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RESEARCH ARTICLE - ENGINEERING

Microstrip wireless antenna used by capsule for stomach internal photography

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Abstract

A wireless capsule endoscopy is a medical device used to examine the digestive system. The big challenge in the development of the capsule is how to get high data rate and also to reduce the size of the capsule. The micro strip antenna has been used which has several advantages such as small size, light weight, low cost. In this paper, Ultra-wideband mini polygonal slotted patch antenna has been designed which has a dimension of 10 x 10 mm^2 and bandwidth of 6 GHz (5.5 – 11.5 GHz). The simulation results for return loss (S_{11}) have -26.32 at 6.6 GHz and voltage standing wave ratio (VSWR) at 1.09. The simulated radiation patterns are Omni directional radiations over the Ultra-wideband bandwidth.

Keywords: UWB antenna; micro strip patch; omnidirectional antenna.

1. Introduction

Wireless capsule endoscopy is used for imagining the digestive system by taking pictures of the entire digestive system during its passing inside the human body by a small camera placed at the top of the capsule. The antenna sends pictures to a receiver which is worn by the patient. Then, after the examination time is going over, doctor will take the information from the receiver and display by a computer for processing, image display and diagnostics. The capsule consists of a camera, lighting led, battery and wireless antenna. It travels along the digestive system through its involuntary movement so it does not require any effort from the patients so they can carry out their daily activities during the examination process. Therefore, its prefered to use this technique instead of the conventional endoscope because it is without pain and the capsule can reach and imagine areas that cannot be reached by conventional endoscopy. [1] Medical Implant Communication Service (MICS) band operates at (402-405 MHZ) [2], and Industrial Scientific and Medical (ISM) band have narrow band, therefore these bands have bad data rate so the examination process may last for 8 hours which is considered one of the most difficulties that a patients suffer from because they will carry the receiver along the examination time so the Ultra-wideband (UWB) antenna will be used for getting real time imagining. Ultra-wideband is a technology for transmitting information spread over a large bandwidth (>500 MHz). So, UWB communication systems offer high speed data transmission of 100 Mbps to 1 Gbps so UWB antenna is an essential element used for wireless capsule endoscopy (WCE) to get high resolution image. UWB offers many advantages such as high data rates, large channel capacity, excellent immunity to multipath interference, Low complexity, low cost and low power consumption [3]. UWB antennas bandwidth is defined by the U.S. Federal Communications Commission (FCC) to have a range from 3.1 to 10.6 GHz [4]. The human body consists of many tissues which

Nomenclature			
UWB	Ultra-Wide Band	h	Substrate thickness
VSWR	Voltage Standing Wave Ratio	W_1	Width of first part of feed-line
MICS	Medical Implant Communication Service	W_2	Width of second part of feed-line
ISM	Industrial Scientific And Medical	L_1	Length of first part of feed-line
WCE	Wireless Capsule Endoscopy	L_2	Length of second part of feed-line
FCC	Federal Communications Commission	R_1	Radius of big polygon
CST	Computer Simulation Technology	R_2	Radius of small polygon
Symbols		ε_r	Radiation efficiency
a	Actual radius of the patch	f_r	Resonant frequency
a_e	Effective radius of the patch	ϵ_r	Relative permittivity dielectric constant
S_{11}	Return loss		

have different electrical properties and therefore highly frequency dependent. Because of the direct relationship between the implanted device and body tissues, the design of WCE is critical. The design of antenna requires knowledge about human tissue electrical properties. So in the design of antenna for wireless capsule endoscopic, the tissues electrical properties must be taken into account [5].

To design a reliable antenna for capsule, an antenna implanted inside the human body model will be simulated in CST Microwave Studio 2014 for accurate results. The rest of this paper is organized as follows: Section 2 presents the capsule structure. Section 3 shows the proposed antenna design. Section 4 produces the simulation method. Section 5 shows the measured results. Section 6 deals with related work and comparison. Section 7 concludes the paper conclusions and finally, future work is presented by Section 8.

2. Capsule structure

Wireless capsule system consists of many components such as camera, LED for lighting, battery pack and antenna. In [6] the conceptual shape of capsule with helical antenna was proposed with dimensions of 22 x 11 mm^2 and small thickness for the micro strip patch antenna. The proposed capsule dimensions are 20 x 11 mm^2 which is considered as the smallest proposed antenna model used in the capsule of medical application as shown in Fig.1.

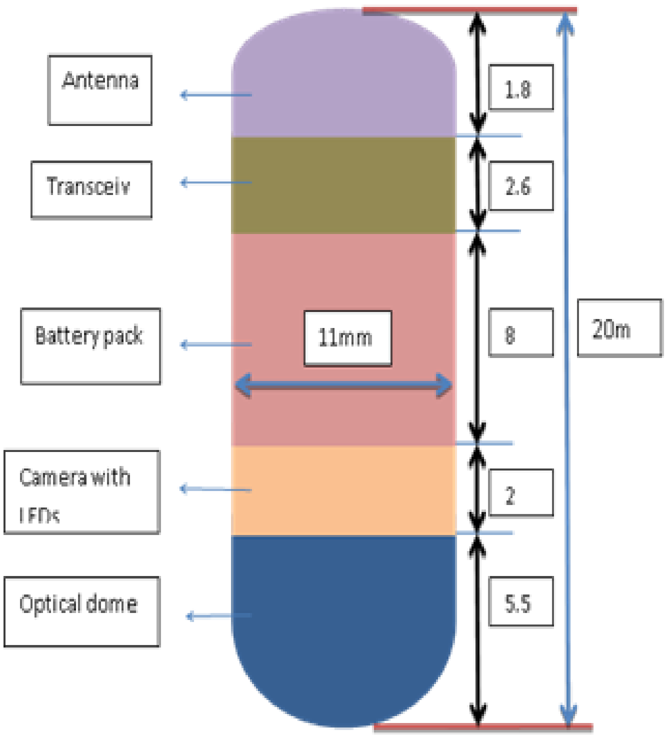


Fig.1 The proposed capsule model

Table 1 presents the comparison of some commercial capsule endoscopic pill [5].

Table.1 commercial capsule endoscopic

model	Dimensions (mm)	operation time (hr)
Pill Cam	11 x 26.0	8
Endocapsule	11 x 26.0	8
Micro Cam	11 x 24.0	11
OMOM capsule	13 x 27.5	8
Smart pill	13 x 26.0	-

3. Antenna structure

It's important to design an antenna with small dimensions that could be fitted in the capsule size. The proposed antenna is a UWB mini polygonal slotted patch antenna. The two semicircles in the patch and partial ground have been used for increasing the antenna bandwidth.

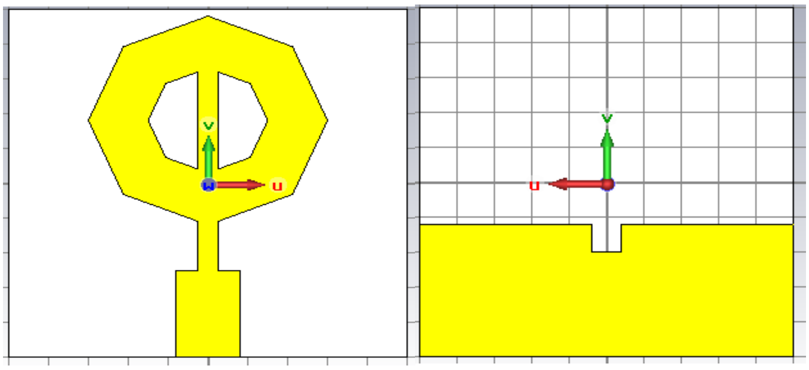


Fig. 2 Front and back views of the proposed antenna

Micro strip line feed technique has been used and its width with two steps for impedance matching which must be 50 Ω [7]. Several parts of the design are discussed below:

3.1. Material

The substrate is made of Rogers RT5870 which has a dielectric constant of 2.33, and a thermal conductivity of 0.22 [8]. This material is harmless to human tissues so, in case of breakdown of capsule inside the stomach, it has no effect on internal surface. This material can be used because it is safe for the tissues and also of its low dielectric constant which makes the bandwidth wider. The ground and patch are made or printed of copper.

3.2. Dimensions

The overall dimensions of the proposed antenna is 10 x 10 x 0.642 mm^3 with substrate material thickness of h = 0.57 mm as illustrated in Fig.2. The dimension size of antenna details is presented in Table 2.

Table.2 Antenna dimensions

parameters	Sizes (mm)
width of ground and substrate	10
Length of substrate	10
Length of ground	3.8
Slot in ground	0.8 x 0.8
thickness of substrate	0.57
Thickness of patch and ground	0.036
Width of feed lines respectively (W_1, W_2)	1.58 , 0.5
Length of feed lines respectively (L_1, L_2)	6, 2.5
R_1	3
R_2	1.5

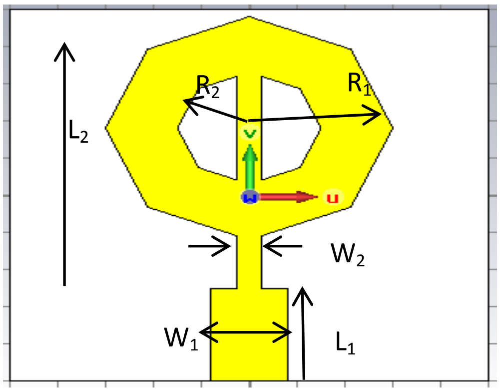


Fig.3 Antenna dimensions

3.3 Compatibility

The antenna of small size can easily be compatible with the proposed capsule which has a dimensions of 20 x 11 mm^2 which leaves enough space or room for other components of the system.

4. Equations of the designed antenna

In this section, the equation of the antenna dimensions is presented [9]:

The actual radius of the patch is given by:

$$a = \frac{F}{\{1+\frac{2h}{\pi \varepsilon_r F}\left[\ln(\frac{\pi F}{2h})+1.7726\ \right]\}^{1/2}} \quad (1)$$

$$F = \frac{8.791x10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

Eq. 1 does not take the fringing effect into consideration. the fringing makes the patch electrically larger, so the effective radius of patch is given by [10]:

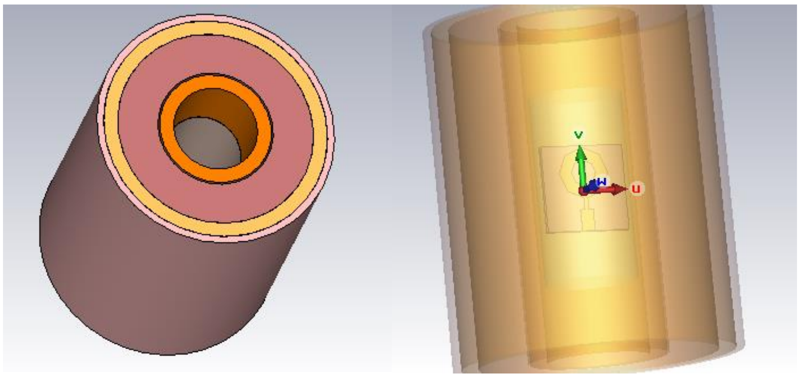
$$a_e = a\{1 + \frac{2h}{\pi\ \varepsilon_r\ a}\left[\ln(\frac{\pi a}{2h}) + 1.7726\ \right]\}^{1/2} \quad (3)$$

Hence, the resonant frequency is given by:

$$f_r = \frac{1.8412\, v_o}{2\pi a_e \sqrt{\varepsilon_r}} \tag{4}$$

5. Simulation

The antenna performance simulation is developed with computer simulation technology (CST) Microwave Studio Test. An approximate environment of the Stomach is created using predefined tissue materials with CST program. The tissues of the body surrounded the antenna in the form of sequential layers. The antenna is placed inside the proposed capsule made of Teflon and then surrounded with the tissues representing the stomach then muscle layer, fat and skin sequentially as shown in Fig. 4.



(a) (b)

Fig. 4 (a) Tissue layers surrounding the antenna, (b) Antenna shown inside tissue layers.

6. Results and discussion

6.1 Return loss and VSWR analysis of the antenna

Figs.5 and 6 show antenna return loss and voltage standing ware ratio (VSWR) respectively when placed inside the human body model. The antenna shows good impedance matching in frequency band of 5.5 – 11.5 GHz. The -10 dB bandwidth of antenna is approximately 6 GHz. The minimum value of return loss shown in Fig. is 26.32 dB at 6.6 GHz.

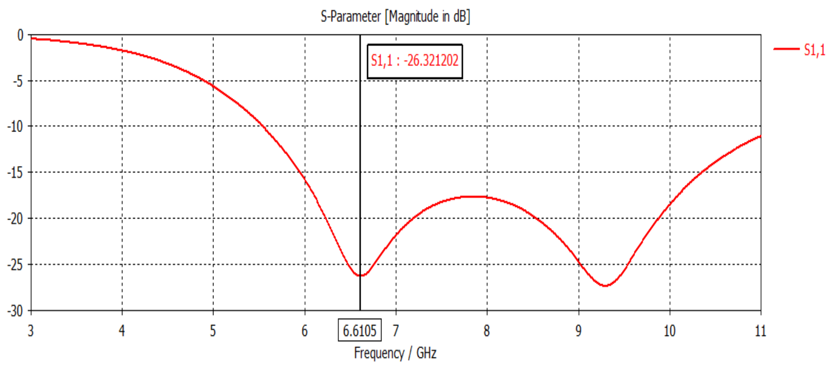


Fig.5 Return Loss of the proposed antenna inside human body

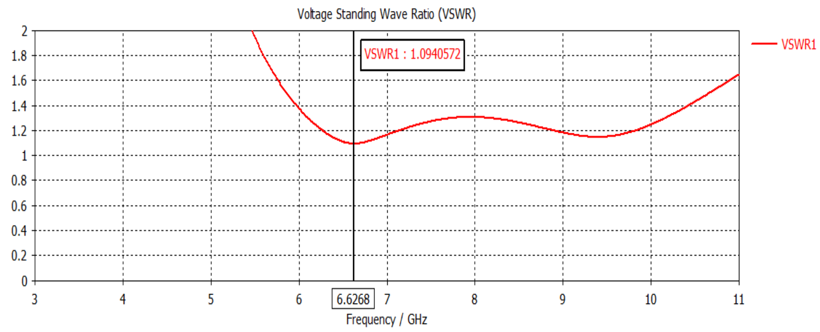


Fig.6 VSWR

6.2 Radiation pattern analysis of the antenna

Fig.7 shows the 3D radiation pattern of the proposed antenna inside the human body model which describe the antenna's Omni directional pattern along the range of UWB frequency. Radiation Efficiency and total efficiency in free space have higher values than they are in the human body model due to its losses tissues.

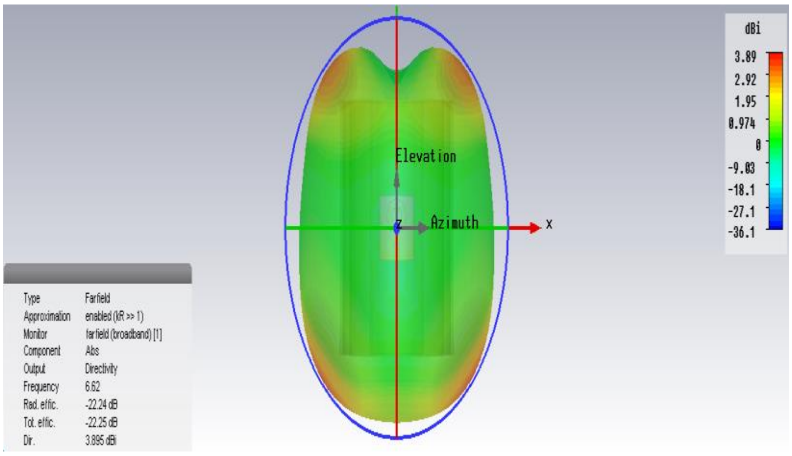


Fig.7 Simulated radiation pattern.

The polar two-dimentional radiation patterns are shown in Fig.8

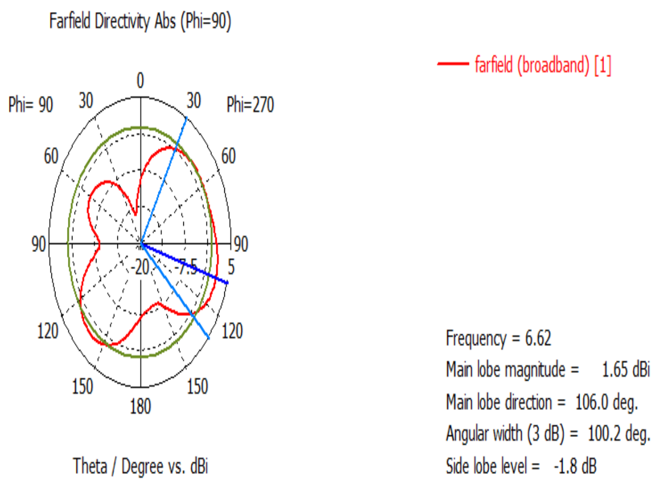


Fig.8 2D radiation pattern at 6.6 Ghz

6.3 Effect of feed line width

Fig. 9 illustrates the effect of changing the width of the line on the return loss s_{11}, where we tested s_{11} at three values of width 0.25 mm, 0.5 mm and 0.75 mm. The Fig.9 shows that the width of 0.25 mm has the best result.

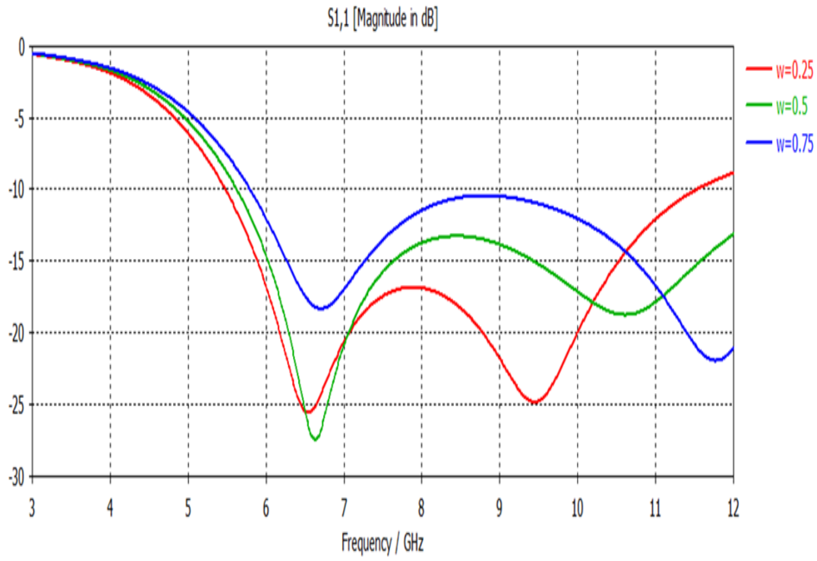


Fig.9 Effect of feed line width

6.4 Effect of ground length

Fig. 10 illustrates the effect of changing the length of ground on the return loss s_{11}, where we tested s_{11} at three values of length 4 mm, 3.8 mm and 3.6 mm. The figure shows that the length of 3.8 mm has the highest bandwidth.

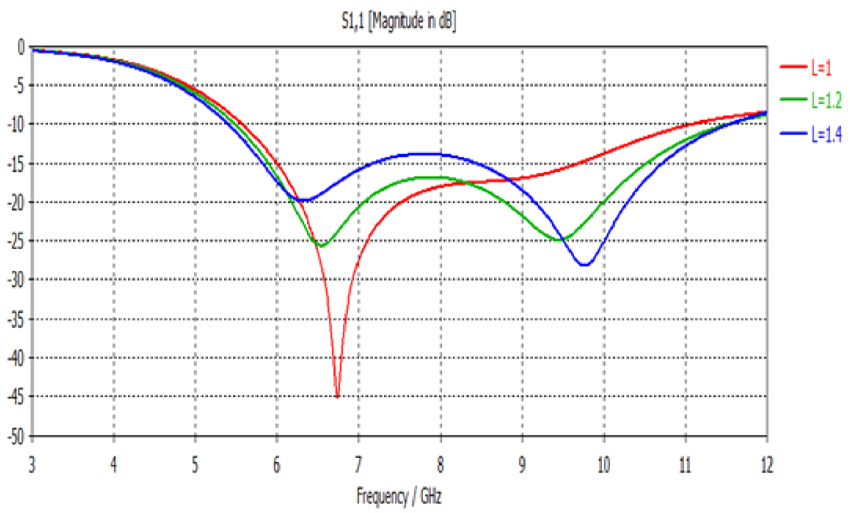


Fig.9 Effect of feed line width

7. Related work and comparisons

Table 3 preents comparison of the proposed antenna based on size and bandwidth with different micro strip patch antennas

Table 3. Comparison with different micro strip patch antennas

No	Configuration	Size(mm)	Bandwidth
1	Bending cylindrical micro strip patch antenna [11]	20 X 30	103 MHZ
2	Circular patch micro strip antenna with square slot [12]	10 x 9	500 MHZ
3	Circular patch micro strip antenna with two rings slot[13]	10 x 10	1.84 GHZ
4	U- shaped bend patch antenna[8]	28 x 24	2.268 GHZ
5	A compact planar slotted micro strip patch antenna [14]	10 x 10	2.9 GHZ
6	The proposed antenna	10 x 10	6 GHZ

8. Conclusions

In this paper, UWB mini polygonal slotted patch antenna has been designed and simulated inside human stomach using predefined tissue material with CST program. The proposed antenna has an overall size of 10 x 10 mm^2. It works at bandwidth of 6 GHz so it has high data rate to transmit the information in real time. The antenna works at Omni directional radiation pattern which is very important since the movement of capsule inside human body is involuntary and it is difficult to determine its orientation. The simulation results of return loss (S_{11}) have -26.32 at 6.6 GHZ and voltage standing wave ratio VSWR at 1.06.

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