Ausbreitung von LoRa und andern Signalen

Andreas Spiess

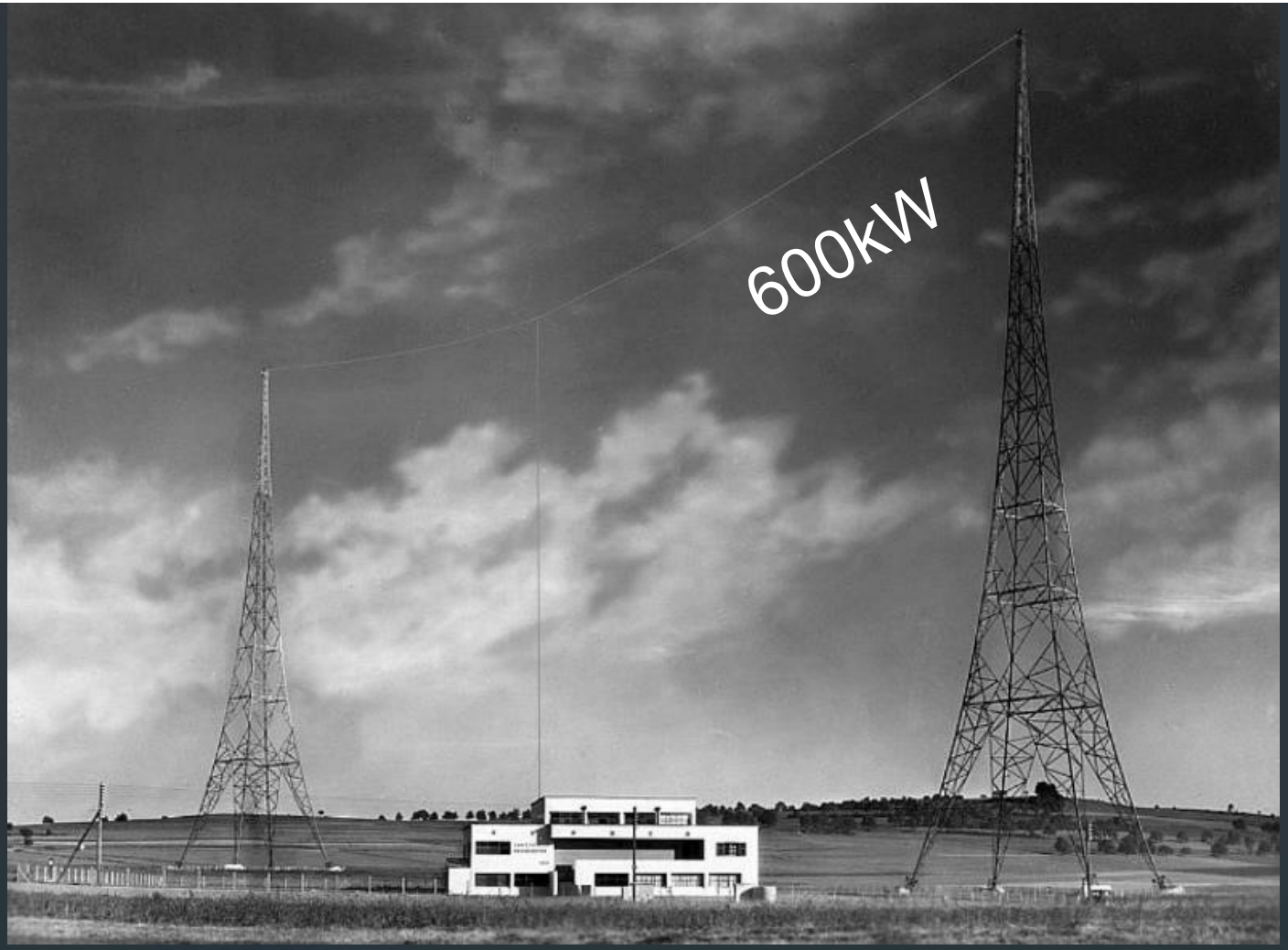
Agenda

- Was ist LoRa?
- Ausbreitung von Radiowellen
- Antennen und Messtechnik
- Ausmessen von mitgebrachten Antennen

LoRa

Long Range, Low Power (mW)

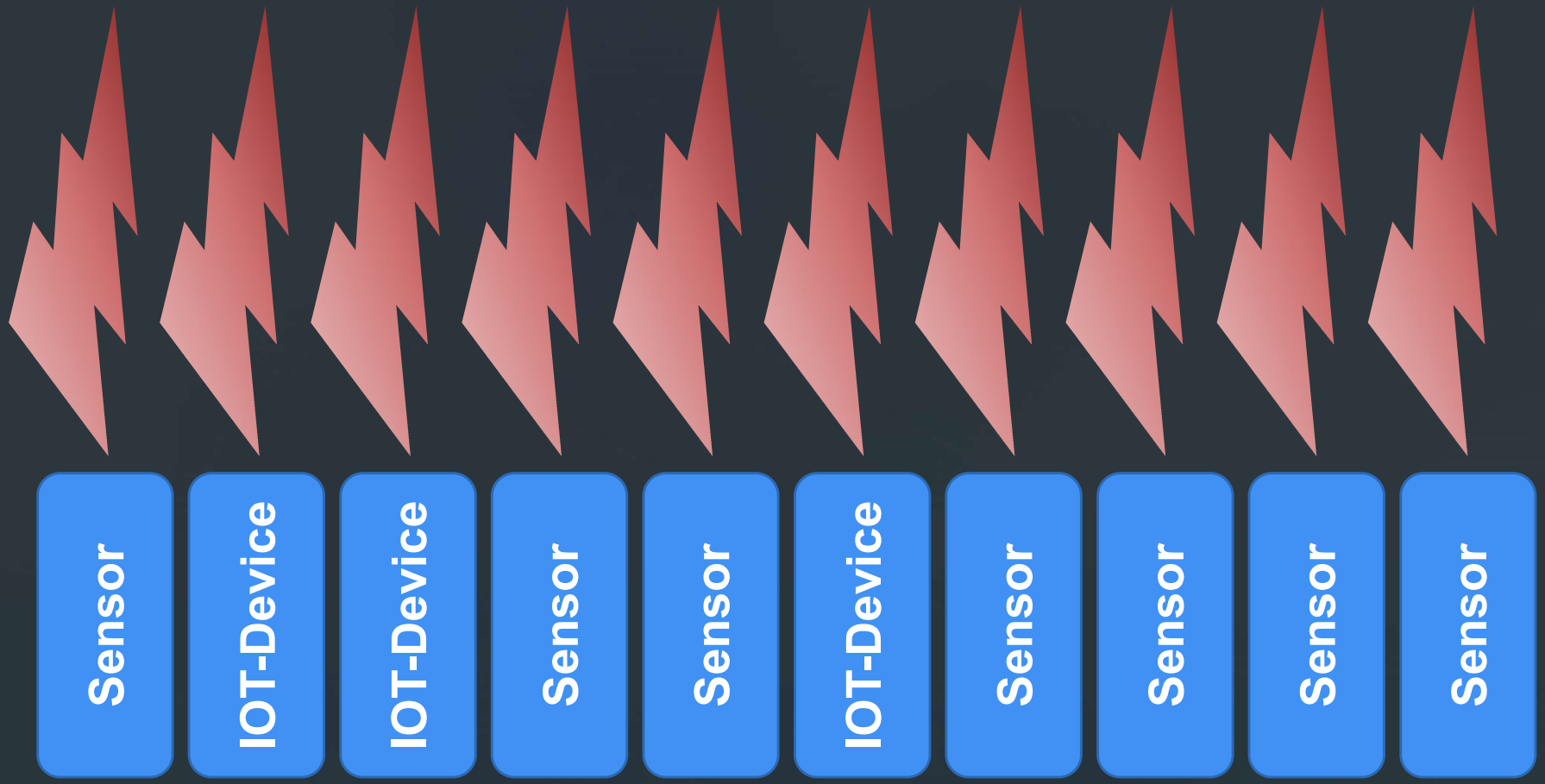
(LPWAN)



http://www.sarganserland-walensee.ch/radio_tv_historisch/AM_Sender/mittelwellensender-beromuenster2.html

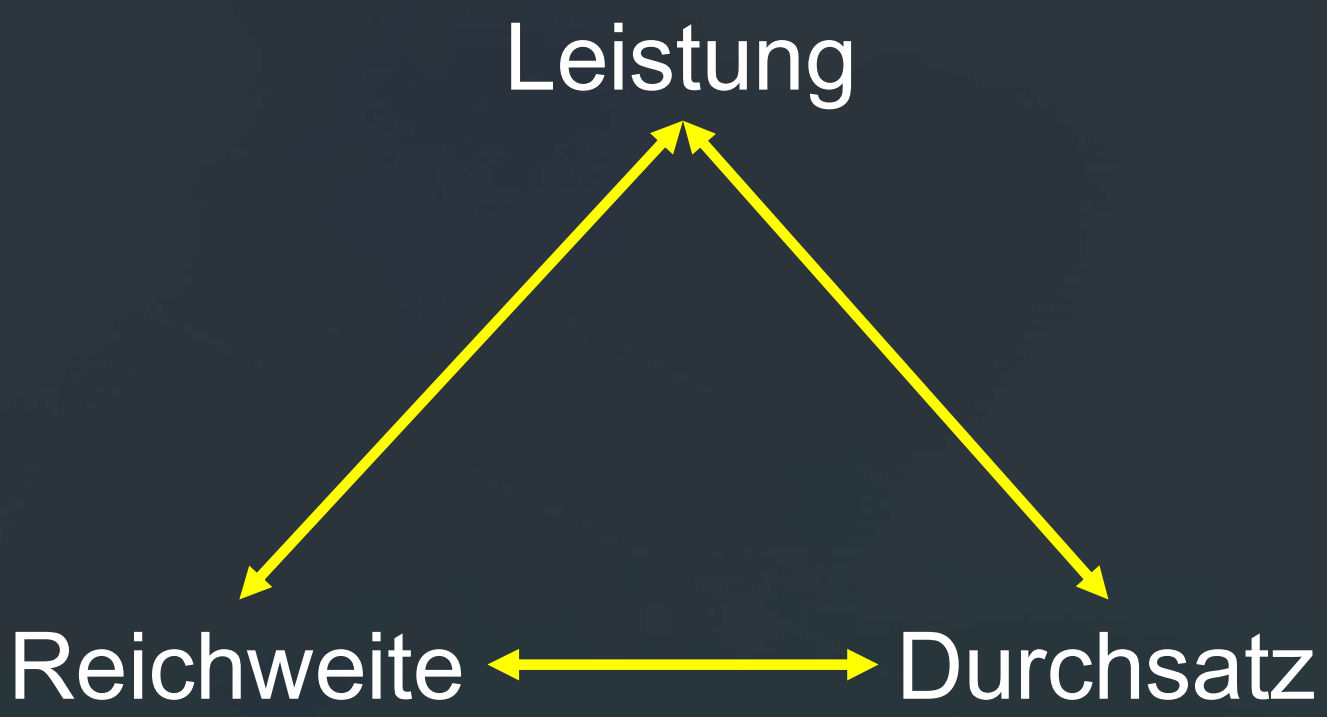
Internet of Things

Standardisiertes Netzwerk (z.B. LoRaWAN)



LoRaWAN Anbieter (CH)

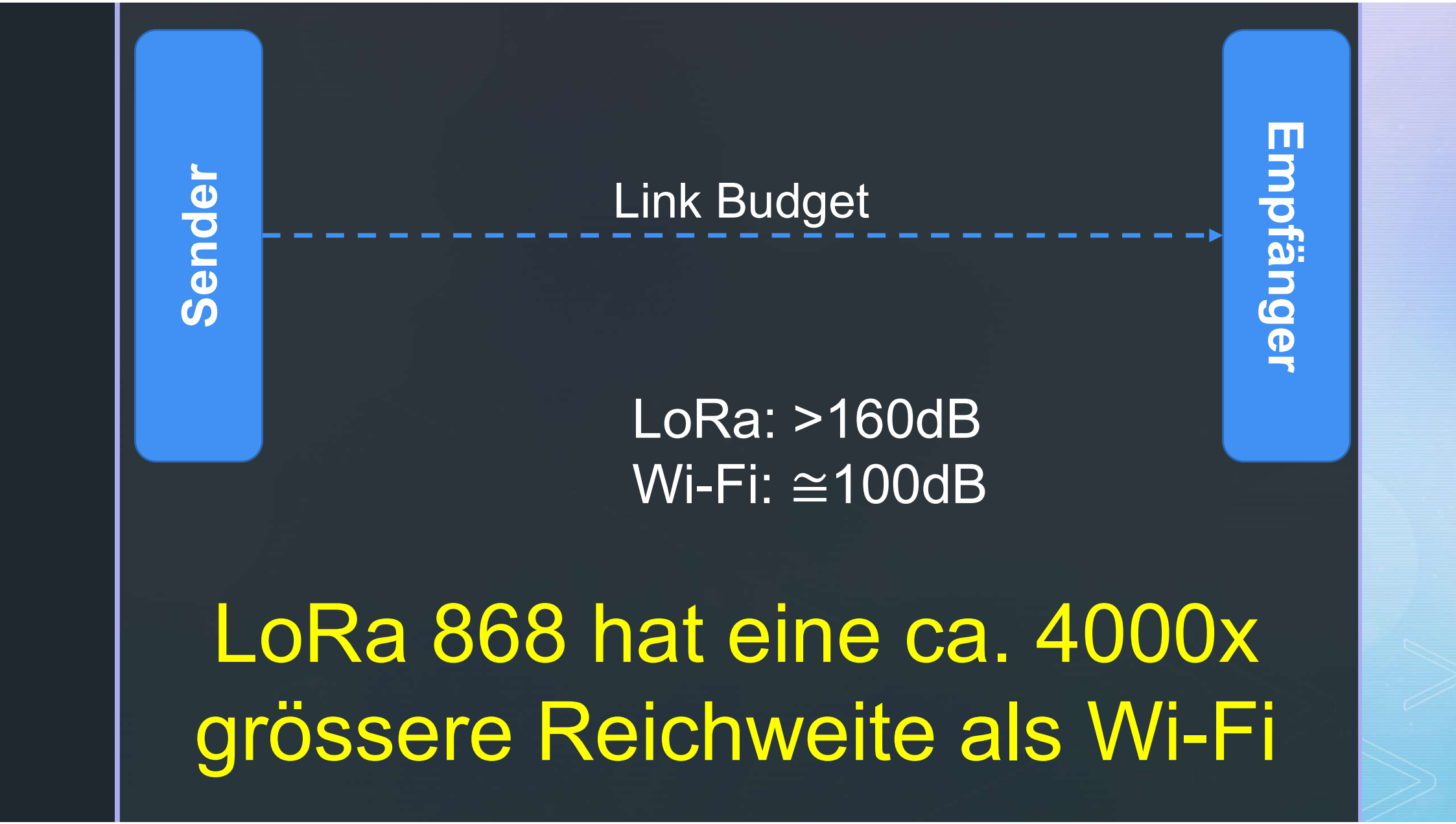
- The Things Network (TTN)
- Helium ($)
- Swisscom ($)


Leistung
Reichweite
Durchsatz

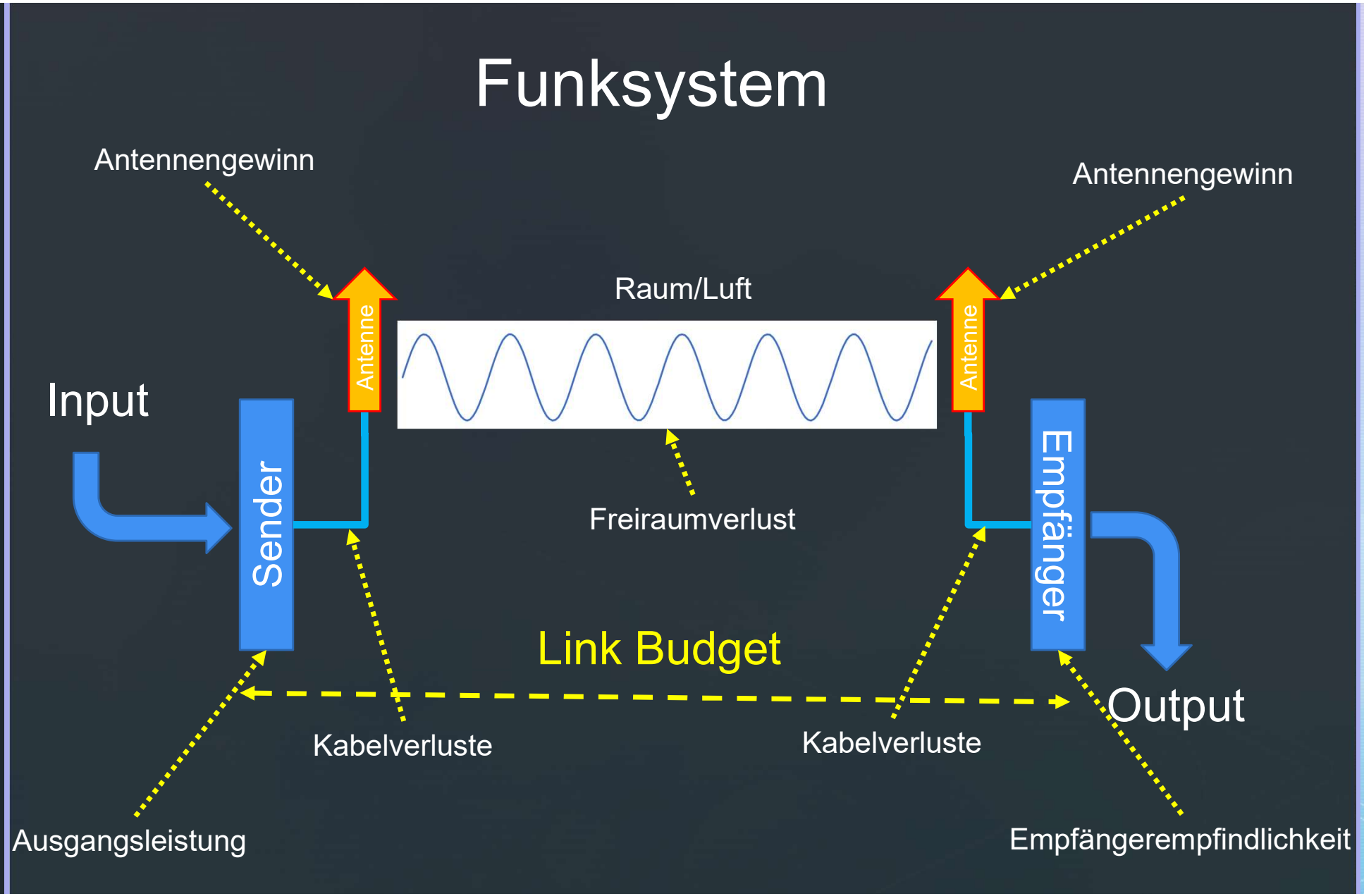

Durchsatz
Wi-Fi
Mobile Internet (2G-5G)
Bluetooth/BLE
LoRa
Reichweite

Vorschriften

- Unlizenzierte Personen dürfen nur fixfertige Geräte brauchen
- Diese dürfen nur in ISM Bändern betrieben werden (433 und 868MHz)
- LoRaWAN läuft im 868MHz Band
- Die Leistung und die Antennen sind sehr beschränkt
- Lizenzierte Amateurfunker (insbesondere HB9er) dürfen mehr


Sender
Link Budget
Empfänger
LoRa: >160dB
Wi-Fi: ≅100dB
LoRa 868 hat eine ca. 4000x grössere Reichweite als Wi-Fi

Funksystem


Antennengewinn
Antennengewinn
Raum/Luft
Antenne
Antenne
Input
Sender
Empfänger
Freiraumverlust
Link Budget
Output
Kabelverluste
Kabelverluste
Ausgangsleistung
Empfängerempfindlichkeit

Freiraumdämpfung

6dB bei Verdoppelung der Distanz

6dB bei Verdoppelung der Frequenz

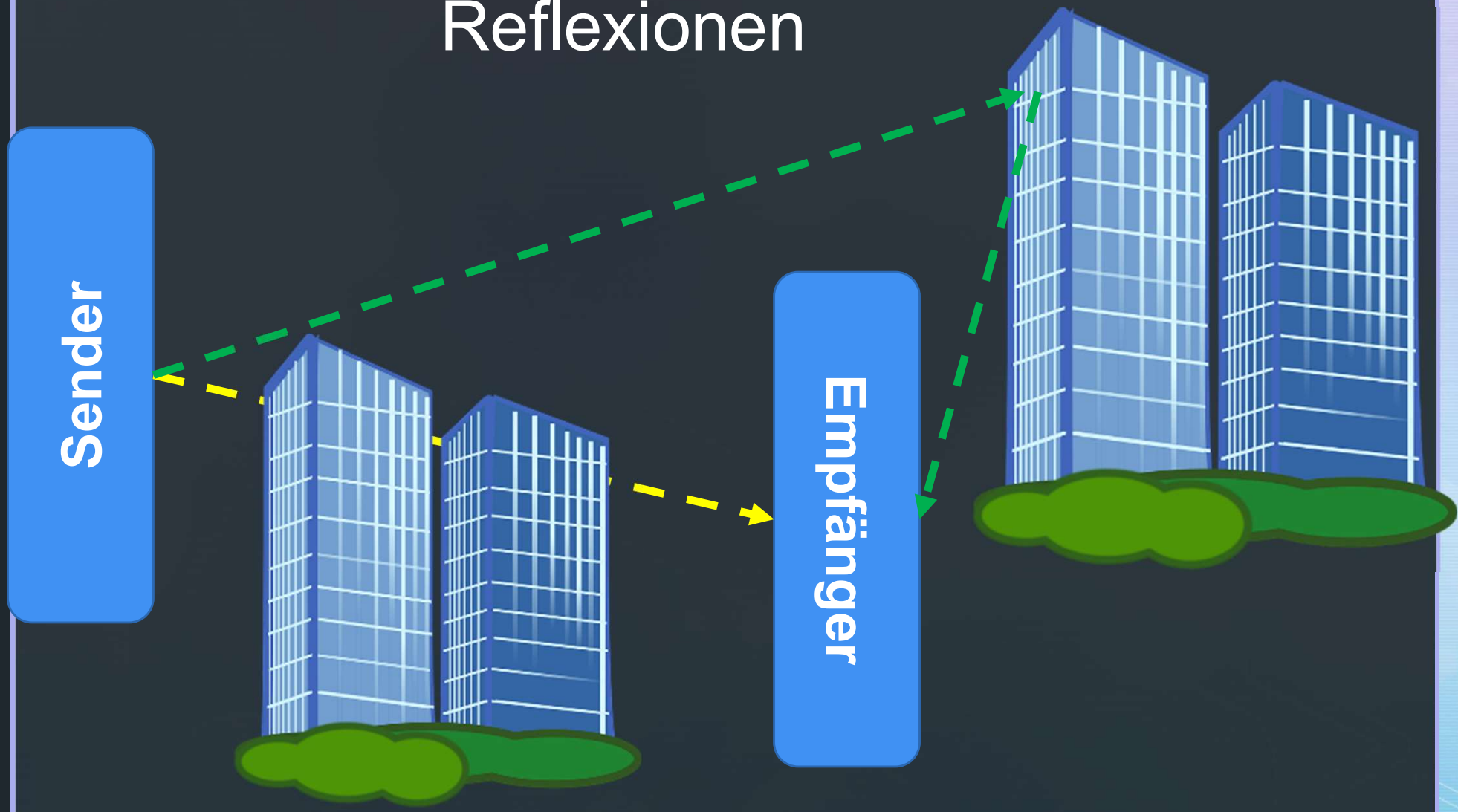
Sender
Empfänger

Verluste nach Material

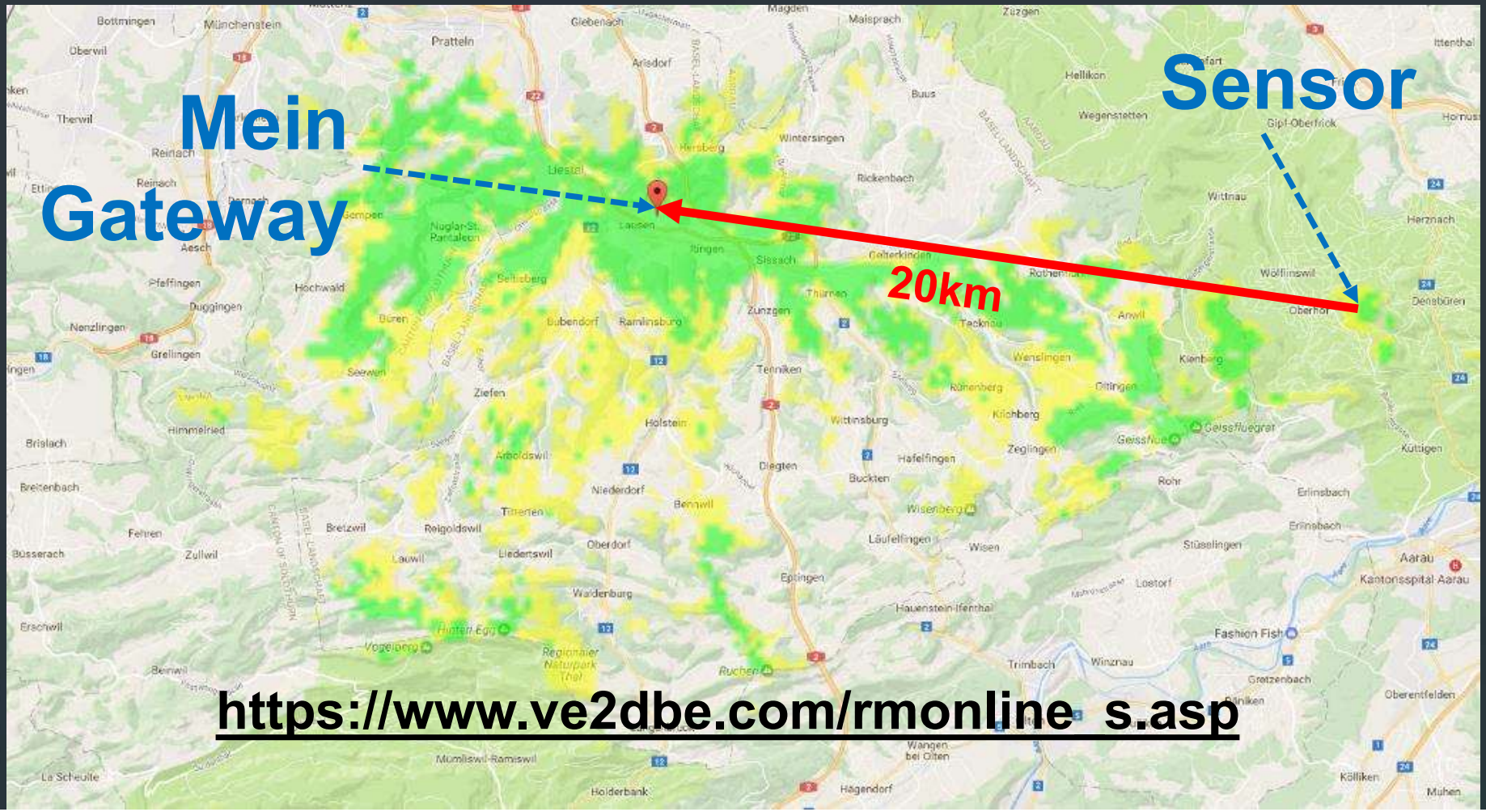
Material	Attenuation @ 900 MHz
Glass 0.25" (6 mm)	0.8 dB
Glass 0.5" (13 mm)	2 dB
Lumber 3" (76 mm)	2.8 dB
Brick 3.5" (89 mm)	3.5 dB
Brick 7" (178 mm)	5 dB
Brick 10.5" (267 mm)	7 dB
Concrete 4" (102 mm)	12 dB
Masonry Block 8" (203 mm)	12 dB
Brick faced concrete 7.5 " (192 mm)	14 dB
Masonry Block 16" (406 mm)	17 dB
Concrete 8" (203 mm)	23 dB
Reinforced Concrete 3.5" (203 mm)	27 dB
Masonry Block 24" (610 mm)	28 dB
Concrete 12" (305 mm)	35 dB

https://securitytoday.com/articles/2012/04/01/indoor-wireless-path-loss.aspx

Reflexionen



Ausbreitung



Gateway

Weissenstein

World Record Attempt:

LoRa™

Longest Distance

#120 LoRa / LoRaWAN Range World Record Attempt. Will I succeed?

215,742 views • Feb 16, 2017

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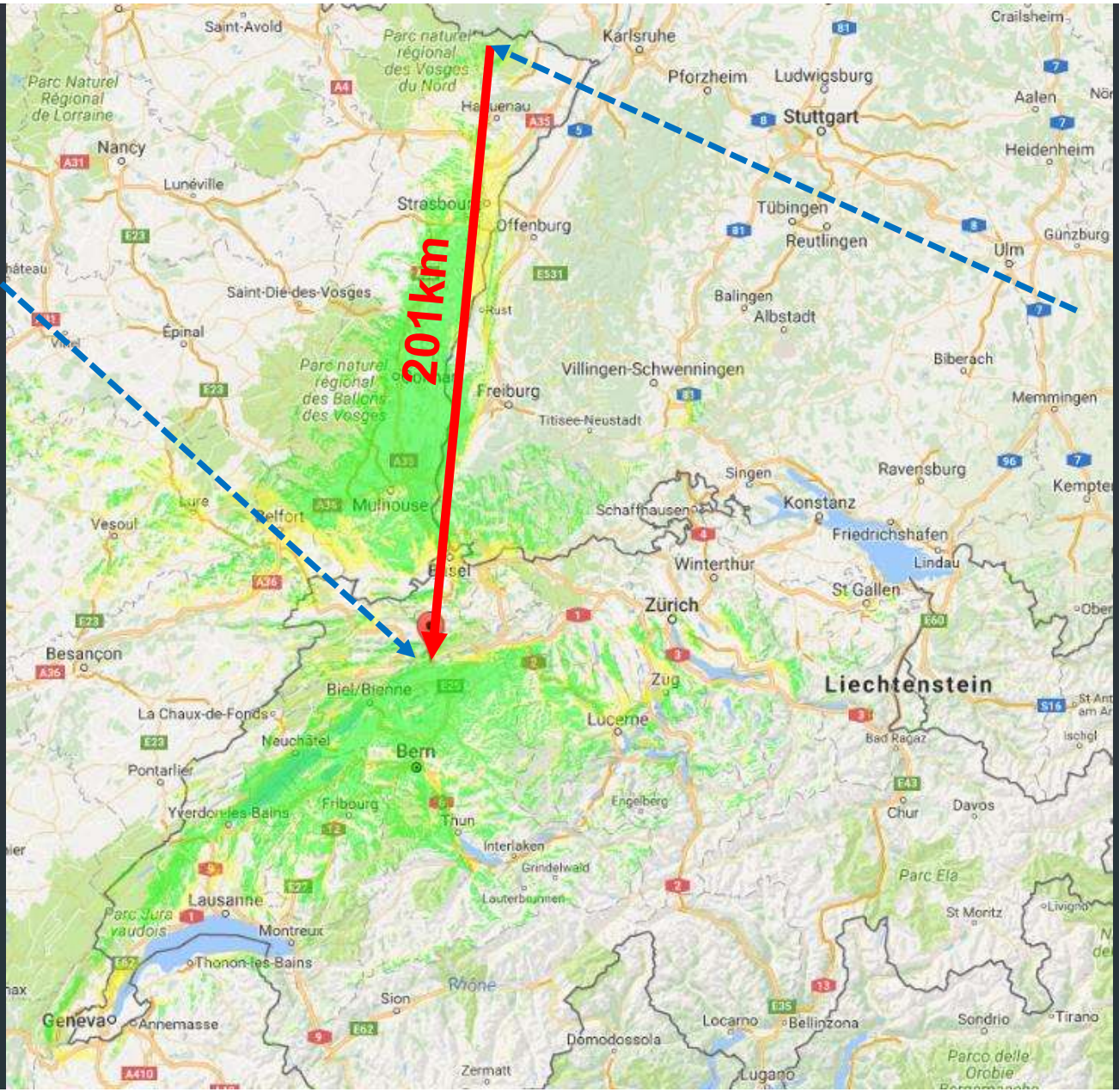
All Antennas Consumer Electronics

LoRa Field Strength

Gateway



Sensor

Fresnel Zone

201 km

Hindernisse

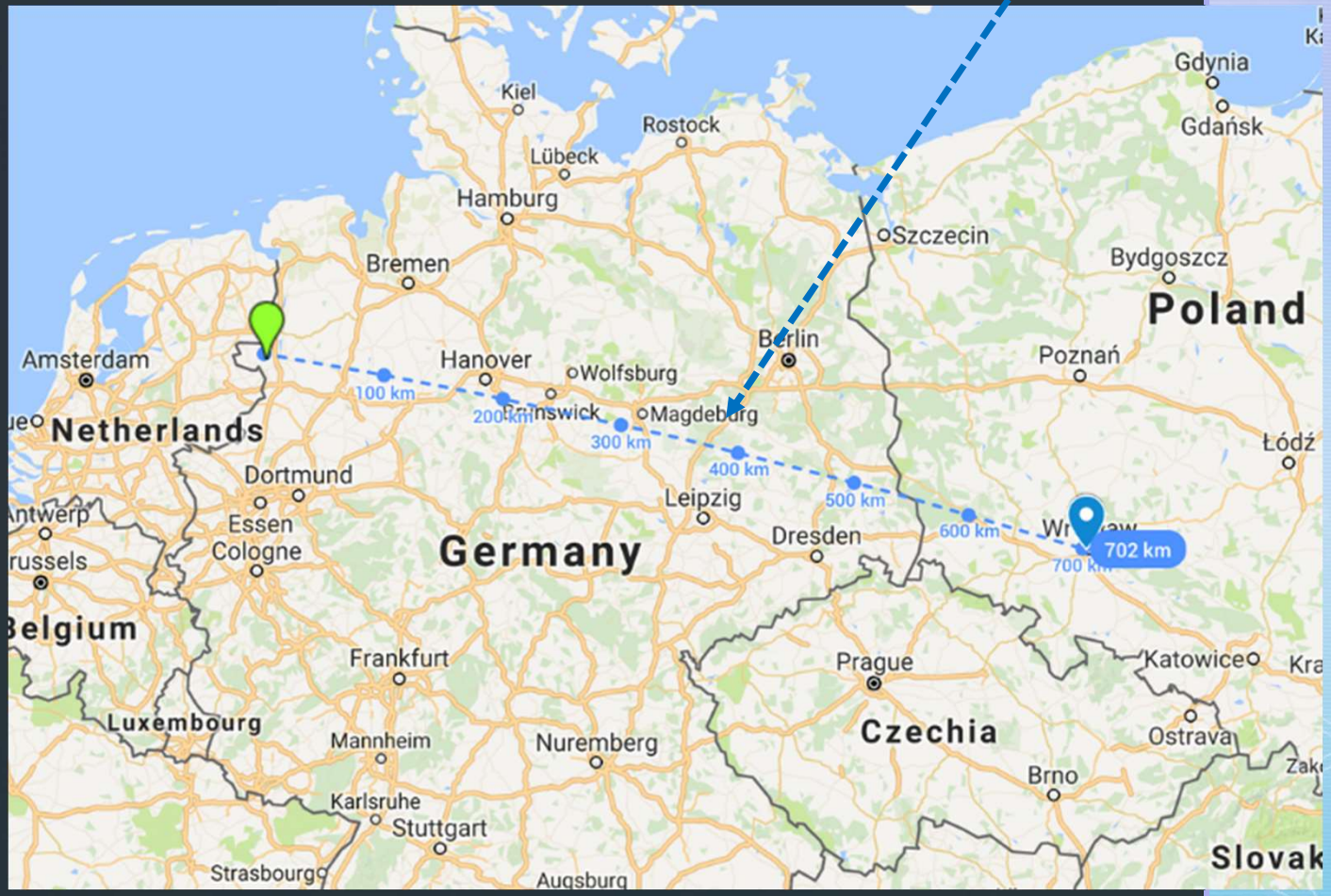
Weissenstein - Hohenbourg****

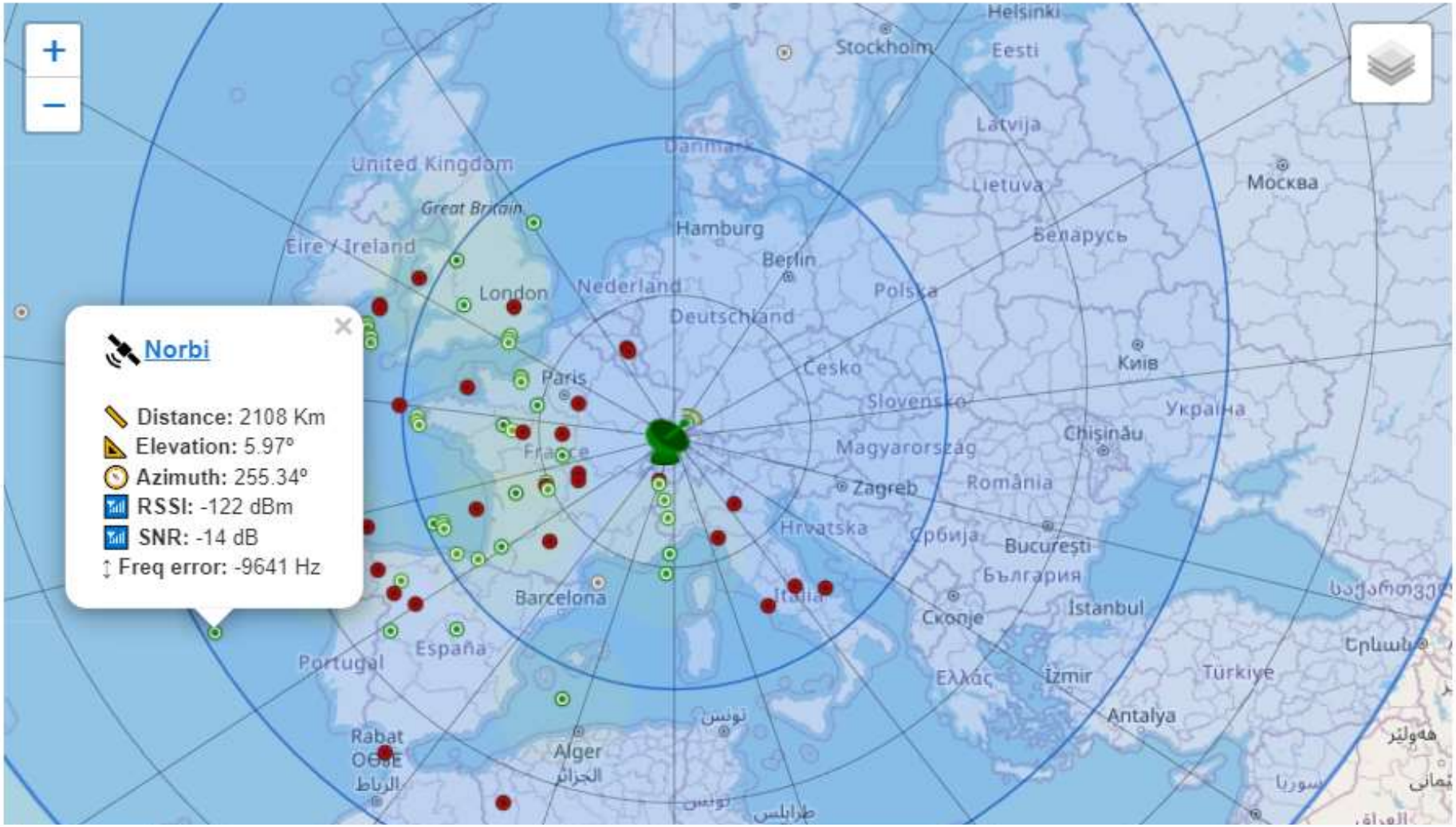
Weissenstein (1)		(2) Hohenbourg	
Latitude	47.253019 °	Latitude	49.055329 °
Longitude	7.510529 °	Longitude	7.783856 °
Ground elevation	1273.7 m	Ground elevation	542.7 m
Antenna height	2.0 m	Antenna height	2.0 m
Azimuth	5.68 TN | 3.87 MG °	Azimuth	185.88 TN | 184.02 MG °
Tilt	-1.11 °	Tilt	-0.70 °

Radio system		Propagation	
TX power	20.00 dBm	Free space loss	137.59 dB
TX line loss	0.00 dB	Obstruction loss	13.17 dB
TX antenna gain	6.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	0.50 dB	Statistical loss	
RX sensitivity	-113.02 dBm	Total path loss	157.00 dB

Performance	
Distance	201.430 km
Precision	100.8 m

Balloons

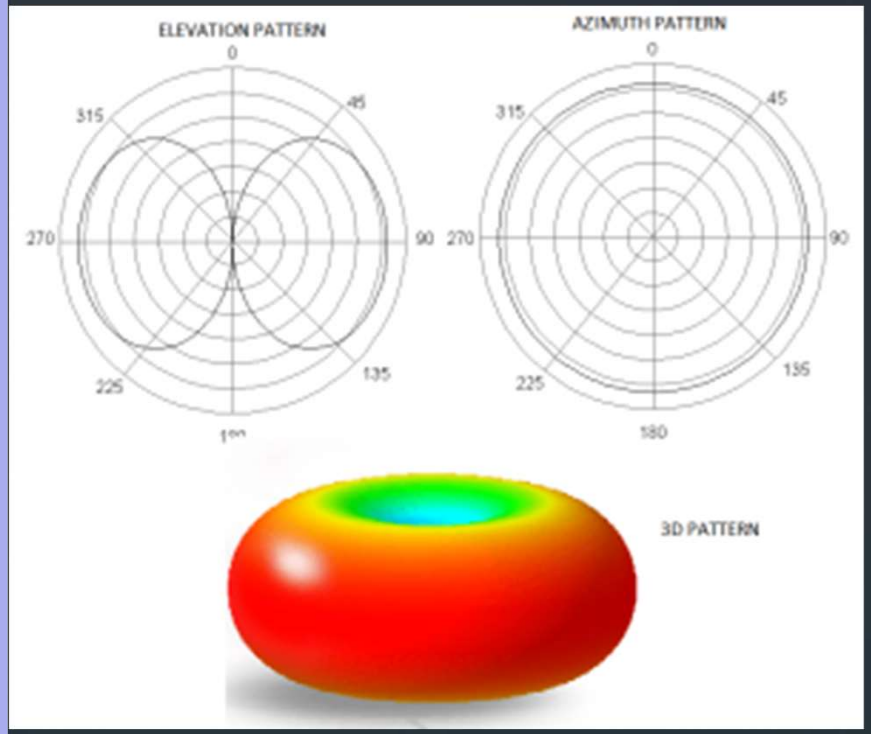

702km
Kiel
Rostock
Lübeck
Hamburg
Bremen
Amsterdam
Hanover
Wolfsburg
Braunschweig
Magdeburg
Berlin
Gdynia
Gdańsk
Szczecin
Bydgoszcz
Poland
Poznań
Łódź
Netherlands
Dortmund
Essen
Cologne
Leipzig
Dresden
Germany
Belgium
Frankfurt
Luxembourg
Mannheim
Nuremberg
Prague
Czechia
Katowice
Ostrava
Brno
Karlsruhe
Stuttgart
Strasbourg
Augsburg
100 km
200 km
300 km
400 km
500 km
600 km
700 km
702 km



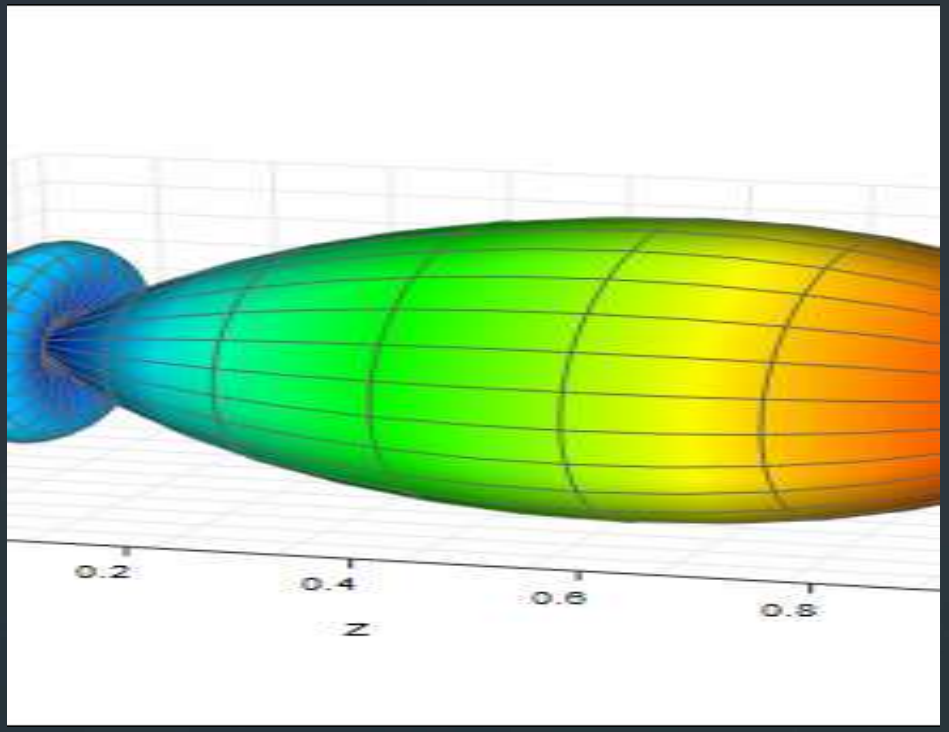
Norby	Mode	Power	Distance	Elevation	RSSI	SNR	Predicted Doppler	Frequency Error
Sep 6, 2022 4:15 PM (a month ago)	LoRa@436.703	2000mW	2108Km	5.97°	-122 dBm	-14 dB	3077.57Hz	-9640.61Hz

Antennen

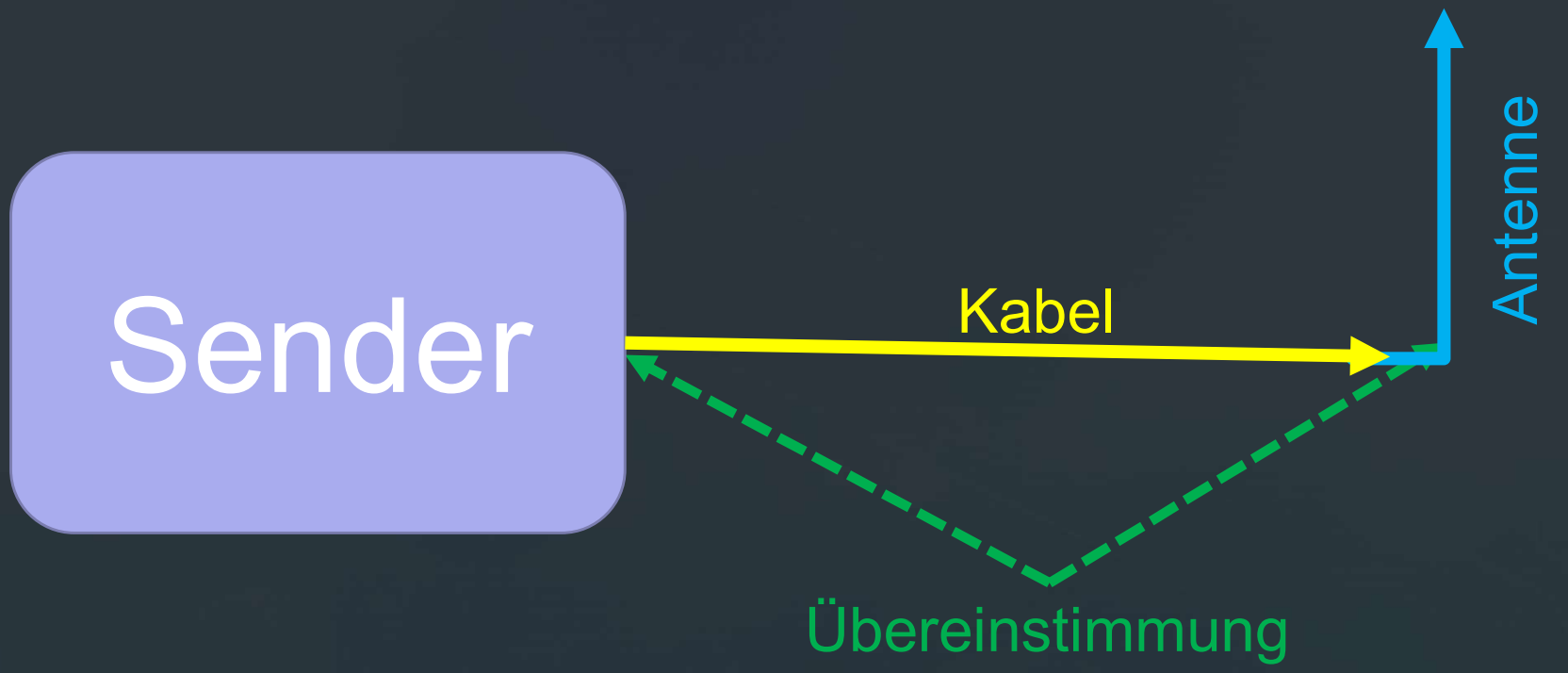
Dipol



Richtantenne



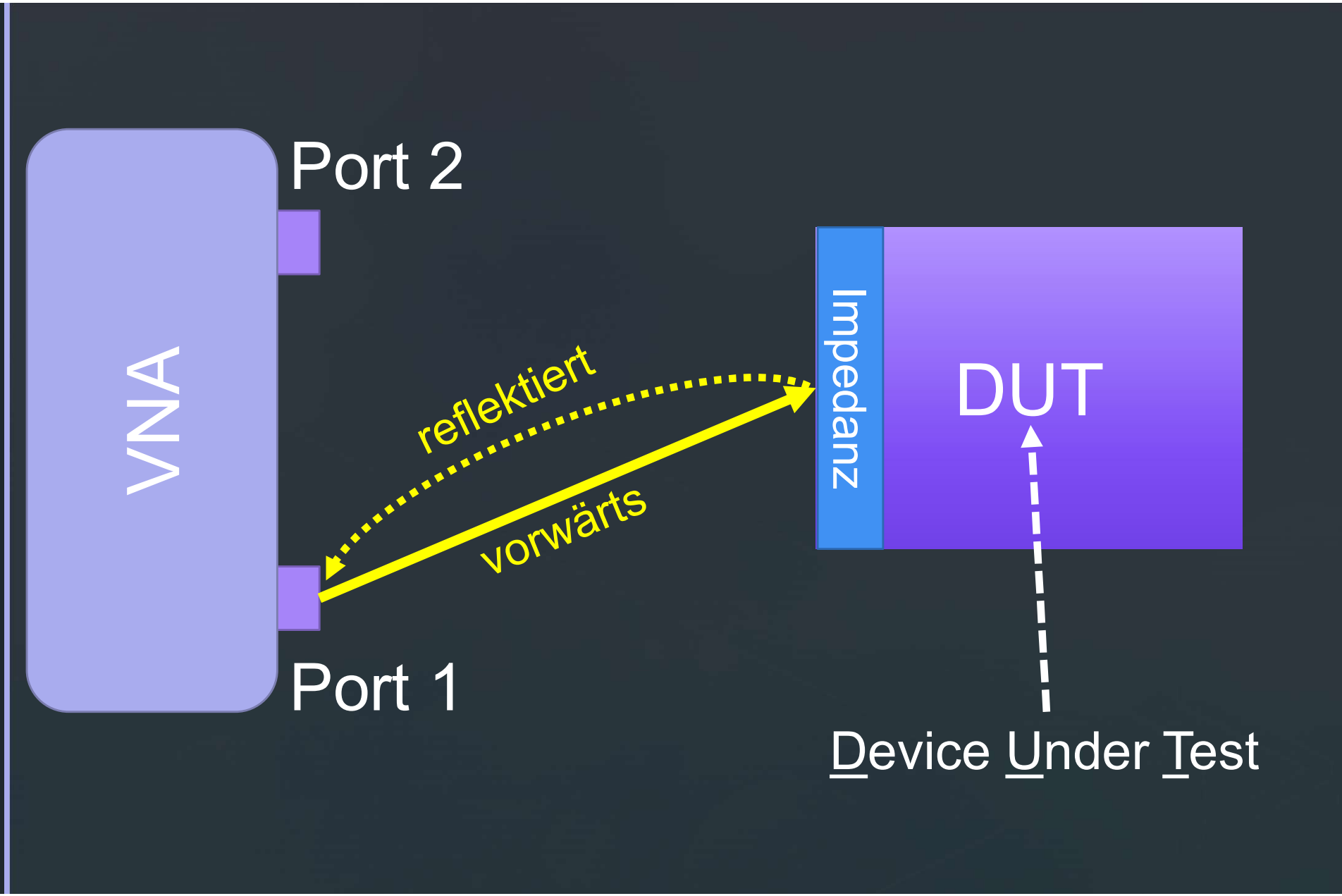
Was hat es auf sich mit den 50 Ω?



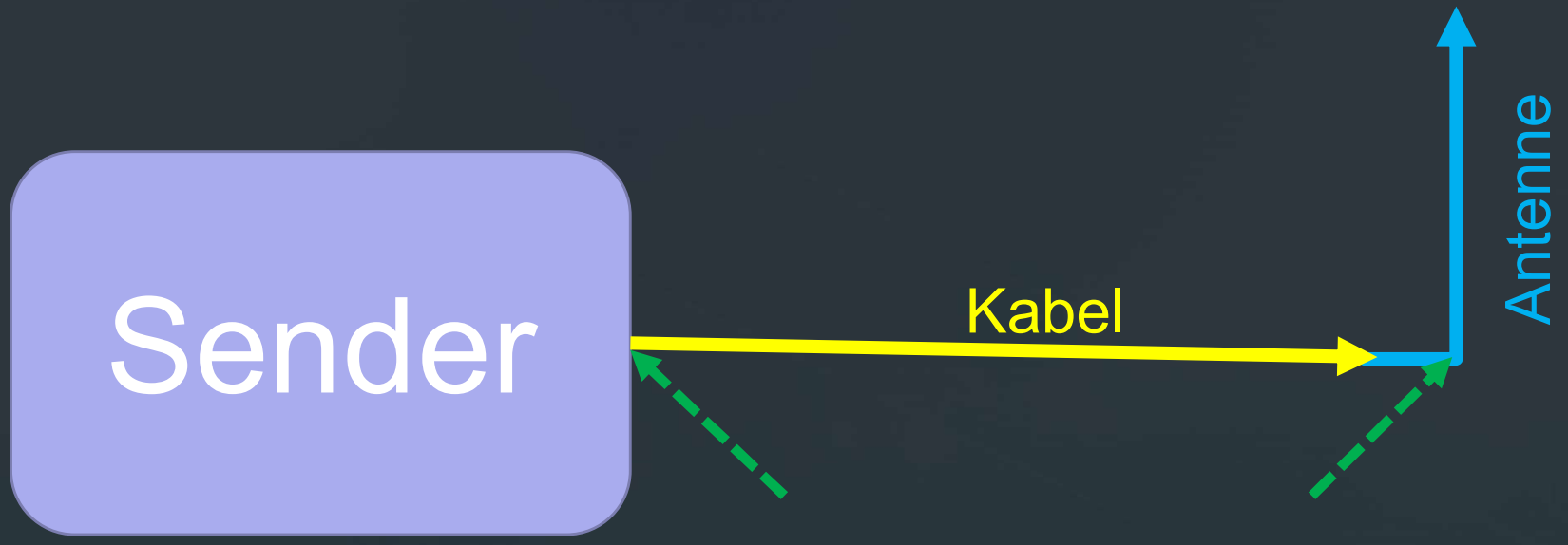
VSWR oder **SWR** Meter

https://www.circuitstoday.com/working-of-standing-wave-ratio-swr-meters

Vector Network Analyzer


Port 2
VNA
reflektiert
vorwärts
Impedanz
DUT
Port 1
Device Under Test

Wo misst man?



Kalibrieren nicht vergessen!

#359 How to properly use a NanoVNA V2 Vector Network Analyzer & Smith Chart (Tutorial)

260,919 views • Nov 1, 2020

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All Oscilloscopes Antennas Listenable

NanoVNA-F - Kalibrieren ganz

Vielen Dank für die Aufmerksamkeit

Eure Antennen ausmessen