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Design of Crescent Shaped 64-Elements Flexible Patch Antenna Array for the Application of Uterine Tumour Detection

Rajasree Hazra, Chandan Kumar Ghosh

Abstract : ***In this paper, a crescent shape 64 (8 × 8) elements microstrip patch array, using rubber substrate is designed and simulated to function at 4 GHz for the application of uterine tumour detection. A comparison using various combinations of antenna array elements is also presented. The centre-to-centre patch element distance is kept 0.5λ (λ = guided wavelength) for the antenna array to control mutual coupling. Electromagnetic simulator Ansoft HFSS 13 is used for the simulation. Characteristic analysis e.g. return loss(RL), radiation pattern of patch antenna array have been investigated. This antenna is placed on human uterine phantom model and simulated to detect uterine tumour. 64-elements antenna array has been fabricated also. In this paper, RL of -26.8384 dB & antenna gain of 21.0271 have been achieved for the proposed array. Human uterine phantom model is designed and simulated by CST Studio Suite 2019.***

Key words : ***Flexible patch antenna array, Human uterus phantom model, Uterine tumour detection, Ansoft HFSS 13, CST Studio Suite 2019***

I. INTRODUCTION

Uterine tumours are made of smooth muscle cells and fibrous connective tissue of the uterus. It is estimated that between 20% to 50% women have fibroids during their reproductive age, but not all are diagnosed. According to few state reports, up to 30% to 77% of women will develop tumours sometime during their childbearing years [1]. Microwave imaging [2], is one of the active wave-based imaging method to contrast the electrical properties between body and tumour tissues . Microwave imaging is largely accepted for tumour detection. In any kind of microwave imaging system, role of patch antenna array is very important [3-8]. One appropriate patch antenna for imaging system should cover various requirements e.g. simple geometric structure, easy integration, gain, compactness, enhanced bandwidth, small dimensions etc. These requirements are fulfilled by number of advantages of microstrip patch antenna array e.g. ease of integration, low profile & weight, planar configuration, low volume & fabrication cost etc.

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Imaging system of uterus working in the range of microwave frequency is also considered for uterine tumour detection. There are two main parts of uterus imaging, efficient microstrip patch antenna design and modelling of human uterus phantom model. Flexible patch antennas [9-11] are widely accepted for tumour detection because of it's light weight and easy of fabrication. In order to make patch antenna flexible, the rubber substrate can be used. The basic idea is to lay a thin copper strip with perfect size and design on top of a flexible substrate and a thin copper strip with perfect size on bottom side as a ground plane.
Several flexible substrates have been used such e.g. micro fluids or liquid metals, paper, polymer, plastic, etc.
Goal of this study is-

1. Design & simulation of crescent shape flexible microstrip patch antenna of 1 element, 1×2 , 2×2 , 2×4 , 4×4 , 4×8 and 8 ×8 elements patch array using Ansoft HFSS 13 software at 4 GHz.
2. Comparison of antenna performance parameter for 1 element, 1×2, 2×2, 2×4, 4×4, 4×8, 8×8 elements flexible microstrip patch antenna array is also presented.
3. Design of five layered human uterus phantom model in CST Studio Suite software 2019.
4. Detection of tumour inside human uterus phantom by crescent shape flexible antenna in CST Studio Suite software 2019 [12].

II. UTERINE TUMOUR

Fibroids are tumours made of smooth muscle cells develop in the uterus [13-14].Unfortunately the cause of uterine tumours are still not known. Generally uterine tumours have no symptoms. Uterine tumours or fibroids are shown in Fig. 1.

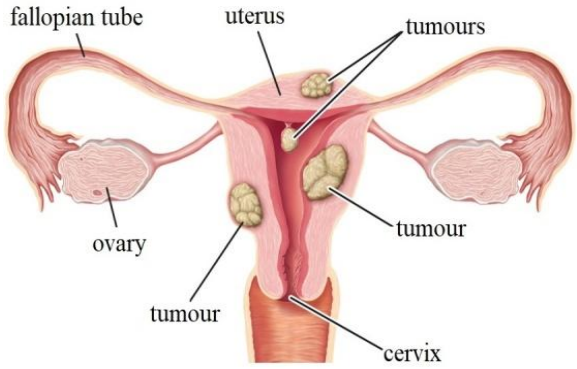

Fig. 1. Uterus with uterine tumours

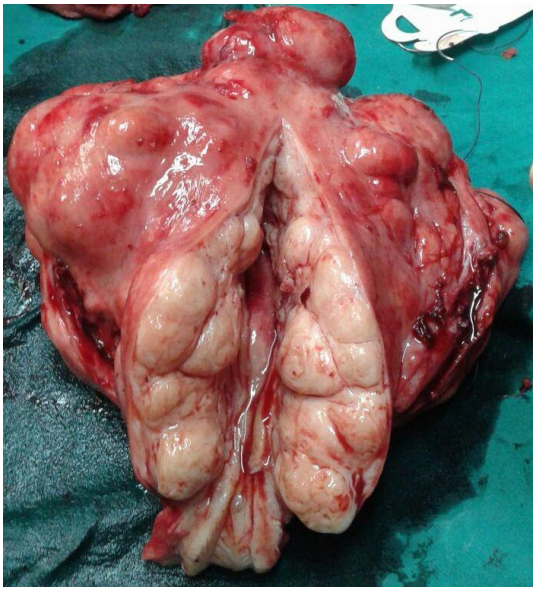

Fig. 2. Operative view of uterus with uterine tumours

Uterine tumours are frequently found incidentally during a routine pelvic exam. Above Fig. 2 shows operative view of uterus with some uterine tumours .

Multiple imaging techniques are used to evaluate the uterus. Uterine tumours can be diagnosed by X-ray, MRI, Endometrial biopsy, Hysteroscopy, USG, Blood test etc. Fig. 3 shows ultrasound image of uterus with uterine tumours.

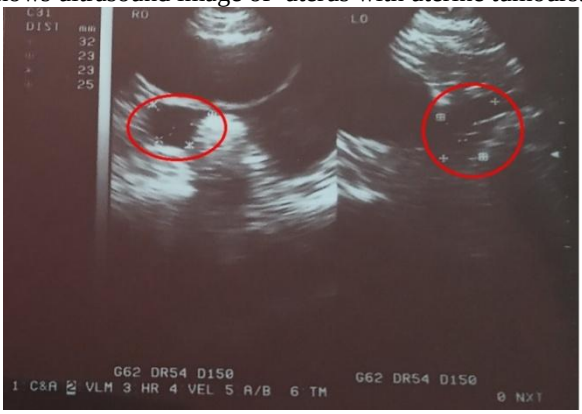

Fig. 3. USG image of uterus with uterine tumours

Fig. 3 shows ultrasound image of uterus with uterine tumours through red circles. Uterus microwave imaging is based on basically the concept on microwave signal , which is emitted from transmitting microstrip patch antenna reflected from target specimen and then it is received by receiving antenna through a software interface. Then this received signal is stored and after this a suitable signal processing algorithm makes result image.

III. ANTENNA DESIGN

Microstrip patch antenna has a flexible substrate made of rubber_hard. The length and width are equal for the substrate which is 50 mm . Thickness of substrate is 1.6 mm from ground plane for single element patch. Back side of the substrate contains the partial ground plane. The ground plane is made up of copper which is a lossy metal. Other side of substrate contains the crescent shaped microstrip patch, that is also made up of copper. The radius of the patch circle is 15 mm which is subtracted by 10 mm radius circle to design this crescent shape and the centre to centre patch element distance is 0.5 λ . The proposed antenna is fed by coaxial probe feed. The coupling of power through probe is one of the mechanism for transferring microwave power. Radius of the inner conductor probe for coaxial line feeding is 0.35 mm which is used to transfer power from a strip line to this crescent shaped microstrip antenna through slot from common ground plane. Radius of this circular feed is 1.6 mm. Crescent shape is a symbol which is used to represent the moon (basically in lunar phase). Crescent also refers other objects like houses forming an arc, glomerular crescent, a type of solitaire game etc.

Initially geometries of a single element, double elements, four elements, eight elements, sixteen elements, thirty two elements and sixty four elements microstrip patch antenna arrays with characteristic parameter like radius, length, width are shown in Figure (4-10).

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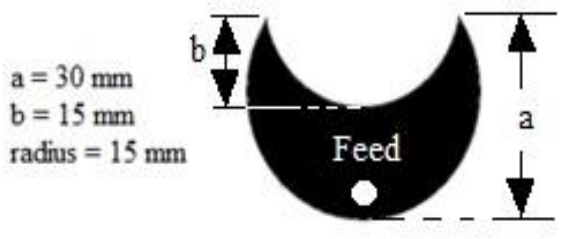


Fig 4. Geometry of single element microstrip patch antenna

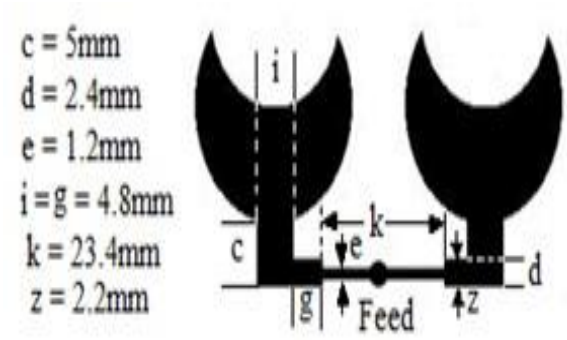


Fig 5.Geometry of double elements microstrip patch antenna array

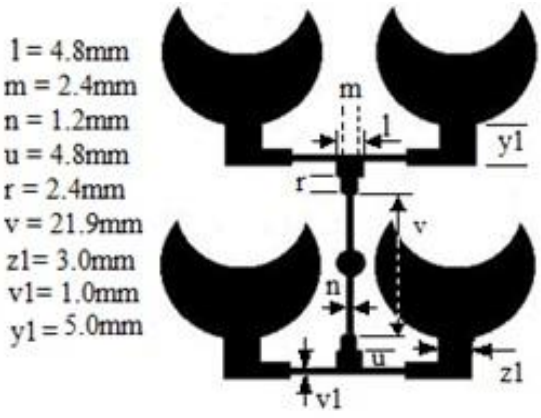


Fig 6. Geometry of four elements microstrip patch antenna array

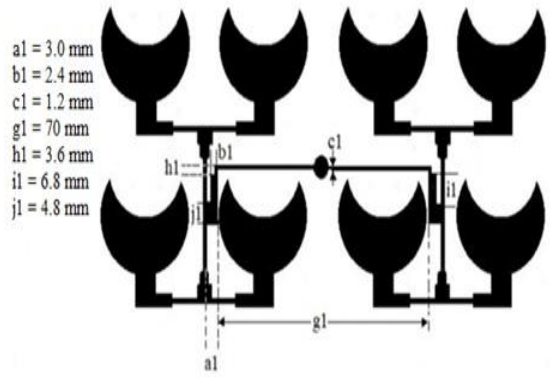


Fig. 7. Geometry of eight elements microstrip patch antenna array

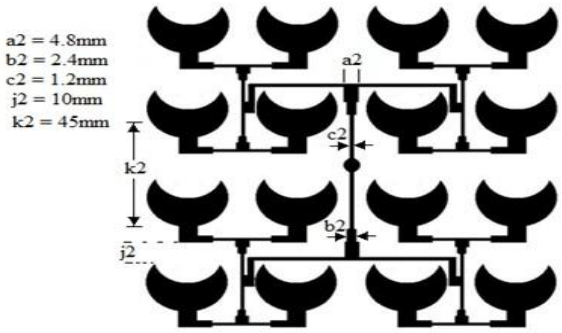


Fig 8. Geometry of sixteen elements micro strip patch antenna array

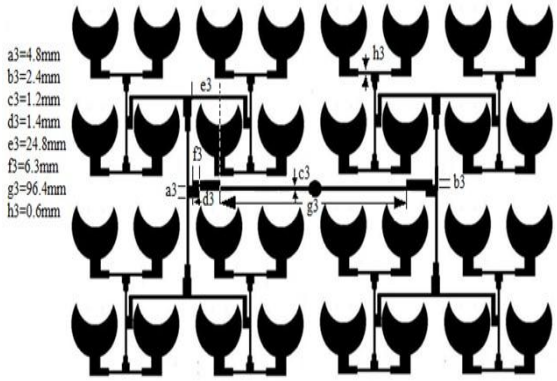


Fig 9. Geometry of thirty two elements microstrip patch antenna array

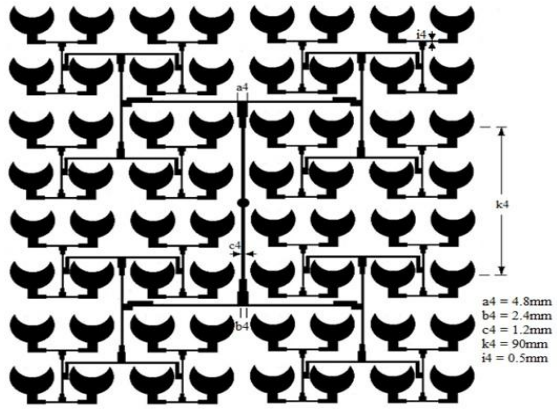


Fig. 10. Geometry of sixty four elements microstrip patch antenna array

IV. SIMULATION RESULTS AND DISCUSSION

The characteristic analyses of these patch antennas e.g. return loss , radiation pattern, bandwidth of this microstrip antenna array have been investigated. Simulated results of the microstrip antenna characteristics for different array combinations are shown below-

A. Return Loss (RL)

The graphical representation of return loss (RL) characteristics of different antenna array combinations are shown in the following Fig.11 and Fig.12.

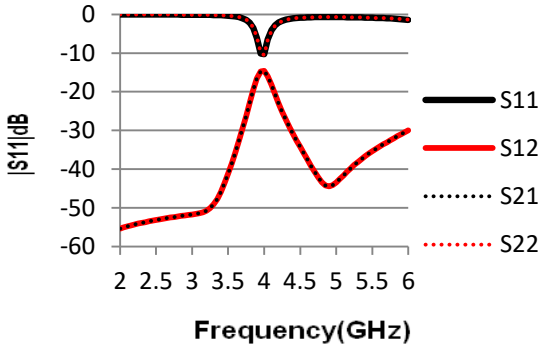


Fig. 11. RL for double patch element with 0.5λ distance

From the above graphical representation return loss(RL) , it is shown that centre-to-centre patch element 0.5λ 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 11.

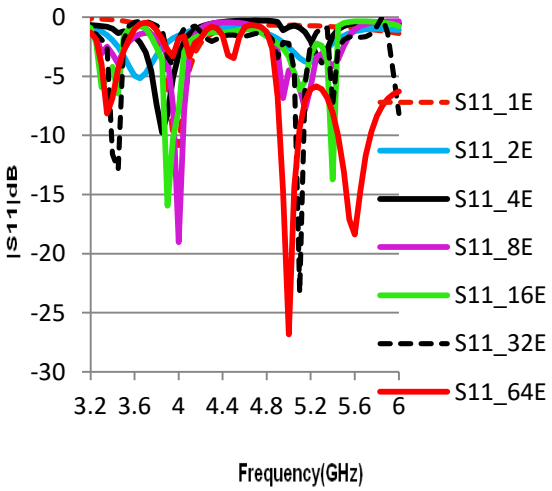


Fig.12 : RL for 1,2,4,8,16,32 and 64-elements microstrip patch array

From the RL characteristics of arrays, it is seen that 64 elements patch antenna's RL value is highest which is -26.8384 .

B. Radiation Pattern

The graphical representation of gain characteristics of different array combinations are shown in the Fig.13.

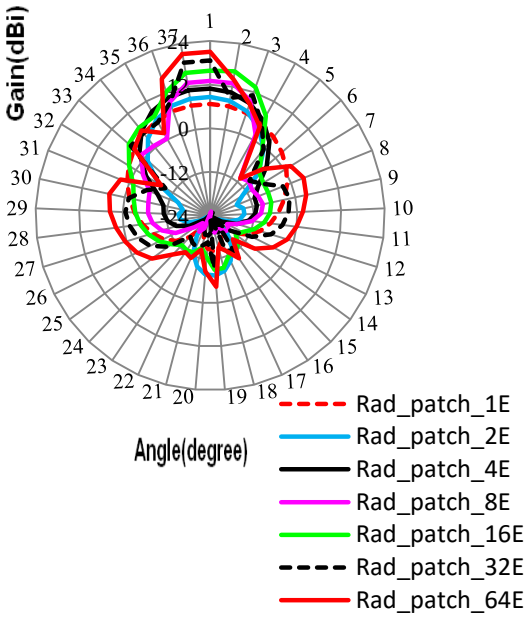


Fig 10 : Elevation pattern gain for 1,2,4,8,16,32 and 64-elements microstrip patch array

From the Radiation pattern characteristics of arrays, it is seen that 64 elements patch antenna's gain value is highest which is -26.8384 .

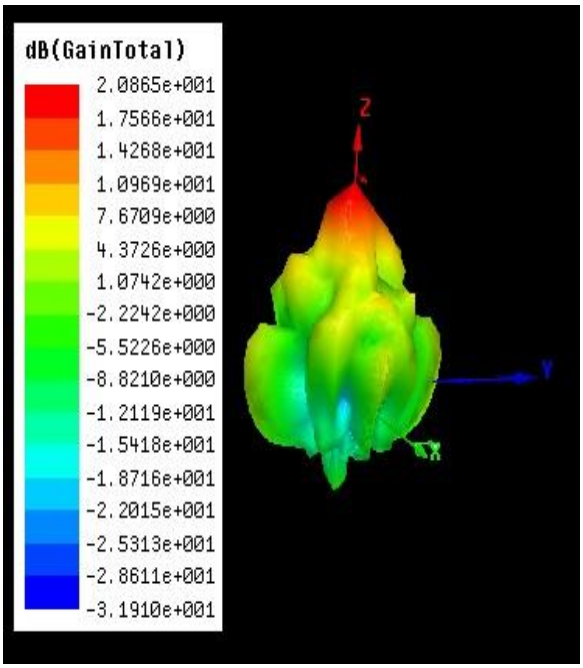
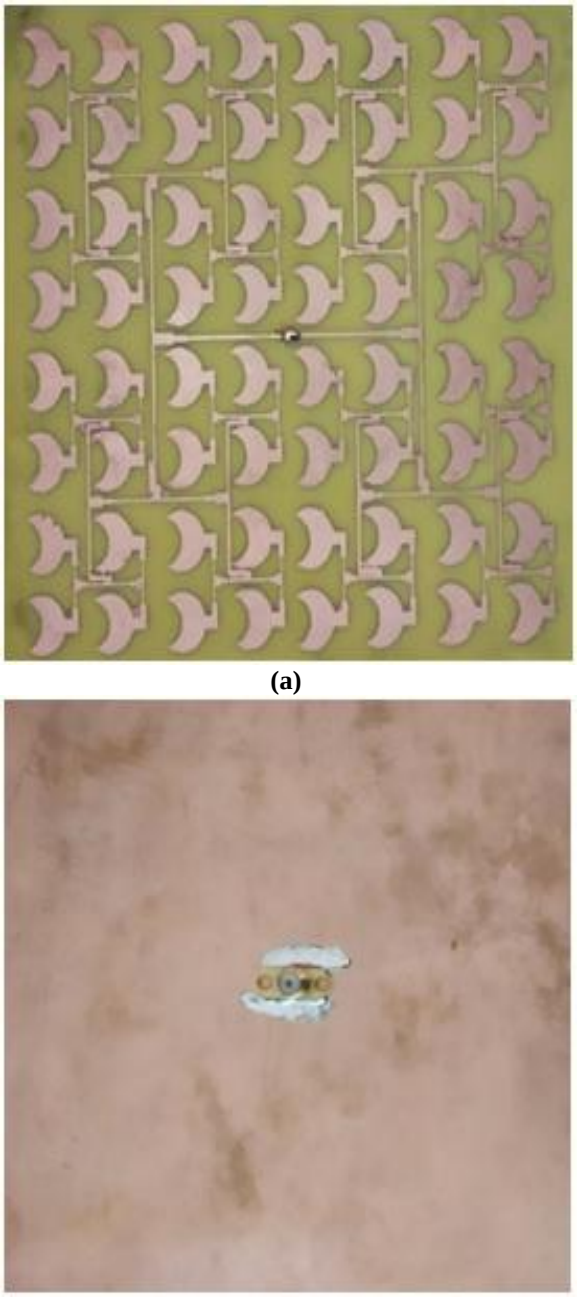


Fig 14 : 3D pattern view of the array of 64-element

The 3D pattern gain of the radiation pattern is shown in the Fig.14. From Fig.14, it is observed that the gain of the array of 64-element is 21.0271 dBi.

V. FABRICATED MICROSTRIP PATCH ANTENNA

The antenna array of 64-elemnt has been fabricated and the fabricated antennas (front and back view) are shown in Fig.15.



(a)

(b)

Fig.15.Fabricated antennas (a) front and (b) back view

VI. HUMAN UTERUS PHANTOM MODELLING & SIMULATION

A. A. Human uterus phantom model

One normal five-layered tumorous human uterus phantom model is made. After simulation one tumour model is inserted inside this human uterus phantom model and simulated. Then this new crescent shaped flexible antenna is attached with human uterus phantom model. The dimensions of this model is chosen randomly that reflects actual one. To get imaging results proposed microstrip antenna is simulated with and without tumor model by CST studio suite software 2019. Radius of Tumour, Uterus, Urinary bladder, Rectus Abdominis, Fat, Skin layers of uterus phantom are given in Table-I.

Table-I: Radius of Uterus, Urinary Bladder, Rectus Abdominis, Fat, Skin Layers of Uterus Phantom and Tumours

Tissues	Radius (mm)
Tumours	4, 2
Uterus	84
Urinary bladder	86
Rectus abdominis	88
Fat	90
Skin	92

Layers of human uterus phantom model with and without tumour is shown below.

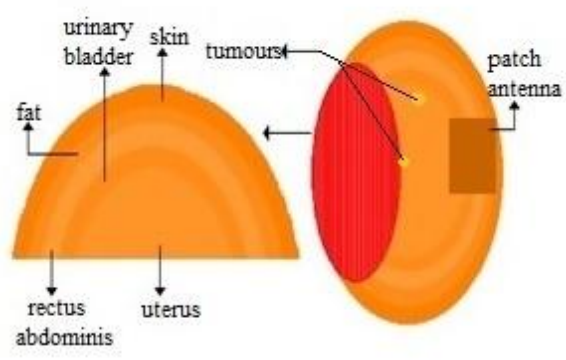


Fig 16 : Layers of human uterus phantom model with tumour

The CST studio suite 2019 has a rich library including some biomaterials tissues . Above Fig. 16 shows the layers of human uterus phantom model with tumour.

B. E field simulation results

E field simulation results of this human uterus phantom model with and without tumour are shown in Fig. 17 and Fig. 18.

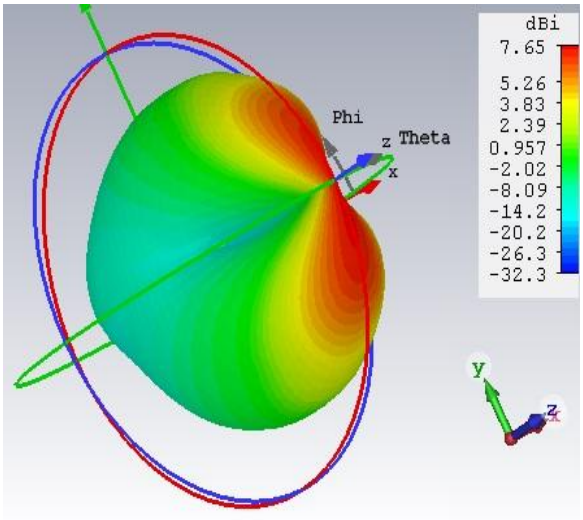


Fig. 17. E field simulation result of this human uterus phantom model without tumour

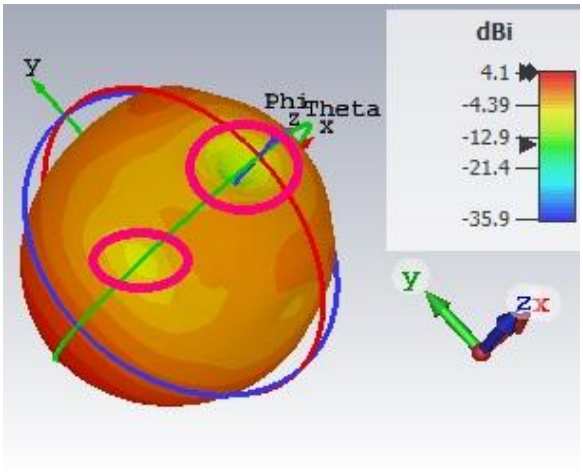


Fig. 18. E field simulation result of this human uterus phantom model with tumour

The performance of this 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. Fig. 17 and Fig. 18 show E field simulation results of this human uterus phantom model without and with tumour simultaneously. It is showed that radiated signals penetrate 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. 18 tumour is shown by pink circle.

VII. CONCLUSION

The conception and simulation of a crescent shape 64 elements microstrip patch array was successfully designed using the Ansoft HFSS 13. Here, we specifically focus on designing crescent shape 64 elements microstrip patch antenna array, using rubber as the flexible substrate and simulating to function at 4 GHz. The characteristic analysis e.g. RL, radiation pattern & gain of microstrip antenna array have been investigated. 64-elements crescent shape antenna array has been fabricated also. 64-elements crescent shape antenna array has been placed on human uterus phantom model and simulated to detect tumour. In this investigation, return loss of -26.8384 dB and gain of 21.0271 dBi have been executed for the proposed array. This flexible microstrip patch antenna array is then in human uterus phantom model and used to detect the uterine tumour through CST studio suite 2019 software. Uterine tumours have many complications like heavy pain, enlarged lower abdomen, pregnancy complication etc. So uterine tumour detection become a popular research topic for researchers. From this paper various patch antenna can be designed to detect tumour.

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