B–3–2 ROCKETBORNE OMNIDIRECTIONAL ANTENNA SYSTEM

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1. Introduction

Rocketborne Command Destruct Receiver (CDR) System is a very important system for the purpose of flight safety.

The CDR antenna system must always keep radio link with ground stations during the flight. Accordingly, CDR antenna must have omnidirectional radiation pattern which covers all over the radiation sphere. Required gain is greater than -14dBI for the N-II rocket which is now under development by the National Space Development Agency of Japan (NASDA).

To simply realize an omnidirectional antenna system, antenna element must essentially have a broad radiation pattern. One-element antenna, however, can not be expected to satisfy the above requirement, because diameter of the N-II rocket is as large as about twenty times of wave length (20λ).

To establish an omnidirectional pattern, multiple-element synthesis method may be very effective. Effect of numbers of element was investigated theoretically.

Investigation was also made from the view points of system reliability and various restriction of rocket configuration such as weight and installation.

As a result, better CDR Antenna System configuration is dual set system, each of which has two elements coupled by power combiner.

2. Analysis

In order to realize an omnidirectional pattern, antenna element required to be excited by both radial and axial components of electric vector. L-shape antenna is the most suitable for this purpose. Coordinate system used in this analysis is shown in Fig. 1. Radiation pattern of L-shape antenna can be obtained by synthesizing the radial and axial componet vector. Each of radial and axial component vector around cylinder was discussed separately by P.S. Carter [1]. In case that numbers of L-shape antenna was layed out on cylinder, radiation pattern can be obtained by point source synthesizing method [2]. Radiation pattern is caluculated with equations (1) and (2) where M is number of elements.

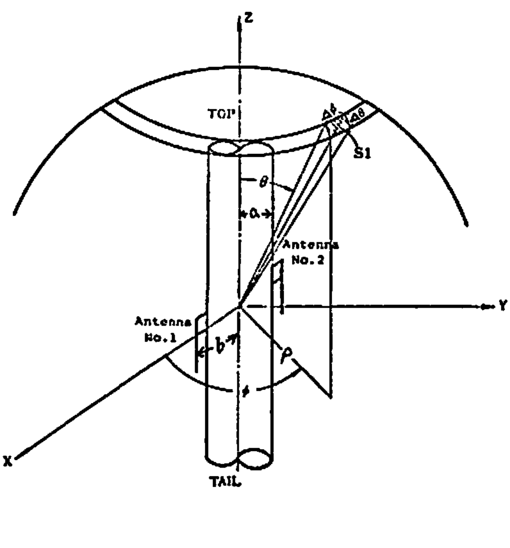

Fig.1 Rocket coordinate system

$$E\theta = K_1 \frac{\exp(j\frac{\pi}{2}\cos\theta)}{\sin\theta} \sum_{m=1}^{M} \sum_{n=0}^{\infty} E_n (j)^n \exp(j\psi m) B_n \cos n(\phi - \frac{2\pi}{M} m) \qquad (1)$$

$$B_n = J_n(kb\sin\theta) - \frac{J_n(ka\sin\theta)}{U_n(ka\sin\theta)} \cdot U_n(kb\sin\theta)$$

$$E\phi = K_2 \sum_{m=1}^{M} \sum_{n=1}^{\infty} E_n \frac{n}{\sin\theta} (j)^n \exp(j\psi m) \int_{P_1}^{P_2} \frac{Z_{n1}(P)}{P} dp \sin n(\phi - \frac{2\pi}{M} m) \qquad (2)$$

$$Z_{n1}(P) = J_n(P) - \frac{J_n'(P_1)}{U_n'(P_1)} \cdot U_n(P)$$

$P = k\rho\sin\theta$ ψ_P = PHASE DIFFERENCE DURING ELEMENTS
$P_1 = ka\sin\theta$ k_1, k_2 – CONSTANTS
$P_2 = kb\sin\theta$ $1 \leq m \leq M$
E_n = THE NUMBER OF NEUMAN

J_n= n th order Bessel function of 1st kind
U_n= n th order Hankel function of 2nd kind

Fig.2 is the calculated results when M=1 and shows very good coincidence with measured value. To evaluate omnidirectivity, covergae factor is defined as the ratio of the area, which gain is greater than a defined value, to the entire spherical surface area, $4\pi\gamma^2$.

Equations of coverage factor are given by (3) and (4).

$$S_n = \int_{\theta_1}^{\theta_2} \int_{\phi_1}^{\phi_2} \gamma^2 \sin\theta \, d\theta \, d\phi \qquad (3)$$

Sn is small area where the required gain is satisfied.

$$S(\%) = \frac{1}{4\pi\gamma^2} \times \sum_{n=1}^{N} S_n \times 100 \qquad (4)$$

Coverage factor of one-element, two-element and four-element antenna are shown in Fig.3 respectively.

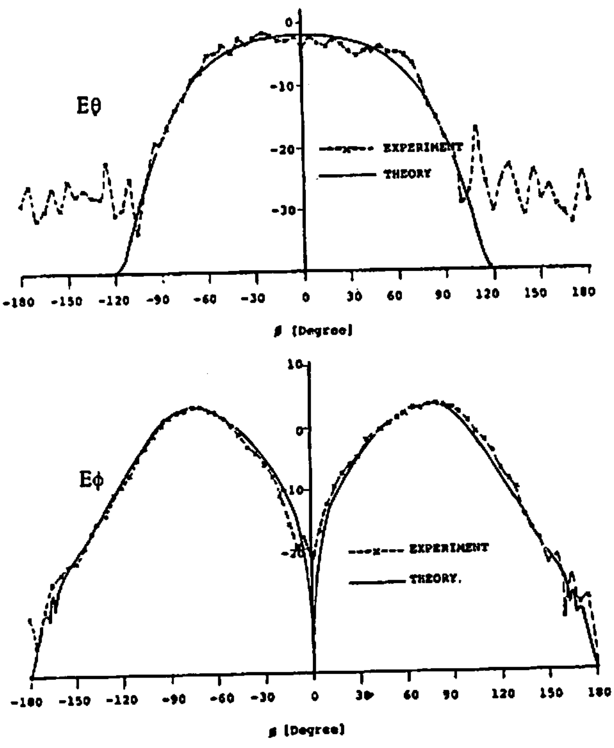

Fig.2 Radiation pattern of L-shape antenna

3. Discussion

Fig.3 shows that four-element antenna has no more distinct advantage compared to two-element antenna. When two two-element antennas are located at the suitable position on the surface of rocket, the gain dips of two-element antenna are covered mutually and coverage factor increases remarkably.

Radiation patterns were measured using blade type element which is a kind of L-shape antenna as shown in Fig.4.

Fig.5 is an example of radiation pattern of two-element antenna measured by th left hand circularly polarized. Coverage factor of that case is approximately 95%.

4. Conclusion

Good coincidence is obtained between analytical and measured values of radiation pattern of rocketborne omnidirectional antenna. Coverage factor used in this analysis is very useful for design and evaluation of omnidirectional antenna.

Reference

[1] P.S. Carter: Antenna Arrays Around Cylinder, Proc. IRE. Dec. 1943

[2] Kamata and Ichikawa: Vector synthesis of multiple antenna elements by point source synthesis (in Japanese) 1977 meeting of IECE.

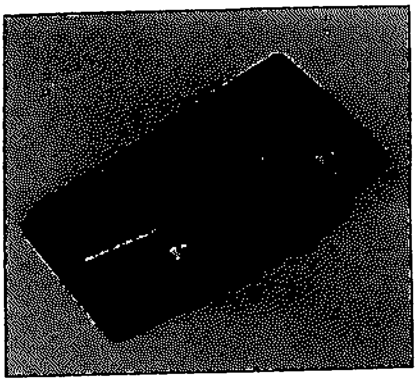

Fig.4 Outline of CDR antenna

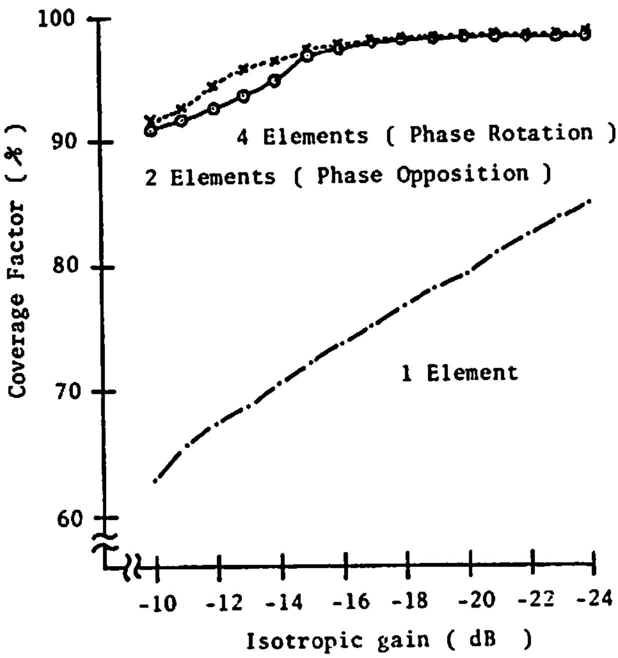

Fig.3 Coverage factor (Theoretical)

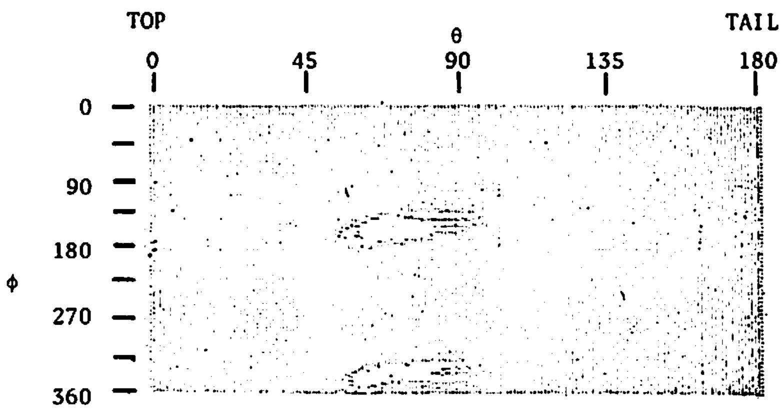

Fig.5 Radiation pattern (Two-element antenna, LHC)
Dot means gain is greater than -14dBI