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Realization and conception of a printed antenna Ultra Wide Band to diversity by the algorithm of Particle Swarm Optimization

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ABSTRACT

The object of this article relates to the conception and the realization of a printed antenna Ultra Wide Band to diversity and the conception of it by use of an optimization algorithm of Particle Swarm Optimizers (PSO). These techniques of diversity are currently considered in the systems of wireless communication, in order to reduce the effect of major weakening's which the envelope of the signal undergoes, when electromagnetic wave propagation.

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Key words: Ultra wide band printed antenna to diversity, Particle Swarm Optimizers (PSO).

1. INTRODUCTION

Inside the buildings, the signals received on the mobile terminals undergo a certain number of deformations due to the nature of the walls or obstacles met. The attenuated signal can be considered or diffracted and arrives of various directions, at different moments. One is then in an environment multi waves or the channel of propagation is variable temporally, because of movement of the objects where people are present in the parts. These conditions generate on the one hand sharp variations of the level of the received signal ("fading" by destroying combinations of the phases of the signals multi waves) and on the other hand a temporal widening of the Complex Impulse Response (C.I.R) which will limit the flow of the communication. The techniques of equalization make it possible to be freed from these difficulties, but they are costly and consuming. On the other hand, techniques with diversity, in the broad sense [1], [2] and [3], can establish a rival approach and low-cost. These techniques can take multiple forms. It is possible to use the diversities of space, of frequency, of time, of polarization or of diagram of radiation. More generally, the devices able to manage these techniques of diversity make it possible to compensate for degradations due to the channel and to reduce the losses by fading caused by multiple ways thus improving quality of the transmission (increase in the signal report on noise). However of many technologies of antennas were proposed and developed in literature and which answer the majority of these needs. More especially in mobile telephony one can quote technologies GSM (890MHz − 960MHz and 1710MHz − 1880MHz), DECT (1880MHz − 1900MHz) and UMTS (1885MHz − 2200MHz), wireless networking's like the BLUETOOTH (2.4MHz − 2.485MHz) and the WiFi (5GHz for the standard 802.11a and 2.4GHz for the standard 802.11b and 802.11g) navigation systems by GPS (1575.42MHz) etc. All these applications and well of others, existing or to come, call on antennas printed to communicate.

The work presented in this article, concerns the elements of conception and of realization of antenna patch Ultra Wide Band (UWB) to diversity. As well as the conception of this one by use the evolutionary optimization algorithms. The basic structure that we adopted for these antennas is a simple structure. It consist of a rectangular patch with a simple meander line slot is inserted into the radiating patch, and two ground plane finished. The antennas are printed on FR4 substrate with dielectric constant of 4.4 and substrate thickness of 1.578 mm.

2. CONCEPTION AND REALIZATION OF THE ULTRA WIDE BAND PATCH ANTENNA TO DIVERSITY

2.1 Structure of UWB antenna

The antenna that we conceived is represented on figure 1. It is about a square structure on only one floor of 21 mm side, made up a rectangular patch of dimension 11.2mm X 10.5 mm, of a slit, supplied with two micro strip lines of width 4.9 mm each one and two finished ground plane of dimensions 5.9 mm X 21 mm and 5.1mm X 15.1 mm. Its prototype was constructed by using a substrate FR4 thickness 1,578 mm, of relative permittivity 4.4.

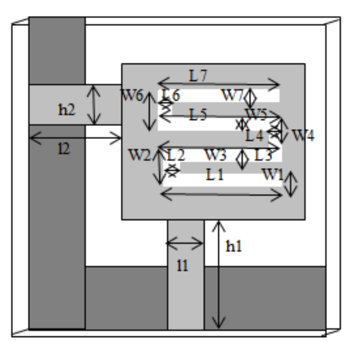

Figure1: Geometry of the antenna.

2.2 Realization UWB antenna

The optimal dimensions selected for the realization of the antenna, as determined from many simulation results are as follows: h1 = 8 mm, l1= 4.9 mm and h2= 4.9 mm, l2= 8 mm. And the slot dimensions are: L1= 6.4 mm, W1= 0.52 mm, L2=0.5 mm, W2 = 1.54 mm, L3= 7 mm, W3= 0.5 mm, L4 = 0.5 mm, W4= 1.5 mm, L5= 6 mm, W5 = 0.5 mm, L6= 0.5 mm, W6= 1.5mm, L7= 7.4 mm, W7= 0.52 mm. The prototype of this antenna is show in figure2.

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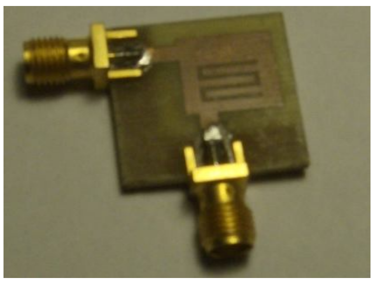

Figure 2: UWB antenna prototype

2.3 Return loss

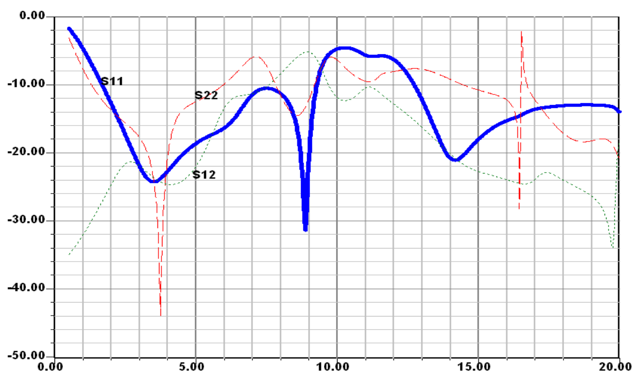

Figure 3: Return losses for the antenna**.**

The figure 3 shows us at which point the performances of the antenna respect the standards of conception. Actually, it is seen well that the coefficient S11 is well adapted enters 2-9 GHz. Also the coefficient S22, it is well adapted enters 2-6 GHz and enters 8 - 9 GHz. As for the coefficient S12, it is adapted enters 2-6 GHz. What represents factors of transgression (compared to – 10 and -15 dB respectively) considerable, which to be reduced or cancelled, require a judicious adjustment of the parameters of conception and more particularly, the positions of the feeders and dimensions of the aerial of elements like those of the two ground plane. What puts a complexity of adjustment and of regulation with avoidable the difficulty.

2.4 Constraints posed by the manual design and clarification

The manual conception of the antennas poses a large number of problems of adjustment and of regulation their parameters of conception, can continue several weeks without managing to obtain optimal performances. What is mainly due to the lack of beforehand definite strategy for the adjustment the variables of conception which are in large number. What complicates with advantage the process of research. Moreover, for other types of antennas such as those with diversity, to the objectives of adaptation of the coefficient of reflection compared to the first port (S11), those of the second (S22) are added, like that of the coupling between them (S12). What complicates the problem: it acts by way of problem of forced conception and multi objective. From where interest to use advanced algorithms of optimization such as those based on models of evolutionary calculation inspired by the world of alive, like the genetic algorithms or the particles swarms for example.

3. OPTIMIZATION EVOLUTIONARY OF ANTENNA PRINTED UWB WITH DIVERSITY

3.1 Optimization evolutionary of the antennas printed

On the basis this point of view, several studies were conducted on the subject. In 2004, Rahmat Samii and al. used a genetic algorithm for optimization of the conception of an antenna patch representative for mobile telecommunication for frequency 1.9 and 2.4 GHz [4]. In 2006, the method of optimization per algorithm multi-minimum heuristics or genetic algorithm was associated with a method of optimization local and applied by Branko M. Kolundzija and Dragan I. Olcan in the conception of antenna [5]. However, the approaches used in most part of these works are based on the optimization mono objective. Consequently they are not well adapted to the resolution of the problems multi objective of optimization with real parameters such as those encountered when designing the antennas patch to diversity.
Indeed, the optimization or rather the adaptation of an antenna patch by genetic algorithms can be approximate in two distinct ways: (I) to discretize the form of the patch by breaking up it into a series of identical squares or (II) to discretize the real parameters defining the form of the patch. In the two cases, on the one hand that introduced the errors of discretization which result in inaccuracies of distances to which add the irregularities of contours for the not rectangular forms. On the other hand the number of bits necessary for a precise representation of a shape of the patch is too much big (some hundred for a precision of the order of the mm). In addition the number of bits necessary for a precise representation of a form of the patch is too large (some hundred for a precision about the mm). Also, in these works the objectives of optimization are included almost always in a single objective by use of weighted average. What causes a problem of compromise with difficulty reachable compromise for all the objectives of conception and consequently the found solutions are not necessarily optimal with the multi objective directions.

3.2 suggested Solution.

In the approach which we propose, the problem is considered in its natural form: (I) the forms are directly defined by their natural geometrical properties and are accurately represented by real vectors of finished size; (II) with the problem is dealt in its form multi objective. What leads to the use of a model of calculation evolutionary adapted to the problems of continuous optimization, such as Particles Swarm Optimizations (PSO) for example, and where the selection between solutions is based on the concepts of predominance which nowadays remain the best suitable ones for the multi comparison criteria necessary to the resolution the problems of multi objective optimization.

3.3 Elements of conception of an algorithm of evolutionary calculation for the optimization of antenna printed UWB with diversity

About is the nature of the composed problem of optimization and any abstraction made as for the nature of the operators of envisaged evolution, the procedure of definition of the elements of conception of the algorithm remains typically the same and can be expressed in a generic way as indicated:

- Definition of the objectives of optimization;
- Definition of the structure of the variables of decision ;
- Specification of the functional constraints;
- Demarcation of the space of research;
- Definition of the operators of evolution;
- Definition of the metrics of similarity.

As for the techniques of implantation and more particularly those of the evaluation of the objective and the management of the constraints, her cannot be generalized: they are conditioned and dictated by the rules of the domain of the envisaged application, where the model of artificial learning by intelligence of swarming is used for the adaptation by optimization of the radiant elements of antennas patch Ultra Wide Band usually used in mobile telecommunications.

3.3.1 Definition of the objectives of optimization

To be able to optimize the performances of a printed antenna multi-ports, at least two scalar functions of evaluation of the objectives must be defined on the interval of frequency considered delimited by the frequencies bass fL and high fH, or F = [fL, fH,].

- The levels of the coefficients of reflections for each p orts and,
- That of the coupling between them

To do it, several functions were introduced recently. For example Rahmat Samii and al. proposes an approach to optimization mono objective where the whole of these objectives are included (by balanced sum) in a single function [4] this for all the frequencies; as for Li. Zhifang and al propose a function which detects the maximum coefficient of reflection in the considered frequency band [6]. However, all these functions are expressed in terms of optimization mono objective and consequently the found solution is not necessarily the best for all the objectives. What brings us in the present study, to consider them separately rather than to merge them in a single objective by aggregating them by a balanced sum, as is made in most of the works on the conception of the printed antennas [7], [8] and [9]. What allows handling the problem of optimization considered directly in its form multi-objective and this very sure by use of the concept of dominance as that of necessary Pareto in comparison with the solutions. What brings us, in the case of a structure in two ports, to define for a variable of decision X, the vector objective function to be minimized (1).

$$F(X) = \frac{1}{N_F}\sum_{k=1}^{N_F}\begin{pmatrix}|S_{11}(X, f_k)|\\ |S_{22}(X, f_k)|\\ |S_{12}(X, f_k)|\end{pmatrix} \qquad (1)$$

However, in practice it is not necessary to minimize these objectives in an absolute way; it is enough that they are below a value which satisfies the desired performances. This important remark important us to modify this function as follows (2).

$$X_{op} = \min_{x \in S}\left(\frac{1}{N_F}\sum_{k=1}^{N_F}\begin{pmatrix}|S_{11}(X, f_k)| - S^*_{ii}\\ |S_{22}(X, f_k)| - S^*_{ii}\\ |S_{12}(X, f_k)| - S^*_{ij}\end{pmatrix}\right) \qquad (2)$$

Where S*ii and S*ij indicates respectively acceptable values specified by the user for the factors of reflection of direct transfer and by the coupling. In the present study, these values are fixed to 10 dB and 20 dB respectively. NF being the number of points of frequencies retained for the evaluation of factors of reflection.

3.3.2 Definition of the variable of decision

3.3.2.1 Structure and parameters of conception of the antenna

All the parameters of conception of a printed antenna in two doors are defines by the geometrical structure of the element shining in the shape of snake given on the figure 4.

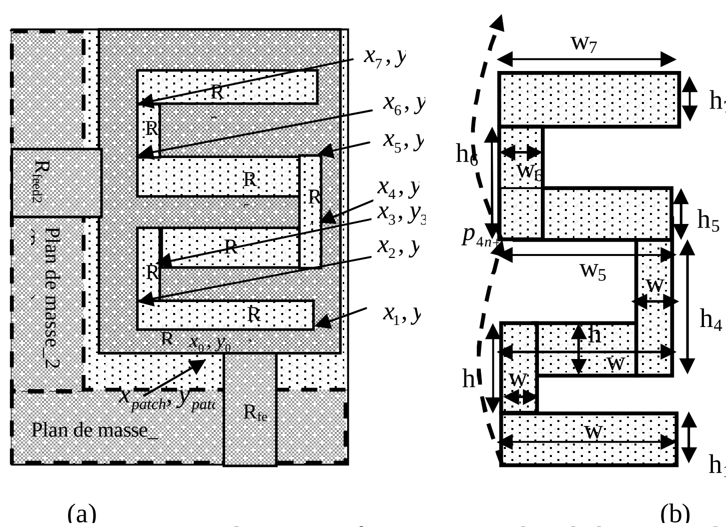

Figure 4 geometrical Structure of an antenna patch with diversity with element shining in the shape of serpentine: (a) antenna, (b) radiant element

All these parameters is grouped in the table 1

Table 1 Parameters of original conception

Symbol	Significat ion	Position x (mm)	Position y (mm)	width w (mm)	height h(mm)
S	Substrate	0.00	0.00	21.00	21.00
G_1	ground plane _ 1	0.00	0.00	21.00	hG_1=5.9
G_2	ground plane _ 2	0.00	hG_1	5.10	21- hG_1
F_1	coplanar Line _1	9.50	0.00	4.90	8.00
F_2	coplanar Line _2	0.00	15.10	8.00	4.90
P	Patch	8.00	8.00	11.00	10.80
G_1	first slot	16.90	9.98	6.40	0.52
G_2	Second slot	10.50	9.46	0.50	1.54
G_3	Third slot	10.00	11.00	7.00	0.50
G_4	Fourth slot	17.00	11.50	0.50	1.50
G_5	Fifth slot	16.50	12.50	6.00	0.50
G_6	Sixth slot	10.50	12.00	0.50	1.50
G_7	Seventh slot	10.00	13.00	7.40	0.52

Among these parameters 42, in a first approach, only the parameters corresponding to the radiant element will be considered as variables.

3.3.2.2 Components of the variable of decision

Several motives or elementary forms can be adopted to compose the radiant element represented on the figure 4b. Seen their simplicity of representation and consequently coding, we could be tried to use rectangular surfaces, which presents however two major inconveniences: i) complication of the management of constraints of limits, and what is more important, ii) low level of training due to the big naturally existing similarity between rectangular forms. To return this more constructive learning, and from there even simplify the management of the constraints, we suggest using slot in 'L' rather than rectangular according to the geometrical representation of the figure 5

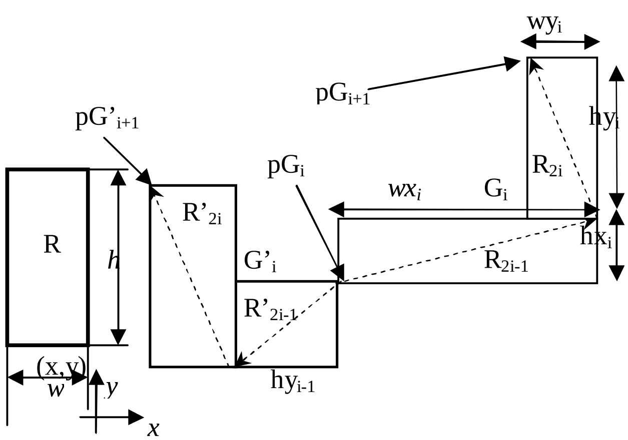

Figure 5: Geometrical properties of the nth elementary slot in one L, straight ahead (Gi) or left (G'i)

In accordance with this representation, by locating a rectangle by the position of its left corner in bottom. The geometrical properties of a slot in the shape of serpentine can be automatically generated by the model of following recurring calculation

$$R \overset{\Delta}{=} (x, y, w, h) \quad , \qquad (3)$$

$$G = \bigcup_{i=1}^{nG} G_i \quad , \qquad (4)$$

$$G_i = R_{2i-1} \bigcup R_{2i} \quad , \qquad (5)$$

$$R_{2i-1} = (xG_i + s'(i) \cdot wx_i, yG_i + s'(i) \cdot hxi, wx_i, hx_i) \quad , (6)$$

$$s'(i) = \begin{cases} 0 & si \quad L \ droit \\ -1 & si \ L \ gauche \end{cases} \qquad (7)$$

$$R_{2i} = (xG_i + s(i).wx_i - wy_i, yG_i + s(i).hx_i, wy_i, hy_i) \quad (8)$$

$$s(i) = \begin{cases} +1 & si \quad L \ droit \\ -1 & si \ L \ gauche \end{cases} \qquad (9)$$

$$xG_{i+1} = xG_i + s(i) \cdot wx_i - wy_i, yG_i + s(i) \cdot (hx_i + hy_i) \quad (10)$$

In the present study one is interested only in the serpentine of simple shape, obtained by alternating the directions of slots L every time, which is

$$sens\ (Gi) = \begin{cases} gauche & si \ \ i \ pair \\ droit & si \ i \ impair \end{cases} \qquad (11)$$

The components of the variable of decision corresponding to the parameters retained for the adjustment are enumerated in the table 2 this below

Table 2 Components of the variable of decision for the optimization of an antenna patch

Significance	Symbol
Position x of the first slot	x_1
Position x of the first crack	y_1
Width of the horizontal rectangle of the ième slot in L	wx_i
Height of the horizontal rectangle of the ième slot in L	hx_i
Vertical width of the rectangle of the ième slot in L	wy_i
Vertical height of the rectangle of the ième slot in L	hy_i

What gives rise to the following the definition

$$\mathbf{X} \overset{\Delta}{=} \left(x_1, y_1, (wx_i, hx_i, wy_i, hy_i)_{i=1,..,n_{BG}}\right) \in S \subset R^{n_D} \qquad (12)$$

where S is the real space of research multi-dimensional considered, Nd being the number of its dimensions (Nd=2+Nbg), Nbg being the number of formed slots in L each one by two elementary rectangles directed one according to the x axis and the other according to that of the Y

3.3.2.3 Delimitation of the space of research

Knowing that the plan of prospecting in the evolutionary algorithms is based on the experience, it is clear that the complexity of the model of corresponding calculation is inversely proportional to the considered space of research, where from the interest to limit it to the maximum. What is generally assured, by taking into account on the one hand technological constraints of manufacturing of printed antenna and on the other hand functional the constraints. So, the space of research can be limited by the lower and superior borders of the components of the variable of decision as follows (13).

$$\boldsymbol{S} \overset{\Delta}{=} \prod_{d=1}^{n_D} \left[x_{Min}(d), x_{Max}(d) \right] \subset R^{n_D} \quad (13)$$

Remark: according to the complexity of the forms used for the radiant elements, these minimal and maximal values for every component of the variable of decision can be or static or dynamic.

3.3.2.4 The PSO Optimization Algorithm

The algorithm used for the purpose of this study is implemented by one moving method that updates particles velocities and moves them according to equations (5) and (6), an objective evaluation procedure and a selection one which is used to update the best previous and best global locations which should be considered as new attraction locations for the next generation.

```
Create Np particles and randomize their position
uniformly in the search space;

While the target objective is not achieved by the best
particle {
  for each iteration of the evolution process {
    for each particle{

      Handle constraints, rewrite design and result
      acquisition scripts;
      execute the output hfss script;
      read results;
      update current and subsequently the previous
      best objective position
    }
  Detect the global best particle;
  For each particle update velocities and move;
  }
}
```

Figure 6: optimization algorithm

In this algorithm, each hfss design solutions or decision a variable is encoded in a separate particle. By particle, one mean an instance of a class object encapsulating a real vector and dotted with movement methods or procedures. As described in figure 6, the algorithm statement begins in the initialization step, by creating Np uniformly sparse particles in the considered search space. After what, for each generation of the optimization process, the implemented methods described above are launched until the meeting of the optimization objective which consists in finding the location of the global optimum that minimizes the characterization error and this with respect to the constraints imposed by the problem under optimization.

4. . CONCLUSIONS

We presented in this article a small antenna patch Ultra Wide Band to diversity, with simple configuration, is printed on a substratum of FR4, with a dielectric constant of 4.4 and a thickness of 1,578 millimeter, we proceeded in one first one place to the conception and to the realization of this antenna and in the second place in the development of the elements of conception by the algorithms of Particle Swarm Optimization (PSO) allowing to fix the main characteristics of this antenna

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