

FADING REDUCTION TECHNIQUES APPLICABLE TO SHIP EARTH-STATION ANTENNAS

(Question 88/8)

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1. Introduction

For low G/T systems, the effect of multipath fading due to sea surface reflection is a severe problem, especially at low elevation angles as pointed out in § 5 of Report 921. This Report surveys possible fading reduction techniques for low G/T ship earth-station antennas and presents field experimental results on the reduction effects. The antennas reported in these tests are described in more detail in Report 921.

2. Survey on fading reduction techniques

The following methods are possible as fading reduction techniques applicable to low G/T ship earth-station antennas:

- diversity method,
- polarization method,
- pattern shaping method,
- maximum level tracking method,
- beam offset method.

2.1 Diversity methods

Diversity techniques such as space, polarization and frequency diversity have already been used practically in radiocommunication systems subject to severe fading. The space diversity technique needs two or more antennas, while other diversity techniques can be effected using a single antenna. In any case, the fading reduction effect largely depends on the correlation of signals with different properties, such as frequencies, polarization and time difference. Figure 1 shows the principle of space diversity with a switch and stay algorithm [Kozono and Yoshikawa, 1981]. As is seen in this figure, the diversity output results in $R(t)$, when signal levels through antenna 1 and antenna 2 are $r_1(t)$ and $r_2(t)$, respectively. With this technique, the greatest reduction effect is expected when the correlation of the signals between the two antennas is lowest. In practice, it may not be possible to set up the antennas with the optimum spacing of a half wavelength.

Frequency diversity can produce a good reduction effect when the path difference between the direct and reflected waves is greater than one wave length of the difference frequency between two frequencies used. Assuming that the height of the ship antenna is 15 m, the elevation angle is 5° and the frequency separation is 15 MHz, which is the maximum separation with the current 1.6 GHz band maritime mobile satellite service allocations, then, at the most, the path difference is only 0.14 wave length of the difference frequency. Therefore, frequency diversity does not seem practicable at this stage, because of the limited separation of the two frequencies. However, if the frequency band were to be widened in the future, this method could be applicable.

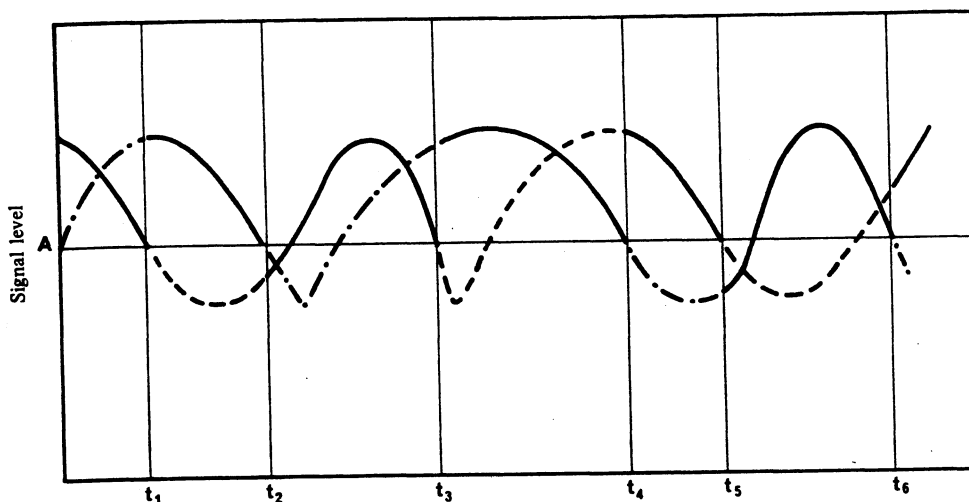


FIGURE 1 – Principle of switch and stay algorithm

- · - · - $r_1(t)$
 - - - - $r_2(t)$
 ——— $R(t)$

Note.— The input to the receiver is switched to the serial from which the output is rising when the input of the selected antenna falls below a pre-determined level "A".

2.2 Polarization method

For reflections from the sea surface at 1.64/1.54 GHz, the horizontally linear polarized wave is almost perfectly reflected, while the vertically polarized wave is reflected with fairly large attenuation at incident angles, with respect to the horizontal plane, of less than 10° . Furthermore, the phase angle of a vertically polarized wave undergoes a continuing change as the elevation angle increases, whereas the phase of a horizontally polarized wave remains unchanged at all but the highest elevation angles. Above around 6° elevation angle, the phase and amplitude relationship between the horizontal and vertical components of an incident circularly polarized wave is such that upon reflection it becomes elliptical and reversed in its sense of rotation, with its major axis nearly horizontal. (An elevation angle of around 6° is the Brewster angle at 1.5/1.6 GHz over sea paths; for more information see Report 1008.) Accordingly, if the polarization ellipse of a shipborne antenna, in the direction of the reflected wave, could be adjusted so that it always stays orthogonal to that of the reflected wave, the reflected wave can be suppressed. This principle [Shiokawa and Karasawa, 1982] can be easily applied to cross dipole fed antennas such as a short back-fire antenna. For instance, if it is arranged that the cross dipole elements are inclined by 45° with respect to the horizontal line, and the phase is adjusted by a phase shifter inserted in one of the ports of the short back-fire antenna feed as shown in Fig. 2a), the axial ratio of this antenna can be arbitrarily controlled. In this case, the major axis of the polarization ellipse is always vertical as shown in Fig. 2b).



Block diagram of a 3-dB hybrid coupler. A cross dipole feeds into a 90° - 3 dB Hybrid block. The top output (T3) goes to a Combiner. The bottom output (T4) goes through an Att. (attenuator) and a Phase shifter before entering the Combiner.

FIGURE 3 – Configuration of polarization method (B)

2.3 Pattern shaping method

It is possible to suppress the reception of a reflected signal by using a shaped pattern antenna which has low gain radiation characteristics in the direction of the sea-reflected wave. This method may be realized by an antenna array or a shaped reflector antenna. Figure 4 shows an example of the radiation pattern of a shaped pattern antenna [Ohmori *et al.*, 1980]. The radiation pattern is shaped so as to be flat in the main beam and to be suppressed in other directions. This antenna is expected to have a good reduction effect when the reflected waves come from directions away from the main beam. The shaped pattern antenna, however, has the disadvantage that the aperture efficiency of the antenna is in general comparatively low.

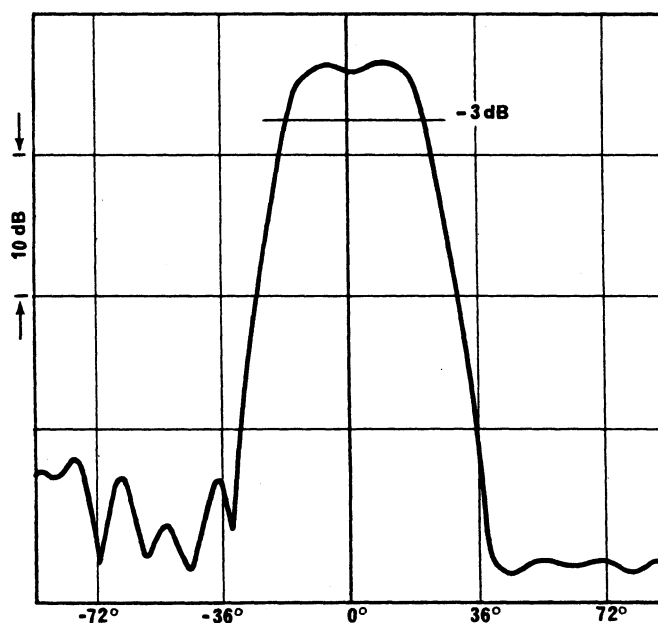


FIGURE 4 – Radiation pattern of shaped pattern antenna

Gain: 16 dBi (1.54 GHz)

2.4 Maximum level tracking method

If the radiation characteristics of an antenna in the direction of the reflected wave are controlled so that the received signal intensity is always maintained at a higher level, the fading could be substantially suppressed. This principle [Shiokawa and Karasawa, 1982] can be easily applied to an antenna array. The phase of a variable phase shifter inserted in the feed circuit for each antenna element is varied by a small amount by changing its control voltage in order to see whether the resultant signal level increases or not. The phase has to be adjusted at a rate sufficiently fast to track the speed of the fading. If the signal level increases, the control voltage is allowed to change continuously in the same direction. If not, the polarity of the control voltage has to be reversed to control the variable phase shifter in the opposite direction. Fading can be reduced by repeating this operation. Figure 5 shows a block diagram illustrating an example of this method applied to a quad-helix antenna.