4).

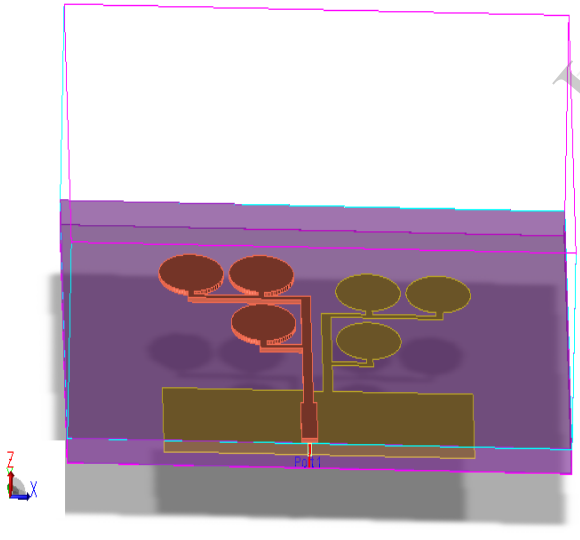

Fig.4 Layout design of double-sided antenna array

4.2 Simulation Results of the Return loss S_{11} of the single-sided and double-sided antenna array

The Return loss S_{11} is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line. It is usually expressed as a ratio in decibels (dB).

The simulation plot of return loss S_{11} of single sided antenna array is -20.19 dB at 5.5 GHz of C band.

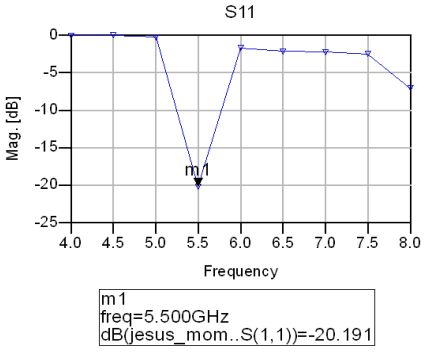

Fig.5. Return Loss S_{11} of single-sided antenna array

The simulation plot of return loss S_{11} of double- sided antenna array is -18.544 dB at 6.5 GHz and -23.657 dB at 9.5 GHz as shown in Fig(6).

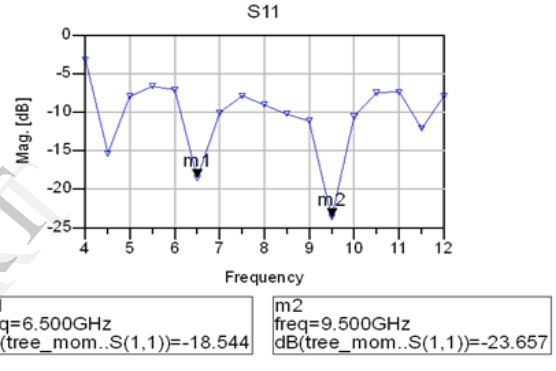

Fig.6. Return Loss S_{11} of double-sided antenna array

4.3 Radiation Patterns of the single-sided and double-sided antenna array

The Radiation pattern refers to the directional dependence of the strength of the radio waves from the antenna. The radiation pattern of the single-sided antenna array of C band is shown in Fig (7).

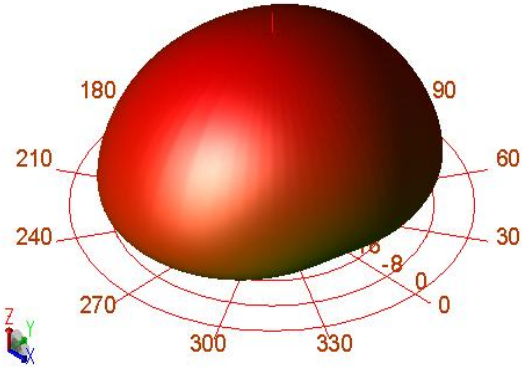

Fig.7 Radiation Pattern of single-sided antenna array

The Radiation patterns of the double-sided antenna array of C/X band is shown in Fig (8).

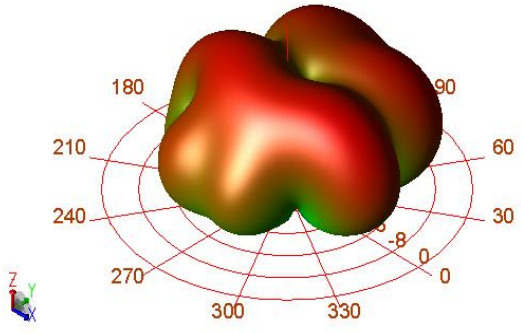

Fig.8 Radiation Pattern of double-sided antenna array

4.4 Antenna Parameters of the single-sided and double-sided antenna array

Antennas are characterized by a number of performance measures in selecting or designing an antenna.

The Antenna Parameters of the single-sided antenna array of C-band at the resonant frequency of 5.5 GHz as shown in Fig(9) and the antenna parameters of the double-sided antenna array of C band and X band applications of the resonant frequencies of 6.5 GHz and 9.5 GHz respectively is shown as Fig(10) & Fig(11).

Table.2 Antenna Parameters of single-sided and double-sided circular antenna array

Antenna Parameters	Single-sided antenna array of C band	Double-sided antenna array of C band	Double-sided antenna array of X band
Operational Frequency	5.25-5.75 GHz	6.05-7 GHz	9-10 GHz
Centre Frequency	5.5 GHz	6.5 GHz	9.5 GHz
Dielectric Constant	4.4	4.4	4.4
Effective angle(Steradians)	2.42382	1.93734	1.62092
Directivity(dB)	7.1471	8.12004	8.89449
Gain (dB)	6.21786	3.12603	3.80233
Return loss(dB)	-20.19	-18.544	-23.657

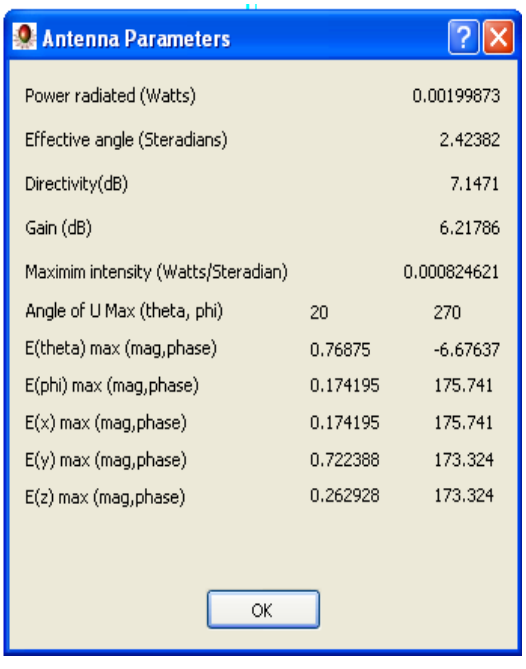

Fig.9 Antenna Parameters of single-sided antenna array for C band

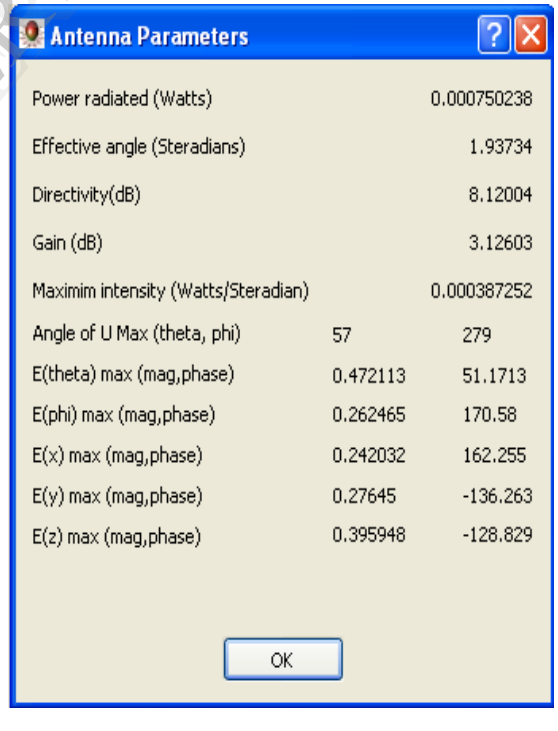

Fig.10 Antenna Parameters of double-sided antenna array for C band

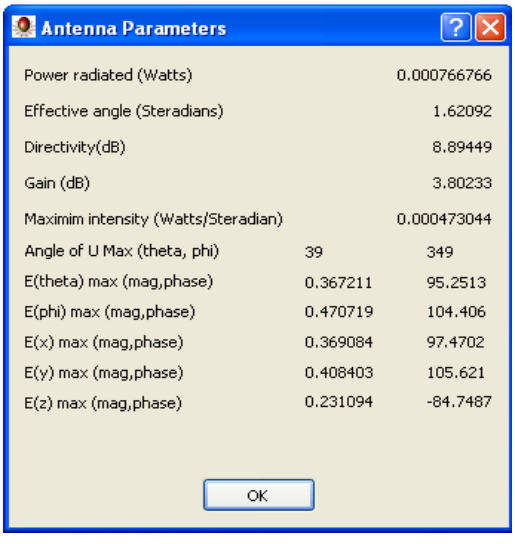

Fig.11 Antenna Parameters of double-sided antenna array for X band

5. Conclusion

The proposed microstrip circular array antenna is designed for single band at 5.25 –5.75 GHz for C band and dual bands at 6.05 – 7 GHz and 9 – 10 GHz to support C/X band Weather Radar applications.

The single band antenna shows omnidirectional radiation pattern with the gain values of 6.2 dBi at 5.5GHz and dual band at 3.12 dBi at 6.5 GHz and 3.8 dBi at 9.5 GHz.

Both antennae were designed with ADS and characterized. Both single band (single sided) and dual band (double-sided) antenna arrays provided omnidirectional pattern with desired gain.

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