



13/07/2020



08:00 p.m.



Zoom

شبكات الجيل الخامس للاتصالات والمخاطر الصحية:
هل هي آمنة للأجيال القادمة؟

5G Mobile Networks and Health Risks: Is It Safe for Future Generations?

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College of Engineering

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IEEE Comsoc Bahrain chapter Chair



A night cityscape with glowing blue 5G network lines and the text '5G' overlaid. The image shows a dense urban environment with numerous skyscrapers and buildings, many of which are illuminated with blue and white lights. A prominent feature is the presence of glowing blue arcs and lines that represent a 5G network, connecting various points across the city. The text '5G' is displayed in large, white, bold letters in the center-right of the image. The overall scene is set against a dark blue night sky, with the city lights providing a strong contrast.

5G

Webinar Outlines

1. What's different about 5G? (Status / deployments around the world)!
2. Health Effects associated with 5G. (Coronavirus (Conspiracy theory))!
3. 5G Spectrum and None ionizing Radiation.
4. Exposure levels and guidelines (EMF metrics) ?
5. Does 5G and mmWaves pose health risks? How worried should we be?
6. Conclusions / Discussion / Q & A

Main References

- [1] Wu, Ting, Theodore S. Rappaport, and Christopher M. Collins. "Safe for generations to come: Considerations of safety for millimeter waves in wireless communications." *IEEE Microwave Magazine*, March 2015
- [2] S. I. Alekseev and M. C. Ziskin, "Influence of blood flow and millimeter wave exposure on skin temperature in different thermal models," *Bioelectromagnetics*, vol. 30, no. 1, pp. 52–58, 2009.
- [3] S. Chalfin, J. A. D'Andrea, P. D. Comeau, M. E. Belt, and D. J. Hatcher, "Millimeter wave absorption in the nonhuman primate eye at 35 GHz and 94 GHz," *Health Phys.*, vol. 83, no. 1, pp. 83–90, July 2000.
- [4] Chiaraviglio, L., Elzanaty, A., & Alouini, M. S. (2020). Health Risks Associated with 5G Exposure: A View from the Communications Engineering Perspective. arXiv preprint arXiv:2006.00944.
- [4] <https://www.icnirp.org>
- [5] <https://www.who.int/news-room/q-a-detail/5g-mobile-networks-and-health>

Disclaimer

This webinar is intended solely to provide information to the public based on the given references.



1G
1980s

2G
1990s

3G
2000s

4G
2010s

5G
2020

Extreme speeds - Gbps
High Capacity – 10x
Low Latency – 1ms



Analogue

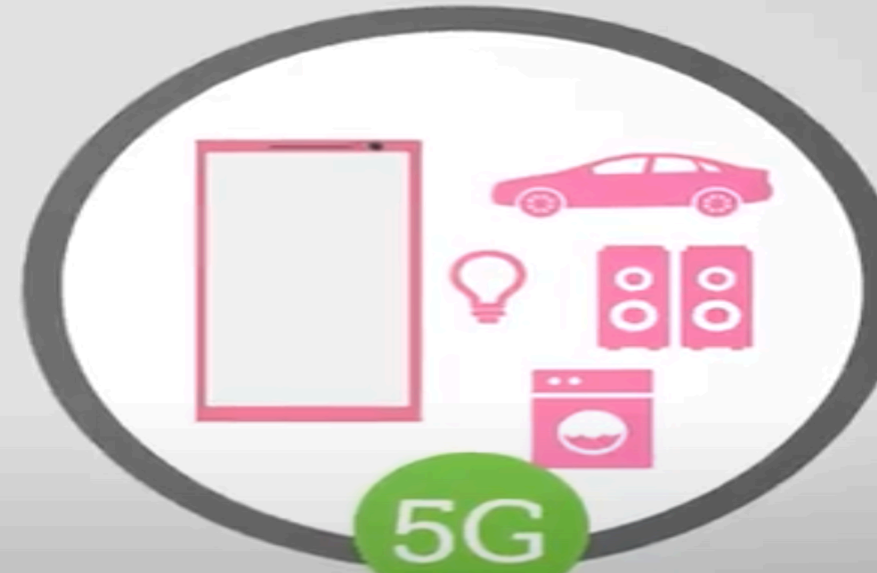
Digital
SMS

Multimedia
Video Calling
Mobile internet

Mobile Broadband
Enhanced Video

Mobile Connected World
Enhanced Mobile Broadband
Low latency applications
Internet of Things
AR & VR

The Evolution of Mobile Communications, from 1G to 5G



1G

2G

3G

4G

5G

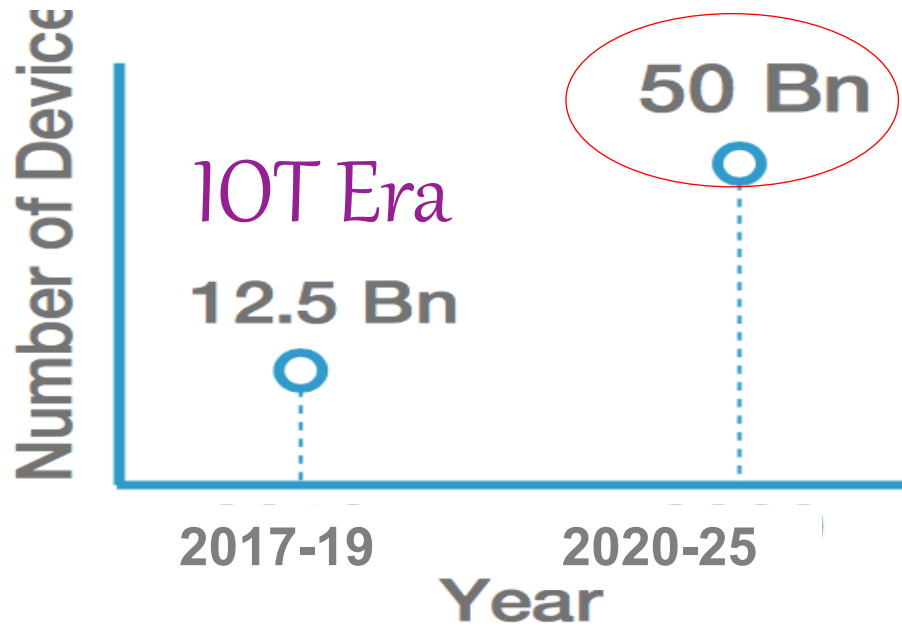
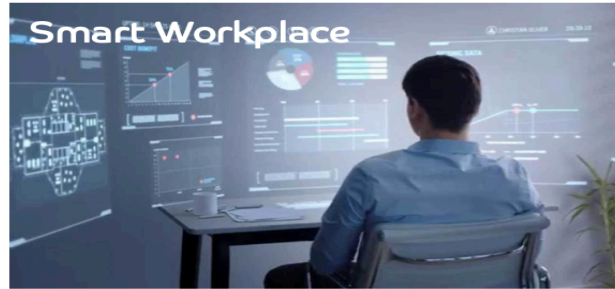
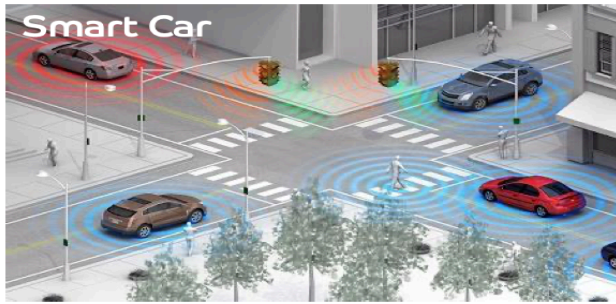
1980's

1993

2001

2009

2020?

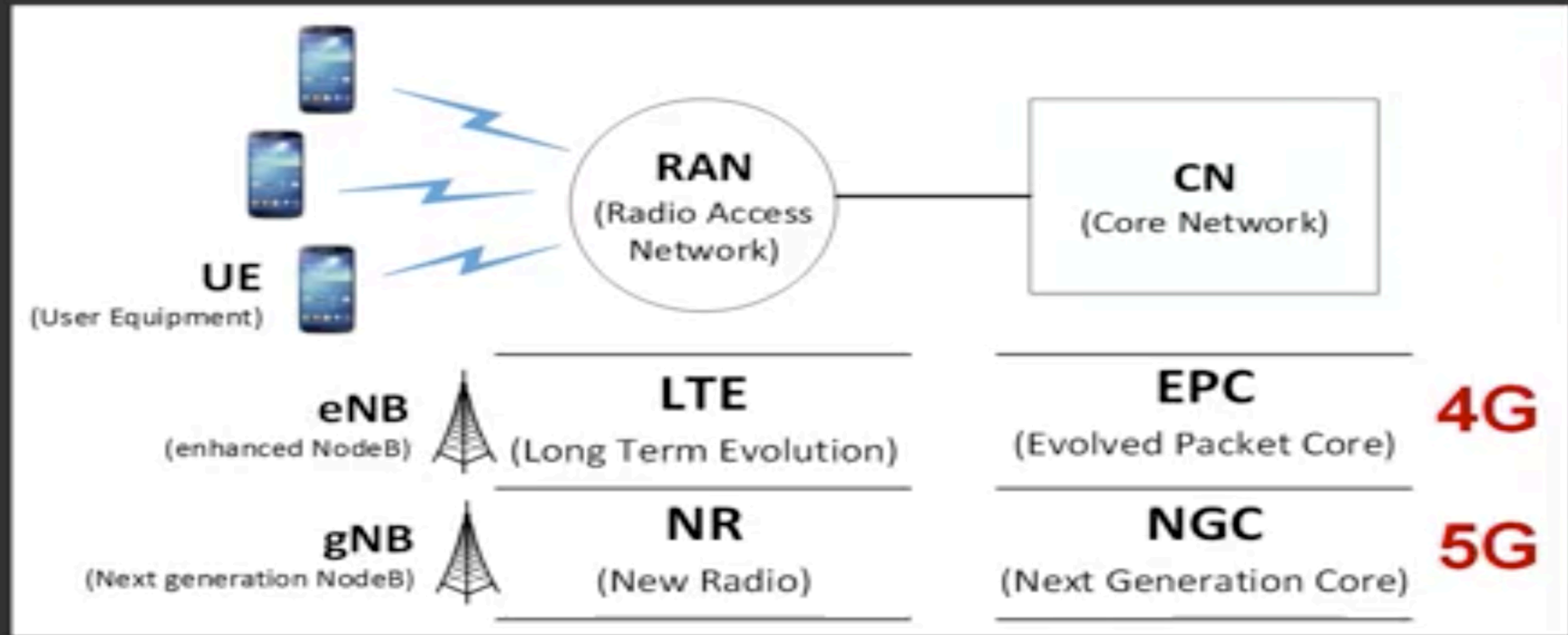


Source: 5G Samsung Report

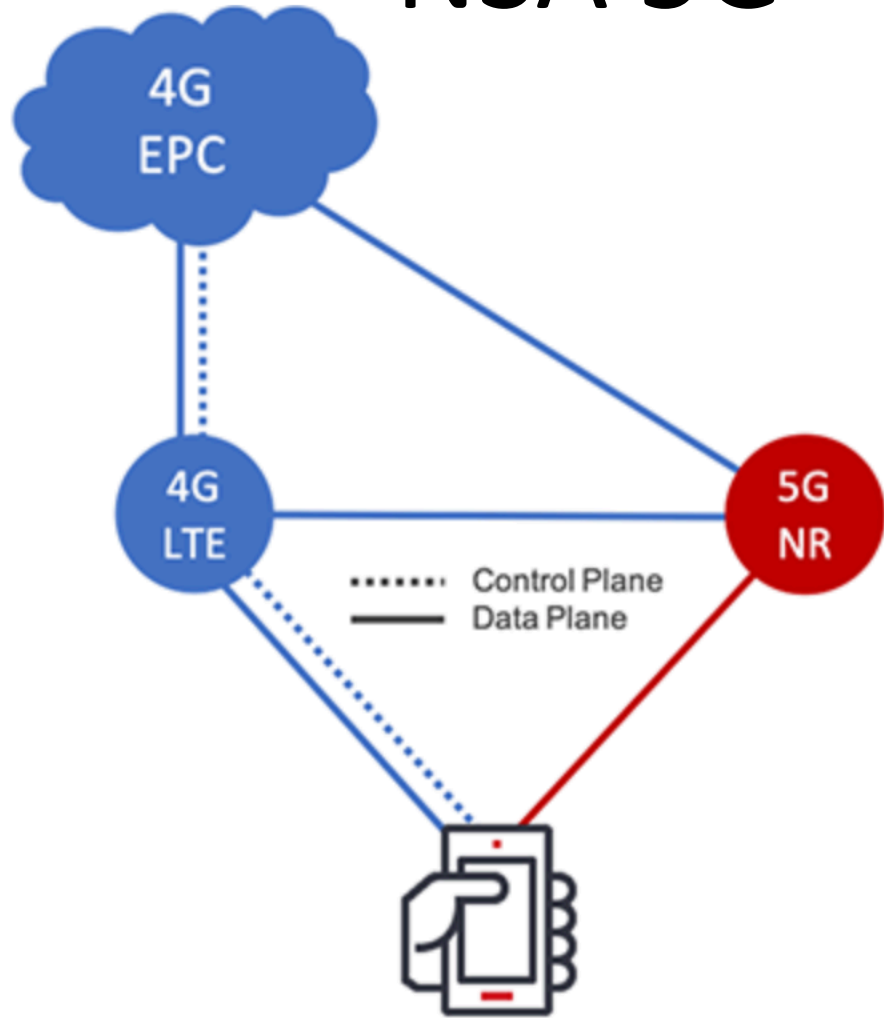
Exabytes = 10^{18} = one billion of gigabytes

5G Architecture

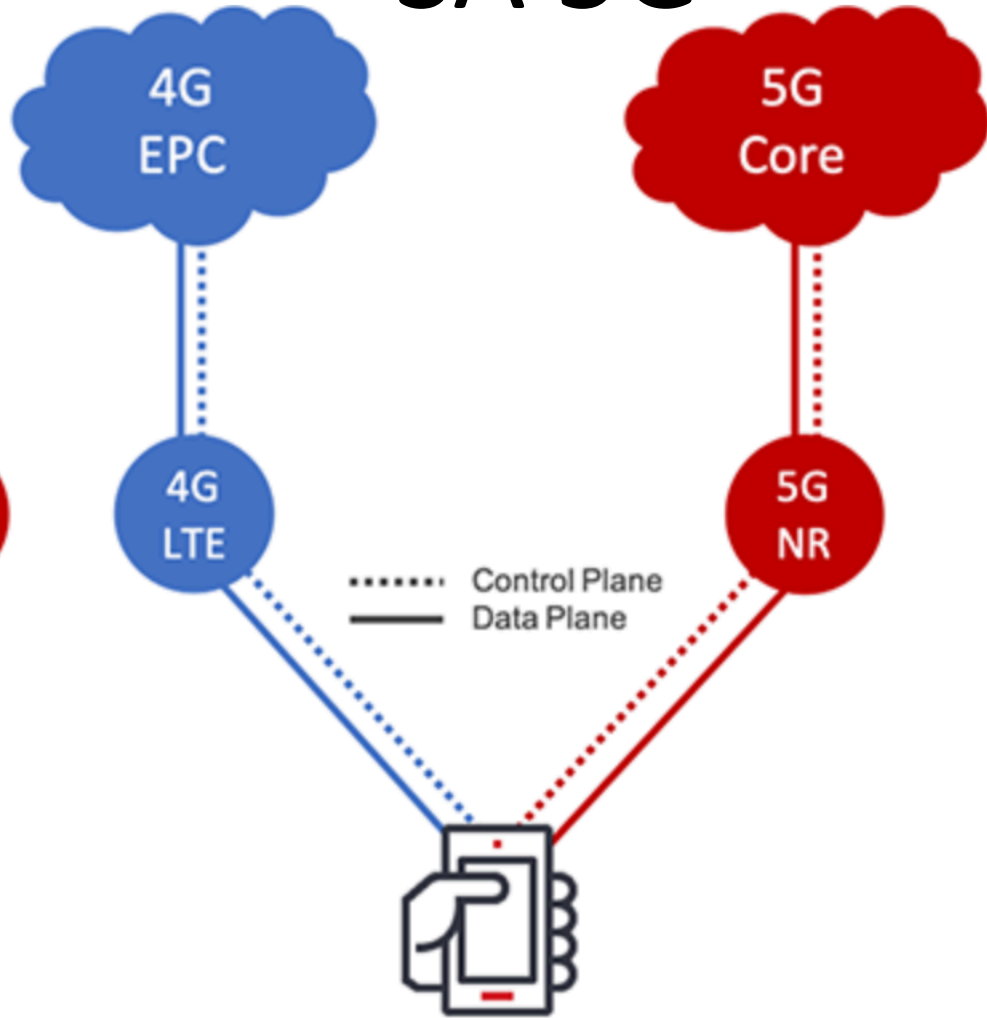
❖ Cellular Network Architecture



NSA 5G



SA 5G

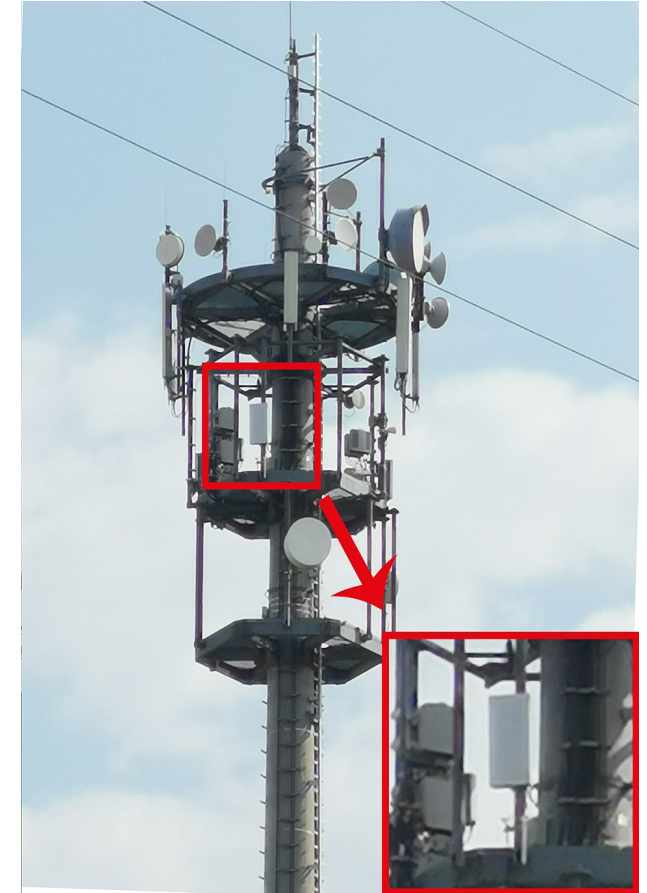




5G 3.5 GHz Cell Site of Deutsche Telekom in Darmstadt, Germany



5G 3.5 GHz Cell Site of Vodafone in Karlsruhe, Germany



5G NR (New Radio) is a new radio access technology (RAT) developed by **3GPP** for the **5G** (fifth generation) mobile network. It was designed to be the global standard for the air interface of **5G** networks. ... **gNB** (i.e. a 5G next generation base station), **NSA Vs. SA options**

5G vs 4G cells



Donald Trump extends Huawei ban through May 2021

Huawei is still in trouble with the White House

By [Chaim Gartenberg](#) | [@cgartenberg](#) | May 13, 2020, 3:52pm EDT

f   SHARE

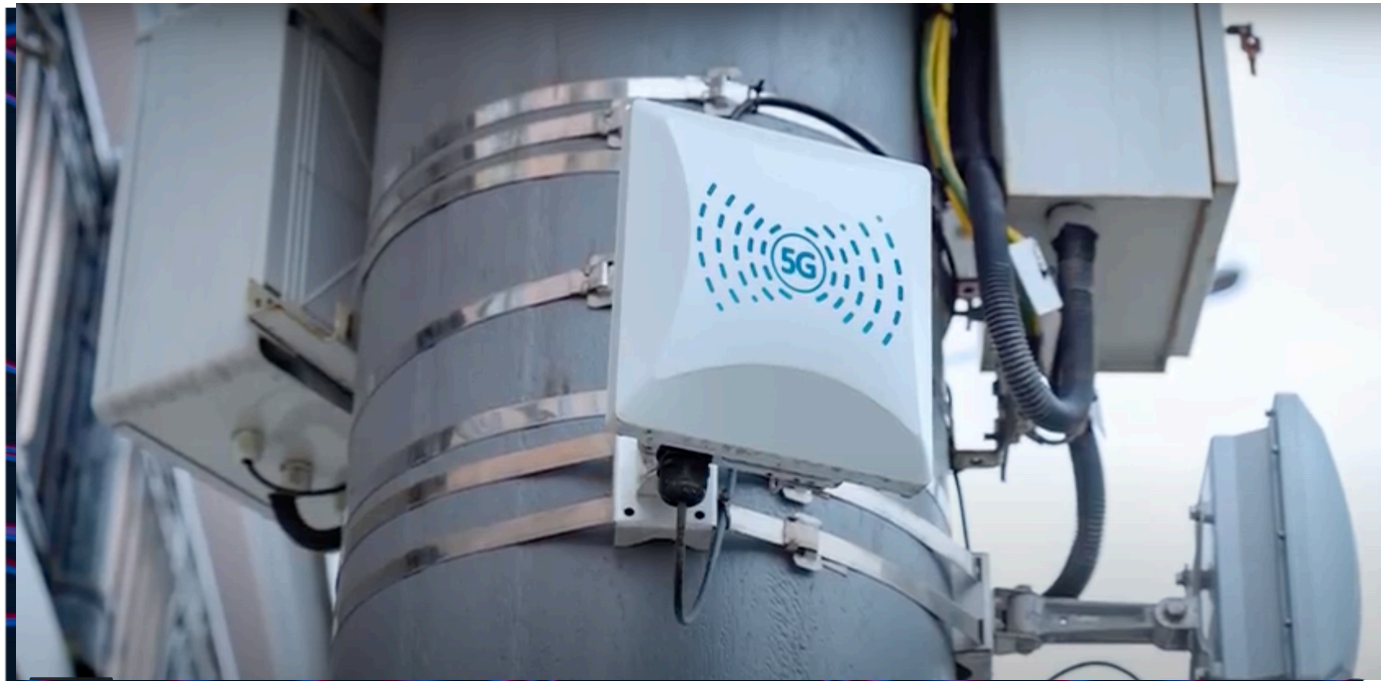


Illustration by Alex Castro / The Verge

President Donald Trump has extended [his executive order](#) banning US companies from working with or buying telecommunications equipment from companies deemed a national security risk until May 2021, [via Reuters](#).



<https://www.speedtest.net/ookla-5g-map>



TRA Updates

Checkout our latest news and updates about what's happening at TRA

MEDIA CENTRE → PRESS RELEASES → 5G DOWNLOAD SPEEDS IN BAHRAIN EXCEED [...]

5G Download Speeds in Bahrain Exceed 1 GB – according to TRA's latest Quality of Service Measurement Report



April 21,2020

The Telecommunications Regulatory Authority of Bahrain announced the publication of their latest Quality of Service Report, shedding light on the progress of 5G Networks.

A comparison between 4G and 5G performance shows average speeds of approximately 80 megabits per second compared to 5G's average of approximately 600 megabits per second, though records higher than 1 GB per second were observed.

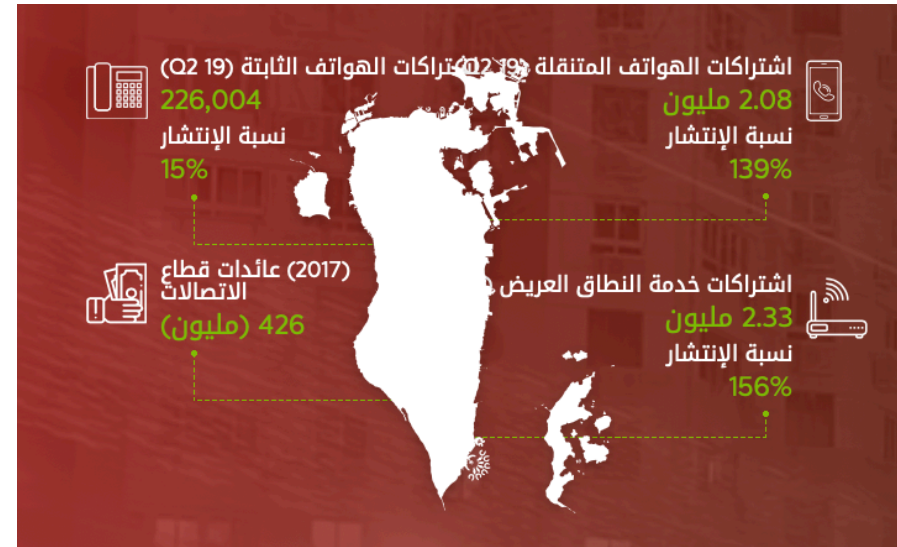
Recent News

April 21,2020
5G Download Speeds in Bahrain Exceed 1 GB – according to TRA's latest Quality of Service ...

April 01,2020
89% increase in disputes, TRA continues efforts in protection of telecoms service consumers: ...

March 23,2020
TRA supports national initiatives in combating COVID-19

February 22,2020
TRA opens registration for Cyber Safety Award

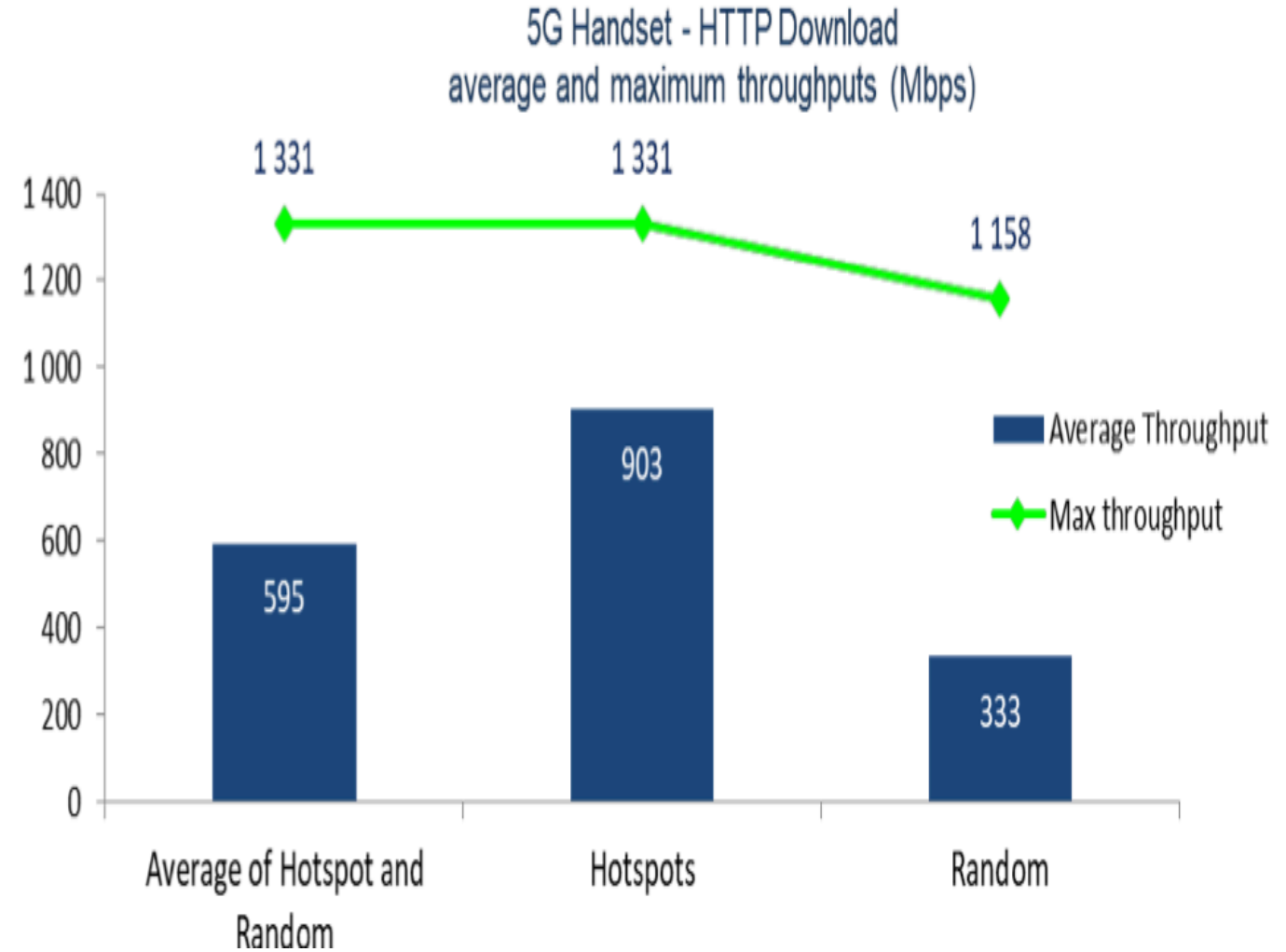
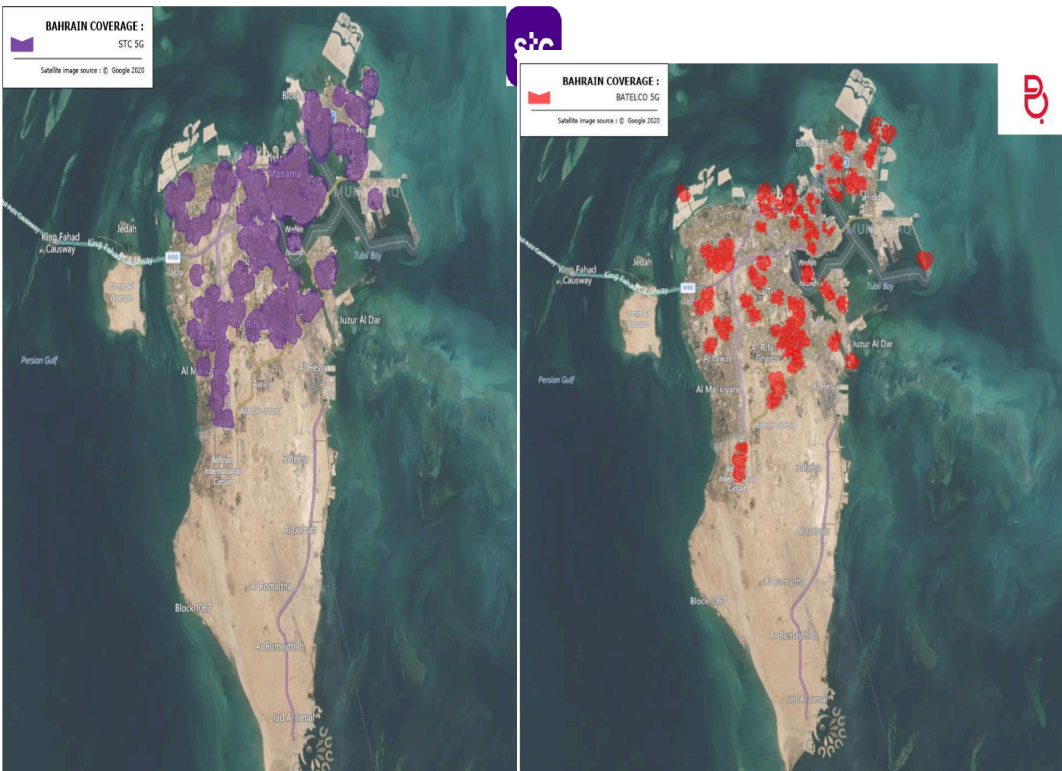


5G NETWORKS

QOS AND COVERAGE AUDIT KINGDOM OF BAHRAIN



4G = approximately **80** megabits per second, compared to 5G's average of approximately **600** megabits per second, though records higher than **1 GB per second** were observed.



5G Map Sites

Capital
Governorate



Location	Block #					
Adliya	336	338				
Hooraa	308	701	815			
Bab Al-Bahrain	301	304				
Karababad	436					
Manama	301	302	304	311	314	
	316	317	319	326	328	346
Juffair	324	340				
Sitra	604	607	615			
Sanad	743	816				
Reef Island	346					

K.H. Hospital	228			
Ma'ameer	607	615	634	
Sanabis	408			
Seef	428	436		

Zubara Road	318
Nabeeh Saleh	381
Mahooz	337
Ras Roman	318

Galaxy S20 | S20+ | S20 Ultra

From \$13.89/mo[®] for 36 months or \$499.99[®]

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5G devices

5G

5G Non-Standalone (NSA), Standalone (SA), Sub6 / mmWave

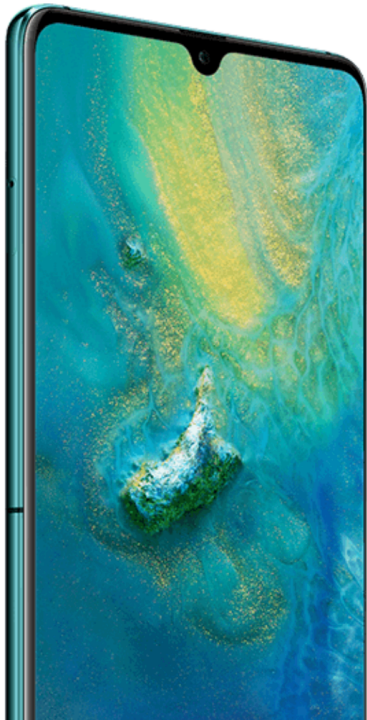
On March 6, 2020 the first-ever all-5G smartphone [Samsung Galaxy S20](#) was released.

first commercial 5G smartphone HUAWEI Mate 20 X (5G) is launched globally.²

HUAWEI Mate20 X^{5G}

CO-ENGINEERED WITH 

Connecting The Future



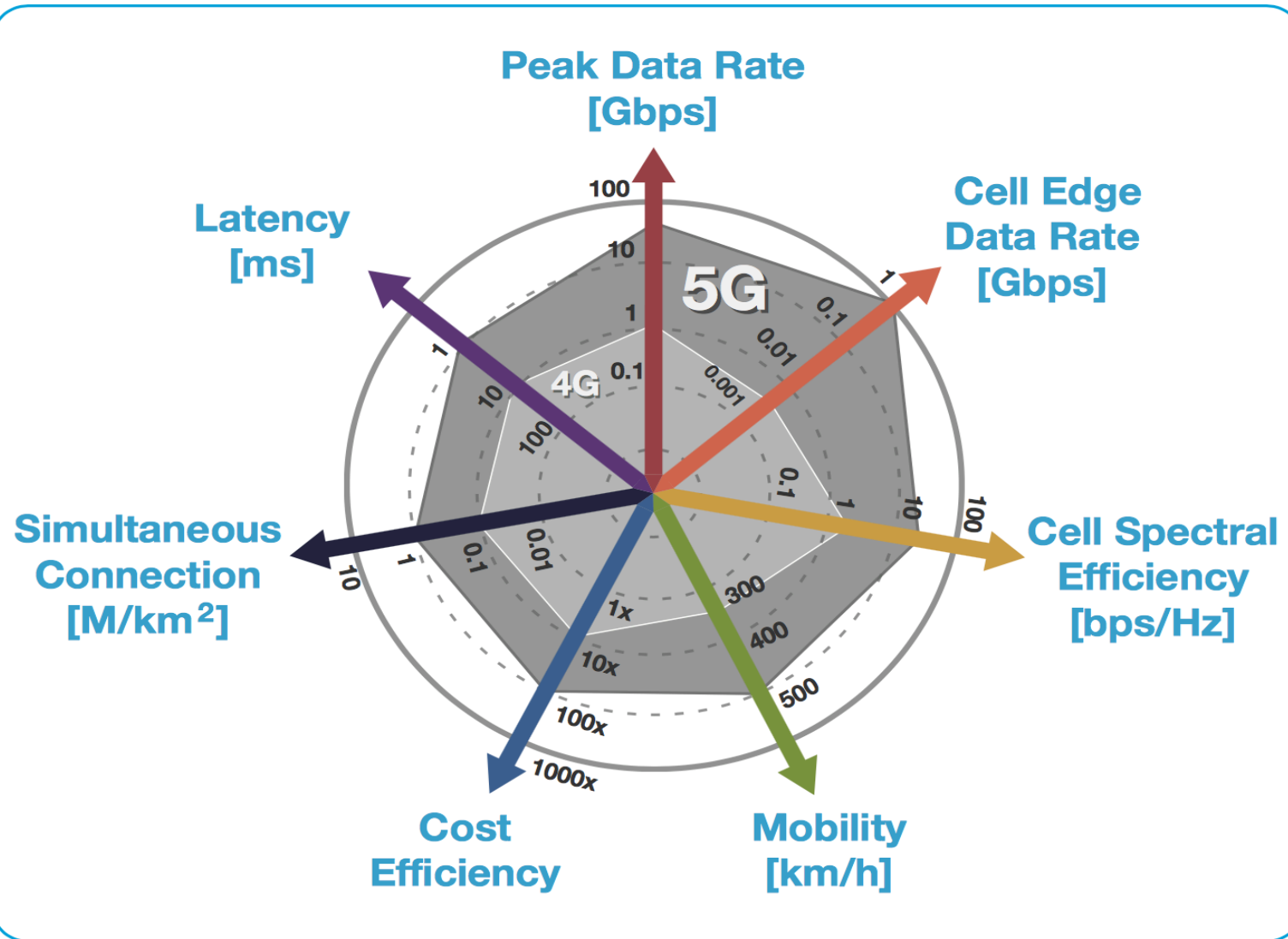
On March 19, HMD Global, the current maker of Nokia-branded phones, announced the Nokia 8.3, support all 5G bands from 600 MHz to 3.8 GHz.^[62]



At the time of writing (July 2020), no **iPhone** models support 5G.

Will the iPhone 12 be Apple's first 5G phone?

5G



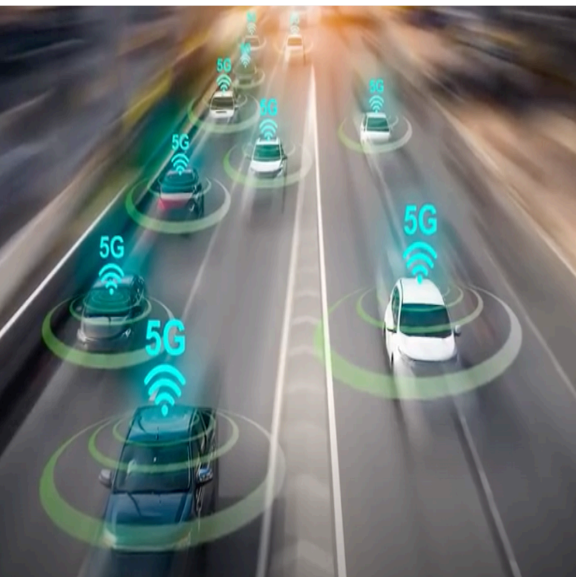
2G : digital voice, 3G : first data services, 4G : mobile broadband

5G : designed to serve not only phones but for connecting everything else

(5G Isn't About the Smartphone @ IEEE Spectrum March 2019)

	3G	3G	4G	5G	
Standard	UMTS	HSPA	LTE/LTE A.	5G NR	URLLC
Latency (ms)	200-400 MS	80-150 MS	15-80 MS	2-5 MS	1-2 MS

4G vs 5G



Performance Metrics	4G	5G
Peak data rate (Gbps)	1	20
User experienced data rate (Mbps)	10	100
Connection density (devices/km ²)	10 ⁵	10 ⁶ (IOT)
Mobility support (kmph)	350	500
Area traffic capacity (Mbit/s/m ²)	0.1	10
Latency (ms)	10	1
Reliability (%)	99	99.99
Positioning accuracy (m)	1	0.01
Spectral efficiency (bps/Hz)	3	10
Network energy efficiency (J/bit) ¹	1	0.01

[IEEE Communications Surveys & Tutorials](#) (Volume: 20 , [Issue: 2](#) , 2018)





5G
NETWORK SLICING

Gigabytes
in a second

5G

Self Driving Car

Industry
automation

5G

HOTEL

HOSPITAL

eHealth

Voice

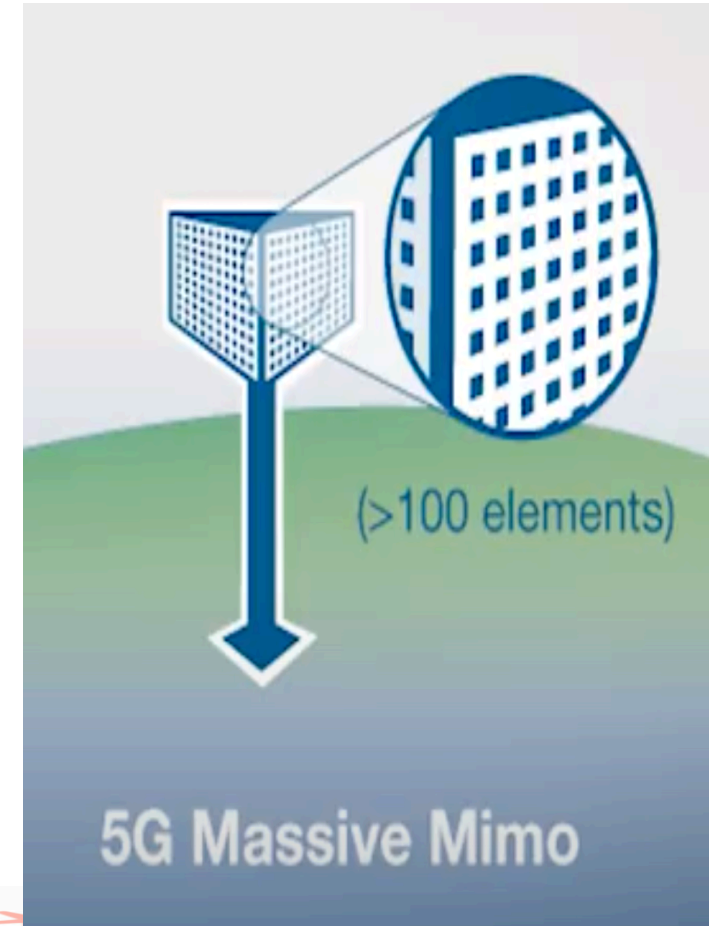
Augmented reality

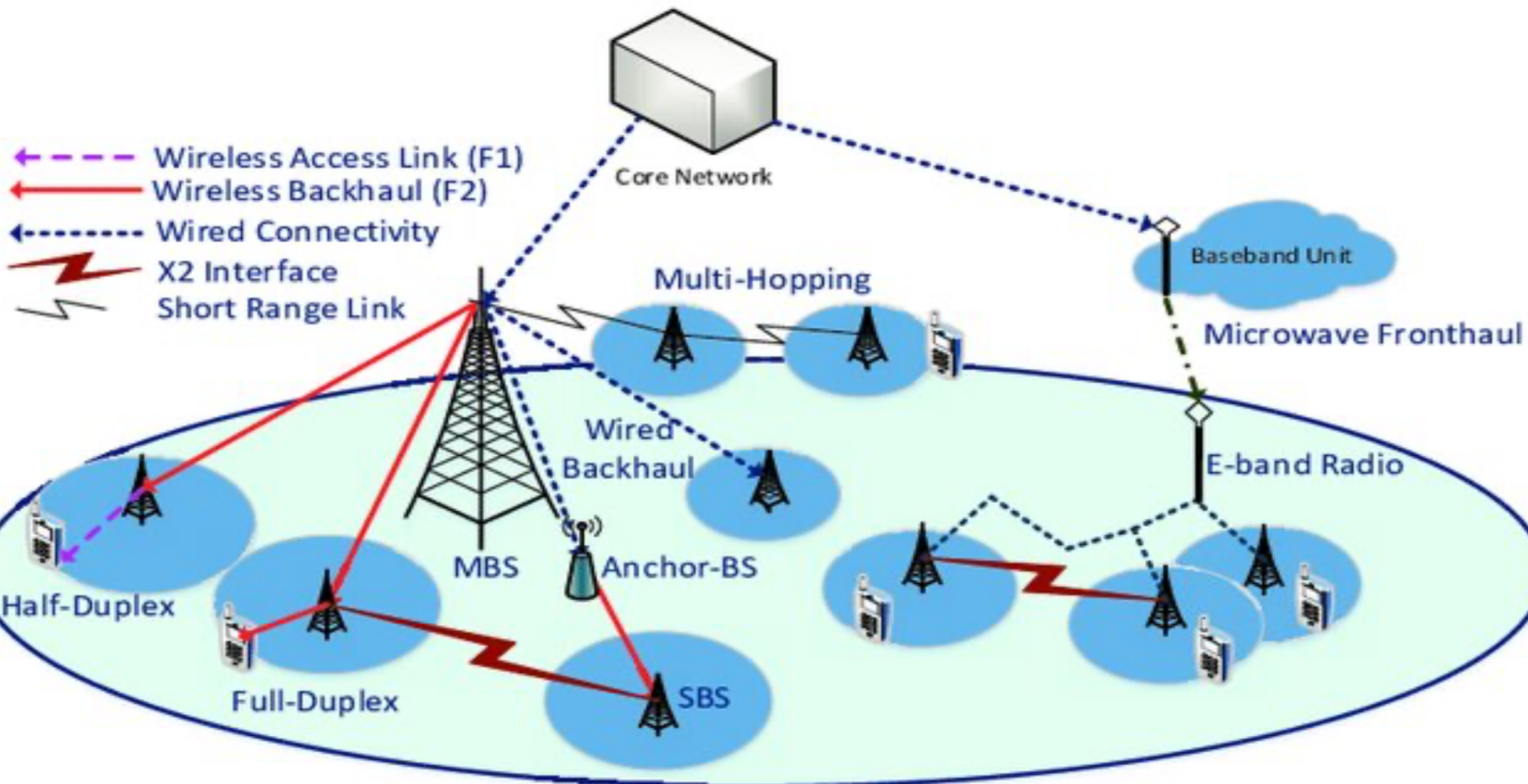
Work and play
in the cloud

3D video, UHD screens

Key Technologies of 5G & IoT

- Millimeter waves
- Massive MIMO
- Multi-RAT (Radio Access Technology)
- Advanced D2D (Device to Device), M2M
- Dense Small Cell deployment





The 5G HetNet

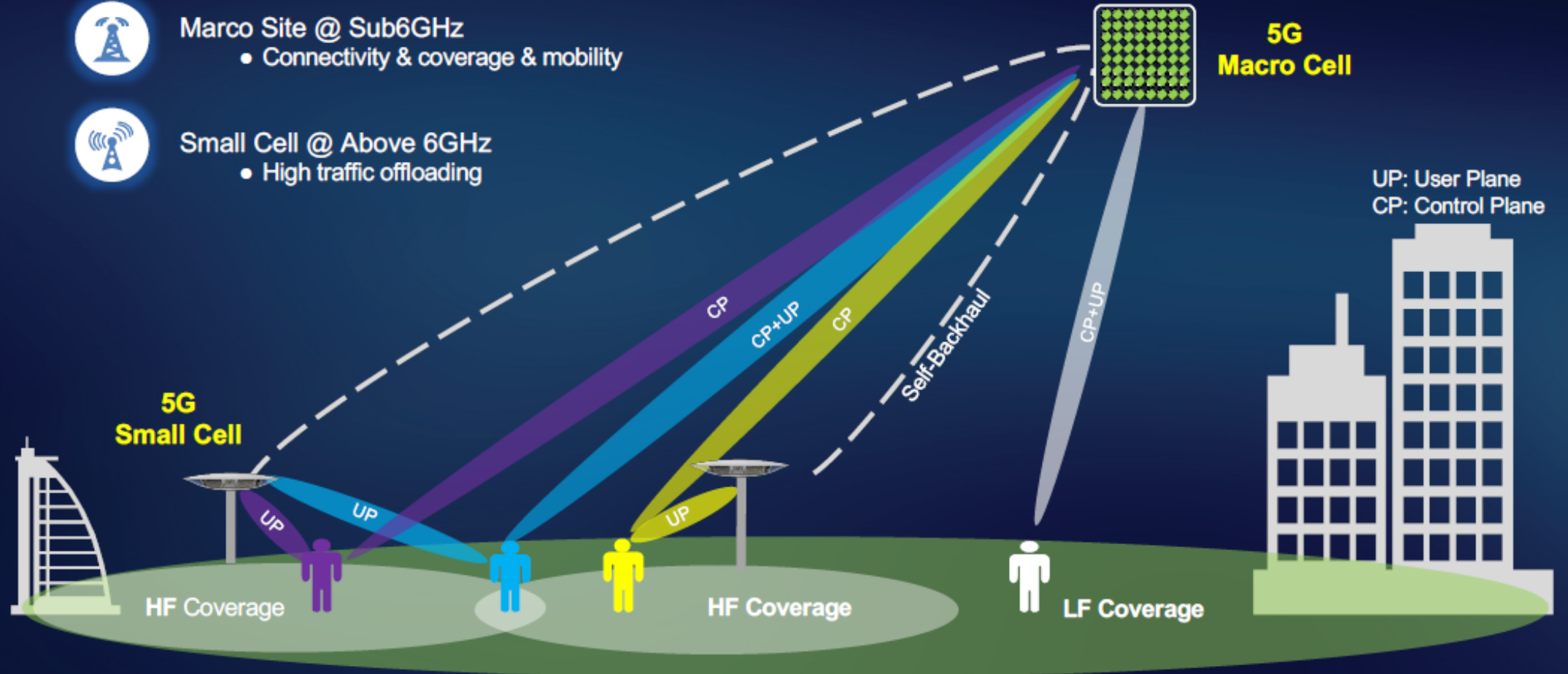
Beamforming/power mangment/U&NU



Macro Site @ Sub6GHz
• Connectivity & coverage & mobility



Small Cell @ Above 6GHz
• High traffic offloading





 Macro Cell - outdoor
200 [W]

 Micro Cell – outdoor/indoor

 Pico Cell – outdoor/indoor

 Femtocell – indoor



Coverage area	100 meters to 250 meters (indoors)
Power	Typically 250 milliwatts
Number of users	32 to 64 users
Backhaul	Wired, fiber connection
Application	Indoor applications (offices, hospitals, shopping centre and schools)
Cost	Low cost



Coverage area	500 meters to 2.5 kilometers
Power	2 to 5 watts
Number of users	up to 200 simultaneous users
Backhaul	Wired, fiber connection and microwave links
Application	Outdoor applications
Cost	Medium cost



Coverage area	10 meters to 50 meters (indoors)
Power	Typically 100 milliwatts
Number of users	8 to 16 users
Backhaul	Wired, fiber connection
Application	Indoor (primarily for indoor application, can be used for outdoor applications)
Cost	Low cost



Health Effects

& Overview over my own
Research on mobile phone
and Base stations effects

Cell phone radiation: Harmless or health risk?

Biological hazards of electromagnetic fields

Thermal effects

Nonthermal Effects



SAR and Exposure guidelines ?

The most apparent biological effects of RF energy at cell phone frequencies are due to heating. (increase in the temperature of the tissues)

EM radiation Non-thermal effects

- **Worms raise safety concerns over mobile phone radiation.** Nottingham University UK found that female nematode worms exposed to mobile phone radiation produced stress hormones, grew 10% larger, and produced more eggs. New Scientist 7 Feb 2002
- **Pigeons get lost near radio masts.** research shows that the prized birds, able to find their way from 700 miles away, get confused near radiation-emitting masts. Exposure also makes pigeons fly much lower than usual. Now pigeon fanciers are demanding curbs on the number of mobile phone masts to protect their birds. Research by the Swiss Bird Study Organisation. Sunday Mirror 18 June 2000
- **Mobile phone radiation causes birth defects in chickens** - 10,000 chicks exposed in eggs to mobile phone radiation. Result = doubled number of birth defects. Dr Theodore Litovitz, Catholic University of America found research confirmed earlier French findings last year. Sunday Telegraph (Australia) 2 May 1999
- **RF radiation IMPROVES brain function.** Tiny study - only 36 people for 30 minute bursts. Bristol University Dr Alan Preece. Lloyds Product Liability International 5 April 1999
- **Mobile phone radiation disturbs sleep patterns.** Electromagnetic fields from mobile phone use in bed significantly increases brain activity during early, non-rapid-eye-movement sleep.

EM radiation Non-thermal (Long term) effects

- Cancer promotion, “glioma and malignant tumors” ! “Possibly carcinogenic”
- Acoustic neuroma and central nervous system
- Alterations in cellular growth / DNA damages
- Effects on embryo development
- Male Fertility (sperm activity)
- Glucose metabolism
- EM hypersensitivity
- Immune system
- Ocular Clouding (cornea, lens) ** (mmWaves)
- Skin Effects ** (mmWaves)

- *Animal based & Population-based Studies.*

1. Vast majority has given a negative answer (non thermal effects)
2. Some positive findings, but, generally, not been replicated (different power levels and exposure)
3. None of previous studies investigate the impact of frequencies in the mm-Wave band.
4. Needs long term studies (years)

EM radiation Non-thermal effects (Animal based studies)

1. Brain cancer in rats after RF radiation exposure

Researchers, dates ^a	Exposure to RF radiation			No. of rats		Cancer	
	Frequency, MHz	SAR, W/kg	Duration, months	RF exposed	Unexposed	Tumor generation	
Brain tumor generation							
C.K. Chou et al., 1992	2450 PM	0.15–0.4	25	100	100	None	
J.C. Toler et al., 1997	435 PM	0.32	21	200	200	No significant difference between groups	
M.R. Frei et al., 1998	2450 FM	0.3	18	100	100	None	
M.R. Frei et al., 1998	2450 FM	1.0					
Brain tumor generation PLUS promotion of chemically induced tumors							
Researchers, dates ^a	Frequency	SAR	Duration	RF exposed ^b	Unexposed ^b	Tumor generation	Tumor promotion
W.R. Adey et al., 1999	837 PM	0.3–2.3	25	60 ^b	60	Insignificant decrease in RF-exposed rats	None
W.R. Adey et al., 2000	837 FM	0.3–2.3	26	90	90	No sig diff.	
B.C. Zook et al., 1999	860 FM	1	22	60	60	No sig diff.	
B.C. Zook et al., 1999	860 PM						

National Toxicology Program (NTP) study
Ramazzini Institute Study.

the claimed about the carcinogenicity of RF can not be applied to 5G gNBs and 5G UE. [4]

Some + findings : male rats?

Source: <http://infoventures.com/emf/spectrum.htm>.



INTERPHONE Project (IARC) – Population based studies

http://www.iarc.fr/en/media-centre/pr/2010/pdfs/pr200_E.pdf

- This is **the largest study of the risk of brain tumours in relation** to mobile phone use conducted to date. Use of mobile phones over ten years **was conducted by IARC. case-control approach, across 13 countries during the years 2000-2012.** more than 5000 patients with glioma or meningioma and 1000 patients with acoustic neuroma. similar group of people, not affected. “case-control approach”
- **Overall, did not prove any connection between glioma or meningioma and acoustic neuroma and use of mobile phones.** There were observation of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation.
- Same results for **Danish Cohort Study** (1990-2007 - 380000 subscriber) , **Million Women Study(UK) 1999-2009, and CEFALO Case-Control Study** (EU, age 7-19){patients were interviewed about UE usage}

WHO: Cell phone use can increase possible cancer risk

By Danielle Dellorto, CNN
May 31, 2011 -- Updated 1749 GMT (0149 HKT)

<http://edition.cnn.com/2011/HEALTH/05/31/who.cell.phones/>



The Telegraph

May 31, 2011

Mobile phones 'possibly carcinogenic' say World Health Organisation experts

Mobile phones may increase the risk of developing brain cancer, an influential health organisation has said admitted for the first time.



31 May 2011

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Lyon, France, May 31, 2011 -- The WHO/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as **possibly carcinogenic to humans (Group 2B)**, based on an increased risk for **glioma**, a malignant type of brain cancer¹, associated with wireless phone use.

Group 2B - possibly carcinogenic (not Group 2A - probably carcinogenic).

That means that there **"could be some risk" of carcinogenicity**, so additional research into the long-term, heavy use of mobile phones needs to be conducted.

http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf



Conclusions

- So far little evidence that mobile phone use affect brain tumor risk
- Incidence trends are not compatible with the few observed risk increases
- However, some uncertainties remain:
 - Still short induction period – up to around 15 years
 - Need to follow-up on the results for heaviest users
- Can only be done with prospective design combining self-reported and registered mobile phone use
 - Must minimize recall bias and non-differential exposure misclassification, as well as selection bias
- Follow brain tumor incidence trends in high quality registers



Conspiracy theory

Does 5G cause of spread the
Coronavirus?

Fear of 5G !!!!!!!

International Protest Day against 5G EMF Radiation 2020

25 Jan 2020



Letter: More cell towers, more radiati...
revelstokereview.com



Anti 5G campaigners protest outside...
onthewight.com



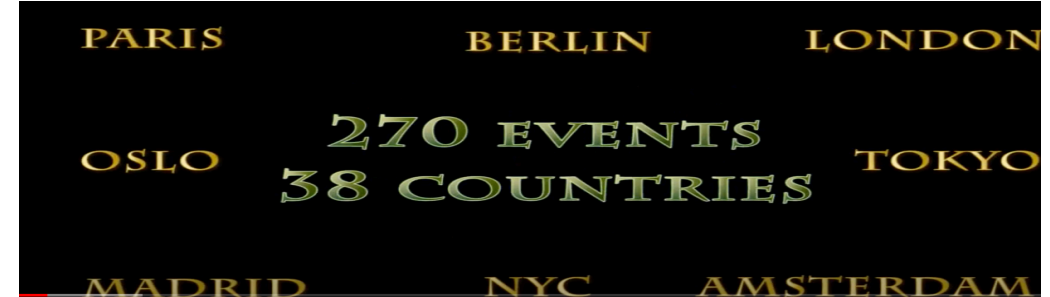
5G Fear: Protesters rally in Grass Vall...



After protests, Fairfield Grace church...
ctpost.com



Electromagnetic Radiation Safety: 5...
saferemr.com



This article is more than 1 month old

How baseless fears over 5G rollout created a health scare

Misconceptions about the technology and lack of consultation with local communities may have boosted conspiracy theories



A toxic misinformation and fake news fabrications



“radiophobia”



Hoax



<https://www.youtube.com/watch?v=dJWlxbznDIQ>



A viral message on social media has claimed that over 297 birds died in The Hague, Netherlands, during an attempt to test 5G connectivity.

the two incidents – 5G radiation and the trees / birds' deaths – are likely unrelated.

Viral video claiming 5G caused pandemic easily debunked

Video spreads false claims linking technology to coronavirus

Katie Nicholson, Jason Ho, Jeff Yates · CBC News · Posted: Mar 23, 2020 5:55 PM ET | Last Updated: March 23

inaccuracies and fabrications



A video that has gone viral with the claim that the coronavirus was caused by 5G technology has been debunked by virologists. (Jeff Yates/CBC)

<https://www.cbc.ca/news/technology/fact-check-viral-video-coronavirus-1.5506595>

<https://www.youtube.com/watch?v=IJwvTmZ4AMU>

Cowan claims that **Wuhan**, the location where the COVID-19 outbreak began, was the first city to be covered by 5G. (two things are linked).

Note, Iran, one of the worst hotspots for COVID-19, does not have a 5G network, alongside other countries like Japan and Malaysia, also hit hard by the pandemic.

...EXPLOITING THE CURRENT
CRISIS TO CREATE
CONFUSION AND **FEAR**



Keri Hilson
@KeriHilson

People have been trying to warn us about 5G for YEARS. Petitions, organizations, studies...what we're going thru is the affects of radiation.

5G launched in CHINA. Nov 1, 2019. People dropped dead. See attached & go to my IG stories for more. TURN OFF 5G by disabling LTE!!!

Who invented 5G?

SOME **"SOURCES"** IN
SOCIAL MEDIA HAVE
EVEN LINKED
5G NETWORKS TO
THE **OUTBREAK...**

Burning Cell Towers, Out of Baseless Fear They Spread the Virus

A conspiracy theory linking the spread of the coronavirus to 5G wireless technology has spurred more than 100 incidents this month, British officials said.



UK ► UK politics Education Media Society Law Scotland Wales Northern Ireland

Crime

This article is more than 3 months old

UK phone masts attacked amid 5G-coronavirus conspiracy theory

Police investigate possible arson attacks as officials and experts reject rumours that 5G causes Covid-19

- Coronavirus - latest UK updates
- See all our coronavirus coverage

Nazia Parveen and Jim Waterson
Sat 4 Apr 2020 13:20 BST
4,221

1:03

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England Local News Regions

IT Network Training, Earn More
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Mast fire probe amid 5G coronavirus claims

4 April 2020

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Coronavirus pandemic

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23,515 views | Apr 5, 2020, 08:24am EDT

UK Phone Masts Are Being Set On Fire Over 'Dangerous' 5G Coronavirus Conspiracies

Carly Page Contributor
Consumer Tech
I cover Tech in Europe, including big tech, PC hardware and telecoms

British 5G towers are being set on fire because of coronavirus conspiracy theories

112

5G is causing anarchy in the UK

By Tom Warren | @tomwarren | Apr 4, 2020, 12:44pm EDT

f t ↗ SHARE



A 5G cell tower | Photo by Mikhail Pochuyev/TASS via Getty Images

5G phone masts are being set alight in the UK, after online conspiracy theories have misleadingly linked the cell towers to the coronavirus pandemic. The [BBC reports](#) that at least three 5G towers were set alight within the last week, and police and fire services were called to extinguish the flames.

A Vodafone UK spokesperson confirmed to *The Verge* that four cell towers were targeted in the past 24 hours. Police have now launched investigations into how the 5G towers caught fire. At least one tower in Birmingham, operated by EE, doesn't even provide 5G services but was still set on fire.

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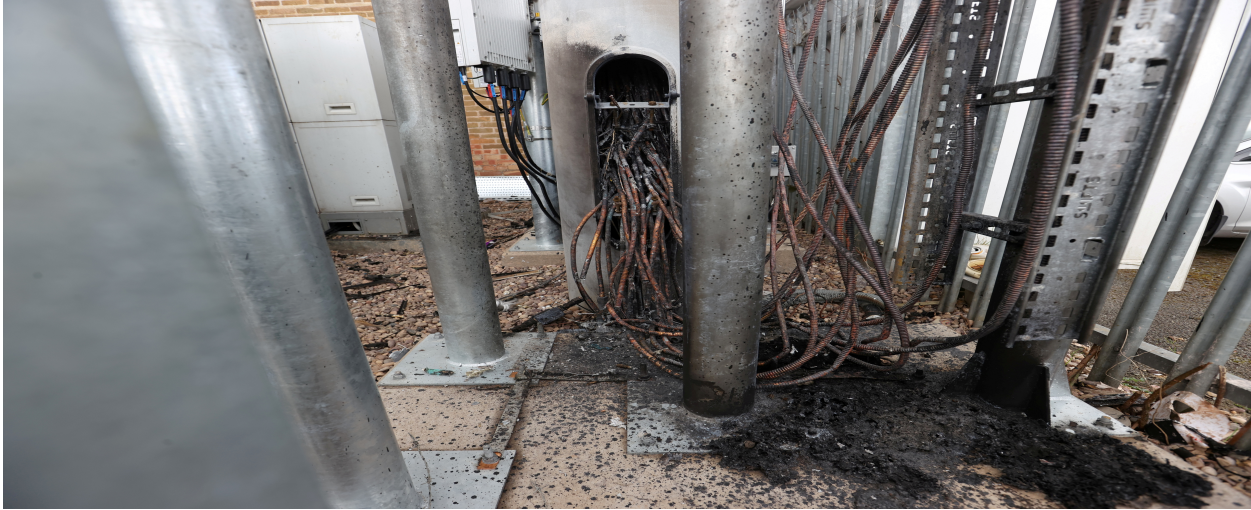
Eero's three-pack of mesh Wi-Fi routers is down to \$170 at Best Buy and Amazon



Toshiba's discounted 50-inch 4K



Damaged cabling and telecommunications equipment in Huddersfield, northern England, on April 17, 2020. The fire comes after a number of mobile phone masts have been set on fire amid claims of a link between 5G and the novel coronavirus COVID-19. | Photo by OLI SCARFF/AFP via Getty Images



Damaged cabling and telecommunications equipment is pictured following a fire at a phone mast, attached to the chimney at the converted Fearnley Mill residential apartment block complex in Huddersfield, northern England, on April 17, 2020. OLI SCARFF/AFP via Getty Images

5G, COVID conspiracy theory claims 77 UK phone masts

By Catherine Sbeglia on MAY 7, 2020

5G, Network Infrastructure



The cause of a fire that damaged telecommunications equipment in Huddersfield, England, is not yet known; several cell towers have been burned amid claims that 5G technology is related to COVID-19. Photograph by Oli Scarff / AFP / Getty

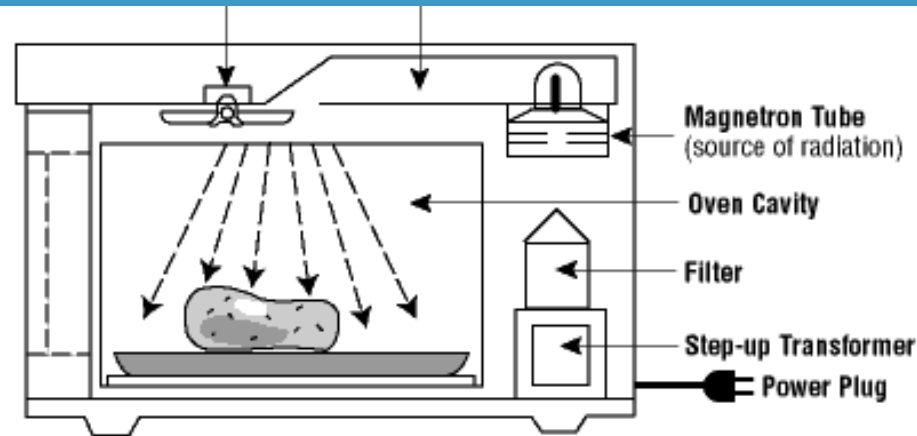
**THERE IS NO CORRELATION
BETWEEN 5G DEPLOYMENT
AND THE OUTBREAK
OF THE CORONAVIRUS!**

5G & Covid19 Spreading

**Fake theories are not
based on any scientific
evidence**



Thermal effects



radiation. Most household microwave ovens operate on a frequency of 2.450 GHz in a continuous wave (cw) mode.

- Typical levels of radiation leakage from microwave ovens is max about 0.2 mW/cm^2
- This level of leakage cannot be sensed by the body.
- The power density decreases rapidly with increasing distance.

Thermal effects

- Dielectric heating, in which any dielectric material (tissue) is heated by rotations of polar molecules.
- cell phone: heating effect: at the surface of the head, causing its temperature to increase by a fraction of a degree. (less than sunlight effect).
- The brain's blood circulation is capable of disposing of excess heat by increasing local blood flow.
- However, the cornea of the eye does not have this temperature regulation mechanism. (cataracts disease of engineers who work on high power radio transmitters at similar frequencies).

Thresholds for the induction of thermal effects to the human body

Target	Effect	Threshold
Whole body	Various physiological effects	1.0 °C
Eye lens	Cataract	3 ÷ 5 °C
Skin	Warmth sensation	0.02 ÷ 1 °C
	Pain sensation / Burns	10 ÷ 20 °C
Brain	Neuron damage	4.5 °C

Experiment on thermal effects of the rabbit eye

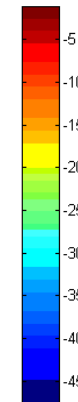
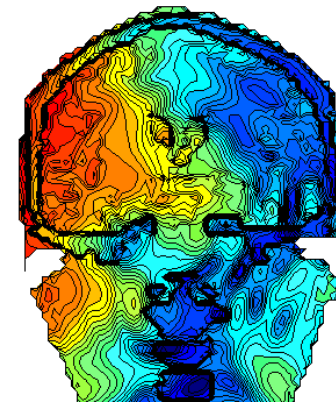
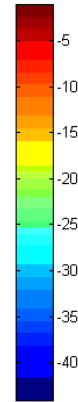
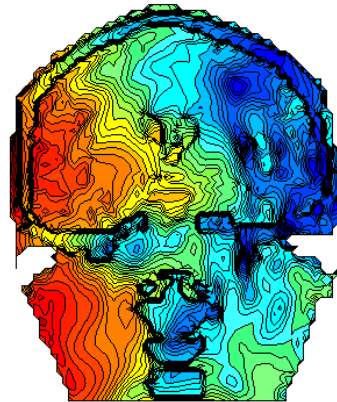
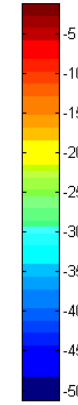
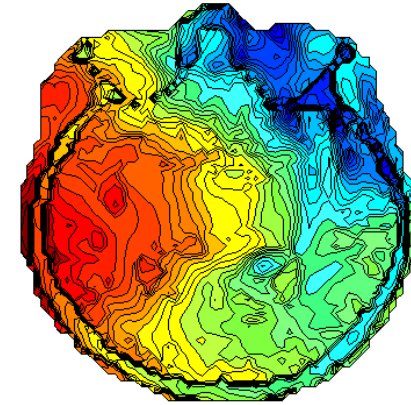
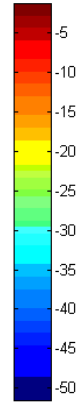
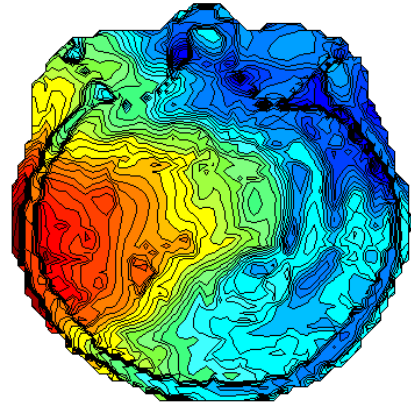
Exposure of the rabbit eye (very similar to human eye) to incident power densities higher than (100 mW/cm²) applied for at least half an hour is able to induce lens opacification (cataract), appearing after a latency period of a few days. Temperature of the lens is increased by at least 3 °C. note: GL (1 mW/cm²).

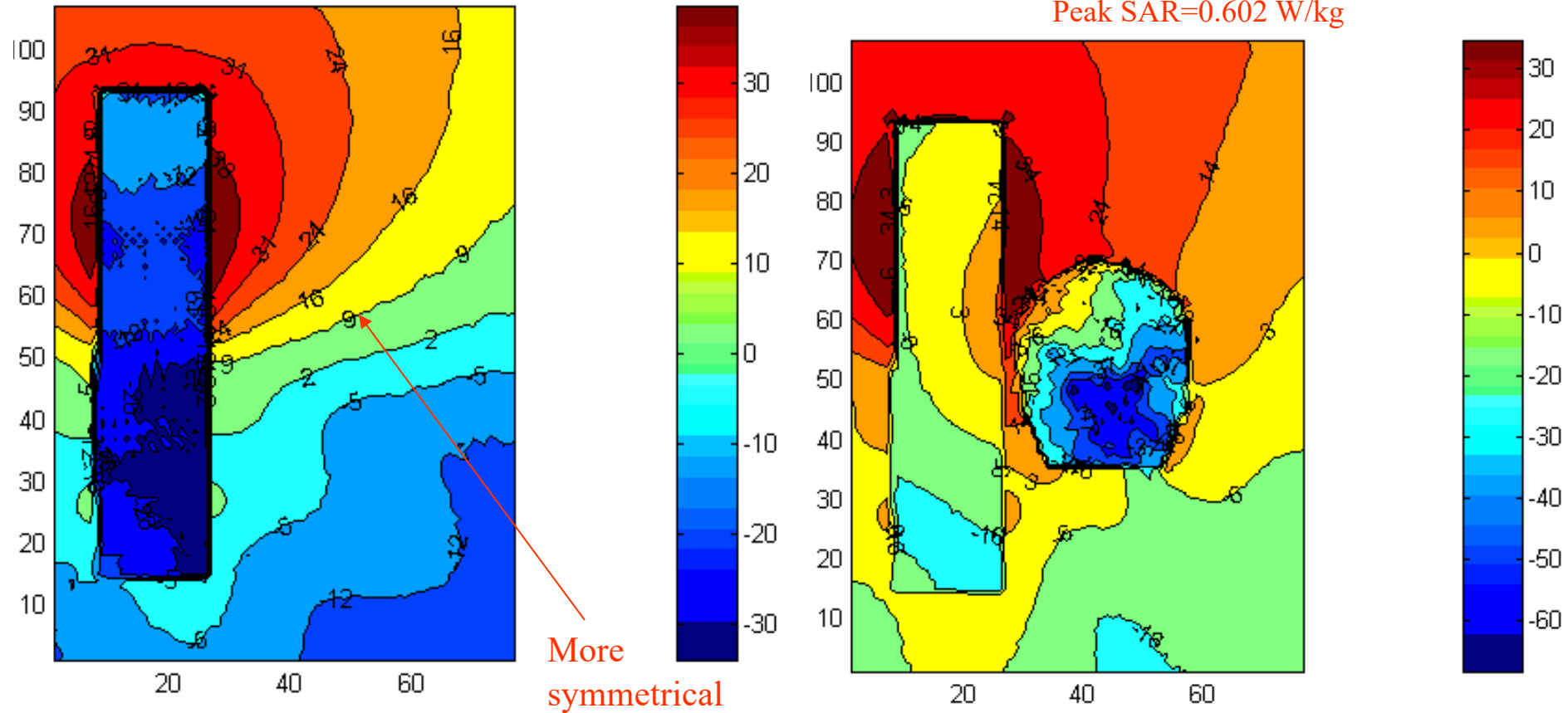
Temperature elevations induced, after 15 minutes, in the user's head
by a phone equipped with helical antenna kept in "touch-cheek" position

$$f = 835 \text{ MHz}; P_{\text{rad}} = 250 \text{ mW}$$

Heating cause	ΔT_{ear} [°C]	ΔT_{brain} [°C]
SAR	0.08	0.02
Phone contact	0.90	0.01
Phone contact + power dissipation in the amplifier	0.94	0.01
Phone contact + power dissipation in the amplifier + SAR	0.98	0.02

Unaveraged MAX SAR, for the realistic head image adjacent to the helical antenna handset, as modelled by the hybrid method.





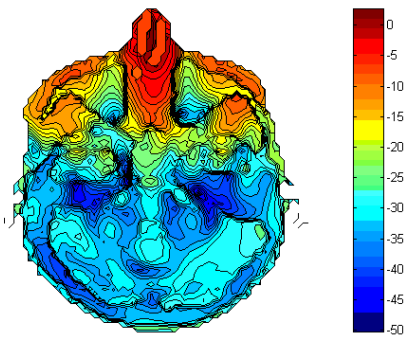
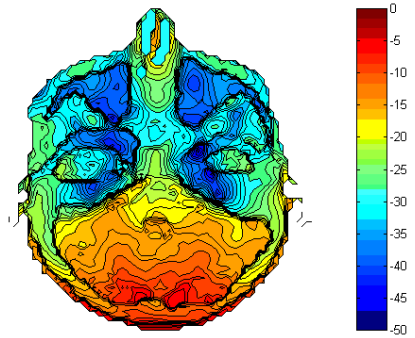
Electric field distribution (in dB) for satellite QHA handset in free space (input voltage of 1 volt for each of the four feed sources) using hybrid method

Electric field distribution (in dB) at central vertical slice of a simulated biological head interacting with satellite QHA handset, with separation distance of 2cm, using hybrid method

Microcells Radiation Head only interaction Study (vodafone , UK)

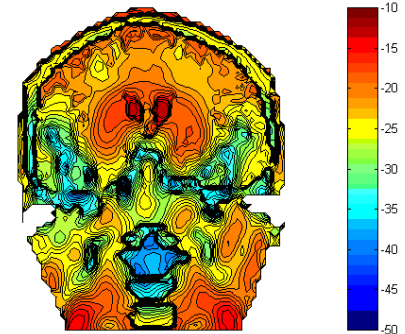
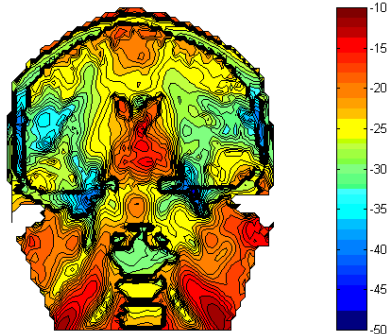
A comparison between the safety distances of a micro cell antenna using electromagnetic field and the specific absorption rate (SAR) assessment is made.

The input power in the antenna is determined such that the electromagnetic fields and the SAR equal the reference levels and the basic restrictions, respectively, at a certain distance.

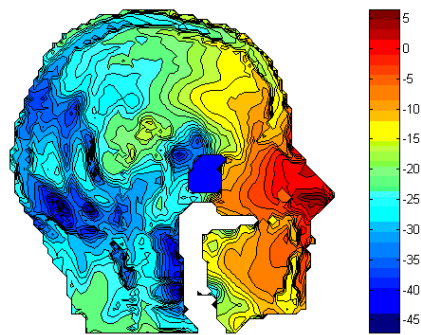
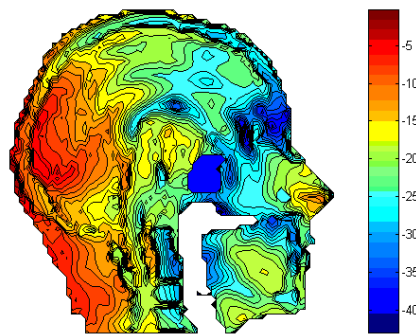


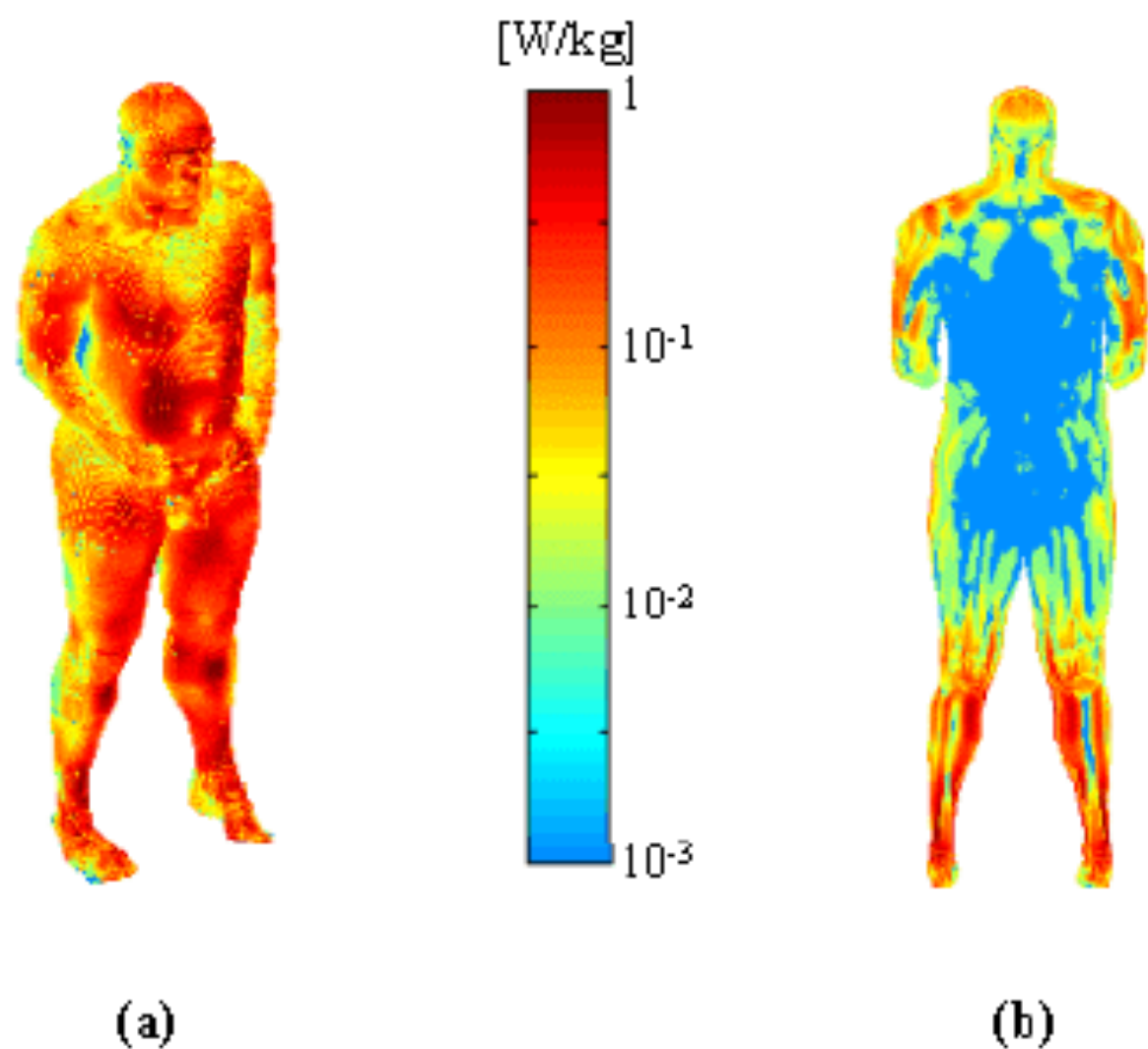
(Notes):

- The local field concentration in the nose



Peak SAR calculations (in dB) for the three main median planes for half wavelength dipole antenna **behind (left column) and in front of (right column)** the head. Frequency **1875.5 MHz**, distance **0.5 wavelength** from nearest point of head. Radiated power normalised to **1W**.





- SAR distribution: (a) over the body surface; (b) in a coronal section
 $f = 900 \text{ MHz}$; $P_{\text{inc}} = 1 \text{ mW/cm}^2$

Far field measurements



Equipments and Software:

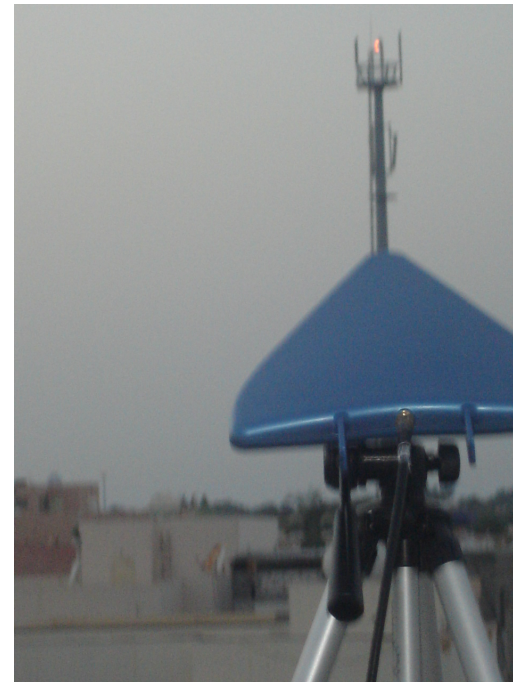
- spectrum analyser (SPECTRAN® HF-6080)
- The antenna (HyperLOG® 6080)
- tripod, adopter and 5 meters extension cable.
- Microsoft® Office Excel
- "Google Earth"
- SPECTRAN spectrum analyser software "LCS"



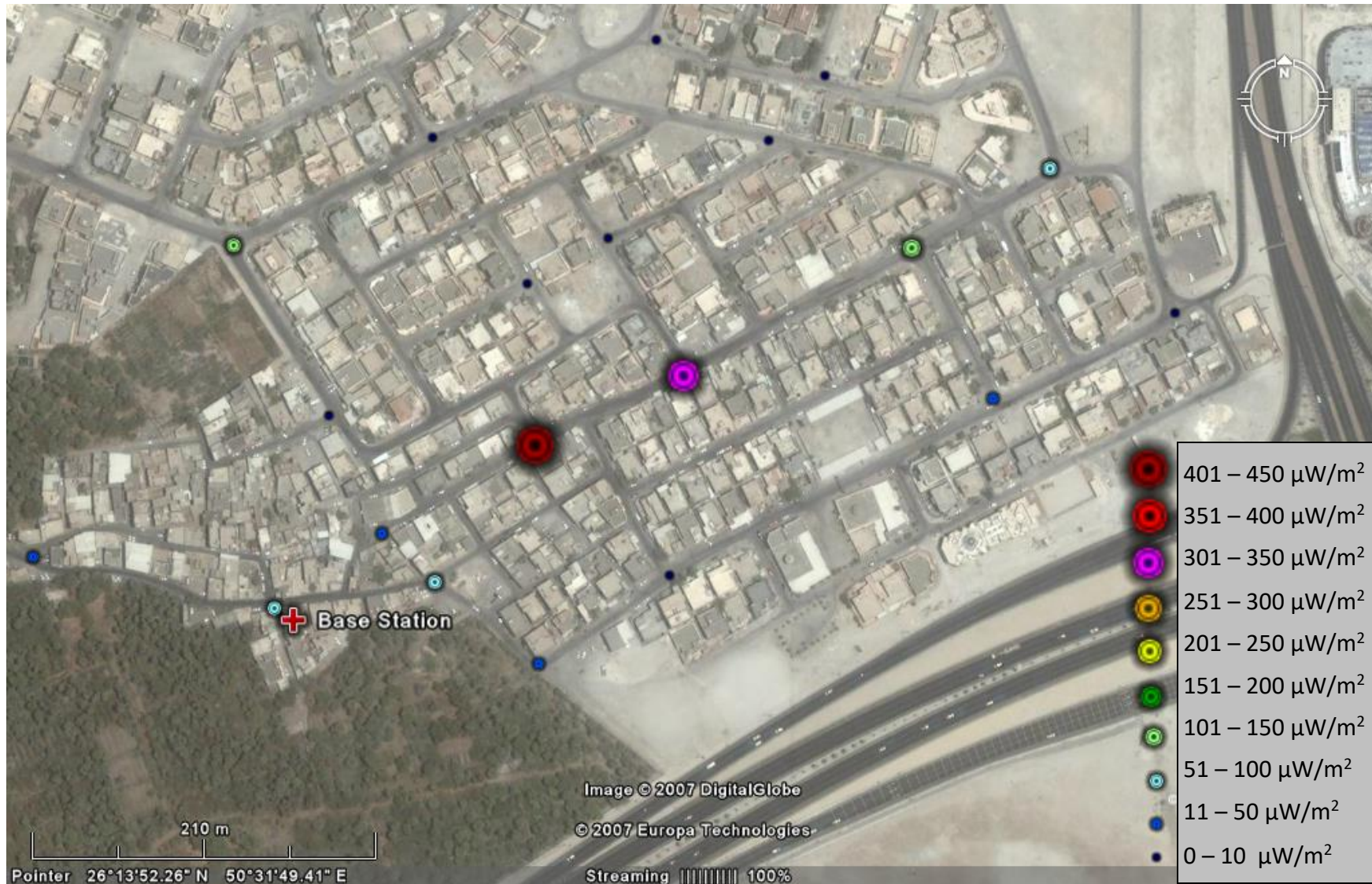
Long term (24 hours) measurement of RF radiation

2-Long-term measurements:

- The antenna was fixed and connected to the spectrum analyser.
- The number of readings was set 240 and the time between readings is 360 seconds.
- After 24 hours the data were downloaded using spectrum analyser software “LCS”.



Street Mapping of Power Density



- The levels of RF radiation from mobile phone base stations in the Kingdom of Bahrain was much less than exposure limits issued by ICNIRP or by PCPMREW.
- Max. RF radiation levels for GSM900:
0.003400 W/m² (E=1.133 V/m and H=3.007 mA/m)
→ 0.073% of ICNIRP limit (4.63 W/m²) ∴ 1362 times less

Max. RF radiation levels for GSM1800:

0.001440 W/m² (E = 0.737 V/m and H = 1.958 mA/m).

→ 0.016% of ICNIRP limit

- Max. RF radiation levels for UMTS:
0.00064739 W/m² (E = 0.494 V/m and H = 1.311 mA/m)
→ 0.016% of ICNIRP limit

ICNRP statement (2G/3G/4G)

Recent surveys have shown that the RF exposures from base stations range from 0.002% to 2% of the levels of international exposure guidelines

10th October 2016
Pre- 5G in BH



Control of Telecom Mast Emissions

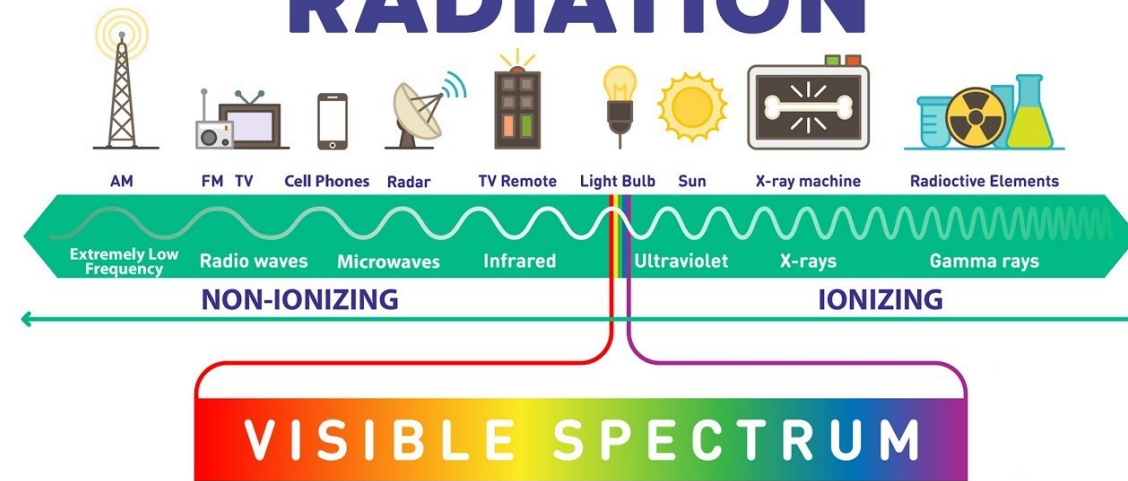
Electromagnetic emissions of any telecom base stations have been proven to be un-harmful by World Health Organization (WHO) and International Telecommunication Union (ITU).

Monitoring Radio Emissions from Base Stations of Public Operators in the Kingdom of Bahrain

Following extensive research, **ICNIRP** has produced guidelines setting out levels of non-ionizing radiation (which includes EMF radiation discussed above), at or below which, **there is no scientific evidence to show any danger** to human health. These levels have been accepted and adopted by the **WHO**.

<https://www.tra.org.bh/Media/Licenses/Measurement%20Mechanism.pdf>

IONIZING VS. NON-IONIZING RADIATION



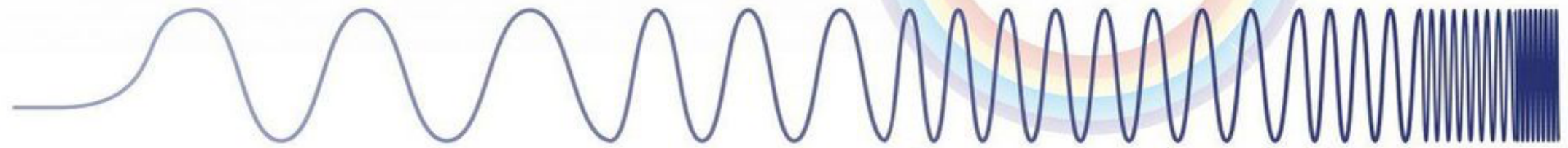
ENERGY

NON-IONIZING IONIZING

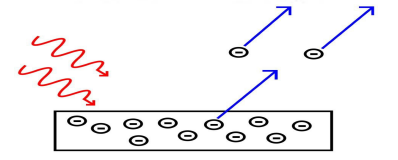
SAFE and BENEFICIAL IN APPROPRIATE DOSAGE * **ALMOST SAFE, LOW DANGER** **DANGER** **SAFE and BENEFICIAL IN APPROPRIATE DOSAGE *** **EXTREMELY HARMFUL**



ELF VLF LF RADIOFREQUENCIES MICROWAVES INFRA-RED VISIBLE ULTRAVIOLET X-RAY GAMMA RAYS

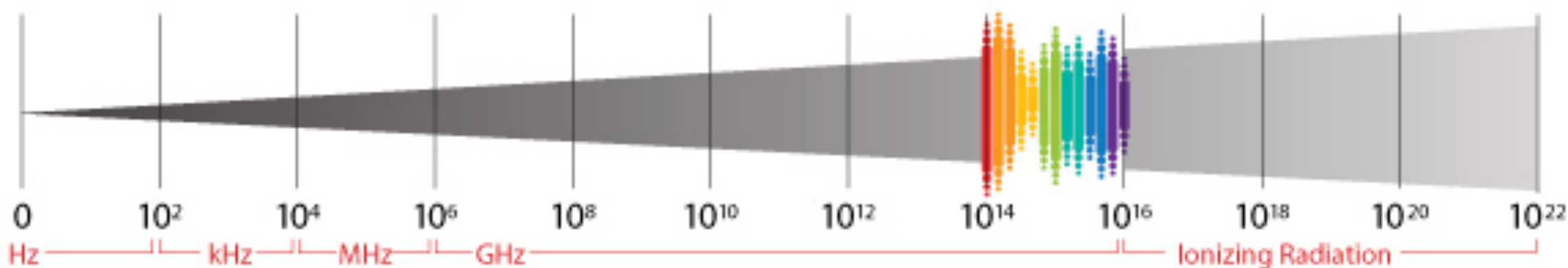


	50 Hz	1 MHz	500 MHz	1 GHz	10 GHz	30 GHz	600 THz	3 PHz	300 PHz	30 EHz
FREQUENCY										
WAVELENGTH	6000 km	300 m	60 cm	30 cm	3 cm	10 mm	500 nm	100 nm	1 nm	10 pm



Electromagnetic Spectrum

Frequency (Hz)



Direct Current

Extremely Low Frequency

Low Frequency

Radiowaves

Microwaves

Infrared Radiation

Visible Light

Ultraviolet Radiation

X-rays

Gamma Rays



Computer
60–100 Hz



Radio
AM 520–1610 kHz
FM 87.5–108 MHz



Cell Phone UMTS
1.9–2.2 GHz



Microwaves
3–30 GHz



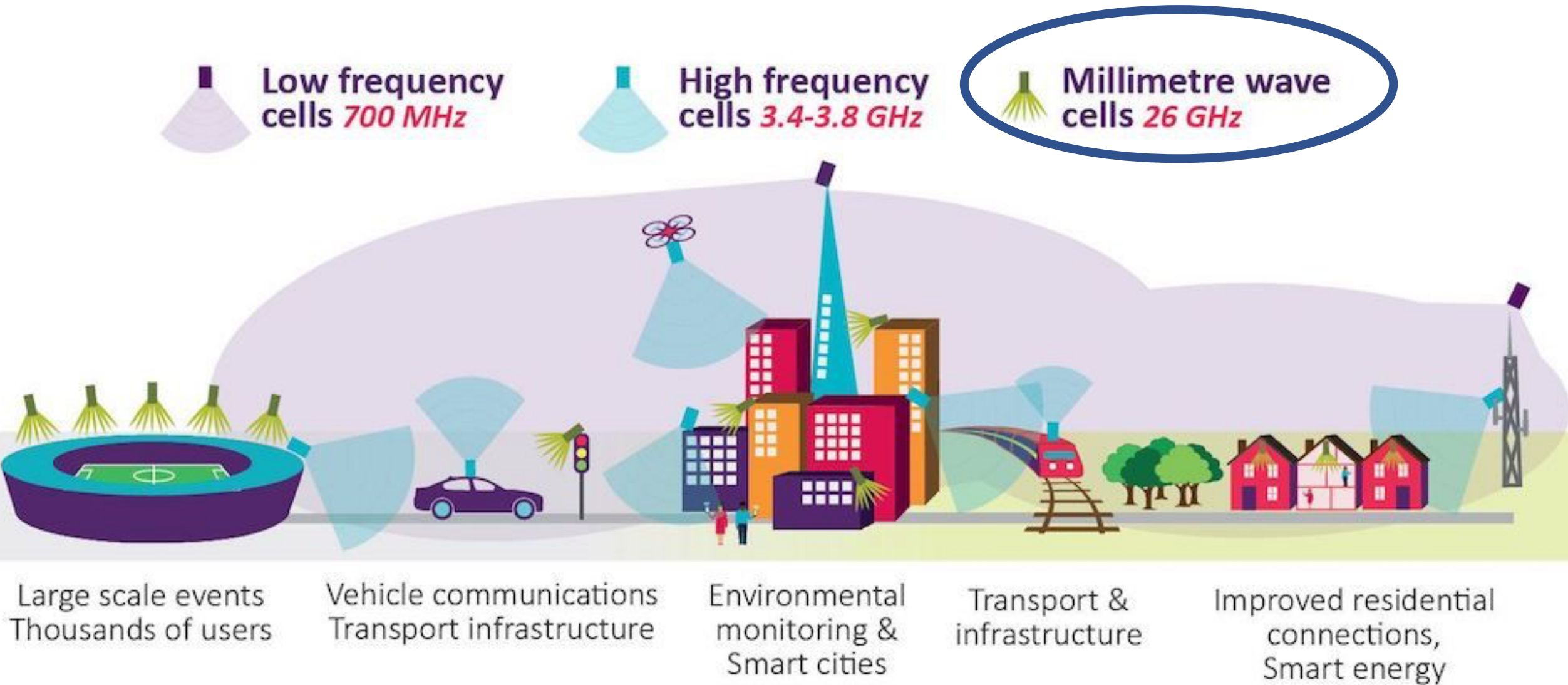
Remote Control
5.8 GHz



Ultraviolet
UVA and UVB



X-rays
range from
 30×10^{16} Hz
to 30×10^{19} Hz



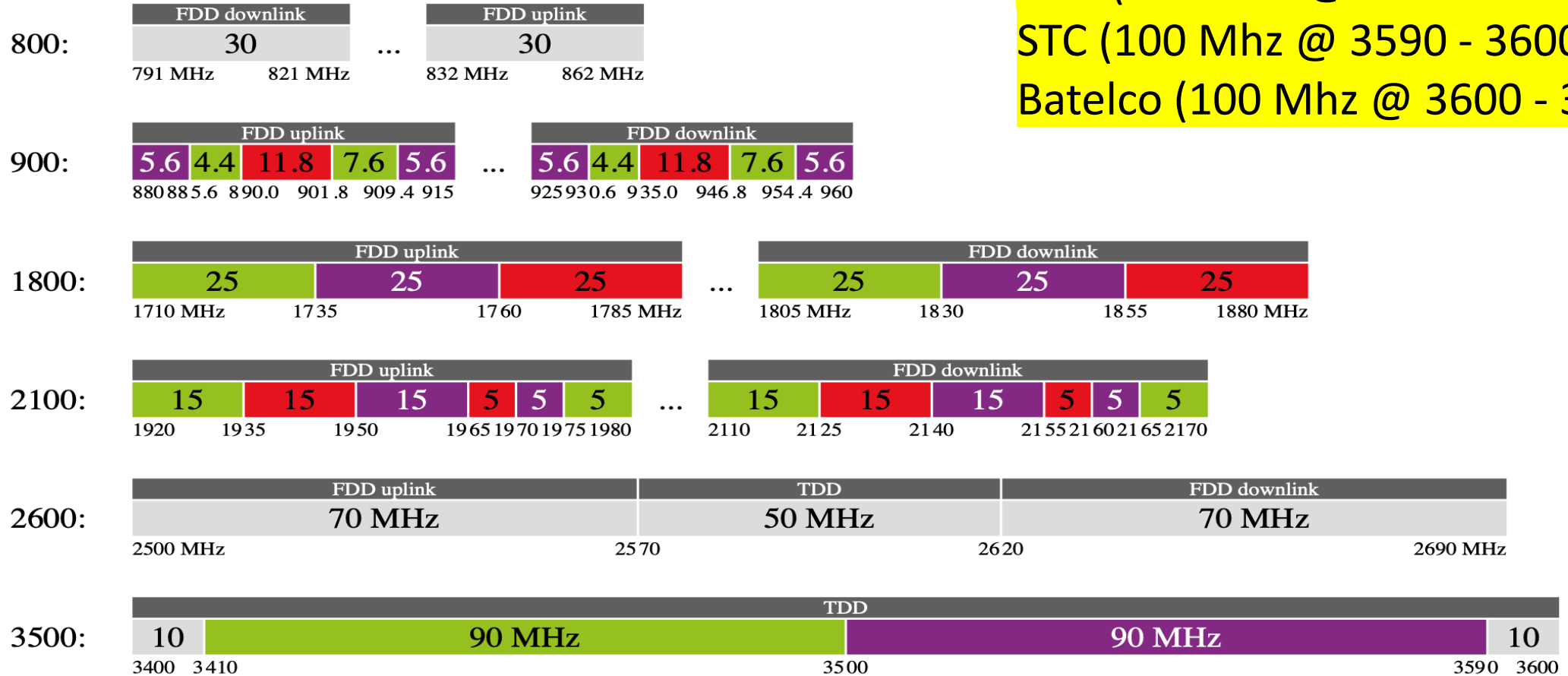
THE millimeter-wave (mmWave) band : is part of the radio frequency (RF) spectrum, comprised of frequencies between 30 GHz and 300 GHz, corresponding to a wavelength range of 10 to 1 mm. The photon energy of mmWaves ranges from 0.1 to 1.2 milli-electron volts (meV). Unlike ultraviolet, X-ray, and gamma radiation, mmWave radiation is non-ionizing, and the main safety concern is heating of the eyes and skin caused by the absorption of mmWave energy in the human body [1][2][3].

5G NR uses two frequency ranges:^[4]

1. Frequency Range 1 (FR1), including **sub-6 GHz** frequency bands
2. Frequency Range 2 (FR2), including frequency bands in the **mmWave** range (**24–100GHz**)

Country or territory	Operator	Band									Notes
		DSS with 4G LTE	n40 2.3 GHz	n41 2.5 GHz	n78 3.5 GHz	n79 4.7 GHz	n257 28 GHz (APAC)	n258 26 GHz (Ei Sort ascending)	n261 28 GHz	Others	
Bahrain	Batelco				90 MHz Jun 2019						[19][20][21]
	stc				90 MHz Jun 2019						[19][22][23]
	Zain				90 MHz Jun 2020						[19][24]
South Korea	LG U+				80 MHz Dec 2018		800 MHz Dec 2018				[1][175][176][177] World's first commercial service
	KT				100 MHz Dec 2018		800 MHz Dec 2018				[1][175][176][177] World's first commercial service
	SK Telecom				100 MHz Dec 2018		800 MHz Dec 2018				[1][175][176][177] World's first commercial service

Zain (100 Mhz @ 3400 - 3410 Band)
 STC (100 Mhz @ 3590 - 3600 Band)
 Batelco (100 Mhz @ 3600 - 3700 Band)



Fundamentals of mmWave Radiation

Nonionizing Characteristic of mmWave Radiation

The **mmWave** band is the part of the RF spectrum between **30 and 300 GHz** that corresponds to a free space wavelength ranging from 10 to 1 mm.

EM of RF is traveling waves, mmWave can also be described as having a particle-like nature. These particle-like components of electromagnetic waves are called “photons.” Each photon has an energy level given by

$$\text{Photon Energy: } E = hf = \frac{hc}{\lambda},$$

Higher frequency → higher energy

The photon energy of mmWaves ranges from **0.1 to 1.2 meV**.

Unlike ionizing radiation (ultraviolet, X-ray, and gamma radiation), which has been linked to cancer due to the displacement of electrons during exposure mmWave radiation is nonionizing because the photon energy is not nearly sufficient to remove an electron from an atom or a molecule (**typically 12 eV is required**).

Exposure levels at 5G frequencies?

**DOSIMETRY of
MILLIMETER WAVES**

Main Safety Guidelines

- **ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998)**. Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Physics 74(4), 494-522.
- **Federal Communications Commission (FCC) (1996) + IEEE Standards Coordinating Committee 28. IEEE standard (US)** for safety levels with respect to human exposure to electromagnetic fields, 0-3 GHz. New York, NY, IEEE - The Institute of Electrical and Electronics Engineers, **2002** (IEEE Std C95.6-2002).
- **WHO - World Health Organization**. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, **2007**.
- National standards : **EC + FCC + China + Russia + Switzerland + Italy standards**



RF EMF GUIDELINES 2020

Mar 2020

<https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html>

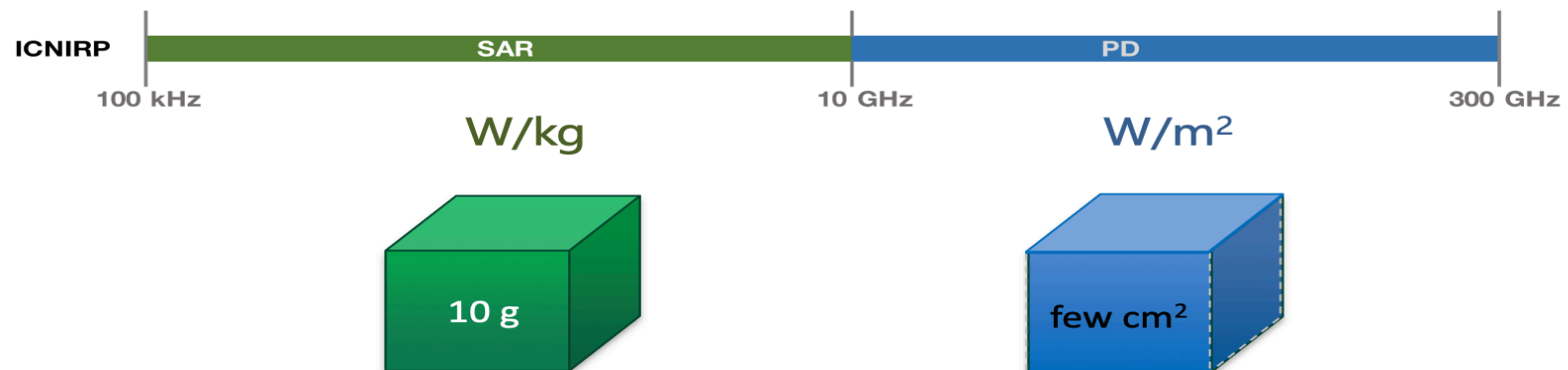
<https://www.icnirp.org/en/applications/mobile-phones/index.html>

Exposure guidelines

RF-EMF Compliance Standards

The two basic dosimetric parameter to establish if the exposure is safe or not are :

- 1. PFD, “S” (Reference Level, Free space measurements)
- 2. SAR (basic restriction, EM inside biological tissues)



Power density , “S” (Free space measurements)

$$PD = \frac{P}{S} = |\vec{E} \times \vec{H}|,$$

where P is the incident power, S is the exposed surface area, and \vec{E} and \vec{H} are the electric and magnetic field vectors, respectively.

The Specific Absorption Rate (SAR) (EM inside biological tissues)

معدل الامتصاص النوعي

SAR is defined as the rate at which energy is absorbed per unit mass of the body tissue, (power absorbed per unit mass) W/kg

$$SAR = \frac{P}{m} = \frac{\sigma |\vec{E}|^2}{\rho} = C \left. \frac{dT}{dt} \right|_{t=0}$$

E : the magnitude of the measured or computed rms electric field.

σ : the tissue conductivity , ρ : the tissue mass density.

m : the tissue mass , C : the heat capacity T : the temperature

- is a quantitative measure of power absorbed per unit of mass and time. In contrast to the PD, it also takes into account the physical properties of exposed samples:
- is a measurement of how much electromagnetic radiation is absorbed by body tissue whilst using a mobile phone.
- The higher the SAR the more radiation is absorbed.

TABLE 1. The variations of exposure limits to RF radiation in several countries.

Heating Limit

Country/Guidelines	PD Restrictions for the General Public in W/m²	PD Restrictions for the General Public in mW/cm²	Frequency Range (GHz)	Basis
ICNIRP [17] (1998)	10	1	2–300	Science based
FCC [16] (1996)	10	1	1.5–100	Science based
China [32] (1987)*	0.1	0.01	0.3–300	Science based
Russia [33] (2003)	0.1	0.01	0.3–300	Science based
Switzerland [34] and [35] (2000)*	0.1	0.01	1.8–300	Precautionary
Italy [36] (2003)*	0.1	0.01	0.0001–300	Precautionary
Typical maximum exposure from cellular base station mounted on 50-m tower (assuming a total effective radiated power of 2,500 W in each sector, summed over all channels)	0.01	0.001	1–2	Example from [29]

*These restrictions only apply to sensitive areas, such as school, hospital, or rooms in buildings, where they are regularly occupied by persons for prolonged periods.

TABLE 2. A comparison of the FCC and ICNIRP local SAR limits in the head and trunk for the general public.

Heating Limit

Exposure Standard	SAR Limits for Near-Field RF Exposure (W/kg)	Frequency Range (MHz)	Averaging Volume
ICNIRP	2	10–10,000	“any 10 g of contiguous tissue” (10-g SAR)
FCC	1.6	0.1–6,000	“any 1 g of tissue, defined as a tissue volume in the shape of a cube” (1-g SAR)

Modern mmWave Example Suggesting Temperature-Based Compliance

TABLE 3. FCC compliance evaluation criteria used for different exposure scenarios [44].

Heating Limit

Frequency (GHz)	Distance Between Radiation Sources and the Human Body (cm)	Criterion
< 6	< 20	SAR
< 6	> 20	PD (direct measurements)
> 6	> 5	PD (direct measurements)
> 6	< 5	PD (numerical modeling)

Guidelines for Limiting Exposure to Radiofrequency Radiation

Comparison between different Reference Levels for general public exposure for frequency band of [UMTS \(2110 – 2170 MHz\)](#):

	E-field strength (V/m)	H-field strength (A/m)	Power density (W/m²)
ICNIRP	61.4	0.16	10
NRPB	194	0.52	100
IEEE	---	---	14.07 – 14.47
FCC	---	---	10
ARPANS	61.4	0.163	10
CANADA	61.4	0.163	10
ITALY	6	0.016	0.1

2.2.2 Electric Field Strength, Magnetic Field Strength and Power Density (10 MHz–300 GHz)

To ensure compliance with the basic restrictions outlined in Section 2.1, at frequencies between 10 MHz and 300 GHz, the reference levels for electric- and magnetic-field strength and power density must be complied with.

TABLE 5: Reference Levels for Electric Field Strength, Magnetic Field Strength and Power Density in Uncontrolled Environments

Frequency (MHz)	Electric Field Strength (E_{RL}), (V/m, RMS)	Magnetic Field Strength (H_{RL}), (A/m, RMS)	Power Density (S_{RL}), (W/m ²)	Reference Period (minutes)
10–20	27.46	0.0728	2	6
20–48	$58.07 / f^{0.25}$	$0.1540 / f^{0.25}$	$8.944 / f^{0.5}$	6
48–300	22.06	0.05852	1.291	6
300–6000	$3.142 f^{0.3417}$	$0.008335 f^{0.3417}$	$0.02619 f^{0.6834}$	6
6000–15000	61.4	0.163	10	6
15000–150000	61.4	0.163	10	$616000 / f^{1.2}$
150000–300000	$0.158 f^{0.5}$	$4.21 \times 10^{-4} f^{0.5}$	$6.67 \times 10^{-5} f$	$616000 / f^{1.2}$

Frequency, f , is in MHz.

TABLE 6: Reference Levels for Electric Field Strength, Magnetic Field Strength and Power Density in Controlled Environments

Frequency (MHz)	Electric Field Strength (E_{RL}), (V/m, RMS)	Magnetic Field Strength (H_{RL}), (A/m, RMS)	Power Density, (S_{RL}), (W/m ²)	Reference Period (minutes)
10–20	61.4	0.163	10	6
20–48	$129.8 / f^{0.25}$	$0.3444 / f^{0.25}$	$44.72 / f^{0.5}$	6
48–100	49.33	0.1309	6.455	6
100–6000	$15.60 f^{0.25}$	$0.04138 f^{0.25}$	$0.6455 f^{0.5}$	6
6000–15000	137	0.364	50	6
15000–150000	137	0.364	50	$616000 / f^{1.2}$
150000–300000	$0.354 f^{0.5}$	$9.40 \times 10^{-4} f^{0.5}$	$3.33 \times 10^{-4} f$	$616000 / f^{1.2}$

Frequency, f , is in MHz.

Important Notes on Exposure guidelines

The highest frequency at which SAR is still considered: 10 GHz for the ICNIRP guideline and European Recommendation, 6 GHz for the IEEE standard and the FCC regulation.

Because the millimeter-wave frequency range absorption is extremely superficial, therefore power density (PD) is used.

Dosimetry Techniques

Analytical

- ❖ available for simple geometries and handsets
- ❖ Problem: These are rather restricted in their application to real life models.

Measurements

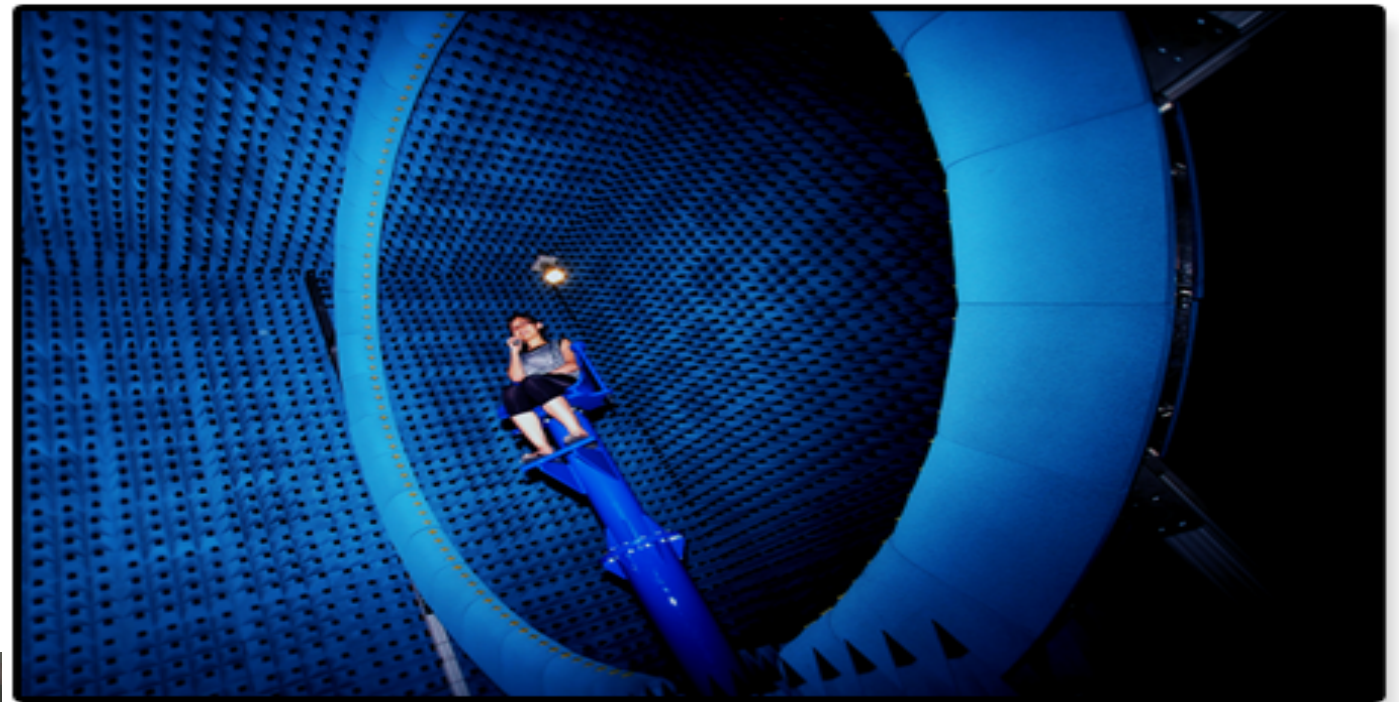
- ❖ Real radiating structure to expose anatomically shaped phantoms of the human body.
- ❖ Problem: rather simplified models of the human body, not able to represent the complexity of a biological subject.

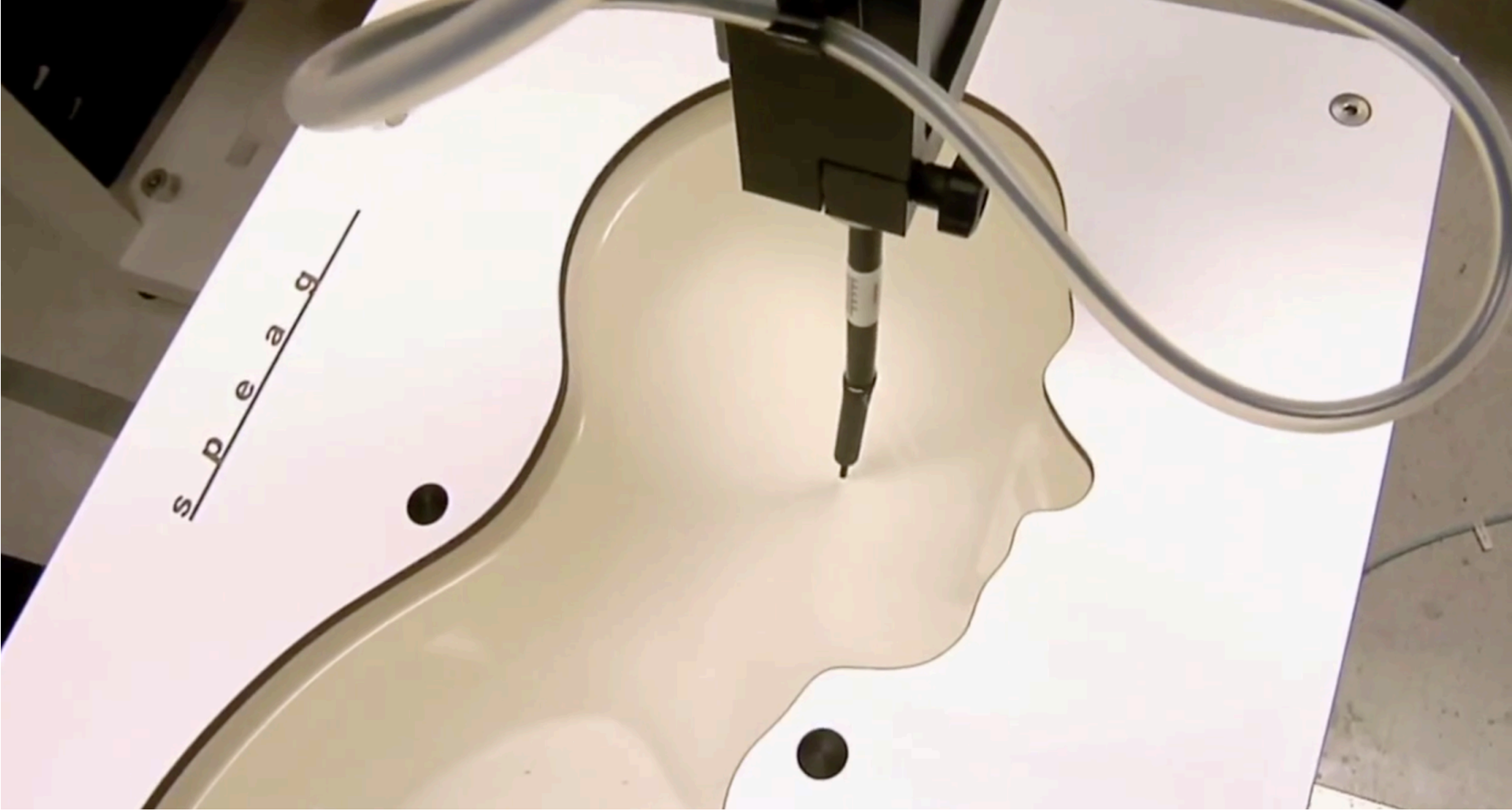
Numerical

- ❖ Very accurate and realistic models of the human body
 - ❖ Problem: The difficulty in modelling complex radiating structures
- Can be overcome by adopting appropriate numerical techniques.

1. Temperature-sensing probes

2. E-field probes





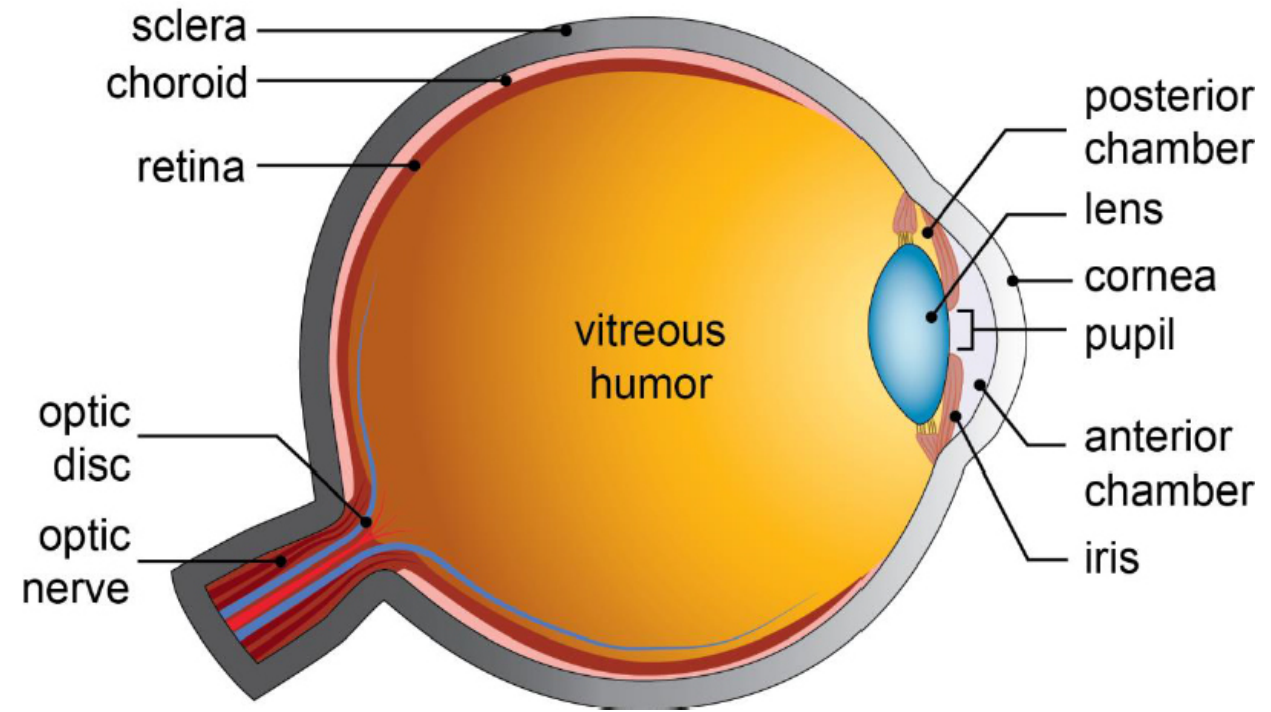


MILLIMETER WAVE
EFFECTS ON HUMAN Eye
and SKIN

*A pragmatic review based on available
studies.*

mmWave Effects on Eyes

The eyes are vulnerable to mmWave induced heating as they are located on the surface of the body.

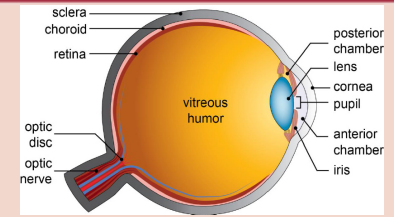


the eyes lack sufficient blood flow (Unlike hands and arms) to redistribute the generated heat.

- care should be taken to prevent unsafe overexposure of the eyes.

TABLE 4. The summary of ocular damage caused by mmWave radiation.

Author	Study Target	Frequency (GHz)	PD (mW/cm ²)	Duration	Results
Rosenthal et al. [47]	Rabbit eyes	35/107	50	15–80 min	Transient corneal damage, began to recover on the next day
Kues et al. [45]	Nonhuman primate eyes	60	10	8 h	No detectable ocular damage
Chalfin et al. [46]	Nonhuman primate eyes	35	2,000–7,000	1.5–5 s	Transient corneal lesions reversible within 24 h
Kojima et al. [48]	Rabbit eyes	60	1,898	6 min	Corneal edema and desiccation

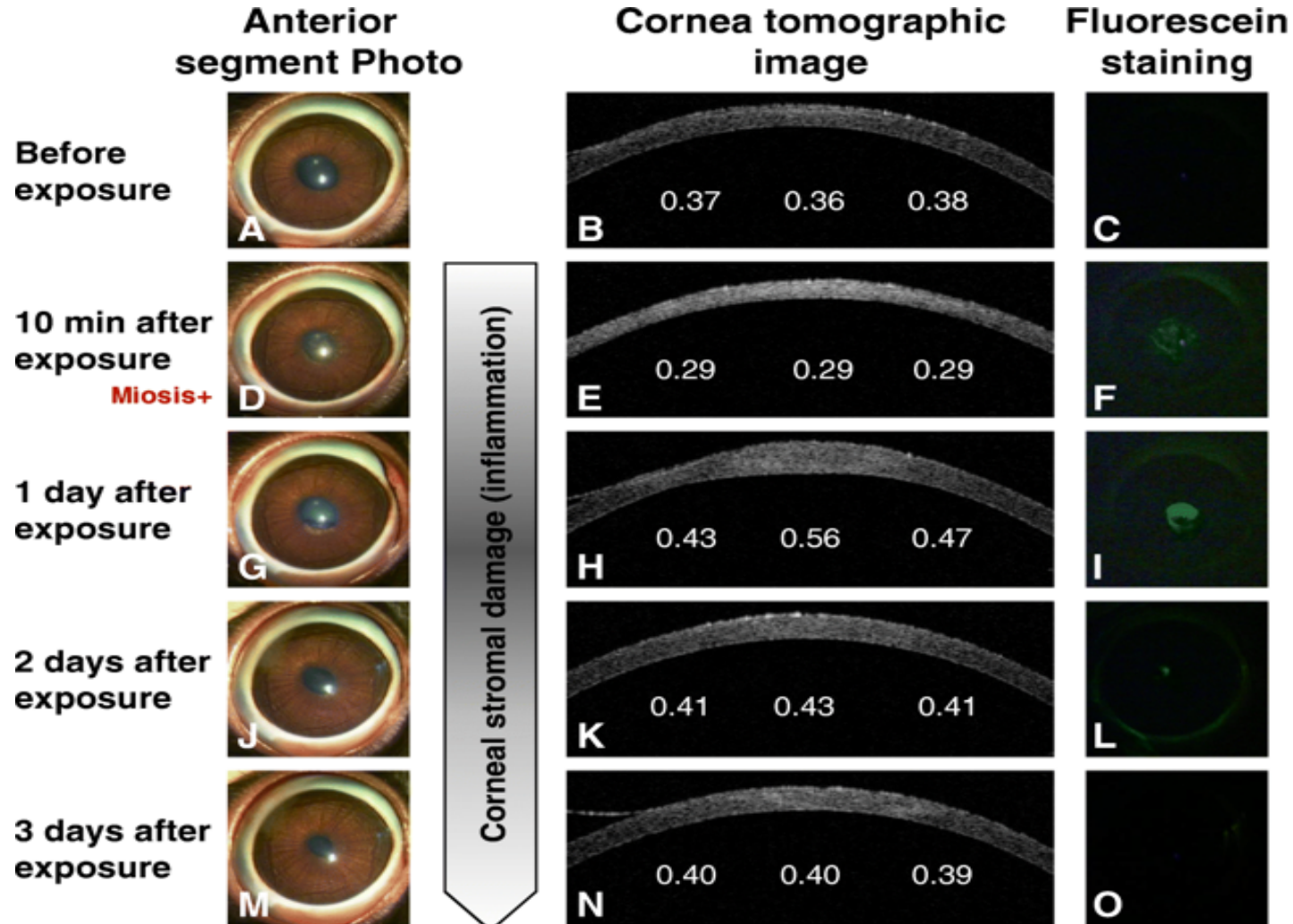


Open Access | Published: 27 May 2018

Ocular Effects of Exposure to 40, 75, and 95 GHz Millimeter Waves

(d) Slight ocular damage observed (reduced corneal transparency around the pupillary area

(g) a round area of corneal opacity in the central area of the pupil



Corneal stromal damage (inflammation)

Corneal epithelial cell damage (surface)

(i) a round area of fluorescein staining (corneal epithelial defect)

(h, k, and n) Corneal edema, indicative of corneal stromal damage, peaked at 1 day after MMW exposure, with thickness gradually subsiding almost reaching that before exposure (Fig. 2b).

mmWave Effects on Skin

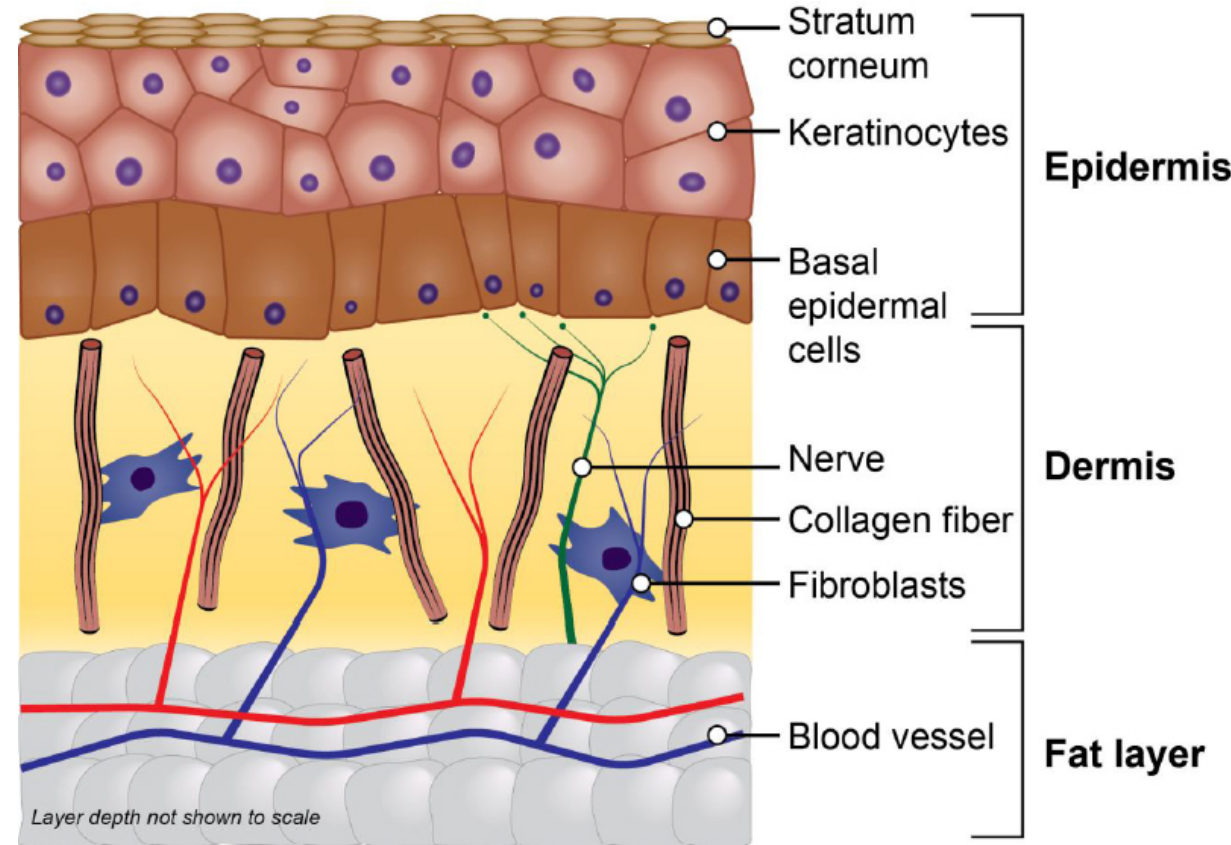
Dielectric Properties of the Skin

Human skin consists of two primary layers: an outer **epidermis** and an underlying **dermis**.

The thickness of the human epidermis and dermis varies in the range of **0.06–0.1** and **1.2–2.8 mm**, respectively.

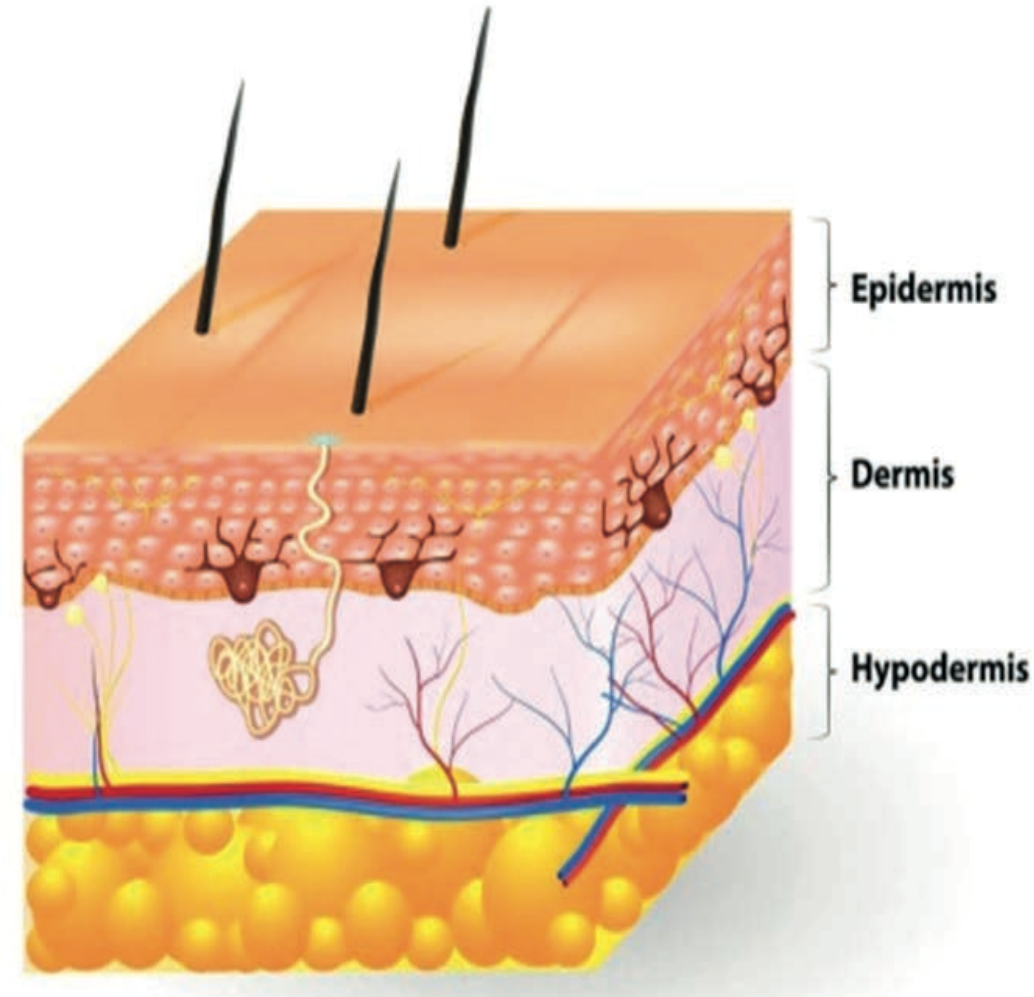
The surface layer of the epidermis is called the “**stratum corneum**” with a thickness of **0.012–0.018 mm**.

The stratum corneum has low water content (**15–40%**), and the total water concentration in the rest of the epidermis and dermis is **70–80%**.



Since mmWave energy is attenuated very rapidly in moist aqueous tissue, this high water content leads to high absorption coefficients of mmWave electromagnetic energy in the tissue.

Thus, mmWave energy penetrates the stratum corneum easily but is rapidly absorbed within the deeper epidermis and dermis and does not propagate further into the body [42], [53].



Millimeter-wave interactions with the human body: state of knowledge and recent advances

MAXIM ZHADOBOV¹, NACER CHAHAT¹, RONAN SAULEAU¹, CATHERINE LE QUEMENT²
AND YVES LE DREAN²

60-GHz exposures, It is shown that **26–41%** of power is reflected at the air/skin interface for the normal incidence, and this value deviates significantly for illuminations under oblique incidence.

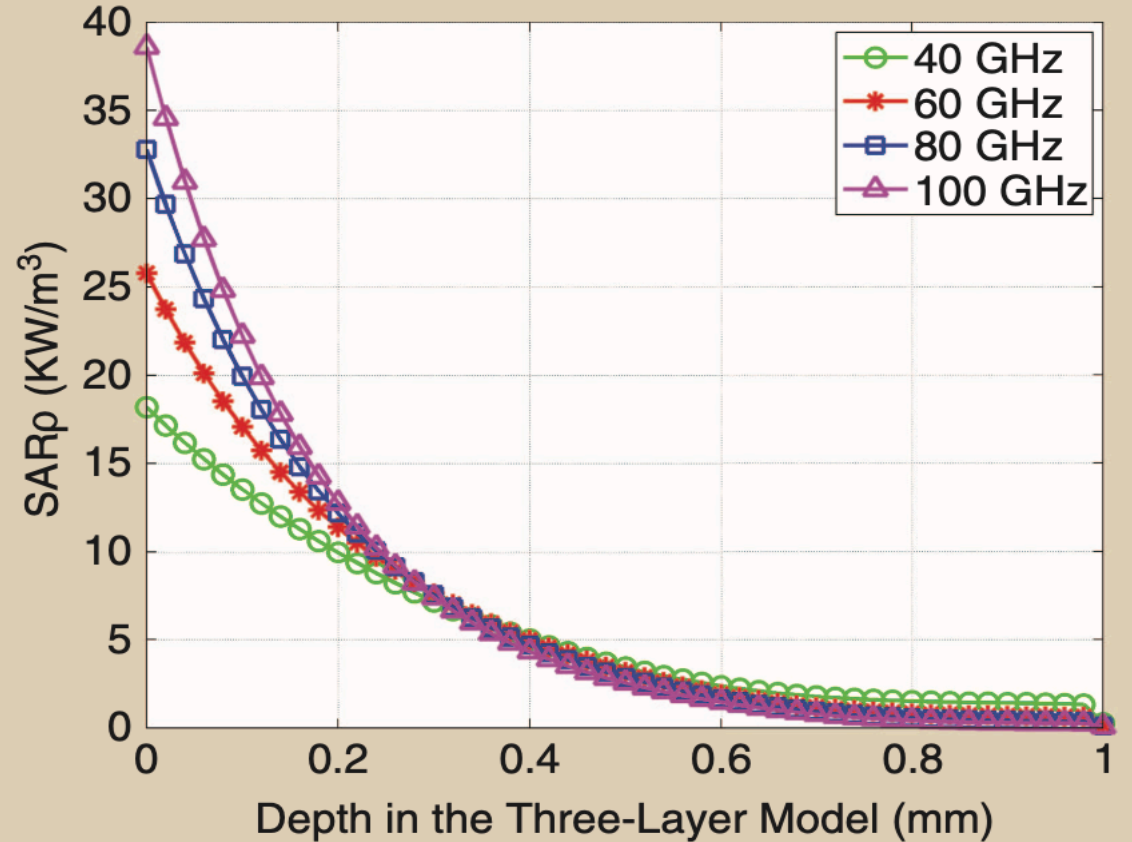
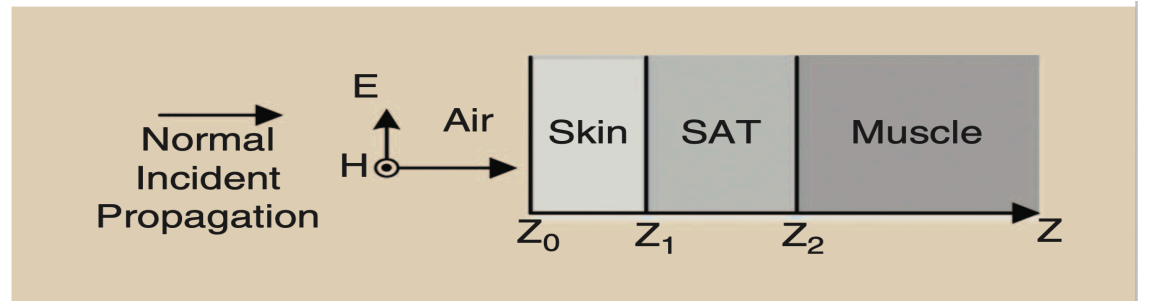
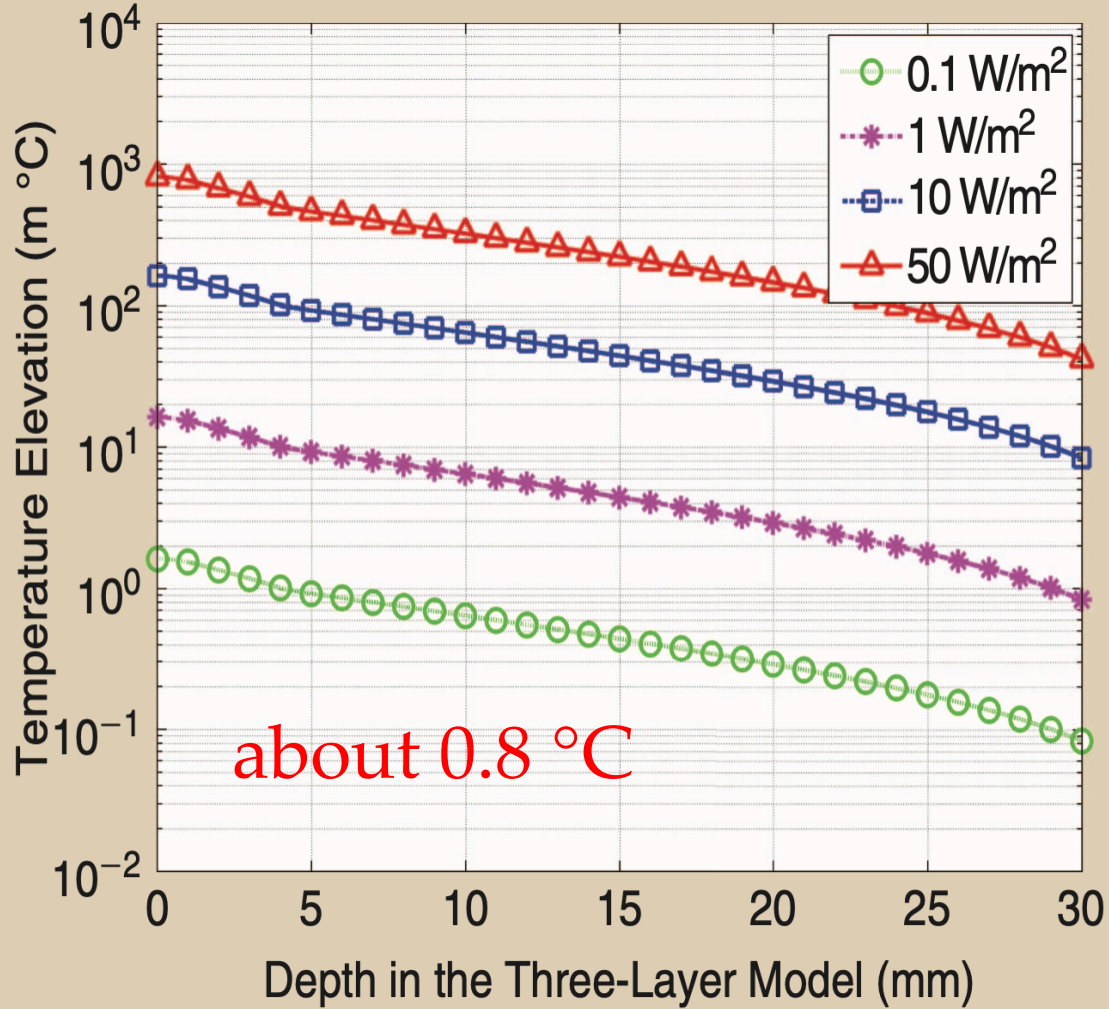
Millimeter Wave Dosimetry of Human Skin

S.I. Alekseev, A.A. Radzievsky, M.K. Logani, and M.C. Ziskin*

*Center for Biomedical Physics, Temple University Medical School,
Philadelphia, Pennsylvania*

the deeper fat layer had little effect on the PD and SAR profiles. We observed the appearance of a moderate SAR peak in the therapeutic frequency range (**42–62 GHz**) within the skin at a depth of **0.3–0.4 mm**. Millimeter waves penetrate into the human skin deep enough (**d=0.65 mm at 42 GHz**) to affect most skin structures

mmWave Effects on Skin



The peak steady-state temperature elevations for 10 and 50 W/m^2 exposure in the one-layer human tissue model are 0.1 and 0.5 $^{\circ}C$, due to 60-GHz exposure

However, for the three-layer human tissue model, the peak temperature elevations are higher, at 0.16 and 0.8 $^{\circ}C$, respectively, for 10 and 50 W/m^2 exposure.



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5G mobile networks and health

27 February 2020 | Q&A

As the frequency increases, there is less penetration into the body tissues and absorption of the energy **becomes more confined to the surface of the body (skin and eye)**. Provided that the overall exposure remains below international guidelines, **no consequences for public health are anticipated.**



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قياس الانبعاثات
الكهرومغناطيسية في أكثر
من 5400 موقع حتى
تاريخه من قبل الهيئة؛
ويقل أعلى قياس تم رصده
بنسبة 91% من الحد
الأقصى للمعايير المسموح
بها حسب إرشادات الهيئة
الدولية للوقاية من
الاشعاعات غير المؤينة

إدارة الطيف الترددي

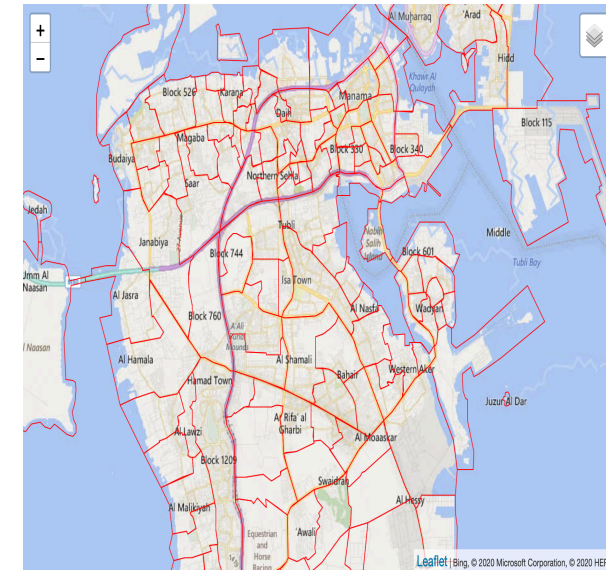
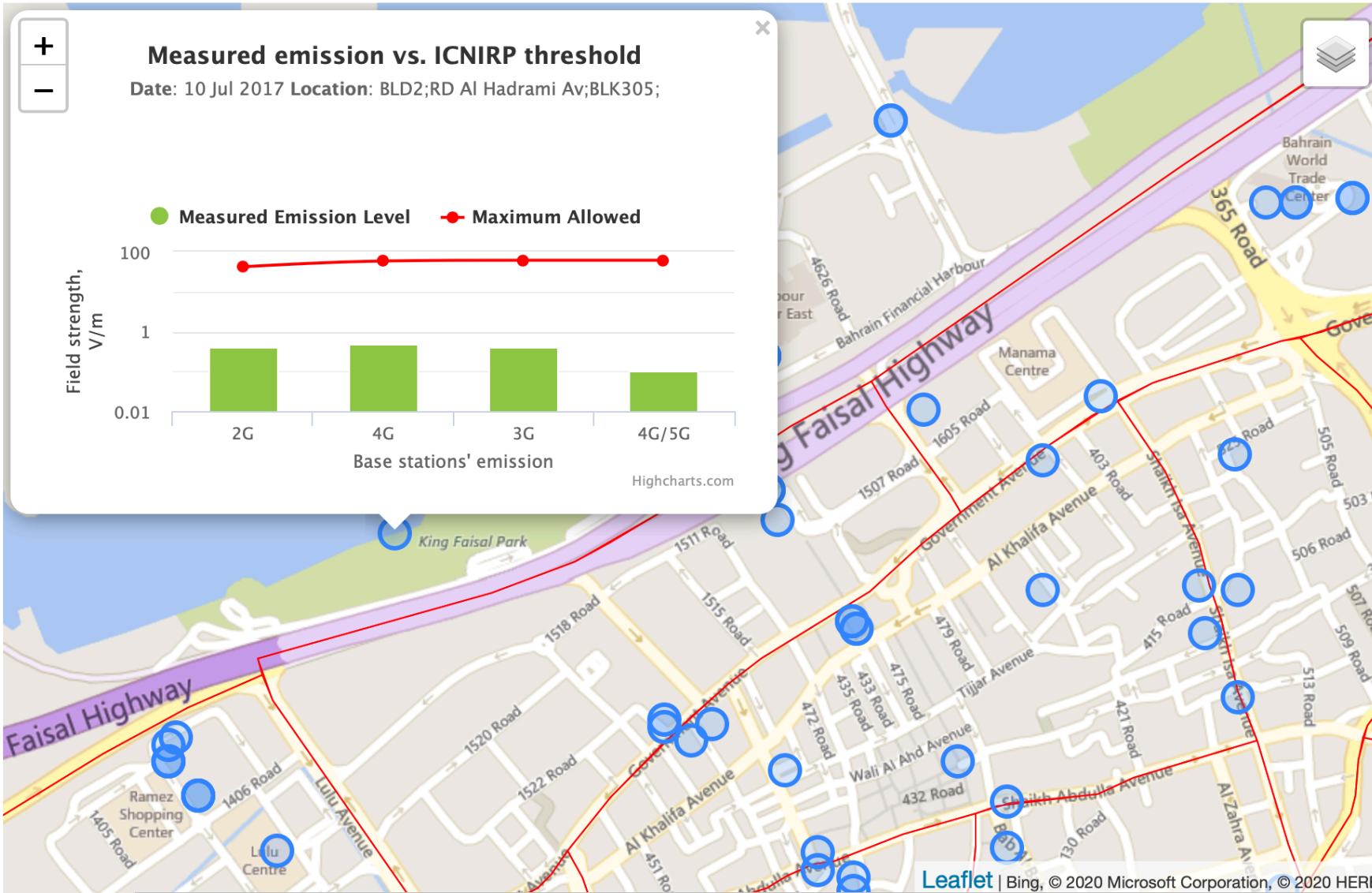
نظرة عامة
ضوابط انبعاثات أبراج الاتصالات
السياسات و التعليمات
خط الطيف الترددي
روابط مفيدة

نوع الاعتماد

نظرة عامة
تقديم طلب نوع الاعتماد
الاجراءات القائمة
قائمة المعدات المعتمدة
أسئلة كثيراً ما تتردد



<https://safetymeasurements.tra.org.bh>



<https://www.tra.org.bh/category/control-of-telecom-mast-emissions>

Date (dd/mm yyyy)	Address of measurement location (Building#, Road#, Block#, Area)	Average Field Strength, V/m			
		2G	4G	3G	4G/5G
June 19, 2019	BLD101; RD5407; BLK254;	0.195	0.241	0.212	0.053
June 19, 2019	BLD483; RD5123; BLK251;	1.516	0.802	0.8	1.336
June 19, 2019	BLD2422; RD5444; BLK254;	0.412	0.913	0.491	0.297

Band (MHz)	Radius of potential risks around base stations (Meters)
900	7.35
1800	5.2
2100	4.5
3500	4.5

Table [2] "Bands & Distances of potential risks"

Measured emission vs. ICNIRP threshold

Date: June 19, 2019 Location: BLD101; RD5407; BLK254;

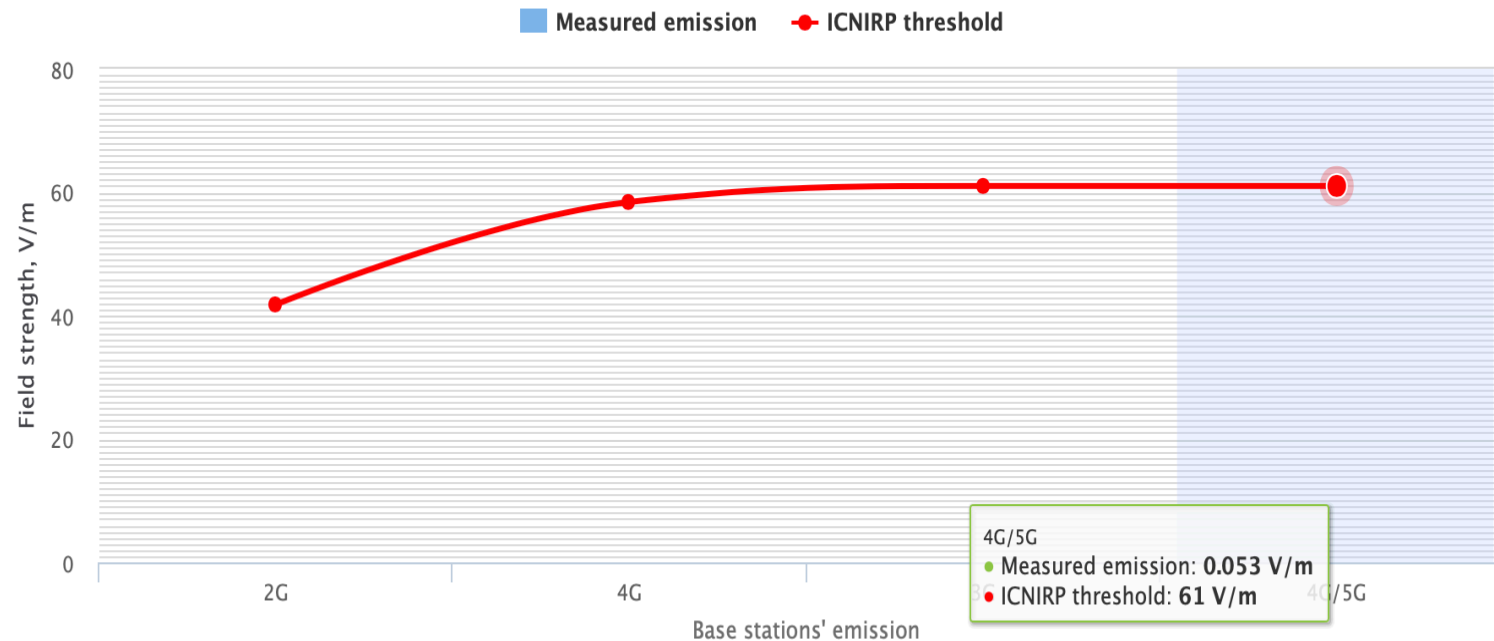


Figure 3 - Details of measurement in a specific location

Band (MHz)	Electrical Field Strength (V/m)	Electrical Field Strength dB(μ V/m)**
900*	41	152.26
1800*	58	155.27
2100	61	155.7
3500	61	155.7

Table [1] "Reference levels for limiting exposure to electromagnetic fields"



Conclusions

Does 5G mmWaves (NR F2)
pose health risks?

How worried should we be?

1) is 5G safe? We do not know for sure, Initial measurement show that it satisfy international guidelines (IEEE, FCC (USA) , ICNIRP (int.)) for “short term” the heating limits. For long term effect, it is just the same as 2G,3G and 4G ,, (uncertainly) research should be continued.

2) mmWave of 5G is a none ionizing radiation, (heating effect).

- 5G and all the telecommunications technology are [none ionizing radiation](#), Dependent on the energy and exposure time, **non-ionising radiation can** cause localized heating increases the risk of damage to the [skin and eyes](#). That is why we focus on the heating effects of mmWaves.

3) 5G new features should be considered in health risks assesments

5G features : extensive adoption of MIMO and beamforming (user or not user?) , densification of 5G sites small cells and IoT , adoption of frequencies in the mmWave bands (Not everybody is exposed like legacy networks)

Therefore, measurement should consider the new features and consider the average exposure (peaks of expusure) for commercial networks.

4) NO relations of 5G and Corona Virus !!

- There is no scientific evidence and no correlation (except these are both two new things).
- Countries with no 5G roll out affected by corona virus
- Years of research for investigations (NIR , current 3.5 GHz deployments (same band as 2G/3G/4G))

6) Should we stop 5G ?

- Do not agree to stop deployments , the Applications is outstanding (car /risk of accidents analogy)
- Recent animal-based studies, demonstrating that the claimed health effects about the carcinogenicity of RF radiation can not be applied to 5G gNBs and 5G UE. (needs to be verified) international protocols when performing measurements needs to be reviewed for 5G.
- reduce the exposure from 5G gNBs and 5G UE, thus minimizing the perceived health risks. (Mitigation techniques)

Final Conclusion

Not stop 5G but we should continue development
and research of risk possibilities

**& Improve EMF public awareness and risk
communication**

Thank you,

Any Questions / Discussions

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