ROUNDED BOWTIE NANOANTENNA FOR SOLAR ENERGY HARVESTER

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ABSTRACT

This paper presents a novel design of a rounded Bowtie antenna. The proposed antenna is simulated in the wavelength of 10µm which have the highest rating of long-wave radiation intensity of terahertz radiation from solar rays emitted. The aim of this work is to study the effect of width of the antenna and material of conductor used on the return loss of the antenna. The antenna designed achieves resonant frequency of 8.685THz with the return loss of more than 30dB.

Keywords: solar antenna, terahertz radiation, return loss.

Introduction

Nowadays, the electricity demands are getting increase due to the rise of the electricity usage. Large production of the power generation by exploiting fossil fuel tends to increment of greenhouse gases emission. According to reference[1] & [2], the maximum electricity demand of Malaysia in the year 2015 is approximately 16,500MW for 30,388,887 Malaysia people which can be seen in FIGURE 1. Hence, renewable energy is considered as an alternative way to cope the electric power shortages and has good potential to be a substitute since the gradually depletion of fossil fuel. It also is a free and inexhaustible energy resource which high possibility to the reduction of the greenhouse gases emission and protect humanity's live against the rising of global warming. Malaysia is located nearly to the equator and the average solar irradiance is emitted 1643kWh/m^2 per year due to abundant sunshine [3]. It is one of the renewable energy used and main contribution to the electricity generation which is 187.17MW, followed by biomass (114.93MW), mini hydro (29.88MW) and biogas (29.25MW) in the second quarter of the year 2015 [1].

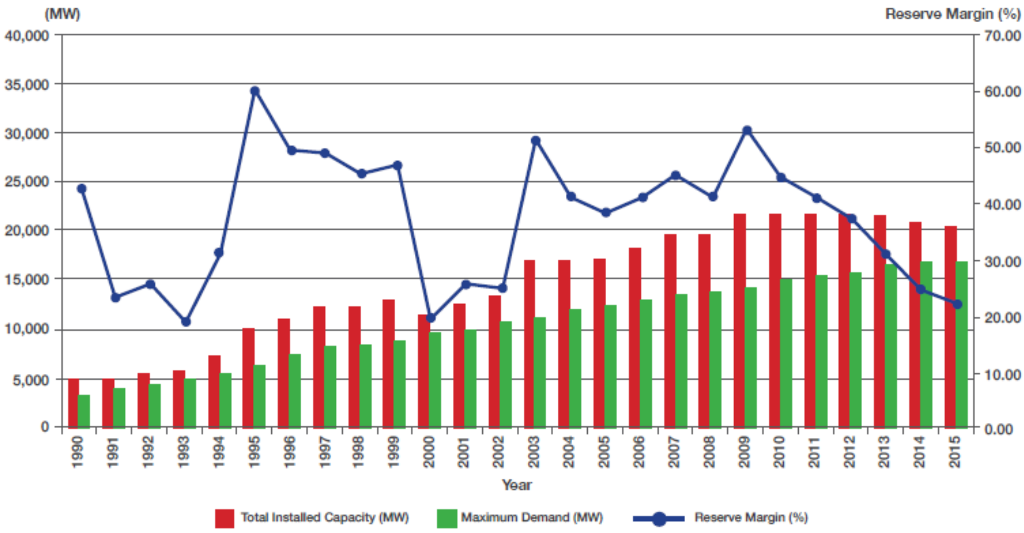

figure 1: peninsular malaysia reserve margin [1]

Solar antenna has been a hot topic in green technologies to preserve environmental integrity from diffuse pollution. Robert L. Bailey was a founder who proposed the idea of solar antenna in 1972 [5]. Solar antenna is used to collect electromagnetic energy of specific wavelengths either from the Sun emits or re-radiated from the Earth and convert it to electrical energy. Nevertheless, its size is proportional to wavelength. Terahertz frequency regime is most promising region in the electromagnetic spectrum and getting attractive to scientists recently. It is also widely used in many applications such as wireless communication, astronomy, medical imaging, detecting explosive and sensing hidden objects [6-9]. This time, the designed solar antenna will be focused more on specific wavelength or unused part of solar spectrum such as incident and re-radiated part of solar radiation from the earth surface, mostly is infrared (IR) wavelength in the range of 4μm to 25μm and also known as long-wave radiation [4]. Among that range, 10μm wavelength is picked as the highest energy in the radiation intensity ($Wm^2/\mu m$) [4].

Terahertz radiation in electromagnetic spectrum is classified as non-ionizing and no health hazard to humanity in the condition of low dosages and without long-term exposure. The designed antenna consists of a conducting round-shaped Bowtie patch and a dielectric medium which known as substrate having a particular value of dielectric constant. Dimension of conducting patch is fine-tuned based on desired resonant frequency. The gap in between two pieces of conductors is supposed to accumulate heat energy and transform to electrical energy.

DESIGN OF THE ANTENNA

The basic configuration of the antenna can be calculated such as [10]:

$$f = \frac{v_p}{\lambda} \quad (1)$$

$$v_p = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{1}{\sqrt{(\varepsilon_o\varepsilon_r)\cdot(\mu_o\mu_r)}} \quad (2)$$

where ε is material dependent permittivity, ε_o is absolute permittivity of free space, ε_r is relative permittivity of material, μ_o is absolute permeability of free space, μ is material dependent permeability, v_p is phase velocity of a transverse electromagnetic mode (TEM) wave, f is operating frequency, λ is operating wavelength.

Substitute equation (2) into equation (1)

$$f = \frac{1 \Big/ \sqrt{(\varepsilon_o\varepsilon_r)(\mu_o\mu_r)}}{\lambda} \quad (3)$$

From the equation (3) above, we are able to obtain approximately value. Antenna arm length is calculated by using [11]:

$$L_P = \frac{\lambda}{2} \quad (4)$$

$$L_1 + L_2 = L_p \quad (5)$$

where L_P is arm length of an antenna and the total arm length of L_1 and L_2. Gain of an antenna can be expressed as [11]:

$$G = e_r \cdot D \quad (6)$$

where D is directivity of an antenna which the ratio of the radiation intensity of the antenna in a given direction to the radiation intensity coming from all the directions. e_r is radiation efficiency of an antenna.

ANTENNA GEOMETRY

Figure 2 shows the geometry of the proposed antenna. The antenna is placed in x-y plane and the normal direction is z-axis. The proposed antenna is placed on a piece of lossy-free silicon substrate with a dimension of 15μm x 15μm. Its thickness is 0.645μm and dielectric constant is 11.9. The upper part of the substrate consists of two-sided arms of printed round-shaped conductor with L1=1.0μm, L2=1.5μm, G1=3.05μm and W1=1.9μm and simulated with different materials such as gold, copper, aluminium and silver. L1 and L2 are lumped sum together to be 2.5μm because it is the nearest to the resonance frequency of 8.65THz and others are away from the resonance frequency.

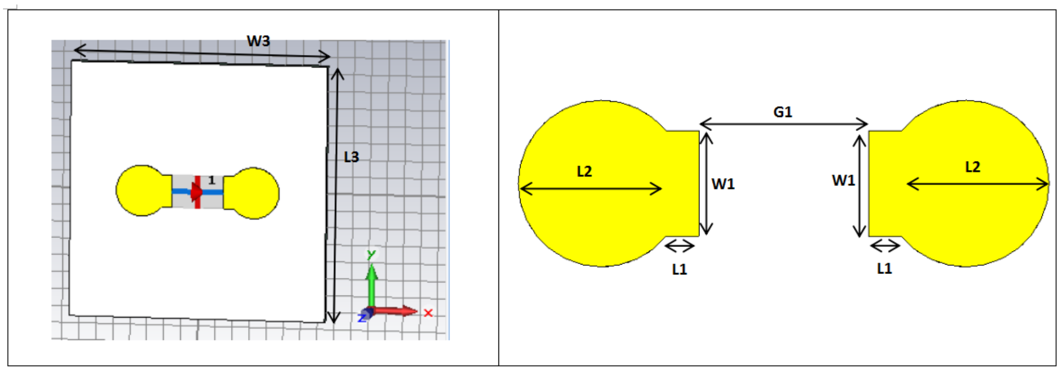

figure 2: geometry of a round-shaped bowtie antenna

RESULTS AND DISCUSSION

A rounded Bowtie nanoantenna is simulated with CST high frequency simulation software and is operating at 8.685THz. It is used as solar energy harvester to absorb specific wavelength of sunlight ray and convert to electrical energy. The return loss at the resonant frequency is -46.46dB in Figure 3 when the parameters are shown in Table 1.

table 1: the parameters of the rounded bowtie nanoantenna

Parameters	Length or Width, μm
L1	1.0
L2	1.5
G1	3.05
W1	1.90

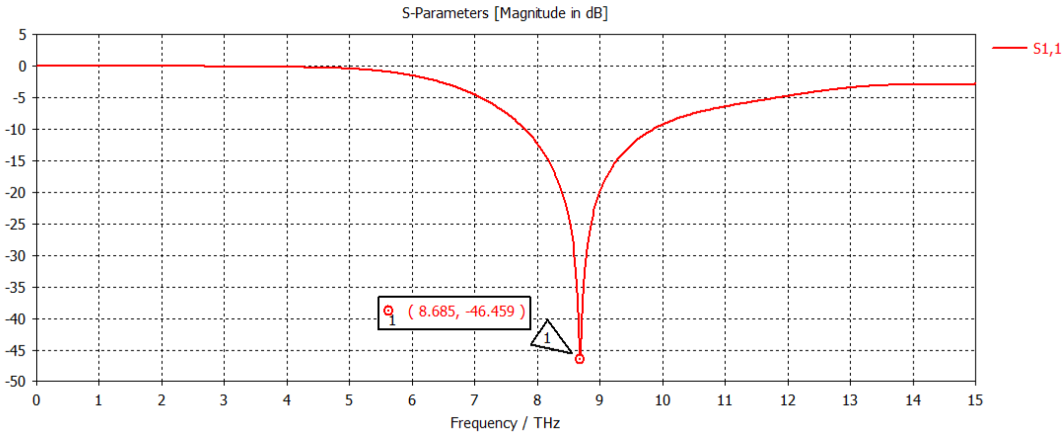

figure 3: the return loss of the operating frequency 8.685thz.

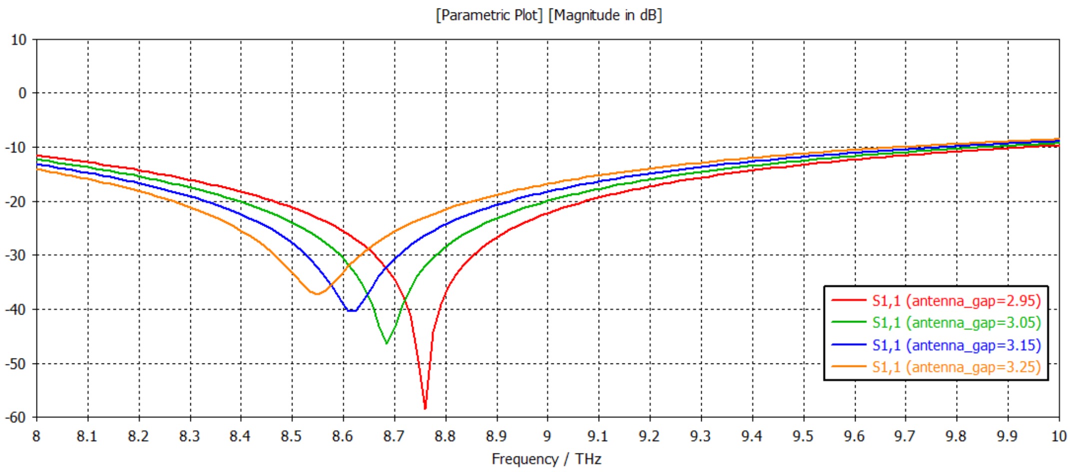

figure 4: return losses for different width of antenna gap.

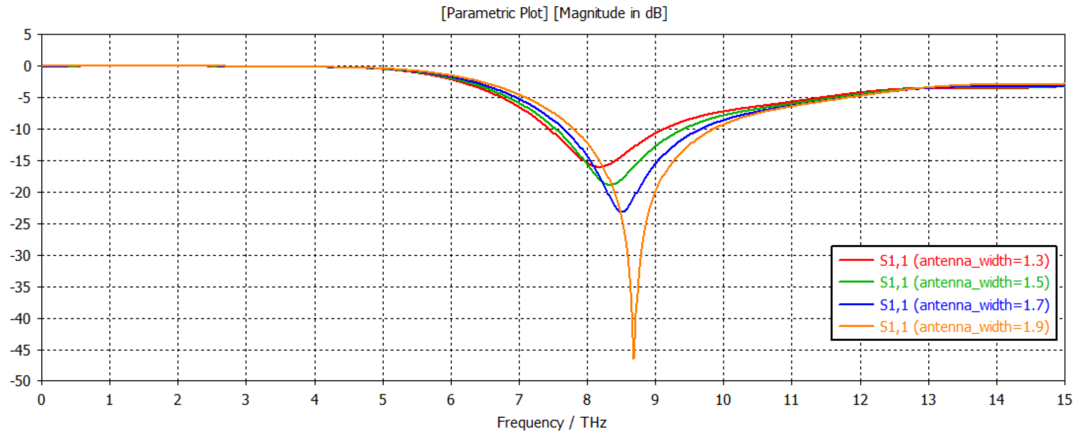

figure 5: return losses for different width of the antenna.

The designed antenna is tested for various width of the antenna and antenna gap, W1 of 1.5µm, 1.7µm, 1.9µm and 2.1µm and G1 of 2.95µm, 3.05µm, 3.15µm and 3.25µm, respectively. From the Figure 4 and 5 above shown that when both of the parameters increase, the return loss of the antenna is reduced and the resonance is away from the resonance frequency of 8.65THz. Figure 6 clearly states that the simulated Voltage Standing Wave Ratio (VWSR) of the antenna is less than 2.0 for the entire frequency range of 7.76THz to 9.90THz. The VWSR is 1.0096 for the resonant frequency of 8.685THz.

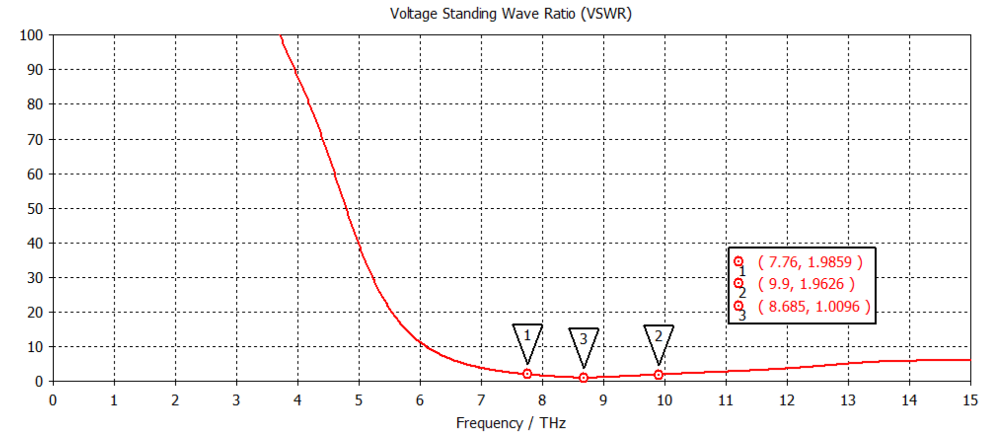

figure 6: vwsr of the resonant frequency 8.685thz.

The input impedance is (49.83-j0.55)Ω is depicted in the Figure 7. the total efficiency and gain of the antenna are 99.33% and 2.03dB in FIGURE 8, respectively. The figure 9 and 10 show the radiation pattern of the antenna. The red line of the electric field lies in the E-plane represents theta=0° while the green line is theta=90° in FIGURE 9 and same goes to magnetic field in H-plane at Figure 10. The patterns in these planes are referred to as the E-plane and H-plane patterns respectively.

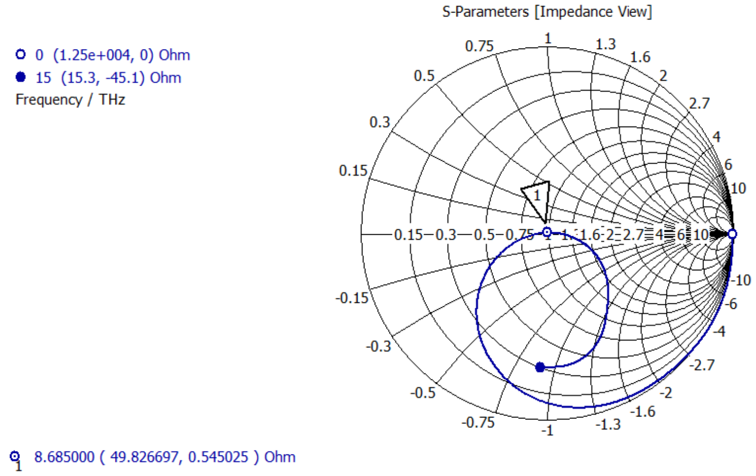

figure 7: input impedance of the antenna

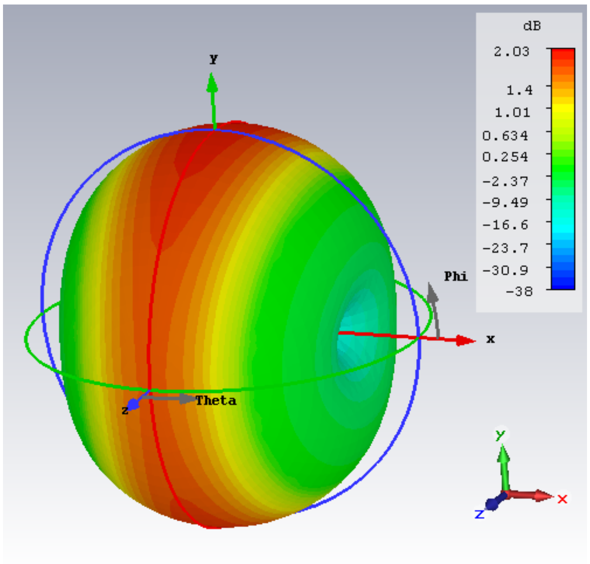

figure 8: gain of the antenna

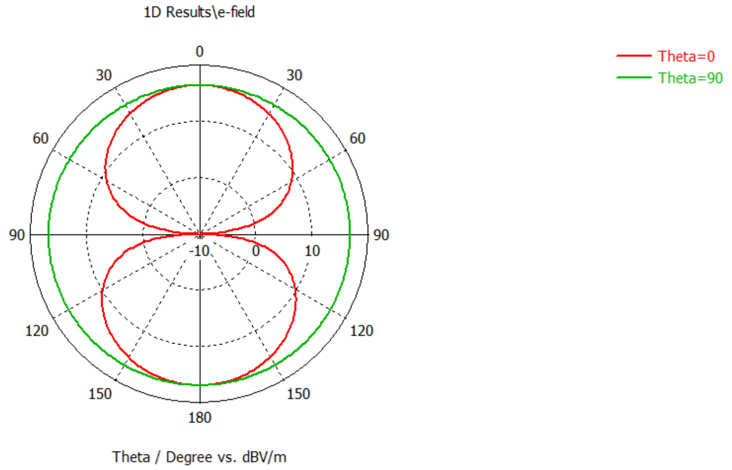

figure 9: e-plane radiation pattern at theta=0° and theta=90°.

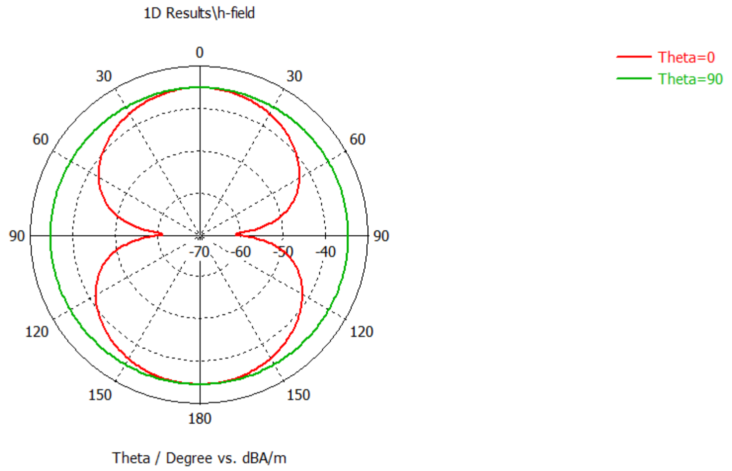

figure 10: h-plane radiation pattern at theta=0° and theta=90°.

Besides that, materials used in the conductor of the antenna such as gold, copper aluminium and silver and those materials resonant with different return loss. The highest return loss is -47.67dB for aluminium material, followed by gold (-46.46dB), copper (-44.84dB) and silver (-44.30dB) which are shown in FIGURE 11.

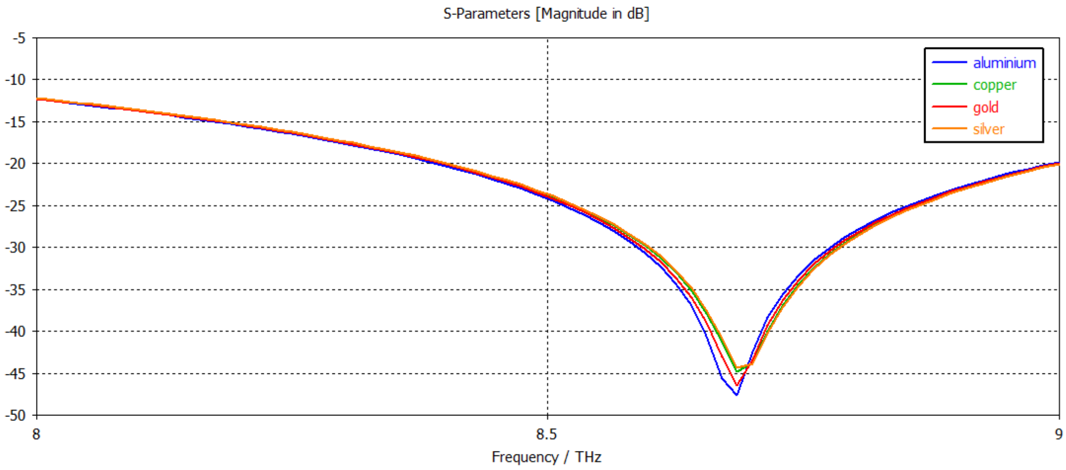

figure 11: different materials of conductor used.

CONCLUSION

A round-shaped Bowtie antenna is proposed for solar antenna at 8.685THz. The antenna has low profile, low weight, high return loss and stable VWSR. The effect of the width of the antenna and material used in the antenna conductor are observed.

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