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Design and Simulation of Conformal Wideband Ingestible Antenna for WCE System

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Abstract

Wireless capsule endoscope systems (WCE) is a easiest and comfort technology for the diagnosis of the gastrointestinal (GI) tract observations. In this paper, the designed conformal wideband antenna which operates at 2.4 GHz is implanted inside the stomach tissue of the ANSYS human body model with smaller size, of dimensions (3.8*3) mm. The ingestible - body capsule transmitter has the characteristics of tuning because of the electronic modules within the capsule. But the Ultra-wideband characteristic overcomes this demerit by tolerating the tuning effects when the capsules travel at the near vicinity of various tissues is the region of interest. The ground plane is made partial to attain the necessary frequency and better gain with a return loss of -16.2 dB. Also the parameters of the patch antenna such as gain and directivity are measured. Specific Absorption Rate is also evaluated inside the stomach tissue of the ANSYS human body model. Finally, the simulated results are compared with the existing system.

Index Terms; *WCE, Ingestible Antenna, Colon tissues, Small intestine, ANSYS human body model, Industrial Scientific Medical(ISM)*

I. INTRODUCTION

Wireless Capsule Endoscopy (WCE) is a technology designed to visualize the digestive tract with help of the cameras fixed inside the capsule. This data will be transmitted to the external recorder to follow further procedures. mages acquired by this technique has an excellent resolution than the conventional Endoscopes. This endoscopy method is less risky than the traditional methods followed by inserting tubes for diagnosing the effects.

As the capsule moves passively along the Gastro Intestinal tract, the magnification approaches the perception of physiological endoscopy. The ANSYS software has tools for analyzing adult human body structures with good accuracy. These models are shown in the Figure 1. The model contains over 300 muscles, organs, tissues, and bones. The chassis material's square, measure Frequency-dependent range from ten CPS to 10 Giga cycle per second. The model may be changed by users for the particular applications and elements, and model objects can merely be removed if not required. For high frequencies, the simulation is very long and computationally complicated. The ANSYS HPC technology permits data processing, specified one has the power to model and simulate very large size and elaborated geometries with complicated physics.[13]

In this paper, the ingestible antenna is simulated inside the tissue of the stomach or abdomen and the outputs are studied.[13]

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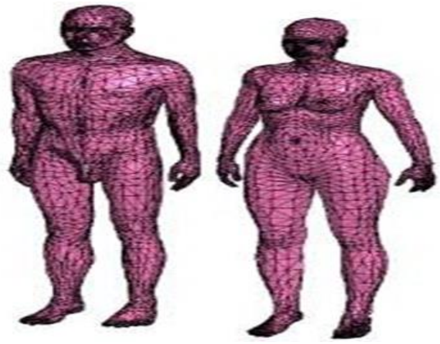

Fig. 1 Ansys Human Body Models

II. ANTENNA DESIGN

The thickness of the proposed antenna is0.2mm and the dimension is given by 3.8mm * 3mm. Roger is the substrate used because of its bending property. This characteristic of Roger material enables the designed antenna to wrap around the capsule. The designed antenna is shown in Fig.2. Combined phased array antenna around the surface is the conformal patch antenna. These antennas are driven by controllers and help the current flow through the transmitter. Unnecessary radiations emitted by the surrounding radiating elements are controlled by interference controlling techniques. At the receiver, the weak signals of radiations are combined and sensed in correct phase and avoid the interference signals. The conformal patch antenna is intended to investigate the abdomen cancer.[14]

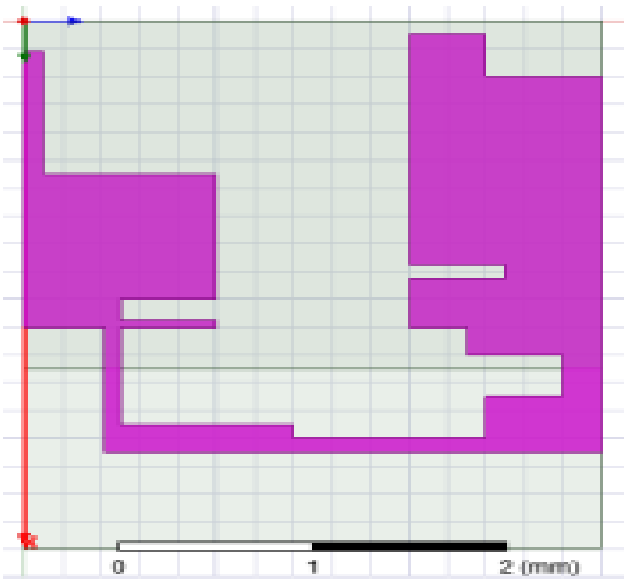

Fig. 2 Conformal Patch Antenna

The antenna consists of partial ground with the dimensions of (2.5mm*3mm) shown in figure 3.The use of partial ground is to increase gain and enhance bandwidth. The proposed antenna is designed to operate at ISM band at a frequency of 2.4 Ghz. This antenna gives a return loss of -16.2 db with high gain. The below Table I shows dimensions of different patch antennas.

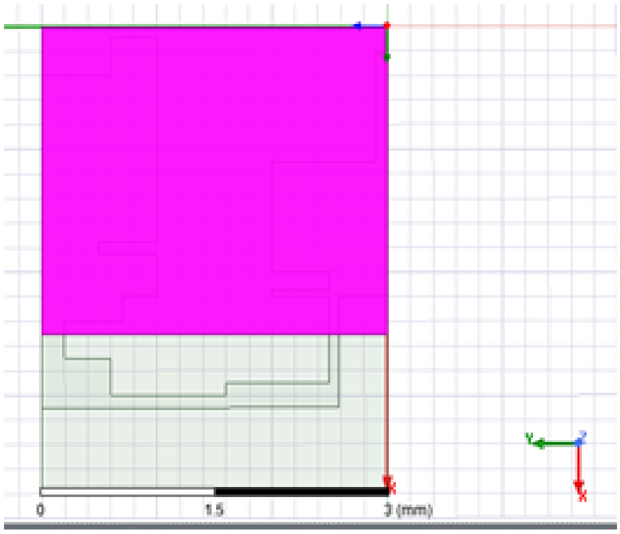

Fig. 3 Partial Ground Plane

Table I Dimensions Of The Conformal Antenna In Mm

L	L1	L2	L3	L4	L5
1.98	0.9	0.7	0.1	0.3	0.3
L6	L7	L8	L9	L10	L11
0.2	0.35	0.1	1.66	0.31	2.7
W	W1	W2	W3	W4	W5
0.5	0.5	0.9	1	0.3	0.5
W6	W7	W8	W9	LA	WA
0.5	0.4	0.6	2.58	3.8	3

TableII Dielectric Properties Of Different Biological Tissues At 2.4 Ghz

Biological Tissue	**Relative Permittivity**	**Conductivity**
Stomach	62.239	2.1671
Small Intestine	54.527	3.1335
Colon	53.969	1.9997

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Table III Comparison Of The Conformal Antenna

S.NO	PARAMETERS	EXISTING ANTENNA	DESIGNED INGESTIBLE ANTENNA
1	S11(Frequency)	433 MHz	2.4 GHz
2	FEED TYPE	LINE FEED	LINE FEED
3	GAIN	-35 dBi	2.15 dB
4	DIMENSION	59 x 52 mm	3.8 x 3 mm

III. SIMULATEDRESULTS

The designed antenna is simulated using High Frequency Structure Simulator and the results were verified. The radiation patterns and return loss obtained from measurements enables us know that this antenna can be used for diagnosing GI and other region of interest mentioned. In this antenna design, the obtained return loss is shown in the figure 4. With the designed antenna, the required bandwidth of frequency about 2.4GHz with high gain and high efficiency are acquired.The antenna resonates at 2.4 GHz with return loss -16.2 dB.

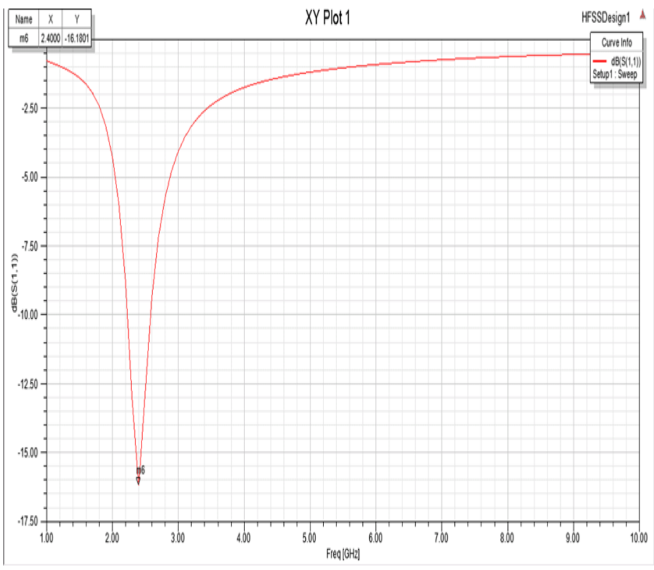

Fig. 4 Return Loss of the proposed antenna

The designed antenna is implanted inside the stomach tissue of the torso of the detailed male body model, as shown in Fig. 5.

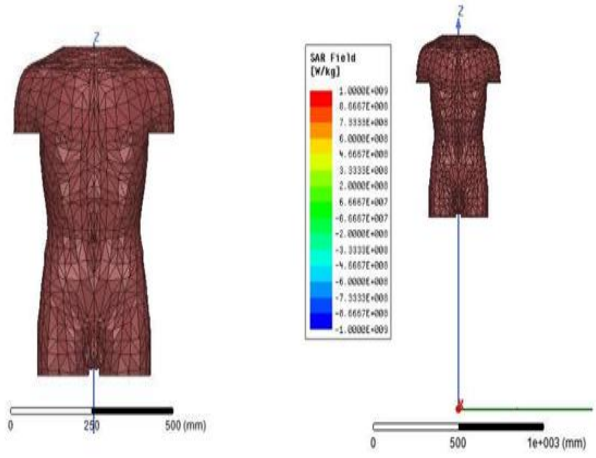

Fig. 5 Male torso of the phantom model and SAR field

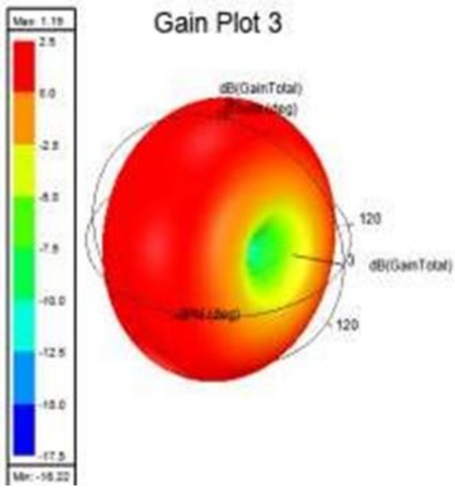

Fig. 6 Gain of the stomach tissue

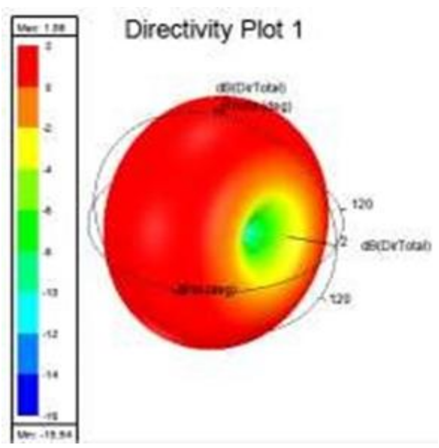

Fig. 7 Directivity of the stomach tissue

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From the above figures it is interrupted that the designed antenna resonates at 2.4 GHz with -16.2 dB reflection coefficient and provides the gain of about 1.19 dB covering the ISM band shown in Fig. 6.

The directivity of the designed antenna for stomach tissue is measured as 1.86 dB as shown in fig.7. It is understood the average radiation intensity is equal to 1/4th of the total power radiated by the antenna.

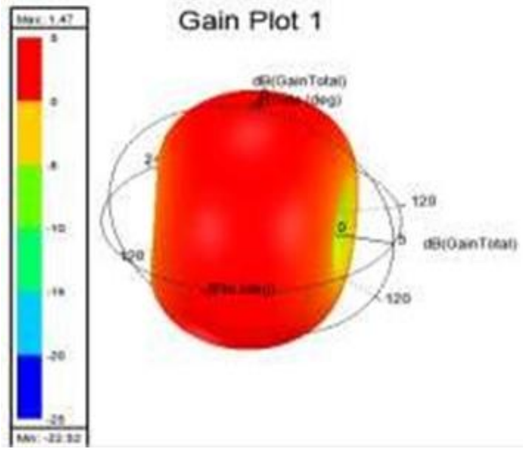

Fig. 8 Gain of the small intestine tissue

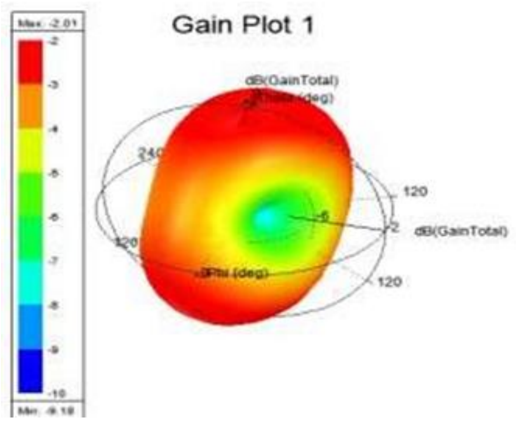

Fig. 9 Gain of the colon tissue

The gain of the antenna when placed inside the small intestineis1.47dB and colon tissues is-2.01dB of the model are shown in the figures 8 and 9. The directivity of the antenna when placed inside the small intestine is 2.25 dB and colon tissues is1.89dB of the model are shown in thefigures 10 and 11.

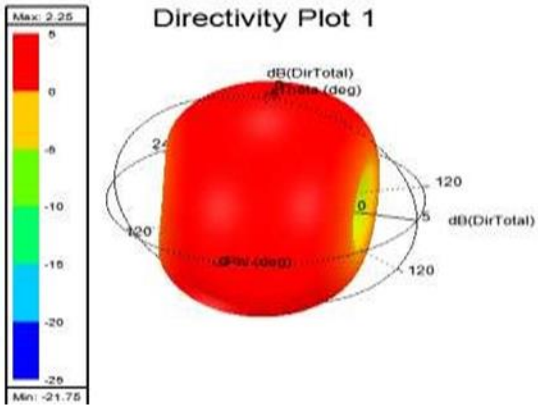

Fig. 10 Directivity of the small intestine

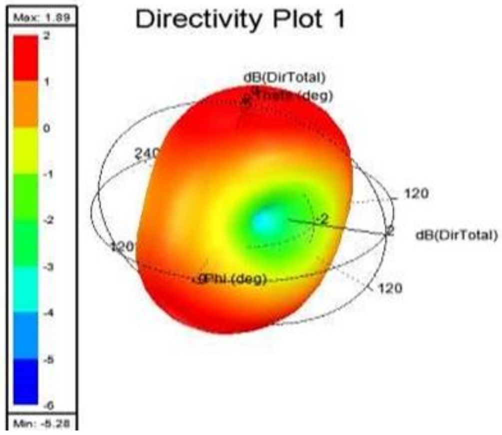

Fig. 11 Directivity of the colon tissue

Gain and Directivity of the designed antenna operating at 2.4 GHz were measured for various body tissues like Stomach, Small Intestine and colon and are listed in the table below.

Table IV Performance Comparison Of Simulation Tissues At2.4 Ghz

SIMULATION TISSUES	GAIN [dB]	DIRECTIVITY [dB]
STOMACH	1.19	1.86
SMALL INTESTINE	1.47	2.25
COLON	-2.01	1.89

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The SAR is measured to evaluate whether a wireless system satisfies the protection limits. ANSYS HFSS offers standard oriented SAR calculations. The below 3D plot shows the local SAR distribution of them a let or so model is shown in Fig.12.Itcan be observed that the stomach has the lesser SAR rate than the standard SAR value. The Table V shows the comparison of antenna parameters such as gain of the existing and proposed system of antenna.

Table V Comparison Of Antenna Results

SIMULATION TISSUE	**PARAMETERS**	**EXISTING SYSTEM**	**PROPOSED SYSTEM**
STOMACH	GAIN	-36.2(dBic)	1.19(dB)
	SAR rate	126.4(W/Kg)	1.0(W/Kg)
SMALL INTESTINE	GAIN	-26.7(dBic)	1.47(dB)
COLON	GAIN	-23.4(dBic)	-2.01(dB)

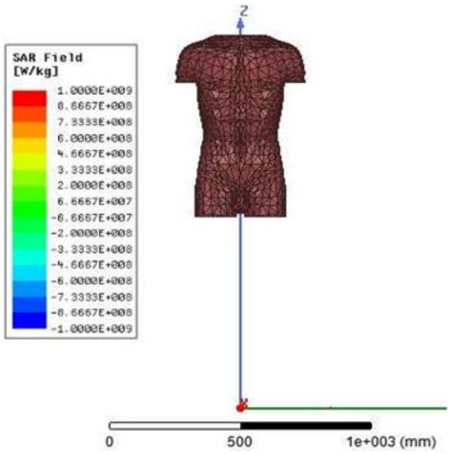

Fig. 12 SAR distribution of the male torso and in the ANSYS human body model at 2.4 GHz

IV. CONCLUSION

In this paper, the designed conformal wideband antenna that operates at 2.4 GHz is implanted inside the ANSYS male torso human body model. The antenna performance is analyzed using the ANSYS HFSS human body model to study the design in a realistic environment. The simulated results produce gain of about 1.19 dB and directivity 1.86 dB. Also, the SAR analysis inside the human body model is 1.0 W/Kg which meets the standard requirements1.6W/Kg. The performance of the other tissues such as small intestine and colon are also compared. Finally, a designed conformal antenna which is Omni-directional is simulated and the results are validated inside the human body model.

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