ITU WORKSHOP

Activities of ITU-R Study Group 3 on radiowave propagation

Working Party 3M – Earth-space, fixed & interference paths

EuCAP 2024, Glasgow

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WP structure

- 3M-1: Terrestrial paths
  - Dr Steve Salamon
  - Prediction methods for both line-of-sight and over-the-horizon links
- 3M-2: Earth-space paths
  - Dr Laurent Castanet
  - Propagation impairments on slant paths from satellites
- 3M-3: Interference and coordination
  - Dr Ivica Stevanovic
  - Path loss models to trigger and perform coordination and for sharing studies
- 3M-4: Digital products
  - Dr Antonio Martellucci

3M-1 Terrestrial Paths

3M-1 Recommendations

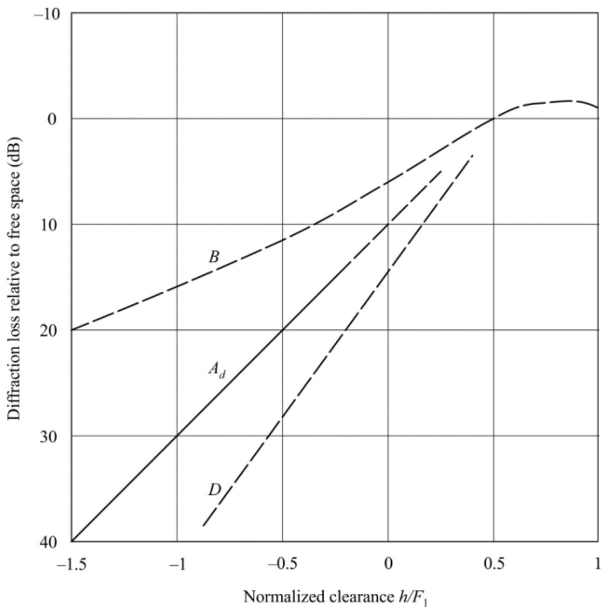
- **P.530** ‘*Propagation data and prediction methods required for the design of terrestrial line-of-sight systems*’ 2021
- P.617 ‘*Propagation prediction techniques and data required for the design of trans-horizon radio-relay systems*’ 2019
- P.1814 ‘*Prediction methods required for the design of terrestrial free-space optical links*’ 2007
- P.1817 ‘*Propagation data required for the design of terrestrial free-space optical links*’ 2012
- P.2041 ‘*Prediction of path attenuation on links between an airborne platform and Space and between an airborne platform and the surface of the Earth*’(terrestrial aspects) 2013

Recommendation P.530 (Fixed Links)

- This Recommendation includes a number of models intended to aid planners of fixed links
- The starting point is usually the prediction of wanted-path fading
- Variations in refractive index will degrade link performance
- Terrain obstruction
  - Simple empirical diffraction estimate
- Multipath fading
- Diversity (Spatial, frequency)
- Tandem hops
- Route diversity

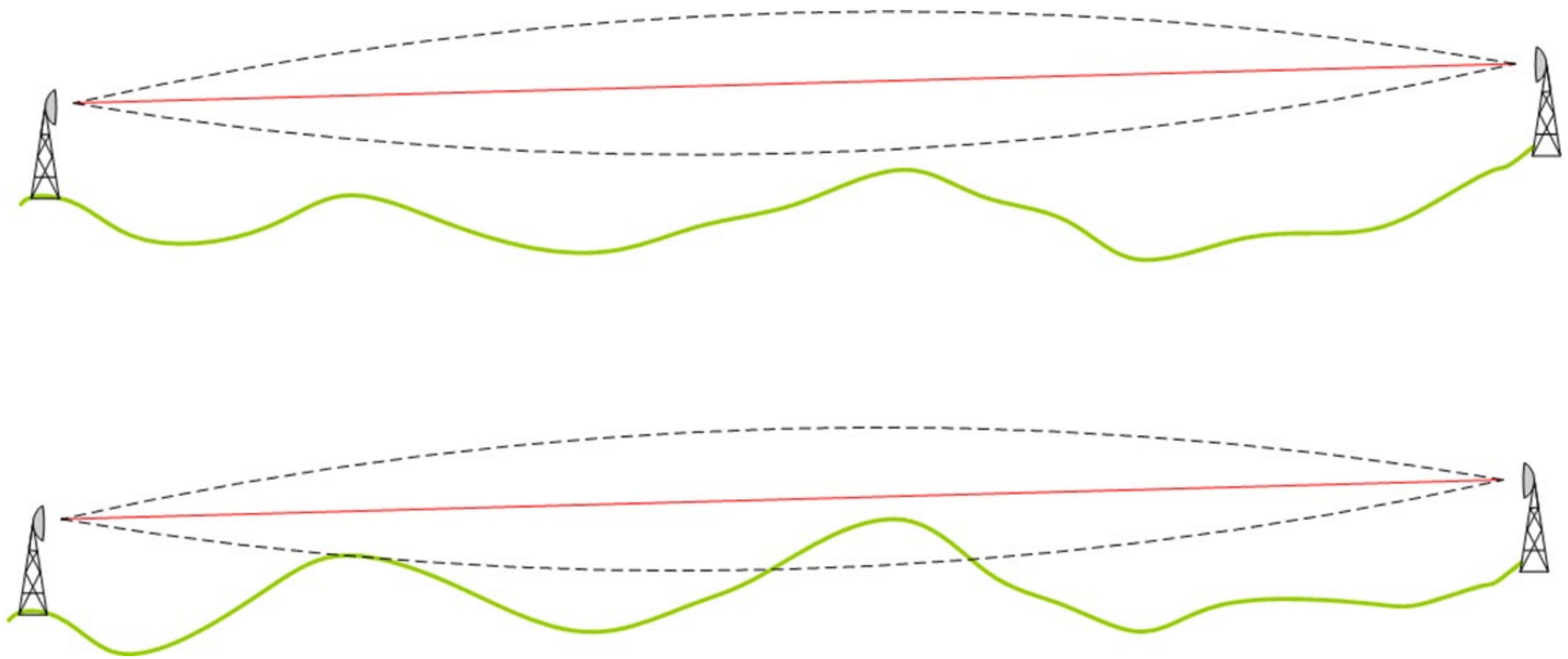
FIGURE 1

Diffraction loss for obstructed line-of-sight microwave radio paths



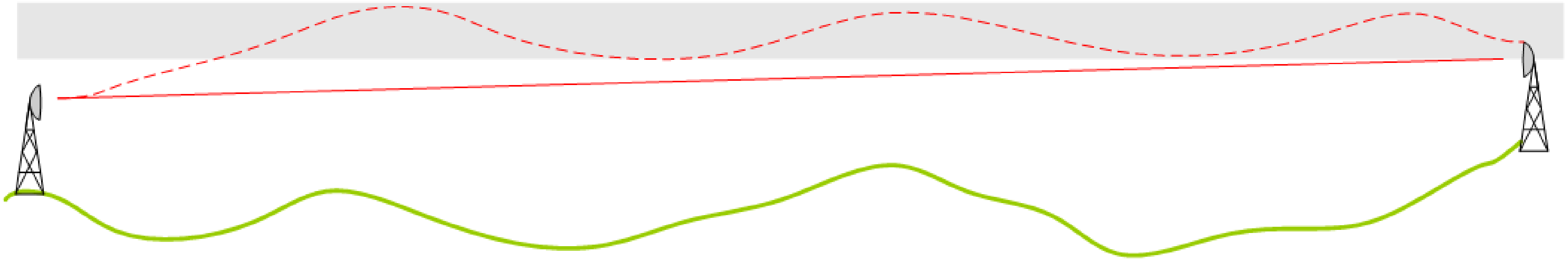
P.530: Impact of refractivity

- Sub-refraction leads to flat fading...
- and changes in ground-reflected multipath



P.530: Impact of refractivity

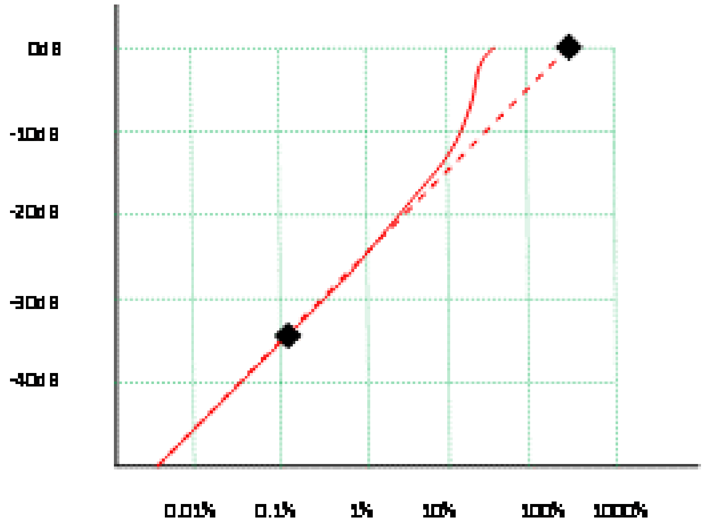
- Stratified troposphere leads to atmospheric multipath

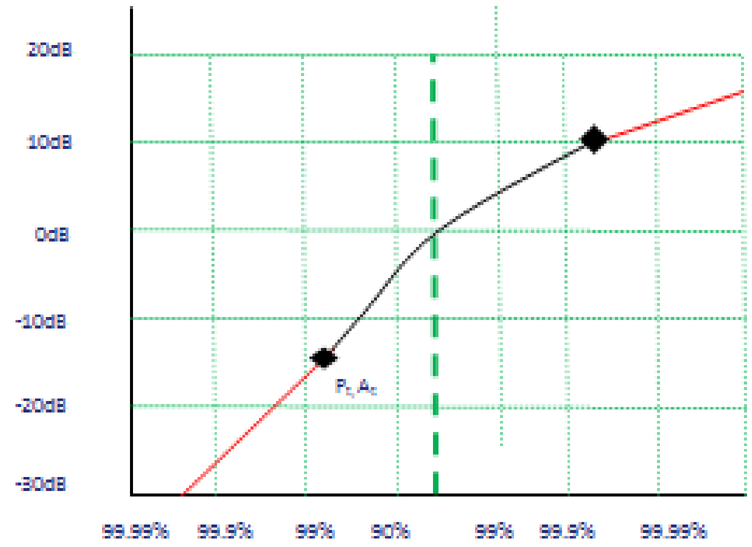


P.530: Multipath fading and enhancement

- Model assumes Rayleigh (10dB/decade) tail
  - Characterised by ‘occurrence factor’ and ‘transition fade’
  - Then interpolates between tail and 2.6dB/decade enhancement regime

$$p_0 = Kd^{3.51}(f^2 + 13)^{0.447} \times 10^{-0.376tanh\left(\frac{h_{c-147}}{125}\right) - 0.334|\varepsilon_p|^{0.39} - 0.00027h_L + 17.85v_{sr}}$$



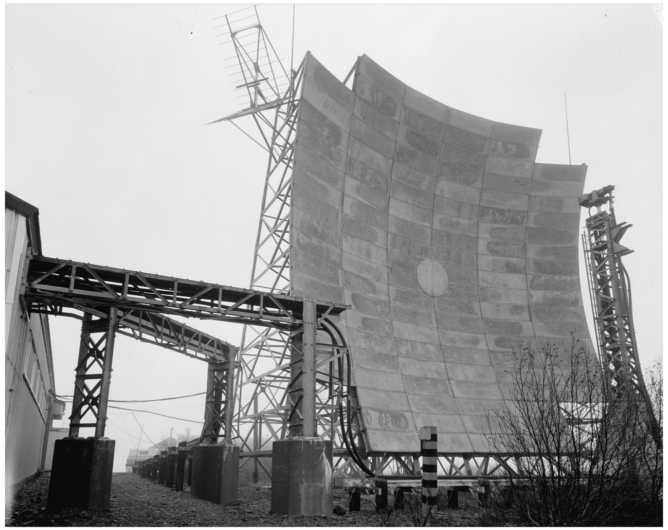


P.530: Current & future work

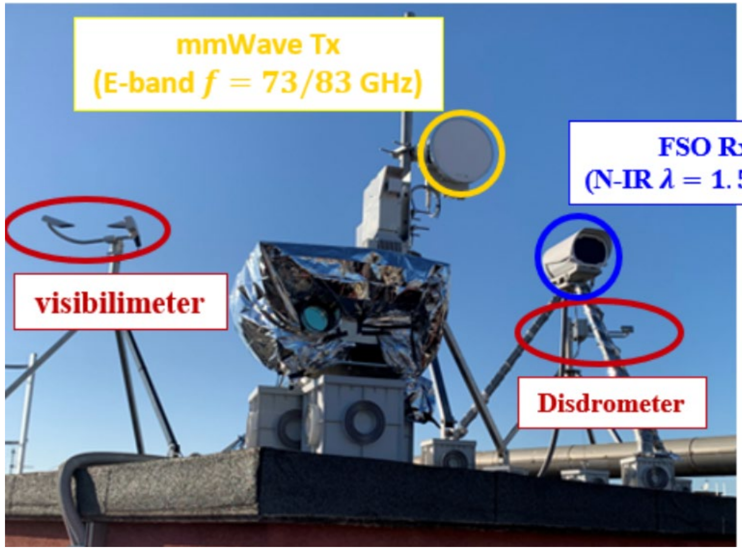
- Rain modelling remains very important
  - Short paths at millimetre wave are increasingly used for backhaul and fronthaul links for base stations
- Improvements:
  - use of the full rainfall rate distributions
  - use rain cell models for deriving effective path length
- Data is required to inform models of LoS MIMO links
- Models (and therefore data) required for sub-THz links

Other 3M-1 Recommendations

- P.617 Troposcatter links
  - Now less important for operational links, but establishes the path-loss limit
- P.1814 Free-space Optics
  - Increasingly relevant for X-haul



Wikipedia/Library of Congress



E. Verdugo et al, "*Rain Attenuation at mmWave and Optical Bands from Visibility and Rainfall Intensity Measurements*", EuCAP 2024

3M-2 Earth-space paths

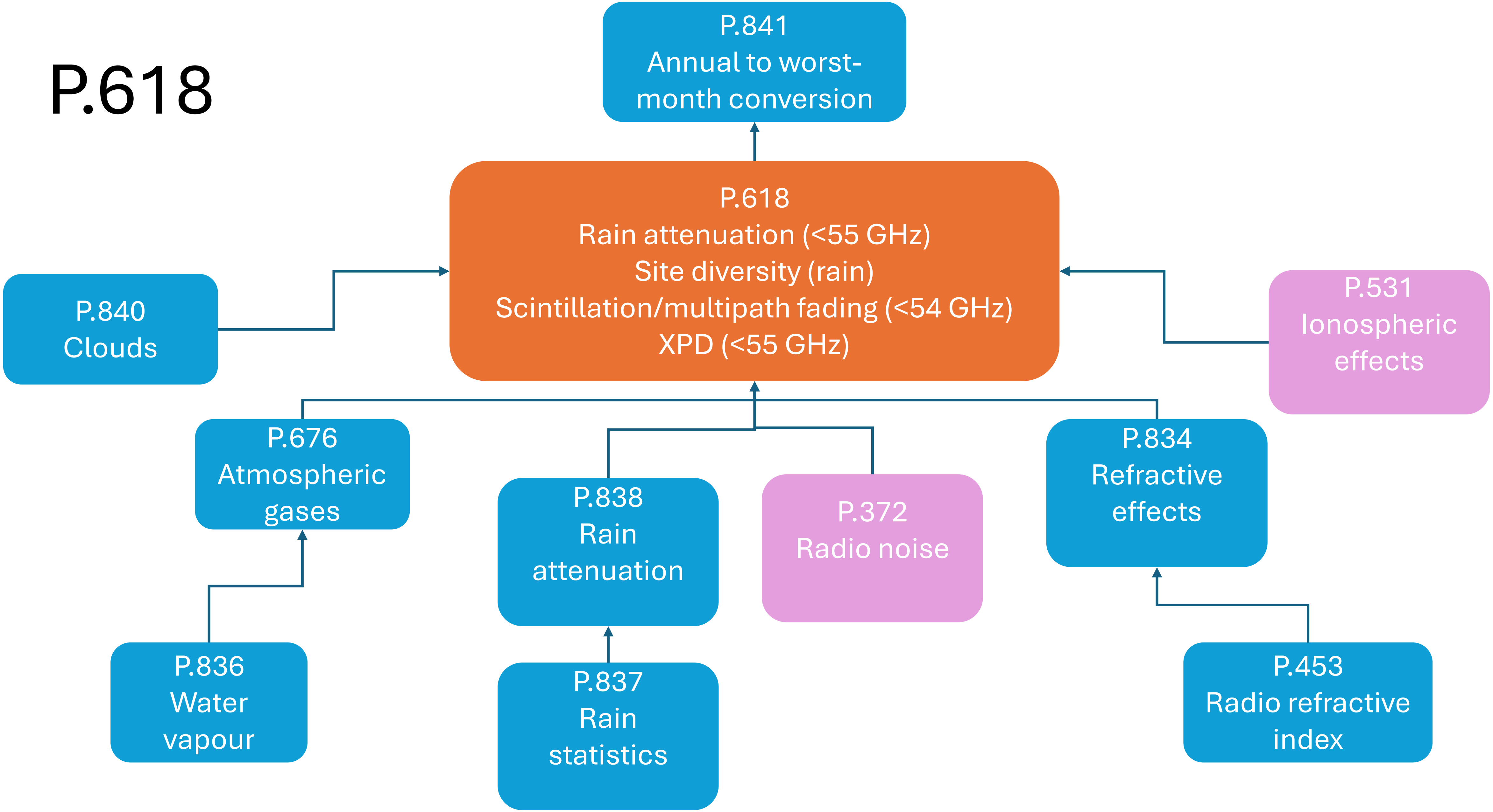
3M-2 Recommendations

- **P.618** ‘Propagation data and prediction methods required for the design of Earth-space telecommunication systems’ 2023
- P.679 ‘Propagation data required for the design of broadcasting-satellite systems’ 2015
- P.680 ‘Propagation data required for the design of Earth-space maritime mobile telecommunication systems’ 2022
- P.681 ‘Propagation data required for the design of systems in the land mobile-satellite service’ 2019
- P.682 ‘Propagation data required for the design of Earth-space aeronautical mobile telecommunication systems’ 2022
- P.1622 ‘Prediction methods required for the design of Earth-space systems operating between 20 THz and 375 THz’ 2022
- P.1623 ‘Prediction method of fade dynamics on Earth-space paths’ 2005
- P.1815 ‘Differential rain attenuation’ 2009
- P.2041 ‘*Prediction of path attenuation on links between an airborne platform and Space and between an airborne platform and the surface of the Earth*’ (non-terrestrial) 2013

P.618: mechanisms

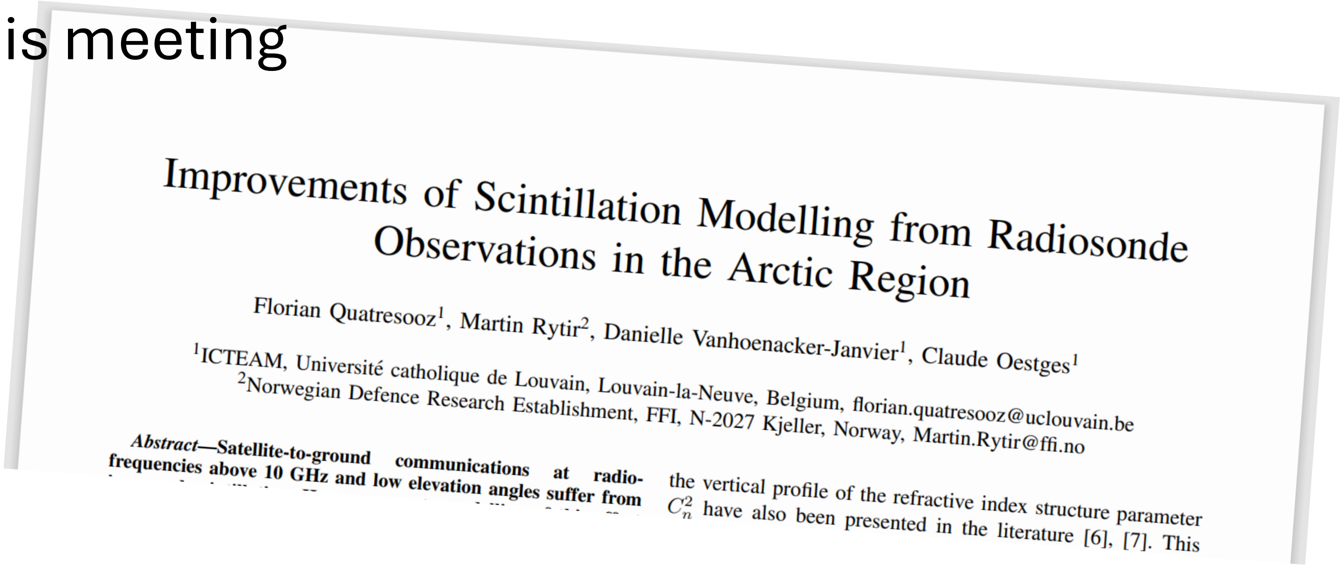
- **Absorption in atmospheric gases**; absorption, scattering and depolarization by hydrometeors (water and ice droplets in precipitation, clouds, etc.); and emission noise from absorbing media; all of which are especially important at frequencies above about 10 GHz;
- Loss of signal due to **beam-divergence of the earth-station antenna**, due to the normal refraction in the atmosphere;
- The decrease in effective antenna gain, due to **phase decorrelation across the antenna aperture**, caused by irregularities in the refractive-index structure;
- **Slow fading due to beam-bending** caused by large-scale changes in refractive index; more rapid fading (scintillation) and variations in angle of arrival, due to small-scale variations in refractive index;
- **Limitations in bandwidth due to multiple scattering or multipath effects**, especially in high-capacity digital systems;
- **Attenuation by the local environment of the ground terminal** (buildings, trees, etc.);
- Short-term variations of the **ratio of attenuations at the up- and down-link frequencies**, which may affect the accuracy of adaptive fade countermeasures;
- For non-geostationary satellite (non-GSO) systems, the effect of **varying elevation angle to the satellite**.
- **Ionospheric** effects

P.618


P.841
Annual to worst-month conversion
P.618
Rain attenuation (<55 GHz)
Site diversity (rain)
Scintillation/multipath fading (<54 GHz)
XPD (<55 GHz)
P.840
Clouds
P.531
Ionospheric effects
P.676
Atmospheric gases
P.838
Rain attenuation
P.372
Radio noise
P.834
Refractive effects
P.836
Water vapour
P.837
Rain statistics
P.453
Radio refractive index

P.618: Current & future work

- Extension of models towards 100 GHz
  - Rain model valid to 50 GHz
- Site diversity, satellite diversity methods needs to be further developed (NB differential rain attenuation in P.1815)
- Scintillation model
  - Current research reported at this meeting



Improvements of Scintillation Modelling from Radiosonde Observations in the Arctic Region

Florian Quatresooz[1], Martin Rytir[2], Danielle Vanhoenacker-Janvier[1], Claude Oestges[1]

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[2]Norwegian Defence Research Establishment, FFI, N-2027 Kjeller, Norway, Martin.Rytir@ffi.no

***Abstract*—Satellite-to-ground communications at radio-frequencies above 10 GHz and low elevation angles suffer from**

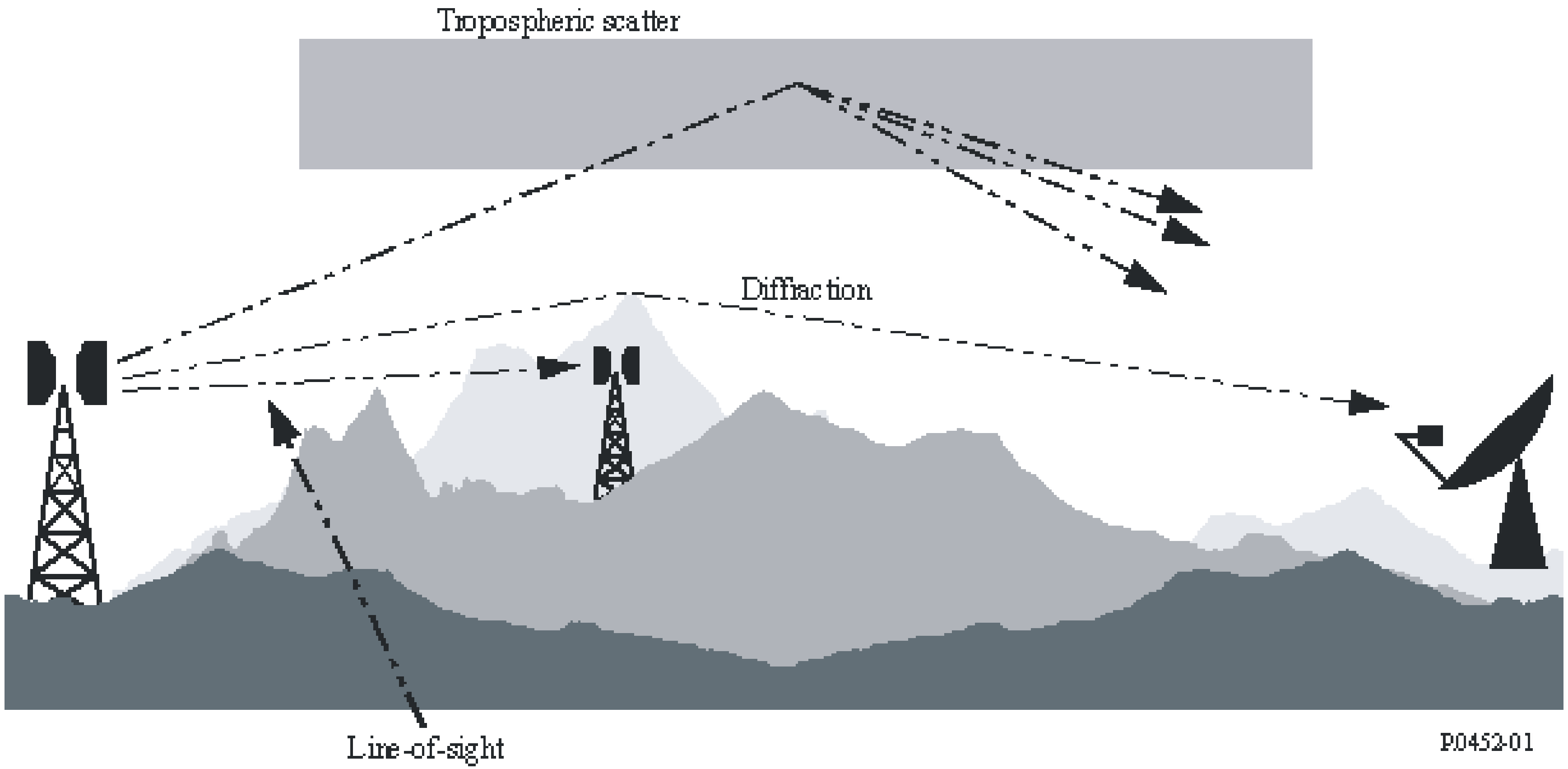
the vertical profile of the refractive index structure parameter C_n^2 have also been presented in the literature [6], [7]. This

3M-3 Interference Paths

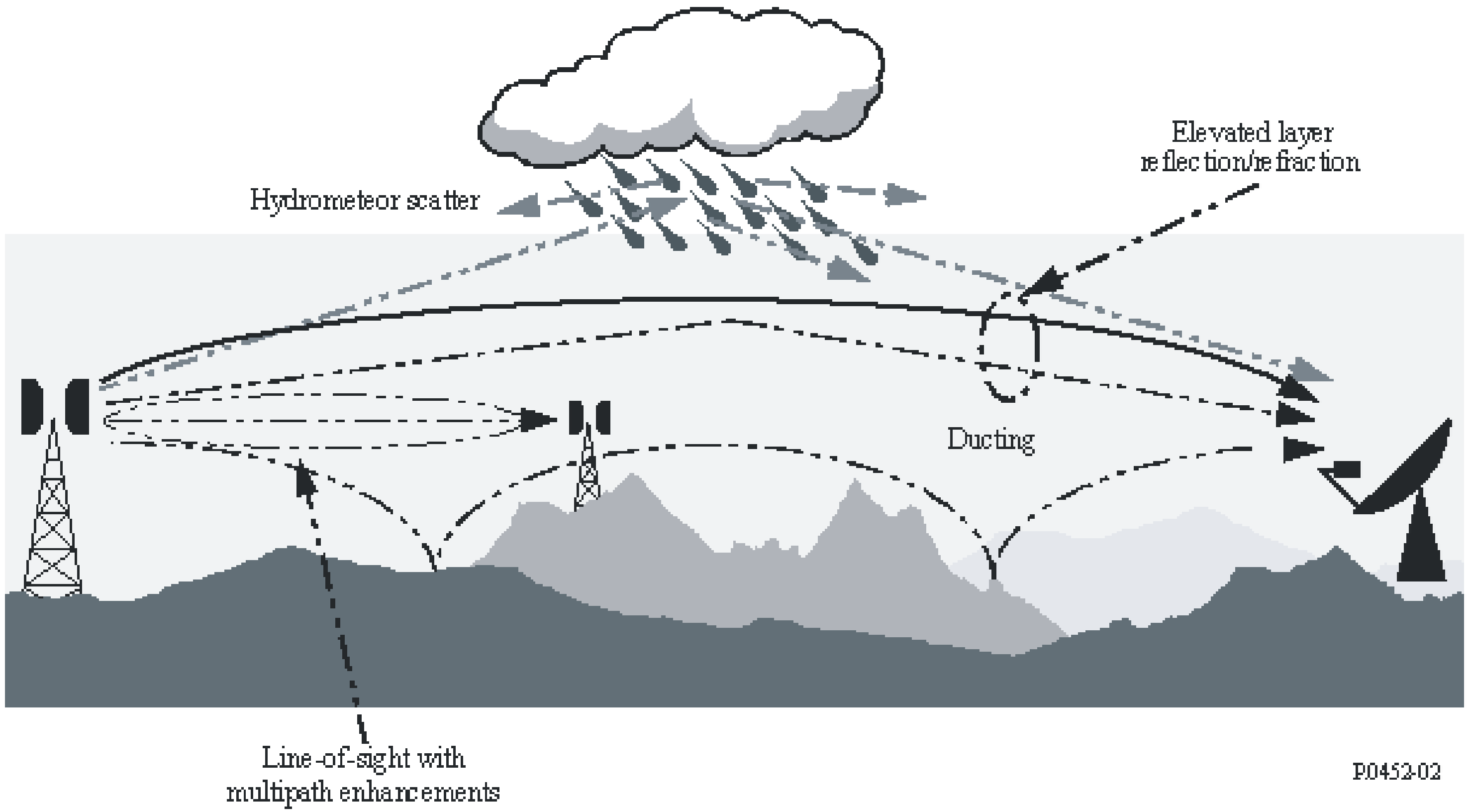
3M-3 Recommendations

- **P.452** '*Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz*' 2023
- P.619 '*Propagation data required for the evaluation of interference between stations in space and those on the surface of the Earth*' 2021
- P.620 '*Propagation data required for the evaluation of coordination distances in the frequency range 100 MHz to 105 GHz*' 2017
- P.1409 '*Propagation data and prediction methods for systems using high altitude platform stations and other elevated stations in the stratosphere at frequencies greater than about 0.7 GHz*' 2023
- P.1412 '*Propagation data for the evaluation of coordination between Earth stations working in the bidirectionally allocated frequency bands*' 1999
- P.1815 'Differential rain attenuation' 2009
- P.2001 '*A general purpose wide-range terrestrial propagation model in the frequency range 30 MHz to 50 GHz*' 2023

P.452: Long-term mechanisms

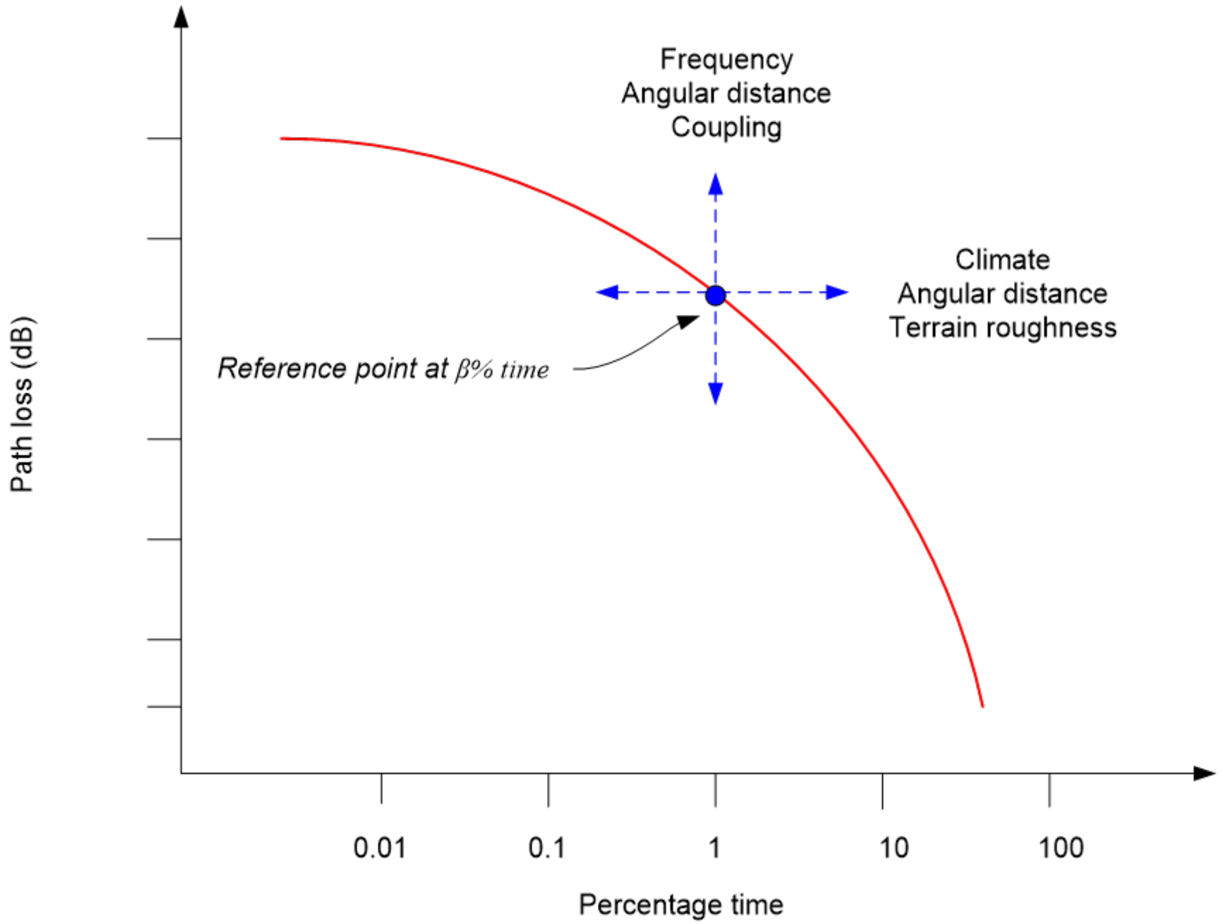


P.452: Short-term mechanisms



P.452: ducting model

- Assumed that the shape of the enhancement CDF is constant
  - Translates according to input parameters



P.452: ducting model

- Loss at the reference time, L_{br}:

Coupling correction for sea ducts

Site shielding at terminals

$$L_{br} = 102.45 + 20\log(f) + 20\log(d_{lt} + d_{lr}) + A_{st,r} + A_{ct,r} + A_{lf} + \gamma_d \theta'$$

FSPL to horizons

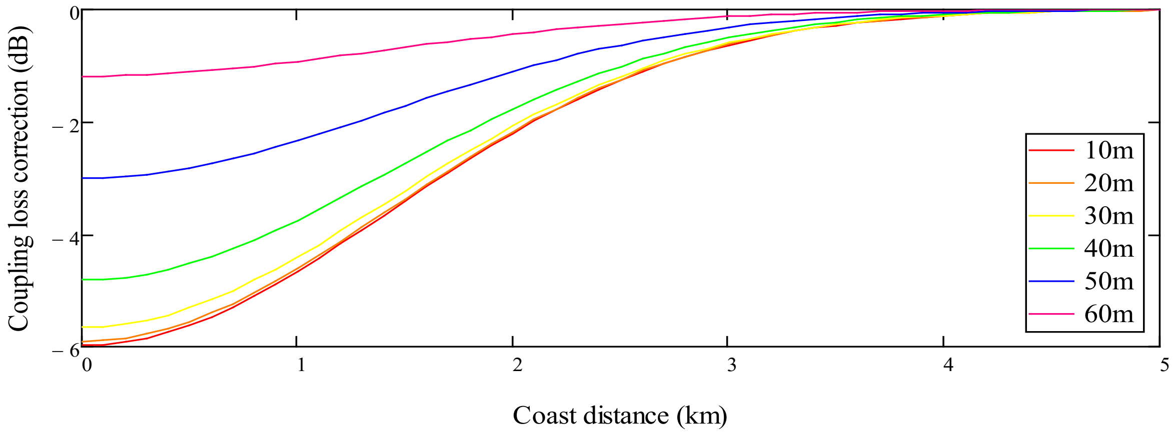
Specific attenuation in duct

Correction for increasing duct losses at longer wavelengths

P.452: ducting model

- Specific attenuation: $\gamma_d = 5 \times 10^{-5} a_e f^{1/3}$
  - The $f^{1/3}$ relationship was determined empirically

- Assumed that coupling into duct generally occurs at horizon (grazing angle at minimum)
  - Near coast, coupling to sea-duct likely at shorter range, hence A_c



P.452: Current & future work

- There is a need to extend the frequency range of Recommendation ITU-R P.452 to cover the range up to 105 GHz. This would allow Recommendation ITU-R P.452 to address the same frequency range as Recommendation ITU-R P.620. There is a lack of data on which to base such modelling.
- Recommendation ITU-R P.452 is increasingly being used for shorter paths, and in some cases where terminals are below the level of clutter, particularly in urban areas.

Other 3M-3 Recommendations

- P.1412
  - Earth-space interference paths
  - 0.001%-50%
  - Nominally valid to 100 GHz

- P.2001
  - Designed specifically for use in MC models
  - Predicts entire loss CDF (P>452 considers only enhancements)

3M-4

- 3M-4 Digital products (Antonio Martellucci)
  - P.311 ‘*Acquisition, presentation and analysis of data in studies of radiowave propagation*’

Coming next

Correspondence Groups

- 3M-2 Status of the DBSG3 databanks (Antonio Martellucci)
- 3M-3 Review of modelling aspects related to Rec. ITU-R P.681 (S. Rougerie)
- 3M-4 Software products, digital maps and reference numerical data products (Thomas Prechtl)
- 3J-3M-4 Statistical issues for testing and testing metric definition (Xavier Boulanger)
- 3J-3M-5 Effect of clouds and precipitation on attenuation and depolarization on slant paths (Antonio Martellucci)
- 3M-8 Earth-to-Space Path Communications Handbook (Luis Emiliani)

Correspondence Groups (ctd)

- 3J-3K-3M-8 Building Entry Loss (Richard Rudd)
- 3K-3M-9 Propagation of radiowaves along aeronautical paths (William Kozma)
- 3M-10 Development of the hydrometeor scatter model in Recommendation ITU-R P.452 (Ryan McDonough)
- 3K-3M-12 Prediction of clutter loss up to 105 GHz (Clare Allen, Reza Arefi)
- 3J-3M-13 Validation Examples (Luis Emiliani)
- 3J-3K-3M-14 Revision of Rec. ITU-R P.1409 (Hajime Suzuki)

Correspondence Groups (ctd)

- 3M-15 Improvement of rain and total attenuation models in Recommendation ITU-R P.618 (Laurent Castanet).
- 3J-3K-3M-16 The atmospheric radio refractive index and its effects on radiowave propagation (Antonio Martellucci, Leke Lin)
- 3K-3M-18 Study specific issues common to Recommendations ITU-R P.452, ITU-R P.1812, or ITU-R P.2001 (Ivica Stevanovic)
- 3M-22 Investigation of rain attenuation measurements indicating path reduction factors exceeding unity on short paths (Lorenzo Luini)

WP 3M priorities

Terrestrial interference paths

To ensure that Recommendations **ITU-R P.452 and ITU-R P.620 produce compatible results,** noting that Recommendation ITU-R P.452 requires extension upwards to 105 GHz in order to match the frequency range of Recommendation ITU-R P.620;

Radiometeorological data & new models

To make use of **improved radiometeorological data** provided as global maps from WP 3J, particularly for Recommendations ITU-R P.452 and ITU-R P.620;

To develop methods for predicting spatial and temporal influences on propagation prediction methods, e.g. climate change effects.

Rain modelling

To develop both yearly and monthly physical prediction methods for rain and for combined rain and wet snow attenuation which **use the complete rainfall rate distribution**, in order to reflect more accurately the characteristics of different climates and the spatial correlation properties of rain attenuation;.

Short terrestrial paths

improve and develop new prediction methods for **short, diffractive and reflective terrestrial paths**, e.g., for point-to-point radio links in cities;

Frequency extension

extend current methods for terrestrial LOS links and Earth-space links up to **105 GHz** both with respect to precipitation and clear air effects;