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Millimeter Wave Patch Antenna Design Antenna for Future 5g Applications

Adamu Mohammed Jajere
Institute of Antenna and Microwave Techniques
Tianjin University of Technology and Education
Tianjin, P.R. China

Abstract- **A simple rectangular patch antenna operating in the unlicensed millimeter wave band is presented. The proposed antenna resonates at 38GHz with the corresponding return loss of -31dB, covering about 4GHz bandwidth which makes it a suitable candidate for the next generation (5G) wireless communication devices. The total profile of the designed structure is 5×4×0.64mm^3, other parameters such as VSWR, gain, and radiation pattern are also discussed in this paper.**

Keywords—Millimeter wave, 5G, patch antenna, wideband, coaxial probe feed

I. INTRODUCTION

One of the challenging factors affecting wireless communication industries today is insufficient frequency resources available for their customers and the ever increasing demand for efficient wireless services continuous as well. In order to solve these problem, the use of the higher frequency spectrum at millimeter wave bands (20 – 300 GHz) which is characterized by enormous amount of bandwidth for higher data transmission rate becomes necessary. Millimeter wave bands have been proposed to be an important part of the 5G mobile network to provide multi-gigabit communication services such as high definition television (HDTV) and ultra-high definition video (UHDV) [1]. We believe the prime spectrum for 5G is between 24 GHz and 57 GHz from both the regulatory and technological perspectives. Among the bands being proposed, it was recommended that the mobile industry prioritize bands within the 25.25 – 29.5 GHz and the 36 – 40.5 GHz frequency blocks as primary targets to secure for 5G in the World Radio communication Conference 2019 (WRC-19) [4]. Therefore, the proposed antenna would be a suitable integral part of wireless communication devices operating at the 36 – 40.5 GHz frequency block.

Patch antenna as a critical component of modern wireless communication system plays a vital role in this evolution. Compared with conventional microwave antennas, microstrip patch antennas are with small size, light weight, simple to manufacture, low cost, and ease of integration such as in mobile radio and wireless communication applications. The future generation wireless networks require systems with broad band capabilities in various environments to satisfy numerous applications as smart grid, personal communications, home, car, and office networking. Its flexibility makes it very much compatible for use in mobile phone, hand held devices, aircrafts, marine craft, trains and cars [2]. While designing such antennas, if the right patch shape and mode are selected, they are very good in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed [3].

In this paper, a simple rectangular patch antenna operating at the millimeter wave band is presented, designed with Taconic RF-60(tm) substrate. In summary, physically small sized, wide bandwidth, and high efficiency as the desired characteristics of antennas in communication systems is implemented.

II. DESIGN GEOMETRY

The structure of the wideband antenna is similar to that of many common useful rectangular shaped antennas operating at microwave frequencies consisting of a radiating metallic patch (normally made of conducting material) or an array of patches situated on top of the grounded dielectric substrate, this antenna is known as patch antenna or microstrip patch antenna. The design was carried out using the Ansoft high frequency structure simulator (HFSS) software. The proposed antenna consists of three layers: the top is the radiating element, the middle is a substrate which provides mechanical support for the radiating patch elements as well as to maintain the required precision spacing between the patch and its ground plane, and the bottom is the ground plane which provide support and increase the bandwidth of the antenna in order to meet up the design requirements. The choice of materials were carefully made which are as follows; the patch length (L_P) is 1.98mm, width (W_P) is 1.49mm resonating on a Taconic RF-60(tm) substrate with thickness of 0.64mm and dielectric constant, ε_r of 6.15. The substrate selection was based on the dielectric constant. A high dielectric constant will result in a smaller patch size but this will generally reduce bandwidth efficiency and might have difficulty in fabricating a very small patch size antenna [3]. The ground plane of the structure setup is 5×4mm^2.

The most popular and often used closed-form equations for the fundamental-mode rectangular patch are given by:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{(\varepsilon_r+1)}} \qquad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad (2)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \qquad (3)$$

$$L = L_{eff} - 2\,\Delta L \qquad (4)$$

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There are many configurations that can be used to feed patch antennas. The most popular are the microstrip line, coaxial probe, aperture coupling, and proximity coupling. The designed antenna in this paper used the coaxial-probe feed method. This method defines; where the inner conductor of the coax is attached to the radiating patch while the outer conductor is connected to the ground plane. The coaxial probe feed is easy to fabricate and match, it is also characterized by low spurious radiation [3].

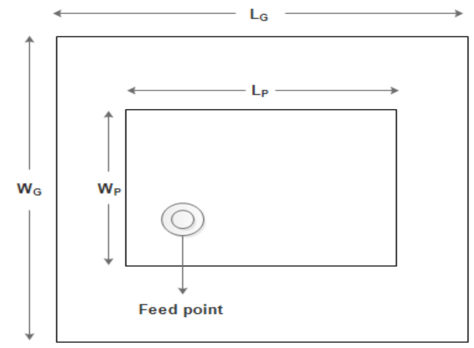

Fig. 1. Model of the patch antenna

TABLE I. GEOMETRY OF THE STRUCTURE

Dimension	L_P	W_P	L_G	W_G	Sub H
Length(mm)	1.98	1.49	5	4	0.64

III. ANTENNA SIMULATION AND RESULTS

The simulation was carried out using the Ansoft high frequency structure simulator (HFSS) software which is based on a finite element method, its accuracy and powerful features makes it a good and common tool for antenna designers. The entire designed structure feed by a coaxial probe was simulated, during which parametric study was carried out for different values of the patch length (L_P) and the width (W_P). The structure was further optimized for the best matching position of the feeding point to the patch. Return loss (S_{11}) was obtained at < -10dB, implying that 90% of the available power is delivered to the antenna. A gain of over 4dB was obtained, the voltage standing wave ratio (VSWR) was gotten to be VSWR < 2 and > 1. Also the bandwidth obtained (35.92 – 39.98 GHz) with center frequency of 38.14GHz is more than 500MHz which satisfied the condition for wideband. The simulation results are presented in the table below. The return loss (S_{11}), VSWR, current distribution on the patch, and radiation pattern represented in terms of *E* and *H* planes can all be seen in the figures below.

TABLE II. SIMULATION RESULT

Freq.(GHz)	S_{11} (dB)	VSWR	Bandwidth(GHz)
38.14	-31.90	1.10	4.06

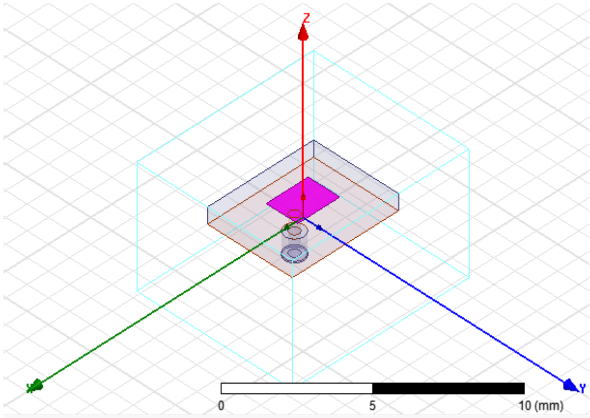

Fig. 2. Isometric view of the antenna Simulation

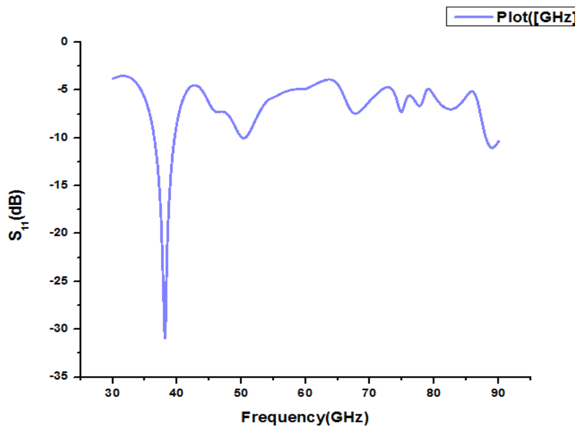

Fig. 3. S_{11} (dB) Parameter or Return loss

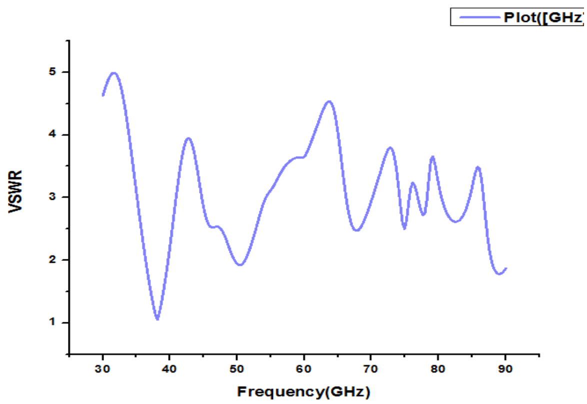

Fig. 4. Voltage standing wave ratio (VSWR)

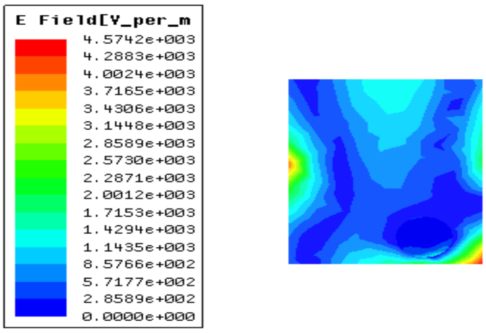

Fig. 5. Current distribution on the radiating patch

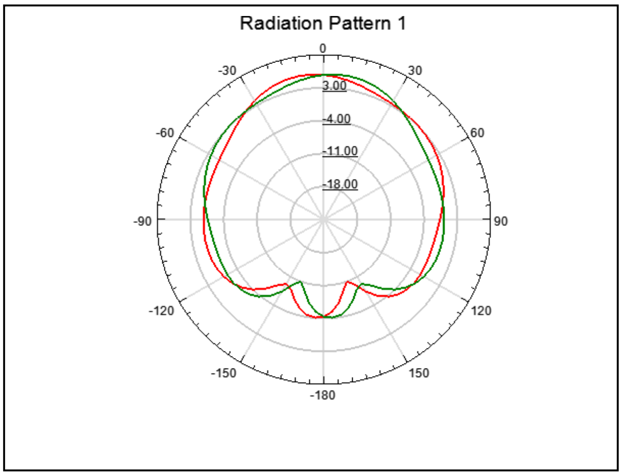

Fig. 6. Radiation Pattern of the antenna at 38.14GHz

IV. CONCLUSION

The analysis and design of a simple rectangular patch antenna operating at 38.14GHz with the return loss (S_{11}) of -31dB presented in this paper proved the theoretical study of rectangular patch antenna properties in relation to the structure profile, as well as substrate material type and the feeding technique used. The designed antenna is a good choice for future communication devices that would be operating on the proposed 36 – 40.5 GHz frequency band. Subsequent studies and design of more sophisticated patch antennas operating on the millimeter wave bands, using several bandwidth enhancement techniques in order to meet up with the demand and requirements of the future 5G networks is recommended.

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