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TOPICAL REVIEW

Revolutionizing Healthcare Delivery Through Wireless Wearable Antenna Frameworks: Current Trends and Future Prospects

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ABSTRACT The arrival of various mechanism applications to healthcare is gaining more attention with various novel breakthroughs in digitalizing healthcare. The use of technology in improving the delivery of healthcare comprises various applications such as electronic health systems, telemedicine, mobile health, remote patient monitoring, and wearable devices. Wearables and implants are making a significant impact on revolutionizing healthcare globally, and the next generation of advanced technology is providing adequate applications in tackling the challenges in digital healthcare. The advancement of various techniques gives future direction to digitalizing healthcare. Antennas play a key part in digitalizing healthcare because of their characteristics and the adaptation to wireless communication with transmission and reception in different human body parts. Although there are a lot of studies done and published on digital healthcare, telemedicine, wearable, and many more mechanisms that enhance healthcare delivery, however, systematic studies that comprehensively review the applications in healthcare such as wearable antenna framework remain scarce. This paper attempts to close the gap in investigating mechanisms for digital health care, and wearable devices with antenna applications. This comprehensive systematic review covers antenna application in healthcare. Furthermore, it provides a state-of-the-art update on recent developments in healthcare with a focus on design, monitoring devices, diagnostic implants, early detection mechanisms, and control. We also examine wearable analysis and performance, fabrication and experimental approaches, and the major types of wearables. This assists with existing chronic disease management and future epidemics with provided tools. This finding will give a blueprint of how zero spread of future epidemics will be achieved by implementing the bio-electromagnetic application in the healthcare sector.

INDEX TERMS Wearable antenna, healthcare, digital, gain, bandwidth, microstrip antenna, bending techniques, mechanism, diseases, specific absorption rate, antenna performance, tele monitoring.

I. INTRODUCTION

The procedure for the flexible wireless device is rapidly growing, and the idea of bio-electromagnetism technologies for health management is gaining more attention globally. One of the main challenges is to investigate new strategies for how bio-electromagnetism will be fully implemented in the health system. The enhancement of human health and living standards represents a major present research area in the bio-medical field. The rate at which wireless and sensing technology is rapidly advancing brings about novel prospects in body area sensing plus simulation with an encouraging novel height of applications in the health and sports sector [1]. This novel technique can improve and monitor healthcare, control chronic health conditions, and reduce the death rate. The growth of such transformative techniques requires serious timely access to diagnostics information, system integration, bio-electromagnetic design, sensor miniaturization, emergency response, energy efficiency, monitoring, detection, and breathing control [2]. In this context, one of the major issues

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focuses on the development of electromagnetics devices that can overcome some of the challenges. The revolutionizing technology on antenna and material can address the challenges in modernizing healthcare with a wellness system. This advanced, innovative development enables the next generation of implanting with wearables to aid bio-electromagnetic applications [3]. The classification of sleep phases is an important tool in sleep research and clinical settings. It divides sleep into stages, such as rapid eye movement (REM) and non-REM, and a precise classification to understand sleep patterns and disorders helps diagnose sleep disorders and develop flight treatments effectiveness, [4] proposed multi-modal physiological signals based squeeze excitation network with domain adversarial learning to capture the features of electroencephalogram and electrooculogram for sleep staging. Additionally, brain-computer interface (BCI) applications such as cognitive BCI and body imaging for wearable devices play an important role. Sensory BCIs enable communication and control based on sensory states, while motor-imagery BCIs facilitate the control of external devices through mental images, making them valuable tools in places of various types [5], In [6], two stream attention- based 3D network was proposed for concatenated in space-time-frequency with feature fusion to support the computer interface applications. Furthermore, the emerging machinery, that can adapt the communication among humans with things, is known as wireless body area networks (WBAN). This function in the bodies' areas results in context-personalized communication in the intelligent wireless environment [7], [8]. The WBAN allows operators to enjoy the applications with additional transmission without interference, little complexity, and low transmission power by network base station [9], [10]. An essential application of wireless body area networks in digital healthcare. The process is when there is the transmission of vital information from the human through various means, such as a sensor to the monitoring mechanism. This is essential in monitoring chronic diseases and their proper management [11], [12]. The wearable device needs a wide bandwidth to support biomedical application technologies, such as wireless body area networks. It is recognized that the device may cause a specific absorption rate (SAR) on the skin external, which is built on radiation protection, and the SAR bound is set to W/kg aimed at an average of 10g tissue [13], [14]. Wireless communication for a wearable device, therefore, needs the antenna to have a small footprint that limits constant radiation disclosure on the body, with the design of the antenna to be standard miniaturization interaction with the body. In designing the antenna, the wideband or multiband ability, flexibility, and integration need serious consideration for advanced wireless communication systems [15]. The wearable antenna design for the wearer's outfit needs to consider several factors, like the coupling among the antenna with the body, which will stop the degradation, and the deformation of the body to get significant performance. Furthermore, in getting better performance in some conditions like humidity, distance to the body, and temperature, the factors to be considered are the high electrical with mechanical assets, light in weight, flexibility, little cost, ease of fabrication, and convenience when wearing. This factor leads researchers to use textile material to design the wearable antenna, especially aimed at medical applications [16]. The nomenclature of the article shows the advancement with the use of textiles as a novel smart wearable with the integration of electronic devices is performing excellent and wireless body area networks [17]. This fabric can sense a response to a change in the environment which can be applied to numerous sectors, like sports, medicine, fashion, with the military [18]. There are several uses of a flexible electronic device, which makes the connection possible with the integration of the antenna frequency [19]. The effect of wearables and implants are to revolutionize global health care, enabling real-time health monitoring, personalizing treatments and enhancing patient outcome with data-driven insight and remote management [20].

Solving the problems confronted in digital healthcare can address data security, connectivity, and scalability challenges using cutting-edge technologies. Issues of compatibility between wearable antennas and health systems can be addressed through standardization efforts and regulatory guidelines. Telemedicine, mobile health, and electronic health systems are enhancing healthcare by enabling remote counseling, personalized monitoring, and data efficiency by using wearable antennas for advanced diagnostics, real-time analytics and predictive analytics, the digital healthcare system can be improved by leveraging the Internet of Things, machine learning, robotics and big data analytics [21], [22].

The objective of this paper is 1: Investigate the application of wearable antenna systems in healthcare by conducting a comprehensive systems analysis. 2: To provide access to the latest advances in health care, with a focus on design, monitoring devices, diagnostic implants, early detection methods, and antenna enforced use. 3: Explore the potential of bio-electromagnetic research in the healthcare industry to support the management of existing chronic diseases and the prevention of future epidemics with the goal of no spread of epidemics through effective management.

This comprehensive review covers the antenna application in healthcare. Furthermore, it provides a state-of-the-art update on recent development in healthcare with a focus on design, monitoring devices, diagnostic implants, early detection mechanisms, and control. We also examine wearable analysis and performance, fabrication and experimental approaches, the major type of wearables, and the assessment of digital technologies. This assists with existing chronic disease management and future epidemiologic by providing tools. This finding will give a blueprint of how zero spread of future epidemics will be achieved with the bio-electromagnetic application implementation in healthcare.

This state-of-the-art review is divided into sections. Section I is the introduction, section II present the problem statement, conceptual framework, and literature review. Section III provides details explanation of the methodology adopted for thus systematic review literature. Section IV discusses the findings presented in this paper, and Section V conclude the review.

II. PROBLEM STATEMENT AND RESEARCH QUESTIONS

Despite the significant advances in healthcare technology, there still exists a gap between patient care and effective health management due to the lack of real-time patient monitoring systems that bridge patient care and effective health management (See Figure 1). Traditional healthcare systems rely on periodic check-ups, which may not provide sufficient data to support early detection and prevention of health problems. To overcome this limitation, wearable antenna devices have emerged as a promising solution for continuous monitoring of patients in real-time. However, the design and implementation of wearable antenna devices face several challenges such as antenna placement, power consumption, and signal processing. Therefore, a comprehensive review of wearable antenna devices for digital healthcare is needed to explore their potential benefits and limitations and identify areas for further research and development. The research questions of the exploratory study are:

- What are the key design and implementation challenges associated with wearable antenna devices for digital healthcare?
- What types of wearable antenna devices have been developed for digital healthcare, and how do they differ in terms of design, functionality, and performance?
- What are the benefits of using wearable antenna devices for digital healthcare, and how do they compare to traditional healthcare monitoring systems?
- How have wearable antenna devices been used to address specific health conditions or diseases, and what have been the outcomes of these applications?

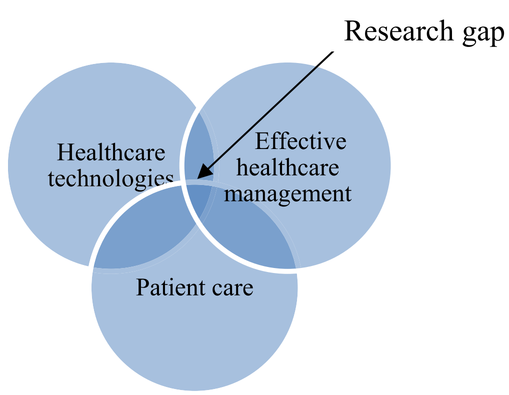

FIGURE 1. Research gap at the intersection of healthcare technologies, patient care and effective healthcare management. (Authors source).

- What are the ethical and privacy concerns associated with using wearable antenna devices for digital healthcare, and how can these be addressed?
- What are the current trends with future directions in the development with application of wearable antenna devices for digital healthcare?

III. CONCEPTUAL FRAMEWORK AND LITERATURE

The magnitude of the literature offers conceptual evidence for defining antenna wearable roles in digital healthcare and the need for impact analysis [23]. The conceptual framework for a wearable device is developed by identifying the key factors, concepts, and variables that are relevant to the design, development, and use of such a device. Some of these factors may include, the antenna model, and identifying the model parameters for the wearable antenna [such as frequency range, bandwidth, polarization, and radiation pattern]. Wearable Requirements - understanding the requirements of the wearable device, such as form factor, power consumption, and robustness, that impact the antenna design. Operating Environment - examining the various environments in which the wearable device will be used, such as indoor vs outdoor settings, proximity to other electronic devices, and human body effects. Radio Frequency (RF) Performance - defining the RF performance metrics for the wearable antenna, such as gain, efficiency, and radiation safety. Signal Processing identifying the signal processing methods that are used to enhance the performance of wearable antennae, such as beamforming, frequency tuning, and interference suppression [24], [25]. Engineering strategies for three different types of biocompatible biosensors: wearable, non-edible, and implantable. In [26] and [27], the focus is on sensor design and application, highlighting best practices and strategies for the successful application of these sensors in health and biomedical applications. In addition, we conduct an extensive literature review on the application of 6G, XR, and IoT big data analytics in healthcare systems, showing how these technologies enable more efficient and flexible healthcare delivery. Digital medical technologies are revolutionary, being the mechanism used in the system of chronic health conditions like as mental disorders, cancer, diabetes, and cardiovascular diseases. There is a need to update the assessment of digital medical technologies to identify which mechanism best fits a particular chronic disease while being both efficient and cost-effective. Digital technologies include applications connected to medical devices and telemedicine. In [28], depression, a mental health disorder, goes undetected and untreated because sometimes the symptoms are not physical. The symptoms deal with emotions, behavior, and thoughts. There is a need to have an effective technique for diagnosing depression with a good mechanism to monitor the patient's condition. In [29], a regular measure of depression symptoms, which was paper with pen valuations like the dejection rate scale with Montgomery asberg depression rate scale was examined. This particular measure is subject to bias with a lack of medical significance with exhibits great changeability, which interprets into the need for a large clinical trial that will sense the clinically relevant management. But in another way, digital technologies have the prospect of providing additional objectives with precise mechanisms that can detect depression-related issues; however, this requires careful assessment with validation in the hospital before implementation. The incorporation of the internet of things (IoT), machine learning (ML), robotics, and big data analysis, with cloud computing in wearable antenna, gives a clue of what more can be expected in the future. The problem of monkey pox was addressed with a model developed by [30], using machine learning to mitigate the risk of overfitting. Furthermore, 20 patients with major depressive conditions and 20 normal healthy volunteers were evaluated. The aim was to assess the feasibility of using digital mechanisms, explore the potential of using digital biomarkers for prediction, and assess the usefulness of the mechanism for diagnosis. This provides preliminary evidence on the virtues of digital technology that need further confirmation with a larger study. To this end, seven digital technologies were evaluated under the mobile application providing actual data and testing performed in hospitals. A one-off mobile application provides nitrating tools with a high-frequency assessment of cognition with mood, while the second mobile app has inert behavioral monitoring and integrates the smartphone data relating to use patterns and social acts. The third app was used as a voice recording platform to get the voiced biomarkers, which contain important information related to depression. The mechanism in the hospital includes a neuropsychological check battery with an eye motorized tracks mechanism that captures the data needed across numerous domains of mood cognition with performance, an electroencephalogram-based mechanism in utilizing the brain system, and with mission enumerating bias emotion insight. This monitoring app listed 85 features, which were scrutinized into 10 important ones that each represent many social functions, namely the entropy of procedure time on public media apps, the number of places visited, and the total interval of all system happenings. The collaborating app provides the measurement of cognition mood with the acquisition of longitudinal information per subject, the mood score and cognitive notch were calculated at respective times the app was in use, and the neuropsychological test battery received data from the hospital in about 230 minutes when the patient was admitted. The average was taken across three-time points with 42 features derived per subject. Combining digital technologies with demographic and hospital information analysis that include some artificial intelligent features like data visualization, supervised learning methods, and classification analysis is used to predict the class of subject health with the use of logistic regression, furthermore, the numerous linear regression is used to model with prediction Montgomery asberg depression rating scale entire score as a task of digital biomarkers. Technology organises this investigation to understand the best value. In [31], simple parsimonious designs were modelled and reasonably extraordinary diagnostic accuracy with perspective in predicting standard hospital results of depression. The main lesson from the investigation is that numerous novel digital technologies produced huge volumes of high-frequency data, and the best hospital is using statistical research principles with the application of its principles to get things done. The collective methods of data investigation, like classification and regression, will handle any type of data. This section has revealed that digital medical technologies, which are revolutionizing the health sector, will do better with the right mechanism to manage chronic health conditions, such as mental disorders, cancer, diabetes, and cardiovascular diseases.

A. CONTRIBUTIONS

This paper makes significant contributions to knowledge and research in the field of digital healthcare and wearable antenna applications. Firstly, it fills a crucial gap in the existing literature by providing a comprehensive systematic review of the applications of wearable antenna frameworks in healthcare. By synthesizing the current state-of-the-art knowledge, this paper offers a holistic understanding of the role of antennas in digitalizing healthcare, their characteristics, and their wireless communication capabilities within the human body. Furthermore, this paper sheds light on the advancements and breakthroughs in digital healthcare, such as design, monitoring devices, diagnostic implants, early detection mechanisms, and control. It also explores the analysis and performance of wearables, fabrication and experimental approaches, and major types of wearable devices. By consolidating this information, the paper provides researchers, healthcare practitioners, and policymakers with a comprehensive overview of the latest developments in the field, enabling them to make informed decisions and drive further advancements in digital healthcare. The contributions made in this paper are valuable for guiding future research endeavours in the area of digital healthcare. The blueprint provided for leveraging bio-electromagnetic applications in the healthcare sector offers new avenues for managing chronic diseases and mitigating the spread of future epidemics. The paper's findings contribute to the growing body of knowledge in digital healthcare and wearable technologies, making it a valuable resource for advancing healthcare delivery and improving patient outcomes.

IV. METHODOLOGY

This systematic literature review (SLR) is an established approach towards identifying, selecting, with reporting entirely specific novel research domains with help of VOSviewer which is a tool that runs out the layout algorithm and constructs the visualizing bibliometric network publications, the tool is used for mining text with identification of major themes from selected literature

The structure SLR adopts PRISMA, (Preferred Reporting Items for Systematic Reviews and Meta Analyses [32]. This adopted approach has a sequence of operation which are identification, screening, eligibility with inclusion presented in Figure 2. The Scopus database was used in identifying the literature with key words, the related research gap.

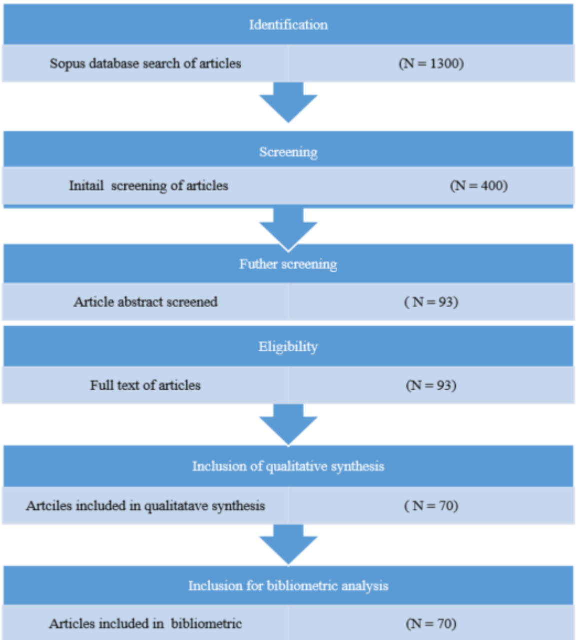

FIGURE 2. Methodology steps.

Each step comprises several activities described as follows illustrated Steps for PRISMA methodology involve Identification, Scopus database search of article with total number of 1300 articles searched, Initial screening was done the total search article which reduce the article to 400, we future screen the selected article for relevant and subject matters through abstract which reduce the article to 93, this are eligible for reading, furthermore, the articles included for qualitative synthesis and bibliometric was 70 finally for review.

A. SEARCH KEYWORDS

The keywords are implicit to their underpinning concepts which are digital healthcare, wearables, antenna wearable. This terms is representing the main objective of this paper, the approach adopted from [33], that limit the search to tiles, abstracts and key words of already published articles.

B. SCREENING

The Scopus search which is revealed in Table 1, entails the selected keywords for the previous years with 1,300 papers, reduced of data is carried out with more filtering of the already captured data on the published articles, all is done mainly on the English language with a reduction to 400 papers. This was refined further to get to date view with more refining in screening to the present year.

C. EXCLUSION AND INCLUSION PRINCIPLES

The output of the 400 papers were abstract screened to replicate the intent of the research questions, 'in what way will digital health care be improved?', ' how can wearable device helps maintain the stability of digital health output?', 'what role will antenna mechanism play in healthcare digitalization?' This was screened with the generation of 93 documents, the synthesis scrutiny of the 93 papers to the reduction of 70. This document now constitutes the subject matter for proper investigation, furthermore, the analysis was performed.

D. BIBLIOMETRIC ANALYSIS

This symmetric literature review (SLR) approach is supplemented with the bibliometric analysis [34].

Bibliometric analysis is a research methodology that employs statistical and quantitative techniques to examine patterns, trends, and relationships within scientific literature. It involves analyzing citations, publication counts, co-authorship networks, and other bibliographic data to gain insights into scholarly communication and impact.

A plethora of science mapping tolls are available, such as the VOSviewer [35]. The VOSviewer was used in this study to network the visualization of the keywords from the literature [36]. The science mapping concept is utilized in creating co-occurrences for mapping the keywords with analyzed trending patterns to extract perception information.

In this paper, an SLR involves selecting important useful elements that will achieve the objective of the paper. The selected papers are analyzed with the updated evolution of digital health care, wearable devices, and applications of the antenna device.

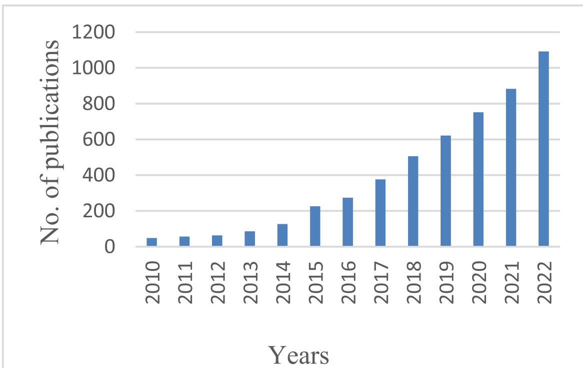

FIGURE 3. Number of publications from 2010 to 2022.

E. DESCRIPTIVE ANALYSIS

The sketch in Figure 3 shows that the subject area of focus is gaining attention, and the rapid development of research publications from 2010 (N = 49) to 2022 (N = 1092) indicates growing interest and activity in the field. This is because of factors such as advances in technology for research in the area. The development of research in this area indicates that there are still unanswered questions or gaps in knowledge that researchers are trying to address. Additionally, as more researchers publish in a particular area, this will lead to collaborations, discussions, and the development of new ideas and approaches.

The research involvement of numerous countries in the review is shown in Figure 4, the brown line indicates the progression from countries' contributions by publications.

TABLE 1. Literature search data's.

Stages	Data capture from Scopus	Numbers of papers	Screening and exclusion applied
A	Main literature statistics	1300	None
B	Data reducing	400	Papers in English, the year 2010 -21
C	Reducing data	93	Papers in English, the year 2016-23
D	Abstract screened	70	Analysis of abstract with relevance
E	Eligibility	65	Full paper retrieval and scrutiny

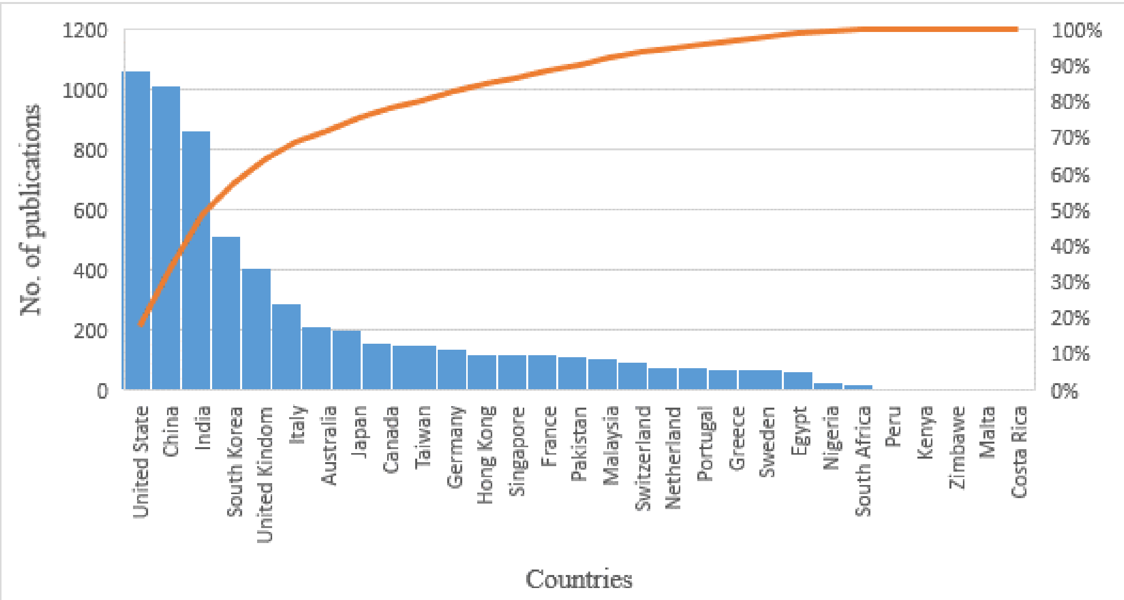

FIGURE 4. Research countibutions from countries of publications authors with the least and highest.

The concept of collaboration work culture is obvious from the magnitude of documents detected. The collaboration from the United States has (N = 1063), the publications collaboration with China has (N = 1011), India has (N = 861), and South Korea has (N = 408). These are the countries with number of publications on subject matter across the world. The lease countries are South Africa (N = 17), Nigeria (N = 22) and Egypt (N = 62). The investigation highlights that researchers throughout the world are actively examining the subject area.

F. CONTENT ANALYSIS

The attention of SLR (Systematic literature review) reflects their main area which is antenna wearable devices, digital health care, and wearable mechanisms. Attempts were to focus on SLR synthesis and identify content or papers that best define the area and supportive theoretical concepts. The in-depth content analysis according to the technological aspect of digitalizing healthcare with antenna wearable mechanism [37].

1) WEARABLE ANTENNA FOR HEALTHCARE

Wearable antennas have emerged as a promising technology for improving healthcare delivery and patient outcomes [38]. With the increasing demand for remote monitoring and tracking of patient health, wearable antennas offer a unique opportunity to bridge the gap between patients and healthcare providers. These wearable antenna methods for healthcare show the design, techniques and type see Figure 5. This integration enables the group, transmission, and investigation of real-time health data, which can inform healthcare providers of the patient's health position with aid in early discovery and prevention of diseases. The potential benefits of wearable antennas in healthcare are significant and could revolutionize the way healthcare is provided in the future [39], [40]. Techniques for wearable antenna design in healthcare applications include conformal antennas, textile antennas, and flexible antennas that can be combined into wearable medical mechanisms such as smartwatches, fitness trackers, and health patches. Conformal antennas are designed to conform to the body shape of the patient, providing improved signal quality

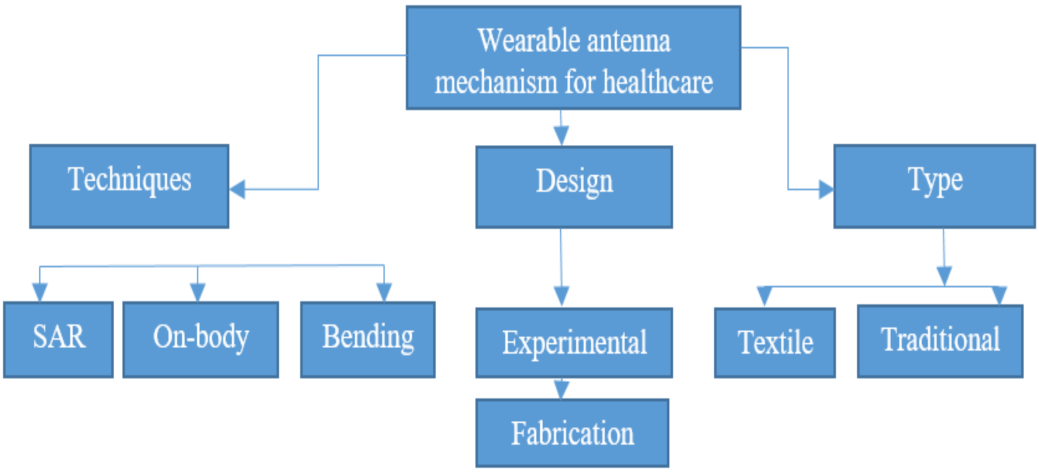

FIGURE 5. Werable antenna technique for healthcare.

and reducing interference [41]. Textile antennas are made from conductive fibers and can be embedded into clothing, providing discreet monitoring without disrupting the patient's daily routine. Flexible antennas are made from materials that can bend and stretch, allowing for comfortable and long-term wear [42]. These techniques presented in Table 2 for wearable antenna design in healthcare applications are critical for enabling remote monitoring and real-time communication, improving patient outcomes, and reducing healthcare costs effectively. To get performance over the years, a review is presented in table 3 which shows healthcare applications enable reliable and robust wireless communication between medical devices and healthcare professionals, leading to improved patient outcomes and reduced healthcare costs.

G. BENDING TECHNIQUES

The important attribute of a flexible antenna is bending, which is important because of its practical application. Furthermore, in reducing body coupling, a wearable antenna with bending properties was proposed in [54] and [55]. The antenna uses an artificial magnetic conductor, with the reflection confidence found better well-preserved in the Y-axis bending over the X-axis. In the latter, the antenna performance is varied to the dielectric constant in the substrate with similar to the air to have stable performance. The substrate thickness effect was studied by [56], and the bending condition was examined and it shows that the bending condition needs a fixed radius to provide a better performance, which is also examined in [57] and [58]. The Antenna was done along the dimension to get the bending performance to determine if the resonance frequency might be shifted, which will fit a wearable antenna. The wearable mechanism needs consistent performance on different bending radius. It was investigated in [59] and [60] that flexible antennae for medical applications had modifications in the ground plane and operation and two different bands. This was fabricated with $38 \times 30\ mm^2$, and the vacuum cylinder varies with three diameters of 50 millimeters, 100 mm, and 80 millimeters, whichever has an available diameter of a human armrest in output.

The study was carried out on a wearable antenna designed for body system in [61], the conductivity material has connected the substrate of the antenna, and this antenna was simulated and validated with an agreement in the free space plus phantom body surroundings, the outcomes showing peak value model of 5.7% and 4.7% with a gain of 8.6dB in the operation. Likewise, research was carried out in [62], and the antenna design was simulated and validated. The wearable antenna with different operating frequencies felt substrate friction coefficients at different GHz's with various bending. This was investigated and shows a shift in the resonate frequency. A study presented in [63], on a wearable antenna medical application functioning at 2.45 GHz, was done with a microstrip spherical shape for the body. The microstrip patch was inserted to get the body mode with the antenna feeding differently with the single related ground plane. They were made out of clothing materials that allow easy integration into a patient's cloth. The results were measured and tested in a free space phantom with it being placed in the center of the phantom and a 4 mm built-up hole inside the antenna with these phantoms. This was simulation measurement with a gain of 4.2 dB to 5.3 dB for the body. Recently, the innovation of antenna insertion on cloth has been making waves because of the conducting materials, which is making researchers bring more novel out of it. An investigation was done in [64], for a flexible antenna in which fabric is used in designing the projected antenna. This antenna operates at various bands from 2.3 GHz - 5.9 GHz.

The antenna takes a gain of 2.5 dB with 4.0 dB with a modification in the resonant frequencies that were subject to diverse angles. Similarly, a cloth-making antenna that opens starting at 3.1 GHz - 10.6 GHz is investigated, and the on-body structure reliability was measured and produced 97% at a distance of 1 meter. In the process of designing

TABLE 2. Techniques for wearable antenna for healthcare.

S/N	Application	Techniques	Structure	Material	Ref
1	Wristwatch (2.4GHz)	HIS(0.29)	Inverted L antenna	Wet etching with the use of FR4 substrate	[43]
2	On-body mechanism (from 2 GHz to 10.6 GHz)	Manual cutting felt substrate	Truncated patch	Full ground plane reflector	[44]
3	Sensor wearable nodes	The parasitic components used are (N.A)	Meander line antenna	The simple adhesive aluminium sheet	[45]
4	Wearable	The electromagnetic band gap (EGB) is used for SAR decrease (0.024)	Fractal-based monopole patch	Textile	[46]
5	Eyeglass for 4G application	The frame uses the ground plane (0.85)	Wire antenna	Etching on PCB	[47]
6	802 11 ac application	Tinny wire mesh sheet (N.A)	Monopole antenna	PCB etching	[48]
7	Mobile phone	Using ferrite radiating for antenna (0.026)	Patch	FR4	[49]
8	Wearable application	Metal shape metasurface (0.66)	Broadband monopole	Ink-jet as printing	[50]
9	Energy harvesting application: GSM and DCS bands	Method of coating measurable is in use (N.A)	Monopole Antenna	Laser cut machine with an adhesive sheet on Zelt fiber	[51]
10	Wearable application	Textile fabrication	Circular patch antenna	Wearable application	[52]
11	Mobile phone	Asymmetric radiating patch (N.A)	Unilateral CPW patch	FR4	[53]

eight coplanar used, the substrate layer was modified for the monopole arrangement influence acting on the reflector, the on-body constraint is examined on a person's body and various bending positions. The antenna has an octagonal shape and is connected in a separate position, specifically on the arm and the chest. The human body tissue vicinity has a major influence with results of the antenna, like as the radiation, efficiency, bandwidth, with gain [65], [66], [67]. There are a lot of benefits in designing with a full ground plane, such as dropping device sensitiveness within human bodies using the backside for proper radiation to the human bodies, achieving a low specific absorption rate, improvement in impedance matching efficiency using the on-body application, and reduction in device coupling energy in normal direction using the full ground plane [7], [68], [69], [70], [71], [72], [73], [74], [75], [76].

In this section, we provide a review of the use of bending wearable antenna performance. Some properties, like dielectric and radiation, need to be examined on human skin with a bending effect. Because of the good properties of wearable antenna, textile material is mostly used for designs because they are lightweight and good for folding. The wearable antenna does a lot of functions on the human body depending on each case it is assigned to. There is a lot of benefit to bending [77], in which experimental design is presented on a wearable antenna by the practice of textile materials. The antenna will have situated at the human body on a particular part, such as the chest and arm. As earlier mentioned, there are positions like concave and convex, which are experimental. Each position was measured winning into consideration usual human bending. It was observed that the cylinder material does not affect the stimulated, validated, and measured results.

The main effect of the matching level is a case scenario that affects the simulation and measures the outcome. The comparison reveals that a minor radius brings the toughest bending, and the detuning should be higher. The percentage of bandwidth reached altogether the antennae with bending radii is showing the rigorousness of deprivation of the antenna output. Simulated and validated result does not comprise the parasitic effect on bending antenna although nearby is a minor shift in bandwidth among the simulated and experimental results to justify several potential cases.

H. ON-BODY ANTENNA TECHNIQUES

The body antenna is needed to be ascertained for proper performance on the human body, which deals with positioning. This positioning will depend on the purpose of installation so

TABLE 3. Review of the performance of the different wearable antennas for healthcare.

S/N	Antenna structure	Performance	Frequency (GHz)	Substrate	Ref
1	Developed mode microstrip patch antenna	By the insertion of shorting via, the electric fielding is contrived which is upright to the exterior of the bodies permitting improved on-body propagation with good elevation.	2.45		[122]
2	CP patch antenna	The antenna withstands the curves on a radius of 37.5 mm it is rigid to keep CP that can be bent.	2.4		[123]
3	Monopole over 2 x AMC	The artificial magnetic conductor is anisotropic as sectors were lone in sole alignment, with the artificial magnetic conductor acting as the foremost radiator with monopole balance reacting, this model will be bent with a reduction of SAR.	2.4		[124]
4	Near-field communication radio frequency identification	Combined with a sweat sensor, that senses like a sticking plaster is demonstrated in working for seven 7 days.	13.56		[125]
5	M design formed with monopole above Jerusalem cross artificial magnetic conductor	These artificial magnetic conductor rises the front and back ratio by 8 dB with a reduction in SAR, carrying the test elasticity with on-body behavior.	2.45		[126]
6	CP patch antenna	Flectron is used for the ground plane due to soldering with paper investigating reducing the foam with bending. The antenna structure is waterproof.	2.4		[127]
7	CPW monopole above 3x3 electromagnetic band gap (EBG)	3 x 3 electromagnetic band gap is effective in reducing SAR, furthermore, the bend in the E plane affects performance over these H plane. These is with increased gain compared to the patch antenna.	2.45 and 5		[128]
8	Circular button	Free space body at minor and high band performs well.	2.4/5	Disc Rogers uses 5880 as ground substrate felt	[129]
9	Circular with a split ring resonator	Free space, on the body with an efficient performance of 97,71. The copper/shield use it (Patch/ground)	2.4	FR4 in ground substrate for felt	[130]
10	Circular button	The performance on the entire band is 3.5 with 79.9 and 70.8 performance on the body.	5.5	FR4 ground substrate, felt, Key disc	[131]
11	Circular cuff button	Both bands are 1.5 with 94 and free space and use copper as a conductor.	2.4/5	PTFE Ceramic	[132]
12	Modular snap-on button	This antenna has a half-wave of 7.8/3.1 and an 8.9-quarter wave.	2.4/5.3/8	Cuming foam	[133]
13	F-Inverted antenna	The antenna on the body with 46.3/69.3 and 4.3 dBi.	2.4/5.3/8	Disc Rogers 4003	[134]
14	Circular array antenna	The total efficiency increased by 86/93 for port 1 and the second port has a good total efficiency of 85.	4.50 /5.5-0	Disc Rogers 4003	[135]
15	A dipole antenna	The efficiency of the antenna is 90%.	1.91	PDMS of 2.67/0.0375	[136]
16	Circular patch antenna	The efficiency is 55.33% (sim).	2.45	Multi-layered textile	[137]
17	Array shape with metamaterials	The antenna's first band is 95 and the second band is 80.	2.11-3.05/5.2	RT/Duriod 5880	[138]
18	Circular patch with soft surface	Despite reducing the back radiation, this antenna was still efficient.	4	Felt	[139]
20	M shaped with AMC	The antenna performance revealed 3.7 gain was able to be improved above 3.7	2.45	Kapton polyimide	[140]
21	SIW slot antenna	The on-body antenna has a 74.3 total efficiency performance.	2.45	Wool Felt	[141]
22	Handbag zipper antenna structure	The efficiency of the antenna is 97 at 2.90 GHz and 97.4 at 2.70 GHz.	2.44	FR4	[142]
23	Watch strap	The antenna has improved performance to 5 dBi.	2.46 to 2.5	Copper	[143]
24	Reconfigurable patch	This has improved performance to 2.6.	2.3 to 2.68	PDMS	[144]

TABLE 3. *(Continued.)* **Review of the performance of the different wearable antennas for healthcare.**

25	Circular patch	The on-body lower upper band is 58.6 and 50.6 good performance.	2400/5800 MHz	PDMS	[145]
26	UWB	The on-body antenna gives 96.6 efficiencies.	3.1-10.6	Felt	[146]
27	Koch Fractal dipole	The antenna improves to 2dBi.	450 MHz	Jeans	[147]
28	Dipole	The antenna uses silver to improve performance.	2.45	Paper	[148]
30	Stretchable	The antenna improves with the use of a copper conductor.	2.86-2.92	Soft silicon	[149]
31	RFID tag (washable)	The antenna results increase because of the stretchable measurable.	UHF	Cotton/polyester	[150]
32	Patch antenna	The antenna efficiency improves to 60.	3.45	PDMS	[151]
33	Dipole	There is an improvement in the plot to -65 dB.	860 MHz	PET	[152]
34	Monopole patch	The antenna improves to 70.6.	2.01 to 2.80	PET	[153]
35	Metal Rim	The on-body antenna was effective at 50.	2.2	Copper	[154]
37	Louis Vuitton logo	The antenna lowers the upper band at 15.2.	2.4/4.5	Leather	[155]
38	Circular reconfigurable	The antenna performance was at 3.83.	2.5/5.8	FR4	[156]
39	Circular with AMC structure	Then the antenna gives 70% efficiency with a gain of 5.2.	2.4	Ag NWs composite	[157]
40	E shape	The antenna is enhanced to 2.98 and 4.56 gain.	3.3,3.4	Felt	[158]
41	Chinese symbols	The antenna gain is 8.2 with good efficiency.	2.4	Copper	[159]
42	Dipole	The antenna uses graphene, which makes it effective.	2.45	Elastomer	[160]
43	Tattoo antennas	The antenna efficiency is at 60 and -19.9 dB.	868 MHz	Thin Adhesive polymer	[161]
44	Patch screen printed antenna	The antenna uses a few cycles with 2.4 and 2.5.	2.45	Cotton/polyester	[162]
45	Rectangular patch	The antenna efficiency is at 87 and the gain of 5 dB.	2.67 TO 2.92	Silicone Nitrate	[163]

that it will be very effective, such as the experimental design carried out in [78]. In investigating space free over the human body, results reveal the return loss for fabricated antenna located on wrist. There was a slight variation for 2.4 GHz and 5.8 GHz. The occurrence of the bottom ground contributed to the outcome of the antenna. The result displays that there was an agreement among the simulated, validated, measurement of the antenna multilayer tissue. This tissue represents the human wrist, which includes skin, fat, bone, and muscle. Another experiment was carried out with textile material by [79]. The antenna prototype was tested under free space settings with validation of the model and performance. The result of the coefficient of the simulation with measurement is in the decent pact.

The value of the antenna covers dual bands of the final fabricated on-body antenna. The on-body performance was observed to be very stable, thus matching about 2.45 GHz which rests unaffected. In the 5.8 GHz band, there was an observation showing the bandwidth marginally reduced with the coefficient remaining below 10 dB, in the band. This configuration of bending copied the bending output of the wearable antenna that is wrapped with polyvinyl chloride. The antenna demonstrates outstanding on-body performance with the addition of low weight plus simple dimension, which makes the antenna very good for body wear, medical monitoring, and biosensor applications. The investigation carried out for the on-body antenna by [80], measures the return loss after the fabricating antenna outcome was checked on the human wrist, and the experimental antenna on the human wrist. These reveal the multilayer tissue mechanism simulation, which isa small variation due to the occurrence of the bottom ground plane. The simulation efficiency of the antenna-free space reveals the large outcome of the antenna efficiency on the loss features in human tissue.

I. SAR (SPECIFIC ABSORPTION RATE) TECHNIQUES

The example of the specific absorption rate (SAR) of distribution generated 1-g with the implanted antenna with thirty-five heads mode [81]. This reveals the maximum SAR with the net power imputed in 1w, with 1 g and 10 g-average SAR plots regularized to 200 with 70w/kg, Investigation of wearable antenna centered on SAR/on-body patient measurement show how effective and efficient it is on body, see table 4.

There was a comparison in the tissue anatomical head prototypes with additional connected SAR distributions observed inside the six tissue anatomical heal design. This

TABLE 4. Investigation of wearable antenna centered on SAR/on-body patient measurement.

Freq. (GHz)	gain (dB)	Polarization/flexibility	Size$(\lambda_0)^3$	Sar(w/kg)	Material/ε_r	Radiation efficiency (%)	Bandwidth (%)	Ref
2.4-5.8	2.0 5.6	linear/yes	0.26 x0.34x0.001 @2.4ghz	0.056 0.067	felt/0.044	55 60	6.54 11.5	[164]
2.46 5.8	4.1 2.33	linear/yes	0.11 x 0.12 x 0.0004	0.7 0.71	polyamide/3.5	48.4 35.7	16.3 8	[165]
2.45	4.2	linear/yes	π x 0.228 x 0.026	0.55	fr-4/4.3	60.7	3.67	[166]
2.45	6	linear/yes	0.19 x 0.1 0.022	0.891	plastic /2.4	70	6.1	[167]
2.5 5.5	not given	linear/yes	0.275 x 0.549 x 0.04	not given	felt substrate /1.22	not given	11.6 13.2	[168]
2.45	6.88	linear/yes	0.56 x 0.3 x0.013	0.244	rt duroid 5880/22	76	4.88	[169]
2.45	6.2	linear/yes	0.5 x 0.3 x 0.028	0.15	rogers 3003/3	not given	5.5	[170]
2.45	6.584	linear/yes	0.62 x 0.62 x 0.0008	0.0072	rogers 3850/ 2.9	38.84	25	[171]
2.4	8.53	linear/yes	1.08 x 1.08 x 0.0008	0.07	polyester 2.8	not given	11.6 13.2	[172]
0.9 1.8	7.46 8.13	linear/yes	0.21 x 0.26 x 0.005 @ 900mhz	1.31 1.20	rubber/ 3	96.2 98.1	8.6 54	[177]
2.38 3.5	1.38 7.7	linear, linear/yes	0.56 x0.56 x 0.016 @ 2.38 ghz	0.722 0.533	wood felt/1.2	82 95	0.4 7	[178]

is credited to the differential properties around the implanted locations. Furthermore, the SAR distribution in a similar healthcare design with diverse dielectric parameters is initiated to be alike; however, if the conductivities decrease by 20%, it will make the SAR distribution spread deeper in the head models. The high- firmness designs of shares of the bodies, like the head, the heart, the lungs, the thorax, and the breast, are essential parts of SAR. The models also exist for animals, like dogs, ducks, and goats [82], [83]. The effect of electromagnetism is localized with diverse near-field sources with just the imparted portion model used. The facts of the prototypical will make the deep transformation on the subjects is producing within the body, the pinnacle [84], and the sizes for adults and children [85]. All features have an impact on the fields. The specific portion of the body like the head has its dependence resonance [86]. There are problems in making a good anatomical design for electromagnetic dosimetry, which comprises the change in the superficial located in the fat plus water-based tissue like the muscle with 5 mm. The magnetic resonance (MR) image, heart, lungs, and other parts of the body are modelled with change in the shape from suck-like toes pointing as a directed position. There is a general difficulty in characterizing the materials in the region among the main organs of the body.

The SAR is generally used in the dosimeter measure because of its use in the regulating guideline [87]. The SAR distribution, two-dimensional and semi-solid phantom, is evaluated with the use of thermographic techniques [88]. Using this technique for measuring a temperature rise in the phantom surface will cause short electromagnetic exposure. SAR can be observed in the plane figure in the equation below

$$SAR = c.\Delta T/\Delta t[\frac{W}{kg}] \tag{1}$$

With the heat-specific phantom C, T represents the temperature increase, with t being the exposure time. If the experience period is small sufficient, the equation will give sensible outcomes. The second benefit is the technique, which can easily be applied to the structure and numerous frequencies due to independent frequency. SAR can be measured with the use of electric field probes in measuring the electric field E with it can be calculated from

$$SAR = c.\Delta T\frac{\sigma|E|}{2p}[\frac{W}{kg}] \tag{2}$$

The σ means the electric conductivity [S/m], and the ρ means the tissue density [kg/m3]. The SAR characteristically averages 1-gram to 10-gram sections of tissue. The guideline now needs the presence of a variation budget in accounting for the projected variability of models and experiments [89], [90]

The major public concern about the health effect of radiation with the legal requests globally has urged engineers, scientists, with researchers to put into consideration the power absorbed by the body. Concerning this, we can say the SAR by the wireless device is presented as two commonly used SAR limits, namely IEEE [91], and 1.6W/kg for just 1 g tissue. An investigation by [92] shows a torso mode being constructed from the CT and MRI image of actual body use of modelling SAR. In [93], the study complied SAR for 10 g of body tissue in Table 5, the reflection coefficient is measured in response to the antenna array in the free space located in the arm, leg, chest, and shoulder. The bandwidth impedance of the array is not affected but the marginality reduces to 4.6% when it was placed on the arm. Another part was monitored by placing it on the part that makes the resonance frequency. A case series of 80 human tissues and organs with an antenna sensor is located on the chest. The SAR distribution is at 2.4 GHz. This antenna-based sensor is placed at a distance of 10 m and percentage of safety is achieved for standard SAR. The task is to get how SAR is performed with various applications. This is presented in table 3, which reveals great impart in the diverse application.

TABLE 5. SAR rate of antenna for health chronic condition.

SAR(10g) W/Kg	Frequency GHz	Body part
1.07	6	Thigh
1.06	6	Shoulder
1.1	6	Chest
1.05	6	Neck
0.84	6	Arm
1.12	5	Thigh
1.09	5	Shoulder
1.13	5	Chest
1.08	5	Neck
0.98	5	Arm

J. DESIGN OF WEARABLE ANTENNA FOR HEALTHCARE

Designing a wearable antenna for healthcare applications requires careful consideration of several factors for easy experimental process and fabrication. The experimental process focuses on designing and optimizing the antenna's performance, while the fabrication process involves physically building the antenna based on the design specifications generated in the experimental process. The factors needed generally include the frequency of operation, antenna size and shape, and the materials used in construction [94]. The antenna must also be designed to be comfortable and unobtrusive for the patient while providing reliable and robust wireless communication with medical devices and healthcare professionals. One common approach to antenna design in healthcare applications is to use a flexible or conformal antenna that will be combined into clothing or other wearable medical devices [95]. These antennas are designed towards lightweight and comfort, while also providing high gain and efficiency. Antenna diversity and beamforming techniques can also be used to improve signal strength and reduce interference, further enhancing the reliability and performance of wearable healthcare antennas [96].

K. FABRICATION PROCEDURE OF HEALTHCARE

The antenna design has several methods of fabrication. The antenna application will determine the fabrication techniques to be used. The fabrication of the antenna involves the physical design implementation, which will be done in the laboratory. There are four major methods for the fabrication of wearable antenna. Copper with rubber is a mixture of conductive nano-particles, and rubbers for the production of flexible with difficult inflexible conductor layers, which are practical in textile antennae generally for electronic arrangements [97]. Copper mesh techniques involve the copper thread woven in the textile substrates, which will be able to offer a stable rigid structure compared to other techniques. The conductive spray technique is explained as the mixture spray of copper with gases stressed, which can get the conductive layer on the surface of the textile when visible to the spray. The copper foil technique is the simplest technique because of its features, which include the claim of normally available copper tape, which will apply straight to the substrate in the textile clothing. This technique has no fabrication process, which makes it the simplest. All these methods provide flexibility with reliability for textile antenna models. The fabrication process is vital because it involves the physical experimental design process for validation [98].

L. EXPERIMENTAL ANTENNA FOR HEALTHCARE

The experimental process of designing an antenna is to practically validate the antenna performance to see how it agrees with the results. In [99], a textile antenna was modelled for body system, the experimental and fabricated antenna is attached to the cloth front pocket while the part is the antenna attached to the side cloth. For communication, the antenna is woven through with copper thread, together as standalone on-the body, compared to others (see Table 6). These antennae will not change significantly from the front-to-back ratio with beam protection. This experimental analysis for textile-fabricated antennas investigates the body's free space. The result reveals the position varying on the body with the flexible substrate. The antenna recital is straight affected by the radiated power equal to the reliability of the system link. The general outcome of the antenna was determined by return loss and radiation pattern for body area networks. The radiation power forms of the antenna deliver knowledge for future applications although with optimization to fit in for the desired application. The experimental antenna was done by [100], and the environmental signal demodulation of the antenna was verified with the casual body drive cancellation methods. In other words, to get agreement on the results, the measurement was performed with 6 GHz portable radars that are used in integrating the quadrature transceiver with the two-based band amplifier with power organization circuit on a one Rogers printed board (R04350B) and the size of 6.8 cm x 7.5 cm. Furthermore, the improved baseband results signal was experimented with a 12-bit malfunction data achievement module, which was fed into for real-time signal processing in lab view showing identical transceivers used for the design and experimental process. Furthermore, this reveals the block diagram for the Doppler radar noncontact dynamic sign recognition. This dimension is performed at both the front and back of the human body; however, the random movement of the body affects accuracy of detections, which means the measurement needs to be done concurrently at other sides to cancel the casual frequency drifts.

M. TYPE OF WEARABLE ANTENNA FOR HEALTHCARE

Dual major kinds of wearable antenna are discussed in this paper. The category of antenna depends on the applications of the antenna. In this paper, we discuss the fabric/textile with regular/conventional type of wearable antenna. Table 4 reviews the recital of the different wearable antenna, which displays that these wearable antenna makes one good influence depending on the application.

TABLE 6. The wearable antenna design comparison with fabric for healthcare.

Performance	Conductive material	Applications	Dielectric material				Ref
			Material	h(mm)	ε_r	tan δ	
Satisfactory	Silver-copper nickel planted woven fabric	Bluetooth (2.4 GHz)	Wollen felt	3.5	1.45	0.02	[102]
Satisfactory	Not given	GSM (900MHz) and Bluetooth (2.4 GHz)	Unspecified	0.236	3.29	0.0004	[103]
Satisfactory to good	Knitted copper fabric	WLAN (2.4 GHz)	Fleece fabric	3	1.04		[104]
Acceptable	Cooper tape	GPS (1.5GHz)	Cordura	0.5	1.1 and 1.7		[105]
Satisfactory to good	Flectron	ISM and GPS 2.4 and 1.5 GHz	Fleece fabric	2.56	1.25		[106]
Satisfactory	Electron	ISM (900MHz)	Polyurethane protective foam	11	1.16	0.01	[107]
Satisfactory	Zelt	WLAND 2.4 GHz	felt	1.1	1.30	0.02	[108]
Satisfactory to good	Cotton/polyester	ISM (2.4 GHz)	Flectron/conductive ink	2.808	1.6	0.2	[109]
Satisfactory	Polydimethylsiloxane (PDMS)	Not specific (2-2.4 GHz)	Embroidered conductive fibers		3.0-13	0.02	[110]
Acceptable	Silver-copper nickel planted woven fabric	Bluetooth (2.4 GHz)	Polymide space fabric	6	1.14	Negligible	[111]

N. TEXTILE ANTENNA

This fabric category of the antenna is also recognized as a textile antenna. The basic thing about antenna design depends on the applications, such as the wearer's antenna on mobile. Owing to the change in body energy, which affects the output of a textile antenna, the body orientation changes over time. In [109], [110], and [111], a circular orientation textile antenna is designed for a wearable application, the circular polarization wave emits the energy in two ways, both vertically and horizontally. The substrate is polyimide part fabric with 6 mm thickness with permittivity of 1.5 mm, the conductive composite used is called nickel on textile. The fabric antenna was connected to the SMA connector. This antenna was fabricated by the use of a printed circuit board [112]. This fabric antenna design showed improved real-life reception. This model produces a circular polarization inserting the feeding fact to the patch with exiting orthogonal TMO1 and TM10 modes. In [50], the electromagnetic band gap, which is best used in electromagnetics research, is the electromagnetic band gap structure for the ground plane to make it a standard magnetic conductor, which will allow the electric current to radiate capably close to the ground plane. This is often used in modeling a double-band body-worn antenna because it creates a layer on the ground plane to advance the return loss of the antenna so that it gets almost the same resonance frequencies, which will increase the antenna efficiency. In [113] and [114], a fabric-based antenna model provides wireless short sound communication in the body and the particular network. The antenna is through with fabric material, with the mechanism being aperture coupled feeding, which will help in increasing the bandwidth in comparison to another classic antenna. This reveals that the antenna performed excellently, and both the validation and the measurement were in agreement. Having explained all this, it shows that for wearable antenna the fabric antenna is playing a major role in good output applications for medical purposes.

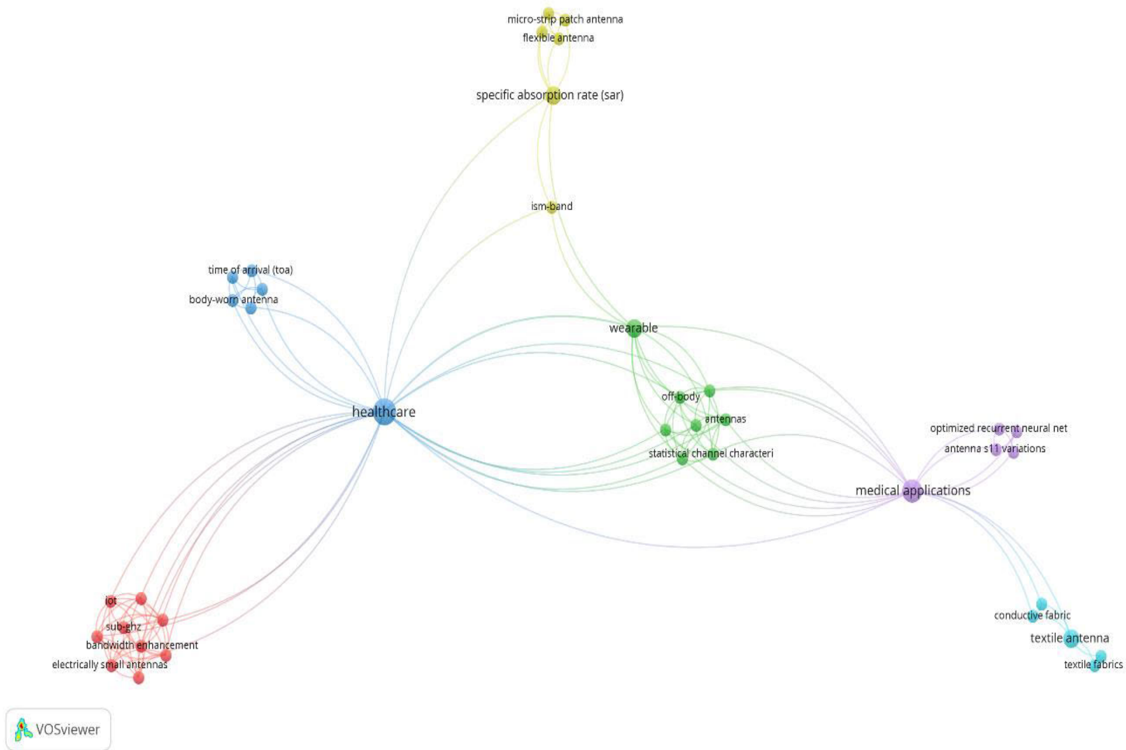

FIGURE 6. Co-occurrence map generated (N = 65).

O. TRADITIONAL WEARABLE ANTENNA DESIGN

The traditional antenna design involves monopoles, microstrip patches, and dipole antenna, which are the recent category of antenna that is wearable. The planar antenna, also the microstrip patch antenna, are modelled over a printed circuit board which made this type of antenna practical because of easy fabrication and low cost. The development of a planar inverted F-shape antenna was designed [115], this antenna's aim is to be placed on fabric material like clothing. This antenna is a quarter wave monopole antenna and a bent structure on the ground plane. This wearable antenna ground plane is directed on strong radiation when designed. Furthermore, the ground plane shield against human radiation that will not radiate to the body, this means the ground plane function as a reflector for radiation with a similar antenna model. In exploring more, another wearable antenna with F-shape was designed for Bluetooth operated system [116], this type of antenna was designed with attachment on the people's body arm with the use of flexible substrate material, all the selection of material was done in accordance to [117], which is low profile to open in 100MHz – 500MHz with the omnidirectional covering the azimuth plane with the production of wide band area return loss and has a vertical or round polarization. It is sometimes desirable to have Omni directional traditional pattern for wearable antenna, this is always good for smart fabric and mobile device. Furthermore, the Omni direction radiation pattern should be modelled towards the side lobe which can be dangerous to the body.

P. BIBLIOMETRIC ANALYSIS

The bibliometric analysis with VOSviewer with 65 document produced 96 keywords, which is cross-checked with plurality, alternative word, and also redundant terms with creation of vocabulary list file. The 65 documents in (ris files) with the thesaurus file resulting in refine co-occurrence mapping 39 connected items with 96 keywords. This is frequent once in the database; this is presented in Figure 6

In the bibliometric investigation, five prominent clusters [red, blue, green, purple and brown] are detected. The keyword/term wearable and medical application are projecting spheres size, signifying high occurrence frequency. Wearable is openly associated with the (linked or co-occur) relations like antennas, off body and statically channel characteristics. Furthermore, it has a strong link to the ism band, Sar, flexible antenna and microstrip patch antenna. The medical application (with purple) is directly associated with antenna variation, optimised recurrent neural net and the medical application strong link to the conductive fabric (mentioned in this paper), textile antenna and textile fabrics. The blue link which is centre on the subject matter (healthcare) is linked to body antenna and time of arrival. It further links on red with IoT (Internet of things), bandwidth enhancement and electrical small antennas. Digitalization value innovations with sovietisation are the features implicit to arithmetical intervention. Furthermore, the integration of antenna mechanism technology is one of the major drivers of digitalizing healthcare.

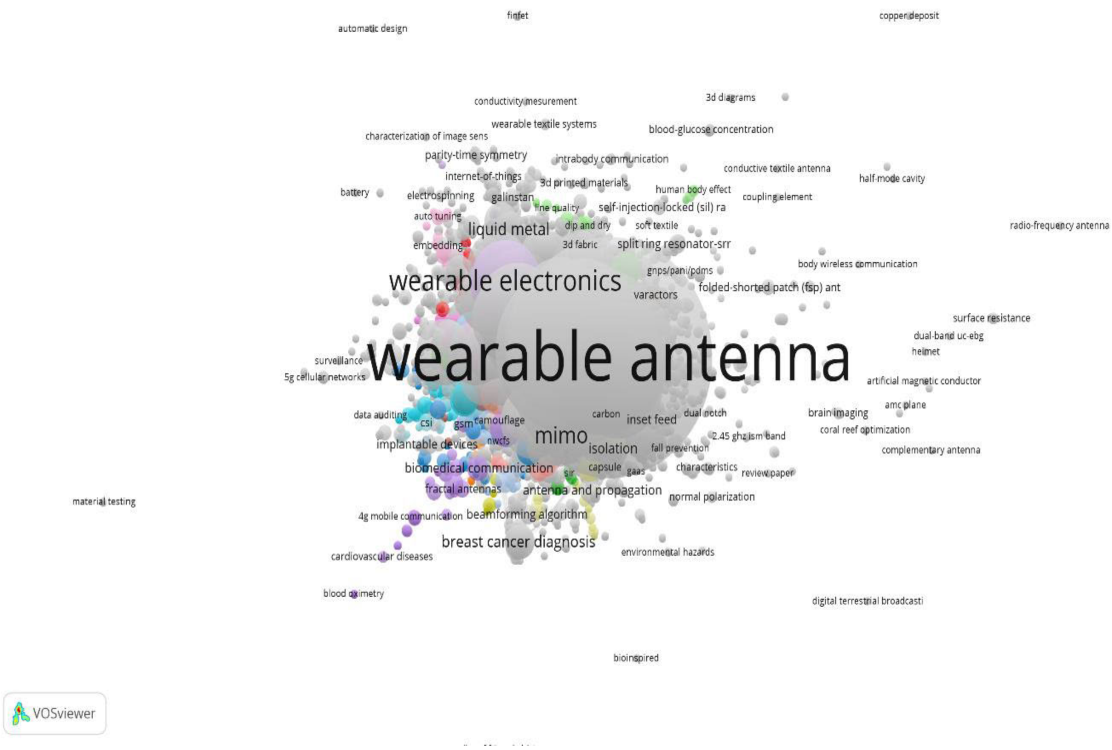

FIGURE 7. was captured with VOSviewer software after running the data algorithm for wearable.

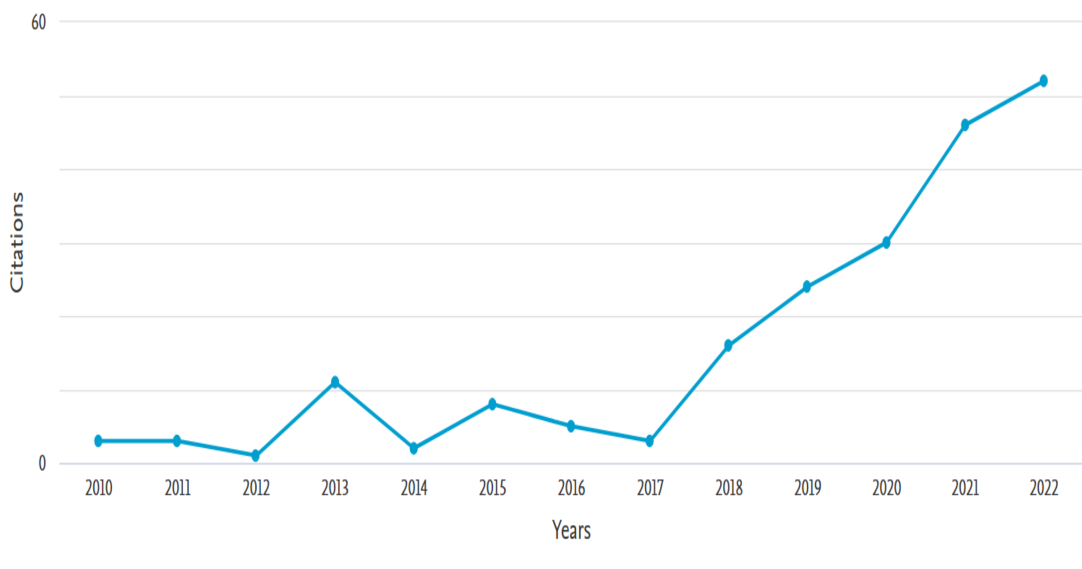

FIGURE 8. citation trend of published work on subject matter (Source Scopus).

- Cluster 1 has 69 items, and it focuses on wearable devices and implants, sensors, antenna wearable devices, body area networks, electromagnetic metamaterial, flexible antenna devices, human-body antenna communication, the design of the antenna, and internet medical applications.
- Cluster 2 contains 66 items and focuses on antenna material, gain with bandwidth of the antenna, 5 and 6G communication, the array, microwave, Nano antenna, millimetre wave, slot, satellite communication siw antenna and sensor, structural health monitors, transceivers and Wi-Fi antenna.
- Cluster 3 has 63 items with attention on ambient sources, electronics textile, harvesting, human body augmented, indicators, liquid metals, microstrip antenna, nanocomposites, radio frequency, rectifier, side channels, textile solderless, wearable medical device, and visible light communication.

- Cluster 4 has 58 items which include an absorber, antenna for sensor application, bio-radar, breathing monitoring, computer vision, deep learning, e-textile, a dielectric substrate, mobile health, photo paper, random forest, potentiometric sensor, liquid sensing, IoT wearable device, and wireless sensing.
- Cluster 5 has 56 items such as bioelectricity, biology and medical computing, notch, path visibility, mutifidelity, polydimethylsiloxane, single antenna, high isolation, body-to-body, dual node antenna, multi-conductor, and on-body antenna.

The last cluster with just 20 items has biomedical engineering m dual resonate frequency, front-to-back ratio, radio frequency sensor, wearable textile materials, wireless network and communication, numerical simulation, environmental engineering, body-centric antennas, and public health in Figure 7.

V. DISCUSSION

A. INSIGHT FROM SLR

One key insight from this article is the importance of integrating antenna wearables with other digital healthcare technologies, such as wireless sensors and data analysis algorithms. We note that by combining these technologies, it is possible to create a comprehensive system for remote medical monitoring and diagnosis that can provide real-time feedback to both patients and healthcare providers.Another important insight from this article is the need for further research and development in this field. The rise in citations is that the research is making a novel or important contribution to the field (see Figure 8). Furthermore, the research is providing insights or solutions to an issue that is of current interest or concern.

We emphasize that while antenna wearables show great promise for digital healthcare, there are still many technical and practical challenges that need to be addressed. For example, improving the accuracy and reliability of medical data collected by antenna wearables, as well as ensuring their compatibility with existing healthcare systems and regulatory frameworks.

This article offers a comprehensive review of the current up-to-date in antenna wearables for digital healthcare. By highlighting the potential benefits and challenges associated with this technology, we provide valuable insights for researchers, healthcare providers, and policymakers working in this field.

B. FUTURE DIRECTION

Looking to the future, there are several potential directions that wearable antenna technology could take in the context of digital healthcare. Future research should identify areas that will need to build from the present study to gain more understanding on wearable antenna for digital healthcare.

One potential future direction is the development of more sophisticated and integrated wearable antenna systems. This could involve the integration of multiple antennas to provide more comprehensive medical monitoring, as well as the development of wireless sensor networks that can transmit data from wearable antennas to healthcare providers in real-time. This would enable more personalized and timely medical care, as well as better tracking of patient outcomes and treatment effectiveness.

Another potential direction is the miniaturization of wearable antennas, making them even smaller and more flexible, and allowing them to be integrated into a wider range of clothing and accessories. This would enable greater ease of use and comfort for patients, as well as more discreet medical monitoring.

The development of implantable antennas is another potential direction for wearable antenna technology in digital healthcare. While implantable antennas present significant technical challenges, they have the potential to provide continuous and long-term monitoring of medical conditions, such as heart function, brain activity, and blood glucose levels. This could enable earlier detection of medical problems, as well as more personalized treatment approaches.

Finally, the usage of artificial intelligence with machine learning algorithms could help to improve the outcome and accuracy of wearable antenna systems for medical monitoring and diagnosis. These technologies could be used to analyze and interpret the large capacities of data generated with wearable antennas and to identify patterns and anomalies that could indicate medical problems. This would enable more effective and efficient medical care, as well as more personalized treatment approaches for patients.

Overall, the future of wearable antennas for digital healthcare is exciting and full of potential. As new research and development efforts continue to advance this technology, we can expect to see even more sophisticated and integrated systems that have the possible to revolutionize the way we monitor and diagnose medical conditions.

VI. CONCLUSION

This paper shows various health mechanism applications for digitalization. The use of technology helps in improving the delivery of healthcare, such as electronic health systems, telemedicine, mobile health, remote patient monitoring, and wearable devices, and the updated review on wearables and

implants for revolutionizing healthcare. This paper has significant implications for practical healthcare, revolutionizing delivery through digitalization and advanced technologies. This paper reveals how the next generation of advanced technology is providing adequate applications in tackling the challenges in digital healthcare. The advancement of various techniques gives future direction to digitalizing healthcare. We examine various studies done and published on digital healthcare, telemedicine, wearable devices, and many more mechanisms that enhance healthcare delivery. The objective of this paper was achieved, the paper attempts to close the gap in investigating mechanisms for digital health care, and wearable devices with antenna applications. We comprehensively cover antenna applications in healthcare and provide a state-of-the-art update on recent developments in healthcare with a focus on design, monitoring devices, diagnostic implants, early detection mechanisms, and control. We also examine wearable analysis and performance, fabrication and experimental approaches, and the major types of wearables. This assists with existing chronic disease management and future epidemics with provided tools. The following are some of the paper's contributions to knowledge:

- This paper attempts to close the gap in investigating mechanisms for digital health care, wearable devices with antenna applications, and addressing challenges of digital health
- A broad overview of the essentials, principles, and techniques for antenna application on digital healthcare-based technology, monitoring, detection, follow-up, and diagnosis is presented.
- Demonstrating how technology, such as electronics health systems, mobile health and wearable will enhance healthcare delivery
- The recent updated trends and achievements in digital medical technologies are analyzed in detail.
- The design requirements for high performance and effectiveness of wearables for sensing and simulations are discussed.
- The updated fabrication and experimental approaches show that simulation and experiment are in agreement.
- The bio-electromagnetic digital tools give the body a complete view of patient health and access to the data with more flexible control.
- The incorporation of the internet of things (IoT), machine learning (ML), robotics, and big data analysis, with cloud computing integrating wearable antenna, is presented to provide future research direction on the digital health system.
- The setting progress for each of the permitting technologies along with the open research challenges is presented.

This paper suggested limitations

Lack of empirical evidence: The abstract states that systematic reviews reviewing wearable antenna systems in healthcare are rare. Evaluating the validity and reliability of abstract data without specific context or empirical evidence is challenging. Limited resources: Although the abstract discusses the range of applications and achievements in digital health, it does not provide specifics or examples, making it difficult to assess the breadth and depth of research.

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