



## L'ÉLECTROMAGNÉTISME, 150-1 UNE SCIENCE EN PLEINE ACTION !

**Titre: Antenne Multifonction et Multi-polarisation basée sur les Métamatériaux**

**Title: Multi-function and Multi-polarization Metamaterial-based Patch Antenna**

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### Abstract

In this paper, for aeronautical purposes we presented a patch antenna allowing to group on a single substrate two very different functions. The first function is the GPS (Global Positioning Systems), frequency  $\sim 1.5754$  GHz (signal L1) or  $1.2276$  GHz (signal L2) with a circular polarization and omnidirectional radiation patterns. The second is the DME (Distance Measuring Equipment) with a frequency  $\sim 1.1$  GHz and monopole-like radiation behaviours. A metamaterial high impedance surface (HIS) composed by a metal periodic grid placed over a grounded dielectric substrate is optimized to operate over the entire two frequency bands. The patch antenna with the different fed coaxial inputs is inserted at the middle of the dielectric substrate and acts as a primary source. Numerical and experimental results of the designed metamaterial-based antenna are presented.

### Introduction

Multi-function and multi-polarization antennas are today widely studied to satisfy the increased demands for polarization diversity and frequency bands [1, 2]. Patch antennas appear to be very attractive for their interesting features such as low profile, light weight, and easy manufacturing. The GPS function (signal L1 at  $1.5754$  GHz or signal L2 at  $1.2276$  GHz), with omnidirectional radiation pattern and circular polarization and the DME function ( $1.1$  GHz) with a vertical polarization and monopole radiation pattern are important for aeronautical communication and securities. As the two frequency bands are close to each other, we grouped them in a single dual-function and dual-polarization antenna.

### 1. Antenna design

The basic configuration of the proposed patch antenna for exciting multi-function and multi-polarization is illustrated hereafter in Fig. 1. We use three-layer architecture (Fig. 1a): the ground plane at the bottom, the microstrip antenna inserted at the half-height of the substrate and the HIS metallic grid at the top. The first and second media are composed by identical dielectric substrates (same permittivity and thickness). Three input ports are connected by coaxial fed to the patch antenna (Fig. 1b). The multi-function antenna design procedure has required three steps. The first one is devoted to the optimization of the antenna sizes, so that, it can operate in the two desired frequency bands. Then, the high impedance surface (HIS) architecture [3, 4] is independently designed (*ie* without the patch antenna) to be efficient inside the two frequency bands. The third step corresponds to the final antenna as described on Fig. 1. The whole design antenna (HIS + fed patch antenna) is optimized to achieve optimal dimensions for both patch antenna and HIS. For this issue, a parametrical study on the influence of the thickness of the dielectric substrate ( $h = 6$  to  $10$  mm) and its permittivity ( $\epsilon_r = 2.2$  to  $10$ ) have been performed. We present now the numerical results obtained with CST simulator.

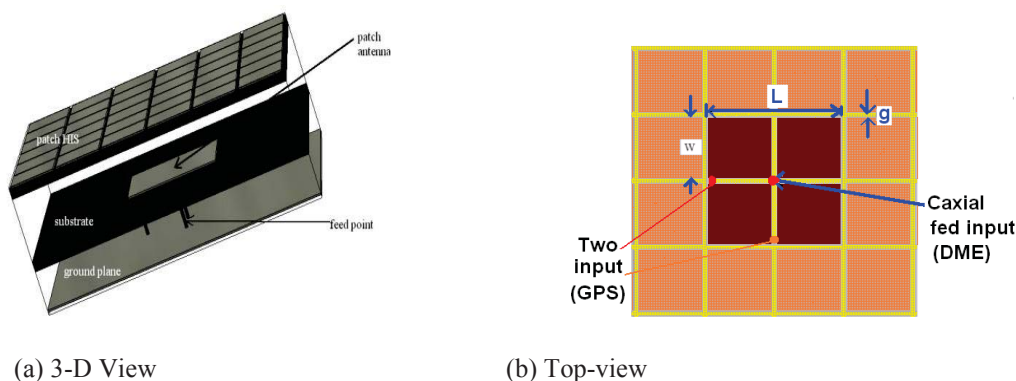
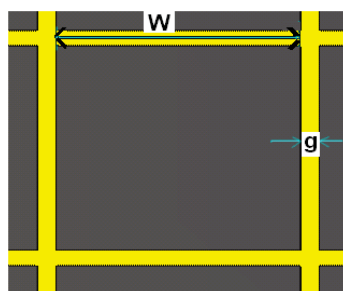


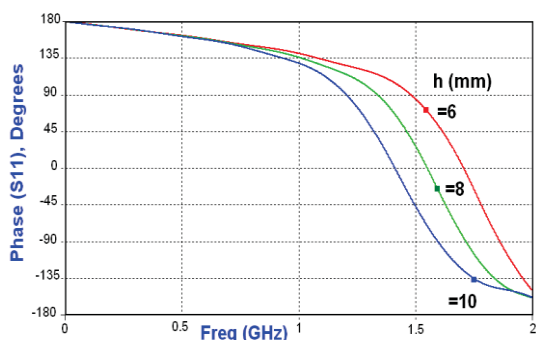
Fig. 1: Proposed antenna configuration (a) Global view and (b) Top view

## 2. High Impedance surface: design and performances

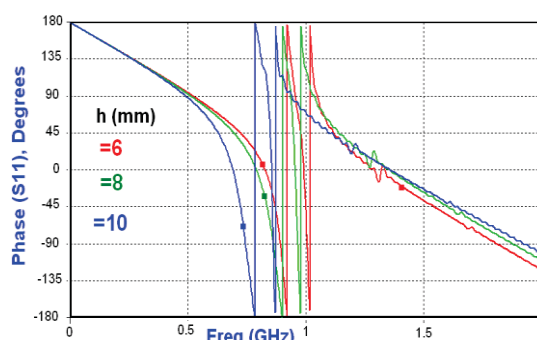
The HIS is a square of 6 x 6 unit cell metallic patches. The unit cell is presented Fig. 2a with the dimensions; wide  $W$  and gap  $g$  (period;  $p=W+g$ ). The grid is placed over a dielectric substrate with a height  $h$  and a relative permittivity  $\epsilon_r$ . Fig. 2b presents the frequency response of the HIS under normal incidence. The phase of the reflection coefficient is determined for two values of the dielectric permittivity ( $\epsilon_r=2,2$  and  $10$ ) for thickness  $h$  varying from 6mm to 10mm. For a permittivity  $\epsilon_r = 2.2$  the resonance frequency is respectively 1.75 GHz, 1.55 GHz and 1.45 GHz respectively for  $h = 6$ mm,  $h = 8$ mm and  $h = 10$ mm. The bandwidth is maintained constant around 24% for all the selected thickness. For a permittivity  $\epsilon_r = 10$ , the frequency behavior show a narrower bandwidth while the resonance frequency decreases when the height  $h$  of the substrate increase (Fig 2c). For  $\epsilon_r = 2.2$  and  $h=8$ mm, the HIS bandwidth defined between  $\pm 90^\circ$  of the phase (S11) goes from 1.15 GHz and 1.6 GHz.



( a )  $W=40$  mm,  $g=3$  mm and  $p=(W+g)=43$  mm



( b )  $\epsilon_r = 2.2$



( c )  $\epsilon_r = 10$

Fig. 2: (a) HIS Metal patch unit cell, (b) and (c) Phase of the HIS reflection coefficient (S11) for different dielectric substrate material (b)  $\epsilon_r = 2.2$  and (c)  $\epsilon_r = 10$  when the height varies from  $h=6$ mm to 10 mm

## 3. Performance of the DME and GPS antenna

Fig. 3 and Fig. 4 show the measured results of the DME and GPS antenna's functions. For the DME function the S11 reflection coefficient (Fig. 3) presents a resonant frequency at 1.08 GHz and a bandwidth of  $\sim 80$ MHz. For the GPS function the S11 reflection coefficient presents a resonant frequency at 1.2 GHz and a bandwidth of  $\sim 50$ MHz. The measured radiation patterns of the DME antenna (Fig. 4a) show around 1.1 GHz monopole-like behaviors. The gain is around -2dB while it is 0 dB in the simulations. The measured radiation patterns of the GPS antenna (Fig. 4b)

show circular and omnidirectional behaviors around 1.2 GHz (signal L2). Similarly, here the gain is around -2dB while it was found to be 0 dB in the simulations.

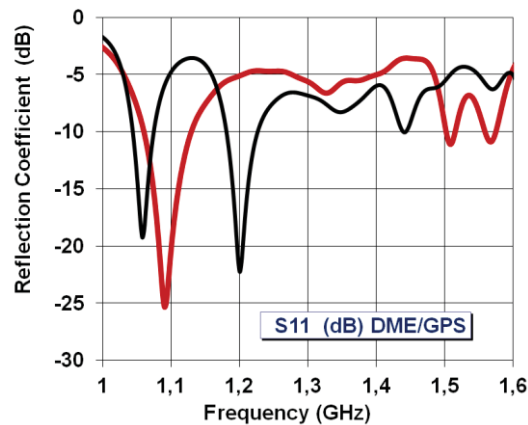


Fig. 3: Measured reflection coefficient S11(dB) of the designed DME (red curve)/ GPS (black curve) functions antenna

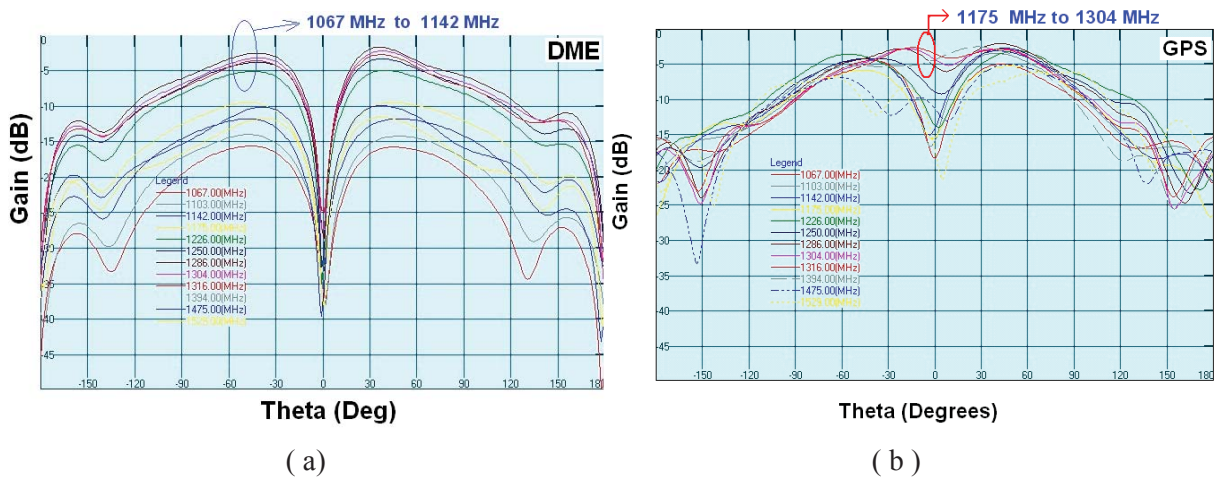


Fig. 4: Measured radiation patterns of the designed (a) DME and (b) GPS functions antenna. The frequency varies from 1067 MHz to 1500 MHz.

#### 4. Conclusion

A multifunction; Dual band and Dual-polarization antenna based on a high impedance surface (HIS) is designed, realized and characterized. The experimental results show a monopole like vertically polarized behavior for the DME function around 1.1 GHz and a circular polarization and omnidirectional patterns for the GPS antenna around the 1.2 GHz (signal L2 of the GPS).

#### References

- 1- Q. Lu, V. Nimbark, E. Korolkiewicz "Design of a Dual-Frequency Rectangular Patch Antenna: a unified approach in visible and surface wave regions" *Microwave & RF*, October, 2007.
- 2- S. Maci, GB. Gentili, "Dual-frequency patch antennas: a unified approach in visible and surface wave regions" *Antennas and Propagation Magazine, IEEE*, vol. 39, no. 6, 13–20, 1997.
- 3- A. Aminian, F. Yang, and Y. Rahmat-Samii, "Bandwidth determination for soft and hard ground planes by spectral FDTD: a unified approach in visible and surface wave regions" *IEEE Trans. Antennas Propagation*, vol. 53, no. 1, 18–28, 2005
- 4- F. Yang, J. Chen, Q. Rui, and A. Elsherbeni, "A simple and efficient FDTD/PBC algorithm for periodic structure analysis" *Radio Sci.*, vol. 42, no. 4, RS4004, 2007