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Original Research Article

Wrist mounted flexible antenna for health monitoring

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Wireless body area networks (WBAN); Transmission line model (TLM); Mircrostrip antenna (MSA); Polyimide.

ABSTRACT
In this paper, a wearable and flexible antenna designs at 2.45 GHz for health monitoring of human body. A wrist phantom designed like human wrist at all dielectric constant of human wrist. Polyimide (Kapton) was chosen as the flexible substrates for its small dielectric constant, mechanical flexibility, and thermal stability. This antenna and human wrist were modelled using the transmission line model (TLM) and optimized via CST Microwave Studio Suite. This antenna has high return loss S_{11} and good gain. This antenna has strong application for next-generation wireless body-area networks (WBAN) for healthcare monitoring, activity tracking of human and IoT devices and systems.

1. Introduction

Antenna is a essential device or part for wireless communication. It radiates and receives of radio wave in free space. It converts electron energy into photon energy or vice versa [1-2]. Different types of antenna are used for wireless communication.Mircrostrip antenna is used everywhere since 1953. But MSA has some limitation in respect to bandwidth and efficiency. Lots of techniques are used to improve bandwidth of MSA like stair and slot in patch, stepped feed with modified slotted ground plane, parasitic elements etc [2-6]. An UWB is used for cover large frequency range with dual rejection bands for WiMAX and WLAN applications [7-10]. Lot of techniques to improved overall efficiency of MSA by SIW structure, pin loaded techniques and Graphene conductor material. Graphene radiating patch providing better conductivity. Selections of substrate materials for graphene based aerial designing has an main role of controlling the transport property of graphene as well as control the resonance property of graphene. [11-14]. Some MSA are very useful to detect human vitals. Many flexible dielectric substrates are used for antenna designing. Polyrethane and Kapton is a polyimide film used in flexible printed electronics circuits, 3D printing, space blankets, X ray equipments, spaceship, and satellites etc. In this paper a 2.45 GHz antenna is used to detect human sign by own wrist. This paper is organized in four sections section first shows the introduction of antenna. Section ii shows the complete structure of MSA and human wrist with all dimension parameters and dielectric constant [15-18].

2. Antenna, and antenna with human wrist design

Required some classical equations are used for MSA designing using transmission line modal

(a) MSA Patch Width (W)

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Here, $c = 3\times10^8$ (velocity of light in free space), Resonance frequency $f_0 = 2.45\times10^9$ Hz (2.45 GHz, free licence band) and dielectric constant of substrate $\varepsilon_r = 3.5$ (used in Polyimide antenna).

(b) Effective Dielectric Constant (ε_{reff})

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}(1+12\frac{h}{W})^{-1/2}$$

(c) Effective Length (L_{eff}) of MSA $L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$

(d) Total length of MSA

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(W/h+0.264)}{(\varepsilon_{eff}-0.258)(W/h+0.8)}$$

(e) Actual Patch Length (L) $L = L_{eff} - 2\Delta L$

(f) Transmission line impedance

$$Z_{T/L}=\sqrt{Z_{PATCH\ EDGE} * Z_{SMA\ PORT}}$$

Generally, we use SMA port impedance is 50 ohms.

All these equations are used to design MSA with 50 ohms SMA port. Flexible dielectric substrate is situated between radiating rectangular patch and ground plane. Some flexible dielectric substrate are used in flexible structures and sign vital detection of human body. These above properties of Kapton are useful in space craft, satellite equipments and MSA designing etc. Some physical properties of Kapton shows in Table 1 [19-24].

Table 1: Some physical properties of Kapton.

Physical Properties	Value	Physical Properties	Value
Dielectric Constant	3.5	Temperatures Range	4 to 673 K
Electrical Loss Tangent	0.0027	Thermal Conductivity	0.5 to 5 W/m·K.
Rho	1400 Kg/m^3	Density	1.42 g/cc

In the Table 2 average human wrist circumference of boy, girl, male, and female are given below.

Table 2: Average wrist size of different human body.

Person	Average Size	Person	Average Size
8 year Boy	141.5 mm	8 year Girl	137.8 mm
18 year Boy	169.2 mm	18 year Girl	151.8 mm
Adult Male	165 to 183 mm	Adult Female	140 to 165 mm

Some physical properties shows of human body in Table 5 like dielectric constant, loss tangent (tan δ) and conductivity at 2.45 GHz. In the Table 4 all optimized values of antenna dimension is shown. Optimized values in mm of MSA with transmision line are given in Table 4.

Table 3: Dielectric properties of human tissues at 2.45 GHz.

Tissue	ε_r (Dielectric Constant)	tan δ	σ (S/m)	Outer Radius(mm)	Inner Radius(mm)
Dry Skin	38.007	0.28262	1.464	28	27
Fat	5.2801	0.14524	0.1045	27	25
Muscle	52.729	0.24194	1.7388	25	0

Table 4: Optimized value in mm of MSA (Polyimide) with transmision line are given.

Parameter	Value	Parameter	Value	Parameter	Value
Ground Length	63.50	Ground Width	80.50	Ground Hieght	0.035
Substrate Length	63.50	Substrate Width	80.50	Substrate Hieght	1.60
Patch Length	31.46	Patch Width	40.25	Patch Hieght	0.035
MS Length	15.88	MS Width	1.16	MS Hieght	0.035

Table 5: Comparison of results (flat antenna and flat antenna with human hand).

Parameters of Antennas	Flat Antenna	Flat Antenna with Hand
S_{11} (dB)	-46.466	-28.678
Gain (IEEE) in dBi	7.03 dBi	6.76 dBi
Realized Gain in dBi	6.41 dBi	6.08 dBi
Directivity in dBi	7.3 dBi	7.33 dBi
VSWR	1.0215	1.1004
Resonate Peak (GHz)	2.4501	2.4624
Resonance Frequency in GHz	2.431 to 2.4688	2.4421 to 2.482
Bandwidth	37.8 MHz	39.9 MHz

Figure 1 shows the structure of MSA. It shows the dimension of patch, transmission line, ground, and substrate plane. In this antenna fundamental mode (TM_{10}) is excited . In this mode field varies one λ/2 (half wavelength) cycle along the length and no variation along the width of the radiating patch. This antenna made by Polyimide substrate and perfect electric conductors.Figure 2 shows the structure of MSA with human wrist dimensions and dimensions of human skin,fat and muscles,

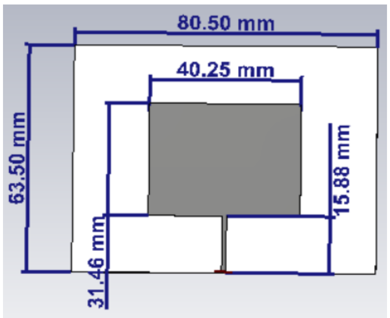
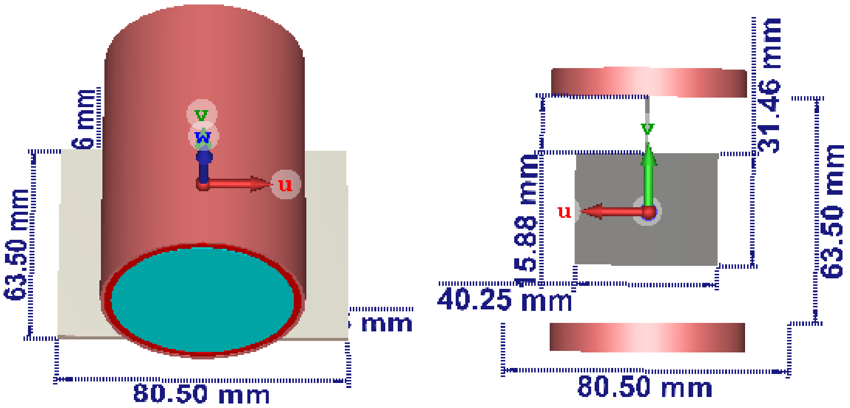


Figure 1: Structure of MSA (Polyimide).



(a)Front View (b) Top View

Figure 2: Structure of MSA (Polyimide) with human wrist.

3. Results and discussion

Figure 3 shows the scattering parameter of flat MSA. It resonates between 2.4311 GHz to 2.4691 GHz so, total bandwidth of this antenna is 38.0 MHz and -46.466 dB resonate peak. Resonate peak shows the good impedance matching between port and radiating patch edge.

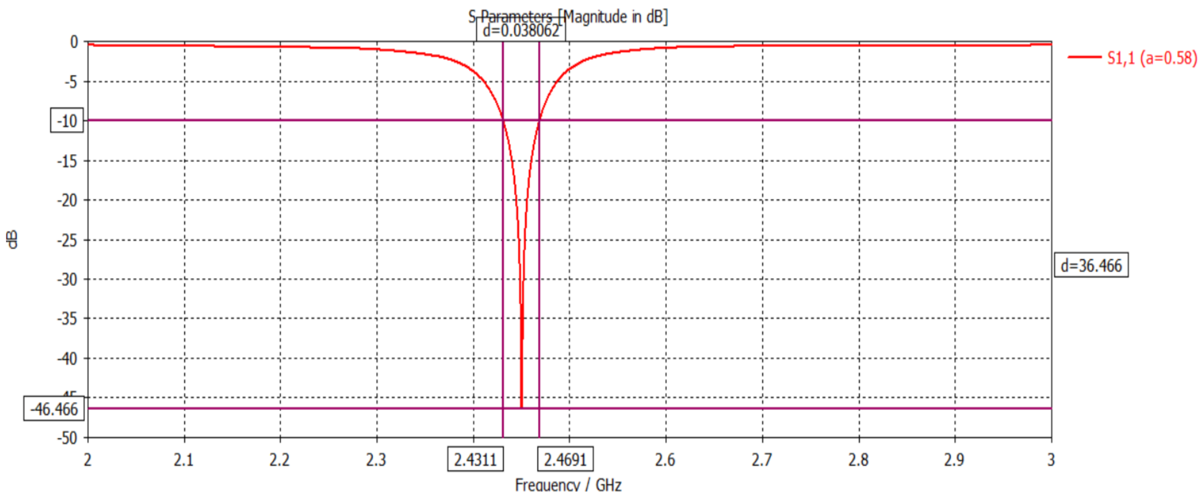


Figure 3: S_{11} of flat antenna (Polyimide substrate).

Figure 4 shows the s_{11} parameters of MSA with human wrist (skin, fat, and muscles of body. This whole system resonate between 2.4421 GHz to 2.482 GHz. Resonate peak shifted to upper side due to absorption of human body.

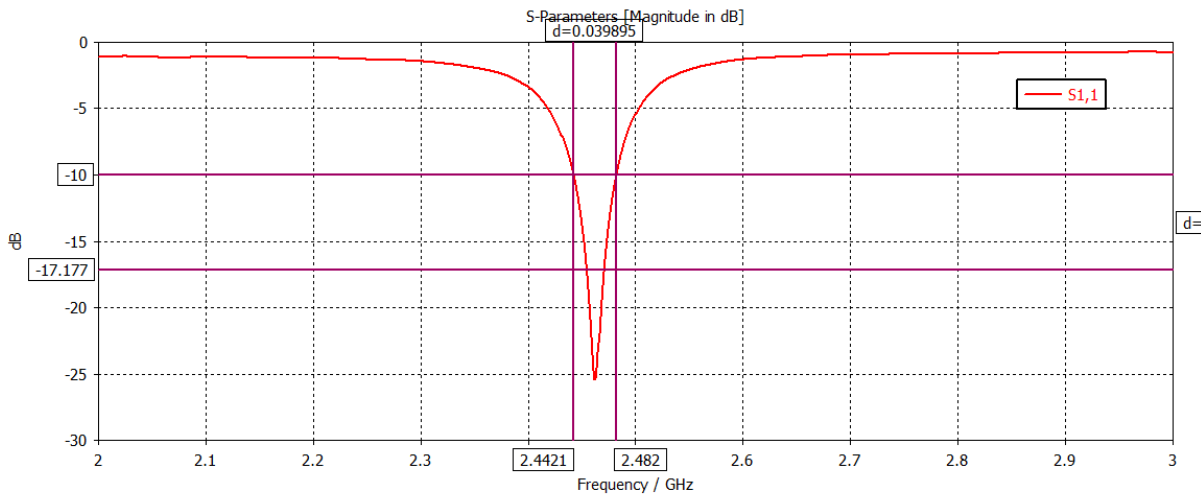


Figure 4: S_{11} of flat antenna (Polyimide substrate) with human wrist.

Figure 5 shows the directivity (7.30 dBi) of flat antenna. It is sufficient for radiation in a particular direction by the antenna. Figure 6 shows directivity (7.33 dBi) of flat antenna with human hand. Figure 7 shows the gain (6.76 dBi) of flat antenna with human hand. Figure 8 shows the radiation pattern of flat antenna with human hand.MSA radiates in unidirectional. In the table 5 a comparison of results of flat MSA and flat MSA with human wrist. Resonance frequency shifted to upper side for human wrist and resonance peak shifted to upper side.Human wrist behave as a ground reflector for flat MSA.VSWR and S_{11} are reciprocal of each other.

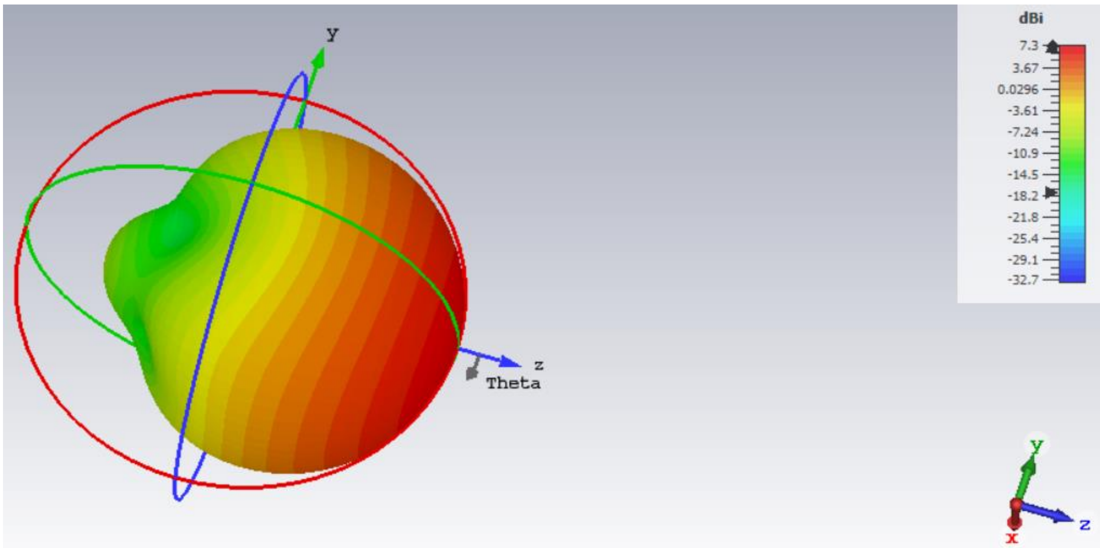


Figure 5: Directivity of flat Antenna.

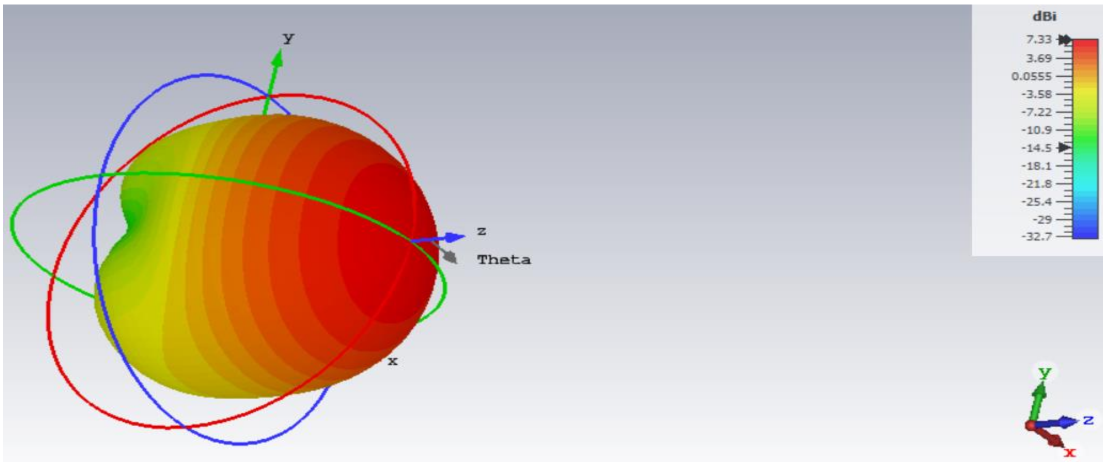


Figure 6: Directivity of flat antenna with human hand.

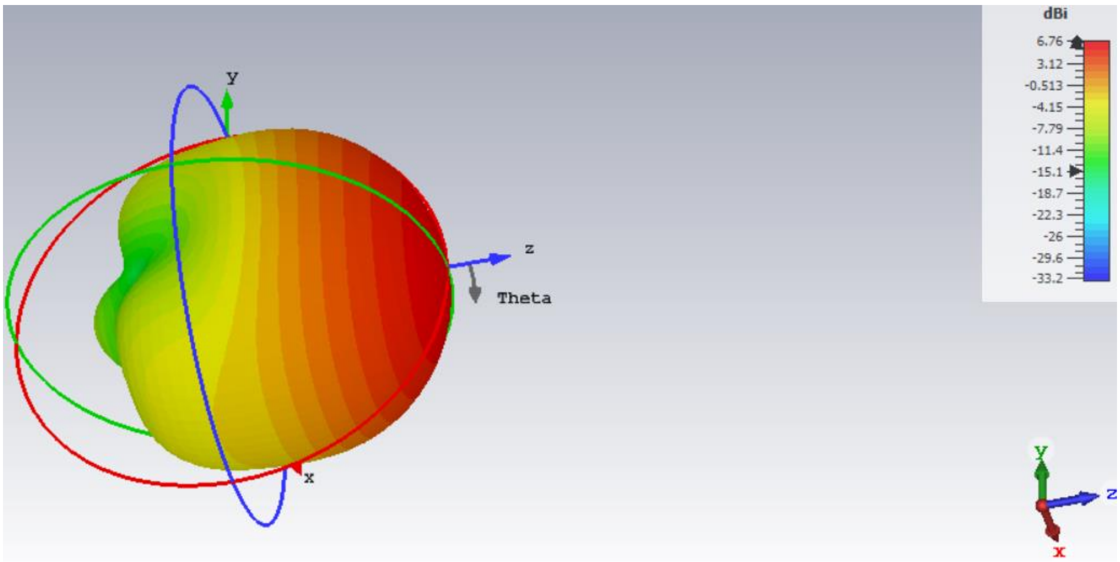


Figure 7: Gain of flat antenna with human hand.

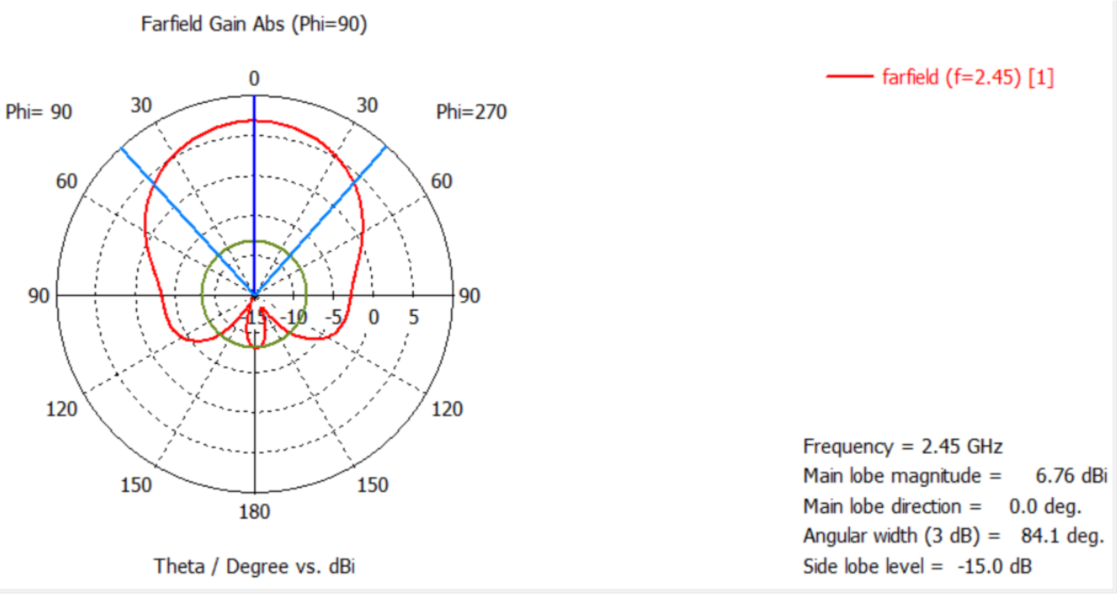


Figure 8: Radiation pattern of flat antenna with human hand.

4. Conclusions

A planar MSA is designed on Kapton flexible substrate at 2.45 GHz frequency range is free liences band so, we can analysis and observe the human body functions like pulse. Flexible antenna attached on human body.Water particle absorb 2.45 GHz frequency. All results of antenna indicates absortion by the body at 2.45 GHz. It will be the challenging task for medical industry for human vital sign detection.

Authors' contributions

All authors contributed equally to the conception, design, experimental work, data analysis, interpretation of results, and preparation of the manuscript. All authors reviewed and approved the final version of the manuscript for publication.

Conflicts of interest

The author declares no conflict of interest.

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Data availability

No new data were created.

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