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A NOVEL APPROACH TO DESIGNING MINIATURIZED MICROSTRIP ANTENNAS FOR WEARABLE AND IMPLANTABLE BIOMEDICAL DEVICES

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Abstract – The fast development of the Internet of Medical Things has significantly change a paradigm shift in healthcare, by enabling continuous and remote monitoring of the patient instead of hospital-based treatments. At the heart of this transformation lie wearable and implantable devices which play an important role to detect early detection of health issues. To ensure reliable communication and data transmission it require robust, efficient, and miniaturized antenna systems. This thesis focus on the design, optimization, and implementation of high-performance antennas that can function reliability within the complex electromagnetic environments of the human body. For the long term operation and patient safety use of biocompatible material is important. The primary challenge in this research addressed the electromagnetic interaction between the antenna and lossy human tissues. Wearable antennas placed in the proximity of the body or in the body leads to impedance mismatch, shift in operating frequency, and the heat absorbed by the biological tissue. Implantable antenna even face more difficulty due to the size limitation heat absorption by the tissue. Characteristics of the antenna are highly influenced by the high permittivity and conductivity of the biological tissue **.**

Keywords: IoMT, Wearable antennas, Specific Absorption Rate (SAR), Dual-band antenna, IEEE/ICNIRP compliance

I. INTRODUCTION

Microstrip antennas having the substrates with great mechanical strength, thermal stability, and fire resistance acquire significant recognition. E. J. Denlinger discovered in 1969 that an open ended discontinued transmission line on a PCB may radiate electromagnetic waveforms and that the intensity of these radiations increases if the discontinuous open ended transmission lines are separated by half the wavelength or larger multiples of it . It was found that the circular and rectangular loops of these integrated transmission lines can radiate efficiently. Analytical models and numerical methods were enhanced by researchers like Robert E. Munson and Kai Chang in the 1970s, where advanced theoretical knowledge and practical design approaches for micro strip patch antennas were investigated to properly estimate antenna performance in terms of radiation patterns, impedance matching, and bandwidth. During the 1980s the microstrip patch antenna finds its utility for many applications and hence it get significant place in commercialization due to compact size, ease of integration, and easy fabrication .Devices that are implanted or introduced into the human body are referred to as "in body" devices. Where the significant part of the channel is inside the body with antenna implanted in the body and the communication is between medical implanted antenna and sensor network. These devices may connect wirelessly with other devices to exchange data or receive orders. They are frequently used for medical and therapeutic applications.

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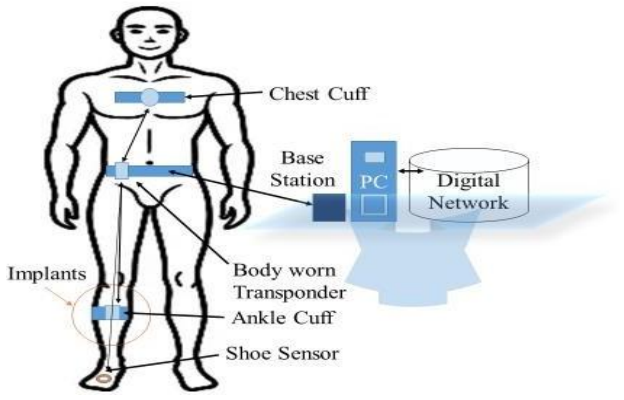

Fig; 1 Body Diagram

IEEE Standard 145-1983, titled "Standard Definitions of Terms for Antennas," is an IEEE (Institute of Electrical and Electronics Engineers) standard that provides a comprehensive set of definitions and terminology related to antennas. Here are some of the key aspects covered by IEEE Standard 145-1983 are Antenna Types, Antenna Parameters, Radiation Pattern Terminology, Polarization Definitions, Antenna Measurement Terminology, Impedance Matching Terms, Radiation Efficiency, Antenna Testing and Measurement, Antenna Arrays, Electromagnetic Fields. The standard specifies and provides descriptions for key antenna characteristics such gain, directivity, radiation pattern, polarization, bandwidth, and efficiency, VSWR, Front-to –Back Ratio, Cross-Polarization Discrimination, Side Lobe Level, Power Handling Capacity. It makes sure that everyone in the field uses and understands these terminologies every time are given below:

Gain: It measures how well an antenna focuses or directs radiated energy in a particular direction. It is usually measured in dB and indicates the antenna's ability to concentrate energy in a specific direction compared to an isotropic antenna. The product of directivity by efficiency gives gain and it is always less than the directivity.

Directivity: It quantifies how strongly an antenna radiates or receives signals in a particular direction. The directivity of an antenna is the ratio of the maximum radiation intensity to the average radiation. It is often expressed as a dimensionless ratio and is closely related to antenna gain. Higher directivity implies a more focused radiation pattern.

Radiation Pattern: It is a graphical representation of how an antenna radiates energy into space and it is an angular function with respect to the axis. It shows the direction and intensity of the radiated electromagnetic waves.

Polarization: Matching the polarization of the transmitting and receiving antennas is decisive for efficient signal transmission. The polarization of a radiated wave can be linear polarization (vertical or horizontal), circular or elliptical polarization.

1.1 Problem Identification:

The design process of wearable antenna must consider important parameters such as:

Designer has to make sure the antenna properly function and has good performance with characteristics such as minimum return loss, gain, efficiency and stable radiation pattern.

The antenna design has to be suitable and comfortable for body worn and easily ingestible application in term of flexibility, size, weight and structure.

The SAR value measured on human body must be less than 1.6W/kg to minimize the hazardous effect of radiation from antenna.

As the human body is the lossy environment, the performance characteristic of the antenna has to be maintained in close proximity or within human body.

The antenna should be designed for high gain and efficiency with light weight and small size as it is embedded on wearable devices which tend to be light weight and small in size.

In the literature review antenna characteristic has been investigated on three layer model of skin, fat and muscles investigation on tissues such as bone and blood has to be carried out.

1.2 Dual band microstrip patch antenna for maritime navigation as well as fixed satellite and mobile communication

A compact triangular extended radiator antenna of size 30mm*30mm with partial ground is designed for radio location, maritime navigation as well as fixed satellite and mobile communication applications. A single patch antenna exhibits 10dB bandwidth from 2.87 GHz to 3.42GHz and 5.89 GHz to 6.79GHz. The compact patch antenna is designed on low cost and easily available flame retardant substrate and simple design enables easy fabrication.With the technological advancement, the sizes of equipment are reduced and are available as handheld devices. This not only requires the miniaturization of the circuits to the scale of very large scale integration to ultra large scale integration, but also these devices needs to communicates with nearby devices, which instigates the requirements of compact and light weight antenna that radiates in multiple bands, so that a single antenna can be used to trans- receive several signal and thereby reduce the cost and space allocated for the antenna. Researchers as proposed several structures for multiband operation such as SRR, CSRR, defected ground structure, meander line structure. These structures allow the antenna to operate on multiple bands. Radiating patch, ground plane, multiple branch strip and slots are commonly employed to

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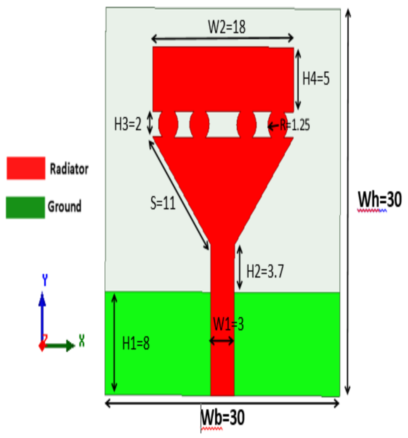
create resonant bands; however this restricts the use of antenna owing to the increase in size and complexity.Researchers has developed structures such as in, a slotted hexagonal patch antenna with slotted partial ground is utilized for multiple bands. In ring type radiator with two rectangular CSRR is responsible for multiple bands. In mho-shaped. In half E- shaped patch is utilized for adjustable twin band operation. In four slotted array is accomplished on full ground in a triple layer antenna with coaxial feed for generating triple band. In a dual current path is provided on two different radiators of antenna for generating two bands. In a dome shaped antenna with complementary SRR in the ground is responsible for multiple bands. In two microstrip patches are imbibed on each end of the full ground plane for dual band operation. In radiator array with circular and rectangular slots and inset feed is employed for dual band operation in THz frequency bands. In dual rectangular radiating structures and SRR in the ground plane results in triple bands.

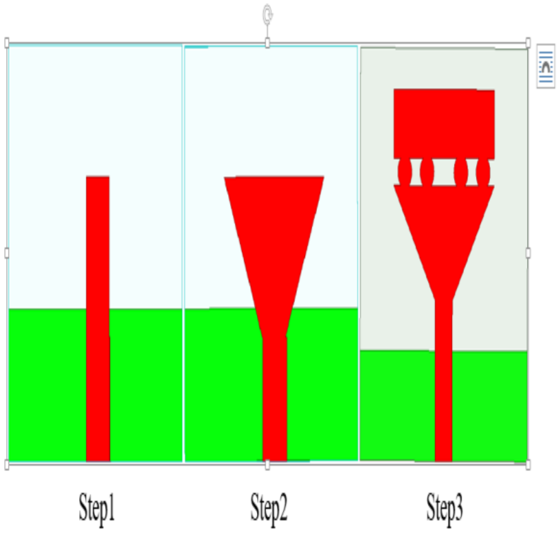
II. PROPOSED ANTENNA CONFIGURATION

The proposed antenna configurations having the rectangular patch (W2*H4) and circular patch of radius R and the partial ground plane and the antenna are fed by a microstrip transmission line. The antenna is designed on Flame retardant FR 4 material with ϵ_r=4.4 and substrate thickness of 1.6 mm. Antenna dimensions (in mm) are shown in Fig 2 (a). The antenna is evolved in four subsequent steps as shown in Fig 3.1(b).

In the first step, a microstrip size of 3mm*11.7mm is accomplished, radiating band of 5.23 GHz to 9.1 GHz is observed as shown in Fig 3.1(c), it is evident that the antenna is not showing any meta material miniaturization property. In the second step, a conical radiator is added to the structure, as the radiating surface is increased, the antenna exhibits single and sharp frequency band from 3.86 GHz to 5.6 GHz. In the final step, a rectangular structure is added to the radiating surface with the help of four circular stubs, thereby increasing the surface current, and the ground is decreased for the antenna to exhibit a dual frequency band of 2.87 GHz to 3.4 GHz as well as 5.89 GHz to 6.79 GHz for radio location, maritime navigation as well as fixed satellite and mobile communication applications as shown in Fig 3.1(c). The three progression steps are shown in Fig 3.1(b).



(a)



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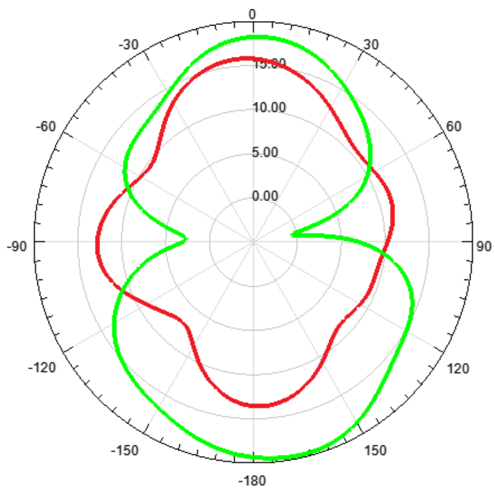
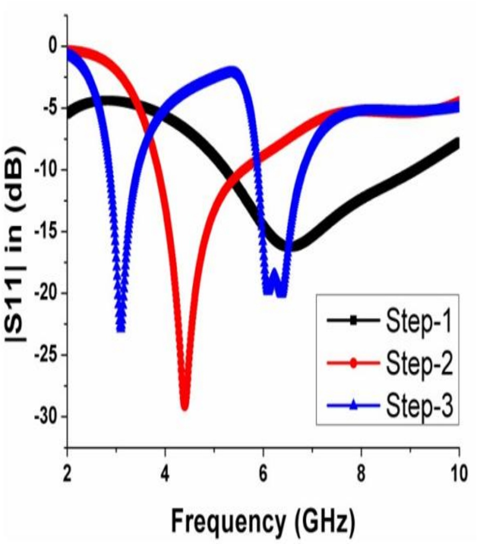




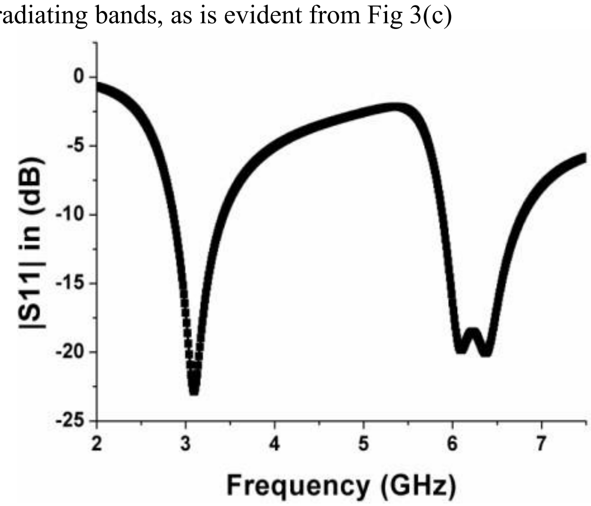
(c).

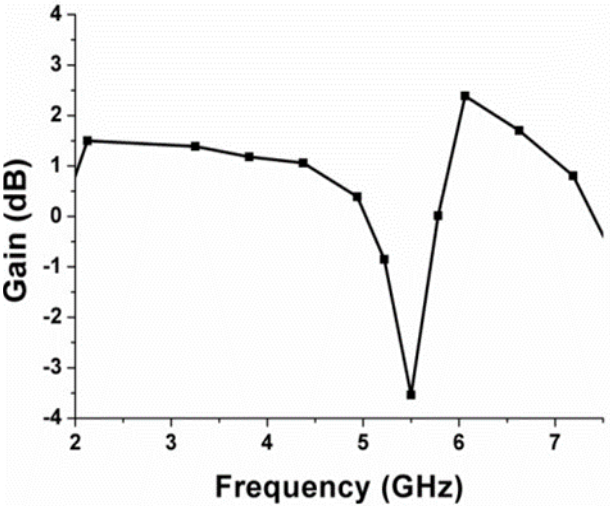
Fig 2: (a) Dimensional statistics of proposed antenna, (b) Progression steps for prototype antenna, (c) |S11| for progression steps

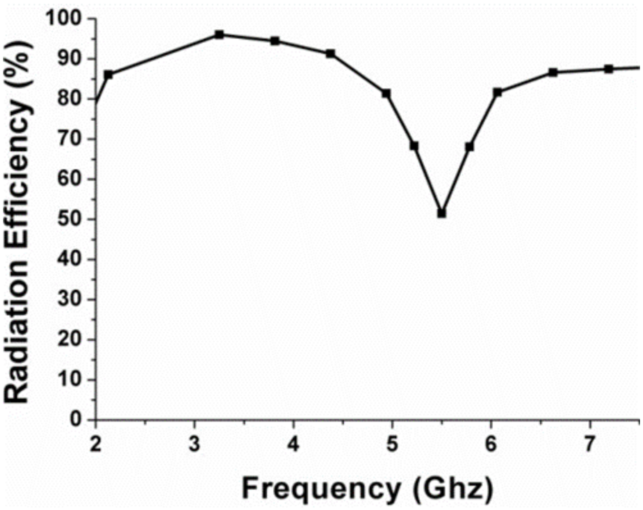
III. RESULTS AND DISCUSSIONS

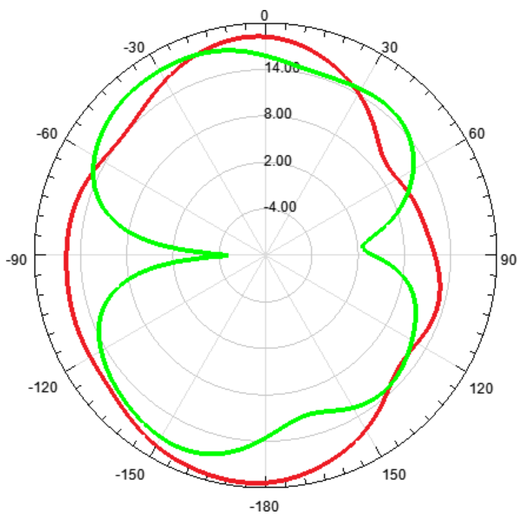
The antenna is simulated using Ansys HFSS and the results are obtained. The return loss is shown in Fig 3(a), where the antenna exhibits two frequency bands that exist from 2.87 GHz to 3.4 GHz and 5.89 GHz to 6.79 GHz resonating at 3.10 GHz and 6.37 GHz respectively.

The gain of the antenna is depicted in Fig 3(b), where it is observed that the antenna attains a gain of 1.5 dB in the lower band, whereas the gain is 2.4 dB in the higher band. The radiation efficiency is more than 90% in both the radiating bands, as is evident from Fig 3(c)









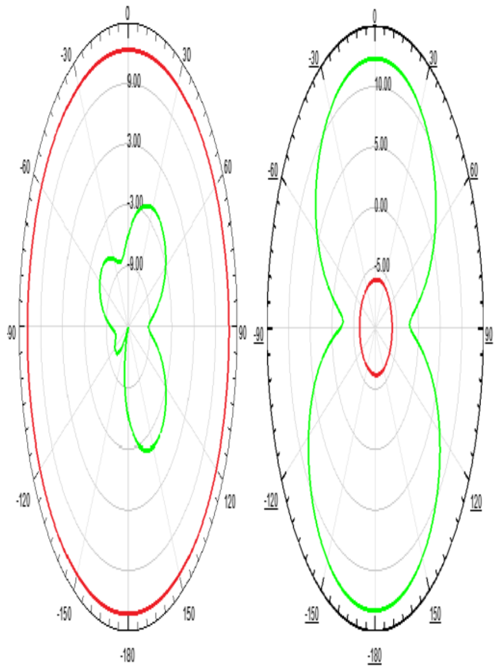


Fig. 3 Antenna Radiation results (a) |S11|, (b) Gain, (c) Radiation Efficiency (d) Radiation in XZ and YZ plane at 3.1 GHz, (e) Radiation in XZ and YZ plane at 6.37 GHz.

IV. CONCLUSION

A dual band microstrip patch antenna for radio location, maritime navigation as well as fixed satellite and mobile communication applications. A single patch antenna exhibits 10dB bandwidth from 2.87 GHz to 3.42GHz and 5.89 GHz to 6.79GHz has been presented in this research. Simulations and measurements are used to examine the antenna's performance. The proposed antenna is suitable because of its small size, simplicity of construction, acceptable return loss, and stable radiation properties. Due to the low profile of the proposed antenna, it can be further used in various applications like global positioning system and various radar applications.

REFERENCES

[1]. E. J. Denlinger, "Radiation from Microstrip Resonators," IEEE Trans. Microw. Theory Tech., vol. 17, no. 4, pp. 235–236, 1969, doi: 10.1109/TMTT.1969.1126937.

[2]. R. E. Munson, "Conformal Microstrip Atennas and Microstrip Phased Arrays," IEEE Trans. Antennas Propag., vol. AP-22, no. 1, pp. 74–78, 1974, doi: 10.1109/TAP.1974.1140723.

[3]. K. Chang, R. A. York, P. S. Hall, and T. Itoh, "Active integrated antennas," IEEE Trans. Microw. Theory Tech., vol. 50, no. 3, pp. 937–944, 2002, doi: 10.1109/22.989976.

[4]. A. Kaur and P. K. Malik, "Multiband Elliptical Patch Fractal and Defected Ground Structures Microstrip Patch Antenna for Wireless Applications," Prog. Electromagn. Res. B, vol. 91, no. March, pp. 157–173, 2021, doi: 10.2528/PIERB20102704.

[5]. M. S. Sadiq, C. Ruan, H. Nawaz, M. Ali Babar Abbasi, and S. Nikolaou, "Mutual coupling reduction between finite spaced planar antenna elements using modified ground structure," Electron., vol. 10, no. 1, pp. 1–8, 2021, doi: 10.3390/electronics10010019.

[6]. Y. J. Sung and Y. S. Kim, "An improved design of microstrip patch antennas using photonic bandgap structure," IEEE Trans. Antennas Propag., vol. 53, no. 5, pp. 1799–1804, 2005, doi: 10.1109/TAP.2005.846775.

[7]. K. Da Xu, J. Zhu, S. Liao, and Q. Xue, "Wideband Patch Antenna Using Multiple Parasitic Patches and Its Array Application with Mutual Coupling Reduction," IEEE Access, vol. 6, pp. 42497–42506, 2018, doi: 10.1109/ACCESS.2018.2860594.

[8]. A. Y. I. Ashyap et al., "Robust and efficient integrated antenna with EBG-DGS enabled wide bandwidth for wearable medical device applications," IEEE Access, vol. 8, pp. 56346–56358, 2020, doi: 10.1109/ACCESS.2020.2981867.

[9]. K. Roy et al., "A recent survey on zeroth-order resonant (ZOR) antennas," Analog Integr. Circuits Signal Process., vol. 112, no. 1, pp. 65–82, 2022, doi: 10.1007/s10470-022-02044-9.

[10]. K. Çelik and E. Kurt, "A novel meander line integrated E-shaped rectenna for energy harvesting applications," Int. J. RF Microw. Comput. Eng., vol. 29, no. 1, pp. 1–10, 2019, doi: 10.1002/mmce.21627.

[11]. A. A. Althuwayb, "Enhanced radiation gain and efficiency of a metamaterial- inspired wideband microstrip antenna using substrate integrated waveguide technology for sub-6 GHz wireless communication systems," Microw. Opt. Technol. Lett., vol. 63, no. 7, pp. 1892–1898, 2021, doi: 10.1002/mop.32825.

[12]. K. Mahendran, D. R. Gayathri, and H. Sudarsan, "Design of multi band triangular microstrip patch antenna with triangular split ring resonator for S band, C band and X band applications," Microprocess. Microsyst., vol. 80, p. 103400, 2021, doi: 10.1016/j.micpro.2020.103400.

[13]. S. Feng, L. Zhang, H. W. Yu, Y. X. Zhang, and Y. C. Jiao, "A Single-Layer Wideband Differential-Fed Microstrip Patch Antenna with Complementary Split- Ring Resonators Loaded," IEEE Access, vol. 7, pp. 132041–132048, 2019, doi: 10.1109/ACCESS.2019.2940279.

[14]. A. Kumar, S. Dwari, and G. P. Pandey, "A dual-band high-gain microstrip antenna with a defective frequency selective surface for wireless applications," J. Electromagn. Waves Appl., vol. 35, no. 12, pp. 1637–1651, 2021, doi: 10.1080/09205071.2021.1914195.

[15]. E. Zhang, A. Michel, P. Nepa, and J. Qiu, "Compact Dual-Band Circularly Polarized Stacked Patch Antenna for Microwave-Radio-Frequency Identification Multiple-Input-Multiple-Output Application," Int. J. Antennas Propag., vol. 2021, 2021, doi: 10.1155/2021/9991748.

[16]. N. O. Parchin, H. J. Basherlou, Y. I. A. Al-Yasir, R. A. Abd-Alhameed, A. M. Abdulkhaleq, and J. M. Noras, "Recent developments of reconfigurable antennas for current and future wireless communication systems," Electron., vol. 8, no. 2, pp. 1–17, 2019, doi: 10.3390/electronics8020128.

[17]. Y. Shi and Z. Shen, "Recent Advances in Flexible RF MEMS," Micromachines, vol. 13, no. 7, pp. 1–27, 2022, doi: 10.3390/mi13071088.

[18]. M. Al Ahmad, S. Kabeer, A. A. Sanad, and L. J. A. Olule, "Compact single- varactor diode frequency-reconfigurable microstrip patch antenna," IET Microwaves, Antennas and Propagation, vol. 15, no. 9. pp. 1100–1107, 2021. doi: 10.1049/mia2.12117.

[19]. S. Da Xu, D. F. Guan, L. Liu, Q. Zhang, H. Xu, and S. W. Yong, "A narrow-band circularly polarized leaky-wave antenna with open stopband suppressed," Int. J. RF Microw. Comput. Eng., vol. 31, no. 7, pp. 1–7, 2021, doi: 10.1002/mmce.22647.

[20]. D. Yang, H. Zhai, C. Guo, and H. Li, "A Compact Single-Layer Wideband Microstrip Antenna with Filtering Performance," IEEE Antennas Wirel. Propag. Lett., vol. 19, no. 5, pp. 801–805, 2020, doi: 10.1109/LAWP.2020.2980631.