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

Submission Title: Presentation on Spectrum Issues at THz Frequencies to IEEE 802.18
Date Submitted: 12 November 2012
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Re: doc. IEEE 802.15-320r1, IEEE 802.15-322, IEEE 802.15-416
Abstract: The document summarizes the current status on spectrum availability for THz communications in the frequency band beyond 300 GHz.

Purpose: Information to IEEE 802.18 form IEEE 802.15 IG THz

Outline

- Summary on possible applications for THz communcations
- Analysis on potential interference with passive services
- Dialogue with representatives from passive services
- Current discussion relevant for THz communications at ITU-R
- Next steps

Possible Applications and Complexity of the Techncial Solutions

Application	Operational Environment	Typical Range	Specific Propagation Conditions	Requirements for Antenna Alignment
Fixed Wireless Links	Links of the backbone network; static use; outdoor	A few hundred meters up to several kilometers	LOS; Atmospheric attenuation becomes important	Highly directive antennas; alignment during the installation process by radio engineers
THz Nano Cells	Part of a hierarchical cellular network; potentially mobile users; indoor as well as outdoor	< 100m	LOS/NLOS; dynamically changing conditions	**automatic beam steering required**
WLAN/WPAN	Connection to access points; nomadic users; mainly indoor	< 100m (mostly < 10m)	LOS/NLOS; dynamically changing conditions	**automatic beam steering required**
Kiosk Downloading	indoor, nomadic use	A few meters (a few cm)	LOS, multiple reflections from Tx and Rx	automatic beam steering (**manual alignment may be possible**)
Connecting Devices on Short Ranges	indoor (typically on a desktop), nomadic use	a few cm	LOS, multipaths from nearby objects and multiple reflections from Tx and Rx	ideally by automatic beam steering, but **manual alignment may be possible**
Board-to-Board Communication	inside computers, fixed use	a few cm	LOS/NLOS, potentially strong multipaths	fixed alignment during design process possible (automatic beam steering as an option)

Source: based on https://mentor.ieee.org/802.15/dcn/11/15-11-0749-00-0thz-scenarios-for-the-application-of-thz-communications.pdf

Situation Radio Regulations after WRC 2012

ITU Radio Regulations Footnote 5.565:

The frequency band 275-1000 GHz may be used by administrations for experimentation with, and development of, various active and passive services.

- Radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, [...]
- Earth exploration-satellite service and space research service 275-277 GHz, 294-306 GHz, 316-334 GHz, [...]

Administrations are urged to take all practicable steps to protect these passive services from harmful interference.

→ Two options for THz communications:

1. Transmission in remaining free parts of the THz spectrum
2. Coexistent spectrum usage with radio astronomy/earth exploration

Source: https://mentor.ieee.org/802.15/dcn/12/15-12-0320-02-0thz-what-s-next-wireless-communication-beyond-60-ghz-tutorial-ig-thz.pdf

Bands not used by EESS

1. Transmission in remaining bands only
   - Very small bandwidths
   - Distributed over entire THz range

→ Not feasible for data rates >> 10 Gbit/s

2. Coexistent spectrum usage
   - Potential interference of active THz systems with
     - radio astronomy
     - spaceborn THz sensors

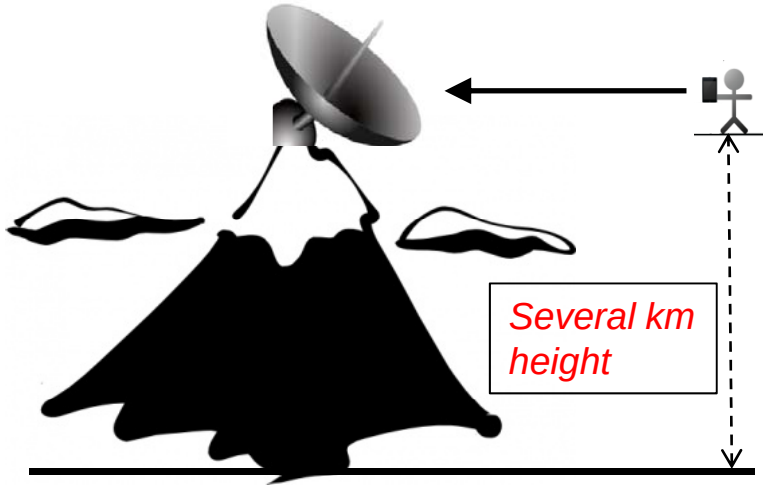
→ Interference investigations inevitable for standardization to comply with the ITU Radio Regulations

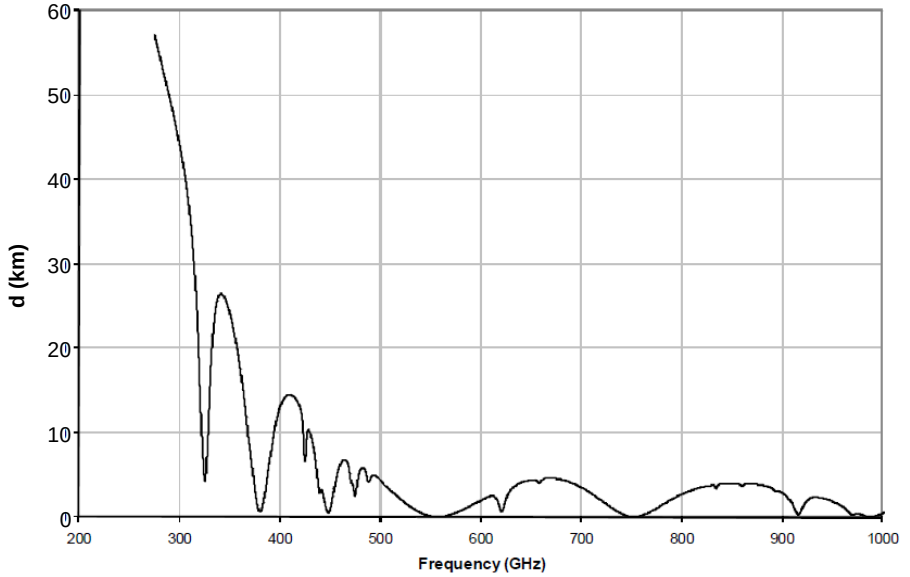
Remaining Frequency Bands	Total available Bandwidth
286-294 GHz	8 GHz
307-313 GHz	6 GHz
356-361 GHz	5 GHz
366-369 GHz	3 GHz
392-397 GHz	5 GHz
399-409 GHz	10 GHz
411-416 GHz	5 GHz
434-439 GHz	5 GHz
467-477 GHz	10 GHz
502-523 GHz	21 GHz
527-538 GHz	11 GHz
581-611 GHz	30 GHz

Source: https://mentor.ieee.org/802.15/dcn/12/15-12-0320-02-0thz-what-s-next-wireless-communication-beyond-60-ghz-tutorial-ig-thz.pdf

Interference with Radio Astronomy

- Studies available by the National Science Foundation
- Distance of THz transmitter from telescope for interference-free conditions in accordance with ITU protection criteria RA.769:
  - *Worst case*: TX pointed directly in direction of telescope at same altitude





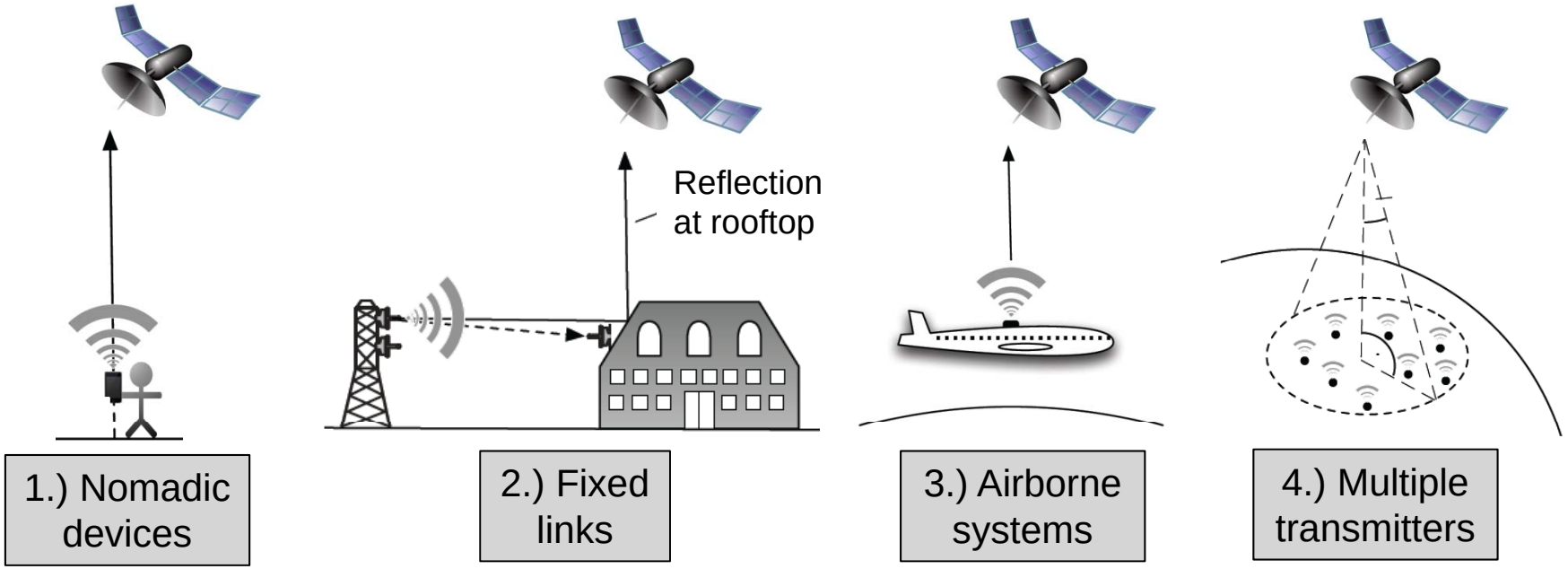
IEEE doc. 802.15-15-10-0829-00-0thz

→ Interference in practice extremely unlikely due high telescope locations on mountains

Source: https://mentor.ieee.org/802.15/dcn/12/15-12-0320-02-0thz-what-s-next-wireless-communication-beyond-60-ghz-tutorial-ig-thz.pdf

Interference with Earth Exploration (1)

- THz transmitters operated outdoor may be pointed skyward:



→ Which is the maximum tolerable interference power?

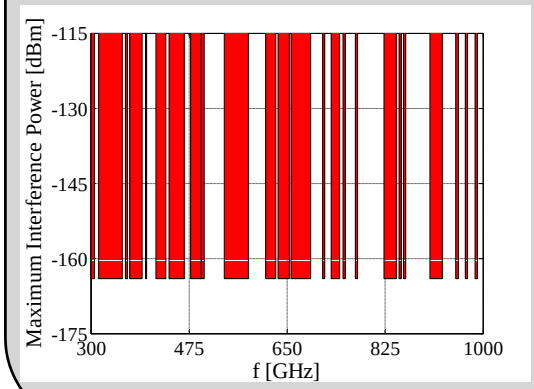
→ How much power will be received by the satellite in the worst case?

Source: https://mentor.ieee.org/802.15/dcn/12/15-12-0320-02-0thz-what-s-next-wireless-communication-beyond-60-ghz-tutorial-ig-thz.pdf

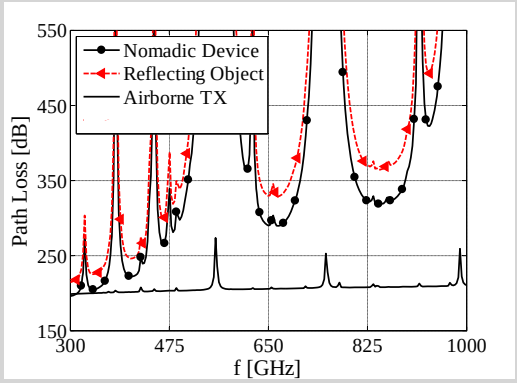
Interference with Earth Exploration (2)

- Determination of maximum allowed TX output powers for interference-free conditions:

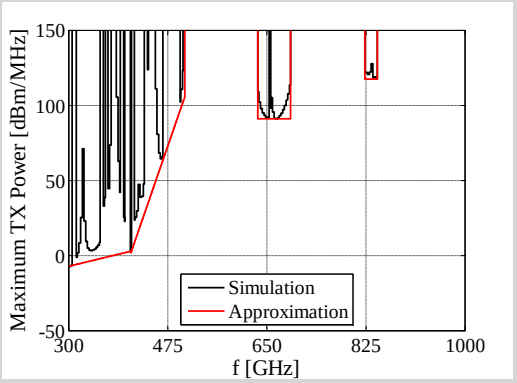
1.) Allowed interference powers according to ITU Rec. 1092



2.) Modeling of path losses from TX to satellite (worst case)



3.) Allowed TX powers for interference avoidance at any rate



→ Interference possible under worst case assumptions

→ Definition of transmit power masks

→ Limitation of output powers to several 10 dBm

Source: https://mentor.ieee.org/802.15/dcn/12/15-12-0320-02-0thz-what-s-next-wireless-communication-beyond-60-ghz-tutorial-ig-thz.pdf

Interference with Earth Exploration (3)

- Maximum allowed isotropic transmit powers (worst case):
  - QPSK modulation
  - 25 dBi RX antenna gain (nomadic, inflight), 55 dBi (fixed link)
  - 5 dB RX noise figure

		300 – 320 GHz 40 Gbit/s	385 – 435 GHz 100 Gbit/s
(1) Nomadic TX	$P_{TX,Max}$	35.9 dBm	47.6 dBm
	d_{Max}	33 m	52 m
(2) Fixed link	$P_{TX,Max}$	40.9 dBm	60.9 dBm
	d_{Max}	964 m	727 m
(3) Inflight	$P_{TX,Max}$	20.5 dBm	19.9 dBm
	d_{Max}	12 m	3 m

WPAN/ WLAN

Backhaul link

Inflight entertainment

→ Sufficient powers allowed to achieve acceptable distances

→ Interference mitigation required for higher powers/longer ranges

Interference Mitigation Concepts

1. Transmit power masks

→ TX power control

2. Automatic shutdown in case of TX mispointing

→ Sensor data usage (e.g. orientation and position)

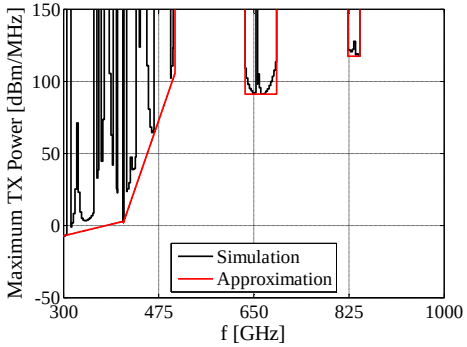
3. Electrically steerable antennas

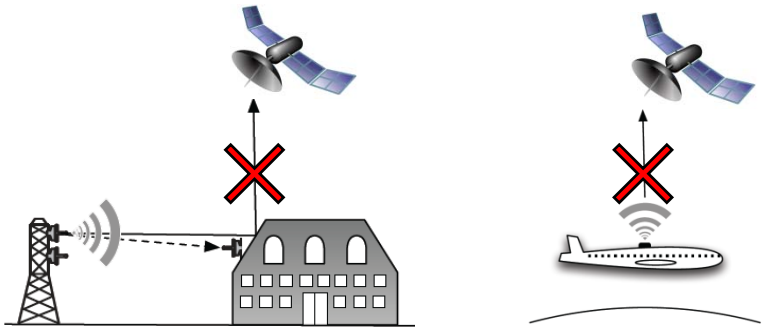
→ Automatic precise beam pointing

4. Environment control
   - Fixed links
   - Airborne systems

→ Careful TX placement

→ Absorbing materials





→ Avoidance of interference in any case with interference mitigation

Dialogue with Representatives from Passive Services

- IG THz has started the dialogue quite early with representatives from passive services
- Presentations have been made to the IG THz both from representatives of Radio Astronomy and EESS
  - https://mentor.ieee.org/802.15/dcn/11/15-11-0765-00-0thz-remote-sensing-applications-of-thz-bands.pdf
  - https://mentor.ieee.org/802.15/dcn/10/15-10-0829-00-0thz-sharing-between-active-and-passive-services-at-thz-frequencies.ppt
- Discussion started also with the Conference on Radio Frequencies (CORF)
  - https://mentor.ieee.org/802.15/dcn/12/15-12-0322-00-0thz-2-status-report-of-meeting-with-passive-sciences-corf-committee.pdf

Conference On Radio Frequencies

CORF – National Academies

May 17, 2012 Meeting

Radio Astronomy
EESS Remote Sensing
AT&T Labs Research
Marcus Spectrum Solutions LLC

CORF represents the interests of U.S. scientists who use radio frequencies for research—for example, radio astronomers and remote sensing researchers. The committee deals with radio-frequency requirements and interference protection primarily through filing comments under the aegis of the National Academy of Sciences in public proceedings of the Federal Communications Commission. The committee acts as a channel for representing the interests of U.S. scientists in the work of the Scientific Committee on Frequency Allocations For Radio Astronomy and Space Science (IUCAF) of the International Council for Science and in working groups of the Radio communication Sector of the International Telecommunication Union (ITU).

Source: https://mentor.ieee.org/802.15/dcn/12/15-12-0322-00-0thz-2-status-report-of-meeting-with-passive-sciences-corf-committee.pdf

Situation at ITU-R

- Next WRC does not include any agenda item dealing with frequencies beyond 275 GHz
- However, a couple of questions related to or having impact on THz communications have been submitted to ITU-R

THz related Question ITU-R

- Question ITU-R 264/4 on technical and operational characteristics of networks of the fixed-satellite service operating above 275 GHz; (WP4A)
- Question ITU-R 235-1/7 on technical and operational characteristics of applications of science services operating above 275 GHz;(WP7B/WP7C/WP7D)
- Question ITU-R 228-1/3 on propagation data required for the planning of radiocommunication systems operating above 275 GHz; (WP3M)
- Question ITU-R 253/5 Fixed service use and future trends; (WP5C)

Source https://mentor.ieee.org/802.15/dcn/12/15-12-0416-00-0thz-thz-standardisation-activities-on-itu-r.pdf

Proposal on New Study Question

- Question ITU-R SM. [THZ], “Technical and operational characteristics of the active services operating in the range 275-1 000 GHz” was proposed at WP1A meeting on July 2012. (1A/25)
- This Question was proposed to study;
  - What are the technical and operational parameters, and the characteristics of active services in the frequency range 275-1 000 GHz.
  - Are sharing studies required for active services operating in the range 275-1 000 GHz?
- This proposal was liaised with the concerned Working Parties via liaison statement (1A/40) and will be redrafted at the next WP1A meeting according to their comments from the concerned Working Parties.
- Administrations interested in this Question are invited to review and input their comments.

Source https://mentor.ieee.org/802.15/dcn/12/15-12-0416-00-0thz-thz-standardisation-activities-on-itu-r.pdf

Question ITU-R 253/5

This Question was proposed to study;

What are the key trends and drivers of technologies and applications for the fixed service across the different FS bands over the 2013-2023 period and beyond, taking into account:

- deployment scenarios, propagation considerations, technology developments, capacity and spectrum requirements;
- *the use of the higher millimeter wave frequency bands (e.g. above 60 GHz);*
- the technical and operational requirements for fixed wireless systems operating in the higher millimeter wave bands, including high capacity, e.g. Gigabit-class, links?

Source https://mentor.ieee.org/802.15/dcn/12/15-12-0416-00-0thz-thz-standardisation-activities-on-itu-r.pdf

DRAFT NEW REPORT ITU-R F.[FS USE-TRENDS] - Fixed service use and future trends

CONTENTS

Source https://mentor.ieee.org/802.15/dcn/12/15-12-0416-00-0thz-thz-standardisation-activities-on-itu-r.pdf

Next Steps

- What should be the role of IEEE 802 in the process of studying these questions?
- What is the advice from IEEE 802.18?