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GENETIC ALGORITHM OPTIMIZATION OF DUAL POLARIZED AND LARGE BANDWIDTH PRINTED ANTENNA.

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Introduction :

In this paper, we present an original application of the genetic algorithm [1] to design dual polarized and large bandwidth printed antenna. Few works have been done towards the automatic research of optimum geometries of antenna in order to obtain both large bandwidth, dual polarization and good cross polarization. Sleeves antennas are well known to perform a broadband behaviour and a good purity of polarization. An extension of the initial design has been performed and a new antenna including one fed dipole and four parasitic elements using printed technology is presented.

The main difficulty to obtain large bandwidth is to optimize the geometry of the antenna. The large number of parameters (the length of feeding dipole, the lengths of parasitic dipoles, the distance between parasitic dipole and feeding dipole for example) yield an untractable problem because of the important number of combinations. The possibilities are too large and an exhaustive research is impratical.

The genetic algorithm has been recently [2-4] chosen because it is a robust stochastic search method which operates on a group of solutions (population) using encoded parameters rather the parameters themselves. The electromagnetic analysis and the genetic algorithm procedure are first described ; experimental results are given for validation.

Theory:

a- Analysis :

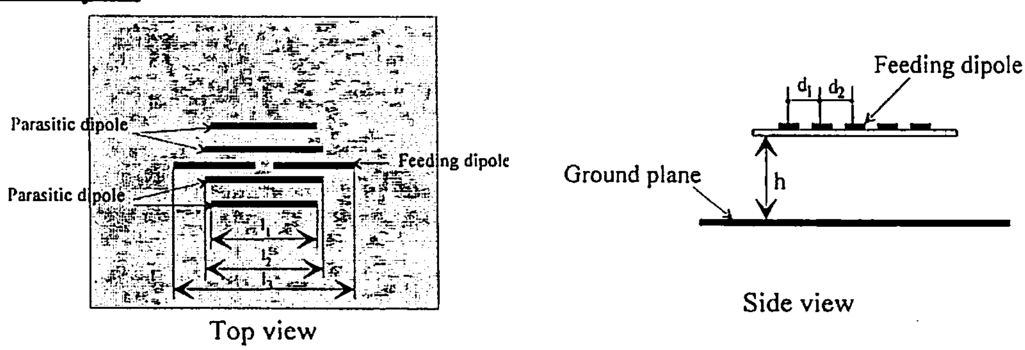


Fig. 1 : Sleeve antenna placed over a ground plane

Printed filar structure are analysed using basically the same procedure developped in [5]. It performs a frequency domain analysis of thin wire antennas. The sleeve antenna is presented on figure 1. Integral equations for conducting wire structures are written in order to satisfy boundary condition on the wire. The resolution of the integral equation is based on the reaction concept and the well known method of moment. As in [5], the dielectric effect is taken via the polarization current $\bar{J}p$ which yields a supplementary term ΔZ_{mn} added to the generalised impedance term Z_{mn}. In our case, a basis function as a piecewise sinusoidal is selected and with the Galerkin method, we obtain the linear equation:

$$[V_m] = [Z_{mn} + \Delta Z_{mn}] \cdot [I_n] \qquad (1)$$

Using the concept of equivalent radius of thin cylindrical antennas, the method described by Richmond [5] can be used for printed antenna. The polarisation current $\bar{J}_p = j\omega\varepsilon_0(\varepsilon_r - 1)\bar{E}$ depends on the knowledge of the $\bar{E}$ field distribution.

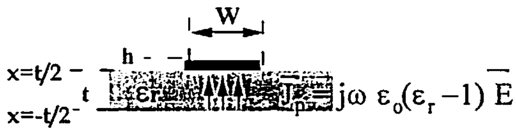


Fig. 2 : Dielectric modelisation with polarisation current $\bar{J}p$ due to $\bar{E}$ field.

The first assumption of a uniform $\bar{E}$ field distribution under the metallic strip yields a simple mathematical relation which needs some refinement in order to take into account the fringing fields. An empiric formula $f(\varepsilon_r)$ has been established for ε_r ranging from $\varepsilon_r = 1$ to $\varepsilon_r = 10.2$. The polarisation current becomes :

$$J_p = -\frac{(\varepsilon_r - 1)}{\varepsilon_r} \frac{1}{2W} \frac{\partial I}{\partial l} f(\varepsilon_r) \qquad (2)$$

where : $f(\varepsilon_r) = \dfrac{1}{7.2691 - 3.0609\varepsilon_r + 0.74962\varepsilon_r^2 - 9.4388.10^{-2}\varepsilon_r^3 + 5.935.10^{-3}\varepsilon_r^4 - 1.4815.10^{-4}\varepsilon_r^5}$

Thanks to this simple expression of $\bar{J}p$, simple expression of ΔZ_{mn} were obtained and we save a lot of computation time.

b- Optimization :

In the second step, we introduce the optimization technique named genetic algorithm which uses the well known sequences (Initialisation of the population, Selection, crossover and mutation).

Population : A set of trial solutions is assembled as a population. The parameter set (l_1, l_2, l_3, d_1, d_2) representing each trial solution is first coded using binary code (also name chromosome).

Reproduction : As shown on figure 3, this step follows a first initialization random process. Then a selection scheme occurs which uses a probability for each individual; the probability is proportionnal to the individual's relative fitness. Following the choice of two chromosomes, children are then generated using two main stochastic operators : crossover and mutation.

Crossover involves the random selection of a crossover site (binomial process) and the combination of the two parent's genetic information included in a chromosome. Mutation is a mechanism for introducing new, unexplored points into the genetic Algorithm optimizer's search domain.

Objective function : In this case, the objective function is the mean value $|\Gamma_i|$ of the return loss over the total bandwidth (evaluated numerically by the filar printed analysis method).

$$|\Gamma_t| = \frac{1}{N}\sum_{i=1}^{N}|\Gamma_i| \quad (3)$$

where Γ_t, Γ_i, N are respectively the average return loss, the return loss for the considered frequency and the number of frequency considered on the bandwidth.
The algorithm determine the parameters of the antenna which provide the optimal solution (minimum value of the average return loss).
The figure 3 summarizes the optimization technique which associates a genetic algorithm and the electromagnetic analysis method presented above.

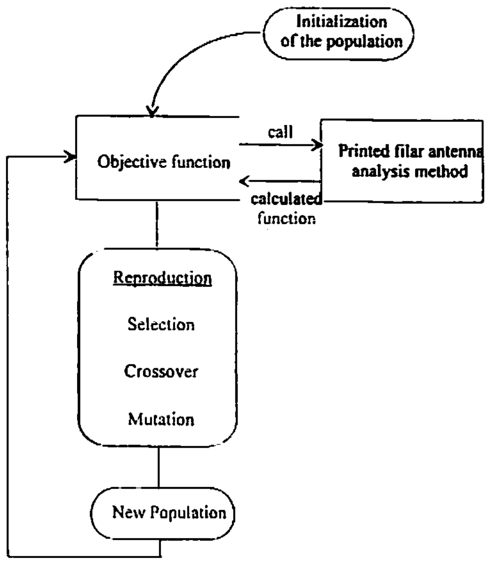


Fig. 3 : Optimization Chart

Application :

The optimization algorithm presented above has been applied to the design of broadband antenna linearly polarized (fig. 1).

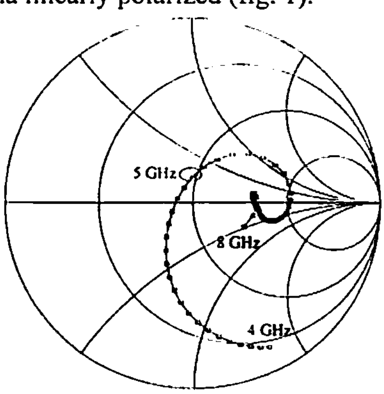


Fig. 4-a

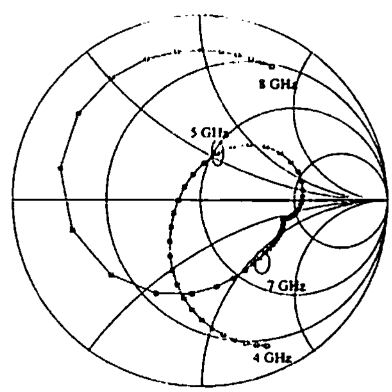
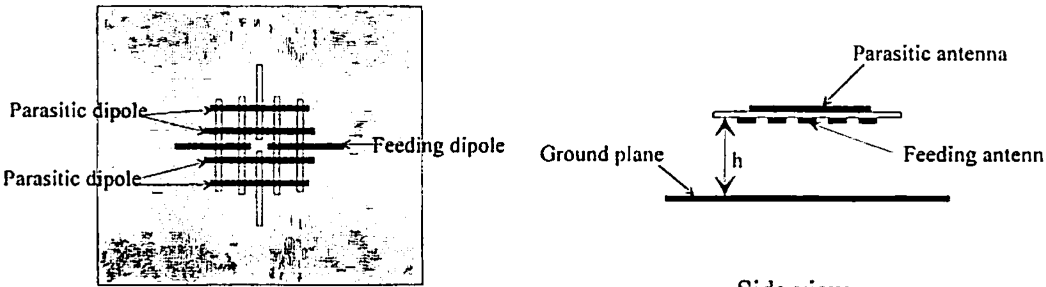


Fig. 4-b

Fig. 4 Theoretical input impedance

The results are plotted on fig. 4-a where the loop between 5 to 8 GHz around 100 Ω corresponds to a relative bandwidth of 46%. The substrate is a DUROID sheet of thickness 0.78 mm and 2.2 dielectric constant. The dimension are : l_1=14.18mm, l_2=18.1mm, l_3=28.49mm, d_1=3.95mm, d_2=1.39mm.The curve given on fig. 4-b shows the new impedance curve of the dual polarized structure of figure 5. The relative bandwidth is 33% near 6 GHz.



Top view   Side view

Fig. 5 : Configuration of the dual polarized antenna

Unfortunately, the mutual coupling between the two orthogonal structures has a strong effect (Fig. 4-b) and a global electromagnetic analysis must be performed.

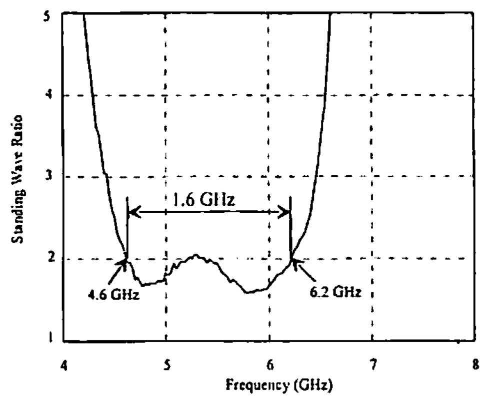


Fig. 6-a

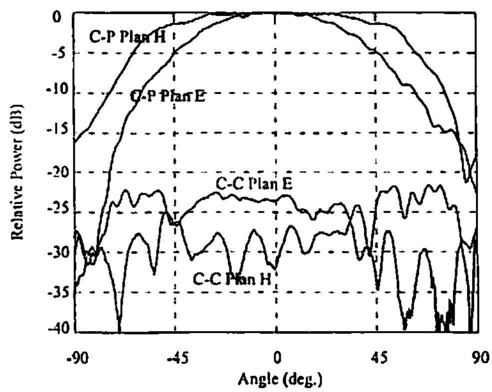


Fig. 6-b

Fig. 6 : Experimental results

Some experiments were carried out on the dual polarized antenna which is fed through a 100Ω printed bifilar transmission line orthogonally located toward the dielectric sheet and followed by a printed balun. Fig. 6-a shows the measured SWR and relative bandwidth of 30%. On figure 6-b are plotted the experimental E and H plane radiation patterns at the central frequency 5.3 GHz. The.cross polarization remains lower than -23 dB.

Conclusion :

In this paper, we have presented an application of the genetic algorithm associated with a printed filar antenna analysis method. The optimisation has been used to determine the parameters of a new broadband dual polarized sleeve antenna. The theoretical results are in good agreement with experience. Further work is necessary to improve the bandwidth through a global optimization including all the mutual coupling. Some results will be given at the conference.

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