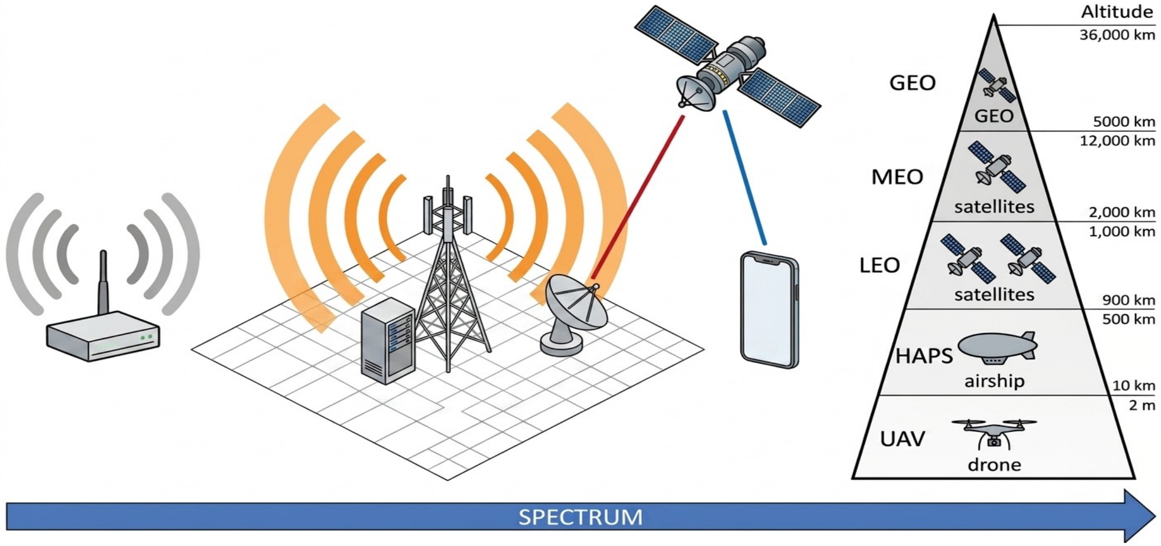
Propagation models in coexistence analysis

8 July 2026

Valeria Petrini
Fondazione Ugo Bordoni

Spectrum sharing as a necessity



- When defining the spectrum for the new wireless communications systems, the need to improve **spectral efficiency** must be considered. In the future it will be increasingly less likely to operate in **free spectrum** but access to the spectrum will have to **be shared between various users**.

- plan actions that promote the **shared use of the spectrum** both between terrestrial networks and between terrestrial and non-terrestrial networks (TN-NTN).

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Coexistence analysis

- The introduction of a **new technology** or **new systems** in a frequency band already used by other systems must **ensure the protection** of existing services, the “**incumbents**” services, whose current and future operation must not be compromised;

- It is necessary to define the **technical** and **regulatory conditions** that **guarantee the coexistence** between different services (e.g. mobile, fixed, fixed satellite services) in the same frequency band or in adjacent bands.

- Example of **CEPT sharing studies**:

    - Mandate of EU to CEPT: **Low/medium power local area networks in 3.8-4.2 GHz**
    - Mandate of EU to CEPT: **Shared use of the 6425-7125 MHz frequency band**
    - Mandate of EU to CEPT: **Direct-to-Device connectivity in IMT bands**
    - **WRC-27 preparation**

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Propagation characterization

In coexistence analyses, a relevant element is characterizing the **propagation** of the **interfering signal**:

1. Estimating and modeling the **path loss**
2. Estimating and modeling the **clutter loss**

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Propagation models in coexistence analysis

Propagation models usually used in coexistence studies for the characterization of the **interfering signal**:

a. **Recommendation ITU-R P.452-18**, which includes a **clutter loss model** (using representative clutter heights, or real clutter data);

b. **Recommendation ITU-R P.452-17** (for path loss) together with **Recommendation ITU-R P.2108-1** (for clutter losses when the distance is larger than 250 m).

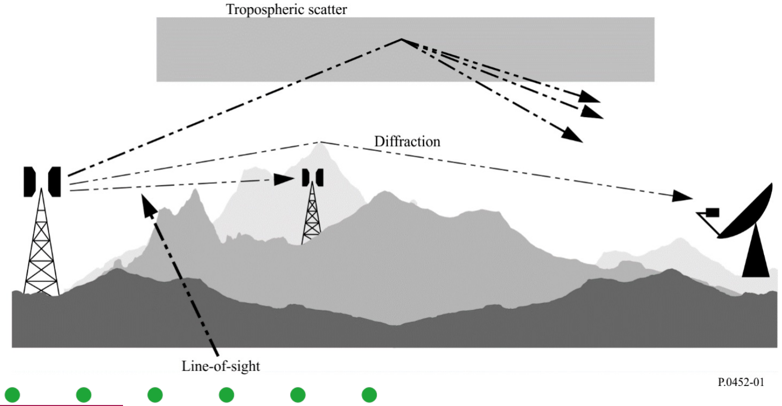
c. **Recommendation ITU-R P.2001-4** (for path loss) together with Recommendation ITU-R P.2108-1 (for clutter losses when the distance is larger than 250 m).

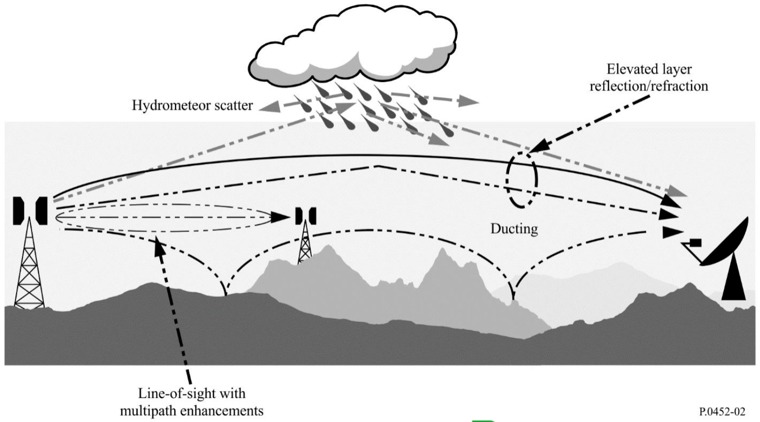
Rec. ITU- R P.452-17 and Rec. ITU-R P.452-18

Recommendation ITU-R P.452-17 and Recommendation ITU-R P.452-18, accounting for both clear-air and hydrometeor scattering interference mechanisms. **Interference may arise through a range of propagation mechanisms** whose individual dominance depends on **climate**, radio **frequency**, **time percentage** of interest, **distance** and **path topography**. At any one time a single mechanism or more than one may be present.

The principal interference propagation mechanisms are as follows:

- **Line-of-sight**
- **Diffraction**
- **Tropospheric scatter**
- **Surface ducting**
- **Elevated layer** (reflection and refraction)
- **Hydrometeor scatter**





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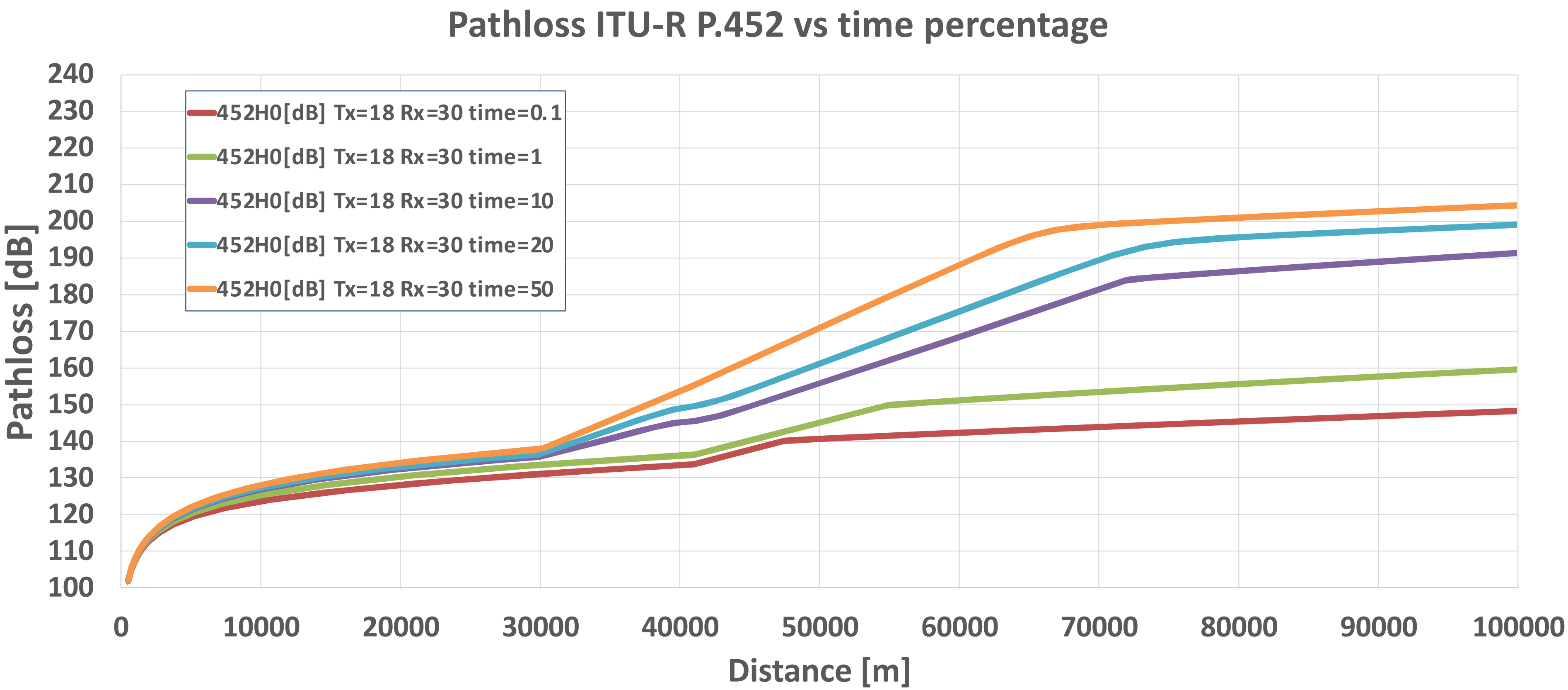
Recommendation ITU- R P.452-17



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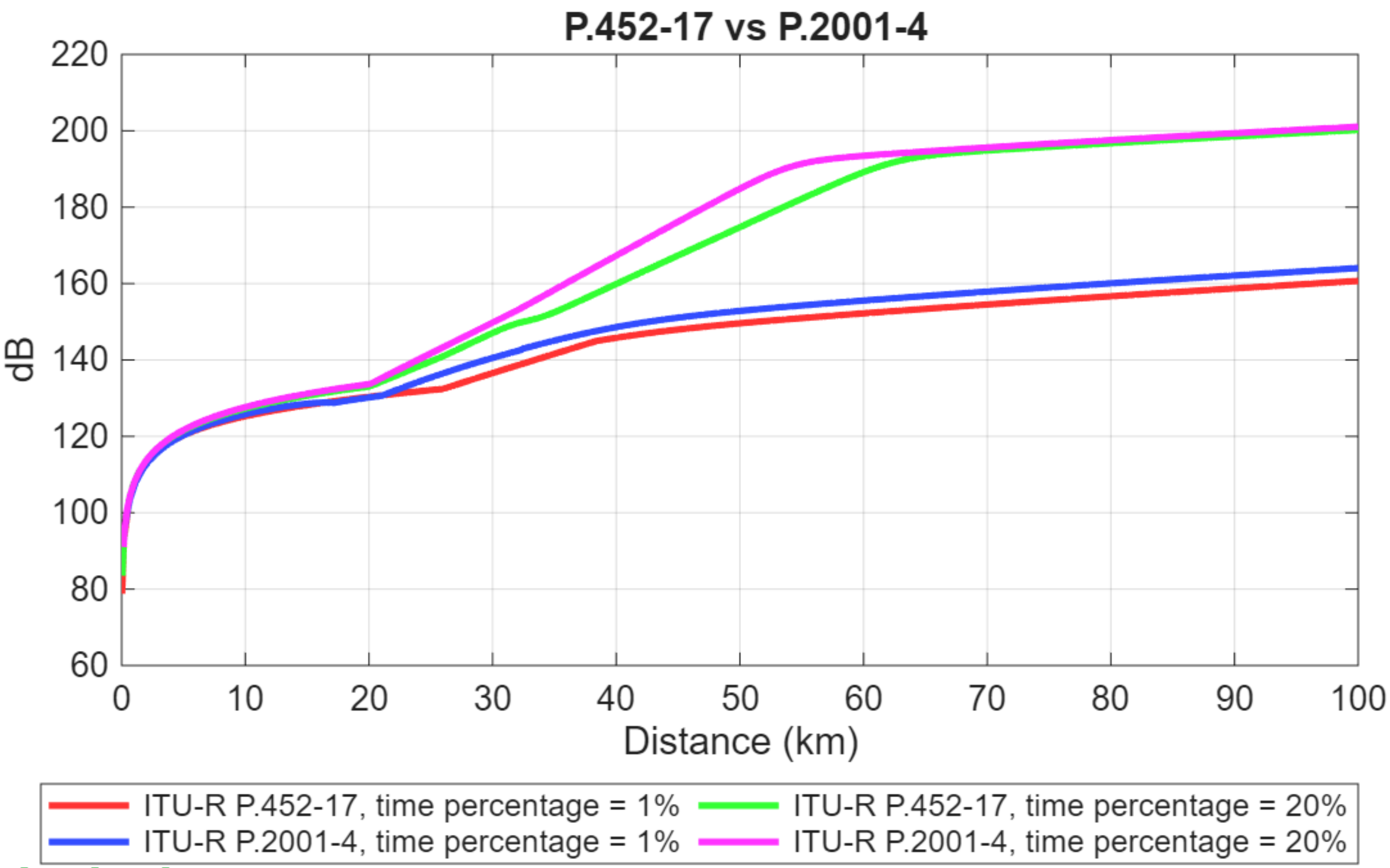
Rec. ITU- R P.2001 vs Rec. ITU-R 452-17

Recommendation ITU-R P. 2001

- General purpose wide-range model for terrestrial propagation for **basic transmission loss prediction**
- Time percentage: **0%** to **100%** of an average year (suitable for Monte Carlo methods)
- Frequency range from **30 MHz** to **50 GHz**
- Distances from **3 km** to at least **1000 km**



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Recommendation ITU- R P.452-17- clutter loss

In Recommendation ITU-R P.452-17 a procedure allows the addition of such **clutter losses.**

This procedure allows for the addition of such clutter losses **at either or both ends of the path** in situations where the clutter scenario is known.

It predicts a maximum additional loss at either end of the path, applied via an S-shaped interpolation function intended to avoid an over-estimate of the shielding loss.

The maximum additional loss is **20 dB above 0.9 GHz**, and progressively less at lower frequencies, down to **5 dB at 0.1 GHz.**

TABLE 4

Nominal clutter heights and distances

Clutter (ground-cover) category	Nominal height, h_a (m)	Nominal distance, d_k (km)
High crop fields Park land Irregularly spaced sparse trees Orchard (regularly spaced) Sparse houses	4	0.1
Village centre	5	0.07
Deciduous trees (irregularly spaced) Deciduous trees (regularly spaced) Mixed tree forest	15	0.05
Coniferous trees (irregularly spaced) Coniferous trees (regularly spaced)	20	0.05
Tropical rain forest	20	0.03
Suburban	9	0.025
Dense suburban	12	0.02
Urban	20	0.02
Dense urban	25	0.02
High-rise urban	35	0.02
Industrial zone	20	0.05

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Recommendation ITU- R P.452-18- clutter loss

The path profiles require path-specific data for terrain (bare-earth) and path-specific clutter (ground cover) categories along the path.

The method includes:

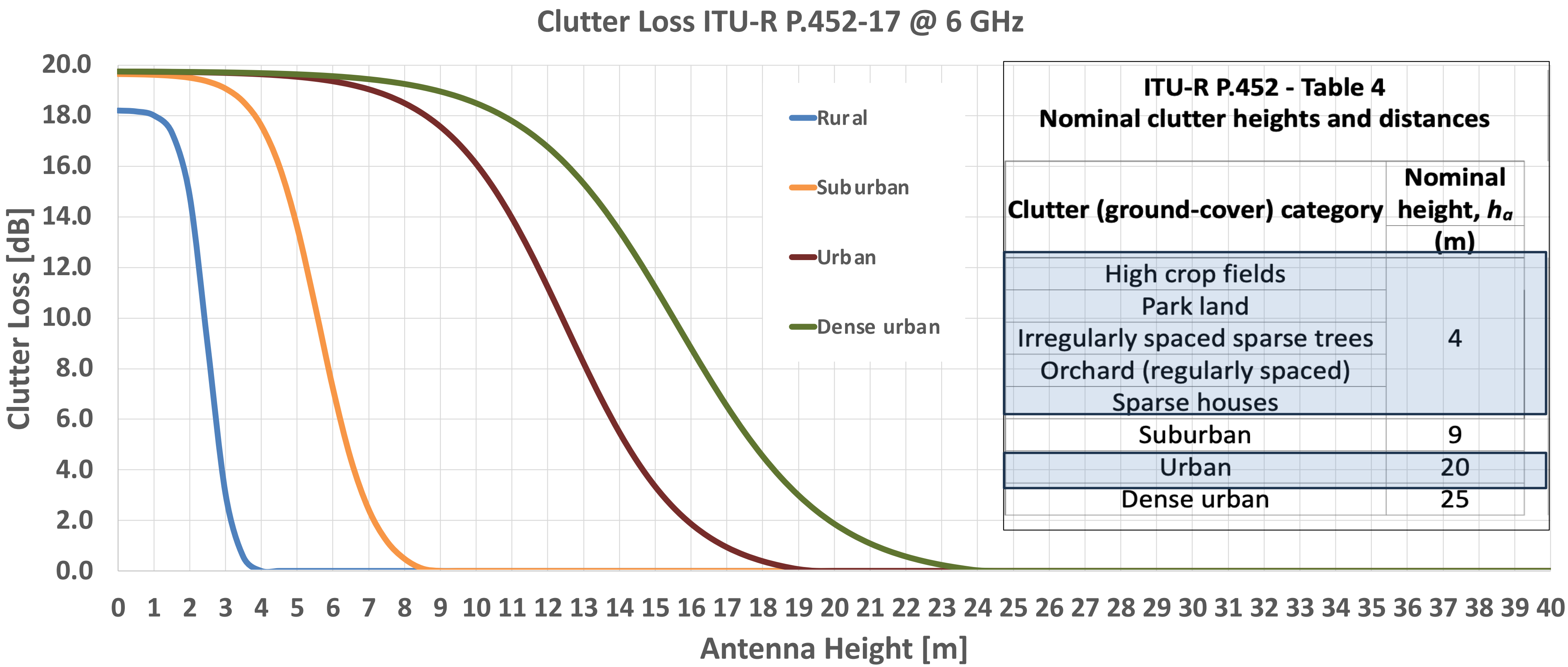
- **the construction of a terrain profile using actual terrain heights**;
- **based on the clutter categories, the addition of representative clutter heights to the terrain profile**.

TABLE 3

Default representative clutter height values

Clutter category	**Representative clutter height (m)** **Add to profile of equation (6e) for $i = 1$ to $n - 1$**
Water/sea	0
Open/rural	0
Suburban	10
Urban/trees/forest	15
Dense urban	20

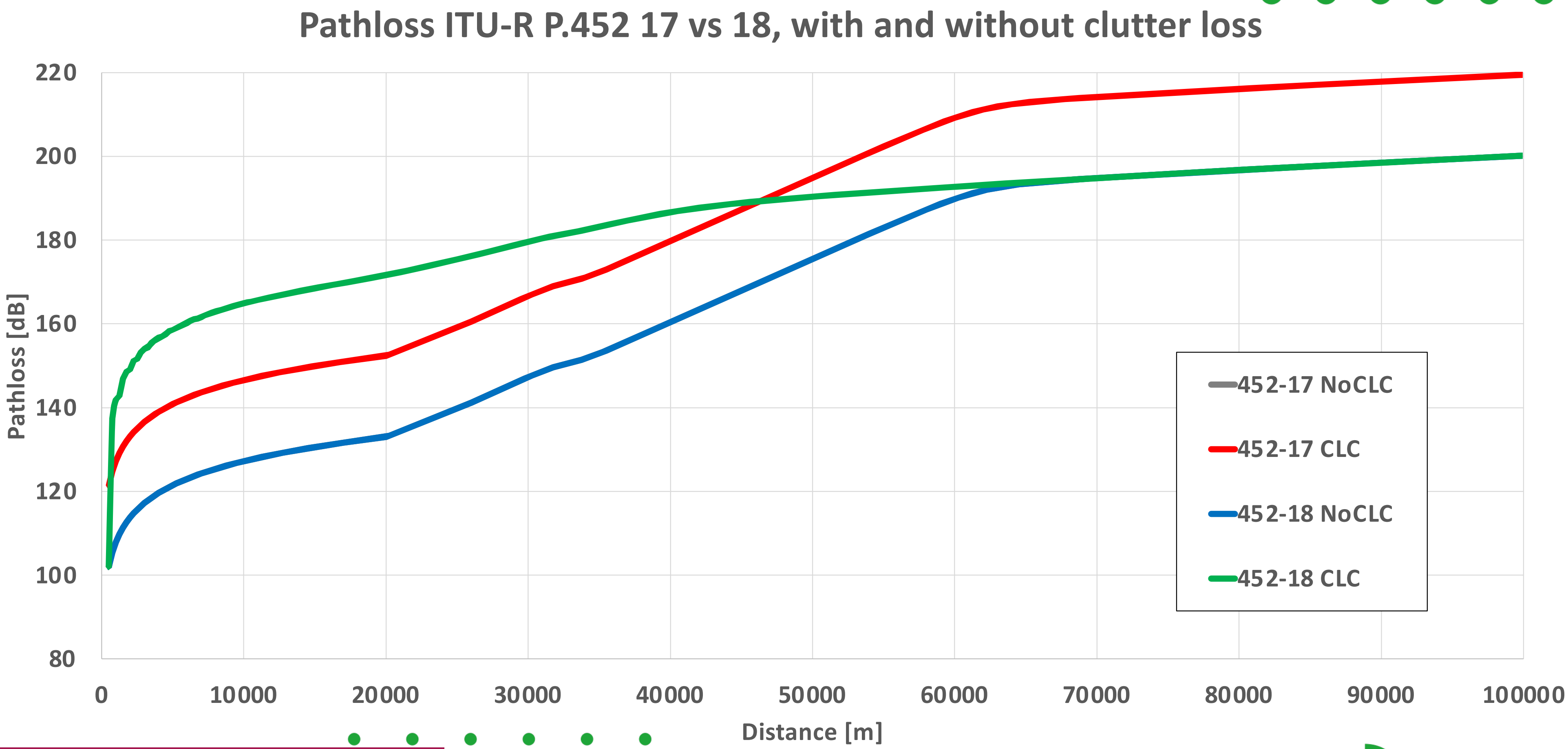
Recommendation ITU- R P.452-17- clutter loss



ITU-R P.452 - Table 4
Nominal clutter heights and distances

Clutter (ground-cover) category	Nominal height, h_a (m)
High crop fields	4
Park land	
Irregularly spaced sparse trees	
Orchard (regularly spaced)	
Sparse houses	
Suburban	9
Urban	20
Dense urban	25

Rec. ITU- R P.452-17 vs Rec. ITU-R 452-18



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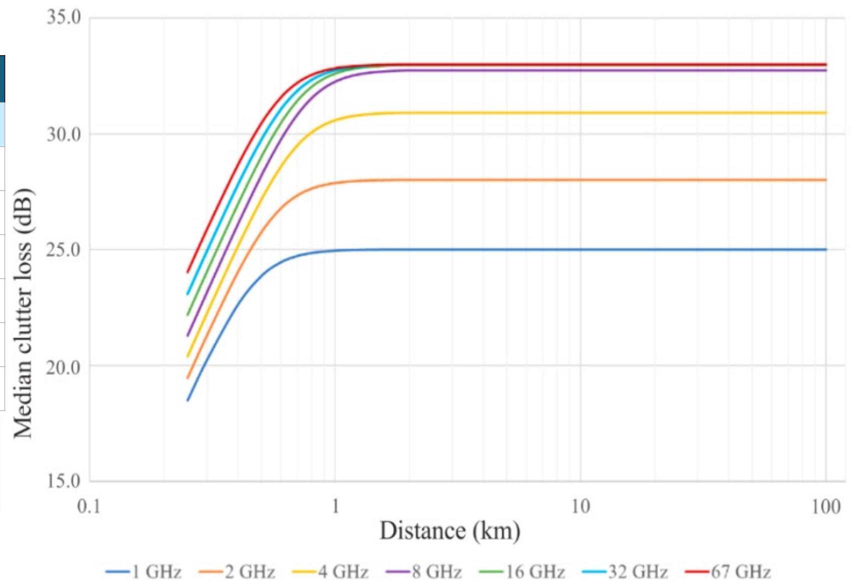
Recommendation ITU-R P.2108 – clutter loss

Recommendation ITU-R P.2108-1 "***Prediction of clutter loss***" describes a set of models that can be used for estimating the loss due to clutter for a number of different environments. These models can be used as an end correction to long distance or over the rooftop models.

LP	1 GHz	2 GHz	3.7 GHz	6 GHz	27 GHz
0.1	12.630	15.623	18.208	19.833	20.588
1	**15.687**	**18.683**	**21.274**	**22.905**	**23.654**
10	19.869	22.868	25.468	27.108	27.846
20	**21.629**	**24.631**	**27.233**	**28.877**	**29.611**
30	22.899	25.901	28.507	30.153	30.884
50	**24.998**	**28.002**	**30.612**	**32.262**	**32.988**
90	30.126	33.134	35.751	37.409	38.126

FIGURE 1

Median clutter loss for terrestrial paths



P.2108-01

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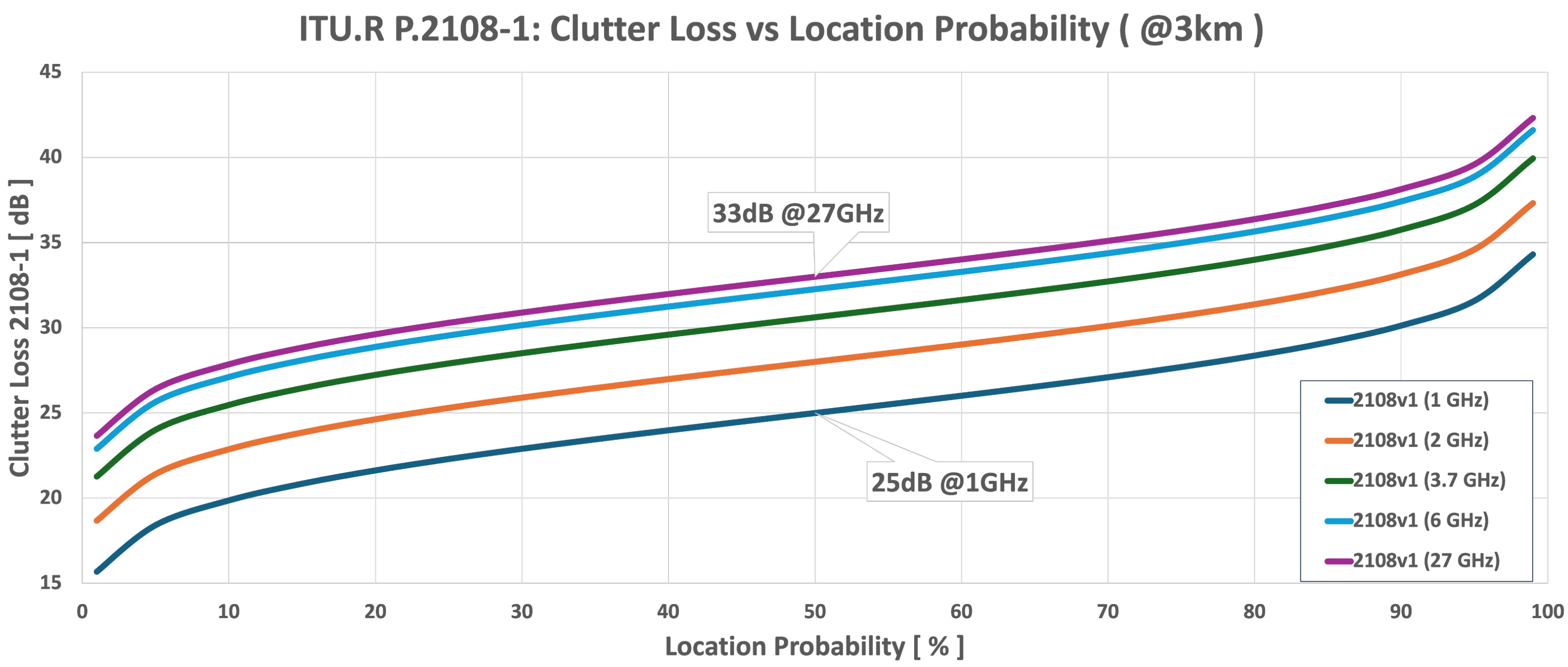
Recommendation ITU-R P.2108 – clutter loss



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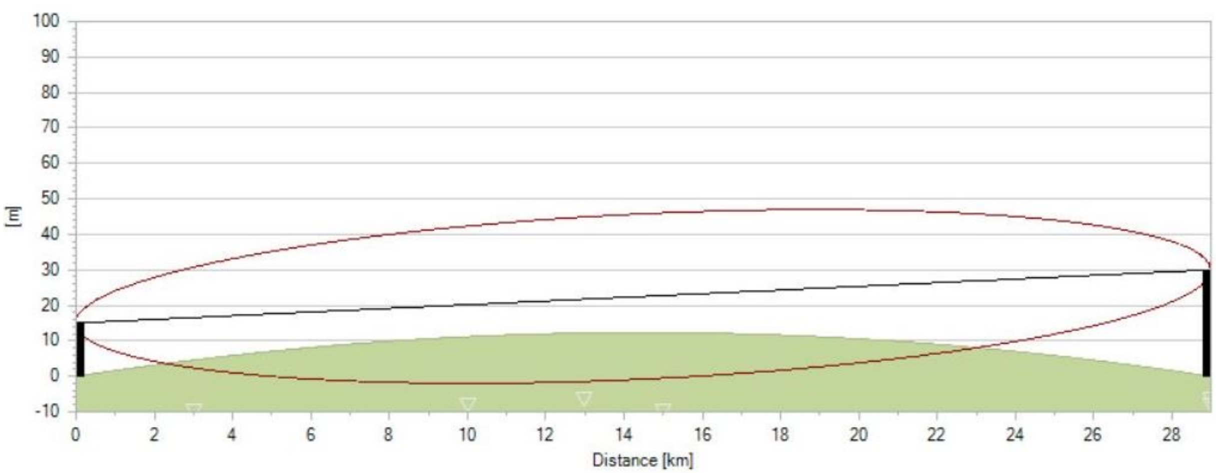
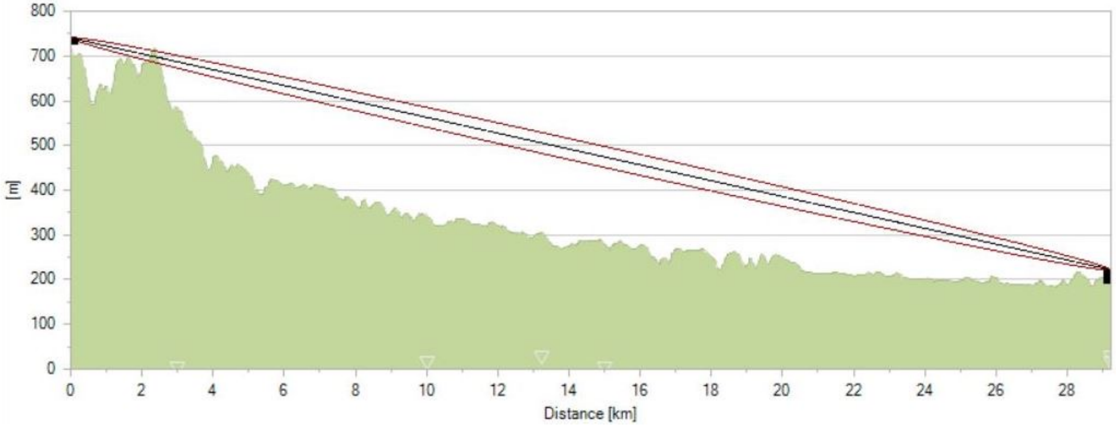
Real altimetry considerations

- the geographical conformation of the territory can **help the coexistence** and, compared to considering flat terrain, the **separation distance decreases**;
- the geographical conformation of the territory can **help the propagation** and, compared to considering flat terrain, the separation **distance increases**.



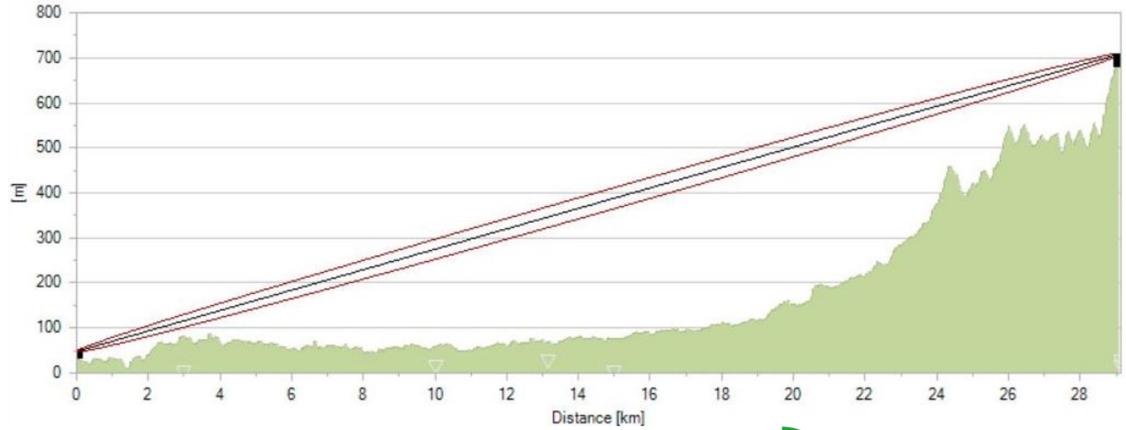
Effect of the obstruction of the Fresnel zone due to the Earth curvature in flat terrain

Real altimetry considerations



Effect of the altimetry that intersects the Fresnel zone

Effect of the altimetry that helps the propagation



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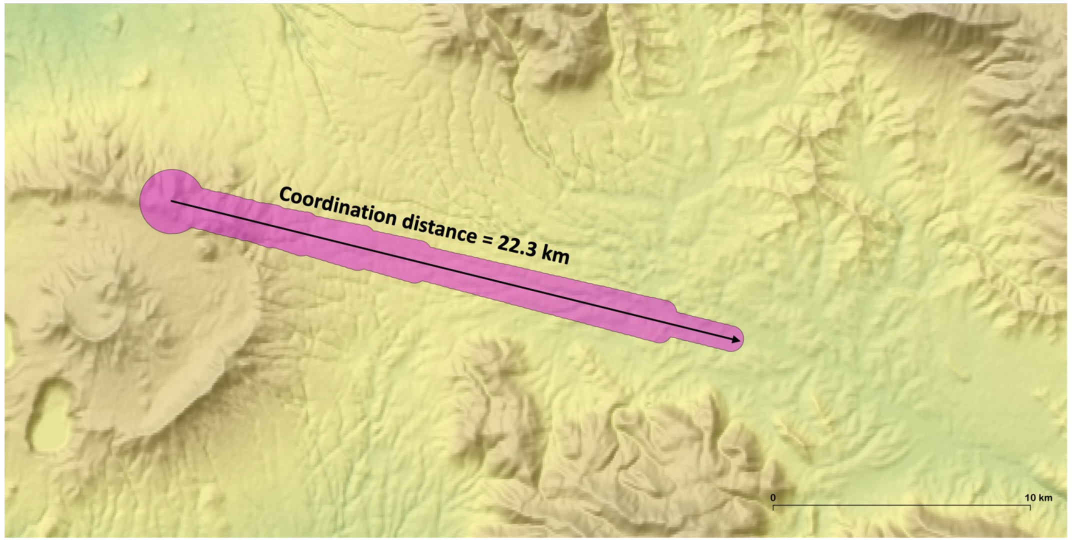
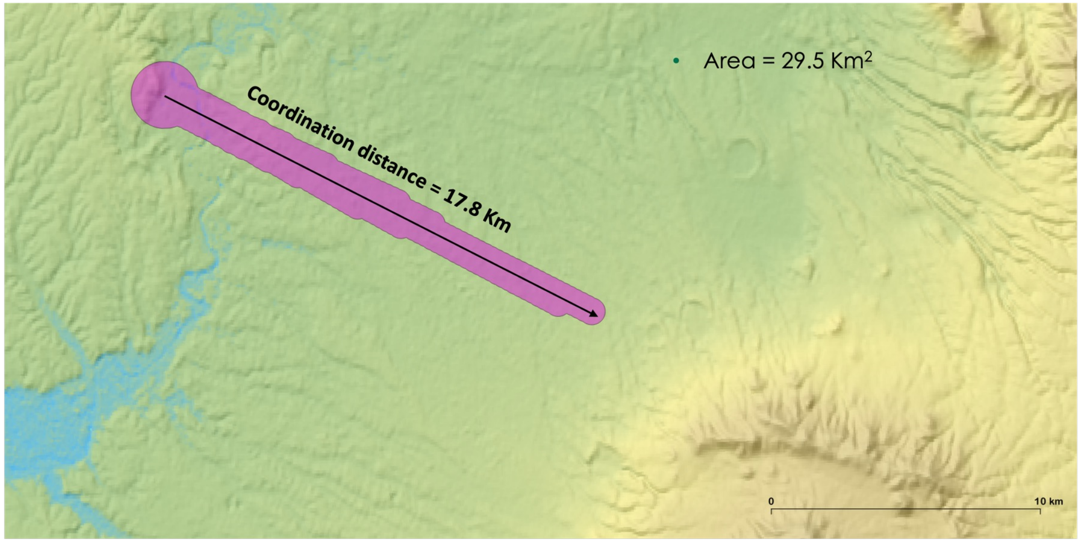
Real altimetry considerations



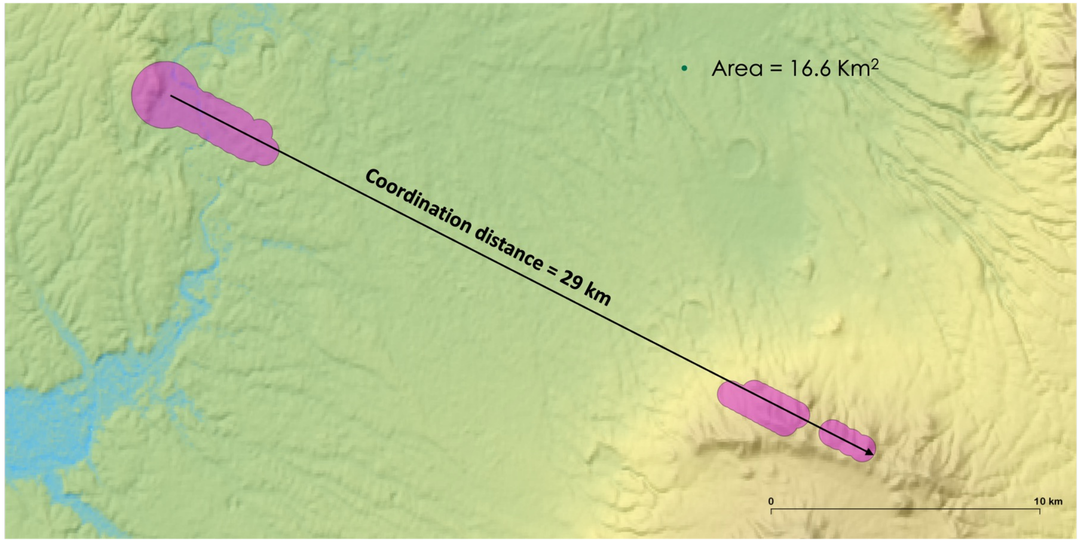
Coordination distance and coordination area around the FS in flat terrain

Coordination distance and coordination area around the FS considering the actual terrain elevation

Real altimetry considerations



Coordination distance and coordination area around the FS in flat terrain



Coordination distance and coordination area around the FS considering the actual terrain elevation

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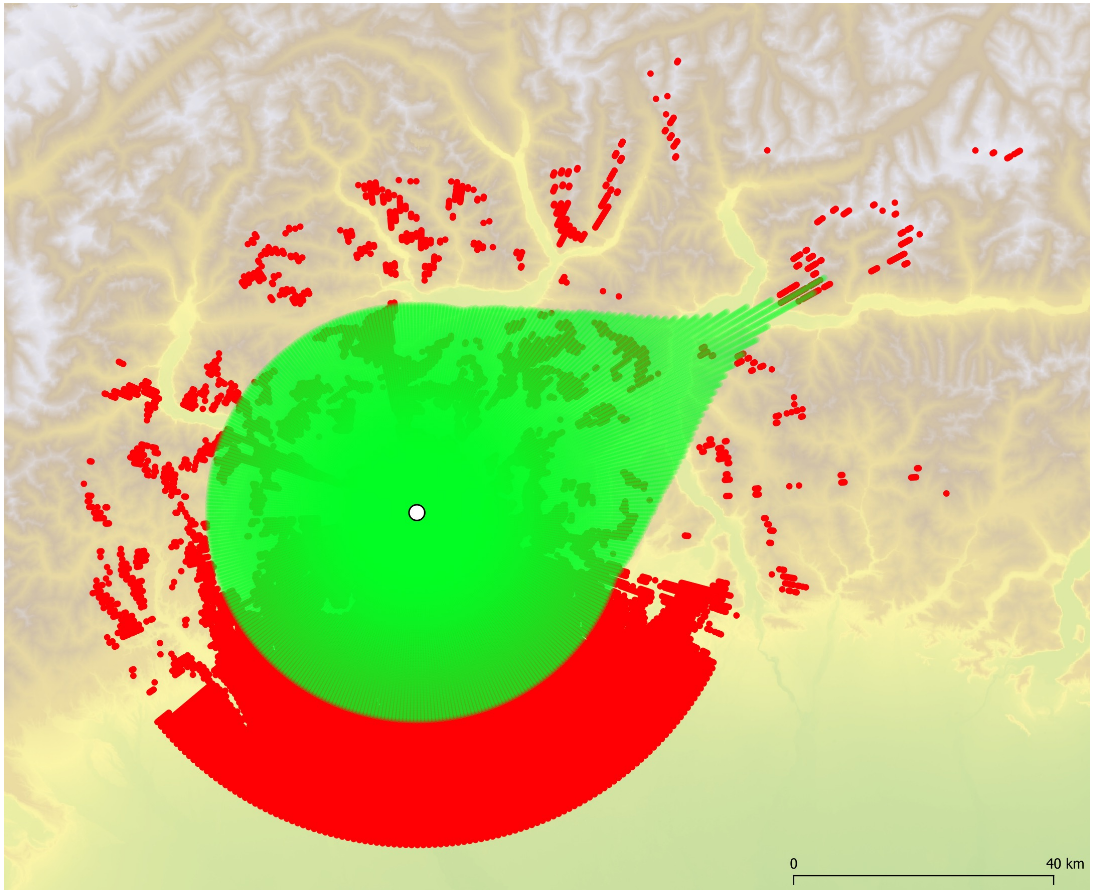
Example of coordination areas



Difference between flat terrain and real altimetry

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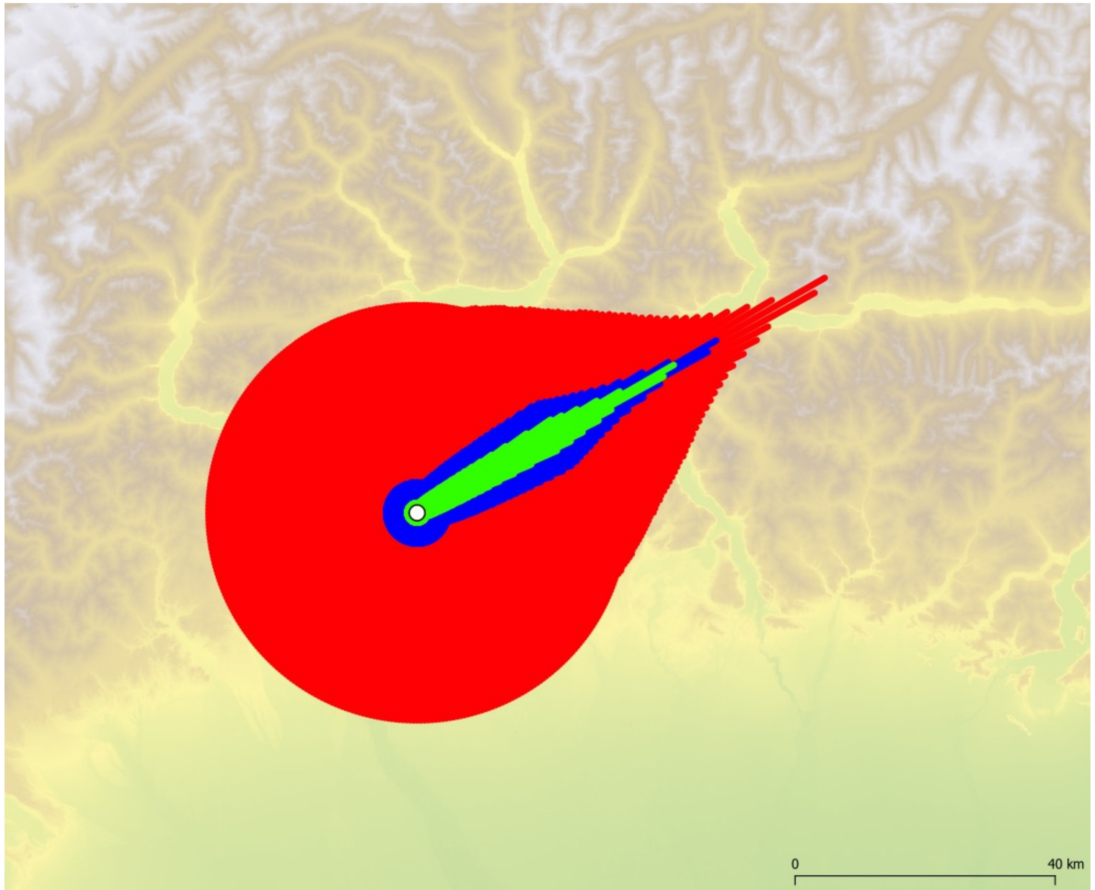
Example of coordination areas



Coordination area in flat terrain:

- P.452
- P.452 + P.2108 (LP 1%, 22.9 dB)
- P.452 + P.2108 (LP 50%, 32.3 dB)

Coordination distances

- 72.3 km
- 53.5 km
- 46.0 km

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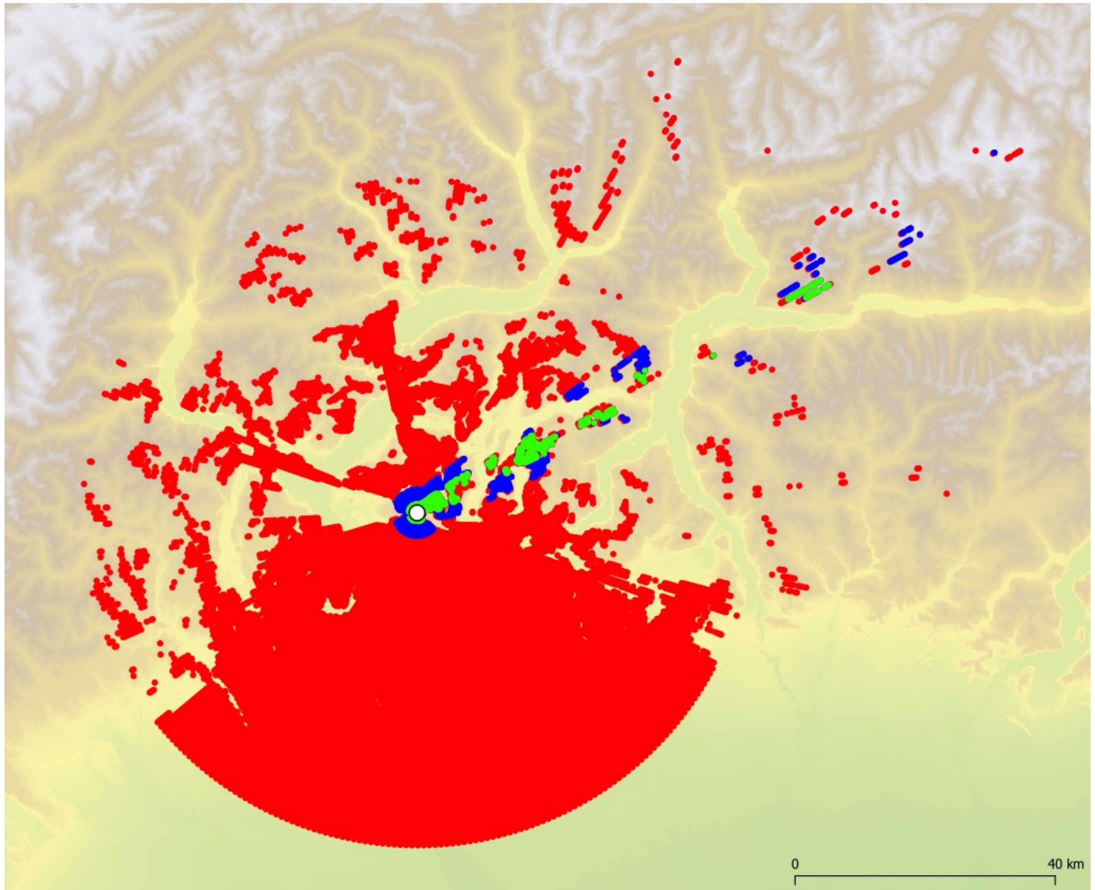
Example of coordination areas



Coordination area with real altimetry:
- P.452
- P.452 + P.2108 (LP 1%, 22.9 dB)
- P.452 + P.2108 (LP 50%, 32.3 dB)

Coordination distances
- 108.7 km
- 104.6 km
- 72.1 km

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Conclusions

- **Radio wave propagation** cannot be easily characterized by **models** capable of accurately describing propagation in **real-world scenarios**.
- Defining the most **suitable propagation model** and selecting the **appropriate parameters** is a highly debated topic in **coexistence studies**.
- Since propagation models are based on **measurements** from specific environments and conditions, their reliability is difficult to guarantee when **simulating different scenarios**.
- **Parameter selection** for environmental characterization in propagation models **is not straightforward**, especially when reproducing **real-world scenarios**.
- Utilizing **terrain profiles** (orography) to simulate **real environments** is a key element that can heavily **influence coexistence studies outcomes**.

Thanks for your attention

Valeria Petrini

vpetrini@fub.it

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