ETSI TR 104 140 V1.1.1 (2025-05)

TECHNICAL REPORT

Propagation measurement and modelling for PtP radio links in the E, W and D bands

Reference

DTR/ATTMTMmWT-0030

Keywords

channel modelling, millimetre wave, mWT, propagation

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI IPR online database.

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™**, **LTE™** and **5G™** logo are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The present document deals with Electro-Magnetic (EM) wave propagation for terrestrial PtP links in the millimetre-wave (mm-wave) range (30 - 300 GHz), where rain plays the most relevant role since rain drops absorb and scatter electromagnetic energy inducing significant path losses, due to their size (about 1 - 5 mm) being comparable to the EM wavelength.

When dealing with attenuation due to rain there are several factors to be considered:

- Specific attenuation due to rain γ_R (dB/km), which is dependent not only on frequency and rain rate but also on the particular Drop Size Distribution (DSD).
- Total attenuation due to rain along the radio link (dB), which is dependent on the spatial variation of the specific attenuation along the link.
- Attenuation due to rain but not related to the propagation path (dB), such as the wet antenna effect.

As for the specific attenuation, several models of DSD have been developed based on both experimental rain data and analytical models of rain attenuation mechanisms. All the analyses converge on the fact that the DSD model is highly dependent on the type of rain in the specific rain zone and in the specific season.

Recommendation ITU-R P.838-3 [i.3] is based on the Laws-Parsons drop size distribution model which describes typical continental temperate rainfall of stratiform kind. When considering a convective type of rain, typical of tropical regions, a different modelling of DSD is needed and different results would be obtained.

As for the total link attenuation, several models of the path reduction factor have been developed in order to take into account the spatial inhomogeneity of rain along the link. All models describe a path reduction factor which decreases below 1 with increasing link length, where the link length is much larger than the length over which the rain rate can be considered homogeneous. Instead when dealing with short links, below about 1 km, where rain rate can be considered constant along the path, the path reduction factor should be reasonably slightly less than or equal to 1.

Recommendation ITU-R P.530-18 [i.4] is based on a model which gives a path reduction factor increasing well over 1 with a decreasing link length, which seems to be not physically sound and gives as a consequence an overestimation of the attenuation due to rain along the link. A proper adaptation of the model limiting the path reduction factor to 1 could be a good way forward to have a more accurate prediction model for short links.

The wet antenna attenuation, due to the thin water film deposited by rain over the antenna of the radio equipment, is a cause of attenuation that should be separated from the propagation loss due to rain along the link. This effect could be the cause of some measurements apparently giving a path reduction factor much higher than unity with short links.

Finally it is important noting that there is no physical reason why the range of applicability of a terrestrial rain attenuation prediction model for mmWave systems should be limited to 100 GHz, as it is currently the case in Recommendation ITU-R P3530-18 [i.4]; as a matter of fact in the mmWave frequency range (30 - 300 GHz) the main attenuation mechanisms are absorption and Mie scattering and only when going towards higher frequencies, well over the mmWave range, the geometric optics scattering model becomes valid.

Introduction

The present document deals with Electro-Magnetic (EM) wave propagation at millimetre-wave (mm-wave) for terrestrial PtP links, with particular consideration of frequencies about and over 100 GHz, in the:

- E (71 - 86 GHz);

- W (92 - 115 GHz); and
- D (130 - 175 GHz) bands.

In this frequency range propagation is subject to several atmospheric effects induced by:

- Gases (mainly oxygen and water vapour).
- Suspended water droplets (fog).
- Hydrometeors (rain, snow, hail).

Among them, at frequencies higher than 10 GHz rain plays the most relevant role since rain drops absorb and scatter electromagnetic energy, thus inducing significant path losses; this effect becomes more and more relevant as long as the wavelength is comparable to the rain drop size (about 1 - 5 mm), in particular in the mm-wave part of the EM spectrum (30 - 300 GHz).

That is why it is of paramount importance to investigate atmospheric effects impairing millimeter-waves, specifically rain attenuation, which is greatly dependent on the operational frequency, on the rain rate and on the rain drop dimensions, described by the Drop Size Distribution (DSD).

As a matter of fact, there are two ITU-R Recommendations dealing with rain attenuation effects:

- Recommendation ITU-R P.838-3 [i.3], which provides specific attenuation as a function of the rain rate and operational frequency.
- Recommendation ITU-R P.530-18 [i.4], which presents a rain attenuation model for terrestrial links.