Study of Beamwidth Variation of Dipole Array Antenna for Microwave Scanning of Biological Target

Dr. Kabita Purkait [1]
[1] Associate Professor,
Department of Electronics &
Communication Engineering,
Kalyani Govt. Engineering College,
West Bengal, India,
kp_lectrpk@yahoo.co.in

Deborsi Basu [2]
[2] M. Tech, Electronics &
Communication Engineering,
Kalyani Govt. Engineering College,
West Bengal, India
deborsibasu2015@gmail.com

Nayan Ranjan Das [3]
[3] M. Tech, Electronics &
Communication Engineering,
Kalyani Govt. Engineering College,
West Bengal, India
nayanranjan1993@gmail.com

Abstract— A broadside quarter wave dipole array antenna has been proposed for microwave scanning of biological body with high contrast in complex permittivity in the near field region. The dimension of inhomogeneities in complex permittivity in different cells of biological target is of the order of millimeter, so the spatial resolution required for medical imaging will be at the same millimeter range. Hence to increase the resolution of the microwave imaging system the beamwidth of the interrogating wave should be minimized. Two different approaches have been studied here for the reduction of beamwidth of near field pattern of dipole array antenna. In the first case the operating frequency is kept constant at 2.4 GHz and the variation of beamwidth has been observed for five different sets of dipole array elements. Beamwidth decreases with the increase of number of array elements. In the second approach the variation of beamwidth of antenna field pattern has been studied with different values of operating frequencies from 2 GHz to 5 GHz while number of dipole elements in the array remains fixed. The beamwidth decreases with the increase of operating frequency.

Keywords-*Dipole array antenna, Field pattern, Beamwidth, Microwave, Complex permittivity.*

*****

I. INTRODUCTION

Microwave imaging of human body has been drawing great interest for a number of years[1,2]. Microwave Tomography may be represented as an alternative to commonly used imaging techniques such as X-ray Computed Tomography, Ultrasound Tomography and Magnetic Resonance Imaging (MRI). It is an inexpensive as well as a non-invasive technique for detecting the changes in the complex permittivities which can be applied as a screening method in clinical applications such as detection of Cancer in breast, Lungs, Kidneys or in any internal organs of human body, monitoring of Brain Stroke and Cardiac imaging[3,4] etc.

Complex permittivity of a biological cell depends on its water content and this water content changes with the infection of diseases[5]. Thus variation of complex permittivity of a cell from its normal value discriminates the diseased one from the healthier one. The resolution of an imaging system depends on how close the two cells are differentiated by their complex permittivity values. This necessitates scanning of the target cell by transmitting signal of narrow beamwidth.

In this paper two different approaches have been focused to make narrow beamwidth in the near field pattern of the transmitting signal. A broadside quarter wave dipole array antenna is proposed for illuminating the model of our interest. The incident field intensity at each cell of the model is calculated with the help of field equations of dipole array antenna in the near field region when each cell is assumed to be filled with saline water. The field patterns are plotted for different number of dipole array elements and observed that the beamwidth gradually reduces with the increase in the number of array elements while operating frequency is kept constant at 2.4 GHz. In the second case, the field patterns are calculated and plotted for different operating frequencies from 2 GHz to 5 GHz while maintaining the number of array elements fixed at 15 in each case. The signal has become more directive with the increase of operating frequency.

II. PROPOSED BIOLOGICAL MODEL AND TRANSMITTING ANTENNA SYSTEM

The dimension of the proposed model is 20 cm X 20 cm consisting of total 10,000 cells each having an area of 2 mm X 2 mm. The model is surrounded by an area of thickness of 2 cm. and filled with matching medium of saline water having complex permittivity value of (76-j40) as shown in figure 1.

The proposed model consist of different regions of arbitrary shape which are assumed to have separate complex permittivity value identical to that observed in different human organs[7]. Differences in complex permittivity values are depicted by color variations. The entire model is developed with the help of Matlab version R2008b.

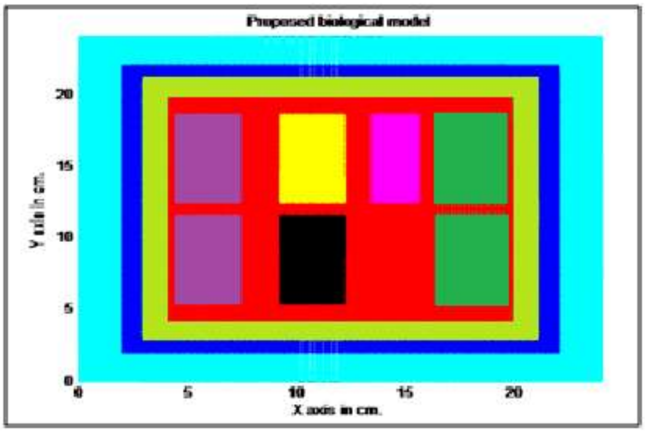

Figure 1: Proposed Biological Model

- Matching medium – Saline water, Thickness 2 cm, Complex permittivity: 76-j40.
- Muscle region, Thickness 1 cm, Complex permittivity: 50-j23, Total number of cell present – 1900.
- Bone region, Thickness 1 cm, Complex permittivity: 8-j1.2, Total number of cell present – 1700.
- Blood cell region, Complex permittivity: 60-j26.
- Lung region, Dimension 2.8cm X 6 cm, Total number of cells – 930, Complex permittivity: 23.2-j16.2.
- Stomach region, Dimension 2.8cm X 6 cm, Total number of cells – 930, Complex permittivity: 60-j18.
- Liver region, Dimension 2.8cm X 6 cm, Total number of cells – 930, Complex permittivity: 46-j10.
- Pancreas region, Dimension 2.4cm X 6 cm, Total number of cells – 682, Complex permittivity: 65-j30.
- Kidney region, Dimension 3cm X 6 cm, Total number of cells – 992, Complex permittivity: 80-j1.2.

ANTENNA SYSTEM

A broadside dipole array antenna of 15 quarter wave dipole elements with a separation of half wavelength between two adjacent elements placed at 42 cm away from the model is used as transmitting antenna. The operating frequency is fixed at 2.4 GHz. The entire set up is immersed into saline water to reduce the effective wavelength and to decrease the losses due to impendence mismatching. The parameters of the antenna are as follows:-

Length of each element = $\lambda / 4$

Separation between two adjacent elements = $\lambda / 2$

III. DESIGN EQUATION OF FIELD PATTERN OF DIPOLE ARRAY ANTENNA

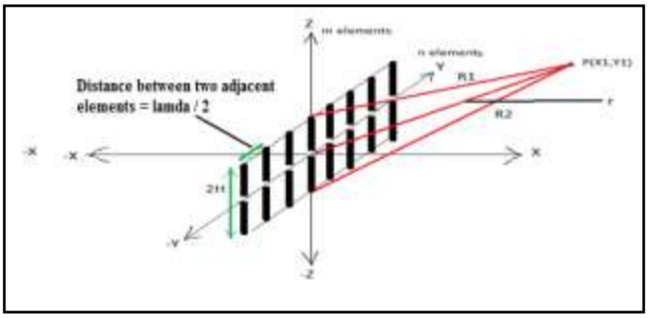

Figure 2: Field calculation of dipole array antenna at a point on the model

For this configuration the field equations are as follows:

$$r_{mn} = [(x1 - x2)^2 + (y1 - y2)^2]^{1/2} \quad ....(1)$$

$$R_{1mn} = [(x1 - x2)^2 + (y1 - y2)^2 + (z + H)^2]^{1/2} \quad ..(2)$$

$$R_{2mn} = [(x1 - x2)^2 + (y1 - y2)^2 + (z - H)^2]^{1/2} \quad ..(3)$$

$$E_{zmn} = -j30I_m\left[\frac{e^{-j\beta(R_{1mn})}}{R_{1mn}} + \frac{e^{-j\beta(R_{2mn})}}{R_{2mn}} - 2\cos(\beta H)\frac{e^{-j\beta(r_{mn})}}{r_{mn}}\right] \quad ..(4)$$

Where I_m = value of current maximum,

μ = permeability of free space,

ε = dielectric constant of free space,

$\beta = \dfrac{2\pi}{\lambda}$ = wave number.

r_{mn}, R_{1mn}, R_{2mn} are the distances as shown in figure 2.

E_{zmn} = Field intensity for m,n th antenna element.

H = $\lambda / 8$ (2H = Length of a dipole antenna)

The equations (1), (2), (3) & (4) are derived from the near field equations of a dipole array antenna[8].

IV. VARIATION OF BEAMWIDTH WITH THE NUMBER OF DIPOLE ARRAY ELEMENTS

The incident field intensity at the centre of each cell of the model is calculated by using equation (4) and the normalized value of electric field is plotted against the model cell positions in a direction parallel to antenna array as shown in figure 3. The procedure is followed for the said dipole array antenna using elements of 11,15,17,19 and 21. The beamwidth is calculated in all five cases and is shown in Table I.

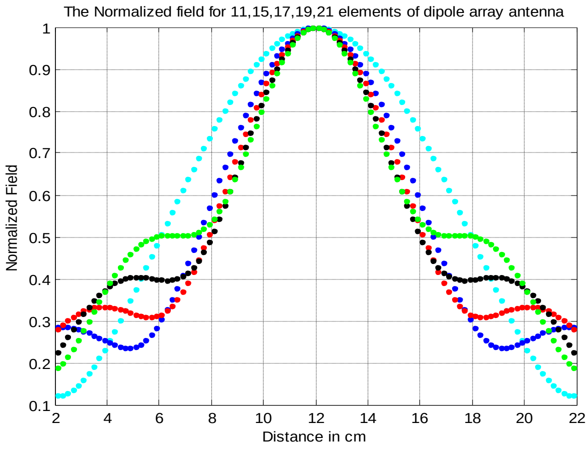

Figure 3: The Normalized Field pattern for 11,15,17,19 & 21 elements of dipole array antenna

- Field pattern for 11 elements.
- Field pattern for 15 elements.
- Field pattern for 17 elements.
- Field pattern for 19 elements.
- Field pattern for 21 elements.

Frequency of operation: 2.4 GHz

TABLE - I

NUMBER OF ELEMENTS	*BEAMWIDTH (DEGREES)*
11	**11.49**
15	**8.83**
17	**7.76**
19	**7.23**
21	**7.23**

V. VARIATION OF BEAMWIDTH WITH FREQUENCY

The dipole array antenna with 15 quarter wave dipole elements is taken and frequency of operation is selected at 2GHz and the same is repeated for 2.4GHz, 3GHz, 4GHz and 5GHz. The incident field intensity at the centre of each cell of the model are calculated by using equation (4) with MATLAB programming. The normalized value of electric field is plotted against the cell positions for each frequency of operation as shown in figure 4. The calculated beamwidth for each frequency of operation are shown in Table II.

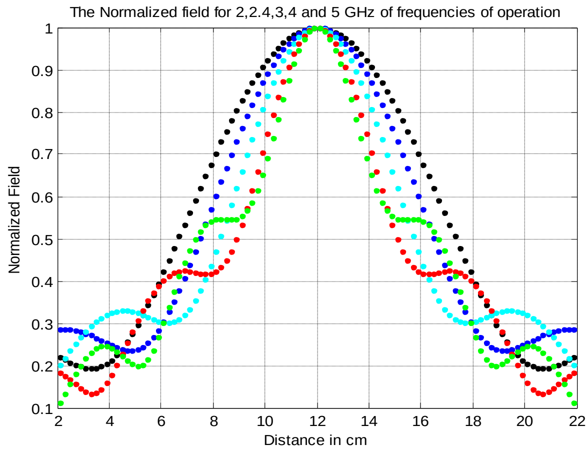

Figure 3: The Normalized Field pattern of dipole array antenna for operating frequencies 2, 2.4,3,4 & 5 GHz

- Field pattern for 2 GHz.
- Field pattern for 2.4 GHz.
- Field pattern for 3 GHz.
- Field pattern for 4 GHz.
- Field pattern for 5 GHz.

Number of dipole array antenna elements: 15.

TABLE - II

FREQUENCY (GHz)	*BEAMWIDTH (DEGREES)*
2	**10.43**
2.4	**8.83**
3	**7.23**
4	**5.63**
5	**5.09**

VI. CONCLUSION

Distribution of incident field in the near field region shows that the proposed antenna may be used for medical imaging of biological target. Beamwidth of the antenna decreases with the increase of the number of array elements because beamwidth is inversely proportional to the antenna aperture size which is directly related with the number of array elements. Beamwidth obtained with 19 and 21 elements are same which indicates that there is a limitation of minimum beamwidth.

From the variations of beamwidth with frequency it is shown that the proposed antenna will operate in ISM band and beamwidth decreases with increase in frequency as beamwidth is inversely proportional to frequency. Using exact algorithm[6,7] the field at the receiver locations can be calculated and finally reconstructed image of a human size biological model will be obtained in near future .

ISSN: 2321-8169
120 – 123

REFERENCES

[1] L.E. Larsen, J.H. Jacobi, “Microwave scattering parameter imagery of isolated canine kidney.” Medical Physics, 6 (1979) 394-403.

[2] J.H. Jacobi, L.E. Larsen and T.C. Hast, “Water immerse Microwave antennas and their application to microwave Interrogation of biological targets.” IEEE Trans. Microwave Theory and Techniques, MTT-27 (1979) 70-78.

[3] S. Semenov, “Microwave tomography: review of the progress towards clinical applications,” Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 367, issue 1900, pp. 3021-3042, 2009.

[4] R. Scapaticci, L. Di Donato, I. Catapano, and L. Crocco, “A feasibility study on microwave imaging for brain Stroke monitoring," Progress In Electromagnetics Research B, Vol. 40, 305-324, 2012.

[5] A. N. Datta & B. Bandyopadhyay, “An Improved SIRT- Style Reconstruction Algorithm for Microwave VOL. Tomography”IEEE Transactions on Biomedical Engineering, BME-32, NO. 9, September 1985,pp. 719-723

[6] K. Purkait & S. Mandal, “Multiview Microwave Tomography of Biological Body”, RTCSP National Conferrance, Electron, Vol-3, March -2011.

[7] S. MANDAL and K. PURKAIT, “A Modified Exact Reconstruction Algorithm for Microwave Tomography for Detection of Disease in Human Body”.ITJS, Vol – 18,F11, pp-82-92 January, 2011.

[8] Edward C. Jordan, Keith G. Balmain “Electromagneti Waves and Radiating Systems”, Prentics-Hall Electrical Engineering Series, William L. Everitt Editor, Englewood Cliffs, New Jersey. (P: 317 to 331, & Chapter 11)