Modern Environmental Science and Engineering (ISSN 2333-2581)
November 2020, Volume 6, No. 11, pp. 1175-1182
Doi: 10.15341/mese(2333-2581)/11.06.2020/004
Academic Star Publishing Company, 2020
www.academicstar.us

The Project “Monitoring Network for EMF Control” in Emilia-Romagna: Statistical Analysis of the Results of RF Measurements

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Abstract: The imminent development of 5G networks will allow to reach a high level of connectivity and capacity through the deployment of different typologies of installations. In this scenario, monitoring of electromagnetic fields is fundamental to measure the field levels actually present in the real environment. The analysis of the measurements data on the territory can facilitate the assessment of the development conditions of the 5G systems in compliance with the exposure limits and in the presence of existing technologies. The EMF Project promoted by the Emilia-Romagna Region and financed by the Ministry of the Environment and the Protection of the Territory and the Sea is part of this context, in particular the project "Monitoring network for the control of electromagnetic fields". As part of this project, radiofrequency electromagnetic field measurements have been carried out on the regional territory in critical and non-critical sites; the data have been analysed in an aggregate way at regional, individual province and single city level, also taking into consideration the details relating to the specific environmental scenario.

Key words: electromagnetic fields, statistical analysis, EMF project

1. Introduction

The electromagnetic fields control and monitoring is one of the tasks entrusted to the Regional Agencies for the Protection of the Environment (ARPA) in the activities defined in art. 14 (“Checks”) of Law 36/2001 [1]. In the Emilia-Romagna region, the Agency was established with Regional Law n. 44/1995 [2] and subsequently renamed “Regional Agency for Prevention, Environment and Energy” (“ARPAE”) by Regional Law no. 13/2015 [3].

The EMF Project realized in Emilia-Romagna provided the updating of the equipment supplied to ARPAE and the execution of measurement and monitoring campaigns on an adequate number of sites characterized by the presence of radiofrequency and/or extremely low frequency field sources.

2. Material and Methods

2.1 CEM Arpae Activity

ARPAE's tasks are aimed at the implementation of a regional database of nonionizing radiation sources, preventive evaluations of installations projects, electromagnetic fields levels monitoring and control, and information campaigns addressed to the population. It is thus possible to follow the evolution of this issues over the years, especially for what concerns mobile telecommunications in a 5G roll out scenario.

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For example, Fig. 1 shows the cumulative trend of the sum of authorized Radio Base Stations (SRB) transmission power levels in our region from year 2006 to 2016, diversified by technology (GSM, UMTS and LTE). Each column represents the sum of the authorized powers for all the base stations (SRB) in the region separated by technology.

The monitoring/control activity is carried out trough "on site punctual surveys" and continuous measurements on the territory performed using relocatable measuring stations that automatically and continuously detect, for prolonged periods of time, the electromagnetic field levels present in the air, allowing to monitor the variation over time.

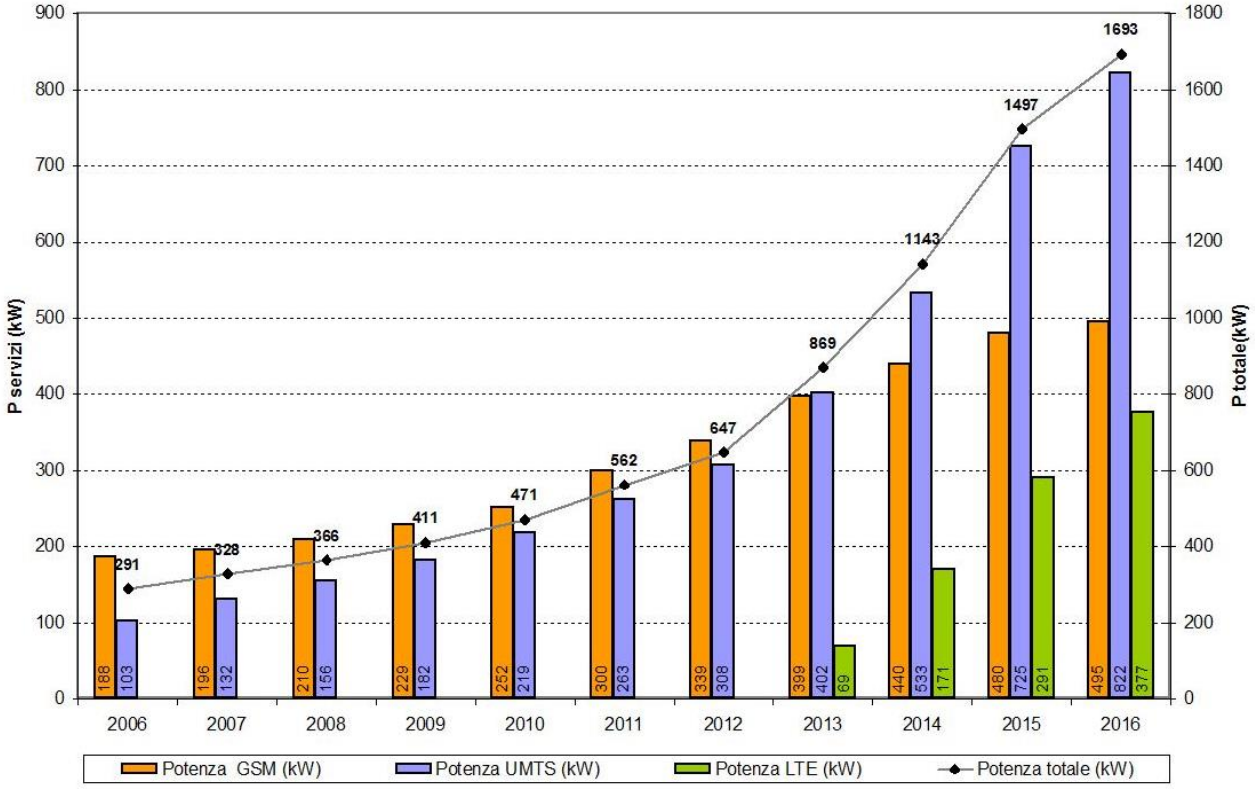

Fig. 1 Sum of authorized powers by type of service provided by SRB plants (2006-2016) (Source Arpae).

The measurement stations are managed by local control centers, located at the ARPAE provincial offices, which perform the data acquisition, validation and periodic transmission to the ARPAE regional control center, which is a part of the Bologna Information Systems Service.

The regional control center provides for the systematic data storage in a single centralized database and their subsequent re-aggregation for processing and reporting purposes, as well as for the publication in an ARPAE website dedicated section.

2.2 Arpae Measurement and Monitoring Activities for the EMF Project

An important part of the "EMF project" involves measurement and monitoring campaigns planned in sites characterized by the presence of extremely low frequency (power lines) and radiofrequency installations.

To address and standardize the controls number and typology, criteria and methods have been defined at national level, leaving to each single Region the possibility to focus on particular aspects deemed most significant.

To direct the choice of the sites to be investigated, criteria based on aspects considered critical, have been defined, in detail:

- "high" estimated (above 4.5 Vm-1) or measured (above 3 Vm-1) E-field values for radiofrequency (RF);
- presence of MV/LV transformer rooms positioned inside residential buildings and/or power lines positioned near densely populated places, for extremely low frequency (ELF);
- absence of recent measures in areas with high density of RF installations or power lines — proximity to schools and hospitals — reports of social issues related to high risk perception, for all the sources.

In Emilia-Romagna, 73 sites of interest have been chosen, 22 for ELF and 51 for RF campaigns. For what concerns ELF campaign, 159 broadband spot measurements and 29 continuous monitoring campaigns have been conducted in selected sites. For radiofrequency fields, have been performed 184 six-minutes broadband measurements, 40 continuous monitoring campaigns, 23 narrow band measurements and 23 six-minutes broadband measurements carried out at 4.5 m above the ground level (corresponding to the 1st-2nd floor of a residential building; the results of this specific campaign will be processed apart to characterize the average "4.5 m from the ground" exposure of the Italian population.

The following tables summarize the results of the low frequency (Table 1) and radio frequency (Table 2) electromagnetic field measurements. For each category of measurements, the average, maximum and minimum obtained value are reported separately by province.

3. Results and Discussion

The statistical data processing of all measurements for high frequency electromagnetic fields (broadband, narrowband, continuous) have been carried out by Ugo Bordoni Foundation (FUB) on the basis of a collaboration agreement between ARPAE and FUB activated within the EMF Project.

The results of the measurement campaigns are presented in aggregate form, classifying the measured field levels in 8 representative ranges (0-1 Vm^{-1}, 1-2 Vm^{-1}, 2-3 Vm^{-1}, 3-4 Vm^{-1}, 4-5 Vm^{-1}, 5-6 Vm^{-1}, 6-20 Vm^{-1}, over 20 Vm^{-1}) (see Fig. 2).

Table 1 Measurements results for low frequency electromagnetic fields.

Province	n. sites	Site tipology	Broadband H field (μT)				Broadband E field (Vm^{-1})				Continuos monitoring H field (μT)			
			n.	min	avg	max	n.	min	avg	max	n.	min	avg (*)	max
Piacenza	2	Line	8	0.12	0.63	1.15	3	3	294	630	3	0.05	2.11	7.75
Parma	2	Cabin/Line	7	0.02	0.38	1.20	2	47	293	539	2	0.02	0.37	0.81
Reggio Emilia	5	Line/Mixed	32	0.01	0.14	0.34	/	/	/	/	5	0.01	0.63	0.94
Modena	2	Line	2	0.80	3.09	5.37	2	145	340	534	2	0.33	5.21	6.22
Bologna	2	Cabin/Line	13	0.45	0.73	1.50	/	/	/	/	2	0.03	0.67	1.08
Ferrara	3	Line	19	0.04	0.71	1.34	21	0.6	52	291	5	0.01	1.39	1.89
Ravenna	2	Line/Cabin	13	0.01	0.72	2.88	/	/	/	/	2	0.02	2.26	5.26
Forlì-Cesena	2	Line/Cabin	10	0.04	0.21	0.69	/	/	/	/	2	0.01	0.27	0.91
Rimini	2	Line	55	0.05	0.30	0.85	/	/	/	/	2	0.09	0.31	0.55
Region		***n. measures***	***159***				***28***				***25***			

(*) maximum median value calculated in the monitoring surveys

Table 2 Measurements results for radio frequency electromagnetic fields.

Prov.	n. sites	Broad band (Vm^{-1})				Narrow band (Vm^{-1})				Continuous monitoring (Vm^{-1})			Broad band (4.5 m) (Vm^{-1})			
		n.	Min	Avg	Max	n.	Min	Avg	Max	n.	Min	Max	n.	Min	Avg	Max
PC	5	23	0.4	2.5	10.6	2	1.1	3.8	6.5	5	0.3	14.6	2	0.3	0.4	0.6
PR	5	12	0.2	1.6	3.9	2	1.5	2.9	4.2	5	0.5	5.3	1	-	1.0	-
RE	6	65	0.2	4.3	14.0	5	3.6	6.4	12.5	5	0.7	15	2	3.4	5.3	7.2
MO	6	8	0.5	3.0	4.9	2	0.9	2.7	4.5	5	0.7	5.8	3	1.0	1.4	1.7
BO	5	29	0.1	1.1	4.9	2	3.0	3.3	3.7	1	1.7	3.9	2	0.5	0.5	0.6
FE	6	14	1.0	1.9	2.8	3	1.1	1.4	2.0	4	0.5	3.8	1	-	1.0	-
RA	6	19	0.7	1.4	4.0	3	1.6	2.5	3.0	5	0.2	6.3	5	0.9	1.1	1.2
FC	5	9	0.6	2.9	4.6	1	-	1.7	-	5	0.3	9.6	5	0.6	2.4	5.8
RN	7	5	2.1	4.6	7.2	3	2.9	3.0	3.1	5	0.5	9.4	2	1.8	2.0	2.3
Tot.	***51***	***184***				***23***				***40***			***23***			

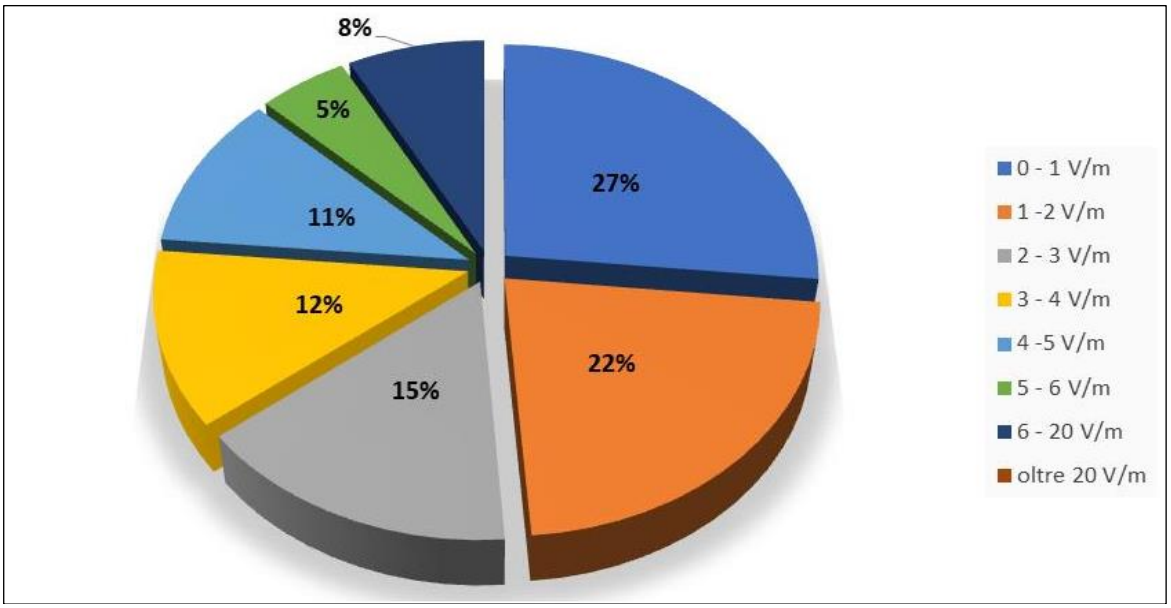

Fig. 2 Electric Field measured values, aggregate.

As can be seen, almost 50% of the measured electric field levels resulted below 2 Vm^{-1}, 92% lower than 6 Vm^{-1} ("attention value") [4]. Field levels above 6 Vm^{-1} were measured only in 8% of the sites, most radio and television (RTV) sites, mixed (SRB+RTV) sites or flat roof for which the exposure limit is 20 Vm^{-1} [4]. No values over the limit of 20 Vm^{-1} were detected.

Fig. 3 shows the results of the measurements carried out on the whole region in relation to the site typology.

From the analysis of the graphs it emerges, as expected, that the highest exposure levels are reached in the RTV sites (17% of the RTV sites have levels measured in the 6-20 Vm^{-1} range, against 10% of the mixed sites and 3 % of SRB sites).

Table 3 presents a direct comparison between the occurrences in three specific ranges of values: low (0-1 Vm^{-1}), intermediate (5-6 Vm^{-1}) and high (6-20 Vm^{-1}).

As can easily be seen, the measurements carried out on radio base stations present the highest percentage of occurrences in the 0-1 Vm^{-1} range (39%) while the RTV sites have the lowest percentage of occurrences in the same range (2%) and the mixed sites are in an intermediate situation (21%). On the contrary, if we consider the 6-20 Vm^{-1} range, it emerges that the radio base stations have the lowest percentage of occurrences (3%), the radio and television sites the largest (10% and 17% respectively).

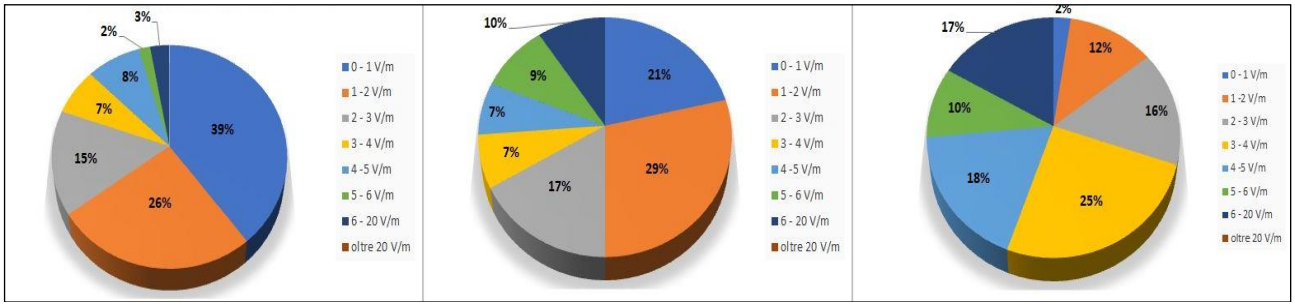

Fig. 3 Electric field levels measured in SRB sites (left), mixed sites (center) and RTV sites (right) – Regional aggregate measurements.

Table 3 Comparison of occurrences of electric field values in specific bands ranges.

Type of site	% measures in 0-1 Vm^{-1} range	% measures in 5-6 Vm^{-1} range	% measures in 6-20 Vm^{-1} range
Radio base station	39%	2%	3%
Mixed site	21%	9%	10%
Radio and television site	2%	10%	17%

This regional set of results represents an aggregate evaluation of what emerged from the specific measurement activity and refers only to the sites measured within the project.

The data have been processed separately for all the region provinces and for a series of selected cities; some results are reported.

3.1 Analysis for Environmental Scenarios

The electric field levels measured in the suburbs and in the center of a medium-sized city are compared, to verify whether the city centers present situations of greater electromagnetic impact. The study has been carried out on the data form four measurement campaigns (2 carried out in a peripheral scenarios and 2 in city centers); three campaigns concerned only radio base stations and one a mixed site), the results are shown in Fig. 4. As can be seen, all the measurements carried out in peripheral areas have provided electric field levels not exceeding 2 Vm^{-1}, in city centers electric field values are recorded also in the ranges 2-3 Vm^{-1}, 4-5 Vm^{-1} and 5-6 Vm^{-1}. The results of this analysis, focused on the difference in impact between the suburbs and the city centers, have been confirmed by the results of a similar study carried out by the Bordoni Foundation in collaboration with Arpae Emilia-Romagna [5].

3.2 Analysis for Different Type of Site

The electromagnetic impact generated by different site technologies (SRB, RTV, SRB + RTV) was analyzed in some provinces, considering a small number of sites (Figs. 5, 6).

The greatest number of occurrences for sites where only radio base stations are present (blue columns) are mainly concentrated in the very first histogram blocks corresponding to E field levels lower than 3 Vm^{-1}, while for radio and television sites (gray column) an

increase in occurrences is evident in the histogram blocks characterized by higher electric field levels. The mixed sites (orange column) corresponds to an intermediate situation in terms of prevalent occurrence of electric field levels classes.

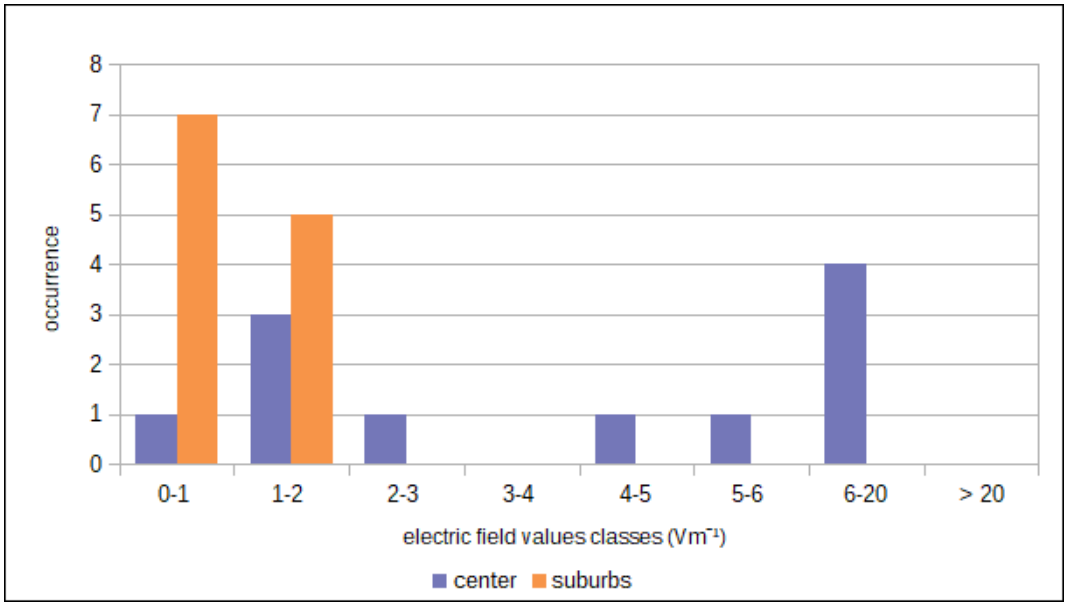

Fig. 4 EMF ranges occurrence in different environmental scenarios.

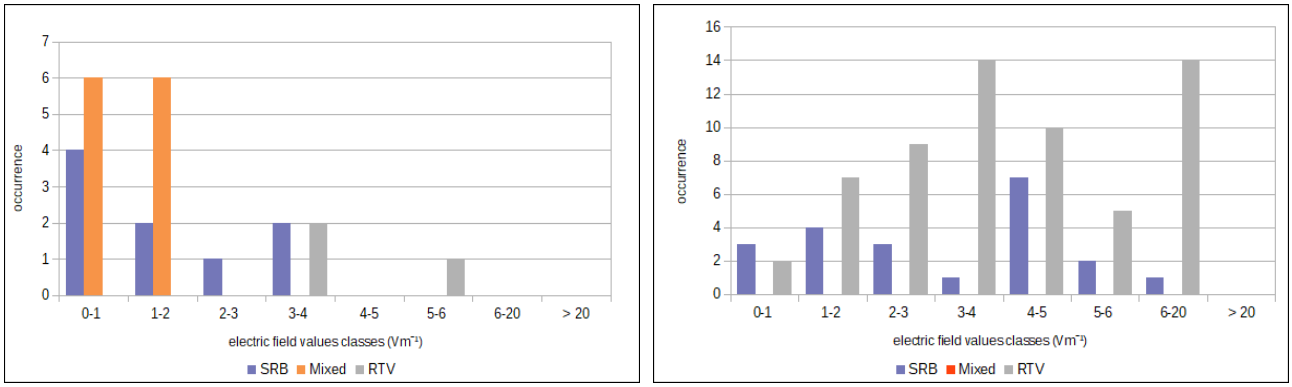

Fig. 5 Electromagnetic impact by type of site — province of Parma (left) and Reggio Emilia (right).

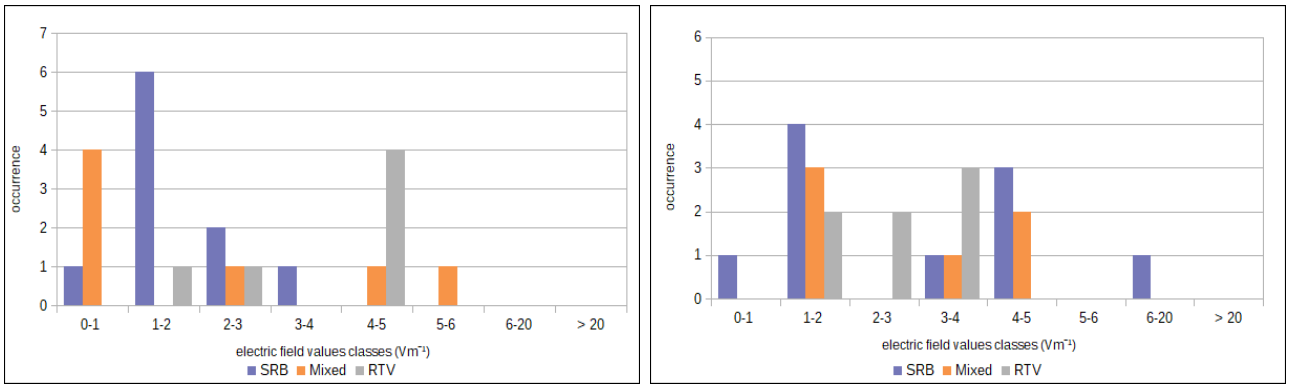

Fig. 6 Electromagnetic impact by type of site — province of Modena (left) and Forlì-Cesena (right).

3.3 Analysis of the Results of Narrowband Measurements

Narrowband measurements, in addition to detailed information on contributions to the overall electromagnetic exposure field levels, can also indirectly provide general indication regarding the use of the spectrum. This last information can be derived on the basis of the contribution percentage of each band to the total measured electric field level.

For this narrowband measurement campaign, 3 specific scenarios have been selected:

- Scenario 1 — radio base station, located in a residential area in a highly populated urban environment;
- Scenario 2 — radio base station located in a medium density urban environment;
- Scenario 3 — radio base station placed in a context of high-density urban environment.

The following graphs present the analysis of the contributions of the various frequency bands to the total electric field level that has been obtained from the narrowband measurements for the 3 selected scenarios.

The graph in Fig. 7 shows the E field percentage frequency contributions obtained from the analysis of the measurement data of scenario 1 consisting of a radiobase station with two co-siting operators.

The measurements were carried out in a single point located on a terrace at a height of 10 m from the ground, at a distance of about 85 m, in line of sight with the installation.

In this specific case, the band that mostly contributes to the total level of the electric field is the 900 MHz (61% of the total field), while the 2100 MHz band contributes for the 33% of the total. The contribution of other bands is minimal and in some cases absent.

Fig. 8 shows the results of the analysis of the measurements data in scenario 2 consisting of a group of three radio base stations hosting four operators, located in a medium density urban environment. The three installations are located inside a sports field area and are mounted on poles at a height of about 15 m from the ground. Measurements were carried out in a single point on a staircase of the sports facility at a height of about 8 m from the ground and at an average distance of 50 m.

In this case, the band that provides the highest contribution to the total level of the electric field is the 1800 MHz with a percentage of 34%. Other bands contributions are quite similar with percentages ranging from 15% to 20%.

The last considered scenario (Fig. 9) corresponds to a four-operators cositing and in addition a WiMax installation placed on the roof of a multi-storey building in a context of high density urban environment. The measurements have been performed on a building flat roof at a height of 22 meters and at a distance of about 50 m in line of sight with the installations.

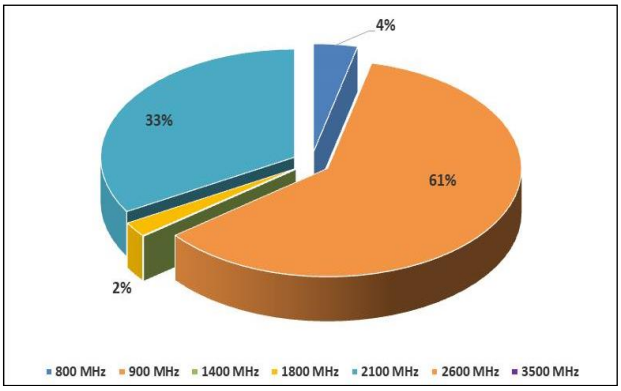

Fig. 7 Total E field percentage contribution measured per band - Scenario 1.

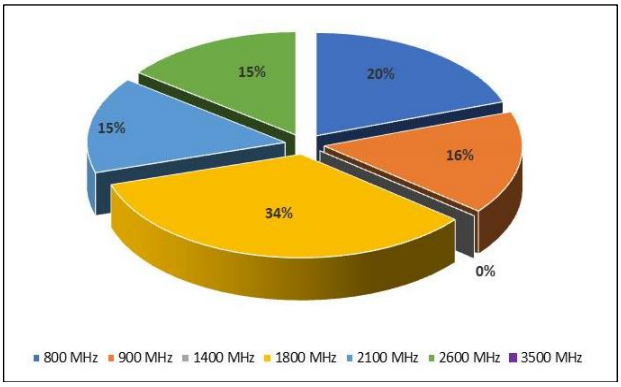

Fig. 8 Total E field percentage contribution measured per band - Scenario 2.

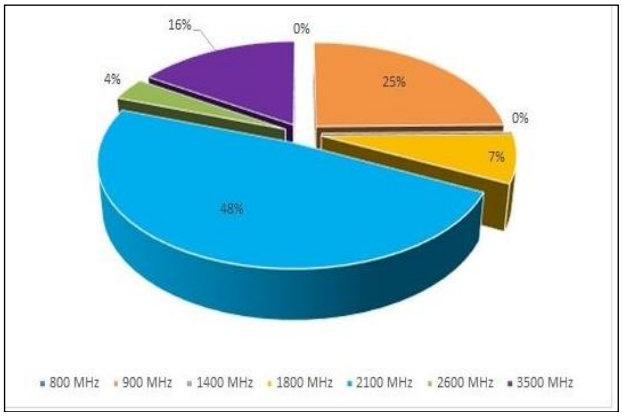

Fig. 9 Total E field percentage contribution measured per band - Scenario 3.

From the analysis it emerges that the band that mostly contributes to the total electric field is the 2100 MHz (48% of the total field), the 900 MHz band contribution is 25% to the total field, while WiMax at 3500 MHz contributes with 16%.

4. Conclusion

The data from all the measurement campaigns carried out within the "EMF Project" have been processed in aggregate form to obtain information on the radio frequency electromagnetic field levels emitted by radio base stations, mixed (radiobase stations + radio TV) sites and radio TV broadcasting sites selected for the investigations. The elaborations are presented at regional and single city level. Other investigations performed on data from measurements concerned the electromagnetic impact as function of environmental scenario (distinguishing between city center and suburbs) and of installation typology (only radiobase stations, mixed sites, RTV broadcasting sites).

What emerged from the aggregate analysis of the data relating to the selected sites is rather interesting: more than 90% of the measured electric field values are lower than the "attention value" of 6 Vm^{-1}. The 20 Vm^{-1} limit is not exceeded in any case.

In some cities the radio frequency electric field levels measured within the selected sites are even lower than the 6 Vm^{-1} attention thresholds.

The presented set of results, being related to only a few dozen sites, cannot be considered conclusive, but the statistical surveys carried out within the project may be considered a starting point for a more complete and detailed investigation to be carried out on the territory in the near future and/or after the 5G roll-out.

The analysis of the data relating to the single cities shows that the E-field levels distribution depends on the number and typology of sites: where radio and television sites are included, or in case of sites located in dense urban areas, the obtained E-field levels are included in the higher ranges.

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