Design of jamming systems through a multi-criterion approach: Assessing the optimal antenna positioning on high complexity indoor environments

Guilherme Santos, Stevan Grubisic and Walter P. Carpes Jr.
Universidade Federal de Santa Catarina, Departamento de Engenharia Elétrica
Grupo de Concepção e Análise de Dispositivos Eletromagnéticos (GRUCAD)
C. P. 476, 88040-900, Florianópolis, Brazil
guilherme@grucad.ufsc.br, stevan@grucad.ufsc.br, carpes@grucad.ufsc.br

Abstract — This paper regards to an enhanced version of a methodology for the study of jamming systems, based in the optimal positioning of the antennas of these devices, which was presented by the authors in previous work. The proposed improvements concerns to the assessment of optimal locations on high complexity indoor scenarios, which are characterized by physical restrictions and unrelated target areas. Once this class of environment requires a special treatment on costing the quality of each antenna location, a multi-criterion method was developed, in a way that the design goals are considered separately for each target area of the scenario under analysis. A hypothetical indoor scenario which simulates real world difficulties is analyzed in order to evaluate the feasibility of our model. Results show that the new method is effective on the design of jamming devices for complex indoor scenarios.

I. INTRODUCTION

A widespread increase of wireless communication has been reported over the last years where major contribution is related to the mobile communication, hence the rising number of users of mobile devices. As a consequence, the requirement of an efficient control on the use of mobile phones is even more important on the safeguarding of a cultured society, aspect that overstated the use of signal scramblers such as the so-called jamming systems.

A jamming system is basically a device that purposely interferes with the physical transmission and reception of mobile communication, disabling the normal operation of cell phones in a closed area, without interfering signals outside it. Thus, it must be guaranteed that the system will attempt to the following conditions:

1) *Interfere any carrier signal inside of a target area;*
2) *Dot not jam mobile terminals outside of it;*

The effectiveness of jamming systems is frequently measured with empirical formulations based in the power of the signals involved (e.g. Jamming to Signal Ratio [1]), where an accurate prediction model is crucial for the calculation of power values over the interest environment.

A different approach was developed by the authors in previous research [2], concerning to the positioning of the antennas of these jammers. In this context, an association of Multi-Objective Particle Swarm Optimization and 2-D Ray-Tracing Technique was presented, in order to find the optimal location for the antennas of a jamming device with respect to its performance in a given indoor environment.

In this paper, the major goal is to properly enhance the above model, for the assessment of indoor scenarios of higher complexity, which are characterized by physical restrictions and unrelated target areas, where the efficacy of a given jamming system cannot be evaluated for the whole environment, but considered for each unrelated target area separately.

II. THE CLASSIC MOPSO/RT MODEL

In this association, the ray-tracing algorithm is taken for the calculation of the carrier-to-interference ratio (C/I) in the reception points distributed in the scenario under analysis. The average value is determined for each region under analysis in a way that two different cost functions can be defined: minimize the average C/I value inside the areas where the signal must be jammed and maximize it outside. These functions are considered to evaluate the quality of each particle in MOPSO, where particles are defined as particular configurations for the antennas of the jamming system, through Cartesian coordinates. At this point, the reader could see [3] for an overview on MOPSO algorithms and [4], for details about the ray-tracing (RT) model considered in this paper.

III. THE PROPOSED METHODOLOGY

As said, the problem of positioning the antennas of a given jamming system is understood as a multi-objective optimization task. Hence, two aspects must be carefully considered: to encode the positioning of these antennas and to select efficient criterions to evaluate their quality.

In cases where the scenario under analysis is symmetric or less complexity is involved, two criterions must be sufficient to represent the quality of a given configuration. Nonetheless, on the study of larger environments (where unrelated target areas or physical restrictions are present), several criterions should be considered for an effective costing. It can be accomplished by splitting the “main goals” (i.e. maximize the interference inside the target areas and minimize it outside) into several objectives, which are related to particular areas where the interference must be maximized or minimized.

For a better understanding, let us assume a scenario defined by m unrelated regions where the interference must work (**M**) and n unrelated regions where it should be avoided (**N)**. The problem can be formally stated as in (1), where f_k is a fitness function defined in this paper by the average value of the C/I ratio, which represents the quality of a given configuration with respect to the k^{th} region. Note that the exchange of signals is associated to the conversion of a maximization problem into minimization.

$$\min \mathbf{F} = [f_1,..., f_i,..., f_m, -f_{m+1},..., -f_j,..., -f_{m+n}]$$
$$s.t. \begin{cases} i = 1,..., m \in \mathbf{M} \\ j = m+1,..., m+n \in \mathbf{N} \end{cases} \quad (1)$$

In this study, due to the bi-dimensional feature of the RT technique, the location of each antenna is characterized by two coordinates (x_p,y_p). Therefore, to represent a certain configuration, each particle in MOPSO must be encoded such as in (2), where all the coordinates regarding to l antennas of a given jamming device are considered.

$$P = [(x_1, y_1),..., (x_p, y_p),..., (x_l, y_l)] \quad (2)$$

Notice that the proposed methodology was developed for the MOPSO/RT model presented at Section II, but it can be easily modified to suit enhanced methods, such as 3-D RT [5] models and different optimization algorithms. Also, it is possible to achieve optimal locations considering a neural network [6] instead an optimizer. In this case, the presented cost functions could be considered as outputs of a given network, which inputs are the feasible configurations for the antennas. We study these improvements in the extended version of this paper.

IV. EXPERIMENTAL RESULTS

In this section, we study a hypothetical problem that is considered with the aim of evaluate the suitability of the proposed methodology. The carrier signal to be jammed is provided by a simulated mobile phone base station (BS). The goal is to find the optimal position for two antennas of a jamming system at the hypothetical scenario depicted by Fig.1, which is characterized by three unrelated interest regions and no physical restrictions. Regarding to the last section, three objectives are going to be considered, in a way that the fitness function to be minimized is given by:

$$\mathbf{F} = [f_1, -f_2, -f_3] \quad (3)$$

Thus, we must find the set of solutions which minimizes the C/I ratio inside the area *1* and maximizes the C/I ratio inside the areas *2* and *3*. With this purpose, a 900 MHz mono-band jamming system with two antennas of 5dBi gain and 30dBm of transmitted power is simulated. The computational cost of each fitness evaluation is about ten seconds using an Intel Core 2 Duo E7400 @ 2.8GHz with 4GB RAM and 500GB HD. As suggested by Grubisic *et al.* in [4], the RT algorithm is set with a reception mesh of *36* points per square meter and a maximum number of reflections equal to two, sustaining a reasonable balance between prediction quality and computational cost. In MOPSO, the population size is set to *50* and the vital parameters are configured according to [3]. MOPSO incorporates some stochastic components to explore the search space, producing different results when executed with different random seeds. In this context, to estimate a reasonable Pareto-front, thirty independent runs were performed in each of the proposed problems, with a stop criterion of *5000* evaluations.

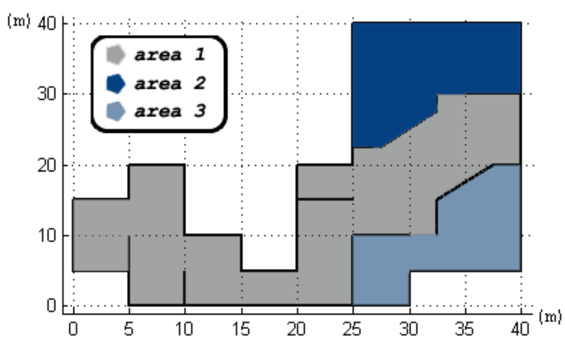

Fig. 1. Hypothetical indoor environment under analysis.

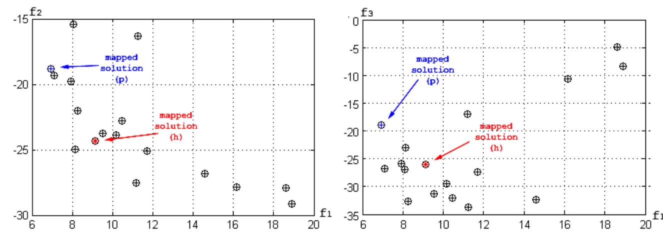

Fig. 2. Pareto-front estimated by MOPSO: f_1-f_2 and f_1-f_3 planes

For the sake of a better visualization about the quality of each optimal configuration obtained, Fig.2 plots the f_1-f_2 and f_1-f_3 planes of the best Pareto-front found among the runs. To emphasize the suitability of our proposed model, two different solutions are selected for investigation (see Fig.2). The first reasonably satisfies all the objectives while the second focuses in the minimization of the C/I ratio inside the area *1*. These optimal locations are stated in Table I, and its effectiveness can be visualized by the C/I mappings given by Fig.3. Observe that the fitness functions were efficient on costing the quality of the configurations and the goals of optimization were perfectly achieved.

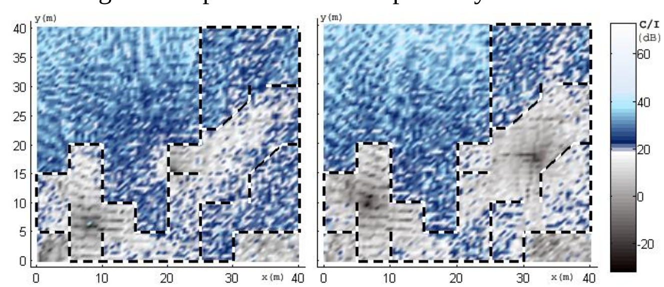

Fig. 3. C/I mapping (in dB) for the configurations *p* and *h* respectively.

V. REFERENCES

[1] V. K. Sambhe *et al.*, "Antenna for mobile phone jammer," *First International Conference on Emerging Trends in Engineering and Technology*, pp. 856-859, 2008.

[2] G. Santos *et al*, "Study of a jamming system positioning using 2D ray-tracing technique associated with a multi-objective particle swarm optimizer" *The 14th Biennial IEEE Conference on Electromagnetic Field Computation – CEFC 2010*, vol. 1, pp.1, 2010.

[3] M. R. Sierra and C. A. C. Coello, "Multi-objective particle swarm optimizers: a survey of the state-of-the-art," *International Journal of Comp. Intelligence Research*, vol. 2, no. 3, pp. 287-308, 2006.

[4] S. Grubisic *et al*., "Ray-Tracing Propagation Model Using Image Theory with a new accurate approximation for transmitted rays through walls," *IEEE Trans. on Magnetics*, vol. 42, no. 4, pp. 835-838, 2006.

[5] W. Lu and K.T. Chan, "Advanced 3D ray tracing method for indoor propagation prediction", *IEEE Electronics Letters*, vol. 34, no. 12, pp. 1259-1260, 1998.

[6] C. Turchetti, P. Crippa, M. Pirani and G. Biagetti, "Representation of nonlinear random transformations by non-gaussian stochastic neural networks", *IEEE Transactions on Neural Networks*, vol. 19, no. 6, pp. 1033-1060, 2008.