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RESEARCH ARTICLE

Performance analysis of microstrip patch antenna using binomial series expansion

B. Tharini[1], R. Rajasudha[2], A. Kannammal[1]

Abstract

This paper uses binomial series expansion to propose a single microstrip patch antenna (MPA) in the presence and absence of ground plane (GP). The coefficients of binomial series expansion are employed. The proposed antenna is designed to serve for satellite service. The antenna is designed and simulation is performed by ADS software. The primary objective is to increase the directivity. FR4 substrate is used as the dielectric material. The performance measures like directivity, gain and efficiency are compared. The performance analysis of MPA residing and not residing on the GP is simulated and results are validated.

Keywords: Antenna, Binomial, Directivity, Gain, Efficiency.

Introduction

Antennas are crucial components in communication systems. Antenna employs electromagnetic radiation for transmission purposes. The antenna can be in any shape. The antenna acts as a transducer converting RF fields into alternating current or vice-versa. A detailed study on antenna, antenna shapes and the parameters for performance analysis can be viewed (Khan, 2017; Kishk, 2017; Fang, 2019. In the literature study, there is only limited study on antenna design with GP using binomial series. But the proposed design focuses on the design of MPA in the presence and absence GP.

Kavitha *et al.* focussed on the optimization in linear arrays using binomial method. The objective of their work is the reduction of side lobe level using binomial series. It also studied the relation between the coefficients of the binomial array and the current amplitude. It also depicts the technique to minimize the side lobe level by increasing the antenna's directivity. The expression for the current in the nth element is included in the study, from which Pascal's triangle can be brought into picture (Kavitha and Aravind, 2014).

Makkawi (2017) compared the characteristics of the radiation pattern of the patch antenna under uniform, Tchebscheff and binomial amplitude for X-band radar working receivers. An array of 1 x 10 antenna array elements are designed for that studied and simulated at 9.5 GHz. The spacing between the elements are considered as 0.5 λ, 0.6 λ, 0.8 λ, and 0.9 λ. The antenna parameters for different spacing are investigated. These antenna structures are designed and simulated using ADS software. For the work, RT Duroid is used as the dielectric material. Also, in that work along with patch a λ/4 transformer is employed. Direct feeding is used for excitation purpose. He showed that the binomial method performs better than uniform and Tchebyscheff.

Aziz et al. (2016) proposed a mathematical model and system level model for the representation of MPA. In that work the optimization is carried out using MATLAB tool to reduce the side lobes and to analyze the radiation pattern. The performance characteristics are analyzed by taking the radiation pattern, reflection coefficient, operating frequency and minimization of side lobes into account.

Chopra and Kumar (2019) proposed a linear antenna broadside to compare and relate the impact of a number of elements in the array, spacing between the elements in the array and its radiation characteristics. 4NEC2 is the simulation software employed. In that work 10 elements are considered in an array and the spacing is varied from 0.1λ

[1]Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore, Tamil Nadu, India.

[2]Department of Mathematics, PSG College of Technology, Coimbatore, India.

***Corresponding Author:** B. Tharini, Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore, Tamil Nadu, India, E-Mail: tharinibm@gmail.com

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Table 1: Design parameters

Parameter	*Dimension of the patch (mm)*
Lp	14.6
Wp	14.6
Lg	14.6
Wg	6.5
Ls	2.8
Wc	3

to 2 λ in steps of 0.02 λ. The maximum achieved gain here is 12.8 dBi. Out of these spacing variations, the one with the best result is found to be 0.82 λ. and the maximum achieved gain is greater in this case.

Mahmood (2018) proposed a linear and planar array for lower side lobe level. The tapered patch width technique and series width type of feeding is employed in that paper. This paper compares seven-element arrays with U-shaped slot with conventional array elements.

Binomial Expansion Method

The binomial series refers to the algebraic expansion of powers of the binomial. Any expression in binomial with the highest power can be solved easily using binomial series or theorem. A detailed study on Binomial series can be viewed (Xu, 2017). The expansion for binomial series is

In the design of an antenna, n indicates the number of radiating sources in an array. The proposed focuses only on single radiating source, so only the first coefficient in the binomial series is considered. In order to reduce the side lobes, the directivity of an array has to be improved by increasing the total length of the array. The radiation pattern with no minor lobes or less minor lobes is preferred. A linear array is considered because the amplitude of the sources is said to be a non-uniform form which the minor lobes can be eliminated. The amplitude of the radiating sources is proportional to the coefficient of the binomial series. The distance between elements is fixed as λ/2. For an n-element array, the current in the n^{th} element is

From the above relation Pascal's triangle is obtained. Symmetric elements in antenna placed are at a distance of λx.

Antenna Design

The antenna is designed under two cases, the single patch antenna in the truancy of GP and the patch antenna residing on the GP. The single MPA in the truancy of GP used for fixed satellite service application. The results presented in Table 1 which is taken from the research article by Aziz et al. (2016) are used for the proposed single MPA which is residing and not residing on GP

The structure of single MPA in the truancy of GP and residing on the GP is given below in Figures 1 and 2, respectively.

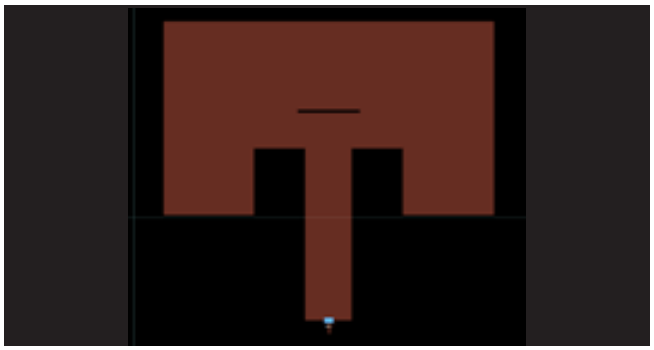

Figure 1: MPA in the truancy of GP

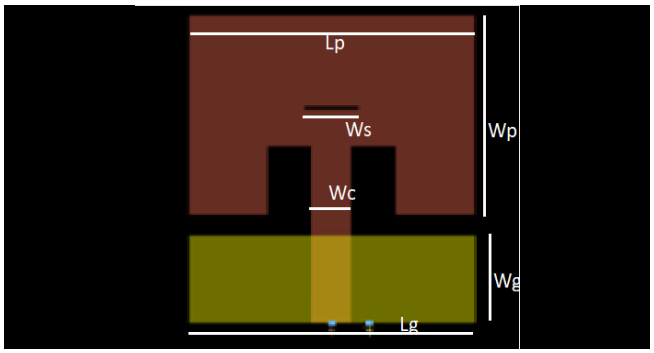

Figure 2: MPA residing on GP

MPA residing on GP is applicable for like broadcasting satellite service. The antenna proposed is designed with FR-4 dielectric material. The antenna is designed and is simulated using ADS software. Microstrip line feeding is applied in this design. The blue color dots indicate the ports placed for excitation.

Simulation Results

MPA in the truancy of GP

For the proposed MPA design, simulation is performed. The results are recorded based on return loss, directivity and gain.

The results of design of MPA in the truancy of GP are presented as first. The results of design of MPA residing on GP are given later.

Return loss of MPA in the truancy of GP

The return loss of MPA in the GP truancy is shown below in Figure 3. The return loss is obtained as -10.999 dB at 14.38 GHz

Directivity of MPA in the truancy of GP

The simulated directivity of MPA in the truancy of GP is obtained below in Figure 4. From the graph the directivity is well obtained.

Gain of MPA in the truancy of GP

Gain of MPA in the truancy of GP is obtained as in Figure 5. From the graph, the gain is fall in expected range of the result well obtained.

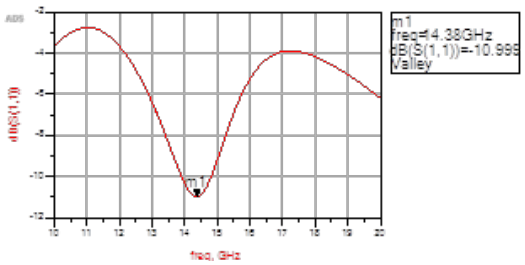

Figure 3: Return loss of MPA in the truancy of GP

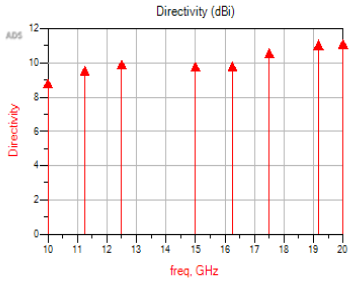

Figure 4: Directivity of MPA in the truancy of GP

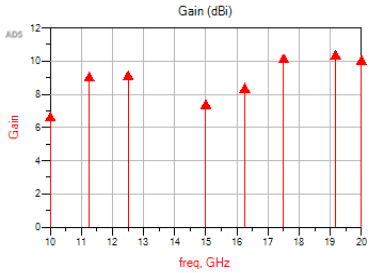

Figure 5: Gain of MPA in the truancy of GP

MPA Residing on GP

The following simulated results are obtained for the MPA residing on the GP.

Return loss of MPA residing on GP

For MPA residing on the GP the return loss is depicted below in the Figure 6. The return loss is -34.449 dB at 12.57 GHz and -32.805 dB at 17.38 GHz

Directivity of MPA in the truancy of GP

The Directivity of MPA in the truancy of GP is obtained in Figure 7. From Figure 7, it is observed that the directivity is well obtained.

Gain of MPA in the truancy of GP

Gain of MPA in the truancy of GP is depicted below in Figure 8. From Figure 8 it is clear that the Gain is well obtained.

Comparison

Comparison on Return Loss

Figure 3 and 4 depicts the return loss in case of MPA residing on GP has better than return loss of MPA in the truancy of GP. And also, the number of operating frequencies is two for MPA residing on GP and one for MPA in the truancy of GP.

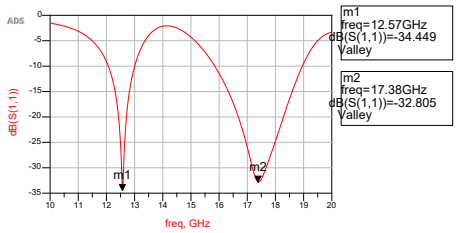

Figure 6: Return loss of MPA residing on GP

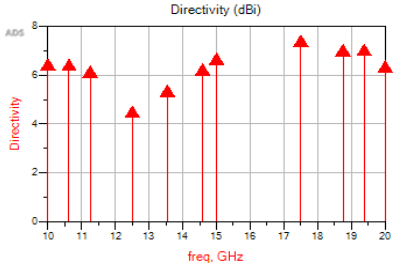

Figure 7: Directivity of MPA residing on the GP

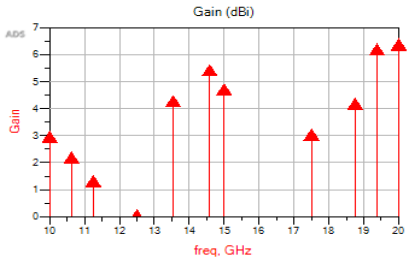

Figure 8: Gain of MPA in the truancy of GP

Comparison on Directivity

The comparison between frequency and directivity for the MPA residing and not residing GP is presented below in the Figure 9. From the graph it is found that the MPA in the truancy of GP has a maximum directivity of 11.37 dB and the MPA residing on GP has maximum directivity of 7.643 dB. So, it can be concluded that MPA in the truancy of GP has better directivity than MPA residing on GP

Comparison on Gain

The comparison between frequency and gain for the MPA residing and not residing GP is depicted below in the Figure 10. From the graph it is showed that the MPA in the truancy of GP has a maximum Gain of 10.66 dB and the MPA residing on GP has maximal gain of 6.5 dB. So, it can be concluded that MPA in the truancy GP has better gain than MPA residing on the GP

Comparison on Radiation Efficiency

The comparison between frequency and radiation efficiency for the MPA residing and not residing on the GP is presented below in Figure 11. From the graph it is showed that the MPA in the truancy of GP has a maximum radiation efficiency of 91.827% and the MPA with GP has maximum radiation efficiency of 100% dB. So, it can be concluded that MPA residing on GP has better radiation efficiency than MPA in the truancy of GP

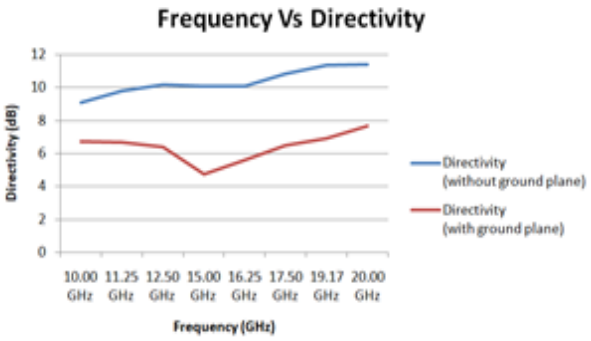

Figure 9: Comparison on directivity

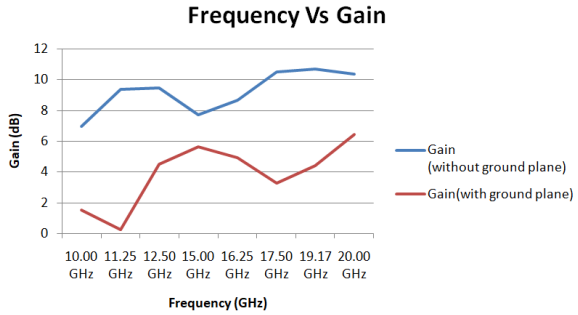

Figure 10: Comparison on gain

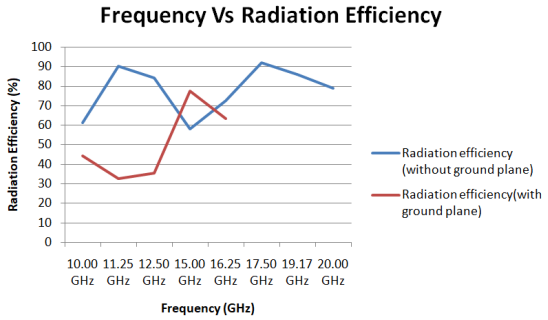

Figure 11: Frequency vs radiation efficiency plot

Conclusion

In the work, the antenna is designed which is residing and not residing on the GP using first coefficient in binomial expansion. The simulation has been done using ADS software. The performance measures like return loss, directivity and gain are obtained. It is found that the return loss is less in case of MPA in the truancy of GP when compared with the return loss of MPA residing on the GP. Similarly, the directivity and gain are better in MPA in the truancy of GP in comparison with MPA residing on the GP. An array of antennas is employed for future study, and its various antenna parameters will be validated.

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