# Conception of Patch Antennas in the GSM and UMTS Band

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**Abstract**— In this paper, we present the results of simulations of a series of patch antennas and also the experimentales measures by means of an networks analyzer. The conception of these patch antennas are realized by software HFSS "Ansoft-High Frequency Structure Simulator" and ADS "Advanced Design System", based themselves essentially on the variation of the shape of the antenna and its conductive material, the nature and the thickness of the substratum to have a structure which resounds in the frequencies used for precices applications. This results is compared of those published in the bibliography.

# 1. INTRODUCTION

Many mobile radio services are expanding and attracting more and more users. Access to these services from a single terminal requires the use of compact antennas multifrequency and multi polarization particularly disappointing for simultaneous FM (Frequency Modulation), DVB (Digital Video Broadcasting), cellular (GSM, UMTS) and GPS (Global Positioning System). It was noted that the frequencies used by these applications are spread over several octaves and is therefore difficult to design a single structure with the characteristics required for access to these services [1–3]. To overcome this problem some authors have proposed some compact antennas GSM-GPS with interesting features. Other researchers have focused their work on the reception by the same antenna broadcasts DAB (Digital Audio Broadcasting) and DVB. The material properties (high permittivity, special forms). Have been exploited by many investigators to design variants of compact, multifrequency antennas [4–7].

In this paper, we present generalities on antennees microstrip or we define the basic parameters of an antenna (gain, bandwidth, radiation pattern), types of food (for microstrip line, coaxial, coupled with opening ret coupled by proximity). To validate the proposed equivalent models, we present the study of patch antennas. We will compare the results of the simulation by HFSS and ADS and the results published in the literature [8–10].

#### 2. SIMULATIONS

We have simulated the printed antennas using the software Ansoft-HFSS (High Frequency Structure Simulator) and ADS (Advanced Design System). This powerful simulation software which allows to represent the distribution of fields and calculate the parameters  $S_{ij}$  passive microwave structures. The simulation technique used to calculate the three dimensional electromagnetic field inside a structure is based on the finite element method (FEM). The principle of the method is to divide the study area into many small regions (tetrahedrons), then calculate the local electromagnetic field in each element. HFSS uses an interpolation method combined with an iterative process in which a mesh is created automatically and redefined in the critical regions. The simulator generates a solution based on the predefined initial mesh. Then, it refines the mesh in regions where there is a high density of errors, and generates a new solution.

# 2.1. Influence of Spatial Parameters of Printed Antennas

The following paragraph illustrates the results of simulations of several cases of printed antennas in the environment HFSS. We will submit applications, in particular calculation of  $S_{ij}$  parameters of a printed antenna fed by a microstrip line and the input impedance.

Food can also be done by direct connection to a coaxial line. The central conductor of the coax is then connected at a point on the axis of symmetry of the radiating element, more or less close to the board to adjust the impedance. The outer conductor is connected to the plane. The major drawback of this technique is that it can be used with the polymer substrate, air or metal plates welded. We note that the resonant frequency and the level of  $S_{11}$  depends on the length of the antenna as shown in Table 2.

The resonant frequency and the reflection coefficient  $S_{11}$  is inversely proportional to the length l of the microline. For a microstrip line, the width W is given by the following formula: W =

Element	Airbox $(mm * mm)$	Thickness (mm)
Substrate	20 * 30	0.1
Ground plane	20 * 30	0
Microstrip $wi \times li$	L*W	0
Patch, $W \times L$	10*14	0

Table 1: Parameters of the antenna.

Table 2: Simulation results of the antenna with variable lenght.

Length (mm)	Resonance frequency (GHz)	$ S_{11} $ (dB)
6	1.06	-21
8	0.98	-17
10	0.9	-16

Table 3: Simulation results of the antenna with variable width.

Width $w \pmod{mm}$	Resonance frequency (GHz)	Reflection coefficient $ S_{11} $ (dB)
2	1.16	-6.92
4	1.31	-13.65
6	1.41	-17.91

Table 4: Simulation results of the patch antenna with variable tickness.

Thickness $h \pmod{m}$	Resonance frequency (GHz)	$ S_{11} $ (dB)
0.5	1.06	-20.56
1	1.09	-13.56
1.53	1.16	-6.85

 $(C/2f_r) * 1/[(1 + \varepsilon_r)/2]0.5$ . To validate this relationship, we analyzed a line of 50  $\Omega$  with a length of 6 mm. The resonant frequency and the level of  $S_{11}$  depends on the width of the antenna as shown in Table 3.

When the width of the microstrip line increases, the resonant frequency and  $S_{11}$  are also increasing, by varying the thickness of the substrate ( $\varepsilon_r = 4.32$  (glass epoxy)) and keeping all other parameters fixed, the curves of  $S_{11}$  as a function of the resonant frequency data in Table 4.

We note that varying thicknesses of the substrate, the resonant frequency and the level varies  $S_{11}$ . The more the thickness increases, the resonance frequency increases, the magnitude of  $S_{11}$  decreases. Note that the resonant frequency increases when  $\varepsilon_r$  decreases. Miniaturization of antennas can be achieved by choosing materials with high permittivity. In conclusion, we note that the resonant frequency of a microstrip line varies depending on its length, its width, the permittivity and thickness of the substrate. The antenna of rectangular microstrip resonator is similar to a microstrip line of length L and width W. The length of w is chosen close to  $\lambda g/2$  where  $\lambda g$  is the wavelength in the line. It can therefore be based on the results found for a microstrip line at the antenna design rectangular or other shapes.

# 2.2. Antenna Line Buried

The antenna line buried structure is performed in two substrates with a microstrip line plated on the bottom substrate that ends in an open circuit in the printed patch on the upper substrate. This close coupling allows to improve bandwidth and reduce stray radiation. The dimensions W = L = 5 mm from the patch fix the resonance of the antenna and f = 10 GHz. Wi = width = 0.635 mm from the microstrip feed, can have an impedance of  $50 \Omega$  at the input antenna. A good adaptation is achieved for a microstrip of length li = 2.5 mm. The two alumina substrates are modeled by two identical dielectric layers of thickness 0.635 mm, the real part of permittivity is 9.6 (Figure 1).

Figure 2 shows the variation of reflection coefficient  $S_{11}$  at the entrance of the antenna versus frequency. It shows that if we consider  $|S_{11}| \leq -10 \,\mathrm{dB}$  we will have a wide band around the resonance frequency ranging from 9.2 to 9704 GHz.



Figure 1: Schematic of the antenna line buried.



Figure 2: Reflection coefficient as a function of frequency: (a) = [7], (b) = HFSS.



Figure 3: Design of the antenna by HFSS.



Figure 4: Variation of  $S_{11}$  as a function of frequency: (a) = [8], (b) = HFSS.

# 2.3. Antenna Form of '2'

In this case, we take  $\varepsilon_r = 4.32$  (glass epoxy) h = 1.53 mm with 2 layers of  $35 \,\mu\text{m}$  copper ground plane with copper ( $80 \,\text{mm}/60 \,\text{mm}$ ) (Figure 3).

Figure 4 presents the variation of  $S_{11}$  in two bands:  $B_1 = 1918$  to 2022 GHz and  $B_2 = 2273 - 2.48$  GHz  $|S_{11}| < -10$  dB.

# 3. EXPERIMENTAL MEASUREMENTS OF PATCH ANTENNAS

Taking into account the design steps mentioned in the previous chapter, we have made various prototypes of antennas as shown in Figure 5, using as substrate the 'glass epoxy' type  $G_{11}$  with a relative permittivity  $\varepsilon_r = 4.38$  and d = 1.6 mm thick with 2 layers of copper 35 microns.

# 3.1. Measurements and Results

The antenna characteristics made, were measured with a vector network analyzer E5061A type operating in the band 300 kHz–3000 MHz. The Figure 6 below shows the variation of  $S_{11}$  as a function of the frequency band [1000–2500] MHz. This antenna structure "Antenna in ('U')" has two resonance frequencies:  $f_{r1} = 1600$  MHz and  $f_{r2} = 2000$  MHz.



Figure 5: Prototype of the the realized antennas.



Figure 6:  $S_{11} = F(f)$  in dB): (a) = measurement by network analyzer, (b) = HFSS.



Figure 7: Variation of reflection coefficient ( $S_{11}$  in dB versus frequency): (a) = measurement by network analyzer, (b) = HFSS.



Figure 8: Variation of reflection coefficient  $(S_{11} \text{ in dB})$  versus frequency: (a) = measurement by network analyzer, (b) = HFSS.

The Figure 7 shows the variation of  $S_{11}$  as a function of the frequency band [1400, 2600] MHz. This antenna structure carried '2' has two resonance frequencies:  $f_{r1} = 1675$  MHz and  $f_{r2} = 2232$  MHz.

The Figure 8 below shows the variation of  $S_{11}$  as a function of the frequency band [400, 1600] MHz, the antenna structure "Antenna as 'P" has a resonant frequency:  $f_{r1} = 1060$  MHz.

Note that the values measured resonance frequencies are very close to those simulated. The difference between them is due to measurement uncertainties. It was found that the value of reflection coefficients for the resonance frequencies is very different from that which was obtained by simulation, this may be due to losses introduced by the dielectric, the mismatch between the source and antenna. Losses associated with the driver to the substrate. In fact, the bandwidth  $\Delta f$  is related to the quality factor of the antenna Q which is proportional to the factors Qd (the dielectric loss) and Qc is the and Qc the loss of driver.

# 4. CONCLUSION

The printed antenna geometries are simple and require further study by different methods developments. Ainsi, many trvaux research on the design and simulation of patch antennas have been made. By following these steps, we designed several antennas while varying several parameters: the length of the antenna is connected to the resonant frequency, width, shape, thickness of the substrate, and the relative permittivity  $\varepsilon_r$ . For this a detailed study of the variation of these parameters and its influence on the resonant frequency is achieved in this course.

The antenna design using the software HFSS, "Ansoft High-Frequency Structure Simulator" and ADS 'Advanced Design System' is based mainly on the change in the shape of the antenna and its conducting material, the nature and thickness of the substrate to have a structure that resonates in the frequency desired for applications specifie. The optimal variation of each of these parameters affects the resonance frequency, the reflection coefficient and the geometrical structure of the antenna patch. In conclusion, the integration of these planar structures may lead to the design of a communication system in a frequency range well defined.

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