Suresh Kumar, S., Dashtipour, K., Abbasi, Q. H., Imran, M. A. and Ahmad, W. (2022) The Challenges in Implementing Wearable Antennas for Large-Scale Health Monitoring. In: 2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Singapore, 04-10 Dec 2021, pp. 821-822. ISBN 9781728146706

(doi: 10.1109/APS/URSI47566.2021.9703857)

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The Challenges in Implementing Wearable Antennas for Large-Scale Health Monitoring

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***Abstract*—The rise of antenna technology, smartphones, and the Internet-of-things (IoT) has enabled wearable antennas for wireless communication between implantable devices such as pacemakers, infusion pumps, etc., and external devices for health monitoring. This work describes the key challenges that need to be addressed for such wireless body area network (WBAN) technologies to be integrated into large-scale health monitoring programs. These include the miniaturization of antennas, fabrication techniques to enable mass production, and methods to protect patients from data infringement and hackers. Furthermore, the role of wearable and implantable antennas is pivotal to realize devices for continuous healthcare monitoring especially during Pandemic situations such as Coronavirus Disease-2019 (COVID-19).**

***Index Terms*—wireless body area networks (WBAN), wearable antennas, health monitoring, internet-of-things(IoT)**

I. INTRODUCTION

Antenna, the basic unit of wireless communication, has come a long way from Marconi's monopole antenna [1]. With the advent of mobile wireless communication, smartphones and the Internet-of-things (IoT) in the past two decades, rapid developments in antenna technology have ensued, including those for wireless communication between external devices and implantable devices on the body such as blood pressure monitors, infusion pumps, and pacemakers. In the current COVID-19 situation, such wireless technologies can help in remote monitoring of patients to reduce hospitalization and thus relieve the burden on health care systems [2]. When it comes to challenges, previous works have mainly focused on technical issues such as bandwidth, efficiency, body losses, etc. [3]. However, there is also a need to address other factors such as comfort, cost, long-term adherence, etc., in developing practical wireless body area network (WBAN) solutions for large-scale health monitoring programs. Some of these issues are discussed in this paper.

II. CHALLENGES

A. *Miniaturization*

Bulky wearable devices and antennas are not comfortable, especially for the physically compromised and the elderly. Hence, there has been a lot of research into the miniaturization of these components. Recently, textile antennas, which consist of embedding antennas in clothes, have been considered a more comfortable, flexible, and lightweight alternative [4]. However, these antennas typically use microstrip waveguides, which suffer from insufficient bandwidth and low efficiency. This is due to a trade-off between bandwidth and efficiency for substrate thickness values, as shown in Fig 1. Wagih et al. demonstrated that an alternative design based on coplanar waveguide (CPW) structures were able to obtain high efficiencies of 86%, and were less dependent on thickness and permittivity [6]. CPW antennas use a different electric distribution compared to standard microstrips that reduce the electric field dissipation in the substrate [6]. However, their fabrication cost is much higher than microstrip waveguides as they require gold ribbons to suppress higher-order modes at every quarter wavelength [7]. Also, a Radio Frequency Identification (RFID) tag for humidity monitoring of face masks was proposed in [].The tag design monitored humidity level of face masks by exploiting auto-tuning mechanism of microchip. Although, this antenna will be use full contribution for human being to dealt with pandemic situation, however standardization, miniaturization and low cost designs are required for mass production of such antennas. Similarly, the authors designed a flexible antenna by integrating with graphene oxide for continuous monitoring of breath. An experiment was conducted by embedding the antenna inside face mask for detection of abnormal patterns of respiration and inhalation/exhalation cycles. However, the size of this design is $71 \times 28\ mm^2$, which is more from ease of wearing perspective.

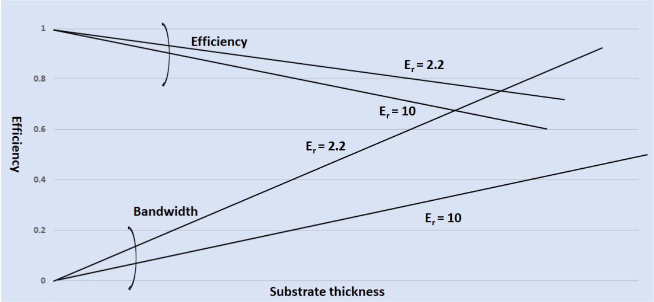

Fig. 1. Bandwidth and efficiency vs substrate thickness for different values of permittivity .

B. *Mass Production*

Mass production of antennas is required to support large-scale programs, and it also helps lower the cost of antennas. Furthermore, disposable antenna sensors reduce the chances of cross-infection, which is quite essential in the COVID-19 situation. Embroidering, a method in which conductive threads are sewed to make flexible antenna designs within clothing, benefits from the availability of computerized sewing machines that ensure high-speed production. Challenges include the high resistance of conductive yarns, and low resolution [8]. It has also been found that conductive threads induce a parasitic capacitance that affects the operational frequency [8]. Inkjet printing enables high-speed printing and high resolution but produces conductive layers with a low thickness that decreases the performance [9]. 3D printing of wearable antennas has gained popularity because it is fast, cost-effective, and can print even complex structures [10]. Unfortunately, the cost of 3D printers can go up to 200,000 USD, which restricts its use, especially in developing countries.

C. *Patient Security*

It has been demonstrated in the past that connected and wireless medical devices such as pacemakers, infusion pumps, and insulin pumps can be hacked, made to malfunction, and possibly kill patients [11]. An antenna can be used to copy the unencrypted radio-frequency (RF) signals emitted by the antennas of the remote controllers and play them back later to control the device. The food and drug administration (FDA) of the US has given six warnings regarding cybersecurity of medical devices till now [12]. Current means of protecting medical data are typically based on cryptographic techniques such as encryption, access control, and identity authentication that require high computational capacity, memory, and energy, which may not be feasible for medical sensors [13]. Li et al. used a simple friendly-jamming method that does not require the features as mentioned above from medical sensors [13]. In their scheme, which is illustrated in Fig 2, friendly jammers are placed at the borders of the actual data transmission region to block all signals outside it. The security of such wireless networks will depend on the signal-to-interference-plus-noise-ratio (SINR) of the legitimate receiver and the intruder. The integration of technologies such as beamforming and full duplexity will further improve the performance of such systems [13].

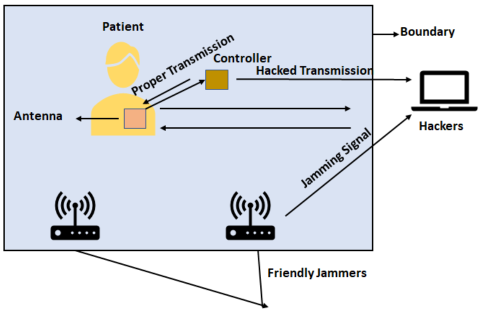

Fig. 2. Friendly jammers to block hackers from controlling implanted medical devices

III. CONCLUSION

This study covered the key challenges of wearable antennas that need to be addressed before being adopted in large-scale wireless patient monitoring schemes. Future work can focus on the regulations and standards required to implement such WBAN solutions.

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