engineering proceedings

*Proceeding Paper*

# A Review on Wearable Antennas †

**Vimokshavardhan Daware [1,*] and Jagadish Jadhav [2]**

[1] Department of Electronics and Telecommunication Engineering, Dr. Babasaheb Ambedkar Technological University (DBATU), Lonere 402103, Maharashtra, India
[2] Department of Electronics and Telecommunication Engineering, R. C. Patel Institute of Technology (RCPIT), Shirpur 425405, Maharashtra, India; Jagadish.rcpit@gmail.com
* Correspondence: vadaware@gmail.com
† Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: https://asec2023.sciforum.net/.

**Abstract:** Specialized antennas called wearable antennas for biotelemetry wireless communication are made to be built into or worn on the body to allow wireless communication between devices like heart monitors, medical implants, and other bio-telemetry equipment. These kinds of antennas are usually incredibly small and need to be able to function properly while near a human body. Wearable antennas for wireless biotelemetry communication can be constructed from a range of materials, such as textiles, polymers, and metals. The UHF, ISM, and Medical Implant Communication Service (MICS) bands are among the several wireless communication frequencies in which they are intended to function. These antennas are essential for the wireless transmission of medical data, including vital signs, that are gathered by biotelemetry devices.

**Keywords:** Medical Implant Communication Service (MICS); ISM (Industrial; Scientific; Medical) band; MIMO (Multiple Input Multiple Output)

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**Citation:** Daware, V.; Jadhav, J. A Review on Wearable Antennas. *Eng. Proc.* **2023**, *56*, 133. https://doi.org/10.3390/ASEC2023-16627

Academic Editor: Nunzio Cennamo

Published: 14 December 2023



## 1. Introduction

Electronic devices that are worn on the body or embedded in clothing or jewelry, or implanted in the body, are known as wearable technology. Fitness tracking, health monitoring, communication, and entertainment are some of the applications that these devices can be used for. These devices are small, lightweight, and comfortable to wear. Fitness trackers, smartwatches, and smart glasses are some examples of wearable technology that are worn on the body. The devices are capable of tracking a user's physical activity, monitoring vital signs like heart rate, and providing notifications of incoming calls and messages. Smart clothing, such as shirts and pants embedded with sensors, are another example of wearable technology that can be used to monitor health, such as posture and breathing, and provide haptic feedback to wearers to improve their movements.

Wearable technology implants include heart pacemakers, cochlear implants, and deep brain stimulators. They are used to treat various medical conditions and can be controlled wirelessly.

It is anticipated that wearable technology will develop into more complex and high-tech devices with a greater variety of uses in the future. There is no doubt that wearable technology will continue to evolve and change the way we live and work in the future.

In short, wearable technology is the term for electronic devices that can perform a variety of activities when they are placed on the body, stitched into jewelry or clothing, or implanted within the body. Fitness tracking, health monitoring, communication, and entertainment are just a few of the many ways in which wearable technology can be employed. The future of wearable technology is expected to bring more advanced and sophisticated devices, with a wider range of applications, changing the way we live and work [1,2].

## 2. Biotelemetry Antenna Design

Biotelemetry antenna design refers to the design of antennas used in biotelemetry systems, which are used to wirelessly transmit and receive biological data from living organisms. These antennas are designed to be small, lightweight, and flexible, and to operate at specific frequencies that are suitable for transmitting data through the body.

1. Printed antennas: These are the most common type of biotelemetry antenna; they are simple to design, and inexpensive to manufacture. They are typically made of a thin metal strip on a dielectric substrate, and are known for their small size, lightweight, and low profile.
2. Miniature antennas: These antennas are made to be extremely lightweight and tiny in size, making them suitable for implantation in the body. They are typically made using microfabrication techniques, and can be integrated into a variety of devices, such as pacemakers and cochlear implants.
3. Flexible antennas: These antennas are designed to be flexible and conform to the shape of the body. They are typically made of flexible materials such as rubber or silicone, and are suitable for applications where the antenna needs to move with the body.
4. Dual-band or multiband antennas: These antennas are designed to operate at multiple frequency bands. This allows for the simultaneous monitoring of multiple physiological parameters or for greater flexibility in changing the operating frequency.

The design of biotelemetry antennas involves considering several factors such as the size of the antenna, the operating frequency, the material used, the transmission power, and the matching network. The antenna should be designed to minimize the interference with the surrounding tissue while maintaining a high level of signal transmission.

In summary, biotelemetry antenna design refers to the design of antennas used in biotelemetry systems, which are used to wirelessly transmit and receive biological data from living organisms. Biotelemetry antenna design involves considering several factors such as the size of the antenna, the operating frequency, the material used, the transmission power, and the matching network. The antennas are designed to be small, lightweight, flexible, and to operate at specific frequencies that are suitable for transmitting data through the body.

Miniaturized wearable antennas for biotelemetry wireless communication refer to the design and development of small, lightweight antennas that can be worn on the body for monitoring and transmitting biological data wirelessly. To ensure minimal interference with other equipment and to meet regulatory requirements, these antennas are often made to operate in the medical ISM (Industrial, Scientific, and Medical) band, which includes frequencies like 402–405 MHz and 433–434.79 MHz [3,4].

As shown in Figure 1, an Al2O3 ceramic layer, a dielectric layer, can be precisely manufactured from the aluminium base metal using the anodized aluminium oxide (AAO) production technique. Compared to traditional dielectric materials used to manufacture antennas, such as polycarbonate ($\varepsilon r = 3.5$) or FR4 substrate ($\varepsilon r = 4.4$), the AAO layer has a greater dielectric constant. This attribute is very advantageous for the antenna's miniaturisation. Furthermore, the degree of freedom in antenna design can be substantially expanded because the ground and dielectric layers can be fabricated integrally and the AAO layer can be put directly to the aluminium metal frame utilised in current mobile phones [5].

Typically, these antennas are made with cutting-edge materials and design methods including metamaterials, MIMO (Multiple Input Multiple Output), and beamforming to achieve small size, high gain and efficiency. Some common types of wearable antennas include patch antennas, planar inverted-F antennas (PIFA), and meandered-line antennas.

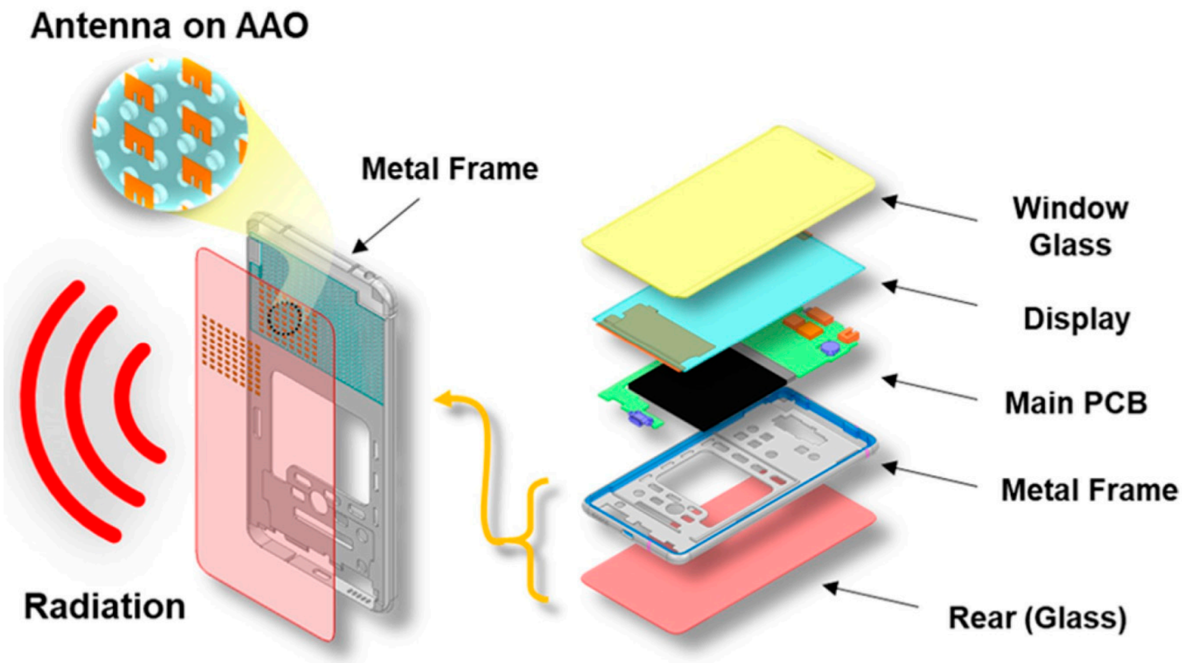


**Figure 1.** Materials used to make miniature antennas [5].

These tiny wearable antennas used for biotelemetry enable noninvasive monitoring of vital indicators including heart rate, blood pressure, and oxygen levels. This is helpful in a number of medical applications like remote patient monitoring, sports medicine, and rehabilitation. It also allows for real-time data transmission between the patient and healthcare providers, enabling faster and more efficient treatment.

The development of miniaturized wearable antennas for biotelemetry wireless communication has been a relatively recent area of research. The first studies in this field started to appear in the early 2000s, but the majority of the research has been conducted in the last decade.

The main objective of miniaturized wearable antennas for biotelemetry wireless communication is to develop small, lightweight, and low-cost antennas that can be worn by patients to monitor their vital signs wirelessly. These antennas are intended for use in medical applications including telemedicine, wireless health, and remote monitoring of patients with chronic conditions. They are made to be compatible with wireless communication technologies like WiFi, Bluetooth, and Zigbee [5,6].

One of the key challenges in developing these antennas is to achieve high efficiency and performance while keeping the size and weight as small as possible. Researchers have used various techniques such as electromagnetic bandgap structures, metamaterials, and fractal geometry to achieve miniaturization and high performance.

The development of these antennas is still an ongoing field of research and many new advances are expected in the future. Miniaturized wearable antennas for biotelemetry wireless communication are anticipated to play a significant role in enhancing the standard of care for patients with chronic diseases as a result of the rising need for remote monitoring and telemedicine.

Miniaturized wearable antennas have been developed and researched for over several decades. The history of miniaturized wearable antennas can be traced back to the 1960s, when the first wearable antennas were developed for use in military applications such as communication with tanks and other vehicles.

In the 1970s and 1980s, research on wearable antennas focused on developing smaller and more efficient antennas for use in portable radios and other personal communication devices. Researchers also began to explore the use of wearable antennas in medical applications, such as in body-worn pacemakers and other implantable devices [7].

Even smaller and more effective wearable antennas were created in the 1990s and 2000s as a result of developments in materials science and microfabrication technology. These antennas were increasingly used in a wide range of personal communication devices, including cellular phones, wireless earphones, and other portable devices.

The research and development of miniature wearable antennas has increased recently with the growth of the Internet of Things (IoT) and wearable technologies. The development of wearable antennas is now underway for a number of wireless applications, including wireless body area networks (WBAN), wireless personal area networks (WPAN), wireless local area networks (WLAN), and cellular communication. The antennas are becoming smaller, flexible, and even integrated with textile materials [8].

A fundamental idea in antenna design, circular polarization has numerous significant uses and benefits. Circular polarization involves the rotation of the electric field vectors in a circular pattern as the wave propagates, in contrast to linear polarization, which has the vectors aligned in a straight line. It is possible for circular polarization to be left- or right-handed (clockwise or anticlockwise). Circular polarization is significant in antenna design for the following reasons:

1. Mitigation of multipath interference: Compared to linearly polarized antennas, circularly polarized antennas are less vulnerable to multipath interference. When signals bounce off objects and enter the receiving antenna at different stages, multipath interference happens. Signal quality is enhanced as a result of the reduction of these reflections caused by circular polarization.
2. Consistent signal quality: Whatever the receiving antenna's direction, circular polarization keeps the signal quality more constant. In mobile communication applications, where the relative orientation of the sending and receiving antennas may vary dynamically, this is especially helpful.
3. Robustness to rotation: Signals that are circularly polarized can continue to be effective even if the receiving antenna rotates. This feature is useful in situations where antenna direction can change, like satellite communication or mobile communication equipment.
4. Satellite communication: Satellite communication systems frequently employ circular polarization. In space, satellites may rotate and position themselves in different ways. Circular polarization helps guarantee that the signal quality stays constant in spite of these changes.
5. Reduced cross polarization interference: In diversity reception systems, which use numerous antennas to receive signals simultaneously, circular polarization is frequently used. The antennas' ability to receive signals of various orientations through the use of circular polarization increases the likelihood of sustaining a dependable communication link.
6. Antenna beamwidth control: The beamwidth of the antenna can be adjusted by using circular polarization. This characteristic is helpful in applications that require targeting a certain coverage area, and modifying the beamwidth enhances the antenna's efficiency.

Thus, the utilization of circular polarization in antenna design presents several benefits, including less multipath interference, stable signal quality, resistance to rotation, and enhanced efficacy in a variety of dynamic communication scenarios. Circularly polarized antennas are a good fit for a number of uses, such as wireless systems, mobile networks, and satellite communication because of their characteristics [9–12].

In conclusion, the history of miniaturized wearable antennas has developed over time with an emphasis on creating smaller and more effective antennas for usage in a number of applications such as military, medical, personal communication devices and IoT.

## 3. Biotelemetry Wireless Communication

Biotelemetry is a field of study that involves the use of wireless communication technology to transmit biological data from living organisms. This technology is used to remotely monitor and collect data on the physiological and behavioral states of animals and humans in various environments.

The wireless communication used in biotelemetry systems typically involves the use of radiofrequency (RF) or infrared (IR) signals to transmit data from sensors or other monitoring devices that are attached to or implanted within the organism. The data are then received by a remote receiver and processed to extract useful information.

Some examples of biotelemetry applications include the following:

- Wildlife tracking: Biotelemetry is used to track the movement, behavior, and health of wild animals, such as migratory birds, marine animals, and endangered species.
- Human health monitoring: In patients with chronic conditions or when athletes are exercising, biotelemetry systems are used to track vital indicators like heart rate, blood pressure, and body temperature.
- Environmental monitoring: In remote or difficult-to-reach areas, biotelemetry systems can be used to track environmental variables including temperature, humidity, and air quality.

The technology of biotelemetry wireless communication is advancing rapidly. Advancements in wireless communication, sensor technology and data processing have made it possible to create biotelemetry systems that are more accurate and sophisticated with a higher resolution and a larger range of applications.

In summary, biotelemetry is a field of study that utilizes wireless communication to monitor and collect data on living organisms. Applications for biotelemetry systems include tracking wildlife, observing human health, and keeping an eye on the environment [13–15].

## 4. Wearable Microstrip Antenna Devices

Wearable microstrip antenna devices are a type of antenna that are designed to be worn on or integrated into clothing or other wearable items. They are typically small in size and lightweight, making them suitable for use in wearable applications.

Microstrip antennas are a type of patch antenna that use a thin metal strip on a dielectric substrate. They are known for their small size, lightweight, and low profile. This makes them ideal for integration into wearable devices and clothing. The microstrip patch antenna is a popular design for wearable applications because it can be easily fabricated using low-cost and flexible materials.

Wireless body area networks (WBANs), wireless personal area networks (WPANs), wireless local area networks (WLANs), and cellular communication are just a few of the applications that use wearable microstrip antenna systems. Additionally, they are employed in medical settings to follow the movement of those suffering from dementia or to monitor vital signs in patients with long-term illnesses [16,17].

As shown in Figure 2, to allow connectivity between devices and the internet, wearable microstrip antennas are widely employed in a variety of wireless communication technologies, including Bluetooth, Wi-Fi, and Zigbee. Wearable antennas in the healthcare industry can be incorporated into garments to track vital signs and send information to centralised systems or medical specialists. For uses such as ambient intelligence, gesture recognition, and location tracking, antennas can be integrated into smart fabrics. Fitness trackers and sports tracking equipment employ wearable antennas to connect to smartphones or other devices.

The wearable microstrip antenna devices are designed to operate at different frequencies such as ultra-high frequency (UHF), microwave, and millimeter-wave frequencies. These antennas are designed to be integrated into different types of materials, like textile and rubber, to make them more comfortable to wear.

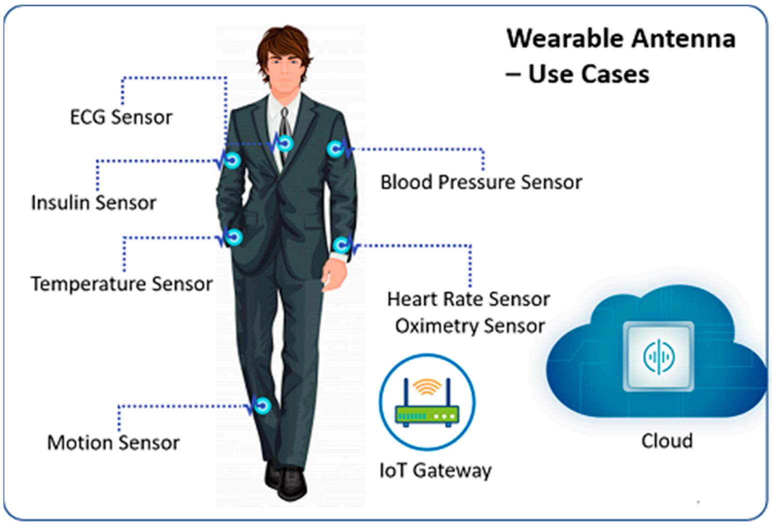


**Figure 2.** Wearable microstrip antenna devices [18].

Wearable microstrip antenna devices are a type of antenna that are designed to be worn on or integrated into clothing or other wearable items. They are small in size and lightweight, making them suitable for use in wearable applications. They are used for a variety of purposes including cellular communication, wireless body area networks, wireless personal area networks, wireless local area networks and medical applications [19].

## 5. Conclusions

The monitoring of vital signs including heart rate, breathing rate, and body temperature can be conducted non-invasively with biotelemetry without the use of cables or wires thanks to the use of miniature wearable antennas. This enables patients to move freely and comfortably while being monitored.

Designing miniaturized wearable antennas for biotelemetry wireless communication can be challenging due to the constraints of size, flexibility, and biocompatibility. Researchers have been exploring different antenna configurations, materials, and fabrication techniques to overcome these challenges. Some examples include the use of flexible and stretchable materials, such as rubber or textile, and the integration of antennas into clothing or other wearable devices.

Overall, this is important field of research which has the potential to improve the quality of life for patients with chronic illnesses and to enable remote monitoring for a variety of healthcare applications is miniaturized wearable antennas for biotelemetry wireless communication.

**Author Contributions:** V.D. conducted the research and writing; J.J. supervised and reviewed the work. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

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