كلية الهندسة بشبرا
FACULTY OF ENGINEERING AT SHOUBRA
ERJ
PRINT ISSN 3009-6049
ONLINE ISSN 3009-6022

ENGINEERING RESEARCH JOURNAL (ERJ)
Volume (53) Issue (4)
October. 2024, pp:20-25
https://erjsh.journals.ekb.eg

Design of a Microwave Endoscopy Antenna Applicator for Early Colorectal Cancer Detection

Mariam Saeed Mekhail[1]*, Sherif Hekal[1], Mohmed Edries[2], Mohamed lotffi[1]

[1] Department of Electrical Engineering, Faculty of Engineering at Shoubra, Benha University, Cairo, Egypt.
[1] Department of Electrical Engineering, Al Shorouk Academy , Cairo, Egypt.
* Corresponding Author.
E-mail: saeedmariam460@gmail.com , sherif.hekal@ejust.edu.eg,m.edries@sha.edu.eg, Mohamed.lottiffi@feng.bu.edu.eg

Abstract: This paper presents an experimental microwave colon imaging system operating from 5 to 9 GHz. In comparison to traditional microwave imaging systems, supporting improved resolution in the detection of malignant tumors. A new antenna with a small dimension of 13×8.16 mm^2 is created. The 3D surface and clearly defined borders of the compressed colon geometry make it easier for tumour detection to operate. The tumour's sites are localised inside a generated model of a colon with a thickness of 10 mm in order to illustrate the current state of research. A one-dimensional scanning system is employed for this. The preliminary findings demonstrate the viability of using portable microwave technology to identify early-stage colon cancer at high resolution.

Keywords : colon cancer, microwave imaging, detection, antenna array

1. INTRODUCTION

Screenings with colonoscopies are crucial in the identification of tumours related to colorectal cancer [1]. Colonoscopy is often feasible and beneficial [2].Tests used for colon tumour detection include barium enema, CT colonography, flexible sigmoidoscopy, foetal haemoglobin, foetal DNA markers, cytological assays, established serum antigen markers, and colononoscopy are the most commonly employed screening cedures [3]. However, the strategies have limits in addition to their benefits. For example, barium enema, the bowel preparation required in this time-consuming treatment, restricted its marketability along with its high cost. Moreover, a lack of well-designed studies assessing its effectiveness as a screening tool has increased scepticism [3]. CT colonography: It is yet unknown if using this screening method may reduce the incidence and death rates of CRC, while meta-analyses have confirmed the diagnosis of large polyps (10mm) has good sensitivity and specificity but not so for smaller polyps [3]. Flexible sigmoidoscopy has the restriction of being able to identify adenomas exclusively in the proximal colon [3]. Faecal haemoglobin, the traditional FOBT relies on the reliable measurement of heme moiety peroxidase activity in stool samples and is thus prone to haemorrhage in the upper and lower gastrointestinal tract is interfering. Likewise, some medications and foods may result in false-positive results, requiring a three-day meat-free diet. and aspirin before sampling, as well as other NSAIDs [3].

Faecal DNA markers although faecal DNA testing is becoming more popular as a screening technique, there are still worries about its cost. Song et al. 45 compared the cost-effectiveness of several screening strategies using a Markov model. In the study, FOBT and colonoscopy were determined to be less expensive than faecal DNA testing [3]. Cytological assays show that Commercial cell count equipment based on immunomagnetic bead purification is too sensitive to be used for population screening; using these instruments, circulating tumour Only between 20 and 60 percent of people with metastatic illness have cells in them. [3]. Established serum antigen markers although it is the most sensitive marker for detecting pancreatic cancer, it is less sensitive for detecting CRC [3]. Colonoscopy is regarded as the gold standard for detecting cancer and colorectal polyps [3]. While colonoscopy is the most effective method for detecting colorectal cancer, its performance is limited by significant visualization restrictions. On the other hand, optical colonoscopy is the most effective method for diagnosing colorectal cancer and is the only method that can remove polyps throughout the entire colon [4]. There is a 22% polyp miss rate and an 8% chance of getting cancer following a negative colonoscopy due to the narrower field of view of the optical camera at the tip of the endoscope (≤170º), polyp occultation caused by colon angulation, and inadequate bowel preparation[4].Despite the development of many tools and technologies in recent years to enhance colonoscopy performance, there is still a need to distinguish between benign and malignant tissues during the procedure and to raise detection rates[4]. Conventional colonoscopy can only produce 170º images; microwave imaging can produce 360º images with a reasonable compromise between resolution and tissue penetration, which could aid in the detection of polyps concealed by folds and colon angulation. Microwave imaging finds widespread use in numerous applications, including non-destructive testing [5]. Compared to alternative methods and procedures, microwave imaging has significant advantages in terms of patient comfort, safety, and cost [6], medical diagnosis and care. Early identification of colorectal cancer (CRC) is a relatively new use of microwave imaging in medicine [7]. This medical diagnostic approach is portable, non-invasive, low-power, low-cost, and non-ionizing [8].

This paper analyses the transmission capability of microwave signals ranging from 5 to 9 GHz via artificial colon tissue. We present a new patch antenna structure with a feasible bandwidth of 7.9 GHz and a reflection coefficient of less than -10 dB.

The remaining portions of this paper are organised as follows: The beginning of the two parts provides an overview of the suggested antenna architecture and the development of artificial colon tissue. The 1D scanning system will be described in the following part. Finally, conclusions will be offered.

2.MODELING OF COLON AND TUMOR

The colon is modelled using the available materials in CST MWS'S material library. AS shown in fig. 1a, the thickness of serosa is 91.33 µm, which of Muclairs mucosa layer is 30.67µm, the layer of Submucosa is 20.17µm thick while mucosa is 16.83µm thick [9] and the height and width of these layers are 10 and 6 mm respectively.

Since the tumor material is not available in the CST's material library, it was created on request. The graph in Figure 1b, which is derived from [9], is utilized to define the colon tumor and displays the dielectric values of the tumor at various frequencies.

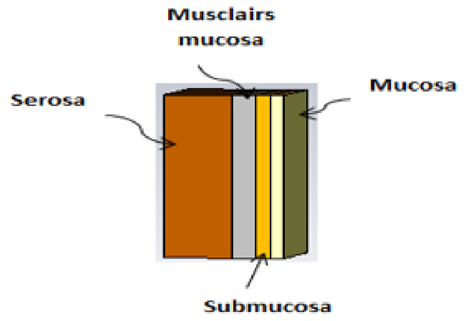

Fig. 1.a. the colon model

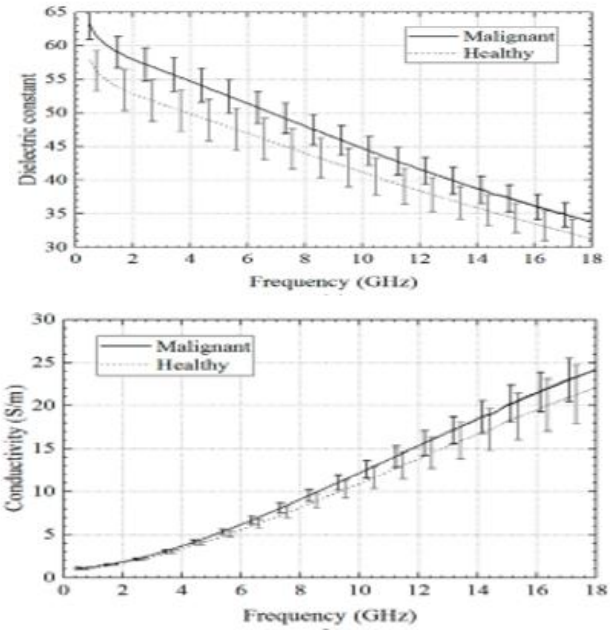

Fig. 1.b dielectric properties of colon tumour [10]

3.Design of an antenna array

The proposed antenna array consists of 14 cavities, 7 for transmission and 7 for reception feeding by a basic f-microstrip antenna with ground separated from U slots. A unit cell of an antenna consists of a cavity with dimensions of $13 \times 8.16 mm^2$ and a thickness of 4 mm, made of copper, lossy foam with dimensions of $10 \times 5.16 mm^2$ and 2.1 relative permittivity and a thickness of 3.75 mm, a slot printed on the extruded face of the copper substrate with a height of 0.035 mm, and a printed f-shaped microstrip on the substrate's reverse. Fig.2 The cylinderical antenna array's geometry. Fig. 3 shows (a)Front view (b)Back view (c) Perspective view.Fig. 4 illustrates the antenna's configuration. The patch's conducting material is copper, which has a thickness

(t) of 0.035 mm. A RT/Duroid 5880 substrate with a thickness of 0.127 mm and a relative permittivity of 2.2 has been used to create the microstrip antenna. All the optimised dimensions of the antenna are mentioned in Table I. The simulations were all run in CST Microwave Studio (CST MWS 2020), and the outcomes of the simulations were compared in real time. Beginning with a basic rectangular cavity of 13×8.16mm^2 , the design was created. Here, this design has a fractional bandwidth of 1.14% and a gain of 6.54 dBi and works at a frequency of 7.9 GHz.

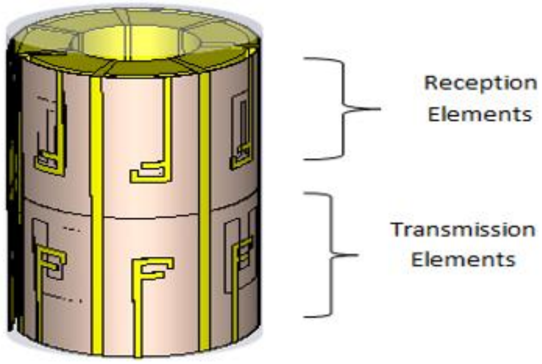

Fig.2 The cylinderical antenna array's geometry

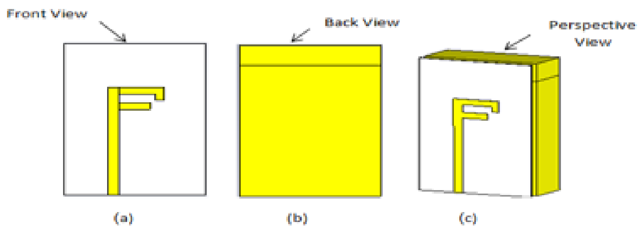

Fig.3 (a) Front view (b) Back view (c) Perspective view.

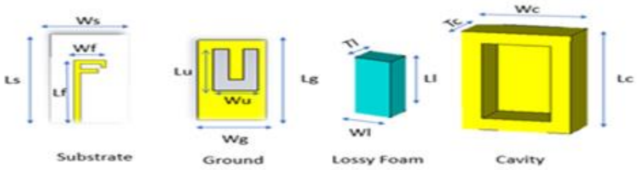

Fig.4 shows the suggested antenna's configuration.

TABLE 1. Dimensions of the antenna used in Figure.4

Parameters and Dimensions in mm						
	Width (mm)		Length(mm)		Thickness(mm)	
cavity	Wc	8.16	Lc	13	Tc	4
Lossy foam	Wl	5.16	Ll	10	Tl	3.75
Ground	Wg	8.16	Lg	15	Tg	0.035
U slot	Wu	5.32	Lu	7.7	Tu	0.035
Substrate	Ws	8.16	Ls	15	Ts	0.127
Feeding line	Wf	3.28	Lf	10.65	Tf	0.035

TABLE 2. Dielectric and conductivity values of colon tissue

Tissue Type	Dielectric ε	Conductivity σ (S/m)
Normal colon tissue	45.9	6.62
Cancerous colon tissue	50.175	7.38

4. SIMULATED RESULTS

A. Return loss

The reflection coefficient, or S11, is the most essential antenna parameter since it sets the bandwidth and impedance matching characteristics. Figure 5 depicts a comparison of the proposed antenna's simulated return loss. According to the modelling results, the resonance frequency is 7.89 GHz, with an S11 of -39.06 dB. The relevant bandwidth is 0.086 GHz, which spans from 7.856 to 7.942 GHz if no colon is used. In the instance of colon, the antenna resonates at 7.9 GHz, with S11 of -17.14 dB, and the relevant bandwidth is 0.102 GHz, extending from 7.892 GHz to 7.994 GHz. In the case of the tumour, the antenna resonates at 7.944 GHz, with S11 of -21.9 dB, and the relevant bandwidth is 0.101 GHz, extending from 7.892 GHz to 7.994 GHz. The findings of the simulation tools are clearly quite close to each other.

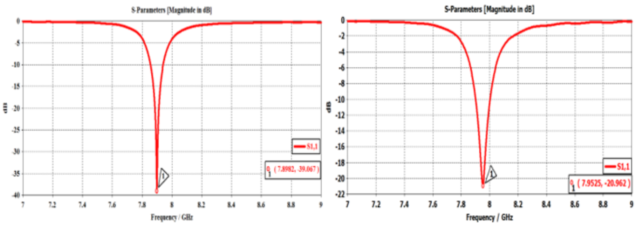

Fig.5. (a)Without colon. (b)With colon with D=5mm

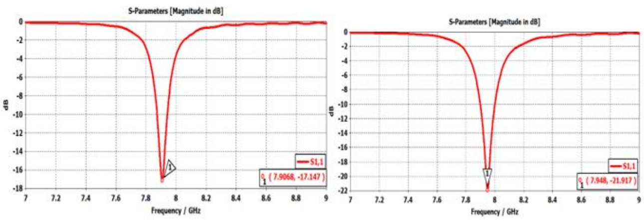

Fig.5. (c)With colon D=10mm (d)With tumor

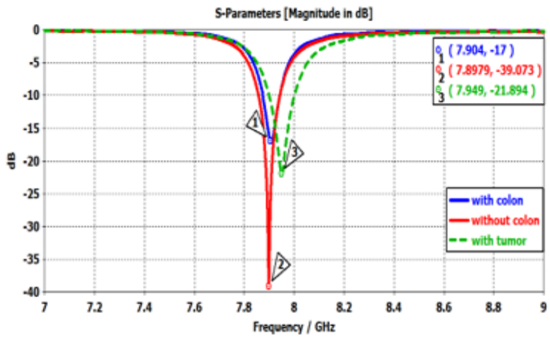

Fig.5. (e) For different cases

Figure 5 shows a return loss plot in CST for the proposed antenna configuration (a) without colon (b) with colon for distance 5mm from colon to antenna (c) with colon for distance 10 mm from colon to antenna (d) with tumor (e) for different cases.

B. Gain and Directivity

Figure6 displays the suggested antenna's gain and directivity as modelled using CST. The gain and directivity at 7.9 GHz are 5.312 dBi and 6.58 dBi, respectively, according to CST simulation results.

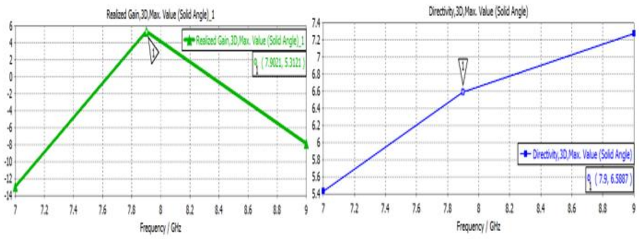

Fig 6 shows the antenna design's gain and Directivity in CST.

C. Efficiency

Figure 7 shows the efficiency values for the proposed antenna. At 8 GHz for the transmission and reception antennas. The radiation efficiency is 0.9340 and 0.8899, respectively, whereas the total efficiency is 0.483 and 0.094, respectively. When modelled on CST, the antenna efficiency calculated is 80.7%.

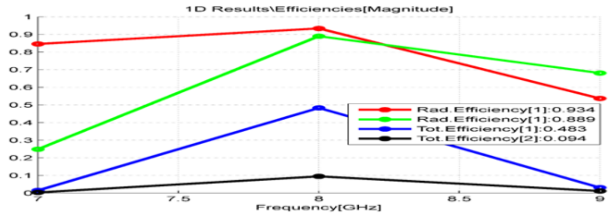

Fig 7 shows the effectiveness of the suggested antenna design in CST.

D. Voltage Standing Wave Ratio (VSWR)

Using the CST simulator, Figure 8 displays the antenna's VSWR response, which is 1.88 at 7.94 GHz. These results indicate that there is good matching because the ratio is between 1 and 2.

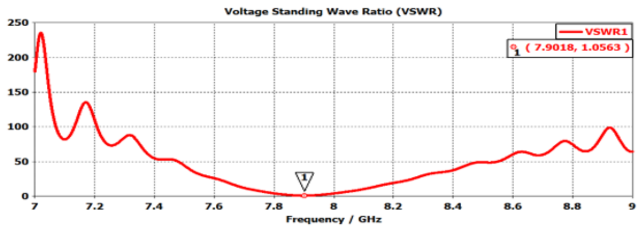

Fig8 shows the suggested antenna design's voltage standing wave ratio in CST.

E. Radiation pattern

The 3-D radiation pattern plot at 7.9 GHz is shown in Figure 9. The suggested antenna exhibits almost omnidirectional characteristics in the SHF band.

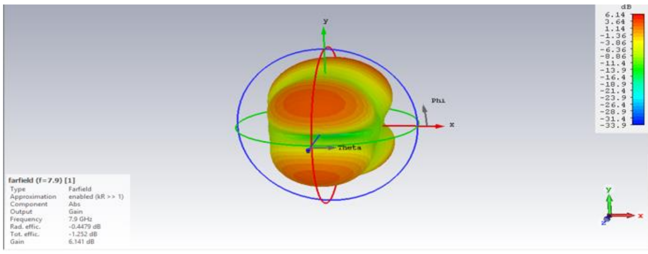

Fig shows the 3-D radiation pattern plot.

E. Comparison

The performance of our proposed antenna is compared with the previous published structures and listed in Table 3. The comparison among antennas is in terms of size, return loss, bandwidth, and gain. The antenna compactness is one of the most essential factors. It can be observed that our proposed antenna represents a single frequency resonance within the frequency bands 5 - 9 GHz. In addition, our proposed antenna is competitive to other structures. regarding the thickness.

TABLE 3.

Ref.	Size	Frequency bands	Bandwidth	Return loss s11(dB)	Gain (dB)	Directivity (dB)	Efficiency %
[11]	145×92 μm^2	5.85-6.18 THz	0.33 THz	37	7.54	13.96	54%
[12]	7 × 7 mm2 size of capsule=26 × 11 mm2	(1015–785) MHz	230 MHz	-20.02	-35.5	-1183	0.03%
[13]	the capsule surface area = 10 mm × 26 mm.	402–688MHz	286MHz	− 18.17	− 31.75	-	-
[14]	12×6 Capsule dimensions=11×26	2.95 - 3.33 GHz	0.38GHz	-40	-32.5	-	-
[15]	6.5×6.5mm^2	0.6-0.9GHz	0.3GHz	-34	-28.2	-	-
[16]	π× 25 × 1.27mm^3	2.4 – 2.48 GHz	0.08GHz	-35	-22.7	-	-
[17]	10×10×0.6mm^3	0.6-1.2 GHz	0.5GHz	-30	-29.33	7.87	3.8%
The proposed	13×8.16 mm^2	7.856-7.942 (GHz)	0.086 GHz	-39.22	5.312	6.58	80.7%

5.CONCLUSION

This paper describes a study of microwave signal propagation from 5 to 9 GHz through biological tissue for early-stage colon cancer diagnosis. This work offers an antenna array design. This design gives us good results, as we can obtain a return loss of -39 dB, a gain of 5.312 dB, a directivity of 6.58, and an efficiency of 80.7%.

These first findings suggest that constructing a small, basic colon cancer detection device at larger frequency ranges is feasible.

References

[1] Kahi, C. J., Azzouz, F., Juliar, B. E., & Imperiale, T. F. (2007). Survival of elderly persons undergoing colonoscopy: implications for colorectal cancer screening and surveillance. *Gastrointestinal endoscopy*, *66*(3), 544-550.

[2] Jafri, S. M., Monkemuller, K., & Lukens, F. J. (2010). Endoscopy in the elderly: a review of the efficacy and safety of colonoscopy, esophagogastroduodenoscopy, and endoscopic retrograde cholangiopancreatography. *Journal of clinical gastroenterology*, *44*(3), 161-166.

[3] Pawa, N., Arulampalam, T., & Norton, J. D. (2011). Screening for colorectal cancer: established and emerging modalities. *Nature reviews Gastroenterology & hepatology*, *8*(12), 711-722.

[4] Guardiola, M., Djafri, K., Challal, M., Ballester, M. A. G., Fernandez-Esparrach, G., Camara, O., & Romeu, J. (2019). Design and evaluation of an antenna applicator for a microwave colonoscopy system. IEEE Transactions on Antennas and Propagation, 67(8), 4968-4977.

[5] Alidoustaghdam, H., & Çayören, M. (2020, March). Non-destructive testing of concrete tunnels with qualitative microwave imaging. In *2020 German Microwave Conference (GeMiC)* (pp. 29-31). IEEE.

[6] Elsdon, M., Leach, M., Fdo, M. J., Foti, S. J., & Smith, D. (2006, September). Early stage breast cancer detection using indirect microwave holography. In *2006 European Microwave Conference* (pp. 1256-1259). IEEE.

[7] Guardiola, M., Djafri, K., Challal, M., Ballester, M. A. G., Fernandez-Esparrach, G., Camara, O., & Romeu, J. (2019). Design and evaluation of an antenna applicator for a microwave colonoscopy system. *IEEE Transactions on Antennas and Propagation*, *67*(8), 4968-4977.

[8] Nikolova, N. K. (2017). *Introduction to microwave imaging*. Cambridge University Press.

[9] Maier, F., Siri, S., Santos, S., Chen, L., Feng, B., & Pierce, D. M. (2021). The heterogeneous morphology of networked collagen in distal colon and rectum of mice quantified via nonlinear microscopy. Journal of the mechanical behavior of biomedical materials, 113, 104116.

[10] Fornes-Leal, A., Garcia-Pardo, C., Frasson, M., Beltrán, V. P., & Cardona, N. (2016). Dielectric characterization of healthy and malignant colon tissues in the 0.5–18 GHz frequency band. Physics in Medicine & Biology, 61(20), 7334.

[11] Ghosh, S., Das, S., Samantaray, D., & Bhattacharyya, S. (2020). Meander-line-based defected ground microstrip antenna slotted with split-ring resonator for terahertz range. *Engineering Reports*, *2*(1), e12088.

[12] Biswas, B., Karmakar, A., & Chandra, V. (2020). Miniaturised wideband ingestible antenna for wireless capsule endoscopy. *IET Microwaves, Antennas & Propagation*, *14*(4), 293-301.

[13] Güreş, E., Yelten, M. B., Özdemir, Ö., & Ferhanoğlu, O. (2021). A meandered dual loop antenna for wireless capsule endoscopy. *AEU-International Journal of Electronics and Communications*, *137*, 153792.

[14] Alemaryeen, A. (2021). Compact wideband antenna for wireless capsule endoscopy system. *Applied Physics A*, *127*(4), 271.

[15] Hayat, S., Shah, S. A. A., & Yoo, H. (2020). Miniaturized dual-band circularly polarized implantable antenna for capsule endoscopic system. *IEEE Transactions on Antennas and Propagation*, *69*(4), 1885-1895.

[16] Xu, L. J., Bo, Y., Lu, W. J., Zhu, L., & Guo, C. F. (2019). Circularly polarized annular ring antenna with wide axial-ratio bandwidth for biomedical applications. *IEEE Access*, *7*, 59999-60009.

[17] Samanta, G., & Mitra, D. (2019). Dual-band circular polarized flexible implantable antenna using reactive impedance substrate. *IEEE Transactions on Antennas and Propagation*, *67*(6), 4218-4223.