IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p-ISSN: 2278-8735
PP 49-54
www.iosrjournals.org

Survey on Wearable Antenna Design For ISM Band Applications

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Abstract: *In recent years, there is a rapid growth in many applications based on wearable devices, which is mainly attributed due to antennas. The wearable antenna design should be compact in size, not affect the body of the human, and light in weight. This paper is about surveying on various antenna parameters of an antenna design. Also studied whether the antenna design is used for Industrial, scientific, Medical (ISM) band applications. ISM band is worldwide operated frequency band and it is unlicensed band. These wearable antennas are designed using the simulators HFSS and CST.*
Keywords*: Wearable antennas, ISM, HFSS, CST.*

I. Introduction

Nowadays, for monitoring the biosignals of human body wearable devices can be used. Wearable antenna can be used for the communication between human body and that wearable device. Wearable antenna can transmit and receive the biosignals from the human body to device. Smart wearable solutions for monitoring of Bio Signals of a patient or soldier, depending upon the focused applications. Wearable antenna should be flexible and it cannot harm to human body. In case of wearable antenna technology the designer needs to ensure the optimum performance without affecting the performance of the other electronic units of the Device under focus. The important work is needed to fit the antenna within a compact area of wearable device, and the performance of the entire wearable device depends only on the performance of the wearable antenna [2].

Other than telecommunications, the band that can be internationally reserved for Industrial, Scientific and Medical applications are ISM band. The operating frequency for ISM band is 2.45GHz. In medical application, machines like shortwave and microwave diathermy use radio waves in the ISM band. For apply deep heating to the body for relaxation and healing. Nowadays, hyperthermia therapy uses microwaves to heat tissue to kill cancer cells. There are several important factors that must be taken into consideration while developing a flexible antenna [1]. Substrate plays an important role in micro strip antenna functioning. If the thickness of the substrate is increased, then the fringing increases. That fringing can decreases the resonant frequency of the antenna. While antenna parameters like return loss, gain and bandwidth improves significantly. Material selection for substrate is also an important factor. For a wearable antenna, the antenna design should be flexible. According to that substrate material can be selected. For designing the wearable antenna, we can use various simulators. Computer Simulation Technology (CST) software is a tool that offers 3D analysis of antenna designs and high frequency devices with high accuracy [1]. Another software is High Frequency Structure Simulator (HFSS). For an electromagnetic structure, it is a finite element method solver. It also offers 3D analysis. Both CST and HFSS are widely used software for wearable antenna design. One of the main antenna parameter is return loss. In definition, the ratio of the light reflected back from a device under test to the light launched into that device, usually it can be expressed as a negative number in dB. The return loss with a negative sign is more properly called reflection coefficient. The S-parameter S11 from two-port network theory is frequently also called return loss.

II. Literature Review

A. Wearable patch antenna

In this paper, development of patch antenna made of Polydimethylsiloxane (PDMS) and Copper (Cu). It is flexible antenna. Flexible circular patch antenna can be designed for medical application. The radius of the patch was 21.5mm. The substrate thickness, length and width are 3mm, 60mm, and 60mm. The dimension of encapsulation layer was 0.6mm. The substrate made here was PDMS+glass mixture. That is hollow glass microspheres were added with pure PDMS. To alter the dielectric permittivity of the substrate, they added hollow microspheres with diameter of 20µm to 50µm. There are four flexible antenna can be presented in this paper. That can be named as A, B, C and D. Antenna A and B can be designed using PDMS substrate. Antenna C and D can be designed using PDMS+glass. It resonated at 1.92 GHz, 2.34 GHz, 2.46 GHz and 2.25
GHz with -16.22 dB, -9.19 dB, -11.3 dB and -38.84 dB. Antenna C resonated in the ISM band and then antenna

D showed a lower return loss factor. The two structures can be used in this paper. They are without layer and with layer. Finally, the PDMS+glass antenna with layer performed well with 2.25GHz resonating frequency. The return loss of -34.84dB [1].

B.Wearable Antenna For Bio Signal Monitoring

In this paper, they can approach simple wearable antenna for smart clothing in the ISM band. These systems which monitor vital parameters like Bio-Signals of patients. Wearable antennas are generally designed for real time applications; mainly it can be designed for health monitoring systems. This paper simple planar antenna can be designed. This antenna can be designed using HFSS.

This antenna has a return loss performance of -31dB. The frequency range obtained here was 2.35GHz. This resonance frequency is suitable for ISM applications. And this resonance frequency is also suited for this proposed wearable antenna for health monitoring applications or Bio-Signals monitoring applications. After that this proposed antenna can be tested using Network Analyzer after fabricated it. The efficiency of this antenna can be measured using Antenna Trainer kits. It was observed that for a transmitted current of 120μA, the Received power was 86μA. It gives an overall efficiency of 70.08%. During emergency the patient's Bio-Signals can be monitored easily through this wearable antenna [2].

C.Dual Band G-Shape Wearable Cuff Button Antenna

This paper the design consists of two parts: the metallic button and the grounded Velcro fabric material. It was designed of three main parts. The upper part was G-shape with 1mm of thickness and half-circled part of radius 7.75mm. The base part was formed as a metallic solid cylinder of radius 5mm and height 1mm. It can be connected with metallic probe of 0.27mm radius and 4mm height. This structure is fed using printed microstrip line on a grounded Velcro fabric material of 25×25 mm^2 and 1.8 mm thickness. In this antenna, the feeding part consists of annular circular patch. The outer radius of annular circular patch was 5.6mm and inner radius was 0.27mm. Here two microstrip line stages were used for matching purpose. So that 50Ω impedance was obtained in this paper. This antenna was designed using HFSS.

This antenna has two resonances around 2.45 GHz and 5.75 GHz, respectively with acceptable impedance matching. It can be operated in WLAN/Hiper LAN bands. This antenna gives good Omni-directional patterns were observed in both bands. 8-shaped radiation pattern can be obtained for 2.45GHz [3].

D. Patch Antenna Operating at ISM Band

This paper presents antenna design for the detection of brain tumor and that can be operated in ISM band. It is a pentagon shape microstrip patch antenna. It is compact in size and it is suitable for wearable applications. This antenna was easily worn on the head of the human. The surface of the human head phantom model was attached with the ground plane of the antenna for avoiding the negative effect of electromagnetic field. This antenna was designed using CST software. This head phantom model consists of six spheres. That can be representing the six layers of the human head. They are the Skin, Skull, Fat, Dura, Cerebrospinal fluid (CSF) and brain.

The return loss for normal head was -30.994 dB at a resonance frequency of 2.448GHz. Whereas the return loss of tumor head was -31.42dB with the operating frequency of 2.43 GHz. The variation obtained in both the return loss is not very noticeable as the size of the tumor is small [4].

E .Patch Antenna for Detecting Brain Cancer

For detecting brain cancer, pentagon shaped microstrip patch antenna can be designed. This paper was also operated in ISM band applications. This antenna also easy to worn on human head. The proposed antenna is designed with Fr-4 dielectric Substrate. Annealed copper (Cu) is used for the patch, ground plane and microstrip feeding line of the antenna. The operating frequency of the antenna was 2.4-2.483GHz. The height of the dielectric substrate is 0.8 mm. The dimensions of substrate width, thickness and length are 23mm, 0.8mm and 3mm. The dimensions of ground width, thickness and length are 23mm, 0.1mm and 10.5mm. The length and width of the feed line was 11.3mm and 2.4mm. In the patch rectangular slot can be made. There are 16 slots can be made in the patch of the antenna for increasing current flowing path. This antenna can be designed using CST.

In this antenna, five analyses can be made. They are S11 analysis of antenna, analysis of maximum E-field Intensity, Radiation pattern, SAR analysis, and VSWR analysis. The return loss is measured -30.99dB without cancerous tumor at the resonant frequency of 2.45 GHz. Using this pentagon shaped microstrip patch antenna brain cancer can be detected [5].

F. Novel Miniature Wearable Microstrip Antennas

There are two designs of miniature wearable microstrip antennas for biotelemetry in ISM band was presented in this paper. Both the antennas are in same dimensions. It can be widely used for WBAN applications. The total size of the antenna is $65\times65\times2mm^3$. 2mm3. It has a ground plane with size of 65 × 65mm2. A square feed layer is located on a Taconic CER-10 substrate that has dimensions of $43\times43\times0.4mm^3$ [6]. This paper is perfectly suitable for human body. This antenna can be designed using HFSS software. The S-parameter, SAR, and E-field distribution can be evaluated in this antenna. It can be seen that the proposed antennas exhibit a lower return loss of -18.74 dB at2.45 GHz and -22.74 dB at 2.42 GHz, respectively. These antennas can be directly placed in the human's skin.

G. Wearable dual-band square slot antenna for ISM and Wimax applications.

This antenna is designed by using Vinyl substrate having dielectric constant of about 2.5 with thickness of 0.47mm.In the ground plane a stub having length 14mm and width 0.6mm are then included. From the ground plane the square slot is removed and this then added to the top of the vinyl substrate [7]. In the bottom of the substrate the microstrip feed line having length of about 34mm and width 1.3mm is added.

The designed antenna resonates at two frequencies 2.4GHz and 3.5GHz.The obtained gain for these frequencies are 2.9dB and 2.7dB.This antenna is simulated by using HFSS. The return loss is - 30.2

H.EBG based antenna for wearable medical applications.

Denim material is used as a substrate for this antenna which have dielectric constant of about 1.7 having thickness 0.7mm.The total dimension of this antenna is about 30mm x 20mm.The four T shaped patches are connected in strip line pattern in order to achieve EBG structure. In order to reduce the mismatch and electrical contact that prevent from short circuit roahcell foam is used as a spacer between the antenna and EBG[8].The foam will have the structure of the surrounding materials in which it is attached due to its higher flexibility and only little changes can be applied to the structure of the antenna.

The operating range of the antenna without EBG structure is2.23 to 2.59 GHz with a bandwidth of 360 MHz and the operating range with the inclusion of EBG structure is 2.17 to 2.83 GHz with a bandwidth of 660 MHz, the return loss for the proposed antenna is - 39dB.

I. Patch Antenna using EBG Structure for ISM Band

This paper was about designed a flexible antenna and it can be proposed is in ISM frequency band. The simple microstrip patch antenna can be designed. The specific absorption rate can be analyzed and measured in this paper. Polyester substrate can be used for designing this antenna. The substrate is grounded using copper layer. A square shape EBG structure was designed for resonant frequency 2.45GHz. To improve the overall gain of the antenna circular slot can be made in EBG structure [9]. This antenna can be designed using CST software. Microstrip patch antenna can be analyzed using with and without EBG structure. The return loss is far much improved with the Patch antenna deployed on EBG at 2.44 GHz. Return loss for Antenna without EBG reached -29.42 dB where as it got improved with EBG and reached -38.74 dB which shows a31.67% improvement of EBG antenna over ordinary antenna. The back lobe radiations are also reduced due to the EBG ground plane. It attained a maximum gain of 8.9dBi. The gain can be improved when it is used in human tissue rather than antenna structure.

J.G-shaped wearable cuff button antenna

In this paper, the small G-shaped microstrip antenna can be designed. This can be operated in the ISM band. There are two parts are present in the design. They are metallic button and the grounded microwave RT/duroid 5870 substrate. There are three parts are available in this design. The upper part of the antenna is in G-shaped, which is placed on top of a circular plate of 12.5 mm radius and 0.825 mm height. The dimensions of conducting post of radius 0.5mm and height 2.175mm. It can be used to give space between G-shaped and solid cylinder plate. To obtain the capacitive effect, the spacing can be made. It will improve the impedance matching of the antenna.

The metallic solid cylinder was a base part which has dimensions of radius 8.25mm and height of 1.8m. This can be connected with the upper layer through an solid metallic cylinder of radius 1.2mm and height 5.37mm. The feeding part consists of annular circular patch of

6.6 mm outer radius and 1.2 mm inner radius [10]. This antenna can be designed using HFSS. It can be obtained that the antenna has two resonances around 2.45GHz with acceptable impedance matching.

K.E-Shaped wearable antenna in ISM band

In this paper, flexible wearable antenna can be designed for ISM band applications. It is operated in the frequency range of 2.45GHz. A copper conductor is used as a E-shaped patch. Here two different types of feeding techniques are used. They are edge mounted feeding and vertical probe feeding. The location of the feed was depends upon were the impedance matches correctly. This paper presents different antenna parameter analysis. The obtained return loss are -22.64 dB, -11dB, and - 17.75dB for different substrate materials. Here VSWR≤2 in 2.4GHz. This indicates that only 10% of power was reflected back. The directivity, gain, radiation pattern, bandwidth and impedance bandwidth are varied depending upon the substrate that can be used in the antenna [11]. The highest gain obtained here is7.59dBi.

L. wearable wideband microwave antenna

This paper was about investigation of microwave wearable antenna. This antenna was also designed for ISM band. As for the case study, wideband vee antenna can be considered. This antenna consists of two coaxial cylinders of height 300mm. The inner cylinder has a radius of 102mm and the outer cylinder has a radius of 271mm. It produced maximum VSWR that is less than 1.3. It can be easy to design and more appropriate for wearable applications [12].

M. Wearable Patch Antenna on Biodegradable Poly Lactic Acid

The planar antenna can be designed for wearable applications. This can be used because of various advantages such as compact size, flexible, low fabrication cost, low cost, etc. In this paper, they had taken two heights for designing antenna. They are h=3mm and h=1.7mm. The dimension of length and width of the patch for h=3mm are 33.45mm and 42.73mm. The dimensions of length and width of the patch for h=1.7mm are 34.18mm and 42.73mm [13]. This antenna can be designed using CST software. Using Finite Integration Techniques, the S-Parameters and far field parameters like gain, directivity and radiation pattern can be evaluated.

The return loss for this antenna is -21dB and -22dB. The proposed antennas have angular beam widths of 98.9 and 106 degrees, main lobe directions towards and side lobe levels of -15.7 and -14.1 dB for substrate height of 1.7 and 3mm respectively. The proposed antenna give gain of 6 and 6.14 dBi ,directivity of 7.58 and 7.54dBi, efficiency of 59 and 70% for1.7and 3mm thicker PLA substrates respectively.

N. Wearable printed Monopole Antenna

This paper mainly focused for side spectrum fields such as entertainment, medical devices and personal communications. This antenna has a Omni-directional characteristics. This printed monopole antenna is more efficient and it has lot of characteristics. It should widely use for wearable applications [14]. This antenna was flexible, compact in size and low profile antenna. Kapton polyimide substrate can be used in this antenna design. The radiating element gives rise to UWB characteristics because of half-elliptical characteristics. In this antenna design, arm structure can be added to provide the ISM band. It produced the resonant frequency of 2.45GHz. The dimensions of this printed monopole antenna is 32mm×42mm. The thickness of the substrate is 50.8μm. It gives an excellent efficiency with good performance. This antenna used for both UWB and ISM applications.

O. Robust low profile EBG structure based wearable antenna

This paper was presented for medical wireless body networks. The structure of antenna was in compact size. The presented antenna was printed monopole antenna and its dimension is $40\times26mm^2$. Backside of the antenna was designed with EBG array for forming artificial magnetic conductor [15]. This structure was used to enhance the performance of the antenna and it can be used in human body. Rohacell form can be used to reduce the impedance mismatch. The gain of the antenna is 6.79dBi. The performance of the antenna was very efficient.

III. Comparative Analysis Of Different Wearable Antenna Design For Ism Band Applications

Different types of wearable antennas are designed for ISM band applications based on type of substrate that can be used in the antenna. The comparative analyses are tabulated in table1.

TABLE I. Comparative Analysis Of Different Wearable Antenna Design For Ism Band Applications

Paper	Type of material used	Return loss(dB)	Software used
[1]	PDMS+glass	-38.84	CST
[9]	Polyester	Without EBG-29.42	CST
		With EBG -38.74	
[4]	FR4	-31.42	CST

Paper	Type of material used	Return loss(dB)	Software used
[2]	Fabric	-31	HFSS
[8]	Denim	-31	CST
[5]	FR4	-30.99	CST
[7]	Vinyl	-30	HFSS
[10]	RT/duroid 5880	-28	HFSS
[3]	Velcro	-24	HFSS
[14]	Kapton polyimide	-23	CST
[11]	Fleece	-22.64	CST
	Denim	-11	
	Velcro	-17.75	
[13]	Polylactic acid plastic	-22	CST
[15]	Denim	-20	CST
[6]	Taconic CER-10	-16.69	HFSS

IV. Conclusion

In this survey, design of various wearable antennas for ISM band has been analyzed. Wearable antennas can be widely used in many applications like medical, textile, industrial, etc. These antennas can be simulated using by software like HFSS and CST. And some of the antennas are fabricated and tested using network analyzer. Based on application substrate material can be varied for each antenna. All the compared antennas are operated in the frequency of 2.45GHz.

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