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Improvement in Image Reconstruction of Biological Object by EXACT SIRT cell Scanning Technique from Two Opposite sides of the Target

Kabita Purkait[1], Sanjib Sarkar[2], Kalyan Adhikary[3]
[1](Associate Professor, Electronics & Communication Engineering, Kalyani Govt. Engineering College, West Bengal, India)
[2](M. Tech, Electronics & Communication Engineering, Kalyani Govt Engineering College, Kalyani, West Bengal, India)
[3](Asstt. Professor, Electronics & Communication Engineering, Modern Institute of Engineering and Technology,West Bengal, India)

Abstract: *In this paper a cell scanning technique from two opposite sides of the target is proposed to reconstruct the complex permittivity of the biological body using Exact Simultaneous Iterative Reconstruction Algorithm. The biological body is illuminated by an array antenna consists of 15x15 half wave dipoles separated by quarter wave spacing from each other with a beam width of 6^0 operating at 1 GHz. The fields are measured by 20 half wave dipoles placed one side of the biological model for 24 transmitter positions on other side of it. The positions of transmitters and receivers are interchanged and views are taken from two opposite sides of the target which improves the quality of the reconstructed image. The accuracy to discriminate the diseased portion from the normal one increases by 5%-10% when reconstruction of complex permittivity of the cells has been done from two opposite sides than that obtained from one single side of the target. Reconstruction of complex permittivity is simulated using FORCE 209 and results are presented using color gradation scale.*

Keywords: *SIRT, double sided scanning, complex permittivity, exact algorithm.*

I. Introduction

Tomography is the pictorial representation of unknown cross section of an object. By this process visualization of the internal structures of an object without the superposition of over- and under-lying structures is possible. Low frequency microwave (about 1 GHz) can be used for this purpose and that's why it is called a non-invasive imaging technique.
Each organ of a biological system has a unique complex permittivity. It consists of a real part called dielectric constant and imaginary part called loss factor or dielectric conductivity. Complex permittivity depends on the tissue type and its condition. When microwave energy is passed through a biological body incident fields at the cells vary with their complex permittivity. Again, complex permittivity in a cell increases with the increase of water content in it. As water content in a cancerous cell increases, complex permittivity also increases in it compared to its normal state. Hence reconstructed complex permittivity can be used to detect cancerous cell in early stage.

Among different reconstruction techniques employed to reconstruct the complex permittivity of the biological target, Simultaneous iterative reconstruction technique shows positive results. In the past few years, iteration reconstruction techniques have been increasingly popular. According to Richmond's moment method dielectric medium is divided into large no. of square cell each of which has constant electric field intensity and complex permittivity. A system of linear equations can be achieved by taking into account that at the centre of each cell total field is equal to incident field and scattered field. Using perturbation technique [3-4] the received field can be used to obtain tomographic image. Subsequent modifications are made in first order and second order algorithm [5].

It has been observed that the above algorithm fails to reconstruct larger model with large number of higher order terms (greater than two) and also fails in case of smaller model with large perturbation.

Considering the limitations of above algorithm, a new exact algorithm [6] has been developed. This algorithm is applied on normal model as well as an diseased model and reconstructed complex permittivity is observed from single side and two opposite sides of the target.

II. An Exact Algorithm For Large Perturbation

The field distribution in unperturbed homogeneous medium is expressed by the following equation:-

$$[C].[E_i]=[E^i] \quad (1)$$

Where E^i is represented as the incident field at i^{th} cell in the free space and E_i represents the internal field at the same i^{th} cell when the medium is assumed to be a homogeneous one having known permittivity distribution and [c] represents the coefficient matrix of homogenous medium.

When the homogeneous biological target is replaced by the inhomogeneous one, the permittivity values of the cell are perturbed simultaneously by small amounts $\Delta\epsilon_i(i=1,2,3..n)$ and if the corresponding changes in the internal field are ΔE_i then

$$[C^{'}].[E_i+\Delta E_i]=[E^i] \quad (2)$$

Where $[C^{'}]$ is the coefficient matrix of the inhomogeneous medium

Subtracting eq 1 from 2 the change in the electric field can be given by

$$\Delta E_i = -x_i E_i^{'} + \sum_{j=1}^{n} x_j E_j \frac{M_{ji(0)}}{\Delta(0)} \quad (3)$$

Where $E_i^{'}$ is the modified field in the i[th] cell under perturbed condition, $\Delta(0)$ and $M_{ji(0)}$ are the determinant and cofactor of (j , i) th element of unperturbed coefficient matrix [C] respectively. x_i is the requisite fractional change in the complex permittivity of the cell with respect to saline water i.e $x_i = (\varepsilon^{'} - \varepsilon_w)/(\varepsilon_w - 1)$ €',€w are the complex permittivity of saline water(74-j40) and model cell respectively. There will be a resultant change in the scattered field at a particular receiver location owing to the change of internal fields at the different cells of the medium caused by perturbation of complex permittivity distribution. The net change in the scattered field, ΔE_R^s (k) at the R[th] receiver location corresponding to the k[th] beam can be determined from the equation

$$\Delta E_R^s = \sum_{j=1}^{n} x_j E_j^{'} \frac{M_{j,R(0)}}{\Delta(0)} \quad (4)$$

Since x_i=0 for all receiver cell as they are located in saleline water.

If E_{Rml} (k) denotes the scattered field intensity at the R[th] receiver location for the kth beam in the inhomogeneous numerical model and E_{Rol}(k) denotes the calculated scattered field intensity at the same receiver location for the same k th beam for the assumed known homogeneous permittivity_ distribution for the object, then the resultant change in scattered field intensity, $\Delta E_k^s(k)$ at a particular receiver location is expressed in terms of the unknown variables xj 's (i.e. the requisite fractional change of unknown permittivity from the assumed initial trial solution of permittivity), relevant cofactors and determinant of coefficient matrix corresponding to the homogeneous medium and perturbed internal fields corresponding to the inhomogeneous model. Therefore, solving previous equation the total change in the scattered field at +

$$\Delta E_R^s(k) = E_{Rml}(k) - E_{Rol}(k) = \sum_{j=1}^{m} x_j E_j^{'} \frac{M_{j,R(0)}}{\Delta(0)} \quad (5).$$

III. Comparative Study between Single Sided Scanning and Multiple Sided Scanning

3.1 Numerical model

The numerical model under study is a biological object, rectangular in shape. The model contains 360 cell of size 1 sq.cm and consists of different human organs viz. liver (46-j10), muscle (50-j23), muscle type material (40-j23) and fat (25-j5). It is surrounded by 340 cells of saline water. It is illuminated by 24 transmitters antenna which is designed with (each of 15x15 dipole array antenna) of beam width 6^0 and the radiation is received by 20 half wave dipoles acting as receiver. The distance between the transmitter and the receiver is 50cm. The total arrangement is immersed in water to get better impedance matching and small antenna size.[5].

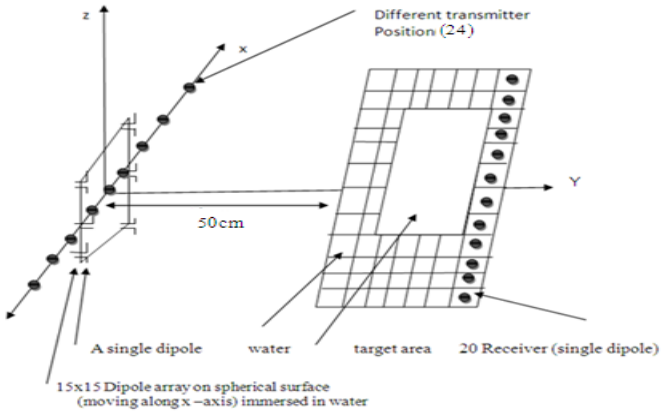

Fig 1 Block diagram of the proposed experimental set up

3.2 Two Opposite Sided scanning of the Biological Target

The quality of the reconstructed image is improved further by incorporating two opposite sided scanning technique which is discussed below in brief:For the different positions of transmitter and receiver complex permittivity is calculated and average is done. A modified cell scanning technique is adopted [7-8] where the beam width of the transmitting antenna is taken as 6^0. Thus the number of cells where change in internal field takes place due to change of complex permittivity in a particular cell is reduced and thereby reduces the error caused by the process of SIRT algorithm itself [3,4,5,6].

.Next, the position of the transmitters and receivers are interchanged and reconstructed complex permittivity of each cell is calculated again by using equation(5). The image of the biological target is reconstructed by using the average value of the complex permittivity in each cell obtained by cell scanning technique from two opposite side of numerical biological object. Employing this, different values of reconstructed complex permittivity are found for the two different positions of transmitters and receivers. Then the average value is calculated.

4.2 Figures and Tables

Using the reconstructed algorithm for all above cases, the experimental data are simulated [9] and corresponding images are shown below:

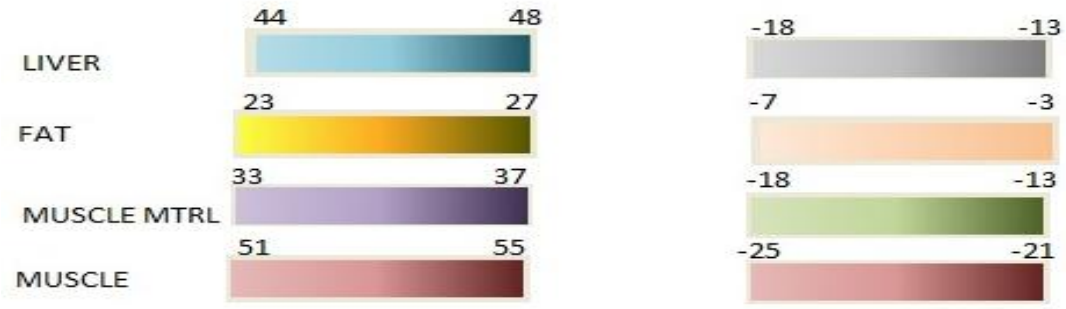

Fig 2 color gradation for real and imaginary parameter respectively

IV. Reconstruction of normal model

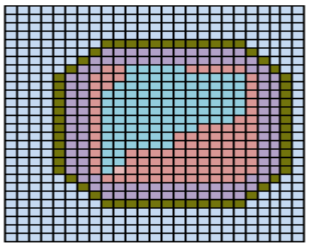

Fig 3.1

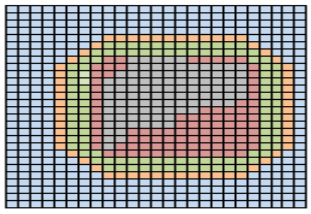

Fig 3.2

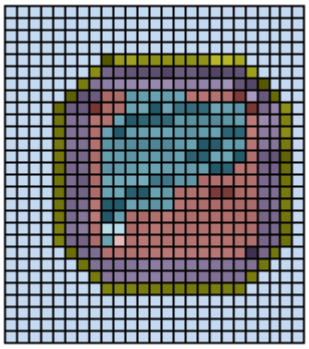

Fig 3.3

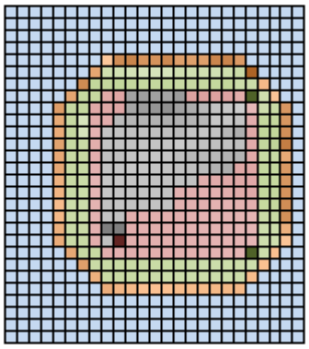

Fig 3.4

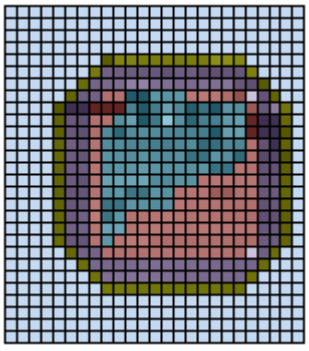

Fig 3.5

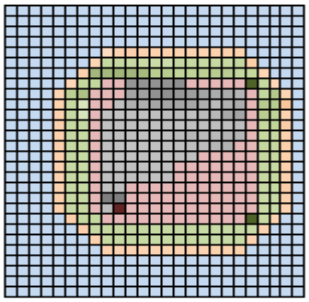

Fig 3.6

Fig 3.1 &3.2: Real and imaginary values of complex permittivity of normal model; Fig 3.3 & 3.4: Reconstructed real and imaginary values of complex permittivity of normal model using single sided view; Fig 3.5 & 3.6 Reconstructed real and imaginary values of complex permittivity normal model using two opposite side views;

V. Reconstruction of Diseased model

The model under study is the same as that considered in earlier case, except its liver region is assumed to be affected and hence characterized by a different value of complex permittivity (48-j12) [1] where as for normal liver it is assumed to the (46-j10).

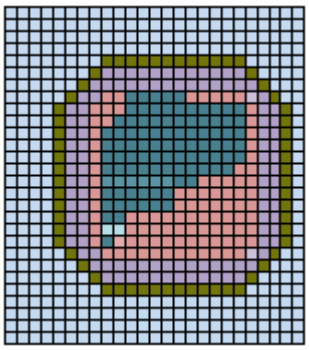

Fig 4.1

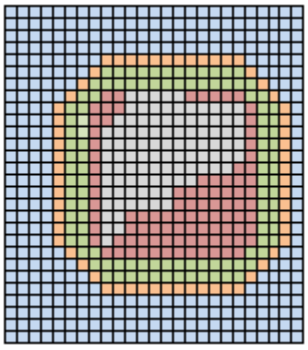

Fig 4.2

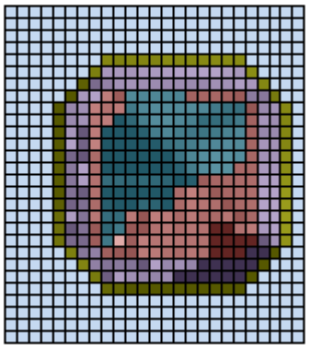

Fig 4.3

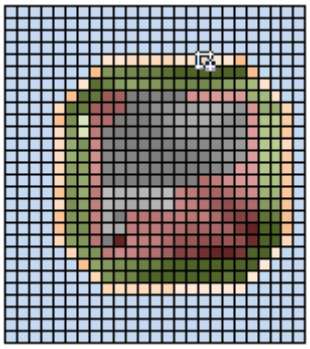

Fig 4.4

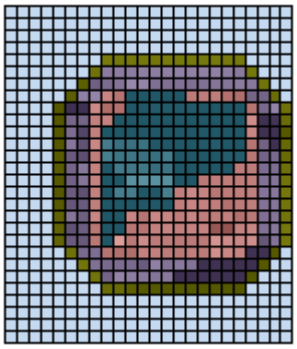

Fig 4.5

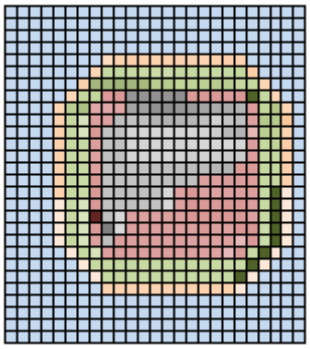

Fig 4.6

Fig 4.1 &4.2: Real and imaginary values of complex permittivity of diseased model; Fig 4.3 & 4.4: Reconstructed real and imaginary values of complex permittivity of diseased model using single sided view; Fig 4.5 & 4.6 Reconstructed real and imaginary values of complex permittivity diseased model using two opposite side views;

Table 1

Average value of permittivity in different organs of the normal model for different cases

Different organs of models	**Average values of complex permittivity of different organs**		
	Normal model	**Reconstructed normal model**	
		Using single side scanning	**Using two opposite side scanning**
Fat	25-j5	24.63-j-4.38	24.70-j4.56
Muscle	53-j27	51.81-j25.12	51.90 -j25.62
Muscle Material	35-j15	33.64-j13.57	34.51-j13.92
Liver	46-j10	44.62-j9.62	45.41-j9.71
Water	76-j40	76-j10	76-j10

Table 2
Average value of permittivity in different organs of the diseased model for different cases

Different organs of models	**Average values of complex permittivity of different organs**		
	Diseased model	**Reconstructed normal model**	
		Using single side scanning	**Using two opposite side scanning**
Fat	25-j5	26.22-j5.96	25.32-j4.56
Muscle	53-j27	51.28 -j22.00	51.91-j29.07
Muscle Material	35-j15	36.33 -j12.93	36.06-j15.43
Liver	48-j12	48.58 -j8.40	48.34-j11.13
Water	76-j40	76-j10	76-j10

VI. CONCLUSION

In this paper an overall improvement in reconstructed image of the biological object has been obtained when Exact SIRT cell scanning technique is applied from two opposite sides of the target.From normal model, the accuracy in reconstructed image of the real part of complex permittivity is increased from (80.4-98.75%) to (92.59%-99.31%) when views are taken from two opposite sides. In case of diseased model the reconstructed image of the imaginary part of the complex permittivity for liver region is far better in double sided cell scanning technique (99.13%) than obtained from single side (70%). The improvement shows that the image quality will be more accurate it will be taken from all sides.

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