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Design of a Microsteip Antenna for the Detection Colorectal Cancer

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Praise be to God, praise be to Him abundantly until praise reaches its limit, and prayers and peace be upon the most honorable of creation whom God illuminated with His light and chose And out of gratitude, he who does not thank people does not thank God, we extend our sincere

thanks and appreciation to the supervising teacher

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Dedication

Praise be to God, by whose grace blessings are completed, and prayers and peace be upon the best of His creation, Muhammad, may God bless him and grant him peace.

To those whose prayers were the secret to my success, and whose satisfaction was the reason for my blessings...

To my dear parents, who instilled in my heart a love of knowledge and were my support and help throughout every stage of my life.

To my dear brothers, partners in success and supporters every step of the way, who have always been close to my heart.

To my favorite person, my lifelong companion, and my source of hope in challenging times, who believed in me and encouraged me silently and with compassion.

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O Allah, make this work sincerely for Your sake, bless it, and make it beneficial to me and those around me. Guide me to what You love and are pleased with, and grant me success and prosperity in all my affairs.

KAOUTER

Dedication

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My friends who have contributed directly or indirectly to the completion of this work

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Finally , to all those who are dear to us.

FATIMA

Abstract

Summary :

Colorectal cancer is among the most prevalent and lethal types of cancer, yet early detection and diagnosis can significantly enhance patient survival rates. This research explores the application of microstrip antenna technology for the diagnosis of colorectal cancer. Microstrip antennas are flat, compact structures that can be seamlessly integrated into medical imaging and diagnostic systems. The study focuses on the design and performance evaluation of microstrip antennas operating in the microwave frequency range to detect colorectal tumors. Through simulations and experimental analysis, the antennas' ability to differentiate between healthy and cancerous tissues—based on variations in their dielectric properties—was assessed. The findings indicate that well-designed microstrip antennas can successfully identify the presence and location of tumors, offering a non-invasive and cost-efficient diagnostic solution. This method has the potential to complement existing imaging techniques and support the early detection of colorectal cancer. However, further research and clinical validation are essential to fully establish the effectiveness of this approach. Overall, this study contributes to the advancement of microwave-based medical imaging and diagnostic innovations.

Keys words: Colorectal cancer , Microstrip antennas , Diagnosis , Microwave .

ملخص :

يُعد سرطان القولون والمستقيم من أكثر أنواع السرطان شيوعًا وفتكًا، إلا أن الكشف والتشخيص المبكرين يُحسّنان بشكل كبير من معدلات نجاة المرضى. يستكشف هذا البحث تطبيق تقنية هوائيات الشرائط الدقيقة لتشخيص سرطان القولون والمستقيم. تتميز هوائيات الشرائط الدقيقة بهياكل مسطحة ومدمجة يمكن دمجها بسلاسة في أنظمة التصوير الطبي والتشخيص. تُركز الدراسة على تصميم وتقييم أداء هوائيات الشرائط الدقيقة العاملة في نطاق ترددات الموجات الدقيقة للكشف عن أورام القولون والمستقيم. من خلال عمليات المحاكاة والتحليل التجريبي، تم تقييم قدرة الهوائيات على التمييز بين الأنسجة السليمة والسرطانية - بناءً على الاختلافات في خصائصها العازلة. تشير النتائج إلى أن هوائيات الشرائط الدقيقة المُصممة جيدًا يمكنها تحديد وجود الأورام وموقعها بنجاح، مما يُوفر حلاً تشخيصيًا غير جراحي وفعّال من حيث التكلفة. تتمتع هذه الطريقة بإمكانية استكمال تقنيات التصوير الحالية ودعم الكشف المبكر عن سرطان القولون والمستقيم. ومع ذلك، لا بد من إجراء المزيد من الأبحاث والتحقق السريري

Abstract

للتأكد تمامًا من فعالية هذا النهج. بشكل عام، تُسهم هذه الدراسة في تطوير التصوير الطبي القائم على الموجات الدقيقة والابتكارات التشخيصية.

الكلمات المفتاحية: سرطان القولون والمستقيم ,هوائيات الشرائط الدقيقة , التشخيص , الموجات الدقيقة .

Résumé :

Le cancer colorectal est l'un des cancers les plus répandus et les plus mortels. Pourtant, une détection et un diagnostic précoces peuvent améliorer considérablement la survie des patients. Cette recherche explore l'application de la technologie des antennes microrubans au diagnostic du cancer colorectal. Les antennes microrubans sont des structures plates et compactes qui s'intègrent parfaitement aux systèmes d'imagerie médicale et de diagnostic. L'étude se concentre sur la conception et l'évaluation des performances d'antennes microrubans fonctionnant dans la gamme des micro-ondes pour la détection des tumeurs colorectales. Grâce à des simulations et des analyses expérimentales, la capacité des antennes à différencier les tissus sains des tissus cancéreux, en fonction des variations de leurs propriétés diélectriques, a été évaluée. Les résultats indiquent que des antennes microrubans bien conçues peuvent identifier avec succès la présence et la localisation des tumeurs, offrant une solution diagnostique non invasive et économique. Cette méthode pourrait compléter les techniques d'imagerie existantes et favoriser la détection précoce du cancer colorectal. Cependant, des recherches supplémentaires et une validation clinique sont essentielles pour établir pleinement l'efficacité de cette approche. Globalement, cette étude contribue à l'avancement des innovations en matière d'imagerie médicale et de diagnostic par micro-ondes.

Mot clé: Le cancer colorectal , Les antennes microrubans , diagnostic , micro-ondes .

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Table of Contents

Acknowledgements.....

De**dication**…… ...II

Abstract.....IV

Table of Contents.....V
List of Figures.....VIII
List of Tables.....X
List of Abbreviations XI
List of Symbols XIII
General Introduction.....1

Chapter One: Colorectal cancer Diagnosis

1.1. Introduction……..……..3

1.2. Characteristics of Colorectal Cancer ……3

a) Electromagnetic Properties
b) Tumor Size and Localization

1.3. Causes and Risk Factors ……4

a) Causes
b) Risk Factors

1.4. Diagnosis of Colorectal Cancer Using Microstrip Antennas 5

a) Role of Microstrip Antennas
b) Detection of Colorectal Cancer

1.5. Conclusion …….....…….....…….6

Chapter Two: Microstrip Antennas

2.1. Introduction …….....….8

2.2. Advantages of Microstrip Antennas ……..9

2.3. Drawbacks of Microstrip Antennas…….9

List of Contents

2.4. Methods for Feeding ……..…..….....10

a) Coaxial Probe Feed

b) Microstrip Line Feed

c) Aperture Coupled Feed

d) Proximity Coupled Feed

2.5. Equations for Microstrip Antennas……. 12

2.6. Methods for Designing ……13

2.7. Applications of Microstrip Antenna…….15

2.8.Conclusion …….….....16

Chapter Three :Design of Microstrip Patch Antennas for Colorectal Cancer Detection

3.1. Introduction…….....……18

3.2. Microstrip Patch Antenna for Colon Cancer Detection ……18

3.3. Challenges and Design Considerations……..19

3.4. Antenna Element Design…….21

3.5. Array of two Antenna Elements ……25

3.6. Simulated result ……26

3.7. Recommendations ……29

3.8. Conclusion…….29

General Conclusion.....31

References.....32.

List of Figures

Figure 1.1:: Colorectal Cancer in the human body …….……3

Figure 1.2: Cancer with 3D imaging ……5

Figure 2.1: This Figure shows microstrip antenna.……...……8

Figure 2.2: Representative shapes of microstrip patch elements.....9

Figure 2.3: Coaxial Probe Feed.....10

Figure 2.4: Microstrip Line Feed ……11

Figure 2.5: Aperture Coupled Feed..... 11

Figure 2.6: Proximity Coupled Feed …...…….12

Figure 3.1: Diagram of the proposed MI system for colonoscopy including the antenna applicator a ttached at the tip of a conventional colonoscope……..20

Figure 3.2: MiEndo's microwave endoscopy system.……21

Figure 3.3: This figure shows the antenna design.…….22

Figure 3.4: This figure represents the wave radiation of the antenna….22

Figure 3.5: This figure shows the entire antenna design.…….23

Figure 3.6: Geometry of the cylindrical U-slot antenna array.……24

Figure 3.7: This figure shows the the cylindrical U-slot antenna array design .Studied antenna configurations …….24

Figure 3.8: shows the antenna design's Return loss ……27

Figure 3.9:

Figure 3.10: shows the antenna design's gain and Directivity in CST…….27

Figure 3.11:

shows the effectiveness of the suggested antenna design in CST….28

Figure 3.12: shows the suggested antenna design's voltage standing wave ratio in CST…….28

List of Tables

Table 3.1: showing the basic engineering characteristics of the antenna……..21

Table 3.2: Proposed Antenna Element Dimensions…….25

LIST OF ABBREVIATIONS

- ✓ **CST :C**omputer **S**imulation **T**echnology
- ✓ **VSWR :** voltage-standing wave ratio
- ✓ **PCB :** printed circuit board
- ✓ **CRC :** Colorectal cancer
- ✓ **MICs :** Microwave Integrated Circuits
- ✓ **MMICs :** Monolithic Microwave Integrated Circuits

List of Symbols

- ✓ $\boldsymbol{\varepsilon_r}$:Relative permittivity of the substrate material
- ✓ **f**: resonant frequency
- ✓ **C**: speed of light (approximately 3 x 10^8 m/s)
- ✓ $\boldsymbol{L}$: effective length of the patch antenna
- ✓ **h**: the height of the substrate
- ✓ **Lp:** Patch Length
- ✓ **W:** Patch Width
- ✓ **GHz:**Giga hertez
- ✓ $\boldsymbol{dB}$**:**Decibel

Introduction

General Introduction

Colorectal cancer is a major global health issue, and early detection is critical for improving patient outcomes. Recent interest has grown in using microstrip antennas for detecting colorectal cancer due to their compact size, ease of fabrication, and compatibility with integrated circuits. These antennas can be placed in the colon or rectum (intraluminal placement), integrated into endoscopic devices for real-time detection, or arranged in arrays to enhance sensitivity and spatial resolution. Research focuses on improving the sensitivity and specificity of microstrip antennas, optimizing their design, and developing algorithms to accurately distinguish between cancerous and non-cancerous tissue. The advantages of microstrip antennas include non-invasive detection, improved accuracy at microwave frequencies, and cost-effectiveness, making them a promising tool for colorectal cancer screening and early detection. This research could lead to better diagnostic accuracy, increased accessibility, and a shift away from traditional invasive procedures, offering a more comfortable and reliable option for patients .

In chapter 1 discusses the most important characteristics of colorectal cancer, and how to diagnose it using microstrip antennas, chapter 2 presents the design of a microstrip antenna element in the antenna applicator, and to present simulations of this design, In the last chapter, presents the design of a microstrip antenna element in the antenna applicator, and to present simulations of this design.[1]

Chapter One

Colorectal cancer

Chapter one:

Colorectal cancer Diagnosis

1.1 Introduction:

Colorectal cancer is a common type of cancer that affects the colon or rectum, both essential components of the digestive system. It ranks as the third most frequently diagnosed malignancy and is the fourth leading cause of cancer-related deaths worldwide. This cancer often begins as noncancerous growths, known as polyps, which form on the inner lining of the colon or rectum. Over time, some of these polyps can evolve into malignant tumors. This chapter explores the key characteristics of colorectal cancer, including its causes and risk factors, while examining the potential application of microstrip antennas in its diagnosis and prevention.



Figure 1.1: Colorectal Cancer in the human body.

1.2 Characteristics of Colorectal Cancer:

a) **Electromagnetic Properties:**

Colorectal cancer cells possess distinct electromagnetic properties in comparison to normal tissue. These variances may involve alterations in dielectric properties, conductivity, and permittivity. Designing microstrip antennas can aid in identifying these

changes in electromagnetic properties, enabling the distinction between cancerous and healthy tissue.

b) Tumor Size and Localization:

Colorectal tumors can differ in size and location within the colon or rectum. It is essential to develop microstrip antennas that can effectively detect tumors of various sizes and precisely determine their location within colorectal tissue. This goal can be accomplished by optimizing the antenna's frequency range, radiation pattern, and sensitivity [2].

1.3 Causes and Risk Factors:

a) Causes:

Genetic mutations play a significant role in increasing the likelihood of developing colorectal cancer. These mutations can either be inherited from family members or arise spontaneously during a person's lifetime.

b) Risk Factors:

1. **Age**: The risk escalates as individuals grow older, with the majority of cases emerging in those aged 50 and above.
2. **Family History:** A heightened risk is observed in individuals who have close relatives, like parents or siblings, diagnosed with colorectal cancer.
3. **Personal History of Polyps or Inflammatory Bowel Disease:** Those who have experienced specific types of polyps in the colon or rectum, or have conditions like ulcerative colitis or Crohn's disease, face a greater likelihood of developing colorectal cancer.
4. **Lifestyle Factors**: Poor lifestyle choices significantly contribute to the onset of colorectal cancer. Risk factors include diets rich in red and processed meats, insufficient dietary fiber, sedentary behavior, obesity, and smoking.
5. **Diabetes:** The presence of diabetes is associated with an elevated risk for colorectal cancer.
6. **Radiation Therapy:** Previous exposure to radiation therapy in areas such as the abdomen or pelvis for other cancer treatments might increase vulnerability to colorectal cancer [3].

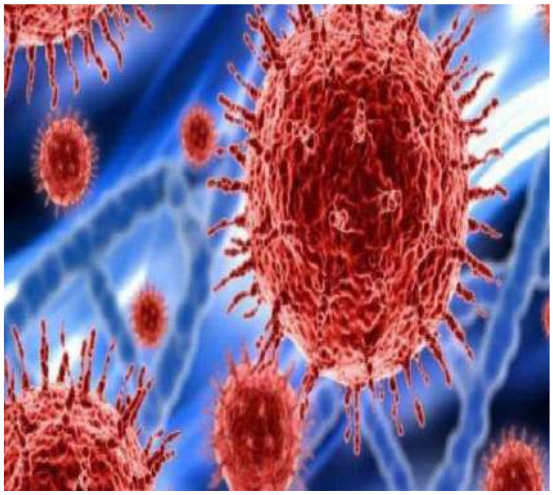

Figure 1.2: Cancer with 3D imaging

1.4 Diagnosis of Colorectal Cancer Using Microstrip Antennas

a) **Role of Microstrip Antennas:** Compact, lightweight, and cost-efficient, microstrip antennas are versatile tools with applications extending to medical diagnostics. Their capability to function efficiently at microwave frequencies makes them particularly effective for identifying irregularities in biological tissues.

b) **Detection of Colorectal Cancer:** In microwave imaging systems, microstrip antennas serve as vital components for detecting and diagnosing colorectal cancer. These systems work by transmitting microwave signals into the body and examining the reflected waves to identify abnormalities in the colon or rectum, including malignant tumors. Imaging Resolution and Accuracy: The effective use of microwave imaging in detecting colorectal cancer depends significantly on the design and characteristics of the microstrip antennas. Factors such as antenna dimensions, geometry, and operating frequency must be optimized to achieve high imaging resolution and reliable diagnostic accuracy [4].

1.5 Conclusion :

Colorectal cancer is considered a serious disease that demands significant healthcare attention due to the high rates of incidence and associated mortality. However, early detection through regular screening, particularly colonoscopy, is one of the most important factors contributing to improved recovery rates and reduced complications. Colonoscopy enables the identification of changes or polyps before they develop into malignant tumors, thereby providing an opportunity for early treatment and effective prevention.

Chapter Two

Microstrip Antennas

Chapter two : Microstrip Antennas

2.1 Introduction:

The antenna is a transducer designed to transmit or receive electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications. These antennas consist of a patch of metal foil, which is usually in the shape of a square, rectangle, circle, or ellipse, on the surface of the PCB. On the other side of the board, there is a metal foil ground plane.

This chapter presents the different Microstrip antenna technologies, their advantages, and disadvantages, the design of microstrip antenna methods, also their applications in different fields.

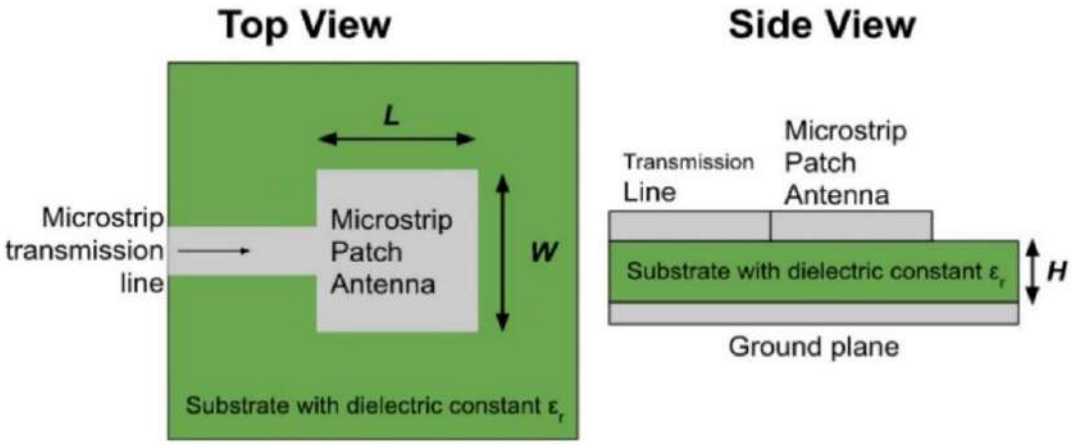

Figure 2.1: Microstrip antennas

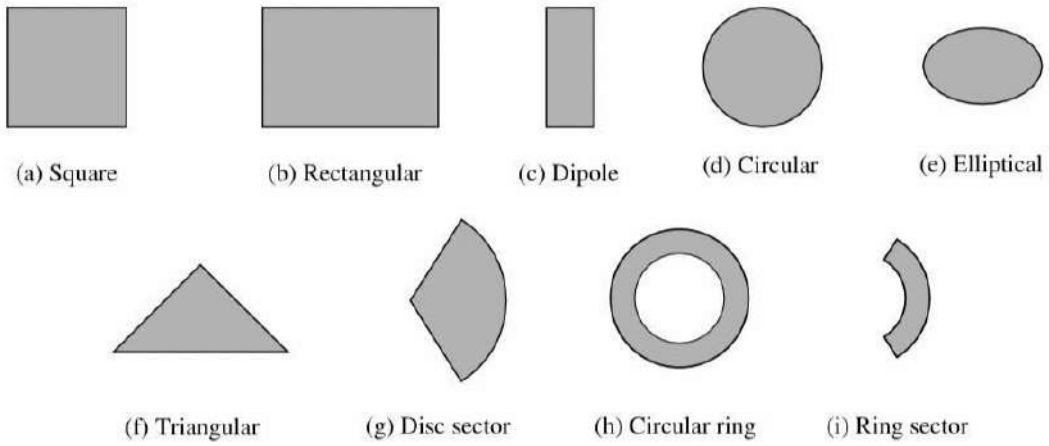

Figure 2.2: Microstrip patch elements.

2.2 Advantage of Microstrip Antenna :

a) Small Size: Their compact size allows for smaller end devices.

b) Easy Integration: These antennas are readily integrated with Microwave Integrated Circuits (MICs) or Monolithic Microwave Integrated Circuits (MMICs), allowing for complex RF systems on a single substrate.

c) Low Fabrication Cost: The simple manufacturing process results in lower fabrication costs, making them suitable for mass production.

d) Multi-Band Support: They can support multiple frequency bands, including dual-band and triple-band operations, broadening their applicability.

e) Polarization Support: They support linear and circular polarization, offering flexibility in signal transmission and reception.

2.3 Drawbacks of Microstrip Antennas :

a) Low Efficiency: Microstrip Antennas have relatively low efficiency, which means they may not radiate or receive signals as effectively as other types of antennas.

b) Lower Power Handling: Microstrip Antennas may have limited power handling capabilities and poor scan performance, which can affect their overall performance.

c) Narrow Bandwidth: These antennas have a very narrow frequency bandwidth, which can limit their use in certain applications. However, this narrow bandwidth can be advantageous for government security systems.

d) Radiation from Feeds: Microstrip antennas can experience faulty feed radiation, which can impact their radiation pattern and polarization characteristics [5].

2.4 Methods For Feeding :

There are several methods for feeding Microstrip Antennas, which can be broadly classified into contacting and non-contacting techniques. These methods provide RF power to the antennas and help establish an input impedance match. Here are some commonly used feeding methods:

a) Coaxial Probe Feed :

- This method involves using a coaxial cable with an inner conductor connected to the Microstrip patch and an outer conductor connected to the ground plane.
- The feeding point of the coaxial probe can be located anywhere inside the patch to establish an input impedance match.
- It offers advantages such as spurious radiation minimization, easy fabrication, and efficient feeding.

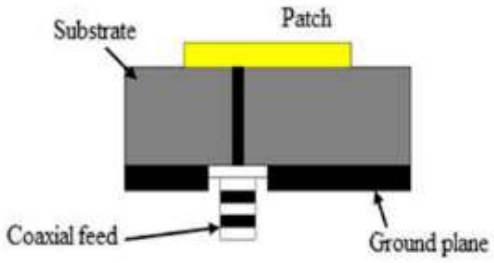

Figure 2. 3 : Coaxial Probe Feed

b) Microstrip Line Feed :

- In this technique, the Microstrip patch is directly connected to a conducting Microstrip feed line.
- The dimensions of the feed line may differ from those of the Microstrip patch.
- It is relatively easy to fabricate and match the feed line to the patch.

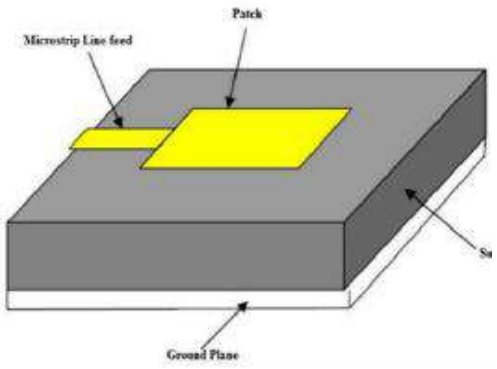

Figure 2.4 : Microstrip Line Feed

c) Aperture Coupled Feed :

- This method involves using two substrates separated by a ground plane.
- The Microstrip patch and feed line are coupled through a slot in the ground plane.
- It offers advantages such as minimization of interference and pure polarization.

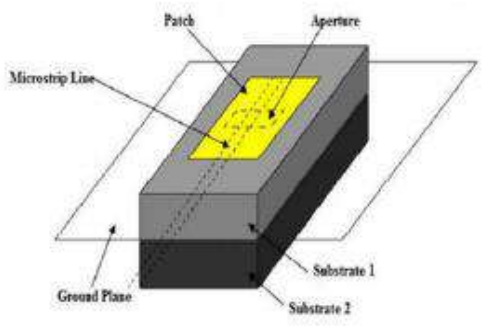

Figure 2.5 : Aperture Coupled Feed

d) Proximity Coupled Feed :

- This feeding method is more complex compared to others and involves using two dielectric substrates.
- The Microstrip patch is located on the upper surface of the upper dielectric substrate, and the feed line is positioned between the two substrates.
- It provides a higher bandwidth and helps avoid spurious radiation.[6]

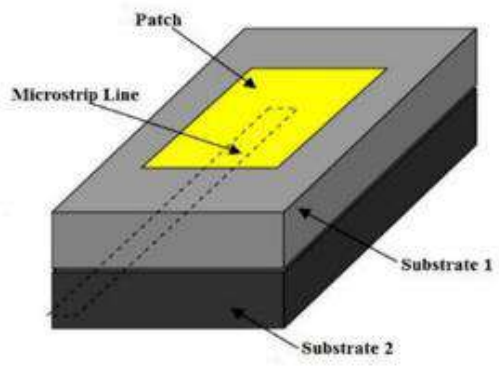

Figure 2.6 : Proximity Coupled Feed

2.5 Equations for Microstrip Antennas :

Microstrip patch antennas are widely used in various applications due to their compact size and ease of integration. The design of a Microstrip patch antenna involves several key parameters and equations. Here are some important equations used in the design of Microstrip Antennas:

a) Resonant Frequency (f) :

The resonant frequency of a Microstrip patch Antenna can be calculated using the following equation:

$$f = c / (2 * sqrt(\varepsilon r) * (L + 0.412 * h)) \qquad (2.1)$$

Where:

- f is the resonant frequency

- c is the speed of light (approximately 3 x 10^8 m/s)
- -εr is the relative permittivity of the substrate material
- L is the effective length of the patch antenna
- h is the height of the substrate

b) Effective Length (L) :

The effective length of the Microstrip patch antenna can be determined using the following equation:

$$L = c / (2 * f * sqrt(\varepsilon r)) - 0.412 * h \quad (2.2)$$

c) Patch Width (W) :

The patch width can be calculated using the following equation:

$$W = c / (2 * f * sqrt(\varepsilon r)) - 2 * (\varepsilon r + 1) * h \quad (2.3)$$

d) Patch Length (Lp) :

The patch length can be calculated using the following equation:

$$Lp = c / (2 * f * sqrt(\varepsilon r)) - 2 * h \quad (2.4)$$

e) Effective Dielectric Constant (εr eff) :

The effective dielectric constant of the Microstrip patch Antenna can be calculated using the following equation :[7]

$$\varepsilon r\, eff = (\varepsilon r + 1) / 2 + ((\varepsilon r - 1) / 2) * (1 + 12 * (h / W))^(-0.5) \quad (2.5)$$

2.6 Methods For Designing :

Designing Microstrip Antennas involves several popular methods that are widely used in the field. These methods help engineers and designers optimize the performance and characteristics of Microstrip Antennas. Here are some of the most popular methods for designing Microstrip Antennas :

a) Substrate Selection: The choice of substrate material plays a crucial role in Microstrip Antenna design. Different substrates have varying dielectric constants, which affect the antenna's performance. Thicker substrates with lower dielectric Constants provide larger bandwidth and better efficiency, while thinner substrates with higher dielectric constants are suitable for microwave circuitry.

b) Patch Shape and Size: The shape and size of the patch element Significantly impact the antenna's radiation pattern, impedance matching, and bandwidth. Common patch shapes include rectangular, circular, and The dimensions of the patch, such as length, width, and height, are determined based on the desired operating frequency and other design parameters.

c) Feeding Techniques: The feeding technique used to excite the Microstrip Antenna also affects its performance. Common feeding methods include Microstrip line feed, coaxial probe feed, aperture coupling, and proximity coupling. The choice of feeding technique depends on factors such as impedance matching, radiation pattern, and ease of integration.

d) Impedance Matching: Achieving impedance matching between the Microstrip Antenna and the feeding network is crucial for maximizing power transfer and minimizing reflection losses. Techniques such as matching stubs, quarter wavelength transformers, or impedance-matching networks can be employed to achieve optimal impedance matching.

e) Radiation Pattern Optimization: The radiation pattern of a Microstrip Antenna determines its coverage area and directionality. Techniques such as adjusting the shape and size of the patch, adding parasitic elements, or using array configurations can be employed to optimize the radiation pattern for specific applications.

f) Simulation and Testing: Simulating and testing the designed Microstrip Antenna is essential to verify its performance and identify any potential issues. Software tools like HFSS, CST, or ADS can be used for simulation, allowing designers to analyze parameters such as frequency, input impedance, return loss, gain, radiation pattern, and efficiency. Testing the antenna using measurement equipment like a network analyzer, antenna chamber, or field probe helps validate the simulation results and assess the antenna's performance in real-world conditions [8].

2.7 Applications of Microstrip Antennas:

a) Mobile and satellite communication application: Mobile communication requires small, low-cost, low-profile antennas. Microstrip patch antenna meets all requirements and various types of Microstrip antennas have been designed for use in mobile communication systems. In the case of satellite communication circularly polarized radiation patterns are required and can be realized using either square or circular patches with one or two feed points.

b) RFID (Radio Frequency Identification): Microstrip antennas are employed in RFID systems for tracking and identification purposes. They enable wireless communication between RFID tags and readers, facilitating applications like inventory management, access control, and asset tracking.

c) Wireless Communications: Microstrip antennas are widely used in wireless communication systems, such as mobile phones, Wi-Fi routers, Bluetooth devices, and satellite communication systems. They provide reliable and efficient wireless connectivity.

d) Global Positioning System Applications: Nowadays Microstrip patch antennas with substrates having high permittivity sintered material are used for global positioning systems. These antennas are circularly polarized, very compact, and quite expensive due to their positioning.

e) Radar Application: Radar can be used for detecting moving targets such as people and vehicles. It demands a low profile, lightweight antenna subsystem, the Microstrip antennas are an ideal choice. The fabrication technology based on photolithography enables the bulk production of Microstrip antenna with repeatable performance at a lower cost in a lesser time frame as compared to the conventional antennas.

f) Medicinal applications of patch: It is found that in the treatment of malignant tumors microwave energy is said to be the most effective way of inducing hyperthermia. The design of the particular radiator that is to be used for this purpose should be lightweight, easy to handle, and rugged. Only the patch radiator fulfills these requirements. The initial designs for the Microstrip radiator for inducing hyperthermia were based on the printed dipoles and annular.

Rings which were designed on S-band. Later on, the design was based on the circular microstrip disk at L-band. There is a simple operation that goes on with the instrument; two

coupled Microstrip lines are separated with a flexible separation which is used to measure the temperature inside the human body.

g) Consumer Electronics: Microstrip antennas are used in various consumer electronic devices, including laptops, tablets, smartwatches, and wireless headphones. They provide wireless connectivity and communication capabilities [9].

2.8 Conclusion :

Microstrip antennas constitute a fundamental component in modern wireless communication systems due to their compact size and ease of integration with electronic circuits. Despite certain technical limitations, continuous advancements have contributed to enhancing their performance and expanding their applications to various fields such as telecommunications, radar systems, and the medical sector through wireless medical devices and advanced medical imaging technologies. Moreover, technical expertise in this area serves as a cornerstone for developing advanced communication applications that contribute to improving quality of life and healthcare services.

Chapter Three

Design of Microstrip Patch Antennas for Colorectal Cancer Detection

Chapter two :

3.1 Introduction :

Microstrip patch antennas are a promising choice for designing applicators in microwave-based colonoscopy systems for colorectal cancer (CRC) detection. Conventional colonoscopy relies on visual inspection, which can be limited by factors like flat lesions and incomplete bowel cleansing. Microwaves interact differently with healthy and cancerous tissues due to variations in their electrical properties. This chapter presents the design of a microstrip antenna element in the antenna applicator and presents simulations of this design. The study
will be conducted in this manner and modifications will be made that improve the required specifications.

3.2 Microstrip Patch Antenna for Colon Cancer Detection :

Microstrip patch antennas are planar antennas fabricated on a printed circuit board (PCB). They offer several advantages for colon cancer detection:

a) **Miniaturization:** Their low profile makes them suitable for integration into colonoscopy probes.
b) **Conformal Design:** They can be conformally shaped to match the curvature of the colon.
c) **Ease of Fabrication:** Microstrip patch antennas are manufactured using well-established PCB techniques, making them cost-effective and reproducible.

The antenna's performance depends on various factors:

1. Substrate Permittivity (εr): The dielectric constant of the substrate material affects the antenna's size, radiation pattern, and efficiency. Lower permittivity substrates lead to larger antennas but offer better penetration into the colon tissue.

2. Patch Geometry: The patch shape (rectangular, square, circular) and dimensions influence the antenna's resonant frequency and radiation pattern.

3. Feeding Mechanism: The method of feeding power to the patch (microstrip line, coaxial probe) affects the input impedance and radiation characteristics.

Here are some key design considerations for the antenna applicator:

1. **Antenna Type:** Microstrip patch antennas, slot antennas, and dipole antennas are potential candidates due to their compact size and potential for conformal design.
2. **Frequency Selection:** The chosen frequency should balance penetration depth, tissue contrast, and safety considerations. Studies suggest frequencies around 8 GHz offer a good balance. Where a frequency range is chosen in the design between 7-8 Ghz.
3. **Array Design:** An array configuration with multiple antennas can improve field focusing and achieve a more uniform heating pattern within the target tissue.
4. **Feeding Mechanism:** The feeding mechanism needs to be designed to deliver microwave power efficiently while minimizing signal leakage.
5. **Cooling System:** A cooling mechanism may be necessary to manage heat generated by the applicator itself [10].

3.3 Challenges and Design Considerations :

A colonoscope is a thin flexible tubular instrument used to examine the interior of a hollow organ or cavity in the body equipped with a light delivery system, a lens, and a camera at its tip. Although colonoscopy screening has significantly increased the survival rate of colorectal cancer patients, it still has fundamental limitations. The reduced field of view of the optical camera placed on the end of the endoscope results in obscuring polyps, as a result of the angles and folds of the colon and insufficient preparation of the intestine.

Other challenges include the movement of the endoscope as it moves through the colon and the movement of the colon itself. The colon is a tubular organ located in the last part of the gastrointestinal tract of 1.5 m in length and between 5-10 cm in diameter with a segmented appearance (i.e. colon folds). Colon polyps are superficial tumors that develop from healthy

mucosa and present several shapes, i.e., protruded, slightly elevated, flat, depressed, etc., the first two being the most common.

During colonoscopy, the colon is generally inflated with air or CO_2 and previously cleaned with a diet and medication to facilitate the camera vision.

The antenna applicator is designed to avoid interfering with the optical.

1. Visualization system at the tip of the endoscope while being safe for the patient and maneuverable for the endoscopist. To meet these requirements, the applicator is designed as a cylindrical compact array attached at the tip of a conventional colonoscope, see Figure 3.1. This design is widely used in colonoscopy accessories and is accepted by doctors [11].

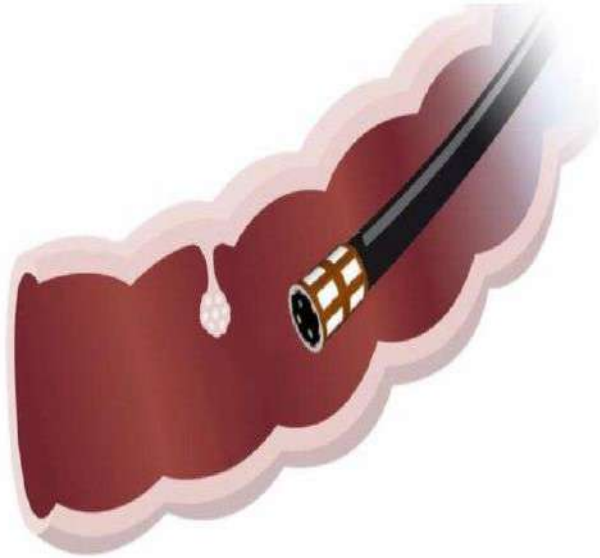

Figure 3.1: Diagram of the proposed MI system for colonoscopy including the antenna applicator a ttached at the tip of a conventional colonoscope.

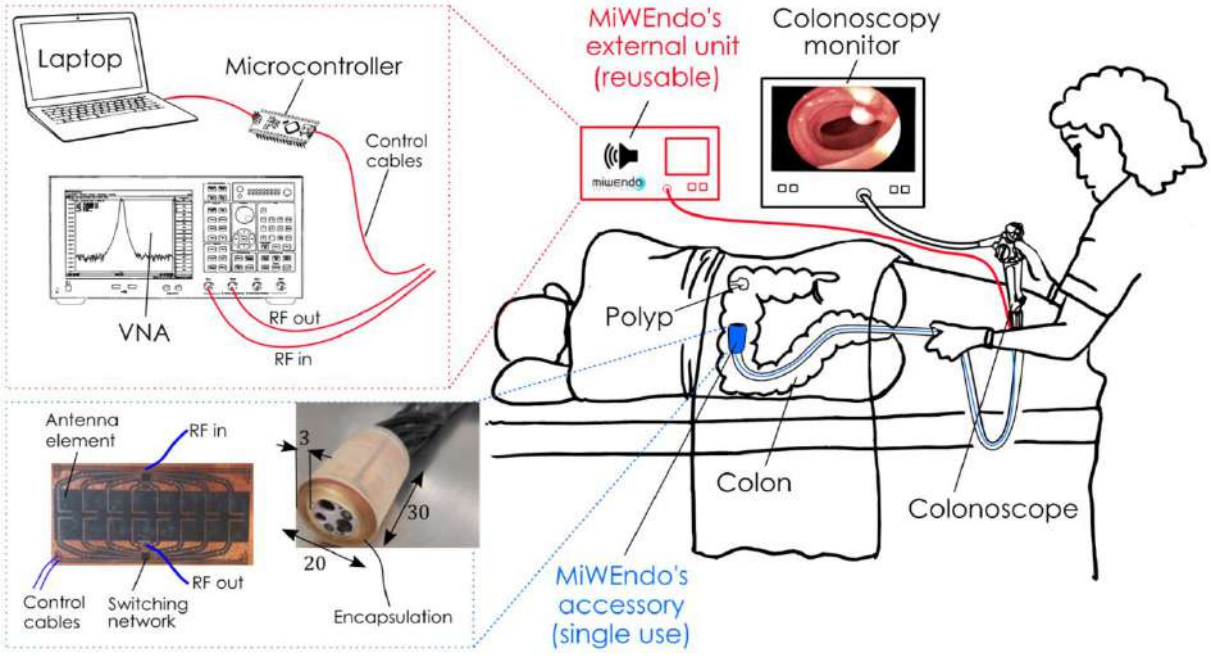

Figure 3.2: MiEndo's microwave endoscopy system.

3.4 Antenna Element Design:

The antenna element used in the applicator is a cavity- backed U-slot fed by an P-shape microstrip line, this is due to its efficiency in working with microwave frequencies and its suitability for medical applications.

Table 3_1: showing the basic engineering characteristics of the antenna

Property	Value
Antenna type	Rectangular microstrip
Hole shape	U_slot
Feeding type	P_shaped feed line
Substrat	Rogers RO3003
Center frequency	8 GHZ

Electrical insulation coefficient	εr = 3.0
Supstrat thickness	0.127 mm

- **Antenna model :**

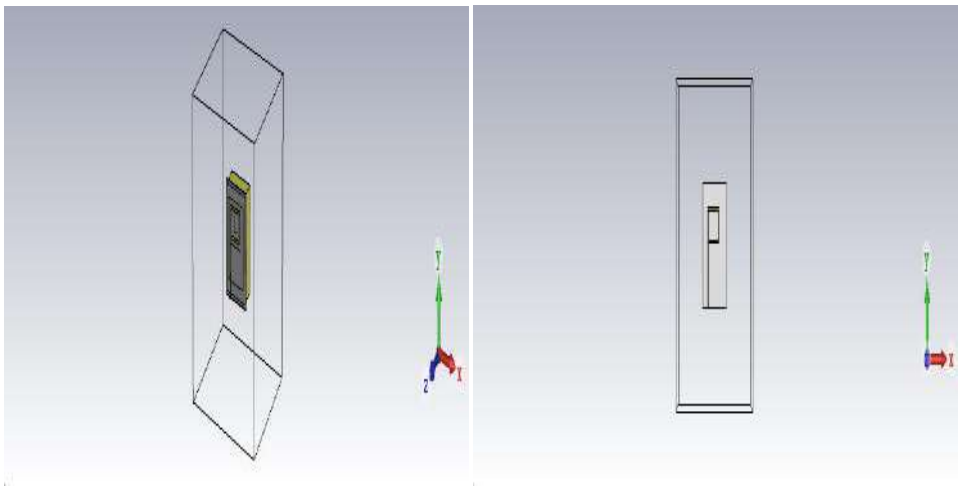

Figure 3_3: This figure shows the antenna design.

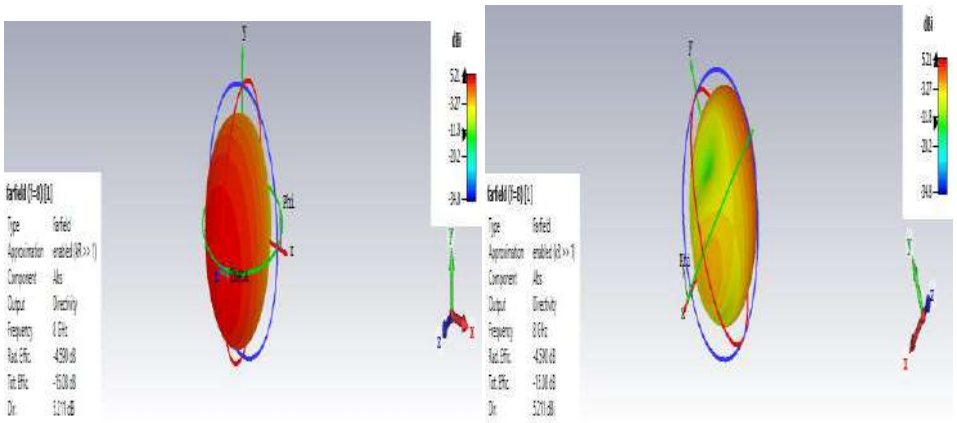

Figure3_4: This figure represents the wave radiation of the antenna.

The elements are arranged in two rows of eight elements each. One row is used for transmission and the other for reception. The elements are wrapped around a conducting cylinder with sixteen recessed cavities.

antenna elements on the same row are separated by metallic walls of a width of 1 mm while transmission and reception rows are separated by a metallic disk of a thickness of 4 mm and a diameter of 24mm. For feeding convenience, each antenna element is backed by an open cavity such that the cavity comprises only three metallic walls. Accordingly, no metallic wall is present in the feeding side of each antenna element.

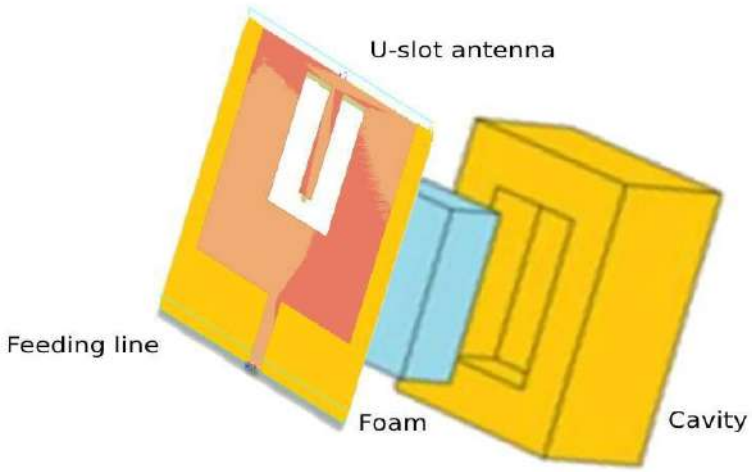

Figure3_5: This figure shows the entire antenna design.

This design is selected to meet the reduced size requirements of the application and enhance the isolation between array elements. The slot is printed on Rogers RO3003 substrate having a relative permittivity of 3 and a thickness of 0.127 mm. The substrate is very flexible and thus can be easily conformed onto a cylindrical surface , as illustrated in Fig 3-6 (a) .

An P-shape microstrip line printed on the back side of the substrate is used to excite the slot. The cavity is filled with a lossy foam with relative permittivity of 2.1 as illustrated in Fig 3-6

(b). The size of the cavity is 13 × 8.16 mm^2, and the cavity depth is 4 mm. The geometrical parameters of the backed- cavity U-slot microstrip-fed antenna are shown in Table 3-2.

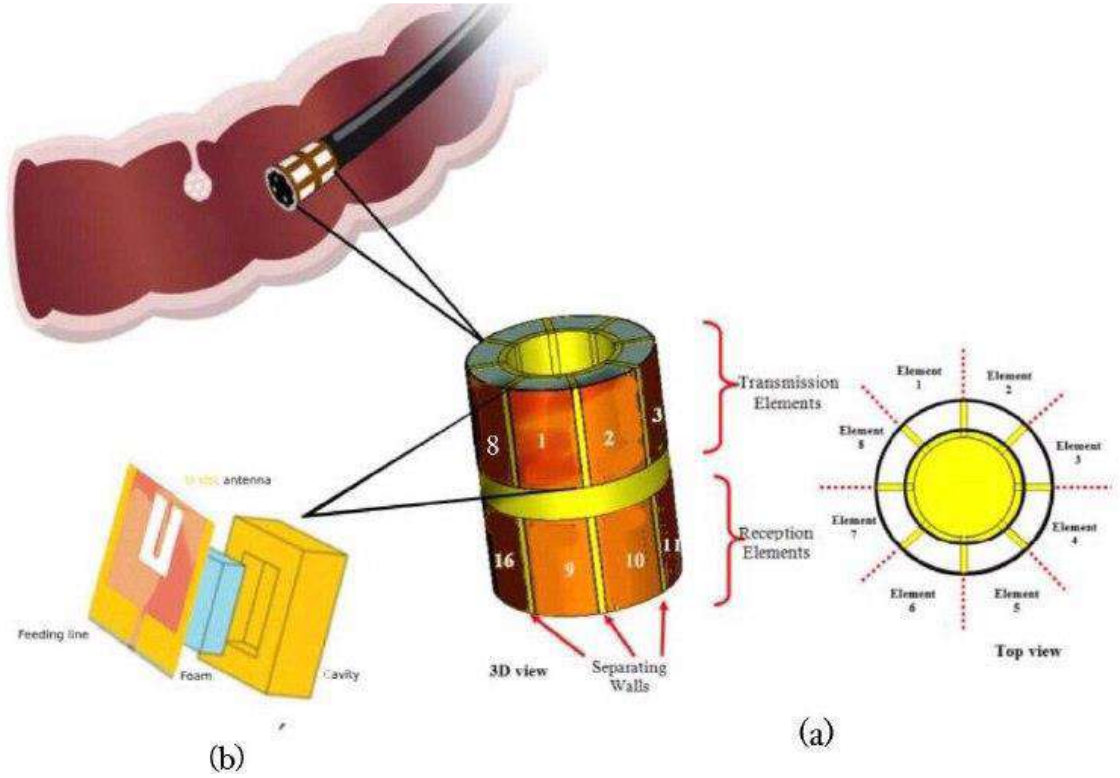

Figure3_6: (a) Geometry of the cylindrical U-slot antenna array. (b) Geometry of the cavity-backed U-slot antenna element.

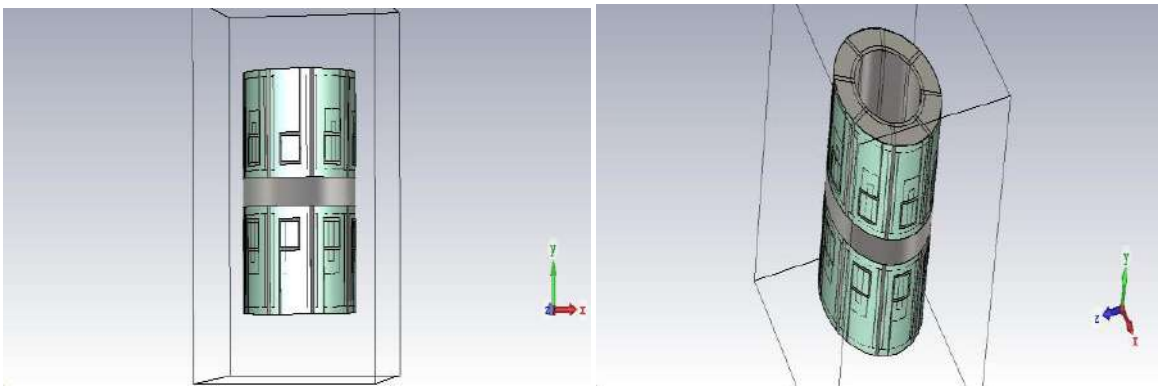

Figure (3-7): This figure shows the the cylindrical U-slot antenna array design .

Table 3-2 : Proposed Antenna Element Dimensions.

Parameter	value(mm)	Parameter	value(mm)
L	13	W_S	7
g_1	1.5	W_P	0.283
g_2	1	P_1	0.5
g_3	0.75	P_2	0.5
g_4	1.5	P_3	4
L_2	7.7		

3.5 Array of two Antenna Elements:

When using an antenna array in beam-switched mode, achieving adequate isolation between antenna elements is critical to ensuring optimal system performance. In this context, two different configurations of two adjacent antenna elements were studied, as shown in Figure (3-8):

***The First Configuration:**

It consists of two adjacent elements, one functioning as a transmitter and the other as a receiver. This arrangement is known as the “Transmit–Receive” configuration.

***The Second Configuration:**

It involves two adjacent elements in the same row performing the same function, either transmission or reception. This arrangement is referred to as the "Side-by-Side" configuration.

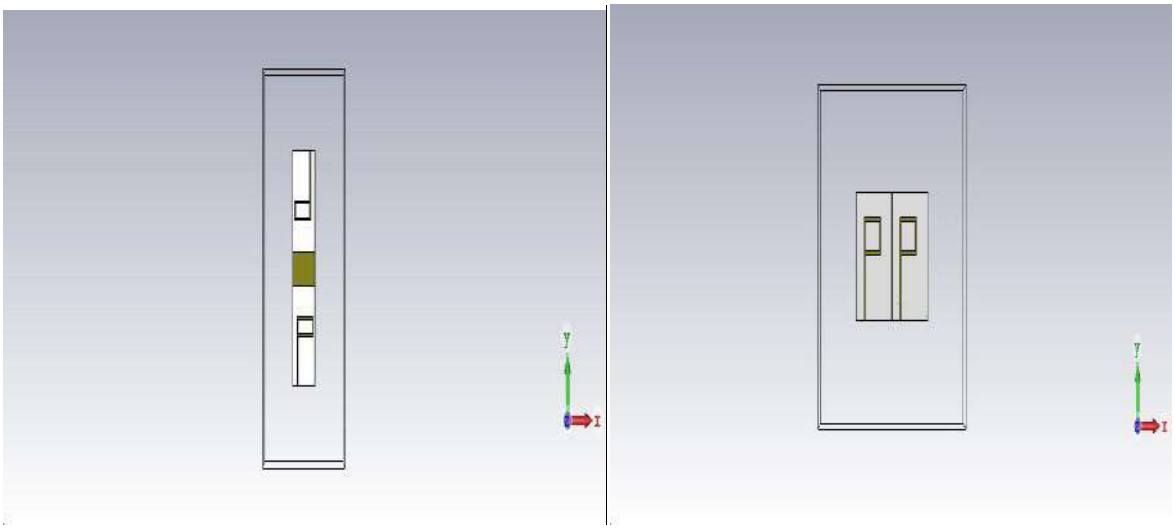

Figure (3-8): Studied antenna configurations: transmission-reception configuration (left), and side by side configuration (right).

3.6 Simulated Results :

A. Return loss :

Return loss Analysis:

Figure (3.9) illustrates the variations of the reflection coefficient as a function of frequency. According to the simulation results, the antenna's resonance frequency is located at 8.55 GHz, with an value of approximately -27 dB, indicating effective impedance matching at this frequency.

The corresponding bandwidth, defined by , extends from 8.44 GHz to 8.64 GHz, resulting in a total bandwidth of 0.20 GHz (or 200 MHz). These results demonstrate that the antenna performs well within this frequency range, making it suitable for microwave sensing applications, particularly for detecting physiological changes in tissues such as the presence of tumors in the colon and rectum.

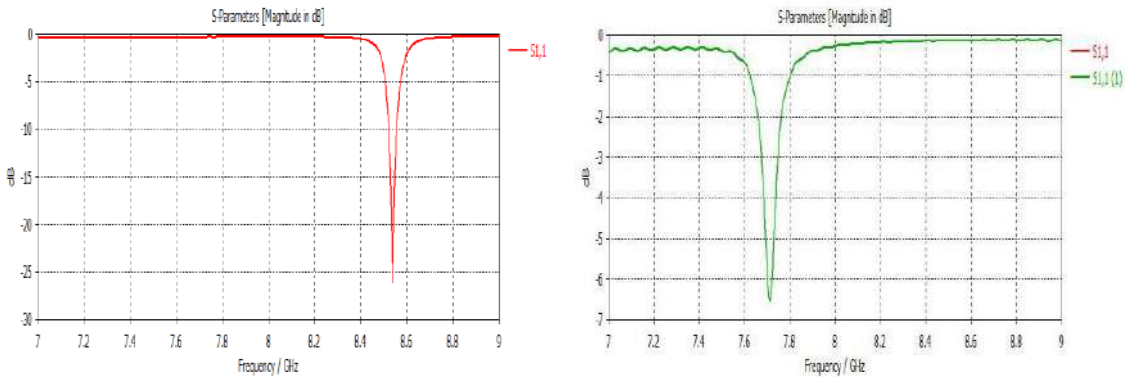

Figure 3.9: shows the antenna design's Return loss.

(a) Without colon (b) With colon D=5mm

B. Gain and Directivity :

Figure displays the suggested antenna's gain and directivity as modeled using CST **.**

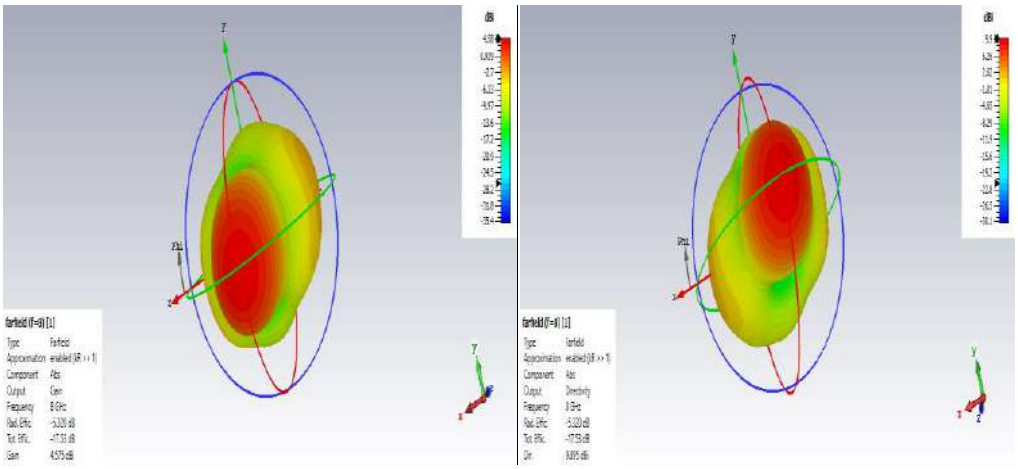

Figure 3.10: shows the antenna design's gain and Directivity in CST.

C. Efficiency :

Antenna Efficiency Analysis:

Figure (X) illustrates the variation in both radiation efficiency and total efficiency of the proposed antenna across the frequency range of 7 to 9 GHz. According to the simulation results, both efficiencies increase gradually as the frequency increases. At the resonance frequency of 8.55 GHz (as identified in the S11 analysis), the total efficiency is estimated to be approximately -4 dB, while the radiation efficiency is around -18 dB. These values correspond to a total efficiency of about 40%, which is considered acceptable for a microstrip antenna intended for biomedical sensing applications.

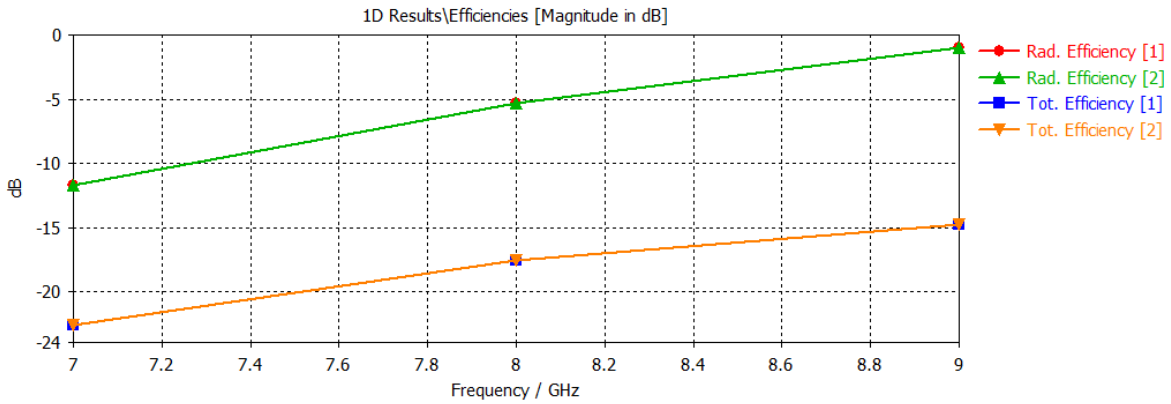

Figure 3.11: shows the effectiveness of the suggested antenna design in CST.

D. Voltage Standing Wave Ratio (VSWR) :

The voltage-standing wave ratio (VSWR) of a microstrip antenna was simulated over the 7–9 GHz frequency range. The results showed that the best impedance match was achieved at 8.55 GHz, with a VSWR of approximately 2, indicating acceptable antenna efficiency at this frequency. A significant increase in VSWR was observed at the lower and upper ends of the range, reflecting a decline in antenna efficiency. This performance is considered suitable for colorectal cancer screening applications.

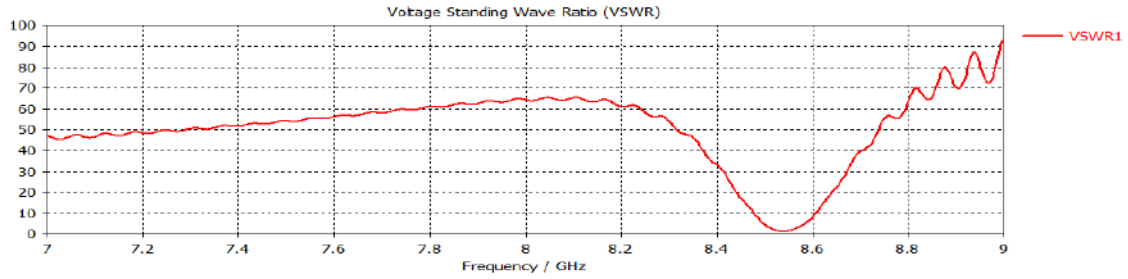

Figure 3.12: shows the suggested antenna design's voltage standing wave ratio in CST.

3.7 Recommendations :

• Enhance the accuracy of models.

• Develop advanced signal processing software interfaces.

• Further improve antenna design.

• Take steps toward integrating antenna technologies into smart medical systems.

3.8 conclusion :

The proposed microstrip antenna design has demonstrated promising characteristics for applications in colorectal cancer detection using microwave techniques. Theoretical analysis and preliminary simulation results highlight the efficiency of the design and its potential integration with conventional endoscopic medical devices, thereby enhancing the development of non-invasive and effective diagnostic tools.

Conclusion

General Conclusion

Microstrip patch antennas represent a promising option for the development of applicator devices used in microwave-based colonoscopy systems for the detection of colorectal cancer. These antennas are characterized by their compact size, ease of integration, and flexibility to adapt to the design of colonoscopy probes. Careful consideration of key design parameters—such as operating frequency, radiation pattern, and Specific Absorption Rate (SAR) distribution—is essential to ensure effective and safe detection.

Computational simulation plays a central role in optimizing antenna performance and fine-tuning its properties to meet medical application requirements. Simulations were conducted using CST software on models representing colorectal tissues. The results showed that the presence of a tumor in the area leads to noticeable variations in antenna performance parameters, indicating that these changes can serve as potential indicators for tumor detection.

Despite the results, further research is still required to develop more accurate and efficient antenna designs, aiming to improve diagnostic performance for colorectal cancer with greater precision and safety .

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