

Review on Wearable Antennas and their Applications

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Abstract

Wearable antennas are one of the primary sources for the Body Area Networks (BAN). It allows the users to sense, communicate, transfer and exchange data to a remote server with the help of IoT gateway. The size, speed, and power consumption play a major role in the design of wearable antennas. In most of the applications, the wearable antennas are connected over the cloth of the user and in rare cases the antenna is fixed over or under the skin of the user. The motive of this paper is to review the technologies behind the design of wearable antennas and their applications in various fields. Moreover, the paper determines the research gap in the field of wearable antenna designing.

Keywords: Wearable devices, body centric communication, wireless body area networks, IoT, antenna design

1. Introduction

Antenna is a kind of transducer that converts the alternating fields into a radio frequency wave. Wearable antennas are designed to do communication to its source station while worn and moving. To attain this, the wearable antennas are made with the textile materials. Therefore the properties of the dielectric materials are manipulated during the design. Similarly certain performance based improvements are also necessary to make a clear working property of a wearable antenna. Because there will be a change in performance of the antenna when it is in free space and other places. The water absorption and the physical changes on human body will make a great change in the performances of wearable antennas. Figure 1 indicates the major applications of the wearable antennas.

Wearable antennas are widely used in medical applications for monitoring the health status of the patients from a remote place. The ingestible antennas are employed for

endoscopy studies and that gives a better result over the conventional probe based techniques. However, the quality of the endoscopy images are majorly depends upon the efficiency of the connected antenna structures. The on-body wearable antennas are used to observe and transmit the body parameters like heart rate, temperature and blood pressure with the help of sensors. The implantable antennas are the other kind of wearable antenna that keeps the device inside the human body. Such antennas are used for retinal prosthesis, brain activity monitoring and oral implants.

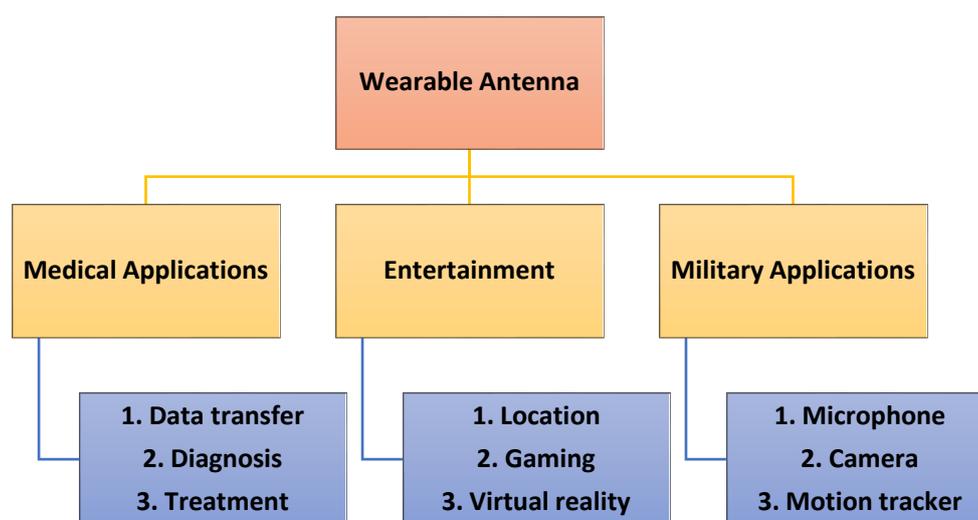


Figure 1. Applications of wearable antennas

The wearable sensors are even applied to the entertainment based applications for gaming and virtual reality interactions. In some places, the sensors and antennas are incorporated to the watches and shoes to make the wearables as intelligent devices. The wearable bands are also utilized for detecting the location of the users through a global positioning system. The miniaturized wearable antennas are used in military applications for microphone and camera module for transferring the data.

1.1 Challenges on making Wearable Antennas

The human body has a nature of observing electromagnetic waves from the surrounding field. Hence it results in affecting the efficiency of an antenna while it is kept near to a human body. An antenna that is showing an efficiency of -2 dB (60%) in free space may give an efficiency outcome of -15dB (5%) while keeping over a human body. Similarly, the wearable antennas are need to be in small in size for the comfortable of a user and its needs to be more convenient in every action of the user.

The wearable antennas are expected to provide 50% of efficiency at on-body and free space scenario. At the same the radiation pattern of the antennas are need to be taken into account to overcome the electromagnetic absorption of the human body. Mechanical properties like size, weight and flexibility are also playing a major role in limiting the antenna several applications. The wearable antennas are expected to produce a low Specific Absorption Rate (SAR) of world standard to maintain the safety of the user.

2. Literature Survey

The experimental attainments and the design metrics followed in the design of wearable antennas are shown in the following table 1. The analysis is taken from the recent studies that are not beyond the year 2018.

Table 1. Survey on Wearable Antennas and its Achievements

S.No	First Author & Citation	Design and materials	Application	Attainments
1.	Smida [1]	semi-flexible material of RT/duroid 5880 ($\epsilon_r = 2.2$, $\tan\delta = 0.0004$)	Bio-Telemetry	Gain = 2.50 dBi at 2.4 GHz Efficiency = 93 % at 2.4 GHz
2.	Roudjane [2]	Multimaterial fiber	Wireless Communication	wireless network applications at 2.4 GHz frequency
3.	Simorangkir [3]	polydimethylsiloxane polymer of 80 mm \times 67 mm	Biomedical application	3.7-10.3 GHz band
4.	Le [4]	Dual band antenna with semiflexible substrate	Wireless body-area network	2.45/5.85 GHz with maximum peak gains of 2.1 dBi and 3.5 dBi
5.	Wang [5]	Denim material and copper tape as substrate and radiating material	Dual band textile wearable antenna	2.45GHz and 5.8GHz
6.	Zu [6]	Graphene film and	Wireless body-	5.8 GHz with a profile

		polydimethylsiloxane substrate	area network	of 0.05λ at SAR of 500 mW
7.	Kiani [7]	Rogers 4003C substrate with $35 \text{ mm} \times 35 \text{ mm} \times 0.508 \text{ mm}$	Biomedical application	Gain = 7.3 dBi at 2.45 GHz with acceptable SAR
8.	El [8]	Textile substrate with reflection coefficient (S11)	UWB antenna for textile wearable application	3.1 GHz to 11.3 GHz bandwidth efficiency = 60% Gain = 4 dB.
9.	Yalduz [9]	Thickness of 4.68 mm in metamaterial with 100×100	UWB antenna	4.55 and 13 GHz Gain = 6dBi
10.	Wagih [10]	Multi-layered fabric substrate	Textile antenna/rectenna	100 MHz with an S11 under -10 dB around 2.4 GHz
11.	Roy [11]	Metamaterial resonator structure	Dual band wearable antenna	bandwidth from 1.6 to 2.56 GHz (46%) with 1.6 dBi and 4.24 to 7 GHz (49.11%) with 5 dBi
12.	Aprizal [12]	Flexible dielectric material of RO3003 in 3×3 square patches with thickness of 0.5 mm	Flexible antenna	Frequency of 2.45 GHz
13.	Karthikeyan [13]	Bed sheet cotton substrate with a relative permittivity of 3.27 with $40 \text{ mm} \times 34 \text{ mm} \times 1.26 \text{ mm}$	Wireless body area network	Frequency of 2.45 GHz
14.	Ram [14]	Jute fabric substrate with circularly polarized design	Wearable antenna	3.5 GHz, 4.9 GHz, and 5.8 GHz

15.	Mustafa [15]	Felt and Teflon substrate with dielectric constant 1.36 and 2.1	Biomedical applications	2.45GHz ISM band
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3. Discussion

The wearable antennas are widely used for biomedical applications where the operating bandwidth is 2.45GHz in maximum. However, the size and substrate materials are not found constant in any applications. The substrate materials play a major role in the efficiency of the antennas, at the same time the size acts as a secondary parameter for the improvement of the operating frequency. In very few places, the wearable antennas are found operating with dual and ultra-wide bands. Making a flexible wearable antenna that achieves more than 50% of operating efficiency on wearable medium is still open for research.

4. Conclusion

Wearable antennas are moving the communication medium to next level by transferring the data from various locations on movement. The major challenge in designing the wearable antenna is to maintain its efficiency with good flexibility. To achieve this, several types of substrates are considered by the designers based on the relative permeability of the materials. The thickness and size play the secondary role in designing a better antenna. This paper analyzes the application of wearable antennas in various scenarios and has projected the concentrated areas of the research. It explores that most of the wearable antennas are designed for biomedical applications rather than defense and entertainment purposes. Therefore, such areas are still open for further research.

References

- [1] Smida, Amor, Amjad Iqbal, Abdullah J. Alazemi, Mohamed I. Waly, Ridha Ghayoula, and Sunghwan Kim. "Wideband wearable antenna for biomedical telemetry applications." *IEEE Access* 8 (2020): 15687-15694.
- [2] Roudjane, Mourad, Mazen Khalil, Amine Miled, and Younés Messaddeq. "New generation wearable antenna based on multimaterial fiber for wireless communication and real-time breath detection." In *Photonics*, vol. 5, no. 4, p. 33. Multidisciplinary Digital Publishing Institute, 2018.

- [3] Simorangkir, Roy BVB, Asimina Kiourti, and Karu P. Esselle. "UWB wearable antenna with a full ground plane based on PDMS-embedded conductive fabric." *IEEE Antennas and Wireless Propagation Letters* 17, no. 3 (2018): 493-496.
- [4] Le, Tu Tuan, and Tae-Yeoul Yun. "Miniaturization of a dual-band wearable antenna for WBAN applications." *IEEE Antennas and Wireless Propagation Letters* 19, no. 8 (2020): 1452-1456.
- [5] Wang, Kai-hong, and Jiu-sheng Li. "Jeans textile antenna for smart wearable antenna." In *2018 12th International Symposium on Antennas, Propagation and EM Theory (ISAPE)*, pp. 1-3. IEEE, 2018.
- [6] Zu, Hao-Ran, Bian Wu, Ya-Hui Zhang, Yu-Tong Zhao, Rong-Guo Song, and Da-Ping He. "Circularly polarized wearable antenna with low profile and low specific absorption rate using highly conductive graphene film." *IEEE Antennas and Wireless Propagation Letters* 19, no. 12 (2020): 2354-2358.
- [7] Kiani, Sina, Pejman Rezaei, and Mina Fakhr. "A CPW-fed wearable antenna at ISM band for biomedical and WBAN applications." *Wireless Networks* 27, no. 1 (2021): 735-745.
- [8] El Gharbi, Mariam, Marc Martinez-Estrada, Raul Fernández-García, Saida Ahyoud, and Ignacio Gil. "A novel ultra-wide band wearable antenna under different bending conditions for electronic-textile applications." *The Journal of The Textile Institute* 112, no. 3 (2021): 437-443.
- [9] Yalduz, Husnu, Timucin Emre Tabaru, Veli Tayfun Kilic, and Mustafa Turkmen. "Design and analysis of low profile and low SAR full-textile UWB wearable antenna with metamaterial for WBAN applications." *AEU-International Journal of Electronics and Communications* 126 (2020): 153465.
- [10] Wagih, Mahmoud, Geoffrey S. Hilton, Alex S. Weddell, and Steve Beeby. "Dual-polarized wearable antenna/rectenna for full-duplex and mimo simultaneous wireless information and power transfer (swipt)." *IEEE Open Journal of Antennas and Propagation* 2 (2021): 844-857.
- [11] Roy, Sourav, and Ujjal Chakraborty. "Metamaterial based dual wideband wearable antenna for wireless applications." *Wireless Personal Communications* 106, no. 3 (2019): 1117-1133.
- [12] Aprizal, Muhammad, Levy Olivia Nur, Bambang Setia Nugroh, and Achmad Munir. "Flexible artificial magnetic conductor reflector for wearable antenna application."

- In 2018 Progress in Electromagnetics Research Symposium (PIERS-Toyama), pp. 1859-1862. IEEE, 2018.
- [13] Karthikeyan, S., Yedduri Venu Gopal, V. Giri Narendra Kumar, and T. Ravi. "Design and analysis of wearable antenna for wireless body area network." In IOP Conference Series: Materials Science and Engineering, vol. 590, no. 1, p. 012022. IOP Publishing, 2019.
- [14] Ram Sandeep, D., N. Prabakaran, B. T. P. Madhav, K. L. Narayana, and P. Rakesh Kumar. "Systematic investigation from material characterization to modeling of jute-substrate-based conformal circularly polarized wearable antenna." *Journal of Electronic Materials* 49, no. 12 (2020): 7292-7307.
- [15] Mustafa, Ameena Banu, and Tamilselvi Rajendran. "An effective design of wearable antenna with double flexible substrates and defected ground structure for healthcare monitoring system." *Journal of Medical Systems* 43, no. 7 (2019): 1-11.

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