TECHNIQUE FOR ARRAYING LARGE NUMBERS OF YAGI DISK ANTENNAS

Fred B. Beck
Electronic Engineer, Communications Research Section
Instrument Research Division
Langley Research Center, NASA

SUMMARY

This paper is concerned with the problem of arraying Yagi disk or disk on rod surface wave structures having large interelement spacings. It is shown that symmetrical arrays having acceptable sidelobe levels (below 13 db) can be designed using simple array theory and the knowledge of a single-element pattern.

INTRODUCTION

The amplitude of the field as a function of radial distance off the axis of a long Yagi type antenna has been determined[1]. These results indicate that the design of an array of Yagi antennas based on simple array theory will require interelement spacings a wavelength or greater to minimize coupling effects. Interelement spacings of a wavelength or more in linear arrays will introduce the problem of handling high grating lobes in the array factor. However, it has been shown theoretically that the amplitude of the grating lobes can be reduced by properly tailoring the element pattern[2]. The purpose of this paper is to point out experimental results which substantiate the following:

(a) Arrays of Yagi disk antennas can be designed with element spacings which simultaneously fulfill the requirements of negligible interelement coupling and grating lobe suppression.

(b) At least for the designs considered, there are no off-principal plane sidelobes or grating lobes higher than those in the principal planes.

(c) The gain for arrays of Yagi disk elements satisfying the above requirements can be accurately calculated from a knowledge of the gain of a single element.

YAGI DISK ELEMENT

The Yagi disk antenna used as the basic array element is shown in figures 1 and 2. Considerable work has been done on the design of such elements[3]. The particular element design chosen here has good beamwidth and gain characteristics over the frequency range of interest, 2200 mc - 2400 mc. The beamwidth and gain of such short elements (2λ - 4λ) are essentially determined by the Yagi structures; however, the sidelobe levels and sidelobe positions are primarily controlled by the details of the feed. It has been shown that tailoring of the element pattern can be accomplished by adjusting the feed dipole spacing s_f, the distance to the first disk l_2, and the addition of shields around the feed[3].

ELEMENT SPACING CRITERIA

The principle of grating lobe suppression by proper element pattern tailoring is pointedly demonstrated in figure 3. Given the array factor and the element pattern, the array pattern is simply the product of the two if interelement coupling is negligible. If the element pattern is known, the grating lobe of the array factor can be made coincident with the first sidelobe of the element pattern by adjusting the interelement spacing. The spacing above, i.e., grating lobe coincident with first sidelobe of the element pattern, appears sufficient for negligible interelement coupling independent of element length (2λ - 6λ). Two linear arrays having 4 and 16 elements, respectively, were designed using the above criteria. That is, the element pattern was measured and the spacing between elements adjusted so that the grating lobe position corresponded to the first-element sidelobe position. Calculated patterns assuming no coupling along with measured patterns are given in figure 4.

The interelement spacing could be increased to situate the position of the grating lobe to correspond to the position of the null between the main lobe and first sidelobe of the element pattern. This would decrease the level of the grating lobe in measured array patterns even further. However, using this approach would make the grating lobe level very frequency sensitive. In addition, most of the nulls between the mainlobe and first sidelobe of measured elements are not appreciably lower than the level of the first sidelobe.

Also, the interelement spacing could be decreased to situate the position of the grating lobe to correspond to the position of the null between the first and second sidelobes of the element pattern. This would also decrease the level of the grating lobe in measured array patterns. With this approach the problem of interelement coupling and a frequency sensitive grating lobe is encountered. Since the object is to eliminate interelement coupling, this approach should be used only with great caution.

SIDELOBES OFF THE PRINCIPAL PLANES

It has been shown that sidelobes in the principal planes can be reduced to a reasonable level. Of equal importance is the control of off-principal plane sidelobes. To study this problem, a symmetrical 16-element array (4×4) was designed with the dimensions shown in figure 5. Measurements of the pattern of this array were made at 5° increments of δ, where δ is the off-principal plane angle shown in figure 5. The results of these measurements plotted in the form of sidelobe levels as a function of δ are shown in figure 6 for $0^\circ \geqq \delta \leqq 45^\circ$. Since the array is symmetrical, this range of δ defines all cases. There were only three significant sidelobes on either side of the main lobe in the measured array patterns. The first two sidelobes are primarily determined by the array factor. The third sidelobe appearing in the measurements is the so-called grating lobe which is dependent upon the level of the element sidelobes and the array factor. Calculations[4] were made assuming the element patterns to be identical independent of δ. Of course, this is not necessarily true yet the calculated curves in figure 6 show that good agreement is still obtained.

GAIN CONSIDERATIONS

It is possible to predict the gain of a large array of Yagi disk antennas from the knowledge of a single-element gain if mutual coupling is negligible. The gain of a 16-element (4 × 4) array was calculated on the basis of a known element gain. A comparison of the calculated and measured array gain is given in figure 7. The agreement is indicative of the fact that interelement coupling is negligible and no excessive energy is lost in spurious sidelobes.

CONCLUSION

It has been shown that a design technique for arraying Yagi disk elements is available utilizing simple array theory.

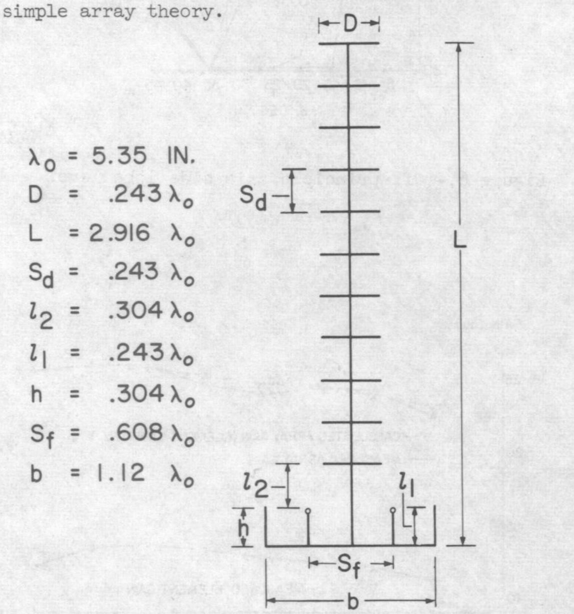

Figure 1.- Diagram of Yagi disk element. NASA

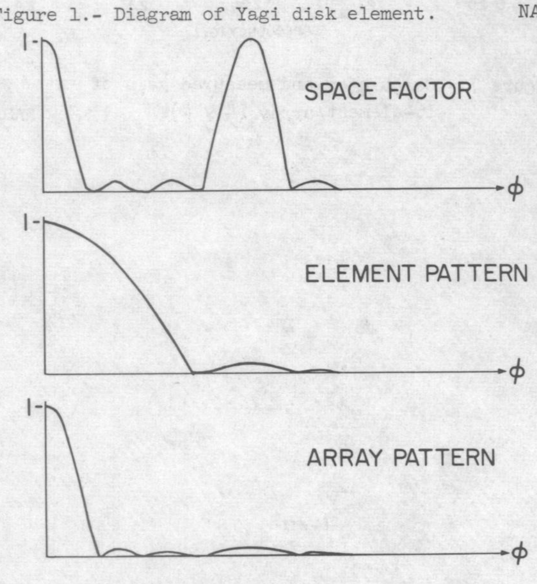

Figure 3.- Principle of grating lobe suppression.
NASA

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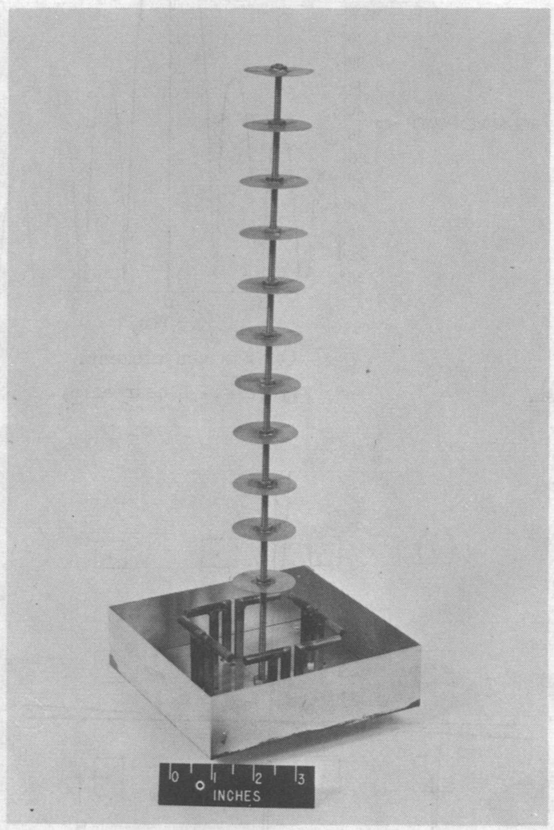
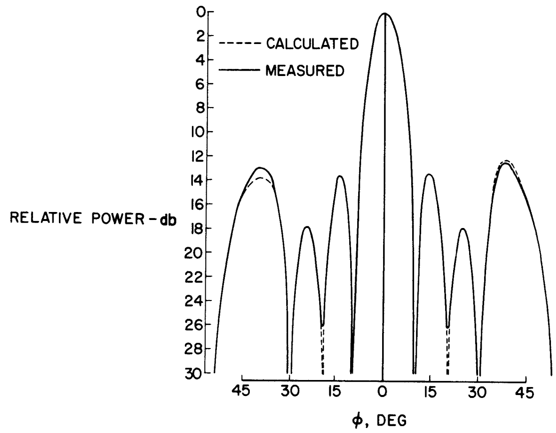
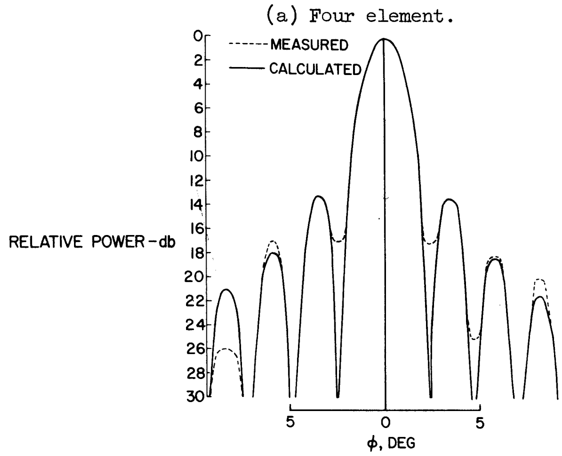


Figure 2.- Yagi disk element. NASA



(a) Four element.



(b) Sixteen element.

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Figure 4.- Linear array.

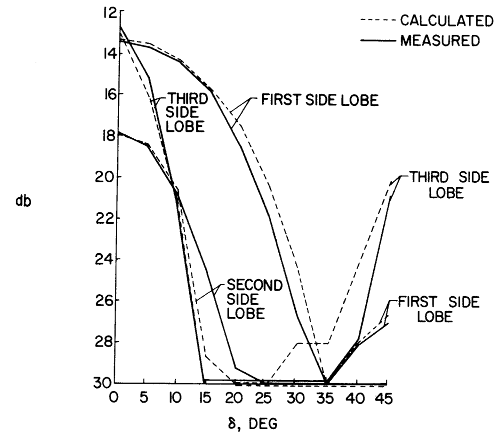

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Figure 6.- Off principle axis side lobe level.

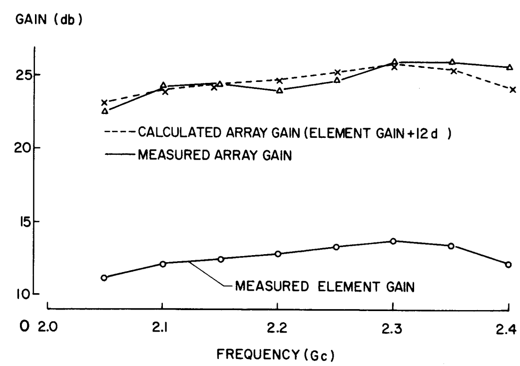

Figure 7.- Calculated and measured gain of 16-element array (4 × 4).

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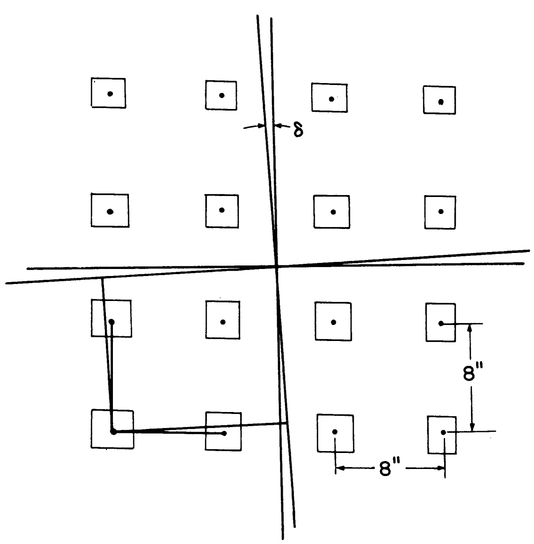

Figure 5.- Sixteen-element array (4 × 4). NASA