A Reconfigurable Multilayer Substrate Antenna for Aerospace Applications

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Summary
In this paper, we have simulated a rectangular microstrip patch antenna for aerospace applications based on graphen as a conductor and a multilayer substrate .as a result of the use of the graphen patch we obtained a reconfigurable antenna on the frequency range (0.6-0.7 terahertz) with a gain up to 12 db. The simulation of this antenna has been performed by using CST Microwave Studio, which is a commercially available finite integral based electromagnetic simulator.

Key words: *Reconfigurable antenna, graphene, Terahertz THz, multilayer substrate.*

1. Introduction

Recently, terahertz (THz) technology has been focused on astronomy applications. Over the past two decades, NASA has successfully designed and deployed scientific satellites equipped with THz instruments and sensors for astronomy applications [1, 2]. Recent research and development activities in THz technologies extend to different broader applications, such as security monitoring, medical imaging, sensors, and wireless communications [3-8]. The demand for data rates and wireless communication capacity for today's applications is unlimited. Thus, new spectrally efficient modulation and interference reduction technologies have been developed to enable the growth of data rates in recent years and to meet the future demand. To attain these high data rates, one feasible solution is to increase the available bandwidth, which is not possible below a frequency of 300 GHz, which is fully allocated.

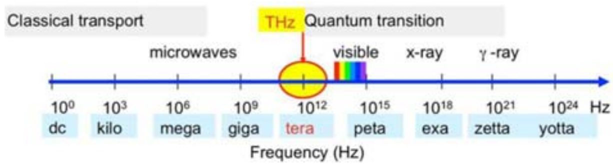

Fig 1. In the THz range of the frequency spectrum, multiple gigahertz channel bandwidths are possible.

This demand is met by utilizing a new frequency spectrum i.e., THz spectrum, frequencies ranging from 300 GHz to 3 THz (Fig 1), as it is unallocated [8]. With the development of technology and the needs of system-on-chip (SOC), the use of multilayer substrate has increased in this frequency range. The use of a multilayer substrate for microstrip transmission lines has many advantages, such as the ability to reduce losses and control the expansion coefficient. In addition, it is also an alternative solution to the circuit layout and the combination of the substrate and the semiconductor layer results in the slow-wave structure .The multilayer substrate is also used in antenna design where it has a good gain in surface wave immunity and improved bandwidth, in addition to good mechanical integration [9].In this paper, we have proposed rectangular microstrip patch antenna with a dielectric multilayer substrate at THz frequency for using higher speed wireless communication systems The design of this antenna is based on the principles of maximizing the current path for a given area using a multilayer substrate to reduce the radiation losses of surface waves to increase efficiency [10,13]. Surface waves can be reduced by short circuiting the poles due to the surface wave discontinuity used in triple dielectric layer structure. The organization of the paper is as follows. Section 2 concerns the microstrip THz antenna simulation model with copper and graphen patch. Section 3 discusses the validation results of the simulation and finally, Section 4 concludes the work.

2. Geometry of the antenna

A multilayered substrate material transmission line is shown in Fig 2. In this figure, a microstrip transmission line

Manuscript received September 5, 2021
Manuscript revised September 20, 2021
https://doi.org/10.22937/IJCSNS.2021.21.9.47

of length l, width w, and conductor thickness t is shown. However, each layer has different relative dielectric permittivity and substrate thickness h s as shown in the figure 2.

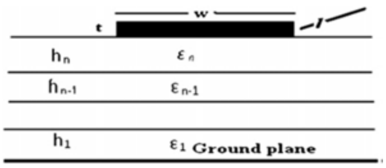

Fig2: microstrip multilayer antenna permittivity

The proposed microstrip patch antenna consists of a rectangular patch on multilayer dielectric substrate materials with three different dielectric permittivity and thickness. The geometrical configuration of the antenna is shown in Figure 2. The dimensions of the antenna ground plane and radiating panel are shown in figure [3]. [9, 10]

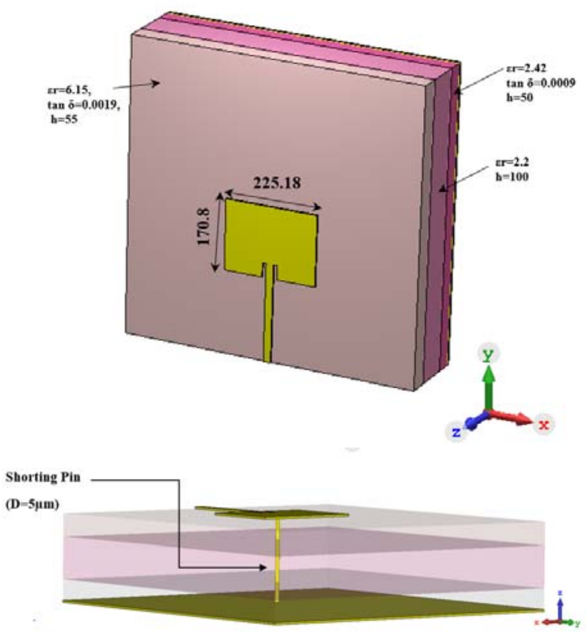

Fig 3 Geometrical configuration of the multilayer dielectric substrate single pin shorted microstrip line fed rectangular patch antenna

The first substrate layer on ground plane is 50 µm thick having an ε = 2.42 with tan ± = 0:0009. This layer is followed by 100µm thick substrate layer with an ε = 2.2 and last layer with 55 µm thick having ε = 6:15 with tan ± = 0:0019.The choice of dielectric permittivity and substrate size will determine the surface wave losses. A thicker intermediate substrate layer has been used to achieve a wide bandwidth. The purpose of taking a high dielectric constant for the upper layer is to decrease the radiation loss from the feed line and a thinner substrate material has been used to achieve maximum bandwidth. When the substrate with high relative permittivity is above the substrate with low relative permittivity, surface wave suppression occurs. [16, 17]. The microstrip line feed used in the proposed antenna. As this feeding technique increases the input impedance, it is commonly used for matching purposes. The advantages of this feeding technique is that a conductive strip is connected directly to the edge of the rectangular microstrip antenna and both the feed and the patch are on the surface of the substrate which gives a good impedance matching between the patch and the feed line. The simulation of the proposed rectangular microstrip patch antenna is performed on CST Microwave Studio simulator, which is finite integral based solver. For a three-layer antenna the effective dielectric permittivity of the multilayered substrate material is expressed as using the following:

$$\varepsilon = \frac{|D1| + |D2| + |D3|}{|D1/\varepsilon 1| + |D2/\varepsilon 2| + |D3 + \varepsilon 3|} \quad (1)$$

Where

$$D1 = \frac{K(k1)}{K\prime(k1)} \quad (2)$$

$$D2 = \frac{K(k2)}{K\prime(k2)} - \frac{K(k1)}{K\prime(k1)} \quad (3)$$

$$D3 = \frac{K(k3)}{K\prime(k3)} - \frac{K(k2)}{K\prime(k2)} - \frac{K(k1)}{K\prime(k1)} \quad (4)$$

And in general,

$$K_n = \frac{1}{\cosh\left(\frac{\pi w}{4(hn + h(n-1) + h(n-2) \ldots\ldots + h1}\right.} \quad (5)$$

$$\frac{k(kn)}{k\prime(kn)} = \frac{1}{\pi}\ln\left(2\,\frac{1+\sqrt{kn}}{1-\sqrt{kn}}\right) \quad (6)$$

Applying equations 2, 3,4,5,6 in 1

We found that our antenna is presented by the following parameters

Tab 1: OPTIMIZED DIMENSIONS OF THE PROPOSED ANTENNA

Design Parameters	**Dimensional Value (µm)**
Length of the patch (L)	170,80
Width of the patch *(w)*	225,18
Width of the feed(Wf)	20
Length of the ground and substrate	800
Width of the ground and substrate	800
Thickness of the patch (t)	5

3. Result and discussion

In Figure 4, we present the return loss characteristic of the microstrip patch antenna with the copper patch

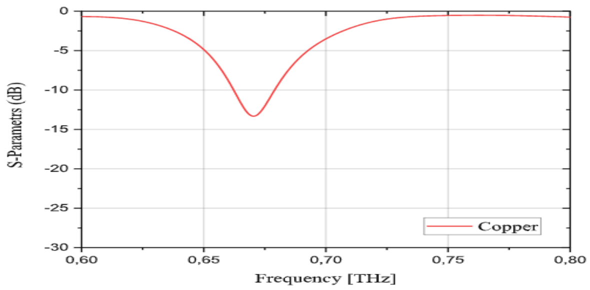

Figure 4. Return loss of the copper-microstrip patch antenna

As depicted in this figure, the use of copper as patch material as well as feed line material gives a frequency of resonance at 0.68 THz with a return loss of only −14 db. We replaced the copper patch by the graphen 0.345nm patch which is an intelligent material that have agile electromagnetic properties, the graphene is a 2D material. We have replaced the volumetric patch made of copper which presents a thickness equal to 5microns, by a planar patch with monoatomic thickness [18, 22]. As shown in Figure 5 the return loss $S11$ for different values of the chemical potential EF *which* Corresponds to different values of the external applied electric field. From this figure, we can see a reconfiguration in the frequency of the coefficient $S11$. The resonant frequency can be tuned continuously from 0.63 THz to 0.7 THz as Fermi level is shifted by the applied voltage gate

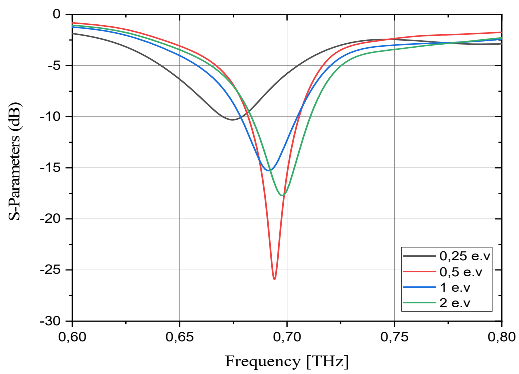

Fig5 Graphene-microstrip patch antenna return loss adjustment vs Fermi level value E_F.

For this value of E_F, the return loss peak reaches −26 dB which is almost twice the value obtained with the copper patch as represented in figure 6.Also the gain of the antenna shown in figure 7 is above 12 dB at the frequency of 700 Ghz . This antenna presents a strong gain thanks to the amplification of the current on the graphene patch induced by the very high mobility of the electrons in the grapheme.

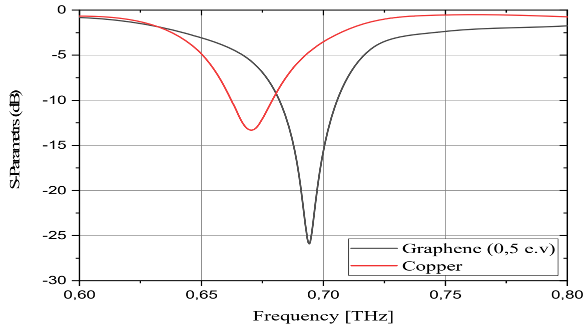

Fig 6. Comparison between the return loss of the copper and graphene microstrip patch antenna

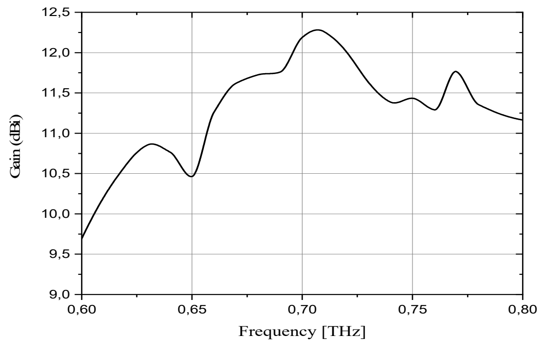

Fig 7: gain vs. frequency

In the table below we have shown a comparison between the performances of single-layer antenna [9] and the multi-layer antenna, presented in this paper, which clearly showed a significant gain increase in the same frequency band

Tab2: Comparison between monolayer and multilayer substrate antennas at 0.7 THZ with different patches

antenna structure	monolayer antenna(copper)	monolayer antenna (graphen) [9]	3 layer antenna (copper)	3 layer antenna (cgraphen)
gain (dB)	5.63	7.11	7.16	12.2
directivity (dB)	6.76	8.24	9.31	14.23

4. Conclusion

The comparison of the radiation properties of a patch antenna where the patch is made either of Copper or Graphene show that the surface conductivity of graphene allows a reconfiguration of the radiating Proprieties and the multilayer structure give the antenna a remarkable gain enhancement.

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