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Flexible Microstrip Antenna in wearable Applications

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Abstract
In last few years, the textile (cloth) material is very popular amongst the researcher for designing the flexible wearable antenna for body area network (BAN). Such antennas having high flexibility due to textile material used as a substrate, small size so that easily wearable on human cloths for transmitting and receiving signals at sufficiently large distance on 2.4GHz ISM frequency band for various medical, military and other applications. It is very simple in design, very low manufacturing cost and easy for placement on human cloths becomes popular in the field of medical science for wireless communications and sometimes for treatment on human body. Microstrip antennas are commonly used in communication system, it having some striking features such as small size, light weight, low profile, flexible, and even low manufacturing cost. For increasing flexibility of microstrip antennas, textile materials are mainly used which is also low cost material with some additional advantage like low SAR. Flexible microstrip antennas are used in different fields, like fitness monitoring, GPS, RFID, medicine, military applications etc.

Keywords: Microstrip antenna, wearable antenna, applications

I. INTRODUCTION

In current situation most of the researchers are increasing their focus towards flexible microstrip wearable antennas design and analysis for different applications. The textile is used as a dielectric material in the fabrication of flexible microstrip antenna which is easily available at low cost, additional benefit of flexible microstrip antenna using textile is that, compact and low cost feed network is achieved by integrating the RF frontend with the radiating elements on the same substrate, so overall manufacturing cost of microstrip wearable antenna will be reduces. In a flexible wearable antenna performance is observed on the human body at 2.4 GHz, ISM band. Wearable antennas used in medical application needs to be flexible with smaller in size by 15% to 20% from the antenna length used in free-space application and it should be safer for medical treatment on human body. The antennas presented in various research papers are found to be used in cellular applications. The frequency band used in medical application is different from cellular applications, and requirements of medical application antenna are also different than cellular applications [1][2]. Flexible Microstrip wearable antennas are extensively presented in various books and research papers in the past years. *Flexible Microstrip antennas in* telemedicine *wearable application are mostly presented by various authors in their research papers and articles in past few years*. A wearable and body mounted antennas designed and developed for various telemedicine applications at different frequency bands over the last decade are often found in various research papers. The wearable microstrip antennas have been presented by various authors in their research papers for treatment on different disease in human body [3]. Microstrip patch antenna consists of a radiating metal element called patch at one side of a dielectric substrate and other side of substrate there is a ground plane which is also a metal (Cu) as shown in Fig. 1.

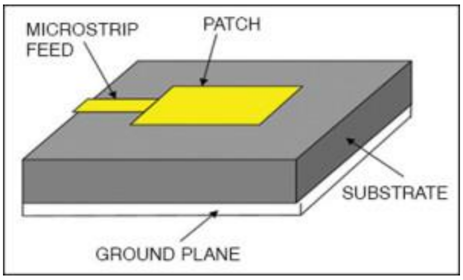

Figure 1: Basic Structure of Microstrip Antenna

If the thickness of substrate martial is large, the dielectric constant is less (less than 6) which gives higher efficiency, large bandwidth and better radiation of an antenna, but such configuration increases the size of antenna. So to design small size microstrip antenna a substrate with high dielectric constant (less than 12) is selected, which leads lower efficiency and less bandwidth. [4]
Microstrip antenna can be classified into four subtypes:

- Microstrip dipoles,
- Microstrip patch antenna,
- Printed slot antenna
- Microstrip travelling-wave antenna.

II. APPLICATIONS OF MICROSTRIP ANTENNA

Microstrip patch antenna has several applications;

A) Satellite Communication:

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For satellite communication the microstrip antenna should have circularly polarized radiation patterns, which can be obtained by using square shape microstrip antenna or circular shape microstrip patch antenna. In GPS systems, the circularly polarized microstrip antennas are commonly used. They are small in size but costly because of their positioning.

b) RFID:

Radio frequency identification system basically uses the frequencies between 30Hz to 5.8GHz. To work on these frequencies normally the microstrip antennas are used. RFID system includes tag and reader. It is used in mobile communication and medical instruments.

c) Telemedicine:

In telemedicine application, normally flexible wearable antenna is suitable for WBAN which operate on 2.45GHz ISM band. The antenna used in telemedicine applications having gain in the range of 6.5dB - 6.7 dB and FBR of 11.7 dB.

d) WiMax:

Worldwide interoperability for microwave access (WiMax) is IEEE 802.16 standard. The rang of communication in WiMax is up to 30-mile (48KM) radius with data speed of 70 Mbps. Microstrip antenna can be design for multiband frequencies so that such type of antennas are used in WiMax-based communication equipments.

e) Medical applications:

The microwave frequencies (energy) are used in medical field for treatments of some hateful tumours. Microwave energy is one of the useful ways of inducing hyperthermia; so that microstrip patch radiator is used to generate microwave frequency, because it is small in size, low cost and rugged. [4]

III. TEXTILE ANTENNAS FOR DIFFERENT APPLICATIONS

The basic requirements of textile wearable antenna are a planar structure and flexible materials for its construction. There are various properties of the flexible material which influences the performance of the antenna, for example, thickness of dielectric material will affect the bandwidth and efficiency of microstrip antenna. Normally, textile material having low dielectric constant, because of that the surface wave losses reduces and increases the impedance bandwidth of the antenna. [5]

In some medical applications biometric data of human body is continuously monitor, to do this the antenna should be placed closed to human body all times, which is used to send biometric data to the outside world. Conventional antenna which is hard in nature is not good solutions for such monitoring system because it cannot be held connected with the human body for long time.

A textile antenna which normally manufactured using normal clothing material is not harmful for human body and it can be kept with human body for longer time.

Textile wearable antennas are used in different fields’ like healthcare monitoring, recreation, fire-fighting, etc.

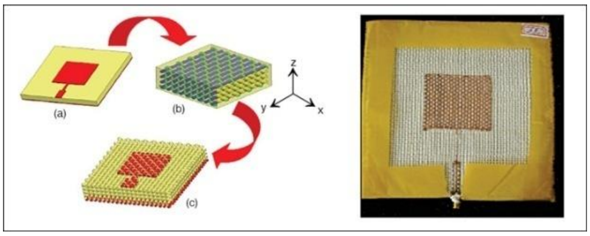

Figure 2: Textile Antenna

In recent days Fabric materials are very popular for design and development of flexible wearable antennas for various applications due to remarkable changes in the development of wireless devices. For the development of flexible wearable antenna, the textile materials form interesting substrates are used, because textile antenna can be easily fit into clothes. Textile antenna above Fig. 2 is made from only textile material in which radiating element (patch), ground plane and even dielectric material used is also textile with specific dielectric constant. In above antenna everything is made up of textile material, so it is called textile antenna. [4][5]

TABLE I: COMPARATIVE STUDY OF EXISTING ANTENNAS WITH ITS APPLICATIONS

Sr. No.	Ref. No.	Year of Publication	Research Focus, Outcomes and Applications
1	[6]	2020	**Focus:** A small and compact symmetrical e-slots antenna is proposed for medical BAN applications operated on 2.4GHz frequency. This is printed antenna on highly flexible fabric material. The EBG material is used to for separation between body and antenna. Defected Ground Structure is used in the design of antenna which increases bandwidth. **Outcomes:**

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			A wearable symmetrical e-slots antenna over a 2 × 2 EBG array with etched DGS was proposed to operate at 2.4 GHz for Medical Body Area Network applications. The integration of antenna with EBG-DGS shows a compact flexible design, better FBR, acceptable gain, and wider bandwidth compared to other wearable antenna. Hence, such antenna with above combination is good choice for body-worn devices. **Applications:** *Medical Body Area Network applications*
2	[7]	2020	**Focus:** Antenna for wearable biomedical telemetry application is presented. This antenna is a wideband, low-profile and semi-flexible antenna. It is semi-flexible because RT/duroid 5880 is used for the development of antenna. In this design the regular rectangular patch is customize by adding rectangular slots so that ground plain is partially modified which increases bandwidth of antenna. **Outcomes:** It has low size, wideband and better performance on human body loading case. The proposed antenna works on 2.4GHz frequency band at 10-db bandwidth. The antenna gives high gain typically 2.50dBi at working frequency of 2.4GHz and efficiency approximately 93 %. **Applications:** *Compact wearable biomedical devices*
3	[8]	2019	**Focus:** A dual band antenna is proposed in which with specially designed L-shaped radiating slot and a cylindrical dielectric resonator is used to generate two frequencies that is 2.4GHz low frequency band and 5.8GHz high frequency band. **Outcomes:** The parametric study confirms that the proposed antenna is independently controllable: the lower band is controllable using L-shaped slot’s dimensions and higher resonant band is controllable using DR parameters (radius and height). In experiments it is found that the PCB board below the antenna acts as a reflector, results in increasing the gain, reducing the backward radiation, and reducing the SAR. **Applications:** *Wearable biomedical devices.*
4	[9]	2019	**Focus:** A dual band antenna with semi-flexible substrate is proposed. In this design Rogers substrate with 3.04mm thickness is used for development of antenna. It is a dual-polarised antenna; the circular polarisation (lower band) is obtained by adding complementary split ring on the antenna patch. The upper band (2.45GHz WLNA) frequency is achieved by etching U-shaped slot on its ground plane. This dual-band and dual-polarized operation enables the use of antenna for indoor/outdoor applications. By adding AMC (artificial magnetic conductor) structure with dual band radiator, the power of radiations against human body decreases. **Outcomes:** The designed antenna works in two frequency bands, that is 2.4GHz (lower) frequency band and 2.45GHz (upper) frequency band. The gain of this antenna is 3.05dBi for lower frequency band and 5.07dBi for upper frequency band. The antenna performance is measured with and without AMC (artificial magnetic conductor) structure and found that the gain of antenna is increased and EM absorption on human body is reduced. **Applications:** *Indoor/outdoor wearable application.*
5	[10]	2018	**Focus:** A flexible wearable CPW antenna using cloth as a substrate is proposed for medical body area

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			network applications. The antenna is designed for 2.4GHz frequency band using EBG-FSS (Electromagnetic bandgap and frequency selective surface). If the antenna is used closed to human body without EBG-FSS, its performance degrades, and SAR is also high, but by using EBG-FSS the backward radiation and SAR reduces. **Outcomes:** A flexible wearable CPW antenna for medical applications is presented. EBG (Electromagnetic bandgap) is used with frequency selective surface for development of antenna in body area network applications at 2.4GHz frequency band. EBG-FSS provides good isolation for human body. By using EBG-FSS structure in the design of antenna, the detuning due to human body and bending effect is largely reduced. The front to back ratio is improved by 13dB and the gain is also improved significantly with reduction in SAR. **Applications:** *Medical body area network*
6	[11]	2018	**Focus:** In this paper the 3-D printing technology is used for design and development of wearable antenna for wrist worn wireless communication. The two different techniques are presented here for developing wrist worn antenna; the first method is a multistep process consisting of: 3-DP of the bracelet, deposition of a smoothing layer, aerosol jet printing of silver inks, flash curing, and electroplating with copper. The main advantages of this process are the high resolution of the printed antennas and the very smooth and thin metallic layer. The second technique involves printing the bracelet with grooves and then painting the metallic layers of the antennas by hand. This process was able to produce three antennas on the same bracelet with various conformal shapes. **Outcomes:** The antenna is designed and develops for wireless LAN communication over the frequency of 2.4GHz to 5.5GHz by keeping reflection coefficients less than -10dB. By fabricating three WLAN antennas on bracelet at different positions and shape angles increases the overall coverage of communication. The radiation pattern of antenna is ominidirectional in free space and directional to human wrist. **Applications:** *Wrist worn wireless communication*
7	[12]	2018	**Focus:** A Z-shape flexible wearable microstrip patch antenna with textile as a substrate is proposed for detection of cancer cells when placed on thyroid gland. For antenna design, the silk is used as a substrate. The use of silk substrate is advantages because it has very low SAR as compared to other textile materials. **Outcomes:** Z-Shaped Microstrip patch antenna when placed on thyroid gland of human tissue, its performance parameters like gain and electrical conductivity changes. The human tissue properties were analyzed for cancer affected/not affected area and it is found that the gain and electrical conductivity of antenna changes in cancer affected area, as cancer cell consists of more water content as compared to normal cells. This type of antenna is very useful for detecting thyroid cancer by placing such antenna on human body. **Applications:** *Wearable biomedical devices.*
8	[13]	2018	**Focus:** This paper presents dual antenna model for eyewear application. These antennas are printed antennas on FR4 substrate. Out of two, one antenna is monopole which placed at the back of eyewear with special shaped ground plane underneath and second antenna which balanced fed

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			loop antenna put in front of eyewear with an integrated balun circuit. This antenna is proposed for the use in different directions for different use: (1) in front of the eyewear to communicate with a laptop; (2) in the side direction of the eyewear to communicate with a fixed hotspot access point: and (3) in downward direction of the eyewear to communicate with a peripheral smartphone in the pocket of the user. While designing the antennas, the specific absorption rate keeps within specified limit. **Outcomes:** A novel monopole/loop dual-antenna is presented for smart eyewear devices. The proposed antenna works at 2.4 GHz for WLAN standard. This antenna is integrated in realistic eyewear devices and Bluetooth headsets for its analysis. Almost 4 dB of simulated gain advantage was observed for the front direction. From the best knowledge of the users, this is the first time that a solution to shape the radiation patterns of 2.4 GHz headset or eyewear devices is presented. **Applications:** *Eyewear applications.*
9	[14]	2018	**Focus:** This paper presented rectangular slot/notch antenna with strip line inserted to form inverted E-shaped antenna for ISM band 2.4GHz applications. This antenna is very simple in structure, small sized and manufactured with jeans cloth material. The antenna is 75% smaller than conventional antenna. The antenna under bending effect proves it’s sustainable under deformation. **Outcomes:** A low-profile and light-weight miniaturized antenna for ISM applications at 2.4 GHz has been presented. The presented antenna gives stable radiation performance with approximately 79% radiation efficiency. The bending effect on such antenna is observed and found that very small deterioration. With the advantages of small size, good radiation pattern, low manufacturing cost the proposed antenna is a effective candidate for ISM band applications. **Applications:** ISM applications.
10	[15]	2017	**Focus:** In this paper the antenna for body area network application is presented, the antenna is single-band antenna but used for dual mode operation that is for on-body and off body operation. This is one of the wearable antennas used for 2.45 GHz ISM band (industrial scientific and medical band). Microstrip ring is used to achieve on-body application where as a compact meandered microstrip patch which placed inside the ring is used to achieve off-body operation. Two separate feed lines are used for dual mode operation but it share common ground plane. This antenna uses only fabric materials for manufacturing, make possible the placement of antenna on to the user’s clothes. **Outcomes:** These antennas achieve good impedance matching and small mutual coupling in the whole ISM band. At deformation the antenna provides good performance within the limits allowed by its rigidity. Radiation efficiency of such antenna is also good. On both LOS and NLOS scenarios, the on-body mode provides a path loss gain of about 5 and 11 dB, respectively, in the whole ISM band. **Applications:** On-body and off-body for body area network’s
11	**[16]**	2017	**Focus:** The use of handbag metal zipper as an antenna for off-body applications is presented. The feeding point of antenna is placed at the bottom of metal zipper; it is specifically fixed on dedicated teeth. This metal zipper antenna operate at 2.44GHz frequency band with acceptable

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			performance on any condition of zipper that is totally open, half open, quarter open or fully closed. Thus, it is to some extent reconfigurable, especially for radiation patterns. **Outcomes:** The proposed antenna is designed for 2.44GHz ISM band for fractional bandwidth of 4.92% with a 5dBi gain is achieved. For off-body applications the hand bag zipper is good option. In this design no need to change hand bag zipper with some special zipper, it is advantages that the size of zipper is large in size than any other wearable antenna for BAN application, so that we get higher gain of antenna with good radiation pattern. The cost of antenna is almost zero because exiting hand bag zipper is used, and no matter for placement of antenna. By changing feeding location we can obtain multiple frequency bands and can obtain different radiation directivities by dragging the handle of the zipper open or closing it. **Applications:** Off-body applications on 2.4GHz ISM band.
12	[17]	2017	**Focus:** A compact wearable antenna using EBG (electromagnetic bandgap) structure is proposed which works on 2.4GHz ISM band for medical applications. The use of EBG structure in the development of antenna make it robust with low profile, small size for any wearable applications **Outcomes:** The EBG structure reduces the back radiation and also reduces the impact of frequency detuning due to the high losses of human body. The proposed compact antenna working on 2.17GHZ – 2.83GHz frequency band with a gain enhancement of 7.8 dBi and more than 95% reduction in SAR. The EBG structure reduces the unwanted radiations towards the human body. In addition, the EBG structure improves the FBR (front-to-back ratio) by 15.5 dB. Therefore, the antenna is a best candidate for used in wearable devices, specifically biomedical technology. The bending does not affect the resonant frequency and the bandwidth of the antenna. **Applications:** Wearable medical application

IV CHALLENGES AND OPPORTUNITIES

There are many challenges and opportunities in wearable antennas. The antennas are designed for one or two specific applications that are limited use only. The antennas designed for medical applications have many limitations, like harmful radiations generated by microstrip antennas will affect the human body, flexibility and placement of antenna on human body. Other challenges are size and shape of antenna, return losses and gain of antenna and radiation pattern. If a researcher focuses on size of antenna then the gain of antenna will be sacrificed. Similarly if low dialectic constant substrate material is used which gives higher efficiency, large bandwidth and better radiation pattern but the size of antenna increases because low dielectric constant substrate material has thick in diameter. So antenna design for various applications has large number of opportunities like, selection of proper substrate material with low dielectric constant, less thickness and it should be highly flexible. Antenna should be designed in such way that it should be used for multiple applications with little changes. It should be highly flexible and easy for placement on different applications, like on-body and off-body applications.

V CONCLUSIONS

In this paper, we have presented the study of microstrip antenna design technique, substrate material used for antenna, and different applications of antenna in different fields. The good research is carried on microstrip antenna with different methods of designing, different substrates are used for implementations of microstrip antennas, different types of shapes are prepared for getting best results. To get desired frequency band the size of antennas are continuously updated by researcher. The concept of dual-band and multiple-band antennas is now very popular amongst the researchers. The proposed wearable antennas were designed on flexible substrates for different frequency bands and for different applications. If we design antenna by using the cloth material as a substrate, with proper shape and structure the flexibility of wearable antenna increases, the antenna will work on multiple frequency bands and it can be used for different applications.

REFERENCS

[1] Gupta, B., Sankaralingam S., Dhar, S., "Development of wearable and implantable antennas in the last decade", Microwave Symposium (MMS), 2010 Mediterranean 2010, Page(s): 251–267.

[2] Thalmann T., Popovic Z., Notaros B.M, et.al, "Investigation and design of a multi-band wearable antenna", 3rd European Conference on Antennas and Propagation, EuCAP 2009. Pp. 462 – 465.

[3] Thomas Thalmann, Zoya Popovic, Branislav M. Notaros, et.al "Investigation and design of a multi-band wearable antenna", Published in: 2009 3rd European Conference on Antennas and Propagation

[4] S.A. Patil and P.C. Dhanawade, "Microstrip Antenna and its Applications" published on 12 Jan 2017 and was recently updated on 15 May 2019. https://www.electronicsforu.com/technology-trends/microstrip-antenna-applications.

[5] Rita Salvado, Caroline Loss, Ricardo Gonçalves, et.al, "Textile Materials for the Design of Wearable Antennas: A Survey", Sensors 2012, 12, 15841-15857; doi:10.3390/s121115841, pp. 15842 - 15857

[6] Adel Y. I. Ashyap, Samsul Haimi Bin Dahlan, Zuhairiah Zainal Abidin, et.al, "Robust and Efficient Integrated Antenna With EBG-DGS Enabled Wide Bandwidth for Wearable Medical Device Applications", IEEE Access, March 19, 2020, date of current version March 31, 2020, *Digital Object Identifier 10.1109/ACCESS.2020.2981867* VOLUME 8, 2020, pp 56346 – 56358.

[7] Amor Smida, Amjad Iqbal, Abdullah J. Alazemi, et.al, "Wideband Wearable Antenna for Biomedical Telemetry Applications", IEEE Access, January 17, 2020, date of current version January 27, 2020. *Digital Object Identifier 10.1109/ACCESS.2020.2967413,* VOLUME 8, 2020, pp. 15687 – 15694.

[8] Amjad Iqbal, Abdullah J. Alazemi, Nazih Khaddaj Mallat, "Slot-DRA-Based Independent Dual-Band Hybrid Antenna for Wearable Biomedical Devices", IEEE Access, December 17, 2019, date of current version December 30, 2019. *Digital Object Identifier 10.1109/ACCESS.2019. 2960443,* VOLUME 7, 2019, pp. 184029 – 184037.

[9] Kashif Nisar Paracha, Sharul Kamal Abdul Rahim, Ping Jack Soh, et.al, "A Low Profile, Dual-band, Dual Polarized Antenna for Indoor/Outdoor Wearable Application", IEEE Access, February 1, 2019, date of current version March 29, 2019. *Digital Object Identifier 10.1109/ACCESS .2019.2894330,* VOLUME 7, 2019, pp. 33277 – 33288.

[10] Adel Y. I. Ashyap, Zuhairiah Zainal Abidin, Samsul Haimi Dahlan, et.al, "Highly Efficient Wearable CPW Antenna Enabled by EBG-FSS Structure for Medical Body Area Network Applications", IEEE Access November 26, 2018, date of current version December 31, 2018. *Digital Object Identifier 10.1109/ACCESS.2018.2883379,* VOLUME 6, 2018, pp. 77529 – 77541.

[11] Sung Yun Jun, A. Elibiary, Benito Sanz-Izquierdo, et.al, "3-D Printing of Conformal Antennas for Diversity Wrist Worn Applications", IEEE TRANSACTIONS ON COMPONENTS, PACKAGING AND MANUFACTURING TECHNOLOGY, VOL. 8, NO. 12, DECEMBER 2018, pp. 2227-2235.

[12] Rexiline Sheeba, Jayanthy T, "Design and implementation of flexible wearable antenna on thyroid gland in the detection of cancer cells", *Biomedical Research 2018; Volume 29 Issue 11*, pp. *2307-2312*.

[13] Aykut Cihangir, Frederic Gianesello, Cyril Luxey, "Dual-Antenna Concept with Complementary Radiation Patterns for Eyewear Applications", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 66, NO. 6, JUNE 2018, pp. 3056 – 3063.

[14] Adel Y. I. Ashyap, Zuhairiah Zainal Abidin, Samsul Haimi Dahlan, et.al, "Inverted E-Shaped Wearable Textile Antenna for Medical Applications", IEEE Access, June 14, 2018, date of current version July 12, 2018. *Digital Object Identifier 10.1109/ACCESS.2018.2847280, pp.* 35214 – 35222.

[15] Carlos Mendes, Custodio Peixeiro, "A Dual-Mode Single-Band Wearable Microstrip Antenna for Body Area Networks" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 16, 2017, pp. 3055 – 3058.

[16] Gaosheng Li, Yi Huang, Gui Gao, et.al, "A Handbag Zipper Antenna for the Applications of Body-Centric Wireless Communications and Internet of Things", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 65, NO. 10, OCTOBER 2017, pp. 5137 – 5146.

[17] Adel Y. I. Ashyap, Zuhairiah Zainal Abidin, Samsul Haimi Dahlan, et.al, "Compact and Low-Profile Textile EBG-Based Antenna for Wearable Medical Applications", IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 16, 2017, pp. 2550 – 2553.