

MEASUREMENTS OF RF RADIATION AROUND BASE STATIONS FOR MOBILE COMMUNICATION IN BULGARIA

M. IVANOVA*, TS. SHALAMANOVA

National Center of Hygiene, Medical Ecology and Nutrition, 15 Dimitar Nestorov Street, 1431 Sofia, Bulgaria

E-mail: m.ivanova@nchmen.government.bg

Abstract. For the period May 2002 up to now EMF around 279 base stations were measured. The measured values of the power density vary from 0.5 to 800 $\mu\text{W}/\text{cm}^2$. The typical data measured on the roofs are about 1.0 to 8.0 $\mu\text{W}/\text{cm}^2$. Only in 10 cases were measured values significantly higher than the exposure limits for general public in use (10 $\mu\text{W}/\text{cm}^2$). These results are due to the presence of other EM sources, such as TV, RF and other emitters near to the base stations. For example, values of power density above 1.0 mW/cm^2 were measured when a single base station was switched off. Values above 10 $\mu\text{W}/\text{cm}^2$ were got in measurements in front of the antennae on the roofs of the buildings as well where any stay of people is not possible. So, we have to say that commonly base stations are not a real problem for exposure to the general population because of the low levels of RF, and the strict legislation concerning these emitters. Risk communication to the population is still a problem.

Keywords: electromagnetic fields, base stations for mobile communication, limit values, hot spots.

AIMS AND BACKGROUND

The last years face exclusive increase of the number and types of sources of electromagnetic fields (EMF) used for personal, industrial and commercial purposes. Such sources are television, radio, computers, mobile phones, microwave ovens, radars and some devices and systems applied in industry, medicine and trade.

These technologies made our life richer and easier. We can hardly imagine the modern society without computers, radio and television. The mobile phones substantially widened our possibilities for contacts and facilitated the emergency health care and police services to people living in towns as well as villages. Radars provide much safer travel by air.

At the same time these technologies provoked serious disputes and discussions focusing on possible related health risks. Such awareness has risen in association with the safety of mobile cellular phones, high voltage power lines and police radar 'guns' for traffic speed control. The scientific publications suppose that exposure to EMF emitted by those devices can produce hazardous health

* For correspondence.

effects as cancer, decreased fertility, memory loss and changes in behaviour and development in children. The real level of health risk is yet unknown although for some EMF types, as they are usually encountered it can be very low or not existing.

The confuse in terminology – mixing of ionising radiation – X-rays or gamma-rays with non-ionising radiation (radiowaves, microwaves, etc.) leads to a confuse of the terms and inadequate comparison of biological effects.

The contradiction between the concern for possible health effects from EMF exposure and the development of facilities for power supply and telecommunications brought about serious economic sequences. For example, the power distribution stations in many countries had to build up their high voltage networks around the residential areas and even to cancel their construction. The installation of base stations for mobile systems was delayed or met obstacles from the public because of the opinion that RF emission from these stations can cause cancer in children.

The measures for significant decrease of EMF in the environment, below generally accepted limits require substantial expenditures. It has been estimated that in USA the problem 'EMF-health' cost some 1 billion dollars annually (data from 1999). Of course, should unacceptable health risks exist, it will be necessary to undertake even more expensive preventive measures.

RESULTS AND DISCUSSION

Limit values for EMF. At present there are great differences between the limits (norms) for EMF approved and recommended by different countries and organisations. The following Table 1 presents the hygienic norms of some countries and organisations for power density of EMF emitted by base stations for mobile communication only for the respective emitting frequencies.

As seen the hygienic norm in Bulgaria is adequately human protecting and is lower than those proposed by ICNIRP and other organisations in the world.

In the last years, though, there is a tendency in some countries to introduce very low maximal permissible levels. The implementation of such values is possibly not the best approach to population health protection as they are often technically unachievable and hardly controlled. Besides, they are not sound in relation to existing evidences for human irradiation risk. The approval of such hygienic limits almost inevitably leads to delay in implementing new technologies and impeding technical progress which, in modern life, is unjustified and inadmissible. That is why hygienic norms have to be soundly justified, based on proven effects on human health and to be a good compromise between the necessity of protecting human health, technological achievements and the state of risk communication to the population, and, of course a reasonable compromise 'risk-benefit'.

Table 1. Hygienic norms of some countries and organisations for power density of EMF emitted by base stations for mobile communication

Standard	Frequency range (MHz)	Maximal permissible value ($\mu\text{W}/\text{cm}^2$)
ICNIRP Guidelines ¹	450	225
	900	450
	1800	900
FCC – Federal Communications Commission, USA ²	450	300
	900	600
	1800	1000
Safety Code 6 – Society for EMF Protection, Canada ³	450	300
	900	600
	1800	1000
Japan TCC/MPT – Telecommunications Company ⁴	450	300
	900	600
	1800	1200
NRPB – National Radiation Protection Bureau, Great Britain ⁵	450	2600
	900	3321
	1800	10000
Russia – national standards ^{6,7}	450, 900, 1800	10.0
Italy ⁸	450, 900, 1800	100
Ordinance No 9 – national limit ⁹	450, 900, 1800	10.0

Refs 1-9 see References.

Results from measurements of EMF around base stations for mobile communication in Bulgaria. In Bulgaria at present there are three mobile operators. Two of them are digital, working as GSM systems (900-1800 MHz), and one analogue – NMT system (450 MHz). Data from measurements around base stations of all three mobile operators are included.

Here we shall present brief compiled results from measurements and evaluations of radiation from base stations' antennae.

The results of EMF measurements around base stations are grouped by types of mobile systems in Bulgaria, analogue and digital, respectively.

Analogue system for mobile communications. The results presented below in Table 2 cover measurements on the territory of one town over a two-year period. The measurements are made on roofs at different locations depending on the way of mounting the antennae – on the facade or on a pole on the roof.

Table 2. Results from measurements around analogue systems' base stations for mobile communication

Measurement place	S_{\min} ($\mu\text{W}/\text{cm}^2$)	S_{\max} ($\mu\text{W}/\text{cm}^2$)
I. Measurements on roofs		
1. Behind sectoral antennae (at 1 m)	0.5	3.5
2. In the internal areas of the roof	> 0.5	1.5
3. Under antennae	> 0.5	7.5
4. Above antennae	0.5	8.0
II. Measurements in inhabited premises		
	1.0	2.5

Measurements have been made within apparatus premises of base stations for assessment of the risk of the service staff. The receiving-transmitting blocks there are well shielded which determines the low measured values in premises ($0.5\text{-}2.5 \mu\text{W}/\text{cm}^2$). EMF values around analogue system antennae are in the Bulgarian hygienic limits.

Digital operators. The results of the measurements are presented depending on measurement place determined by the type of mounting of the base station antennae. The data cover a period of 1.5 years.

Measurements of roofs of residential buildings. The antennae are mounted on poles with different height on the roofs of residential buildings. Depending on the orientation of the emitting surface the measurements are conducted behind the antennae (when they are oriented 'out of' the building), on their sides and before them at different distances.

Figure 1 presents the results of the measurements before antennae at different mounting height at two distances from the antennae. In the figure h (m) are the heights of the geometric centers of the antennae.

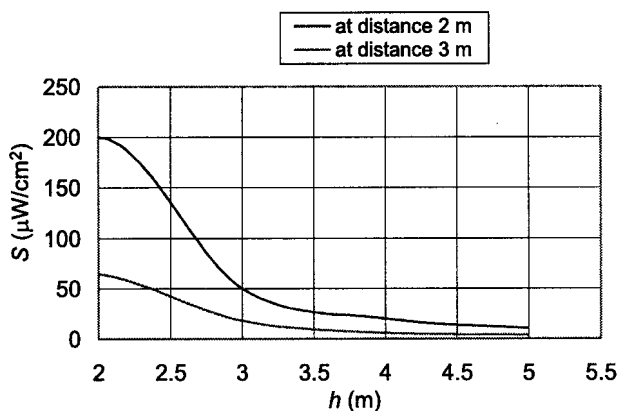


Fig. 1. Results of the measurements before antennae at different mounting height at two distances from the antennae

At measurements before/opposite the antennae the values of EMF power density are logically the greatest at small mounting height versus the surface of the roof. In these cases it is recommended to elevate the antennae at higher poles and placing signs and inscriptions restricting the access to the roof area where the hygienic limits are exceeded.

At measurements aside the antennae higher values are obtained in the following cases:

- when a part of the antenna faces the roof;
- at small height of antenna mounting;
- at presence of conducting surfaces near the antenna.

Results from measurements aside the antennae are presented in Table 3.

Table 3. Results from measurements aside the antennae

Distance (m)	S_{\min} ($\mu\text{W}/\text{cm}^2$)	S_{\max} ($\mu\text{W}/\text{cm}^2$)
1	2.0	15.0 (40.0)*
2	0.5	30.0* (30-100)*
5	0.5	30.0 (60.0)*
10	1.5	7.0 (30)*

* The values refers to antennae mounted on lower poles (up to 2 m) facing the interior of the roof.

The measurements behind the antennae reveal low EMF values, within the hygienic limits. Results from such measurements are presented in Table 4.

Table 4. Results from measurements behind the antennae

Distance (m)	S_{\min} ($\mu\text{W}/\text{cm}^2$)	S_{\max} ($\mu\text{W}/\text{cm}^2$)
1	0.5	4.0
2	0.5	7.5
3	0.5	4.0
5	0.5	2.0 (10.0)*

* The values are due to the effect of another sectoral antenna.

Behind the antennae comparatively high EMF values have been measured – up to $60 \mu\text{W}/\text{cm}^2$, due to emissions from other EMF sources, often of unknown origin.

'Hot spots' have been detected by standard measurement methods. They are areas with relatively higher RF fields intensity and are associated with the presence of conductive objects/surfaces near the antennae creating a complex field configuration. At that the EMF is characterised by very quick changes of its intensity with the distance from the source. Some of the studied roofs showed conditions for 'hot spots'. When detecting them measures were recommended for avoiding stay at such places of the roof.

Base stations with antennae mounted on slope roofs. The antennae are mounted on poles situated at hard to access roofs (usually tiled). The measurements were made in penthouses (in the sub-roof space) at 5-6 m from the antennae, in residential premises and halls between them and in front of the building itself. The results of the measurements in penthouses are from 0.5 to 2.0 $\mu\text{W}/\text{m}^2$, and in front of the building – up to 2.5 $\mu\text{W}/\text{m}^2$.

Base stations mounted on facades. At mounting antennae on facades there are two cases setting different sites of measurement for determination of the possibilities for irradiation of the population:

1. Near the antenna there are no windows of residential premises. In this case the measurements are made behind and over the emitting antennae. Values from 0.5 to 2.0 $\mu\text{W}/\text{m}^2$ were recorded, i.e. below the limits set in Bulgaria.

2. Near windows of residential premises. In this case measurements were made in the premises near the antenna and by the nearest window. The maximal values from such measurements are:

- 4.0 $\mu\text{W}/\text{m}^2$ in the premises, and
- 8.0 $\mu\text{W}/\text{m}^2$ by the open windows of the premises.

Antennae of base stations mounted on iron-grid towers. In this case the base stations are usually situated on uninhabited territories – mainly in mountains, agricultural lands and near to roads. The mounting height is 12 to 45 m.

The measurements were made from terrain elevation at different distances from the antennae projections. The results are presented in Table 5.

Table 5. Results from measurements around base stations on iron-grid towers

Distance (m)	S_{\min} ($\mu\text{W}/\text{cm}^2$)	S_{\max} ($\mu\text{W}/\text{cm}^2$)
10	0.5	2.0
20	0.5	8.0
30	0.5	5.5

In most cases the power density values measured near the towers are low (under 2 $\mu\text{W}/\text{cm}^2$). Single higher values are found – up to 25 $\mu\text{W}/\text{m}^2$, they are detected to be due to induced currents in the measuring equipment by high voltage power lines.

In single cases the towers with antennae are situated in courtyards of residential buildings. In these cases measurements were made in the living premises of the adjacent houses. There values significantly lower than the hygienic limits for residential areas were recorded – 0.5-1.0 $\mu\text{W}/\text{m}^2$.

Measurements in living premises. Here we present measurements in living premises situated right below the base station antennae and in buildings opposite to them. The results are presented in Table 6.

Table 6. Results from measurements in living premises

Measurement site	In flats S ($\mu\text{W}/\text{cm}^2$)	On terraces S ($\mu\text{W}/\text{cm}^2$)
In living premises on the floor just below the antenna	$0.5 \div 1.5$	$1.5 \div 3.0$
In residential premises opposite antennae	$0.5 \div 4.0$	$1.0 \div 3.0$

The recorded values for the studied living premises are lower than the hygienic limits for population.

Results from studies in other countries. Studies in Moscow¹⁰ covering more than 100 base stations show the following results presented in Table 7.

Table 7. Results from studies in Moscow

Measurement site	S_{max} ($\mu\text{W}/\text{cm}^2$)
Upper floor of buildings with mounted antennae	0.69
Premises of buildings of first line around base stations	0.93

Studies in Sweden¹¹, covering base stations and other communication sources on the territory of the country show the following results presented in Table 8.

Table 8. Results from studies in Sweden, covering base stations and other communication sources

Measurement site	Town	Suburbs	Village area	Residential premises	Total
S_{cp}	0.08	0.034	0.16	0.55	0.05

Studies of 26 base stations in Finland¹¹ show the following values – Table 9.

Table 9. Results from studies of 26 base stations in Finland

Measurement site	Maximal values ($\mu\text{W}/\text{cm}^2$)
Cities	0.301
Towns	0.005
Villages	0.001
Indoor	0.001
Offices	0.370

Studies of the Agency for Radiation Protection and Nuclear Safety of Australia¹⁰ show a maximal level of power density as a result of irradiation by base stations (in living premises) – 0.082 $\mu\text{W}/\text{m}^2$.

The results of the presented studies show that in most cases the EMF power density around base stations is below the hygienic limits. The presented data can not be directly compared to our results because the measurements applied different equipment, with various sensitivity and measurement range although the data are of similar order.

CONCLUSIONS

The presented results of EMF measurements around base stations for mobile communications show that in most cases the measured values conform with the Bulgarian hygienic limits in force. This result is important, relaxing for the population and the mobile operators, and is due mainly to the fact that the regulations for preliminary sanitary control in Bulgaria are strictly observed.

The experience from similar measurements in Bulgaria and all over the world shows that at a few meters away from the antenna there can be areas in which the hygienic limits for the population are exceeded. Usually this is due to the following factors:

- mounting of the base station antennae at low poles (small height versus the level of the roof surface);
- geometry creating conditions for ‘hot spots’;
- inadequate adjusting of the irradiation cone versus the building – carrier and neighbouring buildings;
- presence of background from other sources, emitting in the area of base stations antennae in close frequency bands.

The question in this case is whether the high EMF values can generally be considered as unconformity with the limits as most often the cases refer to roofs of residential buildings where population stay are only incidental or associated with repair activities. And, if there is unconformity – what measures shall be undertaken? At established unconformities the global as well as the Bulgarian practice is to recommend the placing of fences and precaution inscriptions for restriction of population access to places where the hygienic limits are exceeded. Such action is efficient at observing the limitations, i.e. population exposure to above-standard EMF levels is avoided.

The issue of the effect of the EMF from base station antennae and additional EMF sources in the area of mounting the base stations on the operators’ employees – those that maintain and service the stations – is insufficiently studied.

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