

RECOMMENDATION ITU-R S.1553

A possible method to account for environmental and other effects on satellite antenna patterns

(Question ITU-R 236/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that environmental and other effects are important factors in determining the end of life performance of a satellite antenna;
- b) that satellite antenna side-lobe levels can vary due to environmental factors, operational factors and ageing;
- c) that satellite antenna radiation pattern is an important parameter in the interference calculations;
- d) that the use of active array antennas in the operational satellite environment is increasing;
- e) that methods to assess the environmental effects on the performance of a satellite antenna depend on the technologies used for the antenna;
- f) that for some systems, the primary source of interference into an earth station is from the satellite antenna side lobes into the earth station,

recognizing

- a) that the exact procedure and error factors may vary as a function of the spacecraft and payload architecture,

recommends

- 1** that the methods and information described in Annex 1 may be used to provide guidance to satellite system designers in determining and evaluating the variances of radiation patterns of a satellite antenna as a function of the off-axis angle from the satellite antenna boresight.

ANNEX 1

1 Introduction

The analyses performed on antennas to guarantee their end of life performance do not depend on the orbit of the spacecraft (geostationary (GSO) or non-GSO) but on the type of antenna which is being used (i.e. active or passive antenna).

For the two types of antennas the general philosophy of the tests is similar:

- the performance of the radiation pattern is tested under degraded conditions of temperature gradient;
- an assessment of the maximum degradation is performed through validated simulations;
- the end of life performance is defined through a combination of the above two steps.

This Annex provides some details on this general approach of antenna performance assessment.

Terminology used in the antenna descriptions is as follows:

- a passive antenna is an antenna for which the radiating component does not include any active equipment (like solid state power amplifier (SSPA), low noise amplifier (LNA), travelling wave amplifier (TWA)). The amplification is centralized and is part of the repeater. The passive antenna is the most commonly used type of antenna. The passive antenna can be linked to a pointing mechanism in order to permit mobile coverage;
- the active antenna is a subsystem in which the active elements are integrated in between the radiating elements of the beam forming network. This technology allows the generation of reconfigurable multiple beams.

One of the fundamental principles of active antenna theory is that the radiation pattern is determined by the amplitude and phase distribution across the aperture. The antenna designer can, in principle, optimize the illumination laws and expect the resulting radiation pattern to be as predicted. In practice, however, there will be unavoidable errors and the actual radiation pattern will differ to some extent from the theoretical one.

2 Passive antennas

Main passive antenna architectures are based on reflector antennas, i.e. a parabolic reflector illuminated by a primary feed or subreflector located at/near the main reflector focus.

Then the antenna radiated performances are affected by mechanical and thermal distortions which will mainly lead to a slight change of the reflector shape and then affect the illumination laws.

Those mechanical and thermal distortions appear at two stages:

- during reflector manufacturing: the manufactured surface will differ from the theoretical one;
- during antenna life: the satellite environment results in certain mechanical and thermal distortions which impact on the antenna geometry and then its radiated performance.

These effects will result in an increase of the side-lobe levels, a reduction in the on-axis gain and, at a lower level, an error in the direction of the main beam.

The errors coming from mechanical and thermal distortion are predictable, and the resulting radiation pattern can be computed by classical methods from the knowledge of the mission, the satellite architecture and the antenna configuration.

Once the antenna configuration has been designed the different steps of the analysis to guarantee the end of life performance are the following:

- characterization of manufacturing errors with respect to theoretical shape (a root mean square (rms) deviation is derived);
- revision of the antenna model taking into account these errors;
- measurement of antenna radiated performance at ambient temperature and correlation with modelling;

- research into the thermal and mechanical environments which lead to worst antenna distortion (worst rms distortion);
- prediction of end of life antenna pattern by analysis.

The performance parameters which are tested at ambient temperature shall show margins with respect to the specification and the analysis listed last in the above list is used to confirm that these margins are sufficient to guarantee the performance until the expected end of life.

3 Active antennas

The evaluation or prediction of the performance of array antennas in the presence of elemental excitation variations (due to environmental and operational factors including failures) is an important part of the engineering effort in the development of high-performance antennas for in-orbit operation. As part of the engineering process error budgets are compiled to define the performance of the antenna over the life of the satellite.

An active antenna radiation pattern will differ from the theoretical pattern because of dispersion of the characteristics between active chains which create a distortion of the amplitude and phase illumination laws, these distortions are commonly called A/ϕ errors.

Different types of errors can be described.

Errors can be divided into two types depending on whether they are predictable or random.

- Predictable errors (such as reproducibility, assembly and thermal gradient defaults) can be compensated by antenna calibration at calibration points (frequency and/or temperature) at equipment level. Dispersion of these errors over the frequency range and/or the temperature range will not be compensated and will then be part of the A/ϕ budget.
- Random errors are caused by the accidental deviations of the antenna parameters from their design value. These deviations will occur at the beginning of life (due to characteristic dispersions of each and between equipments) and will change throughout the antenna life to finally give the end of life antenna performance. Although they may be small they will affect the antenna main beam and side-lobe gain performance.

The three following items in the A/ϕ analysis can be identified:

- A/ϕ calibration error at calibration points;
- A/ϕ dispersions over the frequency range and/or the temperature range;
- A/ϕ dispersions over life.

These three items combined in a statistical analysis will be used:

- to compare measured patterns to theoretical antenna patterns at a reduced set of test conditions (ambient temperature, some frequency points, ...);
- to confirm that the margins (with regard to the specifications) shown for the reduced set of test conditions are large enough to guarantee the performance during the satellite lifetime.

This section identifies parameters that affect antenna performance and provides a method for estimating the antenna side lobe variance for each pointing direction. This variance can then be used to calculate an antenna gain pattern that will not be exceeded for a given confidence level.