IOP Conf. Series: Materials Science and Engineering **106** (2016) 012037 doi:10.1088/1757-899X/106/1/012037

RF waves - Measuring their energy (dBm) in three points into Baia Mare, Romania

A Pop-Vădean[1], P P Pop[1], C Barz[2] and C Lung[2]

[1]Technical University of ClujNapoca, Department of Mechatronics and Machine Dynamics, Muncii str., no. 103-105, 400641 ClujNapoca, Romania
[2]Technical University of Cluj-Napoca, North University Center of Baia Mare, Romania

E-mail: adinaluciapopvadean@yahoo.com

Abstract. For the general public - and even for people with a science education - knowing to be subject to Radio Frequency (RF) radiation may arouse a feeling of uneasiness or even fear. Those feelings are instigated by the fact that you cannot see, hear, smell or feel RF radiation. Furthermore, the term „radiation" in itself has become very sensitive from the moment that the hazardous health effects of excessive radioactive decay (ionizing radiation) have become apparent. Media announcements of mostly unconfirmed scientific studies add to the feeling of uneasiness. So, naturally, whenever a new Global System of Mobile communications (GSM) base station is installed in an urban environment, the people living in the neighborhood may get worried. The same applies when we propose to use RF radiation for powering wireless sensors in office and home spaces using harvesting energy sistem (HE).In this paper we determine if the electromagnetic field intensity values, measured at certain points, respect the limits set by law, the protection against risks to human health.

1. Introduction

I chose this topic because of the growing interest for such measurements as RF sources are more and more. In cities and very populated areas there is a large number of potential RF sources: broadcast radio and tv, mobile telephony, wireless networks, etc.

Today over 80% of the population uses mobile phone and radio and television stations have a wider coverage for a growing number of channels. This is possible by increasing the number of base stations that provide a growing number of GSM cellule and by increasing the number of radio and television stations.

This paper discusses methods for measuring the field strength fixed in 30MHz-1 GHz frequency band. Frequency band that uses these methods, is designed band signals broadcasting, television and mobile telephony.

2. Field strength measurement. Mathematical relations

To evaluate the feasibility of the amount of energy that can be purchased (energy harvesting) from the environment (where RF is radio frequency) in the vicinity of a GSM base station BTS and compliance permissible limits the transmission power, we performed measurements of the electromagnetic field intensity fixed located in the University (North University of Baia Mare Centre of Technical University of Cluj Napoca). The mobile phone system measurements are made to determine the

IOP Conf. Series: Materials Science and Engineering **106** (2016) 012037 doi:10.1088/1757-899X/106/1/012037

electromagnetic field strength in dBm for each radio channel in the frequency spectrum of a base station BTS but it is useful to determine the power density of the electromagnetic field, which is expressed in W/m². For this reason the values measured in dBm are converting in W/m². For measured values seems that is posible to be enough energy from the environment to supply a sensor.

General Conditions for measuring the electromagnetic field intensity are stipulated by International Regulation. These rules have been adopted as National Standards. The methods used for measuring the electromagnetic field intensity in fixed are those that respect the procedures developed by the National Authority for Management and Regulation in Communications.

The growth trend stations radiofrequency and communications services operators the power increase over the permitted limits, to have greater coverage with fewer sites, can lead to disturbances in other stations or even overcoming limits absorbance power permissible power of the human body.

To avoid such situations, both at commissioning and annual measurements are taken to verify it in the permitted limits. Measurements are performed using methods treated in this paper.

Electronic measurements should be concentrated for the investigation of RF electromagnetic field spectrum broadcasting field intensity and variation in coverage of local channels or cable transmission of radio and television frequencies in the 40MHz and 1GHz range. Specific measurements performed on the RF stations is that for each type of communication signal occupies a certain frequency band. In Table 1 below shows the minimum bandwidth for all types of RF signals transmitted by stations [1], [2].

Table 1. Minimum bandwidth for all types of RF signals transmitted by stations

Signal Type	Minimum bandwidth (kHz)
Double sideband AM	9
Single sideband AM	2.4
FM sound broadcasting	120
Narrow-band FM channel spacing: 12.5 kHz 20 kHz 25 kHz	 7.5 12 12
analog TV	200
GSM	200

E - electric field strength is measured, V_o induce a voltage across the antenna. The relationship between electric field strength and voltage induced in the antenna is a function of frequency. Antenna factor is denoted by K is equal to:

$K=E/V_o$

where:

-K Is the electrical component of the electromagnetic field intensity (μV / m);

-V_o Is the output voltage across its nominal impedance antenna (μV)

An isotropic antenna gain Gi note or a dipole antenna in λ / 2 note to Gd is frequently used in practice than K. Relation between antenna factor of antenna gain and antenna factor is:

• nominal resistance load antenna, RN = 50Ω;

$$K = \frac{f/MHz}{30.81 * \sqrt{G_d}} \qquad K = \frac{f/MHz}{39.47 * \sqrt{Gd}}$$

• nominal resistance load antenna, RN = 75Ω;

$$K = \frac{f/MHz}{37.75 * \sqrt{Gi}} \qquad K = \frac{f/MHz}{48.34 + \sqrt{Gd}}$$

Formulas used to calculate antenna factor can be expressed in logarithmic form:
• nominal resistance load antenna, RN = 50Ω
k=-29.77dB-gi/dB+20log(f/MHz)
k=-31.93dB-gd/dB+20log(f/MHz)
• nominal resistance load antenna, RN = 75Ω
k=-31.54dB-gi/dB+20log(f/MHz)
k=-33.69dB-gd/dB+20log(f/MHz)
where:
- gi is relative to isotropic antenna (dB);
- gd is related to the dipole g λ / 2 (dB);
- g -10logG (dB);

Taking into account a_f ,a_c and field strength can be written in logarithmic form:
e / dB (µV / m) = v_o / dB (µV) + k / dB (m $^{-1}$) + a_c /dB +a_f/ dB ,
where:
- e is the electric component of electromagnetic field strength (dBµV / m);
- a_c is cable attenuation (dB)
- a_f is the attenuation produced by attenuator, filter and amplifier (dB)

3. Measuring electromagnetic field intensity emitted by a television station

The measurement system has a symmetrical dipole antenna TV suitable parameters frequency range in which measurements are made to capture the electromagnetic field emitted by a television station. The relevant characteristics are measured electromagnetic field spectral analyzer. Measurement results can be processed with computer [3].

The regulations relevant international bodies on the medium and minimum intensity radiofrequency field generated by television transmitters in reception points are shown in Table 2. Radiofrequency field level is expressed in dBµV / m (the intensity) or dBmW (for power), often using those notations dBm and dBµV [4], [5].

Table 2. Average and minimum intensity radiofrequency field generated by television transmitters in points reception

Conditions of reception		Band	I	III	IV	V
Intensity average interference protection	Urban environment	dB[µV/m]	+48	+55	+65	+71
	Rural area without disturbance	dB[µV/m]	+46	+49	+58	+64
Minimum intensity satisfactory TV picture Q = 3	Urban environment	dB[µV/m]	+47	+53	+62	+67
	Rural area without disturbance	dB[µV/m]	+40	+43	+52	+58

For television broadcasting power to determine the amplitude and the image carrier, the carrier sound, luminance signal component and chromite. The longer determine the bandwidth and frequency difference between the sound signal and image signal. Complex video signal bandwidth of 8MHz, Norm CCIR-G, D / K [6].

IOP Conf. Series: Materials Science and Engineering **106** (2016) 012037 doi:10.1088/1757-899X/106/1/012037

4. Field strength measurement for GSM BTS station

GSM mobile phone system is designed as a cellule radio network, each cell is covered with radio signal from a base station BTS (Base Transceiver Station). Each BTS consists of a set of transceiver equipment for each assigned radio channel. Frequency band allocated to mobile radio communications is 890-915 MHz for mobile phone communication from the BTS and BTS 935-960MHz for communication from the mobile phone. Each transmission direction is allocated a frequency band of 25 MHz. Thus obtained 124 radio channels, which can achieve 124 simultaneous mobile communications. Channels of communication are based on a structure in time division multiplex TDMA / CDMA radio implemented on a carrier frequency. For this reason in GSM telephone system taking measurements to determine the strength of the electromagnetic field in dBm for each radio channel in the frequency spectrum of a base station BTS. Because at high frequencies, close to 1 GHz, there are minimum requirements to protect against risks to human health, established by legislation, it is useful to determine the power density of the electromagnetic field, which is expressed in W / m^2. For this reason in the following tables converting measurement of electromagnetic field strength for each radio channel in the frequency spectrum of a base station measured in dBm, the values of the electromagnetic field power density, expressed in W / m^2.

5. Results

Given the specifics of the study we conducted measurements of electromagnetic field intensity for GSM BTS station in fixed locations located in the University of Baia Mare. Measurements were performed with Agilent E4402B spectrum analyzer and measure Log-periodic antenna, model 3148 EMCO, channels network operators Orange, Vodafone show in Tables 3, 3.1, 4 and 4.1 [7], [8].

Table 3. Results

F	G	H	I	J	K	L
	channel width 0.2 MHz		Ka (antenna factor) 24		958.4 956.2 957 951	
			Ac (cable attenuation) 3		frecv [MHz]	949.6 953.6
					951.4	
measuring points	Placement of the measured				951.8 954.4 952.6	
1	Str. Victor Babeş, no.41					
2	Platouliceu nr.1					
3	Platoucămin					
4						
5	**SC Orange România SA**					
Values measured in dBm						
F MHz	Pct. 1	Pct. 2	Pct. 3			
958.4	-50	-64	-70			
956.2	-53	-65	-58			
957	-49	-61	-67			
951	-62	-69	-77			
949.6	-52	-63	-52			
953.6	-60	-61	-51			
951.4	-69	-69	-60			
951.8	-68	-52	-59			
954.4	-59	-57	-63			
952.6	-57	-67	-59			

Table 3.1. Orange measurements

	A	B	C	D
1	measuring point no. 1 –Str. Victor Babeş no. 41			
2	Freq[MHz]	dBm/0.2 MHz	PFD dB(W/m2)	PFD w/m2
3	958.4	-61	-72.77	0.000000052845
4	956.2	-53	-64.77	0.000000333426
5	957	-49	-60.77	0.000000837529
6	951	-62	-73.77	0.000000041976
7	949.6	-52	-63.77	0.000000419759
8	953.6	-60	-71.77	0.000000066527
9	951.4	-69	-80.77	0.000000008375
10	951.8	-68	-79.77	0.000000010544
11	954.4	-59	-70.77	0.000000083753
12	952.6	-57	-68.77	0.000000132739
13	measuring point no. 2 – Platouliceu nr. 1			
14	Freq[MHz]	dBm/0.2 MHz	PFD dB(W/m2)	PFD w/m2
15	958.4	-64	-75.77	0.000000026485
16	956.2	-65	-76.77	0.000000021038
17	957	-61	-72.77	0.000000052045
18	951	-69	-80.77	0.000000008375
19	949.6	-63	-74.77	0.000000033343
20	953.6	-61	-72.77	0.000000052845
21	951.4	-69	-80.77	0.000000008375
22	951.8	-52	-63.77	0.000000419759
23	954.4	-57	-68.77	0.000000132739
24	952.6	-67	-78.77	0.000000013274
25	measuring point no. 3 –Platoucămin			
26	Freq[MHz]	dBm/0.2 MHz	PFD dB(W/m2)	PFD w/m2
27	958.4	-70	-81.77	0.00000006653
28	956.2	-58	-69.77	0.00000105439
29	957	-67	-78.77	0.00000013274
30	951	-77	-88.77	0.00000001327
31	949.6	-52	-63.77	0.00000419759
32	953.6	-51	-62.77	0.00000528445
33	951.4	-60	-71.77	0.00000066527
34	951.8	-59	-70.77	0.00000083753
35	954.4	-63	-74.77	0.00000033343
36	952.6	-59	-70.77	0.00000083753

Table 4. Results

F	G	H	I	J	K	L
	channel width 0.2 MHz		Ka (antenna factor) 24		935,2 935,4 935,6 935,8 frecv 936 [MHz] 936,2 936,4	
			Ac (cable attenuation) 3			

Measuring points	Placement of the measured		
1	Str. Victor Babeş, no.41		
2	Platouliceu nr.1		
3	Platoucămin		
4			
5	**SC Vodafone SA**		
Values measured in dBm			
F MHz	Pct. 1	Pct. 2	Pct. 3
935.2	-42	-52	-48
935.4	-63	-60	-52
935.6	-50	-57	-50
935.8	-49	-59	-62
936	-61	-49	-70
936.2	-49	-53	-56
936.4	-57	-56	-52

Table 4.1. Vodafone measurements

1.	A	B	C	D
2.	measuring point no. 1 –Str. Victor Babeş no. 41			
3.	Freq[MHz]	dBm/0.2 MHz	PFD dB(W/m2)	PFD w/m2
4.	935.2	-45	-56.77	0.000002103778
5.	935.4	-63	-74.77	0.000000033343
6.	935.6	-50	-61.77	0.000000665873
7.	935.8	-49	-60.77	0.000000837529
8.	936	-61	-72.77	0.000000052845
9.	936.2	-49	-60.77	0.000000837529
10.	936.4	-57	-68.77	0.000000132739
11.	measuring point no. 2 – Platouliceul nr. 1			
12.	Freq[MHz]	dBm/0.2 MHz	PFD dB(W/m2)	PFD w/m2
13.	935.2	-52	-63.77	0.000000419759
14.	935.4	-60	-71.77	0.000000066527
15.	935.6	-57	-68.77	0.000000132739
16.	935.8	-59	-70.77	0.000000083753
17.	936	-49	-60.77	0.000000837529
18.	936.2	-53	-64.77	0.000000333426
19.	936.4	-56	-67.77	0.000000167109
20.	measuring point no. 3 – Platoucămin			
21.	Freq[MHz]	dBm/0.2 MHz	PFD dB(W/m2)	PFD w/m2
22.	935.2	-40	-59.77	0.000001054387
23.	935.4	-52	-63.77	0.000000419759
24.	935.6	-50	-61.77	0.000000665273
25.	935.8	-62	-73.77	0.000000041976
26.	936	-70	-81.77	0.000000006653
27.	936.2	-56	-67.77	0.000000167109
28.	936.4	-52	-63.77	0.000000419759

6. Other possible applications of RF

6.1. What is Rectenna

In cities and very populated areas there is a large number of potential RF sources: broadcast radio and tv, mobile telephony, wireless networks, etc. The problem is collecting all these disparate sources and converting them in useful energy. The conversion is based on a rectifying antenna also called rectenna.

A rectenna is a special type of antenna that is used to convert microwave energy into direct current electricity. They are used in wireless power transmission systems that transmit power by radio waves. A simple rectenna element consists of a dipole antenna with an RF diode connected across the dipole elements. The diode rectifies the AC current induced in the antenna by the microwaves, to produce DC power, which powers a load connected across the diode. Schottky diodes are usually used because they have the lowest voltage drop and highest speed and therefore have the lowest power losses due to conduction and switching. Large rectennas consist of an array of many such dipole elements.

Nowadays there is an active research area investigating a number of alternatives to extract energy energy from the environment and convert it to electrical energy to power an electronic device. Taken one by one, each alternative still provides a low level of energy compared to the power requirements of today's electronic devices, except for specific applications. However, it is expected that energy harvesting will have an important role in future microelectronic devices for a number of reasons.

6.2. RF Harvesting

Some RF harvesting converts electromagnetic radiation into electricity. This can be done in two ways.

• Make use of existing electromagnetic radiation (GSM, FM, WiFi)

• Broadcast an electromagnetic signal at a specific wavelength in order to power a wireless node. The first solution has the advantage that radiation can be used that is already present. The disadvantage is the low energy density (typically µW/cm2). Furthermore, it is not always desirable or even legal to block radiation (e.g. for emergency calls). Therefore, a solution is to use dedicated broadcasting device, which can power sensors in the neighborhood.

A point of concern is the maximum power that is allowed to be transmitted into the environment, which is typically around 100mW. A company called Powercast uses this principle to charge mobile devices. Using 3W of transmitted power at an operating frequency of 900MHz and a distance between device and transmitter around 30 cm, around 100mW of power is received. Larger distances mean larger radiation power, but 3W is already much higher than the allowed energy in Europe (around 100mW). However, the received power decreases very rapidly with distance. Furthermore, 3W as transmission power is not allowed in Europe. There is room for improvement, though, in transmission, receiving (improved antenna design) and the conversion efficiency. For example, at a transmission power of 100mW, values of 1.5mW at 20 cm [9] have been reported. Other techniques still in the research phase are developed by MIT ("non-radiative-resonant-energy transfer"), for distances less than a few meters. The technology relies on copper coils tuned to resonate in identical magnetic fields [10].

In addition, researchers at the University of Tokyo have developed a four-layer plastic sheet with printed coils, organic transistors, and MEMS switches that use inductive coupling to power devices fitted with receiver coils [11]. Both of these technologies are still undergoing research, and commercialization is at least a few years away.

In Table 6 the estimated figures of energy output values per harvesting principle are listed [12].

Table 6. Estimated power output values per RF harvesting principle [12]

SOURCE	SOURCE CARACTERISTICS	PHYSICAL EFFICIENCY	HARVESTED POWER
RF GSM	900MHz 0.3-0.03μW/cm² 1800MHz 0.1-0.01μW/cm²	50%	0.1μW/cm²

These numbers are just first order indications, and they have to be considered to have a large error margin. However, they do give some indication of the typical expected power levels.

7. Conclusion

Given the great distance from sources of electromagnetic radiation (GSM antennas group), values measured do not pose a risk in the University area, the Group Aurel Vlaicu school and student residence.

References

[1] ***Recomandation ITU-R SM.443-3, Bandwidth measurement at monitoring stations
[2] ***Recomandation ITU-R BT.417-5, Minimum field strength for wich protection may be sought in planning terrestrial television service
[3] ***Recomandation ITU-R BT.665-7, Radio Frequency protection radio for AM terrestrial television
[4] ***Recomandation ITU-R BS.412-9, Planning standards for terrestrial FM sound broadcasting at VHF
[5] ***Recomandation ITU-R SM.1268, Method of Measuring the Frequency of FM Broadcast Emission at Monitoring Stations
[6] ***Recomandation ETSI ETR 132
[7] ***Agilent AN 1315 Optimizing RF and Microwave Spectrum Analyzer Dynamic range
[8] ***Agilent spectrum Analysis Basics. Application Note 150 AN 1315
[9] Vullers R J M, Visser H J, Veld B and Pop V 2008 *RF Harvesting Using Antenna Structures On Foil*, Proc. of Power MEMS 2008, Sendai, Japan, November 10-11, pp 209-212
[10] Fildes J *Wireless energy promise powers up*, BBC News, http:// news.bbc.co.uk/2/hi/technology/6725955.stm
[11] Takamiya M, Sekitani T, Miyamoto Y, Noguchi Y, Kawaguchi H, Someya T and Sakurai T 2007 *Design Solutions for a Multi-Object Wireless Power Transmission Sheet Based on Plastic Switches,* IEEE Int. Solid-State Circuits Conf. (ISSCC 2007) Dig. Tech. Pap., San Francisco, USA, February 11-15, pp 362-609
[12] van Hoof C 2008 *Micro-Power Generation using Thermal and Vibrational Energy Scavengers. 12 Years of Energy Harvesting – An overview*, presented at IEEE Int. Solid-State Circ. Conf. (ISSCC 2008), San Francisco, USA, February 3-5