Realisation and Optimization the System of Ridge Waveguide Polarizer by Genetic Algorithms for Telecommunication Satellite Antennas

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Summary
The ridged waveguide polarizer is considered as the better way to get right-hand and left-hand circular polarization in the antennas of telecommunications satellites. In fact, it is a system of three ports used to feed a square waveguide antenna in order to achieve high purity in the right-hand and left-hand circular polarization. Obtaining a great purity of polarization results by the addition from screw from adaptation and blades from correction. A solution with this problem is obtained by the optimization of dimensions of the various ridges. The object of work consists in determining optimal dimensions of the ridges of the polarizer by using the "Genetic Algorithms". The structure is modeled in 3 dimensions then simulated and optimized in order to obtain a 90° phase shift between the two orthogonal components in the system output and this in the waveband [11-13] GHz. The results of simulation and optimization are outlined using the HFSS software.

Keywords: Polarizer, Ridged waveguide, Simulation, Optimization, discontinuities.

1. Introduction

The polarization properties of the fields and the antennas are naturally the first concerned in any problem treating the communication between satellite antennas. The receive antenna power varies from maximum value to the zero according to the field polarization state. Thus the use of the polarizer in the transmitting or receiving antennas is necessary. In general the systems of antennas require fields with circular polarization [1], [2]. This is so that the re-use of the wave in two orthogonal polarizations makes decrease the occupied waveband. The installation of a polarizer making it possible to re-use the same antenna in two right and left circular polarizations involves the reduction in the weight and the obstruction of the satellite compared to a solution including two antennas [3].
In this article, we are interested in the synthesis of the ridged waveguide by the use of a method of stochastic optimization based on the genetic algorithms, in order to determine optimal dimensions of the ridges [4]. The analysis of the polarizer based on the determination of the various parameters-S [5], the coefficients of reflection of entry of modes TE_{10} and TE_{01} as well as phase shift of 90° between the two orthogonal components [6] of the electric fields. The results of simulations and optimization by software HFSS are presented and discussed.

2. Ridge waveguide polarizer

2.1 Characteristics of ridge waveguide polarizer

The ridged guides (figure1) have a low impedance of wave, which makes it possible to achieve good transitions with the planar lines of transmission; they have a broad band-width and a cut-off frequency of the rather low fundamental mode allowing the realization of the components of reduced size and less cumbersome, therefore more compact. In spite of a rather important attenuation and a limited transported power due to the multipactor effect in the area of the gap, the ridges guides are used in many microwaves applications and in particular in the realization of the filters with evanescent modes and the food for the satellites antennas.

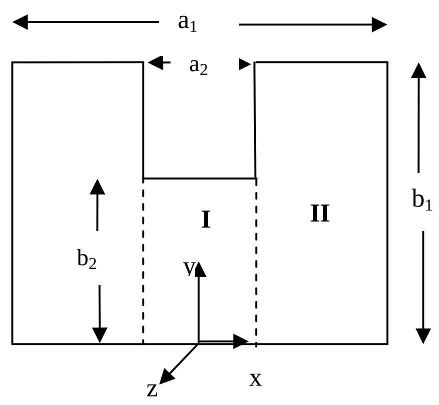

Fig. 1 transversal Coupe of the ridged waveguide.

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2.2 Ridged waveguide polarizer

It consists of a square waveguide divided in half by a metal blade. The division of the square waveguide leads to two identical rectangular guides; taken as the system input; and one square waveguide used as the system output (Figure 2).

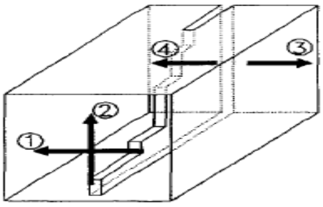

Figure 2: The structure of the ridged waveguide polarizer.

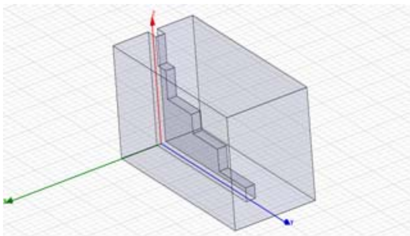
Figure 3: The structure of the ridged waveguide polarizer in HFSS.

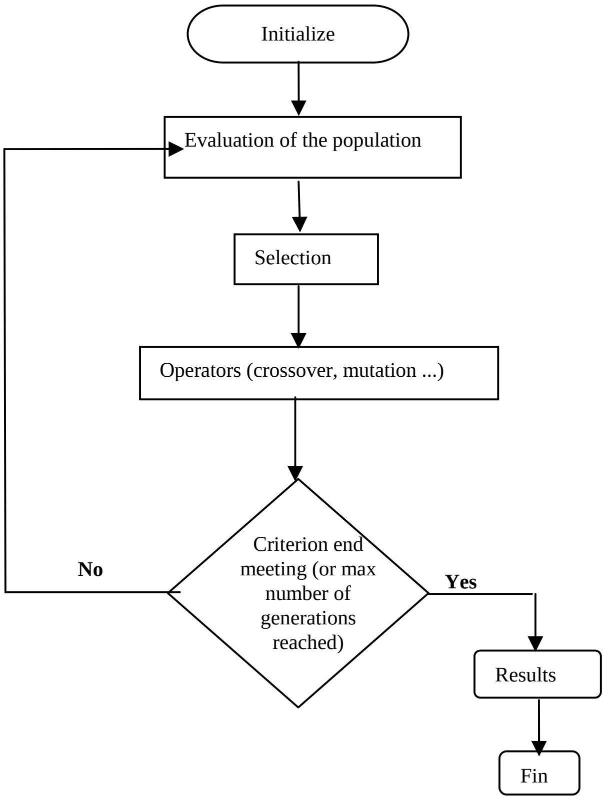

Figure 4: Genetic Algorithms.

3. Genetic algorithms

The genetic algorithm is an algorithm of optimization based on techniques derived from genetics and natural evolution: combination, mutation, selection, etc... The genetic algorithm has a relatively long history since the early work of John Holland on adaptive systems dated to 1962 [7]. This algorithm searches for the extremes of a function defined on a data space. The genetic algorithm structure can be represented as in (Figure 4):

4. Applications

4.1 Simulation of ridged waveguide polarizer

The simulator of structures high frequency of Ansoft HFSS (Hight Frequency Structural Simulator [8]) is a software package (EM) electromagnetic double alternation allowing the electromagnetic calculation of a structure in 3D. HFSS is used in several electromagnetic fields and in particular in the field of Telecommunications for the simulation of satellites antennas. In our application, we took the parameters of the following guide:

- $a_1 = 0.01565$ *m* (width of the guide).
- $b_1 = 0.01565$ *m* (height of the guide).
- a_2 = 0.00035 m (thickness of the ridge).
  Where,
- b_2 (i): is the space between the rectangular waveguide and the height of i^{th} ridged waveguide.
- *Lenght(i): is length of i^{th} ridged.*

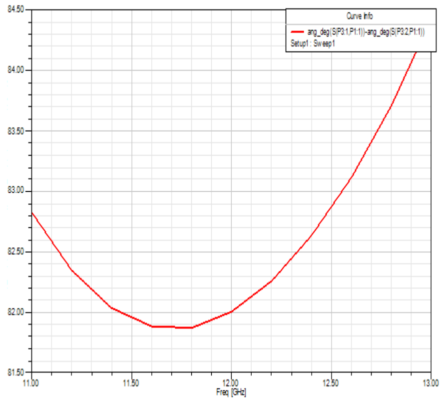

Figure 5: Value of non-optimized phase shift.

4.2 Optimization of ridged waveguide

The application of the"genetic algorithm" enables us to solve the problem of synthesis of the ridged waveguides polarizer. It is a question of determining the lengths and the heights of the ridged, which generate a phase shift of 90°. In our application, we put forward the characteristics of AGs in their applications to optimization [9], [10] the lengths and heights of the ridged waveguide.

In fact, many parameters influence the solution of the problem by the genetic algorithm. After several tests, we noted that a good precision with a relatively acceptable computing time are obtained by applying the following parameters:

- Number of individuals: 30.
- Number of generations: 100.
- Probability of mutation: 0.02.
- Probability of crossing: 0.8.
- Coding of 16 bits.
- Select by Russian roulette.
- Tolerance error = 0.001.ε.
- Terminals variations [11 to 13] GHz.

- The optimal dimensions of the different lengths and heights ridges are in the following table.

Table 1: Dimensions of the optimized Length and height of 5 ridges.

Ridges	***1***	***2***	***3***	***4***	***5***
The optimized height (mm)	15.65	12.18	7.42	4.35	1.90
The optimized length (mm)	7.82	2.62	6.57	6.47	8.45

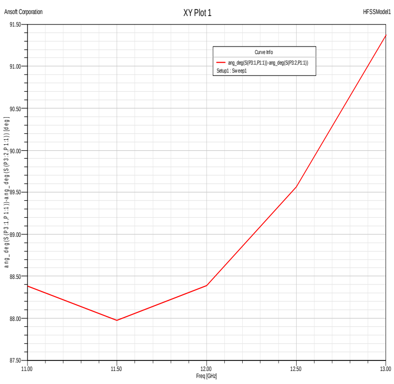

Figure 6: Variation in the phase shift versus frequency after optimization of different lengths and heights of the 5 ridges of the guide by the AGs method.

As it's mentioned above, the obtained results by the "AGs" are accurate and satisfactory, but the optimization procedure takes a very important computational time.

5. Simulation and optimization of the double ridged waveguide

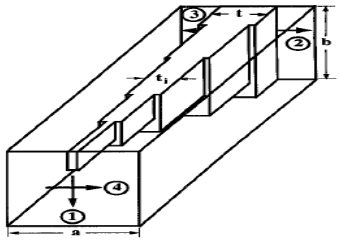

Figure 7: Simulation and optimization of double ridged waveguide.

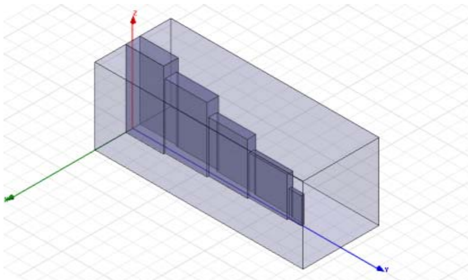

Figure 8: Structure of doubles ridged waveguide polarizer.

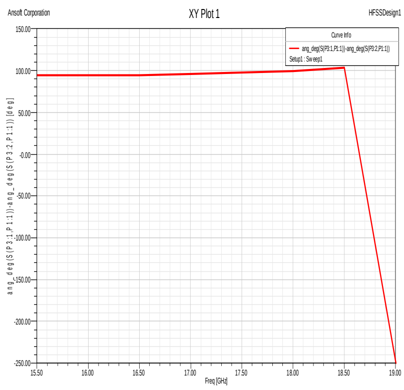

Figure 9: Variation in the phase shift versus frequency after optimization of different lengths and heights of the 5 ridges of the guide by the AGs method.

In our application, we took the parameters of the following ridge waveguide:

a_1 =0.01565 m (lenght of the guide),

b_1 =0.01565 m (heigth of the guide),

a_2 =0.00035 m (thickness of the ridge).

$b_2(i)$: the vacuum enters the rectangular guide and the height of the i^{th} ridge waveguide.

long(i) : length of i^{th} ridge waveguide.

Table 2: Dimensions of the optimized Length and height of 5 ridges.

RIDGES	1	2	3	4	5
The optimized height (mm)	15,65	12,18	7,42	4,35	1,90
The optimized leght (mm)	7,82	2,62	6,57	6,47	8,45
The optimized thickness (mm)	2,03	1,60	1,20	0,80	0,40

6. Simulation and optimization of the circular ridged waveguide

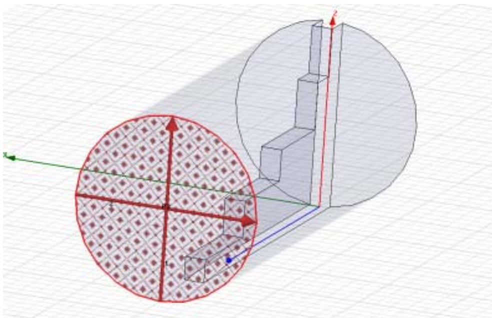

Figure 10: Structure of the circular ridged waveguide polarizer.

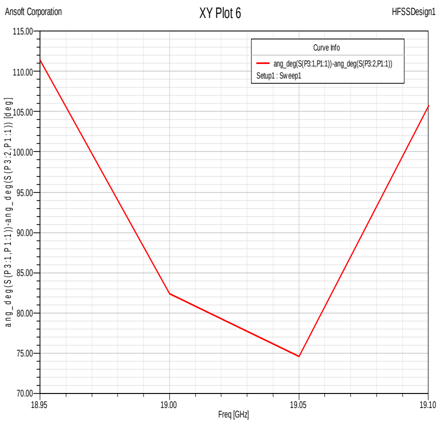

Figure 11: Value of non-optimized phase shift.

In our application, we took the parameters of the following guide:
Long =53,654 mm (Length of the guide),
a=22.86 mm (Diameter of the guide),
a/2 =11.43 mm (Length of the ridges).

Table 3. Dimensions of the optimized Length and height of 5 ridges.

RIGDES	1	2	3	4	5
The optimized height (mm)	22,86	16,93	11,12	7,31	2,84
The optimized leght (mm)	3,50	3,61	11,16	11,47	12,46
The optimized thickness (mm)	2,54	2,54	2,54	2,54	2,54

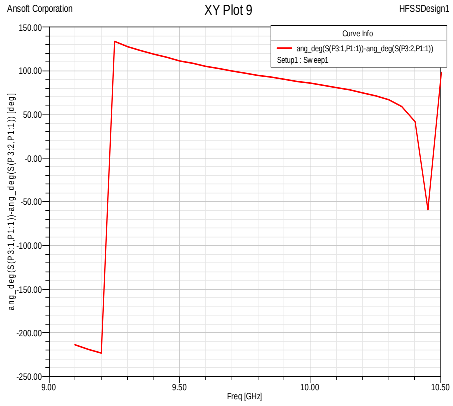

Figure 12: Variation of phase shift according to the frequency after optimization various lengths and heights of the 5 ridges of the circular waveguide by the method of AGs.

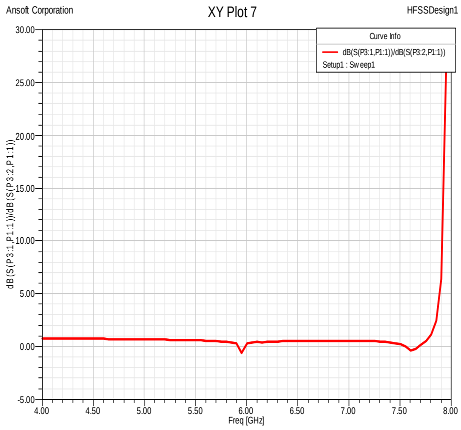

Figure 13 : Value of the rate of the ellipticity the « TOS ».

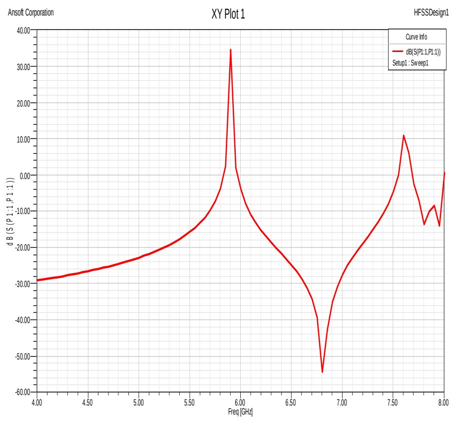

Figure 14: Coefficient of reflection.

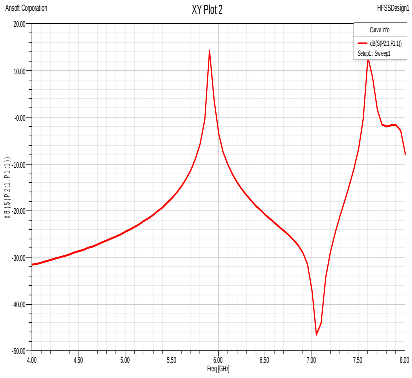

Figure 15: Coefficient of transmission.

Conclusion

The optimization technique based on algorithms is global and stochastic has the advantage of escaping the local solutions on deterministic methods, and achieve faster results. The application of "AG" to optimize the phase shift to 90° will also benefit the simultaneous action of several different parameters performing specific network functions of satellite antennae. However, this approach can present a major drawback represented by the computation time machine and the difficulty of programming and it has little chance of finding the ideal solution.

In our various applications, we have represented the variations obtained in phase according to frequency. For a prefect circular polarization; whose phase must remain constant and equal to 90°. Several optimizations have been performed using simulation software HFSS: optimization software which is robust and very professional performance for analysis, simulation and optimization of 3D ridged waveguide. The results were satisfactory.

In this article, the use of genetic algorithm was effective for the synthesis. The example simulation that has been presented showing that it is always possible to approach a phase shift of 90°.

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