Prediction and measurement of electromagnetic radiation at Krajina square in the city of Banja Luka

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Prediction and measurement of electromagnetic radiation at Krajina Square in the city of Banja Luka

Petar S. Medjedovic[1], Darko S. Suka[2]

Abstract – **This work is only a small part of the research carried out in the project: "Prediction, measurement and analysis of composite electromagnetic (EM) field of artificial radiation sources", funded by the Ministry of Science and Technology of the Republic of Srpska. The main objective of the project is to locate the representative measuring points for future monitoring network for continuous measurements and recordings of maximum levels of EM non-ionizing radiation, in the spreading center of Banja Luka area of about 10km². Regarding that, previously was conducted verification with a software package used for a smaller area, by comparing the predicted and measured values of electromagnetic fields strength. For this purpose the pedestrian zones were treated, which are the surfaces and routes with the largest population flow. This paper gives a brief description of the research of EM radiation levels on the surface of 0.008km² in the frequency range from 50MHz to 3GHz.**

Keywords – **EM radiation, Prediction, Measurement, Analysis.**

I. Introduction

In the mentioned project first was performed the prediction of power density and electric field strength of all existing licensed sources of electromagnetic radiation, except Microwave links and the Professional mobile Radio (PMR), such as GSM 900MHz, DCS 1800MHz, UMTS 2100MHz, FM radio, Television (5-12 and 21-66 TV channels). All necessary relevant technical data about these sources are obtained from the Communications Regulatory Agency of Bosnia and Herzegovina. Area of approximately 10km^2 was observed with a resolution 5m×5m. Due to lack of space in this paper, only the characteristic surface in the center is being considered. The simulation was performed by using a powerful software tool InSite Wireless (WI) [1], developed by Remco company, for electromagnetic modeling with a precise prediction of EM wave propagation in urban, suburban and rural environments. Prediction results are given in the form of color maps, tables and diagrams. The measurements were performed by using a spectrum analyzer FSH3 produced by Rhode&Schwarz and EME Spy 140 dosimeter produced by Satimo. The measurement results are also presented in a form of tables.

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Results of prediction and measurements have enabled the determination of representative measuring points on the observed surface. At the end, the results of prediction and measurements were analyzed while the comparison results between the total electric field strength of predicted and measured values are presented in the form of a diagram.

II. Prediction of EM field on Krajina square

Krajina square shown on Fig. 1, together with seven typical routes, was chosen for this occasion, as the busiest pedestrian zone with the largest population flow in the city.

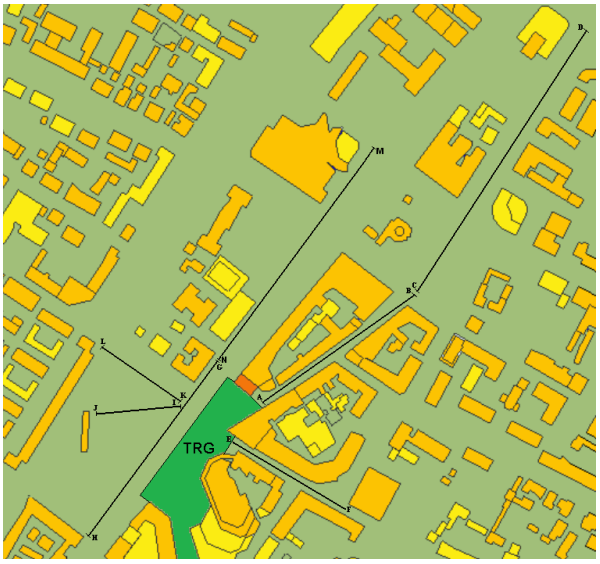

Fig. 1. Observed surfaces and routes in the city center

Before prediction of the spatial distribution of EM fields in the observed area, all relevant data about sources of EM radiation were collected. That enabled the data entry to WI program for 134 transmitters of 47 GSM and DCS base stations (BS) of mobile telephony, 178 transmitters of 61 UMTS BS, 25 TV transmitters, 30 FM radio transmitters. By using WI editing tools, virtual objects and surrounding terrain can be constructed or the same data can be imported from several different formats such as DXF, Shapefile, DTED and USGS. In this case, a digital map of the Banja Luka city in GK6 map projections was used, made by GisData Effective Solutions company from Zagreb. GIS data represents real objects and parameters such as buildings, roads, trees, water flows, height, length and configuration of the terrain, etc. in digital form. Digital ortophotos of observed area is the satellite image with resolution of 1 meter in Tiff format. 3D

models of buildings have all height attributes (the absolute height of the building, the relative height of the building). Data for objects and terrain are given in ESRI shape format, whereby the available terrain model has 20m×20m resolution and height accuracy of 10m. Adaptation of digital data used for WI software was successfully performed only after consultation with the manufacturer of the program and additional data conversion.

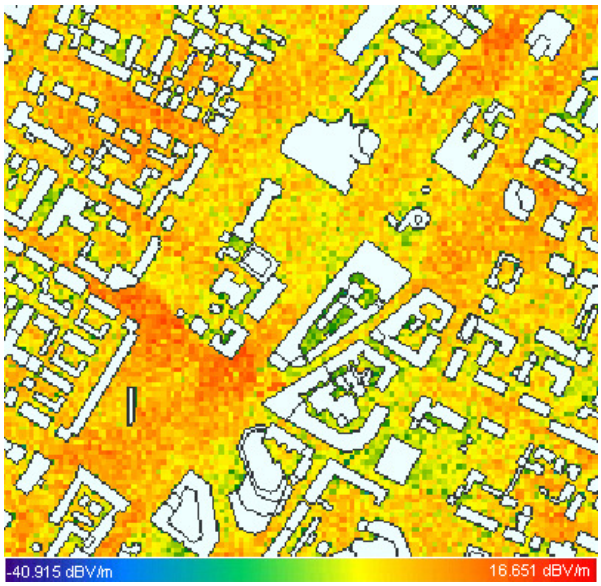

Fig. 2. Prediction of electric field strength for DCS1800MHz

Thanks to the WI program and all submitted data it was possible to make the simulation of physical characteristics of rugged terrain and buildings in urban environment, the calculation of EM field strength due to presence of buildings, facilities and terrain on EM wave propagation and finally evaluation of signal propagation characteristics in the frequency range from 50MHz to 40GHz. More details about this is given in [2] and [3]. As an example, on Fig 2., the spatial distribution of the electric field strength (E) caused by radiation DCS 1800MHz BS mobile was shown on the surface of approximately 0.5 square kilometers in the center of Banja Luka, as there is a lack of space for remaining 6 maps. Prediction of E_{rms} field was performed with a resolution of 5mx5m, which means that the appropriate value of E_{rms} field is assigned to each of approximately 20.000 points and symbolically represented in color and in accordance with the legend below. WI gives also a table representation in which each point in space, with X (m), Y (m) Z (m) coordinates, is defined as the receiver Rx with the assigned number and appropriate value of E_{rms} field. The prediction of E_{rms} field values on Krajina Square is shown on Fig. 3, for DCS1800 band in 320 receiving points (4837-9777) that are measuring points as well (from 1 to 320). Due to the very limited space in this paper, it is not possible to display E_{rms} field values of all 320 points, so in Table I only E_{rms} field values in 24 receiving points were shown, in which were after obtained the maximum levels of total electric field strength. In the first and second rows the selected measuring points (23…304) and receiving points (5706...9344) were marked, respectively.

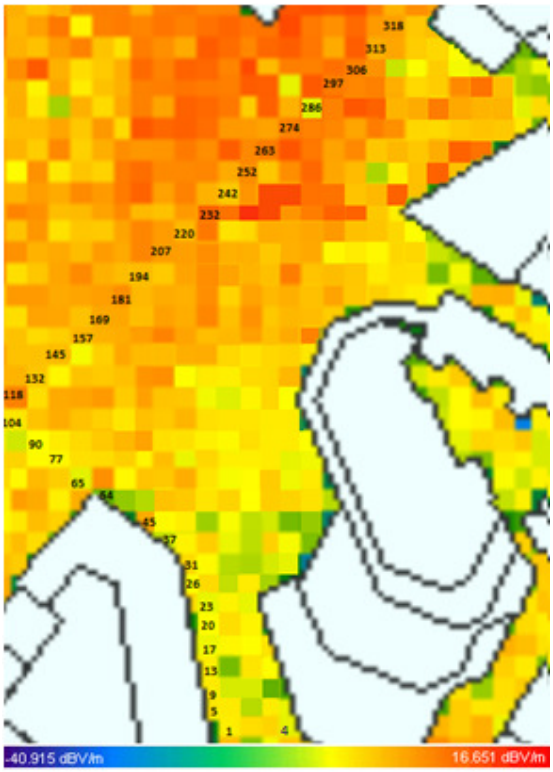

Fig. 3. Krajina square, Prediction of E field in 320 receiving points

TABLE I: PREDICTION OF E FIELD IN 1800MHZ BAND ON KRAJINA SQUARE

MP	Rx	X(m)	Y(m)	Z(m)	Distance	Erms
23	5706	2.50E+02	1.95E+02	165.50	160.43	4.30E-01
94	6861	2.25E+02	2.35E+02	165.50	143.71	9.98E-01
118	7147	2.05E+02	2.45E+02	165.50	151.97	1.80E+00
146	7440	2.20E+02	2.55E+02	165.50	134.9	4.60E-01
181	7877	2.30E+02	2.70E+02	165.50	119.19	1.54E+00
184	7880	2.45E+02	2.70E+02	165.50	108.09	8.04E-01
197	8026	2.50E+02	2.75E+02	165.50	101.76	1.46E+00
209	8171	2.50E+02	2.80E+02	165.50	99.09	1.52E+00
210	8172	2.55E+02	2.80E+02	165.50	95.54	1.09E+00
221	8316	2.50E+02	2.85E+02	165.50	96.6	1.54E+00
232	8461	2.50E+02	2.90E+02	165.50	94.32	2.49E+00
234	8463	2.55E+02	2.85E+02	165.50	92.95	3.97E+00
235	8464	2.60E+02	2.85E+02	165.50	89.44	3.26E+00
237	8466	2.70E+02	2.85E+02	165.50	82.86	1.86E+00
244	8609	2.65E+02	2.95E+02	165.50	81.15	3.04E+00
245	8610	2.70E+02	2.95E+02	165.50	77.74	3.16E+00
247	8612	2.80E+02	2.95E+02	165.50	71.49	2.28E+00
250	8615	2.95E+02	2.95E+02	165.50	63.92	2.05E+00
255	8756	2.75E+02	3.00E+02	165.50	72.22	2.33E+00
261	8762	3.05E+02	3.00E+02	165.50	57.59	2.00E+00
269	8905	2.95E+02	3.05E+02	165.50	58.85	1.72E+00
273	8909	3.15E+02	3.05E+02	165.50	52.89	2.42E+00
288	9193	2.85E+02	3.15E+02	165.50	60.61	2.76E+00
304	9344	3.15E+02	3.20E+02	165.50	47.31	2.41E+00

That way, the software prediction of E_{rms} field and for all others, above mentioned sources of EM radiation, were performed. On observed area from Fig. 3, the same 320 receiving and measuring points were chosen for comparison. The results of those predictions for E_{rms} field values are given in Table II, where the two last columns show the total value of the electric field strength E_{rmsuk} and $\Sigma E_{rms}/E_g$, obtained by using Eqs. (1) and (2).

TABLE II: PREDICTION RESULTS OF E_{RMS} VALUES FROM ALL RADIATION SOURCES

MP	$Erms_1$ (V/m) GSM 900	$Erms_2$ (V/m) DCS1800	$Erms_3$ (V/m) UMTS	$Erms_4$ (V/m) TV 5-11	$Erms_5$ (V/m) TV 21-66	$Erms_6$ (V/m) FM radio	$\Sigma\frac{Erms}{Eg}<1$	$Erms_{uk}$
23	0.7555	0.4305	1.4085	1.4387	0.9917	0.4986	0.3766	2.4580
94	0.9398	0.9975	1.6934	0.6510	0.3210	0.5010	0.2974	2.3503
118	0.2391	1.8032	1.4255	0.4869	0.5969	0.2461	0.2646	2.4484
146	1.0435	0.4599	1.9998	0.5211	0.7023	0.2570	0.2916	2.4760
181	0.9670	1.5412	1.6114	0.3854	0.3399	0.1888	0.2688	2.4913
184	0.6768	0.8040	2.2075	0.3421	0.3449	0.1647	0.2390	2.4981
197	0.9701	1.4591	2.6772	0.2406	0.3323	0.1864	0.2954	3.2312
209	1.0726	1.5207	1.6171	0.1944	0.2493	0.1744	0.2485	2.4917
210	0.6032	1.0894	2.0864	0.2784	0.3244	0.1584	0.2338	2.4722
221	1.1669	1.5360	1.5047	0.2292	0.3028	0.2018	0.2602	2.4839
232	1.0191	2.4900	1.8773	0.2109	0.2909	0.1521	0.3002	3.3038
234	0.4674	3.9698	1.1972	0.2199	0.4099	0.2252	0.3197	4.2045
235	0.4079	3.2560	2.0270	0.2652	0.2852	0.1864	0.3100	3.8811
237	0.4370	1.8556	2.4619	0.3698	0.3698	0.2026	0.2878	3.1638
244	0.7270	3.0402	1.1425	0.2973	0.2883	0.1477	0.2832	3.3571
245	1.0758	3.1574	1.4160	0.4620	0.3320	0.2020	0.3434	3.6737
247	0.7431	2.2760	1.4630	0.2682	0.4582	0.2482	0.2853	2.8664
250	0.4091	2.0542	1.5004	0.0893	0.1993	0.1293	0.2094	2.5890
255	0.5173	2.3343	1.5318	0.3575	0.3075	0.2004	0.2683	2.8854
261	0.7331	1.9980	1.4120	0.2694	0.2594	0.1197	0.2429	2.5841
269	0.3467	1.7218	2.1812	0.2096	0.3410	0.1410	0.2430	2.8324
273	0.2090	2.4158	0.7254	0.0674	0.1074	0.0994	0.1688	2.5361
288	0.9769	2.7587	1.0712	0.4699	0.2299	0.2470	0.3026	3.1697
304	0.4765	2.4089	0.8561	0.1121	0.1921	0.1321	0.2038	2.6133

$$E_{rms_{uk}} = \sqrt{E_{900}{}^2 + E_{1800}{}^2 + E_{UMTS}{}^2 + E_{FM}{}^2 + E_{TV1}{}^2 + E_{TV2}{}^2} \quad (1)$$

$$\sum_{1MHz}^{300GHz} Erms/Eg \le 1 \quad (2)$$

The E_g value is standard threshold electric field strength value expressed in V/m, as a function of frequency *f* defined in [4]. It is obvious that the expected value of the total electric field strength significantly below all limits prescribed in [5]. Also, in all measuring points, a condition for the reference values in Eq. (2) is fully satisfied, in the case of composite electromagnetic fields caused by multiple sources at different frequencies.

TABLE III: MEASUREMENT RESULTS OF E_M VALUES FROM ALL RADIATION SOURCES

MP	Em_1 (V/m) GSM 900	Em_2 (V/m) DCS1800	Em_3 (V/m) UMTS	Em_4 (V/m) TV 5-11	Em_5 (V/m) TV 21-66	Em_6 (V/m) FM radio	$\Sigma\frac{Em}{Eg}<1$	Em_{uk}
23	0.2589	0.3886	0.6889	0.7718	0.4945	0.2822	0.1955	1.2698
94	0.3937	0.5345	0.6337	0.2999	0.2365	0.2332	0.1395	1.0210
118	0.1438	0.5919	0.5433	0.2598	0.2619	0.1574	0.1151	0.9094
146	0.6533	0.4338	0.7891	0.3329	0.2805	0.1905	0.1598	1.2097
181	0.3845	1.0720	0.6421	0.1868	0.1356	0.0754	0.1295	1.3297
184	0.3669	0.6247	0.9586	0.1805	0.2176	0.1022	0.1311	1.2386
197	0.3828	1.5517	1.3982	0.1272	0.1876	0.1274	0.1845	2.1394
209	0.4479	1.4384	0.6244	0.1671	0.1996	0.0857	0.1527	1.6537
210	0.3921	1.0047	0.8301	0.1491	0.1743	0.0784	0.1350	1.3824
221	0.5371	0.7531	0.6184	0.1170	0.2185	0.0812	0.1253	1.1428
232	0.4531	2.4590	0.6887	0.2031	0.1844	0.0833	0.2008	2.6093
234	0.4663	3.8327	0.4863	0.1637	0.2263	0.1851	0.2608	3.9059
235	0.3595	2.8084	0.7879	0.1856	0.2032	0.1231	0.2177	2.9543
237	0.4928	1.6503	0.9499	0.2358	0.2628	0.1741	0.1970	2.0059
244	0.5459	2.7362	0.4102	0.1602	0.2012	0.0664	0.2027	2.8326
245	0.5830	2.6731	0.6678	0.2823	0.2429	0.0881	0.2291	2.8421
247	0.3539	2.1035	0.5573	0.1354	0.2228	0.1427	0.1768	2.2246
250	0.3346	1.9236	0.5154	0.0574	0.1271	0.0563	0.1436	2.0250
255	0.4629	1.8947	0.9746	0.2458	0.2206	0.1632	0.2030	2.2113
261	0.3320	1.8901	0.6324	0.2155	0.1670	0.0580	0.1644	2.0397
269	0.2619	1.6806	0.9953	0.1921	0.2819	0.0698	0.1748	2.0012
273	0.2381	2.3632	0.7945	0.0841	0.0582	0.1205	0.1704	2.5095
288	0.6921	1.7338	0.8995	0.2970	0.1402	0.1502	0.2035	2.1035
304	0.1912	1.9295	0.9795	0.0889	0.1225	0.0783	0.1588	2.1790

III. MEASUREMENT OF EM FIELD ON KRAJINA SQUARE

Measurement of electric field strengths E_m is performed for the same points (320) for which a software predictions was previously performed. A portable spectrum analyzer FSH3 was used and long-term (6 minutes) reliable and frequency-selective field-strength measurements was performed independently of direction and polarization. Table III presents the results of measurements in the same 24 points in which was previously predicted maximum values of Erms, wherein 6 values that represent the measured electric field strength E_{M1} to E_{M6} for specified frequency bands in the header of the table were associated to each measuring point. In the eighth and ninth columns are values of the total measured electric field E_{muk} and $\Sigma E_m/E_g$ obtained by using Eqs. (1) and (2).

IV. COMPARISON OF MEASUREMENT AND PREDICTION RESULTS

Table IV presents a comparative overview of software prediction and measurement of electric field strength results in Excel format.

TABLE IV: COMPARATIVE OVERVIEW OF MEASUREMENT AND PREDICTION RESULTS

MP	Prediction Erms (V/m)	Measure Em (V/m)	Deviation (V/m)	Deviation (dB)
23	2.4580	1.2698	1.1882	2.8684
94	2.3503	1.0210	1.3292	3.6207
118	2.4484	0.9094	1.5390	4.3012
146	2.4760	1.2097	1.2663	3.1106
181	2.4913	1.3297	1.1616	2.7266
184	2.4981	1.2386	1.2595	3.0468
197	3.2312	2.1394	1.0918	1.7908
209	2.4917	1.6537	0.8380	1.7804
210	2.4722	1.3824	1.0898	2.5245
221	2.4839	1.1428	1.3411	3.3716
232	3.3038	2.6093	0.6945	1.0249
234	4.2045	3.9059	0.2987	0.3200
235	3.8811	2.9543	0.9268	1.1850
237	3.1638	2.0059	1.1579	1.9791
244	3.3571	2.8326	0.5245	0.7378
245	3.6737	2.8421	0.8316	1.1146
247	2.8664	2.2246	0.6418	1.1008
250	2.5890	2.0250	0.5640	1.0671
255	2.8854	2.2113	0.6741	1.1555
261	2.5841	2.0397	0.5444	1.0274
269	2.8324	2.0012	0.8312	1.5086
273	2.5361	2.5095	0.0266	0.0458
288	3.1697	2.1035	1.0662	1.7807
304	2.6133	2.1790	0.4343	0.7894

In fifth and sixth column a deviation σ, expressed in V/m and δ in dB, are presented respectively and calculated in accordance with Eqs. (3) and (4).

$$\sigma = Erms_{uk} - Em_{uk} \quad (3)$$

$$\delta = 10 \log \frac{Erms_{uk}}{Em_{uk}} \quad (4)$$

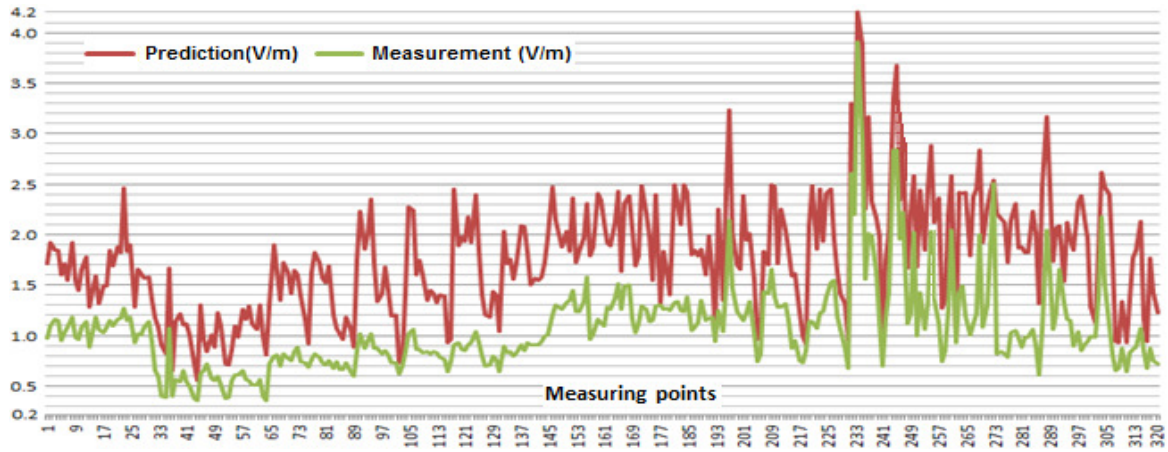

Fig. 4. Predicted and measured electric field strength

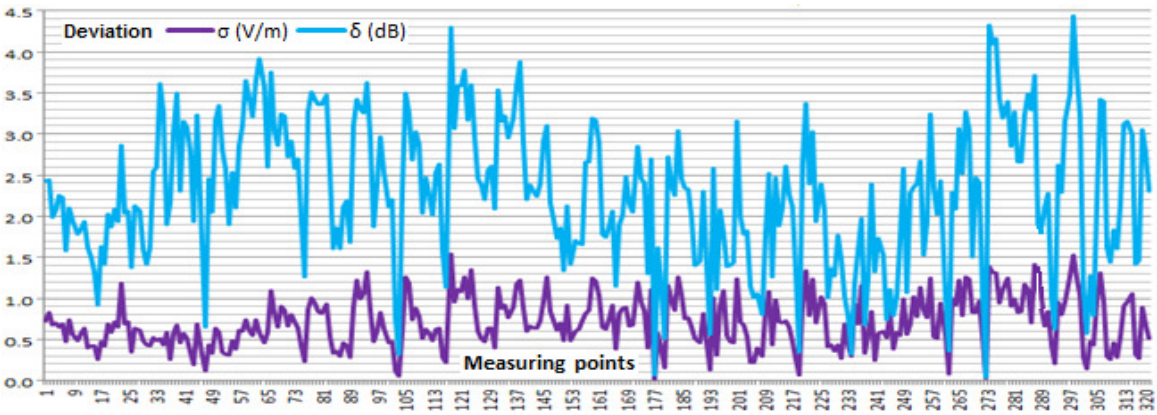

Fig. 5. Deviation and logarithmic quotient of predicted and measured E field strength

As an example, in Table IV. is given a comparative overview of predicted and measured values of E field in 24 selected points and, based on the total predicted and measured values of electric field strength for 320 points, the diagrams shown in Figs. 4 and 5 were made. It is obvious that there is a deviation of predicted values of total electric field strength compared to the measured values of the same field. This deviation is in the range of 0.054 V/m up to 1.525 V/m, respectively, from 0.046 dB to 4.44 dB, with a mean deviation of 0.71 V/m or 2.38 dB. It may also be noted that the predicted values of the total electric field strength are greater than the measured values in all observed points, with the fact that predicted value have their maximums at almost the same points as the measured values. So, predicted and measured maximum electric field strengths are in the same 234-th point (4.2 V/m and 3.9 V/m respectively) on the observed surface.

V. Conclusion

Results obtained by software prediction and measurement are different and that is the consequence of the approximation of some parameters and because of effects caused by propagation of EM waves (reflection, dissemination, diffraction, absorption) due to natural and artificial obstacles that do not exist in the digital map. Therefore, as a rule, the predicted value exceeds the measured values. Also, as the mobile traffic changes significantly over time, measuring results are 6-minute mean values in contrast to the prediction results where they presumed that transmitters work continuously and simultaneously with full power. Yet, it can be concluded that the WI software is reliable and has acceptable accuracy for planning of certain territories signal coverage. As such, it can successfully be used to locate the points at which the maximum value of the electric field strength can be expected.

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