Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Propagation Aspects of Terahertz Outdoor Fixed Wireless Links
Date Submitted: 19 March, 2013
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Abstract: Based on previous presented Link Budget Analysis for Terahertz Fixed Wireless Links (15-12-0582) some additional link aspects for Terahertz Fixed Wireless Links are further discussed, addressing the influence of fog and rain and impairments of pole twist and sway effects for high gain antenna links.

Purpose: Informing IG THz on propagation aspects of Terahertz Outdoor Fixed Wireless Links.

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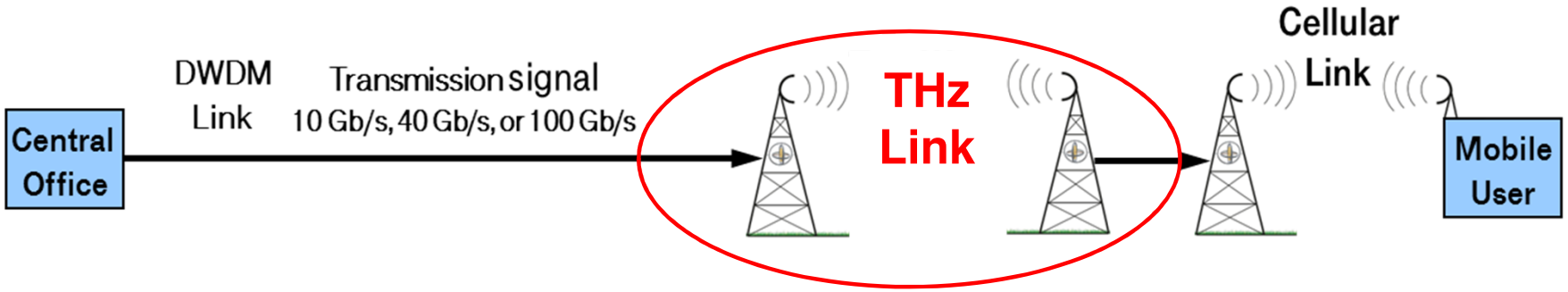
THz Outdoor fixed wireless link aspects

- Considerations on fog and rain conditions
  - Combined fog/rain scenario assessment
  - Scintillation impairments
- High gain antenna link robustness
  - Influence of sway/twist of antenna poles

Outdoor Fixed Wireless Link Scenarios

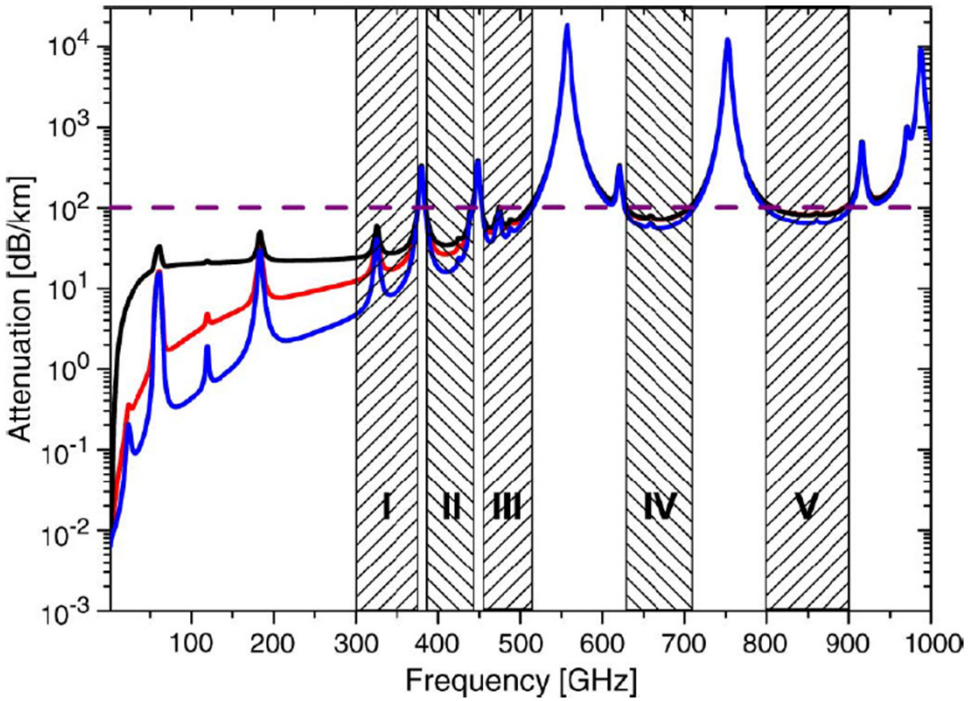
THz Link can provide a High Capacity Bridge for Backbone and Access Networks

Example:
Wireless backhaul extension for cellular Network



DWDM Dense Wavelength-Division Multiplex

Attenuation in THz transmission windows Influence of Fog or Rain



THz Transmission Windows

Window	Bandwidth [GHz]	Center Frequency [GHz]
I	76	338
II	58	414
III	62	484
IV	85	669
V	94	855

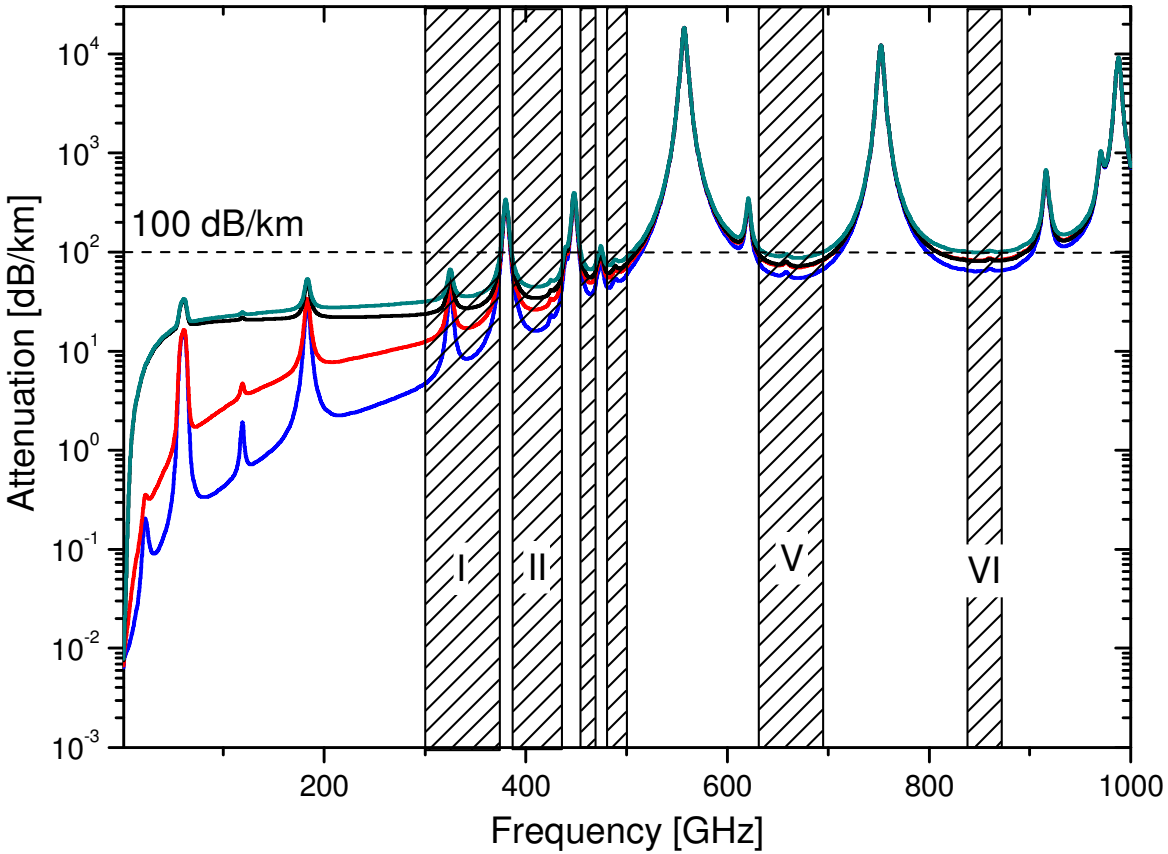
Attenuation as a function of frequency for a clear atmosphere at sea level (**blue**), fog with a range of vision of 50 m (**red**) and Rain with 50 mm/h (**black**).

The shaded regions describe the ranges above 300GHz in which, even for the worst case, the attenuation is below 100 dB/km.

ITU Rec. ITU-R P.676-8, ITU, Oct.2009

"The am atmospheric model, submillimeter array," Tech. Memo #152 [Online]. Available: https://www.cfa.harvard.edu/~spaine/am/

Attenuation in THz transmission windows Influence of Fog/Rain: Additive Scenario



THz Transmission Windows

Window	Bandwidth [GHz]	Center Frequency [GHz]
I	75	337.5
II	52	412
III	18	464
IV	28	490
V	59	665.5
VI	13	849

- Both (fog, rain, and gas)
- 50 mm/h (rain and gas)
- 50 m vision (fog and gas)
- Clear atmosphere at sea level

Shaded regions:
Attenuation < 100dB/km
For worst case conditions

ITU Rec. ITU-R P.676-8, ITU, Oct. 2009

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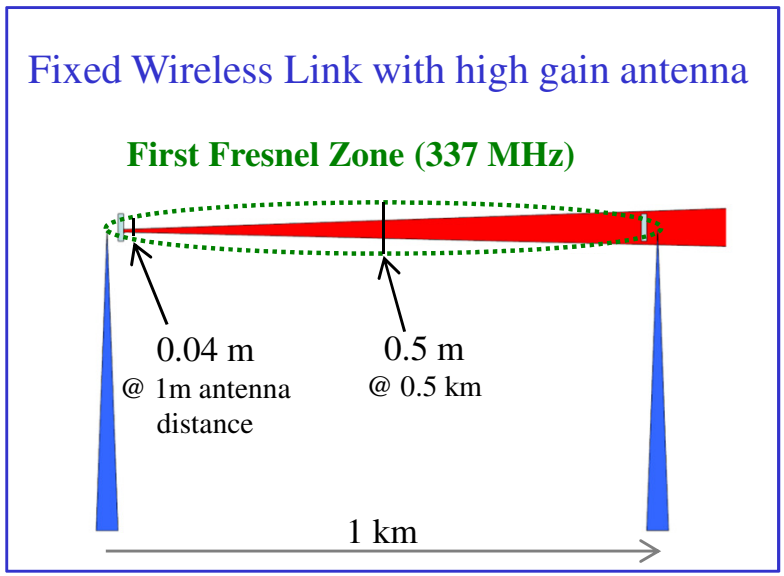
Assessment of rain/fog scenarios

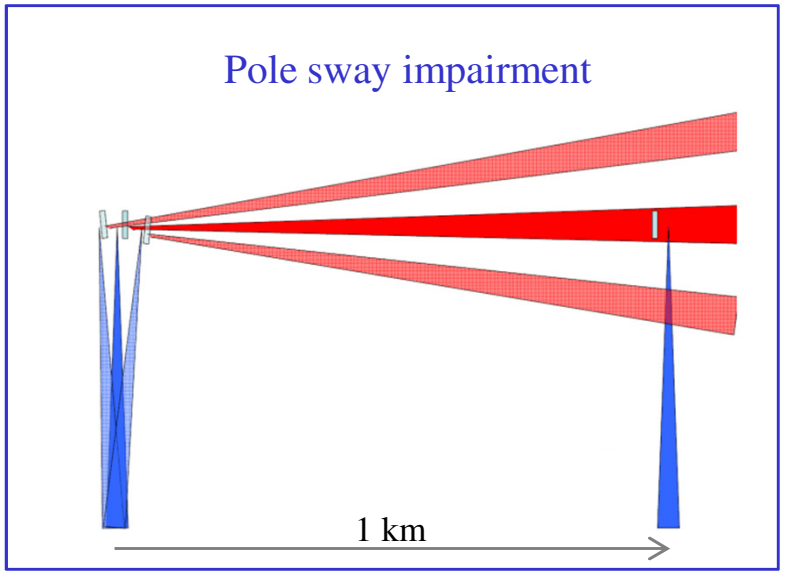
- Assumption: Wireless link may only be partly impaired by rain or fog, respectively.
- Depicted results for rain (50mm/h) + fog (vision range 50m) only a „worst-worst“ case, which will not occur in real-world deployments.
- Heavy rain (50 mm/h) assumed to be worst case condition. Therefore, already presented values in document 15-12-0582 are still valid.
- Contrary to IR links the scintillation impairments are not relevant for THz links, as published by recent research work[1].

[1] “Experimental comparison of performance degradation from terahertz and infrared wireless links in fog”, Ke Su, Lothar Moeller, Robert B. Barat, John F. Federici, Journal Optical Society Am., Feb 2012, Vol. 29, No.2

Fixed Wireless Links
High Gain Antenna Aspects

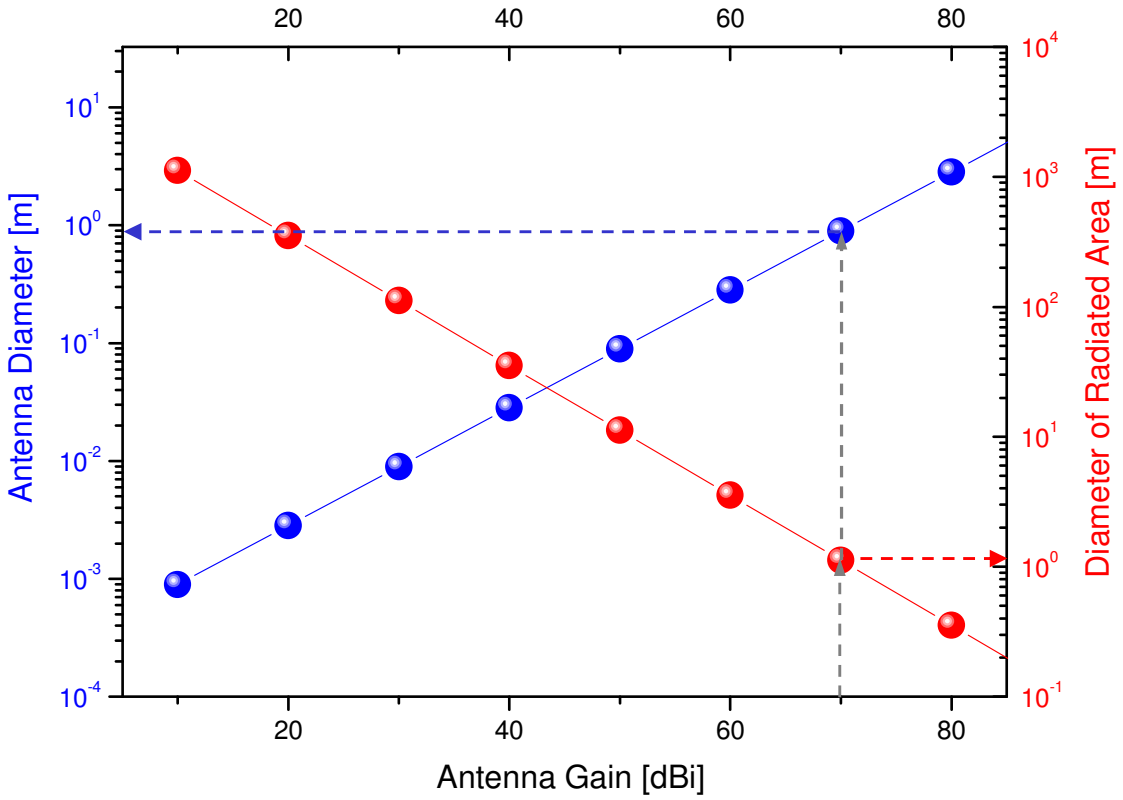
- Depending on the frequency, for a gain of 70 dBi, the diameter of the parabolic antenna is between 0.3 (1 THZ) and 1 m (300 GHz), assuming an ideal antenna
- Tolerable angle for fluctuations of pole is reduced to a range of 1 ° and below





Fixed Wireless Links
High Gain Antenna Aspects

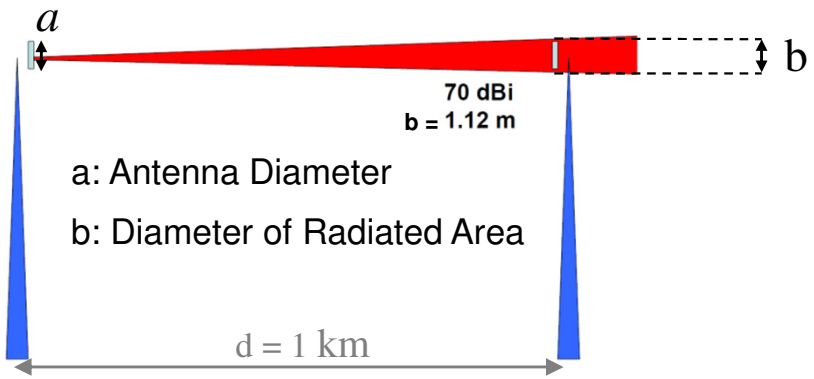
Antenna dimension and radiated area as function of antenna gain for the first THz-window (center frequency 337 GHz)

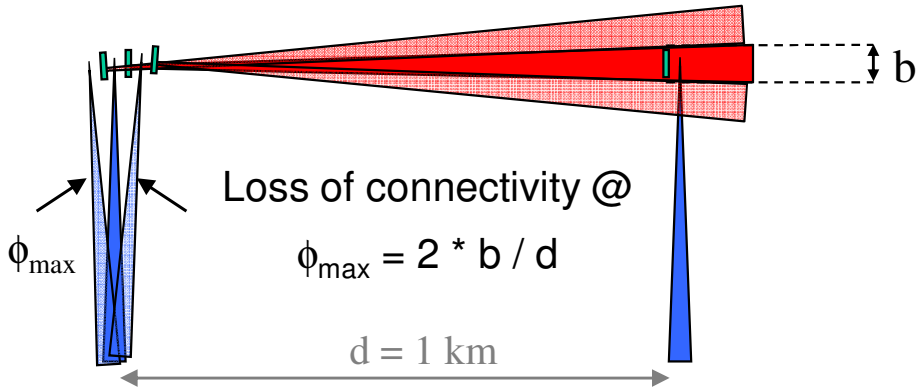


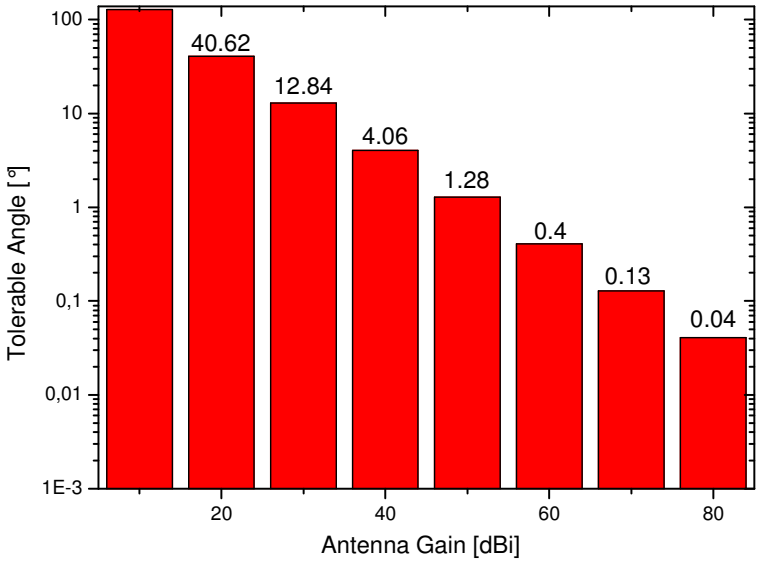
Link distance of 1 km

Fixed Wireless Links
High Gain Antenna Aspects

1) Link impairments by pole sway (f = 337 GHz):



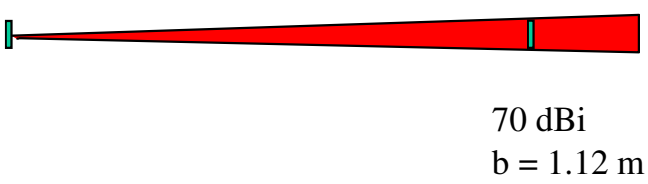




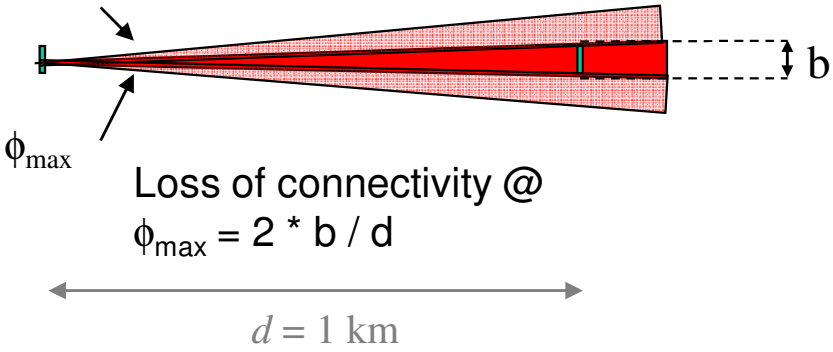
- Pole sway impairment:
  - Loss of connectivity: $\phi_{max} = 0.13°$
    - 70 dBi antenna
    - 1km link distance

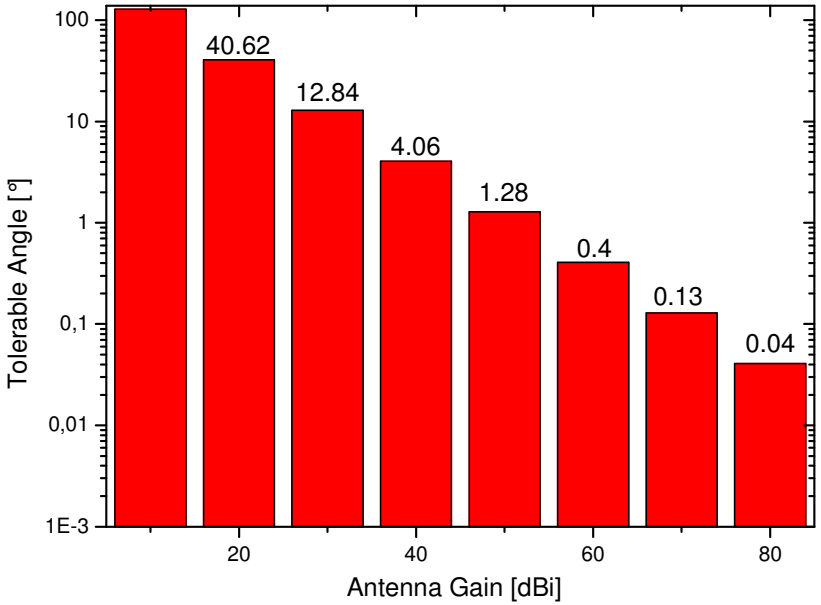
Fixed Wireless Links
High Gain Antenna Aspects

2) Link impairments by pole twist (f = 337 GHz):



70 dBi
b = 1.12 m





- Pole twist impairment:
  - Loss of connectivity: ϕ_{max} = 0.13°
    - 70 dBi antenna
    - 1km link distance

Conclusion

- Although both rain and fog attenuation can occur within a fixed wireless link, worst case is assumed to be under heavy rain conditions.
- Even for the worst case scenario (rain rate of 50 mm/h) THz-wireless links offer extremely high data rates over a link of 1km.
- Recent research results conclude that for fog there is no additional impairment by scintillation effects in comparison to IR links.
- Required high gain antenna solutions up to 80 dBi for outdoor fixed wireless links result in loss of connectivity for angles below 0.04° for antenna pole sway and twist.
- Requirement for active control mechanism to compensate for pole sway/twist depends on the grade of sway/twist impairments, given by antenna installation (type of pole, building).
- Outdoor fixed wireless link technology has to support different features in comparison to indoor based technology to cope with link critical aspects: Atmospheric attenuation and active steering mechanisms for high directive links.