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Wearable Band with Electromagnetic Band Gap Antenna for Heart Rate Detection System

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Abstract

Wearable antennas are antennas that can be applied to the human body and are made of flexible materials, making them ideal for healthcare technology. The quality of the signal received by the antenna directly affects the accuracy of heart rate detection If the antenna measurements indicate strong, clear signal reception, the heart rate monitor can accurately detect and interpret heartbeats. In this stud, a planar monopole antenna was designed and developed using a circular patch with Ultra Wide Band (UWB) characteristics. The FR-4 and copper were utilized for the substrate and the ground plane and patch, respectively. Simulations and measurements were conducted at 2.4 GHz and 5 GHz. The antenna with the added EBG structure showed improved performance compared to the conventional antenna, exhibiting better S11 and VSWR values. Additionally, all radiation patterns were unidirectional. Applying this antenna to transmit heart rate measurements results in an accuracy of 94.34% compared to conventional onsite heart rate measurement. This study demonstrates that the wearable band provides real-time heart rate monitoring, while the EBG antenna enhances sensitivity and accuracy in detecting heart rate. This research can be enhanced by optimizing the EBG design and conducting additional trials to ensure the device performs well for a variety of users.

Keywords: Wearable antenna, Monopole Planar, EBG, Ultra Wide Band

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1. Introduction

Recently, the development of wearable antenna technology has progressed rapidly. In this study, the focus is on designing a wearable antenna for WBAN (Wireless Body Area Network), intended for transmitting heart rate data. Heart rate monitoring is an essential part of checking vital signs, a routine task performed by healthcare professionals. A wearable antenna is a device designed to be worn on the human body[1]. The design of a wearable antenna must take into account the device's flexibility, affordability, and the electromagnetic radiation it emits.

To address these issues, this research proposes a solution: the design of a wearable antenna with a substrate layer made of FR-4 material, which is more affordable and offers good mechanical strength[2]. Copper is used in the ground plane, patch, and structure layers of EBG due to its high electrical conductivity, which enables the transmission of radio frequency signals with minimal power losses. This wearable antenna design also incorporates an Electromagnetic Band Gap (EBG) structure to improve performance and reduce radiation exposure to the human body.

The wearable antenna designed in this research is an Ultra Wide Band (UWB) planar monopole incorporating a Uniplanar Compact Electromagnetic Band Gap (UC-EBG) structure for wireless body communication. The UWB planar monopole antenna supports high-speed wireless communication systems, emitting bursts of multiple radio frequencies with wideband radiation, allowing simultaneous transmission across various frequencies This capability enables very high data transfer speeds[3].

Medical professionals use various methods to measure heart rate, such as stethoscopes electrocardiograms (ECCs), phonocardiograms (PCGs), and auscultation. However, these methods are typically clinical, expensive, and require specialized expertise to perform. Therefore, there is a need for a device that is easy to use, safe, and specifically designed for measuring heart rate[4]. Based on the need for periodic monitoring of heart rate, a wearable device is required to enable convenient, regular checks anytime and anywhere[5]. Previous research on wearable devices for heart rate detection systems has shown some shortcomings when used on the human body. In this study, several solutions were introduced to address these issues, including the addition of an EBG structure to reduce radiation from the antenna, the use of an FR4 substrate to optimize antenna performance, and the design of a flexible, adjustable device.

In this study, the designed wearable incorporates an Ultra Wide Band (UWB) antenna with an added Electromagnetic Band Gap (EBG) structure. A conductive textile EBG is proposed to further reduce radiation exposure to the human body while improving antenna gain and efficiency. A suspended transmission line model is used to evaluate the performance of various EBG designs under bending conditions[6].

The research involved testing the antenna both without and with the EBG structure, designed for healthcare applications at ISM band frequencies of 2.4 GHz and 5 GHz. The results showed that the designed antenna parameters met the required specifications, allowing the antenna to operate effectively at the specified frequencies. The specifications include a VSWR value of ≤ 2, S_{11} of $\leq$ 10 dB, and gain of > 0. The Specific Absorption Rate (SAR) limit follows the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standard, which is $\leq$ 1.6 W/Kg regarding human tissues by the United States Federal Communication Commission (FCC)[7].

2. Method

A. Design Method

The design aims to create a wearable antenna of the planar monopole type with the addition of UC-EBG, capable of operating at frequencies of 2.4 GHz and 5 GHz. Fig. 1 shows a flowchart illustrating the design process of the wearable planar monopole antenna. These frequencies are part of the ISM (Industrial, Scientific, and Medical) band, a radio

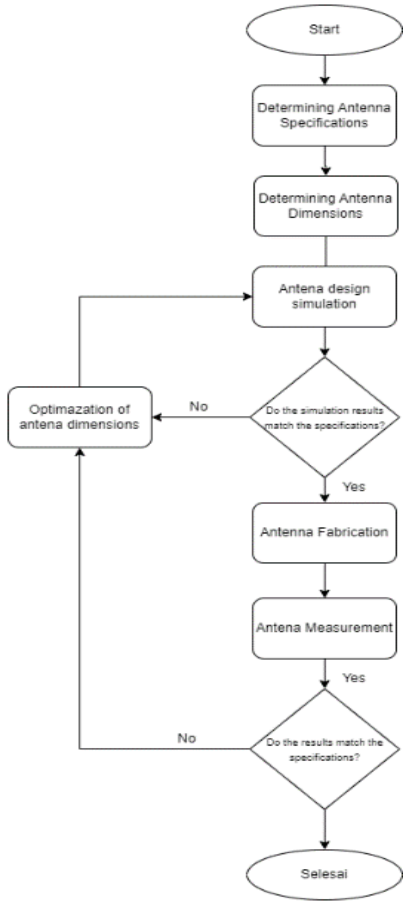


Fig. 1. Flowchart of Wearable Antenna Design

frequency allocation that does not require a license and can be used freely by users[8].

The ISM band encompasses frequencies commonly used in wireless technology such as Wi-Fi, Bluetooth, and medical devices. The use of UC-EBG is intended to enhance the antenna's performance in transmitting and receiving radio signals at the specified frequencies. As a result, the designed antenna is expected to deliver optimal transmission quality for wearable applications across various usage scenarios. Fig. 1. illustrates the design process of the wearable antenna

B. Antenna Design and Specifications

In this study, simulation and design were conducted to achieve the desired antenna specifications. The specifications include a microstrip antenna, chosen for its simple characteristics, small dimensions, lightweight design, and ease of fabrication[9].

Another antenna specification used in this study is phantom, a human body model used to simulate the Wireless Body Area Network (WBAN). A WBAN is an integrated system composed of multiple sensors distributed and wirelessly connected within a specific network structure[10]. The phantom is designed to match the dimensions and properties of various parts of the human body, including physical aspects such as skin thickness, fat, and muscle, as well as specific characteristics like permittivity, permeability, and conductivity. Accurate design based on these original dimensions and properties helps produce simulations that closely align with actual antenna measurement results[11]. Table 1 shows the antenna specifications. The thickness values of the phantom can be seen in Fig. 2. [12]:

Table 1. Antenna Specifications

No	Parameter	Details
1	Operating Frequency	2.4 dan 5 GHz
2	VSWR	≤ 2
3	Bandwidth	≥ 500 MHz
4	SAR	≤ 1.6 W/Kg

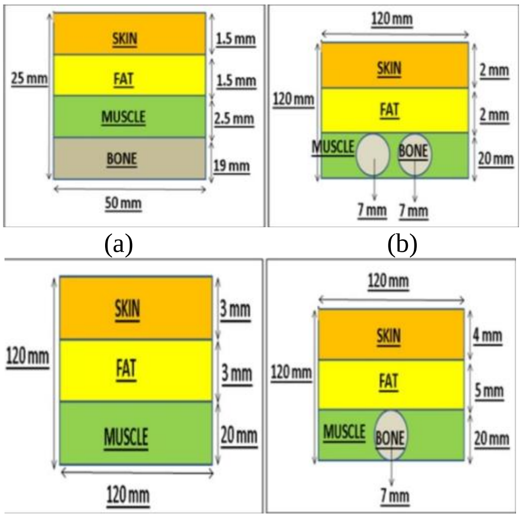
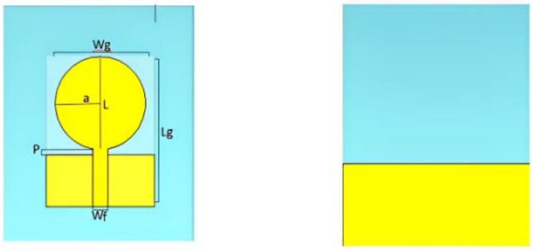


Fig. 2. Phantom Wirst (a), Phantom Arm (b), Phantom Chest (c), Phantom Thigh (d)

Table 2. Parameters of the Conventional Planar Monopole Antenna

Parameters	Symbol	Size (mm)
Width Groundplane	Wg	27.85
Length Groundplane	Lg	23.45
Width Feedline	Wf	2.983
Length Feedline	Lf	11.72
Patch Radius	a	8.45
Thickness Substrate	H	1.6
Distance between Patch and Grounplane	P	1



Front View Back View

Fig. 3. Conventional Planar Monopole Antenna

C. Design of Conventional Planar Monopole Antenna

Planar monopole antennas are the preferred choice due to their advantages, such as wide impedance, bandwidth, and omnidirectional radiation patterns, which has proven effective over time[13]. The design and simulation were conducted using 3D modeling software. Table 2 presents the parameters of the conventional planar monopole antenna, while Figure 3 illustrates the shape of the antenna, designed with a circular patch.

D. Design of Antenna with EBG Structure

In this section, the design and simulation of a planar monopole antenna with the addition of UC-EBG were conducted. The dimensions of the UC-EBG were adjusted to align with the initial design of the conventional antenna. The UC-EBG structure was placed parallel to the patch and feedline. In this design, only two UC-EBG structures were used, and positioned close to the feedline. The UC-EBG is preferred for wearable antennas due to its ease of fabrication and low cost[14]. The incorporation of this feedline design can enhance the antenna's performance. The dimensions of the planar monopole antenna with the UC-EBG structure are presented in Table 3, while the antenna featuring the EBG structure is shown in Figure 4.

Table 3. Dimensions of the UC-EBG Planar Monopole Antenna

Parameters	Symbol	Size (mm)
Square EBG	***x***	8
Width of EBG plus	**y**	3
Length of EBG Plus	**z**	10

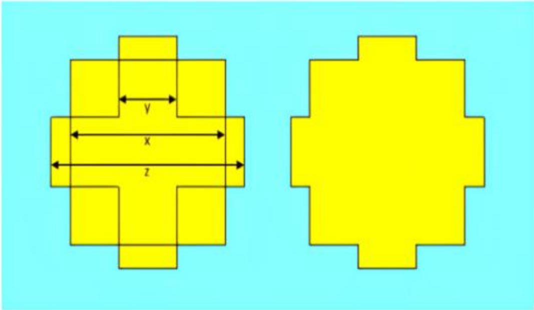
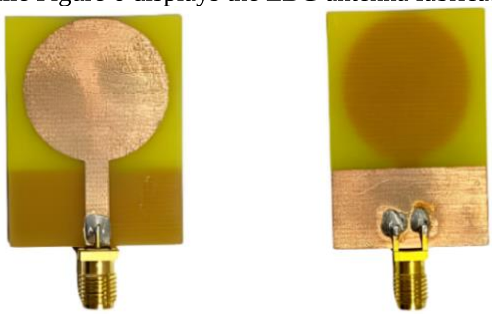


Fig. 4. Planar Monopole Antenna with UC-EBG Structure

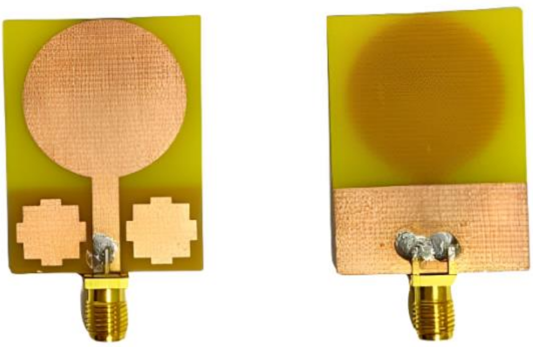
E. Antenna Fabrication

After the design and simulation, the next step is the antenna fabrication process. Fabricating the antenna is a crucial step in bringing the antenna design to realization[15]. Once the antenna is fabricated, measurements will be conducted to observe its S_{11} value and operating frequency. The specifications of the designed wearable antenna include achieving good S_{11} and VSWR at operating frequencies of 2.4 GHz and 5 GHz. The S_{11} and VSWR values from the antenna meet the specifications. The following are the fabrication results for both the conventional antenna and the antenna with the UC-EBG structure. The fabrication of the conventional antenna is shown in Figure 5, while Figure 6 displays the EBG antenna fabrication.



(a) Front View (b) Back View

Fig. 5. Conventional Antenna Fabrication Results



(a) Front View (b) Back View

Fig. 6. EBG Antenna Fabrication Results

F. System Block

In this study, the integration of the wearable antenna with the heart rate sensor utilizes the access point method. In this approach, the ESP32 functions as an access point, allowing other devices to connect to the ESP32 via Wi-Fi[16].

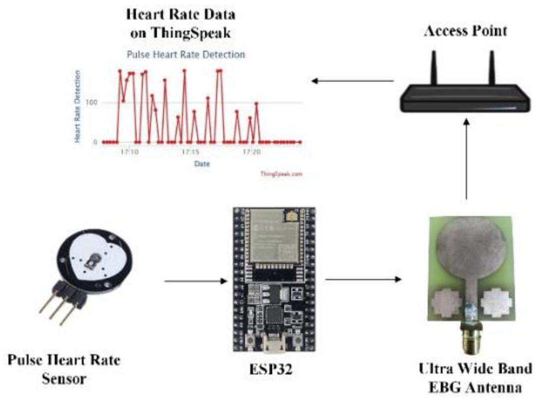


Fig. 7. Integration Wearable Antenna with Sensor

Fig. 7. illustrates the schematic for heart rate sensor data transmission using a wearable antenna. In this schematic, the ESP32 functions as an access point, while the wearable antenna acts as the transmission antenna, sending processed heart rate data from ESP32 to the internet via a Wi-Fi network. The transmitted heart rate data is displayed on the ThingSpeak website[17]. This data is measured in Beats Per Minute (BPM), indicating the number of heartbeats per minute. A normal human heart rate typically ranges from 60 to 100 BPM[18].

3. Result and Discussion

A. Measurement Result Antenna Conventional and Antenna with EBG Structure

The conventional antenna and the antenna with the EBG structure, both of which have been fabricated, were measured using a Vector Network Analyzer (VNA). This was done to compare the S_{11} and VSWR values from simulation and measurement at frequencies of 2.4 GHz and 5 GHz for the conventional antenna.

This comparison aims to evaluate the S_{11} and VSWR values at frequencies of 2.4 GHz and 5 GHz between simulation and measurement for the conventional antenna. In this study, the simulation and measurement results exhibited different values, with the simulation values for the conventional antenna performing better than the measurements. Simulation values for conventional antennas are better than measurements. This discrepancy arises because simulations are typically conducted under

Table 4. Simulation and Measurement Result of the Conventional antenna and EBG antenna

Frequency (GHz)			**2.4**	**5**
Simulation	**Conventional**	S_{11} (dB)	13.374	13.523
		VSWR	1.518	1.533
		Bandwidth (MHz)	380	1.680
	EBG	S_{11} (dB)	13.792	13.681
		VSWR	1.513	1.521
		Bandwidth (MHz)	530	760 MHz
Measurement	**Conventional**	S_{11} (dB)	13.271	13.498
		VSWR	1.598	1.544
		Bandwidth (MHz)	500	840
	EBG	S_{11} (dB)	14.203	14.069
		VSWR	1.433	1.398
		Bandwidth (MHz)	520	1320

interference-free or ideal conditions, while measurements are influenced by surrounding objects, reflections, electromagnetic interference, and losses in cables and connectors. However, for the antenna with the EBG structure, the measured values were better than the simulated ones. Table 4 presents the simulation and measurement result for both the conventional antenna and the EBG antenna.

B. Radiation Pattern

The radiation pattern of an antenna is a visual representation that illustrate the direction and intensity of radiation emitted by the antenna[19]. It describes the distribution of electromagnetic field strength emitted or received by the antenna in various directions, presented in graphical form to aid in understanding and optimizing antenna performance.

Radiation pattern measurements were conducted in both the azimuth and elevation directions by rotating the antenna horizontally from 0° to 360° at intervals 10°. For both azimuth and elevation, radiation patterns were obtained for the planar monopole antenna with the EBG structure at a frequency of 2.4 GHz. The comparison of the the radiation patterns from simulation and measurement are displayed as follows.

Fig. 8. and Fig. 9. show the radiation pattern in the azimuth direction, while Figure 10 displays the radiation pattern in the elevation direction for the frequency of 2.4 GHz. Both the azimuth and elevation radiation pattern exhibit a unidirectional shape. The azimuth polarization at a frequency of 2.4 GHz has a coverage angle of 90°, whereas the elevation polarization at a frequency of 2.4 GHz has a coverage angle of 50°.

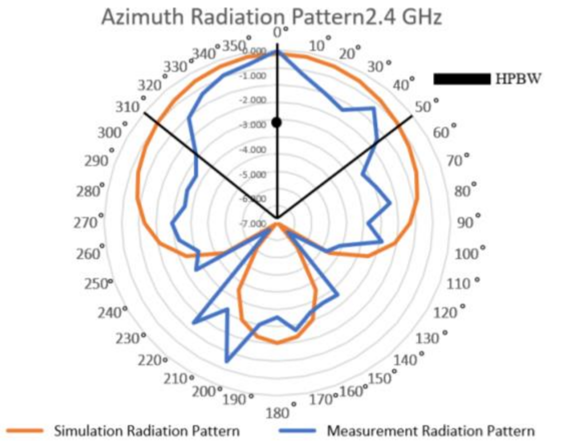


Fig. 8. Azimuth Radiation Pattern at 2.4 GHz

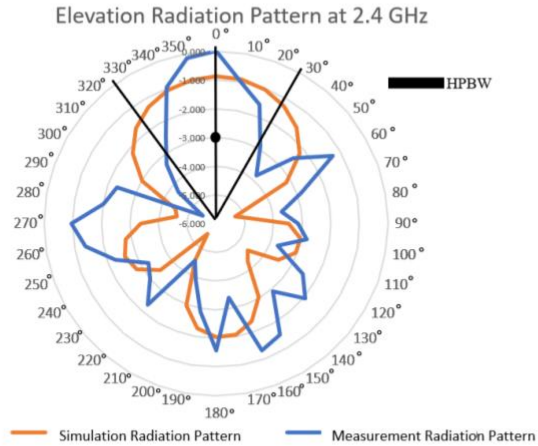


Fig. 9. Elevation Radiation Pattern at 2.4 GHz

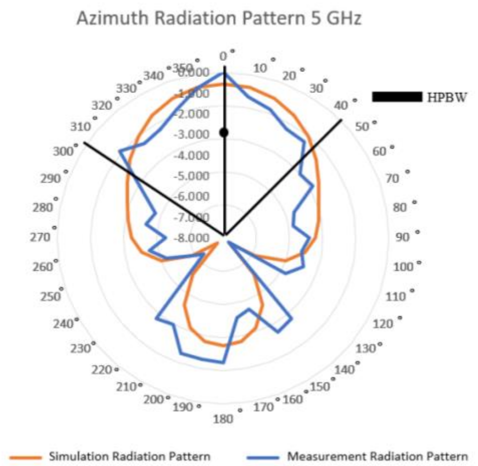


Fig. 10. Azimuth Radiation Pattern at 5 GHz

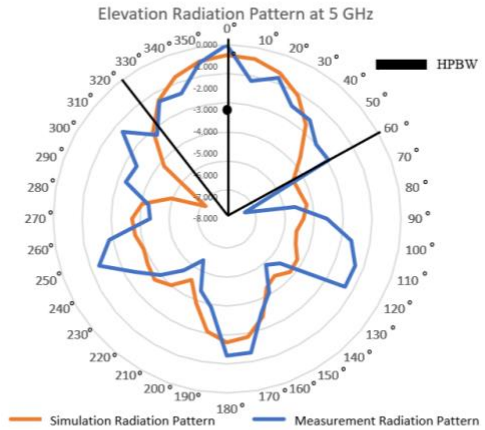


Fig.11. Elevation Radiation Pattern at 5 GHz

Figure 10 and 11 shows the radiation pattern for antenna with the addition of EBG. The azimuth and elevation directions for simulation and measurement at a frequency of 5 GHz. Both the azimuth and elevation radiation pattern exhibit a unidirectional shape. The azimuth polarization at a frequency of 5 GHz has a coverage angle of 80° and the elevation polarization at a frequency of 5GHz has a coverage angle of 90°.

Overall, the radiation pattern measurements of antenna with EBG structure in the azimuth and elevations directions at frequencies 2.4 GHz and 5 GHz resembles the radiation patterns from the EBG antenna simulation results. However, there are differences in the measurement result, as the radiation pattern still exhibits back lobes and side lobes, indicating that the emitted radiation pattern is less than optimal. This can be attributed to the fabrication process and the environmental conditions during the measurement.

C. Gain

Gain is the ratio of the radiation intensity in a specific direction to the radiation intensity that would be obtained if the power received by the antenna at the receiver were distributed evenly in all directions, as with an isotropic antenna[20].

The gain value is calculated by measuring the radiation pattern at specific angles during a 10 second period, focusing on when the received power reaches its maximum. After obtaining the average of the maximum received power values, calculations are performed, accounting for losses using the established formula [21]. The comparison of gain values between simulation and measurement indicates that the simulated values are higher than those obtained during measurement. The results of this comparison can be seen in Table 5.

Table 5. Comparison of Gain Values

Frequency (GHz)	Simulation		Measurement	
	Conventional Antenna	EBG Antenna	Conventional Antenna	EBG Antenna
2.4	4.24 dBi	4.19 dBi	0.206 dBi	1.519 dBi
5	6.64 dBi	6.12 dBi	5.498 dBi	3.206 dBi

D. Data Validation

The validation of the data used in this study involves comparing heart rate data generated by the Arduino IDE software with the data displayed on the ThingSpeak website. From the data presented in Figure 12, it was found that no discrepancies occurred because the Arduino IDE software and the ThingSpeak website are connected. Generally, data transmission to ThingSpeak occurs at intervals of less than 10 seconds.

The graph in the Figure 11 display the results of heart rate measurements obtained from the sensor. The vertical axis (y-axis) represents heart rate values in beats per minute (BPM), while the horizontal axis (x-axis) shows the sequence of data collection from the sensor. Each point on the graph corresponds to a specific heart rate value at a given time, allowing us to observe how the heart rate changes over time based on the collected data.

In this study, 20 trials were conducted using the designed wearable devices alongside heart rate detection tools such as Omron. The purpose of these trials was to assess the accuracy of the heart rate data

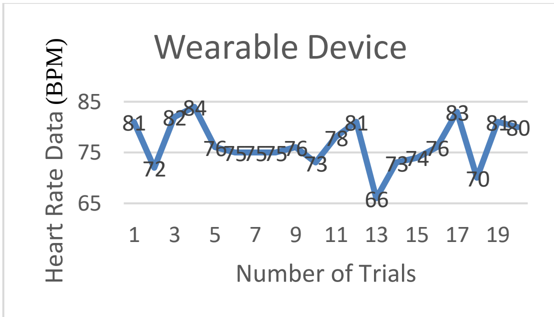


Fig. 12. Heart Rate Testing Data Using the Wearable Band

Table 6. Accuracy Results of Wearable Band Data Compared to Omron

Wearable Band Data (bpm)	Omron Data (bpm)	Difference	Accuracy (%)
81	78	3	96.15
72	76	4	94.74
82	72	10	86.11
84	72	12	83.33
76	73	3	95.89
75	74	1	98.65
75	76	1	98.68
75	74	1	98.65
76	73	3	95.89
73	73	0	100.00
78	75	3	96.00
81	73	8	89.04
66	74	8	89.19
73	80	7	91.25
74	78	4	94.87
76	78	2	97.44
83	79	4	94.94
70	79	9	88.61
81	81	0	100.00
80	78	2	97.44
76.55	**75.80**	**4.25**	**94.34**

produced by the wearable antenna, ensuring it closely matches the data generated by Omron device. Table 6 presents the heart rate accuracy results.

From the results of the table, the accuracy value comparing the wearable band to the Omron device is 94.34%. These results indicate that the wearable band is feasible tool for heart rate detection detection.

4. Conclusion

In this study, the designed antenna for wearable devices meets specifications suitable for heart rate detection, achieving a high accuracy of 94.34%. The antenna with an added EBG structure demonstrates improved performance compared to the conventional antenna, showing better S_{11} and VSWR values. This comparison indicates that the radiation pattern, S_{11} , VSWR, and gain parameters of the wearable antenna can optimally transmit heart rate data in real-time. Although there is a slight difference in heart rate values compared to the Omron device, this difference is not significant. Therefore, this device is suitable for measuring heart rate with good accuracy.

References

[1] N. H. A. Rahman, Y. Yamada, and M. S. A. Nordin, "Analysis on the Effects of the Human Body on the Performance of Electro-Textile Antennas for Wearable Monitoring and Tracking Application," *Materials*, vol. 12, no. 10, May 2019, doi: 10.3390/ma12101636.

[2] T. Amaliya and H. Ludiyati, "Realisasi Antena Mikrostrip Persegi Panjang Menggunakan Substrat FR4 Termodifikasi dengan Mode TM01 dan TM12 Pada Frekuensi Kerja Radar Altimeter Pesawat", *Industrial Research Workshop and National Seminar*, Agustus 2019.

[3] D. I. Setiani, "Rancang Bangun Antena Berbentuk Elips Ultra Wideband (UWB) Berbasis Mikrostrip Untuk Monitoring Radar." Teknik Telekomunikasi, Fakultas Ilmu Terapan, Universitas Telkom, 2013.J. Widodo, B. J. Habibie, and S. B. Yudhoyono "Integrated transportation system for archipelagic country", *International Journal of Sustainable Development*, vol. 3, no. 1, pp. 13-23, 2023.

[4] Agung Gamara, Atika Hendryani*, "Rancang Bangun Alat Monitor Detak Jantung Dan Suhu Tubuh Berbasis Android", VOL. 14 NO: 2;* JURNAL SEHAT MANDIRI, Padang,Indonesia, 2019.

[5] L. A. Hidayat and A. Yudhana, "Rancang Bangun Pendeteksi Psikologis Seseorang Berdasarkan Detak Jantung Berbasis Komputer," *Transmisi*, vol. 20 no. 1, pp. 43–48, 2018.

[6] Tia P. Sari, Darwison dan Ratna Aisuwary, Sistem Monitoring Denyut Jantung Menggunakan Mikrokontroler Arduino dan Komunikasi Modul Xbee, *Seminar nasional sains dan teknologi*, Jakarta, 17 November 2015.

[7] M.I. Hossain, M.R.I. Faruque, M.T. Islam, "Analysis on the effect of the distances and inclination angles between human head and mobile phone on SAR," *Progress in biophysics and molecular biology*, 119, 2, 103-110, 2015.

[6] P. Puspitaningayu, A. Widodo, and E. Yundra, "Wireless Body Area Networks dan Pengaruhnya dalam Perkembangan Teknologi m-Health," 2018.

[7] E. Wang and Q. Liu, "GPS Patch Antenna Loaded with Fractal EBG Structure Using Organic Magnetic Substrate", *Progress In Electromagnetics Research Letters*, Vol. 58, 23–28, January 2016.

[8] R. Pei *et al.*, "Wearable EBG-Backed Belt Antenna for Smart On-Body Applications," *IEEE Trans Industr Inform*, vol. 16, no. 11, pp. 7177–7189, , doi: 10.1109/TII.2020.2983064, Nov. 2020.

[9] S. Romadhona, M. P. K. Praja, and R. A. Rochmanto, "Desain Antena Mikrostrip Rectangular Frekuensi 3,5 GHz Menggunakan Metode Slits", *SCIENCE TECH*, Vol.9, No. 2, August 2023, pp. 140-151.

[10] R. P. Lestari, D. Risqiwati, and Z. Sari, "Wireless Body Area Network untuk Detak Jantung dan Suhu Tubuh," *REPOSITOR*, vol. 2, no. 3, pp. 269–276, 2020
[11] R. Bayu Susanto"Perancangan Dan Realisasi Wearable Antenna Microstrip 2.4 Ghz Untuk Memonitor Pernapasan.No.2 April 2023."
[12] M.I. Maesharoh, L.O. Nur, Edwar, "Perancangan Dan Realisasi Antena Mikrostrip Circular Pada Frekuensi 5,8 Ghz Untuk Mendeteksi Kepadatan Tulang", *e-Proceeding of Engineering* : Vol.10, No.5 Oktober 2023.
[13] I. Kusuma, T. Hariyadi, and Mukhidin "RANCANG BANGUN ANTENA PLANAR MONOPOLE MIKROSTRIP UNTUK APLIKASI ULTRA WIDEBAND (UWB)," *ELECTRANS*, VOL.13, NO.2, SEPTEMBER 2014, 139-146.
[14] A.Y.I. Ashyap et al., "An overview of electromagnetic band-gap integrated wearable antennas," *IEEE Access*, vol. 8. Institute of Electrical and Electronics Engineers Inc., pp. 7641-7658, 2020.
[15] A. Pradana and D. Arseno, "PERANCANGAN DAN REALISASI ANTENA HORN DENGAN METODE 3D PRINTING PADA FREKUENSI S-BAND DESIGN AND REALIZATION OF ANTENNA HORN WITH 3D PRINTING METHOD FOR S-BAND FREQUENCY", *Proceeding of Engineering* : Vol.8, No.6 Desember 2021.
[16] A. Mier, A. Sharp, and Y. Vagapov, "Comparative Analysis and Practical Implementation of the ESP32 Microcontroller Module for the Internet of Things," *2017 Internet Technologies and Applications (ITA)*, Wrexham, UK, 2017, pp. 143-148, doi: 10.1109/ITECHA.2017.8101926.
[17] D. Haryanto, "PERANCANGAN JARINGAN WIRELESS ACCESS POINT UNTUK MENJADIKAN BISNIS UMKM NADINASALIM MENGGUNAKAN PACKET TRACER DENGAN METODE PENGEMBANGAN Network Development Life Cycle (NDLC)," *Jusikom: Jurnal Sistem Komputer Musirawas*, vol. 7. no. 1. pp. 53-60, Jun. 2022, doi: 10.32767/jusikom.v7il.1594.
[18] I. Puspasari, Musayyanah and P. Susanto, "Telereport Target Heart Rate (THR) pada Cardio Exercise Berbasis Metode Karvonen," *Seminar Nasional Aplikasi Teknologi Informasi (SNATI)* 2018. Pp. 42-48. ISSN 1907-5022.
[19] Y. Muhaiban, H. Srihendayana, N. T. Mooniarsih, "ANALISIS POLARADIASI PADA PEMANCAR STASIUN NET TV PONTIANAK," *Journal of Electrical Engineering, Energi, and Information Technology*, 2017.
[20] A. Wahyu, A. E. Jayati, and S. Heranurweni, "RANCANG BANGUN ANTENA MICROSTRIP 900 MHz UNTUK SISTEM GSM," *Jurnal Sains, Teknologi dan Industri*, vol. 12, no. 1, pp. 67–72, 2014.
[21] D. N. Rokhman, A. R. Darlis, and L. Lidyawati, "IMPLEMENTASI ANTENA YAGI 5 ELEMEN SEBAGAI PENERIMA SIARAN TELEVISI DI BANDUNG KOTA," *Jurnal Elektro dan Telekomunikasi Terapan*, vol. 3, doi: 10.25124/jett.v3i1.128. , no. 1, Aug. 2016.

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Additional Information