Design Of Equilateral Pentagon Shaped 4-Elements Flexible Patch Antenna Array For The Application Of Uterine Tumour Detection

Rajasree Hazra , Dr. Chandan Kumar Ghosh

Abstract: In this study, equilateral pentagon 4 (2x2) elements flexible microstrip patch antenna array, using rubber substrate is designed and simulated to function at 5.2 GHz for the application of uterine tumour detection. A study using different combinations of array elements is also presented. The centre-to-centre patch element distance is kept λ (λ = guided wavelength) for the array to control the mutual coupling. Electromagnetic simulator Ansoft HFSS 13 is used for the simulation. The characteristic analysis such as return loss (RL), radiation pattern of the antenna array have been investigated. 4-elements antenna array has been measured. Uterus phantom model is also designed. This flexible patch antenna is experimented on this uterus phantom model for uterine tumour detection. CST Studio Suite 2019 is used for designing uterus phantom model. The measured results have a good agreement with simulated results. In this investigation, return loss of -20.02 dB and antenna gain of 10.47 dBi have been achieved for the proposed array.

Key words: Uterine tumour detection, Flexible antenna, Human uterus phantom, Antenna Array, Ansoft HFSS 13, CST Studio Suite 2019

1. INTRODUCTION

UTERINE fibroid is firm, compact common tumours made of smooth muscle cells and fibrous connective tissue of the uterus. It is estimated, between 20% to 50% women have fibroids during their reproductive age, although not all are diagnosed. According to some state reports, up to 30% to 77% of women will develop fibroids sometime during their childbearing years [1]. Microwave imaging [2] is one of the active wave-based imaging method to contrast the electrical properties between health and tumour tissues .It is largely accepted for tumour detection. In any kind of imaging system, role of microstrip patch antenna array is very important for the performance of imaging [3-7]. One appropriate antenna for such system should cover various requirements e.g. ease of integration, simple geometric structure, compactness, small dimensions, enhanced bandwidth, gain etc. Said requirements can be fulfilled by a microstrip patch antenna array because of a number of advantages e.g. low profile, light weight, planar configuration, easy to integrate, low volume, low fabrication cost etc. Uterus imaging system, working in microwave frequency range is considered for uterine tumour detection.

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There are two important parts of the uterus imaging system, efficient microstrip patch antenna design human uterus phantom model and modelling of human uterus phantom model. Flexible microstrip antennas [11-13] are widely accepted for tumour detection because of it's lightweight and easy of fabrication. In order to make antenna flexible, the rubber substrate can be used with different percentage of filler content. The basic idea is to lay a very thin copper strip with perfect size on top of a flexible substrate and bottom side too as a ground plane. Several flexible substrates have been used such as micro fluids or liquid metals, paper, polymer, plastic, etc.

The goal of this study is:

1. Design and simulation of equilateral pentagon shape flexible microstrip patch antenna of single element, 1×2 , 2×2 , elements array using Ansoft HFSS 13 software at 5.2 GHz.
2. A comparison of antenna performance parameter for 1 element, 1×2, 2×2 elements flexible microstrip patch antenna array is also presented.
3. Design a five layered human uterus phantom model.
4. Detection of tumour inside human uterus phantom by equilateral pentagon shape flexible antenna in CST Studio Suite software 2019[10].

2 UTERINE TUMOUR

Fibroids are benign tumours made of smooth muscle cells develop in the uterus [8-9]. The cause of uterine tumours are not known. Generally uterine tumours have no symptoms at all. Uterine tumours are shown in following Fig. 1.

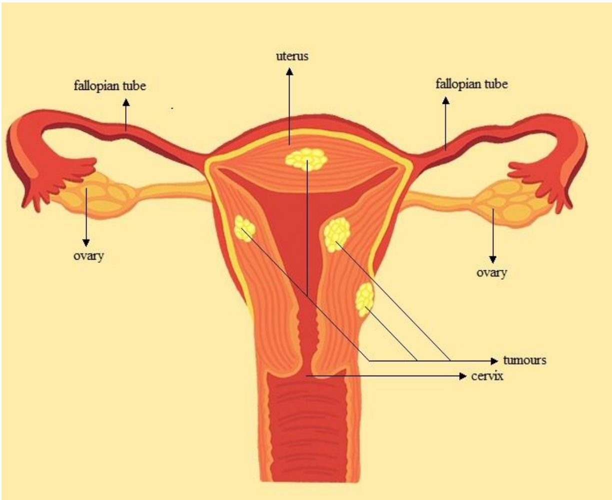

***Fig. 1**. Uterus with uterine tumours*

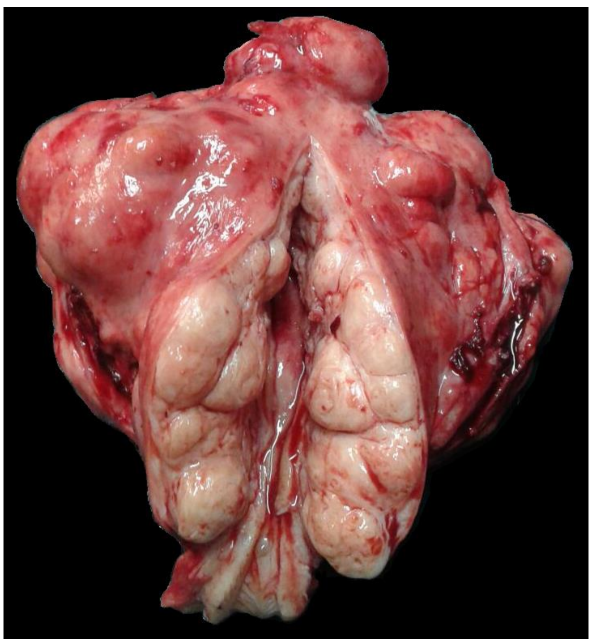

***Fig. 2**. Operative view of uterus with uterine tumours*

Uterine fibroids or tumours are frequently found incidentally during a routine pelvic exam. Fig. 2 shows operative view of uterus with uterine tumours . Multiple imaging techniques can be used to evaluate the uterus. Uterine tumours can be diagnosed by X-ray, MRI, Hysteroscopy, Endometrial biopsy, Blood test, USG etc. Following Fig. 3 shows ultrasound image of uterus with uterine tumours.

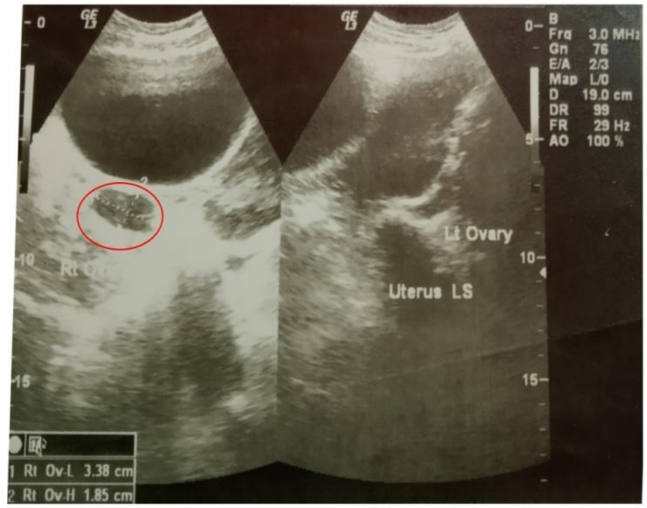

***Fig. 3**. Ultrasound image of uterus with uterine tumours*

Above image shows ultrasound image of uterus with uterine tumours through red circle. Microwave uterus imaging system is basically based on a concept that a microwave signal is emitted from a transmitting patch antenna after being reflected from the target specimen and it is received by the receiving antenna through software interface. Then received signal is stored and a suitable signal processing algorithm makes the result image possible.

3 ANTENNA DESIGN

The Flexible Microstrip patch antenna has a substrate made of rubber_hard which has a relative permittivity 3 and relative permeability value 1. The length of the substrate is 50 mm and the width of the substrate is 100 mm and the thickness of the substrate is 1.6 mm from the ground plane for single element patch. The back side of the substrate contains the partial ground plane. The ground plane is made up of copper which is a lossy metal. The arm size of equilateral pentagon is 11.5 mm .The Centre to Centre patch element distance is λ . The proposed antenna is fed with coaxial probe feed. Coupling of power through a probe is one of the basic mechanisms for the transfer of microwave power. The radius of the probe inner conductor of this coaxial line feeding is 0.3 mm which is used to transfer power from a stripline to a microstrip antenna through a slot in the common ground plane. The radius of this circular feed is 1.6 mm .

Initially the geometries of a single element, double elements, four elements microstrip patch antenna arrays with characteristic parameter like length, width are shown in Fig. 4-6.

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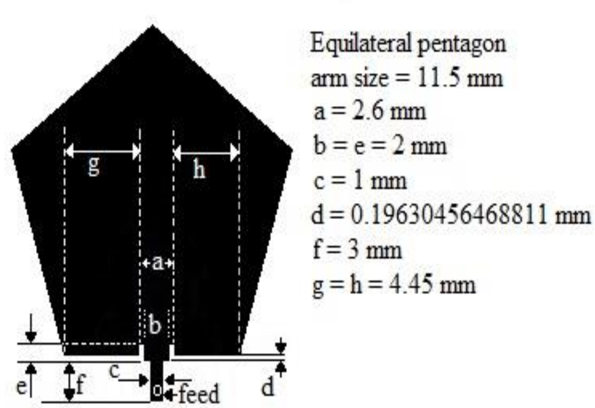

Fig 4. *Geometry of a single element microstrip patch antenna*

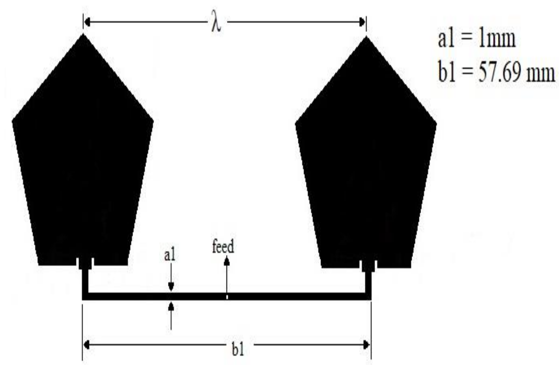

Fig 5.*Geometry of a double elements microstrip patch antenna array*

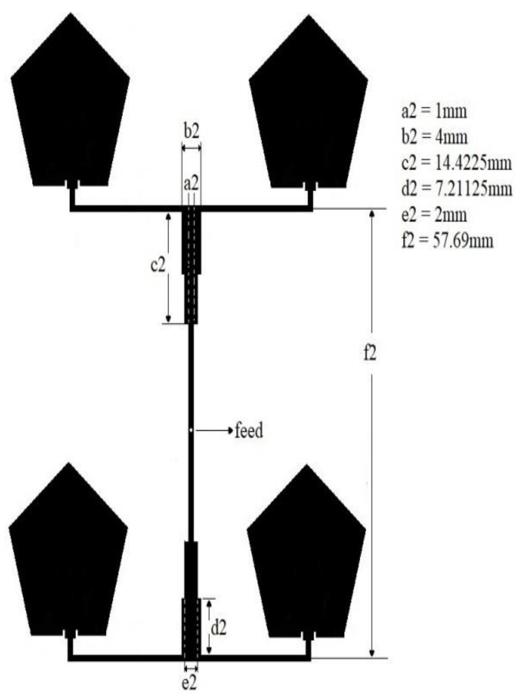

Fig. 6*.Geometry of a four elements microstrip patch antenna array*

4 SIMULATION RESULTS & DISCUSSION

The characteristic analyses such as return loss (RL), radiation pattern, bandwidth of the antenna array have been investigated. The simulated results of the antenna characteristics for different array combinations are shown in the TABLE-1

TABLE-1

RESULTS OF THE ANTENNA CHARACTERISTICS AT 5.2 GHZ

No. of antenna	Return loss(dB)	Gain(dBi)
1	-20.586528	7.708624
2	-12.420513	8.934745
4	-16.343306	10.472961

4.1 Return Loss

The graphical representation of return loss mutual coupling for double elements flexible microstrip patch antenna is shown in the Fig 7 . The centre-to-centre patch element distance is kept λ (λ = guided wavelength) for the array to control the mutual coupling.

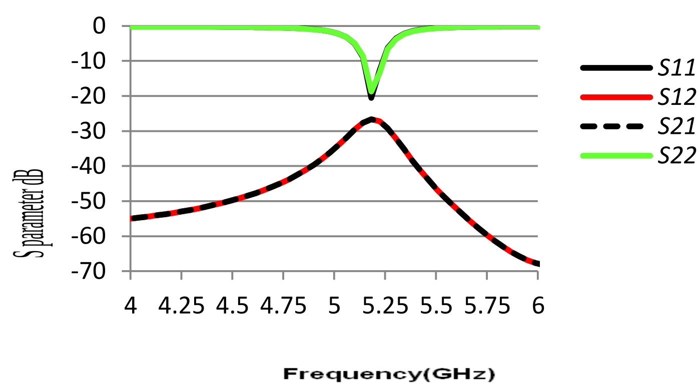

Fig. 7*. RL for double patch element with λ distance*

From the above graphical representation return loss(RL) , it is shown that centre-to-centre patch element λ distance for the array controls the mutual coupling and doesn't effect on each other at the time of radiation. The graphical representation of return loss characteristics of different array combinations is shown in the Fig 8.

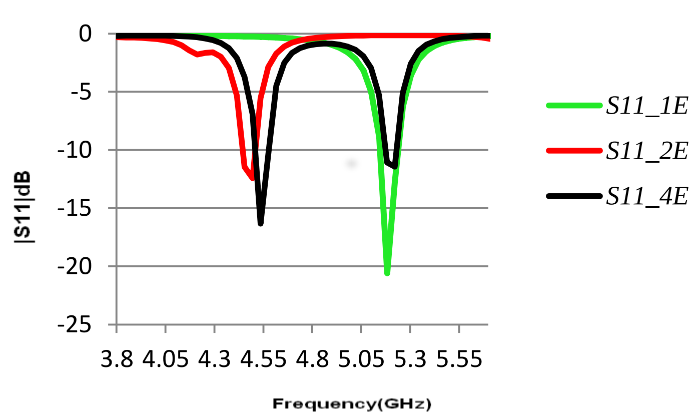

Fig 8 : *RL for 1,2 and 4-element microstrip patch array*

From the return loss (RL) characteristics of the arrays, it is seen that single element patch antenna has the highesr value.

4.2 Radiation Pattern

The graphical representation of elevation pattern gain characteristics of different array combinations are shown in the Fig.9.

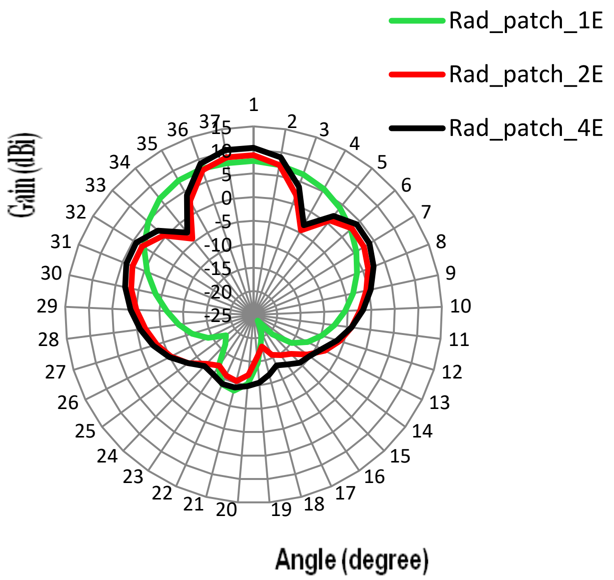

Fig 9 : *Elevation pattern gain for 1,2 and 4-element microstrip patch array*

From the above graphical representation of elevation pattern gain characteristics of different array combinations , it is shown that with increasing the patch element gain is also increased. Fig. 10 shows 3D pattern view of the 4-element microstrip patch antenna array.

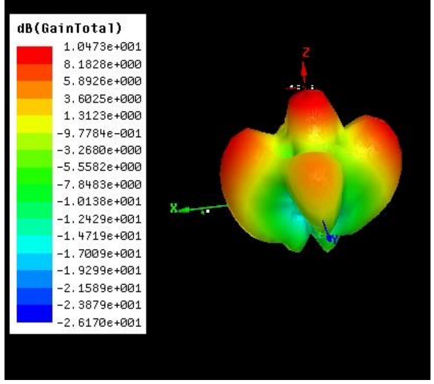

Fig 10 : *3D pattern view of the array of 4-element*

From Fig.10, it is observed that the gain of the array of 4-element is 10.472961dBi.

5 HUMAN UTERUS PHANTOM MODELLING & SIMULATION

5.1 Human uterus phantom model

The normal five-layered tumorous human uterus phantom model is made. One tumour model is inserted inside human uterus phantom model. Then this new equilateral pentagon shape flexible antenna is attached with human uterus phantom model. The dimensions of models are chosen randomly that reflect the actual ones. To get the imaging results, proposed antenna is simulated with tumorous uterus phantom model by CST software. Radius of Uterus, Urinary bladder, Rectus Abdominis, Fat, Skin layers of uterus phantom and tumours are given in TABLE-2.

TABLE-2

RADIUS OF UTERUS, URINARY BLADDER, RECTUS ABDOMINIS, FAT, SKIN LAYERS OF UTERUS PHANTOM AND TUMOURS

	Radius (mm)
Uterus	84
Urinary bladder	86
Rectus abdominis	88
Fat	90
Skin	92
Tumours	5,2

Layers of human uterus phantom model with and without tumours are shown below.

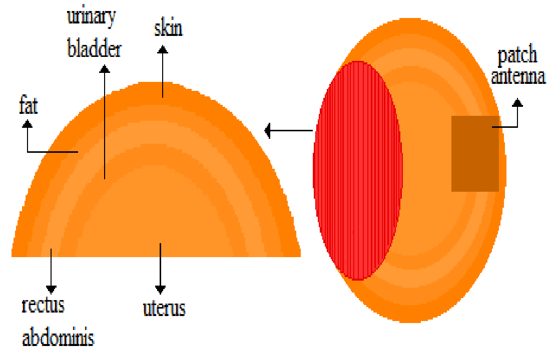

Fig 11 : *Layers of human uterus phantom model without tumours*

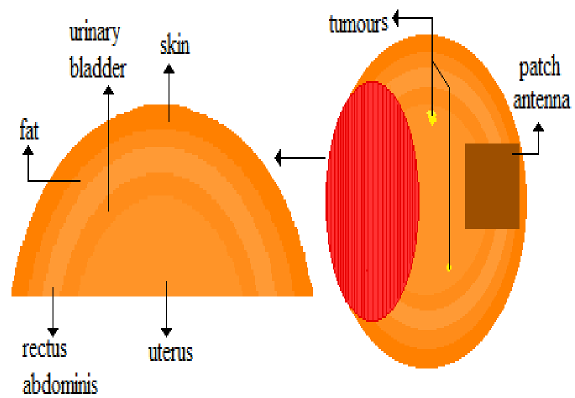

Fig 12 : *Layers of human uterus phantom model with tumours*

The CST studio suite 2019 has a rich library including some biomaterials . Above Fig. 11 and Fig. 12 show the layers of human uterus phantom model with and without tumours.

5.2 E field simulation results

E field simulation results of this human uterus phantom model with and without tumours are shown below Fig. 13 and Fig. 14.

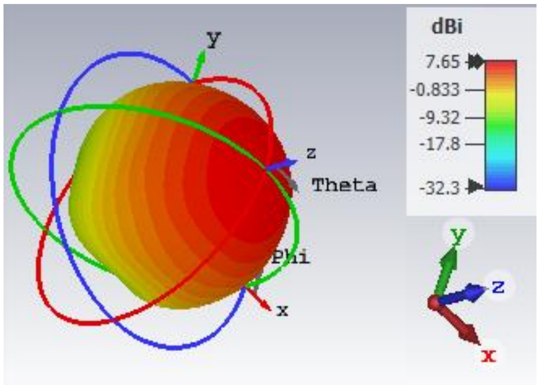

***Fig. 13**. E field simulation results of this human uterus phantom model without tumour*

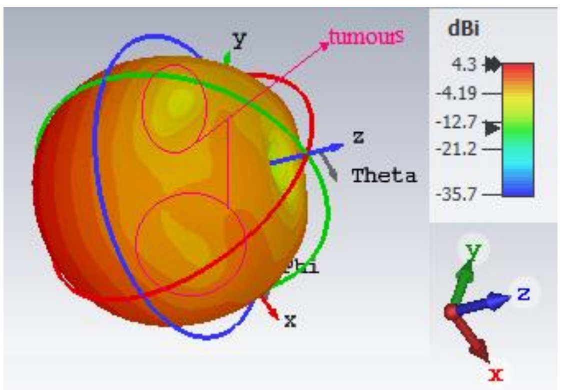

***Fig. 14**. E field simulation results of this human uterus phantom model with tumours*

The performance of the proposed microstrip patch antenna array attached with human uterus phantom model is found by simulating the antenna with computer simulation technology (CST) microwave studio suite 2019. Above Fig. 13 and Fig. 14 show top view of E field simulation results of this human uterus phantom model without and with tumours simultaneously. It is observed that radiated signals penetrate the skin, fat, rectus abdominis, urinary bladder and finally reach to the uterus. Finally tumours in uterus are clearly detected through the E field simulation result image. In Fig. 14 tumours are shown by pink circles. It is also shown that reflected signal also depend on the size of tumours. Large tumour is shown very prominently while small tumour is also shown but not very prominent.

6 CONCLUSION

The conception and simulation of equilateral pentagon shape 4 (2 × 2) elements flexible microstrip patch array was successfully designed using the Ansoft HFSS 13. Here, we specifically focus on designing equilateral pentagon 4 (2 × 2) elements microstrip patch antenna array, using rubber as the substrate and simulating to function at 5.2 GHz. The characteristic analysis such as return loss (RL), radiation pattern, bandwidth and gain of the antenna array have been investigated. 4-elements antenna array has been placed on human uterus phantom model and simulated to detect tumours. The measured results have a good agreement with simulated results. In this investigation, return loss of -17 dB and antenna gain of 22.74dBi have been achieved for the proposed array. This flexible microstrip patch antenna array is also used to detect the brain tumour through Software student edition CST studio suite 2019. Uterine tumours have so many complications like heavy pain, enlarged lower abdomen, pregnancy complication etc. So uterine tumour detection become a popular topic for researchers. From this paper various patch antenna can be designed to detect uterine tumour.

ACKNOWLEDGMENT

The authors like to acknowledge Dr. B. C. Roy Engineering College, Durgapur, India for providing necessary support during this research work. The authors also like to acknowledge Nil Ratan Sircar Medical College & Hospital , India for providing necessary support during this research work. The authors also like to acknowledge Computer Simulation Technology for granting temporary right to make use of the Software student edition CST studio suite 2019.

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