Graphene Based Microstrip Patch Antenna for X Band Applications

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Abstract

Variety of materials with different dielectric constants are available for microstrip patch antenna. In the paper, graphene material is used and analyzed at X-band frequency. The use of graphene patch material as conducting substance for the antenna is assumed to improve the bandwidth and radiation efficiency on account of the outstanding functionalities and electromagnetic properties. The antenna is designed with Duroid RT5880 (lossy) material with a dielectric constant of 2.2 palced between graphene patch and ground plane using Computer Simulation Tool (CST) Microwave Studio 2016. The resonance frequency of the antenna is 10.54 GHz with a gain of 7.86dB, return loss of -24.55 dB, directivity of 8.31 dBi and VSWR of 1.1.2. The antenna operates for frequencies from 8 – 12 GHz with an enormous bandwidth of 1.09GHz.

Keywords: Graphene; ground slotted; partial ground; huge bandwidth; high gain; Earth–satellite uplink; Satellite-earth downlink; X-band; wideband antenna and slot

1. Introduction

Antenna plays a significant function in wireless communication from one point another; it sometimes behave as a transducer, which converts electrical signal to radio waves and aids in transporting the transmitted information. Wireless communication has been incrementally advancing and involving innovative wants in antenna technology [1]. Different materials where used in various designs of antenna to check there fit and various output result. In this work, graphene material was used as both patch and ground material of our antenna with a slot on the ground elements to obtain a broader bandwidth [2]. The microstrip antenna (MPA) happens to be the most innovative area in the antenna engineering. The idea of microstrip antenna was first presented in year 1950s but it only got serious attention in the 1970s. The outstanding features that made the microstrip patch antenna eminent are lightweight, low cost, comparatively easy to fabricate and extremely thin surface protrusion. These microstrip patch antennas have a frequency ranges above 100MHz. Another benefit of having this suitable structure is the ease to fuse into various telecommunication systems [3].

The latest wireless communication systems require operation in different and convoluted environments due to their exposure to extreme pressure and environmental temperature transformations. As a result of these wireless nature of these systems, the antenna as a significant component that transmits signals and information from one point to the needs to overcome some of the mentioned difficulties [1]. Nevertheless, one disadvantage of using a conventional copper conducting material antenna is the possibility for copper failure because of the recurrent bending and deformations. To address a few of these challenges, a flexible graphene-based conducting material is used to replace the etched copper in conventional antennas [2, 3].

Many researches where carried out for MPA for the different frequency bands. In 2014, a wide band microstrip antenna is designed for Ku band applications with defected ground structure; a circular shape defect is integrated in the ground plane [1]. In the same year, a paper investigate the dependency of antenna parameters designed for 10 GHz inset fed rectangular microstrip patch antenna on varying inset width and inset gap for proper impedance matching so as to have minimum return loss and achieve efficient operation [5]. Also in 2014, a comparative study of rectangular and circular shape microstrip patch antennas at an X band frequency, the result shows that a circular patch antenna offers about eight percent higher bandwidth and nearly 2.0dB less side lobe power than that of rectangular patch antenna [6]. Later in 2015, a coaxial probe feed modified swastika shape patch antenna is designed and analyzed to obtain the broadband frequency range in X-band (8-12 GHz) [7]. Also in the same year, a slotted fan shaped microstrip patch antenna with three operating frequencies for radar application is presented; the design model is made to resonate at three frequencies in X-band [8]. In the same year, a Microstrip Patch antenna for radar application is presented, in this paper, conventional shapes like rectangular, triangular and circular microstrip Patch antenna are designed and analyzed at X-band frequency [9]. Also in 2016, a design of a high gain and directivity blind hole substrate slotted microstrip patch antenna for X-band applications was done, the proposed antenna resonates at 7.94 GHz with the minimal return loss of -81.25 dB, high gain of 8.5 dB and directivity of 8.12 dBi with a limited bandwidth [10,11].

Later the same year, another method has been proposed to simultaneously enhance the gain and bandwidth of a microstrip patch antenna [12]. In the same year, a design of both planar ultra-wide band (UWB) antenna and UWB antenna with two rejected bands are given, the rejected bands are the WLAN and X-bands, achieved by inserting slots in the patch and the feed [13]. Also in 2016, Also, a novel design of multiband microstrip patch antenna which resonate at 7 unique frequencies between 4 GHz and 14 GHz by inserting a rectangular slot in the ground plane of the patch antenna [14]. Later in 2017, a design of Microstrip Patch Antenna (MPA) using hybrid fractal slot (Koch-Minkowski and Koch-Koch) along with partial ground plane for wideband applications with two resonant frequencies, good gain and bandwidth [15]. In the same year, a combined and compact double H-shaped X-band microstrip patch antenna is designed for bandwidth enhancement [16]. In the same year, a Hexagonal Patch Microstrip antenna for C Band, X Band and Ku Band Applications with partial and slotted ground plane resulting in a huge bandwidth enhancement of 504 percent [17]. In the same year, a Multiband rectangular shaped Microstrip patch antenna is designed using coaxial feeding techniques which for C and X Band applications [18]. Based on the literature reviewed it is identified that most of the research works have limited bandwidth which is enormously enhanced in this paper using the graphene which is in other context used as passive substrate with variable resistance, as such allowing it to tune microwave devices and obtaining the corresponding matching [19].

Graphene is rapidly becoming an exceptionally interesting choice for a vast variety of electronic components, circuits, systems and devices such as frequency multipliers, metamaterials, organic electronics, high frequency field effect transistors (FET), wireless nano-sensors, modulators, transparent solar cells and devices operating in terahertz band. [1]. It has an outstanding performance with much less power consumption, and the option of fabrication process using a technology similar to the advanced silicon device (CMOS) fabrication [1, 2]. Other good properties that makes graphene the latest trending material in the manufacture of latest devices is that in conducts much electricity within a very small space which provides the room in developing miniaturized devices and super-fast devices which requires minimal amount of power to operate [1,3].

Also to mention; of the various means of enhancing antenna bandwidth which includes: using a material with lower dielectric constant, partial grounding, introducing and/or increasing the inset gap of the antenna and using the defective ground structure (DGS) techniques [4,5]. In this paper, two adjacent slots where introduced to the ground plane which significantly enhances the antenna bandwidth. The frequency ranges as defined by IEE Standard 521 in 2002 in 2002 is the X-Band frequency ranges that vary from 8 to 12 GHz. This frequency range is widely used in applications such as radar applications, air traffic control, military satellite, weather forecasting and monitoring, radio-determination purposes, defense and tracking vehicle speed for law enforcement [6].

2. Methodology

A. Design Formulea

The microstrip patch antenna (MPA) is conventionally designed using the following equations given empirically by [7] as:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \quad (1)$$

h stands for thickness of the substrate and W for patch width.

The effective patch length L_{eff} is given by:

$$L_{eff} = L + 2\Delta L \quad (2)$$

L stands for the length of patch.

For a given resonance frequency, f_o the effective length of the patch given by:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (3)$$

The resonance frequency for a rectangular patch antenna is given by:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{eff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^2 \quad (4)$$

W is the patch width given by [18] as in equation 5:

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (5)$$

For ground plane:

$$Width = 6h + patch\ width \quad (6)$$

$$Length = 6h + patch\ length \quad (7)$$

B. Antenna Design

Microstrip patch antenna (MPA) design is based on the above equations. Duroid (Roggers 5880) substrate and a graphene patch material are used. Table 1 shows the various parameter dimensions:

Table 1. Design Parameters wells

S/N	Parameters	Dimensions(mm)
1	Ground height	0.02
2	Patch height	0.02
3	Substrate height	1.57
4	Feed length	2.00
5	Patch length	7.73
6	Substrate length	17.15
7	Slot length	6.00
8	Feed width	5.58
9	Slot width	2.00
10	Patch width	0.84
11	Substrate width	2.28

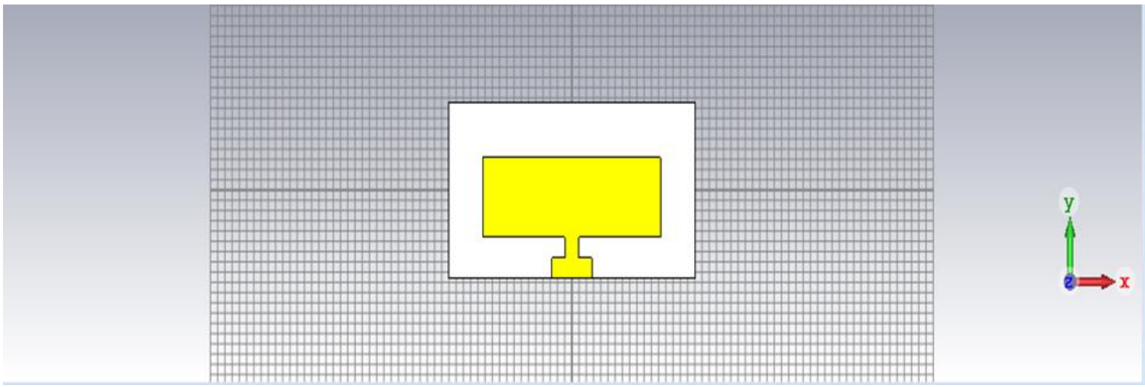

Figure 1. Front view in CST

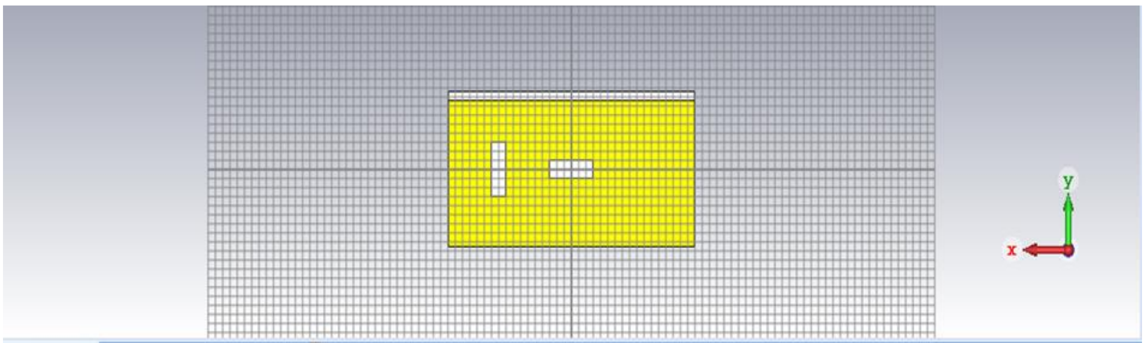

Figure 2. Back view in CST

3. Simulation Results

The microstrip patch antenna (MPA) was designed and simulated using CST microwave studio suite (2016) with its corresponding electrical and physical properties. The obtained values of the VSWR (Voltage Standing Wave Ratio), return loss (RL), gain, directivity and the radiation pattern of the patch antenna is tabulated in Figure 2 - 5. The patch antenna resonance frequency is 10.54 GHz and a return loss (RL) of -24.54 dB as shown below. The VSWR of the antenna happens to be 1.12 which is within the acceptable range. The proposed antenna achieved a high gain of 7.87 dB and a bandwidth of 1.09 GHz that spans between 10.076 GHz to 11.166 GHz. Table 2 summarizes the performance measure of the antenna and also a comparism with the corresponding copper-based antenna of the same parameters

Table 1. Summary of Results

S/N	Performance parameter	Graphene-Base	Copper-Base
1	Return Loss(dB)	-24.54	-24.55
2	Bandwidth(GHz)	1.09	1.07
3	VSWR	1.12	1.13
4	Gain(dB)	7.86	7.85
5	Directivity(dBi)	8.31	8.31

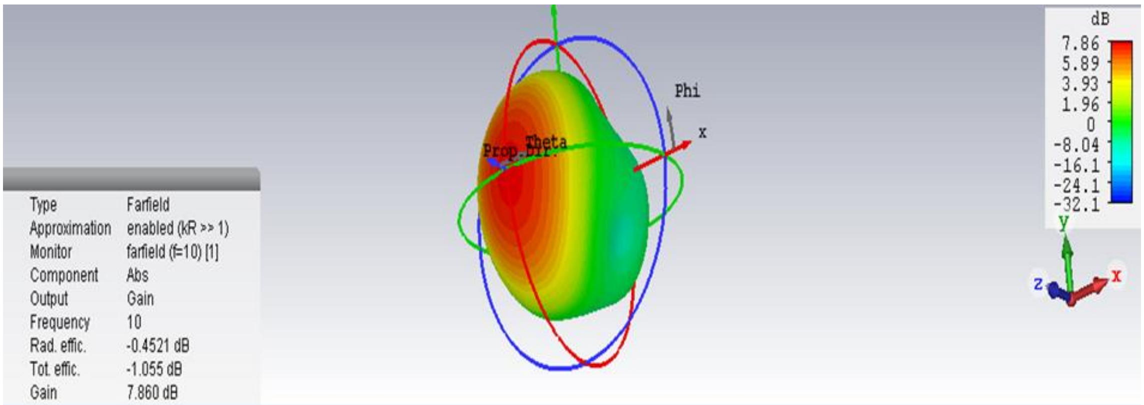

Figure 3. Gain result from CST

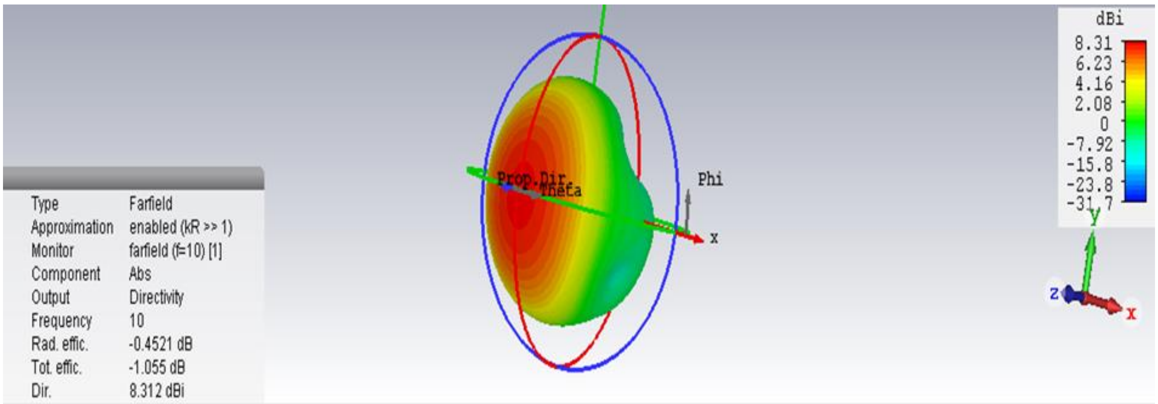

Figure 4. Directivity result from CST

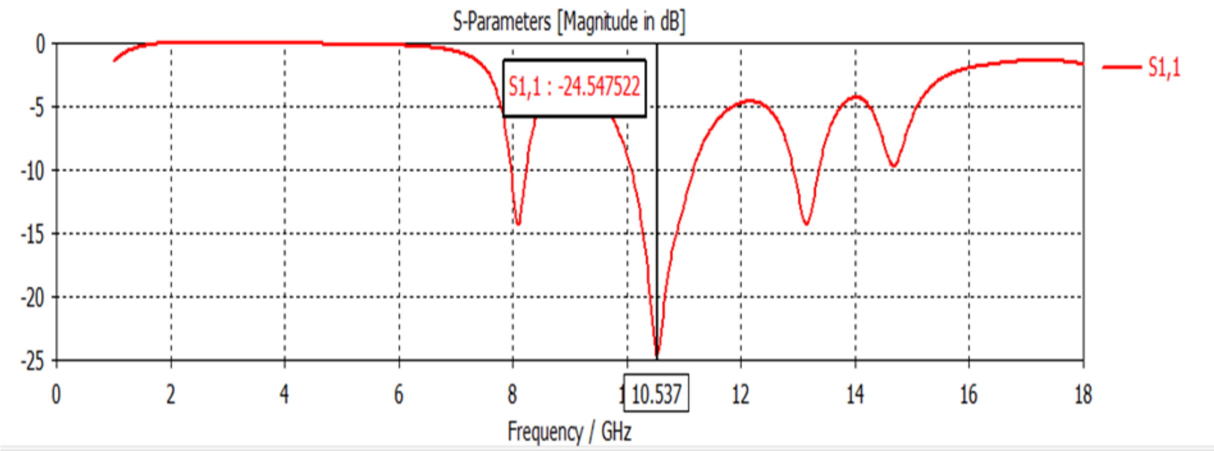

Figure 5. Return loss (RL) result from CST

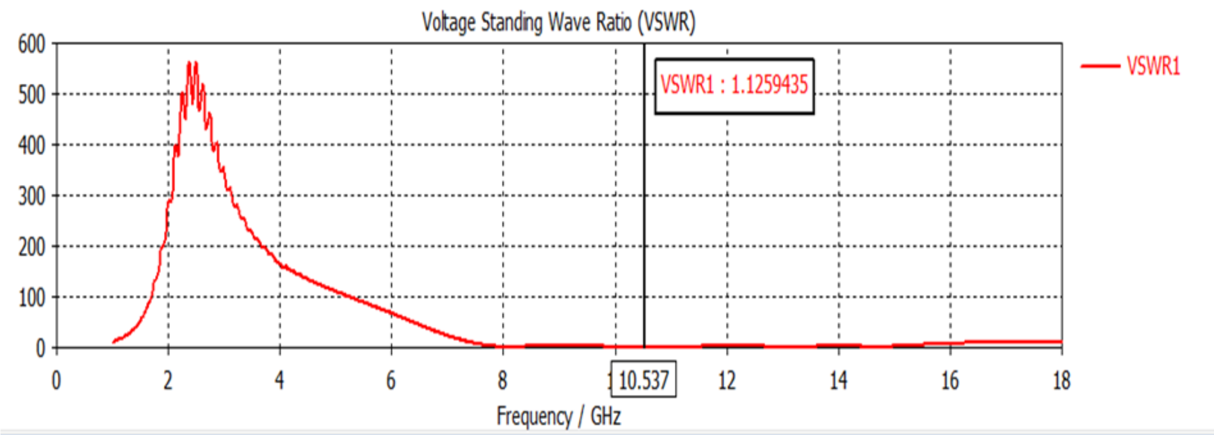

Figure 6. Voltage Standing wave Ratio (VSWR) result from CST

3. Results and Discussion

The use of graphene patch in a microstrip patch antenna as conducting material is assumed to have some exceptional potentials in enhancing the antenna bandwidth and radiation efficiency due to its outstanding electromagnetic properties and functionalities. It now starts becoming clear that graphene is a fascinating material from regarding to its electromagnetic shielding properties. Also looking to its high electrical conductivity, a graphene plane gives a good shielding efficiency against microwave radiation. When it is used as nanofiller, it results with distinct advantages in respect to other conventional nanofillers, with a credit its large surface area, flexibility, high aspect ratio and transparency, and in addition the optimal values of the elastic modulus. Moreover, its excellent thermal and electrical conductivity provide other significant value and advantage.

The proposed antenna with the graphene material shows good results in terms of bandwidth with huge increment that covers the X- band satellite applications. The distinctive frequency ranges works for air traffic control, military satellite, military and government institutions for weather monitoring, maritime vessel traffic control, radio-determination purposes, defense and tracking vehicle speed for law enforcement. Further work will be the fabrication of the simulated design to validate the results.

It can be practically observed from the S11 result that the antenna is a wideband antenna having multiple resonance; hence, it is suitable for multiband wireless applications in X-Band.

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