Design and Simulation of Spiral Antenna for Endoscope

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Abstract

To design and simulate a spiral antenna for endoscopy application to overcome the limitations of conventional endoscopy to examine the Gastro Intestinal disorders of the digestive track. It is an ingestible pill like device which is swallowed. It is an innovative technique without cable, but still further improvement has to be made before implementing. The role of imbedded antenna is to transmit the data signals hence the signal transmission efficiency of the antenna will determine the quality of the received real time images as well as the rate of power consumption, which directly affects the battery life .

Keywords— *Imbedded antenna, spiral antenna, ADS, GI, WCE*

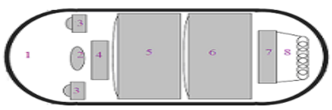
"I. Introduction"

The conventional technique of endoscopy deals with the insertion of long tube through the oral cavity or through the anus to assess the interior surface of an organ with a scope that one is able to see the lesions and other surface condition of various abdominal disorders of the large intestines. Earlier method used a fibre which was inserted and helped in transmitting the pictures of the digestive tract. However it is difficult to examine the delicate part of the small intestine with the conventional endoscopy technique. The other drawback of the existing method is it requires skilled person to perform endoscopy and it causes uneasiness and even pain to the patient. Therefore WCE (Wireless Capsule Endoscopy) was introduced to overcome the drawbacks of the conventional method to enable the visualization of the whole GI tract cable free [1]. The WCE is a sensor device that contains a colour video camera and wireless radiofrequency transmitter, and battery to take nearly 55,000 colour images during an 8-hour journey through the digestive tract. The human body as a lossy dielectric material absorbs a number of waves and attenuates the power of receiving signals, thus having a strong negative influence on microwave propagation. Therefore, the antenna elements should possess the following features [2]:

(a) The ideal WCE antenna should be less sensitive to human tissue influence;
(b) The antenna should have enough bandwidth to transmit high resolution images and large amount of data;
(c) Enhancement of antenna efficiency should facilitate lower power consumption and high data rate transmission. The antenna that has been designed is an imbedded antenna with wider bandwidth and omnidirectional radiation pattern.

"II. Imbedded Antenna"

For a Wireless Endoscopy the transmitter part must be compact, must consume low power and must be optimized for signal transmission through the human body. To design such an antenna is a challenging task. The design must fulfill several requirements to be an effective capsule antenna including miniaturization to save precious space in the capsule cavity, omnidirectional radiation pattern in order to provide transmission regardless of the orientation and location of the capsule or receiver; as well as tuning adjustment to compensate for body effects.



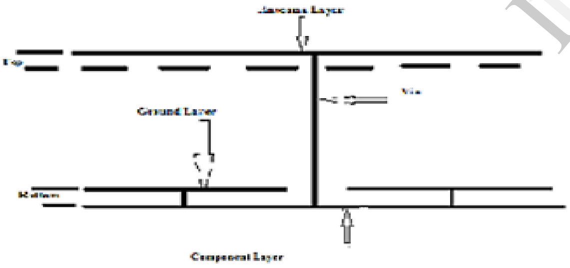
1. Optical dome
2. Lens holder
3. Short focal-length lens
4. LED
5. CMOS imager
6. Batteries
7. Radio Telemetry Transmitter
8. Antenna

"Figure 1. Wireless Capsule and its components"

The Figure 1.depicts the capsule with inbuilt components used for capturing and transmitting the images to the external receivers. The other requirement of the antenna is good electromagnetic isolation and good impedance matching with the linked system for high transmission efficiency. Important parameter for wide band antenna includes impedance matching, bandwidth radiation patterns, gain, radiation efficiency and directivity.

A. Working of Spiral Antenna

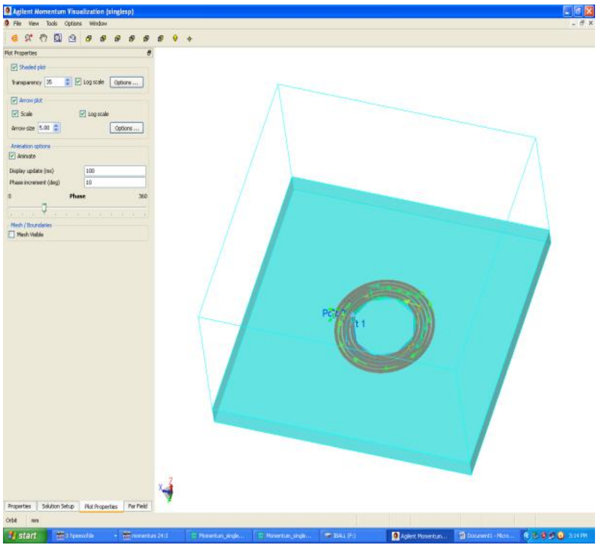
This antenna operates in 3W ways: traveling wave, fast wave and leaky wave. The traveling wave, formed on spiral arms, allows for broadband performance, fast wave due to mutual coupling phenomenon occurring between arms of spiral and leaky wave leaks the energy during propagation through the spiral arms to produce radiation. Ring theory (band theory) explains the working principle of spiral antenna. [3] The theory states that spiral antenna radiates from a region called active region where the circumference of spiral equals wavelength. If the current flowing backwards is smaller than the current flowing forward, there is net current flow through the spiral and radiation occurs. Feeding to the spiral can be done from the centre or from the outside. In the design proposed in this paper feeding is done from the centre through via. Figure 2.The input impedance depends upon the line width together with the distance from the ground, because the characteristic impedance of the spiral arm is dependant of the line width as in the case of a micro strip line.



"Figure 2. Cross Section of PCB Layer"

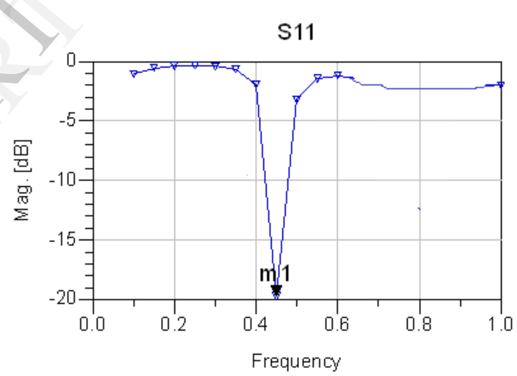
B. Single Spiral Antenna

The single spiral-shaped antenna is designed with the spiral arm length of a quarter-wavelength. It is composed of a radiator and probe-feeding structure. It is fabricated on a substrate with 0.5-oz copper, 3 mm height, and dielectric constant of 2.17. The diameter of the antenna is 10.5 mm with 0.5 mm width conductor.[4]. It has the reflection coefficient S11<-10 db with bandwidth of 110 MHz operating in the range of 400-510 MHz. The spiral antenna can be left-hand or right-hand circularly polarized. The advantage of the spiral antenna is that it has a very wide band but its weakness is that it has a very low gain.



(a)

"Figure 3. Spiral antenna (a) 3D preview"



(b)

"Figure 3. Spiral antenna (b) simulated return losses"

C. S-Parameters

S-parameters are pretty critical in the Microwave Engineering projects because all RF design simulations are applied and analysed using these parameters. S-Parameters are the Scattering Parameters defined from the incident voltage (V_i), the reflected voltage (V_r) and the transmitted voltage (V_t). The voltage at each port of the network is equal to the summation of the incident and reflected voltages.

The maximum power is transferred to the network when the impedance of the source and network are equal [5].

The S-parameters of the n-port network can be shown as $[V_r] = [S] [V_i]$, where

$[V_r]$ is the matrix of reflected voltages,

[S] is the matrix of S-Parameters and

$[V_i]$ is the matrix of incident voltages from each port.

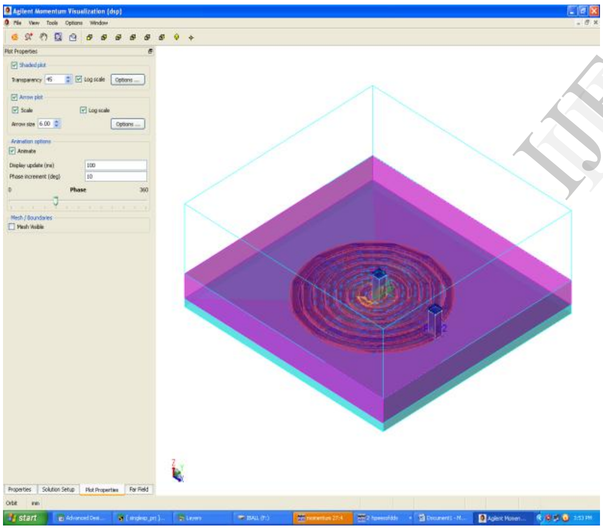
Then, the S-parameters of the 2-port network are given by: $S11=V_{r1}/V_{i1}$, $S12=V_{t1}/V_{i2}$,

$S21=V_{t2}/V_{i1}$, $S22=V_{r2}/V_{i2}$

Matching the impedance of the antenna to 50 Ω so that it will be equal to the source impedance to get a decent input return loss (S11)

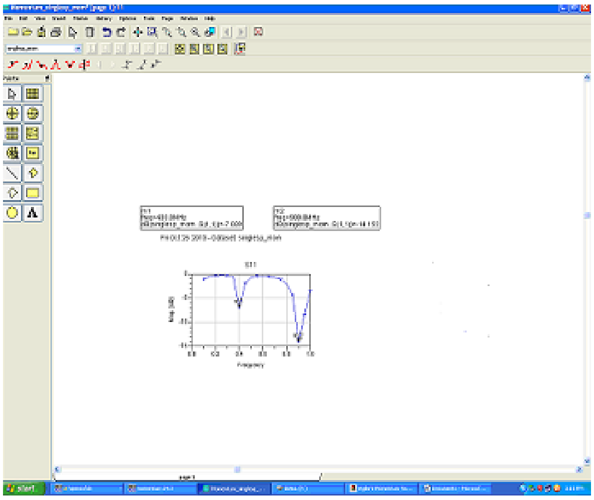
D .Dual Arm Spiral Antenna

The Dual Arm Spiral antenna consists of two spirals placed on two different substrates with same dielectric constant and thickness of 3.5 and 1.524 mm respectively [6]. The two spirals are fed with a single feeding line. The radius of the antenna is 10.1 mm and with a height of about 3.5mm.The number of turns is 5.25 and 5 for the lower and upper spiral respectively. The variable length of the spiral provides better impedance matching.



(a)

"Figure 4. Dual Arm Spiral Antenna (a) 3D preview"



(b)

"Figure 4. Dual Arm Spiral Antenna (b) return loss"

The above Figure 4.depicts the dual spiral antenna placed on two substrates with single feed line. To show the resonating characteristics the spiral antenna are simulated using ADS.

The dispersive properties of the human body suggest that the signals are less vulnerable when they are transmitted at lower frequencies. To have a better resonating frequency and to reduce the size of the antenna varies parameters such as the no. of turns, the substrate and its thickness has been modified

"III. Result"

PARAMETERS	DIMENSIONS
Dielectric Constant of Upper Substrate	3.5
Dielectric Constant Of Lower Substrate	9.6
Thickness of Upper Substrate	1.524 mm
Thickness of Lower Substrate	0.635mm
Return Loss	< -10db
Radius of Conductor	6 mm
Number of turns for Upper conductor and Lower conductor	6 and 6.25 respectively
Height of the Antenna	2.65 mm

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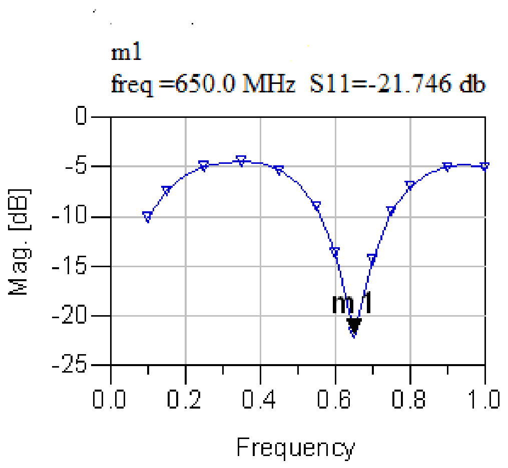

"Figure 5. Proposed Dual Arm Spiral Antenna return loss"

"IV. Conclusion"

Since human body are lossy dielectric material and has it attenuates microwave frequencies. The antenna plays a major role in transmitting and receiving signals in such a system. The antenna must be efficient to operate in the low frequency range with omnidirectional radiation pattern with low power consumption. The most important parameter is the bandwidth of the transmitting antenna should be as wide as possible in order to transmit high resolution images and large amount of data. Transmission efficiency of the antenna will determine the quality of images received in real-time.

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