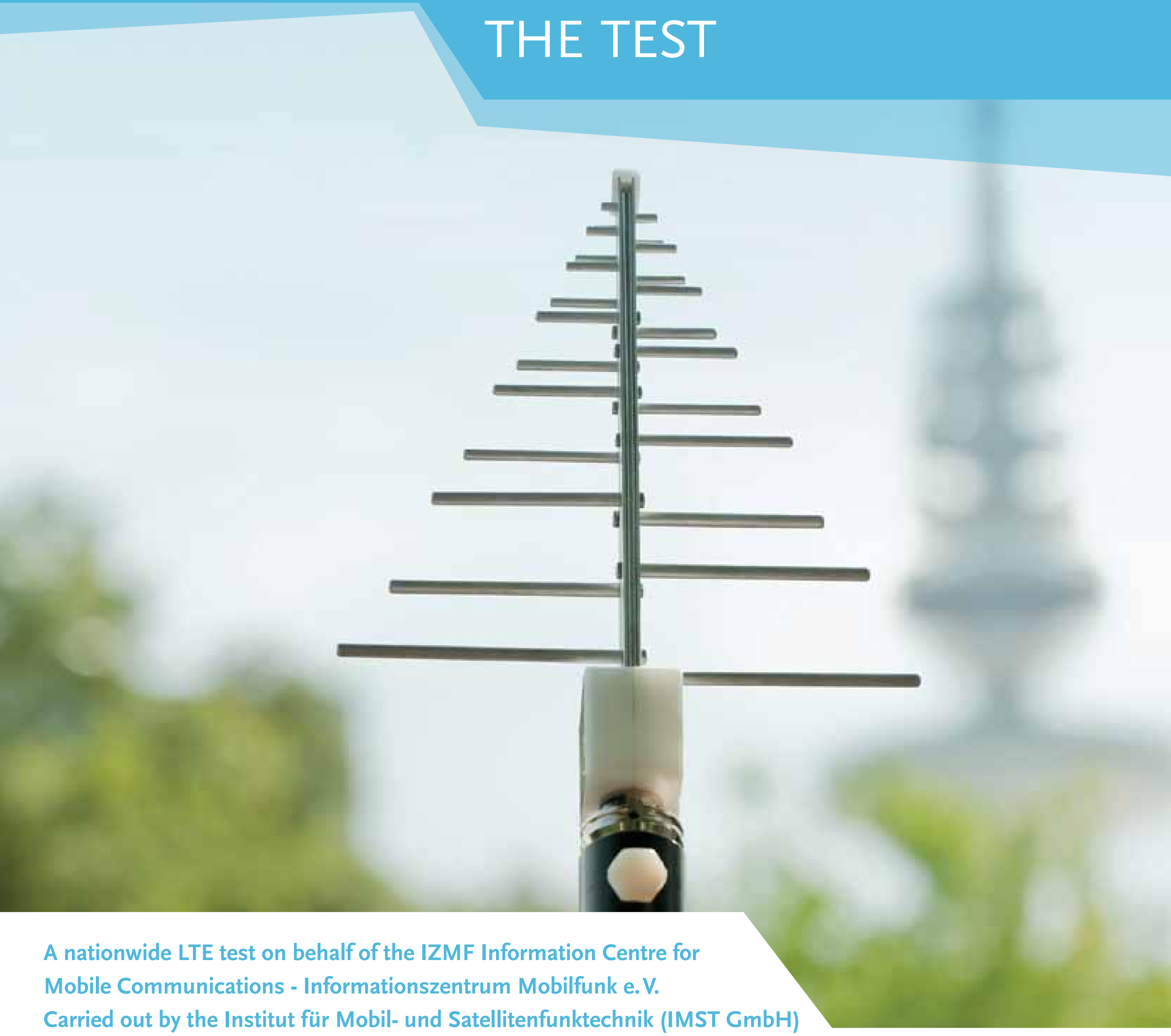
CONFIDENCE BY EVIDENCE – PUTTING LTE TO THE TEST



A nationwide LTE test on behalf of the IZMF Information Centre for Mobile Communications - Informationszentrum Mobilfunk e. V.
Carried out by the Institut für Mobil- und Satellitenfunktechnik (IMST GmbH)

Results | Evaluation | Discussion

INFORMATIONSZENTRUM MOBILFUNK

IMST

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FOREWORD

Dear readers,

The way we communicate via different media has changed tremendously over the past few years. We are much more likely to make calls on our mobile phones than on a traditional telephone and mobile internet is becoming increasingly popular. LTE, the new generation of mobile communications, will meet the demand for more data volume. The LTE standard uses frequencies more efficiently than earlier systems and can therefore guarantee a fast internet with high data transfer rates. It is thus perfectly suited for bringing fast broadband internet to Germany's rural areas.

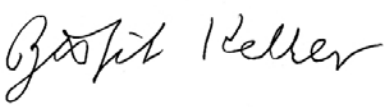
The expansion of the LTE network has reinvigorated the public discussion about the risks of mobile communications. In particular, many people are concerned about whether the extension of frequency ranges will increase electromagnetic fields in their home environment.

The Ordinance on electromagnetic fields – 26 BImSchV – established the limits for electromagnetic fields produced by mobile communications. These limits apply to all forms of radio technology, including LTE.

The frequencies used and the exposure created are the most important factors in the analysis of the health effects of radio technologies. The German Mobile Telecommunication Research Programme (Deutsches Mobilfunk Forschungsprogramm – DMF), which was concluded in 2008, included studies examining the possible health risks of the high-frequency electromagnetic fields used by mobile communications as well as their fundamental biological effects and mechanisms. The frequency range of the studies was intentionally set very broad and some studies included ranges not currently used by mobile communications. This was done to make sure that the findings are relevant to the entire frequency spectrum for telecommunications and will allow the assessment of future technical developments. The results of the DMF studies will therefore allow conclusions to be drawn regarding health risks of the new LTE technology. As the frequency ranges used by LTE are very close to those used by other mobile communications and radio technologies, it is anticipated that their biological-medical effects will be broadly comparable.

The findings from extensive national and international research studies indicate that mobile communications do not cause any health risks. However, many people still fear and mistrust mobile communication technology. This is because there is a lack of competent information on the complex cause-and-effect relationships in radio-based communication technologies. In order to allay these fears there has to be more accessible information available on how the electromagnetic fields affect the environment. This information needs to be based on the results of scientific research.

At the same time, an objective discussion about possible adverse health effects caused by electromagnetic fields requires information on the existing fields. Here, the LTE tests that have already been carried out, with the support of the environmental ministries of all 16 federal states, provide us with a sound basis for deeper understanding. To date, test results prove that even with LTE technology, the intensity of electromagnetic fields remains well below existing exposure limits.



Dr. Birgit Keller, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

Make up your own mind

The mobile phone is our constant companion, increasingly accompanied by tablets and laptops. This all-in-one device provides our mobile workplace, communication platform, calendar, camera, calculator, navigation system and purse and requires ever faster mobile internet access. Current projections see a 15-fold increase in mobile data traffic in Germany by 2016. This rapid growth creates new challenges for the construction and expansion of telecommunications networks.

For the federal government, a powerful mobile network infrastructure is one important prerequisite for economic growth and increasing prosperity. The expansion of the LTE (Long Term Evolution) network, the fourth generation of mobile communication, is therefore a key component of the government's broadband strategy. LTE networks will bring mobile internet to the whole country, first and foremost to those areas where there is currently little or no broadband available. To date, LTE network development in these so-called "white spots" is now complete and network providers are working on expanding the network in larger cities. Germany is a world leader in LTE network expansion.

While it is to be expected that the laws of radio wave propagation that apply to LTE are similar to those of previous generations of mobile communications, not much is known about actual exposure levels from LTE installations as these have only been the subject of a handful of studies.

To address this lack of knowledge, the Informationszentrum Mobilfunk e. V. (IZMF - Information Centre for Mobile Communications) has been carrying out the first nationwide test of LTE base stations under normal operating conditions. The purpose of this study is to provide the public with up-to-date and comprehensive information about their exposure to the electromagnetic fields produced by LTE and other mobile networks. The IZMF had launched a pilot study on LTE base stations operating under test conditions in summer 2010 – before the development of the LTE network – and the latest study is building on its findings. The results of the pilot study were presented at a number of international scientific conferences where they were met with great interest.

The latest study was carried out in collaboration with the environmental ministries of the 16 federal states as well as the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The Institut für Mobil- und Satellitenfunktechnik (IMST GmbH) in Kamp-Lintfort carried out tests at 91 measuring points at LTE stations in all 16 federal states. IMST GmbH is a renowned organisation with a reputation for producing unbiased research findings of the highest quality, guaranteeing the quality and neutrality of the results. This nationwide test is in accordance with the federal environment ministry's recommendation to provide more objective information about new radio technologies such as LTE, based on proven scientific findings. Our brochure provides comprehensible explanations of how the measuring processes are carried out, the test findings and their assessment as well as a wealth of further information for anyone who is interested in finding out more about the exposure levels from mobile communications.

If you have any further questions, please do not hesitate to call our free hotline at 0800 3303133 (from German networks only), and talk to us personally. You can find the complete report on our homepage at www.izmf.de.

Dagmar Wiebusch
Managing director
Informationszentrum Mobilfunk e. V.
(IZMF)

Mobile network technology for fast internet

LTE (Long Term Evolution) technology is an evolution of the 3rd generation (3G) mobile communications standard, better known as UMTS (Universal Mobile Telecommunications System). LTE is often called the 4th generation of mobile communications (4G) and experts predict that it will soon become the most widely-used mobile communications standard.

LTE technology has compelling advantages:

- fast data transfer rates for downlinks (100 MBit/s) and uplinks (50 MBit/s)
- low latencies
- packet oriented data transmission (all-IP network)
- good mobility support, even when moving at high speeds
- downward compatibility
- infrastructure easily upgradable
- high percentage of shared use with existing sites

LTE availability

For the expansion of LTE networks, the mobile network operators use the 800 MHz, 1.8 GHz, 2.0 GHz and 2.6 GHz frequency ranges that were obtained in the spring 2010 auction of frequencies. When the Federal Network Agency (Bundesnetzagentur) assigned the 800 MHz frequencies, licensing requirements were specified for the network providers. They were required to start the development of radio communication networks in regions where little or no broadband was available (the so-called "white spots"). These areas had been identified by the individual federal states, which provided lists of the relevant communities before the auction took place. In the first instance, network providers were required to provide coverage for at least 90 percent of the population in communities with fewer than 5,000 inhabitants. By November 2012, the network providers had fulfilled this requirement for the 800 MHz range in all 13 of the federal states where broadband coverage was inadequate. They have now started the rapid extension of the network in larger cities and conurbations.

LTE frequency ranges

The frequency ranges used for the expansion of the LTE networks have different physical properties, which affect their use. The 800 MHz range, for instance, has very good radio wave propagation characteristics and individual base stations which use it are able to serve relatively large areas. This frequency range is therefore especially well suited to providing wireless broadband to rural areas. Waves in the higher frequency ranges do not have such good radio wave propagation properties; the 1.8 GHz, 2.0 GHz and 2.6 GHz frequencies are therefore mainly used in cities and conurbations. Given the greater demand for higher broadband capacity in these areas, base stations here are much closer to each other anyway.

LTE mobile networks

As it is the case for all mobile phone networks, LTE networks have a cellular structure. LTE is based on an air interface, the "Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)". It transfers the data between the base station and the mobile device. Innovative processes allow very high data rates between the mobile device and the base station, the "eNodeB". These base stations are connected both to the next base station and to the core network, called EPC (Evolved Packet Core). The radius of cells in the LTE network depends mainly on the volume of traffic, the frequency and the number of subscribers in the area it covers. Cell radiuses range from a few metres (microcell) to many kilometres (macrocell).

The use of the multi-antenna technology, "Multiple Input Multiple Output (MIMO)", brings about further improvements. With two or four antennas, the signal takes different routes to its destination. This process improves the quality and the data rate of the wireless connection. Combining this new antenna technology with innovative transmission modes and modern modulation techniques means that the available frequency spectrum becomes more efficient than was possible with the earlier 3G technology.

Focus on the surroundings of the network installations

In 2012, the Informationszentrum Mobilfunk e. V. (IZMF) organized the first nationwide test of LTE base stations under normal operating conditions. The aim of the test was to provide accurate information about the exposure levels for the new LTE standard in the vicinity of mobile network installations. Supported by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and in collaboration with the ministries for the environment of the federal states, specialists at the Institut für Mobil- und Satellitenfunktechnik (IMST GmbH) took readings of exposure levels at 91 measuring points in the immediate surroundings of LTE base stations as well as in residential areas in all 16 federal states. The field strength was measured at 16 LTE base stations (one site per federal state) in the 1,800 MHz and 800 MHz frequency range (the digital dividend) as well as in different residential environments. Wherever GSM and/or UMTS mobile network installations were located at the same site, their field strength was also measured at the same time and the total field strength of all the mobile networks was calculated.

Choice of locations

The LTE sites were chosen in collaboration with the environment ministries of the 16 federal states. Each ministry was asked to propose suitable LTE sites for the test which should be used in their respective states. The IMST then thoroughly analysed this list, focussing on sites used for more than one mobile phone standard and those sites close to buildings, where maximal exposure levels could be expected. As Baden-Württemberg, Rhineland-Palatinate and Saarland had not specified any locations, the IMST itself selected sites in these federal states. All in all, the experts picked one representative site per federal state and determined between five and seven measuring points in its immediate vicinity. Measurements were thus taken at 91 different points in the entire country.

Measurement concept

With their new study "Confidence by evidence – Putting LTE to the test", the IZMF followed up an earlier, preliminary study from summer 2010, which measured LTE mobile phone technology under test operating conditions. The preliminary study had also been carried out by the IMST, which developed the measuring concept for both of the LTE studies. These concept was also used in a present research project on behalf of the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz) for one of their ongoing research projects. The measurement concept investigates typical exposure scenarios to estimate the exposure levels for comparable locations. In addition a 24-hour long-term measurement was carried out to show how exposure levels change during an entire day.

The measurement results were documented in a measurement report and assessed concerning the exposure limits established in Germany's 26th Ordinance Implementing the Federal Immission Control Act (Ordinance on electromagnetic fields – 26 BImSchV).

Results

The results show that values at all measuring points remain considerably below the legal limits established in German law. Even when taking into account additional emissions from GSM and UMTS base stations installed at the same site and projecting the theoretically possible maximum power of all installations, the values only reach a fraction of the legally established exposure limits.

The statistical analysis demonstrates that total exposure levels at the sites studied have increased because of LTE. However, at 86 of the 91 measuring points the total exposure levels do not reach 10 percent of the legal exposure limit in respect of field strength and do not reach 1 percent with regard to power flux density.

The highest LTE value was recorded at Jena: One measuring point in the direction of the main beam at a distance of 24 metres from the LTE base station reached a value of 13.53 percent of the field strength limit. This measuring point also displayed the highest total exposure levels of the study, at 21.82 percent of the field strength limit. The lowest field strength value was measured at Hanau: it reached just 0.01 percent of the legal limit.

Note:
The units electric field strength (E) and power flux density (S) are explained in detail on page 10. The tables with the measurement results for all locations (p. 11 onwards) always show both values.

The measurements provide information about:

- the strength of the electromagnetic fields in the surroundings of the LTE mobile network installations in the 800 MHz and 1,800 MHz ranges
- the radio wave propagation characteristics in the immediate surroundings of the LTE installations
- the emission patterns of the LTE installations and their influence on the radio wave propagation characteristics of the fields
- attenuation effects caused by buildings and topography
- the proportion of the different mobile networks at the site and the resulting total exposure levels

Measurement and extrapolation methods for the test

Measuring emissions from mobile network installations

The measuring procedure for these tests consists of collecting data at all measuring points using the "sweeping method with extrapolation to the maximal operational state of the station". For such measurements, a hand-held measuring antenna is moved through the area that is being tested. With the measuring instrument set on "max-hold", the device records the maximum exposure levels recorded by the measuring antenna.

Maximum load

The law – 26 BImSchV – requires that emissions from mobile network installations are established for stations operating at maximum power. Since the electromagnetic fields produced by the LTE, GSM and UMTS base stations are not constant over time but vary depending on their traffic load and transmission quality, the results of the test measurements need to be extrapolated in order to determine the exposure levels released when the station operates at maximum power. Different calculation methods are used for each of the mobile networks.

LTE installations

In LTE networks, the coding of the reference signals (RS) is station- and sector-specific and their transmission is permanent and carried out at a constant transmission power. RS exposure levels are measured with a code-selective spectrum analyser. The maximum exposure levels of the installation when it is operating at maximum power are then extrapolated. This calculation is based on data provided by the operators in relation to current power settings for the transmission of RS signals and the maximum transmission power for each antenna, as approved by the Federal Network Agency (Bundesnetzagentur).

GSM installations

Multi-channel GSM installations will normally use automatic power control for channels 2 and above, while the signalling channel (Broadcast Control Channel, BCCH) always transmits at maximum power. In order to extrapolate the maximum exposure levels of an installation from the measurements, the field strength from the signalling channel is measured in each sector and then combined with the maximum

number of channels. The basis for this calculation is the maximum operating power as approved by the Federal Network Agency. Network operators provided the number of channels approved by the Federal Network Agency together with the corresponding channel numbers.

UMTS installations

UMTS installations have a pilot signal (Common Pilot Channel, CPICH) that is transmitted at a specific constant power. The field strength of each existing CPICH is determined by code-selective measurements. The maximum field strength is then calculated by multiplying the measured exposure levels of the CPICH by a factor that is determined from the power setting for the CPICH at the time of the measurement and the maximum transmission power allowed for the frequency channel. This factor, which is usually 10 percent of the transmission power, was provided by the network operators. The exposure levels are calculated on the basis of this information and then extrapolated to the number of admissible frequency channels at the site.

Measuring equipment and accuracy

Measurements are carried out with calibrated spectrum analysers and measuring antennas. The measurement uncertainty is calculated as being ± 3 dB maximum. This included such variable factors as the calibration of the measuring antenna, measuring cable and spectrum analyser as well as variations in the sample taking. The measurement uncertainty is not added to the measurement results.

Exposure limits

In Germany, fixed mobile network installations with a certain minimum transmission power are subject to the exposure limits established in the 26th Ordinance Implementing the Federal Immission Control Act (26 BImSchV). These limits are based on recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). According to the federal government, the results of the German Mobile Telecommunication Research Programme (DMF), which was concluded in 2008, and other international research projects on mobile communications show that these limits reliably safeguard the population from scientifically proven health risks caused by the electromagnetic fields produced by mobile communications. The Office for Radiation Protection (BfS) confirms this: "The results of the DMF as well as of further up-to-date national and international studies could not confirm the existence of action mechanisms in the athermal area below the limit values. Overall, the results give no reason to question the protective effect of current limit values". The BfS also stresses that this affirmation equally applies to the frequency ranges of the new LTE mobile phone standard. The Federal Network Agency monitors exposure limit compliance in Germany and carries out nationwide control measurements on a regular basis.

Standard	Frequency	Electric field strength (E)	Power flux density
GSM 900	900 MHz	41.7 V/m	4.6 W/m²
GSM 1,800	1,800 MHz	58.4 V/m	9.0 W/m²
UMTS	2,100 MHz	61.0 V/m	10.0 W/m²
LTE 800	800 MHz	38.6 V/m	4.0 W/m²
LTE 1,800	1,800 MHz	58.4 V/m	9.0 W/m²

Solid test results create transparency

Electric field strength and power flux density

The strength of electromagnetic fields around high-frequency sources is generally measured in electric field strength E (V/m) or power flux density S (W/m²). The two units are correlated and can be exactly compared by employing an established mathematical equation. But what do these two units express and which one of them is used more often?

Electric field strength (E) is a technical unit expressed in Volt per metre. For example, a field strength of 1 V/m generates a voltage of 1 Volt in an antenna of 1 metre length. This unit is used to describe various physical principles such as the propagation properties of high-frequency fields. Under ideal conditions, the electric field strength of spherical waves propagating from the antenna decreases linearly with the inverse of the distance to the sender.

The technical unit called power flux density (S) is mainly used when studying the possible biological effects of high-frequency fields. It measures how much energy an electromagnetic field transports through a certain area per unit of time. This unit measures the intensity of the radiation and is therefore an important parameter to assess biological effects, such as the increase of tissue temperature.

In the public discussion of exposure limits, these two units, electric field strength and power flux density, often cause confusion – even though they refer to the same value, mathematically speaking. Because of the quadratic relationship between power flux density and electric field strength, the same measurement creates two different values to express their exposure limit consumption. For example, when the electric field strength reaches 10 percent of its legal limit, the power flux density of the same measurement will only reach 1 percent of the legal limit. This difference is caused by the equation used for their conversion and has no biological relevance.

Exposure levels from mobile communications

The tables on pages 11 to 18 describe the 16 LTE locations and their 91 measuring points (five to seven per location) in detail. All measurements are given both in electric field strength as well as in power flux density, together with the percentage of the exposure limit these values represent. GSM and/or UMTS base stations were installed at all locations, so their field strength was also measured and listed in the tables.

The values given represent the maximum exposure level of each station when it is operating at its highest possible configuration and power. This maximum exposure level value will be reached if an installation is extended to the full configuration permitted on the site certificate issued by the Federal Network Agency, and if it processes the greatest possible phone and data traffic at maximum transmission power. The calculation of the percentage each measurement reaches regarding the exposure limits set out by the 26 BImSchV is also based on this maximum exposure level. In practice, exposure levels will be below the maximum value and will depend on the corresponding traffic and configuration of each station.

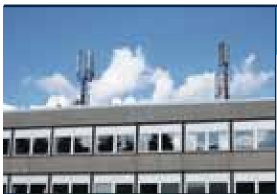
Total exposure levels from the 100 kHz - 3 GHz high-frequency range

At each LTE site, one outdoor measuring point was used to register exposure levels in the 100 kHz to 3 GHz frequency range in order to include exposure levels from other high-frequency sources such as radio, television and the emergency services' radio. These measurements recorded the total exposure levels from all the relevant high-frequency sources. The corresponding results and the percentage of the exposure limit are given in the table on page 19.

Location 01: local subdistrict Büschfeld, cadastral district 6, cadastral unit 120/2, 66687 Wadern, Saarland

LTE system 800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m^2	Percent of legal limit	in V/m	Percent of legal limit	in mW/m^2	Percent of legal limit	in V/m	Percent of legal limit	in mW/m^2	Percent of legal limit
MP 1.1 Indoor measurement in line of sight, Kita Pfiffikus Schulstraße 27/eG, distance: 610 m	0.83	2.15 %	1.83	0.046 %	1.15	2.29 %	3.50	0.052 %	1.42	3.14 %	5.33	0.099 %
MP 1.2 Outdoor measurement in line of sight, Kita Pfiffikus Schulstraße 27, distance: 660 m	0.50	1.30 %	0.67	0.017 %	0.60	1.13 %	0.94	0.013 %	0.78	1.72 %	1.61	0.030 %
MP 1.3 Outdoor measurement in line of sight, Am Scheifberg 48, distance: 225 m	0.64	1.66 %	1.10	0.028 %	0.53	1.17 %	0.75	0.014 %	0.83	2.03 %	1.84	0.041 %
MP 1.4 Outdoor measurement in line of sight, Am Rödchen 2, distance: 370 m	0.35	0.91 %	0.33	0.008 %	0.44	1.01 %	0.52	0.010 %	0.57	1.37 %	0.85	0.019 %
MP 1.5 Outdoor measurement in line of sight, Am Rödchen/Am Scheifberg, distance: 455 m	0.61	1.57 %	0.98	0.025 %	0.81	1.66 %	1.75	0.028 %	1.01	2.29 %	2.73	0.052 %
MP 1.6 Outdoor measurement in line of sight, Am Scheifberg 4, distance: 525 m	0.84	2.17 %	1.85	0.047 %	0.94	1.88 %	2.36	0.035 %	1.26	2.87 %	4.21	0.082 %



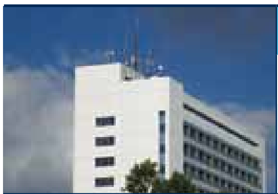
Location 02: Spelzenhofstraße 46, 67678 Mehlingen, Rhineland-Palatinate

LTE system 800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m^2	Percent of legal limit	in V/m	Percent of legal limit	in mW/m^2	Percent of legal limit	in V/m	Percent of legal limit	in mW/m^2	Percent of legal limit
MP 2.1 Outdoor measurement in line of sight, Spelzenhofstraße 41, distance: 110 m	4.16	10.77 %	45.82	1.159 %	3.11	7.40 %	25.65	0.547 %	5.19	13.06 %	71.47	1.706 %
MP 2.2 Outdoor measurement in line of sight, Spelzenhof-/Kirchenstraße, distance: 390 m	0.95	2.47 %	2.42	0.061 %	1.15	2.30 %	3.51	0.053 %	1.49	3.38 %	5.92	0.114 %
MP 2.3 Outdoor measurement in line of sight, Spelzenhofstraße 27, distance: 280 m	2.62	6.78 %	18.18	0.460 %	2.69	5.55 %	19.15	0.309 %	3.75	8.77 %	31.33	0.769 %
MP 2.4 Outdoor measurement in line of sight, Spelzenhof-/Lindenhofstraße, distance: 190 m	3.85	9.98 %	39.35	0.996 %	3.39	7.09 %	30.57	0.502 %	5.13	12.24 %	69.92	1.498 %
MP 2.5 Outdoor measurement in line of sight, Spelzenhofstraße 46, distance: 40 m	1.57	4.06 %	6.52	0.165 %	1.43	3.22 %	5.45	0.104 %	2.12	5.18 %	11.98	0.269 %

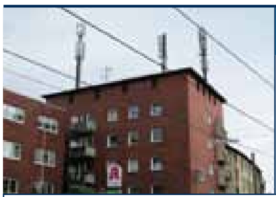
Location 03: Königstraße 27, 70173 Stuttgart, Baden-Württemberg
LTE-System 1,800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
MP 3.1 Indoor measurement in line of sight, Ministry of Science, Königstraße 46/9th fl., distance: 32 m	3.00	5.13 %	23.85	0.264 %	8.38	15.80 %	186.41	2.495 %	8.90	16.61 %	210.26	2.759 %
MP 3.2 Indoor measurement in line of sight, Ministry of Science, Königstraße 46/7th fl., distance: 34 m	1.98	3.39 %	10.38	0.115 %	5.42	9.59 %	78.06	0.921 %	5.77	10.18 %	88.44	1.035 %
MP 3.3 Indoor measurement in line of sight, Ministry of Science, Königstraße 46/5th fl., distance: 36 m, height: 5th fl., location: indoor	0.95	1.63 %	2.41	0.027 %	1.62	2.86 %	6.95	0.082 %	1.88	3.30 %	9.35	0.109 %
MP 3.4 Indoor measurement in line of sight, Ministry of Science, Königstraße 46/2nd fl., distance: 38 m	1.07	1.83 %	3.04	0.034 %	1.32	2.62 %	4.63	0.069 %	1.70	3.20 %	7.67	0.102 %
MP 3.5 Outdoor measurement in line of sight, Ministry of Science, Königstraße 46, distance: 40 m	0.88	1.51 %	2.05	0.023 %	1.51	3.28 %	6.07	0.108 %	1.75	3.61 %	8.12	0.130 %
MP 3.6 MP 3.6 Outdoor measurement not in line of sight, Karstadt Königstraße 27–29, distance: 34 m	0.28	0.49 %	0.21	0.002 %	0.68	1.31 %	1.24	0.017 %	0.74	1.40 %	1.45	0.020 %



Location 04: Leimenstraße 20, 63450 Hanau, Hesse
LTE system 800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
MP 4.1 Indoor measurement not in line of sight, Klinikum Hanau Leimenstraße 20/11th fl., distance: 10 m	0.01	0.04 %	0.00	0.000 %	0.03	0.06 %	0.00	0.000 %	0.03	0.07 %	0.00	0.000 %
MP 4.2 Indoor measurement not in line of sight, Klinikum Hanau Leimenstraße 20/9th fl., distance: 17 m	0.01	0.02 %	0.00	0.000 %	0.01	0.03 %	0.00	0.000 %	0.01	0.03 %	0.00	0.000 %
MP 4.3 Indoor measurement not in line of sight, Klinikum Hanau Leimenstraße 20/7th fl., distance: 24 m	0.01	0.01 %	0.00	0.000 %	0.01	0.03 %	0.00	0.000 %	0.01	0.03 %	0.00	0.000 %
MP 4.4 Indoor measurement not in line of sight, Klinikum Hanau Leimenstraße 20/5th fl., distance: 31 m height: 5th fl., location: indoor	0.00	0.01 %	0.00	0.000 %	0.01	0.02 %	0.00	0.000 %	0.01	0.02 %	0.00	0.000 %
MP 4.5 Indoor measurement not in line of sight, Klinikum Hanau Leimenstraße 20/3rd fl., distance: 38 m	0.00	0.01 %	0.00	0.000 %	0.01	0.02 %	0.00	0.000 %	0.01	0.02 %	0.00	0.000 %
MP 4.6 Indoor measurement not in line of sight, Klinikum Hanau Leimenstraße 20/2nd fl., distance: 42 m	0.00	0.01 %	0.00	0.000 %	0.01	0.01 %	0.00	0.000 %	0.01	0.01 %	0.00	0.000 %
MP 4.7 Outdoor measurement in line of sight, Leimenstraße 2, distance: 199 m	0.53	1.38 %	0.76	0.019 %	0.79	1.90 %	1.66	0.036 %	0.95	2.35 %	2.42	0.055 %



	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 05: Körner Hellweg 76, 44143 Dortmund, North-Rhine/Westphalia LTE-System 1,800 MHz												
MP 5.1 IIndoor measurement not in line of sight, Uhlandschule Heilbronner Straße 4/g. fl., distance: 165 m	0.52	0.89 %	0.71	0.008 %	2.26	4.76 %	13.50	0.226 %	2.31	4.84 %	14.21	0.234 %
MP 5.2 Indoor measurement not in line of sight, Uhlandschule Heilbronner Straße 4/1st fl., distance: 165 m	0.56	0.96 %	0.84	0.009 %	2.13	4.27 %	12.00	0.182 %	2.20	4.38 %	12.84	0.192 %
MP 5.3 Outdoor measurement facing installation, school yard Uhlandschule Heilbronner Straße 4, distance: 155 m	0.30	0.52 %	0.24	0.003 %	2.83	5.79 %	21.28	0.335 %	2.85	5.81 %	21.52	0.338 %
MP 5.4 Indoor measurement below the installation, not in line of sight, Körner Hellweg 76/5th fl., distance: 7 m	0.50	0.85 %	0.66	0.007 %	2.40	4.51 %	15.30	0.203 %	2.45	4.59 %	15.96	0.211 %
MP 5.5 Indoor measurement not in line of sight, Körner Hellweg 76/3rd fl., distance: 13 m	0.05	0.09 %	0.01	0.000 %	0.35	0.70 %	0.32	0.005 %	0.35	0.71 %	0.33	0.005 %
MP 5.6 Indoor measurement not in line of sight, Körner Hellweg 76/1st fl., distance: 19 m	0.02	0.03 %	0.00	0.000 %	0.10	0.23 %	0.03	0.001 %	0.10	0.23 %	0.03	0.001 %

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 06: Hardenbergstraße 16, 28201 Bremen, Land Bremen LTE-System 1,800 MHz												
MP 6.1 Outdoor measurement in line of sight, Kornstraße/ Nettelbeckstraße, distance: 180 m	0.19	0.33 %	0.10	0.001 %	2.87	6.43 %	21.81	0.413 %	2.87	6.44 %	21.91	0.414 %
MP 6.2 Outdoor measurement in line of sight, playground Kita Hardenbergstraße 18, distance: 46 m	0.07	0.13 %	0.01	0.000 %	0.28	0.63 %	0.21	0.004 %	0.29	0.64 %	0.22	0.004 %
MP 6.3 Indoor measurement in line of sight, Buntentorsteinweg 120/4th fl., distance: 166 m	2.15	3.69 %	12.29	0.136 %	3.33	6.81 %	29.40	0.464 %	3.96	7.75 %	41.69	0.600 %
MP 6.4 Indoor measurement in line of sight, Möckernstraße 39/2nd fl., distance: 112 m	0.32	0.54 %	0.27	0.003 %	3.29	7.75 %	28.69	0.601 %	3.30	7.77 %	28.95	0.604 %
MP 6.5 Indoor measurement in line of sight, Kita Hardenbergstraße 18/1st fl., distance: 60 m	0.23	0.39 %	0.14	0.001 %	1.39	2.69 %	5.12	0.072 %	1.41	2.72 %	5.25	0.074 %

Location 07: Monetastraße 3, 20146 Hamburg, Land Hamburg

LTE-System 1,800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
MP 7.1 Indoor measurement not in line of sight, DRK retirement home Monetastraße 3/8th fl., distance: 5 m	0.10	0.17 %	0.03	0.000 %	0.07	0.12 %	0.01	0.000 %	0.12	0.21 %	0.04	0.000 %
MP 7.2 Indoor measurement not in line of sight, DRK retirement home Monetastraße 3/6th fl., distance: 12 m	0.03	0.05 %	0.00	0.000 %	0.04	0.06 %	0.00	0.000 %	0.05	0.08 %	0.01	0.000 %
MP 7.3 Indoor measurement not in line of sight, DRK retirement home Monetastraße 3/4th fl., distance: 19 m	0.03	0.05 %	0.00	0.000 %	0.04	0.07 %	0.00	0.000 %	0.05	0.08 %	0.01	0.000 %
MP 7.4 Indoor measurement not in line of sight, DRK retirement home Monetastraße 3/2nd fl., distance: 26 m	0.01	0.02 %	0.00	0.000 %	0.02	0.02 %	0.00	0.000 %	0.02	0.04 %	0.00	0.000 %
MP 7.5 Indoor measurement in line of sight, Kita Monetastraße 2/2nd fl., distance: 59 m	0.53	0.91 %	0.76	0.008 %	0.34	0.56 %	0.31	0.003 %	0.63	1.07 %	1.06	0.011 %
MP 7.6 Outdoor measurement in line of sight, Born-/Rappstraße, distance: 270 m	0.66	1.13 %	1.15	0.013 %	0.92	1.51 %	2.24	0.023 %	1.13	1.88 %	3.39	0.035 %

Location 08: Knickweg 5, 23569 Lübeck, Schleswig-Holstein

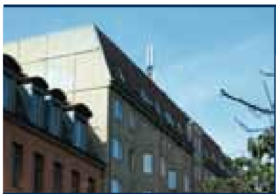
LTE-System 1,800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
MP 8.1 Indoor measurement not in line of sight, Kita Kunterbunt Haferkoppel 11/1st fl., distance: 305 m	0.12	0.20 %	0.04	0.000 %	0.11	0.22 %	0.03	0.000 %	0.16	0.30 %	0.07	0.001 %
MP 8.2 Outdoor measurement in line of sight, Knickweg 5, distance: 22 m	1.13	1.94 %	3.41	0.038 %	1.38	2.54 %	5.07	0.065 %	1.79	3.20 %	8.48	0.102 %
MP 8.3 Outdoor measurement in line of sight, Knickweg 3, distance: 48 m	0.48	0.83 %	0.62	0.007 %	0.81	1.58 %	1.74	0.025 %	0.94	1.78 %	2.36	0.032 %
MP 8.4 Outdoor measurement in line of sight, Dummersdorfer Straße 9, distance: 74 m	0.62	1.06 %	1.02	0.011 %	1.48	3.47 %	5.84	0.121 %	1.61	3.63 %	6.86	0.132 %
MP 8.5 Outdoor measurement in line of sight, Vorderste Fichteln 2, distance: 120 m	0.87	1.50 %	2.02	0.022 %	1.52	3.48 %	6.16	0.121 %	1.76	3.79 %	8.19	0.143 %

Location 09: August-Bebel-Straße 13, 18273 Güstrow, Mecklenburg-Western Pomerania

LTE system 800 MHz

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
MP 9.1 Indoor measurement in line of sight, Anne Frank school August-Bebel-Straße 30/g. fl., distance: 238 m	0.48	1.23 %	0.60	0.015 %	0.89	1.92 %	2.09	0.037 %	1.01	2.28 %	2.68	0.052 %
MP 9.2 Indoor measurement not in line of sight, Anne Frank school August-Bebel-Straße 30/g. fl., distance: 256 m	0.15	0.39 %	0.06	0.002 %	0.19	0.43 %	0.09	0.002 %	0.24	0.58 %	0.15	0.003 %
MP 9.3 Indoor measurement not in line of sight, Anne Frank school August-Bebel-Straße 30/g. fl., distance: 305 m	0.03	0.08 %	0.00	0.000 %	0.06	0.15 %	0.01	0.000 %	0.07	0.17 %	0.01	0.000 %
MP 9.4 Outdoor measurement in line of sight, Anne Frank school August-Bebel-Straße 30, distance: 265 m	0.32	0.82 %	0.27	0.007 %	0.61	1.32 %	1.00	0.017 %	0.69	1.55 %	1.27	0.024 %
MP 9.5 Outdoor measurement in line of sight, Anne Frank school August-Bebel-Straße 30, distance: 213 m	0.54	1.40 %	0.77	0.020 %	0.77	1.67 %	1.57	0.028 %	0.94	2.18 %	2.34	0.048 %

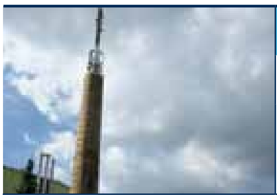


Location 10: Rosenthaler Straße 19, 10119 Berlin, Land Berlin

LTE-System 1,800 MHz

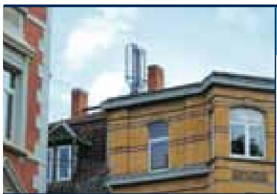
	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
MP 10.1 Outdoor measurement not in line of sight, Rosenthaler Straße 19, distance: 29 m	0.82	1.40 %	1.77	0.020 %	0.81	1.75 %	1.73	0.030 %	1.15	2.24 %	3.50	0.050 %
MP 10.2 Outdoor measurement in line of sight, Weinmeister-/Gormannstraße, distance: 86 m	0.37	0.63 %	0.36	0.004 %	0.70	1.60 %	1.31	0.026 %	0.79	1.72 %	1.67	0.030 %
MP 10.3 Outdoor measurement in line of sight, Weinmeisterstraße 2, distance: 141 m	0.64	1.10 %	1.10	0.012 %	2.60	6.16 %	17.91	0.380 %	2.68	6.26 %	19.01	0.392 %
MP 10.4 Outdoor measurement in line of sight, Weinmeisterstraße 4, distance: 175 m	1.00	1.71 %	2.66	0.029 %	2.33	5.39 %	14.38	0.290 %	2.53	5.65 %	17.04	0.319 %
MP 10.5 Outdoor measurement in line of sight, Weinmeisterstraße 8, distance: 243 m	0.89	1.53 %	2.12	0.023 %	1.89	4.21 %	9.51	0.177 %	2.09	4.48 %	11.62	0.201 %
MP 10.6 Outdoor measurement in line of sight, Weinmeisterstraße/Neue Schönhauser Straße, distance: 269 m	0.71	1.22 %	1.34	0.015 %	0.89	1.86 %	2.12	0.035 %	1.14	2.23 %	3.46	0.050 %

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 11: local subdistrict Gröden, cadastral district 17, cadastral unit 15/0, 04932 Gröden, Brandenburg LTE system 800 MHz												
MP 11.1 Outdoor measurement in line of sight, Großenhainer Straße next to No. 17, distance: 272 m	0.85	2.21 %	1.93	0.049 %	0.08	0.19 %	0.02	0.000 %	0.86	2.22 %	1.95	0.049 %
MP 11.2 Outdoor measurement not in line of sight, Großenhainer Straße in front of No. 17, distance: 272 m	0.44	1.15 %	0.52	0.013 %	0.02	0.05 %	0.00	0.000 %	0.44	1.15 %	0.52	0.013 %
MP 11.3 Outdoor measurement in line of sight, elementary school Gröden Gartenstraße, distance: 610 m	0.59	1.52 %	0.92	0.023 %	0.26	0.63 %	0.18	0.004 %	0.64	1.65 %	1.10	0.027 %
MP 11.4 Outdoor measurement in line of sight, Großenhainer Straße/Alter Schachtweg, distance: 190 m	0.77	1.99 %	1.57	0.040 %	0.17	0.41 %	0.08	0.002 %	0.79	2.03 %	1.64	0.041 %
MP 11.5 Outdoor measurement in line of sight, Landhaus Gröden, Alter Schachtweg, distance: 45 m	0.28	0.72 %	0.20	0.005 %	0.64	1.53 %	1.08	0.023 %	0.70	1.69 %	1.28	0.029 %



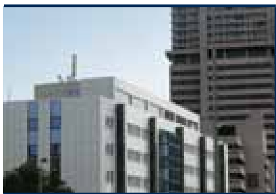
	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 12: Döberkitzer Straße 8, 02633 Göda, Saxony LTE system 800 MHz												
MP 12.1 Indoor measurement in line of sight, elementary school Döberkitzer Straße 8/2nd fl., distance: 25 m	0.95	2.46 %	2.39	0.060 %	1.39	3.34 %	5.16	0.112 %	1.69	4.15 %	7.55	0.172 %
MP 12.2 Indoor measurement in line of sight, elementary school Döberkitzer Straße 8/1st fl., distance: 27 m	1.21	3.14 %	3.89	0.098 %	1.77	4.24 %	8.31	0.180 %	2.14	5.28 %	12.20	0.279 %
MP 12.3 Indoor measurement in line of sight, Döberkitzer Straße 8/g. fl., distance: 29 m	1.60	4.14 %	6.77	0.171 %	1.85	4.43 %	9.03	0.196 %	2.44	6.06 %	15.81	0.367 %
MP 12.4 Outdoor measurement not in line of sight, school playground Döberkitzer Straße 8, distance: 70 m	0.09	0.22 %	0.02	0.001 %	0.13	0.31 %	0.04	0.001 %	0.16	0.38 %	0.06	0.001 %
MP 12.5 Outdoor measurement in line of sight, elementary school Döberkitzer Straße 8, distance: 19 m	0.46	1.19 %	0.56	0.014 %	0.56	1.33 %	0.82	0.018 %	0.72	1.79 %	1.38	0.032 %
MP 12.6 Outdoor measurement in line of sight, Döberkitzer Straße, distance: 167 m	0.57	1.47 %	0.86	0.022 %	1.86	4.46 %	9.17	0.199 %	1.94	4.70 %	10.03	0.220 %

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 13: local subdistrict Weißenstadt, cadastral unit 1621/3, 95163 Weißenstadt, Bavaria LTE system 800 MHz												
MP 13.1 Indoor measurement not in line of sight, Grund- und Teil-hauptschule Schulstraße 33/g. fl., distance: 250 m	0.21	0.55 %	0.12	0.003 %	0.55	1.29 %	0.80	0.017 %	0.59	1.40 %	0.92	0.020 %
MP 13.2 Indoor measurement not in line of sight, Grund- und Teil-hauptschule Schulstraße 33/1st fl., distance: 260 m	0.08	0.22 %	0.02	0.000 %	0.16	0.38 %	0.07	0.001 %	0.18	0.44 %	0.09	0.002 %
MP 13.3 Outdoor measurement not in line of sight, Grund- und Teil-hauptschule Schulstraße 33, distance: 263 m	0.26	0.68 %	0.18	0.005 %	0.76	1.72 %	1.52	0.030 %	0.80	1.85 %	1.70	0.034 %
MP 13.4 Indoor measurement in line of sight, kindergarten Löhestraße 5/g. fl., distance: 162 m	0.41	1.06 %	0.45	0.011 %	0.81	1.88 %	1.76	0.035 %	0.91	2.16 %	2.20	0.047 %
MP 13.5 Outdoor measurement in line of sight, kindergarten Löhestraße 5, distance: 208 m	0.19	0.48 %	0.09	0.002 %	0.35	0.78 %	0.32	0.006 %	0.40	0.92 %	0.42	0.008 %



	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 14: Lutherstraße 46, 07743 Jena, Thuringia LTE-System 1,800 MHz												
MP 14.1 Indoor measurement not in line of sight, retirement home Luisenhaus Semmelweisstraße 14 - 16/3rd fl., distance: 225 m	0.04	0.07 %	0.00	0.000 %	0.04	0.06 %	0.00	0.000 %	0.05	0.09 %	0.01	0.000 %
MP 14.2 Indoor measurement in line of sight, Lutherstraße 61/4th fl., distance: 24 m	7.90	13.53 %	165.63	1.831 %	10.44	17.11 %	289.11	2.929 %	13.09	21.82 %	454.74	4.760 %
MP 14.3 Indoor measurement not in line of sight, Westschule August-Bebel-Straße 23/2nd fl. class room, distance: 280 m	0.05	0.09 %	0.01	0.000 %	0.05	0.09 %	0.01	0.000 %	0.08	0.13 %	0.01	0.000 %
MP 14.4 Indoor measurement not in line of sight, university hospital, building 3281, distance: 235 m	0.22	0.37 %	0.12	0.001 %	0.10	0.16 %	0.03	0.000 %	0.24	0.40 %	0.15	0.002 %
MP 14.5 Outdoor measurement not in line of sight, Forstweg, distance: 295 m	0.29	0.49 %	0.22	0.002 %	0.13	0.22 %	0.05	0.000 %	0.32	0.54 %	0.27	0.003 %

	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 15: Neue Straße 10, 39326 Hermsdorf, Saxony-Anhalt LTE system 800 MHz												
MP 15.1 Indoor measurement in line of sight, kindergarten Kirchstraße 3a/1st fl., distance: 114 m	1.07	2.78 %	3.06	0.078 %	0.98	2.30 %	2.57	0.053 %	1.46	3.61 %	5.63	0.130 %
MP 15.2 Outdoor measurement in line of sight, kindergarten Kirchstraße 3a, distance: 85 m	0.38	0.98 %	0.38	0.010 %	0.54	1.15 %	0.77	0.013 %	0.66	1.51 %	1.15	0.023 %
MP 15.3 Outdoor measurement in line of sight, kindergarten Kirchstraße 3a, distance: 113 m	0.68	1.75 %	1.21	0.031 %	1.09	2.59 %	3.17	0.067 %	1.28	3.13 %	4.38	0.098 %
MP 15.4 Outdoor measurement in line of sight, Kirchstraße 4, distance: 194 m	0.33	0.85 %	0.29	0.007 %	0.41	0.78 %	0.44	0.006 %	0.52	1.15 %	0.73	0.013 %
MP 15.5 Outdoor measurement in line of sight, kindergarten back door, distance: 150 m	1.44	3.72 %	5.48	0.139 %	0.85	2.00 %	1.90	0.040 %	1.67	4.23 %	7.38	0.179 %
MP 15.6 Outdoor measurement in line of sight, Neue Straße 10, distance: 28 m	0.47	1.23 %	0.60	0.015 %	0.49	0.88 %	0.63	0.008 %	0.68	1.51 %	1.23	0.023 %



	LTE exposure levels				GSM and UMTS exposure levels at site				Total exposure levels from mobile networks at site			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Location 16: Hamburger Allee 12 - 16, 30161 Hannover, Lower Saxony LTE system 800 MHz												
MP 16.1 Outdoor measurement in line of sight, Hamburger Allee 25, distance: 165 m	0.54	1.40 %	0.77	0.020 %	1.50	3.36 %	5.98	0.113 %	1.60	3.64 %	6.75	0.132 %
MP 16.2 IIndoor measurement not in line of sight, Hamburger Allee 12-16, below installation, 5th fl., distance: 8 m	0.09	0.23 %	0.02	0.001 %	0.15	0.34 %	0.06	0.001 %	0.17	0.41 %	0.08	0.002 %
MP 16.3 Indoor measurement not in line of sight, Hamburger Allee 12-16/ 4th fl., distance: 12 m	0.05	0.14 %	0.01	0.000 %	0.14	0.31 %	0.05	0.001 %	0.15	0.34 %	0.06	0.001 %
MP 16.4 Indoor measurement not in line of sight, Hamburger Allee 12-16/ 3rd fl., distance: 16 m	0.05	0.13 %	0.01	0.000 %	0.10	0.22 %	0.03	0.000 %	0.11	0.26 %	0.03	0.001 %
MP 16.5 Indoor measurement not in line of sight, Hamburger Allee 12-16/ 2nd fl., distance: 20 m	0.05	0.13 %	0.01	0.000 %	0.16	0.37 %	0.07	0.001 %	0.17	0.39 %	0.08	0.002 %
MP 16.6 Indoor measurement not in line of sight, Hamburger Allee 12-16/ 1st fl., distance: 24 m	0.05	0.12 %	0.01	0.000 %	0.08	0.18 %	0.02	0.000 %	0.09	0.21 %	0.02	0.000 %
MP 16.7 Indoor measurement not in line of sight, Hamburger Allee 12-16/ g. fl., distance: 28 m	0.02	0.06 %	0.00	0.000 %	0.04	0.10 %	0.00	0.000 %	0.05	0.12 %	0.01	0.000 %

Measurements of total HF exposure levels (100 kHz – 3 GHz)

Measuring points (MP)	Mobile networks at site (GSM, UMTS, LTE)				sources nearby				HF in total (site and sources nearby)			
	Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)		Electric field strength (E)		Power flux density (S)	
	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit	in V/m	Percent of legal limit	in mW/m²	Percent of legal limit
Wadern OT Büschfeld 1.5	1.01	2.29 %	2.73	0.052 %	0.24	0.46 %	0.15	0.002 %	1.04	2.33 %	2.88	0.054 %
Mehlingen 2.5	2.12	5.18 %	11.98	0.269 %	0.18	0.36 %	0.08	0.001 %	2.13	5.20 %	12.06	0.270 %
Stuttgart 3.6	0.74	1.40 %	1.45	0.020 %	1.64	3.31 %	7.13	0.109 %	1.80	3.59 %	8.58	0.129 %
Hanau 4.7	0.95	2.35 %	2.42	0.055 %	0.33	0.73 %	0.30	0.005 %	1.01	2.46 %	2.71	0.061 %
Dortmund 5.3	2.85	5.81 %	21.52	0.338 %	0.14	0.35 %	0.05	0.001 %	2.85	5.82 %	21.57	0.339 %
Bremen 6.2	0.29	0.64 %	0.22	0.004 %	0.12	0.43 %	0.04	0.002 %	0.31	0.77 %	0.26	0.006 %
Hamburg 7.6	1.13	1.88 %	3.39	0.035 %	0.19	0.51 %	0.10	0.003 %	1.15	1.95 %	3.49	0.038 %
Lübeck 8.2	1.79	3.20 %	8.48	0.102 %	0.11	0.19 %	0.03	0.000 %	1.79	3.20 %	8.51	0.103 %
Güstrow 9.5	0.94	2.18 %	2.34	0.048 %	0.11	0.21 %	0.03	0.000 %	0.95	2.19 %	2.37	0.048 %
Berlin 10.5	2.09	4.48 %	11.62	0.201 %	0.71	2.31 %	1.32	0.053 %	2.21	5.04 %	12.95	0.254 %
Gröden 11.5	0.70	1.69 %	1.28	0.029 %	0.04	0.07 %	0.00	0.000 %	0.70	1.69 %	1.29	0.029 %
Göda 12.6	1.94	4.70 %	10.03	0.220 %	0.04	0.08 %	0.01	0.000 %	1.94	4.70 %	10.03	0.221 %
Weißenstadt 13.3	0.80	1.85 %	1.70	0.034 %	0.12	0.40 %	0.04	0.002 %	0.81	1.89 %	1.74	0.036 %
Jena 14.5	0.32	0.54 %	0.27	0.003 %	0.44	0.99 %	0.51	0.010 %	0.54	1.12 %	0.77	0.013 %
Hermsdorf 15.4	0.52	1.15 %	0.73	0.013 %	0.24	0.49 %	0.16	0.002 %	0.58	1.25 %	0.89	0.016 %
Hannover 16.1	1.60	3.64 %	6.75	0.132 %	0.59	1.07 %	0.92	0.011 %	1.70	3.79 %	7.67	0.144 %

Mobile networks make up only a small proportion of all high-frequency fields that surround us. Radio transmitters and emergency services' radio also contribute to the total exposure level. At one outdoor point of each location, the IMST measured how much other high-frequency sources in the 100 kHz to 3 GHz range contribute to the total exposure level. These exposure levels were then compared with all mobile network exposure levels at the site. The results show that values at all measuring points remain far below the legal limits even when all high-frequency sources are taken into account.

EVALUATION

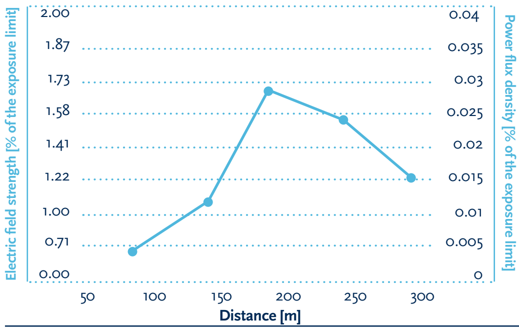
Radio wave propagation characteristics in the immediate surroundings

Shorter distances do not necessarily mean higher exposure levels

The distance from a mobile phone base station is not a reliable criterion for predicting its exposure levels. Even in close proximity, exposure levels can be very low. Field strength is often lower in the immediate vicinity of the base station than further away. This is because the emission patterns of the antenna and the topographic characteristics of the surroundings all play their part in influencing field strength.

At the Rosenthaler Straße 19 site in Berlin, a linear measurement to an LTE base station installed at a height of about 30 metres showed the relation between the exposure level at each measuring point and the corresponding distance to the antenna. Figure 1 shows the results of five measurements at ground level at a distance of 86 to 269 metres in direct line of sight to the installation. The IMST found that the electric field strength at the measuring point that was closest to the antenna reached the lowest percentage of the relevant exposure limit. At 0.63 percent it was the lowest value of any of the linear measurements.

Figure 1: Radio wave propagation characteristics in the immediate surroundings



Example: Berlin, Rosenthaler Straße 19 (measuring point 10, p. 15). The graph shows the results of linear measurements at a distance of 86 to 269 metres.

By comparison, the measurement at a distance of 175 metres showed a considerably higher value, at 1.71 percent. These results demonstrate that the distance to the LTE installation - as well as to installations for other mobile networks - is no meaningful criterion for predicting exposure levels. Figure 1 shows that the values measured in the immediate surroundings of the antenna are considerably lower in direct sight of the antenna than those that were measured at greater distances.

How do we explain these findings that seem to contradict the laws of physics? Theoretically, field strength should decrease as the distance increases. In practice, however, the field strength measured at any measuring point is influenced by various technical, topographical and architectural factors. One reason is that base station antennas do not transmit at the same power in all directions. There is one primary transmission direction and there are several secondary transmission directions. As a result, the expected decrease in field strength in relation to the increasing distance will only occur where the main beam reaches the ground. Depending on the height of the antenna, this point can be up to several hundred metres away from the antenna.

Emission patterns and height of the installation

Height and directionality of the installation are key factors

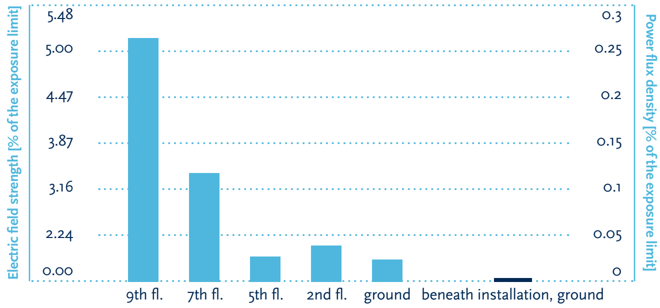
Exposure levels within the immediate surroundings of an antenna do not primarily depend on the distance from the transmitter but rather on the installation's emission patterns and height. Positions which are the same distance from a mobile network installation but at different heights can measure strongly varying exposure levels.

The reason for this lies in the emission patterns of base station antennas, which are always slightly tilted downwards (downtilt). If you observe the radiation from the side, it takes the same form as a light beam from a lighthouse. As well as the primary transmission direction, secondary beams occur for a variety of technical reasons. However, the secondary beams transport much less energy than the main beam. Thus, the exposure level at each measuring point mainly depends on whether or not this point lies along the primary transmission direction.

The example of the site at Stuttgart, Königstraße 27, (cf. figure 2) clearly demonstrates how the relative location of the measuring points to an LTE installation influences the measured exposure levels. Measurements were taken on different floors of a building at about 30 metres in direct sight of the installation as well as at two outdoor points at ground level.

The result: the highest value was measured on the 9th floor, where exposure levels reached 5.13 percent of the field-strength exposure limit. This measuring point was at about the same height as the mobile network installation and thus in the vertical direction of the main beam. Only two floors down, the value had already decreased to 3.39 percent. This measuring point on the seventh floor, as well as all the points on the lower floors, evidently falls below the direction of the main beam. The lowest exposure levels, at 0.49 percent of the field-strength exposure limit, were measured on the ground directly below the base station. This site clearly demonstrates the principle that values remain considerably below the existing legal limits, even in the immediate vicinity of an LTE base station and in the primary transmission beam of the antenna.

Figure 2: Emission patterns and height of the installation



Example Stuttgart, Königstraße 27 (measuring point 3, p. 12): Exposure registered at different floors of a neighbouring building and at two outdoor locations at ground level.

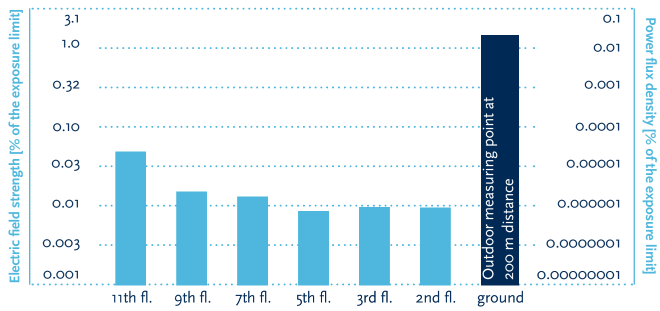
Attenuation of mobile-telecommunication fields

Building materials and topography weaken the energy of electromagnetic fields

Electromagnetic fields produced by mobile networks are generally weaker indoors than they are outdoors, in cases where the distance to the installation and the transmission direction are the same. The reason for this is that building materials attenuate electromagnetic fields. However, attenuating effects can also occur outdoors because of the surrounding buildings or trees. The extent of these attenuating effects depends on the frequency of the mobile network. As a rule, the higher the frequency, the more the attenuating effect.

Measurements at the Klinikum Hanau hospital show how the attenuating effect of LTE fields occurs inside buildings (cf. figure 3). A base station for the LTE network in the 800 MHz frequency range is installed on the roof of the building. Measurements were taken at different floors of a stairwell inside the building on which the base station was installed as well as at an outdoor measuring point about 200 metres from the antenna. Inside the building, the field strength from this installation sharply decreases with each floor. While the field strength on the 11th floor reaches 0.04 percent of the exposure limit, it has fallen to 0.01 percent of the limit by the second floor. At an outdoor measuring point, located 200 metres away and directly in the primary transmission direction of the installation, the field strength reached 1.38 percent of the limit. Thus, even the highest values remain considerably below the exposure limits.

Figure 3: Attenuation of mobile-telecommunication fields



Example from Hanau: Klinikum Hanau hospital, Leimenstraße 20 (measuring point 4, p. 12). The graph shows the reduction in exposure within the building and the exposure levels at one outdoor measuring point.

Field distribution and total exposure levels from mobile networks

How LTE, UMTS and GSM fields compare

The radio wave propagation from LTE, UMTS and GSM antennas is similar because of the proximity of their frequencies. At individual locations, one or another of these technologies will contribute more to the total exposure levels, depending on the site's configuration.

In order to allow a direct comparison of the exposure levels from all the mobile networks, the IMST also measured the field strength from GSM and/or UMTS installations operating at each of the LTE sites, and extrapolated the power of each installation to maximum output power.

The evaluation process compared the exposure levels from the previously existing mobile networks with those from the newly established LTE network. Figure 4 shows the distribution of exposure from individual mobile networks as well as the total exposure from all mobile communications. The results demonstrate that the set up at each site influences which mobile network exposure levels are the strongest. Key factors are the number of mobile network systems, their frequencies, the transmission power and the primary transmission directions of the systems. The statistical analysis of all 91 measuring points in figure 4 shows that total exposure levels increased by an average of about 40 percent when LTE started operating normally. However, this increased percentage starts at a very low level. Even when extrapolated to the theoretically possible maximum power of the installation, values for the majority of measuring points still only reached a few percent of the legal limit for field strength (and a few hundredths of a percent in respect of the power flux density limit).

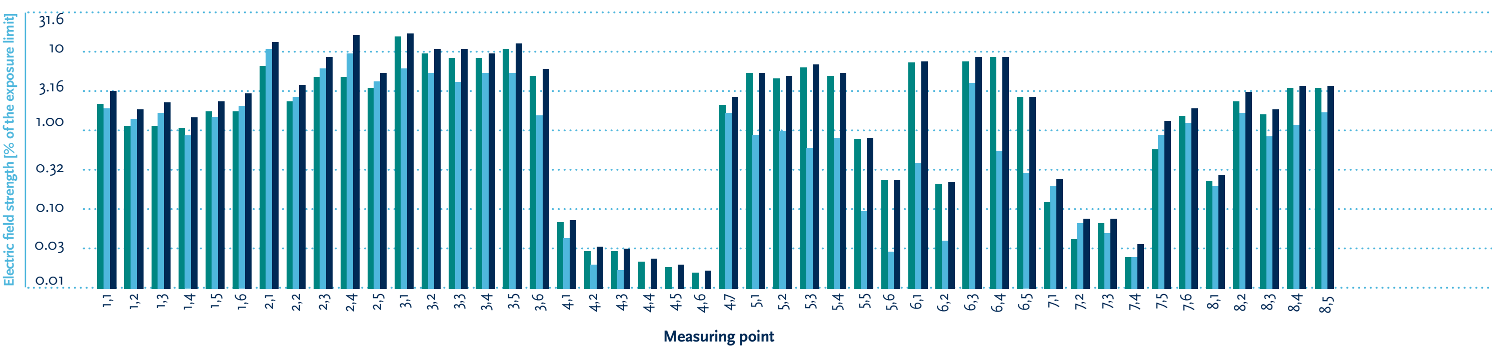
Calculating total exposure levels from individual LTE and GSM/UMTS values

Total exposure levels at each measuring point are usually measured in power flux density (S) or electric field strength (E). In both cases, all the measured exposure levels at the point are then added together. Because of the quadratic relationship between power flux density and electric field strength, different methods are used to calculate the sum. To illustrate the procedure, measuring point 1.2 (Wadern, p. 11) will be used to demonstrate the calculations:

Power flux density: If the evaluation of the total exposure levels is based on the power flux density, the values of the individual mobile networks are added up by linear addition. In this example, the linear sum of 0.67 mW/m² (LTE) and 0.94 mW/m² (GSM/UMTS) is a total of 1.61 mW/m² or, for the percentage of the limit, the sum of 0.017 % (LTE) and 0.013 % (GSM/UMTS) is a total of 0.030 %.

Field strength: If the evaluation of the total exposure levels is based on the electric field strength, the values of the individual mobile networks must be squared before the addition and the square root calculated from the result (geometric addition). In this example, the squares of 0.50 V/m (LTE) and 0.60 V/m (GSM/UMTS) add up to 0.61 V²/m²; the square root of which is 0.78 V/m. For the percentage of the limit, the squares of 1.30 % (LTE) and 1.13 % (GSM/UMTS) add up to 2.9669 %²; the square root of which is 1.72 %.

Figure 4: Field distribution and total exposure levels from mobile networks



Relative field distribution and total exposure levels at 91 measuring points at sites where GSM and/or UMTS and LTE are operating

24-hour long-term measurement

Exposure levels sink to a minimum during the night

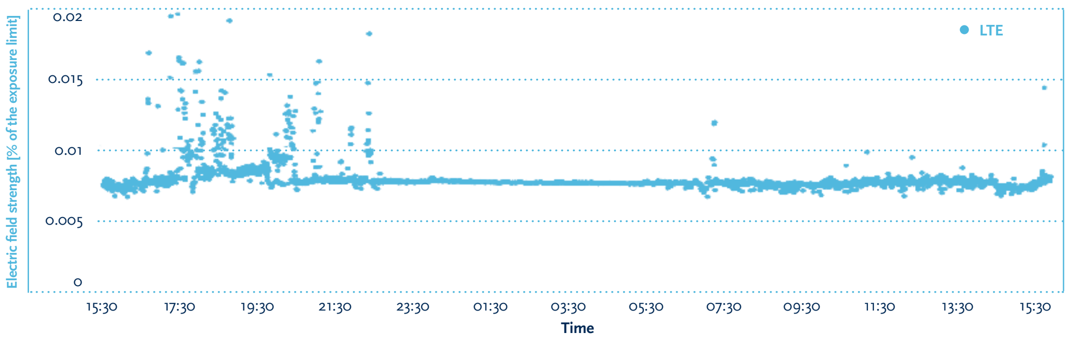
A 24-hour long-term measurement on the second floor of the IMST building in Kamp-Lintfort illustrates how the volume of traffic influences LTE exposure levels (cf. figure 5). For the test, exposure levels from an LTE network installation 380 metres away were measured. The measurement took place from Monday 15 October 2012 to Tuesday 16 October 2012 with direct line of sight to the installation.

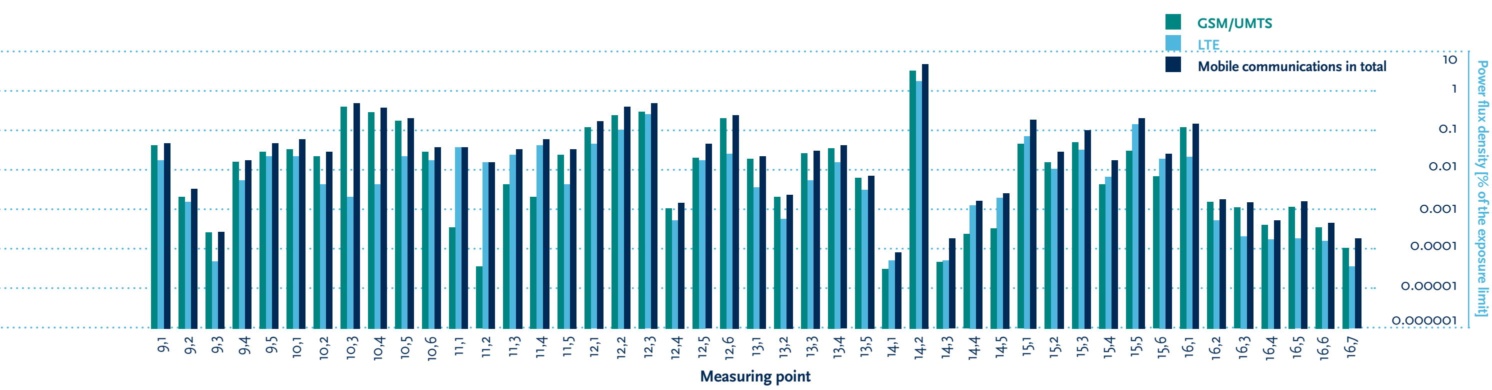
So as to display the fluctuations caused by the volume of traffic, the results of this measurement were not extrapolated to the installation's full output power. Thus, the results reflect the real pattern of use that occurred during the test period. They demonstrate the extent to which exposure levels fluctuate over the course of a day.

The highest user activity during the day occurred between 4:30 pm and 10:30 pm. Almost no volume of traffic is present during the night, picking up again in the early morning. This is clearly visible in the graph from the straight exposure line, which expresses the status of the mobile network installation when only the signal channels are active. User activity rises after 6:30 am, shown when the exposure curve starts changing.

Even at times of the highest user activity, however, the electric field strength only reaches approximately 0.05 percent of the legal exposure limit. During the night, between 10:30 pm and 6:30 am, exposure levels levels drop to a minimum of 0.007 V/m, starting to rise as the work day commences.

Figure 5: 24-hour long-term measurements at an LTE base station in Kamp-Lintfort





Factors influencing electromagnetic fields and total exposure levels at LTE base stations

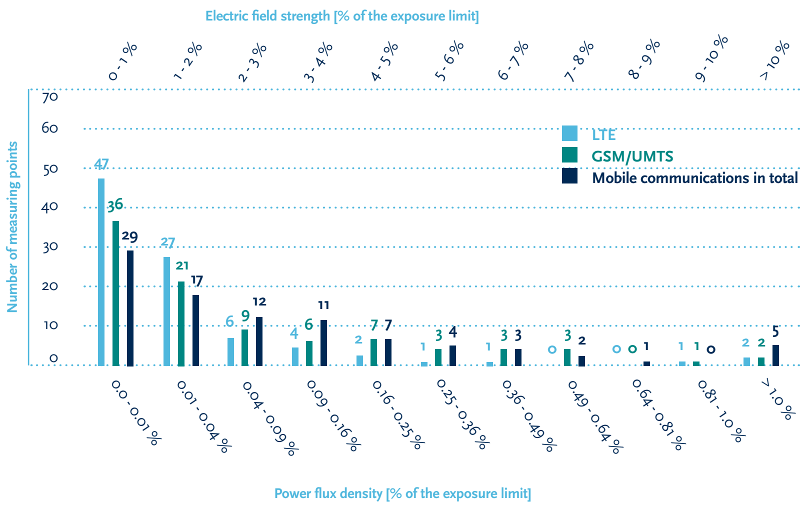
Statistical analysis of the test results

Analysis of the LTE measurements demonstrates that exposure from LTE base stations remains below existing exposure limits for all 91 measuring points. Even taking into account exposure from GSM and UMTS base stations installed at the same site and extrapolation to the theoretically possible maximum power, values still only reach a fraction of the legally established exposure limits.

Figure 6 shows the percentages of the exposure limits reached at all the measuring points. The graph shows that at 89 of 91 measuring points (98 percent) LTE and GSM/UMTS exposure levels and at 86 of 91 measuring points (95 percent) the mobile communications exposure levels in total only reach 10 percent or less of the limit for field strength (and 1 percent or less of the limit for power flux density).

The highest LTE value of the study was recorded at Jena (measuring point 14.2, p. 17). At this location, the measurement was taken in the main beam direction of an LTE base station 24 metres away with the window open. Extrapolated, this value reaches 13.53 percent of the exposure limit for electric field strength (and 1.83 percent of the limit for power flux density). Additionally, this measuring point displayed the highest total mobile communication exposure level in the entire study, with a total of 21.82 percent of the field strength limit (and 4.76 percent of the limit for power flux density).

Figure 6: Distribution of measuring points in percent



The lowest values in the study were measured at Hanau (measuring point 4.6, p. 12). On the second floor of a building with a mobile network installation, the LTE value reached 0.01 percent of the limit for field strength (and 0.0000004 percent of the limit for power flux density). Total exposure levels from all mobile communications networks at this location in Hanau reached 0.01 percent of the limit for field strength (0.000002 percent for power flux density).

The results of the 24-hour long-term measurement demonstrate the strong fluctuations of exposure levels from mobile communications over a day. Base station exposure levels increase as the number of subscribers using their mobiles rises. User activity is especially high in the afternoon and evening, from 4:30 pm to 10:30 pm. At night, when few users are active, exposure levels fall to a minimum and only begin to climb again when the work day starts around 6:30 am.

All in all, the results of the study show that exposure levels from the LTE network are of the same order of magnitude as exposure levels from GSM or UMTS base stations. The normal operation of LTE networks has increased total exposure levels by an average of about 40 percent. However, at most measuring points, this percentage increase starts from a very low base level. Even when extrapolated to the theoretically possible maximum output power of all installations at the site, values for more than half the measuring points (46) still only reach two percent or less of the legal limit for field strength and four hundredths percent or less of the power flux density limit. Only five measuring points reach values of more than 10 percent of the exposure limits for field strength and more than one percent for power flux density.

Predicting exposure levels

Due to the proximity of their frequencies, the type of antennas and the transmission power used, LTE, UMTS and GSM networks demonstrate similar characteristics regarding the propagation properties of electromagnetic fields in their immediate surroundings, in their emission patterns and in the attenuation effects from buildings. Therefore, the results of this LTE study add to the knowledge derived from previous nationwide GSM and UMTS studies and exposure level evaluations initiated by the IZMF in North-Rhine/Westphalia (2003), Hesse (2004), Lower Saxony (2005), Thuringia (2006), Saxony (2007), Saxony-Anhalt (2008) and Bavaria (2009).

Statistical analysis of the test results indicates that several factors must be considered when predicting exposure levels for a certain site. Many of these factors are interlinked.

The following parameters influence the exposure level situation at any given place	This has the following consequences for local exposure level situations
Distance from mobile-network transmitter	Less distance does not necessarily mean higher exposure levels. The distance from a mobile-network transmitter is thus not a reliable criterion for estimating exposure levels.
Height and orientation of the antennas	Especially in the immediate surroundings of an antenna, exposure levels at the site depend less on the distance and more on the emission patterns of the antenna and the height of the measuring point.
Attenuation of mobile-network fields	With distance to the installation and height being equal, electromagnetic fields produced by mobile communication sites are weaker inside buildings than outside.
LTE, GSM and UMTS fields behave similarly	Because of the similarity between their frequencies, waves from LTE, UMTS and GSM antennas are propagated in a similar fashion. The rules governing the radio wave propagation behaviour of their electromagnetic fields are therefore the same for all three technologies.
Fluctuations over the course of the day	Exposure levels fluctuate over the course of the day. This is because mobile phone networks use power control meachanisms to ensure that antennas will always use only the transmission power necessary for the actual volume of traffic. At night, exposure levels fall to a minimum.

Mobile telecommunications and health

In Germany, digital mobile communications technology started about 20 years ago. Ever since, the digital mobile network has been continuously developed and extended: from the GSM standard via UMTS, the third generation of mobile networks, to the newest LTE technology. Improving mobile communications has clear benefits for everyone, but there is an understandable anxiety among the population that this complex technology may possibly have adverse effects on health.

German Mobile Telecommunication Research Programme: limits confirmed

Electromagnetic fields – both natural and artificially created – are part and parcel of our natural surroundings. Scientific studies have investigated their possible biological effects for decades. Safety provisions for mobile communications are based on the results of such studies. These safety provisions themselves are subjected to ongoing scrutiny by national and international experts, who have found that they provide effective protection for the public. However, certain questions do remain unanswered when it comes to mobile telecommunications and health. Studies that have already been completed are waiting for their findings to be confirmed by ongoing research on comparable topics. Over the past few years, several studies have been published in an attempt to close these knowledge gaps.

As an example, Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety initiated the German Mobile Telecommunication Research Programme (Deutsches Mobilfunk Forschungsprogramm – DMF) in 2002. About 50 research projects on different topics in biology, medicine, dosimetry, epidemiology and risk communication studied high-frequency electromagnetic fields to discover any adverse health effects. Projects also examined the question whether some people can indeed suffer from "electromagnetic hypersensitivity" in that they can perceive weak radio-frequency electromagnetic fields. The results of the DMF were presented to the public in 2008. None of the studies confirmed suspicions related to different types of cancer or unspecific health problems such as headaches and insomnia. Also, double-blind studies could not confirm any suspected "electromagnetic hypersensitivity".

INTERPHONE study: No increased risk for brain tumours in mobile phone users

In 2010, the results of the INTERPHONE study coordinated by the World Health Organization (WHO), which had studied approximately 5,000 patients suffering from brain tumours, were presented to an international audience. According to current research, the electromagnetic fields produced by mobile telecommunications do not increase the risk of brain tumours. However, these studies only examined up to 12 years of mobile phone use. In order to cover periods of longer exposure, British scientists initiated the COSMOS project (Cohort Study on Mobile Communications) in spring 2010. COSMOS will monitor some 250,000 mobile phone users in Europe for a period of 20 to 30 years in order to find out if they have suffered any health problems. The monitoring process will consider brain tumours, insomnia, depression, headaches and tinnitus.

The CEFALO study (Mobile Phone Use and Brain Tumours in Children and Adolescents: A Multi-Centre Case-Control Study) published in 2011, is similar in scope to the INTERPHONE study but it examined children and young adults from three Scandinavian countries and Switzerland. CEFALO found that there was no increased risk of brain tumours after five years of mobile phone use.

Based on a small number of indications derived from a few epidemiological studies, the International Agency for Research on Cancer (IARC) in May 2011 classified high-frequency electromagnetic fields as used in mobile communications as "possibly carcinogenic to humans" (IARC group 2B). In other words, the IARC acknowledges that there are some indications that these fields have an effect on humans, but that such indications are not confirmed by evidence from animal studies. In their response to this classification, institutions such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) have stated that they see no reason to change their recommendations for exposure limits.

Further studies to follow

The most important question for the German Academy for Paediatrics and Adolescent Medicine (Deutsche Akademie für Kinder- und Jugendmedizin – DAKJ) respectively the Kinderumwelt gGmbH is whether children are more susceptible than adults to electromagnetic fields produced by mobile telecommunications. The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) of the EU Commission has identified the need for further research into this field. Consequently, the EU provided the funding for the MOBI-KIDS multicentre study. Since 2009, MOBI-KIDS has been investigating whether new communication technologies (such as mobile phones) influence the emergence of brain tumours in young people. It is expected that the first findings will be published by 2015. In the meantime, and until firm findings have emerged from research studies, the German Academy for Paediatrics and Adolescent Medicine (DAKJ) and the Office for Radiation Protection (Bundesamt für Strahlenschutz – BfS) have recommended that children should use mobile phones with prudence and in moderation.

Exposure levels from LTE lie far below legal limits

The public's ever growing demand for mobile data connections has led to the development of the latest mobile network standard LTE (Long Term Evolution). This network utilises existing base stations and will also require further mobile network installations. Regarding the possible health effects of LTE, the Office for Radiation Protection has pointed out that the frequencies used by this new standard are very close to the frequency bands used by other existing mobile communications networks. It is thus to be expected that their biological-medical effects will not be fundamentally different. Even though the BfS expects exposure levels to increase, it assumes that even after the nationwide expansion of the LTE networks, exposure levels will still remain far below legal limits. The results of the measurements carried out for the present nationwide study "Confidence by evidence – Putting LTE to the test" confirm this expectation. As long as the legal exposure limits are observed, it is virtually certain that the public will be protected from the adverse effects of electromagnetic fields. This applies both to the GSM and UMTS transmission technologies, as used for many years, and to the new LTE standard.

At the moment, there are no firm indications that children are more sensitive to the electromagnetic fields produced by mobile communications than adults. However, as a precaution, it is recommended that children use mobile phones in moderation until concrete research indicates otherwise.

Prof. Dr. med. Karl Ernst von Mühlendahl
Paediatrician specialising in endocrinology and environmental medicine
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