International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 12 • Issue 1 pp. 13-18 Jan 2020-June 2020 www.csjournals.com

A Review of Wearable Antenna

Asha P. Ghodake[1], B. G. Hogade[2]
[1]Electronics and Telecommunication Engineering, [2]Electronics Engineering
[1]Bharati Vidyapeeth College of Engineering, [2]Terna Engineering College, [1,2]Navi Mumbai, India

Abstract - Utilization of textiles in antenna designing has been seen due to increase in wireless communication. Wearable antenna is used to perform functions when they are worn and have different applications like light weight, low cost, low profile and less maintenance. There are different examples of wearable antenna like in smart watch there is Bluetooth antenna, WIFI antenna, GPS antennas etc. now a day's wearable antenna is common in consumer electronics. A wearable antenna is used for tracking, communication, navigation, public safety. This paper includes different structures of wearable antenna, different materials used, and different applications according to recent development in wearable technology.

Keywords - Bluetooth Antenna, Low profile, navigation, Wearable Antenna, WIFI antenna

Introduction

Now a day's body centric communication gain more attraction and interest in antennas used for body centric communication is increased. Use different elements that are directly built on different body parts for capturing and communicating of data such as antenna; it is useful for monitoring physiological signs of individual in real time [1]. Most dominant research topic in wearable technology is fabric or textile based antenna. Because cloths are everyday's need of people and it is natural to integrate electronic devices in cloths and convert it in to smart cloths.

Smart cloth means to sense and respond according to environment; again they are divided in to active textile and passive textile. A smart textile has challenge in different fields like sports, fashion, military, medicine and healthcare [2]. Most of the applications requirement is light weight, low cost, almost maintenance-free and no installation, so wearable antenna fulfill the listed requirements [3]. These types of antennas are applicable to all types of aged people and also for sportsman for monitoring purpose.

For designing of textile antenna requirement is study and knowledge of electromagnetic properties of textile related to permittivity and loss tangent of textile material. There are two different types of textile i.e. conductive and non conductive textiles. Conductive textile is used as a radiating element and non conductive textile is used as a substrate. Examples of conductive textile are Zelt, Flectron and non-conductive textile such as silk, felt and fleece. There are different methods of measurement of dielectric properties of textile which is included in [4].

Types of Wearable Antenna

A. Conventional Wearable Designs

Conventional antennas include microstrip patches, different planar structures like monopole, dipole etc. all structures are planar so they are manufactured on printed circuit board (PCB). They have advantages as low cost, easy fabrication. In [5] implementation of planar inverted F antenna, it is comes under wearable technology. Antenna is fitted on the sleeves of cloths. This is a type of quarter wave monopole antenna. Monopole patch antenna is presented in [6] it is designed on FR 4 substrate shown in Fig 1 for body wireless communication. In this rectangular slot is created on top patch and ground, return loss of fabricated and simulated antenna is observed they are similar.

Fig 1 Fabricated antenna using FR 4

International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 12 • Issue 1 pp. 13-18 Jan 2020-June 2020 www.csjournals.com

Proposed spiral wearable antenna in [7] obtains maximum bandwidth. Frequency of antenna is depends up on length of spiral. Antenna is fabricated on FR 4 substrate and simulated using HFSS software. Return loss, radiation pattern and surface current distribution is observed for fabricated antenna.

U- shaped slot dual-band microstrip feed wearable antenna has been designed and fabricated using foam clad for WLAN/Wi-Fi and WBAN applications. Substrate used is foam clad with dielectric constant of 1.05. The return loss observed was -21 dB at 2.425 GHz and -25 dB at 5.750 GHz. The impedance bandwidth is less so challenge is to increase bandwidth for better performance [8]. The antenna can be used for ultra wideband applications, it rejects higher band of WLAN i.e. WLAN 5.25-GHz band. The proposed antenna structure is designed using CST Microwave Studio. This coplanar waveguide-fed UWB antenna has been designed on an ultra-thin liquid crystal polymer (LCP) substrate with relative permittivity of 2.9 and a thickness of 0.05 mm. The observed return loss and radiation pattern have negligible variations when bent at different angles or placed in different atmospheric conditions like heat and humidity [9].

Fig 2 Designed antenna bent at different angles 0^o and 45^o

Open-ended microstrip spiral sensors was designed to measure blood glucose shown in Fig 3. The standing wave that is produced on the spiral-shaped microstrip transmission line is end coupled to an output trace that samples the spiral signal. A microwave vector network analyzer (VNA) was used to measure the swept-frequency response [10].

Fig 3 Close-up of spiral sensor

B. Textile Antenna Designs

In textile antenna design textile is used as substrate rather than conventional FR 4 substrate and it is useful for smart clothing application. In paper [11] wearable antenna design for medical applications is used. Soft textile material is used as substrate. Reflection coefficient is observed according to no bending and bending condition (on arm). So effect of bending is minor on reflection coefficient and radiation pattern. So it is easily embedding this type of antenna in clothing. Wearable antenna design for Bluetooth/WiFi communication is presented in [12]. For the patch and the ground plane the conductive garment is used shown in Fig 4. The antenna is tuned to the center frequency of 2.45 GHz. By the simulation results it has been shown that the antenna with the chosen conducting material has low radiation losses, similar to the case of the copper.

Fig 4 Wearable antenna using jeans substrate

A full textile microstrip ultra wideband antenna is designed for wireless body area networks [13]. The materials used for antenna is shield it super as conductor and felt is used as substrate. It covers 3 to 10 GHz band. The proposed antenna evaluated both in free space and on body. Simulated and measured results are observed similar.

Textile UWB Antennas for Wireless Body Area Network is designed. High conductive metalized Nylon fabric is used as conductor, it has three metalized layers provide high conductivity, and it provides against corrosion and also provides maximum flexibility. Acrylic fabric is used as a substrate [14]. A circularly polarized antenna radiates wave in both the horizontal and vertical planes and all planes in between [15] so if there is change in body orientation the antenna can continuously receive signals. In antenna designing Substrate used is polymide spacer fabric with 6 mm thickness and has a permittivity of 1.5 and conductive material used is a nickel plated woven textile for the antenna patch and the ground plane.

A textile patch antenna Fig 5 designed for WBAN applications at 2.45 GHz ISM band. In this antenna design uses denim as substrate and conductive fabric for the ground plane and radiator layers. The parameters considered in the analysis are the relative permittivity and thickness of denim and the width and length of the rectangular patch radiator. The dependence of the central operation frequency of the antenna on those parameters was studied using the antenna reflection coefficient obtained from EM simulations [16] [17] .

Fig 5 Textile patch antenna Front view and Back view

Coplanar waveguide fed wearable antenna for ISM band (2.4–2.5 GHz), Wi-Fi, WLAN (2.4–2.48 GHz), WiMAX (3.4–3.6 GHz), and fixed satellite service (3.6–3.7 GHz and 9–11.5 GHz) applications. The designed antenna on jeans substrate (50 × 40 × 1.6 mm) provides a 1.7 GHz bandwidth with a gain of 4.6 dB given in Fig 6 [18].

Fig 6 Fabricated model.

II Designing of Wearable Antenna:

A. Material for conducting Patch and Substrate

In this paper [19] four different types of textiles are used as substrate. Cotton, polyesters, Lycra and coudura with different values of dielectric constant at same frequency that is 2.45GHz is selected. Using four substrate different antenna parameters are calculated. Maximum value of gain, directivity and efficiency are obtained using polyester. The monopole antenna is constructed by conductive fabric ShieldIt Super, for both radiators, at the top and ground plane, at the bottom of the antenna. Two different types of substrates are used felt and fleece textiles. Fleece produces larger bandwidth than felt. Felt based antenna produce better return loss [20].

This design includes flannel fabric as substrate material. Flannel fabric is a kind of 100% cotton material and for radiating patch two types of conducting materials are used Firstly, copper conducting sheet with a thickness of 0.03 mm and another is Shieldit conducting fabric with a thickness of 0.17 mm are called as electro textile material [21]. Now a day's polymer based conductive material loaded with conductive nanoparticles gain more attention such as copper, silver, and gold. They have properties like high tensile strength, fabrication viability and hydrophobic properties [22]. Electro textile antenna consists of Nickel plated silver plated which is strong and flexible, Flectron it is a copper-coated nylon fabric, and Nora conductive fabrics are used shown in Fig 7 [23].

Fig 7 Different conductive textile materials

Table 1 shows different textile materials with their permittivity and loss tangent values.

Table 1. Fabric with ε_r and tan ɗ

Sr No	Nonconductive Fabric	ε_r	tan ɗ
1	Felt	1.22	0.016
2	Cordura	1.90	0.0098
3	Cotton	1.60	0.0400
4	Polyester	1.90	0.0045
5	Quartzel Fabric	1.95	0.0004
6	Lycra	1.50	0.0093
7	Silk	1.75	0.012
8	Tween	1.69	0.0084
9	Jeans	1.70	0.025

B. Fabrication Methods

What are the different fabrication techniques are used in designing a textile antenna, is also another important consideration, it is also related to defining and determining the overall cost of the design. So fabrication technique and overall cost will be partially determined by the materials used in designing a textile antenna. The work in [24] used different fabrication techniques. The use of copper tape is the simplest technique, as it can directly be applied to the substrates, and has no extra fabrication process. Another one is a conductive spray technique which is applicable to any textile material. Spray includes a mixture of copper with gases under pressure and it can be used to construct a conductive layer on the textile surfaces.

Another method is to use a conductive textile yarn that can be weave or knit the conductive patterns of the antenna onto any nonconductive textile substrate. A traditional digital embroidery machine is used to weave the radiating elements of the antenna on textile fabrics. Performance is improved using e textile conductive fabric in comparison to the same antenna fabricated using copper tape [25]. Another method is the screen printing method. It is a low-cost solution for the fabrication of wearable antennas. This manufacturing method, the ink is pressed through a screen by using a blade. The screen consists of a mesh of fabric threads whose non image areas are blocked out using a stencil (emulsion) whereas, in the image areas, the screen is left open.

3D Inkjet Printing Technique Conductive materials for printed and flexible antennas include various conductive inks and pastes which provide critical performance characteristics of a printed pattern. The conductive material ink include the metallic solution of silver, gold, copper, and nickel nanoparticles, conductive polymers, carbon nanotubes, and grapheme. All conductive material provides different advantages to the final conductive system. Inkjet printers can be divided into two basic groups based on their operation procedure: continuous and drop-on-demand [26].

Conclusion

Wearable antenna plays vital role in wireless on body centric communication. The fabrication techniques and material used in designing textile antenna play a significant role in defining and determining the overall performance. In this paper the importance of wearable antenna is mentioned along with what are the different types of wearable antenna, which are the different materials are used by considering different fabrication methods and different applications of wearable antenna. So wearable antenna is used on different body parts to communicate and sense.

References

[1] Langereis G.R, Bouwstra S, Chen W. “Sensors, Actuators and Computing Architecture Systems for Smart Textiles.” In Smart Textiles for Protection; Chapman, R., Ed.; Woodhead: Cambridge, UK, 2012; Volume 1, pp. 190–213.

[2] Koncar V. “Introduction to smart textiles and their applications.” In Smart Textiles and their Applications; A Volume in Woodhead Publishing Series in Textiles; Woodhead Publishing: Cambridge, UK, 2016; pp. 1–8.

[3] Merli. F, L. Bolomey, Meurville. E, and Skrivervik. A.K, “Implanted Antenna for Biomedical Applications”, IEEE Antennas and Propagation Society International Symposium, San Diego, CA, 1-4, 2008.

[4] Zhu S.Z and Langley R. “Dual-band wearable textile antenna on an EBG substrate”. IEEE Transactions on Antennas and Propagation, 57 (4). pp. 926-935, 2009.

[5] P. Salonen, L. Sydanheimo, M. Keskilammi, M. Kivikoski, “A small planar inverted-F antenna for wearable applications”. the Wearable Computers, 1999.

[6] Rao, T. R., Reddy, B. N. B., Tiwari, N., Srivastava, P., & Balachary, M. (2017) “Wideband wearable antenna for body wireless communications” Global Wireless Summit IEEE conference (GWS). doi:10.1109/gws.2017.8300292

[7] Vigneshwaran, C., Alex, Z. C., & Shambavi, K. “Design and analysis of spiral wearable antenna.” IEEE International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE). doi:10.1109/icgccee.2014.6922252

[8] Singh, R. K., & Gupta, A. “Design and Development of U-shaped slot Wearable Antenna for WLAN/Wi-Fi and WBAN Applications.” 2018 IEEE International Conference on Advances in Computing, Communication Control and Networking (ICACCCN). doi:10.1109/icacccn.2018.8748834.

[9] Abbasi, Q. H., Rehman, M. U., Yang, X., Alomainy, A., Qaraqe, K., & Serpedin, E. (2013). Ultrawideband Band-Notched Flexible Antenna for Wearable Applications. IEEE Antennas and Wireless Propagation Letters, 12, 1606–1609. doi:10.1109/lawp.2013.2294214

[10] Jean, B. R., Green, E. C., & McClung, M. J. (2008). A microwave frequency sensor for non-invasive blood-glucose measurement. 2008 IEEE Sensors Applications Symposium.

[11] Pei, R., Wang, J., Leach, M., Wang, Z., Lee, S., & Lim, E. G. (2016). Wearable antenna design for bioinformation. 2016 IEEE Conference on Computational Intelligence in Bioinformatics and Computational Biology (CIBCB). doi:10.1109/cibcb.2016.775812

[12] Schilingovski, P., Vulfin, V., Sayfan-Altman, S., & Shavit, R. (2017). Wearable antennas design for wireless communication. 2017 IEEE International Conference on Microwaves, Antennas, Communications and Electronic Systems (COMCAS). doi:10.1109/comcas.2017.8244796

[13] Samal, P. B., Soh, P. J., & Vandenbosch, G. A. E. (2014). UWB All-Textile Antenna With Full Ground Plane for Off-Body WBAN Communications. IEEE Transactions on Antennas and Propagation, 62(1), 102–108. doi:10.1109/tap.2013.2287526

[14] Klemm, M., & Troester, G. (2006). Textile UWB Antennas for Wireless Body Area Networks. IEEE Transactions on Antennas and Propagation, 54(11), 3192–3197. doi:10.1109/tap.2006.883978

[15] C.A. Balanis, Antenna Theory: Analysis and Design. 3rd Ed. New York: John Wiley and Sons. Pg.859, 1997.
[16] Grilo, M., & Salete Correra, F. (2013). Parametric study of rectangular patch antenna using denim textile material. 2013 SBMO/IEEE MTT-S International Microwave & Optoelectronics Conference (IMOC).
[17] A. P. Ghodake and H. B. Sale, "Gain Enhancement of Microstrip Antenna," 2018 International Conference on Advanced Computation and Telecommunication (ICACAT), Bhopal, India, 2018, pp. 1-6.
[18] Mudunuri Padmanabha Raju · D. S. Phani Kishore · B. T. P. Madhav "CPW Fed T-Shaped Wearable Antenna for ISM Band, Wi-Fi, WiMAX, WLAN and Fixed Satellite Service Applications" Journal of electromagnetic engineering and science, vol. 19, NO. 2, 140~146, APR. 2019
[19] Potey, P. M., & Tuckley, K. (2018). Design of wearable textile antenna with various substrate and investigation on fabric selection. 2018 3rd International Conference on Microwave and Photonics (ICMAP). doi:10.1109/icmap.2018.8354539
[20] Rahim, H. A., Abd Malek, M. F., Adam, I., Mohd Affendi, N. A., Saudin, N., Mohamed, L., … Hall, P. S. (2012). Effect of different substrate materials on a wearable textile monopole antenna. 2012 IEEE Symposium on Wireless Technology and Applications (ISWTA). doi:10.1109/iswta.2012.63738
[21] Osman, M. A. R., Rahim, M. K. A., Samsuri, N. A., Elbasheer, M. K., & Ali, M. E. (2012). Textile UWB Antenna Bending and Wet Performances. International Journal of Antennas and Propagation, 2012, 1–12. doi:10.1155/2012/251682
[22] M. Park et al., ''Highly stretchable electric circuits from a composite material of silver nanoparticles and elastomeric fibres,'' Nature Nanotechnol., vol. 7, pp. 803–809, Nov. 2012.
[23] J.G. Santas, A. Alomainy, H. Yang, "Textile Antennas for OnBody Communications: Techniques and Properties". the Antennas and Propagation, 2007. EuCAP 2007.
[24] A. Tsolis, W. G. Whittow, A. A. Alexandridis, and J. Vardaxoglou, ''Embroidery and related manufacturing techniques for wearable antennas: Challenges and opportunities,'' Electronics, vol. 3, no. 2, pp. 314–338, 2014.
[25] Mahmuda Akter Monne, Xing Lan, Maggie Yihong Chen "Material Selection and Fabrication Processes for Flexible Conformal Antennas" Hindawi, Volume 2018 |Article ID 9815631 | 14 pages | https://doi.org/10.1155/2018/9815631
[26] Lakafosis, V.; Rida, A.; Vyas, R.; Yang, L.; Nikolaou, S.; Tentzeris, M.M. Progress Towards the First Wireless Sensor Networks Consisting of Inkjet-Printed, Paper-Based RFID-Enabled Sensor Tags. Proc. IEEE 2010, 98.