Machine learning applied to radio-wave propagation prediction to advance global challenges

The role of GeoAI and Foundational Models in shaping an AI-driven future for all

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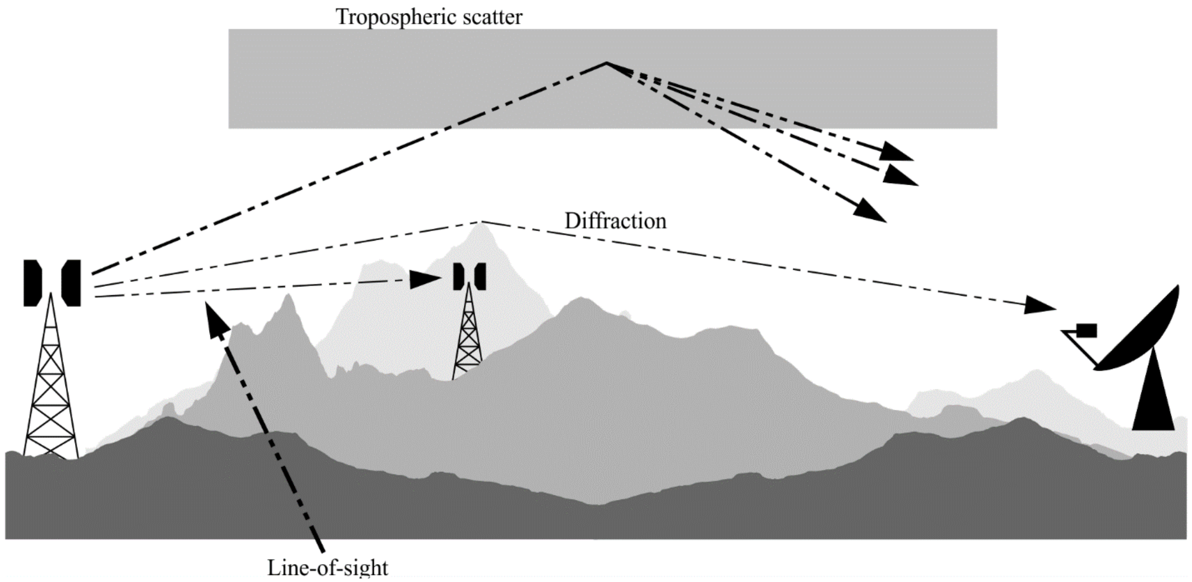
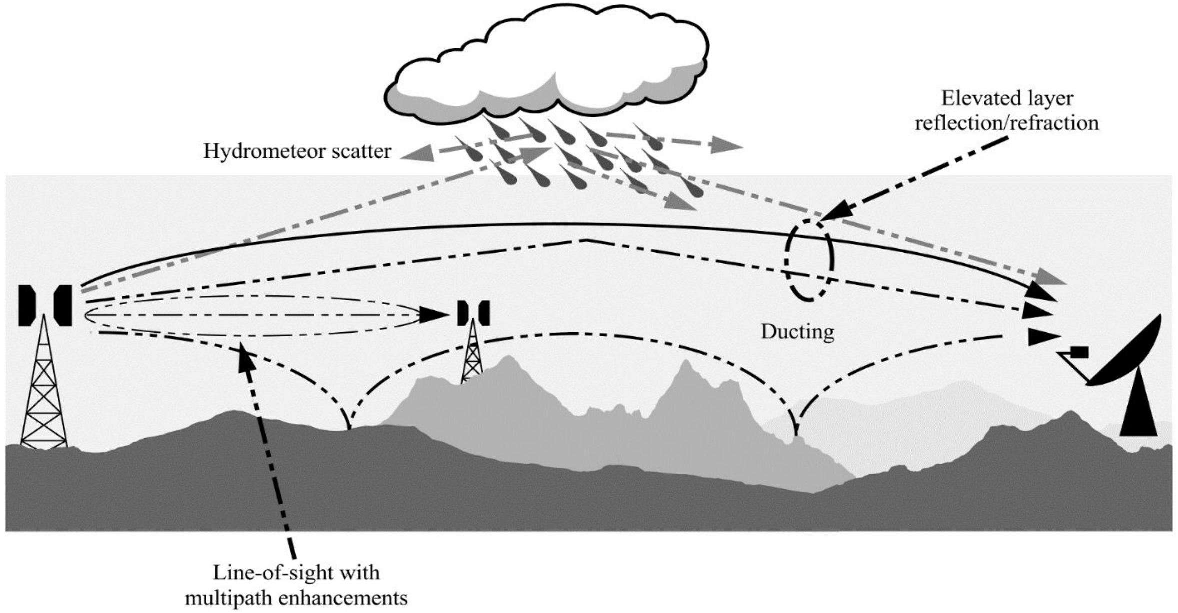
Contents

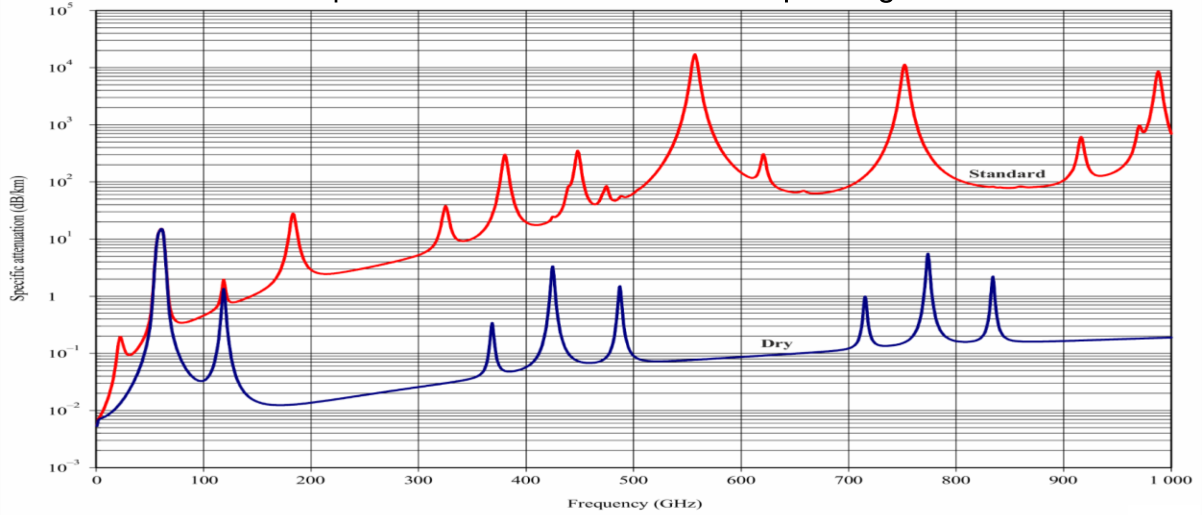
Radio-wave propagation prediction 101

Phenomena affecting radio-wave propagation





Specific attenuation due to atmospheric gases



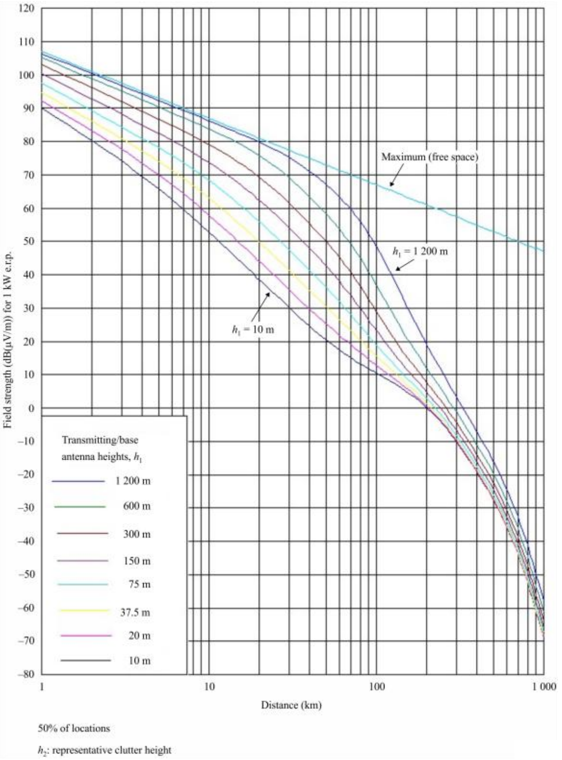
Attenuation due to:

- Gaseous absorption
- Precipitation
- Clouds, fog, water vapour
- Building entry/exit
- Vegetation
- Clutter (surface features/land cover)

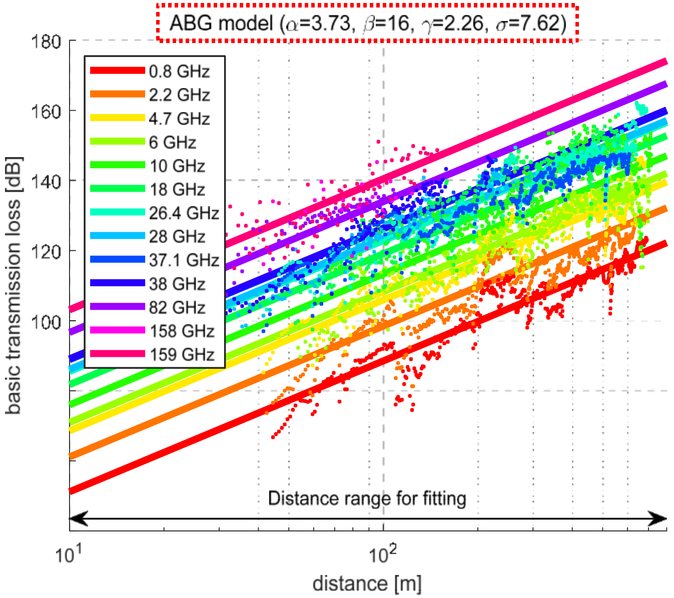
Radio-wave propagation prediction models/methods

Empirical (site-general)

100 MHz, land path, 50% time



ABG Model for NLoS, Urban high-rise



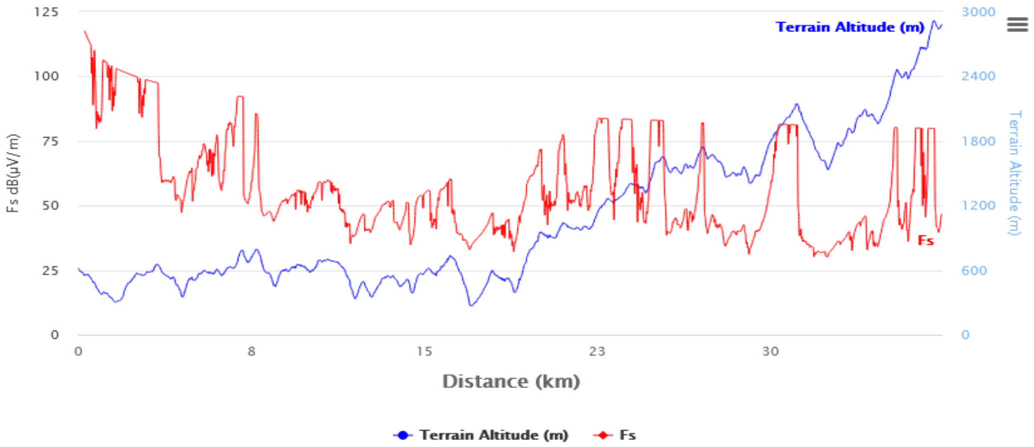
Input parameters:

- **Frequency**
- **Distance (start/end geographical coordinates)**
- Percentage time and location not exceeded
- Polarization
- Terminal heights
- Radio-meteorological data

Recs. ITU-R P.1238, P.1411, P.1546 etc.

Analytical (site-specific)

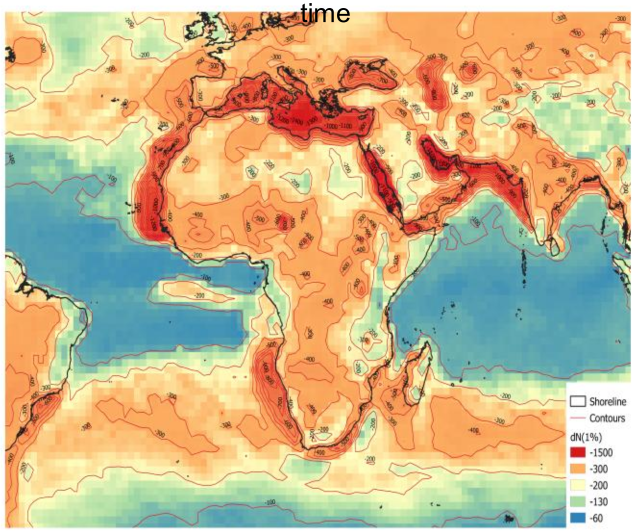
Field strength not exceeded for 1% time against terrain height



Input parameters:

- **Frequency**
- **Start/end geographical coordinates)**
- **Polarization**
- **Terminal heights**
- **Terrain height**
- **Clutter (land use)**
- **Percentage time and location not exceeded**
- **Radio-meteorological data**
  - Atmospheric refractivity
  - Water vapour
  - Temperature
  - Pressure
  - Rain rate

Vertical refractivity gradient N-units/km, Exceeded 1% time



Recs. ITU-R P.452, P.1812, P.2001 etc.

Justifying radio-wave propagation prediction modelling

System design

- Transmit power level
- Power budget
- Technical parameters (antenna, height agl etc.)

- Efficient use of electricity/energy
- Efficient use of infrastructure
- Provide reliable telecommunication

Interference calculation

- Eliminate harmful interference
- Sharing frequency
- Compatibility

- Frequency reuse
- Allow different radio services to operate in same spectrum

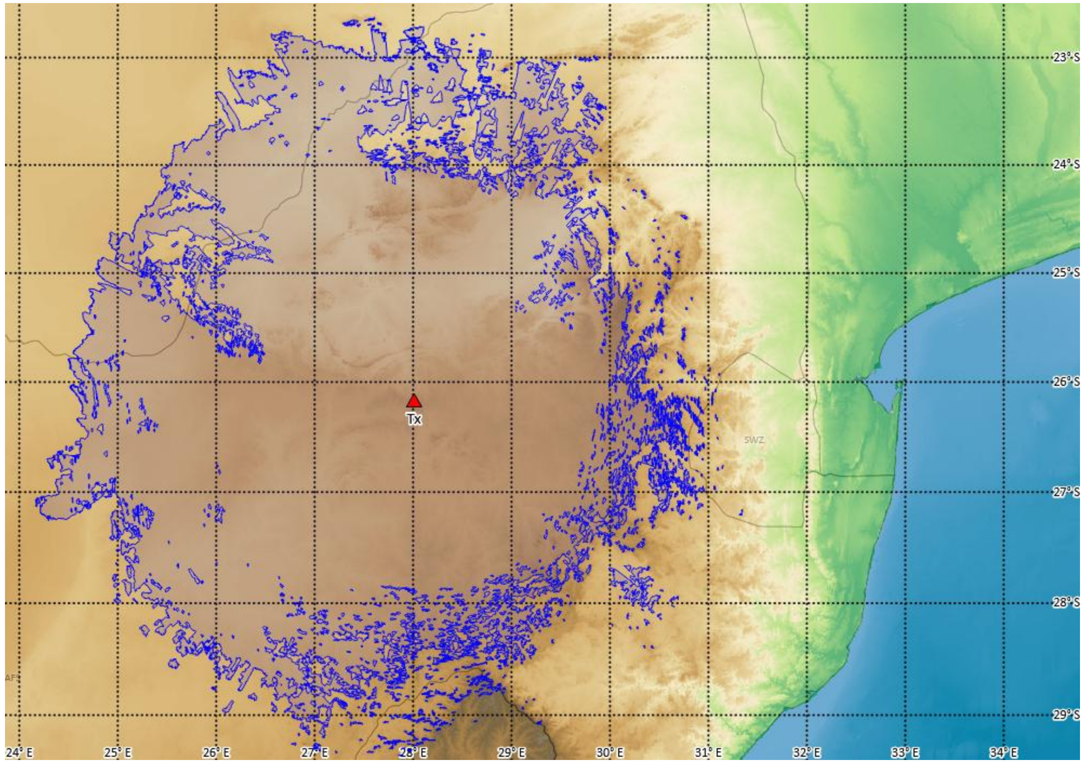
Efficient user of radio spectrum
Efficient use of orbital resources
Meet the UN SDGs

Applying ML in radio-wave propagation prediction modelling

Typical applications

- Direct modelling of radio waves propagating
- Modelling of radio-meteorological phenomena
- Surrogate modelling
- Modelling of sub-models
- Hybrid models (ML and physical models)
- Use of ML to provide land-use (clutter) and height digital models

Coverage prediction Rec. ITU-R P.1812



Considerations on ML in radio-wave propagation predictions

Choice of ML model/architecture

Model suitable for purpose - not only for predicting but also extrapolating

Model explainability
Shapley Additive Explanations

Training data

Sufficient data

Quality data
- avoid “noise”
- pre-processing (post-processing relative to measurement exercise)

Data for training vs for testing/evaluation

Avoid overfitting

Models too complex

Too many features – irrelevant features

Suitable data (insufficient/noise)

Regularization

Status of ML in radio-wave propagation predictions in ITU-R

Question ITU-R 236/3 (Aug 2023) -
"Use of machine learning methods for radio-wave propagation studies"
https://www.itu.int/pub/R-QUE-SG03.236

Correspondence Group 3J-3K-3L-3M-27 –
"Machine Learning for propagation studies"

- Develop guidance on the application of ML in radio-wave propagation modelling
- Work towards producing an ITU-R Report

Individual ML-based radio-wave propagation models to be evaluated by relevant ITU-R Study Group 3 Working Party:

- **WP 3J - Fundamentals of radio-wave propagation in non-ionized media**
- **WP 3K - Radio-wave propagation prediction for point-to-area propagation paths**
- **WP 3L - Ionospheric and ground-wave propagation prediction and radio noise**
- **WP 3M - Radio-wave propagation prediction for point-to-point paths and paths between the Earth and space**

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