EXPERIMENTAL STUDY OF NEAR-FIELD BEAMFORMING IN CONFORMAL K-BAND LINEAR ARRAYS

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I. INTRODUCTION

Microwave Hyperthermia has been used successfully in non-invasive treatment of tumors on the surface or just below the surface of the human body [1]. The precise focusing of beams in the near-field zone of the applicator is quite complex, and conformal antennas, owing to their flexible contour, can blend with the local body surface area. This paper details experimental studies on a K band waveguide array (18-26 Ghz), operating as a linear arc array. The array has two directing waveguides and one focusing waveguide, and conformal shape can be achieved by movement of the only the focusing element.

II. GEOMETRY OF 3 -ELEMENT CONFORMAL ARRAY

The geometry of the conformal linear array is shown in Figure 1. For linear geometry coordinates of the 3 elements are given below in Table 1.

Table 1. Position coordinates of 3 element array

ELEMENT NUMBER	X POSITION (CM)	Y POSITION (CM)	Z POSITION (CM)
1 (Directing)	10.4	0.0	0.0
2 (Focusing)	0	0.0	Variable
3 (Directing)	-10.4	0	0.0

The total field of the array at a near-field point P(x,y,z) can be obtained by superposition. Mutual coupling effects among the elements of the array are very minimal, owing to the large separation between the elements of the array (> 1 wavelength at 20 GHz), as seen from Table 1. Assuming TE_{10} x-directed dominant mode field over each waveguide aperture , the total field of the array is given as [2]:

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$$E_x = \sum_{p=1}^{3} I_p E_{x0}(x - x_p^{'}, y - y_p^{'}, z) \quad (1)$$

where I_p is the current excitation of the pth element of the array, and assumed uniform. E_{x0} is the field of the central element of the array, with its aperture center at point (0,0,0). In an earlier paper [3], simulation results have been reported on this array.

III. NEAR-FIELD MEASUREMENT RESULTS

The near-field antenna measurements were carried out using the HP8720C Network Analyzer at a frequency of 18 GHz. The array comprised of K-band rectangular waveguides with aperture dimension of 10.7 mm x 4.3 mm.The near-field probe used was also a standard K-band rectangular open-ended waveguide. Keeping near-field focusing applications in mind, the array current distribution utilized was [0 –13 0] dB, to give a sharp focus point. The z axis variation of electric field is shown in Figure 2a. In the latter plot, the field variation is shown for two z-positions of the focusing element: z = 10 mm and 20 mm, and it can be seen that, while the field value remains constant, the beam maximum moves along the z axis. Once the z-axis peak is located, in this case at $z = z_{focus}$, the x-y variation of the field is measured at $z = z_{focus}$. Figure 2b shows the measured x-y field distribution in the $z = z_{focus}$= 30 mm plane for the focusing element position of z = 10 mm. Similarly Figure 2c shows the measured x-y field distribution in the $z = z_{focus}$= 40 mm plane for the focusing element position of z = 20 mm.

IV. CONCLUSION

This paper presents experimental results on a 3-element conformal K-band antenna array operating in the 18-26.5 GHz. The results demonstrate that a focused beam can be obtained and steered using the central focusing element of the array. The array has potential application in microwave hyperthermia, where the beam should focus on the tumor area, but direct minimum power onto neighboring healthy tissue.

V. REFERENCES

1. J. Thuery, *Microwaves : industrial, scientific, and medical applications* edited by Edward H. Grant, Artech House, 1992.
2. M.S. Narasimhan & B. P. Kumar, “A Technique of Synthesizing the Excitation Currents of Planar Arrays or Apertures.”, *IEEE Transactions on Antennas and Propagation*, Vol.38, pp. 1326-1332, Sept 1990.
3. Karnik, B.P. Kumar, and G.R. Branner, ‘Conformal K Band 5 Element Waveguide Array For Near-Field Applications’, accepted for presentation at the *2001 IEEE Antennas and Propagation Society International Symposium*, Boston, July 2001.

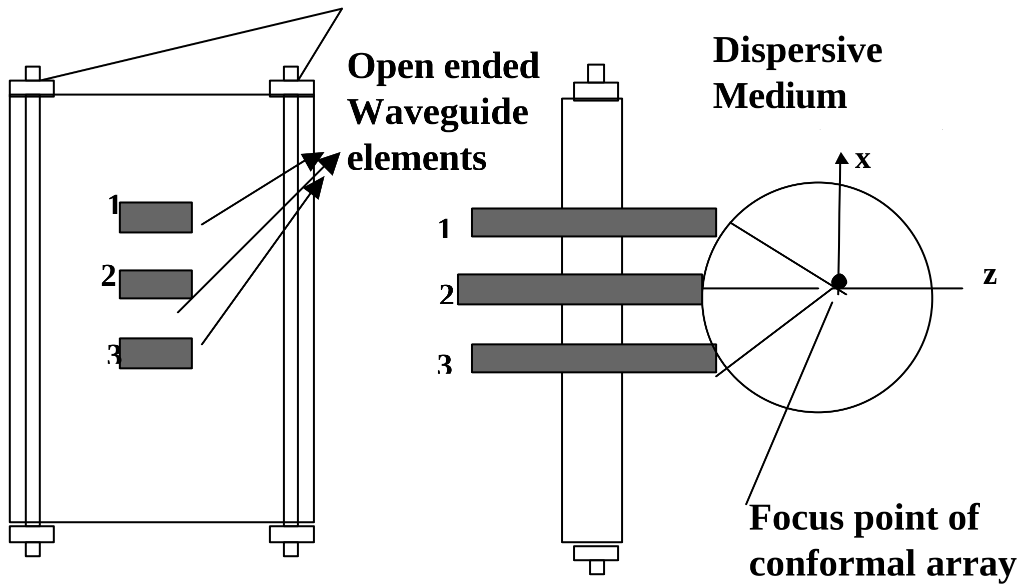

Figure 1. Geometry of the 3 element conformal linear array

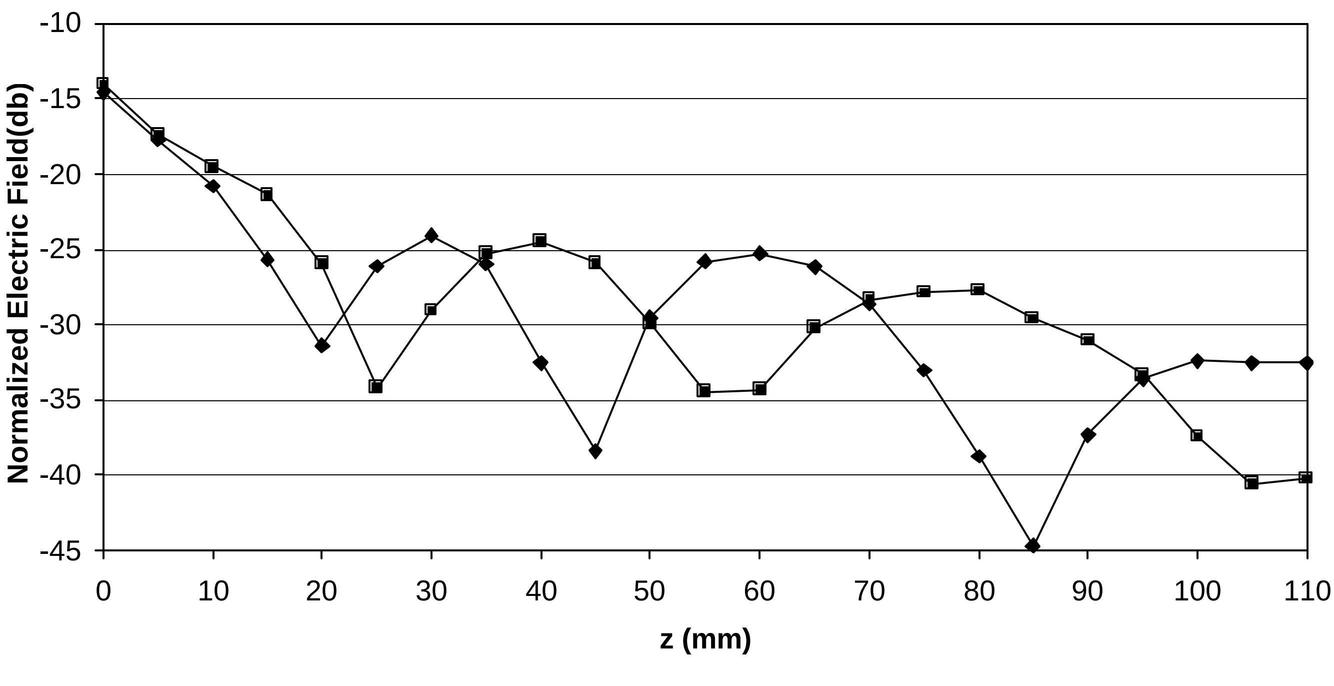

Figure 2a. 3 Element Array with Current =[0 –13 0] dB:
Beam shift by z-position variation of focusing element from 10 mm to 20 mm.

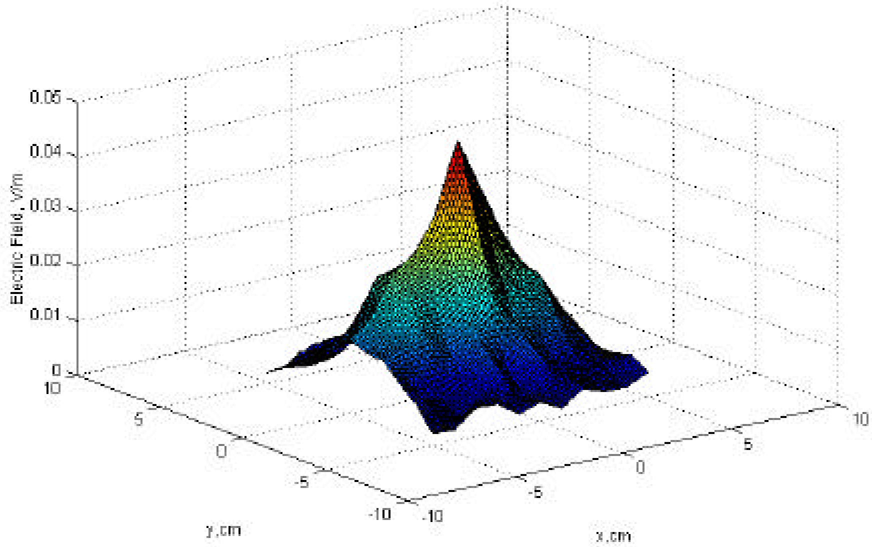

Figure 2b. 3 Element Array with Current =[0 –13 0] dB and focusing element z-position of + 10 mm:
Electric field variation in x-y plane at z-position of +30 mm (peak)

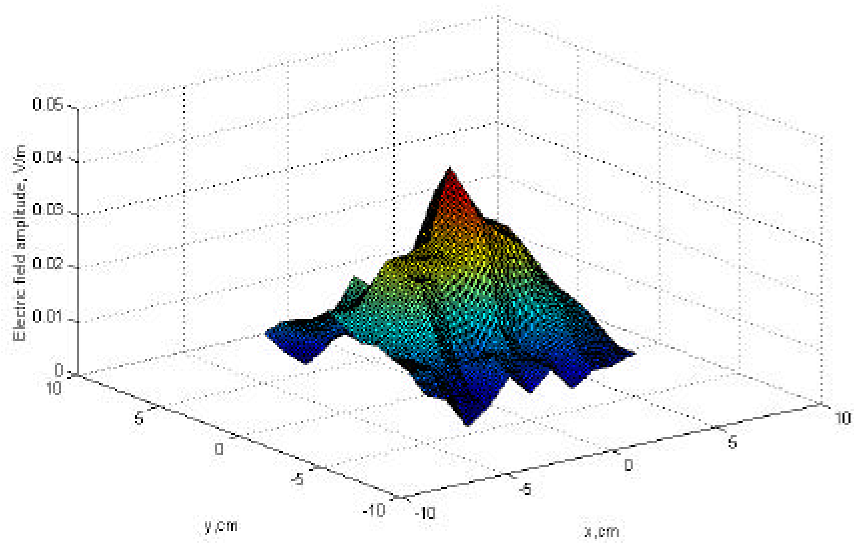

Figure 2c. 3 Element Array with Current =[0 –13 0] dB and focusing element z-position of + 20 mm:
Electric field variation in x-y plane at z-position of +40 mm (peak)