LAND PLANNING OF AN ANTENNA FARM: MEASUREMENTS AND SIMULATIONS AIMED AT RELOCATION OF BROADCASTING STATIONS AND/OR REASSIGNMENT OF FREQUENCIES

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ABSTRACT

A methodology applied to land planning of an antenna farm is presented in this study. The first part of the study refers to measurements made at critical points around the existing antenna farm in order to evaluate the current situation. Broadband measurements have been made in a dense grid of sites that covers the broader area of interest. Narrowband measurements have also been conducted to estimate the contribution of existing broadcasting stations to current radiation levels and the safety index. The second part of the study refers to the future situation, which was predicted by use of computer simulations. The predicted radiation levels have been compared to the present levels and the exposure limits, thus leading to proposals for a new location and structure of the antenna farm.

1. INTRODUCTION

The methodology followed and the results obtained in a case study concerning land planning of an antenna farm are presented in this paper. The antenna farm under consideration consists mainly of FM and TV broadcasting stations. It is currently operating from location A, shown in the map of Fig. 1. The farm has acquired its present form over a period of 20 years, practically without a plan; private FM and TV stations have been settling in there, at times illegally.

Nowadays, the antenna farm comprises more than 50 antenna masts, hosting 62 FM stations and 43 TV stations. Because of the presence of many transmitters in a relatively small area and the random allocation of frequencies, the possibility of intermodulation (IM) products occurrence has increased. There is growing concern about the eventual interference of the aforesaid IM products with the air-ground communication systems that operate at a nearby international airport, which is approximately 13 km away from the antenna farm. Therefore, it has been made imperative to proceed with a new frequency assignment plan and a study that would reconsider relocation of the antenna farm.

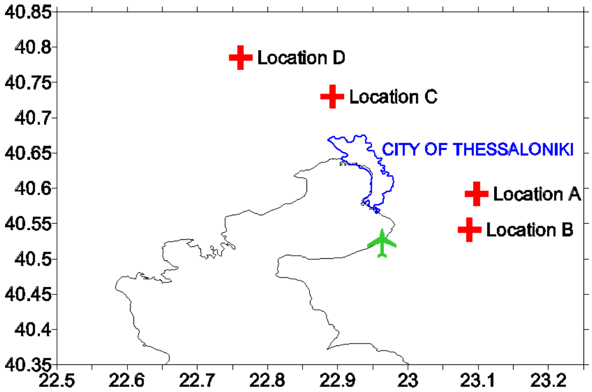


Figure 1: Map of the locations considered for the implementation of the new antenna park

During this study several scenarios have been implemented concerning both the antenna farm location and the assignment of frequencies. Four locations (A, B, C, D) have been evaluated (Fig. 1) for the new antenna farm, based on coverage and accessibility. Aiming at the maximum number of frequencies and the minimum number of IM products, a frequency assignment procedure has been carried out, resulting in various scenarios and, ultimately, in four proposals.

The first proposal has been based on the assumption that the antenna farm will remain at A, but the frequencies will be reassigned; the second proposal has assumed that the antenna farm will move to B; the third and fourth proposals, have considered the possibility of using a pair of locations, either A and C or B and D. All four scenarios have assumed that the state broadcasting facilities will remain in their present location (i.e., Location A).

Population and geographical coverage have been taken into account throughout this study, which has further been focused on the environmental impact of the antenna farm in its vicinity. Therefore, an essential part of this study has been the evaluation, for all four proposals, of the eventual hazards of the electromagnetic (EM) radiation emitted from the antenna farm to the inhabited areas in closest proximity.

2. METHODOLOGY

In order to evaluate the effect on the EM environment of the aforesaid proposals, concerning the future form of the antenna farm, the impact of the existing antenna farm had to be assessed. The contribution of currently operating stations (FM or TV) to the EM spectrum has been evaluated by both broadband and narrowband measurements at selected points. Subsequently, the contribution of the stations to be relocated has been subtracted from the present form of the EM spectrum, thus providing a reference "zero situation," and new EM spectra, corresponding to the relocation/reassignment scenarios, have been calculated for future situations concerning the EM environment to be predicted.

Broadband and narrowband measurements in the frequency range up to 20GHz have been made at cardinal sites near the present antenna farm at location A as well as in the vicinity of the suggested locations B, C, D. Both types of measurements were deemed essential because they provide complementary information about the EM environment. The measurement sites have been selected according to the relief of the terrain at A, B, C, D and the distribution of population around them.

On the one hand, broadband measurements have been conducted at many sites by use of field meters. Broadband measurements are fast, easy to perform and they provide the coherent effect of all radiating sources. Hence, many sites (about 584) have been visited with field meters, especially in the residential areas closest to location A. Yet, it is impossible to isolate the contribution of stations-to-be-relocated to the overall EM radiation level measured by field meters at any point.

On the other hand, narrowband measurements have been conducted, albeit at fewer sites (about 42), by use of spectrum analyzers. Narrowband measurements were time-consuming, mainly because a very wide spectrum had to be swept, and more complex than broadband measurements. Still, they provide information about the effect of individual radiation sources, which is necessary for the determination of the "zero situation" and, subsequently, for the prediction of future, EM spectra.

Narrowband measurements were automated by use of a laptop computer linked to the spectrum analyzer through a GPIB cable (Fig. 2). Three antennae were used to cover the range up to 20GHz. Several bands were considered in the aforesaid range of frequencies and a specific set of parameters were uploaded to the spectrum analyzer for operation in each of those bands. At least fifty traces in every band, taken in the MAX HOLD mode, were downloaded to the computer. Each band was first swept with fine resolution bandwidth (RBW) to determine the frequency of emissions and then again with coarse RBW to determine the power corresponding to every emission, which yielded slightly overestimated results because of the MAX HOLD operation.

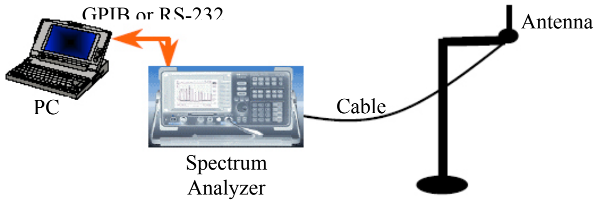


Figure 2: Layout of narrowband measurements

3. CURRENT SITUATION

As narrowband measurements have been conducted in relatively few sites, for the reasons stated above, it has been assumed that the EM spectra acquired from the narrowband measurements can be used in a large number of nearby sites where only broadband measurements were made. Thus, it was possible to estimate which part of the broadband radiation level corresponds to each frequency band (e.g., FM radio, UHF/TV, GSM, DCS etc.) and to compare those levels to the exposure limits set by Greek law, which are 80% of the values set by the European Council recommendation [1]. An alternative, simple and on-the-safe-side approach would be to compare the broadband radiation levels directly to the lowest limit in every band.

4. THE "ZERO SITUATION"

This is the hypothetical broadband result obtained by integration of the measured EM spectra after the contribution from stations to be relocated has been obliterated.

5. PREDICTION OF THE FUTURE SITUATION

Starting from the "zero situation," calculations of the future situation have been made for every scenario. Radiative contributions from relocated/reassigned broadcasting stations have been simulated, added to the EM spectra of the "zero situation," and subsequently integrated to obtain a prediction for future broadband levels in every site. Thus, it has been made possible to compare present as well as future radiation levels to the exposure limits set by state regulations.

Two computer programs have been used for the aforesaid calculations. The first one provides estimates of the field very close to the proposed, new facilities; it has been designed especially for this study and it takes into account the terrain as well as the type of antennae to be used [2]. The second software used (*EDX SignalPro®* of Comarco Wireless Technologies, Eugene, USA) provides radiation levels on a coarse grid throughout the area of interest and it has been used to confirm that adequate coverage is ensured by all four proposals for the future antenna farm.

6. RESULTS

The measurement campaign has shown that, when performing studies such as this, it is important to consider all residential areas within a certain distance from the proposed antenna farm locations. The evaluation of the current situation has shown that there is a small area in the vicinity of the existing antenna farm, where the radiation level exceeds the limit for the FM band (shown in red in Fig. 3).

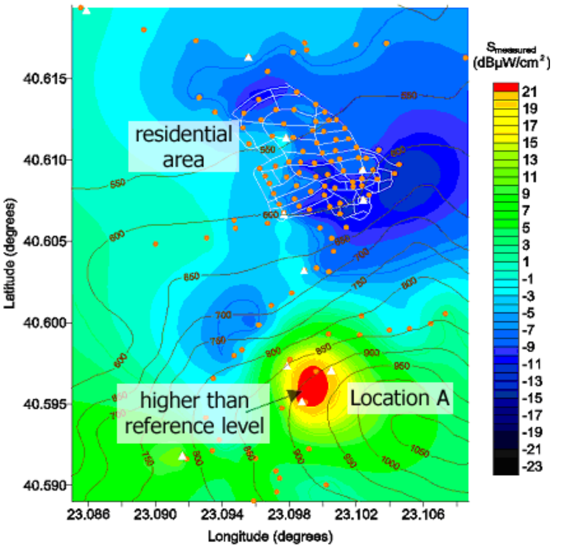


Figure 3: Graphical representation of the power density values around the present antenna park. (● broadband measurements, △ narrowband measurements)

Radiation levels, below the limit, have been obtained in the regions accessible to the general public for all the scenarios examined. Fig. 4, for example, shows the present situation and the prediction for a future situation, which involves moving 44% of the planned maximum EIRP of private broadcasting stations to location D. Only a very small area around the antenna masts is expected to have radiation levels slightly above the present situation. Figure 5a shows a picture of the envisaged installation of the antennas of private broadcasting stations at location B, whereas Figure 5b depicts the distribution of the safety index in the area around the antenna masts.

The Safety Index (SI) or Total Exposure Quotient is used when the far-field exposure to multiple electromagnetic sources with frequencies above 1 MHz is examined. The SI is defined as the sum of the ratios of the measured power density at each frequency, to the value of the reference level for that particular frequency. A value of SI lower than unit denotes compliance to the exposure guidelines with respect to thermal effect circumstances.

Table 1 summarizes the results obtained for each scenario. The table shows the maximum percentage of EIRP per type of broadcasting station, which is assumed at any location of the antenna farm. The maximum relative radiation level (L_i) indicates the ratio of the maximum power density that is estimated inside any residential area normalized to the strictest limit in the Greek regulation, which is that of the FM frequency band.

The uncertainty budget for the narrowband measurements varies with the frequency band. However, even the maximum relative expanded uncertainty of 42% (with a coverage factor of 2 for a double-sided normal distribution) would not change the conclusions on the safety situation inside residential areas.

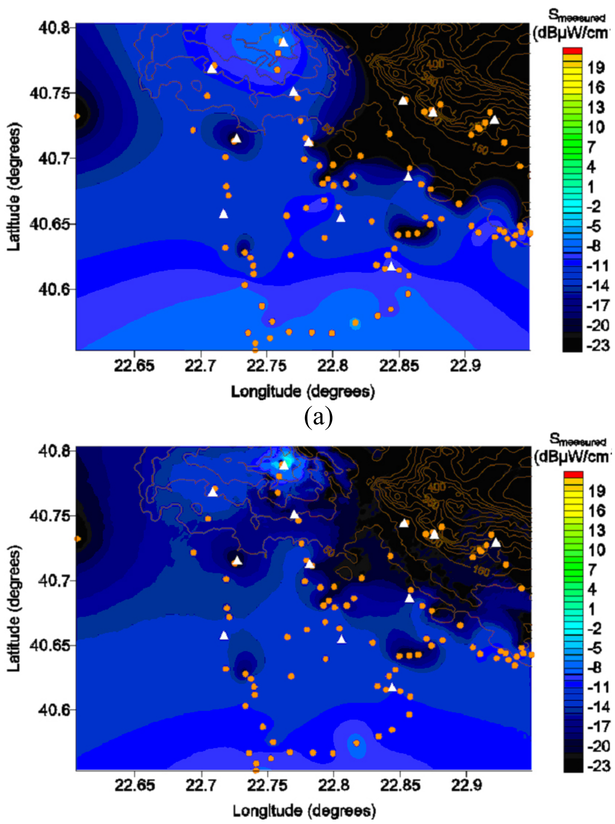
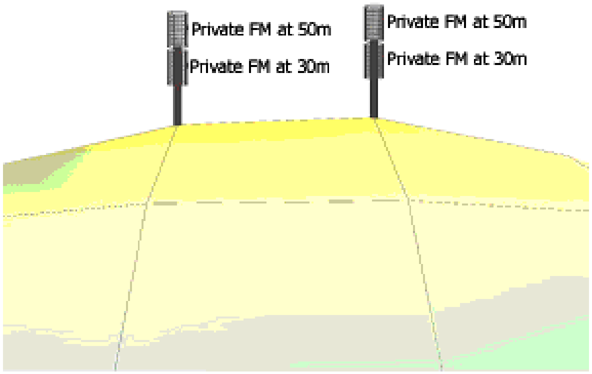


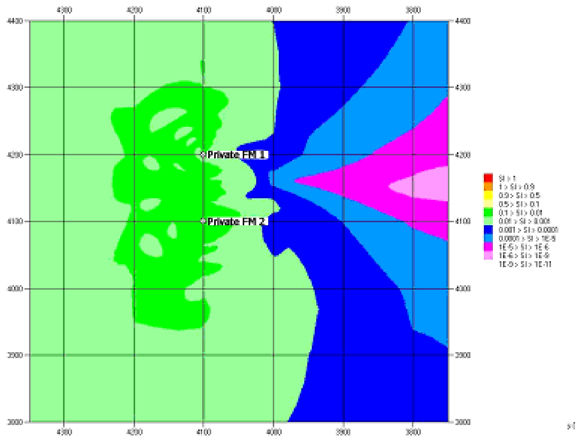
Figure 4: Graphical representation of the power density values in the broader area of Location D
(a) currently (measured), and (b) after the installation of some broadcasting stations (estimated).
(● broadband measurements, △ narrowband measurements)

7. CONCLUSIONS

A procedure for planning the development of a new antenna farm, involving relocation of existing broadcasting stations and/or reassignment of their frequencies, has been presented. Technical and environmental criteria have been applied in conjunction with measurements and simulations. Human exposure to EM radiation has been considered for both current and future situations. The methodology presented in this paper may serve as a valuable tool in the decision-making process.



(a)



(b)

Figure 5: (a) A view of the foreseen installation at Location B, and (b) the safety index distribution around it

ACKNOWLEDGEMENT

The authors wish to acknowledge the support of the Hellenic Ministry of Transportation and Communications for conducting this study.

REFERENCES

[1] European Commission (EC), "Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)", Off. J. Eur. Commun., L 199, 59, 30 July 1999.

[2] Federal Communications Commission (FCC), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", OET Bulletin 65, Edition 97-01, August 1997.

Table 1: Results for each scenario

Location	Percentage of EIRP for each type of broadcasting stations to be installed												Coverage	
	Scenario 1			Scenario 2			Scenario 3			Scenario 4				
	TV	S/FM	P/FM	TV	S/FM	P/FM	TV	S/FM	P/FM	TV	S/FM	P/FM	pop	geo
A	96%	100%	100%	96%	100%	-	96%	100%	56%	96%	100%	-	100%	80%
B	-	-	-	-	-	100%	-	-	-	-	-	56%	90%	45%
C	-	-	-	-	-	-	-	-	44%	-	-	-	97%	76%
D	4%	-	-	4%	-	-	4%	-	-	4%	-	44%	90%	55%
L_i	1/710			1/870			1/825			1/870				

TV: private- and state-owned TV stations
S/FM: state-owned FM stations
P/FM: private-owned FM stations

pop: estimated population coverage in Thessaloniki, Greece
geo: estimated geographical coverage of the intended area