

Millimetre Wave and Short-Range Propagation

程序代写代做 CS编程辅导



Sana Salous

School of Engineering and Computing Sciences

Durham University

Sana.salous@durham.ac.uk

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Outline

程序代写代做 CS编程辅导



1. Why Mm wave band
2. Candidate frequency bands
3. Working Groups **WeChat: cstutorcs**
4. Possible use scenarios Point-to-point and point-to-multipoint
Assignment Project Exam Help
5. Propagation in the mm wave band
Email: tutorcs@163.com
6. Wideband channel functions, and extraction of relevant channel parameters such as delay spread, and Doppler spread
QQ: 749589476
7. Estimation of channel parameters
<https://tutorcs.com>

Mm wave band



MM wave band (1 cm-1 mm); Extra High Frequency (EHF) 30-300 GHz

WeChat: cstutorcs

Research is focussed on Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Primary motivation

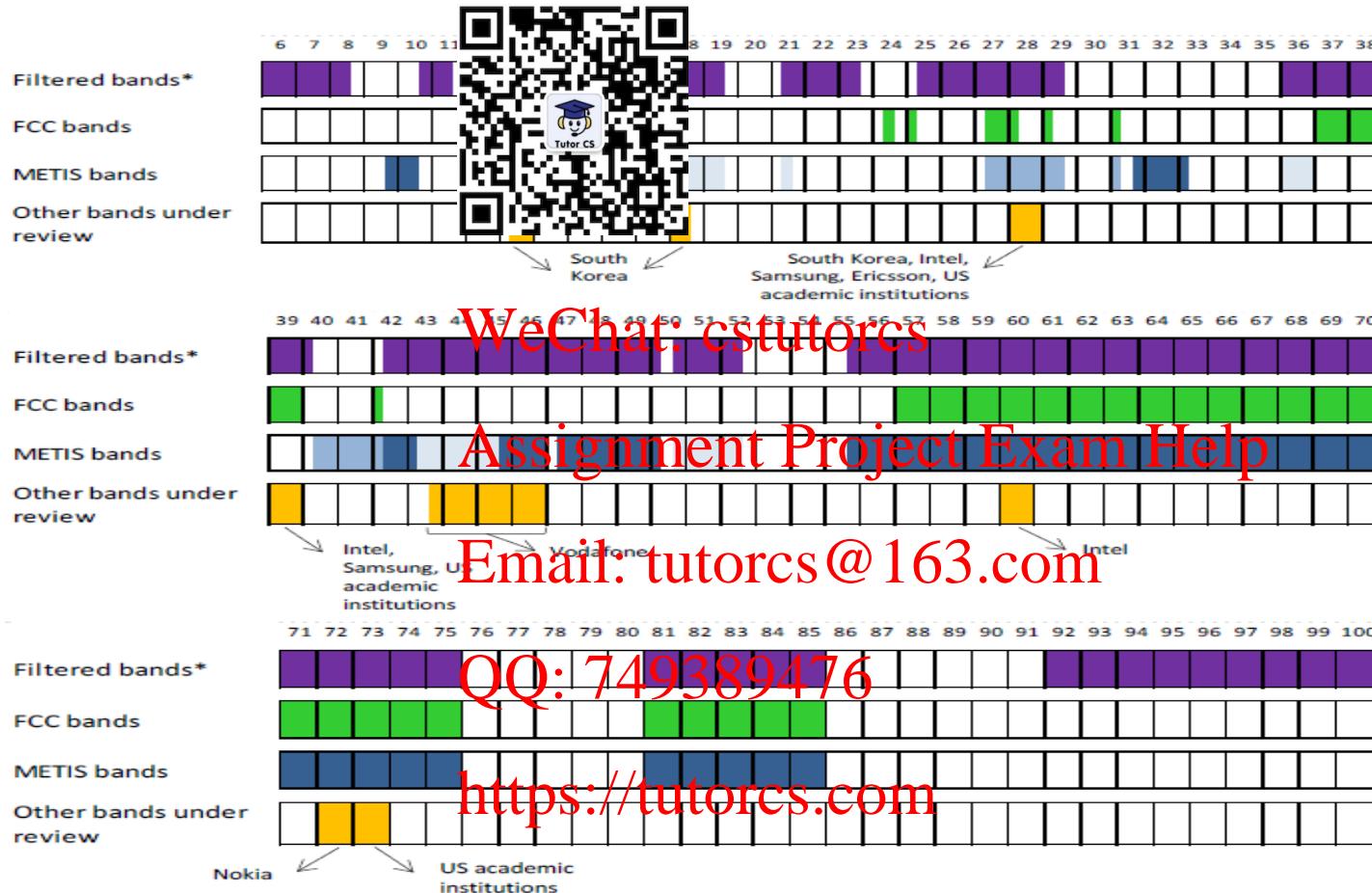
程序代写代做 CS编程辅导

- Projected increase in mobile data traffic
- Availability of large contiguous spectrum in the mm wave band
- RF and transceiver design challenges for carrier aggregation < 6 GHz
- Small wavelength enables beamforming through the use of large antenna arrays

WeChat: cstutorcs
Assignment Project Exam Help



Summary of bands identified by Ofcom as having potential for 5G



Ofcom frequency bands > 6 GHz



Frequency Range	6-20 GHz	20-40 GHz	40-60 GHz	60-100 GHz
Specific bands identified	10.125-10.225 10.475-10.575	31.8-33.4	40.5-43.5 45.5-48.9	66-71
Potential bandwidth	2 x100 MHz	1.6 GHz	5.8 GHz	5 GHz

WeChat: cstutorcs
Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

WRC15 bands



WRC15 Bands	Designation
24.25-27.5	I
31.8-33.4	II
37-43.5	III
45.5-50.2	IV
50.4-52.6	V
66-76	VI
81-86	VII

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Working Groups



1. IEEE 802.11 Next Generation 60 GHz ISM band (NG60) Study Group

2. NIST formed the corner alliance for 5G mm wave-channel model Next Generation 60 GHz IEEE 802.11 TGay

WeChat: cstutorcs
Assignment Project Exam Help

3. ITU: CG 5 on Radio Measurement Equipment and CG6 on channel modelling above 6 GHz

Email: tutorcs@163.com
QQ: 749389476

<https://tutorcs.com>

NG60 Indoor P2P Scenarios

程序代写代做 CS编程辅导

Applications and Characteristics	Propagation conditions	Throughput
Ultra Short Range (USR) Communication -Static, D2D, -Streaming/Download	LOS <10cm	~10Gbps
8K UHD Wireless Transfer at Smart Home -Uncompressed 8K UHD Streaming	LOS , NLOS <5m	>28Gbps
Augmented Reality and Virtual Reality -Low Mobility, D2D -3D UHD streaming	LOS, NLOS <10m	~20Gbps

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com



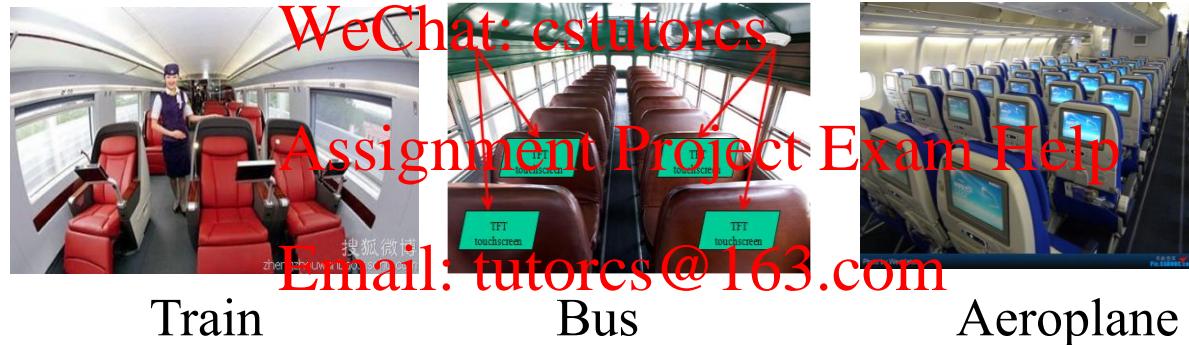
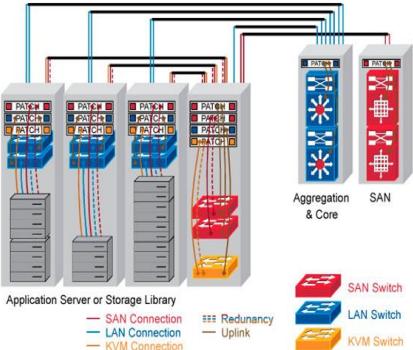
QQ: 749389476



NG60 Indoor P2P/P2MP Scenarios

程序代写代做 CS编程辅导

Data Center NG60 Inter-Rack Connectivity -Indoor Backhaul with multi-hop*		~20Gbps
Video/Mass-Data Distribution/Video on Demand System - Multicast Streaming/Downloading - Dense Hotspots		LOS >20Gbps



Train

Bus

Aeroplane



Class room

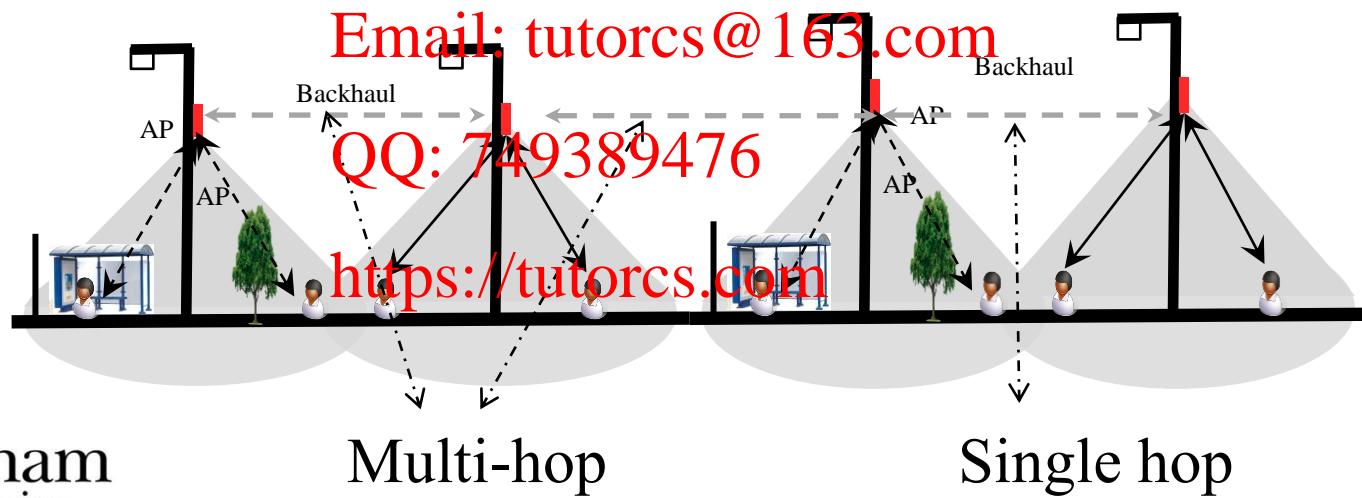
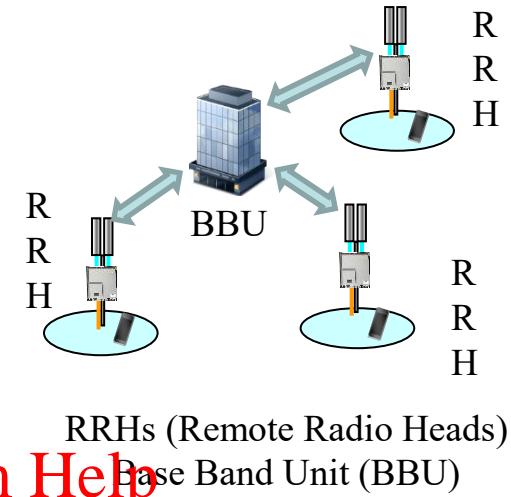
Exhibition

Conference

NG60 Outdoor P2P/P2MP Scenarios

程序代写代做 CS 编程辅导

Applications and Characteristics	Propagation	Throughput
Mobile Front-hauling		~20Gbps
Wireless Backhauling with Single Hop -Small Cell Backhauling with single hop	 <1km	~20Gbps
Wireless Backhauling with Multi-hop -Small Cell Backhauling with multi-hop	Outdoor, LOS <150m	~2Gbps



程序代写代做 CS编程辅导



Radio Propagation of mm waves

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Propagation mechanisms

程序代写代做 CS 编程辅导

Line of sight (LOS)



Reflection smooth surface with very large dimensions with respect to the wavelength

WeChat: cstutorcs

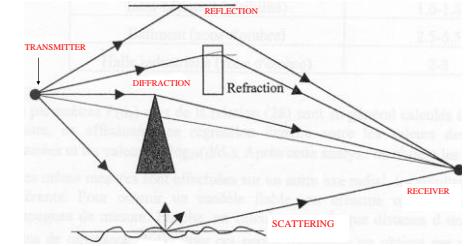
Diffraction transmission path is obstructed by a dense body with large dimensions compared to the wavelength or by a surface with large irregularities.

Assignment Project Exam Help
Email: tutorcs@163.com

Scattering wave incident on surface with dimensions on the order of a wavelength or less). Irregularities such as in tropospheric scatter.

QQ: 749389476
<https://tutorcs.com>

Refraction : variations of refractive index such as in the troposphere and in the ionosphere. light in a prism. Important for HF frequencies



Measured penetration loss



Frequency dependence of penetration loss

Three wall partition between antennas

WeChat: cstutorcs

900 MHz

11.4 GHz

28.8 GHz

18.9 dB

26 dB

36.2 dB

Assignment Project Exam Help

Email: tutorcs@163.com

Report by the

QQ: 749389476

National Telecommunications and Information Administration, US

<https://tutorcs.com>

mm wave penetration loss



Frequency 60 GHz	Plastic 0.8 cm	Wood 0.8 cm	Wood 1.8 cm	Tampered glass 0.7 cm
Vertical polarisation	3.44 dB	6.09 dB	9.24 dB	4 dB
Horizontal polarisation	4.04	5.42	8.48	3.97

WeChat: cstutorcs
Assignment Project Exam Help

Email: tutorcs@163.com

IEEE 802.11 report on Transmission and Reflection
Measurements

<https://tutorcs.com>

程序代写代做 CS编程辅导



Diffracton and scattering

WeChat: cstutorcs
models

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

mm wave band diffraction loss



Empirical model from measurements at 28 GHz for 90° edge around a building:

$$L = 6.5 \text{ dB} \quad 0^\circ \geq \theta_d > 0.1^\circ$$

WeChat: cstutorcs

$$L = 5 \ln \theta_d + 18 \quad 0.1^\circ \geq \theta_d > 5^\circ$$

Assignment Project Exam Help

$$L = 0.74 \theta_d + 75 \quad 5^\circ \geq \theta_d \geq 40^\circ$$

Email: tutorcs@163.com

QQ: 749389476



No difference between different brick or concrete

<https://tutorcs.com>

Rain scattering in mm wave



Rain drop scattering. Rayleigh scattering

$\pi D/\lambda \ll 1$ where D is the diameter of the particle

$\pi n D/\lambda \ll 1$ where n is the refractive index.

Example: D=1mm, at 60 GHz with n=1:

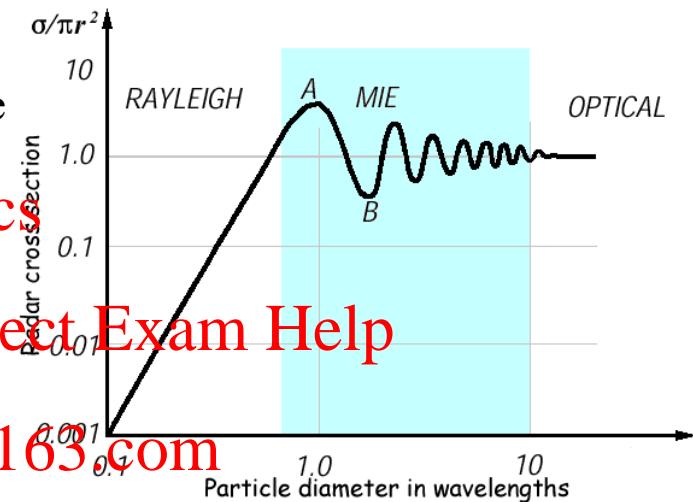
$$\pi n D/\lambda = 0.2 \ll 1$$

Assignment Project Exam Help

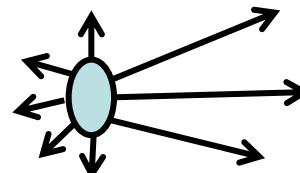
Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Rayleigh scattering



Mie scattering



Durham
University

Scattering LOS



Scattering power space

$$10 \log \left(P_r^{scat} / P_r^{fs} \right) = -10 \log f + 16 \log R + 10 \log V$$

WeChat: cstutors +10 log S - 20 log d - 81 dB

Assignment Project Exam Help
f is the frequency in GHz

Email: tutors@163.com

V is the common volume in km³

QQ: 749389476

S is a correction for non Rayleigh effects above 10 GHz

S=0 for f<10 GHz, <https://tutors.com> 10 log S = R0.4 4x10-3 (f - 10)1.6

d distance between transmitter and receiver

Specifics of propagation characteristics



nm band

WeChat: cstutorcs
Gaseous and rain Absorption
Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

ITU-R recommendations



ITU-R P676-10: Gased absorption

Model input parameters
temperature, ambient pressure, and water vapour density.

Use can be made of

ITU-R P.836-5 water vapour density

ITU-R P1510 mean annual surface temperature

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

ITU-R P.840-6: Fog absorption

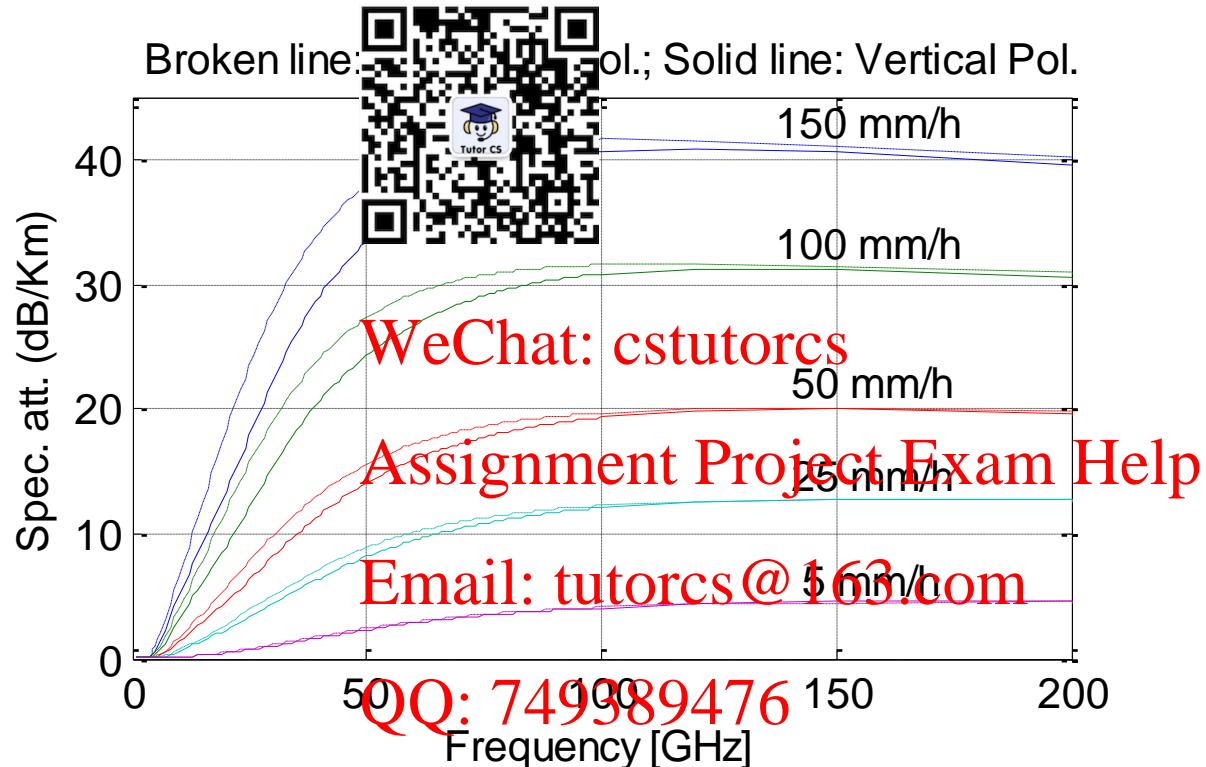
QQ: 749389476

ITU-R P838-3: Rain absorption

ITU-R P 837-6: Rain rates

<https://tutorcs.com>

Rain attenuation model ITU-R P838-3

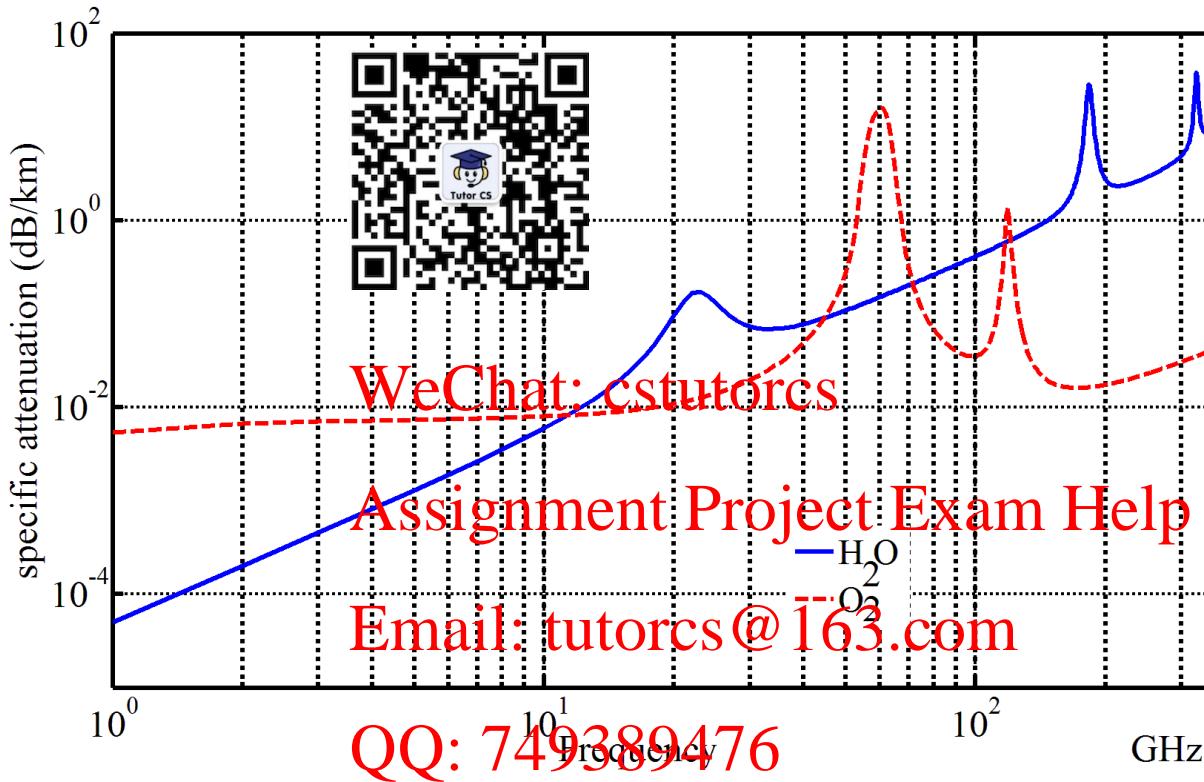


<https://tutorcs.com>

Rain: 10 dB/km at 25 mm/hr increasing to
30 dB/km at 100 mm/hr rainfall

Gaseous absorption

程序代写代做 CS 编程辅导

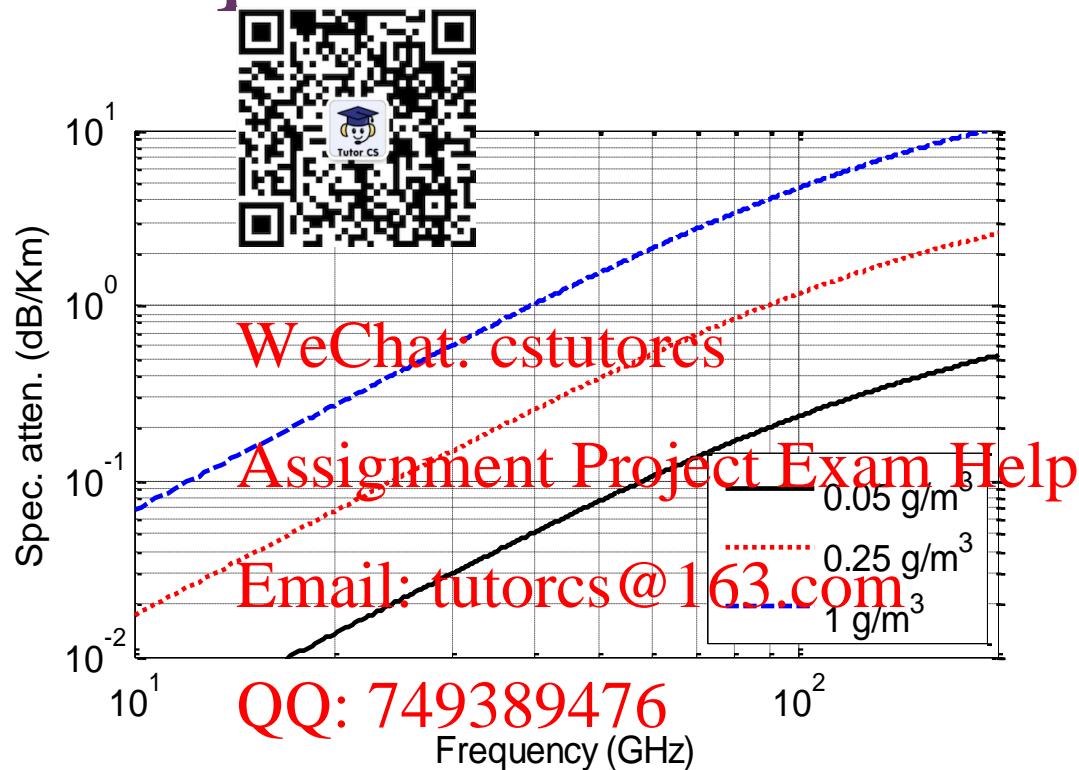


Gaseous: 0.3-0.5 dB/km for frequencies up to 38 GHz
<https://tutorcs.com>
and 70-100 GHz

maximum at 60 GHz of 15 dB/km

Fog absorption

程序代写代做 CS编程辅导



<https://tutorcs.com>
as high as 5dB/km at 100 GHz for 1g/m³

Propagation in the built environment



mm wave band
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

ITU-R Study Group 3 Correspondence Groups



CG 3K-6: ITU-R P. 1410 and ITU-R P. 1411-10
Model harmonization of path loss models (Samsung
Korea) WeChat: cstutorcs

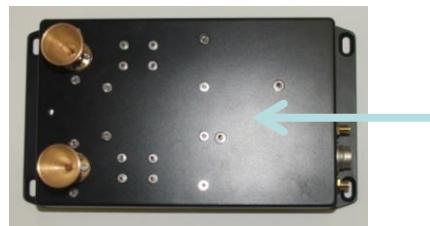
CG 3J-3K-3M-8: Assignment Project Exam Help
ITU-R P. 2109-1 Building entry loss
model (UK) Email: tutorcs@163.com

QQ: 749389476

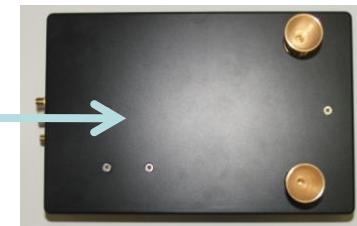
CG 3K-3M-12: ITU-R P. 2108-0 Clutter loss prediction
(Ofcom, Intel) <https://tutorcs.com>

FMCW Channel Sounder

程序代写代做 CS 编程辅导



QQ: 749389476
mm Transmitter
<https://tutorcs.com>
mm Receiver



WRC15/WRC19 frequency bands

程序代写代做 CS编程辅导

WRC15 Band (GHz)	Bandwidth (GHz)
24.25	3.25
31.8	1.6
37-43.5	6.5
45.5-50.2	WeChat: cstutorcs 4.7
45.5-47, 47.2-48.2	1.5, 1
50.4-52.6	Assignment Project Exam Help 2.4
66-76	Email: tutorcs@163.com
66-71	5
81-86	QQ: 749389476 5

<https://tutorcs.com>

With 14.75 GHz harmonized worldwide, ~ 85% of
global harmonization

CG 3K-6: ITU-R P 1411 Environments

程序代写代做 CS 编程辅导

1. Urban very high rise; high density 10's floors



2. Urban high rise: floors over rooftop propagation

3. Urban low rise/suburban; 3 storey

WeChat: cstutorcs
Assignment Project Exam Help

4. Residential: single/double storey
Email: tutorcs@163.com

5. Rural: small houses large gardens
QQ: 749389476

<https://tutorcs.com>

Outdoor mm wave measurements



Outdoor mm wave measurements



程序代写代做 CS编程辅导
WeChat: cstutorcs
Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Path loss model



Single frequency vs multi frequency

$$PL_{logDist}(d) = 10\alpha \log_{10}(d) + \beta \text{ dB}$$

Assignment Project Exam Help

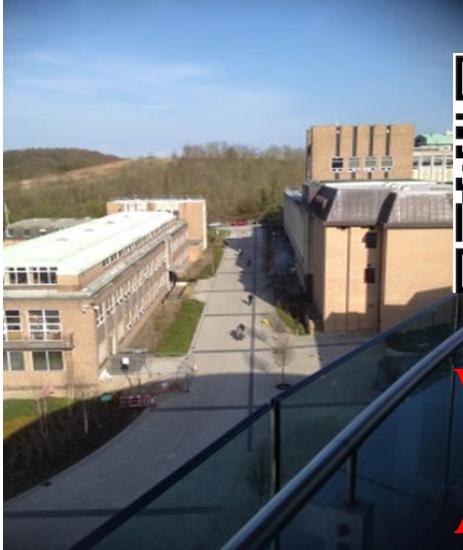
$$PL(d, f) = 10\alpha \log_{10}(d) + \beta + 10\gamma \log_{10}(f) \text{ dB}$$

Email: tutorcs@163.com

with an additive zero mean Gaussian random variable $N(0, \sigma)$ with a standard deviation σ (dB)
<https://tutorcs.com>

Environments: UK, Japan, Korea

程序代写代做CS编程辅导



WeChat: cstutorcs
Assignment Project Exam Help



Email: tutorcs@163.com

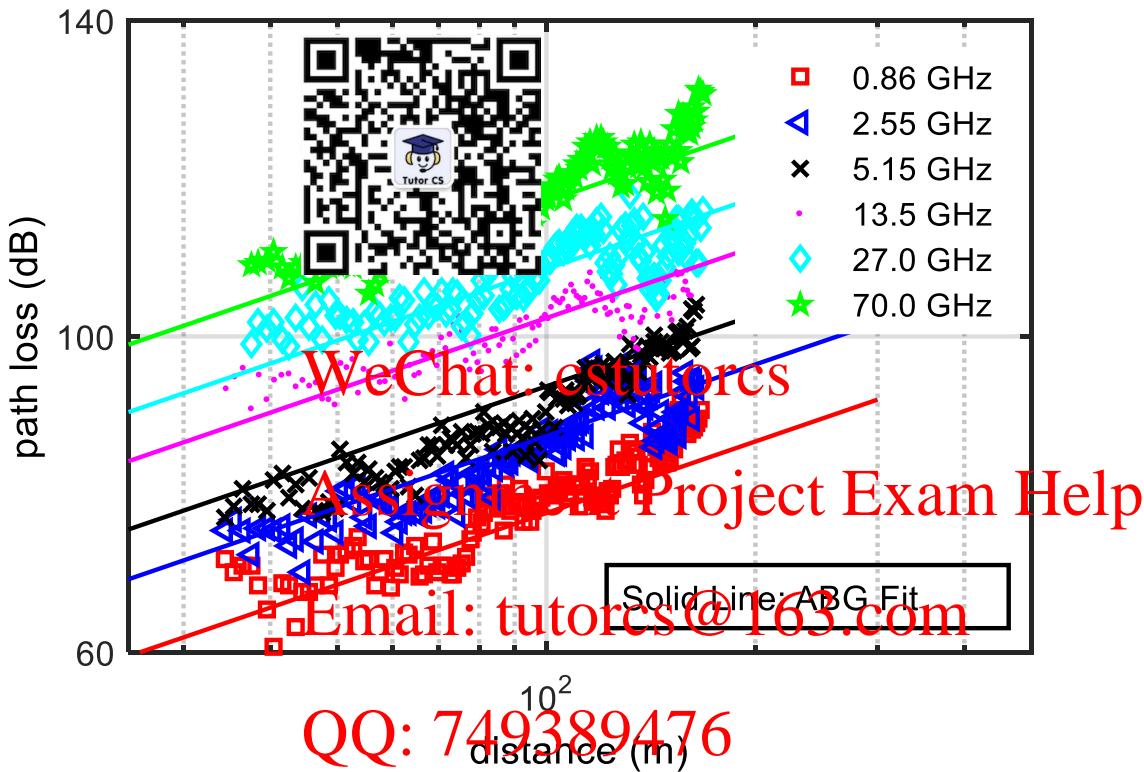
QQ: 749389476

<https://tutorcs.com>



Multi-band Residential NLOS Measurements

程序代写代做 CS编程辅导



<https://AGDrcs.com>

$$(\alpha, \beta, \gamma, \sigma)$$

3.01, 18.8, 2.07, 3.07

Adopted model for below rooftop



Frequency range (GHz)	Distance range (m)	Type of environment	LoS/NLoS	α	β	γ	σ
0.8-73	5-660	Urban high-rise, Urban low-rise/Suburban	LoS	2.12	29.2	2.11	5.06
0.8-38	30-715	Urban high-rise	NLoS	4.00	10.2	2.36	7.60
10-73	30-250	Urban low-rise/Suburban	NLoS	5.06	-4.68	2.02	9.33
0.8-73	30-170	Residential	NLoS	3.01	18.8	2.07	3.07

QQ: 749389476

<https://tutorcs.com>

ITU-R 1238-10 measurement scenarios

程序代写代做 CS编程辅导



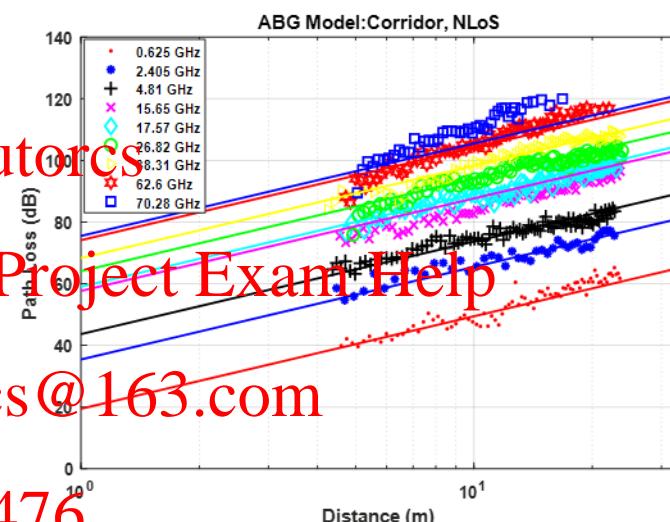
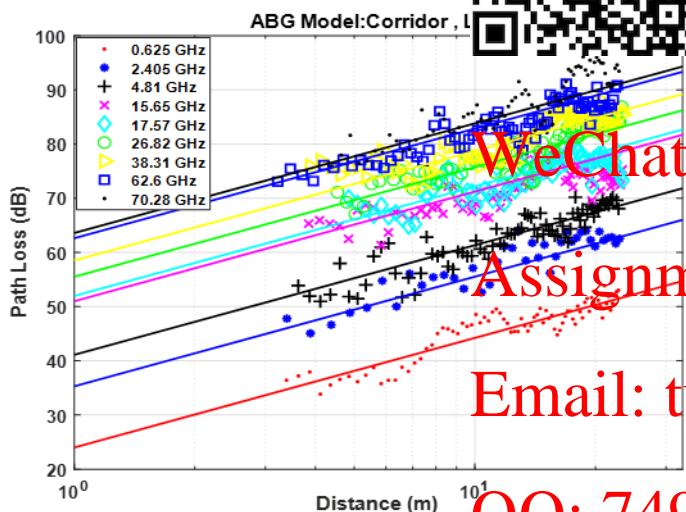
WeChat: cstutorcs
Assignment Project Exam Help

Email: tutorcs@163.com



QQ: 749389476
Indoor Ceiling height to user,
<https://tutorcs.com>

Towards a new model: corridor



WeChat: cstutorcs
Assignment Project Exam Help
Email: tutorcs@163.com
QQ: 749389476

<https://tutorcs.com>

Adopted model for 1238-11

程序代写代做 CS 编程辅导



Environment	LoS /NLoS	Frequency (GHz)	Range (m)	Distance range (m)	α	β	γ	σ
Office	LoS	0.3–83.5	2–27	2–27	1.46	34.62	2.03	3.76
	NLoS	0.3–82.0	4–30	4–30	2.46	29.53	2.38	5.04
Corridor	LoS	0.3–83.5	2–169	2–169	1.63	23.12	2.25	4.07
	NLoS	0.625–83.5	4–94	4–94	2.77	29.27	2.48	7.63
Industrial	LoS	0.625–70.28	2–101	2–101	2.31	24.52	2.06	2.69
	NLoS	0.625–70.28	5–108	5–108	3.79	21.01	1.34	9.05

QQ: 749389476

<https://tutorcs.com>

CG 3J-3K-3M-8: ITU-R P.

2109-1 Building entry loss model



Building classifi

WeChat: cstutorcs

- Thermally-efficient; metallised glass, foil-backed panels
Assignment Project Exam Help
Email: tutorcs@163.com
- Traditional' buildings without such materials
QQ: 749389476
<https://tutorcs.com>

Type of properties measured



Traditional



Victorian House

Modern



WeChat: cstutorcs
Assignment Project Exam Help
Email: tutorcs@163.com



Userhuus



Weinerberger-E4

80s build
QQ: 749389476

Building Research Establishment (BRE) in Watford, UK
<https://tutorcs.com>

CG 3K-3M-12: Clutter Loss Prediction 程序代写代做CS编程辅导

ITU-R P. 2108 Clutter Loss Measurements UK



WeChat: cstutorcs
Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Combined Clutter Loss and Rician Wideband Measurement Scenario



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Combined Clutter and BEL measurement



FIGURE 5

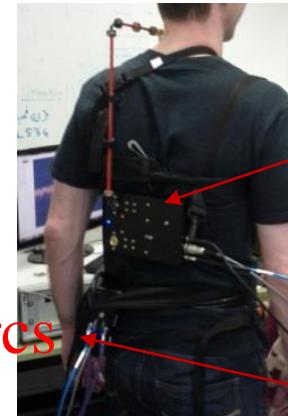
Scenario side view



Measurement scenarios

程序代写代做 CS 编程辅导

On body: dismount



Transmitter

Indoor: WiFi



Receiver

TX=2.35 m, RX=1.5 m
QQ: 749389476

Outdoor:

<https://tutorcs.com>

back haul building to building,
lamp post to user, cellular



Example of Measurements

程序代写代做 CS 编程辅导

Outdoor scenario ~79 m
~22 cm (0.76 ns)



Median MIMO capacity a
SNR=30 dB ~13.2b/s/Hz



VS
17 b/s/Hz theoretical
Rms~2.2 ns 20dB for 90%

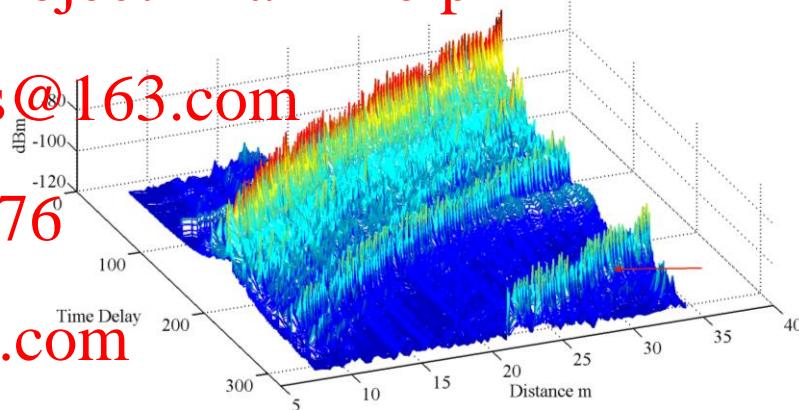
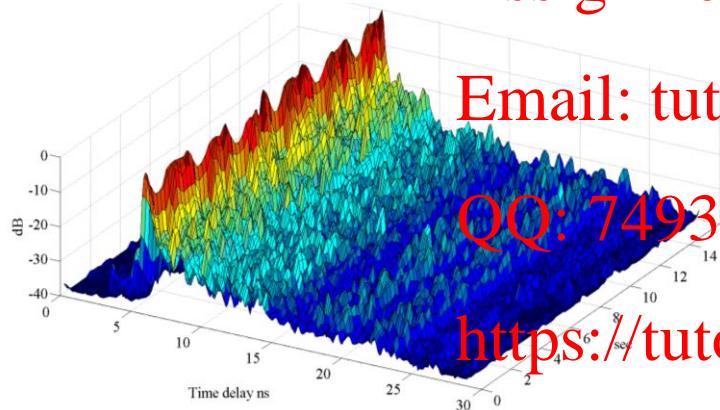
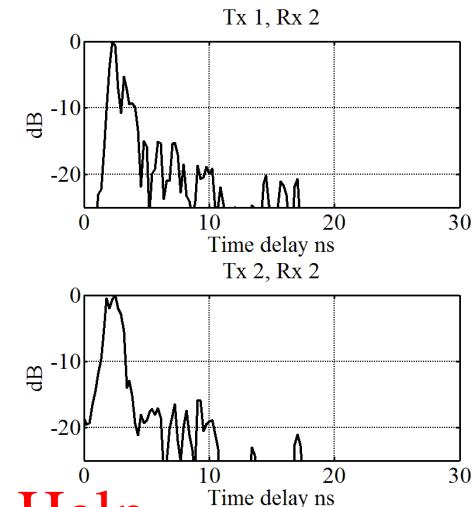
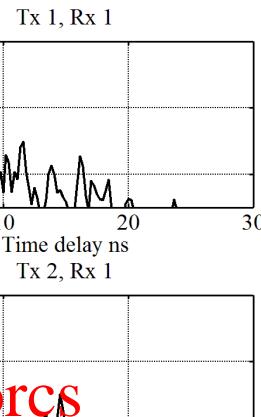
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



On body

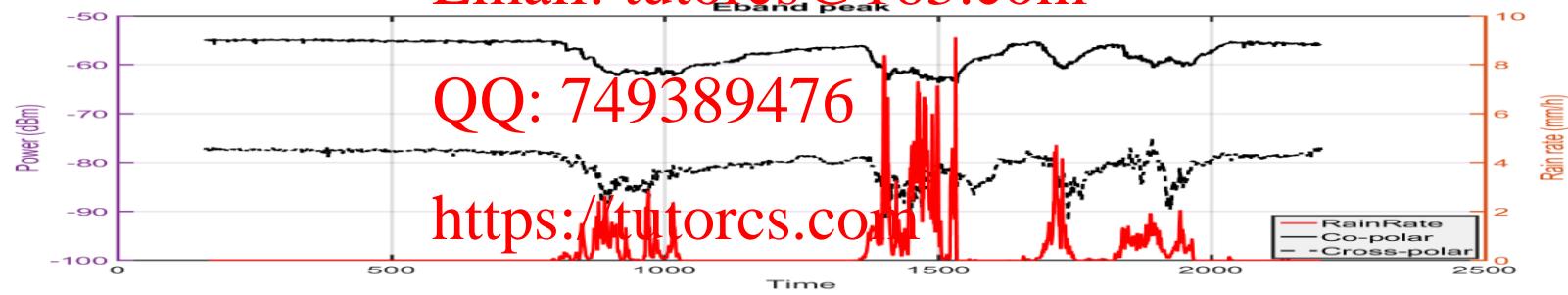
Indoor

rms 0.69 ns at 20dB vs 10.65 at 30 dB ns

Impact of precipitation



Email: tutorcs@163.com



QQ: 749389476

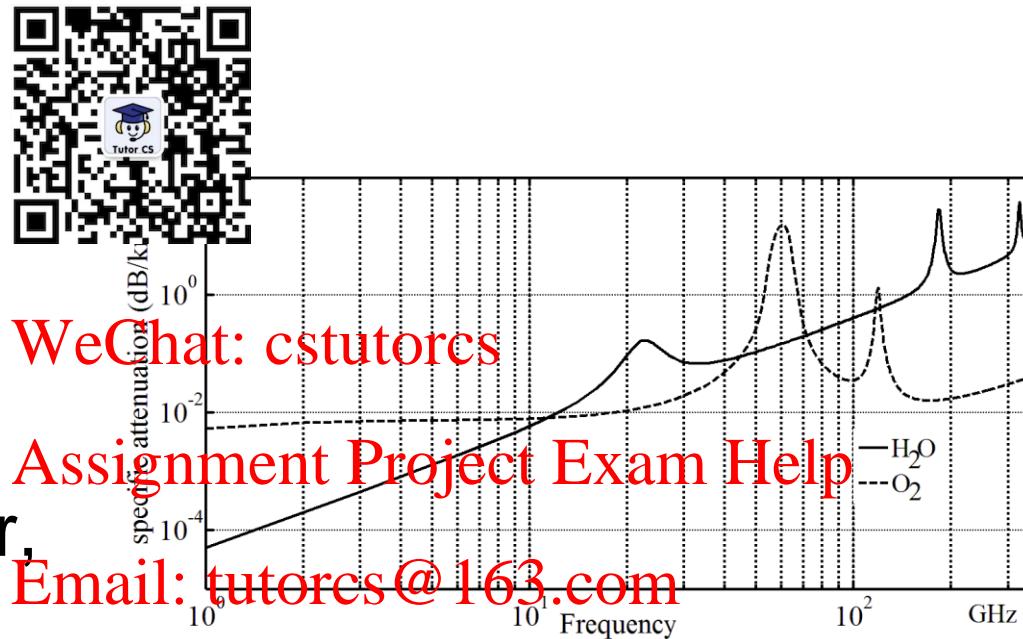
<https://tutorcs.com>

Future plans: 5G/6G

程序代写代做 CS 编程辅导

➤ **WRC23:** 140-
170 GHz, and
235-300 GHz

➤ **Models:** Indoor,
outdoor,
Precipitation
measurements



<https://tutorcs.com>