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Compact 4-Element Beam Steerable Adaptive Array Antenna for 5G Application

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***Abstract*—** Due to the popularity of smart phones and its usage, mobile data traffic is experiencing unprecedented growth. Demand of high data rates for HD video streaming is increasing along with manageable cost and low power system requirements. 4G LTE (Long Term Evolution) spectrum is almost saturated to overcome the future fast communication demands. Therefore, a technological evolution is desperately needed in terms of 5G communication systems. 5G requires a high efficiency antenna system with wide bandwidth for growing high speed media. The conventionally used broad radiation pattern antennas are not good to acquire high gain and efficiency. Simple way to achieve high gain and efficiency is to form an assembly of radiating elements in an electrical and geometrical configuration. These multiples of radiating elements are referred as antenna array. Furthermore, Antenna Beam Steering is now a need of consumer electronics which was previously considered only for radar and satellite systems. This Compact 4-Element Beam Steerable Adaptive Array Antenna is designed, studied and verified using ANSYS HFSS (High- Frequency Structure Simulator) software.

Keywords—Antenna Array, Microstrip, Beam Steering, Resonant Frequency.

I. INTRODUCTION

The current usage of 4G by consumers have left them in a rut. People are experiencing low data and poor wireless communication signals due to the 4G spectrum getting oversaturated. And soon, this will be the case for the upcoming 5G spectrum too. But given the increase in the demands of the people, with respect to their usage of the spectrum, the 5G spectrum, will not survive as much as the 4G spectrum did. In fact, it will also get over saturated quicker than the 4G spectrum. In order to avoid this situation from occurring, we have introduced the concept of "beam steering" here. It is a concept only used in the military grade research applications but we have brought it to the common customer's usage, as it has the power to save the 5G spectrum from becoming over saturated. This is nothing but the placement of multiple radiating patches in an optimum configuration such that all the patches radiate together to give one single major lobe of radiation, with the least amount of side lobes.

A. *Motivation*

There need for wireless communication is now more than ever, with everything become remote these days, from groceries to telemedicine, it has downgraded the spectrum in terms of efficiency. The motivation of this project is to bring back what was once the efficiency factor of a good wireless communication system, to get the system to be in saturation region back again. Hence, this project was developed.

B. *Problem Definition*

This project mainly depicts the problem faced by a common wireless device user, say a smartphone, who faces mobile data traffic issues and less data transmission speeds due to the oversaturation of the current running 4G spectrum, and to avoid the upcoming 5G spectrum from facing the same fate, we have developed this Compact 4-Element Beam Steerable Adaptive Array Antenna for 5G application.

C. *Objective*

The objective of this project is to come up with a small, compressed, or in simple terms, compact, microstrip patch antenna, that is capable of adapting to different radiating conditions, whilst being capable enough to run operate in the frequencies of 5G spectrum, (roughly 28 GHz to 50 GHz). This can be easily achieved with the concept of “beam steering” wherein a multiple number of patches act together on the same ground plane/substrate of a regular patch antenna, to radiate together and operate at a frequency of 38Ghz. With a good gain (5dB). This project will be studied, designed and simulated for result on ANSYS HFSS (High-Frequency Structure Simulator) software.

D. *Limitations*

Every system cannot be perfect and have limitations to which they are confined to. Similarly, this antenna we designed also has few limitations. However, those limitations do no longer affect the capability and usefulness of this antenna.

- Can be used for wireless applications only
- Can be used for 5G applications only.
- Very small in length, therefore it can be used in compact devices rather than heavy machinery.
- The material used to fabricate the substrate of this patch antenna array is FR4 Epoxy, which is not the most durable material and can be broken if mishandled or used roughly.

II. LITERATURE SURVEY

There have been many prior attempts to this one in developing an efficiently working antenna system in the past, using rectangular, triangular and other shaped microstrip patches in the antenna, but they had their own limitations as well. After referring to all the previous base papers and keeping their limitations in mind, we designed an antenna that has the least number of limitations compared to its predecessors. The concept that distinguishes our antenna its predecessors is beam steering and it’s bringing to the domestic sector usage. Previously it was only used in military grade applications but we propose to bring it to commercial sector for its benefits.

A. Existing System

In the existing and long-running era of antennas, the frequency at which they are being operated is not enough for wireless communication users to get the most out of it. As we have stated earlier in this paper, the 4G spectrum got saturated as it’s being used by a greater number of people each passing day, every user is getting little-to-no-data as a whole. They are being operated at a frequency anywhere from 2 GHz to 20 GHz and with a gain of 2 dB, which is clearly not enough for this current generation. Speaking about the size of the antennas, it is indeed compact, but a further reduction in its size is needed for packing a greater number of antennas or a greater number of radiating elements in a single device but better performance. We have simulated the results of the existing patch antenna as well in the below figures.

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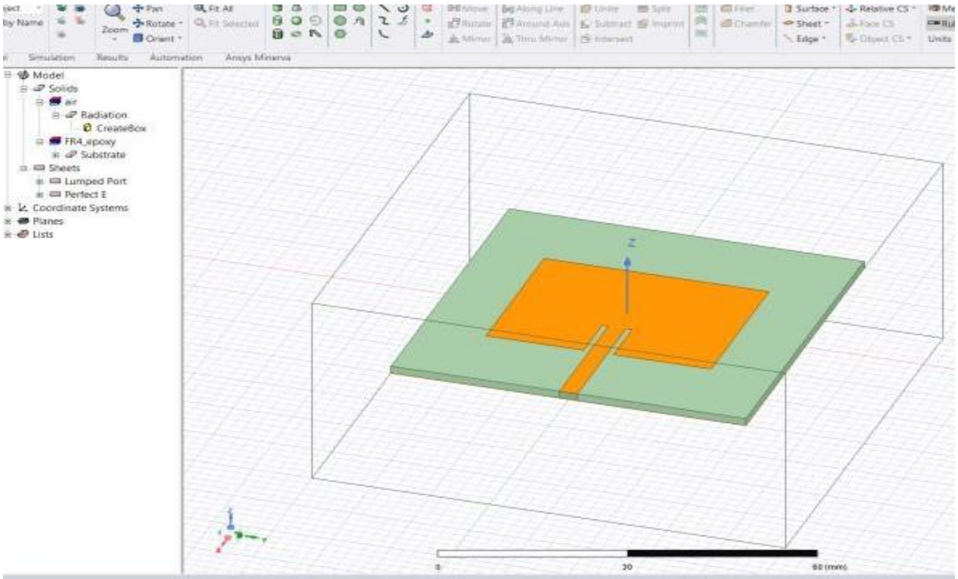

Fig. 1. Existing Rectangular Microstrip Patch Antenna.

C. Proposed System

We propose a Compact 4-Element Beam Steerable Adaptive Array Antenna, capable of operating at a frequency of 38 GHz, which is deemed as optimum for wireless 5G Applications. The concept that is a game-changer in our proposed system is "Beam Steering" which simply means the ability to steer the major lobe of the radiation to an intended direction. This can be achieved by simply arranging multiple radiating elements or patches in a configuration and giving them excitations such that they operate wholly. In this project, we gave each of the radiating rectangular patches, a co-axial probe, instead of a microstrip patch feed line, as co- axial probes are more efficient in antenna data transmission.

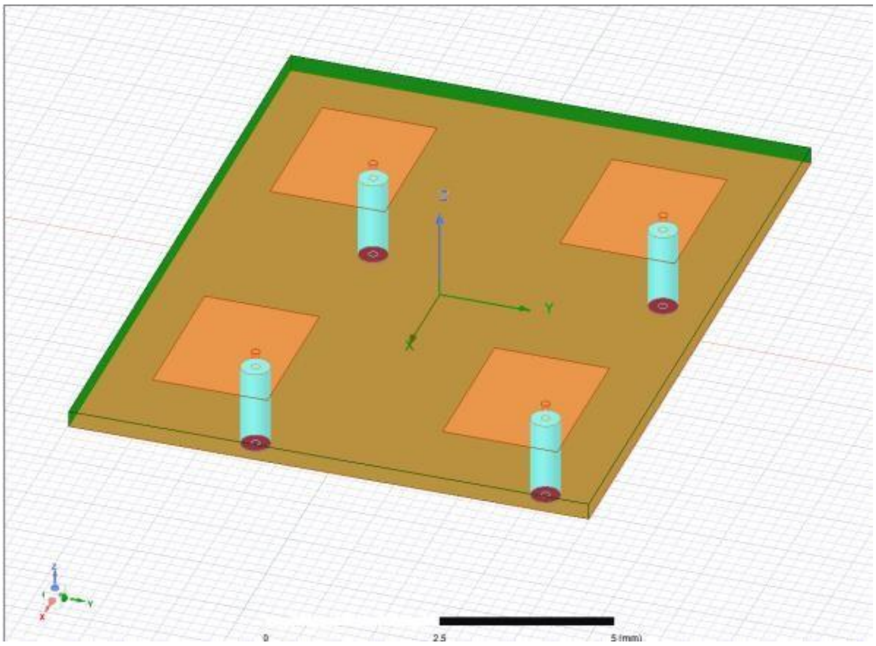

Fig. 2. Proposed System Patch Configuration.

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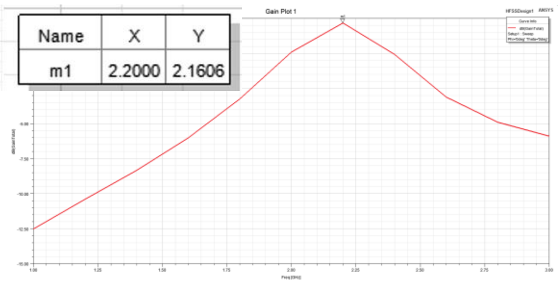

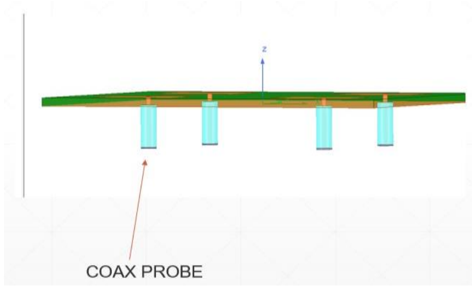

Fig. 3 Existing Rectangular Microstrip Patch Antenna's Frequncy v/s Gain Plot. Resonating at 2.2 GHz with a gain of 2.1606 dB.

B. Drawbacks

There are few disadvantages identified in the existingsystem and are defined below:

- Less operating frequency.
- Size is comparatively large.
- Oversaturated spectrum.
- Less reliable due to decreased speed.
- The proposed system comes with a lot of things, not just with ways to avert the drawbacks in numerous ways. The developed prototype mimics the solution on a miniature scale. Now, when compared to the original existing model, of course there are going to be certain upgrades, the advancements that we are going to find in the newly proposed prototype are mentioned below:

- Increased operating frequency.
- Size is comparatively small.
- Avoids over saturation of the 5G spectrum.
- More reliable due to increased speed.
- Efficiency is increased.
- Can be used a wide variety of wireless applicationdevices.
- Adaptive to different radiating conditions.
- Increased packing density when used in heavydevices.

TABLE I. COMPARISION BETWEEN EXISTING AND PROPOSED SYSTEMS

Sl. No.	**Comparison**		
	Characteristic	***Existing System***	***Proposed System***
1.	Small in size	No	Yes
2.	Performs Beam Steering	No	Yes
3.	Higher operating frequency	No	Yes
4.	Reliable	No	Yes
5.	Oversaturated Spectrum	Yes	No

PARAMETER	**VALUE (mm)**
Substrate Height	0.254
Substrate Length	10.208
Substrate Width	7.969
Patch Length	2.4
Patch Width	1.76
Coax Inner Radius	0.066
Feed length	1.31
Coax Outer Radius	0.224

Fig. 6. Proposed System Specifications.

A. *Software Requirements*

The software requirements to run ANSYS HFSS (High-Frequency Structure System)

- 64-bit Intel or AMD system, running Windows 10.
- 8 GB RAM.
- A dedicated graphics card with latest drivers and at least 1GB video RAM, capable of supporting OpenGL 4.5 and DirectX 11, or higher.
- 10 GB of disk storage.

B. *Design*

First, we have designed a single patch with a resonating frequency of 2.4 GHz and have tested it. The substrate material was FR4 Epoxy with a dielectric of 2.2. The results have been generated to be positive as shown in Fig. 2 for the following specifications.

PARAMETER	VALUE (mm)
Substrate Height	0.254
Substrate Length	4.00
Substrate Width	4.20
Patch Length	2.50
Patch Width	2.65
Feed length	2.00

Fig. 5. Single patch specifications.

Later, we have used the method of trial and error in coming up with an optimum configuration to place a set of 4 radiating elements such that beam steering can take place. After thorough studying of the positioning of the patches, we came up with this 2x2 configuration as show in Fig. 3. And the spacing between each subsequent patch is less than λ/2. The ground plane is made up of the same plane as the existing system, i.e., FR4 Epoxy, which is affordable. After finding the optimum position of the patches, we have given each of them a co-axial probe with excitations respectively. Finally, we have started the simulation and observed various results for the following new specifications of the proposed system of antenna.

In ANSYS HFSS Software, there is no other way to observe the antenna system's working clearly as the results speak for itself. The radiation is set as "air" around the antenna and the simulation is run for different tests, such as E-Field Vector, H-Field Vector, Radiation Pattern, Return Loss and Frequency v/s Gain Plot. The results can be viewed from the "Project Manager" pane on the left-hand-side of the ANSYS HFSS window.

RESULTS AND DISCUSSON

A. *Output*

The simulation was run for various tests such as return loss plot, rE 3-Dimensional Plot (i.e., the major lobe direction of the antenna's radiation), radiation patten for E- Field, radiation pattern for H-Field and Frequency v's Gain Plot as stated above and the results are as follows.

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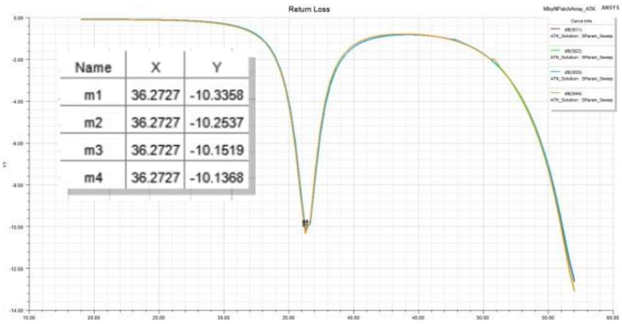

Fig. 7. Return Loss of -10dB.

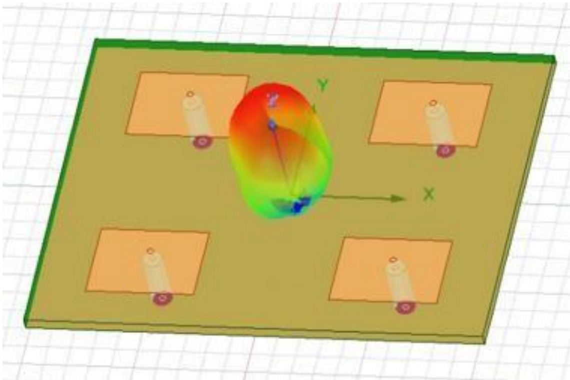

Fig. 8. Major Lobe in One single Direction with no minor Lobes

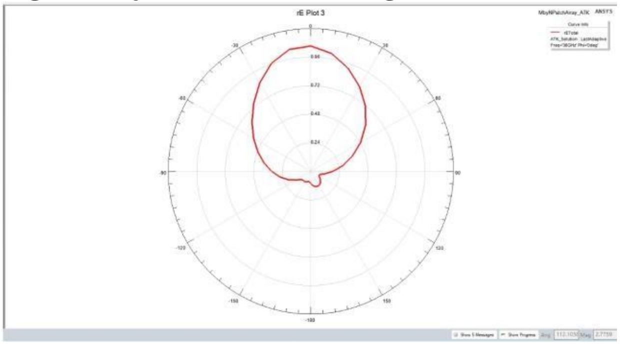

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Fig. 9. Radiation Pattern for E-Plane.

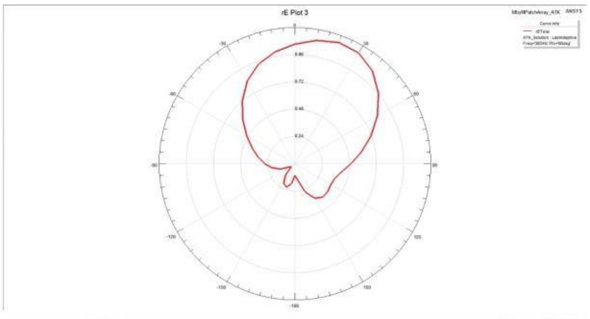

Fig. 10. Radiation Pattern for H-Plane.

B. *Frequency v/s Gain Plot*

The below given frequency v/s gain graph shows the final result of the antenna system. The resonating frequency is at 38 GHz sharp with a gain of 5.1576 dB which is an optimum result for this antenna to function in the 5G spectrum efficiently.

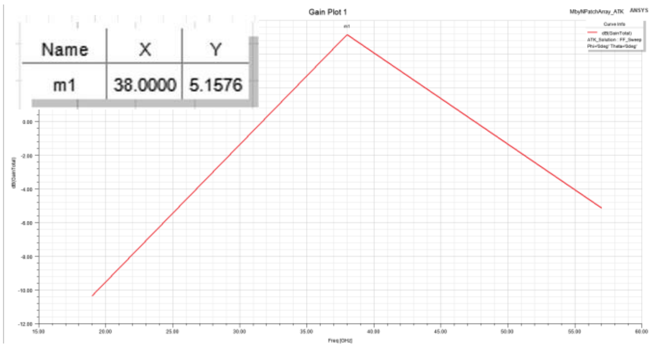

Fig. 11. Frequency 38 GHz with a gain of 5.1576 dB.

CONCLUSION

In this paper, a Compact 4-Element Beam Steerable Adaptive Array Antenna has been designed, studied, simulated for wireless 5G applications such that it can survive the upcoming demands of the everyday users. The concept of "Beam Steering" was once only used in military grade applications but now by brining it into domestic or commercial usage area, its benefits can be reaped by the 5G spectrum so as to not get over saturated like the 4G spectrumand to run hassle free for every user meeting their demands day by day. The results showcased above prove its efficiencyand its power in various conditions.

A. *Future Scope*

As long as the 5G spectrum is away from being over saturated, there is no need for an advancement in this field but by brining beam steering into commercial or daily use, it can find its purpose in other sectors as well such as medicine, for the application of telemedicine or education sector, by bringing the facility of schooling in remote areas, or in the commercial industry, etc.

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