METAMATERIAL DESIGN ANTENNA FOR BIOMEDICAL APPLICATION INTEGRATED WITH SOLAR PANEL

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Abstract: *Today biomedical application holds a vital role in medical diagnosis and treatment and as an academic discipline. In recent days glucose monitoring, insulin pumps, deep brain simulations and endoscopy are a few examples of the medical applications through body implantable units. Antennas are placed into human bodies or mounted over the torso (skin-fat-muscle) to form a biomedical application and exterior instruments can be arranged to be used for short range biotelemetry applications. Remote monitoring allows the diagnosis of diseases and can be serving as the application of hospital at home, this installation of instruments reduces the hospitalization period. A Metamaterial design antenna resonating at 2.45 GHz is proposed work for biomedical application which is made of FR-4 substrate with dielectric constant 4.4. Metamaterial is used to enhance the bandwidth and it is design at ground plane. This proposed antenna is aimed to be used in human body for various applications and also is easily integrated with solar panels. Proposed antenna is feded by a coaxial probe feeding. Simulation is done by HFSS software. The simulated results show the performance in terms of S_{11} Return loss, Gain in dB, Radiation pattern, axial ratio (AR) and VSWR.*

Keywords: *Metamaterial, Biomedical application, Coaxial probe feeding, HFSS software, VSWR.*

1. Introduction

Artificially created materials are Metamaterials. Metamaterials are homogenous materials in which the dielectric properties are customized. These dielectric properties are not available in nature. The involvements of metamaterials in antenna design are the present research topic. The important property of metamaterial is that the creation of double-negative (DNG) materials with ε-negative and μ-negative responses. With the exposure to metamaterial there is an increase in antenna bandwidth. This can be achieved by loading the radiating element of a patch with complementary split-ring resonator (CSRR), employing a metamaterial superstrate or using CSRR in the ground plane. The future mobile applications make use of the solar panel for self-power. The drawback is the size limitation for antenna in mobile devices. The three main design types of mobile photovoltaic antenna include the use of solar cells as an RF ground plane, as a radiating element and as RF stacked parasitic patch element suspended above the radiating element. The key tradeoff in the design is in between RF performance and solar efficiency. The main drawback in using in using the solar cell as an RF ground plane is the reduction in solar efficiency that results from the shading effect of the antenna. The method to overcome this drawback is by meshing the antenna element or through transparent conductive antennas. Transparent conductive antennas show a radiation efficiency of 50%. In the second approach solar cells act as a radiating. This method overcomes the problem of shading. In the third approach solar cells is formed as a stacked element that formed over the radiating element. This method overcome the problem of shading and allows modification of the antenna structure without affecting the solar performance. The application of antennas in biomedical applications includes data telemetry, medical diagnosis and treatment.

Metamaterials are artificial Data telemetry is the communication between the Implanted Medical Devices and external devices. There is a high demand of health care products. The wires used to connect the implanted IMDs and health care devices increase the infection in patients. With the help of wireless devices the continuous monitoring of implanted devices can be achieved. The application of medical devices diagnosis finds its application in the detection of breast cancer, stroke, and water accumulation in human body. Technologies with exact accuracy are required to detect tumors. Medical treatment using microwaves is the application were the heat generated by microwave radiation to increase the local temperature to destroy the abnormal tissues. These methods are more effective compared to ionizing radiation such as X-ray and chemical toxins such as chemotherapy. Telemedicine refers to the use of transfer of health information of the patient from one place to another place. In the data telemetry the physiological data such as temperature, blood pressure, glucose concentration and vital signs of respiration, heart beat were monitored by sensors that are implanted in body of the patients. The collected information were informed to the doctors through wireless transmission. Metamaterials are artificial materials that possess the properties that are not available in nature. The properties of metamaterial led to the formation of metamaterial antennas, sensors and metamaterial lenses for wireless transfer of data. Metamaterial provides a sensitive response to the strain, dielectric media chemical and biological sensing applications. The design concept of metamaterial antenna resonating at 2.45 GHZ is designed for biomedical application in FR-4 substrate and with dielectric constant of 4.4.

2. Related Work

Kai sun et al (2017) Explained that Metamaterials found its application in invisible cloak, superlens, electromagnetic wave absorption and magnetic resonance imaging. There were only few researches made on the metamaterials for wireless power transfer. With the use of metamaterials transfer efficiency was increased, transfer distance was found to be increased. Here this work provided the methods of fabrication and application in wireless power transfer.

Wei Lin et al (2019) This paper used the wireless power transfer and communication system operating in 915MHZ ISM band. It was realized by Huygens linearly polarized (HLP) antenna and HLP rectenna. Each one combined two pair of metamaterial which was Egyptian axe dipole (EAD) and a capacitively loaded loop (CLL).

Sleebi K.Divakaran et al (2018) had presented that the RF power harvesting is the solution for cases were solar power energy is not promising. There are several challenges for implementation of RF power Harvesting. The specific challenges include the overall conversion efficiency, bandwidth and form factor. Important design issues were identified in this system. Vimlesh singh et al (2018) this paper presented an extensive survey of electromagnetic materials used for antenna fabrication. These antennas found its application in civilian life and in defence. This paper studied about the electromagnetic wave characteristics such as dielectric, flexible electronics, electrical and thermal properties, which have vast potential in communication engineering. Sajid M.Asif et al (2019) this paper presented Radio frequency based wireless power transfer method is highly desirable to power deep body medical implants such as cardiac pacemakers. Antenna is one of the essential components of such system. Antenna must be allowed to achieve the desired performance. This supported RF powered leadless pacing.

Sajid M.Asif et al (2019) In this paper novel Wide Band Numerical Model (WBNM)was proposed for implantable antennas. Particularly the system required wideband tissue stimulating liquid. This was fully characterized by dielectric probe. The proposed WBNM was validated experimentally as well as analytically using a reference microstrip antenna.

Xu et al (2019) this work presented a Metamaterials contains a first substrate which shows a dielectric material of high temperature, also contains a array of conductive resonators implanted in a first substrate. The conductive resonators may include a noble metal of high temperature ceramic semiconductor and noble metal alloy. J.Daniel Binion et al (2017) This work illustrated Advanced Short Backfire Antenna (A-SBFA), combined with anisotropic metamaterial surfaces (metasurfaces), are designed to achieve high aperture efficiency across two frequency bands. The less weight, compact design, hexagonal aperture, high dual-band efficiency, high cross-polarization isolation, as well as low multipaction and passive intermodulation (PIM) risk make the A-SBFA used for space borne applications. This transformative design demonstrated how practical metamaterials, applied to conventional antenna technology, can provide vital performance improvements.

Tanweer Ali et al (2018) Here in this paper the use of fractal antenna with metamaterial was discussed. The antenna designed consists of an L-shaped slot, sierpinski triangle which serves as the fractal radiating element and also metamaterial circular split ring resonator as the ground plane. The advent of metamaterial made the antenna to operate at 3.3GHZ middle wimax. The formation of sierpinski triangle and L-shaped slot in the radiating monopole presents the surface current distribution, this increased the total current path length which made the antenna to operate at 5.5 upper WIMAX 7.3 satellite TV and 9.9GHZ X-band. Gohar Varamini et al (2018) This paper presented a two main methods for antenna miniaturization were meta material and fractal antenna techniques. The main idea of this design was the loop formation with meta material load. Metamaterial layer consist of multi parallel rings, results showed that antenna size was reduced and the frequency shift from 7GHZ to 4GHZ. The resultant pattern was omni directional pattern with a gain of 3.5 dBi, then the size was reduced around 40% for 4.5GHZ and another resonance was occurred at 2.5GHZ with more than 60% frequency shift.

Yefang wang et al (2018) had presented the miniature patch antenna was used for handset mobile application by loading an H shaped patch with mushroom structures. Mushroom structure served as an effective high index metamaterial. H-shape lengthens the current path on the patch. The antenna gain measured in this design was 4.2dBi. Hyunsoo Lee et al (2018) This work illustrated the ground plane cloak is designed using metamaterial the mixture of dielectric material and air. In order to guarantee statistical isotropic cloak structure meta materials were randomly connected to form a metamaterial.

Literature review on the metamaterial antennas for biomedical applications is discussed above. Then we look into the motivation and problem formulation in the next section.

3. Motivation and Problem Formulation

Biomedical application is the recent major application of the antennas. These antennas serve for the purpose of medical diagnosis in which the antenna is made up of a metamaterial and self powered by using solar panels. Metematerial antennas were used in the demand of miniaturized size antennas. Metamaterial is the negative indexed material whose refractive index takes negative value over a certain range. These metamaterials are usually arranged in repeating factor at scales that are smaller than the wavelength of the phenomenon they influence.Metamaterials improves the transmission of electromagnetic waves. Metamaterials constructed in the ground planes surrounding antennas offer improved isolation between radio frequency, or microwave channels of (multiple-input multiple-output) (MIMO) antenna arrays. Metamaterial, high-impedance ground planes can also improve radiation efficiency and axial ratio performance of low-profile antennas located close to the ground plane surface. Metamaterials have also been used to increase beam scanning range by using both the forward and backward waves in leaky wave antennas. Various metamaterial antenna systems can be employed to support surveillance sensors, communication links, navigation systems and command and control systems. The radiation pattern of the antennas is classified into

1. Directional Radiation Pattern: It is a pattern of only one main beam
2. Isotropic Radiation Pattern: It is the constant pattern in both the planes.
3. Omni Directional Radiation Pattern: It is a pattern containing one clear main beam in one plane and constant pattern in the other plane.

Directivity of an antenna is defined as the ratio between the radiation intensity and the total radiated power by the antenna, divided by 4 pi.

$$D = \frac{U(\theta,\varphi)}{(\frac{1}{4\pi})P_{rad}} \qquad (1)$$

Here in this section the importance of choosing metamaterial for antenna design for biomedical application was discussed. In biomedical applications metamaterial antennas were used and this ensures wireless communication between devices.

4. Proposed Implementation

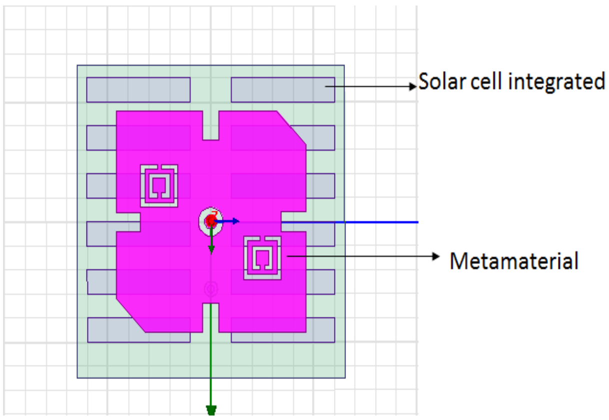

Figure 1. Proposed model

Here in this implementation FR4 substrate is used. The thickness of the substrate is 1.5mm. FR4 substrate is the common material for PCB. A thin layer of copper foil is laminated to one or both sides of an FR-4 glass epoxy panel.

FR4 is used in the construction of

- Relays
- Switches
- Stand offs
- Screw terminal strips.

  Thickness of the FR4 substrate is 1.5mm. The other parameters used for the design is tabulated as below:

Table 1. Parameters of Design

Parameter	Dimension of antenna
Length of the patch	46 mm
Substrate length	65 mm
Truncation corner length	7 mm
thickness of substrate	1.5 mm

The thickness of the FR4 substrate is 1.5mm. A way to feed a antenna is by using a coaxial probe or by a connector mounted at impedance point. These methods of feeding are useful in GPS and WLAN operations.

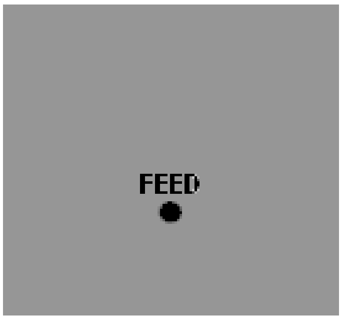

Figure 2. Probe fed patch

Another way to connect to the patch is a microstrip line at the edge of the element as seen below

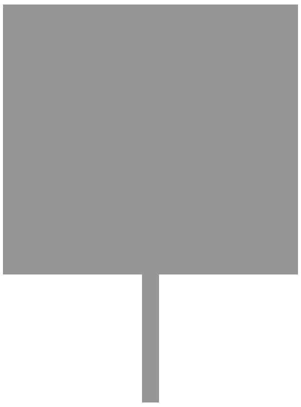

Figure 3. Microstrip line fed patch antenna

In this type of antenna impedance transformation is part of the process. Advantage is the ability to place circuitry near the same substrate. Also here elements can be connected in the same plane in the parallel form as an array. Drawback is that impedance transformation forms a radiating element. This results in the distortion of the radiation pattern of the antenna. The solution to overcome this drawback is the combination of the first two models and can be labelled as seen below:

Figure 4. Insert microstrip line fed patch antenna

Aperture coupling to the patch is a impedance bandwidth enhancement technique. Aperture coupling to the ground plane will be labelled as below

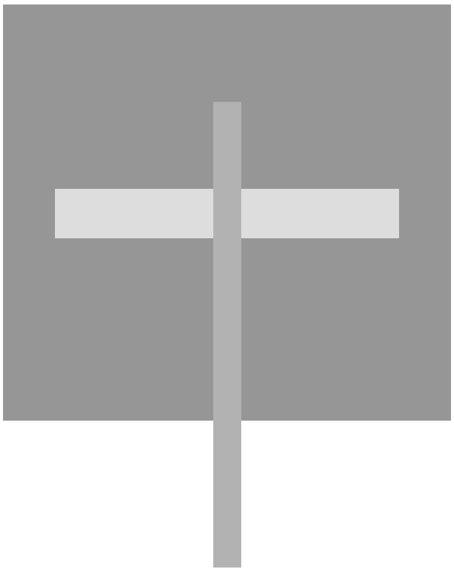

Figure 5. Aperture coupled patch antenna.

The four important parameters to be known for the design of antenna were;

- The operating frequency (f_0)
- Dielectric constant of a substrate (ε_r)
- The height of the dielectric substrate (h)
- The height of the conductor (t)

Dimensions of the patch and ground plane are;

- The width of the patch (W)
- The length of the patch (L)
- Width and length of the ground plane and the substrate. (W_g ,L_g)
- Width of the Patch is;

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

C- Velocity of light

$f_r -$ *Resonant frequency*

$\varepsilon_r -$ *Relative permittivity*

- Effective dielectric constant is;

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\,\frac{h}{w}\right]^{-1} \quad (3)$$

$\varepsilon_r -$ *Relative permittivity*

The height of the dielectric substrate (h)

The width of the patch (W)

- Effective length is

$$L_{eff}=\frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (4)$$

ε_{reff} - Effective Dielectric constant

f- frequency

c- velocity of light

- To find the actual length L

$$L=L_{eff}-2\Delta L \quad (5)$$

L – Length of the substrate

Width and length of the ground plane

$$L_g = 2 * L \quad (6)$$

$$w_g = 2*w \quad (7)$$

w - width of the substrate

The 3-d geometry of the antenna is shown in diagram below.

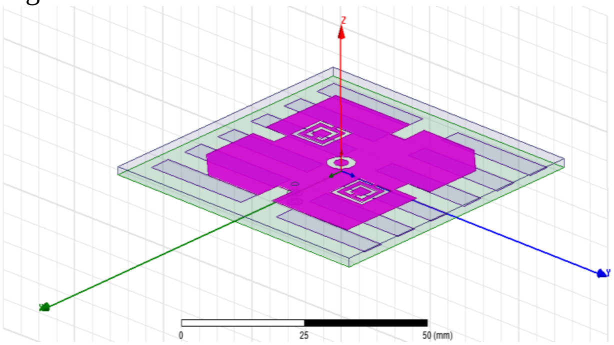

Figure 6. 3-d geometry of design

The antenna design comprises of three sections such as ground plane, substrate and patch design. The antenna design uses FR4 substrate and dielectric constant of 4.4. The antenna feed is given as coaxial probe feeding at the centre of the patch. In this method proposed model was discussed which made use of the metamaterial antenna in biomedical applications.

5. Results and Discussion

The investigation of proposed antenna includes the following parameters such as return loss and radiation pattern. The antenna design was carried out through the HFSS software. The return loss is a measure of reflected and forward power which will be denoted by S_{11}. The figure below shows the corresponding Return loss of the proposed antenna.

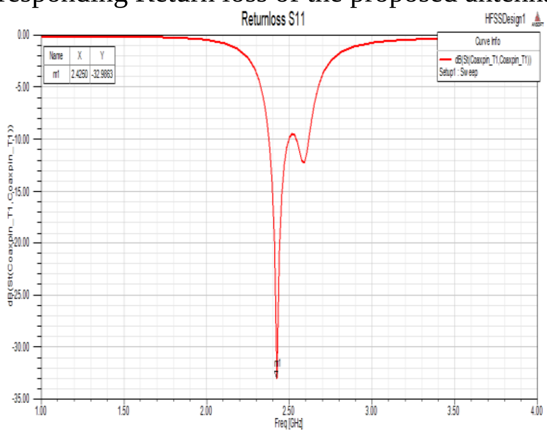

Figure7. Return loss

It shows that the antenna exhibits the frequency of 2.4250 GHz with the return loss of -32.9863dB.

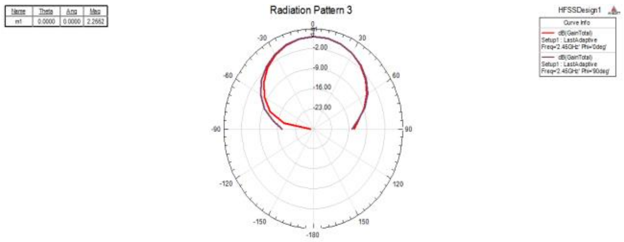

Figure 8. Radiation pattern

Radiation pattern refers to the direction of the electromagnetic waves radiates away from the antenna. The radiation pattern is usually represented in spherical coordinate systems and which is determined in far filed region. The radiation pattern provides how the antenna is propagated in its boundary to a particular direction. The figure above shows the result of the radiation pattern. The gain is the ability of the antenna power between input and output. The proposed antenna provides the gain of 2.2552dBi.

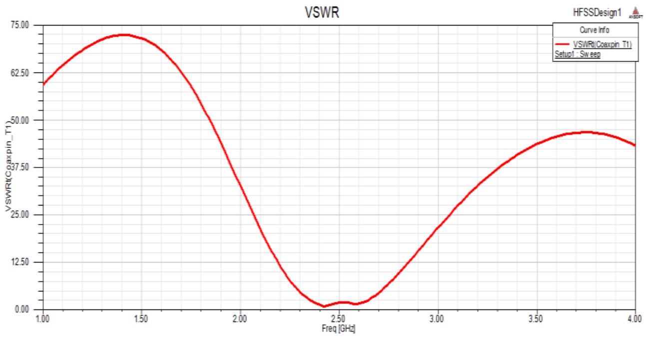

Figure 9. VSWR

The Voltage Standing wave ratio is defined as the measure of how much power is reflected. The minimum value of VSWR indicates that the majority of the incident power is delivered to the antenna and reflections are nearly avoided. The VSWR in dB is 1.125 for 2.425GHz frequency. The Axial ratio of antenna is represented in terms of XY plot which is given in the figure below. This parameter is used to describe the polarization nature of circularly polarized antenna. If the ellipse has an equal minor and major axis it transforms into a circle, and we say that the antenna is circularly polarized. The axial ratio of a linearly polarized antenna is infinitely big since one of the ellipse axis is equal to zero. For a circularly polarized antenna, the closer the axial ratio is to 0 dB, the better. The Axial Ratio (AR) is defined as the ratio between the minor and major axis of the polarization ellipse. The minimum axial ratio has the value of 3db for 2.54GHz. This bandwidth is related to the polarization bandwidth and this number expresses the quality of the circular polarization of an antenna.

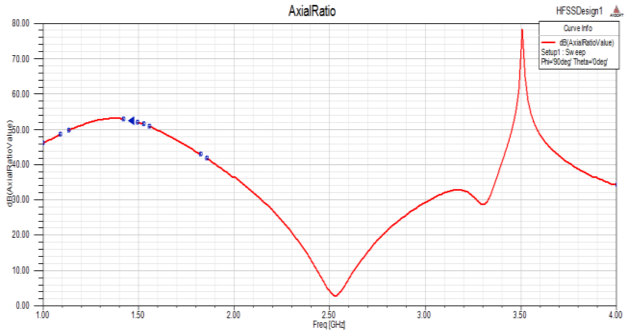

Figure 10. Axial ratio

Here the performance of the antenna was studied using return loss, radiation pattern, axial ratio and voltage standing wave ratio.

6. Conclusion

In this paper literature review of the metamaterial antennas was discussed. The size of an antenna is the key factor to be considered in installing metamaterial antenna on the human body. Through this paper metamaterial antenna for biomedical application powered by solar panel was designed using HFSS software. HFSS stands for high frequency structured spectrum software. Their parameters such as return loss, VSWR, radiation pattern axial ratio were simulated using the software. Performance of the designed antenna was analyzed by above seen parameters. The constructed antenna resonates at 2.45 GHz with a dielectric constant of 4.4.

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