A COMPACT SHIPBORNE ANTENNA SYSTEM FOR MARITIME SATELLITE COMMUNICATIONS

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1. INTRODUCTION

A maritime satellite communication system based on digital transmission technology has been discussed for future generations of INMARSAT(1). In this system, the telephone signal transmission channels are digitized although they are operated by the Companded FM in the current Standard-A ship earth stations (SES). With the use of the digitized transmission systems, three advantages are expected: a saving of satellite power, a wider variety of new services, and an allowance for small-sized shipborne antenna.

The authors have been studying low G/T antenna systems which can be mounted on small ships and vessels, such as fishing boats, with a view to miniaturizing the above deck equipment(2). The primary requirement of low G/T antenna systems is simplicity, i.e. they should be small in size, light in weight and simple in configuration. In addition, usage of the fading reduction technique is required since the multipath fading caused by the sea surface reflection becomes severe due to comparatively wide beamwidth.

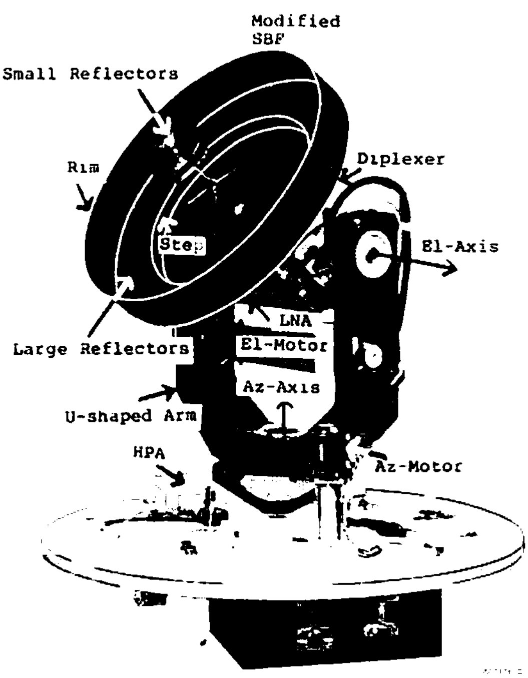

Fig. 1 Compact Shipborne Antenna System

Based on our studies, we have developed a compact shipborne antenna system, in which the G/T and EIRP are -10dBK and 26dBW, respectively. This compact antenna system would be compatible with the digitized system ensuring the third advantage mentioned above. This paper describes an outline of the antenna system. Figure 1 shows a photograph of this antenna system.

Table 1 Main Features of Compact Antenna System

System Performance	G/T = -10dBK EIRP = 26dBW
Antenna	Modified SBF (diameter=0.4m) Gain:15.5 dBi at 1.54 GHz Axial Ratio: 0.7 dB at 1.54 GHz
Fading Reduction	Polarization Shaping Method
Mount	Improved 2 - Axis El/Az
Stabilization	Active Stabilization using Rolling/Pitching Sensor
Tracking	Program Tracking based on Position Information
LNA	GaAs FET (Noise Temp. : 90° K)
HPA	Class-A FET (Output Power : more than 22W)
Diplexer	Comb-Line Type Separation : 80dB at 1.54 GHz :110dB at 1.64 GHz
Weight	about 25Kg
Size (with Radome)	Diameter : about 0.65m Height : about 0.7m

In the system, C-FRP (Carbon-Fiber Reinforced Plastic) and K-FRP (Kevlar-Fiber Reinforced Plastic) are used with a view to reducing the weight. Table 1 summarizes the main features of this antenna system. The antenna system is approximately one-eighth the volume and one-fifth the weight of a current Standard-A SES.

2. ANTENNA SYSTEM

2.1 Modified Short Backfire Antenna

An antenna gain of around 15dBi is necessary to obtain a G/T of -10dBK. One of possible antennas for generating this gain is a modified Short Backfire (SBF)(3) whose details are shown in Fig. 2.

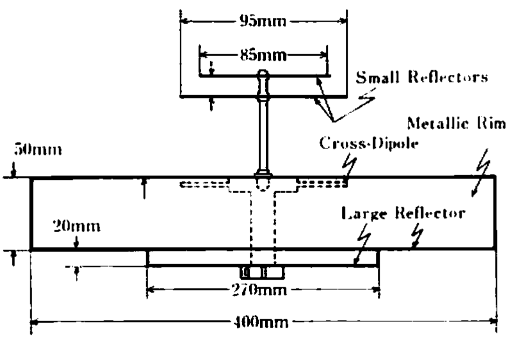

Fig. 2 Modified SBF Antenna

As can be seen from Fig. 1 and Fig. 2, this antenna has dual small reflectors and a large reflector with a step configuration. The former plays a role in improving the frequency characteristics of VSWR. The latter plays a role in improving the radiation characteristics of the conventional SBF(4). There is an improvement of about 1dB in antenna gain and about 0.3dB in axial ratio over that of the conventional SBF. The antenna gain and the axial ratio of the modified SBF with the dimensional parameters shown in Fig. 2 are 15.5dBi and 0.7dB (at 1.54GHz), respectively.

2.2 Two-axial El/Az Antenna Mount

In the case of low G/T antenna systems, for the present, the 2-axial El/Az mount with the function of program tracking using ship position information from navigation equipment may be desirable from the economical and constructional viewpoints. In this antenna system, as shown in Fig. 1, the arm which supports the El-axis is U-shaped and the El-axis is mounted near the central axis of the antenna to maintain the weight balance of the antenna, LNA, diplexer and so on. Accordingly, the weight load on the Az-axis is decreased, resulting in a reduction of size and weight compared with the conventional El/Az mount. However, the following factors must be considered to develop good pointing accuracy in the conventional El/Az mount:

a) reduction of the pointing errors due to the gimbal-lock at high elevation angles; and
b) reduction of the pointing errors due to the rewind operation of the Az-axis.

With the new El/Az mount, a newly developed control algorithm is adopted in order to correct the above pointing errors(5). The pointing error of the conventional El/Az mount operating at high elevation angles (for example, El=85°, Az=90°) amounts to about 30° due to the gimbal-lock, and also frequently exceeds 30° due to the rewind operation under the

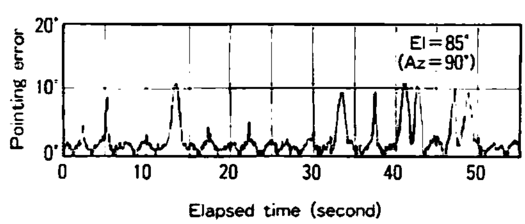

Fig. 3 Pointing Error of New Az/El Mount at a High Elevation Angle (Rolling : 30°, 5 seconds) (Pitching: 10°, 3 seconds)

condition that, for example, the amplitudes of rolling and pitching are 30° and 10°, respectively. On the other hand, errors of the above mentioned new El/Az mount are less than 11° at the same pointing direction (El=85° and Az=90°) as shown in Fig. 3. The degradation of the pointing accuracy due to the gimbal-lock disappeared completely and error due to the rewind operation is remarkably improved. Additionally, the pointing errors at low elevation angles are less than 3°. There existed rolling of about 15° and pitching of about 5° at most in on-board experiments, however, the pointing error was less than 2°.

3. FADING REDUCTION TECHNIQUE

For low G/T antenna systems, the effect of multipath fading due to sea surface reflection will be severe since the beamwidth is wider than that of the current Standard-A SES(6). In this antenna system, the Polarization Shaping Method (PSM), whose principle is mentioned below(7), is adopted. In the case of 1.6/1.5GHz, the horizontally polarized wave incident upon sea surface is reflected almost perfectly while the vertically polarized wave is reflected with a substantial attenuation at grazing angles below about 20°. Thus the polarization of the reflected wave becomes elliptical with the opposite sense of rotation with respect to the incident circular polarization, when the elevation angle is above 6°, and its major axis is nearly horizontal. Accordingly, if we could adjust the polarization ellipse of the ship antenna in the direction of the reflected wave so that it becomes orthogonal to that of the reflected waves, it could be expected to be suppressed. This principle can be easily applied to cross dipole fed antenna such as modified SBF. Figure 4 shows block diagram examples of this method. In the configuration of Fig. 4-(a), the cross dipole needs to be inclined by 45° against sea level. However, in

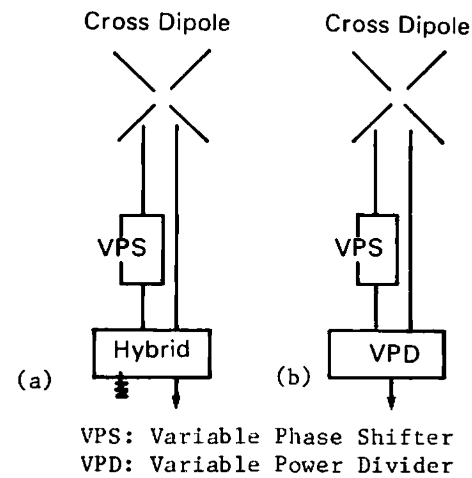

Fig. 4 Block Diagram Examples of PSM

both cases, the optimum orthogonal polarization can be obtained by controlling VPS and VPD.

In 1984, we conducted two on-board experiments in order to evaluate the performance characteristics of this compact antenna system, including the effect of PSM, and also to obtain data on fading by using the INTELSAT V satellite/MCS over the Indian Ocean. In these experiments, we mounted the antenna system aboard the TOKAI DAIGAKU MARU NISEI (700 tons) for a cruise between SHIMIZU port and AMAMI OSHIMA island. The elevation angle ranged from 3° to 12°. Figure 5 shows the fading depth for 99% of the time "with" (ON) and "without" (OFF) PSM, under the condition that the wave height ranged from about 1 to 4 m which were corresponding to the "rough" sea condition. From this figure, it is noticed that the fading depth with PSM is hardly affected by the difference in wave height. Figure 6 shows an example of down-link (received) signal level with an elevation angle of 5° and a wave height of about 1.3 m. In this figure, the fading depth corresponding to 99% of the time decreases from 10.0dB to 5.5dB with the use of PSM, although there exists a polarization loss of about 1dB. One of the important features of PSM is that PSM is applicable to both up- and down-link signals. This fact was also recognized by our on-board experiments.

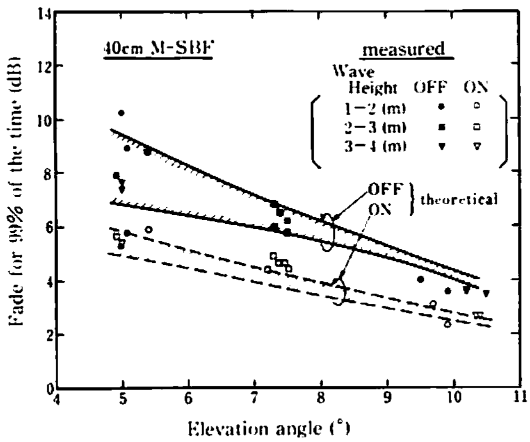

Fig. 5 Fading Reduction Effect at 1.54 GHz
OFF: without PSM
ON: with PSM

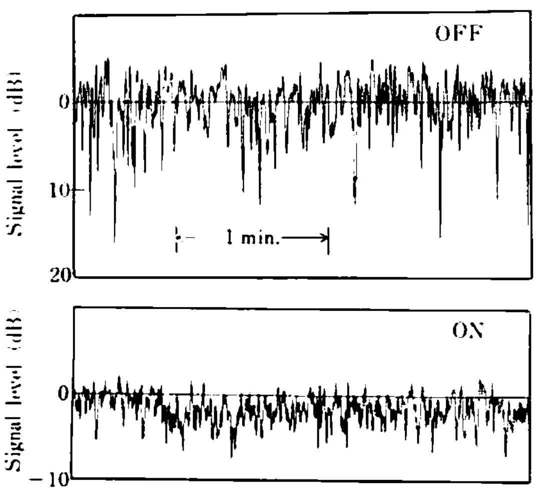

Fig. 6 Examples of Received Signal Level at 1.54 GHz
OFF: without PSM
ON : with PSM
Elevation angle : 5°
Wave height : 1.3 m

4. CONCLUSION

In this paper, the performance characteristics of the compact antenna system which would be compatible with the future INMARSAT low G/T SES have been presented. This compact antenna system can also be mounted on small ships less than 100 tons.

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