Секция 1. ИЗМЕРИТЕЛЬНЫЕ СИСТЕМЫ И ПРИБОРЫ, ТЕХНИЧЕСКИЕ СРЕДСТВА БЕЗОПАСНОСТИ

UDC 621.396.2

A FOAM-BASED PARTIAL GROUND WEARABLE MICROSTRIP PATCH ANTENNA FOR 5G WIRELESS APPLICATIONS

Suhas Raosaheb Kale[1], Dipak Pandurang Patil[2], Akhilesh Kumar[2]

[1]E&TC Department, Sandip Institute of Technology and Research Centre
[2]Sandip Institute of Engineering and Management
Nashik, India

Abstract. The antenna is designed using foam substrate with dimension of 33.30×35.96×1.6 mm^3 operates from 3.3 to 5.2 GHz, covering 5G sub-6 GHz NR bands N77 (3.3–4.2 GHz), N78 (3.3–3.8 GHz), and N79 (4.4–5 GHz) with a bandwidth (BW) of 1900 MHz and S11of –40.59 dB at 4.45 GHz. SAR analysis, using a three-layer body phantom, measures electromagnetic energy absorption by human tissues over 1 g and 10 g, meeting international SAR standards (1.6 W/kg for 1 g, 2 W/kg for 10 g). Results show the antenna maintains efficient radiation across the 5G spectrum while adhering to safety limits.
Key words: 5G Wirelles Communications, Foam,Wearable Antenna, Specific Absorption Rate.

ПЕНОНАПОЛНЕННАЯ НОСИМАЯ МИКРОПОЛОСКОВАЯ АНТЕННА С ЧАСТИЧНЫМ ЗАЗЕМЛЕНИЕМ ДЛЯ БЕСПРОВОДНЫХ 5G ПРИЛОЖЕНИЙ

Сухас Раосахеб Кале[1], Дипак Пандуранг Патиль[2], Ахилеш Кума[2]

[1]Институт технологий и исследовательский Центр Сандип
[2]Институт инженерии и менеджмента Сандип
Нашик, Индия

Аннотация. Антенна разработана на пеноматериале с размерами 33,30×35,96×1,6 мм³ и работает в диапазоне от 3,3 до 5,2 ГГц, охватывая суб-6 ГГц NR-диапазоны 5G: N77 (3,3–4,2 ГГц), N78 (3,3–3,8 ГГц) и N79 (4,4–5 ГГц) с полосой пропускания (BW) 1900 МГц и коэффициентом отражения S11 на уровне –40,59 дБ при 4,45 ГГц. Анализ SAR, выполненный с использованием трехслойного фантома тела, измеряет поглощение электромагнитной энергии тканями человека на 1 г и 10 г, что соответствует международным стандартам SAR (1,6 Вт/кг для 1 г и 2 Вт/кг для 10 г). Результаты показывают, что антенна сохраняет эффективное излучение в спектре 5G, соответствуя нормативам безопасности.
Ключевые слова: беспроводная связь 5G, пеноматериал, носимая антенна, удельный коэффициент поглощения (SAR).

Address for correspondence: Kale S. R, Research Scholar, Deaperment of E&TC, SITRC Nashik, India
e-mail: kalesuhas123@gmail.com

Introduction. Wearable technology is highly popular, driving demand for wearable antennas in items like jackets, watches, and GPS shoes. These antennas support health monitoring, navigation, RFID, military, and safety applications. 5G technology enhances these devices with high speed, low latency, and stability [1].

Arpan Desai et al. [2] presented a transparent, flexible patch antenna on a polyethylene terephthalate substrate with Silver Tin Oxide (AgHT-8), measuring 0.48λ × 0.64λ at 4.28 GHz. It provides 40 % bandwidth (3.89 to 5.9 GHz), over 3 dBi gain, and 80 % efficiency, suitable for sub-6 GHz 5G and WLAN. Zhen Yu et al. [3] designed a flexible, dual-band rectangular patch antenna with a semi-circular gap (44×40×0.2 mm) on polyimide, ideal for ISM, 4G, 5G, Bluetooth, and WLAN uses. S. Suneesh et al. [4] proposed a compact, flexible PTFE-based wearable antenna for 5G IoT, achieving triple-band operation at 2.52, 3.8, and 5.58 GHz

Design of Proposed Antenna Structure. The antenna is a foam-based, wearable microstrip patch design with a 1.6 mm thick substrate, dielectric constant (εr) of 1.07, and loss tangent (tanδ) of 0.0025 [5, 6]. Foam is chosen for its low cost, availability, and flexibility to integrate with clothing. The design is simulated and optimized in Ansys HFSS for desired performance.

Design parameters of the microstrip patch antenna [7] are given below:

Step 1. Calculation of Width of Microstrip Patch Antenna:

$$w = \frac{C_0}{2fr\sqrt{\frac{\epsilon_\gamma + 1}{2}}} \quad (1)$$

Step 2. Calculation of effective dielectric constant (εreff):

$$\epsilon_{eff} = \frac{\epsilon_\gamma + 1}{2} + \frac{\epsilon_\gamma - 1}{2} \times \left(1 + 12\frac{h}{w}\right)^{-\frac{1}{2}} \quad (2)$$

Step 3. Calculation of the length extension ΔL, which is given by:

$$\Delta L = 0.412h\frac{\left(\epsilon_{\gamma_{eff}} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\epsilon_{re_{ff}} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (3)$$

Step 4 Calculation of the length of patch

$$L = \frac{c_0}{2f_\gamma\sqrt{\epsilon\gamma e_{ff}}} - 2\Delta L \quad (4)$$

As per the above equations, the dimension of microstrip antenna are 33.30×35.96×1.6 mm^3.

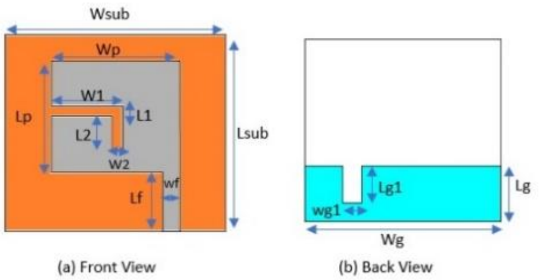

Figure 1 – Geometry of Proposed Rectangular Microstrip Patch Antenna (*a*) front View (*b*) Back View

Table 1 – Geometrical parameters of proposed antenna

Parameter	Wsub	Lsub	Wp	Lp	Lf
Value(mm)	61.68	59.019	35.96	33.30	17.74
Parameter	Wf	Lg	Wg	Lg1	Wg1
Value(mm)	4.84	18	61.68	12	6
Parameter	L1	W1	L2	W2	
Value(mm)	3	20	10	3	

Figure 2 shows step by step development of microstrip patch antenna.

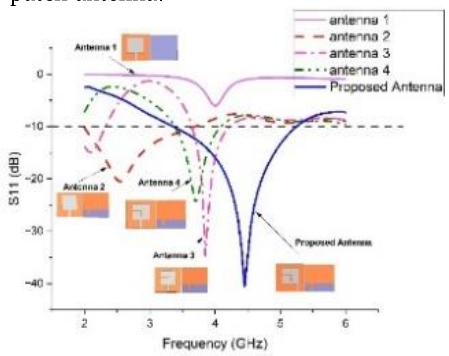

Figure 2 – Return loss performance with variation in geometry

Surface Current Distribution (Figure 3).

SAR Analysis. SAR measures the rate of energy absorption by the human body from EM radiation. Using a three-layer human tissue model, simulated SAR at 4.45 GHz is 0.0012 W/kg for 1 g of tissue, below USA and Europe limits. The SAR is evaluated by Equation (5).

$$SAR = \frac{\sigma\, X\, E^2}{\rho}, \quad (5)$$

where SAR = specific absorption rate (in W/kg), σ = conductivity of sample (in S/m), E = electric field in RMS (in V/m), and ρ = density of sample (in kg/m^3).

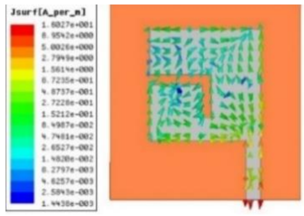

Figure 3 – Surface Current Distibution at resonating frequency 4.45 GHz

Radiation Pattern (Figure 4).

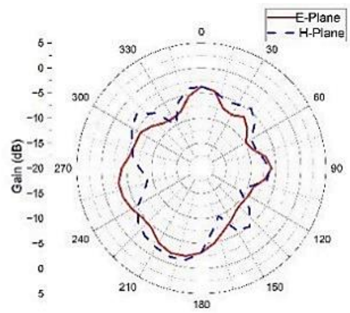

Figure 4 – Simulated radiation pattern in E-plane and H-plane at 4.45 GHz

The three-layer body phantom as shown in Figure 5 of size 90×90×27 mm^3 with 2 mm, 5 mm, and 20 mm thickness for skin, fat, and muscle layer, respectively is simulated in HFSS as shown in Figure 6. The electrical properties of skin, fat, and muscle layers are determined [8, 9] over the frequency of 4.45 GHz

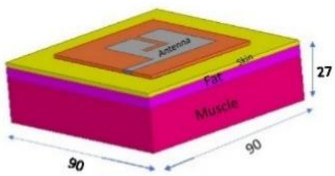

Figure 5 –Three Layer tissue equivalent body phantom model

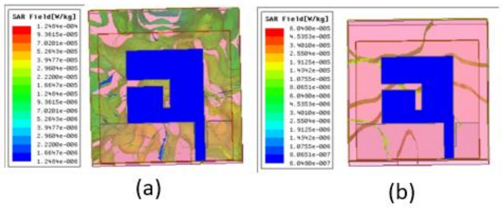

Figure 6 – SAR Analysis of tissue for the three-layer phantom model (a) over 1 gm (b) 10gm

Table 2 – Electrical Properties of Human Tissues

Tissue	Freq	Conductivity σ (S/m)	Permittivity (εr)	Loss tangent	Mass density (kg/m^3)
Skin (dry)	4.45	2.6502	36.22	0.29556	1109
Fat	4.45	0.20891	5.0814	0.16607	911
Muscle	4.45	3.4611	50.25	0.27823	1090

Conclusion. In this paper, a microstrip patch antenna is designed using Foam substrate. To make good performance of antenna at 3.3GHz to 5.2 GHz various analysis is carried out on patch and ground of antenna.

References

1. Bamy Ce Lakpo. Asymmetric-fed triband antenna for military radars and 5G applications using microstrip technology / Bamy Ce Lakpo, Moukala Mpele Pierre // The Journal of Engineering. – 2022. – № 7. – P. 739–745.
2. Flexible CPW fed transparent antenna for WLAN and sub-6 GHz 5G applications / Desai, Arpan H. [et al.] // Microwave and Optical Technology Letters. – 2020. – № 62. – P. 2090–2103.
3. A Wearable Self-Grounding Slit Antenna for ISM/4G/5G/Bluetooth/WLAN Applications / Yu Zhen [et al.] // IEEE Access, Institute of Electrical and Electronics Engineers (IEEE). – 2023. – P. 87930–37.
4. Design of Flexible and Wearable Antenna for 5G IoT Application / S. Suneesh [et al.] // 3rd International Conference on Smart Electronics and Communication (ICOSEC), Trichy, India, 2022. – P. 402–407.
5. Hatte, J. Dwindle coupled loop antenna system for 5G communication applications / J. Hatte, V. Hendre J. // Commun. Technol. Electron. – 2021. – V. 66. – S100–S108.
6. Karad, Kailash Vaijinath. A Foam-Based Compact Flexible Wideband Antenna For Healthcare Applications // Karad, Kailash Vaijinath, and Vaibhav S. Hendre // Progress In Electromagnetics Research C, The Electromagnetics Academy. – 2022. – P. 197–212.
7. Balanis, Constantine A. Antenna theory: analysis and design. John wiley & sons, 2016.
8. Dielectric Properties of Body Tissues [Electronic resource]. – Access mode: http://niremf.ifac.cnr.it/tissprop/htmlclie/htmlclie.php.
9. A SAR Analysis of Hexagonal-Shaped UWB Antenna for Healthcare Applications / Karad Kailash V. [et al.] // EURASIP Journal on Wireless Communications and Networking. Springer Science and Business Media LLC. – 2024. – № 1.

УДК 796.004

DIGITAL TECHNOLOGIES FOR SUPPORTING THE TRAINING PROCESS IN TENNIS

Chen Shilang, Romashko E., Pantsialeyeu K.

Belarusian National Technical University
Minsk, Republic of Belarus

Abstract. This study presents a digital technology for supporting the training process in tennis. It is a broad category encompassing methods of athlete preparation, including physical, tactical, and technical aspects, which are improved through digital technologies. Special attention is given to motion analysis and biomechanics, tracking and performance monitoring systems, virtual and augmented reality (VR and AR) technologies, the use of artificial intelligence and machine learning, wearable devices for physiological monitoring. The paper also provides a review of the literature on the topic of using digital technologies in the training process in tennis.

Key words: digital technology, electronic tools, training control in tennis.

ЦИФРОВЫЕ ТЕХНОЛОГИИ В ОБЕСПЕЧЕНИИ ТРЕНИРОВОЧНОГО ПРОЦЕССА В БОЛЬШОМ ТЕННИСЕ

Чен Шиланг, Ромашко Е. Д., Пантелеев К. В.

Белорусский национальный технический университет
Минск, Республика Беларусь

Аннотация. В данном исследовании представлены цифровые технологии, используемые в поддержке тренировочного процесса в теннисе. Это широкая категория, охватывающая методы подготовки спортсменов, включая физические, тактические и технические аспекты, которые совершенствуются с помощью цифровых технологий. Особое внимание уделяется анализу движения и биомеханике, системам отслеживания и контроля производительности, технологиям виртуальной и дополненной реальности (VR и AR), использованию искусственного интеллекта и машинного обучения, носимым устройствам для мониторинга физиологического состояния спортсменов. Также представлен обзор литературы по теме использования цифровых технологий в тренировочном процессе по теннису.

Ключевые слова: цифровые технологии, электронные средства, тренерский контроль в тенисе.

Адрес для переписки: Pantsialeyeu K., Prospekt Nezavisimosti, 65, Minsk 220113, Republic of Belarus
e-mail: k.pantsialeyeu@bntu.by

The training process for tennis players is a broad category encompassing methods of athlete preparation, including physical, tactical, and technical aspects, which are improved through digital technologies. Digital technologies have become a critical part of training in tennis, helping coaches and athletes enhance performance, monitor progress, and reduce injuries. Among the most relevant digital technologies are the following:

– motion analysis and biomechanics;
– tracking and performance monitoring systems;
– virtual and augmented reality (VR and AR) technologies;
– the use of artificial intelligence and machine learning;
– wearable devices for physiological monitoring.

Using high-speed cameras and sensors allows for a detailed analysis of player technique. In tennis, this can be particularly useful for optimizing movements in serves, forehands, and backhands. These data help correct technical errors, improve injury resistance by identifying excessive strain, develop individual