Austria can count on it.

We`re planning the mobile future of tomorrow.

Mobile communications and technology

The majority of people living in Austria are regular users of mobile devices and apps. And the number is increasing all the time. Everyone wants to be available or online anywhere and at any time. But can we still navigate our way through this flood of information, and do we still have enough time for those things that really matter to us?

As a mobile communications provider, it is important to us that technology gives time and does not cost time. For us, the focus of each new technological advance is not just the progress it brings but also the new opportunities it gives to people.

We therefore see it as our responsibility to shape a positive future in which mobile communications make our lives easier instead of just faster.

A1 was, is and always will be a mobile communications pioneer and technological leader. For this reason, we are already investing today in the network of the future.

With 5G, the next generation of mobile communications, we will make innovative data services and applications available to you in a completely new quality with high data transfer speeds. There's plenty to be excited about!

This brochure explains the basics of how mobile communications work and the benefits they offer you.

If you have questions on the subject of mobile communications, the A1 EMF Team will be happy to help: emf@a1.at

Your A1 EMF Team

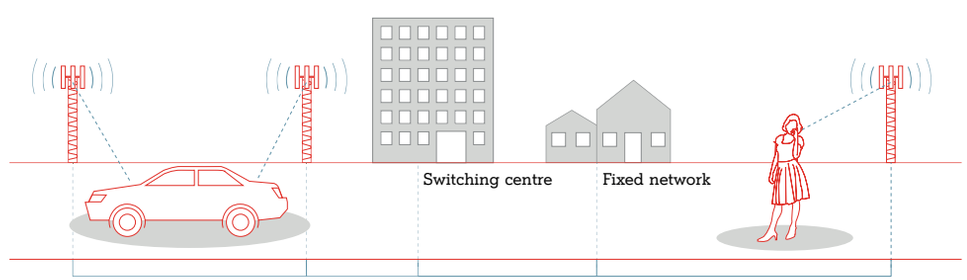
Contents

Basic principles of mobile communications

Communication between mobile phones and base stations is very complex, especially if we move and a call has to be "forwarded" from one base station to the next.

Whenever we make a call or send data on our mobile phone, it sends signals to the antennas of the nearest base station. If we make a call while travelling by car, we repeatedly leave the reception area of one base station and have to be forwarded with our conversation to the next mast. This handover between the masts is a technologically complex task carried out by the mobile phone exchange.

If we want to make calls to a land line or to a subscriber of another mobile network, the mobile phone exchange steps in. The exchange also enables connections between multiple subscribers. In order to establish a connection quickly, the information about the current location of all active mobile phones is saved by the switching centre.



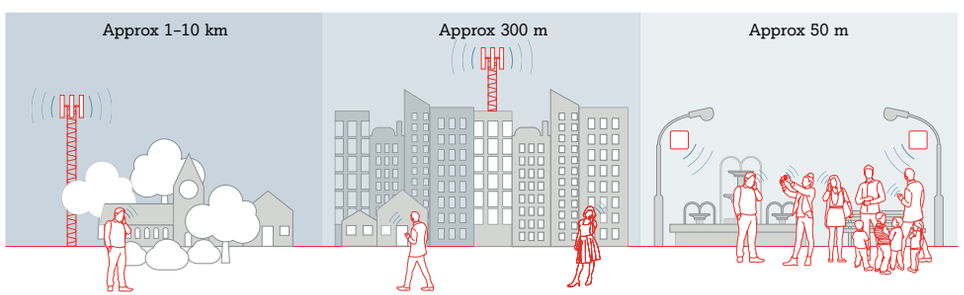
Mobile base stations

The number of mobile base station needed depends on how many mobile end devices have to be supported. In urban areas, more masts are required, in less densely populated areas fewer. The requirements they have to meet is regulated by law.

The location of base station is especially important. The more carefully they are chosen, the better the mobile communication reception. Therefore, there are a number of criteria that are of central importance.

Masts have to be situated where calls are made and data is transferred. They are planned in such a way that the best possible quality of service is provided. Of course, when choosing a location, building density, the number of potential users and the terrain of the coverage area all need to be taken into consideration.

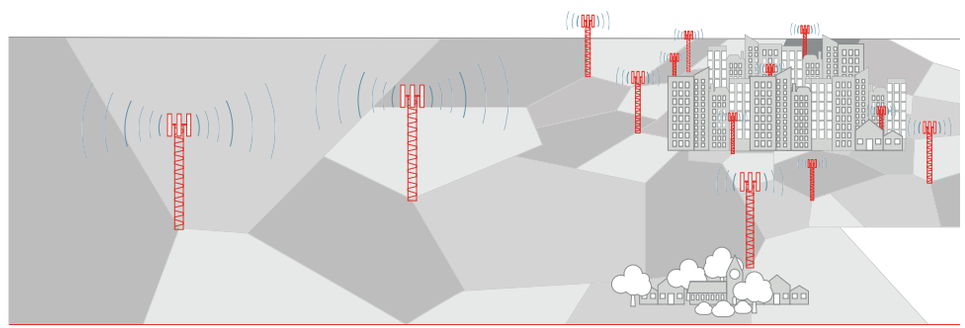
Not only is the geographical reach of mobile phone masts limited, the volume of calls and data that can be transmitted simultaneously is also finite. For network coverage there are therefore various application scenarios with differing ranges. A base station within a building has a range of around 50 metres, in



an urban area an average range of approximately 300 metres and in rural areas up to 10 kilometres.

This means: The more people use their mobile phones for making calls and using data services, the greater the number of masts that are needed. This is why more masts are required in urban areas than in the countryside.

Mobile phones also adjust their transmitting power automatically. They only transmit at the strength that is absolutely necessary. The better the connection between a mobile phone and a base station, the less transmitting power the phone needs. If masts are located away from villages or towns, for example in the surrounding forests, mobile phone transmitting powers and base station transmitting powers will be higher due to the additional distance. The result is that emissions will higher than if the mast was within the town or village.



Cellular radio cells

Expansion of the network

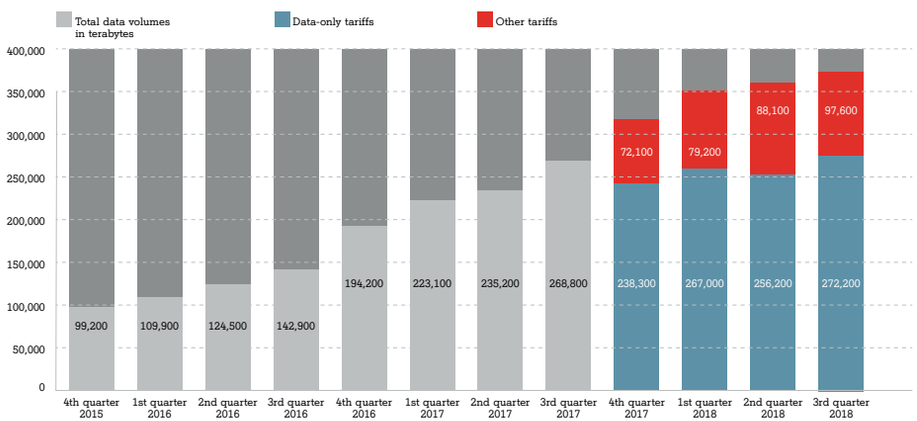
New mobile communication technologies enable higher data transfer speeds. Many customers want fast and easy internet access, which is why Net Cubes are increasingly used as a flexible supplement or alternative to fixed line internet. These devices combine an LTE modem with a Wi-Fi router and offer mobile internet access (for smartphones, laptops, tablets) wherever there is 4G/LTE

mobile reception. However, the network must be expanded or modified for this purpose, mainly by adapting the existing base stations. Antennas are replaced or new ones installed as needed.

Why are more and more base stations still being built?

Demand for mobile internet volumes is growing from year to year making clear the need for a suitable infrastructure and the further development of mobile communication standards. It is now possible to surf the mobile internet in comfort from anywhere in Austria. This is leading to a rapid increase in data traffic.

The Annual Report 2018 of the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR)* states: "After the volume of mobile data used declined in Q2 2018 for the first time since measurements began, data volume rose again sharply in Q3, 2018 for the first time since measurements began, data volume rose again sharply in Q3, rising to 369,800 terabytes. This is an impressive increase of 7.4%."



More data traffic with less transmitting power – the new mobile network technologies make it possible. Due to the lower transmitting power of modern smartphones and increasingly efficient technology, less and less transmitting power

* www.rtr.at/de/inf/telekom-monitor-q32018

is needed to transfer the same volumes of data. This also means lower emissions. However, exact and careful planning of the network is crucial.

> **Emissions** are the radio waves in the environment and can be measured or calculated. Find out more in the section "Emissions and limit values" on page 24.

Mobile communications – legal framework

Radio installations require a permit before they can be put into operation. A licence awarded by the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR-GmbH) or a general permit obtained in accordance with the Telecommunications Act (TKG) 2003 generally also includes authorisation to operate the requisite installations within the framework of the applicable legal conditions and applicable standards. On the basis of the licence, the telecommunications authorities issue a permit to operate transmitting stations. This permit covers all radio installations regardless of their location.

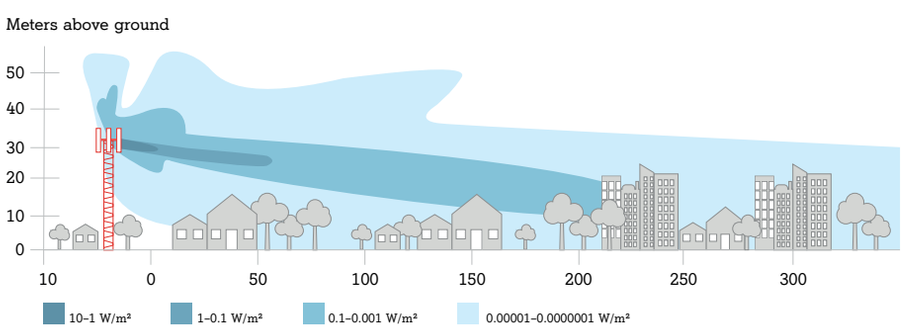
Individual permits are not issued for an individual antenna, as the requirements for transmitting and safety distances to the transmitting masts are type-approved and are verified at a later date. This works in a similar way to cars; the individual models are type-approved, and vehicles are not inspected individually before registration.

Building permits (for foundations, masts etc.) are issued in accordance with the statutory provisions of the provinces. This is the case, for example, with regard to nature conservation areas and building regulations.

How we optimise reception

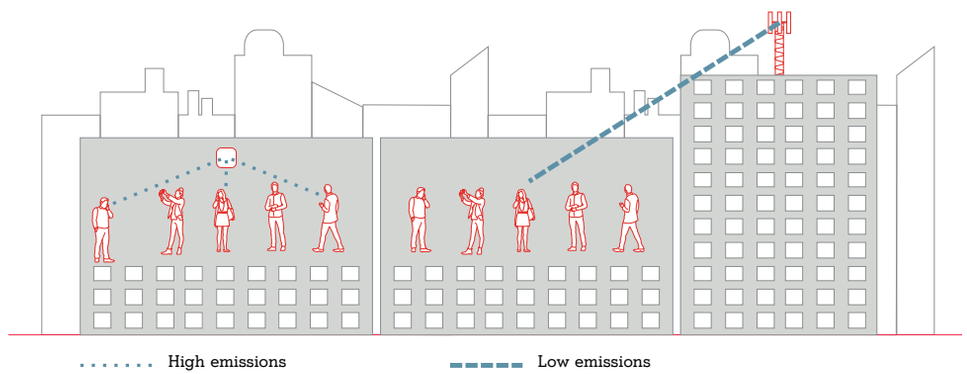
Base stations in areas with high volumes of traffic need support. “Smart cells” offer two advantages here. On the one hand, they provide better reception in urban areas and inside buildings; on the other hand, they ensure that mobile phones use less power.

Base stations are designed in such a way that the radio waves can be transmitted and received as far away as possible rather like a lighthouse that has to have a wide range so that its light is visible from a great distance. However, less light is visible immediately below the lighthouse. It’s a similar situation with radio waves directly underneath the antenna of a mobile phone mast. The signal received when close to a mast can be weaker than the signal 100 metres away.



Dispersion behaviour of radio waves

Modern buildings are often built of highly insulating materials, with windows that have multiple glazing; this can affect reception of the mobile phone signal. Consequently, reception is worse inside the building than outside. In such cases, it helps to have a transmitting station within the building. In large buildings such as offices or department stores, several antennas can be installed within the building in order to provide better reception conditions. This creates good reception and allows individual mobile phones to reduce their power output to a minimum.



The principle of transmitting stations within a building can also be applied in densely populated residential areas: Multiple small antennas (each with only a small range) are installed in addition to the large base station so as to provide coverage in areas where there is a concentration of people. These are known as “small cells”, and they are seen as an important component of the next “5G New Radio” mobile communications generation.

History of mobile communications

Since their discovery, electromagnetic waves have massively changed our daily lives in society. Initially, the application was unidirectional – for radio. Quickly, this evolved into direct communication between individual people. We are still far from exhausting the benefits of this application. The future lies with the Internet of Things (IoT) that enables machines to communicate with each other without human intervention.

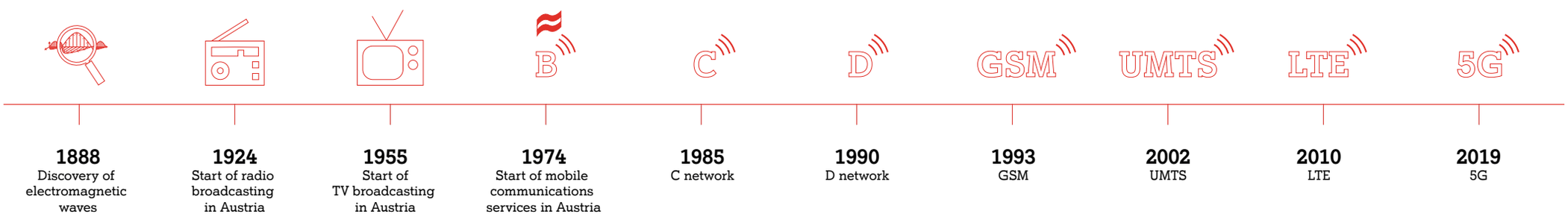
Of course, we all use modern mobile communication technologies in our daily lives, even though the proportion of telephony within that usage is steadily declining. In an age of smartphones and tablets we use data-intensive applications for mobile internet access to an ever-greater extent.

The rapid growth in data traffic continually demands faster mobile communications networks. Whether we are surfing the internet in a coffee shop or talking at home on the mobile phone – more data is being transmitted in parallel, in ever shorter periods of time. This makes it increasingly important to make efficient use of the available mobile communications frequencies. With the latest mobile communications generations such as LTE and 5G New Radio, we are well equipped for the future.

History of radio waves in Austria

In 1888, Heinrich Hertz discovered the existence of electromagnetic waves. A few years later, wireless transfer of information was achieved for the first time – the starting gun for wireless communications. The potential uses of electromagnetic waves were quickly appreciated – the armed forces were particularly interested. In 1924, the first Austrian radio transmitter was brought into use in the Ministry of Defence in Vienna. In 1955, the first TV programmes in Austria were broadcast. Whilst the first mobile communications network was brought into operation in the USA back in 1946, it took another 3 decades before Austria gained a mobile communications network.

The first publicly accessible mobile communications network, the B network, was brought into use in Austria in 1974. This analogue mobile communications system offered subscriber trunk dialling, but in order to connect to the mobile network you had to know the geographical code for the person you were calling. When the B network had expanded to 1,770 subscribers, it hit the limit of its capacity, and in 1985 it was replaced by the cellular C network. This introduced uniform dialling codes across the nation and



created the capability to switch without interruption from one phone mast to another. In 1990, the D network was introduced; this was the last analogue mobile communications generation before the GSM network.

The digital GSM network started in Austria in 1993. Originally it was called the E network. It was the first standard of the second generation (2G), and as the successor to the analogue systems it represented the most widely used mobile communications standard in the world. Twelve years after it came into use, the introduction of an additional modulation capability (EDGE) further improved the rates of data transmission of the 2G network.

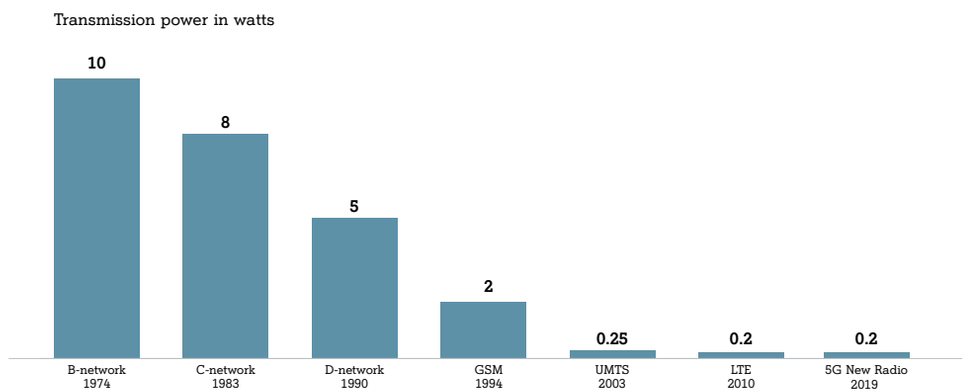
In 2002, Mobilkom Austria (A1) finally started the first national UMTS network in Europe, the third generation (3G) mobile communications network. This enabled significantly higher rates of data transfer to cater for internet access by the population. UMTS also benefited from subsequent extensions to improve the performance of the network.

Since 2007, all A1 customers have benefited from faster rates of data transmission and reception using new transmission protocols (HSDPA/HSUPA). The LTE network uses fourth-generation (4G) mobile communications technology. LTE was introduced in Austria in 2010. The frequency bands required for this were increased in 2010 and again in 2013, which accelerated the network speed. In Austria, 99% of all households have access to fast internet via LTE. Currently, the fastest mobile communications technology is LTE-Advanced. This is an extension of LTE, which once again incorporates technical improvements to increase the transmission rates.

With 5G New Radio, the next mobile communications generation is already on the starting blocks. Whilst in 1974 Austria lagged somewhat behind its international peers in introducing its first analogue mobile communications network, the BMVIT (Federal Ministry for Transport, Innovation and Technology) now wishes to take Austria into a leading position in Europe with the introduction of 5G. The Federal Ministry has published a strategy with a schedule to make 5G available in the regional capital cities by no later than 2020 and throughout Austria by 2025.

The maximum power required for transmission is becoming lower

In recent years there have been rapid developments in mobile communications. Modern end devices require significantly less power for transmission, as a comparison with a B network mobile phone from the 1970s shows. The further development of mobile communications technologies brings not only better responsiveness and longer battery life but also reduced emissions. Whilst first generation mobile phones transmitted all information only in analogue form and without any control over the emission power, the transmission emissions of modern mobile phones are checked automatically and continuously.



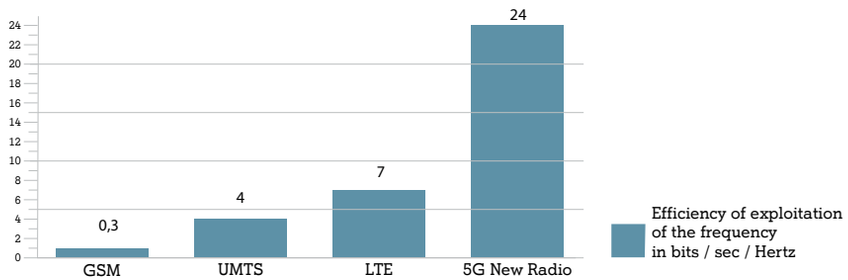
This is how the maximum emissions of mobile phones has changed

Spectral efficiency

The advantages of new technology bring increases in the efficiency of exploitation of the available frequency spectrum compared to previous mobile communications technologies. Thus, data can be transmitted more efficiently and more users can be provided simultaneously with mobile communications.

The spectral efficiency of a radio signal is the ratio between the data transmis-

sion rate and the bandwidth of the signal. It is expressed in bit/s/Hz and denotes how many characters are transmitted per second in comparison with the overall bandwidth (frequency band). This computed value allows comparisons to be made between different transmission technologies.



Spectral efficiency – a comparison between different mobile communications technologies

New technologies are driving forward the development of mobile communications

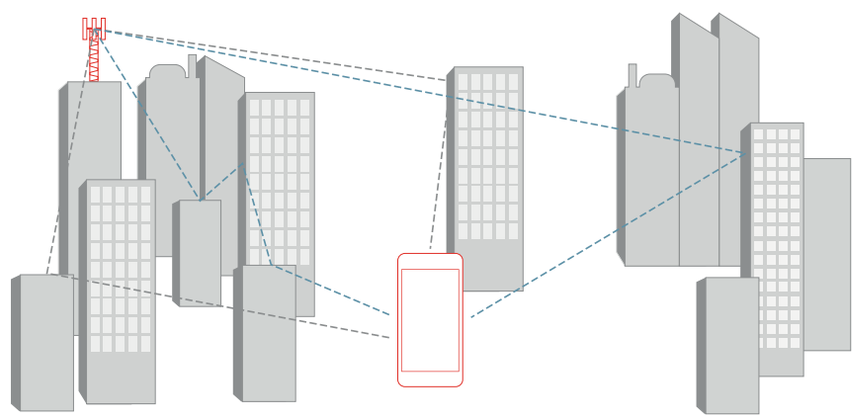
Mobile communications are constantly evolving. Technologies are constantly being optimised and new methods such as Narrowband IoT, MIMO and beam forming are being developed. This increases speed, efficiency and security, whilst at the same time laying the foundations for the next generation of mobile communications.

Narrowband IoT

Narrowband IoT (NB-IoT) is a narrowband machine sensor network which efficiently links machines into the established mobile communications infrastructure. This network uses radio waves across a particularly wide band, thus enabling it to receive signals from sensors that are far away, and issue commands accordingly. For NB-IoT, the main factor alongside range is not speed of data transmission but factors such as ease of maintenance, increased penetration of buildings, short latency times and lower module costs. NB-IoT allows a connection of a multitude of devices and sensors using existing base station. Previously, this was not technically or commercially feasible. As the name of this technology suggests, the motivation behind NB-IoT is the realisation of the Internet of Things (IoT). Thus NB-IoT technology can be viewed as an extension of the mobile communications world which already links many machines. In a few years, this task will be taken over by the new mobile communications generation 5G New Radio.

MIMO

MIMO (Multiple Input/Multiple Output) transmission technology allows large amounts of data to be transferred more quickly. The technology has been proven in Wi-Fi applications and has been available for mobile communications since the introduction of LTE. The principle of MIMO is multi-antenna technology, both for the base station and also for smartphones. The parallel transmission of data using multiple antennas on the same frequency and at the same time achieves better transmission performance and reception performance. The smartphone can reconstruct the data streams even if they come from different directions because of reflections. Using the 5G New Radio mobile communications standard, a further development of this technology, called "massive MIMO" is projected. This envisages a massive increase in the number of active antenna elements. This will allow the spectral efficiency to be greatly further optimised.

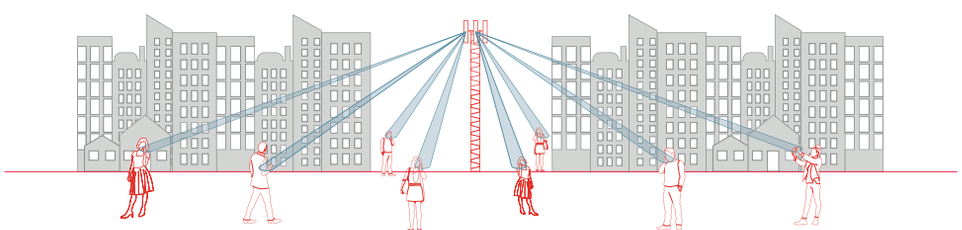


Faster data transfer rate by MIMO

In order to prevent these many antennas operating at the same frequency from interfering with each other, a further function is brought into play – "beam forming".

Beam forming

Beam forming permits the selective provision of participating devices with smart antennas. Conventional antennas broadcast the radio signal over a very wide angle, so that the signal strength decreases rapidly as the distance from the antenna increases. Beam forming creates a much narrower broadcasting angle, so the signal is actively directed towards the recipient. This means that the signal strength is maintained much more effectively and consequently requires less transmission power. Beam forming can in fact be used for 4G signals and is regarded as a key technology for 5G. When used together with "massive MIMO", it allows individual data packets to be broadcast in a coordinated fashion in order to minimise interference, to make most efficient use of the available frequency and to increase the range of the signal.

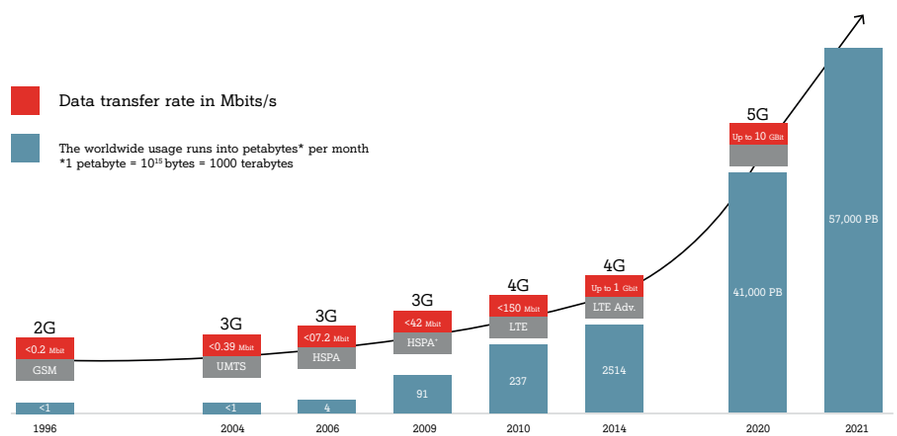


Mobile communication of the 5th generation (5G) is a development of many currently existing and proven technologies, and can be integrated seamlessly into existing technology. The existing network technologies will continue to exist and will be operated in parallel so that mobile communications customers can continue to use their existing devices.

5G New Radio: The next standard in mobile communications

5G opens up many opportunities which, on the one hand, require only small bandwidth and thus consume less energy but, on the other hand, also offer data rates a hundred times faster, thus behaving significantly more efficiently and allowing use for more selective applications. 5G truly warrants the attribute "smart" technology.

The demands on the mobile communications network are increasing year by year. Mobile usage of the internet with fast data transfer rates is now taken for granted, and the annual data usage is increasing massively every year.



In the future, not only people but also many machines and items of equipment will seek to access the mobile communications network. In the "Internet of Things", the 5G New Radio will permit innumerable machines and applications to exchange data amongst themselves, with large bandwidths and at short response times. To achieve this will require the extension of the current mobile communications network, with new transmission frequencies and investment in technological prerequisites.

Overview of advantages of 5G New Radio

- Data rate several times higher than today's LTE network (1–10 Gbit/s)
- Around 1,000 times greater capacity
- 100 billion mobile communication devices throughout the world can be accessed simultaneously
- Extremely low latency times -> Ping response less than 1 millisecond
- 1/1,000 of the energy consumption per transmitted bit
- 90% less power consumption per mobile service

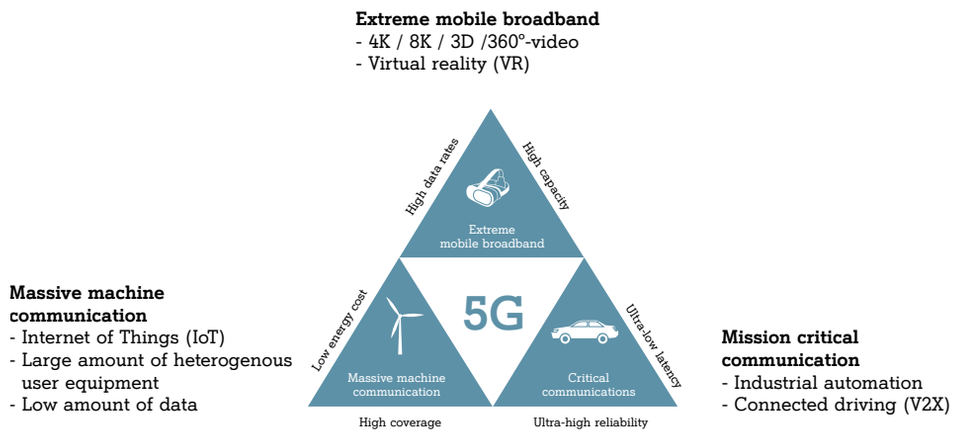
5G New Radio (5G NR) was developed in order to deliver significant improvements in performance, flexibility, scalability and efficiency compared to current mobile communications networks and to make the most efficient use of the available frequency spectrum.

The most important characteristics of 5G New Radio

5G permits unimaginable bandwidths. Since the new technology delivers data more efficiently than previous mobile communications generations, the capacity of the overall mobile network is significantly increased. This is necessary to satisfy the increasing demands of mobile communications users.

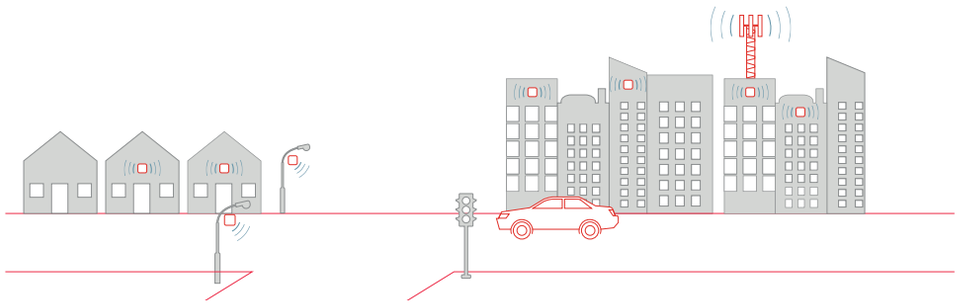
The latency time describes the response time of a network and is denoted as "ping" time. Whilst current LTE networks already achieve a latency less than 40 ms, the latency time for 5G New Radio will be less than 1 ms, and in addition the network will exhibit greater reliability. These characteristics are critical for applications such as autonomous driving or for surgery performed remotely via telemedicine.

One of the impending revolutionary applications of the internet is expected to be in the field of machine-to-machine communications (M2M). What we call the Internet of Things (IoT) consists of machines or devices equipped with sensors which communicate with each other. Here too, 5G New Radio offer a critical advantage. Whilst high frequencies are essential for high data transmission rates (over short ranges) lower frequencies are used by contrast for the energy-saving transmission of small data packets over long distances. Thus, for instance in a "smart city", networked streetlights can monitor the use of parking spaces, or rubbish bins can report their fill level.



Small cells

Small cells play an important role in the provision of the next mobile communications generation 5G New Radio. These use very compact transmission stations (comparable in size to a modern Wi-Fi access point), which are limited to providing a signal within a radius of ten to a few hundred metres due to their low transmission power. These small transmission stations can be used in heavily trafficked places and in urban areas to increase the capacity and network coverage of an existing network.



Mobile phone stations for coverage, small cells for heavily trafficked places and in urban areas

Network slicing

5G New Radio can provide flexible coverage for the individual needs of users and applications in respect of data rates, speed and capacity. This technology allows small parts of the mobile communications network to be made available for special applications, such as at business premises or at airports. Such areas can thus be provided with their own network with special characteristics guaranteeing assured data capacities and response times if, for instance, the public network becomes overloaded.

Is the new technology safe?

The international limit value recommendations of the EU, the WHO and ICNIRP are implemented in Austria by OVE Technical Specification RL 23-1, compliance with which is mandatory. This specification covers the frequencies from 0 Hz to 300 GHz – so it includes the frequencies used for 5G New Radio. These limit values incorporate a 50-fold safety factor in order to ensure comprehensive protection for the general population, including vulnerable groups such as children, pregnant women, the elderly and those who are sick.

Health protection

WHO exposure limits are in use in Austria to protect health. As a mobile communications provider, A1 is of course required to comply with these limits. The biological effect of electromagnetic waves is constantly monitored and minimised as far as possible so that absolutely no effect on health is to be expected.

What are electromagnetic waves?

Electromagnetic waves are everywhere. Their spectrum ranges from low-frequency electrical currents to radio, television and various wireless applications, infrared (heat effect) and visible sunlight to X-rays.

Wavelength is defined as the spatial period of a periodic wave.

The **frequency,** which is measured in hertz (Hz) states how many cycles the wave completes per second.

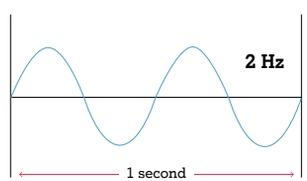
1 Hz = 1/s

Other frequently used units of measurement are:

1 kilohertz (kHz) = 1,000 Hz

1 megahertz (MHz) = 1,000,000 Hz

1 gigahertz (GHz) = 1,000,000,000 Hz



2 oscillations per second – 2 Hz

Depending on the wavelength, they have different effects and areas of application. Radio waves used by base stations and mobile phones are part of this spectrum.

Emissions and limit values

Humans have been using radio waves for more than a century, and over this time much research has been conducted into the potential health risks. The World Health Organisation (WHO) is concerned with keeping abreast of all topics related to human health throughout the world, including whether electromagnetic fields pose a risk to health. For mobile communications, the WHO has issued clear recommendations about the limits that must be applied to the intensity (power) of such fields.

However, a biologically significant effect occurs only when the heat is so intense that the body can no longer compensate for it biologically. The heat generated in the body by radio waves does not present a health risk. It's a lot less for example than the thermal effect of sunbathing or sport. The strength of radio waves can be calculated and measured, so the emissions of radio waves at a particular place can be determined. The limit values that must be complied with differ depending on the respective frequency band.

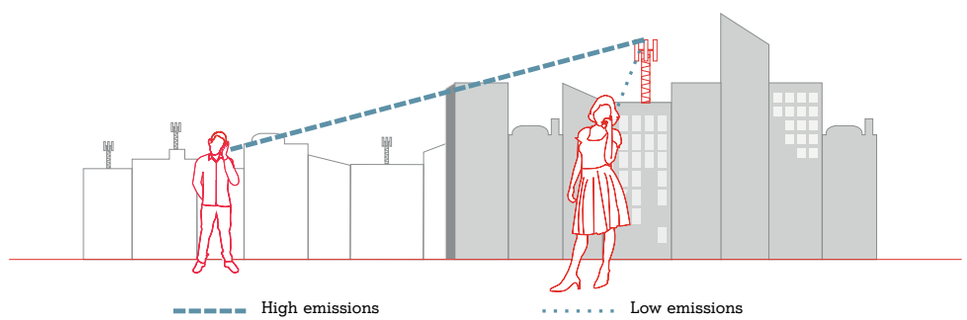
WHO limit values in OVE Specification R23-1:2017			
At 800 MHz	4 W/m²	At 1800 MHz	9 W/m²
At 900 MHz	4,5 W/m²	Above 2000 MHz	10 W/m²

To make certain that the WHO limit values are being complied with, the Mobile Communications Forum (FMK) has been carrying out a series of nationwide measurements of mobile communications emissions throughout Austria since

2007. The results of the current series of measurements from 2017/2018 show that the emissions at all measurement points not only complied with the applicable limit values but actually fell well below them. The results of this series of measurements in Austria are similar to those obtained in many measurements at home and abroad.

A well-configured network generates lower emissions

The users of the mobile communications system are the principal beneficiaries of a well-configured mobile communications infrastructure. A comprehensive and well-planned configuration of the mobile communications network is necessary so that all radio cells can call on the capacity they need. Comprehensive coverage offers customers the best reception. This provides the best voice quality and best data transmission rates. In addition, because the transmission power is regulated automatically by the mobile communications station and mobile phone, the total emissions are reduced and at the same time the demand on the mobile phone battery is also reduced.



Summary: Any enforced deviation from the optimum configuration of the network leads to:

- an increase in the emissions that are required,
- a reduction in the data rate and possibly also to the voice signal breaking up, hence an overall deterioration in the mobile communications provision.

FAQ

? Why do mobile phone companies keep on erecting more masts?

! Mobile phone networks are being used more and more intensively by our customers, and data volumes are constantly growing. This means we need modern mobile communications networks based on better technical principles because they are more efficient at transmitting data. This does, however, create a need for new base stations or for new antennas mounted on existing masts.

? Why must you build mobile phone masts in residential areas?

! Mobile phone antennas are needed in the areas where the majority of users want to use their mobile phones. The better the mobile communications network is configured, the better the connection that users obtain, the faster the data is transmitted and the lower the emissions from the mobile phones and base stations.

? Are there health risks associated with new mobile communications technologies such as 5G?

! Radio waves have been used to transmit data for more than 100 years. Over this time, there has been much research devoted to the possible effects of radio waves on the human body. To date, no health hazards have been proven. The limit values concept of the WHO, which has been adopted 1:1 into Austrian law, span the frequency range 0–300 GHz. This covers all mobile communications technologies, including future network systems.

? Are the emissions from new mobile communications technologies greater?

! No, quite the contrary! Using the LTE system, the maximum transmission power used by a mobile phone is 0.2 watts, which is far less than the power for older GSM networks at 1–2 watts. The more modern the end device and the available network, the lower the transmission power.

? Why do we need new mobile communications technologies at all?

! The constant increase in data applications demands correspondingly high-performance and stable mobile communications networks. Earlier technologies have been struggling for some time to keep up with the demand for data transmission quantities.

? What does the SAR value of a mobile phone or smartphone tell us?

! The SAR (specific absorption rate) specifies how much of the energy emitted by the phone is absorbed by the body. The SAR for a phone is always measured at the maximum transmission power and must not exceed a limit value of 2 watts per kilogram of body weight.

? Do I need a new mobile phone in order to enjoy the benefits of 5G technology?

! Yes you do, because 5G uses new and more efficient transmission technologies. 5G also uses different frequency bands.

Imprint

If you have any questions, please contact the EMF Team:
E-mail: emf@a1.at
Tel: 050 664-0
Further information is available at A1.net/gesundheit

Federal Ministry for Transport, Innovation and Technology (BMVIT):
www.bmvit.gv.at/telekommunikation/index.html

The Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR-GmbH):
www.rtr.at/en

Registry of all broadcasting and mobile communications transmitters in Austria:
www.senderkataster.at

Mobile Communications Forum (FMK):
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