A Survey – Wearable Antenna Techniques and its Applications

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Abstract

Smart Antenna is an array of antennas which uses the smart signal processing algorithms to track and locate the client device using the direction of arrival of a signal. Smart Wearable Antennas are designed to function while being worn. Wearable antennas are used within the context of Wireless Body Area Networks. The wearable antenna is high in efficiency, miniature in size, and simple in structure, and is implemented with electrical performance and polarization effects, which helps in healthcare, medical and military applications, smart glasses, sensor devices in sports, etc. This research study reviews different wearable antenna technologies such as wearable textile antenna, microstrip antenna and wearable antenna array. Furthermore, the integrated different next generation antennas are also discussed.

Keywords: Wireless Body Area Networks; Wearable Antennas; Smart Antenna; Microstrip Antenna

1. Introduction:

Antennas are simple devices which are mainly used to transmit and receive the electromagnetic waves to communicate or broadcast the data at the speed of light. The 5G technology is the fifth generation technology used to broadcast the cellular networks with higher performance and improved efficiency, and connects the users and industries. The technology uses higher radio frequencies to carry the large amount of data at a faster rate. For connecting and transmitting the signals over the air, the antennas are used.

Wearable antennas are antennas that are functioned or designed to be worn [1]. Some of the wearable antenna applications are: smartwatches that are integrated with Bluetooth antenna, smart glasses which can be accessed through the Wi-Fi and GPS antennas, etc. The wearable antenna can also be placed in the human body to check their health by using the ECG sensor, blood pressure sensor, oximetry sensor and so on [2]. These antennas are commonly used in wireless communication systems and bio-medical radio frequency fields.

The traditional communication device cannot add extra power to the signal, thus it simply directs the energy which was received to the transmitter. The redirection of the energy provides large energy in one side and small energy in the other. The role of the wearable antenna helps to monitor the sensors and to transmit the signals to the receiver side. Recently, the wearable antennas have been developed for the medical and military fields. Especially in the medical field, it helps to monitor the old age patients by using the different sensors that are fixed as the Wireless Body Area Network (WBAN). The ECG sensor, blood pressure sensor, oximetry sensor and so on are used for the continuous monitoring of the patients. The first wearable technology which is the pulsar calculator watch [3], was invented in the United States in 1975. For the first time, a calculator was included in a wrist watch created by Pulsar. With the advancement of wearable technologies, it is now used in smartwatches, smart glasses, mobile phones, wearable applications, and so on. Wearable antennas are currently used in military and medical applications, GPS, IoT, WLAN, WBAN, wearable technologies, 5G technologies, and other applications.

1.1 Progress of Wearable Antenna:

The newly structured wearable antennas have been developed and are in use all around the world. Some advanced antenna structures are described.

1.1.1 Wearable Textile Antenna:

Mobile phones are now used and taken anywhere in the world. Similarly, the antennas are manufactured tiny so that they can be carried when the antenna is worn in our cloth [4]. Textile antennas are partially or fully made-up of textile materials that have a low dielectric constant, which decreases surface wave loss and increases antenna bandwidth. The WBAN is a wearable textile antenna that may be used in a variety of sectors. It is embedded in the textile materials to monitor the health of employees, senior people, patients, military personnel, and others.

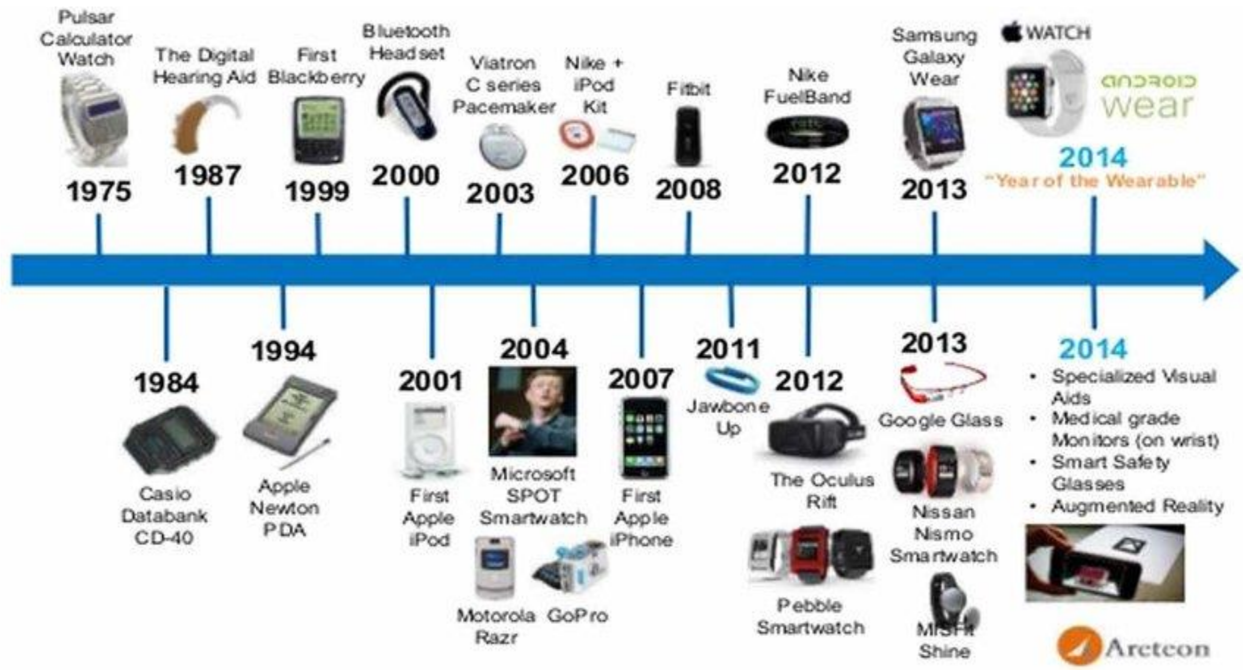

Figure 1. Timeline of wearable antenna [3]

1.2 Conductive Flexible Fabric Antenna

There are usually tests on the flexibility of any material. As a result, the antenna is embedded into fabric or polymers that are readily flexible in nature. Antennas can be created using metalized textiles or by carefully weaving conductive threads together to obtain exact antenna dimensions. When the sensors are attached to the WBAN, the antennas can wirelessly communicate the data via a textile antenna built into the fabric.

1.3 Wearable Antenna Array

A Wearable Antenna Array is a group of antennas that have been integrated and configured to act as a single antenna to broadcast or receive radio waves while being worn. In an antenna array, improved performance is gained, power wastage is reduced, signal strength rises, and higher directional signals are obtained. It is maintained adaptable for wearable applications [5], so that it can receive a big volume of data from the array. As a result, it is employed in data maintenance, such as GPC tracking, IoT applications, 5G technologies, and so on.

Figure 2. Wearable Antenna used in various fields [5]

2. Literature Survey

Salman, et al. [6], proposed a graphene embedded silver nanocomposites for antenna design. The logo-shaped antenna was made of graphene silver nanocomposites on a textile substrate and radiated at 2.45GHz using a microstrip feeding method. Computer Simulation technology studio application software was used to create the results, which enhanced antenna features such as far-fields, return loss, and voltage standing wave ratio. This innovative antenna design is being used for the materials transformation in improved communication and wireless sensing applications. This study provides the wearable antenna properties such as conversion efficiency, antenna size, and gain, as well as an overall exhibited and analysed wearable antenna. Different ideas were discussed in the study for improving the overall wearable antenna design, boosting conversion efficiency, and lowering the size, so that it can be used in WBAN and Radio Frequency Identification (RFID) applications.

In study [7], the wearable antenna releases RF-EMFs from human exposure. A wearable antenna with a frequency set at 2.5GHz was evaluated in an actual configuration, and compared with a male and female model. Computational approaches were used to estimate SAR10g ranges at 1W input power exposure levels. The determined configuration values had a greater exposure value when the antenna was positioned on the arm and a higher exposure on the male model. The exposure was higher when the antenna was put close to the arm, leg, and shoulder when using the Effect of Anatomical Variability model, but the exposure was higher when the antenna was positioned close to the chest and to the ankle when using the Ella model. This study emphasised the significance of exposure antenna performance when fixed on a human wearable, given the advent of wearable technology and its wide range of applications, particularly in medical and military domains.

In article [8], the antenna sensor and E-textile sensor were used to monitor people's health. The usage of a wearable antenna for respiratory monitoring based on a low-profile broadband completely textile antenna was discussed. The antenna reached a steady bandwidth throughout the body and on the chest, allowing for wearable sensing. The suggested construction was basic and did not depend on active particular materials. A simple peak detection technique was employed to demonstrate 100% breathe detection results. Without the need of any other manufacturing procedures, passive wireless breathing sensors were produced and incorporated on various fabrics. Textile antennas were used as very precise sensors for respiration monitoring, with no special sensing materials required.

Bhattacharjee et al [9], proposed a flexible antenna with wideband properties and a conical radiation pattern for appropriate on-body applications. To get a sense of the tiny antenna size, a characteristic model analysis was done first. The ground plane of the antenna was employed to produce the resonant modes, and the quasi-current loop in the feed layer patch generated the other resonant modes. Thus, the combination of the two resonant modes resulted in the antenna's wideband performance ranging from 4.72GHz to 6.08GHz. A planar wideband Artificial Magnetic Conductor (AMC) was installed under the antenna, lowering the Specific Absorption Rate (SAR) to 76.4 percent while increasing the antenna's gain. According to the findings of the study, the performance of the antenna in areas of return loss, flexible design, compact size, broad bandwidth, low SAR, and bending sensitivity makes it a good choice for on-body wearable applications.

The design and implementation of an embroidered meander dipole antenna-based sensor embedded into a T-shirt for real-time breathing monitoring based on chest movement analysis were discussed in work [10]. The sensor's embroidered antenna was constructed of silver coated nylon thread. The suggested antenna sensor was built inside the T-shirt and situated in the chest area. The breathing antenna was intended to work at 2.4GHz. The usage of resonant frequency shift is a sensing mechanism that will be continually monitored in real-time utilising the Vector Network Analyzer to a distant PC or LAN. To capture the respiration data, a Matlab software was created. This system might be utilised in healthcare applications, such as monitoring persons with Pulmonary Edema or Asthma. The suggested antenna-based sensor has the benefits of being wearable, small in size, constant in performance, and free of fabrication challenges.

Wearable applications that are flexible, lightweight, and convenient to carry are in high demand in the rising economy. Wearable antennas must satisfy certain electrical, mechanical, manufacturing, and safety standards for IoT wearable devices. Atanasov et al., [11] proposed studying SAR produced in erythrocyte suspensions by textile wearable antennas. The outcomes of in vitro investigations were on the stability of human erythrocyte membranes under both exposure scenarios. The results showed that irradiating erythrocyte membranes for a short period of time in the reactive near-field of a wearable antenna at 6.3mW input power had a stabilising impact. However, the erythrocyte membrane has a long-term destabilising impact.

In article [12], a minimise in the size of an antenna for medical applications and Internet of Things (IoT) in many nano applications was proposed by employing silicon. It also includes a new form of dynamic patch antenna aimed towards speech-enabled healthcare applications. A dynamic polarised antenna was conceived, analysed, and tried to be built. For the frequency range, the antenna gain was 132db. An antenna's polarised output was 19 dBm. Varactor diodes and voltage regulated diodes were utilised to produce reliable performance. This silicon wearable antenna may be manufactured and evaluated for use in a variety of medical applications such as health monitoring systems and pacemakers. Additionally, micromachining methods can be implemented to reduce silicon's practical dielectric constant and therefore enhance the radiation efficiency.

A Microstrip Ring Resonator was utilised in the paper [13], to investigate the dielectric characteristics of the fabric material used to create the wearable antennas and their bending implications at ISM band frequencies. It investigated the implications of bending for various feeding strategies for a wearable antenna. The robustness of the wearable antenna was evaluated by analyzing the antenna for return loss, gain, and efficiency under various bending curvatures. The E-plane bending has the greatest influence on impedance matching for wearable antennas. The aperture linked antenna has a low impedance bending impact. As a result, the performance of the wearable antenna was implemented.

Table 1. Different wearable antenna techniques and applications

S.No.	Reference	Technique	Application	Outcome	Advantages
1.	Salman et al. [6]	Graphene silver nano composites	Microstrip feeding technology & computer simulation technology	Used in WBAN & RFID	High efficiency, Minimized size
2.	Gallucci et al. [7]	SAR & human exposure	Wearable antenna devices	Exposure is high when antenna on arm, leg or shoulder	Development in different fields
3.	Wagih et al. [8]	Simple peak detection algorithm	E-textile breathing sensor & textile wearable antenna	Maintains stable bandwidth on human body	Used in different textiles

4.	Bhattacharjee et al. [9]	Ground plane of antenna & characteristic modal analysis	Artificial magnetic conductor	Suitable for on-body applications	AMC ground plane was applied, and the radiators were reduced.
5.	El Gharbi et al. [10]	Breathing antenna based sensor & meander dipole antenna-sensor	Vector network analyser, Matlab	Monitor people suffering from breathing disease	Wearable, compact in size and good performance.
6.	Atanasov et al. [11]	SAR, wearable antenna	Vitro experiments & finite difference time domain	SAR with biological effects investigated.	Stable –near field. Non stable-far field.
7.	Vignesh et al. [12]	Silicon wearable antenna, WBAN	For monitoring • Varactor diode • Voltage controlled diode	Range of antenna is 390 to 610 MHz. And the gain of antenna 13±2 db	Health monitoring, Pacemakers.

8.	Mallavarapu et al. [13]	Microstrip Ring Resonator & circuit model	Wearable antennas	Minimal bending	Better minimal bending performance
9.	Papachristou et al. [14]	2D pattern and 3D virtual technology	Fashion design software	Unlimited design choices, and decreased resource waste	Development will be digital
10.	Dejen et al. [15]	Binary-coded genetic algorithm	Three-layer human body phantom model	Multiband wearable antenna	Multi-functionality & impedance bandwidth of the antenna

The 2D and 3D pattern prototyping technology was utilised in article [14], to design conventional clothes with a wearable antenna included in an automated way, eliminating the compromise of the garment's elegance and comfort. To install, create, and include the antenna in a structured and fashioned manner, numerous commercial software were employed. The generated data were loaded into a commercial electromagnetic modelling tool to evaluate the overall antenna performance. Finally, the method provided limitless design alternatives while minimising resource waste.

Dejen et al. [15] designed a multi-band microstrip antenna at mm-wave frequencies for use as a wearable antenna. The patch antenna was built on a flexible polytetrafluoroethylene fabric substrate with dimensions and the patch shape was optimised using a binary coded evolutionary algorithm. The method generated the route surface, assessed the cost function, and delivered the antenna performance that was best-fitted. When the antenna is close to the phantom mode, the gain and radiation efficiency are dramatically reduced, and increased as the gap rises. Fabric substrates were used to assess and compare antenna performance. The optimised antenna is a promising contender for multiband body-centric communications.

3. Conclusion:

Wearable antennas will become more popular in the future, and they will be an indispensable technology for growth. As a result, the antenna should be more compact, micro-sized, and smart-device, and its functionality should transform the digital world. Thus, various wearable antennas will provide a good substitute in 5G and other communication technologies. This survey study describes the numerous wearable antenna technologies, applications and usage in many sectors. The creation and study of the wearable antenna will be advantageous to several areas in a variety of ways. Spray-on antennas and 5G advances antenna systems are the advanced developing antennas in the research stage.

References:

[1] Kaur, Harvinder, and Paras Chawla. "Recent Advances in Wearable Antennas: A Survey." *The Industrial Internet of Things (IIoT) Intelligent Analytics for Predictive Maintenance* (2022): 149-179.

[2] Christina, G. "Review on Wearable Antennas and their Applications." *IRO Journal on Sustainable Wireless Systems* 3, no. 4 (2022): 259-265.

[3] Afyf, Amal & Bellarbi, Larbi & Latrach, Mohamed & Gaviot, E. & Camberlein, Lionel & Sennouni, Adel. (2018). Wearable Antennas : “Breast Cancer Detection”.

[4] El Gharbi, Mariam et al. “A Review of Flexible Wearable Antenna Sensors: Design, Fabrication Methods, and Applications.” *Materials (Basel, Switzerland)* vol. 13,17 3781. 27 Aug. 2020, doi:10.3390/ma13173781

[5] Ikram, Muhammad, Kamel Sultan, Muhammad Faisal Lateef, and Abdulrahman SM Alqadami. "A Road towards 6G Communication—A Review of 5G Antennas, Arrays, and Wearable Devices." *Electronics* 11, no. 1 (2022): 169.

[6] Salman, Ahmad Rifhan, Mohd Muzafar Ismail, Jeefferie Abd Razak, and Siti Rosmaniza Ab Rashid. "Design of UTeM logo-shape wearable antenna for communication application by graphene silver nanocomposites." *TELKOMNIKA (Telecommunication Computing Electronics and Control)* 20, no. 3 (2022): 647-655.

[7] Gallucci, Silvia, Marta Bonato, Emma Chiaramello, Serena Fiocchi, Gabriella Tognola, and Marta Parazzini. "Human Exposure Assessment to Wearable Antennas: Effect of Position and Interindividual Anatomical Variability." *International Journal of Environmental Research and Public Health* 19, no. 10 (2022): 5877.

[8] Wagih, Mahmoud, Obaid Malik, Alex S. Weddell, and Steve Beeby. "E-Textile Breathing Sensor Using Fully Textile Wearable Antennas." *Engineering Proceedings* 15, no. 1 (2022): 9.

[9] Bhattacharjee, Shankar, Manas MIDYA, Sekhar Ranjan BHADRA CHAUDHURI, and Monojit MITRA. "A Wideband Wearable Antenna with AMC Ground Plane for WBAN Applications." *RADIOENGINEERING* 31, no. 2 (2022): 211.

[10] El Gharbi, Mariam, Raúl Fernández-García, and Ignacio Gil. "Embroidered wearable Antenna-based sensor for Real-Time breath monitoring." *Measurement* 195 (2022): 111080.

[11] Atanasov, Nikolay Todorov, Gabriela Lachezarova Atanasova, Boyana Angelova, Momchil Paunov, Maria Gurmanova, and Margarita Kouzmanova. "Wearable Antennas for Sensor Networks and IoT Applications: Evaluation of SAR and Biological Effects." *Sensors* 22, no. 14 (2022): 5139.

[12] Vignesh, N. Arun, Ravi Kumar, R. Rajarajan, S. Kanithan, E. Sathish Kumar, Asisa Kumar Panigrahy, and Selvakumar Periyasamy. "Silicon Wearable Body Area Antenna for Speech-Enhanced IoT and Nanomedical Applications." *Journal of Nanomaterials* 2022 (2022).

[13] Mallavarapu, Sandhya, and Anjaneyulu Lokam. "Circuit modeling and analysis of wearable antennas on the effect of bending for various feeds." *Engineering, Technology & Applied Science Research* 12, no. 1 (2022): 8180-8187.

[14] Papachristou, Evridiki, and Hristos T. Anastassiu. "Application of 3D Virtual Prototyping Technology to the Integration of Wearable Antennas into Fashion Garments." *Technologies* 10, no. 3 (2022): 62.

[15] Dejen, Arebu, Murad Ridwan, Jeevani Jayasinghe, and Jaume Anguera. "Multi-Band mm-Wave Wearable Antenna Synthesized with a Genetic Algorithm." *International Journal of Antennas and Propagation* 2022 (2022).

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