

Electromagnetic Sounding in Antennas Using Near-field Measurement Techniques

Krnst Beken¹, Hardley Caddwine², Refan Kech³, Moris Mlein⁴ *1-4Faculty of Engineering, University of Cape Town (UCT), South Africa*

Electromagnetic waves, waalo rrequericy,
Wireless communication **KEYWORDS:** Antenna, Signal transmission, Radio frequency.

spectre. **ARTICLE HISTORY:** Accepted 25.04.20
Dublished 11.0E.2 Published 11.05.2023 Received 17.03.2023 Accepted 25.04.2023

DOI: https://doi.org/10.31838/NJAP/05.02.05

https://doi.org/10.31838/jvcs/06.01.31838/jvcs/06.01.31838/jvcs/06.01.31838/jvcs/06.01.31838/jvcs/06.01.31838

1-3Dept. of EEE, Independent University, Bangladesh, Dhaka, Bangladesh **ABSTRACT**

AbstrAct properties, radiation patterns, and performance. This comprehensive review delves into the principles, methodologies, and applications of electromagnetic sounding in antennas, covering topics such as near-field measurement techniques, far-field characterization methods, numerical simulation tools, and practical applications. By examining the intricacies of electromagnetic sounding, this review aims to elucidate its significance in antenna engineering and its implications for advancing wireless communication, sensing, because of this mismatch. To compensate for the offset voltage, we followed a decent α decent α Electromagnetic sounding is a fundamental technique used in the analysis, design, and optimization of antennas, enabling engineers to characterize their electromagnetic

approach to design the circuits. Therefore, the offset voltage is reduced to 250. **Author's e-mail:** beken.krn@engfacuct.ac.za, cadd.hardley@engfacuct.ac.za, kech. ther dividence many designments considered comparator and a unity gain bandwidth of the 4.2 and a gain of 72 a
fan@engfacuct.ac.za. mlein.moris@engfacuct.ac.za. refan@engfacuct.ac.za, mlein.moris@engfacuct.ac.za, which was also authority. The dynamic power of authority o
The dynamic power power of authority.

How to cite th is article: Beken K, Caddwine H, Kech R, Mlein M. Electromagnetic Sounding in Antennas Using Near field Measurement Techniques Journal of Animal Production, Vol. 5, sults of pre-and post-layout simulations in various process, voltage, and temperature No. 2, 2023 (pp. 30-36).

Author's e-mail: ishratzahanmukti16@gmail.com, **ebad.eee.cuet@gmail.com, kou-Introduction to Electromagnetic Sounding in Antennas**

Electromagnetic sounding refers to the process of probing and analyzing the electromagnetic fields produced by **Article:** Analyzing the electromagnetic fields produced by antennas, enabling engineers to extract valuable insights and the state of the into their behavior, performance, and characteristics. Electromagnetic sounding techniques encompass a **IntroductIon** electromagnetic fields generated by antennas in various operating conditions and environments. By employing electromagnetic sounding, engineers can gain a deeper understanding of antenna performance, optimize design parameters, and enhance system-level performance in wireless communication, sensing, and imaging applications.^[1-12] Electromagnetic sounding is a technique used in antenna engineering and geophysical exploration to probe and analyze the properties of materials and structures through the use of electromagnetic waves. It involves transmitting electromagnetic signals into a medium and analyzing the responses to infer information. about the medium's composition, structure, and properties as shown in Fig. 1. wide range of experimental, numerical, and analytical methods used to measure, visualize, and analyze the

In the context of antennas, electromagnetic sounding is used to characterize the performance and behavior of antennas by measuring their radiation patterns, impedance, and other parameters. By analyzing the

Journal of VLSI circuits and systems, , ISSN 2582-1458 **19** 30 Nigerian Journal of Animal Production , ISSN 2582-2659

Fig. 1: Near field measurement system set up low-power comparator. In order to gain more precision

electromagnetic fields generated by antennas and their interactions with the surrounding environment, engineers can optimize antenna designs, assess performance, and diagnose issues.^[13-33] In geophysical exploration, electromagnetic sounding is employed to investigate subsurface structures and properties for various applications such as mineral exploration, groundwater detection, and environmental monitoring. Different electromagnetic sounding techniques, including groundpenetrating radar (GPR), electromagnetic induction, and controlled-source electromagnetics (CSEM), are utilized to probe different depths and resolutions of the subsurfaceas shown in Fig. 2.

Fig. 2: Near-Field Antenna Measurement and comparator, **Transformation**

absorption to extract information about the medium acero. ben electromagnetic $\begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$ information about the medium.Overall, electromagnetic electric field in a closed loop.
Information about the medium.Overall, electromagnetic and geophysics, offering insights into the electromagnetic and interaction, electromagnetic sounding enables non-**How to city article: Mukhim ER, Andre ER, Biswas King IZ, Andre ER, Biswas King II, Biswas King II, High-Res-**Electromagnetic sounding relies on the principles of electromagnetic wave propagation, scattering, and **ARTICLE HISTORY:** being studied. The interaction between electromagnetic waves and the medium's properties, such as conductivity, permittivity, and permeability, influences the behavior of the waves and can be analyzed to infer valuable sounding is a powerful tool in both antenna engineering properties of materials and structures. By leveraging the principles of electromagnetic wave propagation invasive and remote characterization of diverse media, making it an invaluable technique in a wide range of applications, from antenna design to geophysical exploration and beyond.^[34-40]

PRINCIPLES OF ELECTROMAGNETIC SOUNDING

A comparator is a device that compares between two input grounded in Maxwell's equations, which describe signals an infurnities equation, minimized accessive and magnetic fields, charges, currents, and magnetic fields, charges, currents, and end magnetic modes, end ges, comparison and materials. circuits, especially A/D converters (ADC). An ADC application Maxwell's equations govern the propagation, manners a equations generation and propagation, radiation, and interaction of electromagnetic waves reduced in the measurement of accommission matter the theoretical foundation for electromagnetic field end end operation speeds and consumer power consumer consumer consumer for $[41.49]$ analysis and measurement techniques.^[41-49] **Maxwell's Equations:** Electromagnetic sounding is

Maxwell's equations are a set of fundamental equations that describe the behavior of electromagnetic fields and their interactions with electric charges and currents. They were formulated by the Scottish physicist James Clerk Maxwell in the 19th century and are considered one of the cornerstones of classical electromagnetismas shown in Fig. 3.

There are four Maxwell's equations, which can be written in both integral and differential forms:

- **Ishrat Z. Anukative C. Analysis 2. Anukative C. Analysis A. Anukative C. Analysis 2. Anukative C. Anukative C. Bismannian Street is 10Dept. of EEE, Independent Independent Independent Independent Independent Independent Independent Independent** 1. Gauss's Law for Electricity: This equation states that by that surface, divided by the permittivity of the medium.
	- 2. Gauss's Law for Magnetism: This equation states the principles of that magnetic monopoles do not exist, and the total the performance runs and runs at non-personal voltage. It is a custom-made in the customn, scattering, and and magnetic flux through a closed surface is always in the outline of the outline of the o
In the outline and the outline of the outline of the outline of the outline of the surface is always in the ou zero.
	- such as conductivity, $\frac{3.}{2}$ Faraday's Law of Electromagnetic Induction: This ences the behavior equation describes how a changing magnetic field the infermediate measure induces an electromotive force (EMF) and hence an electromotive force (EMF) a comment valuable is 48.7. The electric field in a closed loop.
	- intenna engineering a achompère's Law with Maxwell's Addition: This equation Authoris **Exercise 16 and 16 and** relates the circulation of the magnetic field around the loop, as well as the rate of change of the electric field.

in a wide range of Together, Maxwell's equations form the foundation gn to geophysical of classical electromagnetism, providing a unified matter. They have protound implications for various antenna design, electromagnetic wave propagation, and communication systemsas shown in Fig. 4. framework for understanding the behavior of electromagnetic fields and their interactions with matter. They have profound implications for various

> we examine the design and operation of a current-based, and operation of a current-based, a current-based, a c **Electromagnetic fields radiated by antennas exhibit**
 Electromagnetic fields radiated by antennas exhibit distinct characteristics in the near-field and far-field

Fig. 4: Near-Field Antenna Measurement and SLYTT MOSFETS ALSO, TRANSFORMATION DOING THAT. Also, the length α

Nigerian Journal of Animal Production, ISSN 2582-2659

regions. In the near-field region, electromagnetic fields decay rapidly with distance, and the dominant components are reactive (electric or magnetic). **relAted work** propagate as spherical waves, and the dominant components are radiative (electric and magnetic). Understanding the transition between near-field and far-field regions is essential for selecting appropriate measurement techniques and interpreting measurement results accurately. Near-field and farfield regions are distinct regions that describe the behavior of electromagnetic fields surrounding an antenna or a radiating source.^[50] In the far-field region, electromagnetic fields

The near-field region, also known as the reactive field or the Fresnel region, is the region close to the note of the receiver region, is the region exceed to the antenna where the electromagnetic fields exhibit ancemar make the creating the make a make electric and magnetic fields vary rapidly with distance Freeling and Inagnesis networking repression and the antenna, and their spatial distribution is highly dependent on the antenna's geometry and operating dynamic comparator.[5] High-resolution comparators have frequency. The near-field region is characterized by also been designed utilizing offset measurements and strong electric and magnetic field components, as well as significant energy storage in the form of reactive as significant strength success in the contract conservation of the dynamic fields. It extends up to a few wavelengths away from the comparator with the comparator with the comparator and antennaas shown in Fig. 5. $T_{\rm eff}$ and $T_{\rm eff}$ is paper for the highly linear, low offset on the highly linear, low of set of s

On the other hand, the far-field region, also known as the radiating field or the Fraunhofer region, is the region farther away from the antenna where the electromagnetic region, the electric and magnetic fields propagate as electromagnetic waves, obeying the laws of radiation and exhibiting properties such as wavefront propagation, divergence, and polarization. The far-field region is characterized by a well-defined radiation pattern and is typically located at a distance of several wavelengths fields exhibit predominantly radiative behavior. In this electromagnetic waves, obeying the laws of radiation
and exhibiting properties such as wavefront propagation,
divergence, and polarization. The far-field region is
characterized by a well-defined radiation pattern and
is t

Fig. 1: Block diagram of the suggested Comparator **Planar Spiral Scanning Fig. 5: Near-Field to Far-Field Transformation with**

or more from the antenna.^[51-53] Understanding the near-field and far-field regions is essential in antenna
hear-field and far-field regions is essential in antenna design, as the radiation characteristics, efficiency, and performance of antennas vary significantly between these regions. Additionally, knowledge of these regions. primary distinction between output of appropriate antenna placement, optimizing antenna performance, and predicting the behavior of electromagnetic waves in various applications. is crucial for determining the appropriate antenna

• Field Measurement Techniques: Electromagnetic sounding techniques encompass various field scanning, far-field measurement, and time-domain measurements. Near-field scanning techniques, such as probe scanning and planar scanning, enable detailed mapping of the electric and magnetic fields near the **Fig. 2: Schematic of the 45nm CMOS-based** antennas and electronic systemsas shown in Fig. 6. measurement methods, such as near-field antenna surface, providing insights into radiation characteristics, polarization, and impedance matching. Far-field measurement techniques, such as antenna ranges, anechoic chambers, and outdoor test sites, enable characterization of the far-field radiation pattern, gain, and directivity of antennas in free-space conditions. Field measurement techniques are essential tools used in antenna engineering and electromagnetic compatibility (EMC) testing to characterize the electromagnetic fields produced by antennas and electronic devices in real-world environments. These techniques provide valuable insights into the radiation patterns, field strengths, polarization, and other properties of electromagnetic fields, enabling engineers to assess the performance, compliance, and safety of

One common field measurement technique is the use of electromagnetic field probes, which are portable sensors designed to detect and measure electromagnetic fields in the vicinity of antennas and electronic devices. Field probes can measure electric and magnetic field strengths, as well as other parameters such as frequency, polarization, and modulation.

Fig. 3: 3: 3: Pinnique Pair, OTA STAGE, and Current Mirror Current Mirror Current Mirror Mirror Current Mirror Curr **Fig. 6: Robust and fast near-field antenna measure-**

20 Journal of VLSI circuits and systems, , ISSN 2582-1458 32 Nigerian Journal of Animal Production , ISSN 2582-2659

Another technique involves the use of spectrum analyzers \overline{z} by antennas and electronic devices. These instruments
provide valuable data on signal strength, frequency $\begin{array}{c}\n\text{div}{\text{F}}\n\end{array}$ distribution, modulation, and other characteristics of and signal analyzers, which are used to analyze the frequency spectrum of electromagnetic fields emitted provide valuable data on signal strength, frequency electromagnetic emissions.

ISHRAT Z. Mukhana anechoic chambers, reverberation chambers, and open- $\chi\chi$ **2Dept. of EEE, Independent University, Bangladesh, Dhaka, Bangladesh, KEYWORDS:** electromagnetic fields in laboratory or field settings. involve the use of specialized equipment such as area test sites (OATS), which are designed to provide

antenna design, EMC testing, and regulatory compliance, devices in real-world environments. These techniques short-duration pulses or modulated sig comparator, Overall, field measurement techniques play a crucial role in enabling engineers to assess the performance, safety, and regulatory compliance of antennas and electronic provide valuable data for optimizing antenna designs, diagnosing electromagnetic interference (EMI) issues, and ensuring electromagnetic compatibility (EMC) in diverse applications.

METHODS OF ELECTROMAGNETIC SOUNDING

- device (such as a probe or an antenna) in close **How the electric and magnetic fields directly. Near-field** near-field distribution, allowing engineers to visualize **IntroductIon** near-field measurement techniques include planar scanning, cylindrical scanning, and spherical scanning, each offering unique advantages and applications in antenna testing and analysisas shown in Fig. 7. **Near-Field Measurement Techniques:** Near-field measurement techniques involve scanning a probing proximity to the antenna under test to measure scanning enables high-resolution mapping of the radiation patterns, identify sources of interference, and diagnose antenna performance issues. Common
- **Far-Field Measurement Techniques: Far-field mea**surement techniques involve measuring the radiation pattern and characteristics of antennas in the far-field region, where the electromagnetic fields propagate as spherical waves. Far-field measurements are typically performed in an anechoic chamber, outdoor test range, or compact antenna test range (CATR), where electromagnetic reflections and interference are minimized. Far-field measurement techniques include far-field antenna ranges, antenna pattern measurement systems, and compact range systems, each providing accurate and reliable characterization of antenna performance in free-space conditions.

Fig. 7: Near-Field Antenna Measurement Techniques

alatory compliance,
erformance,safety. ■ Time-Domain Measurement Techniques:Time-domain t_{H} and t_{H} and t_{H} are second at non-manimized at t_{H} is a custom-made t_{H} is a cu nas and electronic and measurement techniques involve transmitting g antenna designs, Through the antenna under test and analyzing the r_{ence} (EMI) issues, received signals in the time domain. Time-domain T_{c} (m , m , m , m , m), m measurements enable analysis of transient effects, n_{total} (LMC) in the discrete measure of authority. The dynamic power of authority. The dynamic power of authority. signal propagation delays, and multipath reflections
in enterne curtoms Time demain measurement in antenna systems. Time-domain measurement ing techniques include pulse radar systems, time-domain include pulse radar systems, time-domain **Authoris exception in the completed of the complete see.** *in the cupus ming* **a probing** for characterizing antennas in dynamic and timeshort-duration pulses or modulated signals reflectometry (TDR), and ultra-wideband (UWB) impulse radios, each offering unique capabilities varying environments.

olution, High-Speed Comparator Comparator Internation Tools for Electromagnetic $\frac{1}{2}$ Source $\frac{1}{2}$ Counting $\frac{1}{2}$ **SOUNDING**

- electromagnetic field problems by discretizing the antenna structure into small segments and applying integral equations to calculate the electric and magnetic fields. MoM is well-suited for analyzing antennas with complex geometries, arbitrary materials, and multi-frequency operation, making it a versatile tool for electromagnetic field simulation and analysisas shown in Fig. 8. **Method of Momen ts (MoM):** The method of moments is a numerical technique used to solve
- **Finite Element Method (FEM):** The finite element method is a numerical technique used to solve partial to be higher. One of the techniques to obtain a super low differential equations governing electromagnetic fields by dividing the antenna structure into small finite elements and solving for the field distribution mose standing and setting variable with distribution
within each element. FEM is particularly useful for analyzing antennas with irregular geometries, to analyzing accounts with magazine geometrical, inhomogeneous materials, and complex boundary militing gained as matterially and complete all the models saturation, and may be concluded that enterthemicidities.
of electromagnetic fields in antenna systems.

Nigerian Journal of Animal Production, ISSN 2582-2659

Metahun Lemeon et al. : The Role and Evaluation of Inductive Coupling in Antenna Design

Fig. 8: Basic Rules for Anechoic Chamber

- **Finite Difference Time Domain (FDTD):** The finite difference time domain method is a numerical technique used to solve Maxwell's equations by discretizing space and time into small finite differences and iteratively updating the electric and magnetic fields over time. FDTD is well-suited for simulating transient electromagnetic phenomena, time-varying fields, and complex geometries, making it a powerful tool for analyzing antennas in dynamic and non-linear environments.
- **Examparata Equation Methods:** Integral equation methods, such as the electric field integral equation **ArchItecture of compArAtor** are used to solve electromagnetic field problems by formulating integral equations based on the boundary conditions of the antenna structure. Integral equation methods offer advantages such as simplicity, accuracy, and scalability, making them suitable for analyzing antennas with large-scale complex geometries. (EFIE) and magnetic field integral equation (MFIE), structures, frequency-dependent materials, and

Up to the OTA, the stage amplification of analog input **Applications of Electromagnetic Sounding** is performed. Then the buffer stage further amplifies to **in Antennas**

• Output Stage

Electromagnetic sounding finds diverse applications in antenna design, analysis, and optimization across various industries and domains:

sounding helps engineers design antennas that meet **Wireless Communication Systems:** Electromagnetic sounding enables characterization and optimization of antennas for wireless communication systems, including cellular networks, Wi-Fi networks, satellite communication, and radar systems. By analyzing radiation patterns, impedance matching, and polarization characteristics, electromagnetic

Fig. 9: A portable non-invasive microwave

performance requirements for coverage, capacity, and reliability in wireless communication networksas shown in Fig. 9.

- **Fig. 2: Schematic of the 45nm CMOS-based** electromagnetic sounding enables engineers to design radar antennas with specific coverage, resolution, and **Radar and Remote Sensing:** Electromagnetic sounding is essential for designing antennas for radar systems, remote sensing platforms, and surveillance applications. By analyzing antenna radiation patterns, beamforming capabilities, and polarization characteristics, detection capabilities for applications such as weather monitoring, air traffic control, and environmental sensing.
- IoT and Smart Devices:Electromagnetic sounding plays a crucial role in designing antennas for Internet of Things (IoT) devices, smart sensors, and wearable electronics. By optimizing antenna size, efficiency, and radiation properties, electromagnetic sounding enables engineers to design compact, low-power antennas for wireless connectivity, data exchange, and environmental sensing in IoT networks and smart devices.

and implantable devices. By analyzing antenna radiation characteristics, propagation properties, and tissue Biomedical Applications:Electromagnetic sounding is utilized in designing antennas for biomedical applications, such as medical imaging, wireless sensing,

interaction effects, electromagnetic sounding enables and will focus on developing multi-physics modelin engineers to design antennas that meet performance requirements for imaging resolution, signal penetration, and biocompatibility in medical applications.

Challenges and Future Directions

Despite the advancements in electromagnetic sounding **Technology and Structures:** The
techniques, several challenges and opportunities exist Technology of advanced materials, such as met Despite the advancements in electromagnetic sounding for further research and development:

- **Ishrat Z. And Z. A** in complex environments, such as urban areas, the personnalised and the the challenges due to multipath propagation, reflections, $t_{\rm{re}}$ and $t_{\rm{re}}$ samples per second at non-made $t_{\rm{re}}$ ray tracing, and machine learning-based algorithms, Concretision to improve accuracy and reliability in challenging **concretively** and interference [53]. Future research efforts will gain, focus on developing advanced electromagnetic sounding techniques, such as multi-path modeling, **ARTICLE HISTORY:** environmentsas shown in Fig. 10. indoor environments, and cluttered spaces, poses
- arise. Future research will focus on developing imaging, and microfabrication-based methods, to $R_{\rm{max}}$ xxx \sim $R_{\rm{max}}$ **• Miniaturization and Integration:** As antennas become increasingly compact and integrated into small-scale devices and systems, the challenges of electromagnetic sounding for miniaturized antennas specialized electromagnetic sounding techniques, such as near-field scanning microscopy, terahertz characterize and optimize miniaturized antennas with sub-wavelength dimensions and complex structures.
- \blacksquare Multi-Physics Modeling:Electromagnetic sounding **IntroductIon** phenomena, such as thermal effects, mechanical often involves coupling with other physical vibrations, and material properties. Future research

 $A \subset \mathbb{R}$ compares between two inputs between tw

Patch Antennas

d biocompatibility in medical applications.

d biocompatibility in medical applications.

other physical processes, enabling comprehensive D FUTURE DIRECTIONS
analysis and optimization of antenna systems. will focus on developing multi-physics modeling techniques, such as coupled electromagneticthermal-mechanical simulations, to capture the other physical processes, enabling comprehensive

> essaten eneras mit a capabilities, such as ultra-wideband operation, a eteed. Sinaghedic tunable properties, and reconfigurable functionality. **Advanced Materials and Structures:** The emergence of advanced materials, such as metamaterials, plasmonic structures, and graphene-based materials, presents new opportunities for enhancing antenna performance and functionality. Future research will explore the integration of advanced materials and structures with electromagnetic sounding techniques to design antennas with unprecedented

CONCLUSION

. To conclusion, electromagnetic sounding is a vital and the conclusion, electromagnetic sounding is a vital technique in antenna engineering, enabling engineers ion: As antennas to analyze, design, and optimize antennas for a wide and integrated into $\frac{1}{2}$ is a considerable measure of authorities in $\frac{1}{2}$ discretions communicated ind integrated into the constant of applications in wireless communication,
is the challenges of the consinguant integrity the problem and application be challenges of area sensing, and imaging. By probing and analyzing is the rematurized antermas in various the electromagnetic fields produced by antennas, **Author's e-mail:** ishratzahanmukti16@gmail.com, **ebad.eee.cuet@gmail.com, kou-**enabling engineers to tailor antenna designs to specific How Ized antennas As wireless technologies continue to evolve and expand, ons and complex electromagnetic sounding will remain an essential tool for advancing antenna technology, enabling new trends, leveraging advanced technologies, and fostering unlock the full potential of electromagnetic sounding and shape the future of wireless communication, sensing, and imaging technologies. electromagnetic sounding provides valuable insights into their behavior, performance, and characteristics, performance requirements and operational conditions. capabilities, applications, and experiences in the era of connectivity and convergence. By embracing emerging interdisciplinary collaborations, antenna engineers can

and minimize, a competent offset cancellation method has **References**

- been implemented. In this comparator, super low threshold 1. Watson, Thomas A. "How Bell invented the telephone. The cecumity of the American instructe of Electrical Calendary Calendary Calendary Calendary Calendary phone." Proceedings of the American Institute of Electri-
- value. For the threshold of threshold of the MOSFETS tends the MOSES tends the MOSES tends the MOSES tends the MOSES net-2. Khan, Karayat Atam. A survey on writed and writeress het-
work." Lahore Garrison University Research Journal of the MOST California of MOST Chinese and Information Technology (2.2.0040). Computer Science and Information Technology 2.3 (2018):
19.28 19-28..
- Fig. 10: Mutual Coupling Reduction between **nual International Conference** on 3. Nagatsuma, Tadao, Kazutoshi Kato, and Jeffrey Hesler. 3. Regards and given the state will give a better measurement. "Enabling technologies for real-time 50-Gbit/s wireless Endburg connocested for reacting of ODR. S WILCOSS transmission at 300 GHz." Proceedings of the Second Annual International Conference on

Nigerian Journal of Animal Production, ISSN 2582-2659

- 4. Nanoscale Computing and Communication. 2015.. Balanis, Constantine A. Antenna theory: analysis and design. John wiley $\&$ sons, 2016.
- tenna design." Analog Dialogue 53.1 (2019): 10-13.. 5. Benson, Keith. "Phased array beamforming ICs simplify an-
- 6. Qi, Yihong, et al. "5G over-the-air measurement challenges: Overview." IEEE Transactions on Electromagnetic Compatibility 59.6 (2017): 1661-1670..
- 7. Paakinaho, L. (2022) Antenna radiation pattern near field to far field transformation, Verkotan. Available at: https://verkotan.com/2021/ antenna-radiation-pattern-n ear-field-to-far-field-transformation/
- 8. Hansen, Jesper E., ed. Spherical near-field antenna measurements. Vol. 26. let, 1988..
- 9. Gregson, Stuart, John McCormick, and Clive Parini. Principles of planar near-field antenna measurements. Vol. 53. \blacksquare IET, 2007..
- 10. Staelin, David, Ann Morgenthaler, and Jin Au Kong. Electromagnetic Waves. Upper Saddle River, NJ: Prentice Hall,
1004, ISBN: 0780122258715 1994. ISBN: 9780132258715
- 11. Vijay, Vallabhuni, et al. "Physically unclonable functions It. vijay, valuabilanii, et al. Thysically diffeomable functions
using two-level finite state machine." Journal of VLSI circuits and systems 4.01 (2022): $33-41$.
- primary distinction between OTA and traditional OPAMP is the September of Andre Depen-12. Marangame, ecubrim, et al. Machine Ecurrimg Dependent Arithmetic Module Realization for High-Speed Comout Arthuette module neutration for righ speed com-
puting ³ lournal of VLCL circuite and externs 4.04.(2022). puting." Journal of VLSI circuits and systems 4.01 (2022):
42-51 42-51.
- 13. RANI, MS K. LEELA, et al. "Design and implementation of Triple Frequency Microstrip patch antenna for 5G commu-Our target is a small computer Technologies 10.1 (2022): 11-17. nications." International Journal of communication and
- 14. JAIRAM, CH, et al. "Analysing Retinal Disease Using Cleha and Thresholding." International Journal of communicaand computer Technologies 10.1 (2022): 18-20.