Gain Enhancement of Microstrip Antennas using Array Structures for Wireless Applications

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Abstract: This document represents the design, analysis and perspectives of microstrip patch phased array antenna for the use in advanced communication systems. The antenna facilitates small size, volume, low profile configuration, cost effective and facilitates easy mounting. The antenna with the increasing prospect of high speed link establishment operates at a frequency of 5.2 GHz. The variety of antennas are designed for comparison purposes and also to provide variety for use as per the requirement of communication system. The substrate used is FR4 Epoxy with a dielectric constant of 4.4. The platform used for simulation is Ansoft HFSS. The antenna is microstrip type with edge feed stub. This paper also describes the effects of the different antenna parameters for different antenna types.

Keywords: Phased Array; Phase Shifters; Feed Line; Gain; Beamwidth; Return Loss; Voltage Standing Wave Ratio (VSWR)

I. INTRODUCTION

Antennas are the fundamental links for any wireless communication systems. Most antennas as we know till date are are resonant devices. The reason being their frequency of operation. Antennas work on a single frequency value and operate efficiently over a narrow band [1-9]. Out of the the different varieties of antennas, the one that can be used for handy purposes is the microstrip patch. The early advancements in antenna field brought out the need for a low power, low maintainence antenna that could be used for small scale transmission and also that could be separated from mainstream purpose. Microstrip patch antennas covered all these issues providing a small size, low profile configuration, economic, lightweight and also conformable to planar and non-planar features and surfaces. With the advent of printed circuit technology, it became even easier to manufacture microstrip patch antennas for use at low power, narrow bandwidth and at instances where efficiency could be compromised to some extent due to low power usage. Today microstrip patch antennas are used in many fields for research, technology, medicine etc.

II. DESCRIPTION

A) Microstrip Patch Antenna

A microstrip patch antenna is a thin single layer antenna which is designed out of four components namely: patch, ground plane, substrate and feed line [5]. The patch is a very sleek metal strip that acts as a radiator. It is located on the side of a very thin non-conducting substrate. Normally, the patch is made up of thin foil of copper plated with gold, tin or nickel. The substrate is a dielectric material with dielectric constant ranging from 1 to 10. Here we have used FR4 Epoxy as a substrate material with a dielectric constant of 4.4. Besides being advantageous at instances, microstrip antennas have some disadvantages like low efficiency, narrow bandwidth of less than 5%, low RF power due to small separation between the patch and ground plane that makes it not suitable for high-power transmission applications [9].

B) Types of Microstrip Patches

The different types of antennas that are categorized under the microstrip patch antennas are:

1. Rectangular Patch
2. Circular Patch
3. Square Patch

This particular article discusses the design methodologies of antenna using rectangular patch.

In modern communication technology, microstrip patch array antennas have been enhanced greatly for the use of broadcasting, Radar, Space communication, Radio Frequency Identification, weather research and Human- Machine Interfaces. The main significance of the patch antenna are that it can be designed as phased arrays in which the principle of steering possibility minimizes the interferences to geographical areas. The phased array radar erected on advanced generation United States Naval Force warships and frigates are able to search, track and perform missile guidance functions simultaneously over 100 targets.

III. DESIGNING MICROSTRIP ARRAY ANTENNA

Before any physical design, first the antenna is designed as per the calculation of required parameters. The platform used for this purpose is Ansoft HFSS. The acronym stands for High Frequency Structural Simulator. It is an integrated development environment which designs and gives a practical simulation model for an antenna of required parameters and its behavioural output along with the magnitudes of parameters like gain, beamwidth, and return loss.

A) Antennas Designed

The different array antennas designed are:

- Single Element
- Uniform Linear Array- 2 Elements

All the above mentioned antennas are microstrip patch antenna with the patch and feed line with stub matching edge feed in between the two. The substrate material used is FR4 Epoxy with a dielectric constant of 4.4. Rectangular patch is the most commonly used microstrip patch antenna which looks like a truncated microstrip transmission line. It is approximately of one-half wavelength long. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The resonant length of the antenna is slightly shorter because of the extended electric "fringing fields" which increase the electrical length of the antenna slightly. An early model of the microstrip antenna section of microstrip transmission line with equivalent loads on either end to represent the radiation loss.

The dielectric loading of a microstrip antenna affects both its radiation pattern and impedance bandwidth. As the dielectric constant of the substrate increases, the antenna bandwidth decreases which increases the Q factor of the antenna and therefore decreases the impedance bandwidth. The radiation from a rectangular microstrip antenna may be understood as a pair of equivalent slots. The antenna only has a single radiation edge (equivalent slot) which lowers the directivity/gain of the antenna. The impedance bandwidth is slightly lower than a half-wavelength full patch as the coupling between radiating edges has been eliminated.

a) Single Element Antenna

The single element microstrip patch antenna is a single radiating element that has a plate mounted over an edge feed stub matched with a feed line to radiate power in the field of -180° to 180°. The antenna only has a single radiation edge (equivalent slot) which lowers the directivity/gain of the antenna. The impedance bandwidth is slightly lower than a half-wavelength full patch as the coupling between radiating edges has been eliminated.

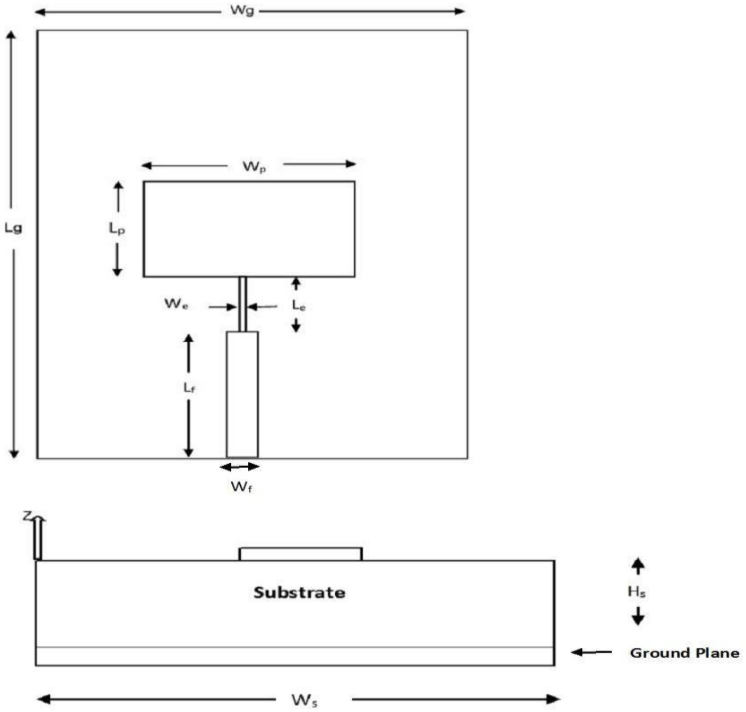

Fig. (1). Sketch of the proposed Microstrip Patch Single Element Antenna along with the cross section.

Table 1: Parameters and Values

Parameters	*Value*
Dielectric Constant(FR4 EPOXY)	4.4
Substrate	L_s=35.9mm;W_s=58.94mm;H_s=1.6mm
Ground Plane	L_g=35.9mm;W_g=58.94mm
Patch	L_p=17.56mm;W_p=12.56mm
Edge Feed	L_e=0.723mm;W_e=8.294mm
Feed Line	L_f=3.059mm;W_f=14.896mm
Air Box	L_a=64.74;W_a=87.68;H_a=30.44

b) Uniform Linear Array of Two Elements

The 2-element array microstrip patch antenna is an element of microstrip patch added to a single element in line to the single element. The linear array has its patches kept at a separation of λ/2 from the center of the patch element. The stub is matched for appropriate impedance and frequency tuning and radiation accuracy.

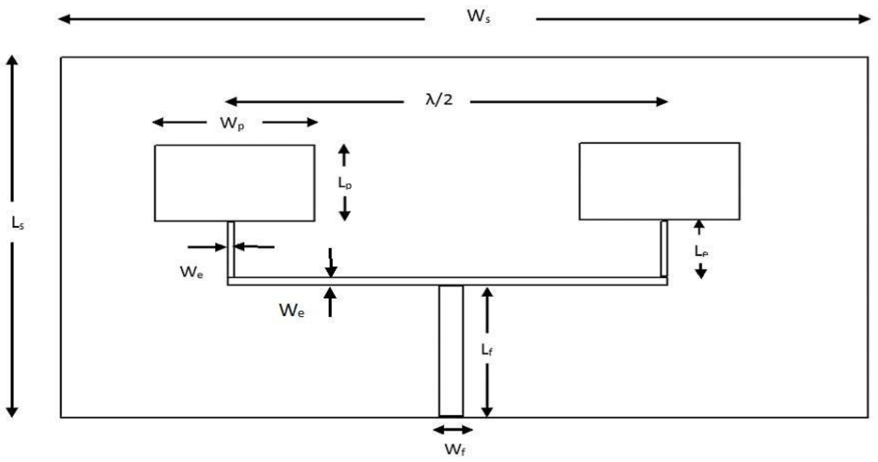

Fig. (2). Sketch of the proposed design of a microstrip patch 2-element uniform linear array.

Table 2: Parameters and Values

Parameters	*Value*
Dielectric Constant(FR4 EPOXY)	4.4
Substrate	Ls=35.9mm;Ws=58.94mm;Hs=1.6mm
Ground Plane	Lg=35.9mm; Wg=58.94mm
Patch	Lp=12.56mm; Wp=17.56mm
Edge Feed	Le=0.723mm; We=8.294mm
Feed Line	Lf=3.059mm;Wf=14.896mm
Air Box	La=64.74mm;Wa=87.68mm;Ha=30.44mm

IV. RESULTS AND ANALYSIS

The results are shown below sequentially from single element to 1x2 array antenna.

Table 3: Parameters and Values

Parameter	*Single Element*	*1x2 Array*
Gain	4.423	5.9503
Beamwidth	81.557	96.4882
Return Loss	38.9228	12.8852
VSWR	1.1121	1.5868
Bandwidth	180 MHz	110 MHz

The above result shows that with increase in the number of linear elements in the antenna design gives greater value of gain. The beamwidth also increases showing its usability more as a broadcast antenna system. The return loss however decreases drastically and there is a very minor change in the Voltage Standing Wave Ratio.

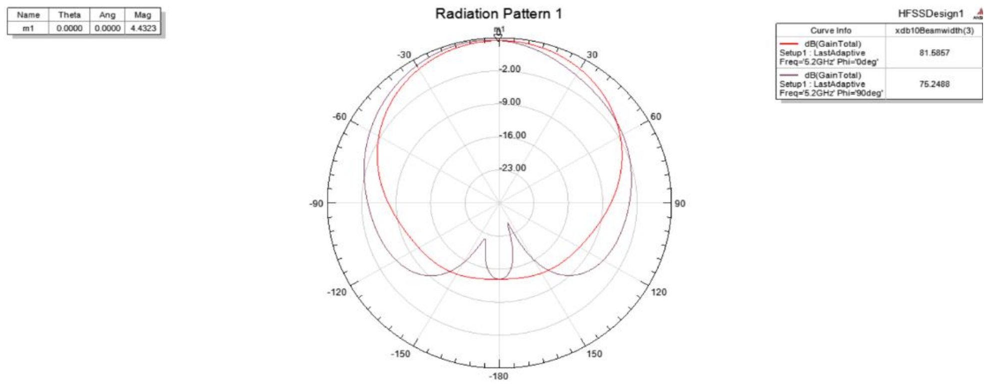

Fig. (5). Gain Plot of Single Element Antenna along with Radiation Pattern

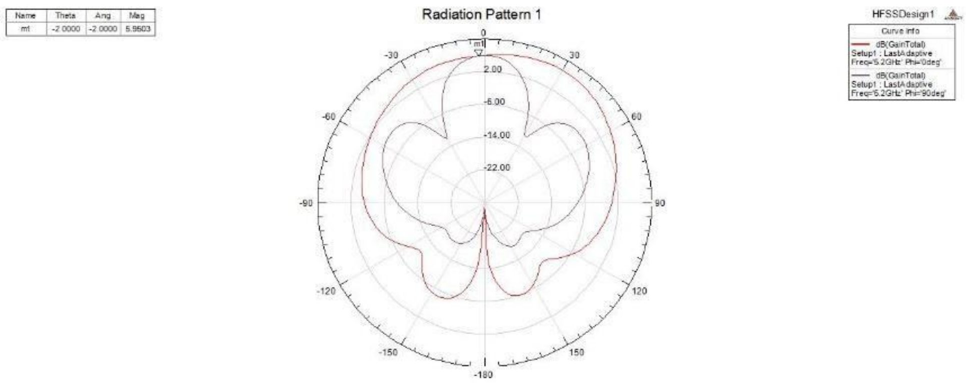

Fig. (6). Gain Plot of 1x2 Array Antenna along with Radiation Pattern

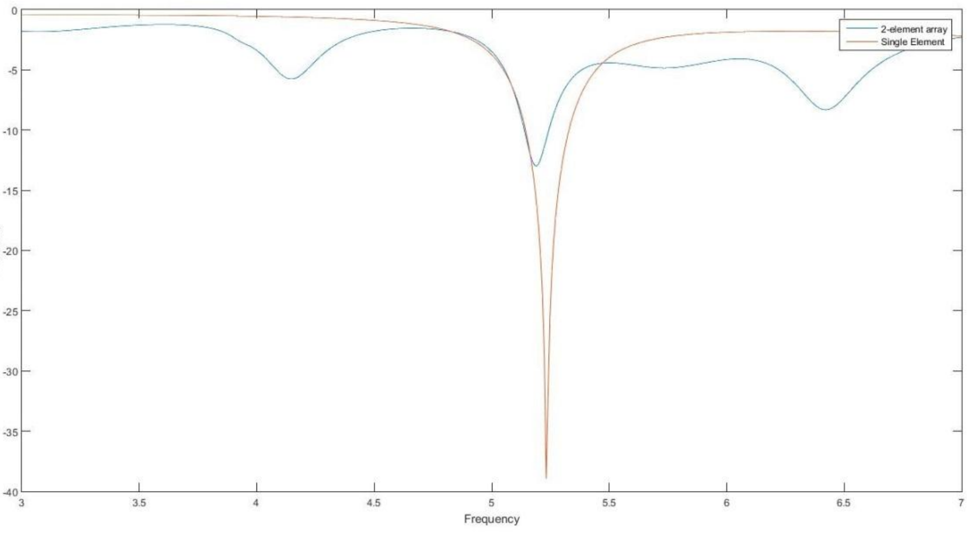

Fig. (9). Return Loss Plot for Designed Antenna

V. CONCLUSION

The antenna was designed as per the calculations and the results were obtained. The results were obtained and it is clearly seen from the radiation pattern. The gain enhancement was found relevant in two element array with respect to the single element. The antenna works at frequency of 5.2 GHz which clearly allows it for use in advanced communication systems. We all know that the frequency of modern communication generations are in the order of GHz's. The antenna parameters show that the antenna gain, beamwidth is suitable for operation for high speed links. The antenna shows a narrow band response. Hence, the antenna can be used for futuristic purposes in every fields of wireless communications.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities

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