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Full Length Research Paper

Mapping of electromagnetic pollution at 1800 MHz GSM (global system for mobile communication) frequency in Konya

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Mobile phones are a vital part of daily life; thus, the rate of usage of mobile phones is increasing on a daily basis. Because they work in connection with base stations, number of base stations has to be boosted as long as the trend in the use of them continues. Because each base station runs by radiating electromagnetic waves, this is a disturbing condition for people from a medical point of view. Thus, it is important to analyze radiation of base stations until we are sure that they are definitely non-harmful in the long term. Mapping of electromagnetic pollution from base stations may be of much importance in this context. This paper aimed at mapping the electromagnetic pollution at 1800 MHz in Konya. To do this, electromagnetic radiation from base stations was measured at 185 points in Konya. Then, electromagnetic pollution maps were accomplished by uniting transactions like database query, statistical analysis with visualization and maps-based spatial analysis. They provide useful information to enable us to analyze and explain some probable health problems, which may be caused by GSM (global system for mobile communication) radiation in future.

Key words: Electromagnetic pollution, GSM, base stations GIS, geographic information system, mapping.

INTRODUCTION

While developing information technology is providing continuous information flow to people, the use of information technology requirements are born to take advantage in increasing the volume of information efficiently and to take healthy decisions. The need to reach correct and necessary information as soon as possible constitutes the geographic information system (GIS). Using Geographical Information Systems in solving the environmental problems is one of the most powerful and most successful application areas. The risk factor of electromagnetic pollution for environment and human health has been discussed by many scientists and a lot of research has been done in developed countries. As a result of technological developments in the world, the trend to geographic information technology is continuously increasing in our country. Also, GIS has been used for electromagnetic pollution in some studies (Ammoscato et al., 2008; Garcia et al., 2003; Gumusay et al., 2007; Sen et al., 2008). In particular, the need for rapid analysis of different contents in same geographical area is considered important as a decision-support tool for the individuals, in addition to public institutions and organizations.

Mobile phones are very important in our daily lives (Inskip et al., 2001). Their usage is continually increasing. Their manufacturers try to benefit from this situation by adding new features to cell phones. They connect each other through base stations that are mounted at specific points in the cities. Thus, base stations radiate electromagnetic energy all day. This means that electromagnetic pollution problem has been added to environmental problems such as air pollution and noise pollution (Chen et al., 2009). Research into health risk due to radiation from mobile phones and base stations is still continuing. These risks include some important diseases such as cancer and tumor growth (Inskip et al., 2001; Hardell et al., 1999; Kan, 2007). Conclusive results on the impacts of these risks have not yet been reached. However, this does not mean that radiation at GSM

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frequencies (900 and 1800 MHz) is not dangerous to human health. According to World Health Organization (WHO) report, current scientific evidence indicates that exposure to RF fields, such as those emitted by mobile phones and their base stations, is unlikely to induce or promote cancers. Several studies on animals exposed to RF fields, which is similar to those emitted by mobile phones, found no evidence that RF causes or promotes brain cancer. However a 1997 study found that RF fields increased the rate at which genetically engineered mice developed lymphoma, the health implications of this result is unclear. Several studies are underway to confirm this finding and determine any relevance of these results to cancer in human beings (World Health Organization). As a result, international standards that limit the amount of electromagnetic radiation have been established, and mobile phone manufacturers and service providers must mind these standards. The limit value of radiation at 1800 MHz frequency was determined as 58 V/m or 9 W/m^2 for the general public by ICNIRP (International Commission on Non-Ionizing Radiation Protection) (Ahlbom et al., 1998).

Because the health risks may still be present, there is need for continuous research into these topics. Moreover, many studies on reducing the effect of radiation directed toward the cell phone users has been conducted (Park et al., 2003; Seyfi and Yaldiz, 2006; Seyfi and Yaldiz, 2008a, b, c; Karthikeyan et al., 2009).

In recent years, the rapid increase in the use of mobile phones requires the planning and establishment of many new base stations each year. Although people do not want it, establishment of base station antenna to the roof of apartment, building side, gardens of school and hospital arise discussions and complaints. Therefore, determination of the severity of electromagnetic field near a base station and informing public about potential impact of the electromagnetic fields and protection methods, are required. In addition, creating centers by the relevant authorities is fairly important, to which the complaints about the base station can be easily transmitted to and resolved in.

Recently, various studies regarding the determination of electromagnetic pollution are being constructed (Genç et al., 2010; Paolino et al., 2001; Ammoscato, 2008). Furthermore, our previous paper evaluates the electromagnetic pollution at 900 MHz GSM frequency (Uygunol and Durduran, 2010).

The first phase of this study should be the creation of maps showing the pollution load of the region. Therefore, the level of pollution is visual and it helps the public more healthy and clearly to be notified. Thus, low, medium, and much polluted area can be clearly defined, and sub-structure of measures to be applied in the future in these areas can be created. In addition, these maps can be used to define planning of city placement in order not to constitute electromagnetic pollution problem in the future. This study intended to put forward the possible resources of problem, to proffer solutions and to demonstrate the electromagnetic pollution on the map by taking advantage of Geographic Information System technology.

METHODS

In this study, measurements were made with a portable electro-magnetic field meter in many different regions of Konya where the electromagnetic pollution can be high and GSM base stations is densely located (Uygunol and Durduran, 2009). The electr-omagnetic field measurement device (Spectran ® HF-6080) is fully automatic and computer-controlled operable. This device can measure the total radiation between 100 MHz - 3 GHz frequencies, which may come from any electromagnetic source (radio / TV transmitters, GSM networks, microwave ovens, etc...). It can also show the frequency spectrum of the radiation measured.

Selçuklu, Karatay, and Meram central districts were selected as the study area in Konya city center to prepare the map of the electromagnetic pollution. The province of Konya is located on longitudes 36.5 - 39.50° north and latitudes 31.5 - 34.50° east. General location of the city of Konya in Turkey is given in Figure 1. Konya is the largest province of Turkey with its 38.183 m^2 area. Measurements were conducted at a distance of 20 m from the base stations during six minutes for each one at 185 different points in these regions where base stations of GSM companies are located. Measured data has been used to make interpolation over complete area in the IDW (Inverse Distance Weighted) module of ArcGIS software. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. Thus, new values can be found by IDW method. This method assumes that each point has a regional effect and this effect is inversely proportional to the distance between interpolation point and measurement point. Similarly, ArcGIS software was used to make a map from the data.

RESULTS

During measurements, electromagnetic fields at 1800 MHz frequency formed by the base stations and the region coordinates of base stations were identified by using the electromagnetic field meter and a handheld GPS. The resulting data and measurement values, which are shown in Table 1, were entered in ArcGIS 9.2 software and raster data that shows extensive electro-magnetic pollution in the region was obtained. The area having intense electromagnetic fields was determined by combining this data with digital map of Konya city center. Maps showing radiation pollution levels in different colours have been set up, by using the data obtained. Through this map, health risk areas were identified easily in neighbourhoods and in districts.

In the map in Figure 2, highlighting of electromagnetic field levels from the base station according to the amount is shown by using the measured values at 1800 MHz frequency. In the map in Figure 3, symbolized electro-magnetic field levels at 1800 MHz frequency from the base station according to the amount are shown by using the measured values.

In Figure 4, 3-dimensional electromagnetic pollution map generated from the measured values at 1800 MHz

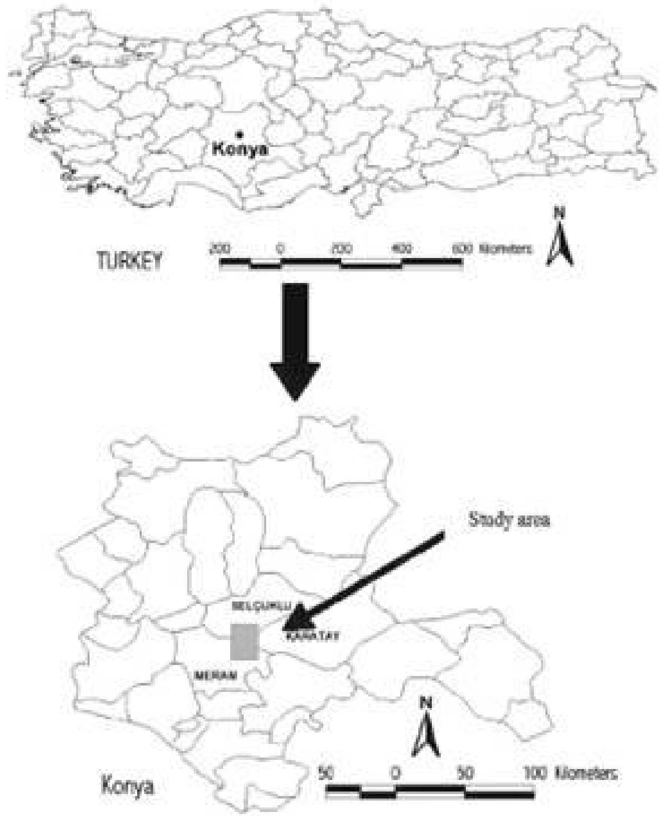

Figure 1. General location of the city of Konya in Turkey.

Table 1. Measurement values of electromagnetic field from GSM base stations.

Region	Number of point	Measurement values (µW/m^2)	Measurement value (Percentage of limit value, %)
SELCUKLU	1	3.45	3.8E-05
SELCUKLU	2	4.67	5.2E-05
SELCUKLU	3	8.83	9.8E-05
SELCUKLU	4	4.67	5.2E-05
SELCUKLU	5	11.21	1.2E-04
SELCUKLU	6	6.48	7.2E-05
SELCUKLU	7	10.07	1.1E-04
SELCUKLU	8	11.74	1.3E-04
SELCUKLU	9	14.31	1.6E-04
SELCUKLU	10	65.49	7.3E-04
SELCUKLU	11	4.31	4.8E-05
SELCUKLU	12	18.41	2.0E-04
SELCUKLU	13	12.87	1.4E-04
SELCUKLU	14	45.81	5.1E-04
SELCUKLU	15	122.65	1.4E-03
SELCUKLU	16	2.54	2.8E-05
SELCUKLU	17	1.13	1.3E-05
SELCUKLU	18	21.38	2.4E-04
SELCUKLU	19	22.56	2.5E-04
SELCUKLU	20	32.62	3.6E-04
SELCUKLU	21	21.12	2.3E-04

Table 1. Contd.

SELCUKLU	22	6.75	7.5E-05
SELCUKLU	23	0.98	1.1E-05
SELCUKLU	24	81.44	9.0E-04
SELCUKLU	25	0.38	4.2E-06
SELCUKLU	26	28.41	3.2E-04
SELCUKLU	27	0.15	1.7E-06
SELCUKLU	28	104.43	1.2E-03
SELCUKLU	29	17.92	2.0E-04
SELCUKLU	30	35.3	3.9E-04
SELCUKLU	31	0.19	2.1E-06
SELCUKLU	32	0.69	7.7E-06
SELCUKLU	33	170.01	1.9E-03
SELCUKLU	34	27.62	3.1E-04
SELCUKLU	35	38.52	4.3E-04
SELCUKLU	36	260.35	2.9E-03
SELCUKLU	37	98.55	1.1E-03
SELCUKLU	38	280.35	3.1E-03
SELCUKLU	39	23.71	2.6E-04
SELCUKLU	40	8.62	9.6E-05
SELCUKLU	41	0.88	9.8E-06
SELCUKLU	42	32.38	3.6E-04
SELCUKLU	43	126.32	1.4E-03
SELCUKLU	44	0.69	7.7E-06
SELCUKLU	45	216.32	2.4E-03
SELCUKLU	46	4.87	5.4E-05
SELCUKLU	47	35.89	4.0E-04
SELCUKLU	48	0.54	6.0E-06
SELCUKLU	49	117.43	1.3E-03
SELCUKLU	50	74.2	8.2E-04
SELCUKLU	51	8.68	9.6E-05
SELCUKLU	52	4.95	5.5E-05
SELCUKLU	53	8.91	9.9E-05
SELCUKLU	54	5.9	6.6E-05
SELCUKLU	55	3.68	4.1E-05
SELCUKLU	56	7.62	8.5E-05
SELCUKLU	57	25.3	2.8E-04
SELCUKLU	58	1.68	1.9E-05
SELCUKLU	59	0.14	1.6E-06
SELCUKLU	60	3.05	3.4E-05
SELCUKLU	61	0.18	2.0E-06
SELCUKLU	62	16.75	1.9E-04
SELCUKLU	63	23.71	2.6E-04
SELCUKLU	64	0.83	9.2E-06
SELCUKLU	65	181.31	2.0E-03
SELCUKLU	66	156.21	1.7E-03
SELCUKLU	67	380.35	4.2E-03
SELCUKLU	68	15.92	1.8E-04
SELCUKLU	69	0.38	4.2E-06
SELCUKLU	70	188.55	2.1E-03
SELCUKLU	71	0.59	6.6E-06
SELCUKLU	72	0.58	6.4E-06
SELCUKLU	73	1.58	1.8E-05
SELCUKLU	74	4.68	5.2E-05
SELCUKLU	75	37.62	4.2E-04
SELCUKLU	76	13.71	1.5E-04
SELCUKLU	77	15.24	1.7E-04

Table 1. Contd.

SELCUKLU	78	28.41	3.2E-04
SELCUKLU	79	28.52	3.2E-04
SELCUKLU	80	0.73	8.1E-06
SELCUKLU	81	5.79	6.4E-05
SELCUKLU	82	6.75	7.5E-05
SELCUKLU	83	0.36	4.0E-06
SELCUKLU	84	31.44	3.5E-04
SELCUKLU	85	500.71	5.6E-03
MERAM	86	3.95	4.4E-05
MERAM	87	107.43	1.2E-03
MERAM	88	18.41	2.0E-04
MERAM	89	6.75	7.5E-05
MERAM	90	5.65	6.3E-05
MERAM	91	1.84	2.0E-05
MERAM	92	0.78	8.7E-06
MERAM	93	47.62	5.3E-04
MERAM	94	6.43	7.1E-05
MERAM	95	141.31	1.6E-03
MERAM	96	19.45	2.2E-04
MERAM	97	0.5	5.6E-06
MERAM	98	0.42	4.7E-06
MERAM	99	23.92	2.7E-04
MERAM	100	23.54	2.6E-04
MERAM	101	0.22	2.4E-06
MERAM	102	25.89	2.9E-04
MERAM	103	25.24	2.8E-04
MERAM	104	55.59	6.2E-04
MERAM	105	9.14	1.0E-04
MERAM	106	7.87	8.7E-05
MERAM	107	281.67	3.1E-03
MERAM	108	0.69	7.7E-06
MERAM	109	0.84	9.3E-06
MERAM	110	143.95	1.6E-03
MERAM	111	7.42	8.2E-05
MERAM	112	4.74	5.3E-05
MERAM	113	0.77	8.6E-06
MERAM	114	0.86	9.6E-06
MERAM	115	21.45	2.4E-04
MERAM	116	22.57	2.5E-04
MERAM	117	0.66	7.3E-06
MERAM	118	129.05	1.4E-03
MERAM	119	1.32	1.5E-05
MERAM	120	0.43	4.8E-06
MERAM	121	31.67	3.5E-04
MERAM	122	0.33	3.7E-06
MERAM	123	0.35	3.9E-06
MERAM	124	11.54	1.3E-04
MERAM	125	674.61	7.5E-03
MERAM	126	0.57	6.3E-06
MERAM	127	0.25	2.8E-06
MERAM	128	13.25	1.5E-04
MERAM	129	43.25	4.8E-04

Table 1. Contd.

MERAM	130	31.67	3.5E-04
MERAM	131	0.94	1.0E-05
MERAM	132	194.38	2.2E-03
MERAM	133	1.23	1.4E-05
MERAM	134	0.54	6.0E-06
MERAM	135	71.26	7.9E-04
MERAM	136	0.44	4.9E-06
MERAM	137	56.47	6.3E-04
MERAM	138	0.65	7.2E-06
MERAM	139	0.45	5.0E-06
MERAM	140	3.57	4.0E-05
MERAM	141	64.78	7.2E-04
MERAM	142	1.34	1.5E-05
MERAM	143	8.46	9.4E-05
MERAM	144	14.53	1.6E-04
MERAM	145	22.34	2.5E-04
KARATAY	146	0.46	5.1E-06
KARATAY	147	16.46	1.8E-04
KARATAY	148	0.45	5.0E-06
KARATAY	149	93.56	1.0E-03
KARATAY	150	4.37	4.9E-05
KARATAY	151	0.34	3.8E-06
KARATAY	152	9.76	1.1E-04
KARATAY	153	15.89	1.8E-04
KARATAY	154	12.15	1.4E-04
KARATAY	155	31.65	3.5E-04
KARATAY	156	1.22	1.4E-05
KARATAY	157	112.34	1.2E-03
KARATAY	158	23.56	2.6E-04
KARATAY	159	2.32	2.6E-05
KARATAY	160	1.02	1.1E-05
KARATAY	161	3.43	3.8E-05
KARATAY	162	25.29	2.8E-04
KARATAY	163	15.91	1.8E-04
KARATAY	164	1.13	1.3E-05
KARATAY	165	277.81	3.1E-03
KARATAY	166	101.44	1.1E-03
KARATAY	167	2.34	2.6E-05
KARATAY	168	1.34	1.5E-05
KARATAY	169	45.63	5.1E-04
KARATAY	170	0.75	8.3E-06
KARATAY	171	78.45	8.7E-04
KARATAY	172	34.45	3.8E-04
KARATAY	173	1.24	1.4E-05
KARATAY	174	0.28	3.1E-06
KARATAY	175	22.16	2.5E-04
KARATAY	176	0.32	3.6E-06
KARATAY	177	22.38	2.5E-04
KARATAY	178	19.57	2.2E-04
KARATAY	179	73.42	8.2E-04
KARATAY	180	101.36	1.1E-03
KARATAY	181	16.62	1.8E-04

Table 1. Contd.

KARATAY	182	5.59	6.2E-05
KARATAY	183	202.43	2.2E-03
KARATAY	184	160.01	1.8E-03
KARATAY	185	20.07	2.2E-04

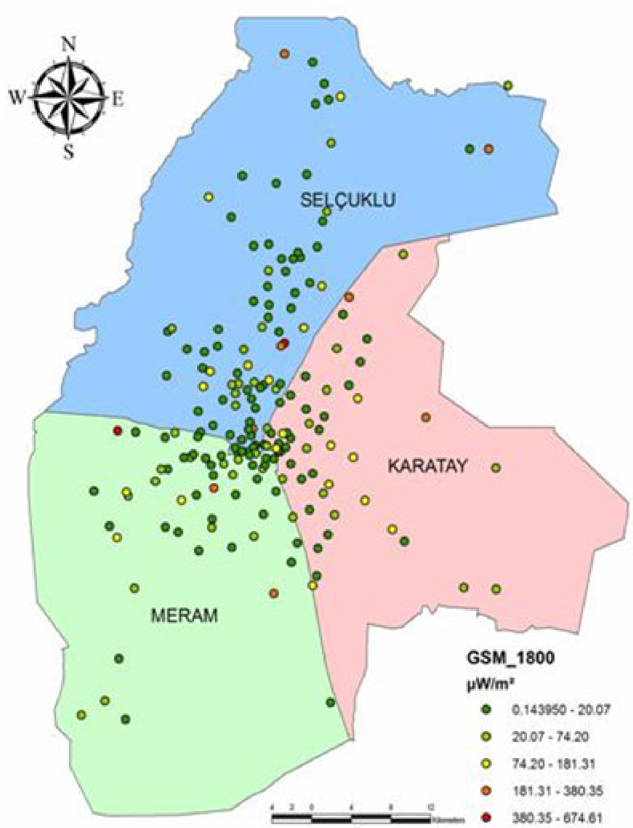

Figure 2. Coloring of the measured values at 1800 MHz frequency (ED_1950_UTM_Zone_36N datum, 3° Universal Transverse Mercator projection).

frequency is shown. The population of Konya is nearly 850,000. Some regions in Meram, Selçuklu and Karatay were determined as relatively high radiation regions.

DISCUSSION

Countries usually use GIS to recognize and identify natural-resource potential, to recognize and carry out maintenance, repairing of the infrastructure and utility of local governments. The electromagnetic pollution map can be created very well by designing an information system at any place, depending on the level of electro-magnetic field.

As a result of the radiation measurements, it has been observed that there is no base station that exceeds the specified limits. However, it has been found that some base stations had relatively higher radiation values compared to the others.

Akyokuş, Anadolu Sanayi, around Meram Sanayi, Mobilyacilar Site, and Selcuk University dormitory were observed to have relatively higher radiation values.

Conclusively, site selection and design is important for base station installations. It cannot scientifically be said that obeying limit values can fully prevent damage in long term. However, running below limit values help evading health damage.

Technically, usage of GSM base stations will be inevi-table to use mobile phone. Therefore, measurement of electromagnetic pollution level, and taking precautions against possible dangers need to be evaluated further in the future.

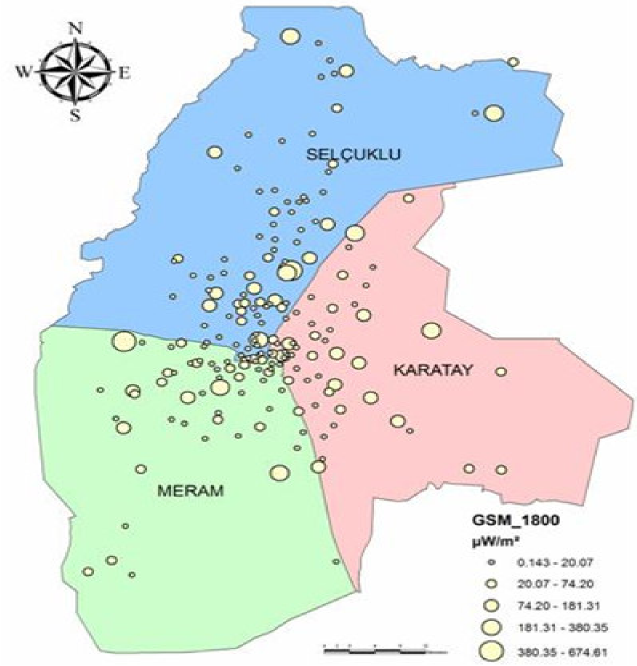

Figure 3. Symbolizing of the measured values at 1800 MHz frequency (ED_1950_UTM_Zone_36N datum, 3° Universal Transverse Mercator projection).

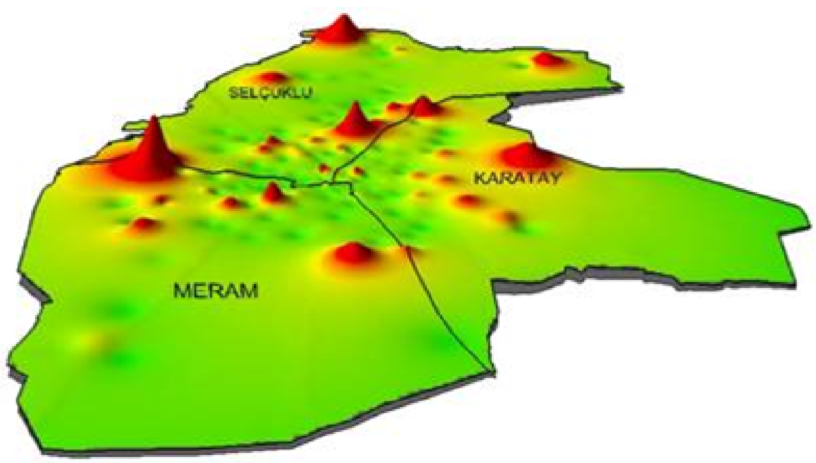

Figure 4. 3-dimensional representation of measured values at 1800 MHz frequency.

Electromagnetic pollution maps have been created with GIS and they may be used to make risk assessment by the relevant institutions to inform the public in future. For instance, various warning signs can be placed around base station at open areas according to electromagnetic field intensity depending on created electromagnetic pollu tion map. And also, the distance of base stations from schools, hospitals, and etc. can be checked. Furthermore, some studies can be carried out by using electromagnetic pollution map to determine what kind of health conditions may reveal at regions having high radiation value.

In this study, the measurements were made in the central districts of Konya. Similar studies can be made in other major cities, which have concentrated population. Along with the base stations, high voltage lines, transformers, television and radio transmitters can be included to the research and their effects on human health can be analyzed at GIS environment. A large number of GSM base stations will technically be required as long as people use mobile phones. Therefore, electromagnetic shielding paint or electromagnetic shielding weaving can be used to protect against possible health effects of electromagnetic fields. The lowest level of damage can be reached by using electromagnetic shielding products at areas having high level electromagnetic pollution in the map or having base stations located near schools, kindergartens, hospitals, parks, etc. Additionally, women and their babies who live in buildings that are located near the base stations may be protected from potential damage of electromagnetic fields by using woven garments electromagnetic shielding during pregnancy.

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