The Salzburg Model: A Precautionary Strategy for Siting of Base Stations*

Dr. Gerd Oberfeld, Dr. Christoph König

Federal State of Salzburg, Public Health Department, Environmental Health
P.O. Box 527, A-5010 Salzburg, Austria, gerd.oberfeld@land-sbg.gv.at

The Salzburg Model is a dynamic developement with the aim to implement a precautionary strategy for the prevention of public health from electromagnetic fields. It started in 1997 when the Department of Public Health of the Federal State of Salzburg was requested by the Salzburg Provincial Parliament, the Director of the Department of Health and several mayors, among others, to provide a medical evaluation of the GSM fields emitted from mobile telecommunications base stations.

After a review of the literature, it became clear that the observation of the thermal effects alone, as was and is still practiced by ICNIRP and WHO is insufficient. The difficulty therein lay in finding studies which could provide evidence for an evaluation based on public health criteria. In our opinion a study done in a sleep laboratory with a GSM mobile phone at a distance of 40 cm [Mann K, Röschke J, Effects of pulsed high-frequency electromagnetic fields on human sleep. Neuropsychobiology. 1996; 33(1):41-47] using the crossover design with the endpoint at EEG changes (in this case the suppression of REM phases) with a power flux density of 500 mW/m² was suited to this purpose. Because neither an exposure effect curve nor the influence of possible variations in sensitivities were known, an uncertainty factor of 500 was introduced analogous to toxicological evaluations. The resulting evaluation value of 1 mW/m² (0.1 µW/cm²) applies to the total of the pulsed GSM signals emitted from mobile telecommunications base stations (GSM 900 MHz and GSM 1800 MHz). The corresponding reference values of the ICNIRP/WHO from April 1998 are 4500 mW/m² for 900 MHz and 9000 mW/m² for 1800 MHz.

In spring 1998, after "Mobilkom" and "max.mobil", the third network operator "Connect Austria" (= "one") began to construct its network without previously informing the citizens of the city of Salzburg. A construction pit for an antenna mast was occupied by local residents in a residential area of the city of Salzburg. This event was reported by the media. It turned out that the erection of similar masts was planned in other parts of the city as well.

The indignation of the citizens was ignited by the fact that in the province of Salzburg approval by governmental authorities is required for the construction of buildings of heights over 1.5 metres, but not for antenna masts. A review of the legal possibilities indicated that issues of health were matters of federal competence. Thus in May 1998 the province of Salzburg was able to implement only a law for governmental review of the community image with regard to antenna mast systems.

Subsequently, the question of effects on health regarding the microwave radiation from the antennas came to the foreground.

The city politicians supported the citizens and a mediation process was initiated among the 12 local residents initiatives and the network operator. The course for further proceedings were set in the first rounds of negotiations. The network operator Connect was successful to limit the discussion to the masts and to exclude the rooftop antennas – the latter leading to higher exposures than the masts –

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but that was a lesson we learned afterwards. It was agreed that all planned mast-sites and alternative mast-sites would be disclosed and discussed with the citizens and that the electromagnetic exposures would be calculated before the masts were erected. The evaluation criterion accepted by both sides was the preliminary evaluation value proposed by the Department of Public Health of 1 mW/m² for the GSM signal, taking into account the existing load of other GSM basestations. In a decision by the city council, the city of Salzburg requested the federal government to establish this value in law.

The calculations showed that in almost all sites, due to the relatively height of the antennas over ground level of about 30-35 m, the type of antenna and the planned transmitting power (17 W with a gain of 18 dBi = 1073 EIRP), the evaluation value of 1 mW/m² was complied with. The calculation was performed for selected properties in the area surrounding the basestations, for which the highest exposures were expected, for the roof height outdoors without attenuation through walls or roofing barriers. In autumn 1998 the compliance with the calculated values was agreed under civil law between the network operator and representatives of the local residents.

Independently of the negotiations with Connect also in spring 1998, an extensive high-frequency field measurement program financed by the network operators (Mobilkom, maxmobil and later Connect) was launched in the city of Salzburg. To a large degree, communities with assumed high emissions from GSM base stations were selected for measurement. The measurements were carried out in May 1998 (GSM 900) and January 1999 (GSM 1800). With regard to the power flux density, GSM signals were, on the average, two to three orders of magnitude higher (factor 100 to 1000) than the levels of other high frequency sources like radio or TV. The 12 mast sites agreed upon between Connect and the citiziens have not been measured, because it was intended to measure especially points of high exposures and the calculations of the 12 mast sites revealed levels below 1 mW/m² (0,1 µW/cm²).

Furthermore, it was shown that at 10 out of 20 emission points, the GSM cumulative value of 1 mW/m² was in part considerably exceeded. In a presentation of the measured values made in July 1999, the citizens requested the network operators concerned to comply with the GSM cumulative value of 1 mW/m². The operators and the Forum Mobilkommunikation (PR agency for network operators and the relevant industry) then pointed out the lack of a legal obligation and left the negotiations with no further discussion. However, the fourth network operator "tele.ring", which received its license for nationwide expansion of the fourth GSM network in May 1999, consented to discussions with the citizens. This consent has been followed up insofar as GSM sites (including roof sites) in the city of Salzburg are being reviewed with regard to the protection of community image and protection from emissions. An evaluation value of 0.25 mW/m² (0.025µW/cm²) without attenuation through walls or roofing barriers and without a more detailed assessment of prior load is used as a tolerance limit. This pragmatic method was chosen based on the results of the field measurements, since an exact assessment of the prior load, especially in the densely built-up city area would be possible only with time-consuming measurements or computer modelling (data and program were not available for the public health department), and measurements considerably in excess of the GSM cumulative value of 1 mW/m² are already known.

Proposal for the Calculation and Evaluation of the Exposure Levels for GSM Base Stations

Insofar as **thermal effects** are expected, the total of all relevant field strengths, including those not belonging to the GSM area, must be calculated in accordance with ÖNORM S 1120 (Austrian Standard S 1120) and compared with the 1998 reference values of the ICNIRP. In practice the reference values of the ICNIRP for GSM antennas are complied with within a few meters at most.

As a rule, the evaluation of **biological effects from low-intensity exposures** thus forms the stricter criterion. This evaluation is discussed in further detail below.

1) Determination of the pertinent points of exposure

2) Calculation of the exposure as power flux density (S)
3) Evaluation through comparison with the proposal of the ICNIRP[8] (for thermal effects) and the Salzburg precautionary value (for low intensity biological effects)

Determination of the Relevant Points of Exposure

The relevant points of exposure are particularly indoor and outdoor areas which can be used as residences for people. Among the relevant exposure points, usually those with the highest expected values are reviewed. These can include, for instance, upper stories of buildings in use or which might come in use oriented towards the base stations or outdoor areas.

For buildings, the calculation should be performed, on the assumption that roof stories are or can be converted, for a height of 3 metres above floor level of the uppermost story. Attenuation factors due to roof coverings should not be calculated, because tile and Eternit roofs provide only negligible reduction. Metal sheet roofs without openings usually provide attenuation of at least 10 dB = factor 10. It can be decided on an individual basis whether to take this into account. Opened windows, window frames made of wood or synthetics and non-reflecting window glass do not provide any noteworthy attenuation. For level outdoor areas the height of 2 metres can usually be assumed for exposure points.

Calculation of the Exposure as Power Flux Density (S)

The following information is required for the calculation of the power flux density at a relevant exposure point.

a) True-to-scale site plan of the relevant area with pinpointed antenna sites and designation of the exposure points for the determination of the horizontal distance between the antenna(s) and the exposure points
b) Height data:
   - Difference in height between ground level and the antenna (lower edge)
   - Difference in height between ground level and the relevant exposure points
   - Variations in the ground level
c) Diagrams showing, for instance, the mast or the roof site including antennas and the exposure points (e.g. buildings), in one height dimension
d) Ratings such as:
   - System and transmission frequency range, e.g. GSM-1800, 1853.2-1869.8 MHz
   - Main transmission directions (sectors) in degrees (NoE=north over east), e.g. 10°, 130°, 250°
   - Antenna tilt in degrees per sector (downtilt/uptilt),
   - e.g. mechanical downtilt 3°, electric downtilt 2°
   - Number of radio channels per sector, e.g. 2 channels per sector
   - Planned maximum output at the amplifier output per channel in watts, e.g. 10 watts/channel and the kind of connection between the antenna and the amplifer (e.g. using combiners)
   - Antenna manufacturer and antenna identification, e.g. Kathrein 739 495
   - Antenna gain G in dBi, e.g. G=18 dBi
   - Antenna data sheet
   - Vertical and horizontal radiation diagrams and tables in the corresponding frequency ranges
   - Attenuation (loss) through cables and plugs in dB
   - Vertical and horizontal attenuation in dB

[8] ICNIRP, International Commission on Non-Ionizing Radiation Protection: Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz), Health Physics, April 1998, Volume 74, Number 4, 494-522.

e) The calculation of the exposure as power flux density in the far field can be performed using the following formula:

$$S = \frac{P[W] * MZ(G[dB] - ß_1[dB] - ß_2[dB] - ß_3[dB])}{4 * r^2[m] * p}$$

S = Power flux density in W/m²
P = Emitted maximum output at the amplifier output in watts
MZ = Dimension figure (data in dB must be converted to a dimension figure after the subtraction - see below)
G_i = Gain in dB, related to the isotropic (spherical) dissemination characteristic
ß = Attenuation in dB:
$ß_1$ for cable attenuation and attenuation through plug connections,
$ß_2$ for vertical attenuation,
$ß_3$ for horizontal attenuation
r = direct distance between the antenna(s) and the exposure point in metres, obtained from vertical and horizontal distance ($c^2=a^2+b^2$)
π = 3.14159

Conversion of a dB unit to a dimension figure:
e.g. for $ß_1$=4 dB
$ß_1 = 10^{\frac{4}{10}}$ = 2.51 as a dimension figure
Note: For the conversion, the function y^x on a pocket calculator can be used, or the Excel formula:"=POWER(10;4/10)". Instead of the number, in this case "4", the corresponding reference cell can be inserted, e.g. "A2".

The previously existing load of GSM base stations (900 and 1800 MHz band) could be calculated analogously, but runs into great methodical difficulties in more densely built-up areas. A pragmatic approach used in these cases is a base station and operator-related evaluation based on extensive measurements taken in the GSM band in May 1998 and January 1999 in Salzburg. At present, due to the fact that four GSM mobile phone networks are operated in parallel in Salzburg, an emission value per operator and base station of 0.25 mW/m² (0.025 µW/cm²) is used as a preliminary evaluation value. The calculation thereby assumes a full load and a maximum transmission output of all planned channels.

Evaluation by Comparison with the Proposal of the ICNIRP from 1998 and the Salzburg Precautionary Value from 1998

a) **Thermal effects:** ICNIRP 1998
The reference value of the ICNIRP is frequency-dependent. The ICNIRP guideline uses the following formula to calculate the reference values for the exposure of the population through electric and magnetic alternating fields for the frequency range from 400 MHz to 2000 MHz: Frequency/200 = Power flux density in W/m².

b) **Biological effects from low-intensity exposures:** Salzburg precautionary value 1998
The Salzburg precautionary value is based on the modulation of the GSM signal and not on the carrier frequency. Thus it is identical for the GSM bands 900 MHz and 1800 MHz.

Frequency	ICNIRP 1998	Salzburg Precautionary Value 1998
	Thermal Effects	Biological effects from low-intensity expo-sures
GSM - 900 MHz	4.5 W/m²	1 mW/m²
GSM - 950 MHz	4.75 W/m²	1 mW/m²
GSM - 1800 MHz	9 W/m²	1 mW/m²
GSM - 1850 MHz	9.25 W/m²	1 mW/m²

Appendix

Conversion between power flux density, electric and magnetic field strengths

Power flux density	S	[W/m²]
Electric field strength	E	[V/m]
Magnetic field strength	H	[A/m]

$S = E^2 / 377$ $E = \sqrt{S * 377}$

$S = 377 * H^2$ $H = \sqrt{S / 377}$

$S = E * H$ $H = S / E$ $E = S / H$

Conversion between mW/m² and µW/cm²

1 mW/m² = 0.1 µW/cm²

1 µW/cm²=10 mW/m²

Calculations of the Power Density with MS Excel[9]

No.	Power Density - Calculated Exposure [mW/m²]
1	1.6
2	1.2
3	0.94
4	1.6

BTS-No.				
Adress and Coordinates of the BTS				
System /Frequencies				
Adress Point of Exposure				
No. corresponding to Map	1	2	3	4
Sector	Sector 1	Sector 1	Sector 2	Sector 2
Number of TRX	2	2	2	2
Power per Channel	43.7dBm	43.7dBm	43.7dBm	43.7dBm
Power per Channel	23.442288W	23.442288W	23.442288W	23.442288W
Direction	60°	60°	180°	180°
Antennatyp	K 739 495	K 739 495	K 739 495	K 739 495
Antenna Gain	18.0dBi	18.0dBi	18.0dBi	18.0dBi
Downtilt mechan.	0°	0°	0°	0°
Horizontal Deviation	15°	15°	0°	10°
Vertical Deviation	2.3°	2.2°	7.1°	4.5°
Angel Loss Horizontal	0.2dB	0.2dB	0.0dB	0.0dB
Angel Loss Vertical	0.0dB	0.0dB	7.4dB	1.6dB
Cable Loss	3dB	3dB	3dB	3dB
General Gain	14.8dB	14.8dB	7.6dB	13.4dB
Antenna Height (Lower Edge)	23.7m	23.7m	23.7m	23.7m
Height of Point of Exposure	10m	8m	5m	6m
Difference between Ground of the Point of Exposure and the Antenna Site	3m	4m	0m	0m
Horizontal Distance	262m	305m	150m	225m
Power Density Point of Exposure	**1.639mW/m2**	**1.209mW/m2**	**0.940mW/m2**	**1.602mW/m2**
Power Density Limit per Site and Operator	0.25mW/m2	0.25mW/m2	0.25mW/m2	0.25mW/m2
Reduced Power per Channel	3.5764W	4.84572W	6.23735W	3.65733W
Reduced Power per Channel	35.53dBm	36.85dBm	37.95dBm	35.63dBm

[9] The Excel spreadsheet including the formulas can be accessed via internet: www.land-sbg.gv.at/celltower