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Analysis and Design of Planar Phased Array Antenna for 5 GHz Applications

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1 Introduction

Nowadays, antennas have been using in every wireless communication systems. It have been found out that microstrip patch is one of the most popular[1] in the world. Also, the patch antenna is cost-effective and easy to fabricate[2]. Many design approaches have been revealed for antenna engineers to follow the procedure. In order to obtain the precise dimension, a deep analysis might've be engaged.

A phased array is the set of antennas that could be a formation as a line or a planar which could steer its beam electrically[3] which means that the direction of the antenna can be control wthout moving any of the mechanic part. Therefore, this proposal is aiming on two of very interesting technologies in this era.

2 Objectives

The propose of this work is mainly focus on analyzing and designing the 5.6 GHz planar phased array antenna based on methods which have been analyzed, formulated or derived in the past.

3 Methodology

This section will provide a full analysis of designing a microstrip antenna and a phased array antenna.

3.1 Dimension Design of the Microstrip Antenna

a dimension of microstrip antenna can be designed easily with this expressions[4].

$$L = \frac{c}{2f_0\sqrt{\epsilon_r\mu_r}} - 2\Delta l W = \frac{c}{2f_0} \tag{1}$$

where L and W are the dimensions of an antenna

f_0 is the resonance frequency

ϵ_r is the relative dielectric constant

μ_r is the relative magnetic constant

c is the speed of light in free space

Δl is the fringing effect at the edge of the antenna However from [3] the best width should be

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \tag{2}$$

where υ_0 is the free-space velocity of light

3.2 Fringing Effect of the Microstrip Antenna

3.2.1 Length Extension

$$\frac{\Delta l}{h} = 0.412\frac{(\epsilon_{r(eff)}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{r(eff)}-0.258)(\frac{W}{h}+0.8)} \tag{3}$$

The length is extended by ΔL on both side so $L_{eff} = L + 2\Delta L$

3.3 Resonance frequency

In TM_{010} mode, the resonant frequency is given by

$$f_{r(010)} = \frac{1}{2L\sqrt{\epsilon_r}\sqrt{\epsilon_{\mu_0\epsilon_0}}} = \frac{v_0}{2L\sqrt{\epsilon_r}} \tag{4}$$

With fringing effect, the equation will be given by

$$f_{r(010)} = \frac{1}{2L_{eff}\sqrt{\epsilon_{r(eff))}}\sqrt{\epsilon_{\mu_0\epsilon_0}}} = \frac{1}{2(L+2\Delta L)\sqrt{\epsilon_{r(eff)}}\sqrt{\epsilon_{\mu_0\epsilon_0}}} \tag{5}$$

3.4 Q Factor

Quality factor desctibes the quotient between the power stored in the reactive field and the radiated power

3.5 Radiation Resistance

Radiation Resistance defines how

3.6 Bandwidth

3.7 Radiation Pattern

3.8 Transmission Line Model

3.9 Cavity Line Model

3.10 Phased Array Antenna

In phased array antenna principle, there are 2 main factor in the equations. First one is an element factor which is the factor that come from only one antenna itself and the another factor is called array factor which is come from the effect of multiple antennas combining together.

$$S(\vartheta) = S_e(\vartheta)S_a(\vartheta) \tag{6}$$

Whereas

S_e is a radiation pattern from only one element
S_a is a element factor with

$$S_a(\vartheta) = \sum_{i=1}^{K} a_i e^{jk(K-i)dsin(\vartheta)} \tag{7}$$

a_i is an amplitude taper.
K is a number of array antenna.
d is a distance of each antenna.
ϑ is a wavefront angle

4 Preliminary results

4.1 Microstrip Antenna

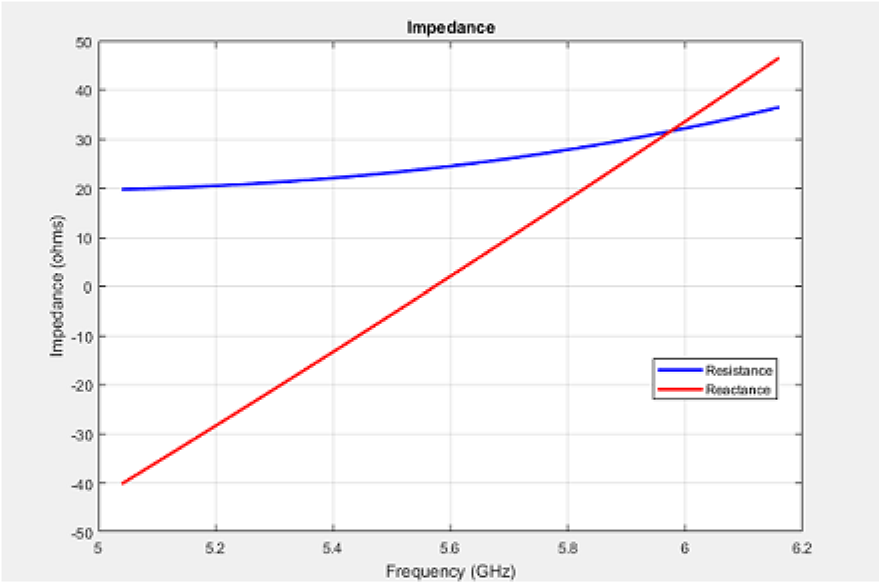

Figure 1: The designed antenna's impedance should have approximately 0 Ohm reactance at 5.6 GHz

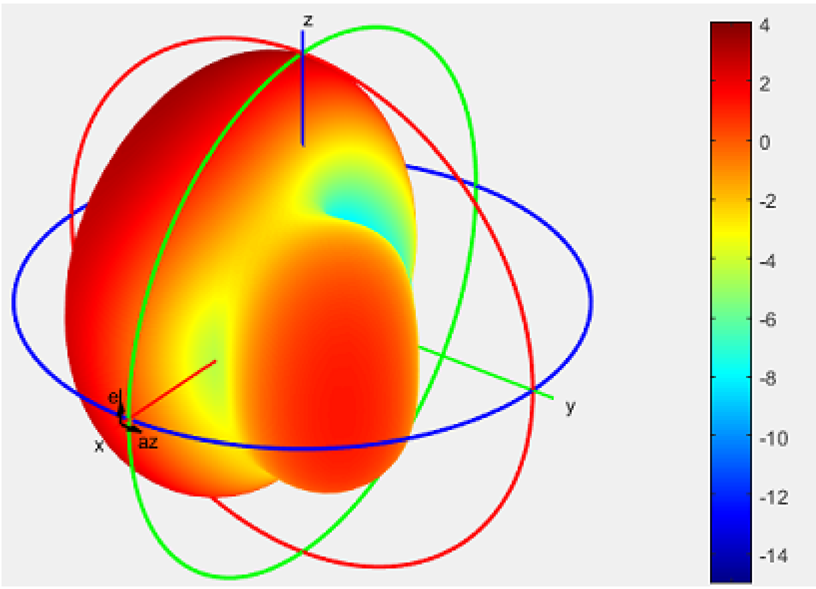

Figure 2: The designed antenna's radiation pattern should have clear directivity

4.2 Array Antenna Patern

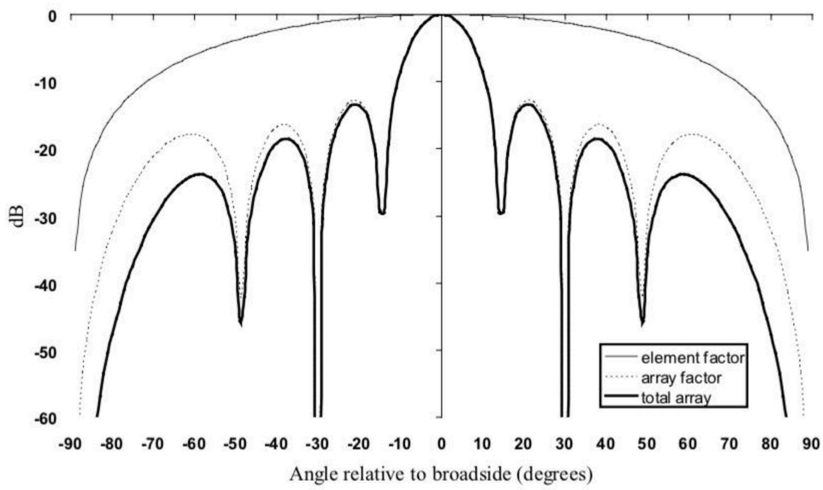

Figure 3: Power radiation pattern without amplitude taper aka. $\forall a_i = 1$

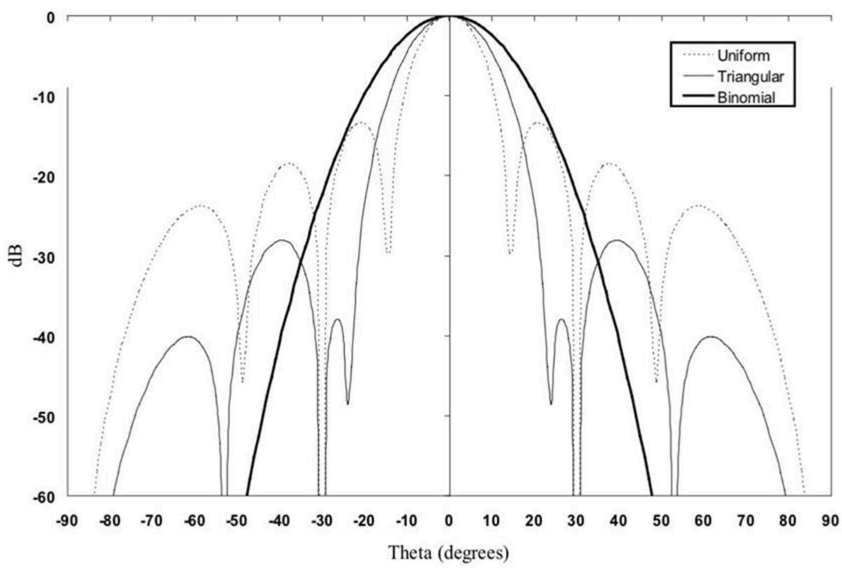

Figure 4: Power radiation pattern with amplitude taper of each type

5 Project overview

5.1 Scope of work

- Analyze the microstrip antenna and phased array antenna
- Design the microstrip antenna and phased array antenna
- Simulate the microstrip antenna and phased array antenna
- Create the microstrip antenna and phased array antenna
- Test the microstrip antenna and phased array antenna

5.2 Expected outcomes

A physical and a simulation file of a phased array antenna with electronic controlled devices and its experimental document

References

[1] P. M. J. Akhtar and P. K. V. Srivastava. Find the change in characteristics impedance and reflection coefficients of the transmission line by changing the dielectric properties of materials embedded between two conductors. [Online]. Available: http://www.iitk.ac.in/mimt_lab/vlab/reflection_coefficients/theory1.html

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[4] N. Kinayman, *Modern Microwave Circuits*. Artech House, 2005.