1-1 B4

BANDWIDTH CHARACTERISTICES OF THE ARRAY ANTENNA AND ITS EFFECT ON SIGNAL

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Introduction:

Array antenna is often used as an antenna for communication system, like electrical despun antenna fo the communication satellite. In this case, the characteristices of the antenna are required not only desired gain and directivity but also wide bandwidth. Dispite of using ideal elements and feeding system, the array antenna generally has amplitude-frequency and phase-frequency characteristices caused by array configulation. This paper discusses the transmission characteristices of the circular array, because of its applicability for the communication satellite.

Transmission function of the array antenna:

Transmission characteristices of the array antenna are defined by the frequency characteristices of the elements, mutual-coupling between elements, and configulation of the array. Let's consider an array antenna composed by N elements. If mutual-coupling between elements can be neglected, the transmission characteristices of the array are included in equation 1.

$$S(t)=r_1\varepsilon^{j\Omega(t-\tau_1)}+r_2\varepsilon^{j\Omega(t-\tau_2)}+\cdots+r_N\varepsilon^{j\Omega(t-\tau_N)}\quad\cdots(1)$$

$\Omega=\omega_c+\omega$

- ω_c : carrier frequency
- r_i : relative amplitude between each waves radiated from elements and reference wave.
- τ_i : relative time difference Between each waves and reference wave.

From the equation 1, normalized transmission function of the array is written as complex power series. The real part of the transmission function, $R_e(u)$, and the imaginary part, $I_m(u)$, are written as followes.

$$R_e(u)=a_0+a_1f+a_2f^2+a_3f^3+\cdots\quad(2)$$

$$I_m(u)=b_0+b_1f+b_2f^2+b_3f^3+\cdots\quad(3)$$

The coefficients in the equation, a_n, b_n, are showen below.

$$a_{2d}=\frac{(-1)^d(2\pi)^{2d}}{A(\omega_c)(2d)!}\Big[\sum_{i=1}^{N}\sum_{p=1}^{N}r_ir_p\cos\{\omega_c(\tau_p-\tau_i)\}(T(\omega_c)+\tau_i)^{2d}\Big]\quad\cdots(4)$$

$$a_{2d+1}=\frac{(-1)^d(2\pi)^{2d+1}}{A(\omega_c)(2d+1)!}\Big[\sum_{i=1}^{N}\sum_{p=1}^{N}r_ir_p\sin\{\omega_c(\tau_p-\tau_i)\}(T(\omega_c)+\tau_i)^{2d+1}\Big]\quad\cdots(5)$$

$$b_{2d}=\frac{(-1)^d(2\pi)^{2d}}{A(\omega_c)(2d)!}\Big[\sum_{i=1}^{N}\sum_{p=1}^{N}r_ir_p\sin\{\omega_c(\tau_p-\tau_i)\}(T(\omega_c)+\tau_i)^{2d}\Big]\quad\cdots(6)$$

$$b_{2d+1}=\frac{(-1)^d(2\pi)^{2d+1}}{A(\omega_c)(2d+1)!}\Big[\sum_{i=1}^{N}\sum_{p=1}^{N}r_ir_p\cos\{\omega_c(\tau_p-\tau_i)\}(T(\omega_c)+\tau_i)^{2d+1}\Big]\quad\cdots(7)$$

$$T(\omega_c)=-\frac{1}{A(\omega_c)}\sum_{i=1}^{N}\sum_{p=1}^{N}r_ir_p\tau_i\cos\{\omega_c\cdot(\tau_p-\tau_i)\}\quad\cdots(8)$$

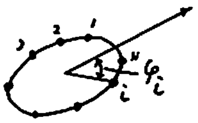
$$A(\omega_c)=\Big(\sum_{i=1}^{N}r_i\cos\omega_c\tau_i\Big)^2+\Big(\sum_{i=1}^{N}r_i\sin\omega_c\tau_i\Big)^2\quad\cdots(9)$$

Circular array transmission function:

In this section, transmission function of the cirqular array are treted by using the method discribed previous section. The results of the coefficients of the circulare array which is consisted N isotropic elements and activated equary amplitude are shoven for example.

$$a_{2d} = \frac{(-1)^d (2\pi)^{2d}}{N(2d)!} \sum_{i=1}^{N} (\cos\varphi_i)^{2d} (1/B_a)^{2d}$$

$$a_{2d+1} = b_{2d} = b_{2d+1} = 0$$



where $B_a = \lambda_c f_c / D$

D : diameter of the array

λ_c : wavelength of the carrier

Fig. 1 indicats the 4th coefficient vs. element number N.

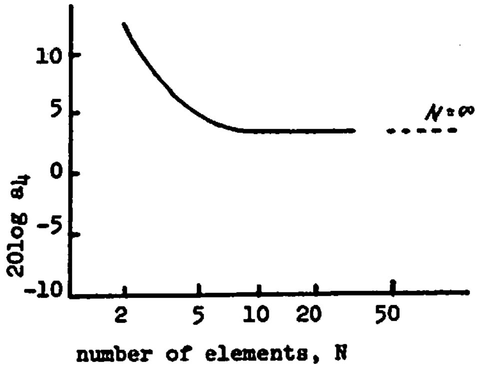


Fig. 1 4th coefficient vs. n

From the analysis made on the other types of circular array, the coefficients of the transmission function are written as below.

$$\begin{pmatrix}\text{nth co-}\\ \text{efficient}\end{pmatrix} \propto \begin{pmatrix}\text{array con-}\\ \text{figulation}\\ \text{fucter}\end{pmatrix} \Big/ \begin{pmatrix}\text{array}\\ \text{band-}\\ \text{width}\end{pmatrix}^{n}$$

where

array bandwidth $B_a = \lambda_c f_c / D$

The array configulation factor is the function of n, number of the elements, type of the elements, and configulation of the elements.

Distortion caused by the array antenna:

The transmission characteristices of the array antenna generate distortion on the signal passing through the antenna. Type of the distortion depends on the type of modulation on the signal. In this section, analysis is made on distortion of the frequency modulated multi-channel telephony. The distortion caused by the array antenna is directly related to the coefficients of the transmission function. And it is also indicated that the value of distortion is the function of the ratio of bandwidth of the base-band and array bandwidth, K_3, and ratio of the r.m.s. deviation of the signal and array band-width, K_2. Fig. 2 illustrates the relation between ratio of signal and distortion, S/D_n, and coefficients.

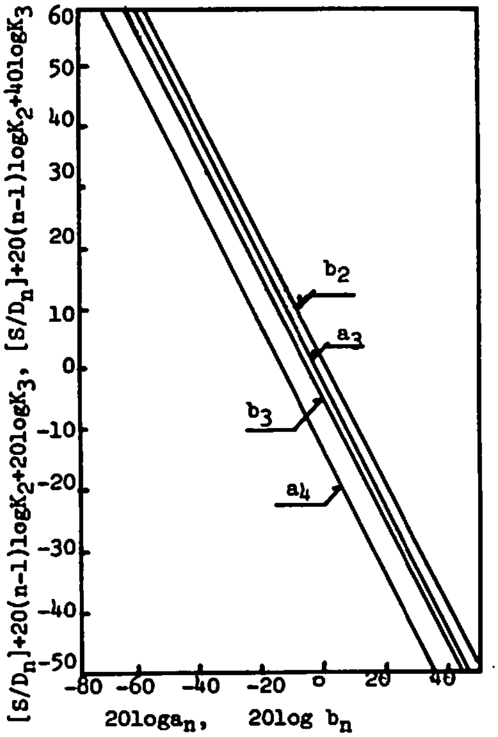


Fig. 2 $[S/D_n]$ vs. coefficients a_n, b_n