A New Designs of Microstrip Wi-Fi-shape Nanoantenna & Microstrip Wi-Fi-shape Slot Nanoantenna at THz region

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Abstract. The Evolution of Terahertz technology led to focus of Scientists and Researchers on this technology field. Terahertz region lies between optics frequency range and electronics, so THz frequencies are lowest frequencies make the free space conventional optics enable still be utilized before microwave components adopt. In this paper, CST studio suite 2018 simulator is utilized to simulate and design a new Microstrip Wi-Fi-shape Nanoantenna (MWNA) & Microstrip Wi-Fi-shape Slot Nanoantenna (MWSNA). Reflection coefficient (S11), Directivity, Gain and Bandwidth are computed. The results that achieved working at Terahertz frequencies in Nano size. The Bandwidth of MWNA design and the MWSNA design working in the range of (103.3 -110.3 THz) and (124.5 -127.8 THz) respectively. The Microstrip nanoantenna that utilized consist of three layers, Patch made from Gold, Substrate layer that utilized Silicon and Ground plane layer made from Gold. So the applications of these bands of THz frequencies work at visible region and near infrared (IR).

1. Introduction

The nanoantenna, is otherwise called the optical antenna. Optical antenna is like the traditional antenna, truth be told, it manages electromagnetic waves with the exception of that nanoantenna works in the optical frequency segment of the electromagnetic spectrum. Antenna measurements are comparable to the working wavelength so that to achieve resonance at optical frequencies, antennas must be shrinking to the nanoscale measurement. Nanoantenna can be defined as "a nanometer scale metallic structure that is capable of enhancing the optical radiation interaction with the matter" [1].

In 1959, Richard Feynman presented an imaginative paper with titled "There’s Plenty of Room at the Bottom". He discussed the problem of controlling materials on a nanoscale measurements. This paper proposed an inspired scientific idea added to open researcher's eyes on the nanotechnology a little decades later. He talked about the likelihood of building nanoscale electric circuits and he said "is it possible to emit light from nanoantenna array, like we emit radio waves from antenna array to beam the radio programs to Europe? Which is similar to beam the light out in a definite direction with high directivity" [1] [2].
The progress made by Feynman in nanofabrication techniques and nanotechnology studies produce Feynman's suggestion a fact and many nanoantennas for several applications have been fabricated [3] [4] [5] [6].

The general features of radio frequency and microwave counterparts are compatible with the optical antenna. On the other side, the analogies among conventional antennas and nanoantennas are limited in light of the fact that the physical properties that have materials and materials reaction to the optical frequencies are various from that at RF/microwave frequencies. For this referenced reason the design and the direct scaled-down interpretation of conventional antenna theory is impossible; thusly the new Nano scaled-down antenna theory should take consider the various phenomena at the optical frequencies [7].

The first concept of Nano optical was introduced by K. B. Crozier group in Stanford University indicating to the Nano photonic device which connects optical-frequency electromagnetic waves to sub-wavelength scale effectively by using surface Plasmon effects [8]. So, Nanoantennas are designed to discover the light in the visible part the infrared part, and farther, perhaps applied in Polari metric imaging systems, optical sensors, and for another application [9].

Newly Nanoantennas have received growing attention in nanotechnology research. This antenna can be used in many applications like microscopy, data-communication, spectroscopy, and even solar energy harvesting [10].

In this paper, we proposed a new design of Microstrip Wi-Fi-shape Nanoantenna (MWNA) & Microstrip Wi-Fi-shape Slot Nanoantenna (MWSNA). So the MWNA & MWSNA are composed from Patch antenna, Silicon material as dielectric Substrate and Ground plane. The Gold materials are used in ground plane and patch. We used gold material since it has high conductivity without changing the properties in THz region. In these two proposed designs the size of patch is proportional to the half wavelength from the size of substrate. So the result that achieved from the two design show good Directivity and Gain since we got a very suitable bands in both designs at THz region for visible region and near infrared (IR) applications.

2. Theory of Microstrip Nanoantenna

The idea of Microstrip antenna comes back to the start of the 1950 and it was presented by Deschamps, and for several years later Microstrip based antenna was presented by Gutton and Baissino, Despite the spread of the Microstrip concept, where there was little activity to develop in 15 years [11] [12] So, In the early of 1970, the development of Microstrip antenna began to increase with the need for thin antennas for spacecraft, conformal, and missiles [13].

Microstrip antenna have attracted in much consideration from engineers, researchers and designers what's more, have been utilized widely in RF and microwave systems, for example, biomedical systems, radar, communications, navigation, and remote sensing. Microstrip antennas can take a several of shapes, for example, dipole, patch, traveling-wave structure, or a slot, intended for specific applications [14].

2.1 Patch Antenna (first layer)

The first layer is called patch, Microstrip patch antennas are conceded one of a most fundamental and essential kinds of planar Antenna. Huge numbers of the ideas and methods utilized with Microstrip Patch Antennas can be connected straightforwardly to other planar antennas [14]. Microstrip patch antenna consider the simplest types of Microstrip Antenna which essentially composed of three layers that is shown in Figure 1. This layer is responsible about radiation. It is manufactured from a thin conducting material for example gold (Au) or copper (Cu) and is printed or etched on the second layer (medium) that is called the dielectric substrate.

The form of patch may take numerous geometrical shape, like square, rectangular, triangular, elliptical and circular or other various shapes [15].
2.2 Substrate (second layer)
The dielectric substrate conceder medium layer that is lie between the patch and the ground. So, to plan a minimized size of Microstrip, the dielectric substrate must be utilized with a high dielectric constant value yet this lets a reduced efficiency and narrow bandwidth. Hence, a tradeoff must be made between the size of the antennas and its performance. One of the consideration that is effect on the substrate material is the dielectric constant on the radiation characteristics. A high dielectric constant resulting a low radiation from a Microstrip patch antenna [11] [15] [16].

2.3 Ground (third layer)
This layer classified as last layer (third) of Microstrip antenna. So, this layer consider corresponding side of the substrate with a conducting material that is called ground plane that is represent the third layer [15].

![Figure 1. Basic structure of Microstrip][11].

3. Nanoantenna Design Configuration
In this section, we illustrate the Microstrip Nanoantenna layers, dimensions, usage material, figures and relationship. So in the new presented designs of Nanoantenna which is called Microstrip Wi-Fi-shape Nanoantenna (MWNA) & Microstrip Wi-Fi-shape Slot Nanoantenna (MWSNA) as shown in Figure 2 and Figure 3 respectively. The above Microstrip Nanoantennas are composed from three layer: Patch, Substrate and Ground. The gold metal used in both patch Nanoantenna and patch slot Nanoantenna. The dimensions of MWNA patch are four circle with (R1=125, R2=275, R3=425, R4=575) nm, the distance between the circle is 150 nm with thickness (t) 20 nm.

The substrate layer dimensions are 900, 900 nm W, L respectively. The dielectric material that is used in substrate is Silicon with thickness (h) 50 nm. We used the silicon because it has high dielectric constant εr=11.9. The ground layer dimensions are 900*900 nm² meanwhile the thickness (t) is 20 nm. Gold metal is used in the design of ground layer.

Moreover, to get a good solution for both reflection coefficient $S_{11}$ and far-field must utilized a waveguide excitation port. The all parameters of MWNA & MWSNA as shown in Table 1.
Table 1, Nanoantenna Dimensions.

| Parameters          | Values (nm) |
|---------------------|-------------|
| First Patch circle R1 | 125         |
| Second Patch circle R2 | 275         |
| Third Patch circle R3 | 425         |
| Fourth Patch circle R4 | 575         |
| Ground width, Wg     | 900         |
| Ground length, Lg    | 900         |
| Thickness of Ground t | 20          |
| Thickness of patch t  | 20          |
| width of substrate W | 900         |
| length of substrate L | 900         |
| Substrate Thickness h | 50          |

Figure 2, overall view of MWNA.
Through the equations that is found in Balanis [17] the length and width of the Microstrip, we can calculate the width and length in both relationship (2-1) and (2-2) with little manipulated the extracted values to the new design.

Actual length $L$:

$$L = \frac{1}{2f_r\sqrt{\frac{\mu_0}{\varepsilon_0} \sqrt{\varepsilon_{reff}}}} \quad \text{(2-2)}$$

$\varepsilon_{reff}$: Effective dielectric constant.

Actual width $W$:

$$W = \frac{v_o}{2f_r \sqrt{\varepsilon_r + 1}} \quad \text{(2-1)}$$

$v_o$: free space velocity of light.

$f_r$: resonant frequency.

$\varepsilon_r$: dielectric constant.

4. Performance Analysis and Result

The two designs are performed using CST Studio Suite 2018 simulator in Time Domain method. So, in the Figures 4 and 5 shows that the $S_{11}$ reflection coefficient of MWNA & MWSNA. So, the $S_{11}$ reflection coefficient is -31.3 dB at 106 THz in MWNA, while the $S_{11}$ reflection coefficient for the MWSNA is -18.2 dB at 126 THz. The Gain of the MWNA & MWSNA are 6.2 dB and 6.57 dB respectively. The Gain as shown in Figure 6 and 7 which shows that a high acceptable values with comparing to the Directivity.
Figure 4, show Reflection coefficient $S_{11}$ of MWNA.

Figure 5, show Reflection coefficient $S_{11}$ of MWSNA.

Figure 6, Gain of MWNA.

Figure 7, Gain of MWSNA.

The evaluation performance of MWNA & MWSNA shows that a good results for the directivity, where directivity considering a very important parameter since it proportional between the gain and the efficiency. Figures 8 and 9 have shown the directivity of MWNA & MWSNA respectively. In additional the value of directivity at 126 THz is 7.24 dB and at 106 THz is 6.3 dB.
We can calculate the Bandwidth range in MWNA & MWSNA from the reflection coefficient $S_{11}$ with proportional to the -10 dB, as shown in Figures 10 and 11. Where the range of bandwidth started from 103.3 to 110.3 THz for MWNA, while the range of bandwidth started from 124.5 to 127.8 THz for MWSNA.
Finally we compared all the parameters calculated above for both MWNA & MWSNA as shown in Table 2.

### Table 2. Comparison between MWNA & MWSNA.

| Parameters       | MWNA      | MWSNA    |
|------------------|-----------|----------|
| Resonant Frequency | 106 THz  | 126 THz  |
| Bandwidth        | 7 THz     | 3.37 THz |
| Reflection coefficient | -31.3 dB | -18.2 dB |
| Gain             | 6.2 dB    | 6.57 dB  |
| Directivity      | 6.3 dB    | 7.24 dB  |

Now, to validate our works with other references we makes a comparison between the results that gets from two types proposed designs and the results of references, as shown in table 3.

### Table 3. Comparison between MWNA, MWSNA and references.

| Name | Sub. type | S_{11} dB | F THz | G dB | D dB | Eff. % | BW THz |
|------|-----------|-----------|-------|------|------|--------|--------|
| [18] | Glass     | -16       | 31.5  | 5.73 | --   | --     | 4      |
| [19] | Silicon   | -46.4     | 8.6   | 2.03 | --   | --     | 2      |
|      | $\varepsilon=11.9$ |           |       |      |      |        |        |
| MWNA | Silicon   | -31.3     | 106   | 6.2  | 6.3  | 98.4   | 7      |
|      | $\varepsilon=11.9$ |           |       |      |      |        |        |
| MWSNA| Silicon   | -18.2     | 126   | 6.57 | 7.24 | 90.7   | 3.37   |
|      | $\varepsilon=11.9$ |           |       |      |      |        |        |

5. **Conclusion**

A novel designs working at visible region and near infrared (IR) is proposed and analyzed in this paper as mentioned above, the first new design called MWNA and the second called MWSNA has been framed and simulated utilizing CST Studio Suite 2018 simulator. There are a different frequencies got from MWNA & MWSNA, MWNA resonant at 106 THz with reflection coefficient -31.3 dB and the MWSNA resonant at 126 THz with reflection coefficient -18.2 dB. The first band of the MWNA covers a range from (103.3-110.3) THz, while the second band covers a range from (124.5-127.8) THz, So where the first band has a wide ratio bandwidth. The Waveguide port is utilized in the two designs above since it consider simple types of feeding technique, so the first band operate at near infrared (IR) while the second band operate at visible region.
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