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A proposed algorithm to determine breast smallest tumor location and size

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Abstract— Tumor detection, diagnosis, therapy and treatment remain serious problems for human life. Among different kinds of human organism tumor size and location represent an important issue. There are many techniques and methods present in letireature deal with breast tumor detection, therapy and treatment. One of the most willknown among these techniques is the x-ray mammography, which remains a prime tool irrespective of its cost and drawbacks. The x-ray lies in the ionizing destructive band of the electromagnetic wave energy spectrum. Many researches oriented to the microwave band of electromagnetic wave for imaging and inspection to attain a less harmful and invasive radiation effect. The present paper introduces an inspection system module that leads to derive criteria and metric parameters for determining the smallest tumor size and location. A proposed algorithm has been introduced using the deduced criteria and metric parameters to compute the location of tumor and determine its size.

Index Terms — Absorbation, antenna, breast model, examination chamber, inspection module, invasive, metric criteria.

1 INTRODUCTION

Tumor detection, diagnosis , therapy and treatment remain serious problems for human life . They accupy wide band area of research in medicine and biomedical engineering.

Among diferrent kinds of human organism, tumor size and location represent an important issue. One of the major tumors that represent a big issue in human medication is a breast tumor. There are many techniques and method are present in literature deal with breast tumor detection, therapy and treatment. One of the most willknown among these techniques is the x-ray mammography which remains a prime tool irrespective of its cost and drawbacks. Fig. 1 shows an illustrationfor the locationof thex-ray energy in the electromagnetic wave (EMW) spectrum. From this figure it's seen that the x-ray lies in the ionizing destructive band of the EMW spectrum.

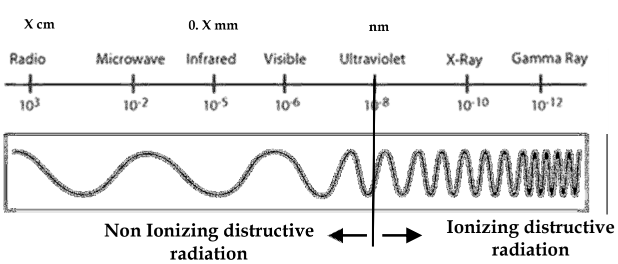

Fig. 1. EMW energy spectrum.

There for the today present investigation search for some other techniques, tools or methods in many present works, many researches oriented to the microwave band of the EMW for imaging and inspection to attend a less harmful, invasive radiation effect. Consedaring the properties of EMW propagation in matter, it has three trains: transmission, reflection or absorbtion. Many researches in the medical field use the EMW either for tumor imaging detection and treatment.

The need to lower energy EMW derives scientist and researches to imploy the wide knowlage of microwave signal generation, tools and design, measurement, cost and performance.

Propogation of EMW is crachtaris by energy transfare according to:

$$E_I = E_T + E_R + E_A \qquad (1)$$

Where E_T is the amount of energy transmitted throw the matter, E_R is the amount of energy back scutter (reflected from matter) and E_A is the amount of energy apsorber (patialy or totally).

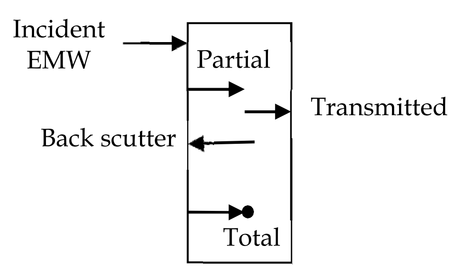

Fig. 2. Types of EMW propogation.

This paper introduces proposals for aninspection system module to determine breast tumor size and location using the EMW radiation in the microwave band.

2 INSPECTION SYSTEM MODULE

The inspection system module consists of tumor located inside a breast, which is inserted inside an examination chamber. The hall is exposed to a microwave signal source as shown in fig. 3.

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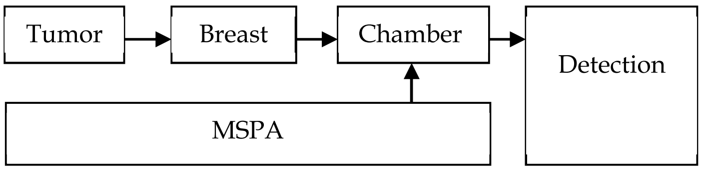

Fig. 3. Organization block diagram of inspection system module.

3 THE PROPOSED SYSTEM MODELINGS

3.1 The Breast Model

The breast is assumed as a semi-ellipsoid with a major axis r_j and minor radius r_b. The analyzed breast model consists of a fat layer that has heterogeneous tissue, as shown in fig. 4. The skin layer is not included in order to reduce the complexity of the model and to reduce the simulation run time. The breast model must include a tumor at a nominated location(s) Q_n (x_n, y_n, z_n), as shown in figure (1). The conductivity of the used materials was choosing as maximum as given in table (1) [3, 7].

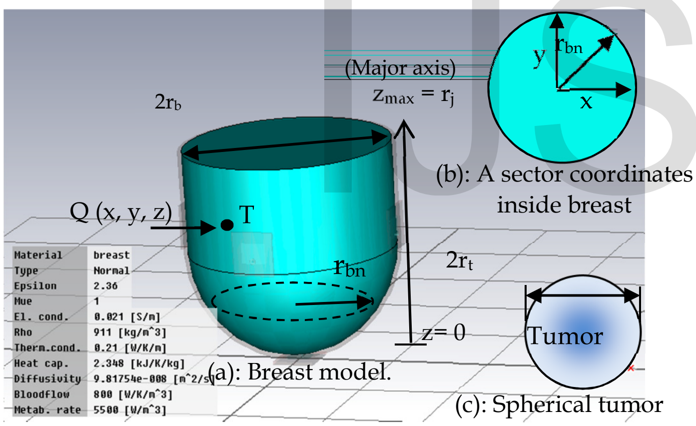

Fig. 4. The proposed breast model coordinates.

3.2 The Microwave Source

The Microwave signal is fed through a microstrip patch antenna (MSPA), due to its merits. Fig.2 shows the structure of the selected MSPA. The dimension of the selected MSPA with coaxial feed structure is given in table (1) [4-6].

The selected MSPA is placed at different positions (θ, x, y, z) for sides of the semi-ellipsoid. The examination will be carried out along the major axis from z=0 (nipple) to zmax = r_j.

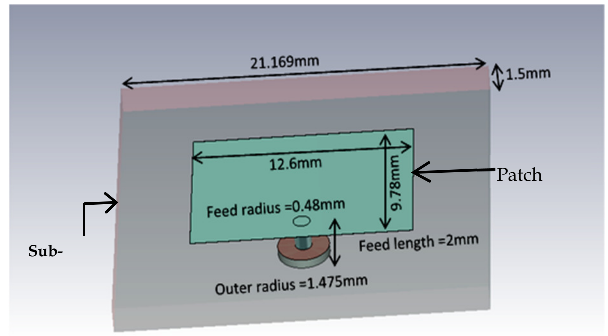

Fig 5. The selected MSPA with coaxial feed.

TABLE 1
THE OBJECTIVES PARAMETERS AND MATERIALS USED

Item	Name		Symbol	Value
MSPA	Substrate length	(mm)	L	21.169
	Substrate thickness	(mm)	t	1.5
	Dielectric constant (Coulomb^2 / meter^2 / Newton)		ϵ	2.2
	Patch length	(mm)	L_p	9.78
	Patch width	(mm)	W_p	12.6
	Feed Rad	(mm)	r	0.48
	Feed offset	(mm)	L_o	1.5
Chamber	Dielectric constant (Coulomb^2 / meter^2 / Newton)		ϵ_c	4.3
	Major axis	(mm)	r_j	115
Breast	Dielectric constant		ϵ_b	2.36
	Conductivity	(S/M)	σ_b	0.012
Tumor	Dielectric constant (Coulomb^2 / meter^2 / Newton)		ϵ_t	37.3
	Conductivity	(S/M)	σ_t	4

It is worth to note that permitivity constant and conductivity of tumor are near to 16, and 333 respectively times that of the surrounding breast.

Fig. 6 shows the 2D and 3D far-field for the selected MSPA with coaxial feed.

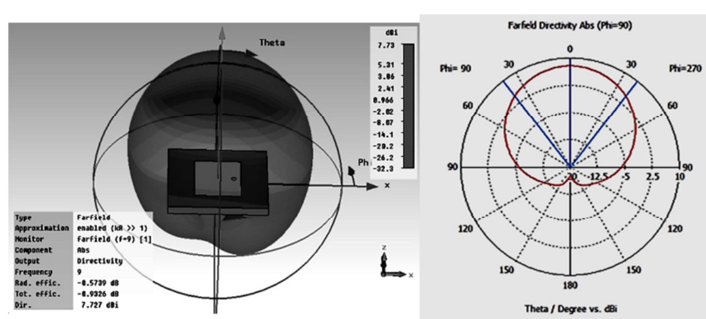

Fig. 6. The 2D and 3D far-field for the selected MSPA.

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3.3 The proposed inspection chamber structure.

The breast proposed container is a chamber of semi-ellipsoidal shape consisting from an FR-4 (lossy) material. The chamber structure shown in fig. 7 and its dimensions are given in the table (1).

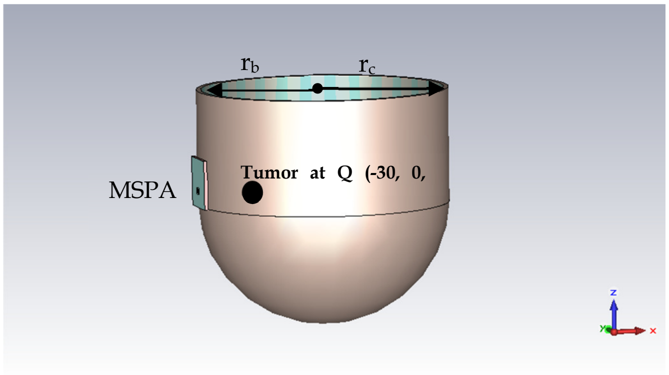


Fig. 7. The Proposed structure of the inspection chamber and the proposed MSPA location(s).

4 Measurment Parameters

The study and analysis of tumor existence inside a breast basicaly depend on EMW behavior with matter, transmission back scutter or absorption. For tumor imaging transmetion or back scuttering are commonly used where as absorbtionis heavely dependent on the mass, size and location of tumor. So in the present analysis the EMW will be taken to determine the tumor size and location using the will known equestion:

$$SAR = \frac{\sigma E^2}{m} \quad (2)$$

Where σ is the conductivity of the matter, E is electromagnetic wave field strength and m is mass. In the following the selected MSPA, examination chamber, breast model and tumor are studied using the CST, microwave studio [8]. The CST is a full future software tool backadge for studing and analysis of EMW propagation.

The parameters to be measured are: max (SAR), its simulated location Q_s (x_s, y_s, z_s), and tumor size radius r_t. A deviation δ between the nominated location Qn and simulated location Qs is to be defined as:

$$\delta = |Q_n - Q_s| \quad (3)$$

The SAR is widely used for expressing quantity interactions of microwave electromagnetic (EM) energy with biological systems matter [4, 9, 10], so the SAR must be used to determine the coordinate of simulated location Q_s (x_s, y_s, z_s), maximum SAR value inside or outside a tumor and the tumor size radius inside a breast tissue.

5 SIMULATION AND RESULTS

The following subsection explains how to determine the tumor location and deduce the required criteria for its size radius. Also an experimental procedure flow chart is introduced, and then the simulation results are to be analyzed.

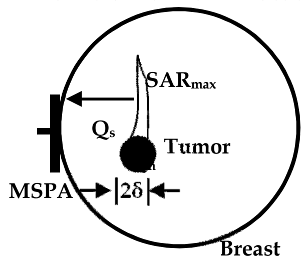
5.1 Tumor Location and size criteria

A proposed spherical tumor has: radius r_t inside breast, a nominated location Q_n (x_n, y_n, z_n), and a simulated deviation (δ) from the nominated location Q_n.

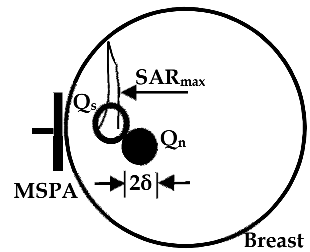
The deviation (δ) determines either the SAR is inside the tumor volume or outside it.

The mentioned above coordinates location and size are to be tasted according to the following criteria:

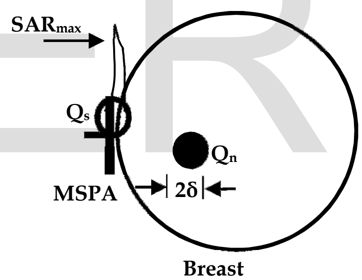
1. The maximum SAR location is inside breast, and simultaneously inside tumor.
2. The maximum SAR location is inside breast, but outside tumor.
3. The maximum SAR location is outside breast.



(a) The maximum SAR is inside the tumor.



(b) The maximum SAR is outside the tumor but inside the breast.



(c) The maximum SAR is outside the breast.

Fig. 8: Illustration of tumor probable locations.

Fig. 8 illustrates the probable tumor locations. The criteria can be formulated according to the following decision rules:

1. If x_s or $y_s > r_{bn}$, the maximum SAR location is outside breast. (4)
2. If x_s & $y_s \le r_{bn}$, the maximum SAR location is inside breast. (5)
3. If $r_b > \delta > |r_t|$, the maximum SAR location is outside the tumor, and inside breast. (6)
4. If $\delta \le |r_t|$, the maximum SAR location is inside the tumor. (7)
5. With $\delta_{max} = r_t$ (8)

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5.2 A proposed Algorithm for maximum SAR

To determine the location of tumor according to the mentioned above criteria, the following algorithm parameters are to be assumed and simulated.

1. Assign maximum probable tumor size radius δ_{max} locus to be calculated.
2. Nominate a location for a tumor to be studied.
3. Compute the simulated maximum SAR coordinates Q_s.
4. Compute the deviation δ.
5. Test for tumor location.
6. Check the mentioned above criteria.
7. Define the smallest tumor size and location.

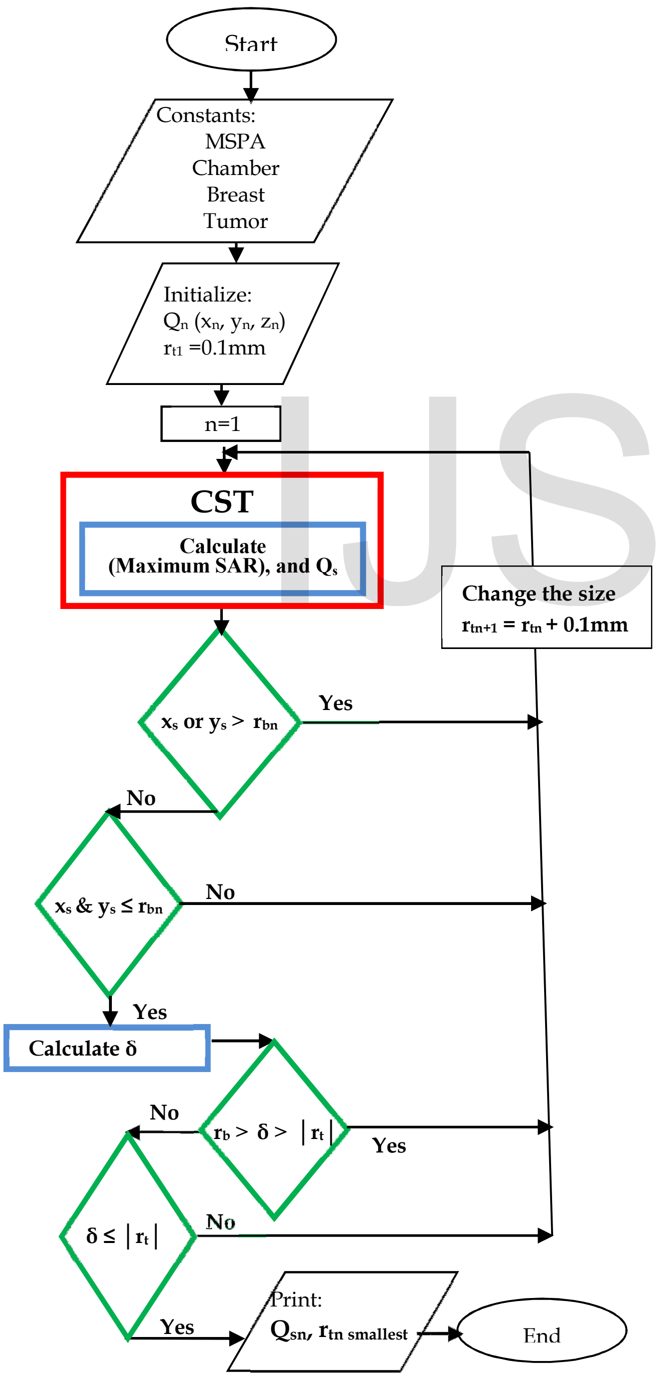
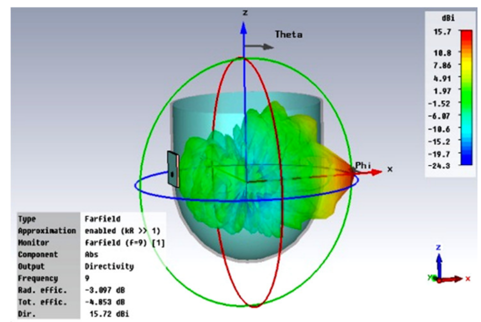


Fig 9. The proposed algorithm for determination of tumor smallest size and its locations.

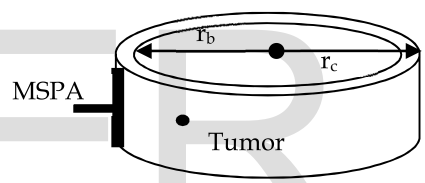
5.3 Experiment result

5.3.1 Breast sector:

The following experiment is carried out to analyze the location of maximum SAR and its distribution. It is composed of breast sector that has cross-sectional area radius of r_b = 53mm placed in chamber of radius r_c = 55mm, and the MSPA positioned in front of the breast sector.



(a): The farfield structure.



(b): Breast sector.

Fig. 10. The MSPA far field and the breast sector.

Result

Fig. 10-a, shows the simulation results for the strength of the near and farfield distribution as a result of tumor insertion inside the breast and in front of the MSPA. From this figure it is worth to note that the directivity pattern induced in the breast tissue has been confined radially compared with the directivity pattern of the MSPA in air, fig. 6.

The maximum SAR location is calculated for the mentioned above MSP Antenna and the given breast sector configuration fig 10-b. The results are given in table (2). In this table the successive simulated coordinate are tabulated for different tumor sizes as well as the deviation (δ) from the nominated coordinates. The actual tumor size to be tested is taken as the maximum allowable deviation (δ_{max}) for maximum SAR location. Other deviation value $\delta \leq \delta_{max}$ means that the maximum SAR is located inside the tumor, whereas deviation $\delta > \delta_{max}$ means that the maximum SAR is located outside the tumor (either inside breast or outside breast) according to the mentioned above decision rules.

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TABLE 2
THE MAXIMUM SAR FOR DIFFERENT TUMOR SIZE AT NOMINATED LOCATION Q_N = (-30, 0, 60).

Tumor size (mm)	simulated results				Deviation				decision
	Max SAR (W/Kg)	x_s	y_s	z_s	δ_{max} (mm)	δx	δy	δz	
1	27.64	-56.6	-1.4	63.3	±0.5	26.6	1.4	3.35	Outside breast
2	24.62	-52.8	-3.7	61.2	±1	22.8	3.7	1.28	
3	33.29	-30	0	61.5	±1.5	0	0	1.5	Inside tumor
4	59.29	-31.5	0	60	±2	1.5	0	0	
5	238.4	-31.5	0	60	±2.5	1.5	0	0	

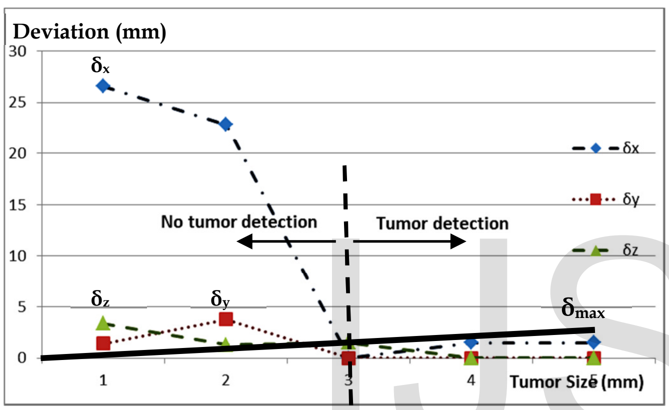

Fig. 11. Tumor size versus maximum SAR and deviation.

Fig. 11 is constructed for: the allowable maximum deviation δ_{max}, and the x, y, z coordinates deviation δ_x, δ_y and δ_z respectively from the nominated Q_n. This coordinates clarify which tumor size can be detected, thus full fill the criteria ($\delta \leq \delta_{max}$) for tumor existence. For any deviation values δ above the δ_{max} line there will be no detection for such tumor, and for δ(s) under the δmax line the tumors can be detected. From the Table. 2 and fig. 11 (δ graph) it is seen that tumors of size less than 3mm (left of the vertical dotted line) will not be detected. Whereas tumor of size equals to 3mm or greater must be detected (right of the vertical dotted line).

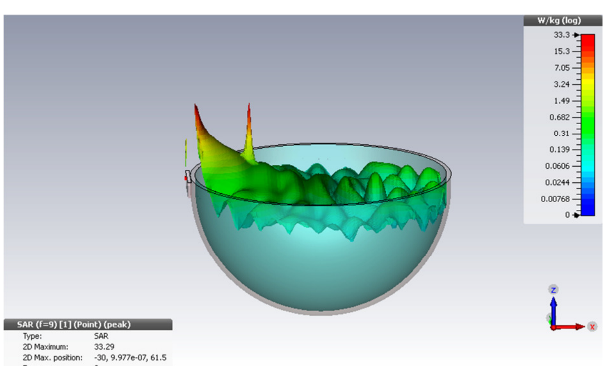

Fig. 12. The SAR distribution for 3mm Tumor size.

Fig. 12 shows the result of SAR distribution for the given case, where tumor size is 3mm. the table (2), and fig. 12 it's evident that the deviation (δx, δy and δz) are within the allowable δmax = ±1.5 mm with the SAR maximum = 33.29 W/Kg. Any tumor of size greater than 3mm it will be detected as shown in table (2).

6 CONCLUSION

The present paper introduces an inspection system module consisting of a microwave source, microstrip patch antenna, examination chamber and a breast model. The study and analysis of tumor existence inside the breast model lead to derive criteria and metric parameters taken for determining the smallest tumor size and its location.

The proposed algorithm has been introduced using the deduced criteria and the metric parameters as well as the CST software as a tool box to compute the location of the tumor and to determine its size.

The implemented experiment system for the given constant of the introduce inspection module, criteria and algorithm enable to detect tumors down to 3mm size.

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