VHF/UHF propagation basics

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"What is the range of my set of UHF handheld radios?"

"I cannot operate the local VHF repeater! What can I do?"

VHF/UHF propagation basics

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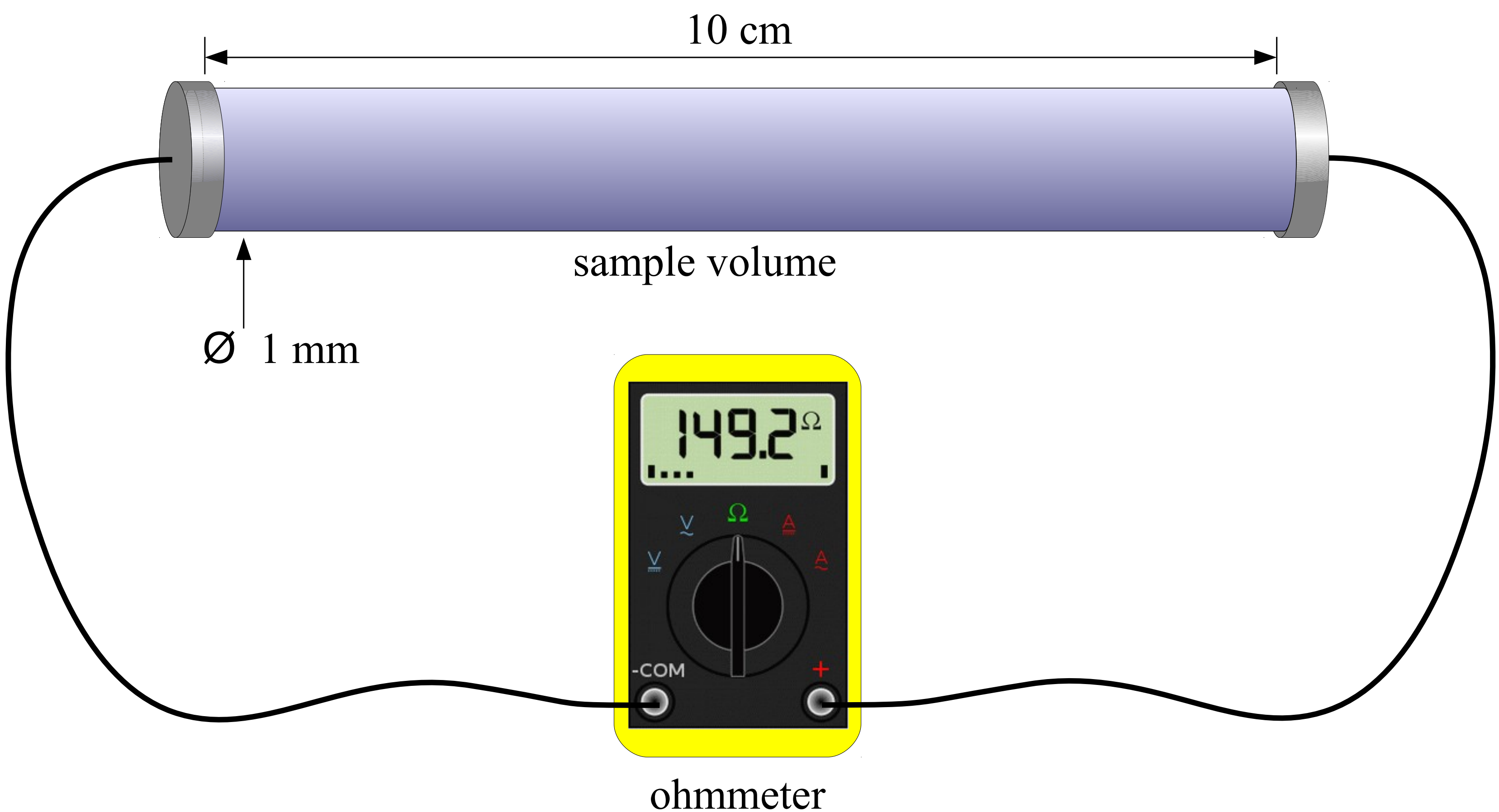
Conductivity of Ground

material	**conductivity** σ in S/m
copper	58 000 000.0
aluminium	36 000 000.0
iron	10 000 000.0
stainless steel	1 400 000.0
seawater	5.0
tap water	0.05
pure water	0.000 005
ground, wet	$\sim$ 0.03
ground, dry	$\sim$ 0.001
concrete, wet	$\sim$ 0.04
concrete, dry	$\sim$ 0.01
granite rock	$\sim$ 0.000 001
PE, PP, PVC	$\sim$ 0.000 000 000 000 000 1
air	0.0

Important Physical Effects

Conductivity of Ground



Important Physical Effects

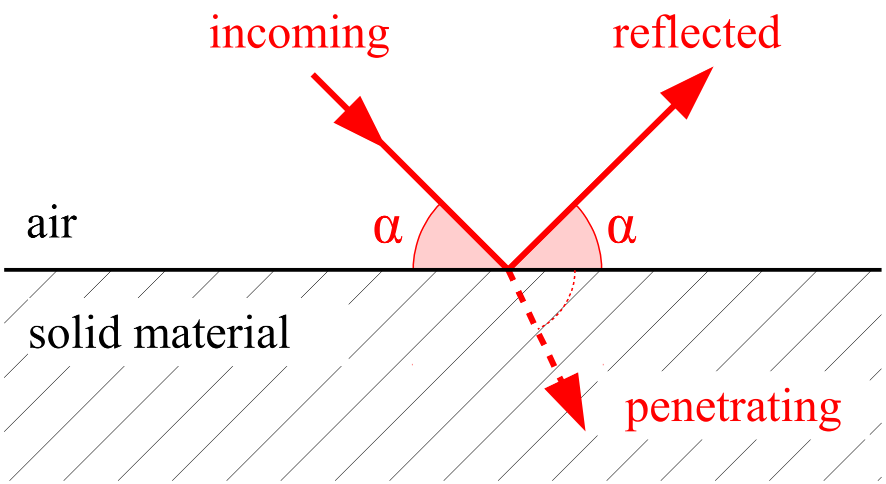
Conductivity of Ground

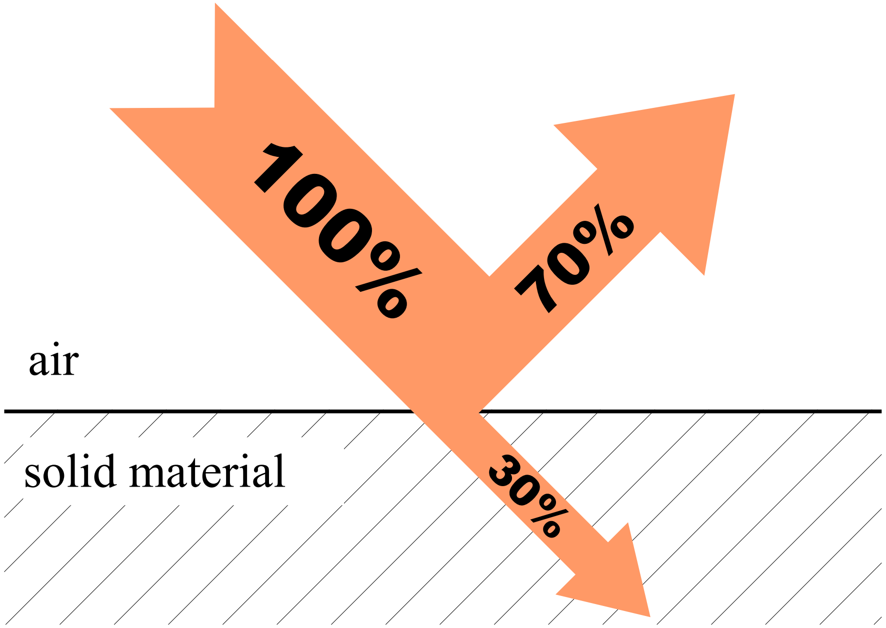
material	sample resistance R in Ω
copper	0.002
aluminium	0.004
iron	0.013
stainless steel	0.091
seawater	26 000.0
tap water	2 600 000.0
pure water	26 000 000 000.0
ground, wet	4 200 000.0
ground, dry	1 300 000 000.0
concrete, wet	3 200 000.0
concrete, dry	13 000 000.0
granite rock	130 000 000 000.0
PE, PP, PVC	$1.3 \cdot 10^{21}$
air	infinite

- Ground, concrete and rock are no conductors.
- Even sea water is no good conductor, but a poor insulator.
- Its conductivity is worse than iron by a factor of 2 million!

Important Physical Effects

Reflection on Smooth Surfaces





At a smooth bounding surface of any two materials an incoming radio wave will

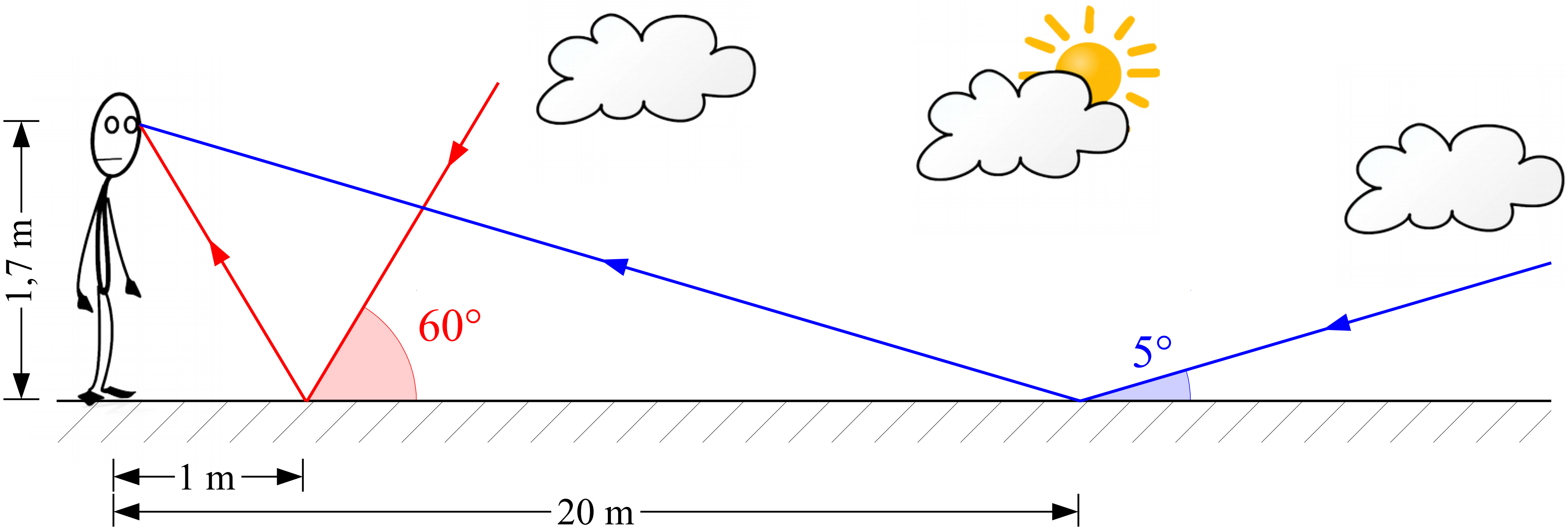
- penetrate the other material
- be reflected from the surface

The grade of reflection is called *reflection factor*.

Reflection occurs with any electromagnetic wave: *radio* as well as *light*.

Important Physical Effects

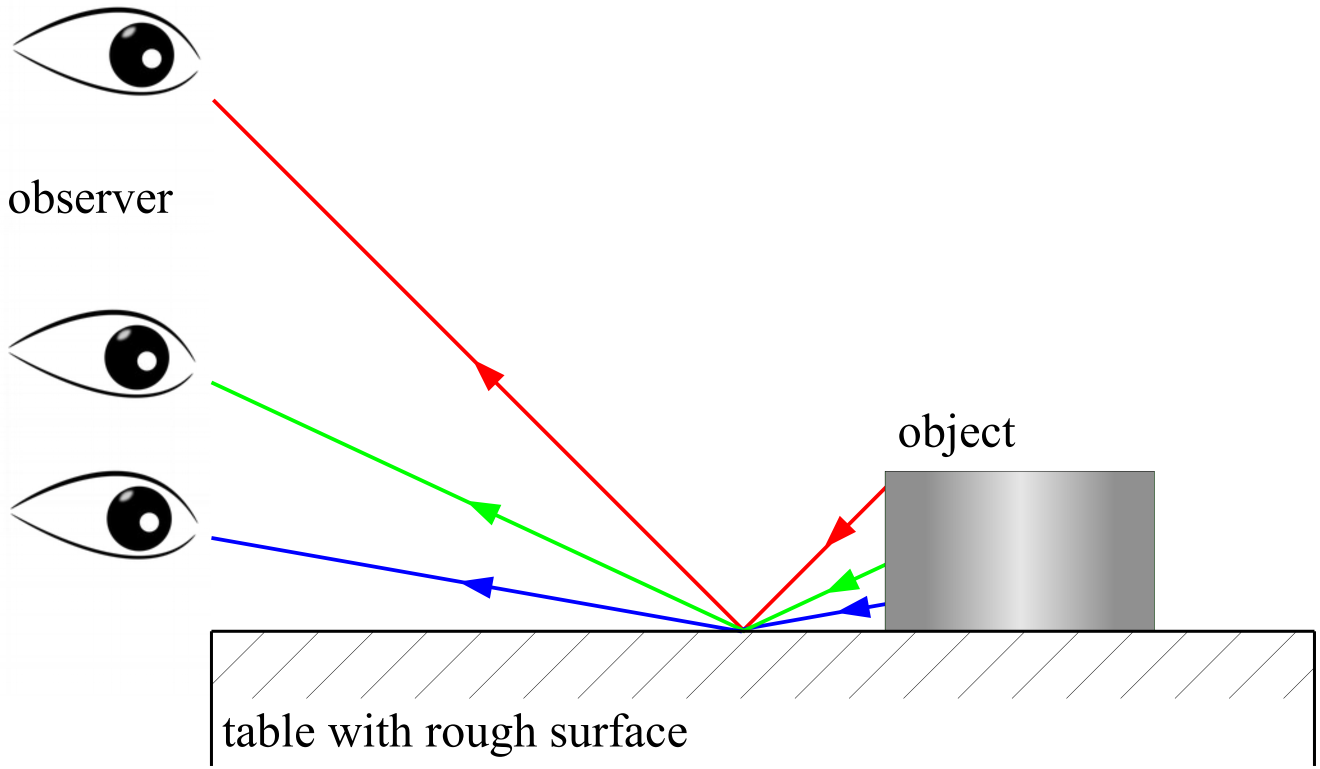
Reflection on Smooth Surfaces



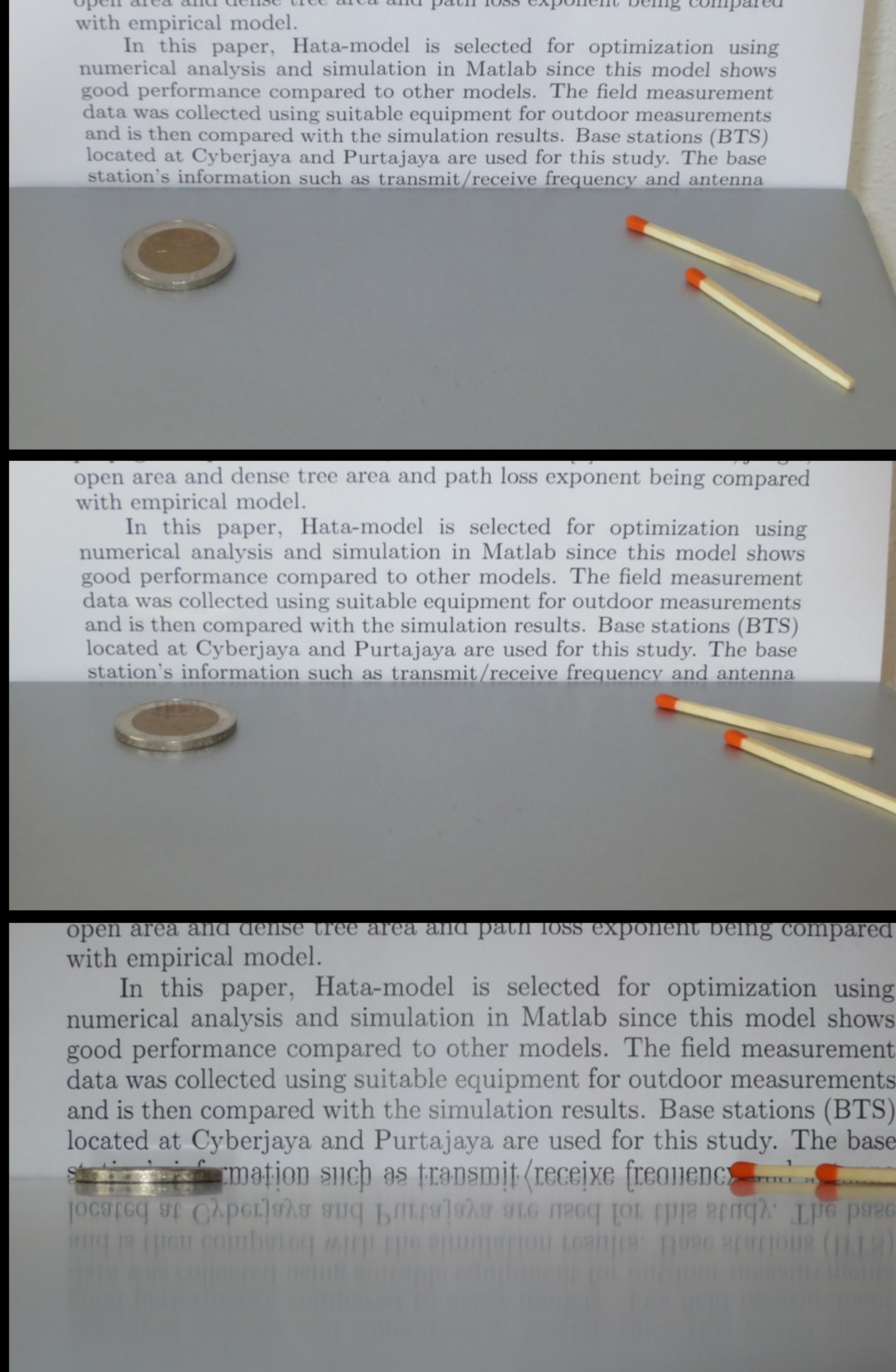
- Poor reflection at high angles.
- Good reflection at low angles.

Important Physical Effects

Reflection on Rough Surfaces



- Poor and diffuse reflection at high angles.
- Perfect image reflection at very low angles.


open area and dense tree area and path loss exponent being compared
with empirical model.
In this paper, Hata-model is selected for optimization using
numerical analysis and simulation in Matlab since this model shows
good performance compared to other models. The field measurement
data was collected using suitable equipment for outdoor measurements
and is then compared with the simulation results. Base stations (BTS)
located at Cyberjaya and Purtajaya are used for this study. The base
station's information such as transmit/receive frequency and antenna

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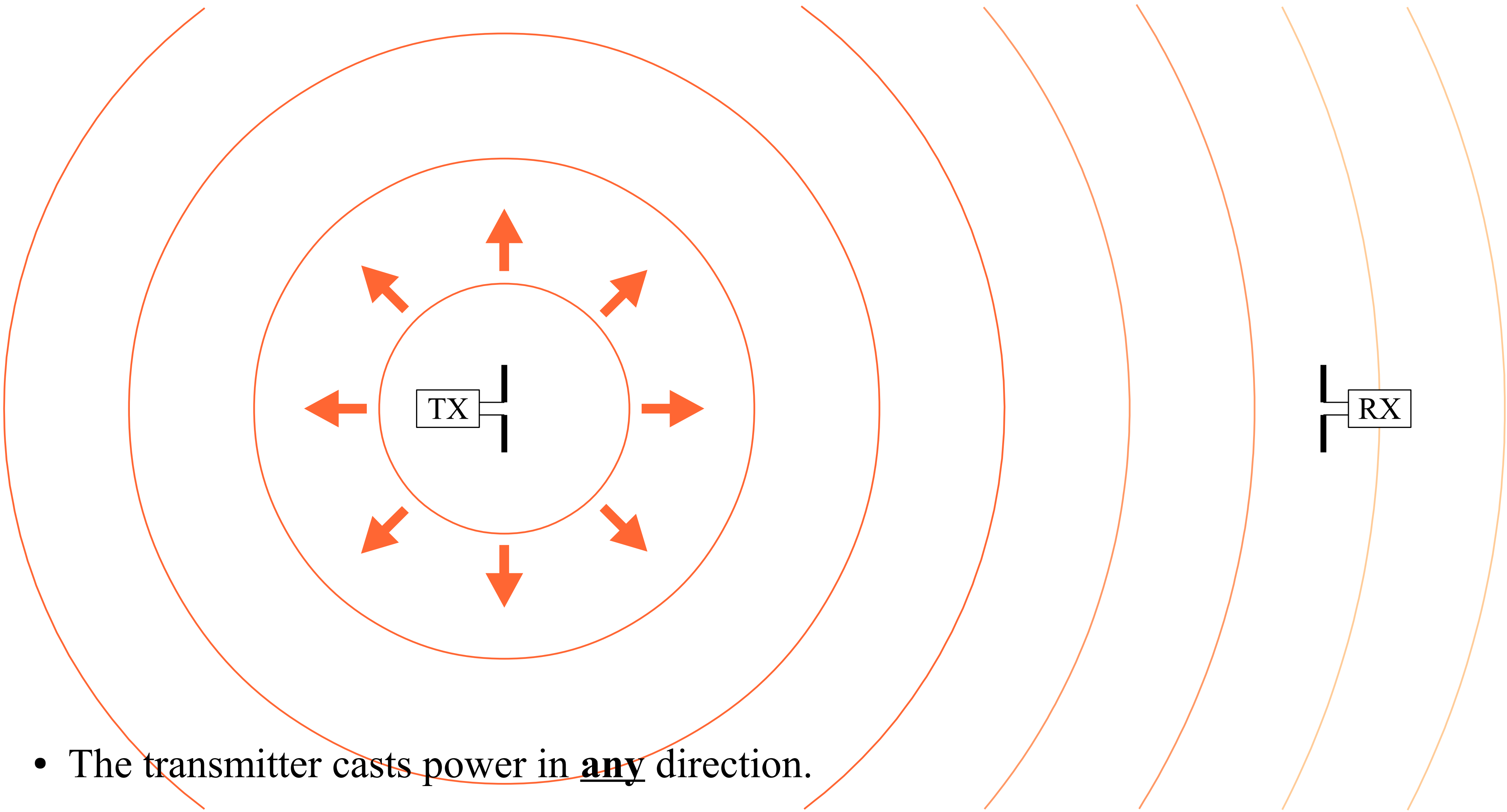
Physical Propagation Models

Free Space Model

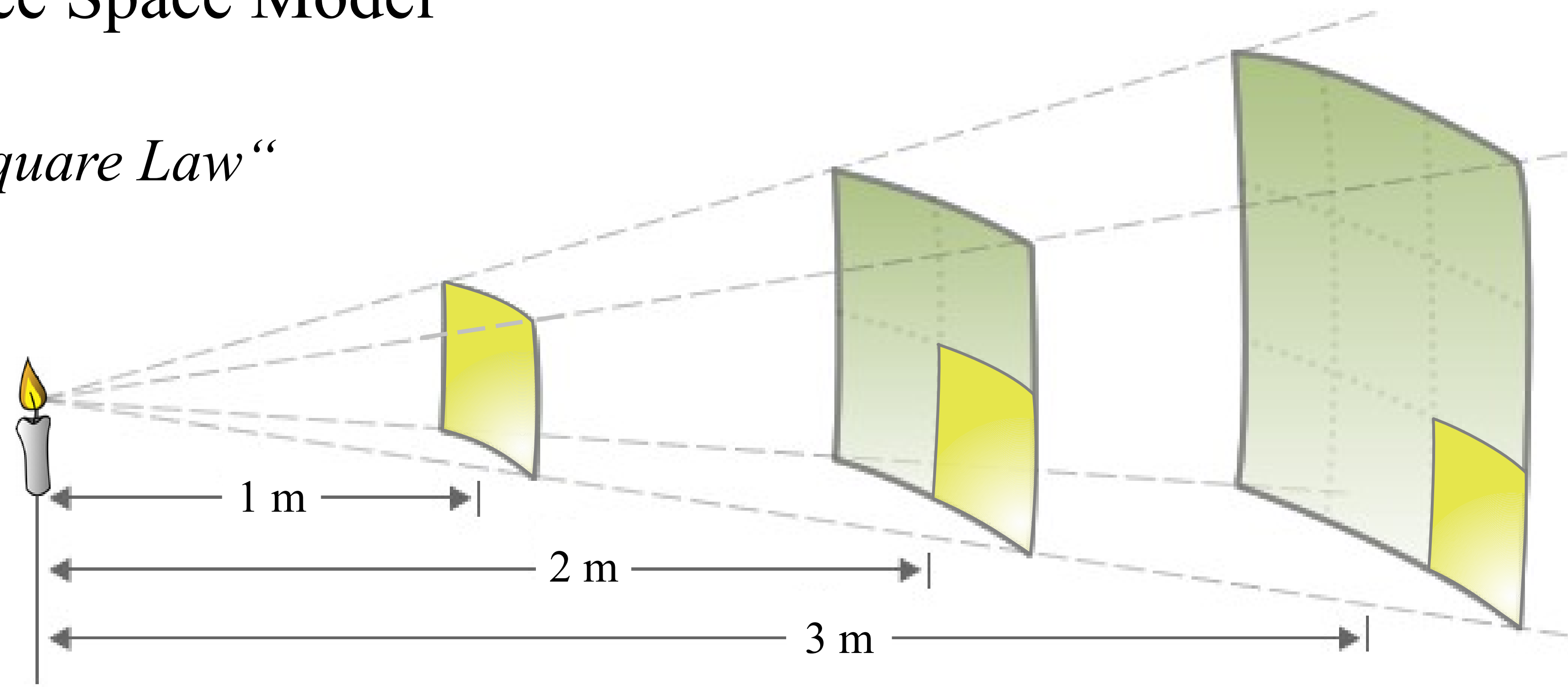


- The transmitter casts power in **<u>any</u>** direction.
- The transmitted power extends spherically into space.
- A small portion only will arrive at the receiver.

Physical Propagation Models

Free Space Model

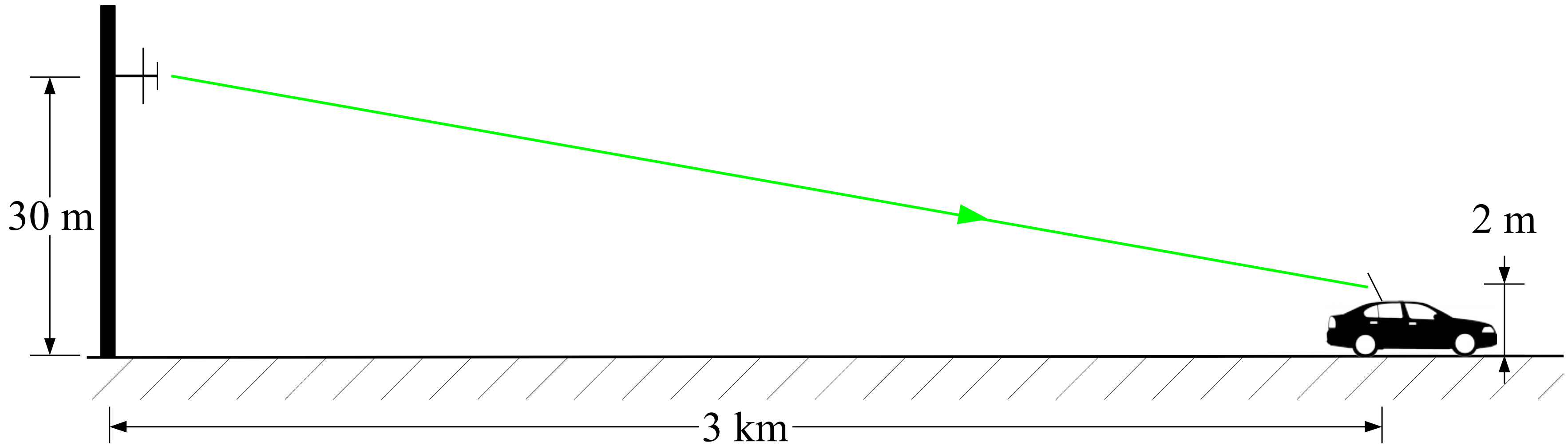
"Square Law"



- Signal Power at receiving antenna depends on
  - Distance: Doubling distance reduces signal by factor 4
  - Frequency: Doubling frequency reduces signal by factor 4
- It can be directly calculated by a simpel formula.
- This is the best case for a radio wave! There is no better way to travel without wave guides (cables).
- Strong restrictions apply for using this model!

Physical Propagation Models

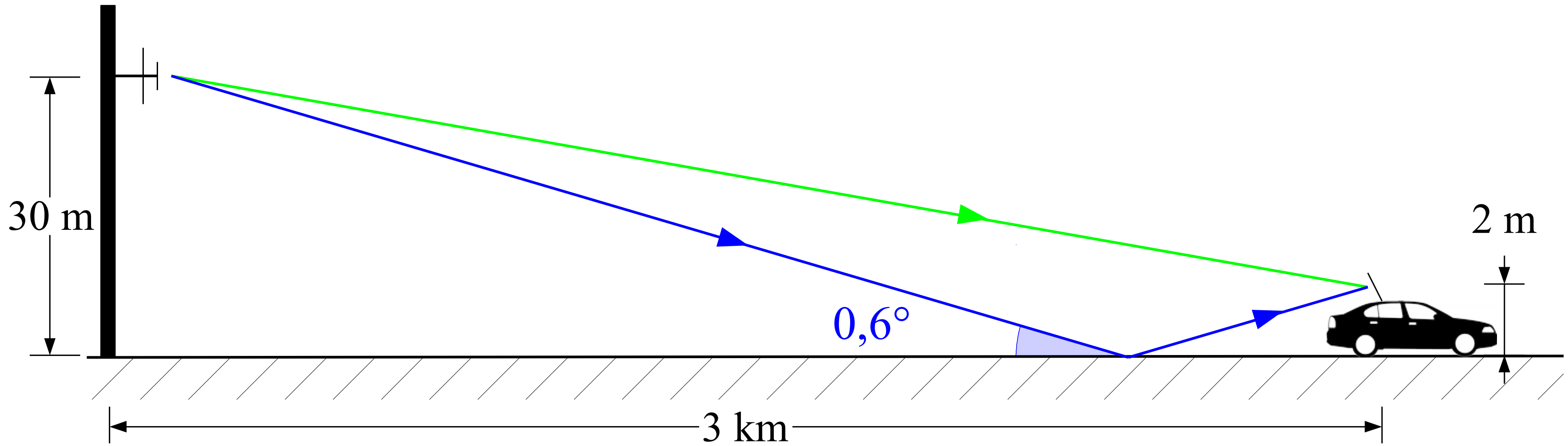
Plane Earth Model



Radio waves travel from TX to RX via the direct path ...

Physical Propagation Models

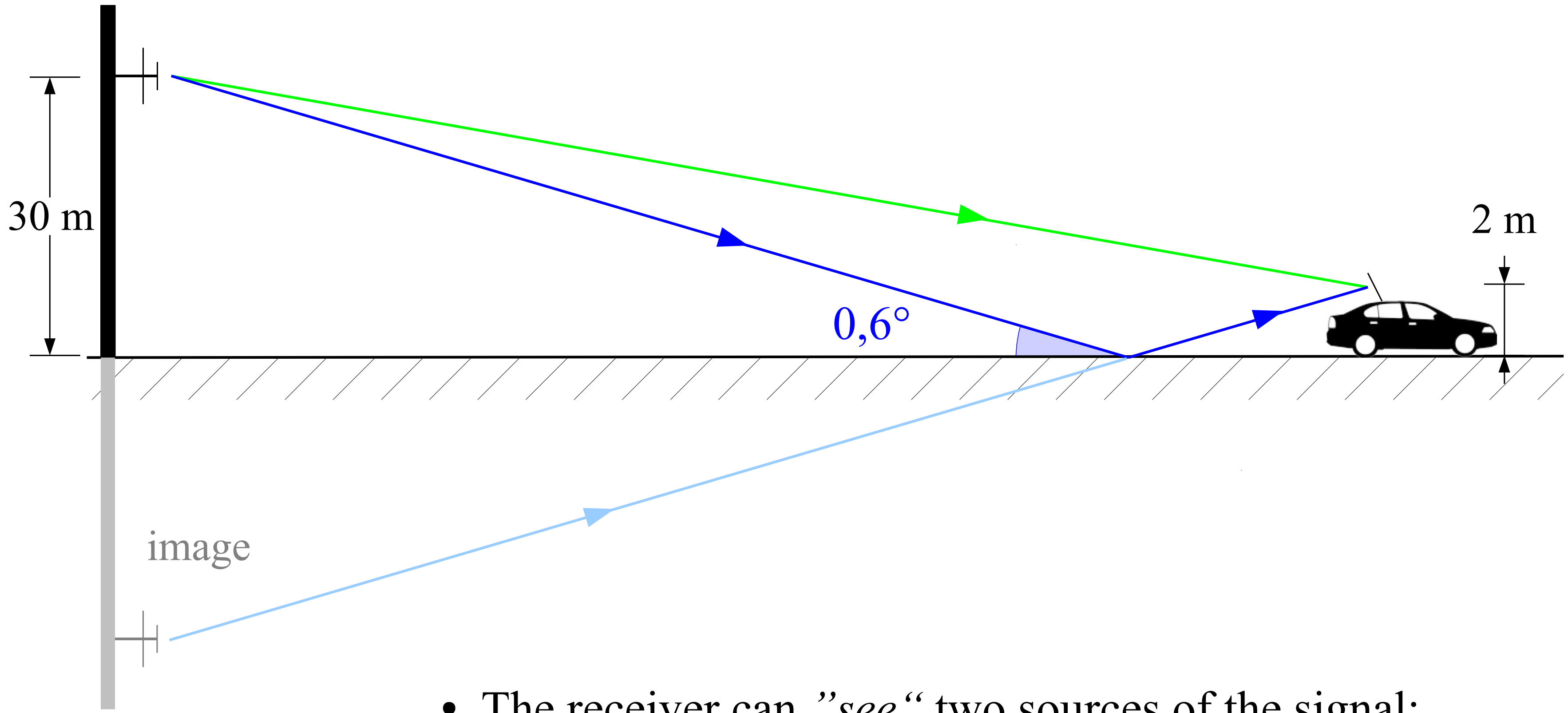
Plane Earth Model



Radio waves travel from TX to RX via the direct path and via the reflected path.

Physical Propagation Models

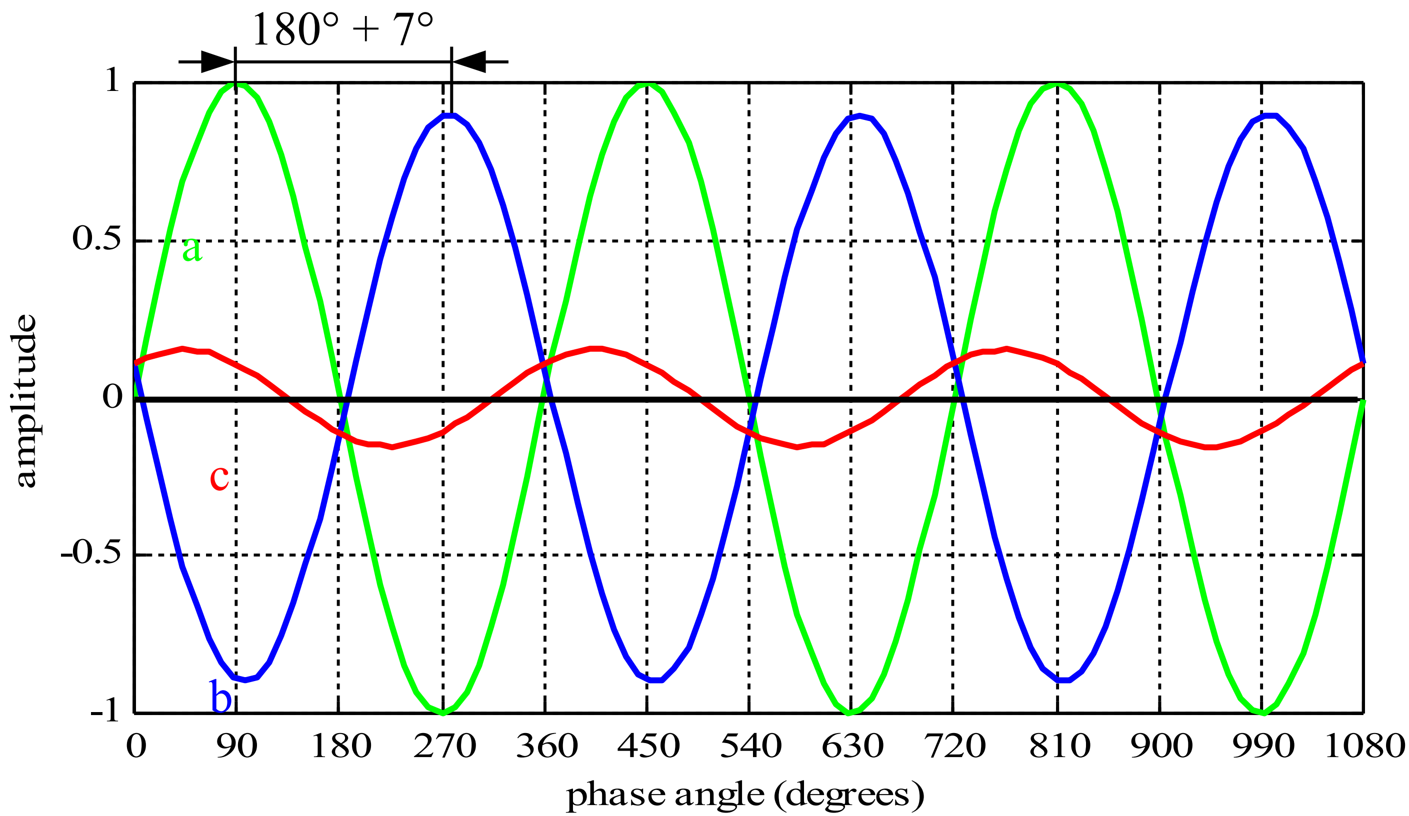
Plane Earth Model



- The receiver can *"see"* two sources of the signal:
  - the real tower and
  - its image on the highly reflective ground.
- Both signals add up at the receiver!

Physical Propagation Models

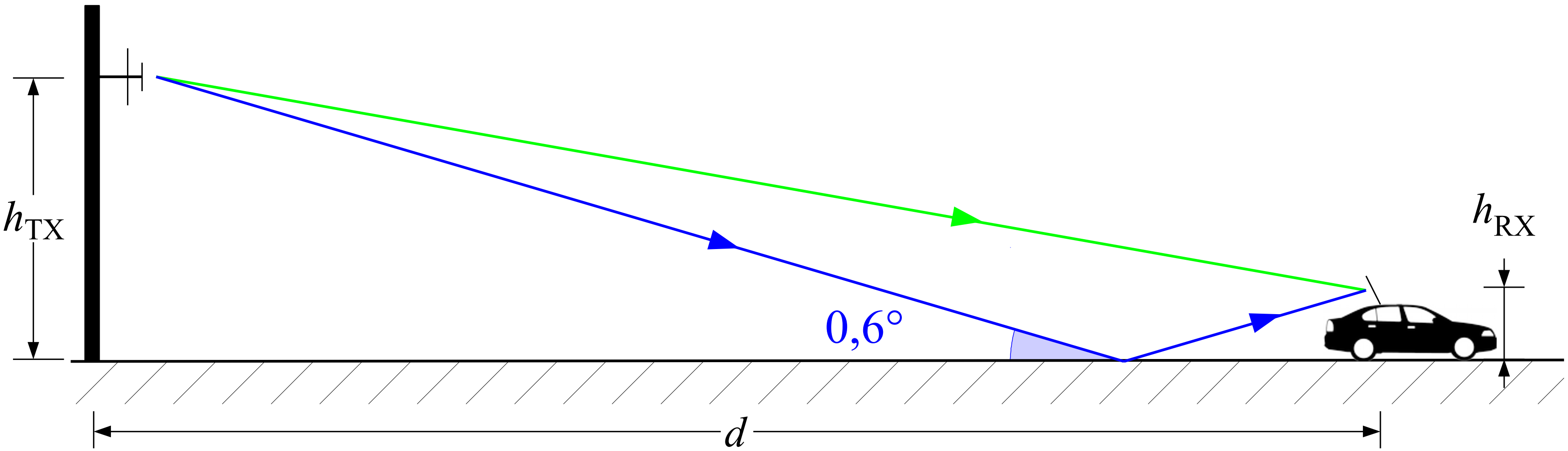
Plane Earth Model



- Reflected signal is phase inverted (180°) to the direct signal!
- Both signals almost cancel entirely.
- Fortunately the reflected signal is delayed due to longer path length, so extinction is not perfect. (Example: 4 cm → 7° at 145 MHz)
- The reflection kills 97.2% or 35/36 of the available receiving power (-16 dB).

Physical Propagation Models

Plane Earth Model



- Signal Power at receiving antenna can be directly calculated by a formula.
- It depends on
  - Distance: Doubling distance reduces signal by factor 16
  - Height: Doubling either antenna height increases signal by factor 4
- Strong restrictions apply for using this model!

VHF/UHF propagation basics

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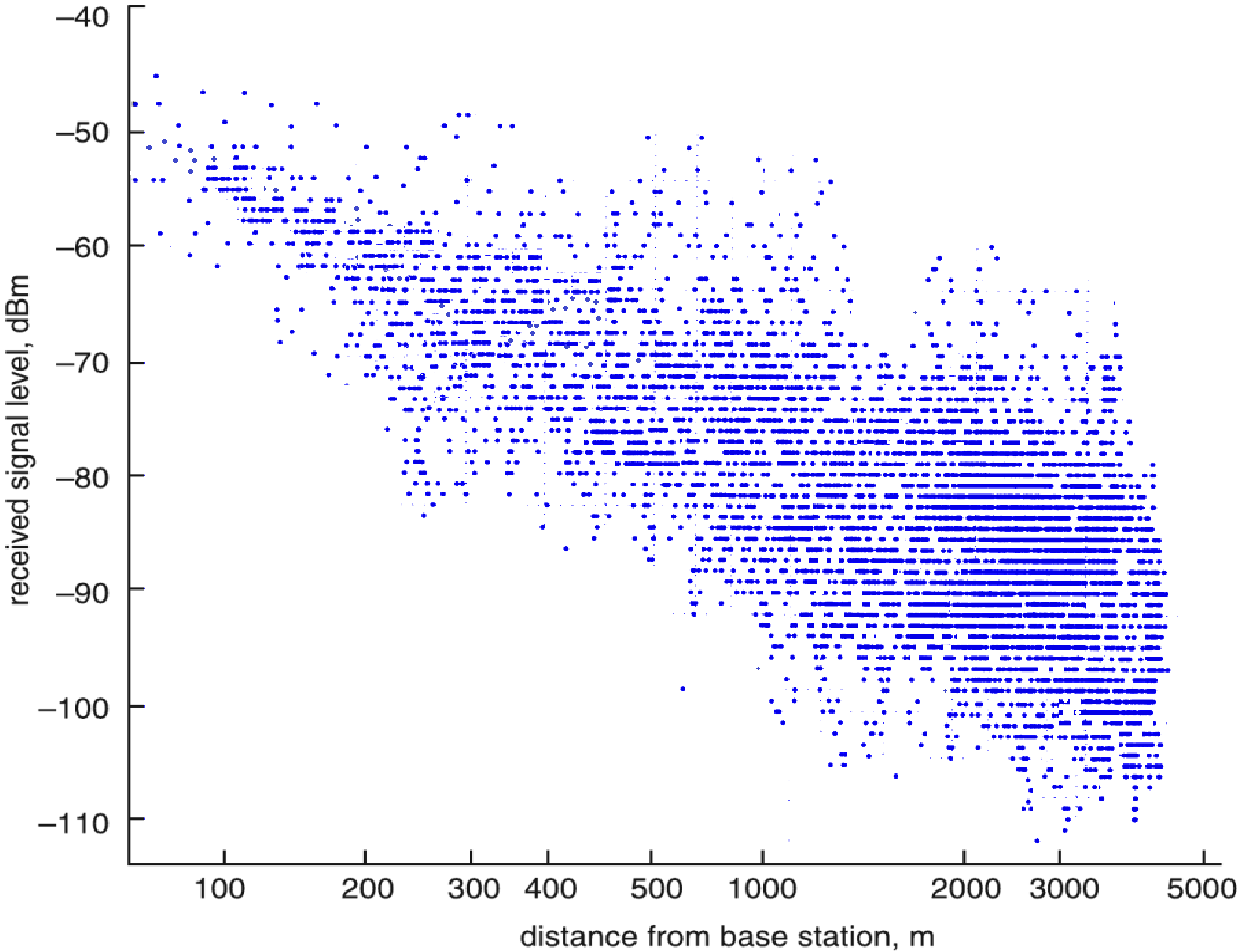
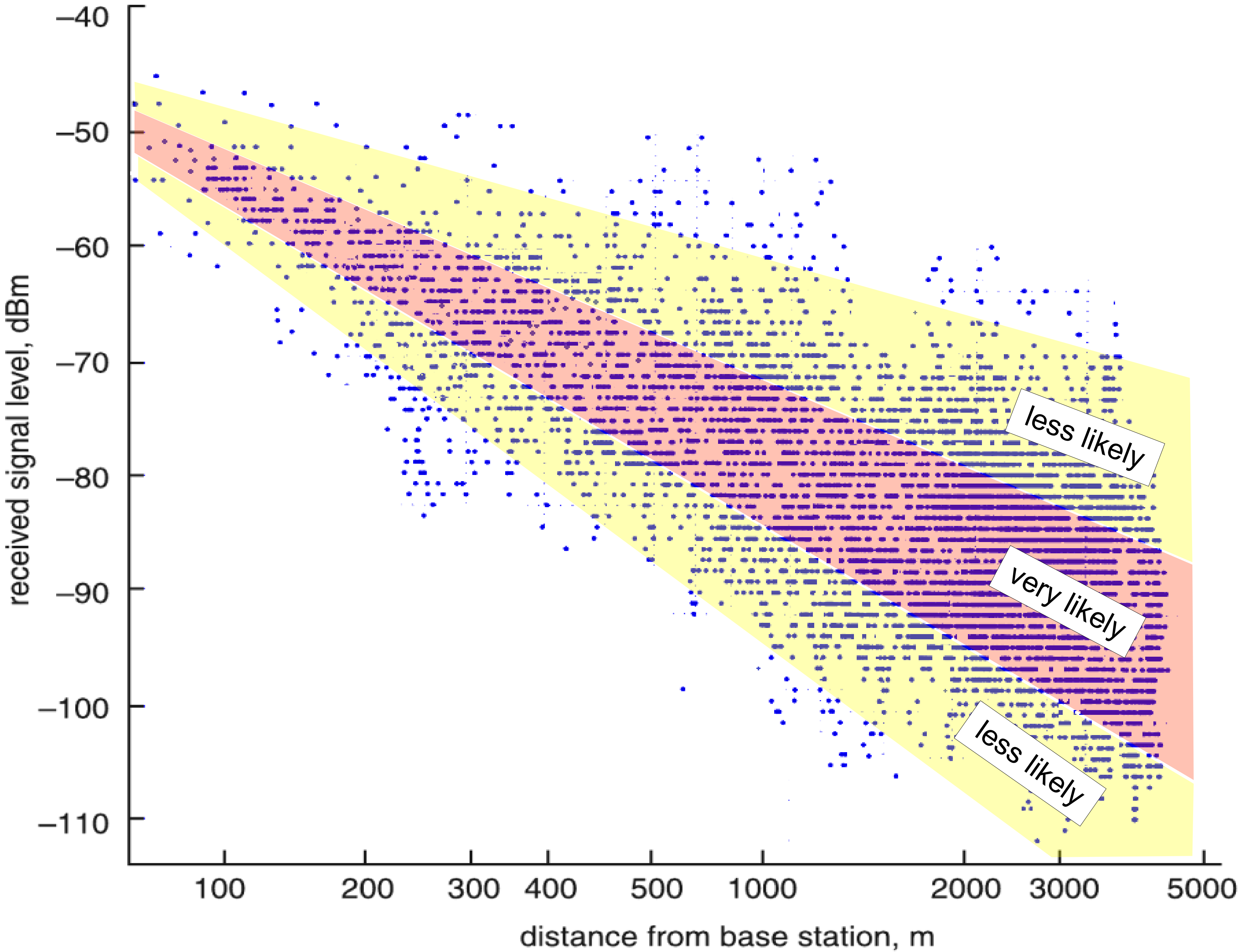
Empirical Propagation Models



The original of this modified diagram was taken from the book:
Les W. Barclay, *Propagation of Radiowaves*, 2002, page 190

Empirical Propagation Models



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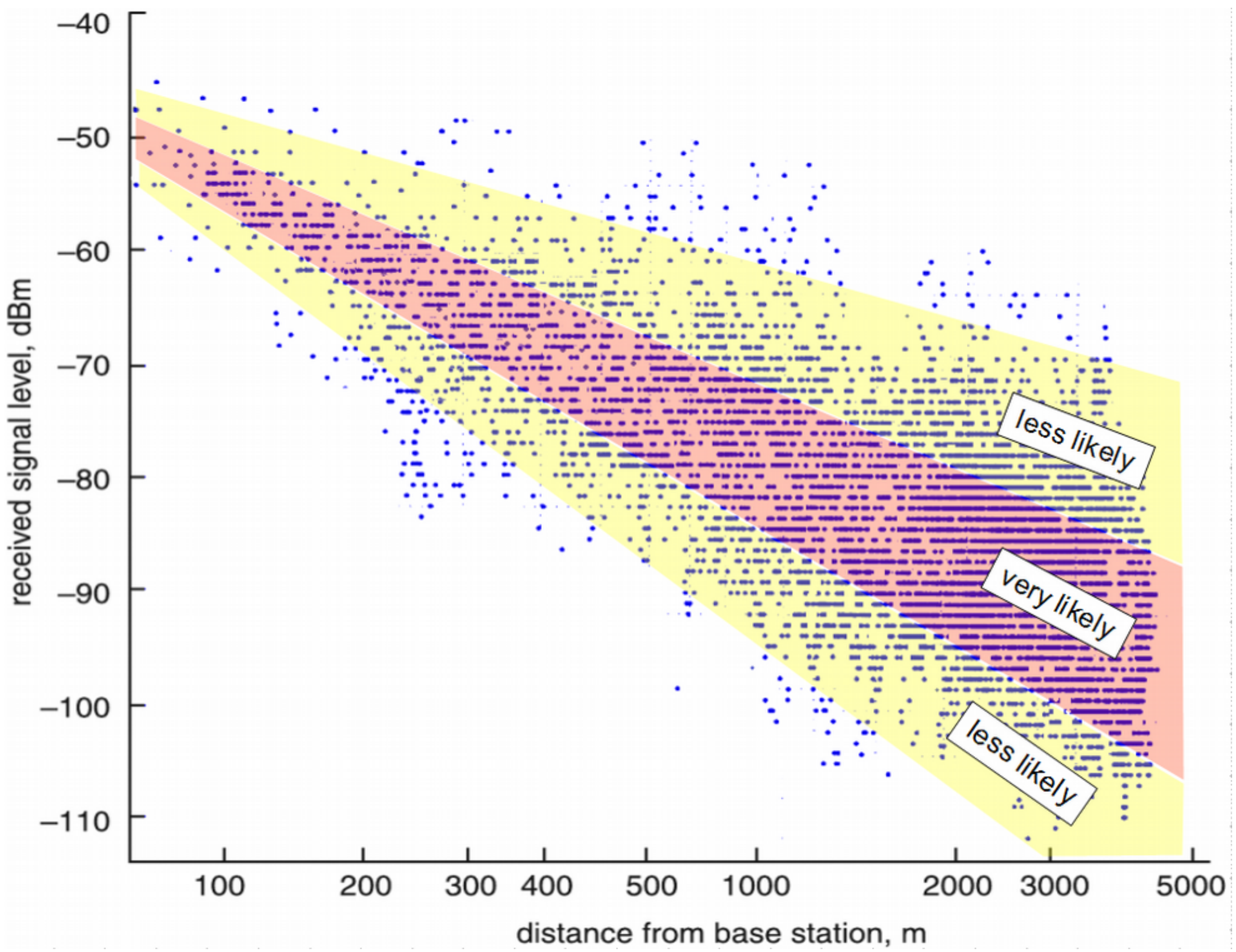
Empirical Propagation Models

Empirical Models...

- are made of real word measurements.
- are designed to better agree with real world scenarios and terrains.
- are restricted to that certain terrain they were developed for.
- cannot produce precise results, they are estimations only.
- their results agree with reality with a certain likelihood.



Empirical Propagation Models

Egli‘s Model

History:

- 1957 John Egli performed measurements in New Jersey, U.S.A.
- He found a correction term for the plane earth model to fit his measurment results.
- The model was used for VHF communication and broadcast planning.
- The model is simple, but comes with limitations:

Limitations:

- Frequency 40 MHz ... 1 GHz
- RX to TX distance 1 km ... 50 km
- Antenna height must be small compared to the RX to TX distance
- Terrain with low vegetation, no obstacles, gently rowling
  with average hill heights of 15m

Empirical Propagation Models

Okumura-Hata Model

History:

- 1957 Dr. Y. Okumura performed measurements in Tokyo, Japan.
- 1980 M. Hata created a formula to fit Okumuras measurements.
- It is known as the Okumura-Hata model since.
- It has been used for planning the first cell phone networks
- Adaptions of this module are still used these days.

Limitations:

- Frequency 150 MHz ... 1.5 GHz
- RX to TX distance 1 km ... 20 km
- Antenna height 30 m ... 200 m for the base station (TX) and
  1 m ... 10 m for the mobile station (RX)
- Four types of terrain availabe: rural, suburban, small city, large city

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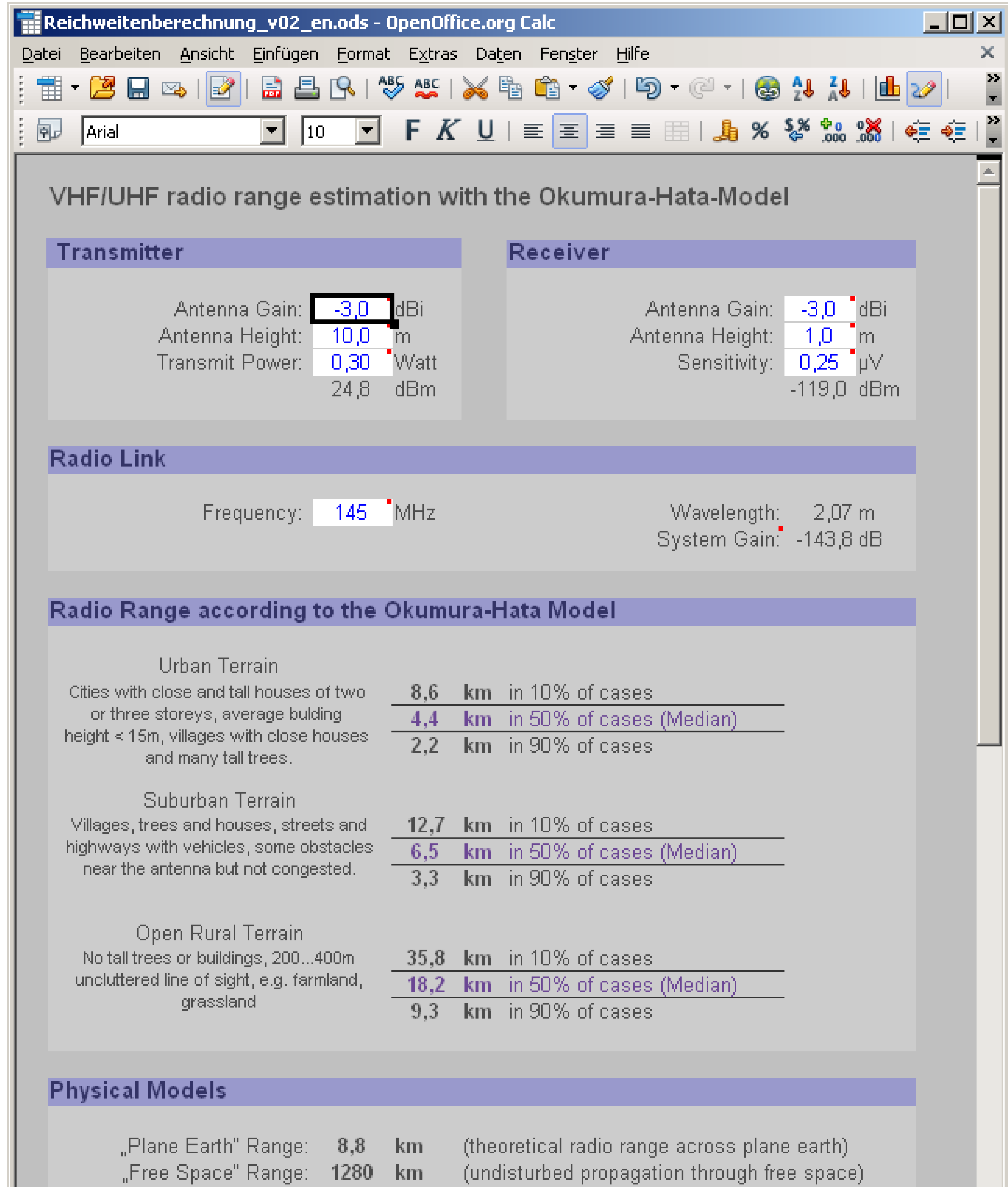
Quick Calculation of Radio Ranges

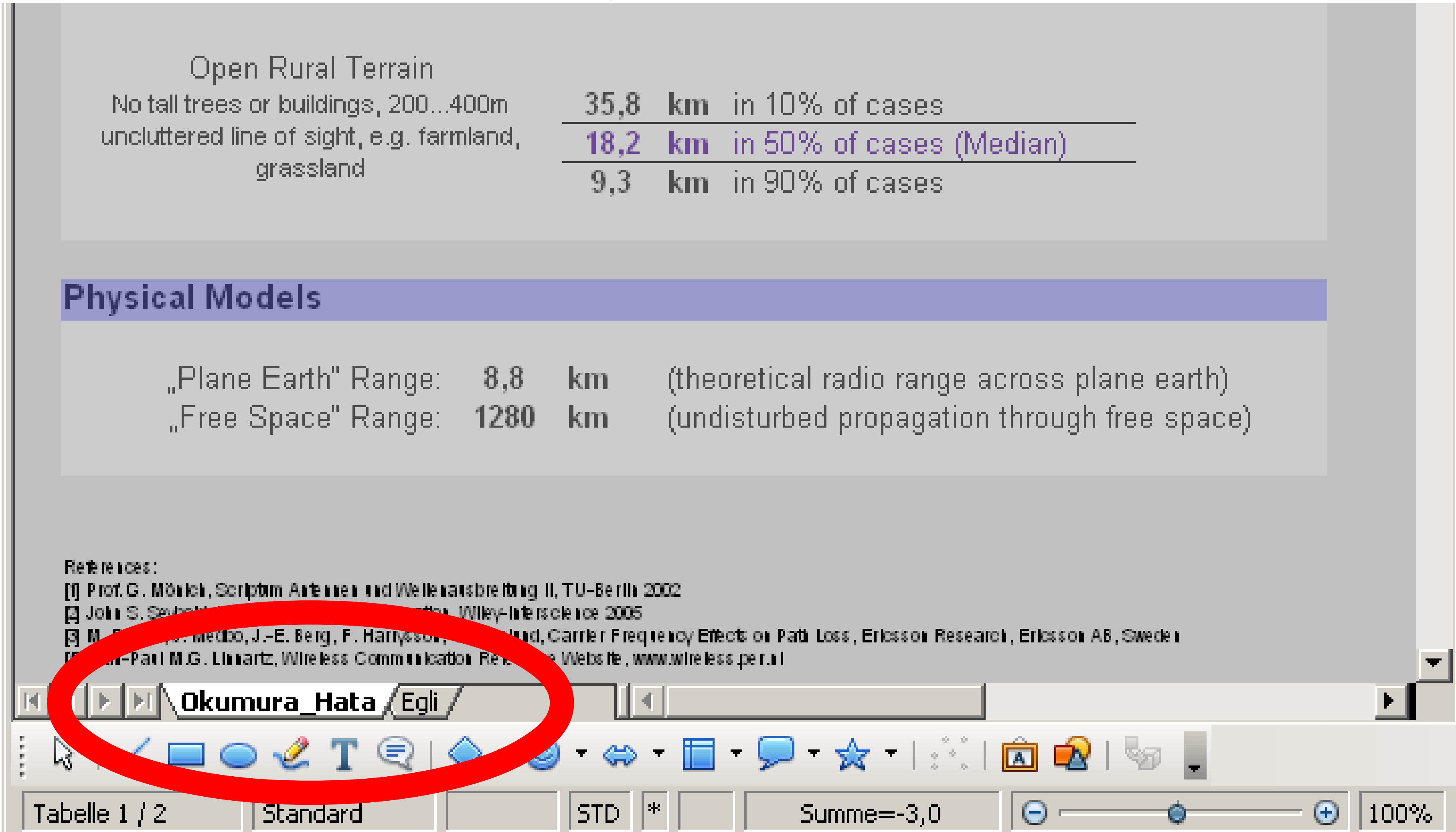
Spreadsheet File

- Spreadsheet file for quick and easy calculation of radio ranges.
- Egli, Okumura-Hata and physical models.
- Available for MS Excel or OpenOffice.
- White fields are input fields.
- Pop-up help texts.



Quick Calculation of Radio Ranges

Spreadsheet File



Remember those tabs to switch between models!

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