Reducing Electromagnetic Field (EMF) on wireless routers with configuration optimization

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Laurea University of Applied Sciences **Abstract**

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The work of these wireless laboratory tests is to find the optimal configuration settings for reduced emission, specifically for home and a small office for a short range of 1 – 12 meters, to produce a reduced emission of the signal being broadcast by the device, either a router, modem, access point, repeater and or similar wireless device. Due to raised concerns of Health and Safety also limitations of the body in absorbing EMF. The process involves measurement of dBm quality, E-field, H-field and radiation levels in mW/m2 with appropriate meters.

At the initial stage, a review of the wireless technology and their level of security involved is described, includes future technologies, also protocols connections types of NFC, Bluetooth, Wi-Fi 5.00Ghz, Wi-Fi 6, Encryption and OpenVPN. Tests of their advantages and disadvantages, a review of the protocols and their relation to new protocols including interference caused and limitations of combined protocols being utilized during this process that will be conducted.

The laboratory test covers transmission rates, package drops, quality of connection, video buffering to establish if the connection has acceptable speed and bandwidth acceptable for daily usage. Some of the protocols used measured: Transmission (Tx) signal modulation, streaming of video content on High Definition, ping test and encryption using OpenVPN. Further to that, checks on the stability of connections will be pointed at reasonable acceptance in reducing the signal for extra safety and or concerns from the end-user point of view.

A review of the Finnish and European Laws that govern wireless devices, analyzes the best practices approach that could be used for future and previous technologies that uses Wi-Fi antennas. For better Health and Safety procedures and to avoid excess emitted EMF radiation, a concept of future features for wireless devices is advised with options to adjust the increased or reduced levels of TX according to customer needs. Regulators had discrepancies in their safety measures, showing that an external political organization dictates regulations for new wireless devices safety whereas biologists and other organizations within the field shows considerable lower safety numbers.

Results show that even with maximum reduced TX rate, within the parameters of the room, the wireless devices were still capable of transferring data at a high rate, stream high definition content and use VPN with the highest encryption without package loss. A concept proposal for manufacture is given where an easier option or mode should be implemented in their software for broader use of this ethical safety measure.

Keywords: EMF, Wi-Fi 6, router, firmware, radiation, E-field, H-field, mW/m2, dBm, OpenVPN

Contents

1 Introduction

The project is conducted through a series of tests with various parameters to cross analyze the levels of EMF (E-Field, magnetic level, and H-field, electrical level) emission from wireless devices such as routers, access points, modems and similar that are commonly used at home and small offices. Further to the EMF levels, we will analyze regulations that regulate each device according to the specific geolocation of the country.

The main reason behind the need for the test is that there is concern that excess EMF emission can be harmful or lead to other side effects either biologically or pose a security issue having a long-range broadcasted network, which will be covered in the analysis and results further ahead.

From the many types of wireless technologies available the focus is given on the highest levels normally transmitted by wireless devices such Bluetooth, NFC, Wi-Fi 6.0, although there are more frequencies involved this research is primarily focused on Wi-Fi due to the mainstream use such as 2.4Ghz, 5.0Ghz and Wi-Fi 6.

This controlled scenario aims to stipulate whether it is feasible to diminish the emission of signal dBm/EMF/magnetic field for a reduction of wireless exposure related to the environment, the health of a person and lastly for better security.

Using the ITIL framework explained by the industry standard of Information Technology Infrastructure Library (ITIL foundation, 2007) “While ISO/IEC 20000 is a standard to be achieved and maintained, ITIL offers a body of knowledge useful for achieving the standard”. We can expect good results with practical guidelines to be followed and incorporating RAD (Rapid Application Methodology) as the methodology in use seems to be the best suited for this project as the approach the type of scenario involved in a laboratory test. Using the 4 distinct phases of RAD; 1. Requirements planning phase, 2. User design phase, 3. Construction phase, 4. Cutover phase (Martin, 1991).

Regulatory boards will be discussed in this paper to cross-reference the functionality, safety of such and efficacy involved with wireless devices also local and European laws regulators and their latest information regarding the subject for routers with wireless capabilities.

2 Objectives

The reason behind this project and laboratory test is to check whether it is possible to diminish the transmission (Tx) power of devices that we frequently use and analyze their actual emission either decibel milliwatts (dBm), radiation level on watts per square meter (W/m2), Magnetic field (H-field) and Electrical field (E-field).

We hope to be able to use a much lower emission adjusting the settings of the wireless device and still be able to access the internet at a reasonable speed, this objective is advisable especially due to the reason that technologies are pushing devices for faster speeds and EMF radiation can be disregarded and this could cause health issues (Ramesh, 2019).

With IoT becoming the next boom in the technological world, more devices with wireless capabilities will be added to the equation subsequently causing congestion, a congested spectrum can cause not only stability issues but also biological stress if excess exposure is caused.

Ethically we will discuss a possible concept or approach by electronics manufactures to add or produce devices that have adjustable EMF levels on device menus or installation guides. A possible business approach will be analyzed with the concept to be adopted if the manufacture feels the need to release such an option into the market either a software approach or a hardware button option. A more regulated environment into the commercial use of wireless devices in their workplace if there is a need for it with their capabilities. A possible concept model for the new wireless device and or certification with measurement to comply with minimum emission possible would idealize a good scenario, safety is not being fully given priority to devices that are being released or have limited terms and conditions regarding health and safety.

Also, analyze a possible approach from a customer point of view about devices in the market, the usual approach that, if it is in the shop it has gone through tests and it is safe to use, what repercussions this has on the market today, what type of new technology the market requires either from manufactures or consumer point of view with its safety around it.

With security at most importance, what would be the ideal scenario for a user to adopt and have its privacy-enhanced? This will be analyzed in the last section with regards to security. From the ethical point of view, it is important to check all possible discrepancies within new technologies being released if it is of best benefit to the consumer and to companies alike and their use regarding emission furthermore to the latter security is of utmost importance not only for the consumer but for protection of one's rights, we will investigate the latest trends and technologies to achieve the best approach for anonymity.

The main goals for this study are to analyze the EMF emission from the 3 router units chosen using appropriate tools and equipment to cross-reference with a regulation adopted for such. Secondly, to reduce Tx in a controlled environment to see if it is feasible to use in this scenario and thirdly, to improve security from the standard to a stricter level for user benefits.

3 Technology Involved

The technology involved is governed by 3 major organizations that set standards to be used with electronics and they share an important set of instruction, they are: The Institute of Electrical and Electronics Engineers abbreviated as (IEEE 802.x), The Institute of Electrical and Electronics Engineers Standards Association (IEEE SA) and The International Organization for Standardization/International Electrotechnical Commission (ISO/IEC).

Those regulators above are important for new and old technologies to function properly and without much interference with one another. Used to be an issue in the past where each firm had their standard making each new release incompatible with one another. Despite those standards still, Bluetooth can cause some interference with Wi-Fi 2.4Ghz as it uses the same bandwidth, caused by overlapping, which will be explained later ahead.

3.1 RFID and NFC

RFID stands for Radio-Frequency Identification, it gives communication between two devices where only one device requires power, RFID has an antenna and a transponder known as a tag, which could be active with their power or passive where they require EMF power from their reader, normally used for tracking and location from logistic departments. Having three different frequency range, low frequency (LF - 125 kHz - 135 kHz up to 10 centimetres range), high frequency (HF - 13.56mhz up to 30 centimetres) and ultra-frequency (UF - 856 MHZ - 960 MHZ up to 100 meters range).

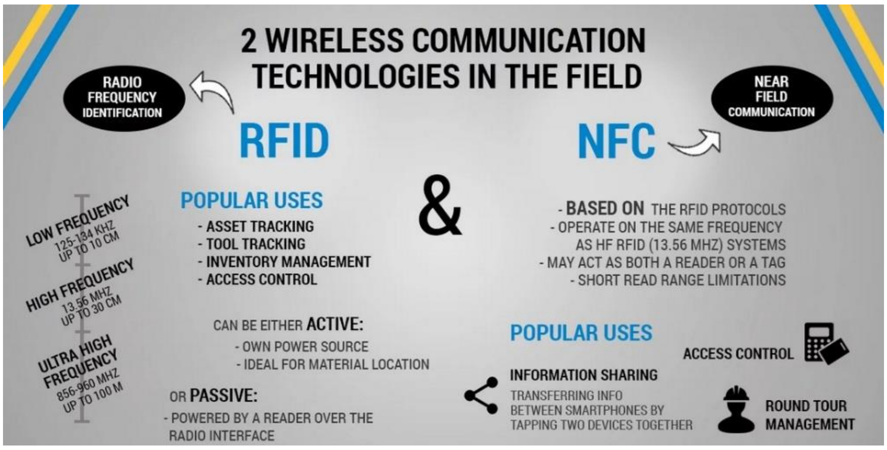


Figure 1: RFID and NFC frequency range and distance amount illustration source: ecom-ex.com/blog/post/rfid-vs-nfc-what-is-the-difference/

NFC stands for Near-Field Communication another wireless technology, NFC is also based on the RFID protocols, the main difference to RFID is that an NFC device can act not only as a reader but also as a tag (card emulation mode, in peer-to-peer mode, it is also possible to transfer information between two NFC devices, NFC systems operate on the same frequency as HF RFID (13.56 MHz) systems, because of the short-range limitations. NFC devices must be in very close proximity - usually no more than a few centimetres.

That is why NFC is often used for secure communications like credit cards and other forms of authentication, especially for access controls or in the consumer sector for contactless payment explained in the website rfid4u.com (RFID Regulations | How RFID is regulated worldwide, 2021), the site also demonstrates that RF regulations typically vary from one country to another or from one region to another, due to the legacy usage of various portions of the RF spectrum. In the technology's countries signs bands according to their legislation, chunks of the RF spectrum for different uses. No worldwide standard was available, and even now none exist for many parts of the spectrum. Finding a worldwide RF range for new RF applications is a problem. For example, in the US, the UHF RFID systems are allocated a frequency range of from 902 to 928 MHz, but in European countries, that range was already assigned to other uses and is therefore not available. In Europe, UHF RFID systems are assigned a frequency range of 865 to 868.

3.2 Bluetooth

Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using UHF radio waves in the industrial, scientific and medical radio bands, from 2.402 GHz to 2.480 GHz, and building personal area networks (PANs). It was originally conceived as a wireless alternative to RS-232 data cables, the Bluetooth® trademarks are owned by the Bluetooth Special Interest Group (SIG).

There have been many generations of Bluetooth certified models 1.0 and 1.0B, Bluetooth 1.1, Bluetooth 1.2, Bluetooth 2.0 + EDR, Bluetooth 2.1 + EDR, Bluetooth 3.0 + HS, Bluetooth 4.0, Bluetooth 4.1, Bluetooth 4.2, Bluetooth 5, Bluetooth 5.1, Bluetooth 5.2, on 31 December 2019, the Bluetooth SIG published the Bluetooth Core Specification Version 5.2, the new specification adds new features with the improvement of speed with their new codec either if it is for use on Low Energy (LE) and Basic Rate/Enhanced Data Rate (BR/EDR) radios, latency and battery consumption optimization are shown in the diagram according to a recent whitepaper from Bluetooth 5.2 generation (Raghavan et al, 2020).

	Bluetooth Low Energy (LE)	Bluetooth Basic Rate/ Enhanced Data Rate (BR/EDR)
Frequency Band	2.4GHz ISM Band (2.402 – 2.480 GHz Utilized)	2.4GHz ISM Band (2.402 – 2.480 GHz Utilized)
Channels	40 channels with 2 MHz spacing (3 advertising channels/37 data channels)	79 channels with 1 MHz spacing
Channel Usage	Frequency-Hopping Spread Spectrum (FHSS)	Frequency-Hopping Spread Spectrum (FHSS)
Modulation	GFSK	GFSK, π/4 DQPSK, 8DPSK
Power Consumption	~0.01x to 0.5x of reference (depending on use case)	1 (reference value)
Data Rate	LE 2M PHY: 2 Mb/s LE 1M PHY: 1 Mb/s LE Coded PHY (S=2): 500 Kb/s LE Coded PHY (S=8): 125 Kb/s	EDR PHY (8DPSK): 3 Mb/s EDR PHY (π/4 DQPSK): 2 Mb/s BR PHY (GFSK): 1 Mb/s
Max Tx Power*	Class 1: 100 mW (+20 dBm) Class 1.5: 10 mW (+10 dbm) Class 2: 2.5 mW (+4 dBm) Class 3: 1 mW (0 dBm)	Class 1: 100 mW (+20 dBm) Class 2: 2.5 mW (+4 dBm) Class 3: 1 mW (0 dBm)
Network Topologies	Point-to-Point (including piconet) Broadcast Mesh	Point-to-Point (including piconet)

Table 1: Specification of LE and BR/EDR Bluetooth source: electronics-lab.com/project/using-the-ble-functionality-of-the-esp32/

Whilst RFID and NFC do not pose theoretical interference in Wi-Fi communication Bluetooth Shares the same band at 2.4Ghz which can cause some issues of interference if precaution is not taken in the configuration of the network explained by Goldtouch website.

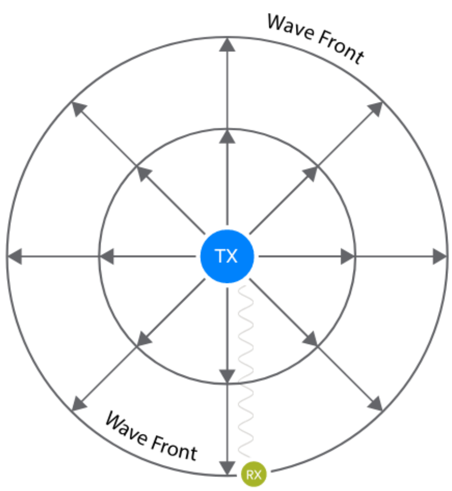


Figure 2: Waveform of transmitting data from Radio-Frequency source: Radmanesh, 2001.

Rx means Receive, and Tx means Transmit. They are relative to the device you're on. What's Tx to you is Rx to somewhere else, and vice versa. The only difference is the wires they hit. There is no difference.

Figure 3: Frequency spectrum of Bluetooth picture source Bluetooth SIG.

Packets going in opposite directions - RX (Receive) vs. TX (Transmit) follow the same conventions, have the same breakdown of fields, adhere to the same rules. A Tx packet, if you think about it, is an RX packet at the receiver's end. It's a matter of perspective only. In networking, we usually refer to the direction of traffic from the perspective of an interface.

3.3 Wi-Fi

Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 standards, which are commonly used for local area networking of devices and Internet access. Wi-Fi is a trademark of the non-profit Wi-Fi Alliance, and there are continuous works on the release of a new and faster standard.

Generation/IEEE Standard	Maximum Linkrate	Adopted	Frequency
Wi-Fi 6 (802.11ax)	Half-duplex[41][42] 600–9608 Mbit/s	2019	2.4/5 GHz 1–6 GHz ISM
Wi-Fi 5 (802.11ac)	Half-duplex 433–6933 Mbit/s	2014	5 GHz
Wi-Fi 4 (802.11n)	Half-duplex 72–600 Mbit/s	2008	2.4/5 GHz
Wi-Fi 3 (802.11g)	Half-duplex 3–54 Mbit/s	2003	2.4 GHz
Wi-Fi 2 (802.11a)	Half-duplex 1.5 to 54 Mbit/s	1999	5 GHz
Wi-Fi 1 (802.11b)	Half-duplex 1 to 11 Mbit/s	1999	2.4 GHz

Figure 4: Generations specification of Wi-Fi picture source duckware.com (Jongerius, 2020).

Wi-Fi Generation 2, and 5 can also interfere with each other due to the adjacent channel positioning of each other explained. This poses serious interference threats due to transmit (Tx) leakage and adjacent channel leakage ratio (ACLR) in respective bands, which can greatly impact data rates if appropriate filtering isn't used. Besides, there is the potential risk of hardware damage due to high power signals reaching receive (Rx) paths explained by Raghavan.

4 Framework and Methodology

We will use the ITIL framework for the conducting of this research as a guideline for procedures, this particular framework has great expertise for over 2 decades in service management-related objectives, also it is vendor-neutral and nonproprietary making a more accessible to utilize any equipment of our choice, similar to opensource which is ideal for this type of work. (Kaiser, 2017).

Figure 5: ITIL Framework Continual Service Improvement illustration from ITIL framework AXELOS version 3.0 source: (ITIL foundation, 2007).

The methodology in use is Rapid-application development although it has much use in software development it is not bound to only software applications, RAD put less importance on planning and more emphasis on adaptation and prototyping instead of design specifics. (Martin, 1991). This methodology has the best approach for our needs to achieve the desired results within the timeframe stipulated by the project guidelines.

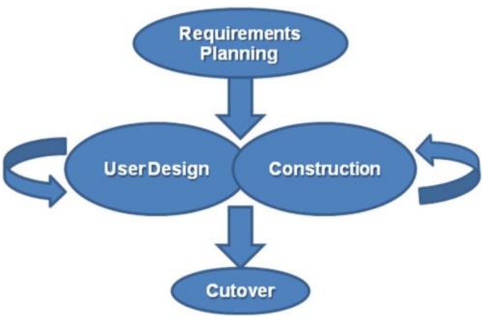


Figure 6: Rapid Application Development (RAD) Guideline illustration source: RAD by Martin 1991.

James Martin states that his approached model is: "A data model is an important part of the system design, especially in complex systems built by multiple teams and in systems that link into a shared database environment". This approach is ideal for this type of experiment in a laboratory because many trials will be used, and new approaches need to take place if the previous model has not succeeded (Martin, 1991).

4.1 Measurements details

The reason we focus on the E-field and H-field is that they are the magnetic and electrical waves emitted by electronic devices that have repercussion and possible side effects biologically and from the security point of view security also, due to extended range of broadcast of the Service Set Identifier (SSID).

Electromagnetic waves are made up of Electric Fields (often called the E-field) and Magnetic fields (also known as H-fields). The H-field is a vector quantity (has a magnitude and direction) and is measured in Amps/Meter [A/m]. Recall that the E-field points away from a positive point charge. H-field curls (or wraps) around a wire of moving charge, H-fields are associated with moving electric charges. “One of the reasoning of H-field and E-field there are no isolated magnetic charges as of 2008, so an H-field can't be defined as a force per unit magnetic charge in the way an E-field can be defined”. However, magnetic dipoles do exist (magnets) which have a positive and negative end (or North and South), the magnetic field lines travel away from the Northside and terminate on the south side (Bevelacqua, 2008).

4.2 E-Field and H-Field

The H-field is orthogonal to the direction of propagation in a plane wave, as well as perpendicular to the E-field. It is the interaction of the E-field with the H-field in space that allows for wave propagation. Electromagnetic waves are made up of Electric Fields (often called the E-field) and magnetic fields.

$$\mathbf{E} = A\cos\left(\omega t - kz\right)\hat{\mathbf{y}}$$

Technically, the E-field at a point in space is a measure of how strong the force would be on a unit point charge (a small sphere with an electric charge of 1 Coulomb on it). Hence, the units of the E-field are Newtons/Coulomb [N/C]. These units are equivalent to Volts/meter [V/m], which is what the E-field is commonly quoted in (for instance, 10 V/m). The E-field is a vector quantity - this means at every point in space it has a magnitude and a direction. For instance, let's say an E-field exists in space given by:

$$\mathbf{E} = -\nabla V$$
$$V = -\oint \mathbf{E} \cdot \mathbf{dl}$$

This is the E-field of a plane wave travelling in the +z-direction, and the E-field is linearly polarized and 'points' in the y-direction (k is the wavenumber). The amplitude of the wave is A Volts/meter. At time t=0 and z=0, the E-field is A Volts/meter in the +y-direction. This means that a unit point charge (1 Coulomb) at this location would experience a force of A Newtons in the +y-direction. The electric field also relates to voltage - a stronger E-field incident upon an antenna will induce a larger voltage difference across the antenna's terminals. However, except for low frequencies, the relationship between E-fields and Voltage is not simple (the voltage is a potential that is subject to different definitions). A d.c., when the fields are static (no variation with time), the E-field and voltage V are related to each other by The electric field associated with a point charge with a positive charge point away from it at every location; the fields associated with a point charge with a negative charge point towards it.

4.3 Radiation W/m2

There are many results of radiation absorption through the wireless device that can be harmful and cause various side effect to the human body, many documents prove that and in Finland, there is a research paper called: “The Health Risk of Wi-Fi, 2013” by Ramesh Karki, Turku University.

According to the World Health Organization notification fs226 states that RF fields below 10 GHz (to 1 MHz) penetrate exposed tissues and produce heating due to energy absorption. The depth of penetration depends on the frequency of the field and is greater for lower frequencies. The absorption of RF fields in tissues is measured as a Specific Absorption Rate (SAR) within a given tissue mass. The unit of SAR is watts per kilogram (W/kg). SAR is the quantity used to measure the "dose" of RF fields between about 1 MHz and 10 GHz (WHO, 2007).

4.4 dBm and dBi

dBm and dBi are the major methods of measuring signal being broadcast and the main difference between them is that: dBi (decibels per isotropic dB[isotropic]) is a measure of the forward gain of an antenna: The gain in power emitted by an antenna signal. dBm (decibels per milliwatt): The relative power emitted by an amplifier: Refers to decibels as a relative measure of milliwatts according to George Hardesty from the website data-alliance.net/blog.

Wavelength is one of the properties of a wave, from its distinctive attributes that can be measured in amplitude, frequency and phase (Radmanesh, 2001. 252) Also is very useful information for equalization for systems that utilize waves and channel automatic switching channels i.e. Asus and Zyxel, optimizes the data transmission by mathematical calculation of coefficients. (Glisic, 2011. 338).

Figure 7: dBi range illustration source: data-alliance.net/blog/dbi-db-dbm-dbmw-defined-explained-and-differentiated/

dBi is a measurement that compares the gain of an antenna concerning an isotropic radiator (a theoretical antenna that disperses incoming energy evenly over the surface of an imaginary sphere.) dBd compares the gain of an antenna to the gain of a reference dipole antenna (defined as 2.15 dBi gain) taking an example of 1dBm using the formula below we can calculate the amount of power in mW utilized:

$$x = 30 + 10\log_{10}\frac{P}{1\mathrm{W}}$$

$$P = 1\mathrm{W}\cdot 10^{\frac{x-30}{10}}$$

power level	power
23 dBm	200 mW

Table 2: dBm equivalence conversion to power in mW.

The technology used and to be analyzed in this project is the EIRP for IEEE 802.11n wireless LAN 40 MHz-wide (5 mW/MHz) channels in 5 GHz subband 4 (5,735–5,835 MHz, US only) or 5 GHz subband 2 (5,470–5,725 MHz, EU only). Also applies to 20 MHz-wide (10 mW/MHz) IEEE 802.11a wireless LAN in 5 GHz subband 1 (5,180–5,320 MHz) if also IEEE 802.11h-compliant, otherwise only 3 mW/MHz → 60 mW when unable to dynamically adjust transmission power, and only 1.5 mW/MHz → 30 mW when a transmitter also cannot dynamically select frequency. (Carr, 2002).

The unit of dBd compares the gain of an antenna to the gain of a reference dipole antenna for example as 5.00 dBi gain. To convert dBi to dBd we have gain in dBd = gain in dBi - 5.00 dB and gain in dBi = gain in dBd + 5.00 dB. “The measurement of dBi and dBd is used to measure the focusing power (gain) of antennas”(Carr, 2002). dBi is a measurement that compares the gain of an antenna for an isotropic radiator, a theoretical antenna that disperses incoming energy evenly over the surface of an imaginary sphere.

4.5 Quality of signal dBm

The measurement of dBm (sometimes dBmW or decibel-milliwatts) is a unit of level used to indicate that a power ratio is expressed in decibels (dB) regarding one milliwatt (mW). It is used in radio, microwave and fibre-optical communication networks as a convenient measure of absolute power because of its capability to express both very large and very small values in a short form compared to dBW, which is referenced to one watt (1000 mW). (Olenawa, 2016. 44)

4.6 Amplitude, Frequency, Phase and Spectrum

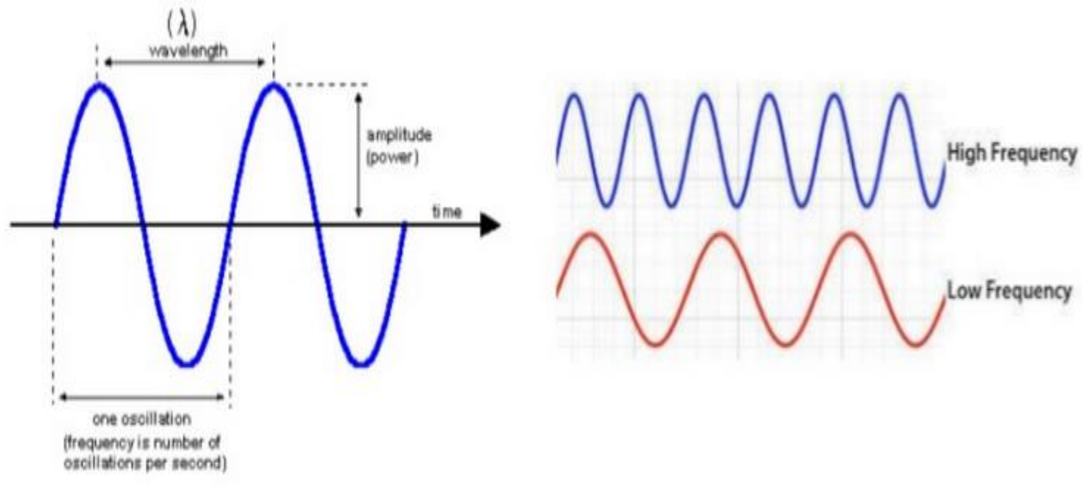


Figure 8: Amplitude signal modulation enhanced illustration from Radio-Frequency (Radmanesh 2001).

The amplitude is a periodic variable that can be measure change in a single period. There are various definitions of amplitude, which are all functions of the magnitude of the differences between the variable's extreme values Olenawa explains.

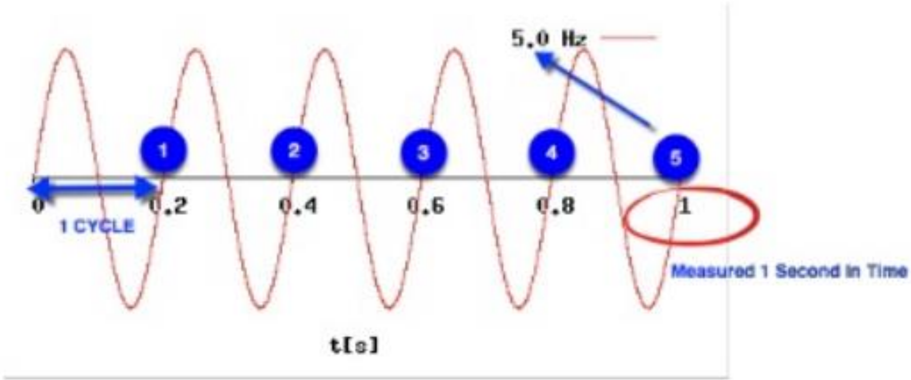


Figure 9: Frequency modulation enhanced illustration from Radio-Frequency (Radmanesh 2001).

Frequency is the number of occurrences of a repeating event per unit of time. It is also referred to as temporal frequency, which emphasizes the contrast to spatial frequency and angular frequency. Frequency is measured in units of hertz which is equal to one occurrence of a repeating event per second.

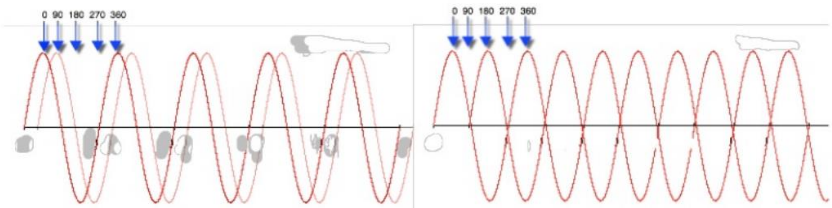


Figure 10: Phase modulation enhanced illustration from Radio-Frequency (Radmanesh 2001).

Phase measures in some real variable is an angle representing the number of periods spanned by that variable. It is denoted and expressed on such a scale that it varies by one full turn as the variable goes through each period.

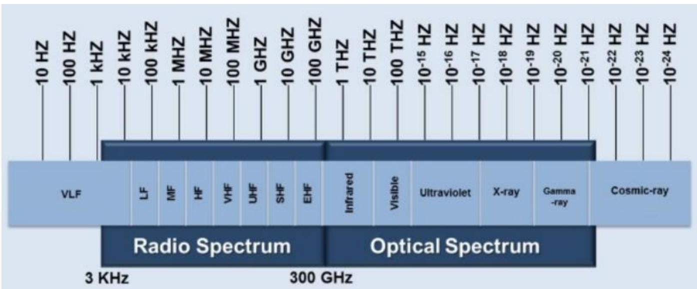


Table 3: Spectrum band designators and bandwidths table source: NASA, 2018 nasa.gov/directorates/heo/scan/communications/outreach/funfacts/txt_band_designators.html.

On the table above Nasa shows the many spectrum from Radio to Optical and their specific waveband in hertz, it is important to notice that they are all invisible to the naked eye, and measurement of safety is set upon the specific regulator in each country, Finland uses STUK and ICNIRP, but the public wouldn't know what is the real number if not measured with the correct equipment.

5 Room Scenario

A common scenario where an average person who lives in a small flat uses a small office, and or a similar type of user. The tests will be conducted in an isolated room of 12 meters in diameter, where meters will be used to check for dBm, H-filed, E-field and w/m2 radiation level for the distances of 1m, 3m, 6m and 9m.

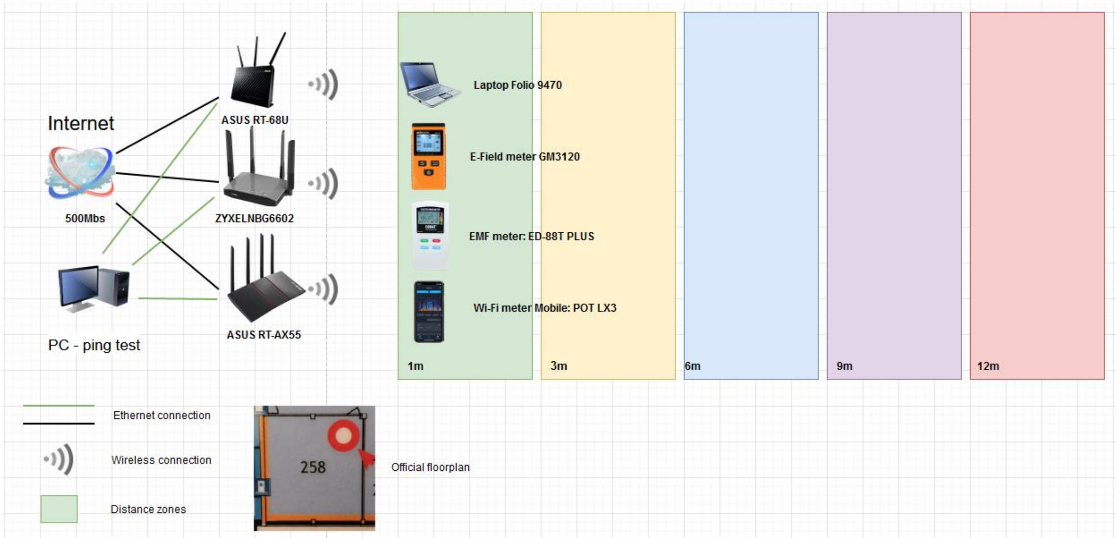


Figure 11: Laboratory set up with types of equipment and floorplan.

It is important to state that there are many ways to test, and this approach is the "line of sight" approach. Various forms of obstacles can cause wireless signalling increase or reduction such as glass, concrete walls, wooden, metal material, etc. A router will be placed in a room that measures 12 meters in extent diagonally, where markings on the floor will measure the distances of 1, 3, 6, 9 and 12 meters and on each point, the measurement will be taken when Tx is adjusted for data collection.

6 Laboratory equipment

The equipment chosen are listed below and we used the most popular in the Scandinavian countries as for the wireless devices, and the measurement tools are also broadly used. We have the Asus RT-AC68U which has Wi-Fi 2 and 5 capabilities, Zyxel Exibel NBG6602 this brand is typically provided by Network contracts either freely or under low price making the most popular brand in Finland, Asus RT-AX55 which has the new Wi-fi 6 technology with faster speeds, supports 80MHz bandwidth and 1024-QAM at 1800 Mbps, we are checking if new technologies emit higher or lower numbers.

For the measurement of Electrical field (E-field) Kmoon GM3120 H-field meter, for radiation level on watts per square meter (W/m2) and Magnetic field (H-field) the Cornet ED-88Tplus, also we are using a laptop model Folio-9470 for the video streaming, ping test and other configurations and lastly a mobile phone model: POT-LX3 for the Wi-Fi analyser to check signal strength levels.

- Asus RT-AC68U technical specifications: IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.11ac, 802.11n : up to 450 Mbps 802.11n TurboQAM : up to 600 Mbps 802.11ac : up to 1300 Mbps, External 4 dBi antenna x 3, RJ45 for 0/100/1000/Gigabits BaseT for LAN x 4, RJ45 for 10/100/1000/Gigabits BaseT for WAN x 1.

Figure 12: Asus router RT-AC68U picture from device taken on laboratory.

The Asus RT-AC68U still a fairly new device with many capabilities and security options to be implemented, was choose for the ease of use and the option of OpenVPN security option to be tested in the research also can have different firmware for extra wireless options i.e. Official Asus MerlinWRT firmware.

- Zyxel Exibel NBG6602, technical specifications: Wireless Standard, IEEE 802.11 b/g/n 2.4 GHz, IEEE 802.11 a/n/ac 5 GHz, Wireless Speed, Transmit: 300 Mbps* for 2.4 GHz, 867 Mbps* for 5 GHz, Receive: 300 Mbps* for 2.4 GHz, 867 Mbps for 5 GHz, Wireless Security, WPA-PSK/WPA2-PSK, WPS, 4 antennas 5dBi.

Figure 13: Zyxel Exibel NBG6602 picture from device taken on laboratory.

Zyxel is the major contractor with Finnish network providers for ADSL connection, making the majority of the devices connected in the whole country due to usually being free with the contract signed with the network.

- Asus RT-AX55, technical specifications of Asus RT-AX55 Wi-Fi 6: Network Standard IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.11ac, IEEE 802.11ax, IPv4, IPv6, 4 external antennas.

Figure 14: Asus RT-AX55 Wi-Fi 6 enabled picture from device taken in the laboratory.

The Asus RT-AX55 has been chosen due to its new release in December 2019, having the new standard Wi-Fi 6 using a frequency band of 2.4Ghz and 5.0Ghz, that can reach a speed limit of up to 1800Mbs, this is a good example for measuring the EMF on new devices claiming higher internet speeds. There is another generation of the device coming to the market called Wi-Fi 6E which will have extra capabilities of 6Ghz frequency band.

- Kmoon GM3120 E-field and H-field meter

VII. Technical parameters

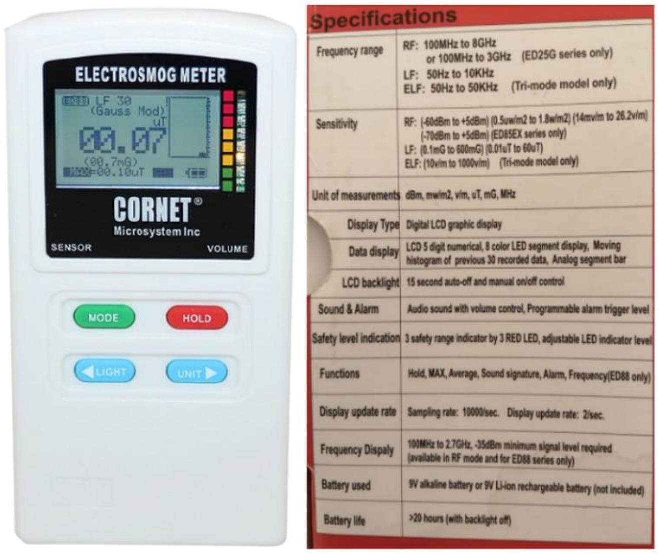
	Electric field	Magnetic field
Unit	V/m	μT
Precision	1V/m	0.01μT
Range	1V/m-1999V/m	0.01μT-19.99μT
Alarm threshold value	40V/m	0.4μT
Reading display	3-1/2-digit LCD	
Testing bandwidth	5Hz—3500MHz	
Sampling time	About 0.4 seconds	
Test mode	Bimodule synchronous test	
Over range indication	LCD displays "1"	
Operating temperature	0℃~50℃	
Operation humidity	relative humidity < 80%	
Operating voltage	9V	
Power supply	6F22 9Vbattery	
Size	63. 6*31*125. 8mm	
Weight	146g	

Reference standards:
GB8702-1988 Regulations for Electromagnetic Radiation Protection
HJ/T10.3-1996 Environmental Impact Assessment Methods and standards on Electromagnetic Radiation
GB9175-88 Hygienic Standard for Environmental Electromagnetic Waves

Figure 15: E-field and H-field meter GM3120 and technical specifications.

This is the Kmoon GM3120 a simple E-field, H-field meter that is used due to popularity, but mainly to check electrical magnetic field at peak levels, which will help us identify if the device is emitting a large amount of voltage.

- ED88TPlus Electrosmog Meter with specifications shown in the figure below:



Specifications

Frequency range	RF: 100MHz to 8GHz or 100MHz to 3GHz (ED25G series only) LF: 50Hz to 10KHz ELF: 50Hz to 50KHz (Tri-mode model only)
Sensitivity	RF: (-60dBm to +5dBm) (0.5uw/m2 to 1.8w/m2) (14mv/m to 26.2v/m) (-70dBm to +5dBm) (ED85EX series only) LF: (0.1mG to 600mG) (0.01uT to 60uT) ELF: (10v/m to 1000v/m) (Tri-mode model only)
Unit of measurements	dBm, mw/m2, v/m, uT, mG, MHz
Display Type	Digital LCD graphic display
Data display	LCD 5 digit numerical, 8 color LED segment display, Moving histogram of previous 30 recorded data, Analog segment bar
LCD backlight	15 second auto-off and manual on/off control
Sound & Alarm	Audio sound with volume control, Programmable alarm trigger level
Safety level indication	3 safety range indicator by 3 RED LED, adjustable LED indicator level
Functions	Hold, MAX, Average, Sound signature, Alarm, Frequency(ED88 only)
Display update rate	Sampling rate: 10000/sec. Display update rate: 2/sec.
Frequency Dispaly	100MHz to 2.7GHz, -35dBm minimum signal level required (available in RF mode and for ED88 series only)
Battery used	9V alkaline battery or 9V Li-ion rechargeable battery (not included)
Battery life	>20 hours (with backlight off)

Figure 16: EMF Meter Cornet ED-88TPlus and technical specifications.

This is a more advanced meter device with extra capabilities Plus series, it has a built-in histogram to be able to assess the past 15 seconds of measurement graphically and also records peaks even if at a short interval. We must understand that those devices are handheld and are not the official field meters, normally sold by Wavecontrol as SMP2, WPF40 Field Probe and WaveMon. The equipment chosen will give us an average knowledge of the emission being emitted by the device.

7 Data collection guideline

The wireless devices will be placed at one point of the room, markings on the floor will take measurements to collected from the distances of 1, 3, 6, 9 and 12 meters using the measurement equipment ED88TPlus Electrosmog Meter and Kmoon GM3120 for the EMF levels and a mobile device for the strength of the Wi-Fi wireless signals.

- Asus RT-68U will be tested for E-Field, H-Field, Wi-Fi 2 and 5 and OpenVPN protocols;
- Zyxel Exibel NBG6602 will be tested for E-Field, H-Field, Wi-Fi 2 and 5;
- Asus RT-AX55 will be tested with the new Wi-Fi 6 standard;
- Setup of a router with an internet connection and adjust the Tx level from maximum to minimum on the web-portal settings adjustment of the router;
- Take EMF readings with every new set of Tx mode;
- Stream a large video over the internet using Wi-Fi to measure router under activity;
- Conduct a ping request to see if there is package loss during this process;
- Set up a secure VPN tunnel using OpenVPN at the protocol and check the CPU load.

8 Data collection

For the data collection procedures we focused on the following data being acquired for each of the wireless devices, the tables below will show the following data: 1) E-Field in V/M peak at close distance, 2) H-field in μT peak at close distance, 3) EMF in mW/m^2 peak at close distance, 4) The wireless band used 2.4Ghz, 5.0Ghz, Wi-Fi 6, 5) Radiation level in mW/m^2 at 1,3,6,9,12 meters, 6) Signal Strenght Level of the Wi-Fi in dBm at 1,3,6,9,12 meters.

Please be aware that the manufacture Asus chooses to use different nomenclature for its signal levels transmission on their software interface, which usually varies from 0%-100% Asus utilizes: power saving, fair, balance, good, performance, we could adopt 10, 25, 50, 75 and 100% for practical understanding.

For every transmission level on Asus devices at Tx levels: 10, 25, 50, 75, 100% and Zyxel: 10, 25, 50, 75, 90 and 100% we will carry out a ping test to see if the connection has stability during playback of a video from the internet, to see if there is any buffering issue and lastly we will apply OpenVPN as an intensive load of data to check connection stability.

The ping is a computer network administration software utility used to test the reachability of a host on an Internet Protocol (IP) network. It is available for virtually all operating systems that have networking capability, including most embedded network administration software. Ping measures the round-trip time for messages sent from the originating host to a destination computer that are echoed back to the source explained at the website linux.die.net (ping(8) - Linux man page, 2021).

We will test a video stream online in all distances of the wireless device with 2K video resolution at 2560x1440 screen resolution and 30 frames per second to test the reliability of the connection, this type of scenario can easily show buffering problems if the connection is not reliable.

OpenVPN is a free, open-source application that uses high encryption to communicate in a network, uses client-server connections to provide secure connectivity. It has many capabilities and high encryption is one of the main reasons it is highly adopted in today's market, we will be using the highest level, AES-256-GCM encryption algorithm with a 4096-bit Diffie-Hellman key, this will make the connection very data demanding and it is good to check if packages are dropped during connection. Further information regarding this protocol can be found at openvpn.net.

The reason we discuss the use of encryption is that it is becoming a standard and most browsers are already setting up as default from the installation point for example Firefox Web Browser has activated HTTPS encryption by default and this has implications on the amount of data transmitted, which causes more data from 5% up to even 15% according to Norton article: Internet Security Privacy does VPN use data. Those numbers can drastically change for more percentage if the protocol used is of higher bit rate for example OpenVPN, Wireguard, ToH, DoT, Tor, Obfuscation and others. Cyberwaters.com conducted a test and managed to measure up to a 32% increase of data on a mobile phone test with high encryption levels. Subsequently having longer data transmission increases the time of transmission and EMF altogether.

Router 1: Asus AC-RT68U

ROUTER ASUS RT-AC68U						
peak/mW/m²	1264			E-FIELD:	1332V/M	(PEAK)
frequency	2.4 GHZ			H-FIELD:	16.57µT	(PEAK)
unit	mW/m²					
		RADIATION LEVEL IN mW/m²				
	TX level	power saving	fair	balance	good	peformance
distance	1 meter	1.70	2.10	2.70	3.51	4.38
	3 meters	0.11	0.09	0.21	0.70	0.91
	6 meters	0.63	0.34	0.11	0.06	0.08
	9 meters	0.21	0.07	0.03	0.04	0.10
	12 meters	0.16	0.04	0.07	0.05	0.04

Table 4: Measurements of EMF on RT-AC68U at 2.4Ghz spectrum.

Table 5 shows the Radiation level measured in mW/m^2 on 2.4Ghz frequency for the RT-AC68U, even though at maximum “performance” or 100% Transmission rate of 4.38 mW/m^2 if we look at the peak it shows a very high number at 1264 at close range.

ROUTER ASUS RT-AC68U						
peak/mW/m²	1264			E-FIELD:	1332V/M	(PEAK)
frequency	2.4 GHZ			H-FIELD:	16.57µT	(PEAK)
unit	mW/m²					
			SIGNAL LEVEL dBm			
	TX level	power saving	fair	balance	good	peformance
distance	1 meter	-30	-27	-27	-30	-34
	3 meters	-39	-40	-33	-36	-38
	6 meters	-40	-43	-41	-44	-45
	9 meters	-44	-45	-42	-38	-49
	12 meters	-50	-49	-49	-45	-55

Table 5: Measurements of Signal dBm on RT-AC68U at 2.4Ghz spectrum.

Table 6 shows the signal level of the Wi-Fi in dBm relatively good, even at lower transmission levels varying from -27dBm the best reception to -55dBm the lowest point. Please be aware that the closer to 0 the stronger the signal is being emitted. All tests of ping, buffering and encryption at all levels of Tx worked without any issues.

ROUTER ASUS RT-AC68U						
peak/mw/m²	1355			E-FIELD:	1347V/M	(PEAK)
frequency	5.0 GHZ			H-FIELD:	19.96µT	(PEAK)
unit	mW/m²					
			RADIATION LEVEL IN mW/m²			
	TX level	power saving	fair	balance	good	peformance
distance	1 meter	0.71	0.62	3.50	4.90	17.00
	3 meters	0.57	0.43	0.25	0.55	1.31
	6 meters	0.03	0.04	0.10	0.12	0.39
	9 meters	0.07	0.04	0.02	0.02	0.02
	12 meters	0.05	0.06	0.01	0.02	0.02

Table 6: Measurements of EMF on RT-AC68U at 2.4Ghz spectrum.

Table 7 shows the results at 5.0Ghz band frequency, showing similar levels to the other band 2.4Ghz but at performance close range 1 meter 17.00mW/m^2 which is relatively high compared to the other samples, peak level at 1355 although high number with 91 units higher from the 2.4Ghz. All tests of ping, buffering and encryption at all levels of Tx worked without any issues.

ROUTER ASUS RT-AC68U						
peak/mw/m²	1355			E-FIELD:	1347V/M	(PEAK)
frequency	5.0 GHZ			H-FIELD:	19.96µT	(PEAK)
unit	mW/m²					
			SIGNAL LEVEL dBm			
	TX level	power saving	fair	balance	good	peformance
distance	1 meter	-33	-32	-25	-34	-30
	3 meters	-41	-39	-30	-43	-39
	6 meters	-45	-43	-42	-47	-41
	9 meters	-49	-38	-42	-45	-48
	12 meters	-55	-45	-49	-49	-54

Table 7: Measurements of signal dBm on RT-AC68U at 5.0GHZ spectrum.

Table 7 shows levels taken at 5.0Ghz band frequency with lowest at -55dBm and highest at -25dBm, although the 5.0Ghz has a higher frequency the range is smaller, so as the frequency band grows the range diminishes so some manufactures increases the numbers of antennas to cope with emissions range.

Router 2: Zyxel NBG6602

ROUTER ZYXEL NBG6602							
peak/mw/m²		727		E-FIELD:	968V/M		
frequency	2.4 GHZ			H-FIELD:	3.89µT		
unit	mW/m²						
		RADIATION LEVEL IN mW/m²					
	TX level	10%	25%	50%	75%	90%	100%
distance	1 meter	0.55	1.33	1.66	1.02	2.01	5.31
	3 meters	0.66	0.12	0.09	0.10	0.15	0.36
	6 meters	0.11	0.06	0.09	0.08	0.07	0.04
	9 meters	0.06	0.07	0.03	0.04	0.02	0.04
	12 meters	0.04	0.04	0.02	0.03	0.02	0.02

Table 8: Measurements of EMF on Zyxel NBG6602 at 2.4Ghz spectrum.

Table 7 shows the Zyxel device on 2.4Ghz frequency with much lower numbers compared to the Asus model at EMF 727 at peak and also an electrical field at 968 V/M. The radiation levels vary from 5.31 at maximum and 0.02 at the furthest point at 12 meters.

ROUTER ZYXEL NBG6602							
peak/mw/m²	727			E-FIELD:	968V/M		
frequency	2.4 GHZ			H-FIELD:	3.89μT		
unit	mW/m²						
		SIGNAL LEVEL dBm					
	TX level	10%	25%	50%	75%	90%	100%
distance	1 meter	-41	-42	-44	-41	-42	-50
	3 meters	-49	-56	-54	-50	-53	-64
	6 meters	-56	-63	-62	-54	-61	-65
	9 meters	-61	-62	-60	-64	-62	-68
	12 meters	-54	-55	-62	-58	-61	-59

Table 9: Measurements of Signal dBm on Zyxel NBG6602 at 2.4Ghz spectrum.

Table 7 shows the Wi-Fi signal levels with the strongest at -41dBm and the lowest -68dBm, very close to Asus with the slightest lower levels.

ROUTER ZYXEL NBG6602							
peak/mw/m²	727			E-FIELD:	1342V/M		
frequency	5.0 GHZ			H-FIELD:	14.64μT		
unit	mW/m²						
		RADIATION LEVEL IN mW/m²					
	TX level	10%	25%	50%	75%	90%	100%
distance	1 meter	1.05	0.41	1.52	1.81	0.55	6.19
	3 meters	0.40	0.25	0.15	0.21	0.44	0.40
	6 meters	0.14	0.15	0.17	0.18	0.17	0.14
	9 meters	0.04	0.07	0.09	0.10	0.11	0.10
	12 meters	0.02	0.02	0.03	0.02	0.04	0.03

Table 10: Measurements of EMF on Zyxel NBG6602 at 5.0Ghz spectrum.

Table 7 shows the radiation EMF results at 5.0Ghz band frequency with the highest at 6.19mW/m^2 at close range and lowest at 0.02mW/m^2 the furthest point at 12 meters. We can see that the peak for E-Field and H-field do not vary from 2.4Ghz and 5.0Ghz in all the devices, so the markings are the same.

ROUTER ZYXEL NBG6602							
peak/mw/m²	727			E-FIELD:	1342V/M		
frequency	5.0 GHZ			H-FIELD:	14.64μT		
unit	mW/m²						
		SIGNAL LEVEL dBm					
	TX level	10%	25%	50%	75%	90%	100%
distance	1 meter	-51	-48	-45	-40	-38	-41
	3 meters	-57	-49	-48	-45	-48	-44
	6 meters	-64	-54	-56	-54	-49	-47
	9 meters	-62	-60	-57	-57	-53	-57
	12 meters	-61	-69	-54	-55	-58	-54

Table 11: Measurements of Signal dBm on Zyxel NBG6602 at 5.0Ghz spectrum.

Table 7 shows the signal level results at 5.0Ghz band frequency, with the highest level at -38dBm and lowest at -69dBm, there will be some discrepancy for example at 90% the signal is stronger than at 100% this can be caused by various factors, but normally a reflection of signal and impulse peak from the wireless device during the video stream.

Router 3: Asus RT-AX55 – Wi-Fi 6

ROUTER ASUS RT-AX55 – WiFi6						
peak/mw/m²	340			E-FIELD:	1424V/M	
frequency	5.0 GHZ			H-FIELD:	18.59µT	
unit	mW/m²					
		RADIATION LEVEL IN mW/m²				
	TX level	power saving	fair	balance	good	peformance
distance	1 meter	4.10	1.80	2.89	3.60	6.19
	3 meters	0.09	0.15	0.41	0.30	0.35
	6 meters	0.07	0.08	0.15	0.15	0.20
	9 meters	0.08	0.05	0.06	0.22	0.15
	12 meters	0.02	0.03	0.03	0.08	0.07

Table 12: Measurements of EMF on Asus RT-AX55 - WiFi6 at 5.0Ghz spectrum.

Table 7 shows the results of the Asus RT-AX55 Wi-Fi6 radiation levels at 5.0Ghz band frequency with the highest at 6.9 mW/m^2 and lowest at 0.02 mW/m^2 at the furthest point. Interesting enough on the peak it shows a very low level compared to previous devices at 340 mW/m^2 it is a good improvement.

ROUTER ASUS RT-AX55 – WiFi6						
peak/mw/m²	340			E-FIELD:	1424V/M	
frequency	5.0 GHZ			H-FIELD:	18.59µT	
unit	mW/m²					
			SIGNAL LEVEL dBm			
	TX level	power saving	fair	balance	good	peformance
distance	1 meter	-35	-31	-26	-24	-22
	3 meters	-40	-38	-37	-35	-35
	6 meters	-47	-45	-42	-41	-40
	9 meters	-51	-49	-46	-48	-42
	12 meters	-50	-49	-45	-47	-47

Table 13: Measurements of Signal dBm on Asus RT-AX55 - WiFi6 at 5.0Ghz spectrum.

Table 7 shows the results at 5.0Ghz band frequency very good signal strength at strongest point -22dBm and lowest at -50dBm on the furthest point of the room.

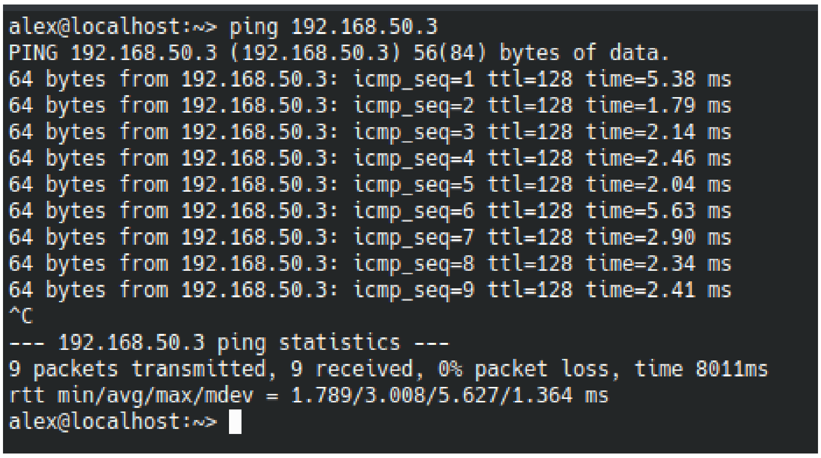


Figure 17: Ping on Asus RT-AX55 at lowest Tx, streaming 2K video content at 12 meters.

Figure 17 we have a ping result, we utilized this tool in every zone for each category to be able to access if we had any lost package, it calculates the sending and return of a package with the milliseconds and amount of data transmitted, for all the instances we had 100% return of all the packages with 0% loss for all devices and distances tested, this alone shows a good result even with the video stream and encryption activated, proving our initial idea that it would be viable to reduce EMF and no loss would occur at that environment.

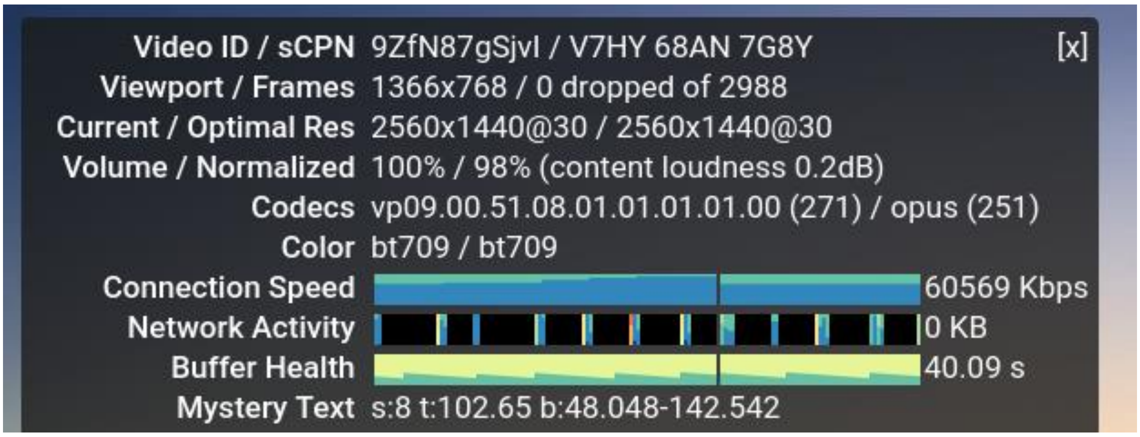


Figure 18: Video streaming technical details of resolution, frames and others.

Figure 18 we have some statistic from the High Definition video being streamed from the internet at 2560x1440 resolution with an average of 60Mbs of data being transmitted, handled without any buffering or stater to the video being played on the Laptop via Wi-Fi connectivity, we had 100% no buffer in all case scenarios which again proved that lower EMF did not affect the video being played.

Figure 19: Side by side comparison CPU load of the router under 2K stream, left not activated, right encryption on.

Figure 19 shows the use of a very data-intensive security encryption OpenVPN, which is becoming very popular amongst user across the globe, above we have some statistic regarding the wireless device being used with encryption on the right and without on the left. We can see a big spike in the CPU usage of the RT-AC68U device as it needs to handle all those encryption at a high bit rate, AES-256-GCM encryption algorithm with a 4096-bit Diffie-Hellman key. This scenario can increase up to 32% of the amount of data going through the device, also time to transmit increases the EMF time overall. The results showed that on all zones, it had no problem with ping lost during video playback.

9 Results and findings

We have concluded that from this controlled scenario, the measurements were found that it is reasonable and adequate to use a reduced Tx mode to receive a similar amount of data without disruptions. Streaming video at 2K resolution did not impose any problems with buffering and all tests resulted in good reception of the signal, in some extreme cases where the user requires very low latency would be recommended a higher output, such as gaming and 4K and or 8K streaming.

This proves our initial belief that wireless devices are set to the high levels on initial installation, but this could be adjusted to very low levels without affecting data transmission, another point that the manufacture should improve and allow the user to adjust or even optimize efficiently and perhaps even during installation procedures.

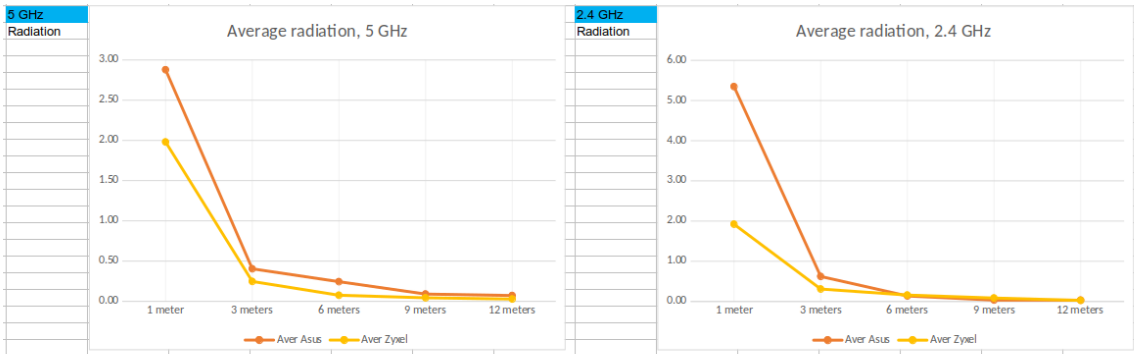


Chart 1: Radiation levels differences between Asus and Zyxel 2.4Ghz and 5Ghz.

Although there was an average variation of 20 dBm from the maximum Tx transmission to the lowest this amount on our environment which is a line of sight between the testing machine to the router did not impose any restriction to the connection nor to the data transmitted which was a success in this sense, which means a user can reduce Tx for a reduced wireless exposure if within a room of small scale.

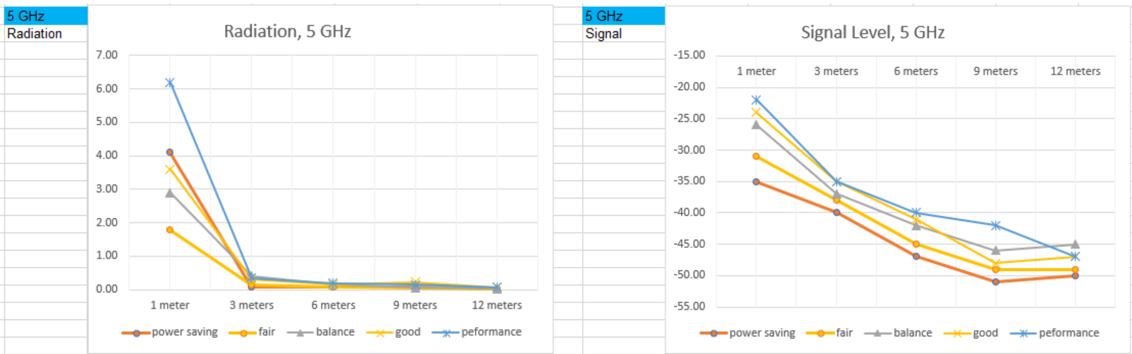


Chart 2: Radiation and Signal levels on the Wi-Fi 6 device, during video streaming.

Wi-Fi 6 is the new protocol recently added to the market which incorporates faster speeds using the 5Ghz spectrum, there are plans in Europe to be approved next-generation Wi-Fi devices which will use the Wi-Fi 6Ghz spectrum expected in the first quarter of 2021 according to the website theverge.com (Kastrenakes, 2020). The E-field measurement had values of above 1000 v/M in the Asus modem with exception of the Zyxel that showed lower values at 968 on 2.4Ghz spectrum, overall they were both in this range, as for the H-field Asus also showed the highest number at 19.96 µT at 5.0Ghz and Zyxel the lowest 3.89 µT at 2.4Ghz.

10 Conclusion

From the analysis of the EMF emission of the 3 devices in question, they present satisfactory emission according to STUK and European Council ICNIRP, the emission was quite high at the proximity of the device and exponentially lower as further from it shown in the graph below.

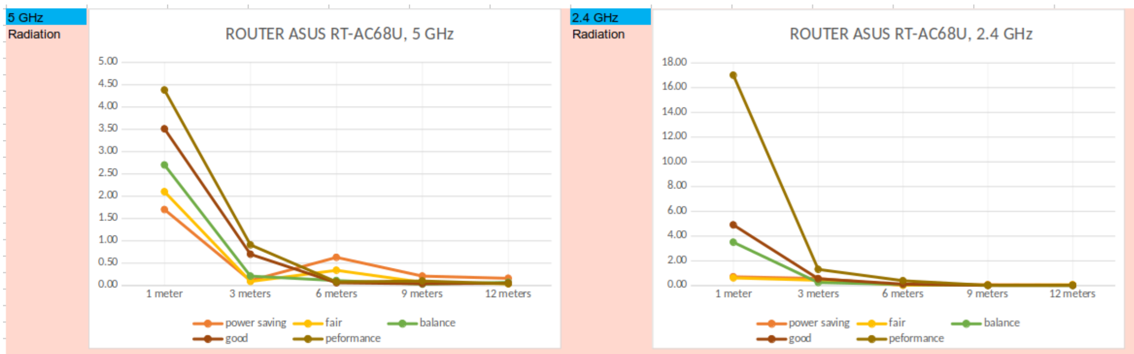


Chart 3: Distance reduces the amount of EMF 2.4ghz and 5ghz RT-AC68U.

The graph above shows the Asus RT-AC68U at how the radiation levels are considerably high at close range and gradually reduces once the distance is higher, not only from 2.4Ghz also 5.0Ghz frequency bands. Making us suggest that a person should not be at close range of their devices for precaution reasons.

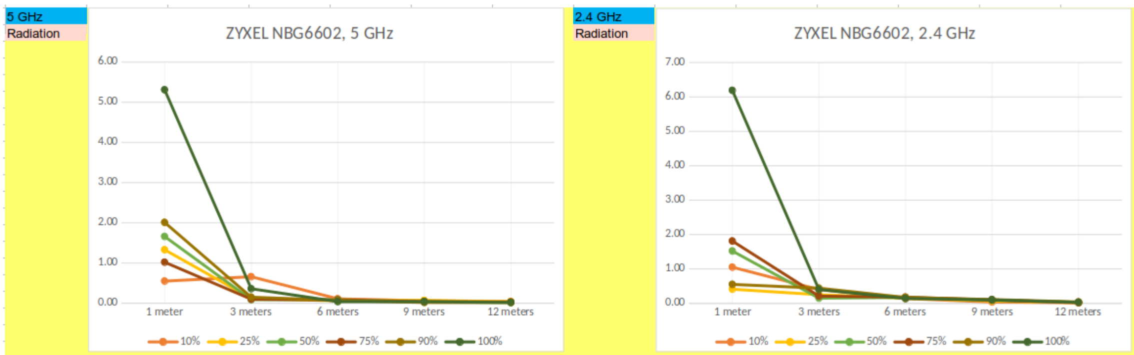


Chart 4: Distance reduces the amount of EMF 2.4ghz and 5ghz NBG6602.

The graph above shows the Zyxel NBG6602 device at 2.4Ghz and 5.0Ghz frequency range and it reduces considerably a lot of the radiation from 3 meters onwards.

Regulation that governs wireless technology has given the green light for the new technology to be used without concerns, published material from both sides of pros and cons of wireless devices are being used for different purposes making the public confused regarding the safety or prolonged side effect.

Manufacturers should take the ethical approach and start providing devices with better information or option with lower EMF emission, where the consumer can easily reduce or even turn off where there is no need for use, ensuring either way of discussion if it is safe or not to use the new technologies, also security should be enabled by default so that the end-user does not have to research to activate those functions. The signal of Wi-Fi can be very difficult in buildings if different types of structure as concrete or brick walls, a good recommendation for those types of environment would be to use wireless mesh network technology which utilizes a good system of nodes for countervailing this issue those types of scenario can be further analyzed in a future paper.

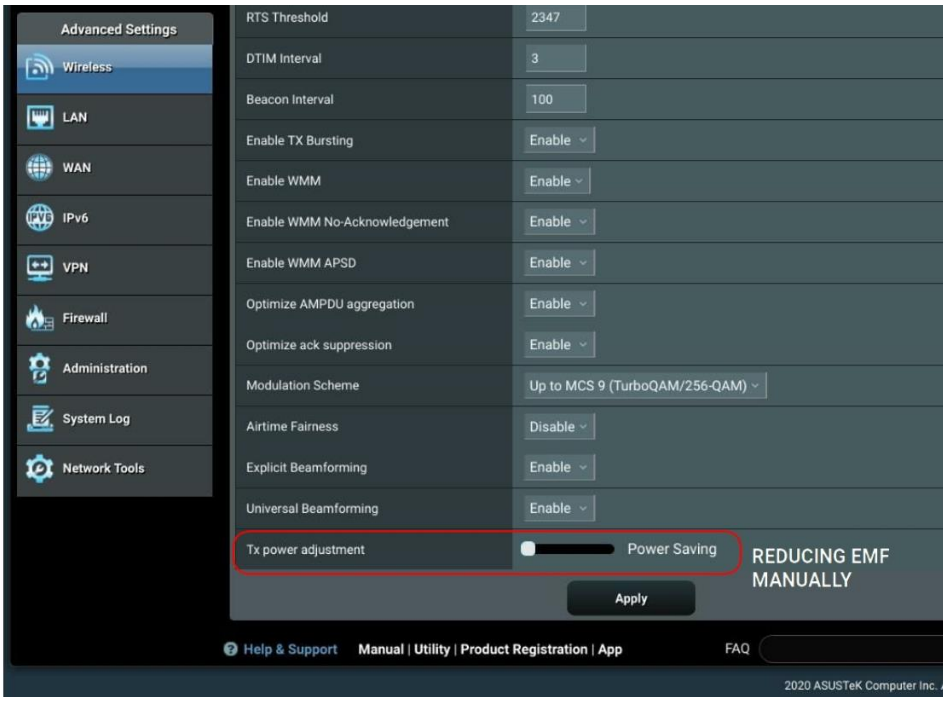


Figure 20: Visualization on Asus router configuration menu under wireless settings, reduction of Tx emission.

A consumer who wishes to reduce manually the settings of their wireless device until an option arrives broadly at the technology market, it is advisable to reduce emission in your device by going through the manual and following the steps on how to reduce the Tx signal for lower EMF, almost all devices from the past 5 years have this capability and can be done either via, mobile application from the router, web browser or other options related to the specific device shown in the picture above.

After analysing the market there are even more Business oportunities where manufactures could include the reduction of the emission in their software (firmware) and provide an extra option for the end consumer to choose what it prefers during installation of the equipment.

Figure 21: Low EMF emission modem/router concept, source: pexels.com.

Most of the wireless devices are based on open-source projects such as Linux based OpenWRT, DD-WRT, Tomato and similar some are Linux based other BSD Unix and they provide a highly customized interface where those adjustments can be easily implemented for the benefit of consumers wishing to have their device with lower EMF emission. Although most devices are internet provider custom software the majority of the devices purchased in IT shops can be implemented with that software.

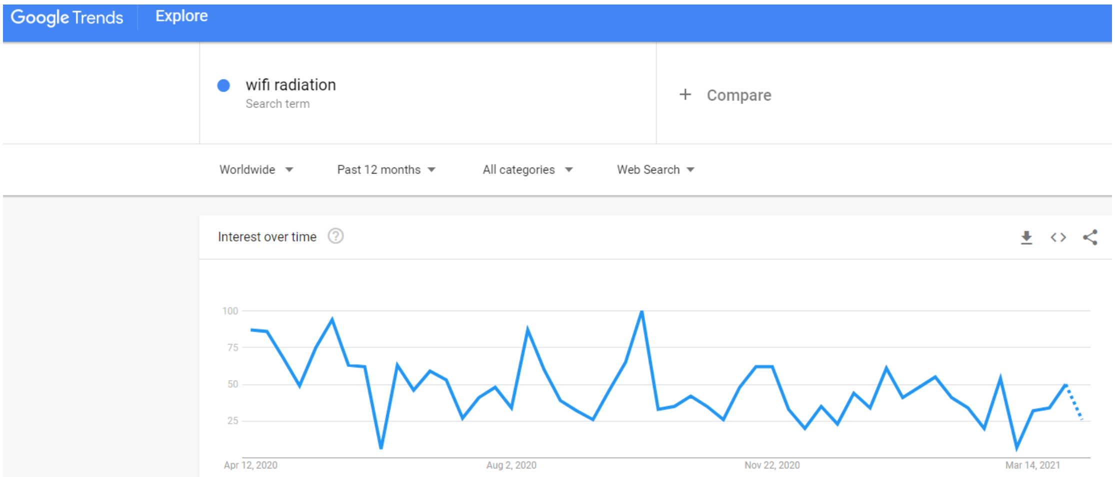


Chart 5: Graphical analyse of Wi-Fi radiation subject popularity for the past 12 months worldwide source: Google trends.

Analyzing the graph above it shows a large interest from the public on the subject of Wi-Fi radiation in a 12 months Google trends graph, this presents a great opportunity prospect in implanting wireless EMF safety into the device and marketing them properly, should have great acceptance and use from consumers, giving them flexibility and more options when buying and choosing a new device.

In Finland governance of wireless radiation is controlled by STUK[1] and they state complete safety for all wireless equipment sold in Europe according to decree 1045/2018, which is in line with Council recommendation 1999/519/EC, it is based on guidelines published by ICNIRP[2]. STUK pointed to us the relevant documentation for this protection which is based on the independent body of regulators called, International Commission on Non-ionizing Radiation Protection (ICNIRP). The publication showing safety is the document: 1998 ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields(up to 300ghz)published in: health physics 74(4):494-522;1998.

There are certain concerns from the general public not only for a local institution following external bodies guidelines, normally for new technologies an old decree is used because it is covered by the EMF range accepted, this process is unfortunates because it leads to new technolgies not being tested properly instead of using previous law for acceptance.

We contacted the National Institute of Occupational Health in Finland[3] asking for instructions and why insurance company do not cover general public cases for wireless exposure. They explained that because there is no previous cases of wireless issues, they are unable to cover potential customer claims. This makes public even more cautions on the reasons behind this attitude.

World Health Organization has stated at one point that “IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans” but has been since taken out saying they found no evidence for the claims raising even more concerns from the public shown in the website iarc.fr (Raghavan et al, 2020).

In Europe, a former wireless and radiation scientist member of staff from STUK department of radiation PhD Dariusz Leszczynski has published a series of concerns related to the numbers of safety being changed from one decree to another raising those limits numbers in some cases to 100 thousand folds and pledging the public to take action regarding the issue of EMF (Leszczynski, 2015).

Having researchers being conducted taking both sides of the analysis, stating it is safe and others showing it is harmful, only creates confusion amongst the public making decision impossible on how to approach this issue. For example the dissertation “The Health Risk of Wi-Fi, 2013” by Ramesh Karki, Turku University taking the side of it is causing damages and “No Effects of Acute Exposure to Wi-Fi Electromagnetic Fields on Spontaneous EEG Activity and Psychomotor Vigilance in Healthy Human Volunteers” (Zentai et al, 2015).

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Figures

Appendices

[1] FINNISH STUK email response

STUK NIR-kyselyt < N/A @stuk.fi>
To: N/A
Thu, 27 Aug 2020 at 14:14

Dear Mr. Bezerra,
The decree 1045/2018 is in line with Council recommendation 1999/519/EC, which is based on guidelines published by ICNIRP. The exposure limits protect from all scientifically proven health hazards.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31999H0519
https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf
Mobile network operators are responsible for complying with the exposure limits. The operators must assess the general public’s exposure to radio frequency radiation before putting a new base station in service. STUK has published a guide on how to install the base station antennas so that the exposure is below the limits.
http://www.julkari.fi/handle/10024/126619
If there is reason to suspect that members of the general public are at risk of exposure to radiation exceeding the limit values, STUK will ask for the operator’s safety evaluation or carry out a surveillance measurement for the base station...

Best regards,
Sami Kännälä
Senior Scientist
STUK - Radiation and Nuclear Safety Authority
Non-Ionizing Radiation Surveillance
n/a Helsinki
phone N/A
N/A @stuk.fi
www.stuk.fi

[2] ICNIRP International Commission on Non-Ionizing Radiation Protection **email Response**

From: Info ICNIRP Secretariat < N/A @icnirp.org>
Sent: Wednesday, October 7, 2020 4:41:47 PM
To: Alessandro Bezerra < N/A @student.laurea.fi>
Cc: N/A @icnirp.org>
Subject: Icnirp clarification on wireless regulation

Dear Alessandro Bezerra,

Thank you for your request.

Would it be possible to know the research based on that utilized?
ICNIRP evaluates the scientific research and produces reviews, statements and guidelines which form altogether the ICNIRP advice for different frequencies. The research basis is detailed in the documents published by ICNIRP. For the low frequency range you may want to consult those via https://www.icnirp.org/en/frequencies/low-frequency/index.html and for the high frequency range https://www.icnirp.org/en/frequencies/radiofrequency/index.html.

And how frequently research is conducted for new devices (emission and receivers i.e. towers and portable devices).
ICNIRP monitors the science and produces its advice either when new research results make its advice obsolete or when scientific progress allows for improvement of the advice. ICNIRP produces its work plan on its website at https://www.icnirp.org/en/activities/work-plan/index.html. The work plan for the next years is currently in the making and will be updated shortly on this site.

For some reason ICNIRP does not mach the recommendation from European Council (what is the reason for that?) Promote new technologies?
The European Council is a political organization which operates through own political dynamics rather than scientific ones. The ICNIRP advice results from scientific analysis based on frequencies. ICNIRP is not about promoting new technologies. ICNIRP's aim is to protect the health against detrimental effects of non-ionizing radiation.

With best wishes,
Karine Chabrel
on behalf of the
ICNIRP Secretariat

ICNIRP
INTERNATIONAL COMMISSION ON
NON-IONIZING RADIATION PROTECTION

ICNIRP c/o BfS, Ingolstaedter Landstr. 1
N/A, Germany
T. + N/A
N/A @icnirp.org, www.icnirp.org

[3] National Institute of Occupational Health email response

From: Alessandro Bezerra < N/A @student.laurea.fi>

Sent: torstai 1. lokakuuta 2020 9.13

To: Leikas Matti < N/A @ttl.fi>

Subject: Current situation in wireless exposure

Hi Matti,

My name is Alex Bezerra, I was given your contact by Lahi-Tapiola, the reason of this email is just to ask a quick question about wireless exposure regulation in Finland.

… Lahi-Tapiola told me there is no work insurance for wireless allergy or wireless exposure conditions at this present moment in Finland.

What is the regulation that the institute follows, or the guidelines?

I was given the following chart which made me even more confused.

EUROPAEM (2016) 2G, 3G, 4G ------ 10 μW/m2 Yöaikainen altistus a)

- " - 100 μW/m2 Päiväaikainen altistus

European Council (2011) ----------- n.1000 μW/m2 Pitkäaik altistus sisätiloissa (0.6 V/m) b)

- " - n.100 μW/m2 Tavoite sisätilojen altistukseksi (0.2 V/m)

www.baubiologie.de (2015) ------ >1000 μW/m2 Hälytysraja, ongelma korjattava c)

ICNIRP ja Suomen säteilylaki ---- 10.000.000 μW/m2 d)

- " - 200.000.000 μW/m2 Paikallisesti, keskiarvona 1cm2 alalta

Huom ! EUROPAEM arvot ovat huippuarvoja, ICNIRP- arvot ovat keskiarvoja, joihin voidaan piilottaa korkeita pulssihuippuja.

Could you clarify which exactly is the standard in Finland?

I contacted STUK but they told me yes, we follow one of the standard above, but the decree allows us to go over European Council.

------------------------------------ STUK response ------------------------------------

The decree 1045/2018 is in line with Council recommendation 1999/519/EC, which is based on guidelines published by ICNIRP. The exposure limits protect from all scientifically proven health hazards.

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31999H0519

https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf

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Kind Regards,

Alessandro Bezerra

---- Response ----

Leikas Matti < N/A @ttl.fi>

Thu 01/10/2020 14:20

Hi Alex,

The STUK answer is correct. In Finland the EMF regulation for public is Stma 1045/2018 "Sosiaali- ja terveysministeriön asetus
ionisoimattoman säteilyn väestölle aiheuttaman altistuksen rajoittamisesta" which has the same guidelines as European Council recommendation 1999/519/EC, next on the table 2:

Table 2

Reference levels for electric, magnetic and electromagnetic fields (0 Hz to 300 GHz, unperturbed rms values)

Frequency range	E-field strength (V/m)	H-field strength (A/m)	B-field (μT)	Equivalent plane wave power density S_{eq} (W/m²)
0-1 Hz	—	$3,2 \times 10^4$	4×10^4	—
1-8 Hz	10 000	$3,2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8-25 Hz	10 000	4 000/f	5 000/f	—
0,025-0,8 kHz	250/f	4/f	5/f	—
0,8-3 kHz	250/f	5	6,25	—
3-150 kHz	87	5	6,25	—
0,15-1 MHz	87	0,73/f	0,92/f	—
1-10 MHz	$87/f^{1/2}$	0,73/f	0,92/f	—
10-400 MHz	28	0,073	0,092	2
400-2 000 MHz	$1,375\ f^{1/2}$	$0,0037\ f^{1/2}$	$0,0046\ f^{1/2}$	f/200
2-300 GHz	61	0,16	0,20	10

Notes:

1. *f* as indicated in the frequency range column.
2. For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any six-minute period.
3. For frequencies exceeding 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any $68/f^{1.05}$ -minute period (f in GHz).
4. No E-field value is provided for frequencies < 1 Hz, which are effectively static electric fields. For most people the annoying perception of surface electric charges will not occur at field strengths less than 25 kV/m. Spark discharges causing stress or annoyance should be avoided.

For example: B-field 50 Hz, ref.value for public is 100 microT (0,1 mT).

EMF regulation for work places is Vna 388/2016 where the reference values are the same as in directive 2013/35/EU.

Hope this helps.

Ystävällisin terveisin!

Matti Leikas

asiantuntija

Työterveyslaitos

N/A

n/a TYÖTERVEYSLAITOS

käyntiosoite Arinatie 3, Helsinki

p. N/A