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Horizon 2020 Grant Agreement no: 814523

Tera**h**ertz end-to-end wireless systems supp**o**rting ultra-high data **R**ate applications

ThoR

D7.7

Report on standards activity 24M

Coordinator (EU): Thomas Kürner
Organisation: Technische Universität Braunschweig

Coordinator (Japan): Tetsuya Kawansihi
Organisation: Waseda University

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Leader in charge of deliverable: Akihiko Hirata
Chiba Institute of Technology

Project co-funded by the European Commission within the Horizon 2020 programme and the National Institute of Information and Communications Technology in Japan (NICT)		
Dissemination level		
PU	**Public**	**X**
PP	**Restricted to other programme participants (including the Commission Services)**	
RE	**Restricted to a group specified by the consortium (including the Commission Services)**	
CO	**Confidential, only for members of the consortium (including the Commission Services)**	

Contents

Change register

Version	Date	Author	Organisation	Changes
A	24-Jun-2020	Akihiko Hirata	Chiba Institute of Technology	Initial
B	28-Jun-2020	Yigal Leiba	SIKLU	Initial

Reviewed by Yigal Leiba SIKLU A 28-Jun-2020

1. Statement of independence

The work described in this document is genuinely a result of efforts pertaining to the ThoR project. Any external source is properly referenced.

Confirmation by Authors:

Akihiko Hirata	Chiba Institute of Technology
Thomas Kürner	TU Braunschweig
Eisaku Sasaki	NEC Corporation
Shintaro Hisatake	Gifu University

2. ABBREVIATIONS

AI 1.15	Planned Agenda Item 1.15 of WRC-19
APT	Asia-Pacific Telecommunity
AWG	The APT wireless group
ETSI	European Telecommunications Standards Institute
FS	Fixed Service
FWS	Fixed wireless system
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITU-R	International Telecommunication Union - Radiocommunication Sector
LMS	Land Mobile Service
NGMN	Next Generation Mobile Networks
RR	Radio Regulations
TAG	Technical Advisory Group
TC	Technical Committee
TG	Task Group
THz	Terahertz
TSC	Terahertz Systems Consortium
WRC-19	World Radiocommunication Conference 2019

3. Executive summary

This deliverable provides the report of standards activity for THz wireless communications.

The international standardization contributions input into international standardization conference are as follows:

- IEEE 802
  "Simulation and Automatic Planning of 300 GHz Backhaul Links - First Results from H2020-ThoR," I doc.: IEEE 802.15-19-0278—01-0thz_Simulation and Automatic Planning, July 2019 (Annex 1)
  "Results of WRC 2019 AI 1.15 and their impact on THz Communications," IEEE 802.15-20-0149-00-0thz, June 2020. (Annex 2)

- AWG-24
  "PROPOSED MODIFICATION TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW APT [RECOMMENDATION/REPORT] ON 'MODEL[S] FOR FWS LINK PERFORMANCE DEGRADATION DUE TO WIND'," AWG-25/INP-24, July 2019 (Annex 3)

4. Introduction

Terahertz (THz) communications in the frequency range from around 300 GHz to 3 THz has no allocation and only used for research purposes. With huge bandwidths and by nature very limited transmission distances (e.g. up to 300 m with directive antennas), THz links are a very promising solution for these short range backhaul links. Nevertheless, there are passive services operating in this frequency range providing valuable information e.g. in the composition of earth's atmosphere or outer space. These services, identified in Footnote 5.565 [1] of the Radio Regulations, must be protected from harmful interference.

WRC 2019 agenda item 1.15 has called for studies to identify frequency bands for use by administrations for the LMS and FS applications operating in the frequency range 275-450 GHz, in accordance with Resolution 767 (WRC-15). Resolution 767 (WRC-15) invites ITU-R to conduct sharing and compatibility studies between LMS and FS applications and passive services applications planned to operate in the frequency range 275-450 GHz and to identify candidate frequency bands for use by systems in LMS and FS applications, while maintaining protection of the passive services applications identified in RR No. 5.565. The new footnote 5.564A [2] that identifies the frequency bands for use by administrations for the LMS and FS applications had been determined at WRC 2019.

The investigation about WRC 2019 agenda item 1.15 had finished, however, there are other standardisation bodies or associations, which are relevant to ThoR. These include IEEE 802, the APT Wireless Group, IEC, ETSI, TSC, and NGMN. The potential agenda item on the identification of spectrum for radio location applications in the range 275-700 GHz will require sharing studies with THz communications as the incumbent application. This may trigger another potential regulatory activity towards WRC 2027.

This deliverable provides the report of standards activity relating to ThoR for THz wireless communications from July 2019 to June 2020. In the following chapters, we provide an overview of each international standardization contribution or inputs into international standardization conference of the above-mentioned standards bodies or associations. All contributions ThoR has made in project year 1 are attached as annexes.

5. Institute of Electrical and Electronics Engineers (IEEE) 802

Standardisation of either THz communications links in the Working Group 15 (Wireless Specialty Networks – WSN). On 12 October 2017, a first standard for frequencies in the bands 252 to 275 GHz has been published (IEEE Std. 802.15.3d), which was created within IEEE 802 WG15 since 2014. The corresponding Task Group has been led by Thomas Kürner from ThoR partner TUBS, who also chairs the IEEE 802.15 Technical Advisory Group THz (TAG THz). Interaction with IEEE 802 is of great relevance for ThoR and IEEE 802.15 since ThoR is – to the best of our knowledge - the first project to implement an IEEE Std. 802.15.3d-2017 compliant demonstrator.

In project year 1 ThoR's has made three contributed to IEEE 802, which has been already reported in D7.4 [ThoR2019] and continued by 2 contributions in project year 2:

- [IEEE19] ThoR presented the approach for automatic planning of backhaul/fronthaul links developed in ThoR WP5 at the IEEE 802 Plenary Meeting in Vienna in July 2019
- [IEEE20] describes the outcome of WRC 2019 and its impact on THz communications and is based on ThoR D5.3 [ThoR2020] and [KH20]. This contribution has been presented at the IEEE 802.15 TAG THz online meeting in June 2020.

References:

[IEEE19] Jung, B. K.; Dreyer, N., Eckhardt, J.; Kürner, T: Simulation and Automatic Planning of 300 GHz Backhaul Links - First Results from H2020-ThoR, IEEE 802.15 Document 15-19-0278-01-0thz, electronic publication (21 pages), Vienna, July 2019.

[IEEE20] Kürner, T.; Hirata A.: THz Communications – An Overview and Options for IEEE 802 Standardization. IEEE 802.15 Document 15-20-0149-00-0thz, electronic publication (15 pages), Online Meeting, June 2020.

[ThoR19] A. Hirata.; Report on standards activity 12M; ThoR Deliverable D7.4; available at https://thorproject.eu/results/

[ThoR20] A. Hirata, T. Kürner, Analysis of the Consequences of the Results of WRC 2019, ThoR Deliverable D5.3; available at https://thorproject.eu/results/

[KH220] T. Kürner, A. Hirata, On the Impact of the Results of WRC 2019 on THz Communications, accepted for publication in Proc. International Workshop on Mobile THz Systems, 2-3 July 2020

6. The APT Wireless Group (AWG)

AWG-25 meeting was held at Tangerang Indonesia in July 2019. We submitted a contribution to TG-FWS.

TG (Task Group)-FWS (Fixed Wireless Systems), its chair is Dr. Tetsuya Kawanishi, is one of TGs under AWG. The terms of reference of this TG are below.

- To gather following national information regarding fixed wireless systems
  - Frequency planning and usage
  - Licensing conditions
  - Usages and applications
  - Standardization activities
- To study on following questions regarding fixed wireless systems
  - Current status of frequency planning and usage, frequency assignment, bandwidth, main usages and applications
  - Trends on technology development and R&D prospects on future usages and new applications
- Based on the above studies, to develop reports and/or recommendations as appropriate.

Document title:

"PROPOSED MODIFICATION TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW APT [RECOMMENDATION/REPORT] ON 'MODEL[S] FOR FWS LINK PERFORMANCE DEGRADATION DUE TO WIND"

Abstract:

At the AWG-23 meeting held at Da Nang Vietnam in April 2018, TG-FWS started to develop a preliminary draft new APT [Recommendation/Report] on model(s) for FWS link performance degradation due to wind. At the AWG-24 meeting held at Bangkok Thailand in September 2018, Japan input the model for FWS link facility including influence of dynamic factor in addition to static load of antenna and pole due to wind. By this contribution, the model closed to more actual FWS link performance degradation. On the other hand, the Chair pointed to adding different parameters of FWS link facility so that the report would be more generally available.

In this contribution, Japan proposes to add some examples of FWS link facility to the working document of new APT [Recommendation/Report] (AWG-24/TMP-02) as attached. This additional information includes antenna diameter of 0.6m, pole length of 10m, and combination of both parameters. By this addition, the [Recommendation /Report] will become able to provide more generalized information, and contribute to the users who use millimetre wave link with narrow beam.

This information was added as Annex 1 "Attenuation Models under Wind Conditions" into the original APT report APT/AWG/REP-81. This annex includes the following information.

By this information addition, the [Recommendation /Report] becomes able to provide an estimation model which is closer to the actual link performance degradation, and contribute to the users who use millimetre wave link with narrow beam.

AWG-26 meeting was planned to be held at Bangkok Thailand in March 2020, however the meeting was postponed to the 3Q of 2020 due to COVID-19.

We submitted an additional contribution to the above-mentioned working document before the decision of the postponement. This contribution will be covered in the last report next year.

7. International Electrotechnical Commission (IEC)

Scope of the technical committee 103 (TC103), Transmitting Equipment for Radiocommunication, is standardization of transmitting equipment for radiocommunications purposes and electronic devices employing similar techniques. The standardization work deals with methods of measurement, safety requirements and transmitter control and interconnection.

WG (Working Group) 6 is one of WGs under TPC103. The scope of WG6 is to create Radio on Fibre (RoF) system standards.

The IEC General Meeting (GM) was held at Busan, Korea in October 2018. In this GM, a working item on “Antenna near-field pattern measurement by optical techniques in terahertz-wave bands” has been approved to start as IEC TR 63099-3.

IEC TC103 Interim Meeting was scheduled from 19 to 20 February 2020 in Seoul, Republic of Korea, however it was postponed because of Covid-19. The document has been revised and it will be discussed at web Interim Meeting which will be held on June.

Proposal of preliminary work item on IEC TR 63099-3:
Edition 1.0

Transmitting equipment for radiocommunication - Radio-over fibre technologies for electromagnetic-field measurement
- Part 3: antenna near-field pattern measurement by optical techniques in terahertz-wave bands

Summary
Japan National Committee proposes to start a new work item on Measurement method of antenna near-field pattern in millimeter-wave and THz wave bands. This work item provides technical details of antenna characterization and provides useful technical specifications for measurement of antenna gain and radiation pattern, and finally publishes as TR.

Schedule of IEC TR 63099-3:

2018	2019	2020
PWI		
	preDTR	
		DTR

8. Terahertz Systems Consortium (TSC)

Terahertz Systems Consortium (TSC) (Chairman: Makoto Ando) was established on September 29, 2015 in Japan, in order to promote system development based on terahertz technology and achieve early social development and industrialization, while deepening the cooperation of related organizations, new technological development and social development. TSC promotes terahertz technology through examinations and proposals for issues, surveys of technology trends and user needs trends, standardization activities based on research and development results, examination of inspection techniques, etc. The members of TSC include industries that develop terahertz devices and systems, government research organizations, telecommunication companies, and academic fields. Prof. Hirata (CIT) acts as Deputy Secretary General of TSC.

Standardization Section of TSC had held a debriefing session about the result of WRC 2019 on 28-Feb-2020. On 15-May-2020, standardization section of TSC had discussed the activity policy after WRC 2019. TSC will start the investigation about the contribution for IMT-2020 evolution based on the technical trend of THz system, sharing studies between LMS/FS system in 252-296 GHz bands, and study about the antenna and propagation at 252-296 GHz bands.

The results of ThoR Research Activity will be input into the international standardization contributions via TSC.

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

Submission Title: Simulation and Automatic Planning of 300 GHz Backhaul Links - First Results from H2020-ThoR

Date Submitted: 15 July 2019

Source: Bo Kum Jung **Company:** TU Braunschweig, Institut für Nachrichtentechnik
Address: Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice: +495313912439 FAX: +495313915192, E-Mail: bokumjung@ifn.ing.tu-bs.de

Re: n/a

Abstract: The implementation of IEEE standard 802.15.3d enables the wireless backhaul links operating at 300 GHz to provide >100 Gbit/s data rate. One of the goals of the EU-JAPAN Horizon 2020 project (ThoR) is to develop suitable automatic planning algorithms for the backhaul/fronthaul links. In this presentation first simulation results of the developed automatic planning algorithm for the 300 GHz backhaul in the are provided in the Hannover scenario, which is one of the ThoR simulation scenarios..

Purpose: Information of the Technical Advisory Group THz

Technische Universität Braunschweig

Institut für Nachrichtentechnik

Simulation and Automatic Planning of 300 GHz Backhaul Links First Results from H2020 ThoR

Bo Kum Jung, Nils Dreyer, Johannes Eckhardt, Thomas Kürner

Acknowledgement

- This presentation is based on B. K. Jung, N. Dreyer, J. Eckhardt, T. Kürner„Simulation and Automatic Planning of 300 GHz Backhaul Links“ accepted for publication at IRMMW-THz 2019, Pari September 2019.

- The work presented here, has been performed within theHorizon 2020 ThoR project. This project has received funding from Horizon 2020, the European Union’s Framework Programme for Research and Innovation, under grant agreement No. 814523. ThoR has also received funding from the National Institute of Information and Communications Technology in Japan (NICT).

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Outline

1. Introduction
2. Planning Approaches
3. Simulation Results
4. Conclusion

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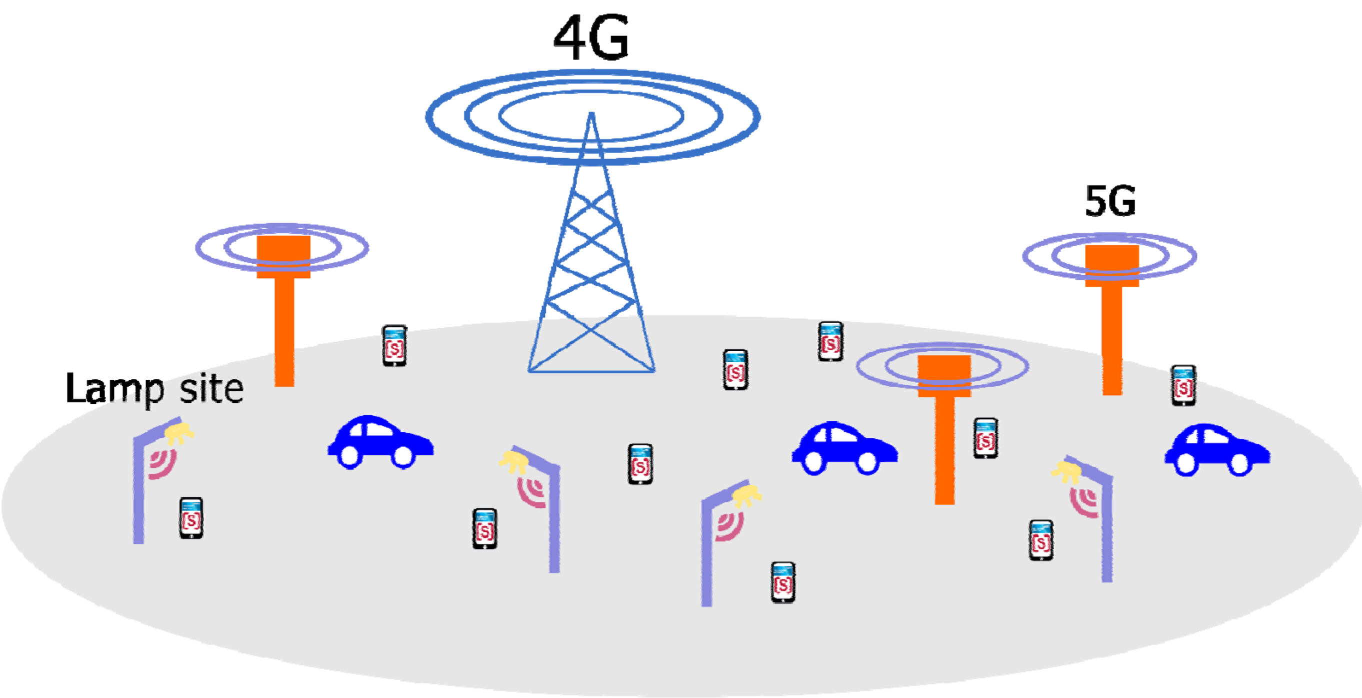
Introduction

5G Integration with 4G



Backhaul

Fibre vs ***Wireless***

Introduction

- IEEE Standard 802.15.3d
  - Wireless backhaul at 300 GHz with 100+ Gbit/s Data rate

- ThoR project(European Horizon 2020)
  - >40 Gbit/s real data transmission
  - Developing algorithms for the automatic planning front/backhaul links
  - Deriving planning guidelines

Outline

1. Introduction
2. **Planning Approaches**
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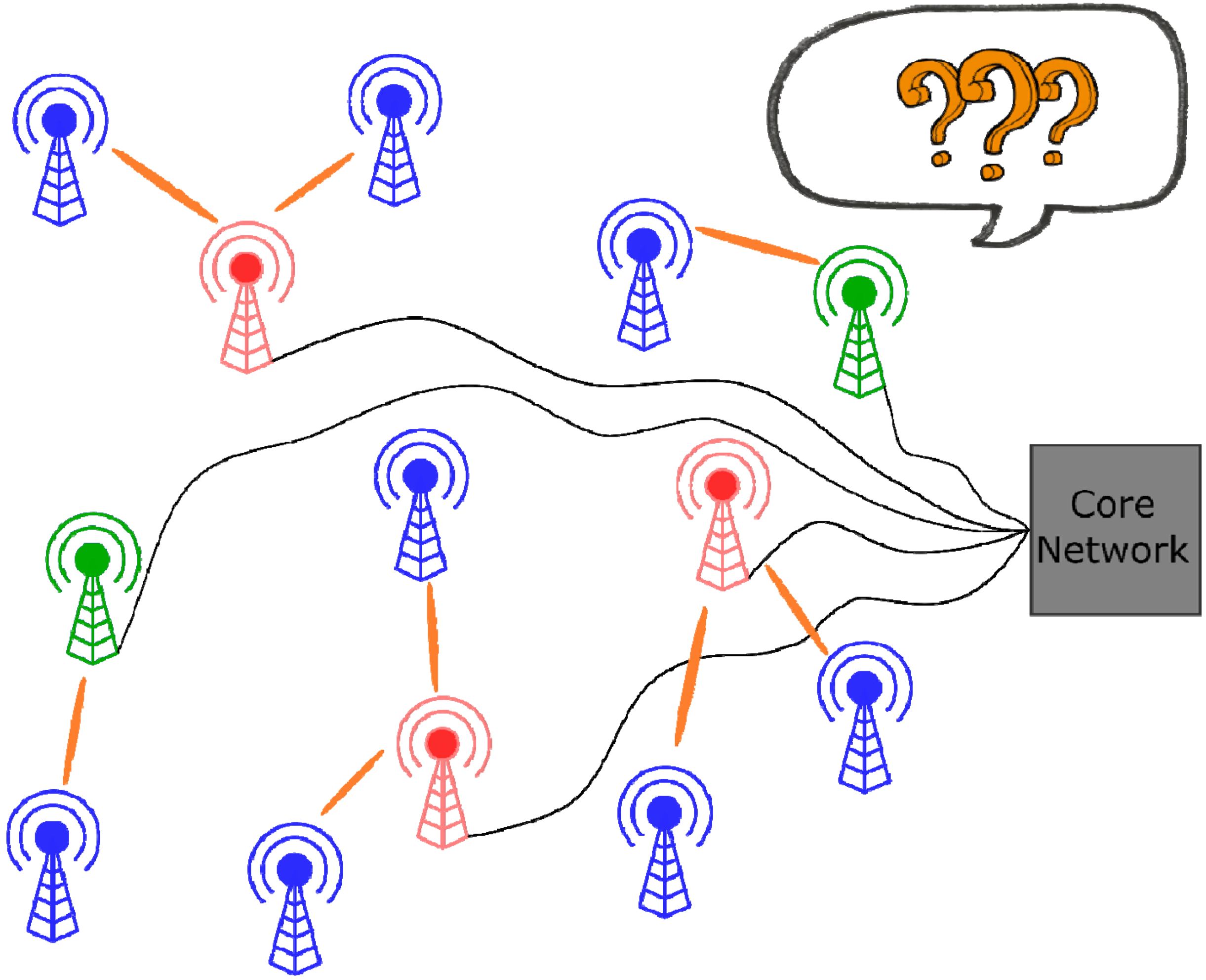
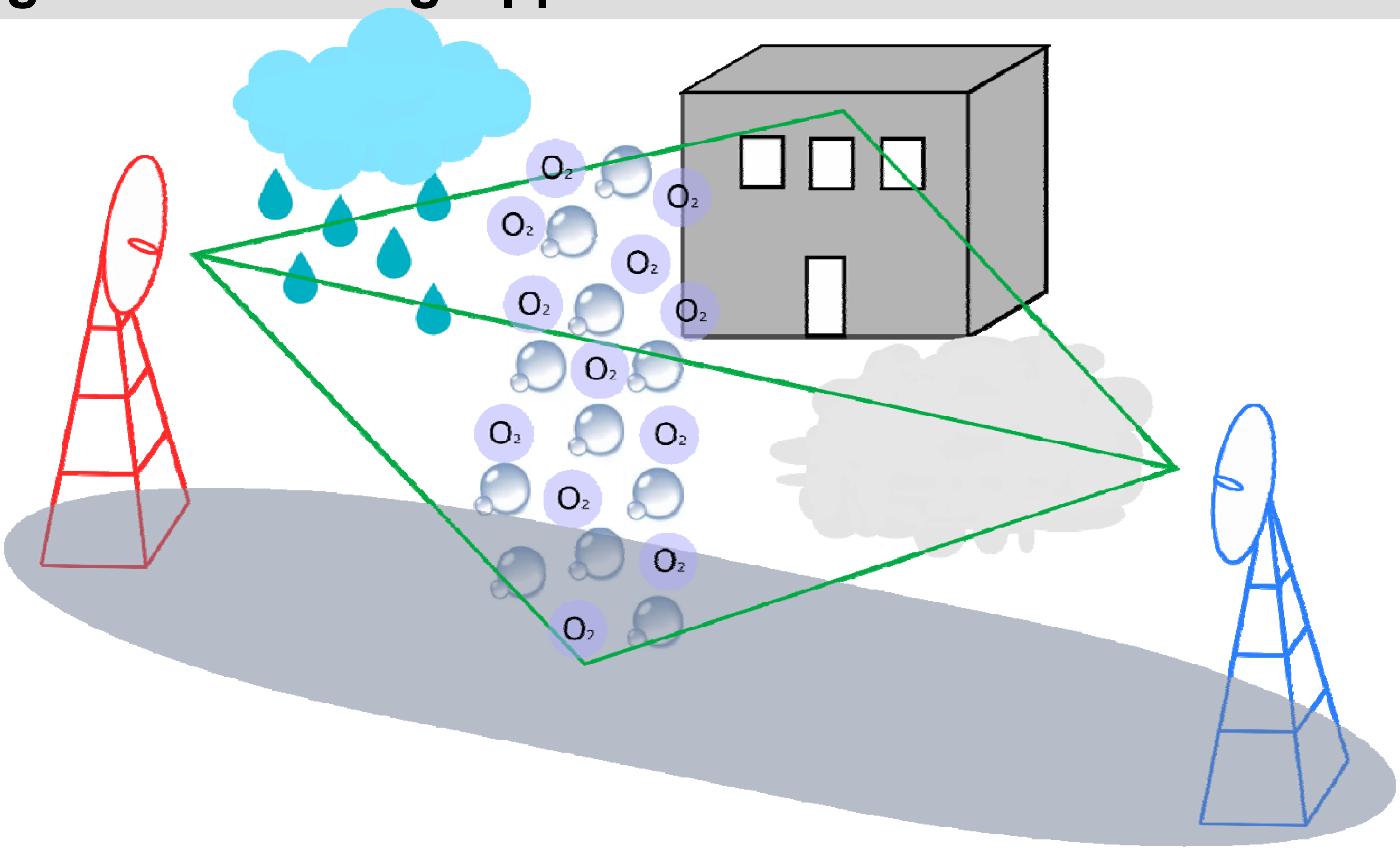
General Approach

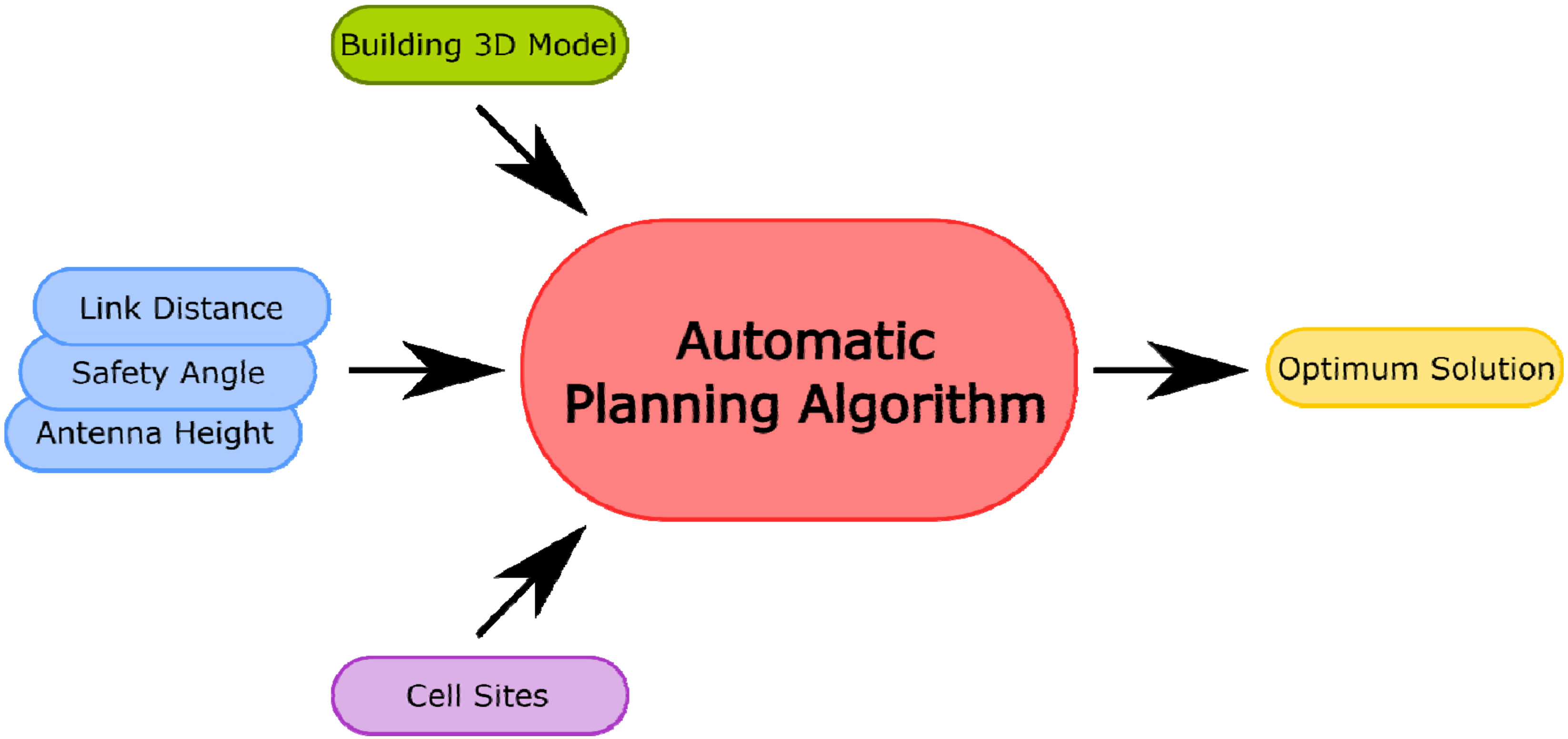


Propagation Modeling Approach



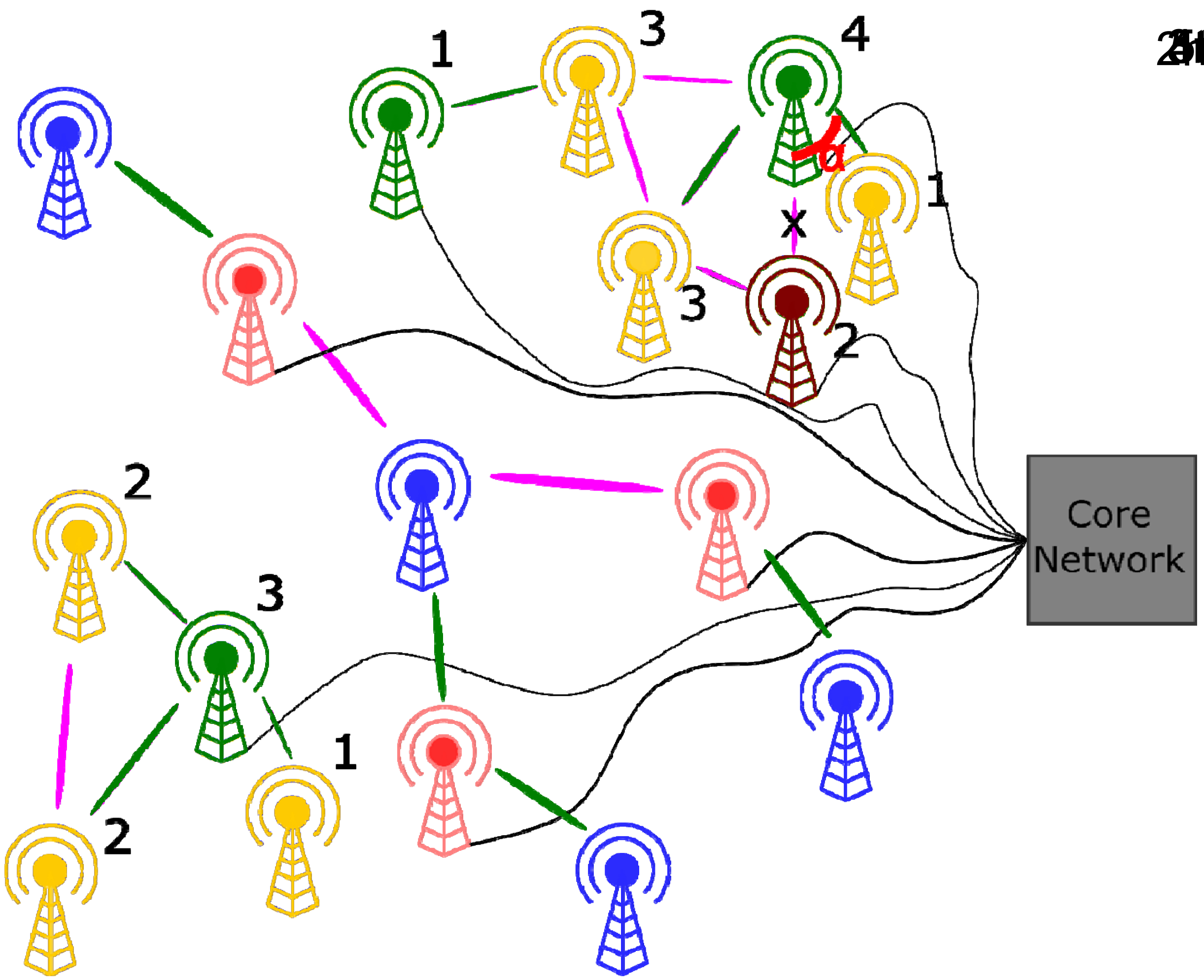
Path Loss / dB = 92.4 + 20 log(*r / km*) +20 log(*f / MHz*) + $(\gamma_0+\gamma_w+\gamma_R+\gamma_c)$ *r / km*

Automatic Planning Approach

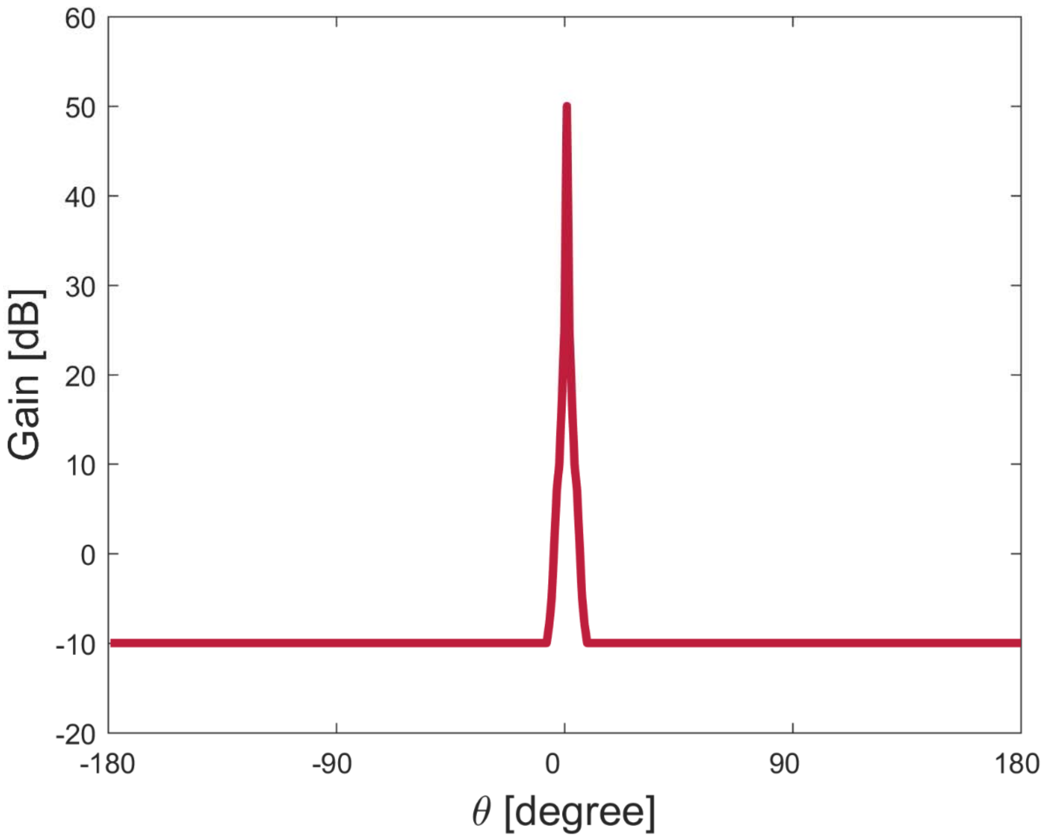


Algorithm

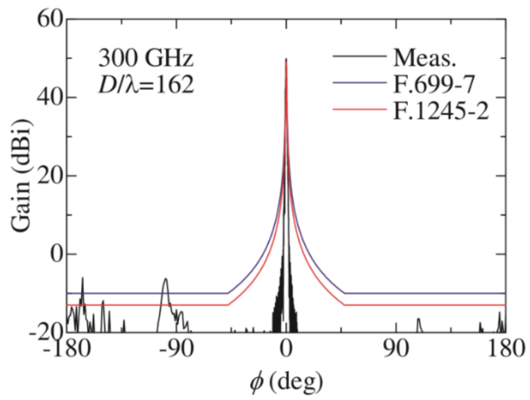
4th stage



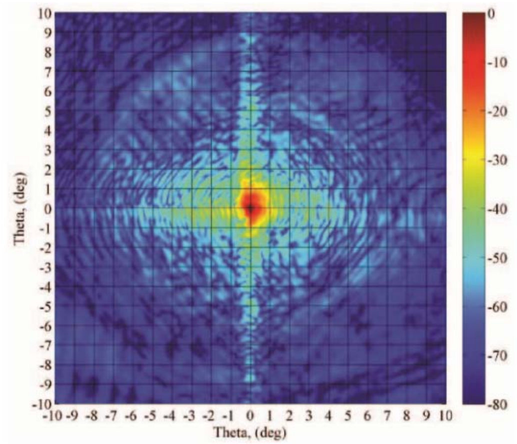
Antenna Diagram



- A simplified radiation pattern of 50 dBi antenna

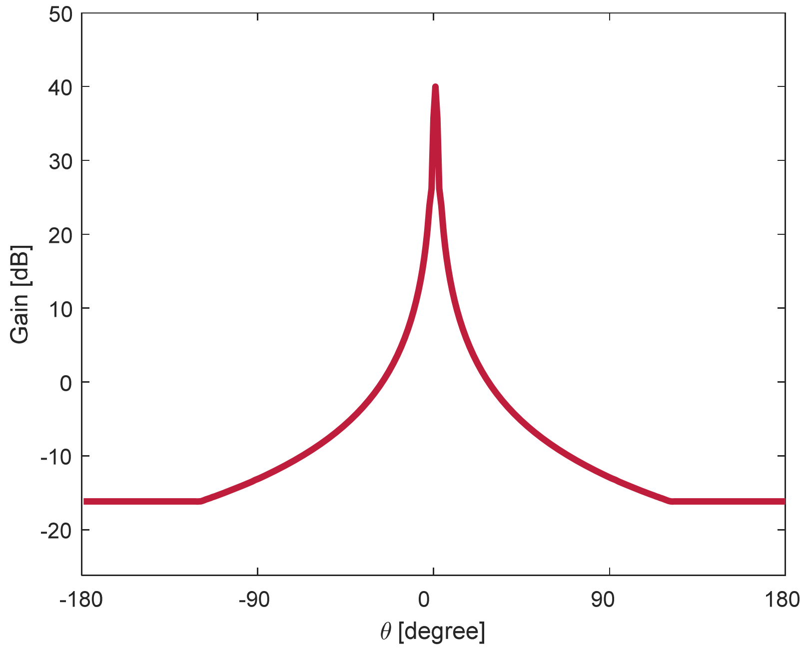


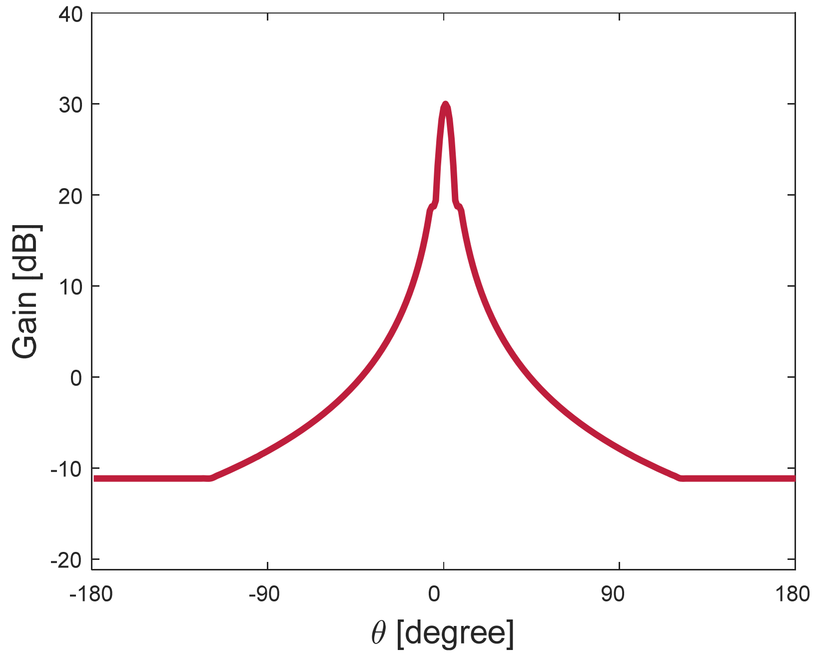
Sawada, H and Kanno, Atsushi and Yamamoto, Nobuyuki and Fujii, Katsumi and Kasamatsu, A and Ishizu, K and Kojima, F and Ogawa and H and Hosako, I, "High gain antenna characteristics for 300 GHz band fixed wireless communication systems" , Progress in Electromagnetics Research Symposium in Singapore,pp. 1409-1412, Nov 2017.



A. Martínez, I. Maestrojuan, D. Valcazar and J. Teniente, "High gain antenna for sub-millimeter wave communications," *2016 46th European Microwave Conference (EuMC)*, London, 2016, pp. 37-40.

Antenna Diagram



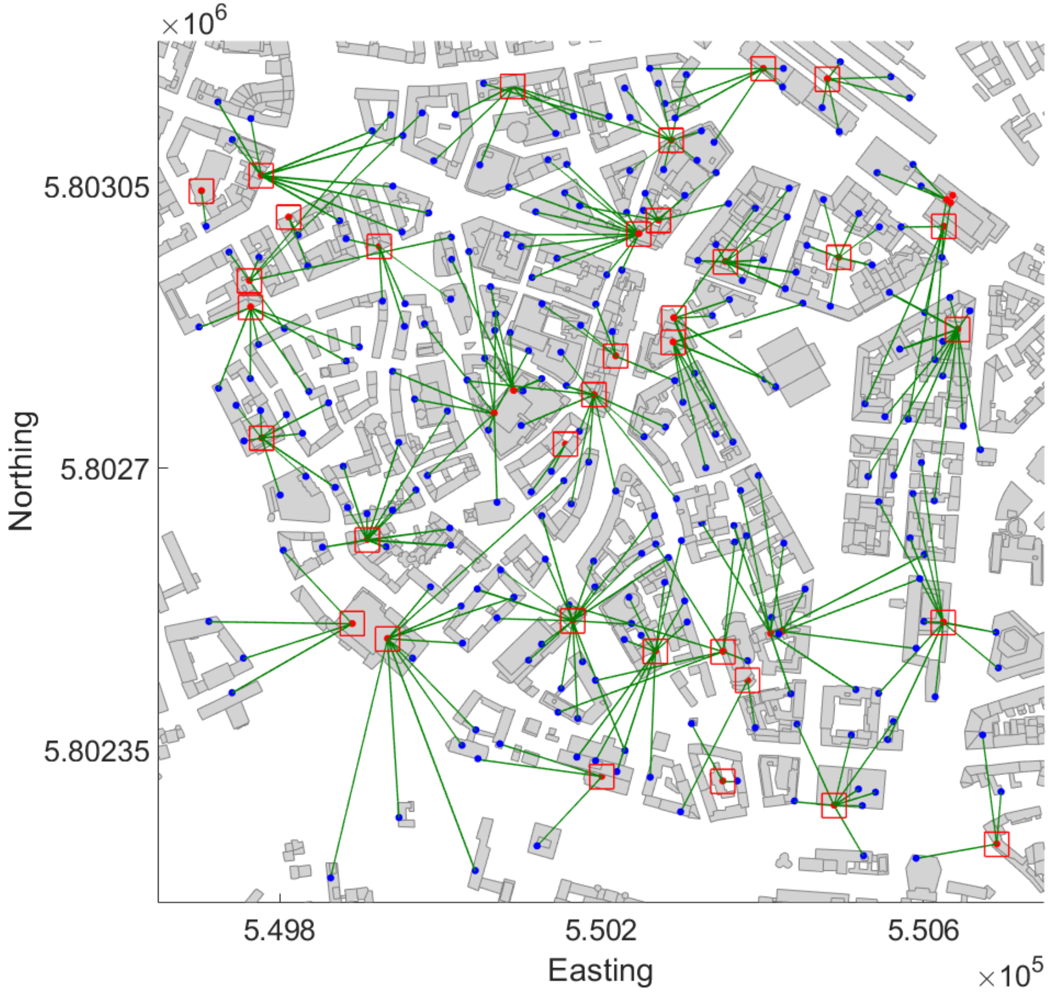


- ITU-R F.1245-3 Mathematical model of radiation patterns

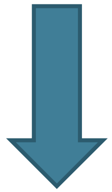
Outline

1. Introduction
2. Planning Approaches
3. **Simulation Results**
4. Conclusion

Automatic planned wireless Backhaul Links

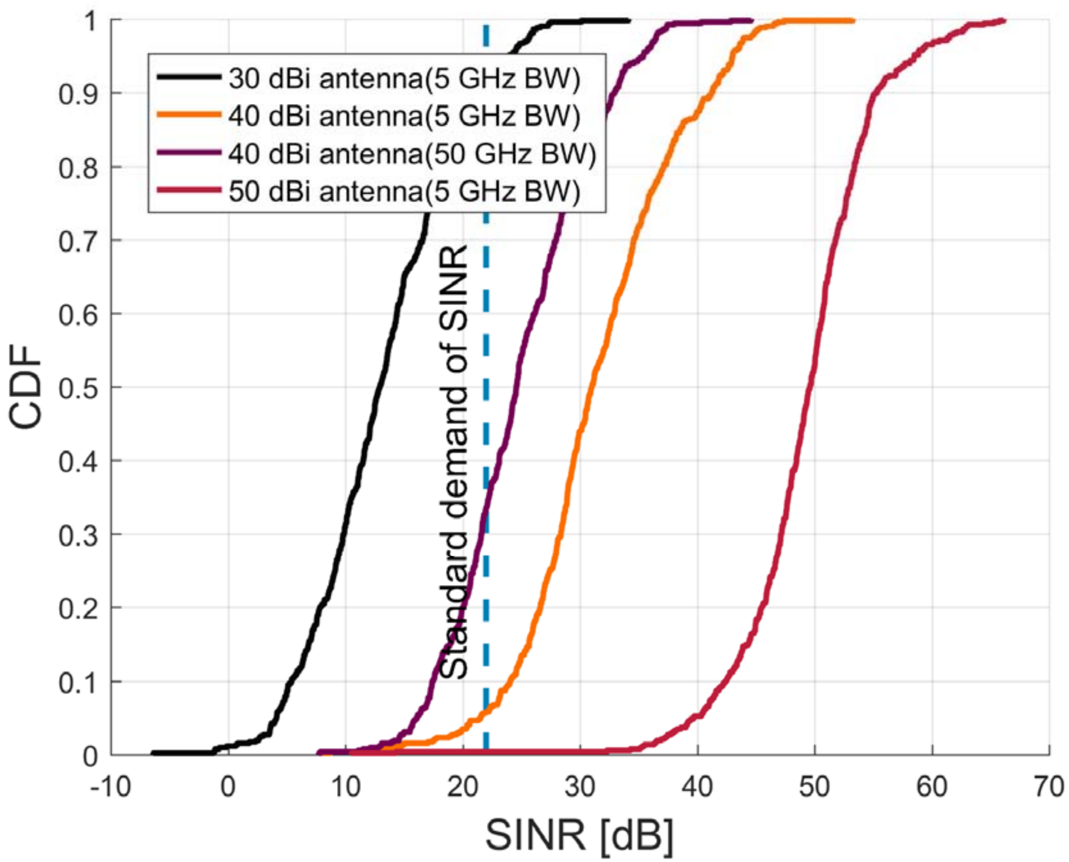


- Hannover scenario
  - 3 Macro cell sites
    (7 sector antennas)
  - 300 new cell sites



- 34 from 300 cell sites
  - Fibre required
  - ~ 89% wireless link

SINR various Antenna Gain



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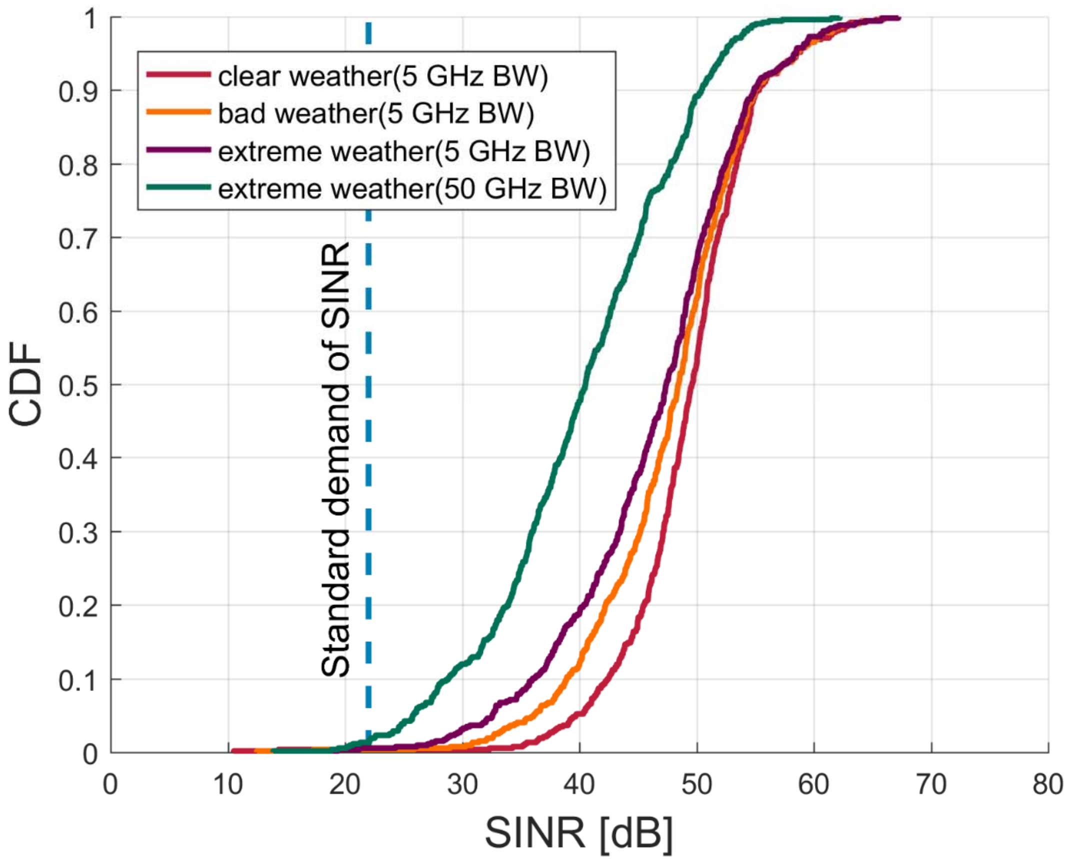
SINR various Weather Condition



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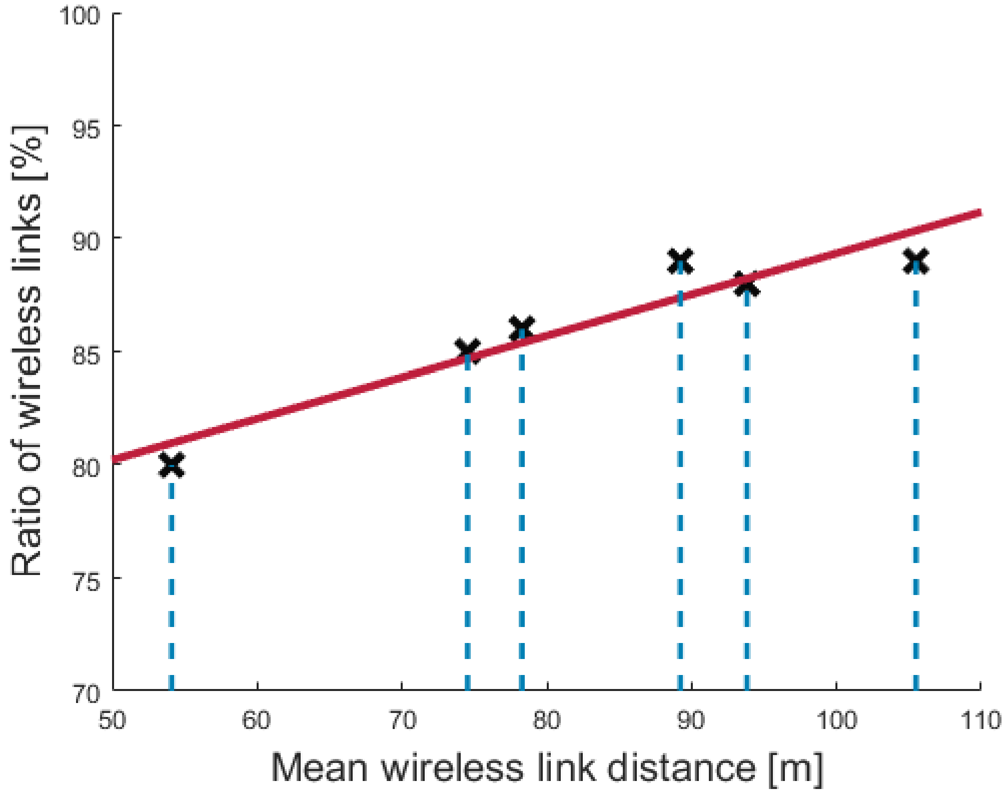
Ratio of wireless links comparing with fibre links

allowed link distance [m]	100	150	200	250	300	350
mean link distance [m]	54.1	74.5	78.3	93.8	89.2	105.5



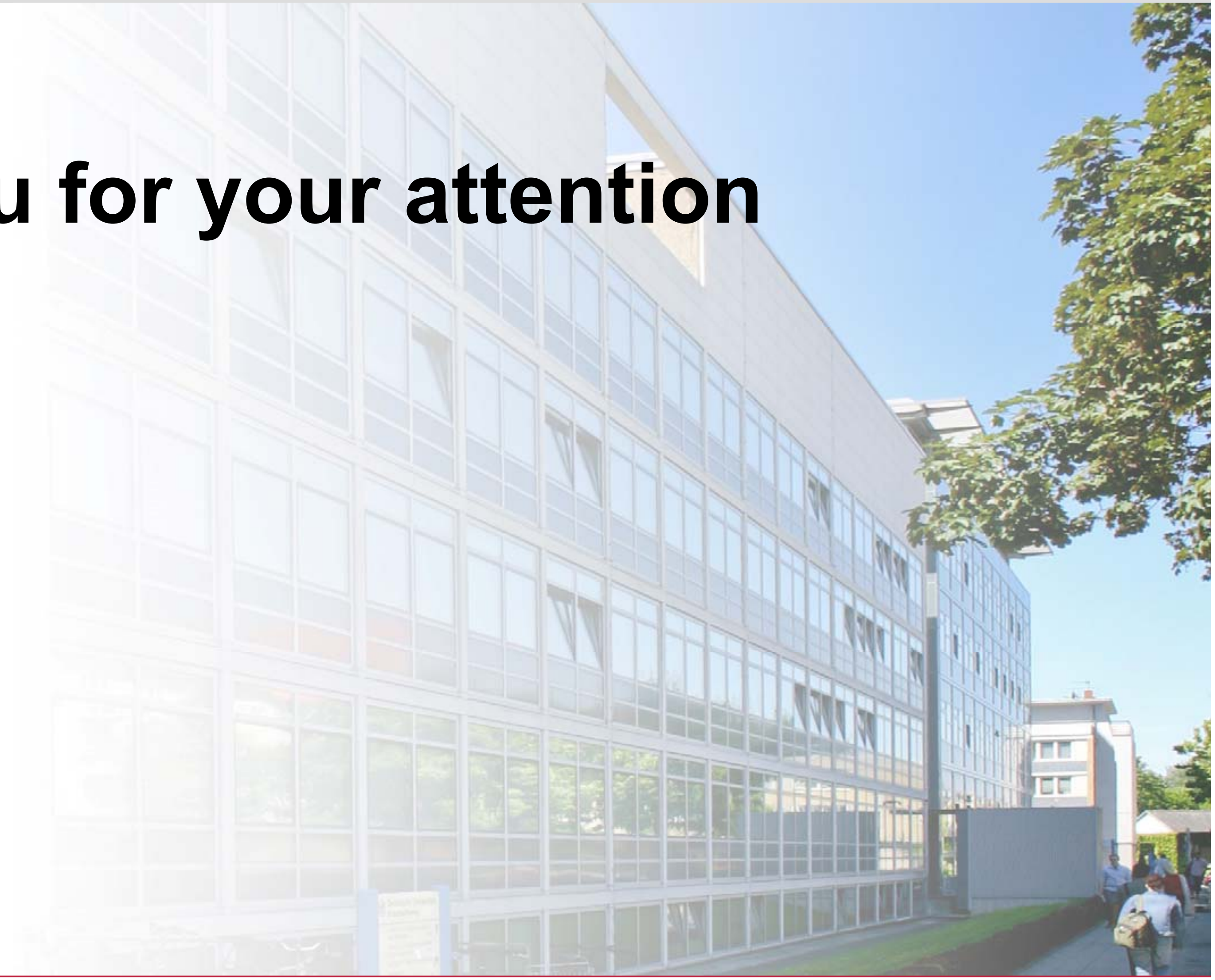
Outline

1. Introduction
2. Planning Approaches
3. Simulation Results
4. **Conclusion**

Conclusion

- Automatic planning algorithm determines wireless backhaul
- Dependency of the planned network on the cell sites and inputs
- Requirement of the high gain antenna (Interference)

Thank you for your attention



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

Submission Title: Results of WRC 2019 AI 1.15 and their impact on THz Communications
Date Submitted: 8 June 2020
Source: Thomas Kürner (Editor) **Company:** TU Braunschweig, Institut für Nachrichtentechnik
Address: Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice: +49 531 391-2416 FAX: +49 531 391-5192, E-Mail: t.kuerner@tu-bs.de
Re: n/a
Abstract: This document presents the results on Agenda Item 1.15 of WRC-2019 and discusses the impact on THz communciations

Purpose: Information of the Technical Advisory Group THz

Results of WRC 2019 AI 1.15 and their impact on THz Communications

Thomas Kürner[1], Akihiko Hirata[2]

[1]Technische Universität Braunschweig, Institut für Nachrichtentechnik, Germany
[2]Chiba Institute of Technology, Japan

This document is based on [1] and [2]

Outline

- Introduction
- Outcome of WRC 19
- Total available Spectrum for THz Communications
- Assessment of WRC 19 outcome
- Possible next steps in IEEE 802
- Conclusions

Introduction (1/2)

- Development of IEEE Std. 802.15.3d-2017 uses the band 252-321 GHzz and has been based on the 2016 version of the Radio Regulations (RR) [3]:
  - The RR include an allocation of the bands from 252 to 275 GHz for the use by land mobile and fixed service
  - Use of band between 275 GHz and 1000 GHz is ruled by footnote 5.565 requiring that passive services such as earth exploration satellite service (EESS) and radio astronomy (RA) have to be protected from harmful interference by any active service, such as THz communications

- Almost all bands above 275 GHz are used either by EESS or RA

=> Sharing studies are required

Introduction (2/2)

- World Radiocommunication Conference WRC 2015 had invited ITU-R to perform “Studies towards an identification for use by administrations for land-mobile and fixed services applications operating in the frequency range 275-450 GHz”

=> WRC AI 1.15

- focus on the sharing studies in preparation to WRC 2019 has been on EESS, see e.g. [4,5], since earlier studies have shown, that RA is less critical.

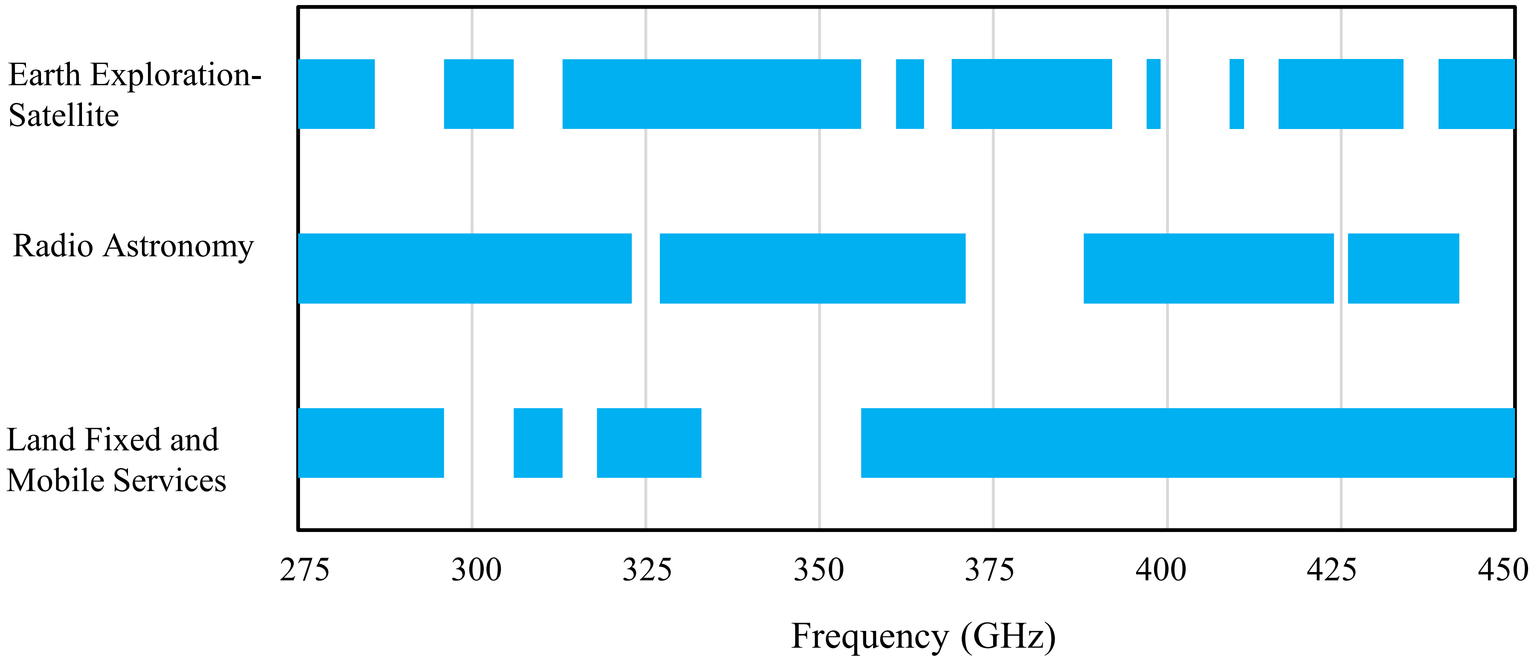
Outcome of WRC 2019 (1/2)

- The outcome is described in the Final Acts of WRC 2019 [6], where the specific outcome of AI 1.15 is the introduction of a new footnote 5.564A, which contains four key items
  - In total, 137 GHz in the band 275 to 450 GHz have been identified for use for land mobile and fixed service, where sharing with EESS is possible and no specific conditions are necessary to protect EESS
  - The remaining 68 GHz of spectrum may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are met.

Outcome of WRC 2019 (2/2)

- In total, 137 GHz in the band 275 to 450 GHz have been identified for use for land mobile and fixed service, where sharing with EESS is possible and no specific conditions are necessary to protect EESS
- The remaining 68 GHz of spectrum may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are met.
- For the whole frequency band 275-450 GHz, specific conditions to protect radio astronomy service may apply.
- The use of the identified bands for land mobile service and fixed service does not preclude the use of the bands by other application or radio service, e. g. radar or imaging

Total available Spectrum for THz Communications



The frequency bands identified for use by administrations for the implementation of LMS and FS applications.

Conditions for the Use of Spectrum for THz Communications

Frequency in GHz	Status in Radio Regulations
252-275	Allocation for land mobile and fixed service on a co-primary basis [3]
275-296 306-313 318-333 356-450	Identification for use for the implementation of land mobile and fixed service according to FN 5.564A; no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications [6].
296-306 313-318 318-356	may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev.WRC-19) [6].

Assessment of WRC 19 outcome

- Outcome of WRC 2019 provides a sound regulatory framework for the implementation of future THz communication systems in the frequency band 252 to 450 GHz.
- Within this band, four contiguous bands are available with bandwidths of
  - 44 GHz between 252 and 296 GHz
  - 7 GHz between 306 and 313 GHz
  - 15 GHz (between 318 and 333 GHz) and
  - 94 GHz between 356 and 450 GHz
- Due to its atmospheric conditions, the band 252 to 296 GHz is favorable for fixed outdoor links with several hundred meters link distances
- The other three bands can be also used for example for short range indoor applications, e. g. wireless links in data centers.

Possible Next Steps for IEEE 802

- IEEE Std. 802.15.3d-2017 covers the frequency bands 252 to 321 GHz.
- Two potential future activities may be triggered in the context of this standard:
  - The continuing use of the frequency bands 296-306 GHz and 313-318 GHz by this standard will be only possible, if additional sharing studies in accordance with Resolution 731 (Rev.WRC-19) show that no harmful interference to EESS occurs

    => potential regulatory activities towards WRC 2023

  - to make use of the large chunk of spectrum between 356 GHz and 450 GHz, an amendment to IEEE 802.15.3d-2017

    => potential stahdardisation activities in IEEE 802.15

Further long-term activities

- Potential agenda item at WRC 2027 on the identification of spectrum for radio location applications in the range 275-700 GHz

⇒Sharing studies with THz communications as the incumbent application.

=> Potential regulatory activity towards WRC 2027.

Conclusions

- Outcome of WRC 2019 w.r.t. THz communications is described.
- A new footnote to the radio regulations, which describes the conditions for the use of the spectrum between 275 and 450 GHz by land mobile and fixed services.
- Totally, 160 GHz of spectrum are now available for THz communications, where no specific conditions are necessary to protect EESS including two big contiguous spectrum bands with 44 GHz and 94 GHz bandwidth, respectively.
- This provides a sound basis for the future implementation of THz communications.
- A couple of future regulatory and standardization activities have been identified.

References

[1] A. Hirata, T. Kürner, Analysis of the Consequences of the Results of WRC 2019, ThoR Deliverable D5.3; available at https://thorproject.eu/results/

[2] T. Kürner, A. Hirata, On the Impact of the Results of WRC 2019 on THz Communications, accepted for publication in Proc. International Workshop on Mobile THz Systems, 2-3 July 2020

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Japan

PROPOSED MODIFICATION TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW APT [RECOMMENDATION/REPORT] ON 'MODEL[S] FOR FWS LINK PERFORMANCE DEGRADATION DUE TO WIND'

1. Introduction

At the AWG-23 meeting held at Da Nang Vietnam in April 2018, TG-FWS started to develop a preliminary draft new APT [Recommendation/Report] on model(s) for FWS link performance degradation due to wind. At the AWG-24 meeting held at Bangkok Thailand in September 2018, Japan input the model for FWS link facility including influence of dynamic factor in addition to static load of antenna and pole due to wind. By this contribution, the model closed to more actual FWS link performance degradation. On the other hand, the Chair pointed to adding different parameters of FWS link facility so that the report would be more generally available.

2. Proposal

Japan proposes to add some examples of FWS link facility to the working document of new APT [Recommendation/Report] (AWG-24/TMP-02) as attached. This additional information includes antenna diameter of 0.6m, pole length of 10m, and combination of both parameters. By this addition, the [Recommendation /Report] will become able to provide more generalized information, and contribute to the users who use millimetre wave link with narrow beam.

Attachment: 1

Contact: NAME
Organization, Country
Email:

ATTACHMENT

DRAFT REVISIONS TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW APT [RECOMMENDATION/REPORT] ON 'MODEL[S] FOR FWS LINK PERFORMANCE DEGRADATION DUE TO WIND'

[***Editor's note: Through the discussion at the AWG-23 meeting, the members agreed that whether to set the goal as a recommendation or a report should be decided according to the future inputs and discussion. The following is the skeleton of main body in the case of the recommendation.***]

The Asia-Pacific Telecommunity (APT),

considering

a) that many Asia-pacific region countries are often under severe weather conditions including tropical cyclones, hurricanes, and typhoons which the maximum wind speeds are very large;

b) that when antennas are exposed to strong winds and their antenna supporting structures start to vibrate, sometimes the directions of the main beams deviate from their desired directions and this causes the antenna gains to drop;

c) that the above antenna gain drop causes the degradation of link performance;

d) that if methods to compensate the degradation of link performance are recommended, it is an ease for communication infrastructure manufactures to implement any one of them to guarantee their link performance;

e) that it is necessary to have effective and easy to install techniques for the systems to realize above methods;

noting

a) that APT Report No. APT/AWG/REP-81~~XX~~ on FWS LINK PERFORMANCE UNDER SEVERE WEATHER CONDITIONS reports the severe weather conditions in APT countries, impact of severe weather conditions on link performance of fixed wireless communication, the mitigation techniques for those impact of severe weather conditions, and the case study of one of its techniques;

~~[***Editor's note: The report number XX will be replace by the actual number once it is approved at AWG-23 meeting.***]~~

b) that there is no APT Recommendation specifically address the link performance under wind conditions before this Recommendation.

recognizing

the needs of countries to complement the degraded FWS link performance due to strong winds.

recommends that APT administrations:

1 use the appropriate attenuation model shown in Annex 1 when an antenna is vibrating due to wind for link analysis;

[2	adopt the technique(s) as shown in Annex 2 to improve or compensate the degraded FWS link performance due to wind.]

Annex 1

Attenuation Models under Wind Conditions

(1) Background

As the increasing number of small cells to satisfy the traffic need per area, it is unavoidable to install radio equipment even on low and vibrating structures (utility poles, street lamps, walls of buildings, etc.), in addition to the conventional high-strength steel towers. In such cases, the equipment installation would be in bad condition, and that leads to the concern of radio quality degradation. Especially when installing antennas with narrow beams in millimetre-wave on an unstable pole, it is necessary to consider the influence of the wind.

(2) Measurement system

We observed the influence of wind to the millimetre wave devices on the pole for 6 months at 85.5 GHz. A parabolic antenna with a diameter of 350 mm, a radio equipment, a weather sensor and an acceleration sensor were installed on a steel pole with a thickness of 89 mm and a length of 5 m. Figure 1 shows the measurement system.

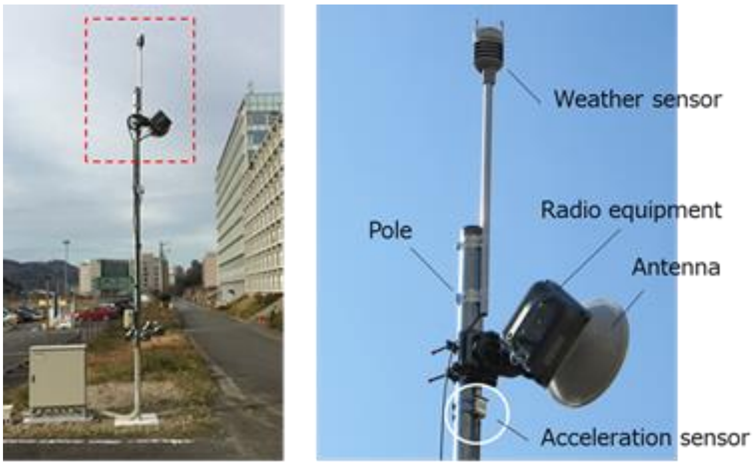

Figure 1 Measurement system

We assume the static load given to the pole and the antenna due to wind and consider it as follows. The calculation model is described in Figure 2.

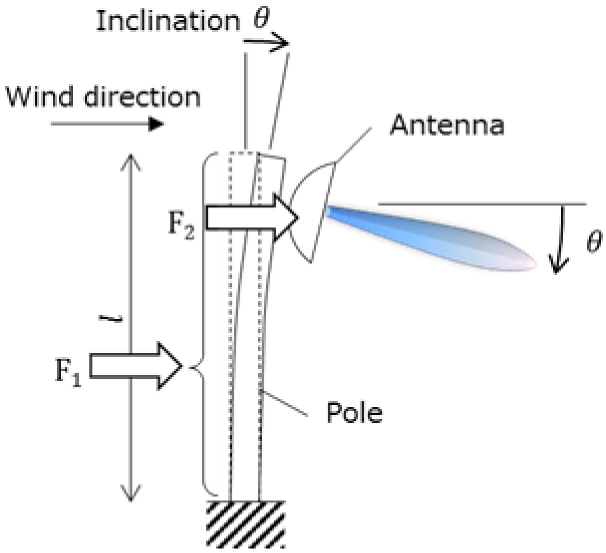

Figure 2 Calculation model

Figure 3 shows an example of the relationship between RSL(Received Signal Level) and wind speed. In this figure, the RSL is composed of two components. One is a static component and the other is a dynamic component like vibration. The inclination of the pole due to static and dynamic wind load is evaluated based on this thought and the model of the degradation of RSL is made. In this measurement system, the inclination of one side is small relative to the other side so the degradation of RSL is estimated.

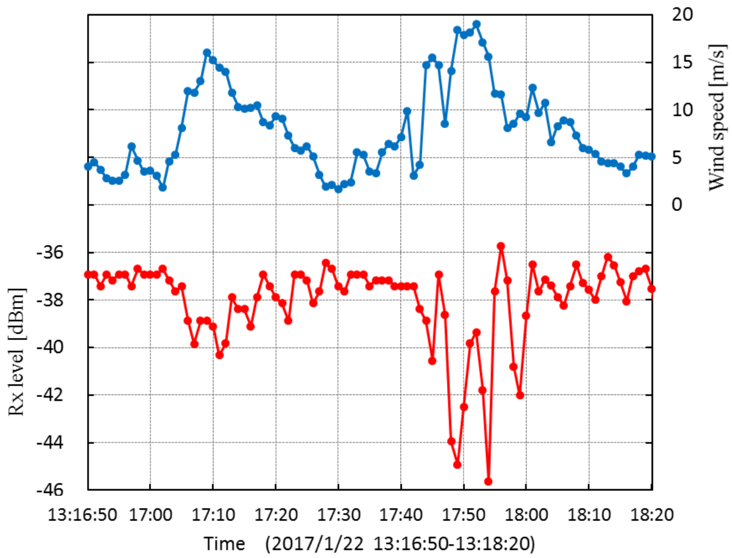

Figure 3 RSL and wind speed

(3) Static component of the inclination due to wind

The inclined angle of the pole assuming the static load taken on the pole and the antenna due to wind is derived as follows.

The velocity pressure when the wind velocity is v is shown as follows.

$$q = \frac{1}{2}\rho v^2 \quad (1)$$

q: Velocity pressure [N/m^2]

ρ: Air density (=1.226[kg/m^3])

v: Wind speed [m/s]

The static load F_1 applied to the pole and the static load F_2 applied to the antenna are shown as follows.

$$F_1 = qC_1A_1, \qquad F_2 = qC_2A_2 \tag{2}$$

F_1: Wind load applied to the pole [N] F_2: Wind load applied to the antenna [N]
C_1: Drag coefficient of the pole C_2: Drag coefficient of the antenna
A_1: Wind receiving area of the pole [m^2] A_2: Wind receiving area of the antenna [m^2]

Inclination angle θ_s is shown as follows.

$$\theta_s = \frac{F_1 l^2}{6EI} + \frac{F_2 l^2}{2EI} = (F_1 + 3F_2)\frac{l^2}{6EI}[rad] = (C_1A_1 + 3C_2A_2)\frac{\rho l^2}{12EI}v^2\frac{180}{\pi}\ [deg] \tag{3}$$

E: Young's modulus [Pa]
I: Second moment of area [m^4]
l: Length of the pole [m]

From the above, the inclination angle θ_s is proportional to the square of the wind speed. The parameter in the mesurement system are shown in Table 1. For simplification, (3) is expressed as (4). The static wind load coefficient C_s in the mesurement system is 4.2 x 10^{-4} deg/(m/s)^2.

Table 1 Parameter of the measurement system

Item	Value
C_1: Drag coefficient of the pole	0.8
A_1: Wind receiving area of the pole	0.445[m^2]
C_2: Drag coefficient of the antenna	1.1
A_2: Wind receiving area of the antenna	0.07[m^2]
E: Young's modulus	2.05 x 10^{11}[Pa]
I: Second moment of area	1.01 x 10^{-6}[m^4]
l: Length of the pole	5[m]

$$\theta_s = (C_1A_1 + 3C_2A_2)\frac{\rho l^2}{12EI}v^2\frac{180}{\pi} \equiv C_s \cdot v^2 \quad [\text{deg}] \tag{4}$$

(4) Dynamic component of the inilicliation due to wind

In the next place, the vibration of the pole is analysed from the measurement results. The pole was vibrating by wind at natural frequency which is 2.3 Hz and the inclination of the pole is derived from the dynamic amplitude which is filtered from measurement results. Maximum value of wind speed and amplitude every ten seconds are adopted. The dynamic inclination angle θ_d of the pole is proportional to the square of the wind speed as static wind load. The coefficient C_d that shows relationship between wind speed and the dynamic inclination is expressed as (5). The C_d from the measurement result is 4.6x10^{-4} deg/(m/s)^2.

$$\theta_d \equiv C_d \cdot v^2 \quad [\text{deg}] \tag{5}$$

(5) FWS link performance degradation

From the above, the inclination of the pole due to static and dynamic wind is modelled. Radiation pattern $g(\theta)$, where θ is deviation angle, is expressed as (6). Where J_1 is Bessel Function of the first kind and θ_{BW} is half power beam width. Figure 4 shows an example of radiation pattern. Its θ_{BW} is 0.9 deg. For simplification, this formula may be changed for polynomial approximation. The degradation of RSL due to wind $R(\theta)$ is expressed as (7). This formula indicates the worst value of RSL against certain wind speed. Regarding the inclination of the pole, misalignment angle of θ_0 should be considered when the antenna is installed.

$$g(\theta) = 20log\left\{2\frac{J_1(u')}{u'}\right\} \text{ [dB]} \quad (6)$$
$$u' = \frac{60\pi}{\theta_{BW}} sin\theta$$

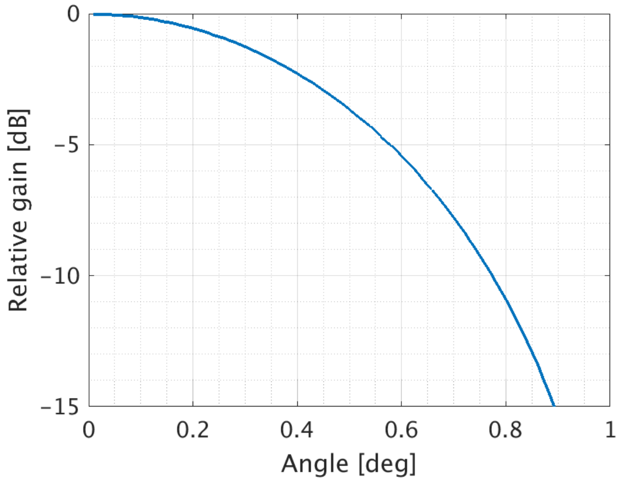

Figure 4 Example of Radiation pattern

$$R(v) = g(\theta_0 + (C_S + C_d)v^2) \text{ [dB]} \quad (7)$$

Figure 5 shows maximum wind speed vs. minimum RSL by every ten seconds. The effect of each term and approximate curve of measurement values are also shown on the figure. According to the figure, the degradation of RSL due to misalignment of the measurement system is about 1.2 dB which corresponds to 0.28 deg. One of the factors of this differences between the two cures is that the effect of the opposite site is not considered. The coefficient C_d is similar to the coefficient C_s. Both coefficients depend on the structure of the pole therefore high correlation is expected and C_d can be approximated to C_s.

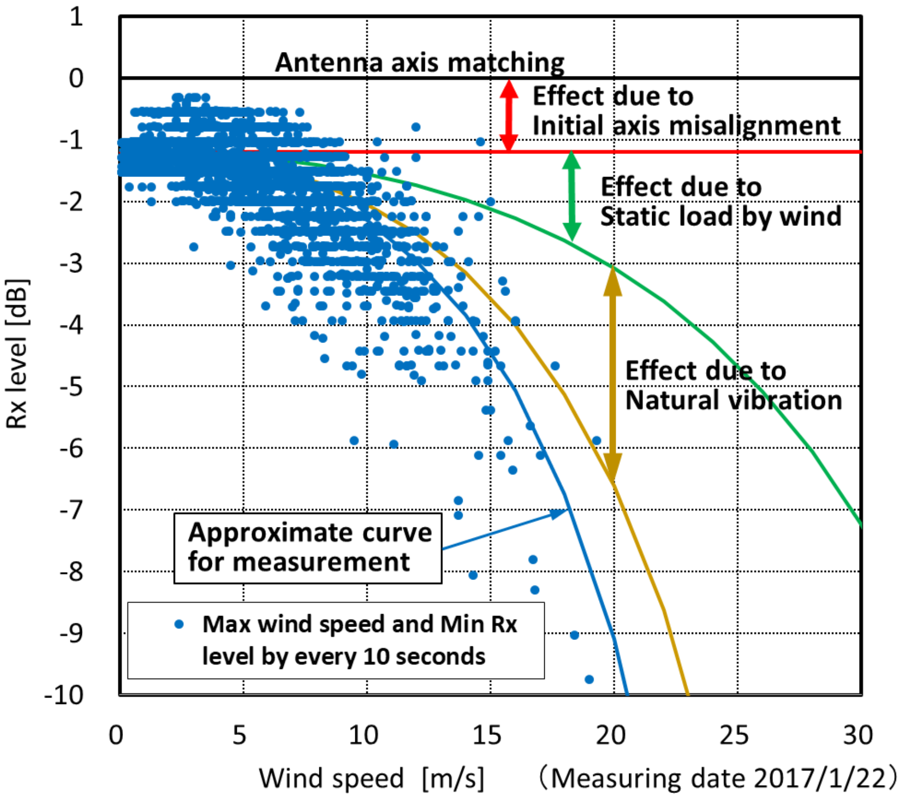

Figure 5 Maximum wind speed vs. Minimum RSL

Regarding opposite site, minimum RSL is calculated as well. Therefore the worst RSL of the FWS link is estimated as sum of minimum RSL of both site (8). Where R_1 and R_2 are minimum RSL of respective site.

$$R_{total} = R_1 + R_2 \tag{8}$$

From the above, the measurement results of the inclination of the pole corresponds to the calculation model thus FWS link performance degradation can be estimated from some parameters and coefficients of the FWS link configuration.

Furthermore, probability of the RSL is estimated from wind speed as follows. The cumulative probability distribution of wind speed is expressed by the Weibull distribution as shown in (1). An example result of this measurement is shown in Figure 6. Weibull coefficient, scale factor *k* equals to 0.86 and shape factor *c* equals to 1.03. The wind speed corresponding to the probability of 99.999% was 17.8 m/s.

$$p(v) = 1 - exp\left\{-\left(\frac{v}{c}\right)^k\right\} \tag{9}$$

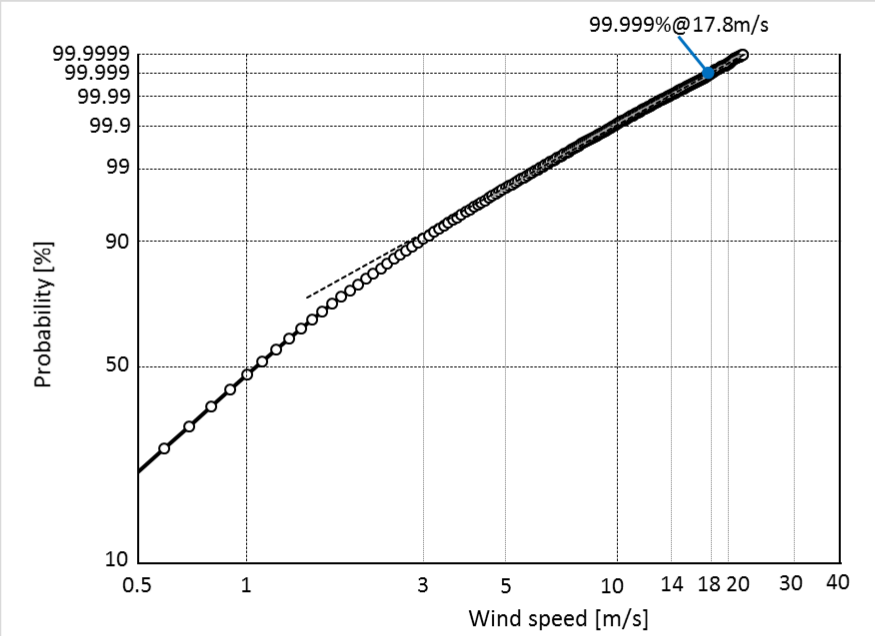

Figure 6 Wind speed distribution

The wind speed is expressed by (10) derived from (9). The relationship between cumulative probability and the degradation of RSL is derived from (10) and (11) considering the initial misalignment of the antenna as shown in (12).

$$v(p) = c\{-\log_e(1-p)\}^{1/k} \text{ [m/s]} \tag{10}$$

$$\theta(p) = \theta_0 + v^2(p)(C_s + C_d) \text{ [deg]} \tag{11}$$

$$R(\theta) = g\{\theta(p)\} \text{ [dB]} \tag{12}$$

Figure 7 shows the probability of gain degradation derived from the relationship between wind speed and the degradation of RSL. The initial alignment error θ_0 is considered. The model corresponds to the measurement results relatively though still some differences remain.

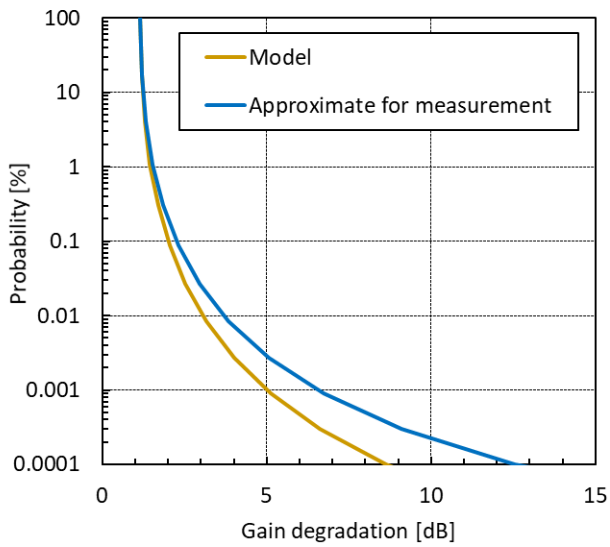

Figure 7 Antenna gain degradation (θ_0=0.28 deg.)

In conclusion, the measurement results of the inclination of the pole corresponds to the calculation model thus FWS link performance degradation can be estimated from some physical parameters and coefficients of the FWS link structure.

(6) Calculation example

Six cases for calculation example are shown as follows. Table 2 shows the parameters of each case. The differences of the cases are diameter and length of pole, antenna diameter and initial alignment error.

Table 2 Parameter examples

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Parameter of the pole							
C_1: Drag coefficient of the pole		0.8	0.8	0.8	0.8	0.8	0.8
l:Length of the pole	m	5	5	10	5	5	10
Diameter of the pole	mm	89	89	165.2	89	89	165.2
Thickness of the pole	mm	4.2	4.2	10	4.2	4.2	10
A_1: Wind receiving area of the pole	m^2	4.45×10^{-1}	4.45×10^{-1}	1.65	4.45×10^{-1}	4.45×10^{-1}	1.65
E: Young's modulus	GPa	205	205	205	205	205	205
I: Second moment of area	m^4	1.01×10^{-6}	1.01×10^{-6}	1.47×10^{-5}	1.01×10^{-6}	1.01×10^{-6}	1.47×10^{-5}
Parameter of the antenna							
C_2: Drag coefficient of the antenna		1.1	1.1	1.1	1.1	1.1	1.1
Diameter of the antenna	m	0.32	0.32	0.32	0.65	0.65	0.65
A_2: Wind receiving area of the antenna	m^2	8.04×10^{-2}	8.04×10^{-2}	8.04×10^{-2}	3.32×10^{-1}	3.32×10^{-1}	3.32×10^{-1}
Beamwidth of the antenna	deg	0.9	0.9	0.9	0.45	0.45	0.45
C_s: Static wind load coefficient		4.40×10^{-4}	4.40×10^{-4}	3.07×10^{-4}	1.03×10^{-3}	1.03×10^{-3}	4.68×10^{-4}
C_d: Dynamic wind load coefficient		4.40×10^{-4}	4.40×10^{-4}	3.07×10^{-4}	1.03×10^{-3}	1.03×10^{-3}	4.68×10^{-4}
θ_0: Initial alignment error	deg	0	0.2	0.2	0	0.2	0.2

The calculation results are shown as follows. Wind speed vs. inclination of the pole is calculated from (11) and its results are shown in Figure 8.

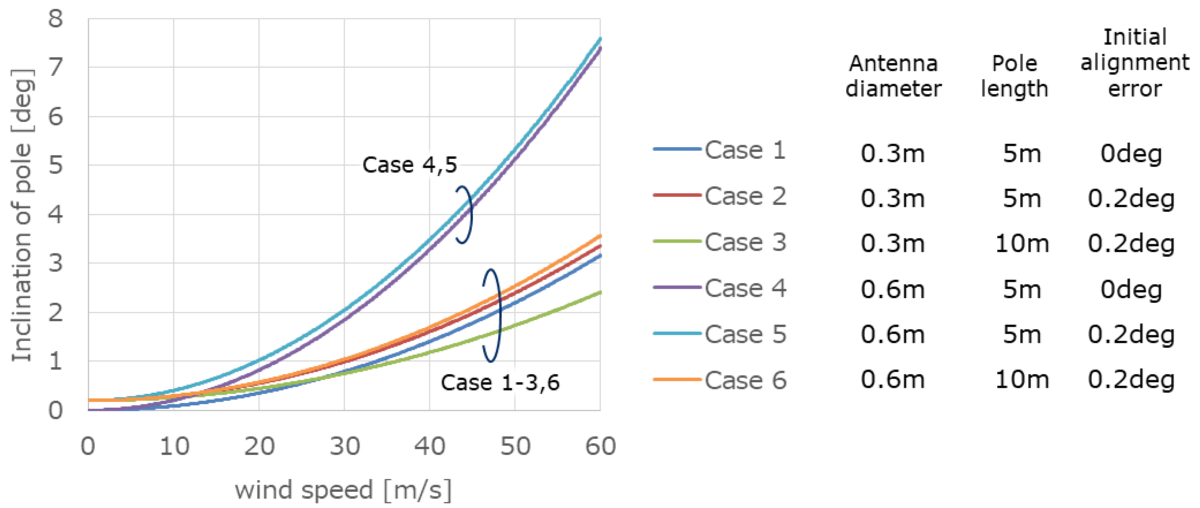

Figure 8 Inclination of pole

Figure 9 shows gain degradation.In this figure, 0 dB means gain degradation of 0.6 m antenna. As the wind speed becomes strong, the gain degradation of the 0.6 m antenna becomes larger than the one of 0.3 m antenna.

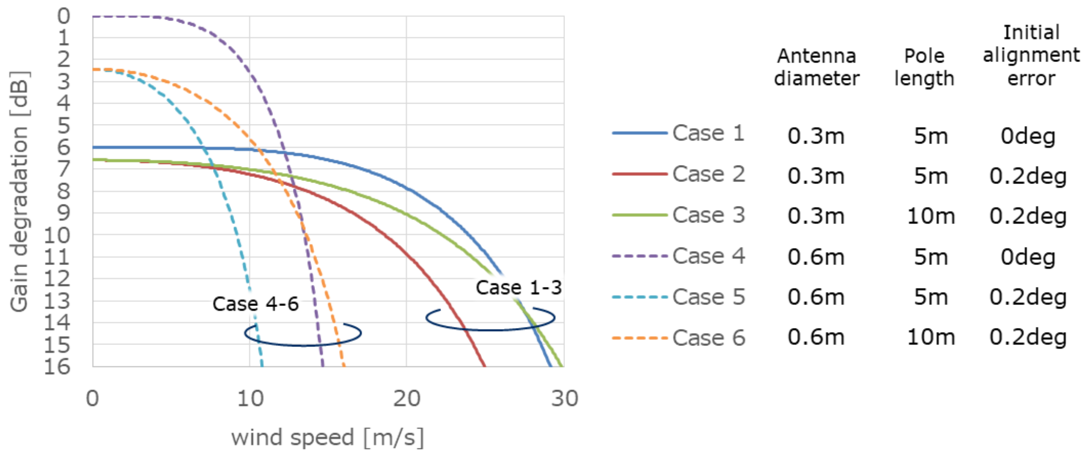

Figure 9 Gain degradation

Probability of gain degradation is calculated from (12) and its results are shown in Figure 10. The probability of gain degradation is not good for the 0.6 m antenna, however good for the 0.3 m antenna under the strong wind condition.

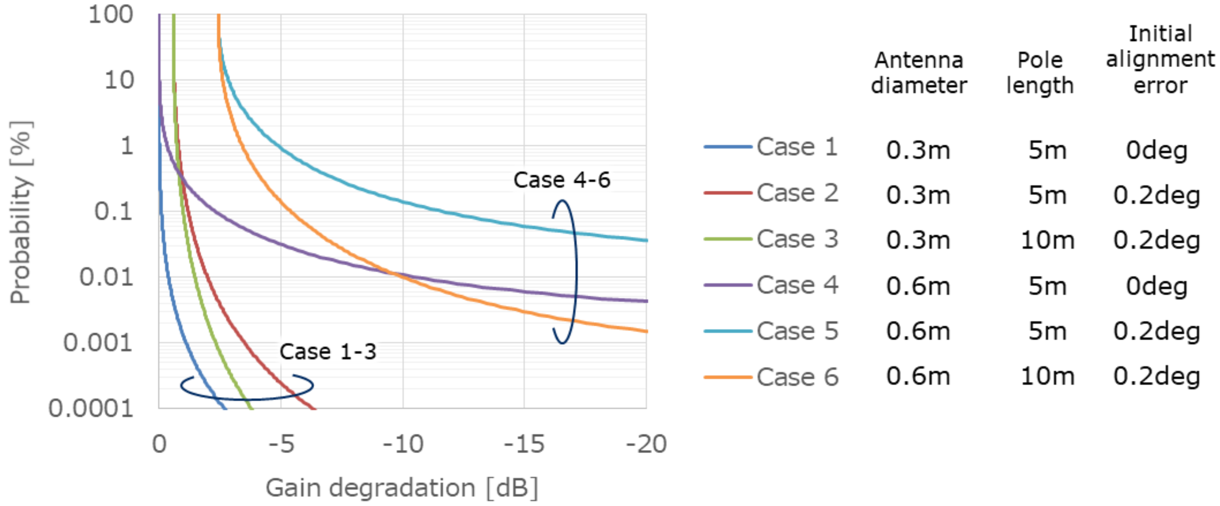

Figure 10 Probability of gain degradation

In these examples, more robust pole is required for the 0.6 m antenna.

[Annex 2

Technique(s) to improve or compensate the degraded FWS link performance due to wind]