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# INVESTIGATION OF THREE ARRAY GEOMETRIES FOR FOCUSED ARRAY HYPERTHERMIA

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## Introduction:

Microwave hyperthermia has made significant advances over recent years and increased interest is being shown in phased array systems for localizing power in the tumor region without overheating surrounding normal tissue [1,2]. The array geometry, element spacing and applied tapering offer many degrees of freedom for the designer to optimize the performance of the focused array. Various array geometries have been investigated [3,4].

The imaging properties of three array configurations, filled planar, quad, and crossed array have been studied for radar applications [5]. The purpose of this paper is to investigate the properties of these array configurations when they are operated as focused arrays in lossy medium. The resultant power patterns will help to find their usefulness for hyperthermia application.

## Analysis of focused arrays:

An expression for the near field of the focused array can be derived following the analysis of Guo 6 . The antenna is treated as a localized current distribution due to small apertures. Then it can be shown that the normalized electric field is given by:-

$$\vec{E}(\vec{r}) = \sum_{n=1}^{N} C_n \frac{\mathrm{EXP}(-j\gamma|\vec{r}-\vec{r}_n|)}{|\vec{r}-\vec{r}_n|} \sin\theta_n \left(\cos\theta_n \cos\phi_n \vec{a}_x + \cos\theta_n \sin\phi_n \vec{a}_y\right) - \sin\theta_n \vec{a}_z)$$

where $\gamma$ is the propagation constant, $\vec{r}$, $\vec{r}_n$ are vectors representing the observation point and the center of the nth element respectively with respect to the array center. $C_n=I_n e^{j\Psi_n}$ is the weighting factor necessary to focus the array. $\Psi_n$ is chosen such that the N elements of the array produce constructive interference at the focal point and $I_n$ is chosen according to the required tapering.

## Computer simulation:

The imaging properties of filled planar, quad and crossed array configurations have been studied for radar applications [5]. The focusing properties of these configurations are studied here by computer simulations. Each of the arrays, see Fig. 1, consisted of 16 elements located on a square area of 9 x 9 cm. Figure 2 shows normalized power variation along normal axis to the array when it is focused at 5.5 cm in water and driven with $I_n = 1$ at 2.45 GHz. Although maximum power is obtained at the focus by the quad array, the planar array has much better power localization as shown in Fig. 2. The crossed array has significantly lower side lobes as shown in Fig. 3.

In the above comparison, equal size and number of elements for the three arrays were used which resulted in different element spacing for the three arrays. Since element spacing highly affects side lobe level, the element spacing and the antenna dimention for the quad and crossed arrays are now fixed to that of the planar array of Fig. 1a to get the arrays shown in Fig. 4. The normalized power variations along normal axis for these arrays are shown in Fig. 5. Comparing with Fig. 2, the quad array is not affected by the number of elements and element spacing but the penetration of the crossed array is now decreased with smaller number of elements. The power patterns at the focal point for the three arrays are shown in Fig. 6. Higher side lobes were obtained for the quad and crossed arrays compared to those shown in Fig. 3, however, the crossed array is still of lower side lobes among the configurations of Fig. 4.

Conclusions:

The effect or array shape, size and number of elements on the focusing properties has been demonstrated by comparing the performance of three array configurations. The filled array has better focusing performance while crossed array has lower side lobe and lower number of elements.

References:


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6 - Guo, T.C. et al., "A local field study of a water-immersed microwave antenna array for medical imagery and therapy", IEEE Transc., Vol. MTT-32, No. 8, 1984, pp. 844-854.

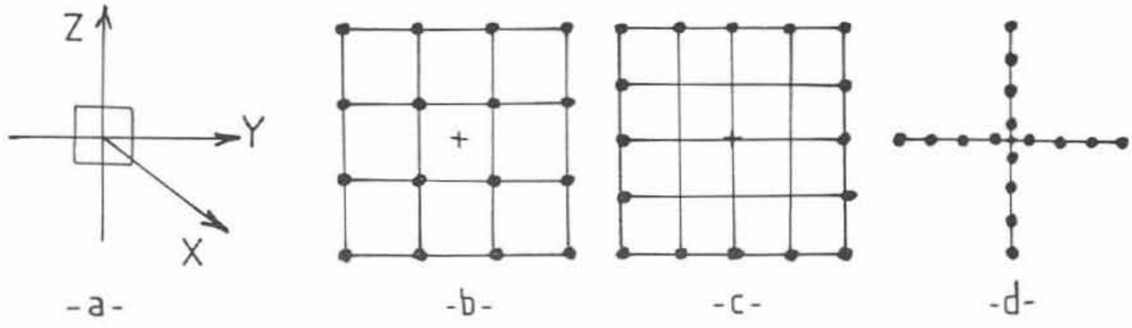


Fig. 1 Three array geometries of 16 elements and 9x9 cm size focused at 5.5 cm depth in water. a) coordinates, b) planar array, c) quad array, Dd) crossed array .

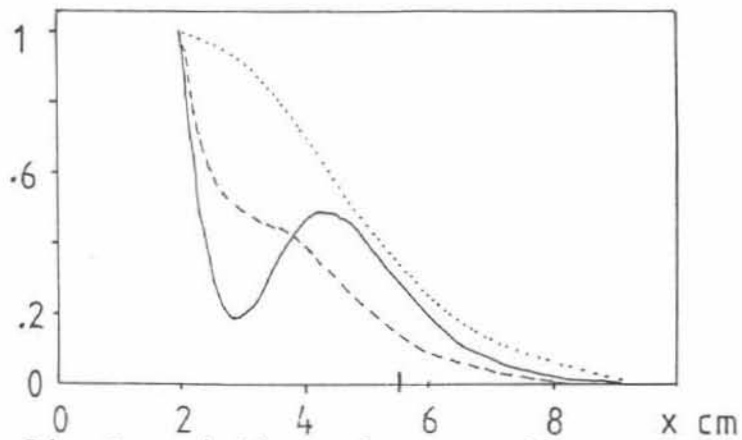


Fig. 2 Normalized variation of power along normal axis to the arrays of Fig. 1 , (———) planar array, (··········) quad array, (-------) crossed array .

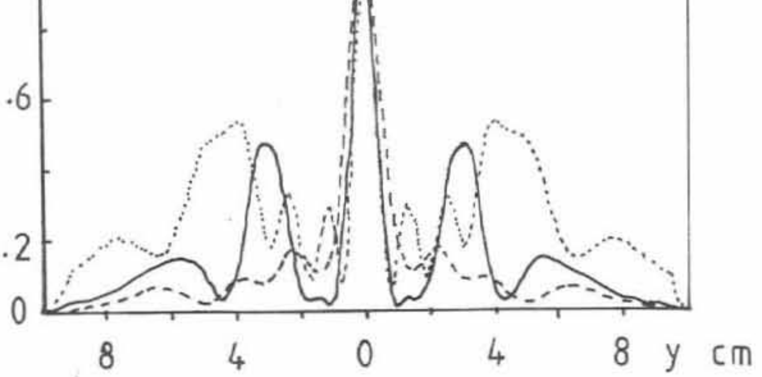


Fig.3 Focal plane power patterns of the three arrays of Fig. 1 , (———) planar array, (·········)quad array, (------) crossed array.

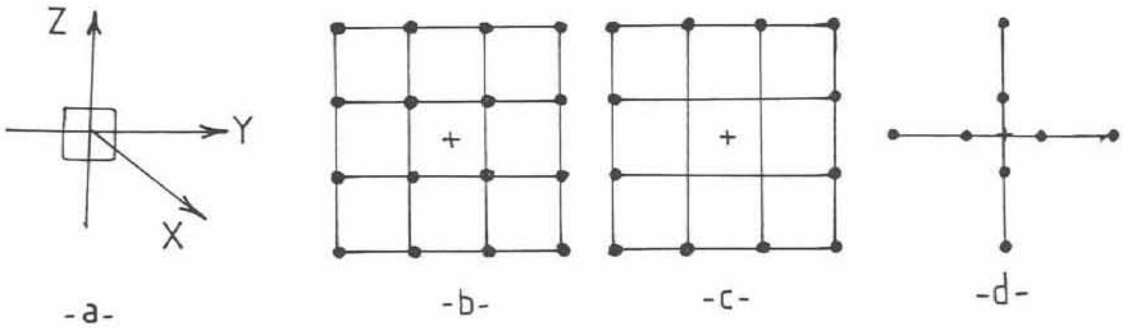


Fig. 4 Three array geometries of equal size (9x9 cm) and element spacing ( 3 cm) focused at 5.5 cm depth in water. a) coordinates, b) planar array, c) quad array, d) crossed array.

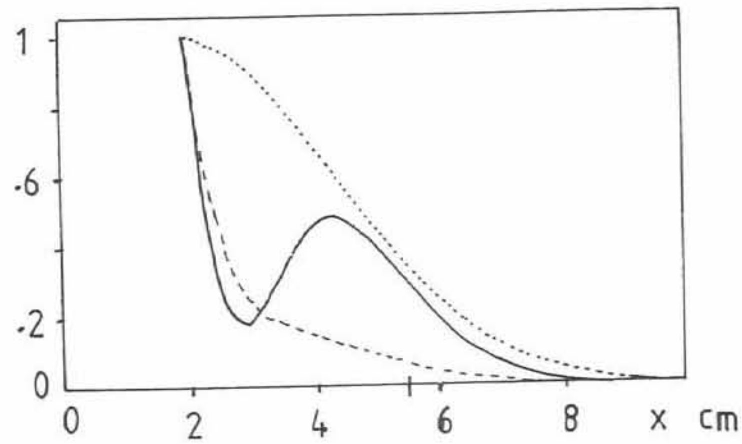


Fig. 5 Normalized variation of power along normal axis to the arrays of Fig. 4, (———) planar array, (··········) quad array, (-----) crossed array.

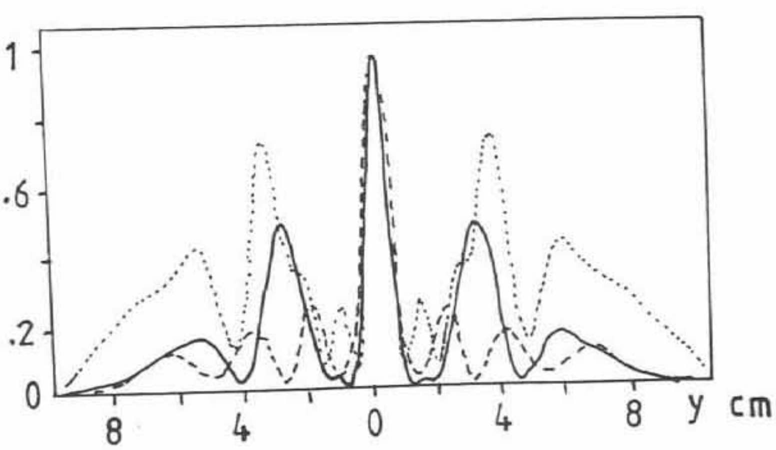


Fig. 6 Focal plane power patterns of the three arrays of Fig.4, (———) planar array, (··········) quad array, (-----) crossed array.