A Review: Design and Implementation of Microstrip Patch antenna for Cancer Detection.

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Abstract

The increasing growth of cancer within human bodies, development of new and better efficient detection methods becomes pertinent. This review paper pertains to designing and implementing a Microstrip Patch Antenna designed for cancer detection. A comprehensive survey of 25 scholarly articles has been put forth to highlight the various designs of an antenna and their applications in the biomedical field. Some of the key themes are likely to be biosensing elliptically slotted antennas, multi- slotted configuration for sensing breast cancer, and wearable patch antennas on the skin for identifying skin cancer. The performance of different frequency bands, such as ISM and MICS, is also evaluated while estimating ultra-wideband and defected ground structures performance. This paper attempts to synthesize literature findings in order to provide some insights into the current state of research in MPA technologies for the early detection of cancer and what future trends as well as challenges might be in this critical area of research.

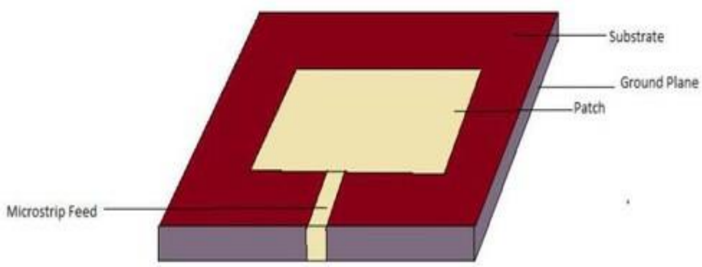
Keywords: Microstrip Patch Antenna, Cancer Detection, Biomedical Applications, Biosensing, Breast Cancer, Skin Cancer, Wearable technology, Ultra Wideband, Defected Antenna Structures, Antenna Design.

1. Introduction

Cancer has long been one of the major causes of morbidity and mortality in the world and makes everyone seek novel technologies for diagnosis. As though the methods of X-ray, MRI, and CT scan are gaining accomplishments in these fields, they are expensive, time-consuming, and involve radiation exposure to a patient. The integration of antenna technology into biomedical applications, therefore, presents an interesting alternative for non-invasive cancer detection with better sensitivity and specificity. Due to their lightweight, compact structure and ease of production, MPAs have been one area of great interest in much research. Due to their flexibility in designing the antennae to operate at specific frequency bands, various types of biological tissues, and abnormalities may be detected. Improving in configuration, such as the slotted configuration, has further enhanced the performance of these antennas in the detection of cancer. This paper attempts to provide an overview of the available existing researches on MPAs, its applications in cancer detection, including a review of 25 studies of different designs such as the elliptically slotted antenna for biosensing application, multi- slotted antennas for breast cancer detection, and also for wearable patch antennas on detecting skin cancer. It also highlights that various frequency bands, like the Industrial, Scientific, and Medical (ISM) band and the Medical Implant Communication Service (MICS) band, play a critical role in increasing efficiency for such antennas. Through the synthesis of literature on this, we aim to identify trends, challenges, and future directions of the MPA technology in cancer detection, eventually contributing towards the efforts evolving for enhanced early diagnosis and patient outcomes.

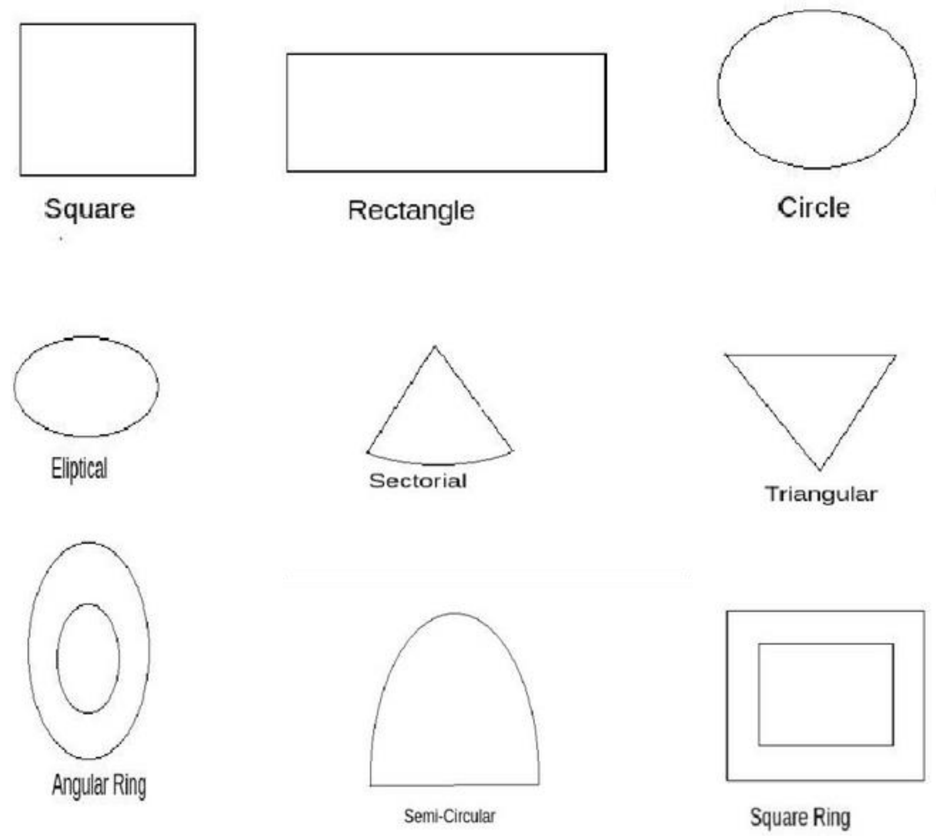
2. Microstrip Patch Antennas

The design of slot loaded rectangular microstrip patch antenna for breast cancer detection is discussed in this paper. The proposed antenna is implemented by using cost effective RT-Rogers 5880(lossy) substrate, which comprises of horizontal narrow slots on the radiating element and a ground plane.[1] This work presents the performance of a Dual-band patch antenna with L-shaped slot for biomedical applications. The antenna works at 2.4 GHz and 3.33 GHz.[2] This paper introduces an elliptically- slotted patch antenna (ESPA) designed to perform optimally in biosensing applications. The verified performance shows resonance frequency difference of the ESPA is 2.5% compared with the primary slot-less patch antenna of 6.6%.[3] The model consists of two multi-slotted rectangular patch antennas and a three-layer breast phantom containing two tumors. A multi-slotted antenna was designed at 2.45 GHz[4] This study aims two antenna structures, as both transceiver and receiver, have same dimensions are designed to produce solution of the difficulties in pathology.[5] In this paper, a novel design for an ultra-wide-band (UWB) microstrip antenna with enhanced bandwidth for early detection of breast cancer has been proposed. It has been designed using CST software, which is a 3D analysis software package for electromagnetic components and systems design, analysis, and optimization. FR- 4 has been used as a substrate[6] This paper presents a model l involves a square microstrip antenna and breast phantom comprising a tumor cell. The radiation properties of the designed antenna at the ISM bands[7] In the paper firstly the T-Shaped Slotted RMPA (Rectangular Microstrip Patch Antenna) is designed for ISM band application at 2.45 GHz and resonated at particular frequency by iterations in the simulation software[8] The design of slot loaded rectangular microstrip patch antenna for breast cancer detection is discussed in this paper. The proposed antenna is implemented by using cost effective RT-Rogers 5880(lossy) substrate[9] This paper presents the early detection of breast cancer as it detects the presence of tumor in the breast tissue using a Rectangular Patch Microstrip Antenna(RMSA) operating at 2.45 GHz.[10] This paper represents a wearable Micro-strip patch antenna, which works at Industrial, Scientific and Medical (ISM) band[11]



3. **Design Techniques:** A microstrip patch antenna was designed which operates at ISM Band in order to detect the presence of cancerous tumours. ISM band works at the range of (2.4-2.48 GHz). Copper

been used to create both the ground plane and the patch.[12] The antenna design features a circular patch with a 28.84 mm diameter. Four smaller circular patches, each 16 mm in diameter, are arranged symmetrically around the center to form the patch portion.[13]In this antenna design, the patch and ground are made up of copper, substrate is of FR4 epoxy. The feed line is inset fed as it increases the performance of antenna rather than transmission fed. [14] Rectangular patches provide higher return loss but have higher VSWR compared to circular patches. Circular patches, however, offer better bandwidth. The proposed antenna detects breast tumors by analyzing reflection coefficient changes and SAR values, which are higher for tumors. Made with copper for conductivity and FR-4.[15] A partial ground technique was used to reduce back lobe radiation and improve bandwidth and gain. The antenna design includes specific slots in the ground and patch, with dimensions adjusted for better performance and impedance matching. The substrate is FR-4, and copper is used for the radiating surface, with a circular patch of 18 mm radius.[16] A rectangular microstrip patch antenna, designed at 7.3 GHz for brain imaging, uses a Rogers R03003 substrate for better performance at high frequencies. The higher frequency improves tumor image resolution and allows for a compact design. Though a thicker substrate enhances efficiency and bandwidth, it can create surface waves, reducing radiated power.[17].



4. Frequency Bands and Their Importance.

- ISM Band (Industrial, Scientific, and Medical): Frequency Range(2.4 to 2.48 GHz) Widely used for various applications, including medical devices, due to its license-free status. In cancer detection, the ISM band enables non-invasive imaging techniques and real-time monitoring of tumors.
- MICS Band (Medical Implant Communication Service): Frequency Range (402 to 405 MHz) Specifically designated for medical implant communications, this band ensures secure and reliable data transmission from implants to external devices, facilitating patient monitoring and diagnostics.
- UWB (Ultra-Wideband):Frequency Range(Typically 3.1 to 10.6 GHz) UWB technologyAa allows for high-resolution imaging and precise location tracking. In cancer detection, it enhances the ability to identify tumors through improved spatial resolution and reduced interference.
- L Band: Frequency Range(1 to 2 GHz) Commonly used in radar and satellite communications, L band frequencies can also be utilized in some medical imaging applications, providing a balance between range and resolution.

5. Applications of Microstrip Patch Antennas in Emerging Fields

Microstrip patch antennas known for their low profile, light weight, and ease of fabrication have extended their utility beyond conventional communication and biomedical systems. Due to their versatile design characteristics they are increasingly being adopted in a variety of emerging technological domains. This section discusses the integration and advantages of microstrip patch antennas in fields such as robotics, Internet of Things (IoT), unmanned aerial vehicles (UAVs), automotive systems, and satellite technology.

5.1 Robotics

In this paper, two different types of robot head shaped patch antennas are proposed and a comparative study is presented. Both the proposed antennas have same dimensions except at the mouth position. These antennas are fed by coaxial feeding technique and are etched on an FR-4 substrate with relative permittivity 4.4[28]. Drone based surveillance and communication systems are playing a vital role in modern days for both military and civilian applications. The fractal-inspired hybrid microstrip patch antenna is a promising candidate for drone-based surveillance and communication applications owing to its miniaturization and good directional radiation properties [29]. This article presents the Micro-strip Patch Antenna (R-MSP) in a simple rectangular shape which operates at 882 MHz for industrial robotic applications. The designed antenna consists of FR4 as a dielectric medium with 4.4. The R-MSP antenna has been modelled using the Finite Element Method (FME) [30]. At 882 MHz, a simple rectangular microstrip patch antenna was implemented especially for industrial robotic applications. FR4 was the dielectric substrate material chosen with 4.4 as the dielectric constant. The projected antenna has been modeled using the finite element method (FME) [31].

5.2 Internet of Things (IoT)

This paper presents a compact microstrip antenna designed fordual-band IoT applications. The antenna operates at 2.5 GHz and 5.2 GHz, making it suitable for various IoT frequency bands. The design utilizes a monopole feed and a coplanar ground plane to achieve the desired performance [32]. This study proposes a novel antenna design aimed at enhancing the performance of IoT applications, particularly in the 868 MHz frequency band. The antenna was designed, simulated, and tested, demonstrating a high level of performance suitable for IoT wireless communications. This study proposes a novel antenna design aimed at enhancing the performance of IoT applications, particularly in the 868 MHz frequency band. The antenna was designed, simulated, and tested, demonstrating a high level of performance suitable for IoT wireless communication [33]. This paper discusses the design of a miniature microstrip antenna optimized for IoT applications. The study compares a conventional microstrip antenna with an optimized U-shaped structure, highlighting improvements in bandwidth, gain, and return loss, making it more suitable for modern IoT devices [34]. This research introduces a portable L-shaped microstrip patch antenna with enhanced gain for 2.4 GHz ISM band IoT applications. The antenna's compact size and high fractional bandwidth make it suitable for various IoT environments, including indoor localization and smart home scenarios.[35]

5.3 Unmanned Aerial Vehicles (UAVs)

This study presents the design of highly directive single-band 2×2 and 4×4 antenna arrays operating at 5.8 GHz and 28 GHz, respectively, for UAV applications within 5G networks. Utilizing Rogers RT5880 substrate due to its low dielectric constant, the antennas achieve high directivity and efficiency, making them suitable for long-distance UAV communications [36]. This paper introduces a compact dual-band circularly polarized microstrip patch antenna designed specifically for UAVs. With dimensions of 40 × 40 × 1.6 mm^3, the antenna operates effectively in the Wi-Fi frequency bands of 2.4 GHz and 5 GHz, featuring a low axial ratio and enhanced bandwidth, which are crucial for reliable UAV communication [37]. This research focuses on a back-to-back F-shaped slotted rectangular patch antenna operating in the C-band at 6 GHz, tailored for Synthetic Aperture Radar (SAR) applications in UAVs. The design achieves desirable return loss and bandwidth, essential for high-resolution imaging and surveillance missions [38].

5.4 Satellite and Space Applications

This paper presents the design and simulation of a microstrip patch antenna operating at 31.5 GHz in the Extremely High Frequency (EHF) range, tailored for space applications. The study analyzes key parameters such as return loss, Voltage Standing Wave Ratio (VSWR), gain, radiation pattern, and current distribution, demonstrating the antenna's suitability for various space communication needs [39]. This research focuses on designing a four-band microstrip patch antenna intended for satellite applications, particularly in the K-band frequency range. Notably, one of the bands exhibits a wide bandwidth of up to 8 GHz, making it highly suitable for high-data-rate satellite communications [40]. This paper introduces a novel multi-band microstrip patch antenna designed to serve several satellite and space communication applications. The compact design and multi-band capabilities address the growing demand for versatile antennas in modern satellite systems[41]. This study proposes a rectangular microstrip patch antenna measuring 25mm x 30mm x 1.6mm, operating at 4.3 GHz with a return loss of -19.7936 dB. The antenna is designed using a glass epoxy substrate (FR4) and is analyzed for its potential in satellite communication applications [42]. This research discusses the use of microstrip antennas in small satellite platforms. It highlights the design of a single- element dual aperture-coupled rectangular microstrip patch antenna with two superstrate layers, emphasizing its suitability for small satellite applications due to its compact size and efficient performance [43].

5.5 Automotive Systems

This study proposes a single-layer via-less rectangular patch antenna designed for automotive applications in the C-band. The antenna achieves a realized gain of approximately 6.85 dB, with an H-plane beamwidth narrower than ±32°, an E-plane beamwidth larger than ±45.5°, and a return loss exceeding 20 dB with a 3 dB bandwidth of 500 MHz. Its compact dimensions facilitate direct integration within a radio front-end, making it suitable for vehicular dedicated short-range communication protocols [44]. This research focuses on designing and constructing a microstrip array antenna specifically intended for vehicle millimeter-wave radar applications in the 77–81 GHz frequency range. Building upon earlier research on single-patch antennas, the full array design meets the demanding performance requirements necessary for advanced automotive radar systems [45]. This study proposes an innovative millimeter-wave microstrip edge-fed antenna (EFA) for 77 GHz automotive radars. The radiator contour is modeled with a sinusoidal spline-shaped profile, optimized using a customized System-by-Design paradigm. The synthesized EFA layout, integrated within a linear arrangement of identical replicas, exhibits suitable impedance matching, isolation, polarization purity, and stability of beam shaping/pointing within the target band [76:78] GHz. Experimental assessments validate the antenna's suitability for automotive radar applications [46].

6. Conclusion

The rising incidence of cancer underscores the urgent need for innovative and efficient detection technologies, with microstrip patch antennas (MPAs) emerging as a promising solution in biomedical applications. This review has consolidated findings from 46 scholarly studies, highlighting diverse MPA designs such as elliptically slotted antennas, T-shaped slotted structures, and wearable patch antennas tailored for skin and breast cancer detection. The analysis of antenna performance across various frequency bands—including ISM, MICS, and ultra-wideband ranges—demonstrates the versatility and adaptability of MPAs, further enhanced by techniques like defected ground structures and multi-slotted configurations. Additionally, the exploration of MPAs in emerging fields like robotics, IoT, automotive systems, UAVs, and satellite communications broadens their applicability beyond healthcare. By presenting a comprehensive synthesis of current advancements and pinpointing future challenges such as miniaturization, biocompatibility, and higher sensitivity, this paper aims to serve as a valuable reference for researchers and engineers, ultimately contributing to the development of next-generation cancer detection systems and improved patient care.

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