Design of a Circular Polarization Array Antenna Using Linear Polarization Patches

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Abstract – **This paper presents a new circularly polarized array antenna using linearly polarized microstrip patches with a gain of 7.47 dBi. The array structure consists of four square patch antennas with feed network. The feed network is designed using microstrip lines on the obverse side of the dielectric substrate and slot line on the reverse side of the substrate. The Teflon glass fiber substrate is used with a permittivity of 2.15. The design frequency of the proposed array antenna is 10 GHz where simulated return loss is less than -45dB. The unequal feed line is used in order to realize 90° phase difference between the linearly polarized patches. Therefore, the circular polarization is realized by the combination of linearly polarized patches and unequal feed line. Advanced Design Systems (ADS) by Agilent Technologies is used for the simulation of the proposed array antenna.**

Keywords - circular polarization; patch antenna; linear polarization; array antenna

I. INTRODUCTION

Circular polarization (CP) is widely used in many microwave application as it offers multiple benefits over linear polarization. This polarization avoids polarization losses due to misalignment. This property is useful for RFID systems [1]. It has the ability to decrease interference between direct and reflected signal due to multipath propagation. Circular polarization is also immune to Faraday rotation. This is the main reason for using CP in almost all Earth–satellite communication systems [2].

An antenna is to be circularly polarized when two orthogonal field components with equal amplitude but in phase quadrature are radiated [3]. Many CP antenna design techniques have been reported. Circularly polarized antenna with a cross slot of unequal arm lengths using single feed has been demonstrated in [4], [5]. Due to slot perturbation, the excited patch surface current path is lengthened which splits the dominant resonant mode of the microstrip patch into two orthogonal near degenerated modes. By selecting the proper slot length and the patch at a suitable position, the two near degenerate orthogonal resonant modes can have equal amplitudes and a 90° phase difference; as a result CP radiation can be achieved. Applying same concept, Y-shaped slot in antenna can also be used for CP radiation [6]. By inserting slits or spur lines to the boundary of a microstrip patch, CP radiation can be achieved [7], [8].The method of producing single-feed CP operation of a square microstrip antenna by truncating a pair of patch corners has been widely used [9]. A circularly polarized equilateral-triangular-ring microstrip antenna design has been reported with a truncated tip and a Y-shaped conducting strip [10]. Tuning stub can be an effective way to excite circular polarization due to the frequency tuning capability of the tuning stub. It is expected that, with a proper stub length, the resonant mode in the direction parallel to the stub can have a slightly lower resonant frequency than that in the direction perpendicular to the stub orientation. In this case, two near-degenerate orthogonal modes can be excited using a single probe feed, which makes CP operation possible. This design concept has been successfully applied to a circular patch [11], a square-ring patch [12], and a triangular patch [13].

It is also possible to radiate circular polarized waves using single square or circular patch if the patch is excited using an external power divider such as the quadrature hybrid, the ring hybrid, the Wilkinson power divider and the T-junction [14]. In this configuration the dual-orthogonal feeds excite two orthogonal modes with equal amplitude but in-phase quadrature. An array that generates circularly polarized radiation can be constructed conventionally by using circularly polarized patches where each circularly polarized element generally requires two feed ports with a hybrid element. Arrays of linearly polarized patches can be configured for circular polarized radiation [14], [15]. Array of two linearly polarized antennas will radiate circularly if the patches are placed orthogonally with one of the patches being fed 90° out of phase. A method has been presented in [16] for generating circularly polarized radiation from an array composed of linearly polarized elements having unique angular and phase arrangements.

In this paper a circularly polarized array antenna using microstrip square patches is proposed where all the patches are linearly polarized. The patches are arranged in such a way that the resultant array radiation is circularly polarized. The feed network is designed using both mirostrip lines and slot line instead of using only micostrip lines that reduces the problem of step by step impedance matching and provides a simple circuit configuration.

II. CONFIGURATION FOR ARRAY ANTENNA

Fig. 1 shows the complete layout of proposed array antenna. Its configuration consists of radiating square patches with a special feed network on one side of the dielectric substrate which has a ground plane on the other side.

The feed network shown in Fig. 2 is composed of microstrip lines on the obverse side and a slot line on the reverse side. There are two types of branch circuits in this feed network. One is the microstrip-slot branch circuit and another one is the slot-microstrip branch circuit. The microstrip-slot branch circuit is connected in parallel and slot line impedance has to be double than microstrip line for proper impedance matching. In this case two output signals at the equal distance point from the branch point on the slot line are of same amplitude and in phase [17], [18].

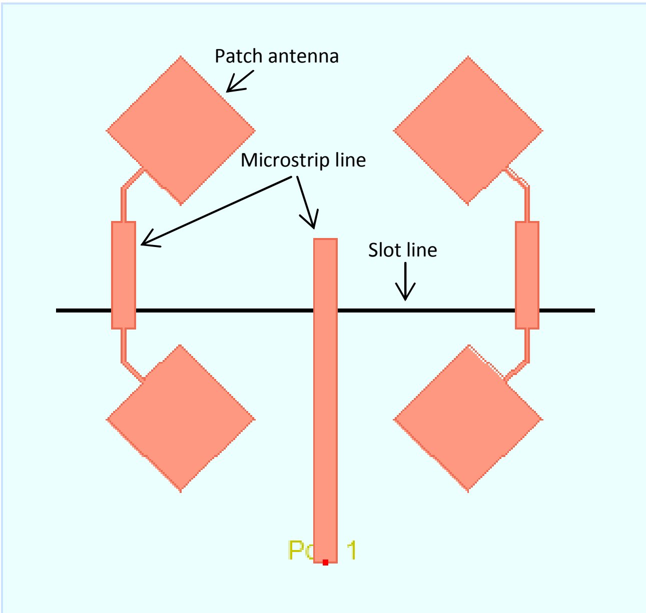

Fig. 1. Layout of proposed array antenna

Moreover, there are two slot-microstrip branches at the two end of slot line. In this case slot-microstrip branch circuit is series coupled and the condition for impedance matching is impedance of microstrip line has to be half than that of slot line. Due to the series coupling, two output signals at the equal distance point from the branch point on the microstrip line are of same amplitude and out of phase. The impedance of the slot line in this design is to be chosen as 100 ohm and the microstrip line impedance is 50 ohm. Frequency performance of feed line network is shown in Fig. 3.

The design frequency of the four element array antenna is 10 GHz. The dimension of each square patch is 9.46×9.46 mm^2. Distance among patches horizontally and vertically is kept same. Each patch element is placed at 45° angle with respect to horizontal plane. Positional distance of upper patch elements from slot line is determined in such a way that the feed line length is quarter wave length (λ\4) greater than that of lower patch elements. This strategy ensures that the proposed array antenna is excited for circular polarized waves. Impedance transformer is used to match the each patch with slot-microstrip branch circuit.

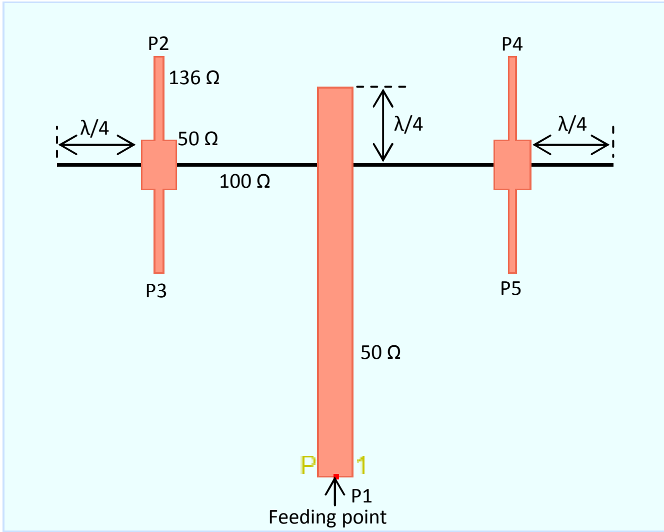

Fig. 2. Basic configuration of feed line network

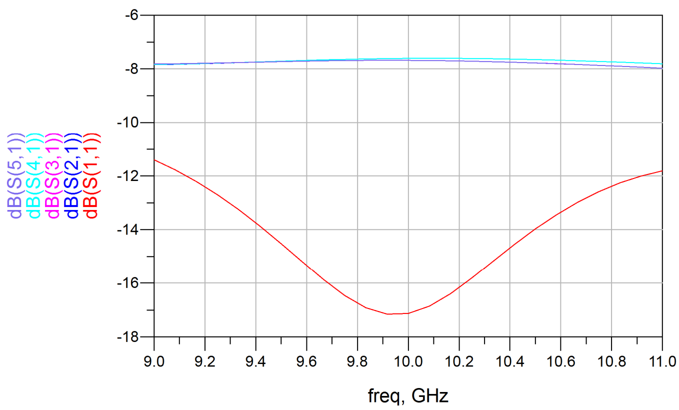

Fig. 3. Frequency performance of feed line network

The antenna is designed using Teflon glass fiber substrate with a thickness of 0.8 mm and dielectric constant of 2.15. Copper with a thickness of 0.018 mm is used as radiating plane and ground plane conductor.

III. BASIC BEHAVIOR OF THE ARRAY

To generate circular polarized waves, two orthogonal signals with 90° phase shift between them are needed. The basic behavior of the proposed circularly polarized array antenna can be explained using Fig. 4. When the patch #1 and the patch #4 are +45° linearly polarized, the patch #2 and the patch #3 are -45° linearly polarized. Combining the signals of patch #1, #4 and patch #2, #3, the modes are orthogonal.

Moreover the length of feed lines is attuned such a way that there is a 90° phase shift between patch #1 and #4, and patch #2 and #3. Therefore, in the proposed array structure, two orthogonal signals are formed with 90° phase shift and as a result circular polarized signal is excited.

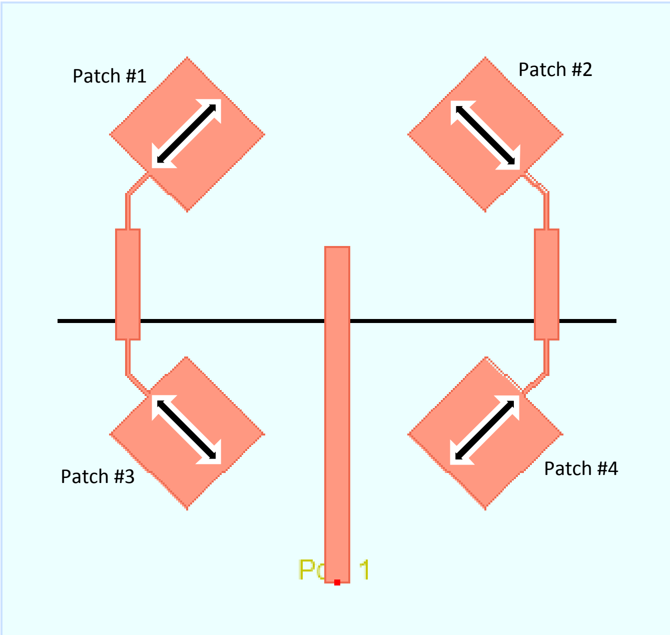

Fig. 4. Basic behavior of the array antenna

IV. SIMULATION RESULTS OF ARRAY ANTENNA

Advanced Design System (ADS) of Agilent has been used to simulate and optimize the proposed circularly polarized array antenna.

The simulated return loss of the array antenna is shown in Fig. 5. The result indicates that the return loss is less than -10dB from 9.8 to 10.38 GHz and it is the lowest at near of the design frequency of 10 GHz.

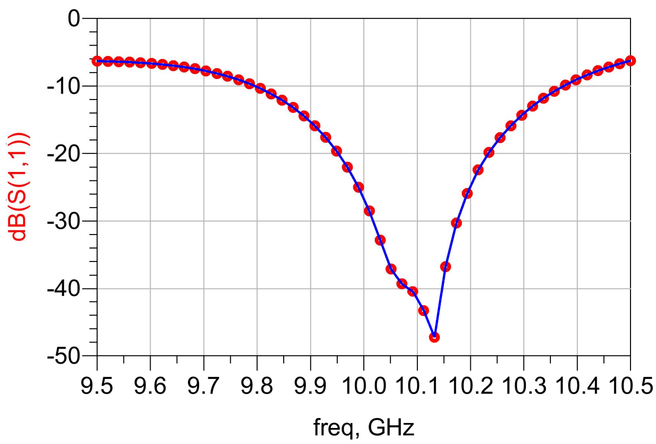

Fig. 5. Input return loss of the array

The Input impedance for the array is shown in Fig.6. The figure shows a dip in the impedance locus near 10 GHz, which indicates that two resonant modes are excited at very close frequencies. This suggests that the fundamental mode in the present design is split into two near-degenerate resonant modes [19].

It can be found that, when upper patch elements are ahead by quarter wave length from lower patches, these two resonant modes can be excited with equal amplitudes and a 90° phase difference, resulting in circular polarized radiation.

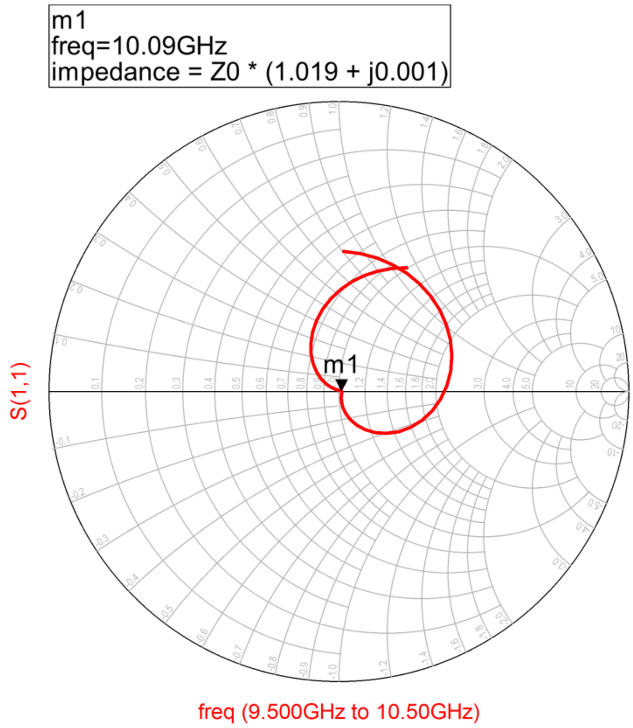

Fig. 6. Input impedance for the array antenna

Simulation result of the array antenna gain is shown in Fig.7.The peak gain is 8.53 dBi at 10.5 GHz, whereas the gain is 7.47 dBi at 10.09 GHz. A flat gain is also obtained from 9.9 to 10.3 GHz. Radiation pattern of the designed antenna for $\phi = 0°$ plane at 10.09 GHz is shown in Fig.8. The directivity at 10.09 GHz is 8.09 dBi.

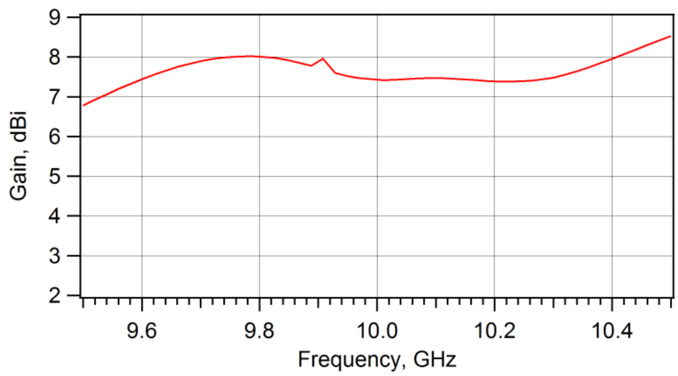

Fig. 7. Gain of the array antenna at $\phi = 0°$

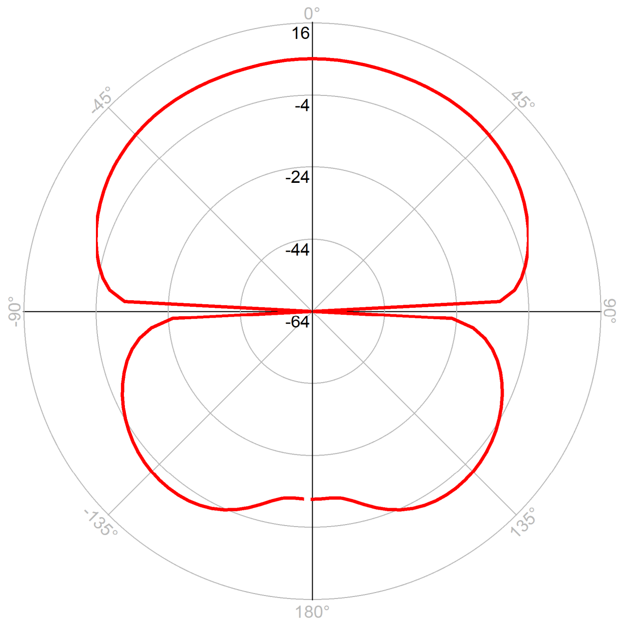

Fig. 8. Radiation pattern of the array antenna for ϕ = 0° at 10.09 GHz

V. CONCLUSION

In this paper, a circularly polarized array antenna has been reported. The most remarkable feature of this array antenna is that CP radiation is excited using only linear polarized patches with special feed line network that consists of microstrip lines and slot line. This feed line structure minimizes the impedance matching problem that is faced in conventional microstrip feeding circuits. Moreover, each patch element is excited at a single point. All results indicate that the proposed array antenna radiation is circularly polarized with better return loss performance and proper impedance matching. From this study, it is also clear that, the newly designed array antenna has simple and symmetric configuration. The experimental investigation of the proposed array antenna will be conducted very soon.

REFERENCES

[1] J. Garcia, A. Arriola, F. Casado, X. Chen, J. I. Sancho, and D. Valderas, "Coverage and read range comparison of linearly and circularly polarized radio frequency identification ultra-high frequency tag antennas," IET Microwaves, Antennas and Propagation, vol. 6, no. 9, pp.1070–1078, 2012.

[2] K. Davies and E. K. Smith, "Ionospheric effects on satellite land mobile systems," IEEE Antennas and Propagation Magazine, vol. 44, no. 6, pp. 24–31, Dec 2002.

[3] R. Garg, P. Bhartia, I. Bhal, and A. Ittipiboon, Microstrip Antenna Design Handbook, Artech House, London, pp. 493, 2001.

[4] H. Iwasaki, "A circularly polarized small-size microstrip antenna with a cross slot," IEEE Trans. on Antennas and Propagation, vol.44, pp.1399–1401, Oct. 1996.

[5] J. H. Lu, C. L. Tang, and K. L. Wong, "Single-feed slotted equilateral-triangular microstrip antenna for circular polarization," IEEE Trans. on Antennas and Propagation, vol.47, pp.1174–1178, July1999.

[6] K. P. Yang, K. L. Wong, and J. H. Lu, "Compact circularly-polarized equilateral-triangular microstrip antenna with Y-shaped slot," Microwave Opt. Technol. Lett. 20,pp.31–34, Jan. 5, 1999.

[7] J. H. Lu, C. L. Tang, and K. L. Wong, "Circular polarization design of a single-feed equilateral-triangular microstrip antenna," Electron. Lett. 34, pp. 319–321, Feb. 19, 1998.

[8] H. M. Chen and K. L. Wong, "On circular polarization design of annular-ring microstrip antennas," IEEE Trans. on Antennas and Propagation, vol. 47, pp. 1289–1292, Aug. 1999.

[9] W. S. Chen, C. K. Wu, and K. L. Wong, "Novel compact circularly polarized square microstrip antenna," IEEE Trans. on Antennas and Propagation, vol. 49, pp. 340–342, March 2001.

[10] C. L. Tang and K. L. Wong, "A modified equilateral-triangular-ring microstrip antenna for circular polarization," Microwave Opt. Technol. Lett. 23, 123–126, Oct. 20, 1999.

[11] K. L. Wong and Y. F. Lin, "Circularly polarized microstrip antenna with a tuning stub," Electron. Lett. 34, 831–832, April 30, 1998.

[12] W. S. Chen, C. K. Wu, and K. L. Wong, "Square-ring microstrip antenna with a cross strip for compact circular polarization operation," IEEE Trans. Antennas Propagat. 47, 1566–1568, Oct. 1999.

[13] J. H. Lu and K. L. Wong, "Single-feed circularly-polarized equilateral-triangular microstrip antenna with a tuning stub," IEEE Trans. Antennas Propagat. 48, 1869–1872, Dec. 2000.

[14] R. Garg, P. Bhartia, I. Bhal, and A. Ittipiboon, Microstrip Antenna Design Handbook, Artech House, London, pp. 494-500, 2001.

[15] J. Huang, "A Ka-band circularly polarized high-gain microstrip array antenna," IEEE Trans. on Antennas and Propagation, vol. 43, no.1, pp. 113-116, Jan. 1995.

[16] J. Huang, "A Technique for an Array to Generate Circular Polarization with Linearly Polarized Elements," IEEE Trans. on Antennas and Propagation, vol. AP-34, no.9, pp. 1113-1124, Sep. 1986.

[17] K. Kodama and E. Nishiyama and M. Aikawa, "Slot array antenna using Both-sided MIC technology," IEEE International symposium on Antennas and Propagation , Vol. 3, pp. 2715-2718.

[18] K. Egashira and E. Nishiyama and M. Aikawa, "Microstrip array antenna using Both-sided MIC feed circuits," Asia-pacific Microwave conference, APMC, 2002.

[19] Kin-Lu Wong, Compact and Broadband Microstrip Antennas, John Wiley & Sons, Inc., New York, pp. 165, 2002.