Tegola Tiered Mesh Network Testbed in Rural Scotland

Giacomo Bernardi
g.bernardi@sms.ed.ac.uk

Peter Buneman
opb@inf.ed.ac.uk

Mahesh K. Marina
mmarina@inf.ed.ac.uk

School of Informatics
The University of Edinburgh, UK

Talking Points:

- What is the goal of this paper?
- What is special about the "Tegola Testbed" compared to other work?
- What is the influence of the tidal level to the signal strength?
- What is a possible solution that the authors propose for the varying signal strength?

Communication in Distributed Systems

5 WiLD - Hardware and Link Budget

Dr.-Ing. Michael Rademacher

2021-05-04

Hardware

Hardware for WiLD

Important hardware for WiLD:

1. Embedded boards and enclosures
2. IEEE802.11 transmitter (WiFi cards)
3. High-frequency cables
4. Antennas and masts

Embedded boards and enclosures

- Normal routers are **not** suitable for outdoor environments
- Special embedded boards and enclosures
  - Outdoor usage (IP64 - IP67)
  - External antenna connectors
  - Concept for power supply: Power over Ethernet or Solar

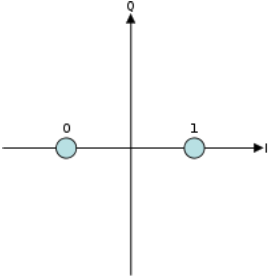
IEEE802.11 transmitter (WiFi cards)

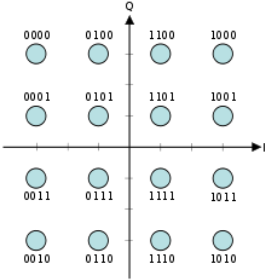
- The most important parameters are:
  - Transmission Power P_{TX}
  - Sensitivity $RXLevel_{min}$
- **The more complex the modulation...**

- ...the less the max. P_{TX}
- ... **the higher** $RXLevel_{min}$

Example values:

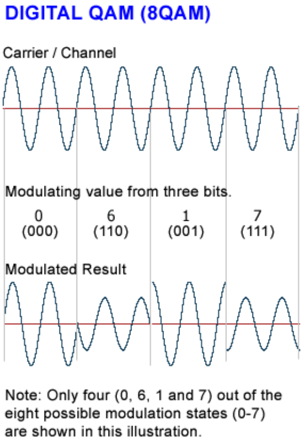
	Phy-Rate	MCS	P_{TX}	$RXLevel_{min}$
802.11a	6 Mbps	BPSK - 1/2	28 dBm	-96 dBm
	54 Mbps	64QAM - 3/4	28 dBm	-81 dBm
802.11n	7.2 Mbps	BPSK - 1/2	28 dBm	-96 dBm
	72.2 Mbps	64QAM - 5/6	27 dBm	-77 dBm
802.11ac	7.2 Mbps	BPSK - 1/2	28 dBm	-96 dBm
	86.7 Mbps	256QAM - 3/4	24 dBm	-72 dBm



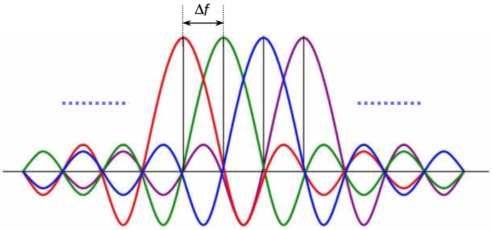


IEEE802.11 physical layer

- **Orthogonal frequency-division multiplexing (OFDM)**
  - 802.11a 20 MHz: 52 OFDM channels: 48 data, 4 pilot symbols



Standard	b	g	a	n	ac
Year	1999	1999	2003	2009	2013
Band [GHz]	2.4	2.4	5	2.4/5	2.4/5
Bandwidth [MHz]	20	20	20	20/40	20/40/80/160
Streams	1	1	1	4	8
Physical Rate [Mbps]					
20MHz/1Stream	11	54	54	72.2	86.7
Maximum	11	54	54	600	6900

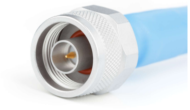


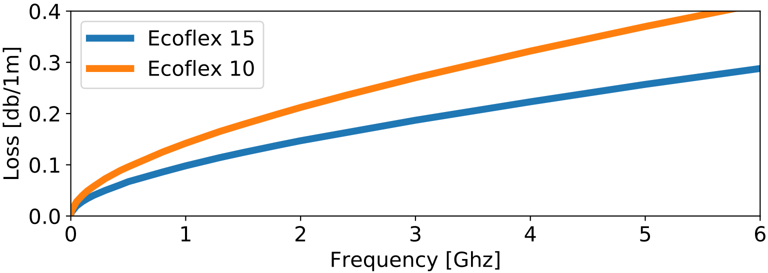
Cables and connectors

Cables = Attenuation

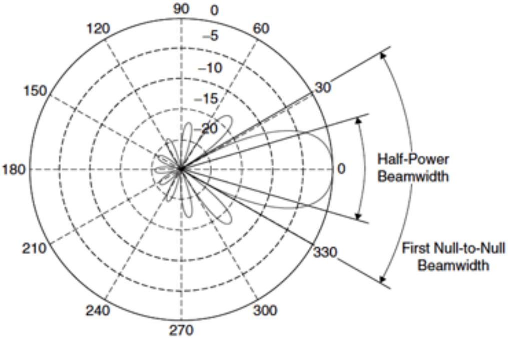
Cables and **connectors** operating at high frequencies lead to non-negligible attenuation.

- Important factors:
  - Price / Diameter
  - Frequency
  - Length





Antennas

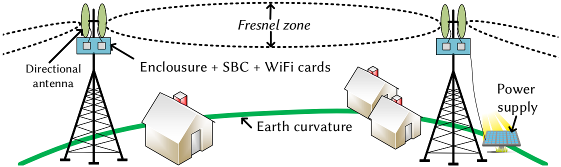


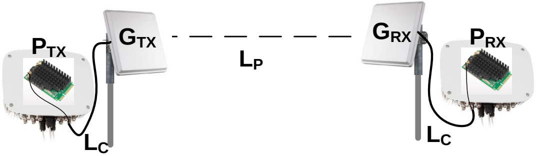
Important: Impedance, Polarization, Antenna Gain,3 dB Beamwidth

Exampkle Antenna	Frequency [GHz]	Gain	3dB beamwidth
2,4 GHz: WiMo	2,3 - 2,5	24 dBi	18°;20°h
5 GHz: H&S Pannel	5,18 - 5,87	18,5 dBi	18°v;18°h
5 GHz: Grid	4,9 -6,0	30 dBi	5°v;6°h

Link Budget

Link Budget calculations





$$P_{RX} = P_{TX} - L_{C,TX} + G_{TX} - L_P + G_{RX} - L_{C,RX} >> RXLevel_{min}$$

- L_C Cable Loss in dB
- L_P Path Loss in dB
- P_{RX} Output Power of the transmitter in dBm
- G_{TX}, G_{RX} Antenna Gain in dBi
- $RXLevel_{min}$ Modulation depended Sensitivity of the Receiver in dBm

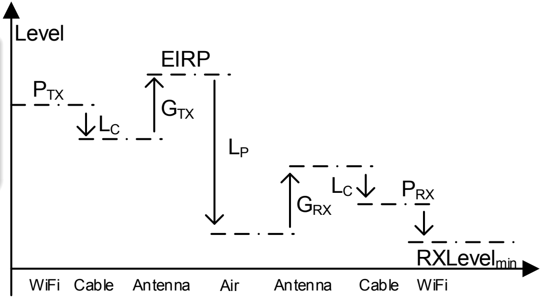
Equivalent Isotropic Radiated Power

EIRP

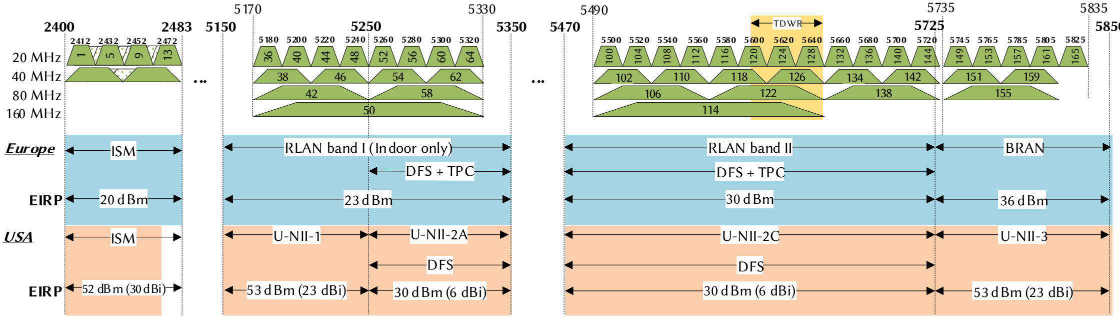
Is the amount of power that a **theoretical isotropic antenna** (which evenly distributes power in all directions) would emit to produce the peak power density observed **in the direction of maximum antenna gain**.

$$\textbf{EIRP}[\mathrm{dBm}] = P_{TX} - L_{C,TX} + G_{TX}$$

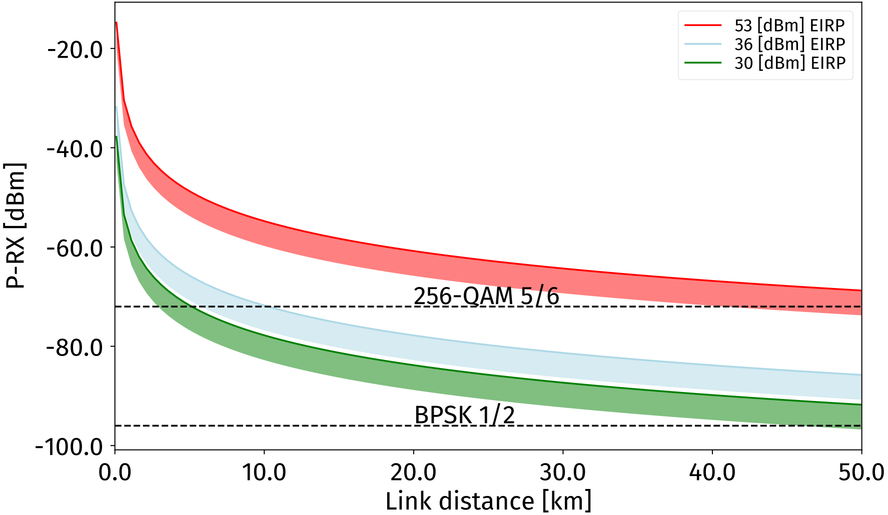
$$P_{RX}[\mathrm{dB}] = \textbf{EIRP} - L_P + G_{RX} - L_{C.RX}$$



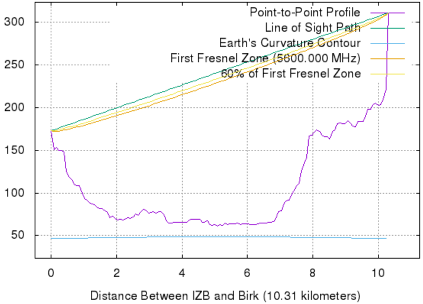
Wi-Fi Channels and EIRP

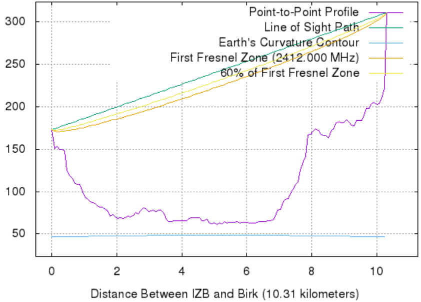


Estimated Link Budgets



Example build-up (FhG - Lohmar-Birk)



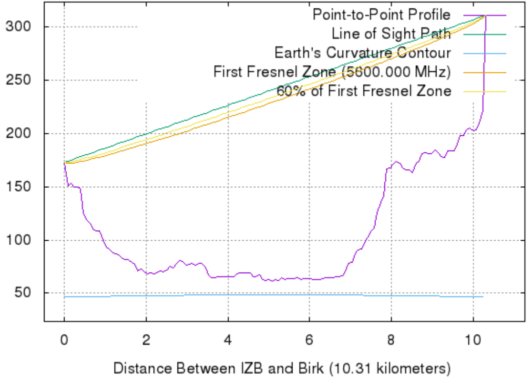


Spectrum	**2,4 GHz**		**5 GHz**	
Standard	IEEE802.11g		IEEE802.11/a	
Transfer method	OFDM		OFDM	
Bandwith [MHz]	20		20	
Spacing/Channels	5/13		20/19	
Frequency [MHz]	2412	2472	5180	5700
FSPL [dB]	**120,4**	**120,6**	**127**	**127,9**

Link Budget example

Spectrum	2,4 GHz	5 GHz Panel	5 GHz Grid
Transmitter:			
P_{TX} **[dBm]**	28	28	28
$L_{C,TX}$ **[dB]**	3	6	6
G_{TX} **[dBi]**	24	18,5	30
EIRP [dBm]	*49* (20)	*40,5* (36)	*52* (36)
Receiver:			
G_{RX} **[dBi]**	24	18,5	30
$L_{C.RX}$ **[dB]**	3	6	6
$RXLevel_{min}$**[dBm]**	-86	-86	-86
Path Loss:			
L_P **[dB]**	120,4	127,5	127,5
Margin	***36* (7)**	***12* (7)**	***34,5 (18,5)***

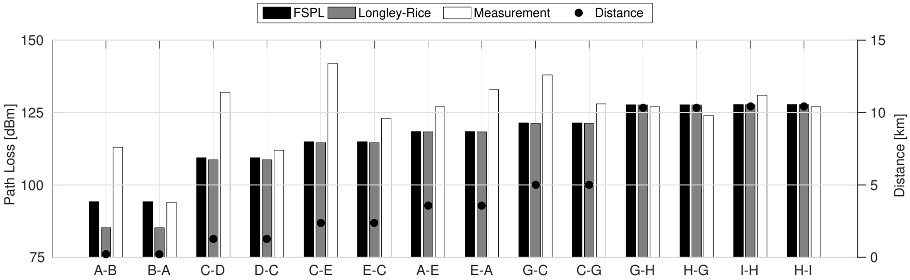
Our research: The Rhein-Sieg Wireless Testbed [5]

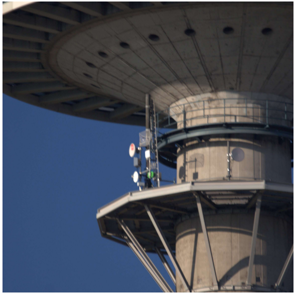


- The Rhein-Sieg testbed: H-BRS and Fraunhofer FIT
- Distances from 0.3 to 10.3 km. Focusing on a practical build-up
- Path loss calculations and signal measurements on every link

M. Rademacher, M. Kessel, K. Jonas, "Experimental Results For the Propagation of Outdoor IEEE802.11 Links" VDE ITG-Fachbericht Mobilkommunikation, 2016.

Our research: Path Loss Prediction [5]





Location H

Location A

Location C

Thank you for your attention.
Are there any questions left?

Room K331
Rathausallee 10
Technopark
Sankt Augustin

michael.rademacher@h-brs.de
www.mc-lab.de
https://michael-rademacher.net

References

[1] Bernardi, G., Buneman, P., and Marina, M. K.
Tegola tiered mesh network testbed in rural Scotland.
In *Proc. ACM workshop on Wireless networks and syst. for developing regions* (2008), p. 9.

[2] Garg, V.
Wireless Communications and Networking, 1. ed.
Morgan Kaufmann, 2010.

[3] Goldsmith, A.
Wireless Communications.
Cambridge University Press, 2005.

[4] Hall, M. P. M., Barclay, L. W., and Hewitt, M. T.
Propagation of Radiowaves.
Institution of Engineering and Technology, 2012.

[5] Rademacher, M., Kessel, M., and Jonas, K.
Experimental results for the propagation of outdoor ieee802.11 links.
In *Mobilkommunikation - Technologien und Anwendungen. Vorträge der 21. ITG-Fachtagung, 11. - 12. Mai 2016 in Osnabrück. ITG-Fachbericht, Bd. 263* (2016), pp. 32 – 36.

References II

[6] Rappaport, T. S.
Wireless Communications: Principles and Practice, vol. 207.
Prentice Hall, 2002.

[7] Salous, S.
Radio Propagation Measurement and Channel Modelling.
John Wiley & Sons, Inc., March 2013.

[8] Saunders, S., and Aragón-Zavala, A.
Antennas And Propagation for Wireless Communication Syst.
John Wiley & Sons, Inc., May 2007.