Miniaturized UWB Elliptical Patch Antenna for Skin Cancer Diagnosis Imaging

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Abstract— The biomedical imaging shows promising results in many applications such as protein characterization and cancer detection using non-ionizing radiation. Skin cancer is one of the most common types of cancer because it is exposed by sun rays during the day. Many techniques have been offered to detect the tumor in the early stage such as ultrasonic and MW imaging. However, most of these studies showed a large printing area with lower BW so as the low resolution. To overcome these drawbacks, a new low profile UWB elliptical patch antenna with high performance is designed on PTFE as a substrate. Then a layer of Indium Tin Oxide (ITO) applies to improve the antenna radiation characteristics. The proposed antenna has a broad BW from 3.9 GHz to 30 GHz along with a resonance at 2.4 GHz. Furthermore, the antenna presents a maximum gain of 7.3 dB, maximum directivity of 7.78 dBi, the maximum radiation efficiency of 92%, and consistent, stable radiation pattern throughout the frequency band. Besides, the time-domain characteristics show that the antenna can be a suitable candidate for microwave imaging of skin cancer.

Keywords: UWB, Indium Tin Oxide (ITO)

I. INTRODUCTION

Microwave technology developed fast in both biomedical imaging and satellite communications with promising potentials. For example, they were used in quality control, protein characterization, pharmaceutical, cancer detection using non-ionizing radiation, and satellite communications integrated with solar cells. Skin cancer is one of the most general kinds of cancer among all types of cancer throughout the world. It is because the human body is exposed to sunlight during the day a lot. Thus, the chance for the human body to get affected by the sunlight and its destructive rays is high, and the cancerous cell formation increases since the skins are getting affected by the UV.

The UV could harm the skin cells when the body exposed for an extended period during the day. Many imaging systems and devices were applied for vast applications that are listed such as localization, finding concealed threats like weapons in airport, security and surveillance, and medical imaging. One of the exciting applications used ultra-wideband technology for biomedical imaging, notably to differentiate between unhealthy and healthy tissue such as cancer detection in skin and chest.

MW imaging used to differentiate the material with different dielectric properties. For instance, they employed to detect the differentiation between the dielectric properties of healthy and unhealthy tissues to detect cancerous cells in the skin. Usually, our skin has three layers known as epidermis, dermis, and the external one, and their thickness varies between 0.1 and 0.5 mm, the outermost layer is called the epidermis. The epidermis owns an external part which is Stratum Corneum (SC) with varying thickness of 15 and 150 µm.

Skin cancer is an uncontrolled growth of abnormal skin cells. The UWB technology shows promising outcomes since it can give a wide BW with lower power. Ultra-wideband (UWB) technology used for biomedical imaging, notably to differentiate between unhealthy and healthy tissue such as cancer detection in skin and chest. Skin cancer imaging in a different range of frequencies like MW, millimeter waves (mm-wave), and Terahertz (THz) waves for various parts of the body such as skin and breast.

II. RESEARCH METHOD

The elliptical patch is considered as the most common and the simplest shape of microstrip patch antenna applied for UWB applications which help in having a high percentage of fractional BW (FBW). The proposed antenna comprises a vertical elliptical patch as shown in Figure 1, a truncated ground, stubs, shorting pins for loading, and square shape EBG structure. A conventional elliptical patch is designed at the center frequency of 15 GHz initially using the transmission line (TL) method and the equations presented in to get the total dimensions of the substrate and the patch. The patch is a vertical elliptical microstrip patch antenna with specifications of semi-major axis b and semi-minor axis a, the foci are at $x=\pm c$ and c determine the foci of the elliptical patch. The antenna is designed on three substrate layers a Roggers 5880 (εr=2.2, h=0.787 mm), a PTFE layer (εr=2.55, h=2.5 mm) as a cover, and layer of ITO ITO (h=0.1 µm) in between. After investigating the results from the conventional antenna, the antenna performances should be improved as well as having resonance at lower bands while not to increase the antenna dimensions. Hence, to enhance the BW and reduce the stopbands level in reflection coefficient result which might occur due to the size reduction and changing the materials, the GND is truncated to the length of almost $\lambda/8$ as shown in Figure 1. Afterward, to transfer the working BW to the lower band and keep the size unchanged at the same time the antenna is loaded with a stub connected to the junction of the feed line and the patch . The total length of this stub is designed based on the frequency and the wavelength at 2.4 GHz. Adding this stub to the antenna benefits us to resonate at a free licensed band as ISM. Unfortunately, the radiation efficiency is decreased due to the surface wave and the coupling when this stub is added. Hence, a technique should be applied to suppress these surface waves and compensate for this decrement. As aforementioned, the stub length should be related to the resonance at the lower band that it is desired to resonate at 2.4 GHz. Figure shows the current distribution around the stub to prove the resonance at 2.4 GHz. Apart from the surface wave and negative coupling, some stopbands occurred in BW after connecting this stub. These stopbands are removed by applying the Electronic Band Gap (EBG) structure as shown in following Figure.

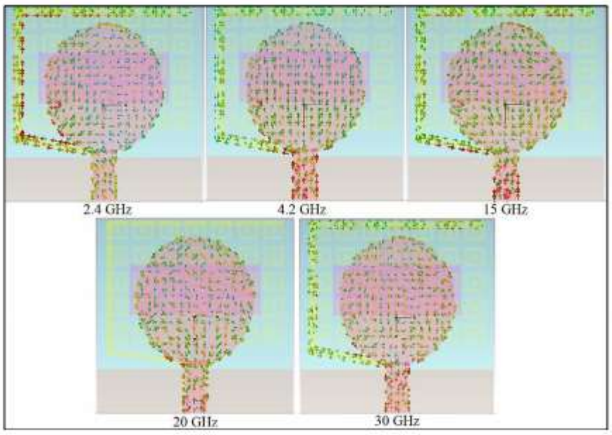

Fig. 1: The surface current distribution

III. LITERATURE REVIEW

A. Miniaturized UWB Log-Periodic Square Fractal Antenna

The authors Amrollah Amini, HomayoonOraizi, Mohammad Amin Chaychizadeh proposed a log-periodic square fractal geometry is presented for the design of a miniaturized patch antenna for the ultrawideband (UWB) services (3.1-10.6 GHz).

A miniaturization factor of 23% is achieved with a constant and stable gain in the desired band. The radiation pattern is broadside, which finds suitable applications in the UWB radars and medical imaging.

B. A Miniaturized Elliptical patch Antenna with Modified Feeding Structure for UWB applications

The researchers A.Madannezhad, H.Ameri*,S. Sadeghi proposed a a miniaturized Elliptical Patch antenna for ultrawideband (UWB) applications is proposed. The antenna is designed to operate in the entire UWB spectrum from 3.1 to 10.6 GHz. A new modified feeding structure is employed to miniaturize the Elliptical patch antenna.

IV. RESULT AND ANALYSIS

After applying the TL method, the obtained antenna dimensions for a typical rectangular patch antenna based on the lowest resonance (2.4 GHz) should be around 125×125 mm2 . Furthermore, the monopole antenna for the length of λ, $\lambda/2$, and $\lambda/4$ are 125 mm, 62.5 mm, and 31.25 mm, respectively (to show the dimensions of monopole antenna based on the wavelength).

The final dimensions and values for each parameter in Figure 1. is presented in Table 1. Each parameter is optimized to get the best result of the radiation characteristics of the antenna. However, the total dimensions of the antenna are less than $\lambda/4$, but good stability is achieved due to applying EBG and proper loading of the antenna. Another technique that used here to improve the antenna performances is adding a layer of ITO between the antenna and the cover layer of PTFE.

Table 1. Proposed Antenna Final Dimensions

Param (mm)	value	Param (mm)	value	Param (mm)	value
L_s	15	L_4	1.6	a	4.5
L_1	5	L_5	1.5	b	5
L_2	10.25	L_f	3.8	W_s	15

Following figure 1 shows the simulation and measurement setup of the array antennas. In simulation and measurement, all the antennas are sending and receiving UWB signals. Each antenna array is located on a layer of skin, muscle and bone with the thickness of 2 mm, 6.5 mm and 13.5 mm, respectively. For more explanation, Figures 8 and 9 present the simulated reflection coefficient and transmission coefficient results of the proposed antenna when they are located on the skin, muscle, and bone. It illustrates that the antenna's reflection coefficient results in the skin are not altered a lot in comparison with the result in the air except a stopband produced after 20 GHz to 24 GHz. Besides, the lower end of the UWB antenna is shifted to a higher band slightly. The alteration between the results in air and skin is because of higher permittivity and the physical structure of the skin, muscle, and bone as compared to free space.

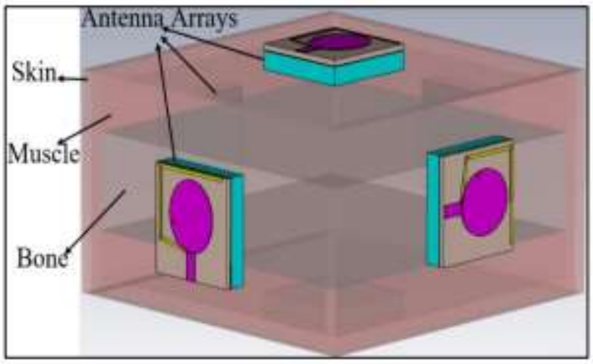

Fig. 2: Simulation setup of the array antennas

Figure 2 illustrates the reflection coefficient result of the antenna for each step of the design. The results presented in Figure 3 shows that when the antenna has its conventional structure, several stopbands occurred in the BW. Then, the truncated GND and the cover layer are added to the antenna to make passband, especially at the lower than 20 GHz. Afterward, the ITO layer is added to shift the frequency to the lower band, increase the radiation efficiency, and the impedance BW of the antenna (the gap between the EBG rectangular structures, the shorting pins, and the stub should be adjusted appropriately not to enhance the unwanted coupling).

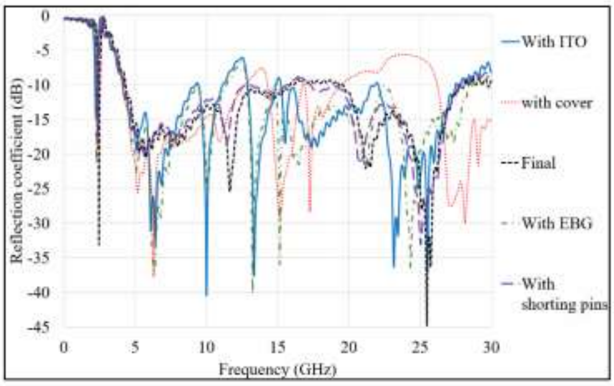

Fig. 3: Reflection coefficient result of the proposed for each step

V. CONCLUSION

An elliptical patch antenna is printed and presented in this paper. The proposed antenna has a smaller printing area and better performances in comparison with the recent works. The proposed antenna obtained a broad BW from 3.9 GHz to 30 GHz. Thus, it can achieve high resolution since it has wide BW and most of the high-frequency bands are in working BW of the proposed antenna. In addition to that, the proposed antenna achieved a maximum gain of 7.3 dB and the maximum directivity of the 7.78 dBi.

The radiation efficiency of the antenna shows the maximum percentage up to 92% after using the ITO layer. Due to the outstanding outcome of the antenna even with small dimensions (15 mm×15 mm), it can work for medical imaging (skin cancer detection) in GHz band as well as the satellite communications (solar cells integration).

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