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Performance Analysis of Patch Antenna with Different Insulating Materials

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Abstract:

Rectangular Microstrip patch antenna with graphite material at nano regime has been designed using Ansoft HFSS 13.0. The paper emphasizes on the design of a microstrip antenna with rectangular patch for terahertz applications by simulation through the structural optimization according to the desired design specification like width (w) and length (l) and bandwidth of an antenna, relative permittivity ($\mathcal{E}_r$), and thickness of a substrate are considered for the calculation of patch dimensions. Substrates having the less di-electric constant were usually preferred for better performance hence few materials with less Ɛr are used as the substrate. The conducting element can take any shape because of less complexity to analyse; so rectangular configurations are most commonly used. The different materials are Graphite, Quartz, Silica, Silicon, Polyamide, Aluminium, Gold and FR4 Epoxy which were used in this project. The impedance bandwidth or return loss(S_{11}) and voltage standing wave ratio (VSWR) for the above mentioned materials were observed, analysed and it is proved that the design of the Microstrip antenna at nano scale is suitable for terahertz application. In this work, the comparison analysis for different substrate materials for a graphite based microstrip rectangular patch antenna has been done.

Keywords *Nano patch antenna, Ansoft HFSS 13.0, Terahertz, Substrate Materials, Return Loss, VSWR.*

1. Introduction

The band of electromagnetic spectrum which has its range extended from 0.1THz–10THz is generally considered as terahertz frequency band. This band has been named as 'Terahertz BandGap' by the researchers because of the fact that there is no availability of detectors, powerful sources and additional hardware. The recent development in the semiconductor technology has given the huge opportunity for this field to enhance its applications in science and technology [1]. Imaging and sensing applications, defense applications, earth and space sciences, medical sciences are the major areas of applications for this regime.

Penetration,Non-ionizing,Spectroscopy,Intensity, Scattering, Resolution are the unique radiation characteristics of this terahertz range which leads it to the broad areas of applications. Besides conventional applications, wireless communication system in terahertz regime is the new area of discussion. High data rate can be obtained by following two methods which are mentioned below. Initially with the increase in the communication systems bandwidth at the expense of system compatibility with narrow bandwidth and in majority of situations the bandwidth of device is only 10% of its operating frequency. Raise in the operating frequency is the alternative solution for the above mentioned problem such that a communication system even with narrow bandwidth can fetch a high data rate. In recent times, communication systems to meet the higher order data rates of the range 60GHz to 90GHz have been designed but still they found out to be insufficient in performance [2]. Shifting the operating to the terahertz regime is an ultimate key for the previously mentioned issue. It is feasible to use both the electronic and photonic methods to lay the way for terahertz range as it was sandwiched between the two explored regimes of the spectrum.

2. Importance of Antennas

For an efficient communication system, antennas play a major role . The generalized and standard definitions of an antenna are given as 'transitional structure between the guiding device and free space'. It can also be defined as 'a means for radiating and receiving radio frequency waves.'

All the antennas should obey the reciprocity theorem and maximum power transform theorem for matching the load and source impedance. Majority of the antennas are always considered as resonating devices which performs effectively for a narrow band of frequency. Whenever an antenna got excited with an electromagnetic signal, it will emit the radiation distribution in free space.

The few common terms which are strongly related to the antennas performance are Input Impedance; Return loss, Bandwidth, Beam width, Directivity, Gain, Radiation Pattern, Polarization [3].

3. Significance of Microstrip Antennas

Size ,weight, ease of installation, performance and cost are the major constraints in the high performance aircrafts and space craft's applications. Hence antennas with low profile are preferred . As microstrip antennas are low profile and conformable to both planar & non-planar surfaces, simple and inexpensive they are used to fulfill the requirements of the high performance

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applications [4]. The versatility in terms of resonating frequency, polarization, and impedance and radiation pattern are based on the selection of shape and mode of the patch.

A very thin metallic strip will be in the microstrip antenna regularly placed at minuscule ($h<<\lambda_0$, generally $0.003\lambda_0 \leq h \leq 0.05\lambda_0$) beyond the ground plane. The length of the element for the patch is mostly $\lambda 0/3 < L < \lambda 0/2$.

The substrate materials whose di-electric constants are in the range of $2.2 \leq \mathcal{E}r \leq 12$ are frequently preferred during the design procedure of the microstrip rectangular patch antenna. Substrate whose di-electric constants belongs to the lower end of the range are considered, because they provide better efficiency, larger bandwidth and ahead of this good antenna performance at the expense of larger element size. In order to minimize the undesired radiation and to lead a smaller element size for a microwave circuitry, thin substrates with high di-electric constants are desired, they are less efficient and have smaller bandwidth because of their losses.

Microstrip antennas are usually referred as patch antennas. Photo etching process is used to introduce the radiating elements and feed lines onto the di-electric substrate [5]. Even though any shape can be adapted to the patch, square and rectangular are the most commonly used shapes because of the ease in both the analysis and fabrication. Single elements or array of microstrip antennas can be used to achieve linear and circular polarization.

4. Design of Antenna in Nano Regime

The operating frequency and the substrate thickness and di-electric constants are the parameters which are to be considered initially in the design of microstrip patch antenna with rectangular patch [6].

In this work, seven different substrates namely quartz, silica, polyamide, silicon, aluminum, FR4 epoxy and gold with dielectric constants ($\mathcal{E}r$) of 3.78, 4, 4.3, 11.9, 1, 4, 4, 1 are chosen respectively. A substrate with 3µm height and a loss tangent of 0.001 is selected. Following are the procedural steps which use the transmission line model equations for the design of a patch at desired frequency of operation f_0 [7-8].

The following are the design equations using transmission line model.

$$f_r = \frac{1}{2L\sqrt{\in_{reff}\ \mu_o \in_0}} \quad (1)$$

$$Pw = W = \frac{\lambda_0}{2}\sqrt{\frac{2}{\in_r + 1}} \quad (2)$$

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad (3)$$

$$P_L = L = \frac{1}{2f_r\sqrt{\in_{reff}}\sqrt{\mu_0 \in_0}} - 2\Delta L \quad (4)$$

The Location of the feed of Microstrip rectangular patch antenna can be given as

$$X_{fl} = \frac{P_L}{2}(\varepsilon_{reff})^{1/2} \quad (5)$$

$$Y_{fl} = \frac{P_{fl}}{2} \quad (6)$$

The simulation process has been carried out by using ANSOFT High Frequency Structure Simulator software.

The dimensional parameters of the antenna are as follows:

Table 1. Dimensions of Graphite Based Terahertz rectangular microstrip antenna with rectangular patch.

Parameter	Value
Band of Frequency f_0	2.96 THz to 3.2 THz
Substrate dimensions W_s x L_s x h_s	104µm x 103µm x 3µm
Width and length of the square patch W_p x L_p	31µm x 23 µm
Width and length of a λ/4 transmission line W_1 x L_1	1.5µm x 14.5µm
Width and length of feed W_2 x L_2	5µm x 24µm
Height of the patch, feed and edge feed transmitter	4µm
Dimensions of Air box	103µm x 104µm x 55µm

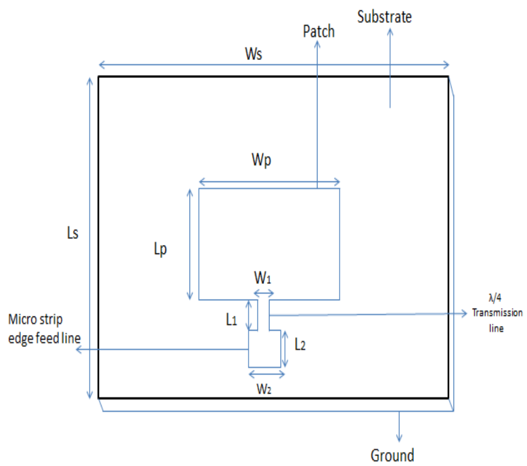

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Figure1. Graphite Based Rectangular Microstrip patch antenna.

The graphite scalar conductivity as a function of bias electric field essentially follows Drude-like behavior at sub millimeter and terahertz regime. One atom thick graphite can exhibit mobility of value as high as 20,000 cm2V-1S-1. The density of graphite at 293K is 2.26 g/cm3 [9-11]. The relative permittivity and permeability values of graphite are 1.The dielectric and magnetic loss tangent of graphite is zero[12-15].

5. Results And Discussions

By using HFSS (High Frequency Structure Simulator) software, simulation was carried out in order to analyze the graphite based terahertz microstrip nano rectangular patch antenna, for different substrate materials.The impedance bandwidth suggesting the impedance matching conditions for different substrate materials has been plotted and observed that S_{11} for each material reach their best values below -10dB at operating frequency.The better performance is however achieved for polyamide with impedance bandwidth reaching to the maximum value of -21.6498dB. The VSWR values satisfying the required conditions with values as 1.21, 1.29, 1.18, 1.18, 1.43, 1.23 & 1.44 for quartz, silica, polyamide, silicon, aluminum, FR4 epoxy and gold respectively at their resonating frequency.

The polyamide material has various advantages such as resilient, robust and low friction coefficient and highly resistant to temperature .

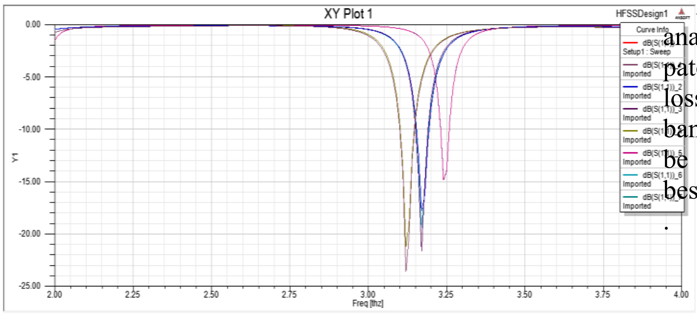

Figure 2. Return Loss in dB for various substrate materials.

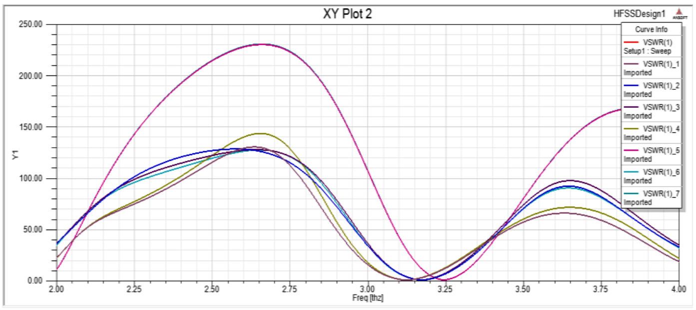

Figure 3. VSWR curves for various substrates materials.

6. Performance Analysis

The comparative analysis of radiation parameters for the designed antenna for various materials are tabulated as follows:

Table 2.Performance analysis in terms of S_{11} and SWR

Substrate Material	Dielectric Constant (ε_r)	Frequency	Return Loss S_{11}	SWR Value
Quartz	3.78	3.13THz	-20.1763	1.21
Silica	4	3.17THz	-17.8077	1.29
Polyamide	4.3	3.17THz	-21.6498	1.18
Silicon	11.9	3.12THz	-21.2411	1.19
Aluminum	1	3.24THz	-14.8795	1.43
FR4 Epoxy	4.4	3.17THz	-19.4289	1.23
Gold	1	3.24THz	-14.8214	1.44

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7. Conclusion

Here in this pursuit, an attempt has been made to analyse a graphite based Microstrip nano rectangular patch antenna. The antenna radiates at maximum return loss of -21.6498dB, VSWR value of 1.18 and sufficient bandwidth enhancement of 0.04THz.Accordingly it can be concluded that the polyamide as a substrate is the best selection while designing a graphite based antenna .

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