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ANTENNA PATTERN SYNTHESIS OF ARBITRARY CURVED DISTRIBUTED WAVE SOURCE

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1. Introduction

Directive antennas have long been classified into three types; array, aperture, or progressive wave. The authors have shown a new type of directive antenna can be obtained by controlling continuous circular current source distribution.[1]

The theory is expanded to the general solution of pattern synthesis of arbitrary curved distributed line wave source. In this paper, the general solution is described briefly, and the solution of circular source is shown to be derived from the general solution.

Several practical antennas with Binomial Pattern are developed through the theory.

2. Arbitrary Curved Line Source

Arbitrary curved line source on x-y plane is devided into N numbers of small segments as shown in Fig. 1. Where the starting point of $\#p$ segment is $P(r_p,\theta_p)$, the angle between the segment and x-axis is β_p, the complex value of the source segment is g_p, and the total length of the source is ℓ. Assuming r_p, θ_p, β_p, and g_p are constant in $\#p$ segment, directive pattern on x-y plane can be expressed by infinite terms Fourier Series.

$$D(\phi)=C_0+\sum_{m=1}^{\infty}(C_m \cos m\phi + S_m \sin m\phi) \quad (1$$

$$C_m=(j)^{m-1}\frac{\ell K}{N}\sum_{p=1}^{N} g_p(J_{m-1}(kr_p)\sin A - J_{m+1}(kr_p)\sin B) \quad (2$$

$$S_m=(j)^{m+1}\frac{\ell K}{N}\sum_{p=1}^{N} g_p(J_{m-1}(kr_p)\cos A - J_{m+1}(kr_p)\cos B) \quad (3$$

$$A=\beta_p+(m-1)\theta_p, \quad B=\beta_p-(m+1)\theta_p$$

where K is constant, and k is propagation constant.

On account of Bessel Function, the convergence of formula (3) and (4) is rapid, and the series can easily approximated by finite terms ($m \leq \nu$).

The source distribution is solved as follows, if N is chosen as $N=2\nu+1$.

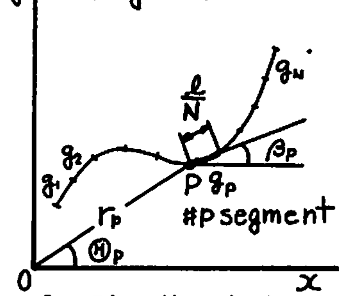
$$\begin{bmatrix} g_1 \\ \vdots \\ \vdots \\ g_N \end{bmatrix} = \begin{bmatrix} F_{mp} \end{bmatrix}^{-1} \begin{bmatrix} C_0 \\ \vdots \\ C_\nu \\ S_1 \\ \vdots \\ S_\nu \end{bmatrix} \quad (5$$

$$F_{1p}=jJ_1(kr_p)\sin(\beta_p-\theta_p)$$

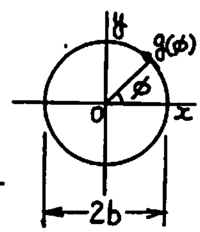
$$F_{mp}=(j)^{m-1}\left\{J_{m-1}(kr_p)\sin A + J_{m+1}(kr_p)\sin B\right\}, \quad 1<m\leq\nu$$

$$F_{mp}=-(j)^{m-1}\left\{J_{m-1}(kr_p)\cos A + J_{m+1}(kr_p)\cos B\right\}, \quad \nu<m\leq 2\nu+1$$

<Fig 1>



<Fig 2>



3. Distributed Circular Source

If the wave source is circular loop current (Fig. 2), $r_p=b$ (radius of loop wire), $\theta_p=\phi$, $\beta_p=\phi+\pi/2$, and $\ell=2\pi b$. Asympototic form of formula (3) is as follows when $N\to\infty$, and $S_m=0$ ($m=1,2,\cdots$), for x-axis-symmetric current distribution.

$$C_m = (j)^{m-1} \ell K(J_{m-1}(kb) - J_{m+1}(kb)) \cdot \frac{1}{N} \sum_{p=1}^{N} g_p \cos m\phi$$

$$\xrightarrow{N \to \infty} (j)^{m-1} \ell K(J_{m-1}(kb) - J_{m+1}(kb)) \qquad (6$$

where; i_m is the m^{th} coefficient of Fourier Series of current distribution

$$i_m = \frac{1}{\pi} \int_0^{2\pi} g(\phi) \cos m\phi \, d\phi \qquad (7$$

$$g(\phi) = \sum_{m=0}^{\nu} i_m \cos m\phi \qquad (8$$

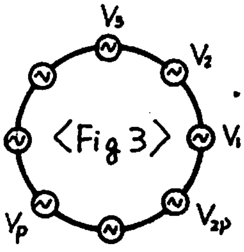
4. Realization of Current Distribution

According to Sampling Theorem, current distribution (8) can be realized by 2ν numbers of sampling point feeding (Fig. 3), or lamped impedance loading (In some cases, negative resistances are necessary).

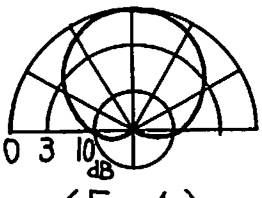
Feeding voltage vector **V** or loading impedance vector Z_L are solved by following equasion, where [z] is impedance matrix of sampling points, and **I** is sampling values vector of current distribution.

$$V = [z] \, I \qquad (9$$

$$V = - Z_L \cdot I \qquad (10$$



<Fig 3>



<Fig 4>

5. Practical Antennas

Two practical antennas are shown; AN-22 (for VHF TV: PHOTO 1) and AN-31 (for FM: PHOTO 2).
Each antenna has the directivity of $\nu = 2$ Binomial Pattern (11). (Fig. 4)

$$D(\phi) = 0.375 + 0.5 \cos \phi + 0.125 \cos 2\phi \qquad (11$$

AN-22 is designed to be a directive antenna only for High Channel (170-222MHz), while in Low Channel (90-108MHz), it works as a dipole on account of a couple of rods connected to the loop wire through tank circuits, whitch resonate and cut out the influence of the rods, in High Channel.

The characteristics of the antennas are as follows.

	AN-22	AN-31
Frequency Range:	170-222MHz,	76-90MHz
Diameter of Loop:	320mm,	950mm
$2\pi b/\lambda$:	0.625 (190MHz),	0.825 (83MHz)
Power Gain(dB):	-1 ~ 6,	+1.5 ~ -0.5
Front Back Ratio(dB):	8-34,	19-44

PHOTO 1
AN-22

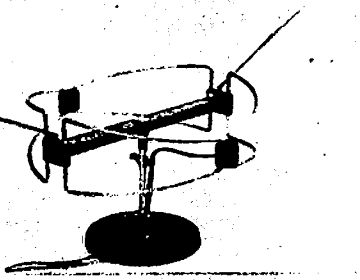
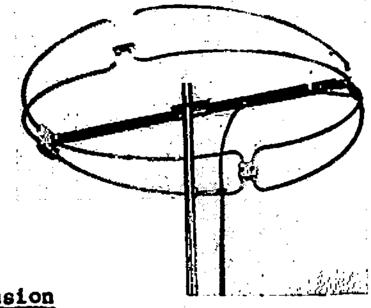


PHOTO 2
AN-31



6. Conclusion

Pattern Synthesis of distributed wave source anables to realize arbitrary pattern by arbitrary curved wave source.

The theory is applied to several practical VHF antennas, which proved that small antennas with fairly good directive pattern are easily obtained.

(1) T.Doi, R.Sato; "Pattern Synthesis and realization of circular distributed current source" 1969 International IEEE/G-AP Symposium and Fall VSNC/URSI Meeting) II-2 (Dec. 1969).