Enhancing Performance of Fifth Generation Signal Portable Dongles with a COMSOL 5.5 Simulated 5GHz Patch Antenna

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Abstract:- Strip patch reflectors with significant attributes such as low cost, lightweight, low profile and compatibility with monolithic Microwave Integrated circuits are used widely in mobile communication most importantly in the recent mobile communication known as fifth-generation network. The paper presents the design and simulation of the 5GHz patch, the design was done using the substrate material (RUTOID 588) with the following design parameters: Dielectric constant of 2.20, relative permittivity 2.20, Lost tangent 0.0009, Dissipation factor of 0.0009 and substrate height of 0.003 inches. The compact antenna design is compact, making it a good candidate for 5G mobile communication applications. The design also showed that the radiation pattern is omnidirectional with a minimized reflection coefficient of -5.7dB and maximized power transfer. The antenna has a directivity gain of 6.9 dB and a possible return loss of -2.38 dB.

Keywords:- *Patch, Substrate, Omnidirectional, Dielectric and Comsol.*

I. INTRODUCTION

The widespread usage of patch antennas in electronic warfare and remote control has drawn a lot of attention in the modern era. It is perfect for sensing, wireless communication (including cell phones), space exploration, and several other electrical systems because it is simple to operate. Installation, affordability, compactness, and lightweight. With the development of technology, antenna design is becoming more and more challenging. The comprehensive treatment of the antenna problems cannot be solved with analytical methods alone due to the complexity of the antenna structure and its radiation fields; instead, a computational electromagnetic model (CEM) is needed [20, 22, 11,13]. It addresses both science and art using numerical approaches to solve Maxwell's equations or simulate electromagnetic fields. Since traditional analytical methods cannot successfully meet complete radiation and scattering conditions, numerous numerical methods have been developed over the past few years to solve antenna electromagnetic problems and microwave instruments.

The fifth generation (5G), often known as the New Radio, refers to a significant improvement in wireless technology over earlier generations like 2G, 3G, and even 4G. Enhanced broadband, ultra-reliable low latency communications (URLLC), and high machine communications are just a few of the applications for which 5G technology can be used. According to a technical perspective, it required the exploitation of new paradigms, such as the use of millimetre waves, variable numerology, bandwidth parts, and more advanced implementation of techniques introduced in 4G, like Time Division Duplex (TDD) and Multi-User Multiple Input (MU-MIMO) technologies at the spatial domain level and high flexibility in the implementation of beam sweeping [7].

Wireless networks and communication technology have significantly advanced over the past ten years, creating our economy and society [8, 9]. From voice-only services to cellular broadband, from GPRS (2G) to 4G and beyond, we have made the transition from simple to computerized, and Nigeria is no longer a choice. Each generation of mobile technology, from analogue to LTE, has been driven by the need to satisfy a difference between that technology and its forerunner. The change was anticipated to increase data connectivity while making mobile internet consumer devices available. Technological innovation makes a wide range of users possible which both supports and pushes the limits of various policy uses. This may be true specifically for 5G technologies, which enable higher spectrum bands for quality than previously anticipated potentials [3,5]. The fifth generation of cellular technology, or 5G, offers a variety of characteristics that are advantageous to all types of individuals, including students, professionals like doctors, engineers, and instructors, as well as governmental agencies, administrative bodies, and the average person. The use of mobile phones with actual high bandwidth will soon be replaced by fifth-generation technology. 5G is a packet-switched wireless application with improved area broadcasting and high throughput, Communications are carried out using CDMA, BDMA, and millimetre-wave technology, and the authorized seed speed is greater than 100Mbps at full speed and greater than 1Gbps at low speed. It is a remarkable, significant accumulation of technology computed into a small device since it possesses all types of leading attributes that shape the system and equally made it the most effective and in high demand in the future. Customers of cell phones get more features and efficiency from them. The customer's mobile phone can easily connect to the 5G system gadget with computers and tablets to access the broadband internet [6].

The flawless real World Wide Wireless Web (WWWW) is made possible by this system's ability to communicate wirelessly without any restrictions. The real wireless world will be supported by 5G, which will also include LAS-CDMA (Large Area Synchronized Code Division Multiple Access), OFDM (Orthogonal Frequency Division Multiplexing), MC CDMA Multi-Carrier Code Division Multiple Access, UWB (Ultra-wideband), Network-LMDS (Local Multipoint Distribution Service), and IPv6. With the most recent mobile operating systems, Fifth Generation technology delivers enormous information capacities, unlimited call volumes, and boundless data broadcasts [4, 15].

II. 5G EVOLUTION

The evolution started in 1980 with the development of 1G which contain an analogue system that supported the first generation of analogue cell phones with speed up to 2.4kps. It introduces mobile technologies such as mobile telephone systems (MTS), advanced mobile telephone systems (AMTS), improved mobile telephone systems (IMTS) and push-to-talk (PTT). It uses an analogue radio signal which has a frequency 150MHz, Voce call modulation is done using a technique called frequency division multiple access (FDMA). This allows users to make voice calls in 1 country. But it had low capacity, unreliable, handoff, poor voice links and no security at all since voice calls were played back in radio towers susceptible to unwanted eavesdropping by third parties [19,23].

III. SECOND GENERATION (2G)

2G emerged in the late 1990s, commercially launched on the GSM standard in Finland (1991).it uses digital signals for voice transmission and has a speed of 64 kbps.2G network allows for much greater penetration intensity and provides services such as text message, picture message and Multimedia Messaging Service (MMS) which uses the bandwidth of 30-200KHz. Text messages are digitally encrypted next to 2G, 2.5G system packet-switched and circuit-switched domains and providing data rates up to 144kbps. E.g. GPRS, CDMA and EDGE [19, 23, 24].

IV. THIRD GENERATION (3G)

It uses Wideband Wireless Network with which clarity is increased. The data are sent through the technology called Packet Switching. Voice calls are interpreted through Circuit Switching. Along with verbal communication it includes data services, access to television/video, and new services like Global Roaming.

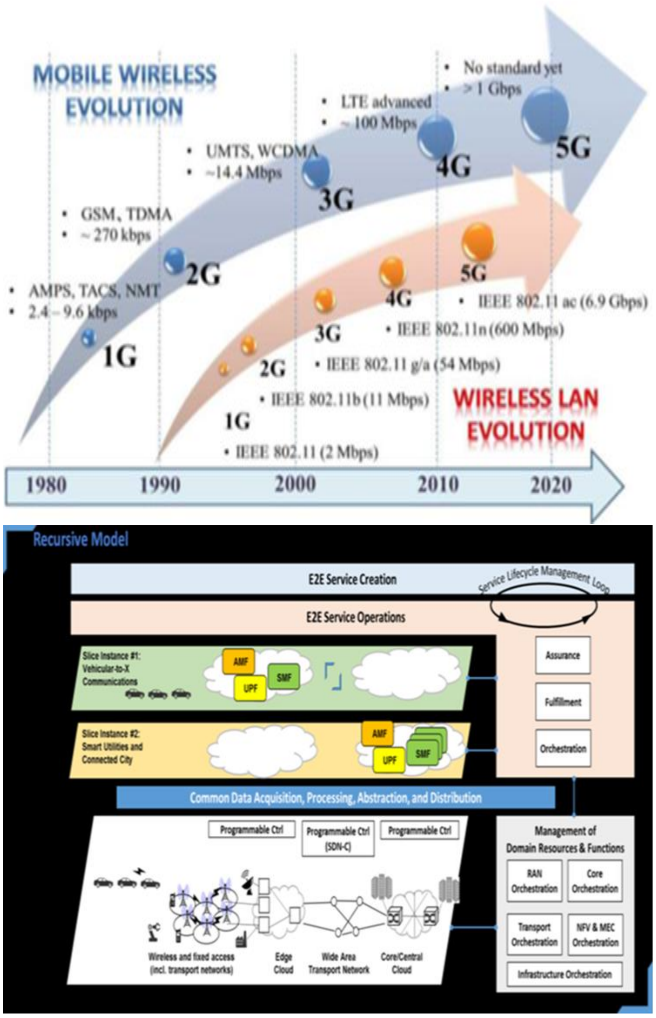

Fig 1 5G Architecture

V. PATCH ANALYSIS METHODS

Three popular models for the analysis of Microstrip antennae are the Transmission line model, the Cavity model and the Full Wave model. The transmission line model is the simplest, it gives a good physical insight but is less accurate. The cavity model is quite complex but gives good physical insight and is more accurate. The full wave model is the most complex, it's very accurate in the design of finite and infinite arrays or stacked structures [2, 5, 17].

The quantity associated with radiated EM wave is the pointing vector given as:

$$S = E \ x \ H \qquad \text{i.}$$

Where S is the instantaneous Poynting vector, E is the instantaneous electric field intensity and H is the instantaneous magnetic field intensity. The complex fields E and H are related to their instantaneous counterparts [2,10,14].

$$E(x, y, z, t) = Re[E(x, y, z)e^{iwt}] \qquad \text{ii.}$$

$$H(x, y, z, t) = Re[H(x, y, z)e^{iwt}] \qquad \text{iii.}$$

Using the Identity

$$R_e(X \ \ e^{-i\omega t}) = \frac{1}{2}\left(X_e{}^{iwt} + X_e{}^{iwt}\right) \qquad \text{iv.}$$

The equation can be rewritten as:

$$S = \frac{1}{2} \ R_e(E \ x \ H) + S = \frac{1}{2} \ R_e(E \ x \ He^{-i\omega t}) \qquad \text{v.}$$

Hence, the time average pointing vector can be written as [3, 10, 16, 17]:

$$S = \frac{1}{2} \ R_e(E \ x \ H)Wm^{-2} \qquad \text{vi.}$$

Factor ½ appears because the E and H fields are peak values, not rms.

VI. NUMERICAL 5G ANTENNA DESIGN

This presents the design of a slot E-shape patch antenna for a 5G network signal with the use of a COMSOL Multiphysics simulator to simulate the antenna using the following parameters to determine the antenna performance parameters.

➢ *Design Parameter*

- *Calculation of the Width*
- *Effective dielectric*
- *Calculation of effective length*
- *Calculation of length*

Table 1 Antenna Design Parameter

Substrate	RUTOID 588
Dielectric Constant	2.20
Relative Permittivity	2.2
Loss Tangent	0.0009
Dissipation factor	.0009
Substrate height	0.003inches

The designing process followed the following designing equations:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad \text{vii.}$$

Where v_0 is the free space velocity of light?

The effective dielectric constant is obtained using the equation:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-0.5} \qquad \text{viii.}$$

The patch dimensions along with the length are extended on each end ΔL, which is a function of the effective dielectric constant ε_{reff}, the width-to-height ratio ($\frac{W}{h}$), and the normalized extension of the length. The extension length is given as:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad \text{ix.}$$

The actual length of the patch (L) can be calculated using equation 1.7:

$$L = \frac{1}{2fr\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L$$

The electromagnetic plane radiation is determined using the equation

E-plane pattern

$$E_\varphi = \frac{kV_0w}{2\pi r} \ e^{-jkr}\left[\sin\theta\left(\frac{\sin\left(\frac{kw}{2}\cos\theta\right)}{\frac{kw}{2}\cos\theta}\right)\right] \qquad \text{x.}$$

H – plane pattern $\qquad H_o = \frac{E_\emptyset}{\gamma}$

Characteristics impedance of Microstrip line feed for w/h less than 1

$$Z_o = \frac{60}{\sqrt{E_{reff}}}ln\left(\frac{8h}{w} + \frac{w}{4h}\right) \qquad \text{xi.}$$

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For $\geq 1 Z_{o}= \frac{120\pi}{\sqrt{\epsilon_{reff}\left[\frac{W}{L}+1.393+.667\ ln\left(\frac{W}{h}+1.44\right)\right]}}$ Beam width E – plane

$$\theta_{\in} \cong 2Cos^{-1}\sqrt{\frac{7.03}{4(3Le^2+h^2)\pi^2}} \qquad \text{xii}$$

The transmission line method is the easiest compared to the rest of the methods. This method represents the rectangular Microstrip antenna as an array of two radiating slots separated by a low-impedance transmission line of a certain length [16]. The effective length is then given as Equation xiii

$$\epsilon_{reff} = \frac{(\epsilon_r - 1)}{2} + \frac{\epsilon_r + 1}{2}\left(1 + 10\frac{h}{w}\right)^{-\frac{1}{2}} \qquad \text{xiii}$$

The Effective width is then written as:

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \qquad \text{xiv}$$

Parameters	**Values(mm)**
L	**19.84**
W	**23.70**

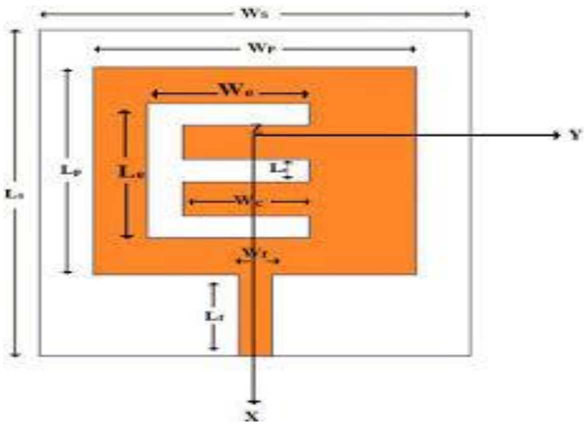

Fig 2 Design Schematic of the Patch

VII. DIRECTIVITY

Antenna Directivity is defined as the ratio of maximal radiation intensity to the average radiation intensity and both are considered for the test antenna [18].

Thus, it can be written as:

$$D = \frac{P(\theta,\varphi)_{max}}{P(\theta,\varphi)_{av}} \qquad \text{xv}$$

Where $P(\theta,\varphi)_{max}$ is the maximum radiation intensity while $P(\theta,\varphi)_{av}$ is the average radiation intensity. In Decibel (dB.), Directivity is given as;

$$D(db) = 10log_{10}D \qquad \text{xvi}$$

VIII. RESULT AND DISCUSSION

The simulation of the designed Microstrip patch structure was carried out using COMSOL 5.5 Multiphysics software an electromagnetic simulator. The norm electric field inside the antenna substrate is described in the figure, where the electric field's arrow plot is included. The Arrow direction indicates the dominant polarization in the higher if 50ohm fed from the edge and low. The directivity of the antenna in the far field is 6.9dB (4.32). This implies that the antenna is capable of receiving 4.32 times more power in all directions, hence, maximizing power transfer as shown in Figure 1. The gain is obtained to be 6.9db under lossless conditions with an efficiency factor of 1. The actual length of the patch is calculated to be 19.84mm or approximately 1.98cm while the width is obtained as 23.70mm or 2.37cm. The patch's length, width and height showed the compactness of the antenna design, which is suitable for 5G mobile communication applications. The highest oscillating frequency of the antenna is 5.0GHz while the reflection coefficient is -5.7db, with the minimized reflection coefficient, the power transfer has been maximized; the possible return loss is -2.38db. The antenna has a radiation pattern that is omnidirectional (Isotropic antenna). The norm of the electric field inside the antenna substrate is described in Figure 2, where an arrow plot of the electric field is included. The direction of the arrows indicates the dominant polarization in the direction of maximum radiation. The antenna impedance is higher if 50 Ω fed from the edge and lower if 50 Ω fed from the centre. While the visualizes the decay of field amplitude in the figure within the proposed geometry of the antenna at resonant frequency 5GHz. It shows that variation in the number of electric field lines per unit volume within our proposed geometry having values varies from -25.67 to 68.43.

The front-to-back ratio in the radiation pattern is greater than 15 dB, and the scattering parameter (S11) is better than -10 dB. shows the frequency response measured with a 100 kHz resolution. It demonstrates that the Microstrip patch antenna behaves in a single band and only detects a single resonance band at 4.56GHz. By looking at the suggested antenna's resonance point, it is possible to estimate that its operating range will be between 4.5 GHz and 5.76 GHz, which shows an improvement in the reflection coefficient and a broader bandwidth at each point of resonance. The antenna impedance is matched to 50 at roughly 4.55GHz, according to the S-parameter (S11).

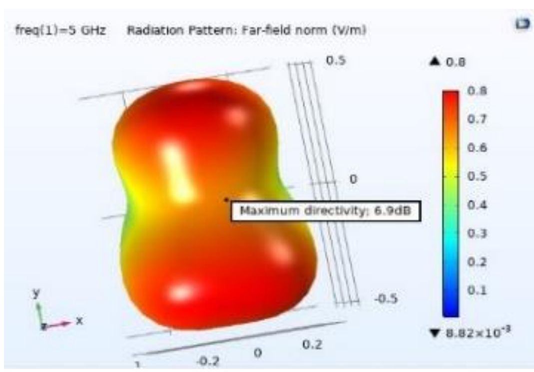

Fig 3 3D Far Field Radiation Pattern

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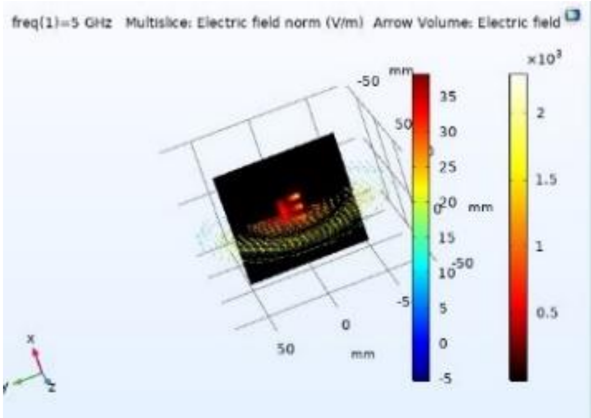

Fig 4 Electric Field Distribution

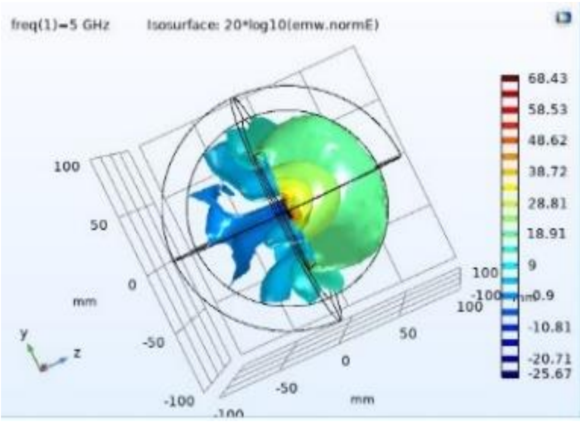

Fig 5 Iso-Surface Plot

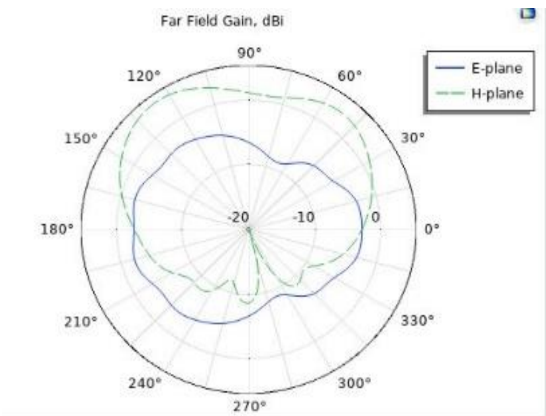

Fig 6 2D Far Field Gain

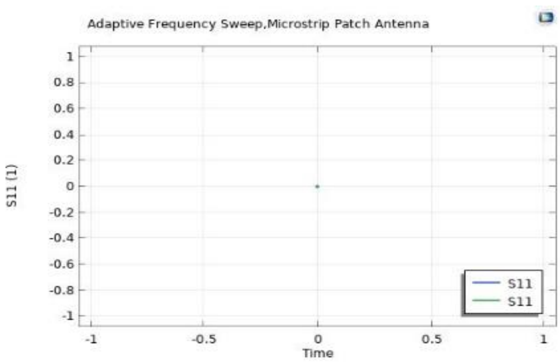

Fig 6 Adaptive Frequency Sweep Micro-Strip Patch Antenna

IX. SIMULATION AND DISCUSSION

The 5G Microstrip antenna simulation was analysed using COMSOL 5.5 series with the substrate material RT/Duroid 58880 relative permittivity Er, the thickness of 1.4mm. the simulated standard wave ratio SWR

X. CONCLUSION

The geometry of the proposed antenna is much more compact than that of other antennas. Using a rectangular Microstrip patch antenna design, we get better polarisation at the edge than in the centre of the proposed antenna's geometry. The radiation pattern of a single patch antenna in the E and H planes, the Microstrip patch antenna, demonstrates the antenna's directivity and gain improvement. The proposed antenna's resonance frequency is 5GHz, which is suitable for bandwidth enhancement and better impedance matching. As a result, the efficiency of the micro-strip patch antenna is high. As a result, we can say that this type of aerial is useful for wireless communication systems such as mobile, Wi-Fi, television and radio broadcasting, satellite communication, and radar systems.

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