

RECOMMENDATION ITU-R S.733-2

DETERMINATION OF THE G/T RATIO FOR EARTH STATIONS
OPERATING IN THE FIXED-SATELLITE SERVICE

(Question ITU-R 42/4)

(1992-1993-2000)

The ITU Radiocommunication Assembly,

considering

- a) that the primary figure of merit for earth stations operating in the fixed-satellite service is the ratio of the antenna power gain-to-system noise temperature (G/T);
- b) that there are two commonly used methods for measuring earth station G/T , each of which has advantages for different situations and one method for its prediction,

recommends

- 1 that one method of measuring the ratio of antenna power gain-to-system noise temperature (G/T) is by the measurement of noise power emanating from a radio star, using the method explained in Annex 1;
- 2 that an alternative method for measuring this ratio is the measurement of a reference signal from a geostationary satellite, using the method explained in Annex 2;
- 3 that when neither of the methods explained are applicable, the ratio must be determined by a measurement of the antenna gain and an estimation of the system noise temperature;
- 4 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – The G/T of an earth station can be degraded by various naturally occurring processes. Increases in receiving noise temperature due to the atmosphere and precipitation, ground radiation and cosmic sources are treated in Appendix 1 to this Recommendation.

NOTE 2 – Information on determining the G/T of earth stations operating at frequencies greater than 10 GHz and the effects of various noise sources on the performance of earth stations operating in this frequency range is given in Annex 3 of this Recommendation.

NOTE 3 – The accuracy of the alternative method in § 2 depends on the measuring accuracy of the power flux-density of satellite emissions at the reference earth station, which is of the order of ± 1 dB. Further information regarding G/T measurements of receiving systems is given in ex-CCIR Report 276 in Volume 1 (Monitoring of radio emissions from spacecraft at fixed monitoring stations) and International Electrotechnical Commission (IEC) Publication 835 Part 3.

ANNEX 1

Measurement of the G/T ratio with the aid of radio stars

1 Introduction

It is desirable to establish a practical method of measuring the G/T ratio with high accuracy, which will permit comparison of values measured at various stations. This Annex describes a method for the direct measurement of the G/T ratio using radio stars. It should be noted however, that the radio star method is not practical in certain cases (see § 5).

2 Method of measurement

By measuring the ratio, r , of the noise powers at the receiver output, the G/T ratio can be determined using the formula:

$$\frac{G}{T} = \frac{8 \pi k (r-1)}{\lambda^2 \Phi(f)} \quad (1)$$

where:

k : Boltzmann's constant ($1.38 \times 10^{-23} \text{ J/K}^{-1}$)

λ : wavelength (m)

$\Phi(f)$: radiation flux-density of the radio star as a function of f , frequency ($\text{W}/(\text{m}^2 \cdot \text{Hz})$)

$r = (P_n + P_{st}) / P_n$

P_n : noise power corresponding to the system noise temperature T

P_{st} : additional noise power when the antenna is in exact alignment with the radio star

G (antenna gain) and T (system noise temperature) are referred to the receiver input.

In equation (1), account is taken of the fact that the radiation of the star is generally randomly polarized and only a portion corresponding to the received polarization is received. The radiation flux-density $\Phi(f)$ is obtained by radio astronomical measurements.

This method has a basic advantage when compared with the calculation of G/T from G and T measured separately as only one relative measurement is necessary to determine the ratio, instead of two absolute measurements.

3 Suitable radio stars

The discrete radio sources Cassiopeia A, Cygnus A and Taurus A appear to be the most appropriate for measurements of G/T by earth stations in the Northern Hemisphere, while Orion, Virgo and Omega are similarly appropriate for earth stations in the Southern Hemisphere. The flux-densities of Cygnus A and Virgo, however, may not be sufficient in every case. Table 1 gives values of the flux-density of the radio stars indicated, where the frequency is between 1 and 20 GHz.

TABLE 1
Flux-densities from radio sources

Radio source	Flux-density at f GHz ($\text{W}/(\text{m}^2 \cdot \text{Hz})$)
Cassiopeia A	$\Phi(f)_{Cass A} = 10^{-26} \times 10^{[5.745 - 0.770 \log_{10}(1\,000 f)]^{(1)}}$
Taurus A	$\Phi(f)_{Tau A} = 10^{-26} \times 10^{[3.794 - 0.278 \log_{10}(1\,000 f)]}$
Cygnus A	$\Phi(f)_{Cyg A} = 10^{-26} \times 10^{[7.256 - 1.279 \log_{10}(1\,000 f)]}$
Orion	$\Phi(f)_{Orion} = 10^{-26} \times 10^{[3.317 - 0.204 \log_{10}(1\,000 f)]}$
Virgo	$\Phi(f)_{Virgo} = 10^{-26} \times 10^{[6.541 - 1.289 \log_{10}(1\,000 f)]}$
Omega	$\Phi(f)_{Omega} = 10^{-26} \times 10^{[4.056 - 0.378 \log_{10}(1\,000 f)]}$

⁽¹⁾ Value of January 1980 (see § 4.2).

For the measurements at frequencies above 10 GHz, the use of the radio waves from planets, Venus for example, as well as above-mentioned radio stars could be advantageous. Flux-densities of the radio waves from planets increase with frequency and their solid angle is very small giving rise to negligible correction errors due to angular extension. The flux-density $\Phi(f)$ is expressed by:

$$\Phi(f) = \frac{4 \pi k T_b(f)}{\lambda^2} (1 - \cos \psi) \quad (2)$$

where:

$T_b(f)$: brightness temperature of a planet (K)

ψ : semi-diameter.

The value of $\Phi(f)$ derived from equation (2), is substituted in equation (1) to obtain the value of G/T of an earth station. The value of ψ can be found elsewhere in American Ephemeris and Nautical Almanac (US Government Printing Office, Washington DC 20402). In the case of the planet Venus, the values $T_b(f)$ are thought to be about 580 K and 506 K at 15.5 and 31.6 GHz, respectively. Since the values of $T_b(f)$ are based on a limited amount of measured data at the frequencies mentioned, and have not yet been determined for other frequencies, further study is required to confirm and extend the results given here.

4 Correction factors

The corrected value of G/T is given by:

$$(G/T)_c = G/T + C_1 + C_2 + C_3 \quad (3)$$

where:

C_1 : correction for atmospheric absorption

C_2 : correction for angular extension of radio stars

C_3 : correction for change of flux with time.

All factors to be given in decibels.

The value of atmospheric absorption C_1 can be estimated using § 2.2 of Recommendation ITU-R P.676.

4.1 Angular extension of radio stars

If the angular extension of the radio star in the sky is significant compared with the antenna beamwidth, a correction must be applied. The following equations are close approximations for the angular extension correction factor, C_2 , also plotted in Fig. 1.

$$C_2 \approx -10 \log_{10} \left[\frac{ABS(1 - e^{-\chi^2})}{\chi^2} \right]$$

where:

$$\chi_{Cass A} \approx \chi_{Tau A} \approx \chi_{Orion} \approx \chi_{Virgo} \approx \chi_{Omega} \approx \frac{4.6}{1.2012 \theta_{3 \text{ dB}} \times 60}$$

$$\chi_{Cyg A} \approx \frac{2.5}{1.2012 \theta_{3 \text{ dB}} \times 60}$$

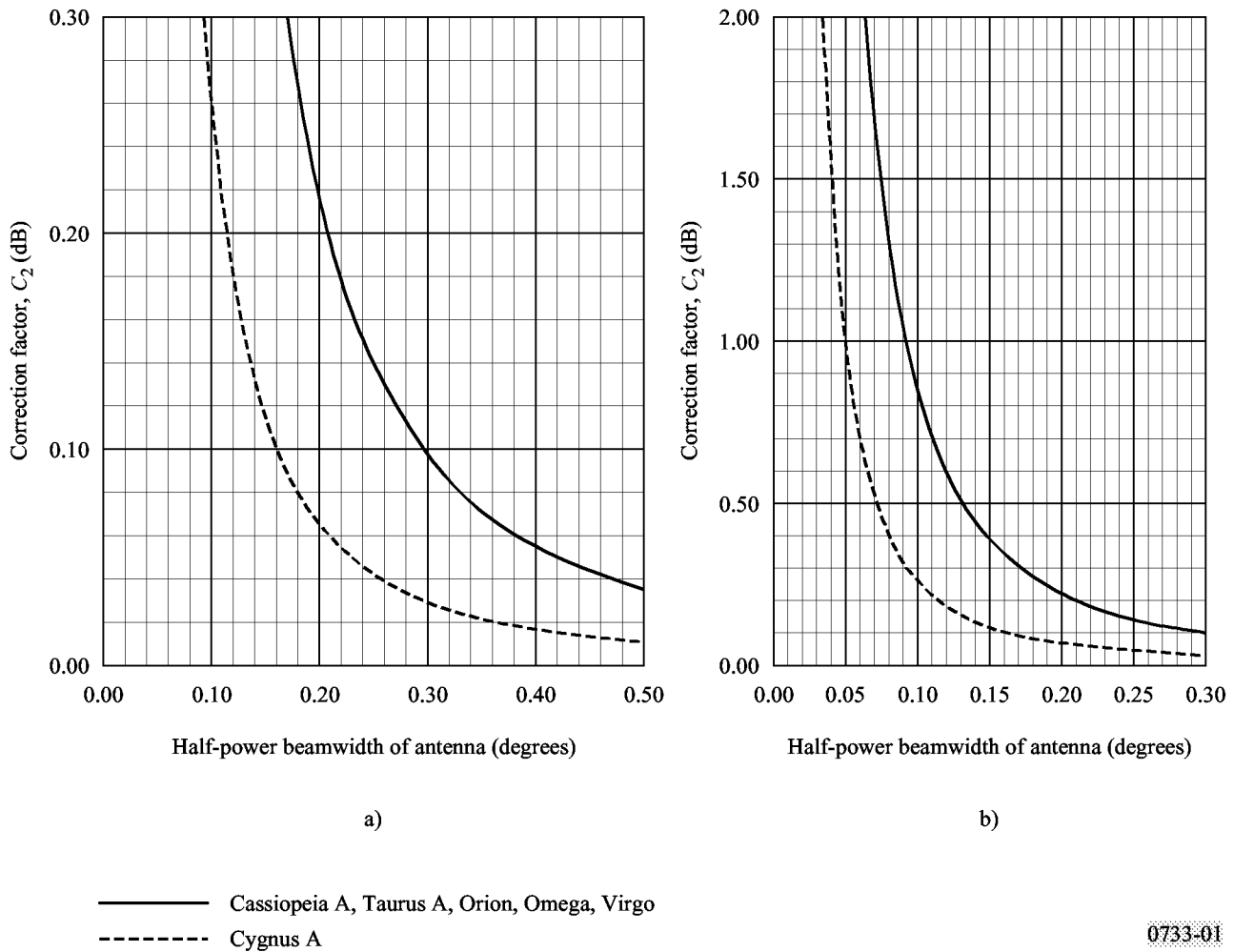
$$\theta_{3 \text{ dB}} = \frac{62 \lambda}{D}$$

: 3 dB beamwidth (degrees)

λ : wavelength (m)

D : antenna diameter (m).

FIGURE 1
Correction factor for the angular extension of radio stars



The measured brightness distribution for Cygnus A can be adequately described by a dual columnar shape with 0.02 min of arc in each column's diameter and 2.06 min of arc in angular distance.

If the annular model for Cassiopeia A and the dual columnar model for Cygnus A are adopted, a convenient approximation is available for the correction factor. These models may also be useful to measure the half-power beamwidth of antennas by observing the half intensity width of the drift curve. This also means that the correction factor for the angular extension of radio stars can be determined from the observed drift curve itself without the knowledge of the half-power beamwidth of the antenna.

4.2 Change of flux with time

Cassiopeia A is subject to a frequency dependent reduction of flux with time. The correction may be obtained from:

$$C_3 = -10 \log_{10} \left[1 - \frac{0.97 - 0.3 \log_{10} f}{100} \right]^n \quad \text{dB} \quad (4)$$

where:

n : number of years elapsed, with $n = 0$ in January 1980

f : frequency (GHz).

4.3 Polarization effects

Taurus A, Cygnus A, Orion, Virgo and Omega are elliptically polarized and it is necessary to use the mean of two readings taken in two orthogonal directions. These precautions are not necessary when using Cassiopeia A.

5 Limitations of the radio star method

The method described in this Annex has several disadvantages. These are:

- accuracy is not very good for smaller earth stations, however, given modern equipment, and careful measurement setup, consistently accurate antenna gain measurements are achievable with γ -factors > 0.2 dB (see Table 2 for approximate minimum antenna sizes);
- this technique may not be possible for stations with limited steerability.

TABLE 2

Minimum allowable antenna diameter for using a radio star to measure antenna gain, assuming 25° elevation angle and γ -factors > 0.2 dB

Radio star	Minimum antenna diameter at C-band (m) ($T_{sys} = 78$ K)		Minimum antenna diameter at Ku-band (m) ($T_{sys} = 130$ K)	
	Cassegrain	Prime focus	Cassegrain	Prime focus
Cassiopeia A	4.6	5.4	9.3	11.0
Taurus A	5.1	5.9	8.0	9.5
Cygnus A	6.0	6.0	16.0	18.5

APPENDIX 1

TO ANNEX 1

Contributions to the noise temperature of an earth-station receiving antenna

1 Introduction

The noise temperature of an earth-station antenna is one of the factors contributing to the system noise temperature of a receiving system, and it may include contributions associated with atmospheric constituents such as water vapour, clouds and precipitation, in addition to noise originating from extra-terrestrial sources such as solar and cosmic noise. The ground and other features of the antenna environment, man-made noise and unwanted signals, and thermal noise generated by the receiving system, which may be referred back to the antenna terminals, could also make a contribution to the noise temperature of the earth-station antenna. Numerous factors contributing to antenna noise, particularly those governed by meteorological conditions, are not stable and the resulting noise will therefore exhibit some form of statistical distribution with time. A knowledge of these factors and their predicted variation would be a valuable aid to earth-station designers, and there is therefore the need to gather information on the antenna noise characteristics of existing earth stations in a form which can best be interpreted for future use.

This Appendix presents results of antenna noise measurements made at 11.45 GHz, 11.75 GHz, 17.6 GHz, 18.4 GHz, 18.75 GHz and 31.65 GHz. From the results measured at 17.6 GHz and 11.75 GHz, cumulative distributions of temperatures have been derived together with the dependency of the clear-sky noise temperature on the elevation angle.