



3D RayTracing Interference Analysis in V-Band

PREVIEW
iTech STANDARD
(standards.itech.ai)
Full standard:
<https://standards.itech.ai/catalog/standards/sist/1a00054-447-4718-84c7-d91658999c4b/etsi-gr-mwt-010-v1.1.1-2018-04>

Disclaimer

The present document has been produced and approved by the millimetre Wave Transmission (mWT) ETSI Industry Specification Group (ISG) and represents the views of those members who participated in this ISG.
It does not necessarily represent the views of the entire ETSI membership.

Reference

DGR/mWT-0010

Keywords

3D ray-tracing, 60 GHz, FWA, interference
analysis, listen before talk, mWT, network
performance, V-band

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

The present document can be downloaded from:<http://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the only prevailing document is the print of the Portable Document Format (PDF) version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at

<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:

<https://portal.etsi.org/People/CommiteeSupportStaff.aspx>

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2018.

All rights reserved.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members.

3GPP™ and **LTE™** are trademarks of ETSI registered for the benefit of its Members and
of the 3GPP Organizational Partners.

oneM2M logo is protected for the benefit of its Members.

GSM® and the GSM logo are trademarks registered and owned by the GSM Association.

Contents

Intellectual Property Rights	5
Foreword.....	5
Modal verbs terminology.....	5
Executive summary	5
Introduction	6
1 Scope	7
2 References	7
2.1 Normative references	7
2.2 Informative references.....	7
3 Abbreviations	8
4 System model for 3D RayTracing simulations	9
5 3D RayTracing interference analysis	10
5.1 Washington simulation scenario.....	10
5.1.1 Simulation cases	10
5.1.2 Mesh network topology at street level	11
5.1.3 Simulation method and results.....	12
5.1.4 Street to roof network topology	13
5.1.5 Additional WiGig interferers	14
5.1.6 Long street paths.....	15
5.2 Shanghai, China simulation scenario.....	18
5.2.1 Roof-to-roof.....	18
5.2.2 Nodal specific case	19
6 2D interference analysis	21
6.1 Rooftop deployment scenario simulation	21
6.2 Street-level deployment scenario simulation.....	25
7 3-D RayTracing Simulations of Outdoor Coexistence in V-band.....	27
7.1 Suitability of V-Band for FWA use case	27
7.1.1 Introduction.....	27
7.1.2 San Jose simulation scenario	28
7.1.3 FWA link characteristics	28
7.1.4 FWA C/I simulation results	28
7.2 Coexistence of FWA and Fixed Services (FS) in the V-band	29
7.2.1 Analysis	29
7.2.2 FS Exclusion zone analysis.....	29
7.2.3 Statistical analysis.....	30
7.2.4 Section of San Jose deployment	32
7.2.4.1 Introduction.....	32
7.2.4.2 Scenario 1a.....	32
7.2.4.3 Scenario 1b: FS links perpendicular to street.....	32
7.2.4.4 Scenario 2: directed BF at FWA nodes.....	33
7.3 San Jose simulation conclusion	34
8 Distribution Networks and Short Range Devices Coexistence	34
8.1 Overview	34
8.2 Outdoor to indoor penetration with DN to CN transmission	35
8.3 Outdoor to indoor penetration with CN to DN	37
8.4 Outdoor to indoor penetration with CN to DN summary	39
9 Network Analysis.....	40
10 Listen Before Talk.....	41
10.1 Overview	41

10.2	System model	41
10.3	Simulation results	42
Annex A:	Network simulation parameters	44
A.1	Parameter definition	44
A.2	Simulation assumptions.....	44
Annex B:	mmWV FWA.....	47
B.1	Overview	47
Annex C:	Authors & contributors.....	49
Annex D:	Change History	50
History		51

iTeh STANDARD PREVIEW
 (standards.iteh.ai)

Full standard:
<https://standards.iteh.ai/catalog/standards/sist/1ab6ad54-44f7-4718-84c7-d91658999c4b/etsi-gr-mwt-010-v1.1.1-2018-04>

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) millimetre Wave Transmission (mWT).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The simulation results, reported in the present document, upon the Mesh network model for FWA, provide a positive feedback to deploy this outdoor application in V-Band.

It is shown that it is possible to run a network with only one frequency channel with high throughput (1,6 Gbps per link and a total 6,6 Gbps when the traffic generated from four equipment reach the fibre point of presence) and relative small delay (The performance is reached when the last link capacity is not exceeded.).

Further simulations show that high density networks can be deployed at low interference level by using steerable antenna and that on a Manhattan Grid topology the interference level experienced by using fixed beam antenna or steerable antenna is practical the same.

It has been shown that FWA links operating in V-Band can coexist well by using the same frequency channel (i.e. reuse-1) provided proper timing synchronization, assignment of TX/RX roles and working TPC.

In addition, also outdoor coexistence studies between FWA and FS applications are presented and collocated FWA links affect FS links in relatively small percent of cases (mostly below 10 %).

Exclusion zones for FS links are meaningless for street level deployments since reflections from interfering signal outside of the exclusion zone can bring interfering signal back to the receiver.

It is also confirmed that mmWV distribution network STAs do not harm indoor operation.

Finally, it is shown that LBT can guaranteed good performance in term of Average Transmit Capacity by allowing fair spectrum usage too.

Introduction

V-Band communication links are foreseen to be used for both access and transport applications.

Access applications, which are the main subject of the present document, include street level connectivity, urban/suburban fixed broadband residential access and business connectivity.

They are widely known as Fixed Wireless Access (FWA).

Transport applications include connecting devices such as Wi-Fi access-point and smart-city sensor.

These applications are compatible with V-Band equipment short range and small foot print characteristics used for FWA, which make street level installations using either P2P or P2MP topology possible.

V-Band equipment may also be used in rooftop to street connectivity, for access applications and as a feeding point for street-level chains.

The links range using beam-steering antennas is limited due to their relatively low gain to about 200 m (typical), and is additionally restricted by the availability of clear line-of-sight [i.2]. Link operation is strongly protected from interference by line-of-sight blockage (typically by structures and foliage) and by Oxygen absorption which reaches at maximum 15 dB/km in the band (around 59 GHz).

There are also secondary protection mechanisms such as the antenna spatial filtering, i.e. the low transmit power spread across wide bandwidth, leading to low spectral power density and robust modulation schemes typically being used.

NOTE: To circumvent residual interference and enhance operation reliability, sharing algorithms such as dynamic frequency selection (DFS) and listen before talk (LBT) medium access protocols may be deployed but are not object of the present document.

1 Scope

The present document presents results of an interference analysis, carried on parts of a real city scenarios, supported by a 3D ray tracing SW tool.

Also, network capacity, delay and LBT performance evaluations are provided for specific simulation cases.

A focus has been put on the new usage model called "mmWave Distribution Network", also known as "Mesh Network", as recently proposed by IEEE 802.11 [i.1] in July 2017.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] IEEE 802.11™-2015/0625r5: "IEEE 802.11 TGay Use Cases", July 2017.

NOTE: Available at <https://mentor.ieee.org/802.11/dcn/15/11-15-0625-07-00ay-ieee-802-11-tgay-usage-scenarios.pptx>.

[i.2] CEPT ECC SRD/MG SRDMG(17)062 19 April 2017: "60 GHz considerations for discussion" (Huawei contribution).

[i.3] IEEE 802.11ad™-2016: "IEEE Standard for Information technology--Telecommunications and information exchange between systems--Local and metropolitan area networks--Specific requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 3: Enhancements for Very High Throughput in the 60 GHz Band".

[i.4] M. Zaaamia, R. Touhami, A. Hamza and M. C. E. Yagoub: "Design and performance evaluation of 802.11ad phys in 60 GHz multipath fading channel", International Workshop on Systems, Signal Processing and their Applications (WoSSPA) 2013 8th Algiers, pp. 521-525.

[i.5] ETSI EN 302 217-2 (V3.1.1) (05-2017): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2: Digital systems operating in frequency bands from 1 GHz to 86 GHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.6] Recommendation ITU-R F.699-7 (04-2006): "Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz".

[i.7] CEPT ECC ERC Report 173: "Fixed Service in Europe Current use and future trends post 2011" and revisions.

[i.8] ETSI GS mWT 004 (V1.1.1) (06-2016): "Millimetre Wave Transmission (mWT); V-band street level interference analysis".

- [i.9] CEPT ECC ERC Recommendation 70-03 : "Relating to the use of Short Range Devices (SRD)".
- [i.10] ETSI EN 302 567 (V2.1.1) (07-2017): "Multiple-Gigabit/s radio equipment operating in the 60 GHz band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".
- [i.11] European Commission, Broadband strategy & policy.
- NOTE: Available at <https://ec.europa.eu/digital-single-market/en/broadband-strategy-policy>.
- [i.12] IEEE P802.11 - Task Group ay - Meeting Update.
- NOTE: Available at http://www.ieee802.org/11/Reports/tgay_update.htm.

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

A-BFT	Association Beam-Forming Training
AG	Aktiengesellschaft
NOTE:	German: Stock Corporation.
AP	Access Point
ATPC	Automatic Transmission Power Control
BER	Bit Error Ratio
BF	Beam Forming
BI	Beacon Interval
BS	Base Station
BTI	Beacon Transmission Interval
BW	BandWidth
CBAP	Contention-Based Access Period
CCA	Clear Channel Assessment
CDF	Cumulative Distribution Function
CN	Client Node
DFS	Dynamic Frequency Selection
DL	Down Link
DN	Distribution Node
DOA	Direction Of Arrival
DOD	Direction Of Departure
DTI	Data Transfer Interval
eCCA	extended Clear Channel Assessment
ED	Energy Detection (threshold)
EIRP	Effective Isotropic Radiated Power
FBR	Front to Back Ratio (antenna parameter)
FCC	Federal Communication Commission
FS	Fixed Service
FWA	Fixed Wireless Access
HPBW	Half Power Beam Width
I	Interference (i.e. interference signal both single or aggregate)
IAP	Interferer Access Point
LBT	Listen Before Talk
LOS	Line Of Sight
MAC	Medium Access Control (Layer)
MCS	Modulation and Coding Scheme
MDU	Multi-Dwelling Unit
mmWV	millimetre WaVe
MP	Multi-Point
MPDU	MAC Protocol Data Unit
NF	Noise Figure
NFD	Net Filter Discrimination
NLOS	Non-Line Of Sight

P2MP	Point to Multi-Point
P2P	Point to Point
PD	Power Detection (threshold)
PEC	Perfect Electromagnetic Conductor
PHY	Physical
PMP	Point-Multi-Point
POP	Point Of Presence
PtMP	Point to Multi-Point
PtP	Point to Point
QPSK	Quadrature Phase-Shift Keying
RF	Radio Frequency
RPE	Radiation Pattern Envelope
RT	Remote Terminal
RX	Receiver
S	Signal (i.e. wanted signal)
S/I	Signal to Interference ratio
SINR	Signal to Interference and Noise Ratio
SNR	Signal to Noise Ratio
SP	Service Period
SRD	Short Range Device
STA	STAtion (node)
SW	Software
TD	Threshold Degradation
TDD	Time Division Duplex
TPC	Transmission Power Control
TRN-T/R	Transmit or Receive Training
TS	Time Slot
TX	Transmitter
U	Number of interference links
UL	Up Link
WiGig™	Wireless Gigabit Alliance

4 System model for 3D RayTracing simulations

The simulation procedure, which has been performed for various scenarios, is based on a 3D map, over which a set of network elements are placed, in accordance with the analysed case. Links within this network are then analysed on each transmission directions (i.e. both DL and UL), to evaluate the received signal, noise and interference levels.

Two kinds of nodes, provided with steerable antenna, have been defined AP (Access Point) and RT (Remote Terminal). In each AP node two sectors (or directions) can be covered.

Systems operate in TDD mode and simulations are executed in absence of rain (i.e. clear sky).

Two different frequency arrangements have been used: the former with a single channel frequency and the latter with two channels available.

The EIRP value is fixed at 40 dBm as maximum value allowed by CEPT in Europe and FCC for non-fixed P2P application in USA.

NOTE: At current moment only for indoor application and for non-fixed outdoor application.

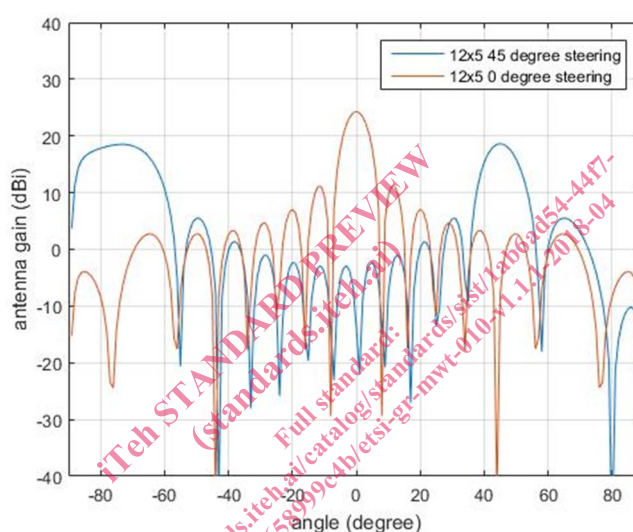
The steerable antenna is simulated as a Phased-Array antenna with 60 elements (a 12 x 5 array was used, with phase shifters for each element) with 6,5 dBi gain/element.

In Table 1 the main characteristics of the simulated systems are shown and in two simulated RPE diagram examples are reported in two steering directions (i.e. 0° and 45°).

Only in clause 6 a 2D geometric interference analysis has been performed.

Table 1: Main system characteristics

Parameters	Value
EIRP	40 dBm
TX power level	17,5 dBm
Noise figure	7 dB
Bandwidth	2 160 MHz (WiGig RF Channel)
Front to back separation	90 dB
Adjacent channel separation	20 dB (NFD)
Receiver sensitivity	-61 dBm (for IEEE 802.11ad MCS 8) [i.3]
Antenna main lobe gain	22,5 dBi
Max steering angle (range)	45° only on azimuth plane
HPBW azimuth	±5°
HPBW elevation	±10°
Installation Height	3 m except otherwise specified
Reference modulation and coding scheme	MCS 8
SINR (BER 10 ⁻⁶)	7 dB (Table A.1)

**Figure 1: Antenna RPE diagram at 0° (boresight) and 45° pointing directions**

5 3D RayTracing interference analysis

5.1 Washington simulation scenario

5.1.1 Simulation cases

The considered area is a portion of Washington D.C. (USA), a typical dense urban clutter (Figure 2). The green square is the actual map available for the simulation tool but, due to symmetry of the topology and buildings shielding, only the yellow sector has been analysed in detail.

Equipment with antennas are placed at height ranging from 3 m to 5 m.

Two simulation cases have been considered:

- Mesh network.
- Linear network topologies, to consider street canyoning.



Figure 2: Washington D.C. considered sector

5.1.2 Mesh network topology at street level

In Figure 3 the basic arrangement for mesh network topology is shown. In the simulated network model there are:

- 3 fibre Points of Presence (PoP), depicted as blue diamonds (node 1, 7 and 11).
- 9 Access Points (AP), depicted as yellow placeholders (nodes).
- Other 3 APs are placed in same positions of PoPs.

A specific graph has been selected to connect PoPs and APs and it is depicted with solid arrows. Furthermore, each PoP is assumed to reach some APs by means of a preferential path resulting in 3 different "network island" (blue dashed ellipses).

The three different network islands are based on network topology, in relation with simulated traffic flow through network nodes (such as spanning tree).

Possible alternative paths are represented by dashed arrows.

Simulations have been carried out only for the preferential path (i.e. solid connection lines).

Transmission direction from each PoP onwards is assumed as "downlink" (DL) and the opposite is considered as "uplink" (UL) in the present document.



Figure 3: Specific portion analysed

5.1.3 Simulation method and results

For each link and for each direction (UL/DL), the wanted received signal (S) and the aggregated level of interference coming from all other links in the network (I) are computed by means of a 3D ray-tracing tool.

Results are shown in terms of Signal to Interference Noise Ratio (SINR) and Signal to Noise ratio (SNR).

Table 2: One single channel used

AP	AP	Length [m]	SINR_DL [dB]	SINR_UL [dB]	SNR [dB]
AP02	AP03	140	22,6	18,4	22,6
AP10	AP11	221	4,88	9,07	9,07
AP08	AP07	118	21,5	21,6	21,6
AP09	AP05	167	13,1	10,1	14,3
AP06	AP05	105	20,1	19,6	24,3
AP06	AP07	161	8,28	12,5	12,5
AP01	AP04	120	9,94	11,7	14,1
AP03	AP04	51,6	13	14,1	18,3
AP10	AP13	117	19,1	15	19,1

Table 3: Two RF channels used

AP	AP	Length [m]	SINR_DL [dB]	SINR_UL [dB]	SNR [dB]
AP02	AP03	140	22,6	22,5	22,6
AP10	AP11	221	9,07	9,07	9,07
AP08	AP07	118	21,5	21,6	21,6
AP09	AP05	167	14,2	14,2	14,3
AP06	AP05	105	24,2	24,2	24,3
AP06	AP07	161	12,4	12,5	12,5
AP01	AP04	120	14,1	14,1	14,1
AP03	AP04	51,6	18,2	18,2	18,3
AP10	AP13	117	19,1	15	19,1

Table 2 and Table 3 show that the availability of a single channel in the network is enough to guarantee the use of MCS 8, while the addition of a second channel exhibits a SINR improvement on average of 2 or 3 dB.

5.1.4 Street to roof network topology

In this simulation scenario (Figure 4 and Figure 5) the network elements density has been increased by adding some more RT nodes as access terminals on the rooftop corners of buildings (such as in a FWA use case). Antenna vertical HPBW characteristic only is used to access the roof terminals (no steering capability assumed in Elevation plane). As usual direction towards the access point is referred as uplink (UL) and the opposite is downlink (DL).

Results for the simulated links are shown in case the buildings and the streets are realized by a partial reflecting material (concrete) or by a perfectly reflecting one.



Figure 4: Simulation scenario



Figure 5: Antenna Vertical HPBW

Table 4 is showing results in case material constituting buildings and road are not reflective.

Result show that most links can have SINR much higher than 10 dB by reaching values up to about 38 dB. Such links are in Line of Sight conditions.

For other links, where LOS condition is not met, the propagation is dominated by diffraction, and the SINR appears much lower. These links, AP07-RT10 and AP11-RT03, cannot operate.