The influence of value limit
structure of mobile communi
from mobile radio

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In the debate concerning the locations of mobile radio transmission installations, inhabitants in the vicinities of such installations have made the reduction of the maximum safety value limits for humans, e.g. based on the Swiss model, a central topic. In this article, it was investigated what kind of effect a safety value limit reduction would have on the structure of mobile communication networks and on total emissions from mobile radio base stations.

Introduction

In the past few months a broad public debate has escalated concerning mobile radio communications, spawned by the new UMTS technology (universal mobile telecommunications systems) and the 40,000 new base stations which Germany alone will require. The debate is focusing not on the mobile terminals (cellphones) but rather on base stations. Concerned residents in the vicinity of base stations are demanding some kind of protection, they want new safety value limits to replace the current safety value limits for humans (this will be referred to in the rest of the article as simply value limits), they want these value limits to be made more stringent to protect the population from electromagnetic radiation.

Against this background the Ministerium für Umwelt und Naturschutz, Landwirtschaft and Verbraucherschutz (MUNLV) *Ministry for the Environment and Nature Conservancy, Agriculture and Consumer Protection* of the state of North Rhine-Westphalia commissioned the Institute for Mobile- and Satellite Radio Technology (IMST) in Kamp-Lintfort to conduct a study “An investigation on emissions from mobile radio base stations”. The main emphasis of the study was to assess typical emission values which can generally be expected and especially to record systematically the technical emission measurements. From this information reference points in the vicinity of base stations concerning the current concrete emission situation were derived and minimization concepts were established. The findings of the study are available to the public and can be viewed on the Internet at the following site: http://www.munlv.nrw.de/sites/arbeitsbereiche/immission/mobil.htm.

A part of the study dealt with the question, what effects will reducing value limits have on the structure of mobile radio networks and on total emissions from mobile radio base stations. In particular, the following should have been determined:

- To what extent will a reduction in value limits actually lead to a reduction in total emissions for the population (Will a reduction in value limits by factor 100 result in a reduction of total emissions by factor 100 as opposed to the original situation?)
- To what extend is a concentrated transmitter concept (fewer installations, higher power) or a distribution transmitter concept (many installations, lower power) to be preferred regarding the overall emission, and
- To what extent do we have to count on increasing the number of antennas.

Exactly this is not a factor to be underestimated, since there is a correlation between the concerns in some parts of the general public and the number of visible mobile radio installations.

The investigation that has been described here was primarily conducted for mobile radio installations according to GSM-standards; the essential findings of this study are also transferable to UMTS-networks.

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What is the typical situation for emissions?

Before an investigation is conducted on the effects of a reduction in value limits on the structure of mobile radio networks, the current situation with regard to location and the level of emissions from the mobile radio base stations (emissions at one particular place) has to be first discussed, in order to estimate how much leeway is available (i.e. to what extent the current value limits are exhausted). This can be estimated with technical calculations or determined with technical measurements.

Just recently with regard to technical measurements, this study and several other investigations have been conducted and published. e.g. [4].

All of the investigations come to similar conclusions: all of the mobile radio emissions measured outside the safety zone of base stations, even in locations directly next to the installation were below and a percentage was very much below the valid value limits for Germany, 26. BImSchV (26 ordinance executing the federal emissions protection law). When using Swiss installation values for locations with sensitive use [5] for comparison, it was established that only at a few locations, where measurements were taken, those value limits were reached or exceeded.

This basic statement can also be made by using simple calculated estimations: diagram 1 shows the calculated power flux density over the lateral distance from a base station. In this case a normal commercial sector antenna Kathrein K 735147 with 2^0 electric and 0^0 mechanical down tilt was observed. The height difference between the transmitting antenna and the measurement site is assumed to be 5m. The free space model was used as a calculation model, which is also used by the regulation authorities for Telecommunication and Postal Services (RegTP) for calculating safety distances for location certificates. In diagram 1, the parameter is the total input power in the sector antenna. The following general statements can be made concerning diagram 1:

1. Emissions fluctuated greatly up to a distance of 80m (depending on how high the antenna is installed). This can be explained by the fact that the entire range of side lobes (next to the main radiation direction there are secondary radiation directions, the so-called side lobes) is covered. Starting at 80 m emissions begin to decrease steadily in relation to the distance; at this point one only finds the main radiation direction. Dependent on the antenna used, there can be in the area of the minor lobes lateral distances where the emissions are comparable to those of the main radiation direction.

2. A change in the transmission power will move the emissions curve into a vertical direction. What is meant by transmission power here is what is radiated altogether in one sector with the installation at full load. i.e., channel number times maximum transmission power per channel. 5W and 20W are the common values at many base stations. 50W could occur at some individual installations, which are fitted with the maximum of transmission channels; this is, however, not regarded as the general case. 100W is really not realistic for a single installation/sector. Howev-

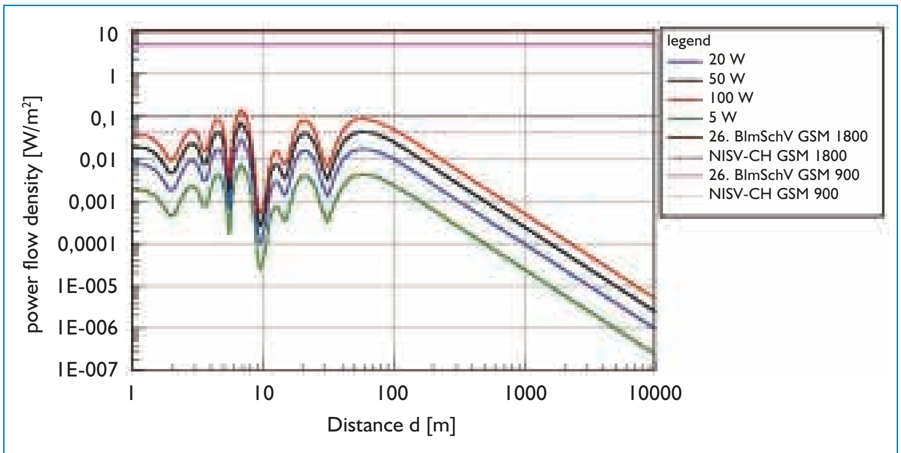


Diagram 1 : the calculated power flow density dependent on lateral distance at transmission power variations; one sector, height differences between the transmitting and the receiving location 5m, free space model er, it is conceivable that a location could be used at the same time by several network operators or that a network operator could also set up a UMTS transmitting installation next to a GSM installation that they operate. With regard to a similar alignment of the sector antennas the radiated power could overlap.

3. At all transmission powers the calculated exposure values are well below the limits of the 26. BlmSchV. At 50 W and 100 W of total sector power, the Swiss installation values (NISV-CH) are reached or even exceeded (diagram 1).

Obviously local exposures depend on many other factors, e.g., the kind of transmitting antenna, down tilt, height differences between the transmitter and the receiver location, alignment of the antennas and the propagation conditions between the transmitter and the receiver location (including conditions of visibility).

Total emissions

If we define total exposure, as opposed to local exposure, as power from base stations that irradiates the entire environment (i.e., ground, trees, houses, etc.), then from this we can draw the following conclusion:

a reduction in protective value limits for people, e.g. by factor 100 (by this factor the Swiss installation value limits are stricter than the 26.BlmSchV) would not be reflected in total exposure being reduced by factor 100, but rather total exposure reduction would be substantially less.

The reason for this is the fact that the actual existing emissions from locations depending on the installation and the type of adjacent buildings, as a rule are below the value limits for 26. BlmSchV and only at a few places were the Swiss installation values exceeded. Due to the large safety zone concerning the legal value limits, measures to reduce local emissions would only be necessary:

- at installations where the Swiss installation values were exceeded and
- at these locations to a much lesser degree than a reduction of the value limits

A value limit reduction by a factor x would only result in the same way in a reduction in total emissions when all stations operate near the legal value limits. This has however been proven not to be the case.

A reduction in protective value limits for people, e.g. by a factor of 100 would not be reflected in total emissions being reduced by the same factor 100, but rather the total emission reduction would be substantially less.

Possible measures for reducing local emissions at installations are as follows:

1. Reducing the maximum transmitting power of the base station.
2. Increasing the height difference between the base station and emission site, e.g. by increasing the number of transmitting locations.

What consequences these measures will have on the mobile radio networks (cell size, density of the base stations etc.) should be investigated by means of the following simulation with the example of the area of a town. In comparison to the proceeding section a sophisticated wave propagation model will be used here. This is necessary, since the free space model is correct for the immediate area around the installation, but is from a radio provisional standpoint much too optimistic near the cell limits. However, a realistic calculation of the cell sizes is for the following investigation of decisive significance.

With the COST-Walfisch-Ikegami (COST-WI) model [6] a numerical model is used that is especially suited for city environments and is used for radio network design. The COST-WI model, as opposed to the free space model, takes into account statistical conditions of visibility, buildings and street details.

Reducing the transmission power of base stations

Reducing the transmitting power of base stations can be done in the following ways:

1. reducing the channel transmission power while keeping the same number of channels per installation.
2. reducing the number of channels and moving them to new stations and
3. the rebuilding of operating sites that are jointly used by several network operators, in such a way that only one operator is working out of one location.

In the following the first possibility will be dealt with in detail.

If the transmission power is reduced then the radius of the mobile radio cell is also reduced, since at the edge of the cell the power flow density of the station is not strong enough to make a phone call. Diagram 2a shows a reduction in the size of the cell, for a small town scenario with a channel transmission power of 5 W and a station height of 15m. At a transmission power of 5 W (corresponding to a 0dB change in transmission power) the cell radius is circa 1800m. If the transmission power is reduced by 3 dB, i.e. from 5 W to 2.5 W, the cell radius is reduced to circa 1500 m.

Diagram 2b shows how a change in the cell radius reflects a change in the cell area. In order to ensure that continual mobile radio coverage is provided for the area and that no gaps in coverage will occur, correspondingly more base stations will have to be set up. A change in the number of base stations is counter current to changes that occur in the cell area (the right axis in diagram 2b). 100% of the cell area or the number of base stations corresponds to the original state. By reducing the power transmission by 3 dB the cell area is reduced to 70% of its original value. The number of base stations must, therefore, increase by 40%.

What is especially interesting here is to have a look at the total transmission power of this new network. Does more or less power than before have to be fed into the new more compressed network, albeit with smaller individual power transmitting base stations? Since the total emissions are proportional to the total power fed in, a prediction can be derived from this concerning how total emissions will develop.

The answer can be calculated from the respective ratio of the individual transmission power to the illuminated area; the results are shown in diagram 2c. From this it is obvious that at reduced transmission power and with it the accompanying compression of the base stations the entire transmission power of the network and with it total emission will sink. In the example presented, 70% of the original value is left when at the individual stations the transmission power is halved.

Thus, an important finding can be established: With more base stations, where, compared to the original situation, the transmission power per channel is lowered, the entire transmission power of the network is reduced and thus the impact on the environment with regard to total emissions from base stations is also reduced.

This trend which was originally calculated under the assumption that the number of channels per installation remains the same, becomes stronger when additional channels are moved to new installations, so that the overall capacity of the system remains constant. Including typical mobile radio power regulations, which were for the time being not taken into account with the calculations, strengthens the trend as well. A rebuilding of locations used jointly into locations for single use will reduce local emissions, but will have no effect on total emissions, because every network operator will only transpose its own network without reducing channel transmission and an associated increase in network density.

However, in contrast to the advantages of reducing total emissions, there are also some practical disadvantages.

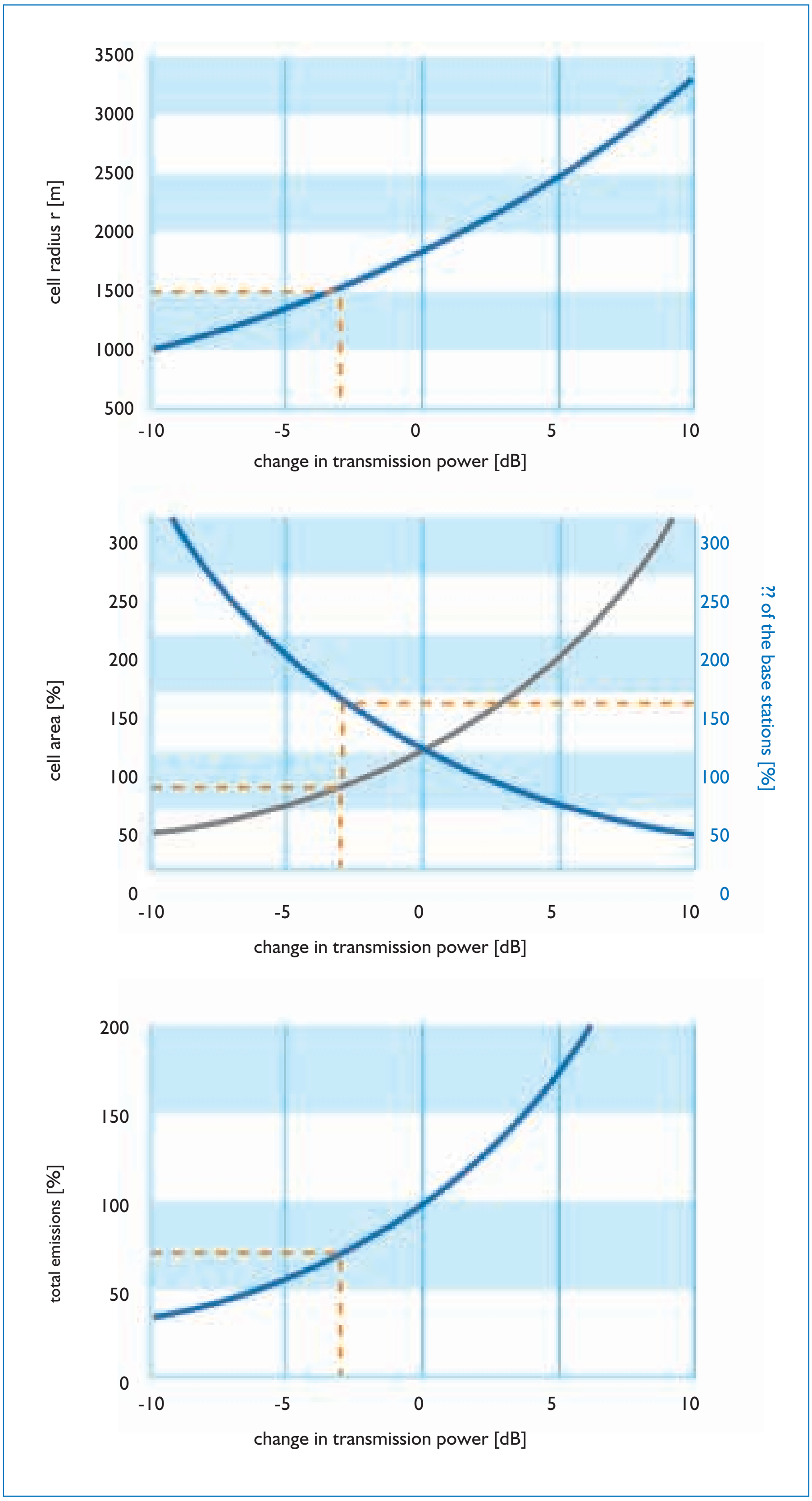
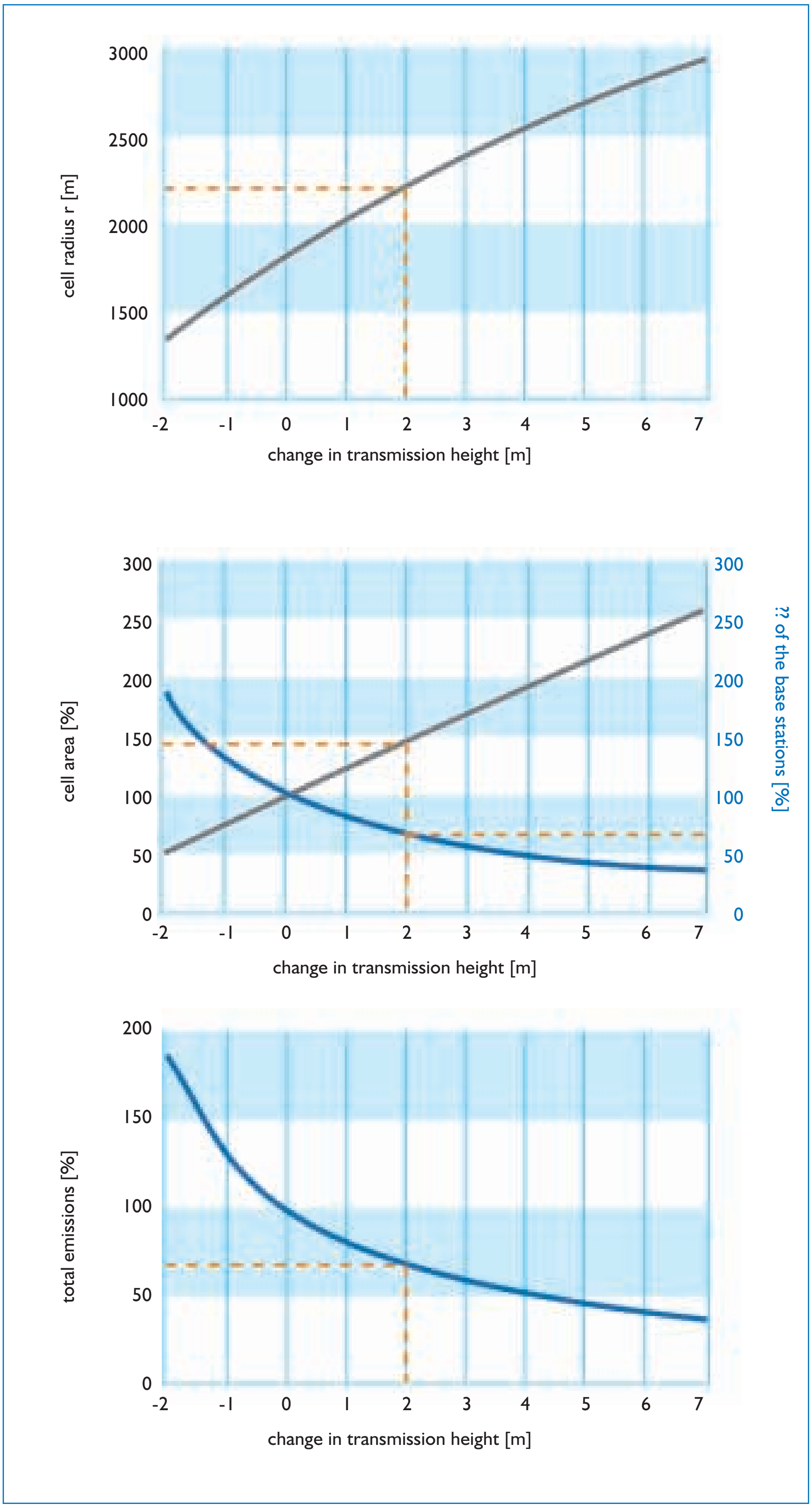


Diagram 2a-c: dependence of cell radius (top), cell area or the number of base stations (middle), total emissions (bottom), on the transmission power of the base station with respect to the original situation (COST-WI model)



Diagrams 3a-c: Dependance of the cell radius (top), cell area resp. the number of base stations (middle), and total emissions (bottom) based on the original situation with regard to the transmission height of the base station; small town scenario, COST- WI model

The power transmission cannot be arbitrarily reduced, since in some sub-ranges of the radio cell there would not be, circumstances permitting, adequate radio coverage, (e.g. in-house gaps in coverage). Moreover, it is to be expected that with the required increase in the number of necessary base stations, the network operators along with more costs will be faced with more problems when they have to look for new sites. Since increasing the number of base stations will be difficult to convey to the public. In order for this concept to be successful a constructive dialogue among all of the participants is an absolute prerequisite, in particular between network operators and communities.

With more base stations, compared to the original situation where less channel transmission power is transmitted, the entire transmission power of the network is reduced and thus total emissions. Nevertheless, a problem arises out of this situation, namely conveying an increase in base station density to the public.

Increasing base station height

An increase in base station height leads to an improvement in radio "visibility" of the installations; as a result the cell radius, and the illuminated cell area expand. The number of base stations required by the networks decreases. If the transmission power per base station remains the same, the total emissions are reduced when compared to the original situation because of the expansion of the cell areas.

For the small town scenario, which was described in the previous section, simulations for the changes in station height are described in the diagrams 3a, 3b, and 3c.

If a transmitter is raised by 2m, which means from 15 to 17 m, the cell radius expands from 1800 m to 2000 m (diagram 3a). This is equivalent to an expansion of the cell area of 50% (diagram 3b); the number of base stations could be reduced to 70% of the original value. In this way total network transmission power and total emissions would be reduced to 70% of the original value (diagram 3c).

Consequently, moving the base station to higher locations would lead to an enlargement of the radio cells and to a reduction in the number of base stations. The total network transmission power and thus total emissions would be reduced.

Here as well, there are a number of practical disadvantages which have to be considered. Transmission locations cannot just arbitrarily be moved to higher locations, since interference form neighbouring cells would increase and this is a fact which is of major significance for the UMTS-network. Moreover, in the simulation example given above the system capacity, that is the number of maximum possible calls per area, would be reduced so that the installation, if need be, would have to be equipped with new channels. This would mean that the total transmission power is increased and the effect reducing total emissions would be weakened. As was mentioned in the previous paragraph where a reduction in transmission power was dealt with, finding a suitable location will be problematic, particularly as the sites are "visible to everyone". Zoning aspects and aesthetics of the townscape also have to be taken into consideration. Here a constructive dialogue among all of the participants, especially among network providers, is indispensable.

Moving the base stations to higher locations leads to an expansion of the cell area and to a reduction in the number of base stations. The total network transmission power and total exposure are reduced. In contrast, interference problems with neighbouring cells has to be considered. The "visibility" of the base stations will increase.

Summary

At generally accessable locations in the area surrounding mobile radio installations, the actual local emissions are generally below and partly well-below the value limits of 26. BlmSchV. Since there is enough "leeway" concerning the value limits a value limit reduction by, e.g. a factor 100 would not result in a reduction in total emissions by a factor 100 but the reduction in total emissions would be much less.

To reduce local emissions there are the following possibilities:

- reducing the transmission power
- moving the antennas to higher locations.

A reduction of the transmission power leads to a reduction in the cell radius and the cell area when compared to the original situation and therefore, this requires that the number of base stations be increased. Total emissions, i.e., the sum of the transmission power (network transmission power) required for the new denser network results in a *reduction* of total emissions when compared to the original network. In practice operational transmission power cannot be arbitrarily reduced because otherwise there would be coverage gaps in some areas. Moreover, problems will arise in finding locations and conveying this distribution concept to the public.

Distributing locations so that they can be operated by several network operators as a possible way to reduce transmission power, has no effect on total emissions.

An increase in the height of the base stations leads to cell expansion and correspondingly to a reduction in the number of base stations that are required. Also in this case total emissions are reduced. In reality an unlimited increase in the height of transmission locations is not possible because of interference from neighbouring cells would increase and problems would also be expected in finding locations. In order to convert both concepts a constructive dialogue among all of the participants is indispensable, especially between the network operators and the communities.

Both scenarios, reducing transmission power and increasing the height of transmission locations have been viewed individually and independently of one another. Basically, there is the possibility that both variations could be combined, i.e., moving the base stations to higher locations and reducing the transmission power so that the cell areas remain the same.

All of the findings presented in this article deal with calculations done with examples. From a practical point of view it is necessary to calculate or measure with actual cases.

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