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## [54] AERIAL FIELD SIMULATION


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[51] **Int. Cl.** ..... **G01s 7/40**

[58] **Field of Search** .....343/844, 853, 854, 343/100 R, 100 AP, 703



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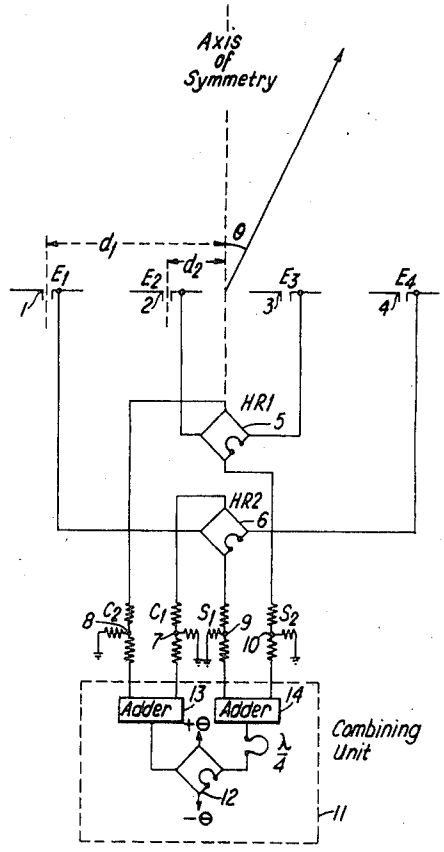
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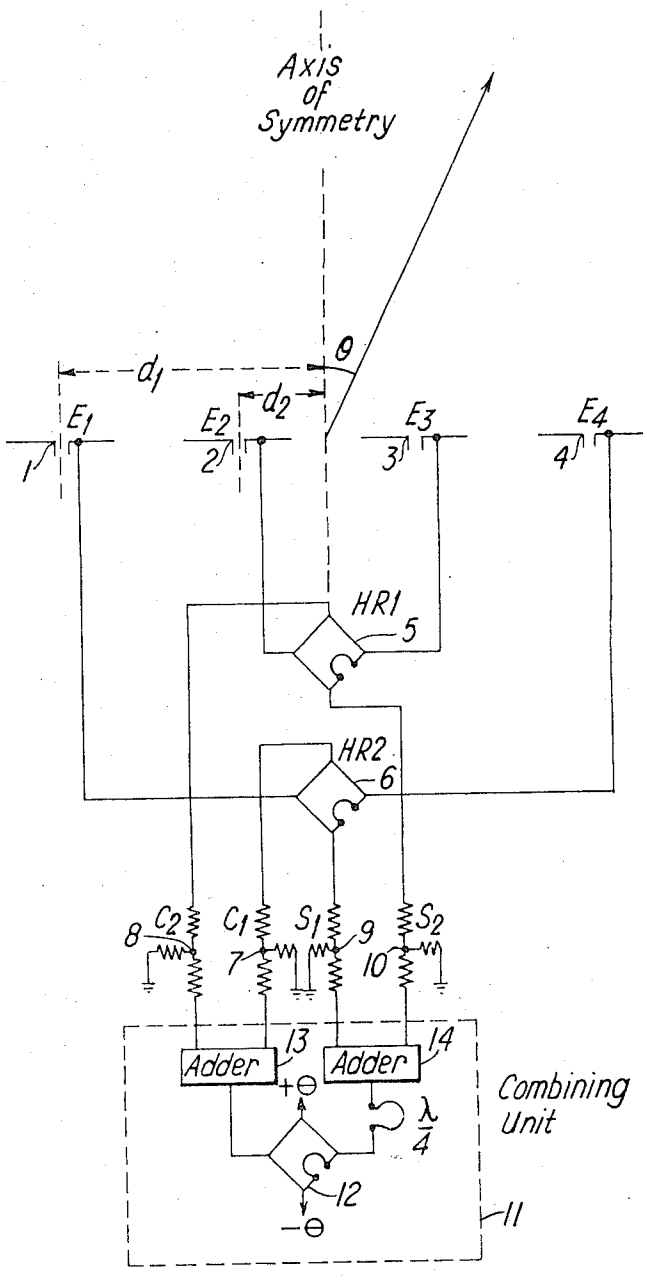


[57] **ABSTRACT**

Any arbitrary antenna array distribution can be represented as the sum of a symmetric and an antisymmetric function. The radiation at any point in the far field of the aerial array can then be simulated by adding together the symmetric and antisymmetric outputs in quadrature with the correct amplitude. This simplifies the construction of subsequent combining units since these reproduce the far field at any point by amplitude wieghting along without the need for differential phasing.


**4 Claims, 1 Drawing Figure**






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# AERIAL FIELD SIMULATION

## BACKGROUND OF THE INVENTION

This invention relates to aerial arrays and to a method of simulating the far field of a symmetrical aerial array for monitoring purposes.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of simulating the far field of a symmetrical aerial array at any point by amplitude weighting alone, without the need for differential phasing.

According to a broad aspect of the invention, there is provided a method of simulating the far field at any arbitrary point thereof of any arbitrary symmetrical aerial array comprising dividing the array distribution of field into symmetric and antisymmetric components, sampling the currents flowing instantaneously in the individual aerials, combining the sampled currents so as to produce symmetric and antisymmetric functions, and adding the symmetric and antisymmetric functions in quadrature with predetermined amplitude weighting.

Any arbitrary aerial array distribution can be represented as the sum of a symmetric and an antisymmetric function. Samples of the currents on the individual aerials making up the array can then be combined to reproduce these symmetric and antisymmetric functions. The radiation at any point in the far field of radiation of the aerial array can then be simulated by adding together these symmetric and antisymmetric outputs in quadrature with the correct amplitude weighting.

The division of the array distribution into symmetric and antisymmetric components simplifies the construction of the subsequent combining units, since these then reproduce the far field at any point by amplitude weighting alone, without the need for differential phasing.

The invention will now be further described with reference to the accompanying drawings, in which:

## BRIEF DESCRIPTION OF THE DRAWING

The sole drawing illustrates an array of four dipole antennas symmetrically placed, together with the requisite combining and weighting units.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, there is shown a linear array of four dipole antennas **1,2,3** and **4** identified by $E_1$, $E_2$, $E_3$, $E_4$, which also represent the R.F. voltages on the elements in the array. The time varying factor $e^{iwt}$ is ignored for simplicity. In general the E's are arbitrary complex numbers and may each represent the sum of several R.F. voltages at different frequencies without loss of generality unless the frequencies are sufficiently spread to limit the accuracy of the system as a result of the limited bandwidth of subsequent devices. Each of these dipoles is monitored for current flow in the dipole. As described in applicant's copending application Ser. No. 164,759, filed July 21, 1971, the radiated field of a dipole at any point is directly related in amplitude and phase to the current in the dipole arms. This can be sampled by a slot cut in the dipole arm. The voltage across this slot is fed to a transmission line which may be matched to subsequent processing units by the suitable positioning of a resistor. This enables both the RF current from the power feed to the dipole and the current produced by interaction with other radiated elements to be measured. The current samples are applied in symmetrical pairs to phase shifting hybrid arrangements **5** and **6** denoted **HR1** and **HR2**, and from these to weighting networks **7**, **8**, **9** and **10** denoted **C1, C2, S1,** and **S2** respectively, and thence to combining unit **11**, all of which will be referred to in due course.



The voltage in the far field at an angle $\theta$ to the center line of the array may be written as:

$$V = f(R) \times f(\theta) \times f(E\lambda, d, \theta) \quad (1)$$

In this expression, the first factor is a factor dependent on radial distance alone of the array, the second factor is a factor dependent on $\theta$ alone, and corresponds to the polar diagram for individual antenna elements of the array, and the third factor, describes the variations which arise owing to the differing distances $d$ of the complex sources $E$ on either side of the center point of the array. For the symmetrical array shown, only two distances $d_1$ and $d_2$ are concerned, positive and negative values being taken for the respective sides of the array, positive on the left, negative on the right, and $\lambda$ is the wavelength at the particular radiation frequency being studied; and $e$ and $i$ have their usual significance in complex algebra. The third factor may then be expanded to read

$$E_1 e^{i\frac{2\pi}{\lambda} d_1 \sin\theta} + E_2 e^{i\frac{2\pi}{\lambda} d_2 \sin\theta} + E_3 e^{-i\frac{2\pi}{\lambda} d_2 \sin\theta} + E_4 e^{-i\frac{2\pi}{\lambda} d_1 \sin\theta} \quad (2)$$

This expression would continue for as many factors as there are antenna elements, but in this case terminates with the fourth.

Equation (2) contains all the variation in $V$ due to variation in the $E$'s. It is this factor it is required to reproduce in order to simulate the effect in $V$ of changes in the $E$'s.

One method of doing this is to take samples of all the $E$'s and insert cables of different phase lengths $\phi_1$, $\phi_2$, $\phi_3$, $\phi_4$ . . . where

$$\phi_1 = l + (2\pi/\lambda) d_1 \sin\theta;$$

$$\phi_2 = l + (2\pi/\lambda) d_2 \sin\theta;$$

$$\phi_3 = l - (2\pi/\lambda) d_2 \sin\theta;$$

$$\phi_4 = l - (2\pi/\lambda) d_1 \sin\theta$$

and **1** is an arbitrary fixed length for all the cables concerned between the respective monitoring points and hybrid networks **5** and **6**; The sum of these is then proportional to the third factor in (1) above (i.e. equation 2). However, where there are a large number of elements in the array and it is required to simulate the far field at more than one angle $\theta$, a worthwhile simplification results if we replace this phasing of the samples by weighting in amplitude alone. This can only be done if the array is symmetrical.

Re-writing the expression for the last factor above:

$$\frac{E_1+E_4}{2}\left(e^{i\frac{2\pi}{\lambda}d_1\sin\theta}+e^{-i\frac{2\pi}{\lambda}d_1\sin\theta}\right)+\frac{E_2+E_3}{2}\left(e^{i\frac{2\pi}{\lambda}d_2\sin\theta}+e^{-i\frac{2\pi}{\lambda}d_2\sin\theta}\right)+\frac{E_1-E_4}{2}\left(e^{i\frac{2\pi}{\lambda}d_1\sin\theta}-e^{i\frac{2\pi}{\lambda}d_1\sin\theta}\right)+\frac{E_2-E_3}{2}\left(e^{i\frac{2\pi}{\lambda}d_2\sin\theta}-e^{-i\frac{2\pi}{\lambda}d_2\sin\theta}\right)$$

$$=(E_1+E_4)\cos\left(\frac{2\pi}{\lambda}d_1\sin\theta\right)+(E_2+E_3)\cos\left(\frac{2\pi}{\lambda}d_2\sin\theta\right)+i\left[(E_1-E_4)\sin\left(\frac{2\pi}{\lambda}d_1\sin\theta\right)+(E_2-E_3)\sin\left(\frac{2\pi}{\lambda}d_2\sin\theta\right)\right] \quad (3)$$

This in fact corresponds to the division of the arbitrary array distribution into two components, a symmetric one ($E_1+E_4$, $E_2+E_3$) and an antisymmetric one ($E_1-E_4$, $E_2-E_3$). This can be accomplished by means of a set of 180° hybrid rings as indicated at HR1 and HR2 in the drawing. Expression (3) can then be reproduced by amplitude weighting of the symmetric and antisymmetric outputs from these rings with weights:

$$C_1=\mathrm{Cos}\,(2\pi/\lambda\, d_1\mathrm{Sin}\theta)$$

$$C_2=\mathrm{Cos}\,(2\pi/\lambda\, d_2\mathrm{Sin}\theta)$$

$$S_1=\mathrm{Sin}\,(2\pi/\lambda\, d_1\mathrm{Sin}\theta)$$

$$S_2=\mathrm{Sin}\,(2\pi/\lambda\, d_2\mathrm{Sin}\theta)$$

which are readily derived for any required angular $\theta$ since all the constants are known. These outputs are then added in a combining unit 11 to give an output proportional to the far field at $\theta$; the factor i in expression (3) means that an extra quarter wavelength of line is necessary in the antisymmetric side. This, however, is the same for all angles $\theta$. As shown in the drawing, combining unit 11 includes hybrid circuit 12, and adders 13 and 14.

This system is readily extended to any symmetric array containing an even number of elements. It can also be applied if there is an element on the center line, i.e. an odd number of elements. In this case, the center element only contributes to the symmetric component of the array distribution and not to the antisymmetric component, so that its 180° hybrid ring or equivalent unit can be dispensed with, and the sample merely added to the symmetric side of the combining unit with appropriate weighting.

It is to be understood that the foregoing description of specific examples of this invention is made by way of example only and is not to be considered as a limitation on its scope.

I claim:

1. A method of simulating the far field at any arbitrary point thereof of any arbitrary symmetrical aerial array comprising:
- sampling the radio frequency currents flowing instantaneously within the individual aerials;
- combining the sampled currents in symmetrical pairs to phase shifting hybrid arrangements so as to produce symmetric and antisymmetric functions with respect to the center line of the array;
- applying predetermined amplitude weighting to the individual samples; and
- adding the symmetric and antisymmetric functions in quadrature to obtain a representative output.

2. A method according to claim 1 wherein said array contains an even number of aerial elements spaced symmetrically about a center line of said array.

3. A method according to claim 1 wherein said array contains an odd number of aerial elements, of which the central element is placed at the center line of the array and the remainder are spaced symmetrically on either side thereof, said central element being associated with those elements from which there are derived said symmetrical functions.

4. An apparatus for simulating the far field at any arbitrary point thereof of any arbitrary symmetrical aerial array comprising:
- means for sampling the current flowing within each aerial of said array;
- phase shifting hybrids connected in symmetrical pairs to the sampling means for combining said current samples into symmetric and antisymmetric pairs;
- a plurality of weighting networks for weighting each output of said means for combining; and
- a combining unit for combining said symmetric and antisymmetric pairs in quadrature.

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