

Shared-Aperture Dual-Band Microstrip Array

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Abstract We present here two linear arrays mounted in the same aperture: the first array with 4 elements at 2.7 GHz (spacing 0.7λ) and the second array with 4 elements at 7.0 GHz (spacing 1.8λ). It is shown that by special design of the single high frequency element grating lobes are eliminated. The isolation between the two arrays is better than 14 dB.

Index Terms — shared aperture, microstrip array, multi-functional arrays

I. INTRODUCTION

Antenna arrays with multiple elements are frequently used in radars, communications, astronomy and other radio systems and devices. In many cases, it is desired to operate more than one antenna within a given aperture. For example, in radars, the designers wish to incorporate also communication systems, passive or active sensors, direction finding and mm-waves small-size radars [1]-[3]. These applications, known as "shared apertures" involve sometimes the removal of certain areas of the array, known as "thinning", while the cleared area is occupied by different antenna elements [4]-[5]. In other cases, some multi-layers structures can be used to include several radiators in different frequencies on the same area. One of the problems is when the applications in use are operated in totally different frequencies. The distance between adjacent elements may exceed one wavelength in the higher frequency and undesired grating lobes are created.

Here we propose a quite rare configuration [6]-[7] of two microstrip arrays that occupy the same aperture, at frequencies 2.7 GHz and 7.0 GHz. The array in the high frequency includes 4 pairs of horizontal elements where the spacing between elements is 1.8λ . The array in the low frequency has 4 vertical elements with spacing of 0.7λ . The arrangement reduces the mutual coupling as required. Due to special design of the single element in the high frequency, we can prevent the appearance of grating lobes, although the distance between elements is 1.8λ .

The paper includes the geometry of the arrays, simulation results, measurement results and conclusions. The aim is to prove the concept and not to build a specific product.

II. THE CONCEPT

The appearance of grating lobes in any array, their quantity and their directions are governed by formula (1):

$$\theta_{GL} = \arcsin (+/- n\lambda/d) \quad (1)$$

where θ are the angles for different orders of n
 λ is the wavelength
 d is the distance between elements

For example, if we design for distance of $d = 0.7\lambda$, the grating lobes are eliminated. If we design for distance of $d = 1.8\lambda$, two grating lobes appear at $\pm 34^\circ$.

Figure 1 shows the pattern of 5 isotropic elements with spacing of 0.7λ . Figure 2 shows the pattern of 5 isotropic elements with spacing of 1.8λ . Figure 3 shows the pattern of a 5 element array where each element is designed theoretically to have a null at $\pm 34^\circ$. We see a clear pattern without grating lobes and with quite low sidelobes. This is the essence of the proposed study.

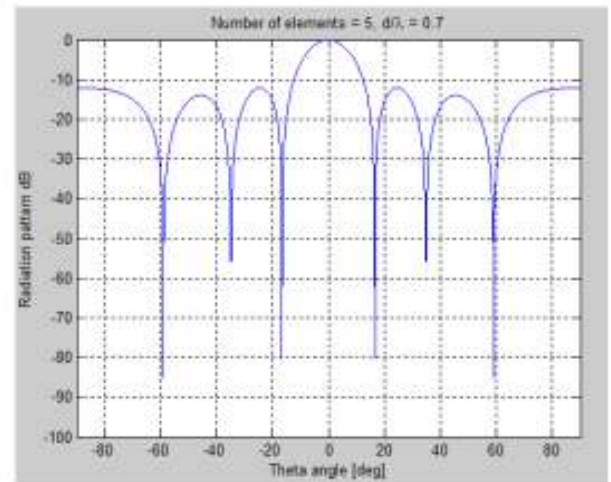


Fig. 1 Radiation pattern of 5 isotropic elements $d/\lambda=0.7$.

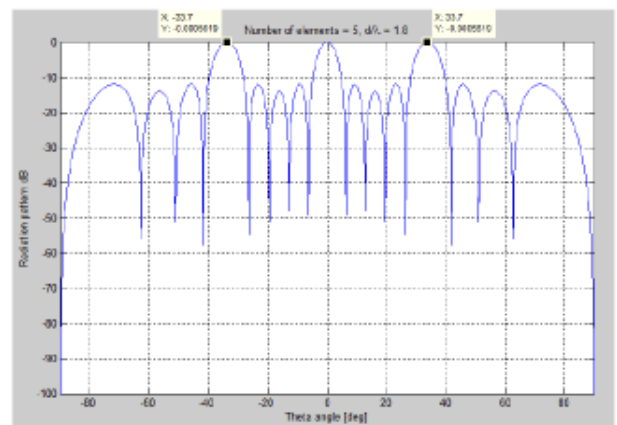


Fig. 2 Radiation pattern of 5 isotropic elements $d/\lambda=1.8$.

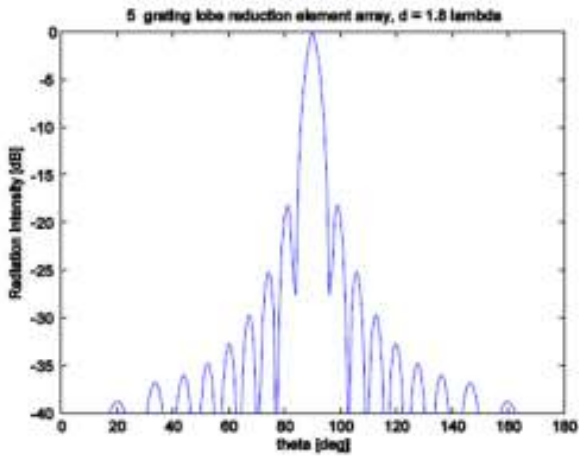


Fig. 3 Radiation pattern of 5 elements that have nulls at $\pm 34^\circ$ (by theory) with distance $d/\lambda = 1.8$.

III. GEOMETRY

The overall geometry of the arrays is shown in figure 4. We see here 4 unit cells - the high frequency element is a pair of two close elements as shown in Fig 5. The distance between the two patches is the key parameter - it enables to direct nulls at $\pm 34^\circ$. The low frequency element is a vertical radiator shown in Fig 6. The mutual mounting of the unit cell is shown in Fig 7. The distance between unit cells is 7,7 cm for the two arrays, hence in the low frequency of 2.7 GHz the spacing is $0,7\lambda$ and in the high frequency of 7.0 GHz the spacing is 1.8λ .

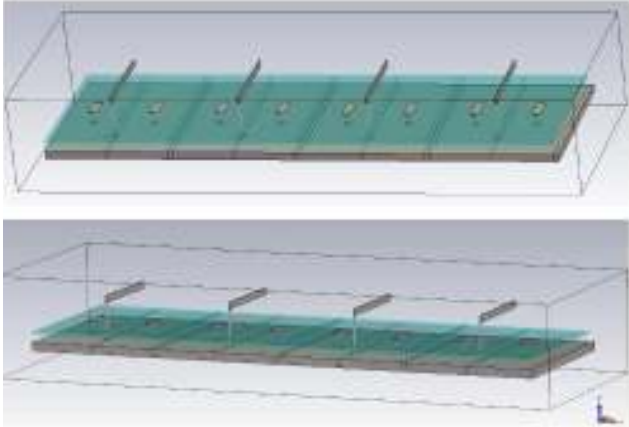


Fig. 4 Geometry of the arrays.

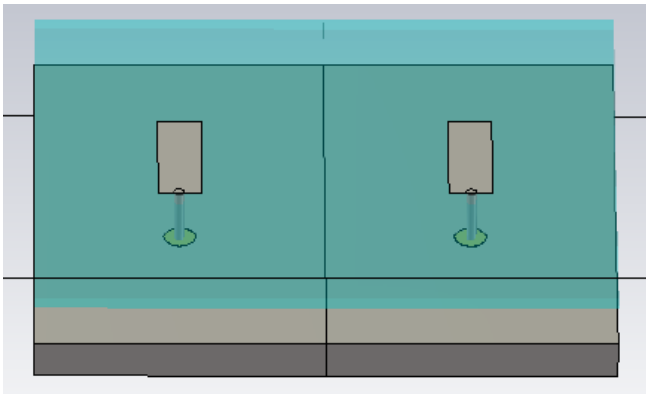


Fig. 5 Geometry of the high frequency element.



Fig. 6 Geometry of the low frequency element.

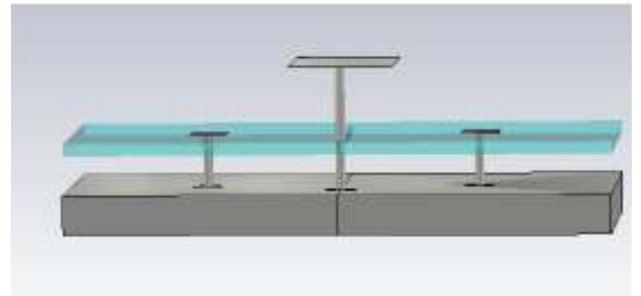


Fig. 7 Geometry of two elements at different frequencies.

The mutual coupling between the elements in the two arrays must be low in order to keep clean patterns. The mutual coupling is controlled by the orthogonal orientation of the elements and by the geometry. The sizes of the high frequency elements are 15.5×5.0 mm and the height is 6.5 mm above ground. They are printed on Taconic RF-35 with thickness 1.5 mm and dielectric constant $\epsilon_r = 3.5$. The sizes of the low frequency metallic elements are 54×4.1 mm, the height is 22 mm above ground and the thickness is 0.5 mm. The distance between elements is 77 mm in both frequencies.

IV. SIMULATED RESULTS

The return loss in the high frequency is shown in figure 8 and the return loss in the low frequency is shown in figure 9. The mutual coupling between the high-frequency elements had been reduced to -19 dB and the mutual coupling between the low-frequency elements had been reduced to -23 dB by careful optimization of the element sizes. The mutual coupling between neighbor elements in different arrays are -15 dB in the low frequency and -14 dB in the high frequency.

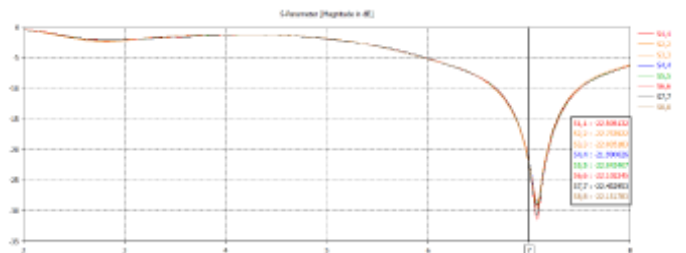


Fig. 8 Return Loss in the high frequency in all ports.

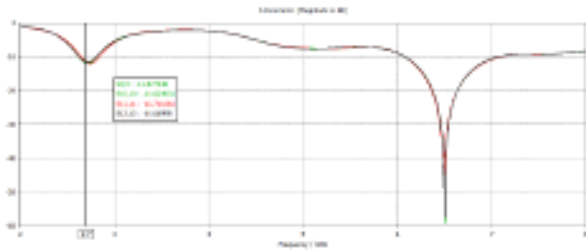


Fig. 9 Return Loss in the low frequency in all ports.

The radiation pattern of the low frequency array in the H-plane is shown in Fig.10. The gain at 2.7 GHz is 14.5 dBi. The half power beamwidth is 20° and the first side lobe is -13 dB. This is a perfect pattern for 4 element array with uniform illumination and optimal spacing.

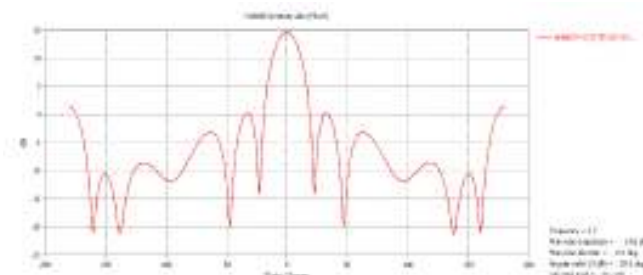


Fig. 10 Radiation pattern of the array in the low-frequency.

The radiation pattern of the high frequency array in the H-plane is shown in Fig.11. The gain at 7.0 GHz is 18.2 dBi. The half power beamwidth is 7.3° and the first side lobe is -18 dB. This is a good pattern for 8 element array with uniform illumination and unusual spacing of 1.8λ . It can be achieved only due to a perfect cancellation of the grating lobes. Indeed we can see in Figure 12 a typical pattern of a single element in the high frequency with good nulling towards $\pm 34^\circ$.

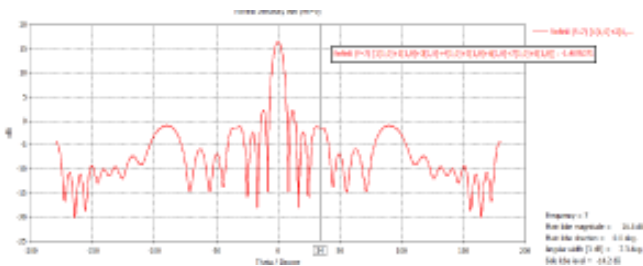


Fig. 11 Radiation pattern of the array in the high-frequency.

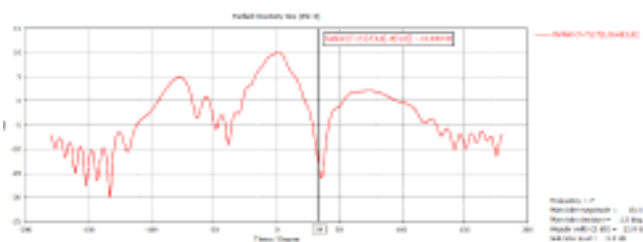


Fig. 12 Radiation pattern of a single high-frequency element.

V. MEASUREMENTS

A laboratory prototype shown in Figure 13 has been built and tested in HIT. The return Loss results in Figure 14 are - low center frequency 2.7 GHz with bandwidth (VSWR = 2) of 200 MHz and high center frequency 7.0 GHz with bandwidth (VSWR = 2) of 850 MHz. Pretty close to simulations as were shown in Figures 8-9.

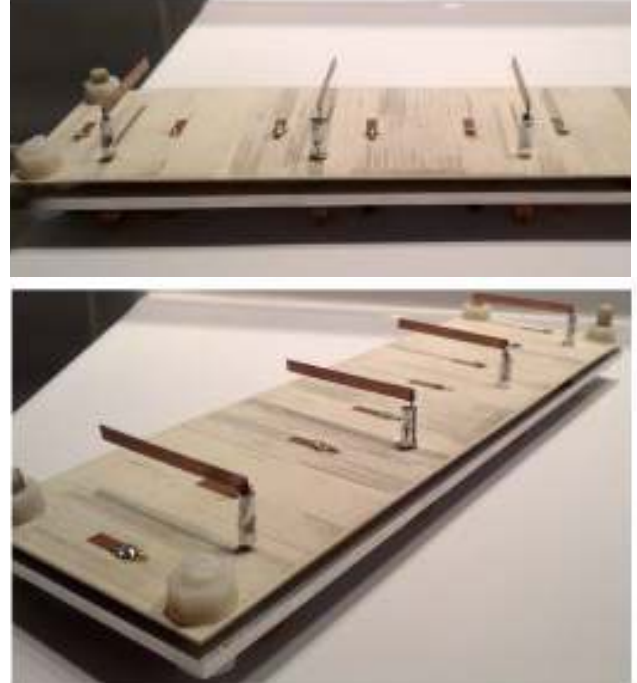


Fig. 13 Laboratory Prototype.

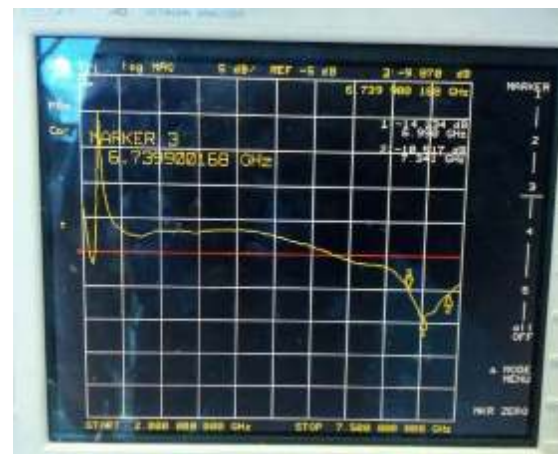


Fig. 14 Measured Return Loss in two frequency bands.

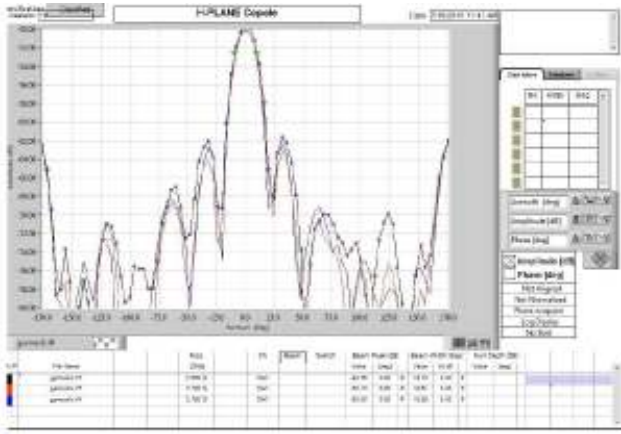


Fig. 15 Radiation pattern in H plane, in low frequency.

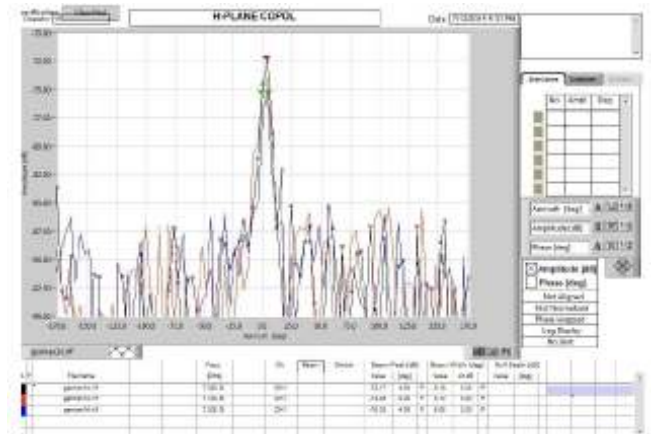


Fig. 16 Radiation pattern in H plane, in high frequency.

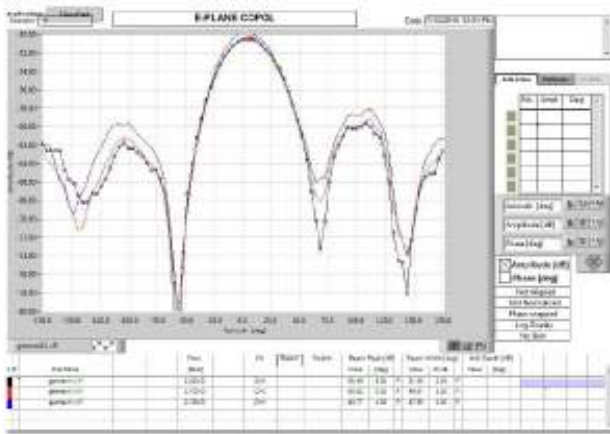


Fig. 17 Radiation pattern in E plane, in low frequency.

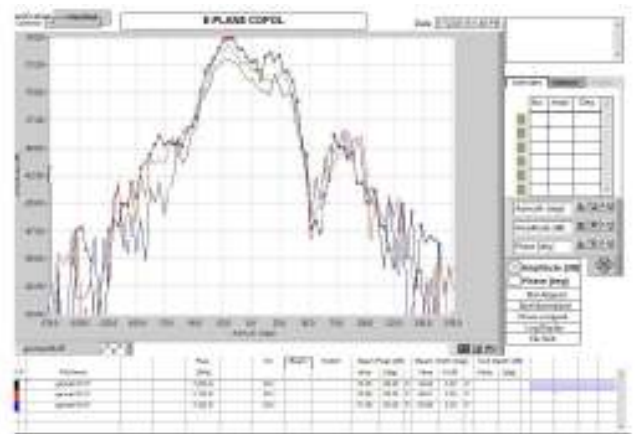


Fig. 18 Radiation pattern in E plane, in low frequency.

Figures 15-16 show the H plane measured pattern in the two frequencies. Figures 17-18 show the E plane measured patterns in the two frequencies. Table 1 compares measured and calculated beamwidths. They are quite close as well as the sidelobe levels in Figures 11-12.

TABLE 1 Beamwidth

| E-plane | | |
|-----------|------------|----------|
| Frequency | Calculated | Measured |
| 2.7 GHz | 50.1° | 49.9° |
| 7.0 GHz | 70.2° | 44.8° |
| H-plane | | |
| Frequency | Calculated | Measured |
| 2.7 GHz | 19.5° | 18.5° |
| 7.0 GHz | 7.3° | 6.2° |

VI. CONCLUSION

A convenient configuration of 2 arrays in two frequencies, mounted in the same aperture has been presented. The ratio between the frequencies is $7.0/2.7 = 2.6$. The ratio between distances is also $1.8\lambda/0.7\lambda = 2.6$. The two arrays have clean patterns and optimal gain, although for distance of 1.8λ one would expect grating lobes at $\pm 34^\circ$. The grating lobes are eliminated by directing nulls towards $\pm 34^\circ$. Thus configuration can be used for many applications. Key factors for good patterns are building the high frequency elements from pairs (to control the nulling) and keep low coupling between elements by orientation and by optimization of sizes.

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