REPORT 922-1

REFERENCE RADIATION PATTERN FOR SHIP EARTH-STATION ANTENNAS

(Study Programme 17A/8)

(1982–1986)

1. Introduction

Consideration is given in this Report to the reference antenna pattern for ship earth stations to be used in assessing interference between ship earth stations and either terrestrial stations or space stations of different satellite systems sharing the same frequency bands.

The objective of this Report is to present actual measurement of antenna patterns taken on a test range and show that these measured patterns are well below the reference pattern proposed by other Study Groups and defined by the WARC-79.

2. Existing reference radiation patterns

Reference radiation patterns have been developed in various Study Groups of the CCIR: Report 390 and Report 391 in Study Group 4, Report 771 in Study Group 8 and Report 614 in Study Group 9. These Reports give a reference radiation pattern for antennas with diameter less than 100 λ, as stated below.

$$G = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi \quad \text{dB} \quad \text{for } 100 \frac{\lambda}{D} \leq \varphi < \varphi_1$$

$$G = G_1 \quad \text{dB} \quad \text{for } \varphi_1 \leq \varphi$$

where:

D: antenna diameter } expressed in the same unit
λ: wavelength } expressed in the same unit

φ: angle from beam centre, in degrees

In Report 391, G_1 is taken to be -10 dB. On the other hand, in Report 614, G_1 is taken to be 0 dB. For values of φ less than 100 λ/D, WARC-79 has defined the following reference radiation pattern for interference calculations:

$$G = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2 \quad \text{dB} \qquad \text{for } 0 < \varphi < \varphi_m$$

$$G = 2 + 15 \log \frac{D}{\lambda} \quad \text{dB} \qquad \text{for } \varphi_m \leq \varphi < 100 \frac{\lambda}{D}$$

$$\text{where, } \varphi_m = \frac{20\lambda}{D} \sqrt{G_{max} - 2 - 15 \log \frac{D}{\lambda}} \qquad \text{(degrees)}$$

and G_{max} = maximum gain of the antenna relative to isotropic.

These equations assume the case of a circular paraboloidal reflector antenna, which might not be relevant for some kinds of antennas which could be used in the future for ship earth stations. Therefore, the use of this kind of pattern should clearly be restricted to the case of circular paraboloidal reflector antennas. Moreover, the above Reports have not specifically considered the question of the applicability of these equations to very small values of D/λ; therefore, for antennas of such diameter as small as 4λ, the value of G_1 must be carefully established taking into account measured radiation patterns.

3. Measured antenna patterns

All production designs of ship earth stations manufactured to date for use in the MARISAT system have employed a parabolic reflector antenna having a diameter of between 1.2 and 1.3 m with a G/T of -4 (dBK^{-1}). This value of G/T is the current requirement for INMARSAT Standard-A ship earth stations.

Figures 1 and 2 present measured antenna patterns for 1.3 m antenna for transmit and receive frequencies, respectively. Figures 3 and 4 present measured antenna patterns for 1.2 m antenna for transmit and receive frequencies, respectively. Figure 5 presents measured antenna pattern for 0.8 m antenna for receive frequencies.

In submitting information on measured radiation antenna patterns, the following guidelines should be adopted:

- for each antenna diameter, only two Figures should be presented, one for transmit band and one for receive band, which should include all available data for this type of antenna;
- only the peaks of the side lobes measured over the appropriate frequency band and antenna pattern cut should be plotted, for any angle from beam centre;
- the reference radiation pattern as described in § 5 should be included in all Figures;
- the Figures should be one-sided (right-hand) with measured peaks from both sides superimposed;
- the caption of the vertical axis should read "Gain relative to isotropic (dB)" with a scale of 2 dB/cm;
- the caption of the horizontal axis should read "Angle from beam centre (degrees)" with a linear scale of 10°/8 mm;

Figures 1 to 5 in this Report have been prepared using these guidelines.

4. Effect of reflection due to sea and ship's superstructures

Considerations have been given to the concept that the design objectives and the reference radiation pattern for interference studies may be defined separately, because the reference radiation pattern should include the effect of local reflections from the sea and ship's superstruture.

However, it is very difficult to estimate quantitatively such effects, which may be of the order of several dB, because the directions of reflected waves vary in accordance with the ship movement. Moreover, the time probability of the interference caused by such reflected side lobes is very difficult to assess. Further study is needed to clarify the effect of such reflections.

5. Reference radiation pattern for ship earth stations

Based on the above and using a conservative approach, it may be reasonable to adopt the following reference radiation pattern for the antennas of ship earth stations:

$$G = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi\right)^2 \quad \text{dB} \qquad \text{for } 0 < \varphi < \varphi_m$$

$$G = 2 + 15 \log \frac{D}{\lambda} \quad \text{dB} \qquad \text{for } \varphi_m \leq \varphi < 100 \frac{\lambda}{D}$$

$$G = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi \quad \text{dB} \qquad \text{for } 100 \frac{\lambda}{D} \leq \varphi < \varphi_1$$

$$G = 0 \text{ dB} \qquad \text{for } \varphi_1 \leq \varphi$$

where: $$\varphi_m = \frac{20\lambda}{D} \sqrt{G_{max} - 2 - 15 \log \frac{D}{\lambda}} \quad \text{(degrees)}$$

$$\varphi_1 = 120 \left(\frac{\lambda}{D}\right)^{0.4} \quad \text{(degrees)}$$

and where other variables are defined in § 2.

This pattern has been indicated on Figs. 1 to 6.

6. INMARSAT side lobe performance requirement

Based on the measured radiation patterns of paraboloidal antenna with diameters between 0.8 m and 1.2 m, the following expression has been determined as the performance requirement for the sidelobe envelope of INMARSAT Standard-A ship earth stations:

$$G = 8 \quad \text{dB} \qquad (16° \leq \varphi \leq 21°)$$
$$G = 41 - 25 \log \varphi \quad \text{dB} \qquad (21° < \varphi \leq 57°)$$
$$G = -3 \quad \text{dB} \qquad (\varphi > 57°)$$

where G is the antenna gain relative to isotropic at an angle φ from beam centre.

The INMARSAT antenna pattern is illustrated in Fig. 6, together with the reference radiation pattern derived from § 5, for 1.2 m antenna diameter (24 dB maximum gain).

7. Conclusion

Based on the measured radiation patterns of ship earth stations, it is proposed to adopt provisionally the reference radiation pattern for interference studies as given in this Report, for the circular paraboloidal reflector antennas of D/λ higher than 4 to be used for ship earth stations. In order to assure the suitability of this reference radiation pattern, administrations are invited to study further and submit measured radiation patterns of ship earth stations of various sizes, using the guidelines delineated in § 3.

To take into account that antennas other than parabolic may be used for ship earth stations, it would be desirable to examine additional measured radiation patterns, and administrations are invited to submit such information on various antenna types and sizes, using the guidelines delineated in § 3.

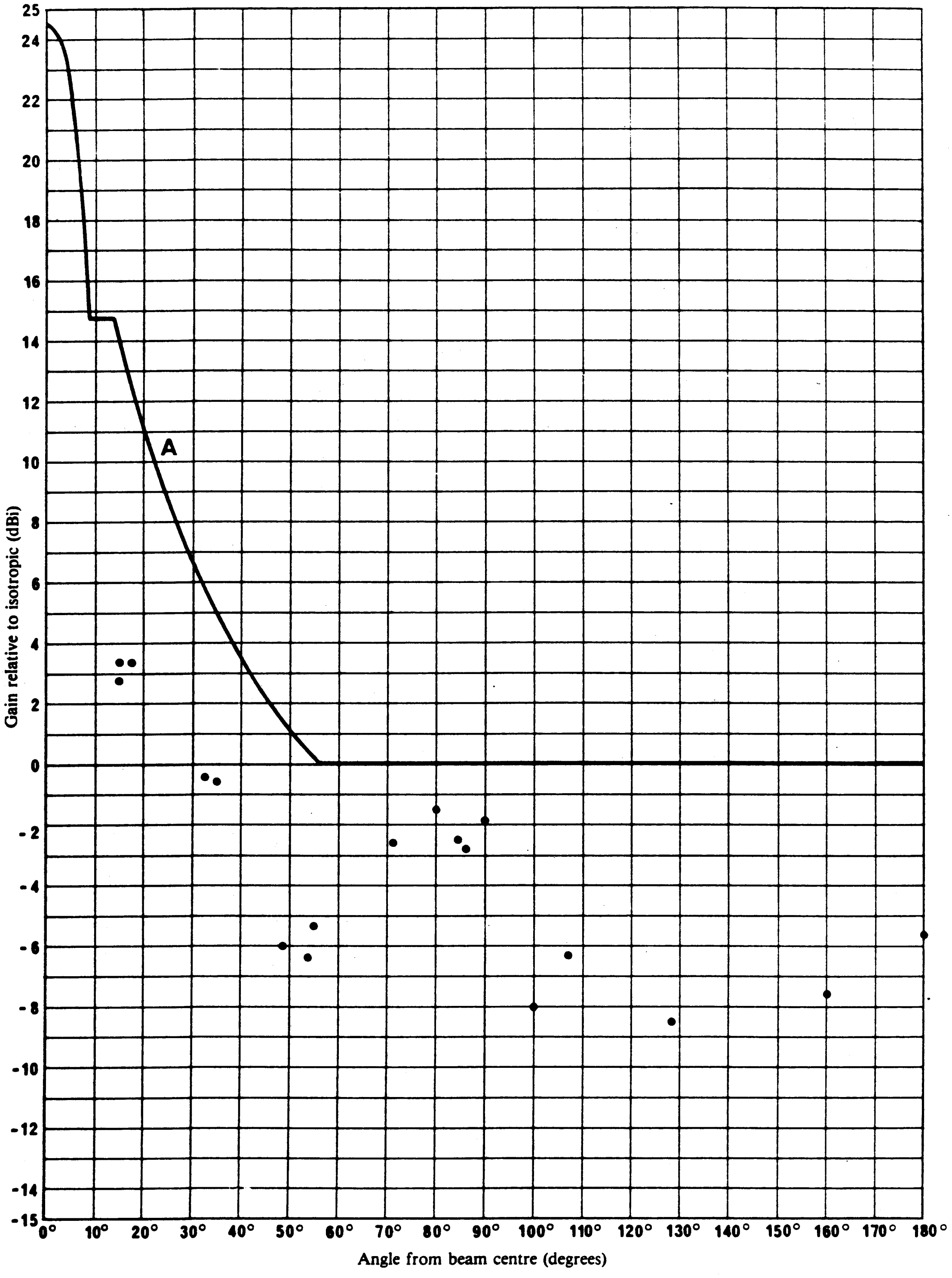

FIGURE 1 – *Measured antenna pattern for a ship earth station antenna*

Type of antenna: circular parabolic
Frequency band: 1636.5-1645 MHz (transmit)
Diameter: 1.3 m

●: maximum gain: 24.6 dBi   Polarization: RH circular   Manufacturer: UK
A: reference radiation pattern

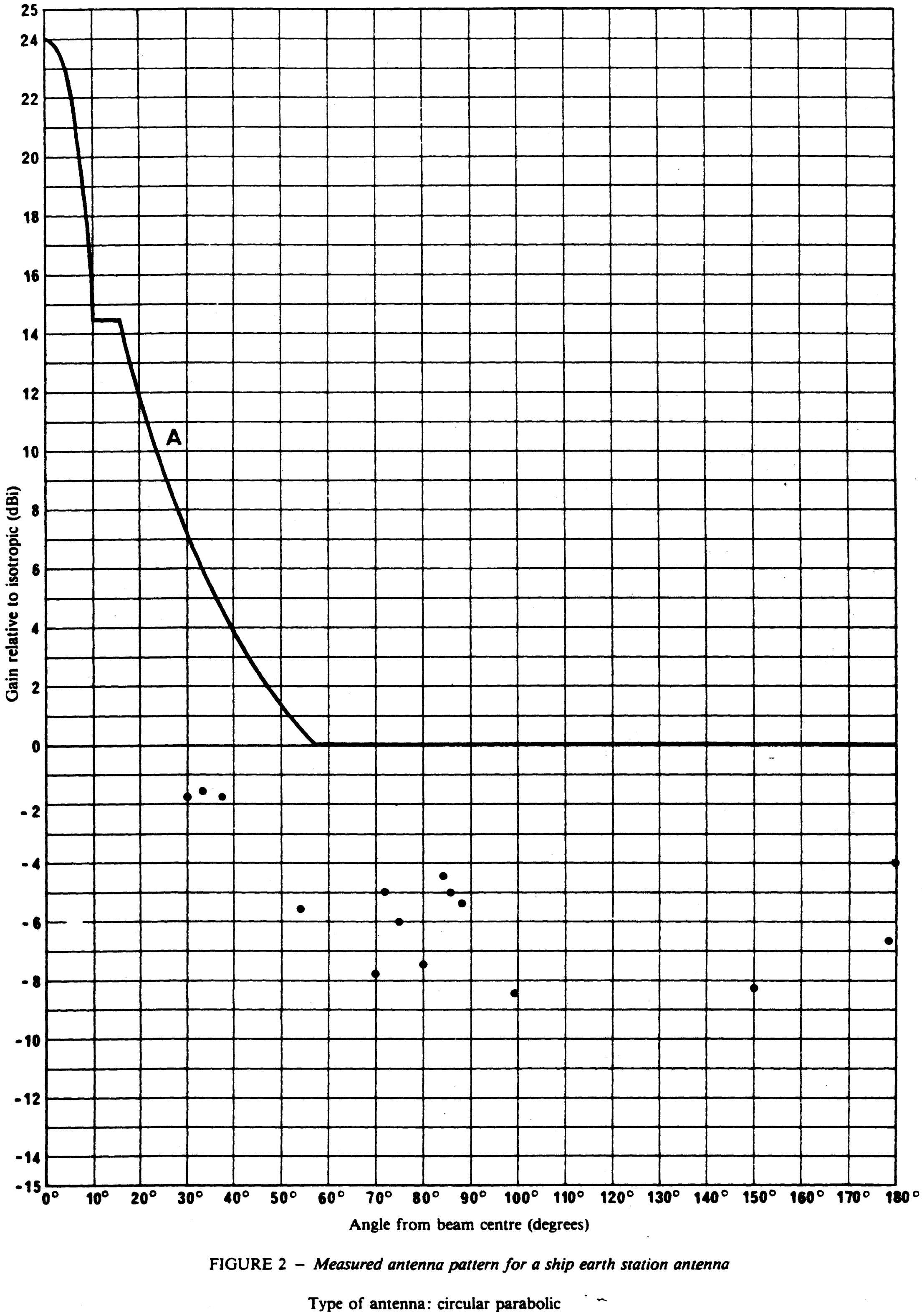

FIGURE 2 – *Measured antenna pattern for a ship earth station antenna*

Type of antenna: circular parabolic
Frequency band: 1535-1543.5 MHz (receive)
Diameter: 1.3 m

●: maximum gain: 24 dBi Polarization: RH circular Manufacturer: UK
A: reference radiation pattern

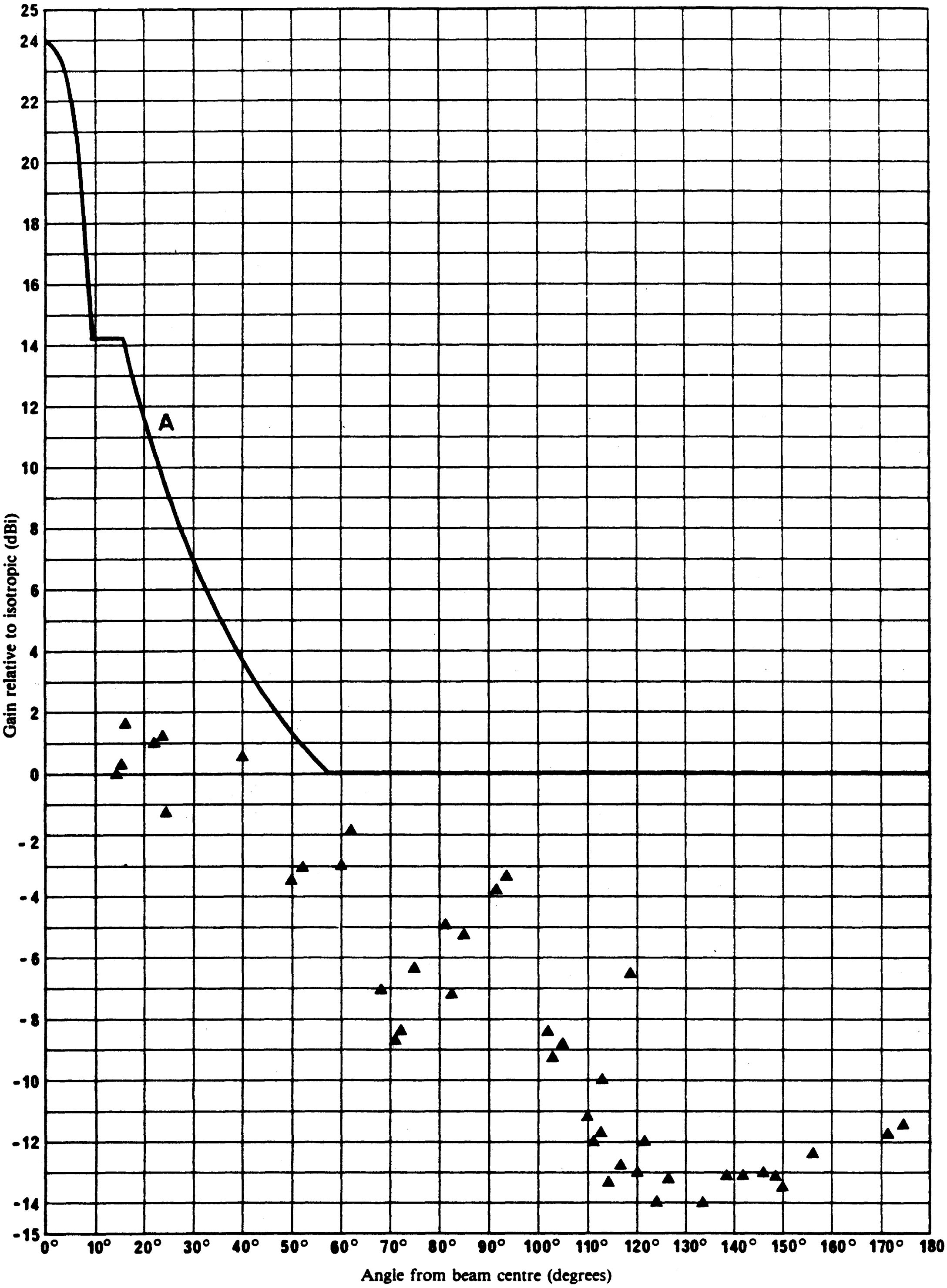

FIGURE 3 – *Measured antenna pattern for a ship earth station antenna*

Type of antenna: circular parabolic
Frequency band: 1636.5-1645 MHz (transmit)
Diameter: 1.2 m

▲: maximum gain: 24 dBi Polarization: RH circular Manufacturer: USA
A: reference radiation pattern

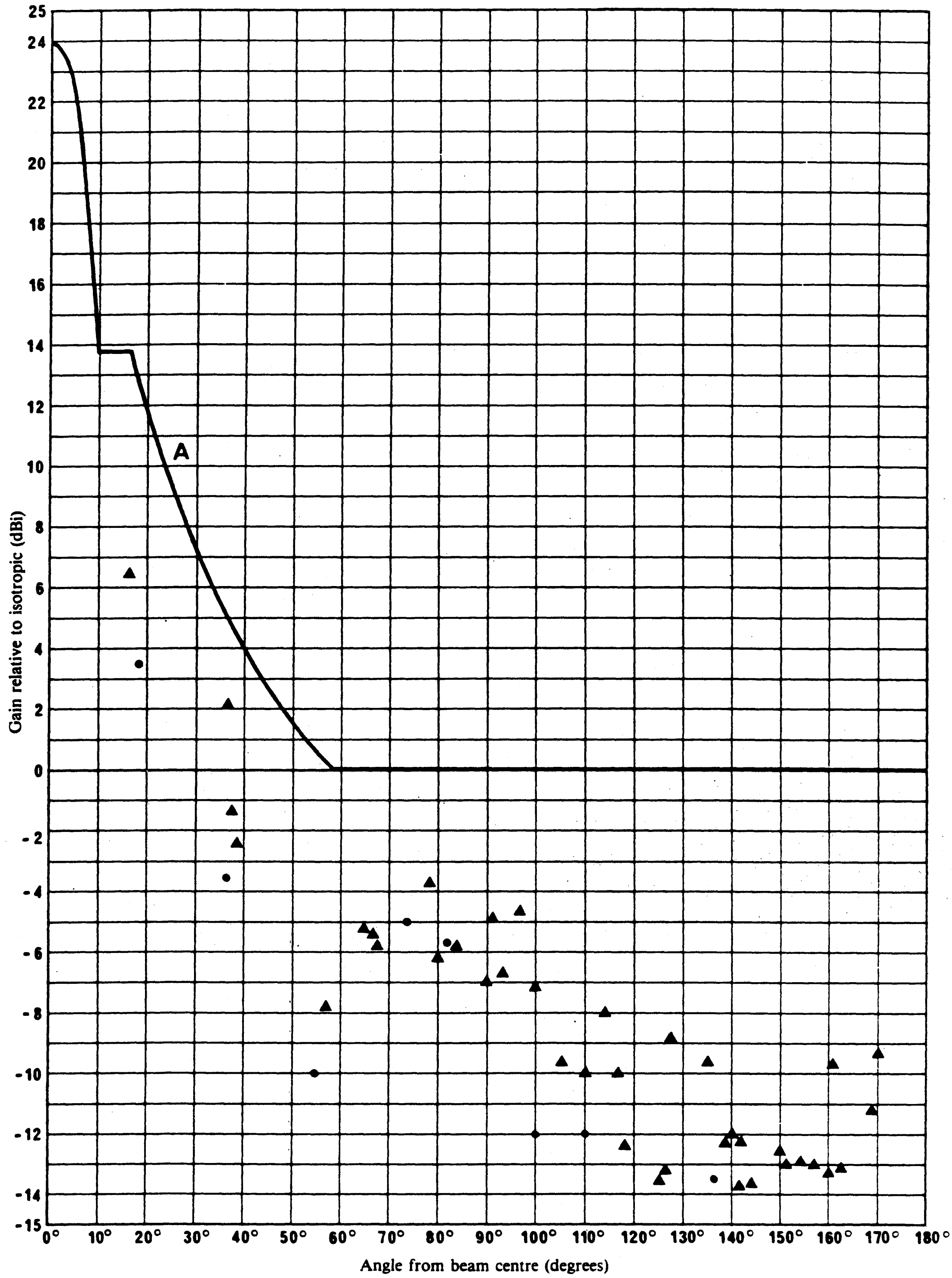

FIGURE 4 – *Measured antenna pattern for a ship earth station antenna*

Type of antenna: circular parabolic
Frequency band: 1535-1543.5 MHz (receive)
Diameter: 1.2 m

●: maximum gain: 23.9 dBi Polarization: RH circular Manufacturer: Japan
▲: maximum gain: 23.5 dBi Polarization: RH circular Manufacturer: USA
A: reference radiation pattern

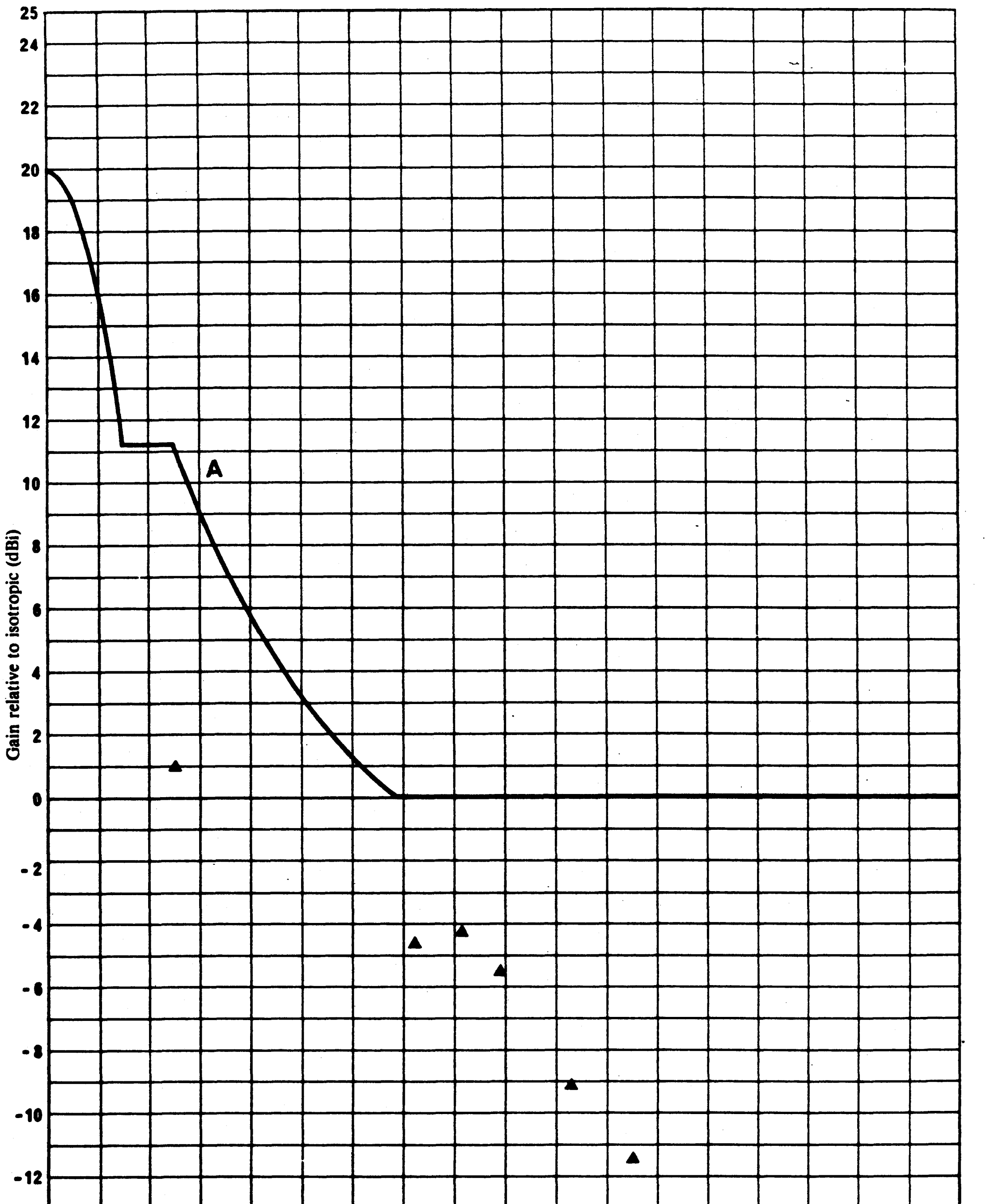

FIGURE 5 – *Measured antenna pattern for a ship earth station antenna*

Type of antenna: circular parabolic
Frequency band: 1535-1543.5 MHz (receive)
Diameter: 0.8 m

▲: maximum gain: 20 dBi Polarization: RH circular Manufacturer: Japan
A: reference radiation pattern

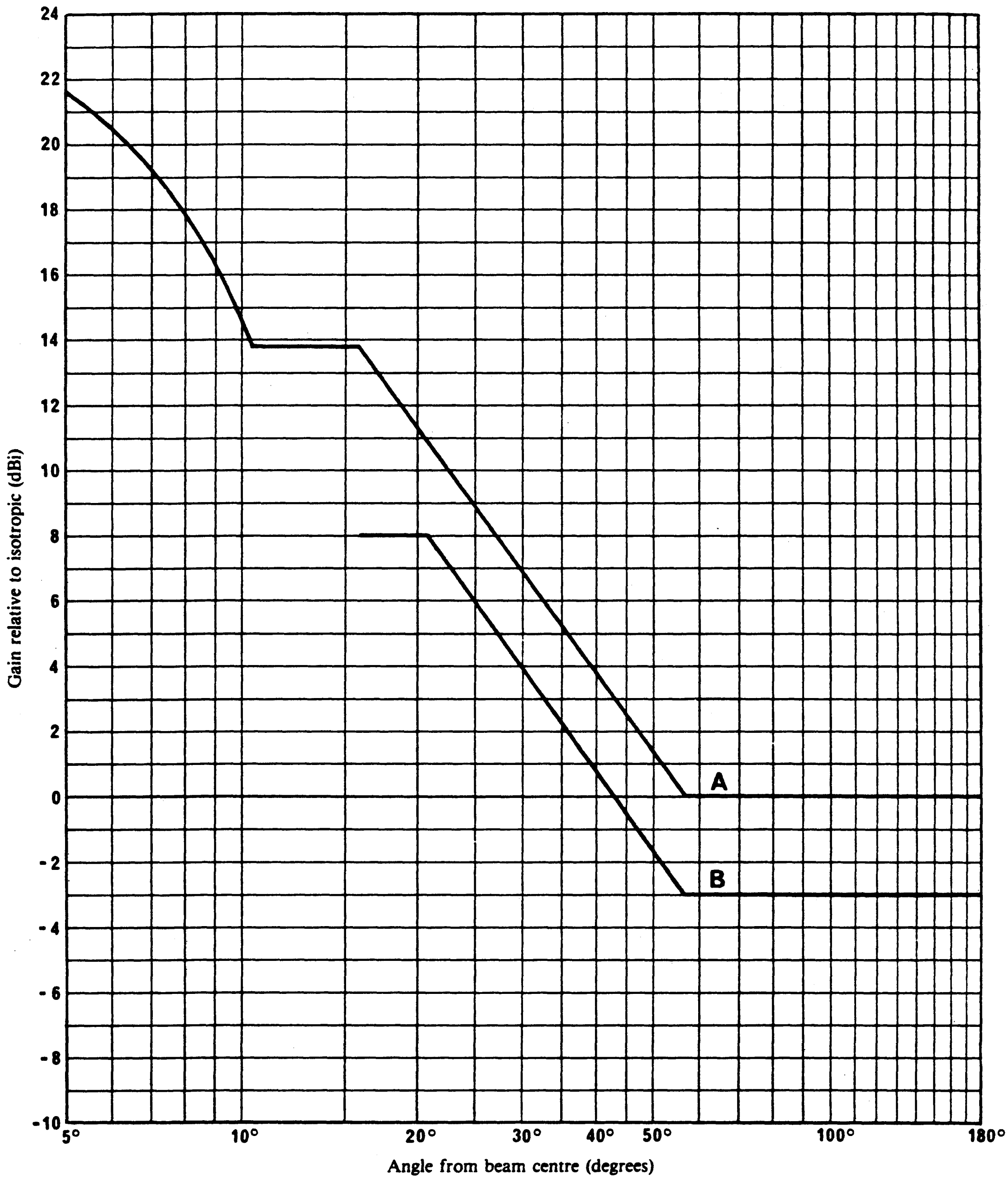

FIGURE 6 – *INMARSAT antenna side lobe envelope for Standard-A ship earth stations*

A: reference radiation pattern (1.2 m antenna diameter, 24 dBi maximum gain)
B: INMARSAT pattern

ANNEX I

A SMALL LOW-COST ANTENNA FOR USE WITH LOW *G/T* SHIP EARTH STATIONS

This Annex provides the measured radiation patterns of an antenna of simple design using an equi-angular spiral feed and low cost construction with a gain of 13 dBi and a beamwidth wide enough to obviate the need for a sophisticated stabilization system. The side-lobe performance compares favourably with the INMARSAT requirements for a standard A antenna (Figs. 7 and 8). Although the antenna was primarily designed for use with a low *G/T* ship earth station it could well have other applications in the mobile satellite service.

A fuller description of this type of antenna is given in Report 921.

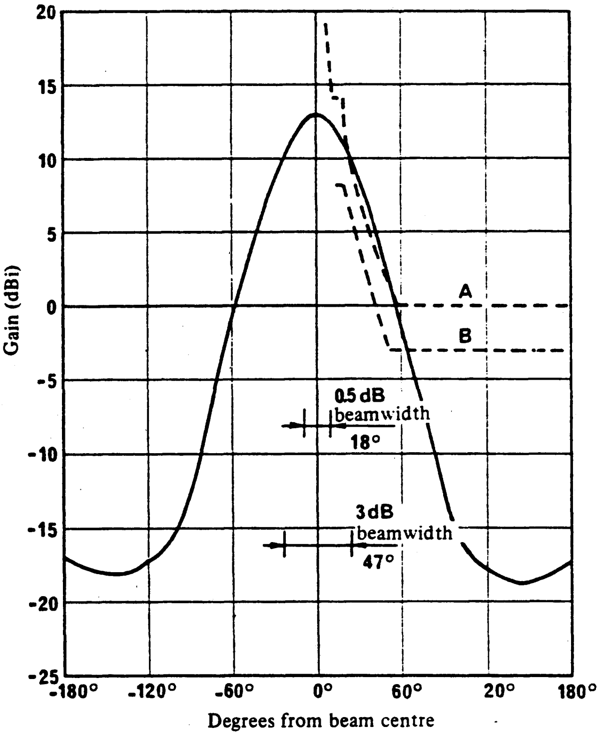

FIGURE 7 – *Measured radiation pattern from a short back-fire antenna*

Type of antenna: short back-fire
Diameter: 0.4 m
Frequency band: 1535–1543.5 MHz
Maximum gain: 13 dBi
Polarization: RHC

A: CCIR reference pattern
B: INMARSAT reference pattern

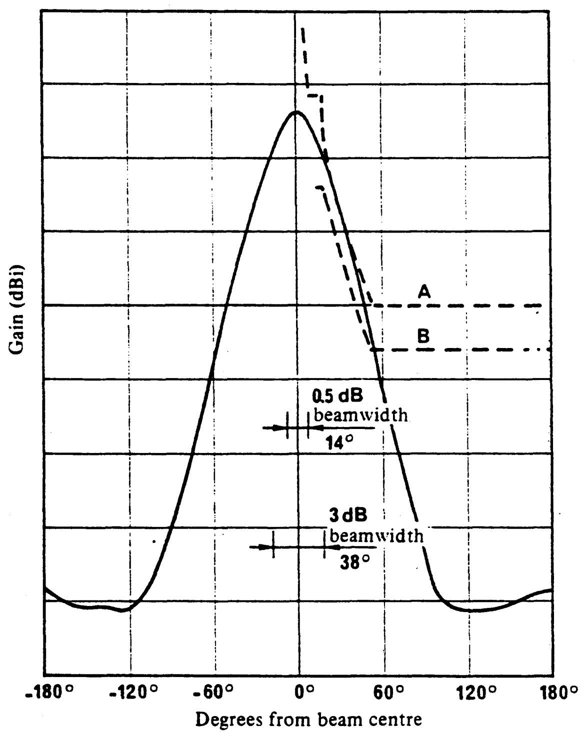

FIGURE 8 – *Measured radiation pattern from a short back-fire antenna*

Type of antenna: short back-fire
Diameter: 0.4 m
Frequency band: 1636.5-1645 MHz
Maximum gain: 13 dBi
Polarization: RHC

A: CCIR reference pattern
B: INMARSAT reference pattern