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RECOGNITION OF CONGESTIVE HEART FAILURE USING S-SHAPED SLOT ANTENNA

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ABSTRACT

In this paper S-shaped slot antenna has been designed that can be implemented in a microwave system to detect the Congestive Heart Failure. This antenna fed through waveguide port for a frequency 2.4GHz used for ISM band operating frequency (2.3-2.5) GHz. An antenna is the most important element of biomedical application. This paper is focused on the analysis of S-Shaped Slot antenna with dimensions of 60x60mm^2. Here we are designing two different structure of the antenna (i) Dual S-Shaped Slot Antenna (ii) Quad S-Shaped Slot Antenna. By comparing both antennas, Quad S-Shaped Slot antenna has the maximum gain and minimum return loss compared to the Dual S-Shaped Slot Antenna by increasing the thickness of the substrate. The antenna is designed on CST Microwave Studio Simulation Software with a significant Return loss, Gain, Directivity, VSWR Power and efficiency which shows a good performance. Its total volume is only 6cm.

Keywords: dielectric constant, rogers (RO4003), S-shaped slot antenna, resonant frequency, return loss, directivity, gain, VSWR.

1. INTRODUCTION

Heart failure (HF), often used to mean chronic heart failure (CHF), occurs when the heart is unable to pump sufficiently to maintain blood flow to meet the needs of the body. The terms congestive heart failure [6] (CHF) or congestive cardiac failure (CCF) are often used interchangeably with chronic heart failure. The present invention relates generally to implantable medical schemes, and more specifically to an implantable device for detecting and monitoring the progression of congestive heart failure [11].

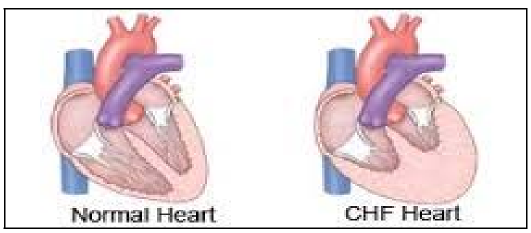

Figure-1. Normal and CHF heart.

Many patients who have suffered one or more myocardial infarctions subsequently require treatment for congestive heart failure (CHF). The left heart fails while the pumping function of the right heart remains adequate, because the latter has only about 20% of the workload of the prior. This leads to rise in blood capacity congested to the lungs, causing in pulmonary congestion, accumulation of edema, and congestion of internal organs including the stomach and intestines [5]-,[4]. Increased fluid in the stomach and intestines reduce their ability to absorb drugs prescribed for behaviour of CHF, mainly diuretics. The congestion is often accompanied by a worsening of myocardial function, with following drop in blood pressure and reduced renal perfusion, which only further magnifies the congestive situation [3]. Thus, late detection of congestion leads to increased amount of oral diuretics that are unsuccessful to treat the situation finally demanding that the patient be hospitalized. We designed an antenna which is used to detect the above mentioned CHF. Various studies have done to detect the CHF.

In previous papers it is detected through mapping the changes in amplitude of the reflected or transmitted signal from the torso phantom [1], [2]. In another paper CHF is detected through analysing the changes in the phases where long term monitoring is needed. In this paper to detect the Congestive Heart Failure antenna is accompanied with the Microwave system. The microwave system contains the following elements Transceiver, Laptop, Torso phantom, antenna, USB cable. The system operates under mono static radar approach which is a term given to radar in which the transmitter and receiver are collocated. In this system antenna plays an efficient role placed near to the torso phantom at a distance of‘d’. Thus heart is monitored using the devices [12], [13].

ISM (industrial, scientific and medical) radio bands are reserved for the use of RF energy for industrial, scientific and medical resolutions other than communication. These bands include radio-frequency process heating, microwave oven and medical diathermy machines [10].

2. ANTENNA DESIGN

We are designing the two different structure of the antenna. They are Dual S-Shaped Slot Antenna and Quad S-Shaped Slot Antenna in figure 2 and 3. Substrate properties used for patch are RO4003 with the substrate thickness of Dual S-Shaped Slot antenna is 3mm and Quad S-Shaped Slot Antenna is 4mm, loss tangent factor of 0.002 and dielectric constant of 3.55.

Slots with rectangular shape are embedded on the patch in opposite position, which form the S-shape of the slot antenna [7], [8], [9].

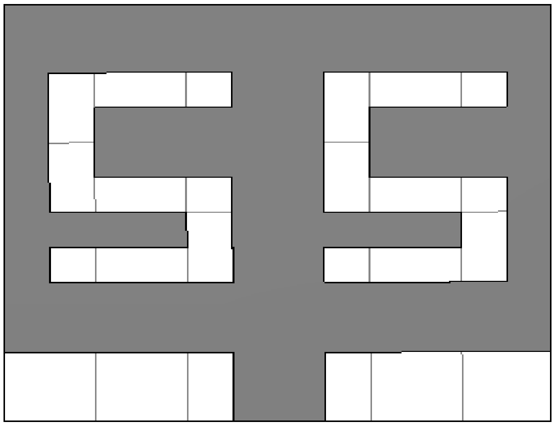

Figure-2. Dual S-Shaped slot antenna structure.

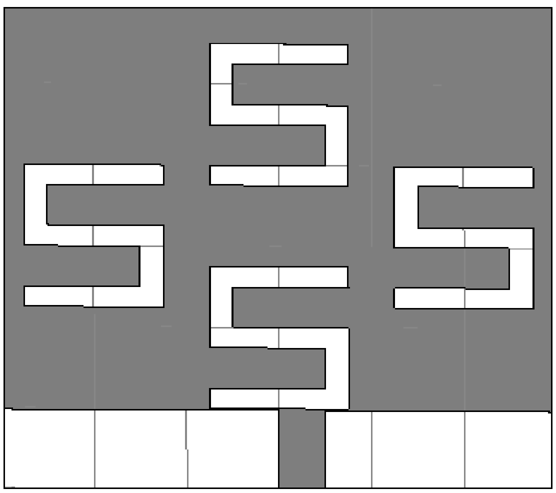

Figure-3. Quad S-Shaped slot antenna structure.

Dimensions of the structure

Dual S-Shaped slot antenna

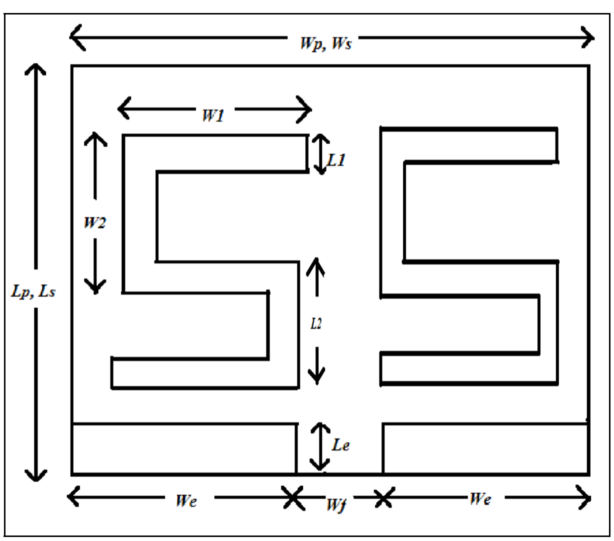

Table-1. Dimensions of the Dual S-Shaped slot antenna

Lp	60mm
Ls	60mm
Wp	60mm
Ws	60mm
Le	3mm
We	25mm
L1	5mm
W1	25mm
W2	30mm
Wf	10mm

Quad S-Shaped slot antenna

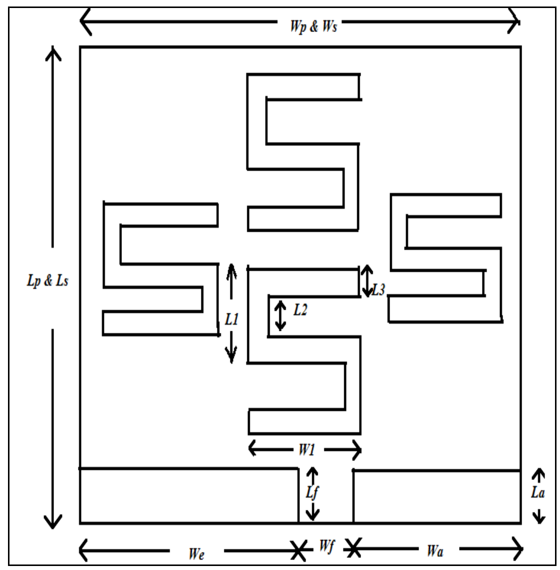

Table-2. Dimensions of the Quad S-Shaped slot antenna

Lp	60mm
Ls	60mm
Wp	60mm
Ws	60mm
Le	9.8mm
We	30mm
L1	10mm
W1	15mm
Wf	10mm
L2	10mm
L3	2.5mm
Wa	25mm
La & Lf	9.8mm

Table-3.

Substrate	**Roger (RO4003)**
Dielectric Constant	3.55
Resonant Frequency	2.4GHz
Operating Frequency	2.3-2.5 GHz
Length of the Patch	60mm
Length of the substrate	60mm
Width of the Patch	60mm
Width of the Substrate	60mm
Height of the Substrate in Dual S-Shaped Slot antenna	4mm
Height of the Substrate in Quad S-Shaped Slot antenna	4mm
Height of the Patch	0.035mm
Input Impedance	50ohm

Since the target bandwidth of the antenna is approximately 2.3-2.5GHz, the resonant frequency of 2.4GHz.

Substrate

RO4003

RO4003 Series High Frequency Circuit Materials are glass reinforced hydrocarbon/ceramic laminates (Not PTFE) designed for operation sensitive, high volume commercial usages. RO4003 laminates are intended to offer exclusive frequency performance and low cost to fabricate the structure. The result shows a low loss material that can be fabricated using standard epoxy/glass (FR4) processes offered at competitive prices.

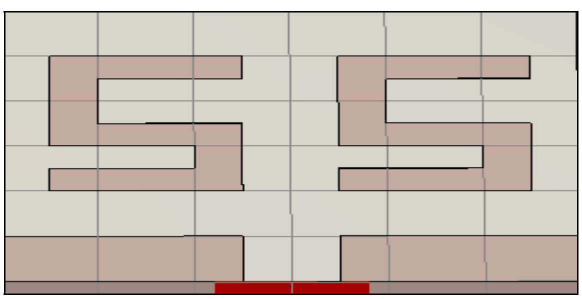

Figure-4. Waveguide port in feed structure for dual s-shaped slot antenna.

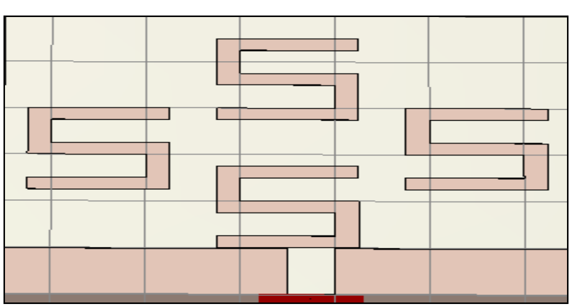

Figure-5. Waveguide port in feed structure for quad s-shaped slot antenna.

3. DESIGN METHODOLOGY

The antenna is designed using a Computer simulation technology (CST) which is transient solver for efficient calculation for loss-free and lossy formation. The solver fixes a broadband estimation of S-parameters from one single calculation run by applying DFT's to time signals.

The structure can be viewed either as a 3D model or as a representation. The later permits for easy link of the EM simulation with circuit simulation. Extremely good performance due to Perfect Boundary Approximation (PBA) and Thin Sheet Technique (TST) for solvers using hexahedral grids. Efficient build-in optimizer.

Analysis

CST DESIGN STUDIO offers several simulation tasks. A task encapsulates simulation settings and result options. During the execution of such a task, a suitable simulation method is chosen and the selected results are produced.

Visualization

CST DESIGN STUDIO offers some standard result plots to visualize the results. A user-defined result plot can be added by choosing Navigation Tree.

Parameterization

Dealing with parameters in CST DESIGN STUDIO is quite simple. Using the parameter list, you can define new parameters, modify the parameter values or delete them.

Parameter sweep and optimization

After understanding the parameterization of a design, you are able to use the advanced analysis features that are implemented in CST DESIGN STUDIO. To perform a parameter sweep, open the Parameter Sweep dialog box, select the parameters to vary, define at least one watch to record some results during the sweep and press start. It produces the parameter results of the entire structure.

Except for some basic simulation tasks, a valid design requires the presence of external ports, which represent the sources and sinks of the system, i.e., they mark its inputs and outputs.

4. RESULT AND DISCUSSIONS

In this paper, length, width and the patch have been optimized to resonate the S-Shaped Slot Antenna at 2.4GHz. Taking the following equations resonant frequency (fr) of the antenna structure is given by

$$f_r = \frac{c}{2L\sqrt{(\varepsilon_{reff})}}$$

Here c is velocity of light.

Equation for ε_{reff} is given as below:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-0.5}$$

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The resonant length of patch is not exactly equal to the physical length due to the fringing fields on the flanks of patch. Effective length Leff of patch is lengthier than its physical length and is given as:

$$L_{eff} = (L + 2\Delta L)$$

Increase in patch length (ΔL) is given as:

$$\Delta L = 0.412 \frac{h(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

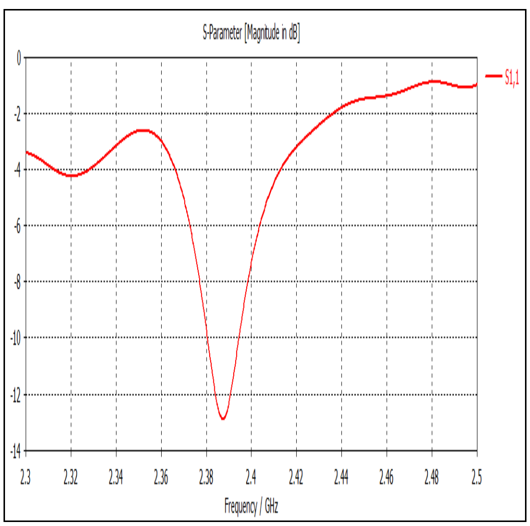
Considering the fringing fields on flanks of the patch, resonant frequency of patch is given by:

$$f_r = \frac{c}{2L_{eff}\sqrt{\varepsilon_{reff}}}$$

Calculation of width:
By the formula

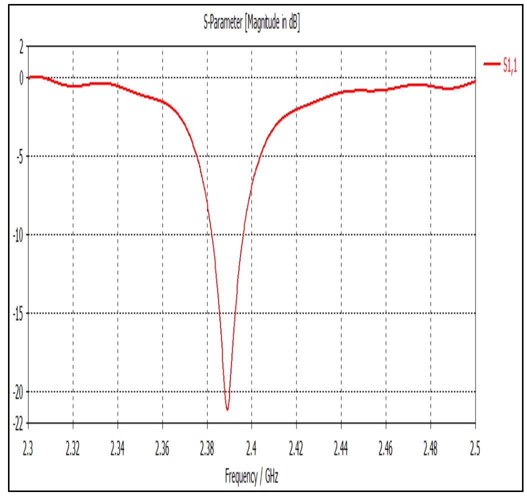
$$Width = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

i. Return loss - Dual S-Shaped slot antenna



This graph shows frequency versus magnitude in db. Antenna's simulated return loss S11=-12db in the (2.3–2.5) GHz range showing the effect of parameter S. The loss of power in the signal returned/reflected by a discontinuity in a structure.

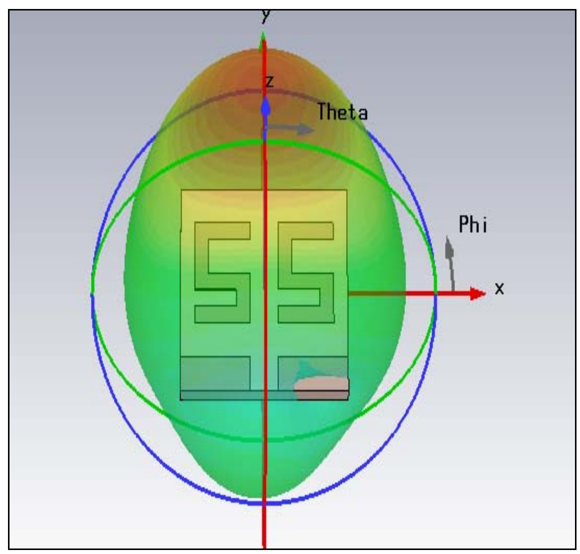
ii. Return loss - Quad S-Shaped slot antenna



This graph shows frequency versus magnitude in db. Antenna's simulated return loss S11=-21db in the (2.3–2.5) GHz range showing the effect of parameter S.

iii. 3D radiation pattern

Dual S-Shaped slot antenna



This figure shows the 3D radiation pattern. The gain of the designed antenna is 3db. In order to analyze the radiation efficiency and total efficiency etc. The term "Antenna Gain" describes how much power is transmitted in the direction of peak radiation to that of an isotropic source.

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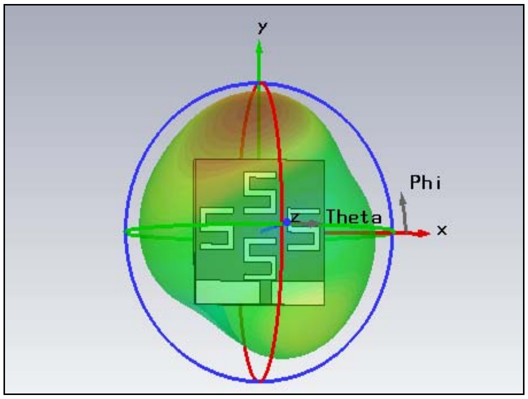
Quad S-Shaped slot antenna

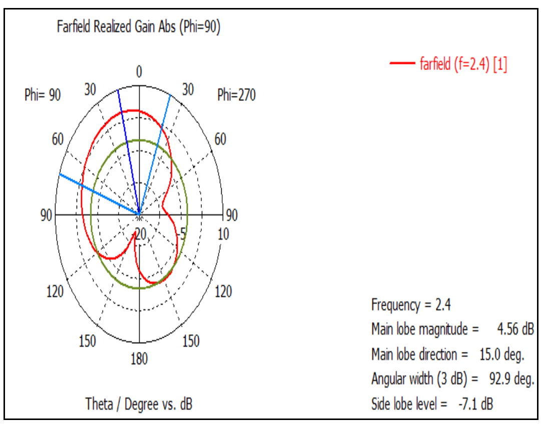


This Figure shows the 3D radiation pattern. The gain of the designed antenna is 4.2db. In order to analyze the radiation efficiency and total efficiency etc.

5. FIELD PATTERN

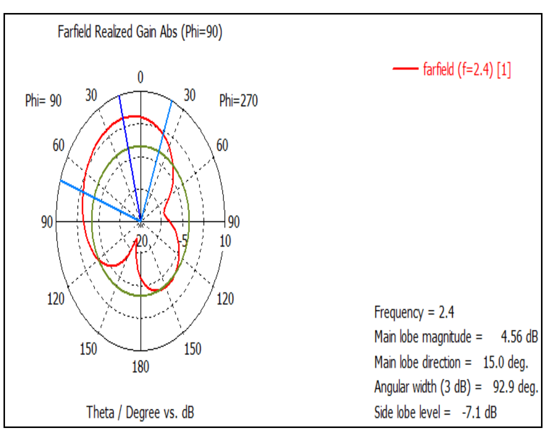
Dual S-Shaped slot antenna

i. E-FIELD



(a)

ii. H-FIELD

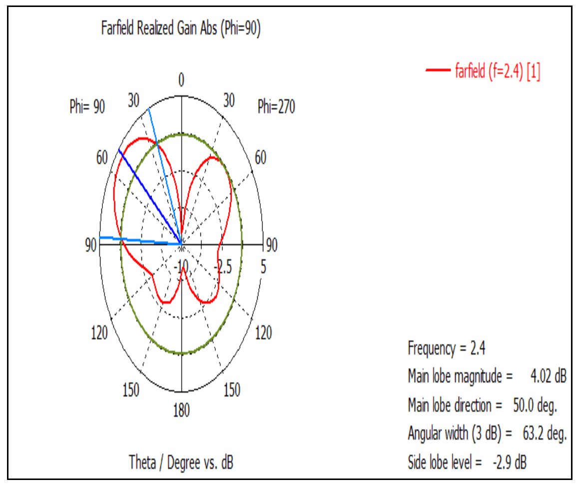


(b)

Simulated radiation patterns of the Dual S-Shaped Slot antenna in the horizontal (x-y) and vertical (x-z) planes at 2.4GHz. Both components (Theta and phi) are shown. The results show excellent agreement. (a) Horizontal plane, 2.4 GHz (b) Vertical plane, 2.4 GHz. In order to analyze the main lobe magnitude, main lobe direction, angular width and side lobe level.

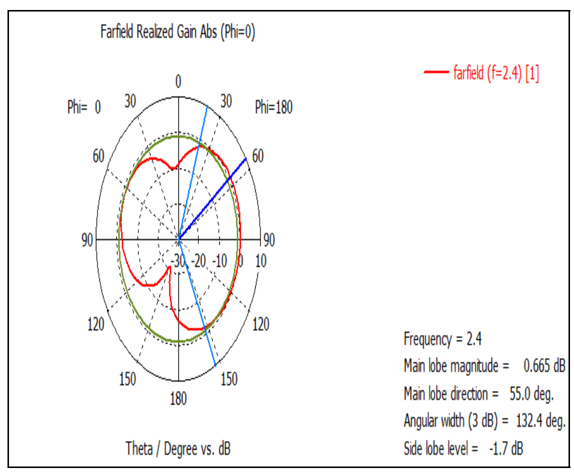
Quad S-Shaped slot antenna

iii. E-FIELD



(a)

iv. H-FIELD



(b)

Simulated radiation patterns of the Quad S-Shaped Slot antenna in the horizontal (x-y) and vertical (x-z) planes at 2.4GHz. Both components (Theta and phi) are shown. The results show excellent agreement. (a) Horizontal plane, 2.4 GHz (b) Vertical plane, 2.4 GHz. In order to analyze the main lobe magnitude, main lobe direction, angular width and side lobe level.

6. VALIDATION

In this section, different types of parametric study of the proposed antenna are carried out and presented. For the parametric studies, the geometric simulations have been performed by the Finite Integration Technique based microwave simulator Computer Simulation Technology 2014. The antenna characteristic such as bandwidths, return loss, gain etc., is obtained. The simulated results are shown in figure.

Table-4. Compare the antenna parameter between Dual S and Quad S-Shaped slot antenna.

Parameter	Dual S	Quad S
Return Loss	-12db	-21db
Gain	3db	4.2db
VSWR	1.58	1.2

The above table is comparison between the S-Shaped Antenna. To achieve the maximum gain and minimum return loss in Quad S shaped slot antenna.

7. CONCLUSIONS

A wideband three-dimensional antenna has been presented. The antenna is designed for a microwave-based heart failure detection system. The antenna is designed to achieve three targets needed for the system: compact size, wideband performance at the UHF band and unidirectional radiation. The proposed Quad S-Shaped Slot antenna is then implemented in a heart failure detection system. Besides the antennas and the platform needed to fix it, the system includes a custom-made microwave transceiver, signal processing and image reconstruction algorithms based on the synthetic aperture focusing technique. Further we are going to proceed with the system is tested using a realistic human torso phantom. This is tested on an artificial torso phantom to verify the potential of such a system in the early detection of heart failure**.**

The obtained results support the potential to use microwave techniques for the early detection of congestive heart failure.

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