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Microstrip patch antenna designed using frequency reconfigurability for 5G applications

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***Abstract*— The presented work is a "Y"shaped mm-wave reconfigurable patch antenna, suitable for satellite communication, millimeter wave energy harvesting, 5G generation wireless network and Radar. The frequency reconfigurability is achieved using 5 different resistors i.e 100Ω, 250Ω, 500Ω, 750Ω, 1000Ω integrated into the radiating element of the antenna. Five frequencies are obtained by using our designed antenna, which is respectively 51GHz, 45.5GHz, 44GHz, 44.45GHzand 44.65GHz showing strong performance in term of return loss, Gain and VSWR. The proposed antenna is designed using an electromagnetic simulator based on finite element method (FEM) HFSSv11 .**

***Keywords*— Reconfigurable patch antenna, frequency reconfigurability, Resistors.**

1. INTRODUCTION

Nowadays, electromagnetic spectrum has become a rare resource which is in danger, and in future this spectrum will be in worst situation, because of the excessive growth of communication technologies, especially in case of the high frequency useful bands including VHF (Very High Frequency), UHF (Ultra High Frequency) and lower SHF (Super High Frequency) In this case the strength of the signal wavelength is observed in decimeter and centimeter. The High frequencies can propagate for long distance and can even penetrate into the ionosphere without being refracted, these sort of technique is suitable for satellite communications and cellular communication such as WIFI, broadcast TV, Bluetooth, and the majority of the current applications, however, the high frequencies are drenched and are closed to collapse, due to the increase of mobile web utilization, and the need of Internet of Things (IoT) technology in our day to day life [1]. That is the reason, to save this essential resource which will are coming to an end, Many of the researchers, scholars and antenna designers are focusing on the solutions to overcome this spectrum damage, still focusing on consumer requirements, These problems include them to migrate to millimeter wave portion of the spectrum [2].

In general, millimeter wave frequencies, are most commonly known as Extremely High Frequencies (EHF), and are considered to be in the range of frequency from 30 GHz to 300GHz [3], which wavelength is defined between 10 to 1 millimeter and the main advantage to use this spectrum as it can transmit huge amount of data as compared to lower bands. The millimeter wave frequencies are used in many applications, where a rectenna (array with small form factor) may gain RF signals from external sources and transfer these signals in order to power many devices which are used for millimeter wave applications. Mainly this portion of the spectrum is used in satellite cross links in the high earth orbit for frequencies which are above 50 GHz, which allows satellites to communicate with each other, with the help of the high absorption in the stratosphere where there is no oxygen in the space [5].

However, There is a tremendous challenge to use the spectrum efficiently; In this case advanced antennas that respond to global communication needs are a natural requirement. That is the reason why antenna reconfigurability came as a solution to using an antenna per each operating frequency. Reconfigurable antennas are one among present technology which have become highly desirable in wireless communication systems for their versatility and ability. In order to change antennas frequency, polarization and radiation pattern, we use an inner mechanism which is been integrated inside the structure of an antenna, these integrated elements are PIN diode switches, varactors, MEMS (Micro-Electro-Mechanical System) or tunable materials [6- 8]. This technique are mainly used to achieve as much as possible strong antenna performance, in changing applications or to satisfy changing operating such as gain, return loss, VSWR. [8]. Among various antenna the most used

basic antennas to achieve reconfigurability are microstrip patch antennas because of their advance features of ease of fabrication, robust design, and their extremely low profile and lightweight [9].
The present design is a millimeter wave "Y" shaped patch antenna, where frequency reconfigurability is achieved using various resistors these resistors change the value of voltage which results in the change the current distribution, hence effect the frequency. The proposed design is characterized by good matching, return loss, VSWR and gain in all resistor combination.

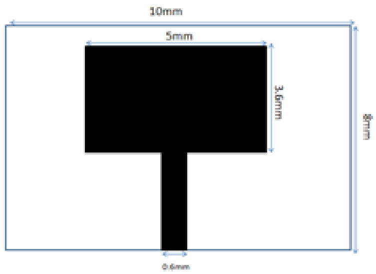


Fig.1 Etching of Proposed Antenna from Rectangular patch

2. ANTENNA DESIGN

The millimeter waves reconfigurable "Y" slotted antenna presented in this paper is made with a copper i.e lossy material designed on Rogers RO3003 substrate [10], with a relative permittivity =3 and a loss tangent =0.0013, and bounded by a ground plane made with same material as the radiating element (copper). Table.1 presents various physical dimensions of the proposed antenna.
As illustrated in Fig. 1, to form a "Y" shaped structure with a width of 0.6mm for each strip. The antenna is fed with 50Ω microstrip feed, the radiating element is a rectangular patch antenna (3.6mm x 5mm) from which we have cut another rectangular patch of dimensions (2.6mm x 2.6mm) from its upper edge.
Table I.Physical dimensions of proposed antenna

Frequency of Operation	50 GHZ
Substrate length in mm	8
Substrate width in mm	10
Substrate thickness in mm	0.254
Cladding thickness in mm	0.009

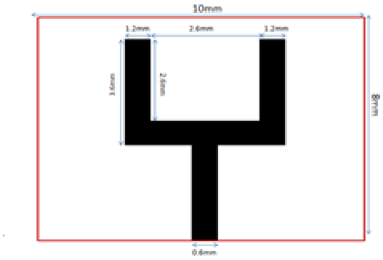
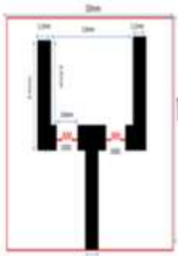
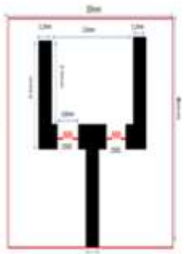


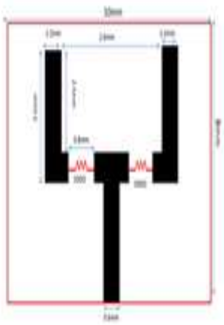
Fig 2. Reconfigurable antenna structure



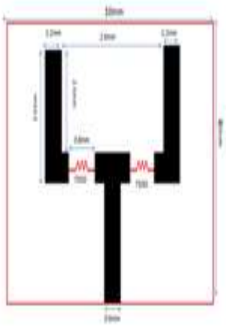
Case 1: 100Ω



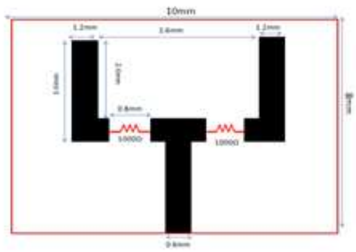
Case 2: 250Ω



Case 3.500Ω



Case 4:750Ω



Case 5: 1000Ω

Fig 3. Symbolic Representation of Different Cases of Proposed Reconfigurable Antenna.

Moreover, in order to achieve frequency reconfigurability, various resistors are added between two stubs, in order to switch between different frequencies, thus, to be used in different applications (Fig.2). has been selected, an equivalent circuit model is designed in HFSS, the equivalent circuit model is shown in fig. 2, and the cases investigated are symbolically presented in the Fig.3.

3. RESULT AND DISCUSSION

Simulation results of return loss, gain and VSWR are presented using HFSS electromagnetic simulator.

3.1 HFSS RESULTS

3.1.1 RETURN LOSS:

From return loss reported in Fig.4, five frequencies are produced using our proposed antenna (51 GHz, 45.5GHz, 44GHz, 44.45GHz and 44.65 GHz having respectively.

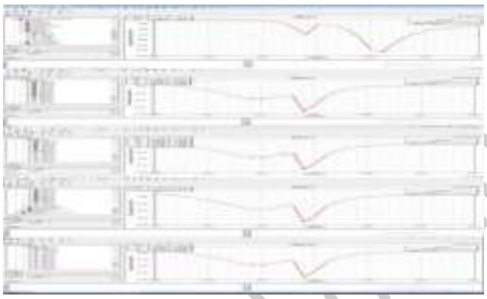


Fig 4. Return loss of all resistors cases using HFSS

3.1.2 VSWR:

The measure of impedance matching of our antenna in all resistor states are presented in VSWR (Fig.5). We can observe from the plots that the “Y” antenna presents a good VSWR<2 in all resistor states. The reported values for each combination are respectively: 1.6,1.1558,1.16282,1.1554 and 1.1681.

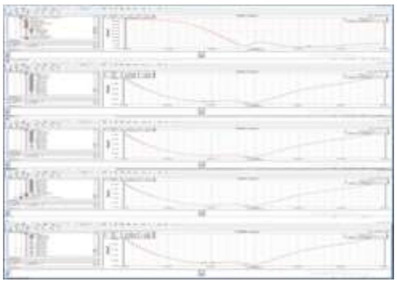


Fig 5. VSWR of all resistor Cases using HFSS

3.1.3 GAIN:

Antenna gain is defined as the ratio of power produced from a far-field on the antenna’s beam axis to power produced by lossless antenna, which is sensitive to signals from all directions. It also tells us how strong a signal an antenna can send or receive .The increase gain we have chosen ROGERS R03003 as substrate affects the parameter gain.

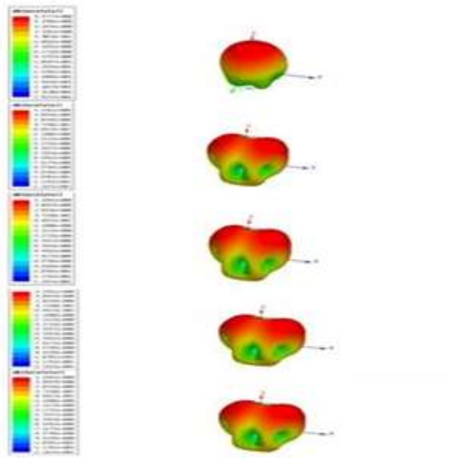


Fig 6. Gain of all resistor Cases using HFSS

From results plots presented of both HFSS simulators, we can clearly observe that using five resistors we can switch between five different frequencies depending on desired application.

From simulation results summarized in Table.2, we can deduce that using 5 resistors, we can achieve frequency reconfigurability between 5 different frequencies, using a simple microstrip patch antenna. Each produced frequency is suitable for an application; in particular, 50GHz and 45.45GHz frequencies are suitable for radar, satellite communications and the next generation telecom network (5G), having as a main role, powering the enormous number of Internet of Things (IoT) devices.

Table II. Results of frequency reconfigurable antenna

	RESISTOR Ω	FREQUENCY GHz	S_{11} dB	VSWR	GAIN dB
Y Antenna with resistors	100	51	-12.6948	1.6	8.477
	250	45.5	-23.6473	1.1558	4.161
	500	44	-22.9793	1.1628	4.1561
	750	44.45	-22.1725	1.1554	4.1581
	1000	44.65	-22.6819	1.1681	4.1593

4. CONCLUSION

The goal of this project is to design an antenna which can operate at different frequencies that are suitable for millimeter wave applications, in particular, Radar, 5G generation wireless network, satellite cross- linking using a simple microstrip patch antenna, which is easy to fabricate and characterized by a small form factor, making it compatible for integration in circuits. The designed antenna is a “Y” shaped pattern made with cooper, in which it is composed of five resistors. The combinations of various resistor has led to 5 different frequencies in each resistor combination, which are respectively: 51GHz, 45.5GHz, 44GHz,44.45GHz and 44.65GHz The presented antenna shows good results in term of VSWR ,Return loss and gain, which makes it suitable for different applications in the millimeter wave range, and still providing better customer requirements.

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