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Breast Cancer Detection: Analysis by Wideband Antennas

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ABSTRACT

Calculation of the numerical values of the depth of cancer tissues have been presented in the cancerous organs. In this work we have developed a wideband antenna to detect the cancerous organs. An EF shaped wideband antenna with 2x2 grid pattern has been designed with its geographical coordinates by mathematical modelling; simulated by Advanced Design Simulator (ADS) using Moments of Methods (MoM); fabricated their design in the form of a prototype using Microwave Monolithic Integrated Circuits (MMIC); and analysed by Agilent N99917A Microwave Analyser, which has been represented in this primary goal of research. It comprises a compact dimensional of 18.64x17.92x1 mm3. It includes the 2x2 array pattern with four EF shaped radiating slots, which printed on the 1-millimetre dielectric thickness of FR4 material and the conductive ground plane. It has been delivered at 5.417 GHz operational frequency, which covers the wideband spectrum of 4.89 GHz to 6 GHz. Furthermore, it has a wideband antenna, a low-profile structure with four numbers of radiating slots. These wideband antennas have been implemented for breast cancer detection application, which is represented by the secondary delivery of research. These wideband antenna with human breast equivalent dielectric model under existing Debye testbeds. These wideband antennas have impressed on the coupling materials, which act as the coupling medium. They have provided better scattering results than air medium. These coupling materials have presented higher and lower dielectric strengths respectively. The average of scattered responses has gathered on it. It has determined the depth of cancerous tissues presented in the cancerous organ with the help of velocity of propagation, the distance between the cancerous organ and transceiver antenna, dielectric strength and travelling time of scattered responses respectively. Therefore, these scattered responses have been obtained from the cancerous organs under Debye testbed. Hence, the numerical value of depth and spreading the coverage of depth in cancerous organ is validated under existing Debye testbeds.

KEY WORDS: BREAST CANCER, 2X2 ARRAY PATTERN; EF SHAPED PROTOTYPES; MICROSTRIP PATCH ANTENNA.

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INTRODUCTION

The microwave spectrum has been used during past twenty decades in medical, industrial and scientific applications. The microwave imaging is one of the most suitable breast cancer detection techniques. Its main objective is the hypothesis that the dielectric properties, electrical properties, impedance matching, conductivity, permittivity of the cancerous breast's tumor tissues are slightly different from the normal breast tissues and the cancerous organ's tissues. Microwave frequencies are millimetre wavelengths of the electromagnetic spectrum. The MI system provided the non-ionizing and non-invasive approaches and showed reasonable penetration in the breast tissue surrounding of breast organ. The microwave imaging techniques were used in one pair of antennas (transmitter, receiver antenna).

The transmitter transmitted the microwave signals to the breast and the internal tissues surrounding it. The receiver side scattered signals were reflected on it, which were gathered by the receiver antenna. The cancerous (malignant tumors) and normal breast tissues have different dielectric permittivity and conductivity properties. Microwave signal is reflected by the cancerous tissue and the scatter signal will collect from the body as differently. Microwave signals through diagnosis trials detected a malignant tumour of 5-10 millimetre range with an accuracy of 85%. Moreover, the ultra-wideband microwave imaging systems have been used to examine the breast cancer diagnosis, (Meaney et al., 2000, Fear et al., 2002, Gibbins et al., 2009, Sakthisudhan et al., 2020).

A wideband antenna has been operated under 4.5 GHz-10 GHz microwave frequencies. It was designed by cavity –backed patch antenna with a 3D array pattern which was replaced by monopole antennas with a 2D array pattern. The microwave imaging system, focusing on the following challenges and issues were discussed as, i)Ultra-Wide-Band antennas, ii) Compact size, iii) Steerable antennas, iv) Interference rejection factors,and v) Improved radiation efficiency. Chu Yu et al (Yu et al., 2008) examined a prototype model for Microwave Imaging systems. This system consisted of one pair of dipole antennas to avoid mutual coupling losses between two ports.

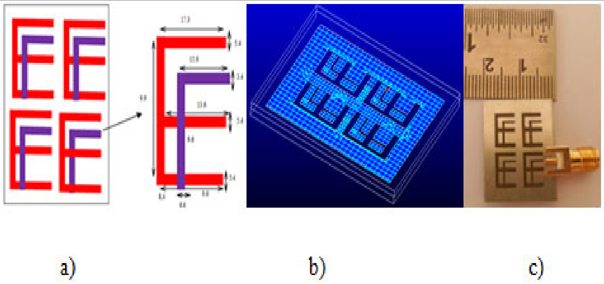
This proposed system can effectively detect the dielectric size of object is 5 mm at 1.74 GHz imaging frequency. Similarly, the various microstrip patch antennas of surveys have demonstrated the various test beds such as, Dipole Antennas; Dielectric Resonator Antennas; Patch antennas; Slot antennas; Vivaldi antennas; Horn antennas and MEMS Micro electro mechanical systems -steerable antennas (Woten and El-Shenawee, 2008, Shi et al., 2009, Amineh et al., 2009, Huang and Kishk, 2009, Gibbins et al., 2009, Al-Joumayly et al., 2010, Bourqui et al., 2010, Hutchings and El-Shenawee, 2010, Amineh et al., 2010, See et al., 2012, Sakthisudhan et al., 2020).

The Microwave Imaging system, coupling materials are mandatory to reduce the mismatching between the antenna systems and the breast tissue. Transverse. The comparative study of slot antennas and stacked antennas were used in the imaging systems (Sakthisudhan et al., 2020).In this research the microstrip patch antenna design and fabrication have been found suitable for cancerous diagnosis applications.

MATERIAL AND METHODS

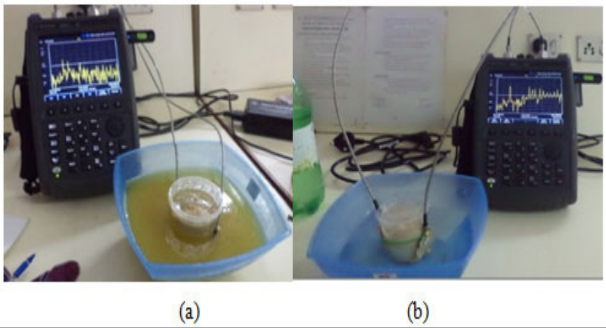
A 2x2 array pattern of EF shaped Microstrip patch antenna has been illustrated in Figure 1. The proposed prototype is to be required the following design parameters, such as, selection of 5 GHz resonator frequency; FR4 dielectric substrate with dielectric constant is 4.6; and thickness of dielectric layer is 1mm. It consists of conductive strip of 12.64x17.9 mm2with mounted on 1 mm dielectric layer thickness. Therefore, it achieves a compact design of 18.64x24.9x1 mm3dimensional area.

Figure 1: a) geometric coordinates (units in milimeter); b) simulation snapshot & c) fabricated prototypes of EF Shaped with 2x2 grid pattern.



A proposed design is designed by mathematical modelling equation. The excitation port is etched on the ([a] matrix element) a23EF shaped element of the array pattern via 50Ω of RF-SMA connectors. The proposed structure is fabricated with 4.6 dielectric constant with 1 mm thickness of FR4 material, mounted on the conductive ground plane strip via Surface Mount Adaptor (SMA) connector. The SMA connector is measured by Microwave Analyzer (Agilent N99917A) and this testing results are reliable and compared with the simulated prototype.(Sakthisudhan et al 2016, 2020).

Figure 2: Proposed prototypes impressed in coupling materials a) higher & b) conductive medium



A delivery of secondary research, the proposed prototypes with dielectric phantom model has been examined the scattered signal, which is illustrated in Figure 2. The dielectric phantom model consists of human equivalent model. It consolidated the different biological contents, which dielectric strengths are plotted in Table 1. Hence, these test bed have delivered the four different stages of results, they are early stage; minor stage, growing stage and major stages respectively.

Table 1. Contents of breast phantom model

S.No	Dielectric Materials	Biological Breast Contents	Standard dielectric strength	Equivalent dielectric strength	Dielectric strength examined by measurements
1.	Human Breast Model	Cancerous Tissue	42-45	Coal Piece	43
2.		Breast Tissue	27-35	Wheat Flour	27.654
3.		Skin Layer	36-42	Glycerin	35.129
4.		Blood Components	50-60	Big Sugar Sugar	53.2 51.5
5.	Textile Woven Materials	Cotton Woven	3.9-7.5	Cotton	4.83
6.		Polyester Woven	2.8-4.5	Polyester	3.8
7.	Coupling Materials	Glycerin	43	Glycerin	40.41
8.		Vegetable Palm Oils	3.75	Vegetable Palm Oils	3.87

Table 2. Performance study of proposed 2x2 Array of EF Microstrip slots and Existing slots

		Existing Microstrip slots			2x2 Array of EF Microstrip slots			
S. No	Antenna Parameters	Simulation design	Fabricated prototype	(Denidni et al., 2008)	(Hazra et al., 2013)	(Liu et al., 2010)	(Liu et al., 2011)	(Archevapanich et al., 2007)
1.	Shape of Patch Strips	2x2 Array of EF Shaped	E Shaped	P Shaped	Inverted L Shaped	Inverted L Shaped	E Shaped	
2.	Resonance f_r (GHz)	5.156	5.417	5.8	2.45	2.42, 5.2	2.3, 3.6, 5.04	2.46, 5.3
3.	Return Loss S_{11} (dB)	17.473	21.274	<10	17.5	<10	>20	40.31
4.	Reflection Coefficient ()	0.13	0.09	0.316	0.133	0.316	0.1	0.1
5.	VSWR Ratio	1.31	1.19	1.92	1.3	1.92	1.22	1.22
6.	Reflected Power (%)	1.69	0.81	9.9	1.8	9.9	1	1
7.	Reflected Power (dB)	-17.7	-20.9	-10.03	-17.45	-10.03	-20.08	-20.08
8.	Mismatch Loss (dB)	0.08	0.03	0.45	0.08	0.45	0.04	0.04
9.	Non Reflected Power- dB	0.9665	0.9838	0.9	0.98	0.9	0.99	0.99
10.	Bandwidth Coverage GHz	4.8 to 6	4.89 to 6	4.8-6	2.35-2.25	2.34-2.55 4.8-7.2	2.14-2.52 2.82-3.74 5.15-6.02	2.4-2.52 4.82-6.32
11.	Fractional BW (%)	23.27%	20.49%	20.69	4.08	8.67,46.1	16.5, 25.56, 17.3	4.87 28.3
12.	Antenna Q Factor	4.3	10.8	4.83	24.5	97.1	5.79	3.53
13.	Dimension of Design (mm^3)		18.7x23.9x1 x5.78	15x25 x1.52	110x158.5	25x30x05	20x30	27x17.3x 1.575

RESULTS AND DISCUSSION

The comparison of the fabricated MPA prototype with the simulated MPA design is shown in Figure 3. The return loss of 17.473 dB has been achieved at a resonant of 5.156 GHz and coverage of wide band of 4.8 to 6 GHz in the simulation structure. The return loss of 21.274 dB has been obtained at a resonance of 5.417 GHz, coverage of 4.89 to 5.3 GHz in the fabricated MPA prototypes. A comparison of the proposed MPA with the existing MPAs is listed in Table 2. MPAs require the UWB band of frequencies and ISM application standards. The fabricated MPAs results are justified with that of the simulated MPAs design and has improved FBW than the simulated MPA design. Hence, it is called as wideband prototypes (Sakthisudhan et al 2020).

Figure 3: Comparison of fabricated & simulated prototypes

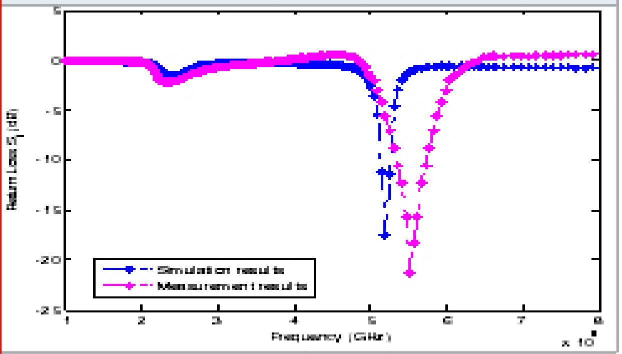
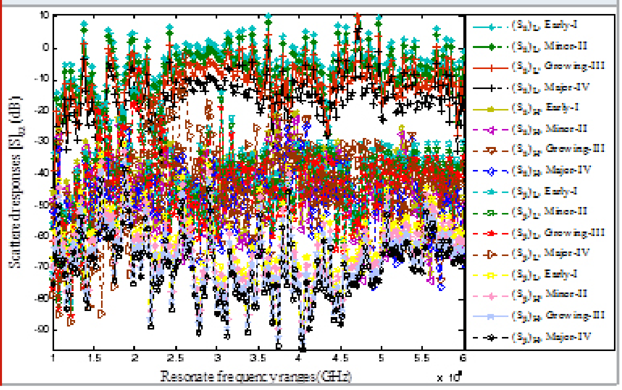


Table 3. Analysis of tumor characteristics of microstrip slot of EF with an Existing Debye Test Beds

	Category of Screening stages	Depth of tumor At Major Stage Frequency f_{major}(GHz)	Depth of tumor At Early Stage Frequency f_{early} (GHz)	Travelling Time δt (ns)	Proposed microstrip antennas: Dielectric Strength of Tumor	Proposed microstrip antennas: Velocity of Propagation (mm/s)	Proposed microstrip antennas: Depth of Tumor by Numerical Analysis (mm)	(Fear et al., 2002) Analyzed in Existing Debye Test Beds Parameters: Dielectric Strength of Tumbeen or	(Fear et al., 2002) Analyzed in Existing Debye Test Beds Parameters: Velocity of Propagation (mm/s)	(Fear et al., 2002) Analyzed in Existing Debye Test Beds Parameters: Depth of Tumor by Numerical Analysis (mm)	Physical Distance Between the Tumor with MPAs (cm)
Proposed MPAs Based Debye Test Beds	Early-I 1cm	5	3.4	0.625	48.5	$4.3x10^{10}$	53.75	9	10^{11}	125	129.8
	Minor-II 2cm	5	3.45	0.65	48.5	$4.3x10^{10}$	55.9	9	10^{11}	130	127.4
	Growing-III 2.5 cm	5	3.5	0.667	48.5	$4.3x10^{10}$	57.36	9	10^{11}	133.4	109.2
	Major-IV 3 cm	4.99	3	0.503	48.5	$4.3x10^{10}$	43.26	9	10^{11}	100.6	110.4
(Kiruthika and Sharma, 2011)	5	3.4	0.625	21.3	$6.5x10^{10}$	81.25	9	10^{11}	125	129.8	129.8
	5	3	0.503	21.3	$6.5x10^{10}$	65.39	9	10^{11}	100.6	127.4	127.4
	5	3.45	0.65	21.3	$6.5x10^{10}$	84.5	9	10^{11}	130	110.4	110.4
(Salvador and Vecchi, 2009)	5	3.4	0.625	20 to 40	$5.3x10^{10}$	66.25	9	10^{11}	125	129.4	129.4
	4.99	3	0.503	60 to 80	$3.1x10^{10}$	31.186	9	10^{11}	100.6	109.2	109.2

Figure 4: Scattered Signals have gathered by Existing Debye Test-beds



These proposed microstrip slots have been evaluated by the Existing Debye test bed setup, illustrated in Figure 2 (a & b).It consists the pair of transreceiver antenna with human's dielectric equivalent breast model. These scattered responses have examined under lower and higher coupling medium respectvely. Since, these proposed slots have impressed in these coupling medium. Figure 4 has gathered scattered signals from different resolution stages under Debye test beds. Finally, these results have analysed and segregated with dielectric equivalent of healthy organs. These results have described the early, minor, growing and major stages of cancerous organ respectively. Therefore, the spreading cancer tissues, depth has calculated in the Table 4.

CONCLUSION

A 2x2 grid pattern with EF shaped fabricated prototypes has been demonstrated and validated by Network Analyzer in this research. Moreover, these prototypes have been compared with the existing prototypes. It has delivered the resonant frequency of 5.417 GHz, wide band spectrum of bandwidth 4.89 to 6 GHz. The different tumor resolution characteristics have been demonstrated under the existing Debye model. Hence, these data have provided the clinical diagnosis of the breast cancer. Furthermore, these analyses have offered the depth of cancerous organ under different resolution stages, which can be used suitably by radiology professionals.

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