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A QUAD-BAND PATCH ANTENNA FOR GALILEO AND WI-MAX SERVICES

Edoardo Zeni, Renzo Azaro, Paolo Rocca and Andrea Massa

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A quad-band patch antenna for Galileo and Wi-Max services

E. Zeni, R. Azaro, P. Rocca and A. Massa

The design of a patch antenna working in E5 - L1 Galileo, 2.5 GHz and 3.5 GHz bands is discussed. Starting from a classical rectangular patch antenna with four resonant modes located around the required spectrum regions, the tuning of the operating frequencies is obtained by perturbing the perimeter of the antenna shape according to a pre-fractal Koch-like erosion process. In order to show the effectiveness and reliability of the synthesized structure, a selected set of numerical and experimental results are reported and discussed.

Introduction: The growing diffusion of multiple telecommunication standards and wireless services has implied the development of radiating systems able to transmit and receive signals in several frequency bands. In such a framework, the use of multiple antennas, each of them working in a single different band, has been usually adopted. However, even though very simple, such a solution causes some problems due to the mutual coupling among radiators, low level of integration, and non-miniaturized dimensions. As a matter of fact, a more interesting solution is represented by the synthesis of a single integrated electromagnetic structure fully embedded in the electronic device (e.g., a mobile phone). Towards this purpose, there is the need to define a suitable reference geometry able to efficiently operate in the user-defined bands, but avoiding complex and/or expensive solutions.

Because of the vertical hemispherical radiation pattern, suitable for both satellite signals reception and mobile communications [1], and the attractive geometrical features (i.e., low profile, limited weight, inexpensive fabrication process, and easy integration in electronic devices), patch shapes are certainly good candidates. Moreover, some researchers have shown that proper perturbations of their original structures can be profitably exploited for improving both geometrical and electrical characteristics. For example, the use of an H-shaped geometry [2] or the adoption of a Koch fractal shape [3] [4] for a patch inverted F antenna (PIFA) [5], have been proposed for miniaturization purposes. On the other hand, the introduction of slit cuts in the antenna geometry has been considered in [6] for tuning the resonant frequency and reducing the patch dimension.

Concerning fractal shapes, they have proved to be very effective not only in miniaturizing the antenna extension, but also in dealing with multiband requirements [3][4]. In such a paper, the approach proposed in [7][8] when dealing with monopolar antennas is extended to planar geometries for defining a low profile quad-band patch antenna.

Quad-band antenna design: The quad-band antenna constraints were: operation in $E_5 - L_1$ Galileo ($f_{E5} = 1191.795$ MHz, $f_{L1} = 1575.42$ MHz) and the $f_{WM1} = 2.5$ GHz and $f_{WM2} = 3.5$ GHz Wi-Max bands; Return Loss values lower than -10 dB in the frequency bands; gain values greater than 3 dBi at $\theta = 0°$ and 4 dBi at $\theta = \pm 70°$ in the Galileo bands; minimum gain value of -5 dBi at $\theta = \pm 88.5°$ and on average -2 dBi in the angular range $-90° \le \theta \le -70° \cup 70° \le \theta \le 90°$ for the Wi-Max bands; maximum planar

dimensions equal to $10 \times 10\,\mathrm{cm}^2$ on an *Arlon* substrate of thickness $h = 0.8\,\mathrm{mm}$ and dielectric characteristics $\varepsilon_r = 3.38\,\mathrm{mm}$ and $\mathrm{tg}\delta = 0.0025$ at $f = 10\,\mathrm{GHz}$.

The quad-band antenna has been synthesized by means of an iterative perturbation process aimed at determining the final radiating shape through a Koch-like pre-fractal erosion of the perimeter of a standard rectangular patch (Fig. 1). More in detail, the parameter to be optimized for frequency tuning and impedance matching were: the descriptors of the perturbed Koch-like pre-fractal perimeter and also the position of the antenna input port belonging to the antenna extension. In order to fit the project requirements by varying the optimization parameters, a method of moment (MoM) electromagnetic simulator [9] has been integrated with a perturbed pre-fractal patch perimeter generator and a particle swarm optimizer (PSO) [10]. The solution optimality has been quantified through a cost function proportional to the difference between simulated performances (expressed in terms of VSWR and gain values computed by means of the MoM simulator that models the electric behaviour of the trial antennas) and requirements. Starting from a population of trial shapes, the solutions evolved according to the PSO strategy aimed at minimizing the cost function.

Numerical and experimental results: According to the synthesis approach previously summarized, a convergence solution has been obtained after 98 PSO iterations. Figure 1 shows the evolution of the trial solution until the final shape [Fig. 1(*d*)] characterized by the following dimensions: $L_x = 73\,\mathrm{mm}$ and $L_y = 62\,\mathrm{mm}$ with the feeding port located at $x_P = 32\,\mathrm{mm}$ and $y_P = 46\,\mathrm{mm}$.

The impedance matching condition has been experimentally verified by using the antenna prototype shown in Fig. 2 and by comparing the measurements with simulated data. As it can be observed, both simulated and measured results satisfy the project specifications and are in good agreement. Moreover, also the radiation properties expressed in terms of gain diagrams are compliant with requirements.

Acknowledgments

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Figure captions:

Fig. 1 Evolution of the patch antenna shape: (*a*) starting iteration, (*b*) after 25 iterations, (*c*) after 75 iterations, (*d*) final solution

Fig. 2 Photograph of the prototype of the quad-band patch antenna

Fig. 3 Measured and predicted Return Loss values of the quad-band patch antenna
——— simulated
- - - - - measured

Fig. 4 Radiation pattern of the quad-band patch antenna: (*a*) horizontal plane ($\theta = 90°$), (*b*) vertical plane ($\phi = 0°$)

Figure 1

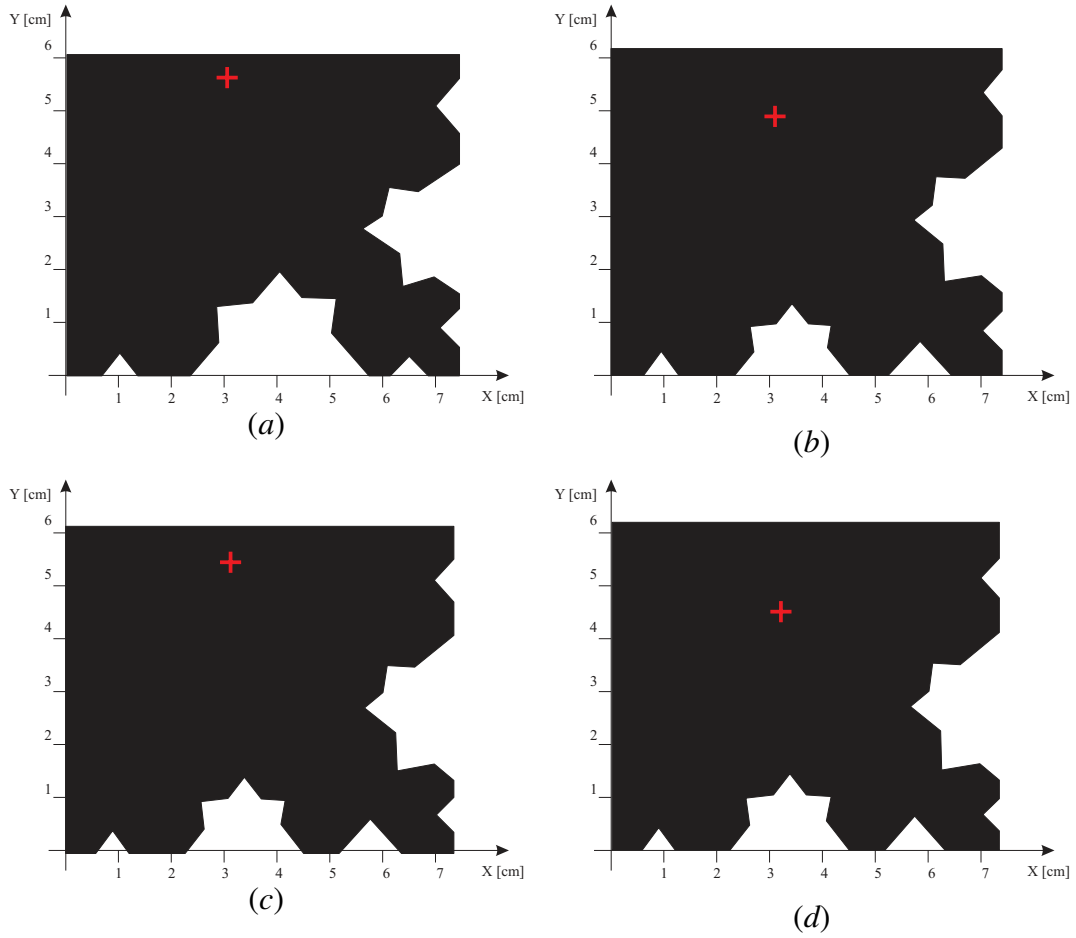

Figure 2

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Figure 3

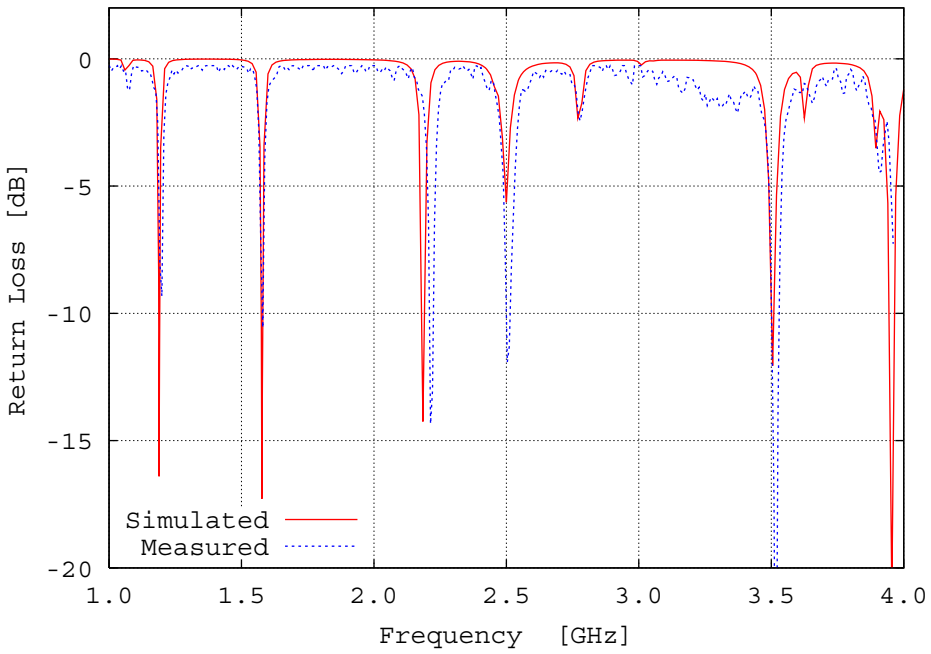
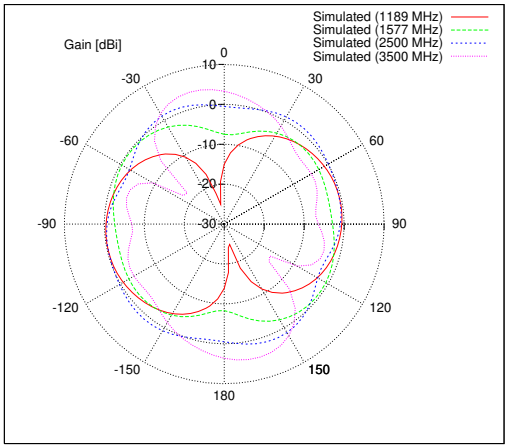
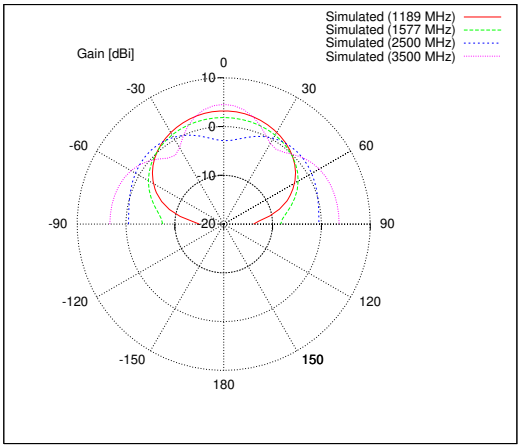

0
-5
-10
-15
-20
Return Loss [dB]
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Frequency [GHz]
Simulated
Measured

Figure 4


Gain [dBi]
Simulated (1189 MHz)
Simulated (1577 MHz)
Simulated (2500 MHz)
Simulated (3500 MHz)
0
30
60
90
120
150
180
-30
-60
-90
-120
-150
10
0
-10
-20
-30

(*a*)


Gain [dBi]
Simulated (1189 MHz)
Simulated (1577 MHz)
Simulated (2500 MHz)
Simulated (3500 MHz)
0
30
60
90
120
150
180
-30
-60
-90
-120
-150
10
0
-10
-20

(*b*)