ARCHIVES OF ELECTRICAL ENGINEERING VOL. 73(4), pp. 1161 –1181 (2024)

DOI 10.24425/aee.2024.152116

Optimal design of Vivaldi antenna with corner reflector: a Multiobjective Minimax Method

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(Received: 14.09.2024, revised: 24.11.2024)

Abstract: The paper presents the optimization of a reflector-backed Vivaldi antenna which was designed to operate at the 1.8, 2.1, and 3.5 GHz frequencies used in the fourth and fifth generation of wireless systems. Reducing antenna back radiation is the primary goal of the optimization; at the same time, however, antenna impedance matching has to be preserved for the considered set of frequencies, this way generating a conflict of goals. The proposed design method is based on a minimax formulation of each goal against frequency and a Pareto-like tradeoff of solutions. Both goals were achieved as a consequence of the optimization process, and the antenna now exhibits a voltage standing wave ratio below 3, front-to-back ratio of 14 dB and a gain in the front direction not smaller than 8 dBi.

Key words: automated optimal design, genetic algorithm, numerical optimization, reflector antenna

1. Introduction

The permanent pursuit of higher data rates and expanded network coverage in modern wireless communication systems that utilize a wide range of frequencies necessitates the development of antennas capable of operating across many frequency bands. Fourth generation of wireless systems (LTE technology) utilizes frequencies from 1.8 GHz to 2.1 GHz while the fifth generation (5G) together with very high frequencies above 20 GHz, utilizes the so-called "mid-band" with 3.5 GHz. Consequently, there is a demand for antenna solutions that can effectively accommodate broad bandwidth covering the entire indicated range or have multi-band properties that allow one to operate in different separated bands simultaneously.

Directional antennas with electrically controlled radiation patterns offer a solution for enhancing network capacity and coverage. For this purpose, the 5G radio equipment utilizes antenna arrays with a beam-forming circuit, that dynamically directs antenna radiation to the desired direction by adjusting the phase and amplitude of signals at each of antenna array element. By directing the radiation towards the desired signal, such antennas reduce interference and improve transmission quality, leading to faster download speeds and more reliable connections for users [1].

Multiband antennas can be also employed in modern wireless systems for measurement purposes due to their ability to receive signals from different wireless systems [2]. A directional multiband antenna can effectively receive the signal from one specified direction. This enables engineers to accurately measure signal properties, characterize wireless environments, test wireless devices, and identify sources of interference. By directing the antenna towards a specific location or device, it is possible to gain valuable insights into network performance and identify areas for improvement. Directional antennas are designed to have maximum gain in front direction G_f with possibly small gain in back direction G_b. This allows effective reception of the desired signal that the antenna is directed to and rejection of interfering signals that may come from the back direction. This concept is shown schematically in Fig. 1. Unidirectional properties of antennas are often controlled by the front-to-back ratio (FBR) that is the ratio of G_f to G_b. In the logarithmic scale, the FBR can be calculated from (1) [3]:

$$\mathrm{FBR} = G_f - G_b[\mathrm{dB}]. \tag{1}$$

For the purpose of identifying the signal source, high values of the FBR are desired.

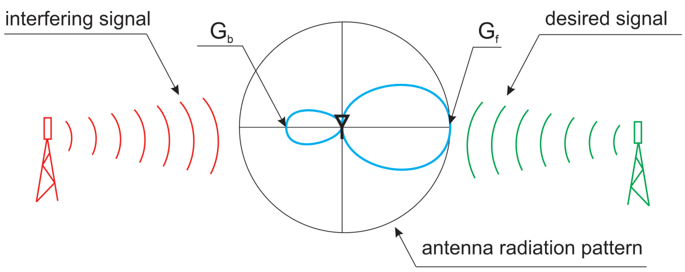

Fig. 1. Definition of antenna gain in front direction G_f and back direction G_b

Another important feature of the antenna is impedance matching. The closer the input impedance of the antenna to the reference impedance of the feeding network, the lower is the loss of signal caused by reflection. This can be characterized by VSWR parameter (2) [4]:

$$\mathrm{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}, \tag{2}$$

where Γ is the voltage reflection coefficient (on the antenna port) (3):

$$\Gamma = \frac{Z_A - Z_0}{Z_A + Z_0}. \tag{3}$$

Z_A is the antenna input impedance [Ω].

Z_0 is the reference impedance of the antenna feeding system [Ω].

For perfect antenna impedance matching, $Z_A = Z_0$ and VSWR = 1. The greater the value of the VSWR, the greater the impedance mismatch and the loss of signal caused by reflection.

The Vivaldi antenna, is a directional broadband antenna [4, 5]. It is renowned for its simple yet efficient design, has emerged as a promising candidate for broadband or multi-band applications. This planar antenna, characterized by its tapered slot configuration, exhibits a good impedance matching in a broad bandwidth, making it suitable for various wireless technologies. However, a fundamental limitation of the traditional Vivaldi antenna lies in its suboptimal back lobe radiation pattern, which can degrade the performance of the measurement system especially if it aims at the identification of desired signal parameters in the presence of interference.

To address this challenge, a design that incorporates different reflectors into the Vivaldi antenna structure was proposed in the literature [6, 7]. The placement of the reflector is expected to significantly enhance the antenna's radiation characteristics, notably by suppressing back radiation however it can deteriorate antenna impedance matching.

In this paper, the Vivaldi antenna with a corner reflector is proposed. The geometrical dimensions of both the reflector and the antenna were meticulously optimized through an automated algorithm to achieve the desired performance metrics. This optimization process aimed to balance the trade-off between good impedance matching in the considered bands and improved back lobe suppression. By combining the inherent broadband capabilities of the Vivaldi antenna with the directional properties of the corner reflector, the proposed design offers a promising approach to fulfilling the stringent requirements of contemporary wireless communication systems operating in the mid-band spectrum.

From the methodological viewpoint, an original combination of Pareto-like optimality and minimax formulation of objective functions is here proposed in the search for innovative, i.e. previously unexplored solutions in terms of the geometric shape of the antenna and reflector. Resorting to evolutionary computing makes it possible to implement the proposed optimization method in a cost-effective way.

2. Vivaldi antenna design

The Vivaldi antenna is a planar, broadband antenna characterized by its tapered slot configuration [4, 5] that is presented in Fig. 2. This unique geometry enables it to operate effectively across a wide range of frequencies, making it a versatile choice for numerous wireless applications. Moreover, the simplicity of design and ease of fabrication contribute to its popularity. Key design parameters of a Vivaldi antenna include the overall length, the shape and dimensions of the tapered slot, the dielectric substrate thickness, and the feed point location. By carefully optimizing these parameters, designers can tailor the antenna's performance to specific frequency bands and radiation patterns, ensuring optimal performance in diverse wireless communication systems.

For the purpose of Vivaldi antenna design, the MATLAB Antenna Toolbox was used [8]. The Antenna Toolbox employs the Method of Moments (MoM) [9] as its primary numerical method to compute various electromagnetic properties of antennas such as input impedance, current distribution, efficiency, and near-field as well as far-field radiation patterns. This toolbox provides a comprehensive suite of functions and applications for the design, analysis, and visualization of antenna elements and arrays. Users can design standalone antennas or build arrays using predefined elements with parameterized geometry, arbitrary planar structures, or custom 3D structures described with STL files2. Specifically, the function "vivaldi" is used to generate a Vivaldi notch antenna on a ground plane, with options for exponential or linear tapering, with several customizable parameters. These parameters include:

- l_t – Taper Length: The length of the taper, with a default value of 0.2430 meters.
- w_a – Aperture Width: The width of the aperture, defaulting to 0.1050 meters.
- o_r – Opening Rate: The rate at which the taper opens, with a default value of 25.
- w_s – SlotLineWidth: The width of the slot line, defaulting to 0.0005 meters.
- d – Cavity Diameter: The diameter of the cavity termination, with a default value of 0.0240 meters.
- s – Cavity to Taper Spacing: The distance from the cavity to the taper transition, defaulting to 0.0230 meters.
- l – Ground Plane Length: The length of the ground plane, with a default value of 0.3000 meters.
- w – Ground Plane Width: The width of the ground plane, defaulting to 0.1250 meters.
- f – Feed Offset: The distance from the feed along the x-axis, with a default value of –0.1045 meters.

Figure 2 shows the definition of parameters that control geometry of a Vivaldi antenna.

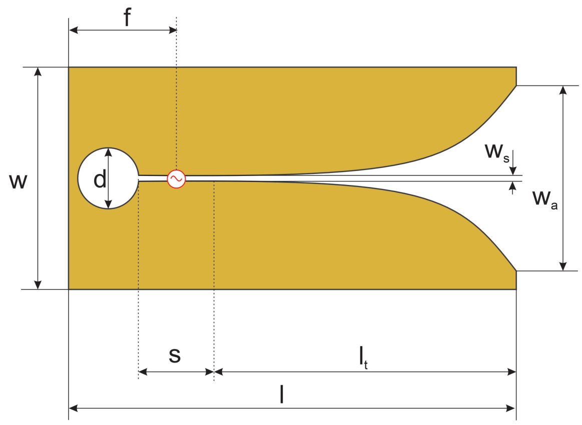

Fig. 2. Parameters of Vivaldi antenna geometry

To examine the performance of a Vivaldi antenna the preliminary simulations were made with a default values of antenna parameters. As indicated in the MATLAB documentation by default, the antenna operates at a frequency range of 1–2 GHz. Figure 3 presents the geometry of the default Vivaldi antenna in the X–Z plane, for which the direction of front gain G_f is parallel to the $+z$-axis and back gain G_b is parallel to the $-z$-axis.

The radiation pattern of the antenna with default geometry is unidirectional: it is presented in Fig. 4 for 3.5 GHz frequency. Impedance matching of this antenna is shown in Fig. 5, while Fig. 6 presents the gain of the antenna in front direction G_f and Fig. 7 in back direction G_b. The antenna FBR is presented in Fig. 8.

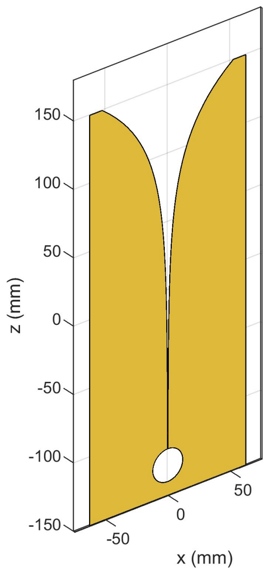

Fig. 3. Geometry of the Vivaldi antenna with default geometrical parameters

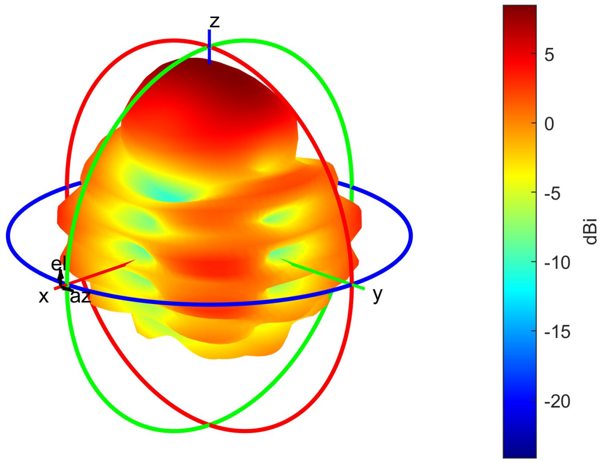

Fig. 4. Radiation pattern of Vivaldi antenna with default geometry at 3.5 GHz

The results of the simulations that were made for the Vivaldi antenna with default geometry show that this design exhibits excellent impedance matching over a wide range of frequencies. This is attributed to its tapered geometry, which ensures a smooth transition between the feed point and the radiating aperture. However, the Vivaldi antenna's performance is compromised by its relatively low front-to-back ratio and relatively large gain in the back direction. These characteristics can be mitigated through careful design and optimization techniques, but they remain inherent limitations of the antenna's geometry.

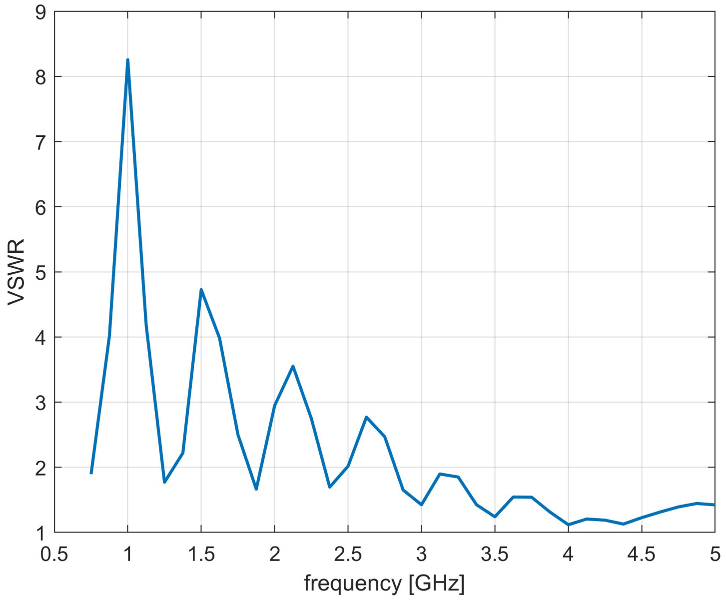

Fig. 5. Impedance matching of Vivaldi antenna with default geometry

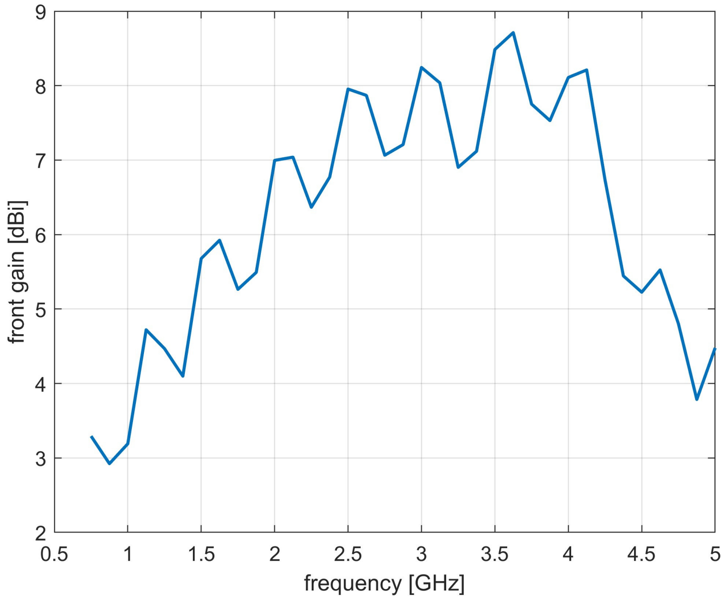

Fig. 6. Gain in front direction G_f of Vivaldi antenna with default geometry

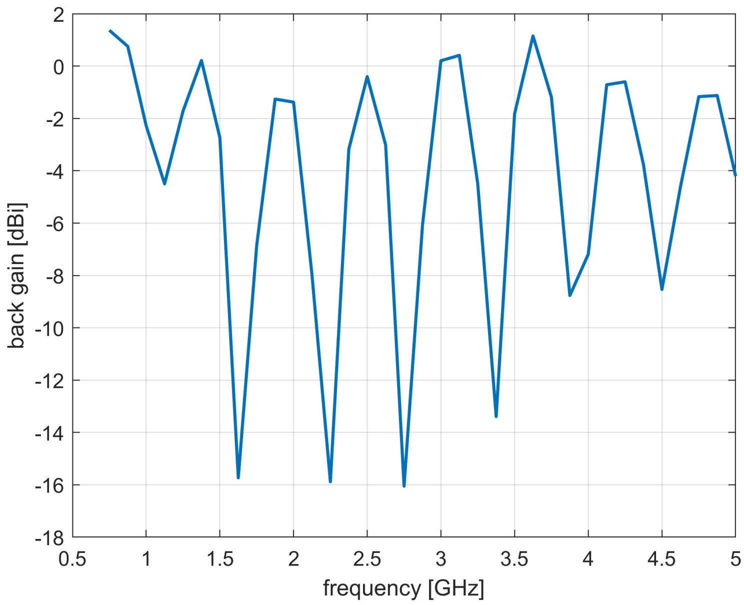

Fig. 7. Gain in back direction G_b of Vivaldi antenna with default geometry

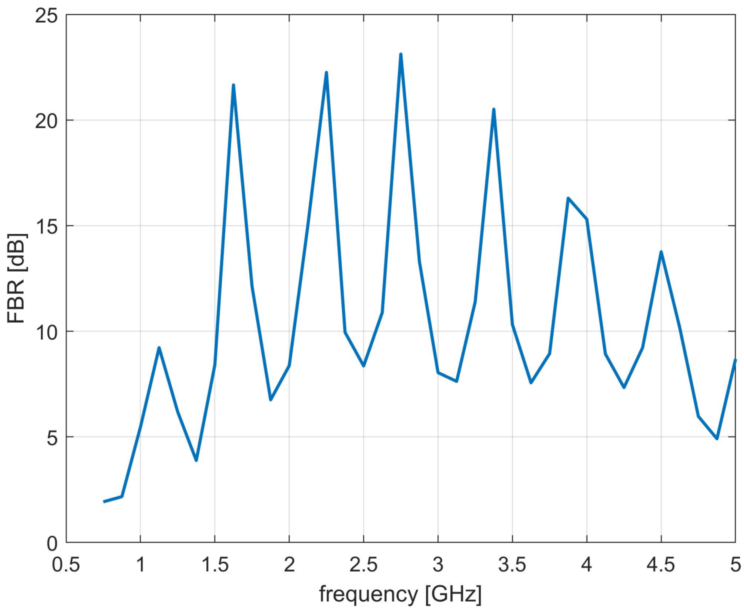

Fig. 8. FBR of Vivaldi antenna with default geometry

3. Corner reflector backed Vivaldi antenna

The addition of a corner reflector to a Vivaldi antenna can significantly enhance its front-to-back ratio, thereby reducing unwanted back radiation. This improvement is achieved by reflecting the radiated energy back towards the front aperture, effectively suppressing the backward lobe. The geometry of the Vivaldi antenna with the corner reflector is presented in Fig. 9.

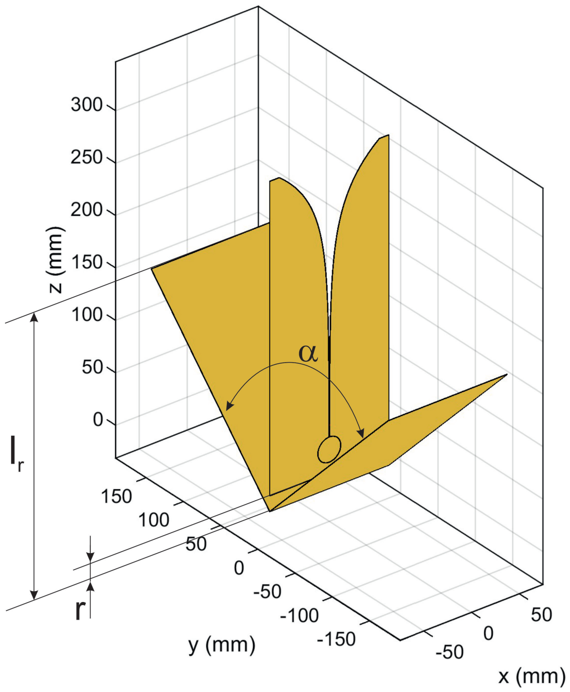

Fig. 9. The geometry of the Vivaldi antenna with the corner reflector

Adding the reflector element can also lead to impedance mismatches at certain frequencies, particularly within the lower frequency range. This is due to the interaction between the reflected waves and the antenna's radiation. To analyze this effect, the simulations of the antenna with default geometry backed with a sample reflector were performed. The geometry of this antenna is presented in Fig. 9. The length of the reflector, l_r, was 220 mm and the angle α was equal to 90°. The impedance matching of this antenna is shown in Fig. 10, while Fig. 11 presents the gain of the antenna in front direction G_f and Fig. 12 in back direction G_b. The antenna FBR is presented in Fig. 13.

Based on the simulations performed, it can be observed that adding a reflector to the antenna can significantly increase the FBR parameter value. At the same time, it causes a deterioration of the impedance matching at some frequencies. In order to simultaneously improve the antenna directivity and not significantly deteriorate the matching, the antenna optimization procedure was performed, which is described below.

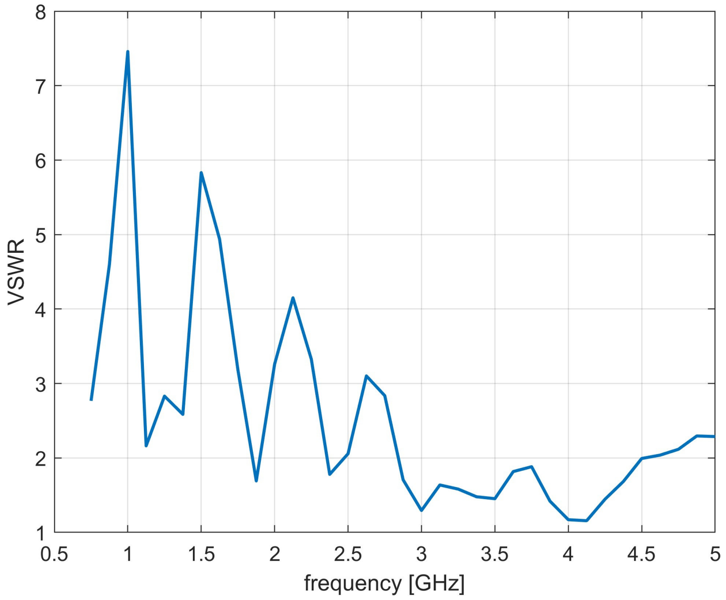

Fig. 10. The impedance matching of the default Vivaldi antenna with the corner reflector

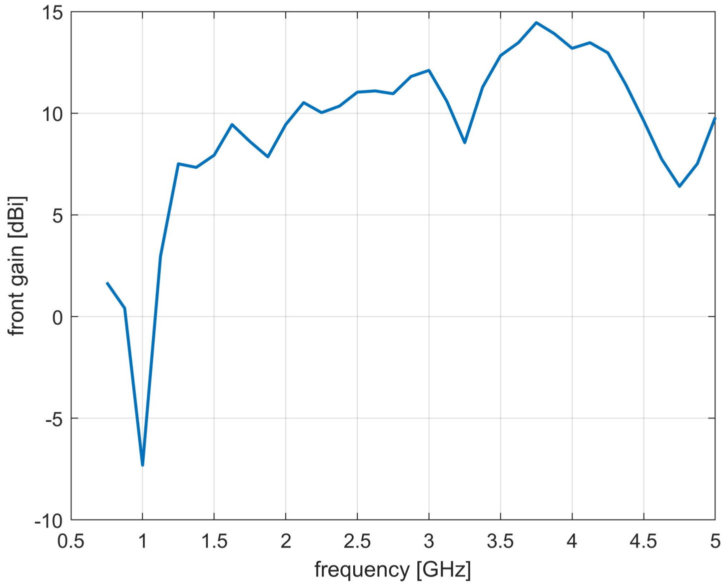

Fig. 11. The gain of the antenna in front direction G_f of the default Vivaldi antenna with the corner reflector

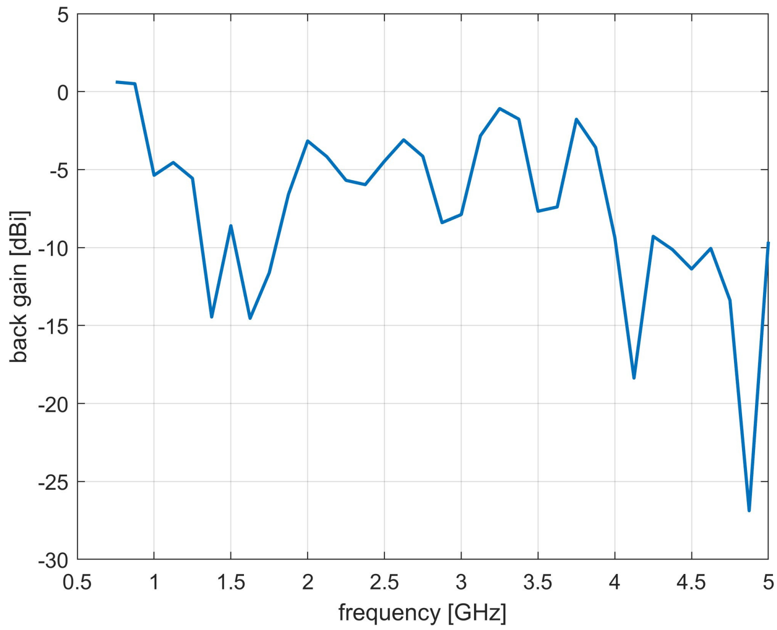

Fig. 12. The gain of the antenna in back direction G_b of the default Vivaldi antenna with the corner reflector

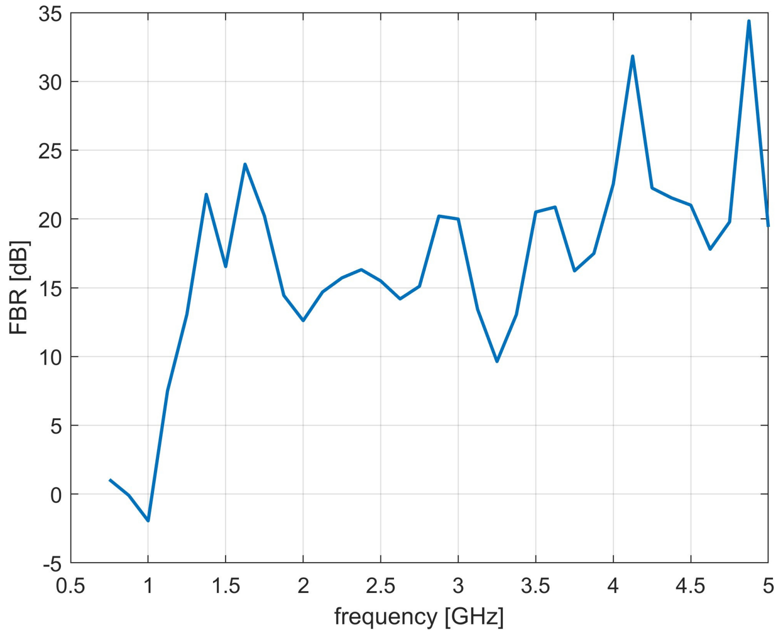

Fig. 13. FBR of the default Vivaldi antenna with the corner reflector

4. Optimal design problem

4.1. Formulation

The problem with the optimal shape design of the radiator and reflector can be posed as follows: given an initial design, find geometry (g) of the radiator and reflector with a twofold goal: minimize the antenna's backward gain and the Voltage Standing Wave Ratio (VSWR) represented by objective functions $f_1(g)$ and $f_2(g)$, respectively, in a band composed of three values frequency φ, i.e. 1.8, 2.1 and 3.6 GHz that are used in 4G and 5G wireless systems.

The following definitions are used in the model formulation:

$g \in \Re^6$, the design vector, i.e. the set of six design variables identifying the dimensions of Vivaldi's radiator as well as the angle of the reflector and its dimensions. The design vector components and design variable names are listed in Table 1 together with their minimum and maximum values.

Table 1. Design vector components g

Element number	Design variable	Minimum value	Maximum value
g (1)	w_a – Aperture Width [m]	0.0300	0.1200
g (2)	o_r – Opening Rate	0.1	500
g (3)	w_s – SlotLineWidth [m]	0.0001	0.002
g (4)	d – Cavity Diameter [m]	0.005	0.029
g (5)	l_r – Length of the Reflector [m]	0.03	0.65
g (6)	α – Reflector Angle [°]	10	190

Ω_g: the feasible domain, i.e. the set of admissible values of the g subject to geometric model constraints;

B: the [1.8, 2.1, 3.5] GHz band.

Starting from a feasible solution g_0 in Ω_g, the following $f_1(g)$ objective is to be minimized with respect to g in Ω_g:

$$f_1(g) = \mathrm{FBR}(g, \phi), \tag{4}$$

i.e. the minimum value of the FBR with a minus sign (so the minimizing strategy of f_1 results with maximization of the FBR.

Simultaneously, the following f_2 objective is to be minimized with respect to g in Ω_g:

$$f_2(g) = \mathrm{VSWR}(g, \phi). \tag{5}$$

In particular, from (4) and (5) it can be noted that a minmax formulation of the objective functions makes it possible to track the worst design case against frequency.

Given a value of g in Ω_g, objectives $f_1(g)$ and $f_2(g)$ are computed by means of the boundary element method, implemented in the MATLAB Antenna Toolbox, which solves the field analysis problem for each frequency of interest.

Globally, a bi-objective optimization problem can be formulated: starting from a guess solution, find the values of a six-dimensional design vector g (dimensions of reflector and radiator) yielding a Pareto-optimal solution, i.e., a best compromise point trading off the FBR and the VSWR.

A numerical approximation to the solution of Eqs. (4) and (5) is found by means of the optimization algorithm presented in the following subsection.

4.2. The algorithm

Due to its robustness, the Non-Dominated Sorting Genetic Algorithm (NSGA-II) is particularly suited to identify the Pareto front solving a multi-objective optimization problem. The idea behind the NSGA is that a selection method is used to emphasize current non-dominated solutions, and a niching method is used to maintain diversity in the population of individuals. The NSGA varies from a simple GA in the way the selection operator is used. Crossover and mutation operators, in fact, remain as usual in GA methods. However, before the selection is performed, the population is ranked on the basis of the non-dominance level of an individual, and then a fitness value is assigned to each individual.

The main algorithmic steps are here summarized. In particular, a fitness assignment procedure (in fact, the kay procedure) takes place as follows.

Consider a population of $n_p > 1$ individuals x, each having $n_f > 1$ objective function values $F(x)$; a non-dominated set of solutions is found based on the following procedure.

i) begin with $i = 1$;
ii) for $j = 1, n_p$ and $j \neq i$, compare solutions x_i and x_j according to the definition of dominance applied to all n_f objectives;
iii) if, for any j, x_i is dominated by x_j , mark x_i as "dominated";
iv) if all solutions in the population are considered, go to step v;
else set i as $i + 1$ and go to step ii;
v) all solutions that are not marked as "dominated" are non-dominated solutions;
vi) end.

All the non-dominated solutions found are assumed to identify the first non-dominated front in the populations and are assigned a large fitness value (e.g. taken equal to n_p). At a first glance, the same fitness value is assigned to all non-dominated individuals in the front to give them an equal reproductive potential. However, in order to maintain diversity in the population, the fitness values are perturbed according to a sharing technique. Basically, sharing is achieved by dividing the individual fitness value by a quantity (called niche count) which is proportional to the number of individuals around the individual itself. The lowest shared fitness value in the solutions of the first non-dominated front is kept for reuse.

After sharing, non-dominated individuals are ignored temporarily to process the rest of population members. This step-by-step procedure is iterated to find the second front of non-dominated solutions in the population. Once they have been identified, a fitness value, which is slightly smaller than the worst fitness value occurred in the first front, is assigned. Thereafter, the sharing procedure is performed among the solutions of the second non-dominated front, and shared fitness values are found as before. The process is continued until all population members are assigned a shared fitness value.

As far as constraint handling is concerned, the constraint-dominance principle is resorted to; in this respect, given two solutions x_1 and x_2, x_1 is said to constraint-dominate solution x_2 if any is true

– x_1 is feasible and x_2 is not;
– x_1 and x_2 are both unfeasible, but x_1 exhibits a smaller constraint violation;
– x_1 and x_2 are both feasible and x_1 dominates x_2.

The whole population is then reproduced depending on the shared fitness values: since individuals in the first front have better (higher) fitness values than solutions of any other front, they always get more copies than the rest of the population. The rationale is to search for non-dominated regions of the objective space, which will finally lead to the Pareto front approximation. The non-dominated sorting procedure results in a relatively quick convergence towards the front, while the sharing technique helps to distribute individuals over this region.

A drawback of the algorithm is its lack of memory, i.e. the lack of an inherent technique for active use of the solution history. In fact, in a future generation, an unnecessary waste of runtime could occur in evaluating the problem objectives for an individual which is very similar – or equal – to one evaluated in the past. Typically, this happens towards convergence, eventually increasing the computational cost. Nevertheless, the algorithm has proven to be robust, thanks to its ability to work against a broadest variety of optimization problems.

Specifically, to solve the antenna design problem, the Fast and Elitist Multiobjective Genetic Algorithm NSGA-II algorithm was applied [10], with $n_g = 30$ generations, $n_p = 90$ individuals and random starting population. The probabilities of cross-over and mutation operators were set to $p_c = 0.9$ and $p_m = 1/n_p$, respectively.

5. Optimization results

5.1. Optimization with 2 objectives

In Fig. 14, a cloud of solution points is represented in the objective space: they correspond to feasible solutions generated during the evolutionary optimization process. The South-West boundary of this cloud is an approximation of the Pareto optimal front solving problems (4) and (5) and is presented in Fig. 15. The selected solution is indicated in red, for which $f_1 = -14.48$ and $f_2 = 2.88$.

In Fig. 15 an approximation of the Pareto optimal front: its non-convex shape is evident, a feature which makes the identification of solutions non trivial. In Fig. 16 a selected Pareto optimal solution, i.e. the selected geometry of the Vivaldi antenna with the corner reflector is shown. This exhibits a good tradeoff between objectives (4) and (5), since $f_1 = -14.4852$ and $f_2 = 2.8884$ that refers to the minimum value of the FBR = 14.48 dB and the maximum value of the VSWR = 2.89 among considered frequencies. Accordingly, the values of geometric parameters are reported in Table 2, while the corresponding electrical parameters are reported in Table 3 at each frequency of interest.

The radiation pattern of the antenna that was optimized with 2 objectives was obtained for the considered set of frequencies. In Fig. 18 the results for 1.8 GHz are presented while Figs. 19 and 20 show the radiation pattern for 2.1 GHz and 3.5 GHz, respectively. They exhibit directional properties with low gain in the back direction. It can be noted that for a frequency of 3.5 GHz, the antenna has a relatively low gain in the front direction (1.51 dBi) that is much lower than the typical value for the Vivaldi antenna (approx. 8 dBi). Moreover, for this frequency, the main beam splits having maximum values shifted by 20° in the z–y plane from the antenna axis. This is a disadvantage in the potential application of the antenna in the measurement and signal source identification scenarios.

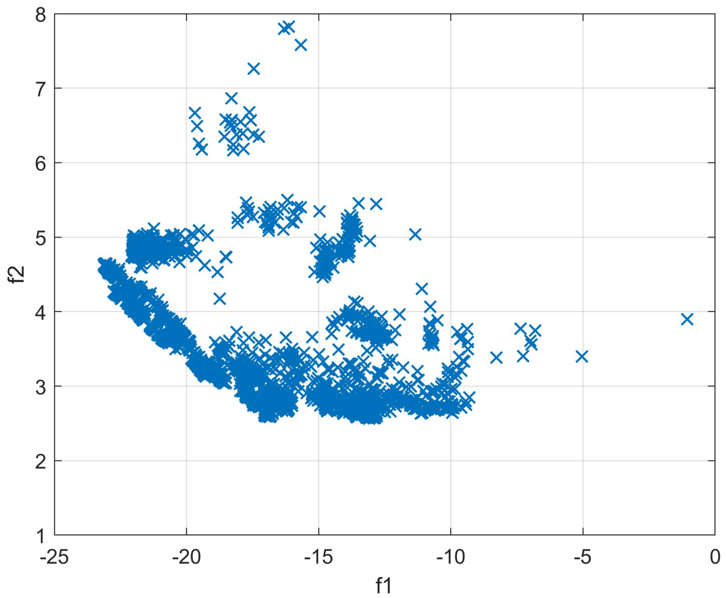

Fig. 14. Cloud of solution points in the objective space

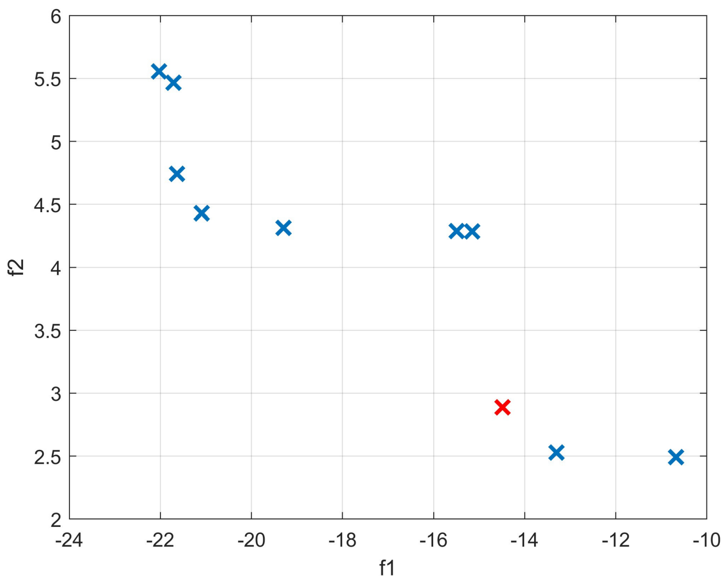

Fig. 15. Approximation of the Pareto front, red indicates the selected solution (for which $f_1 = -14.4852$ and $f_2 = 2.8884$)

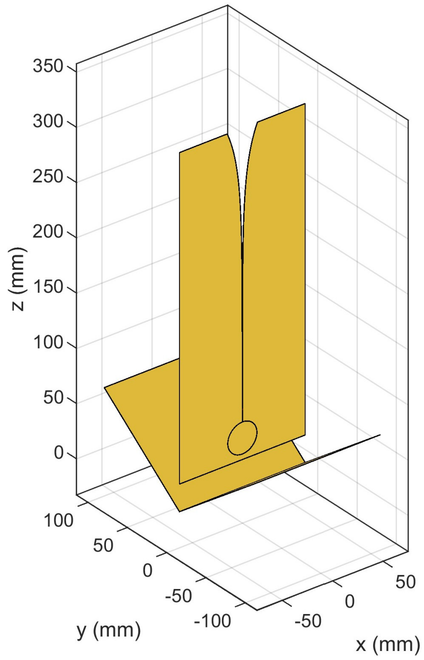

Fig. 16. The selected Pareto optimal solution 2-objective case

Table 2. Geometric parameters of selected solution – 2 objectives

Element number	Design variable	value
g (1)	w_a – Aperture Width [m]	0.0300
g (2)	o_r – Opening Rate	28.84
g (3)	w_s – SlotLineWidth [m]	0.0001
g (4)	d – Cavity Diameter [m]	0.0290
g (5)	l_r – Length of the Reflector [m]	0.2357
g (6)	α – Reflector Angle [°]	108.5825

Table 3. Electrical parameters of the optimized antenna – 2 objectives

Parameter	Frequency		
	1.8 GHz	**2.1 GHz**	**3.5 GHz**
VSWR	2.54	2.88	1.43
FBR [dB]	14.65	14.47	14.88
Front Gain	7.45	9.55	1.51
Back Gain	–7.17	–4.92	–13.37

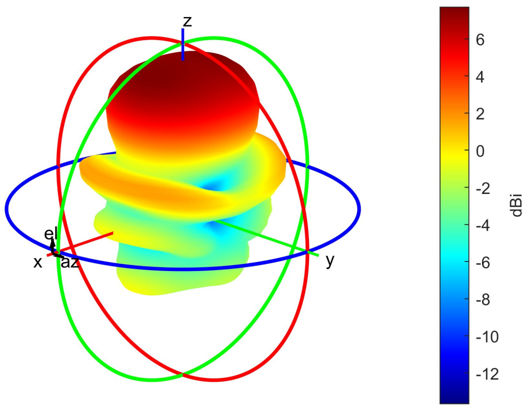

Fig. 17. Radiation pattern of optimized antenna with 2 objectives formulation for 1.8 GHz

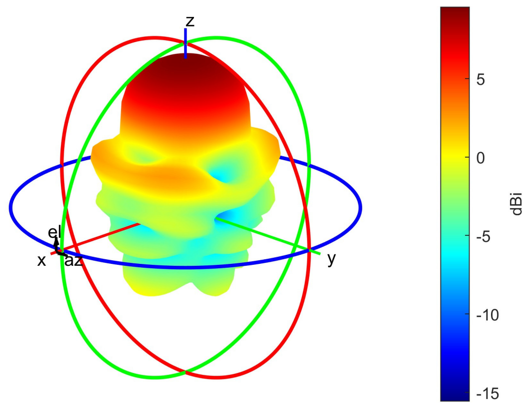

Fig. 18. Radiation pattern of optimized antenna with 2 objectives formulation for 2.1 GHz

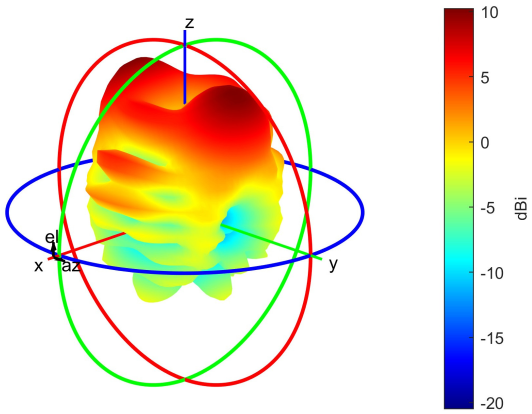

Fig. 19. Radiation pattern of optimized antenna with 2 objectives formulation for 3.5 GHz

5.2. Optimization with 3 objectives

To improve the radiation of an antenna in the front direction, an extension of the optimal design problem stated in Section 4.1 could be the following: *starting from a guess solution, find the values of a six-dimensional design vector (dimensions of reflector and radiator) which minimizes both the backward power gain and the impedance mismatch and, simultaneously, maximizes the power transmitted in the forward direction*. Accordingly, a three-objective optimization problem originates and a best compromise point trading off the three design criteria should be identified. Starting from a feasible solution g_0 in Ω_g, $f_1(g)$, $f_2(g)$ and $f_3(g)$ objectives are to be minimized with respect to g in Ω_g, where $f_3(g)$ is the function of antenna gain in front direction (6).

$$f_3(g) = G_f(g, \phi), \tag{6}$$

i.e. the minimum value of G_f with a minus sign (so the minimizing strategy of f_3 results in the maximization of G_f).

In Fig. 20 a cloud of solution points is presented in the tri-objective space $(f_1(g), f_2(g), f_3(g))$. The approximation of the Pareto optimal front solving problems (4)–(6) is presented in Fig. 21. A selected solution is indicated in red, for which $f_1 = -17.21$, $f_2 = 2.86$ and $f_3 = -8.27$.

The selection of one solution from the Pareto front is an arbitrary decision of the designer. Here, the antenna that has good impedance matching was chosen (VSWR = 2.86) and at the same time the FBR = 17.2 dB and $G_f = 8.27$ dBi. The geometry of the selected design is presented in Fig. 22. The geometric parameters of this design are reported in Table 4, while the corresponding electrical parameters are reported in Table 5 at each frequency of interest.

Table 4. Geometric parameters of selected solution – 3 objectives

Element number	**Design variable**	**value**
g (1)	w_a – Aperture Width [m]	0.0300
g (2)	o_r – Opening Rate	48.88
g (3)	w_s – SlotLineWidth [m]	0.0001
g (4)	d – Cavity Diameter [m]	0.0238
g (5)	l_r – Length of the Reflector [m]	0.553
g (6)	α – Reflector Angle [°]	93.5

Table 5. Electrical parameters of the optimized antenna – 3 objectives

Parameter	**Frequency**		
	1.8 GHz	**2.1 GHz**	**3.5 GHz**
VSWR	2.81	2.86	1.46
FBR [dB]	17.49	17.21	23.94
Front Gain [dBi]	8.27	10.33	8.39
Back Gain	–9.22	–6.87	–15.55

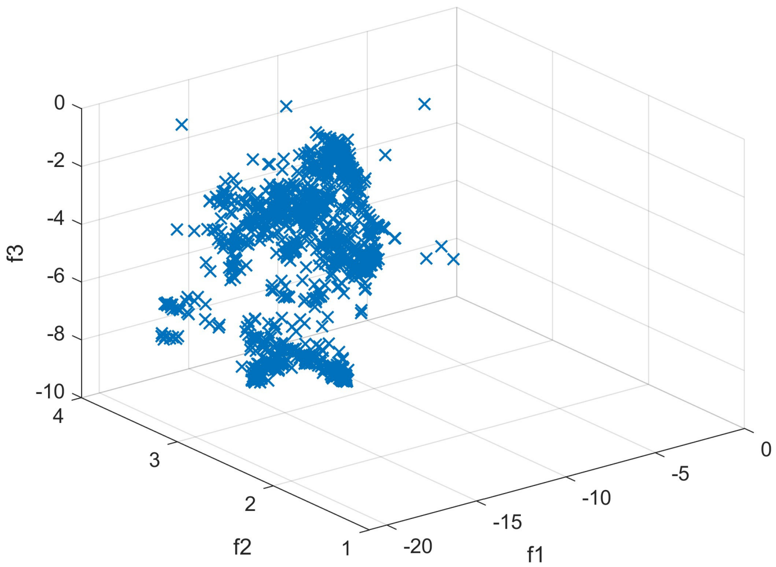

Fig. 20. Cloud of solution points in the 3-objective space

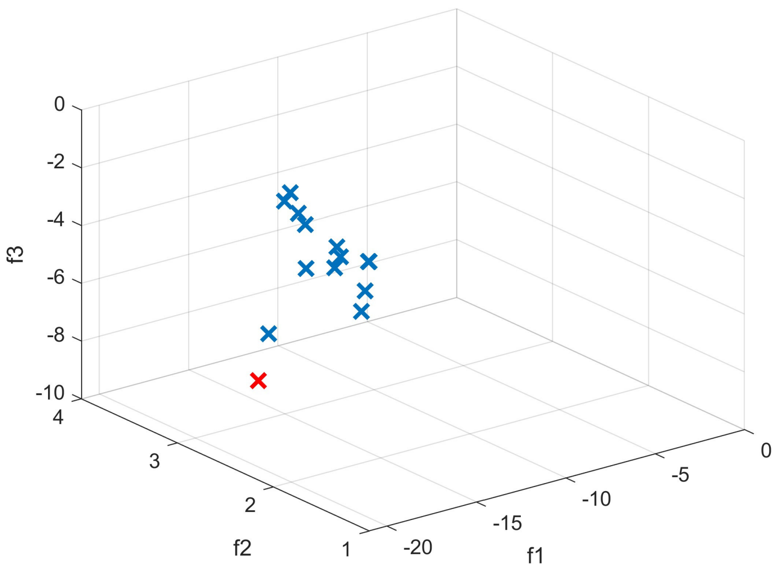

Fig. 21. Approximation of the Pareto front (3-objectives), red indicates the selected solution (for which $f_1 = -17.21$, $f_2 = 2.86$ and $f_3 = -8.27$)

Based on the data in Table 5, it can be observed that the antenna obtained as a result of optimization taking into account the 3 criteria has a higher gain in the forward direction compared to the antenna obtained for the case of 2 objectives. For all considered frequencies G_f is not smaller than 8.27. In order to analyze the properties of the antenna in more detail in terms of

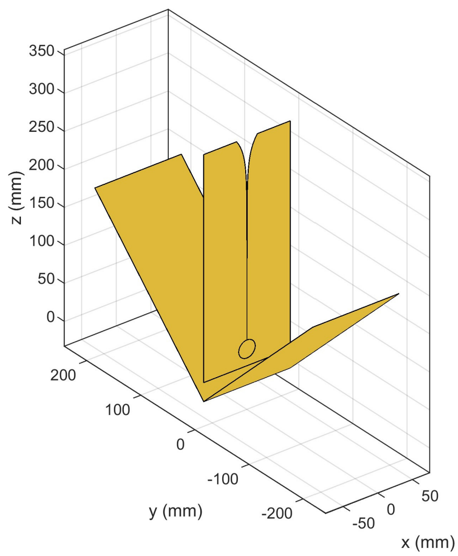

Fig. 22. The selected Pareto optimal solution obtained from 3-objective optimization

its radiation, simulations of its radiation pattern were performed for all 3 frequencies. Figure 23 shows the radiation pattern for a frequency of 1.8 GHz, Fig. 24 for 2.1 GHz, and Fig. 25 for 3.5 GHz. Analyzing the radiation pattern for 3.5 GHz (Fig. 25), it can be seen that the maximum gain coincides with the z-axis direction and there is no splitting of the main beam. Thus, the undesirable effect visible in the case of the antenna obtained using the 2-criteria optimization, which does not take into account the gain in the forward direction, has been eliminated.

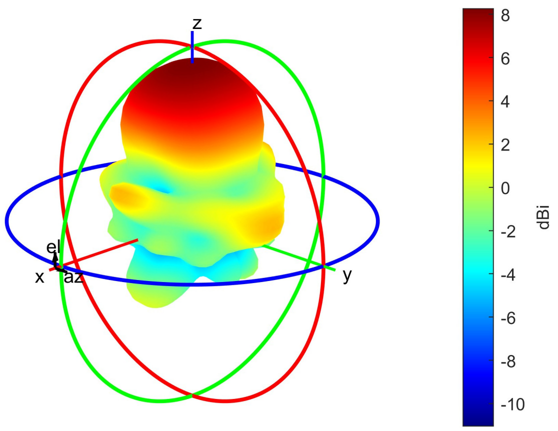

Fig. 23. Radiation pattern of optimized antenna with 2 objectives formulation for 1.8 GHz

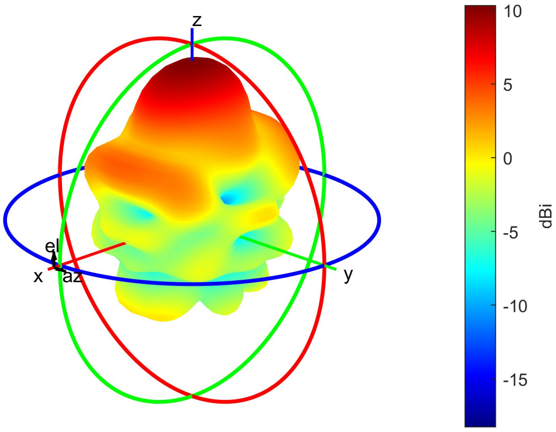

Fig. 24. Radiation pattern of optimized antenna with 2 objectives formulation for 2.1 GHz

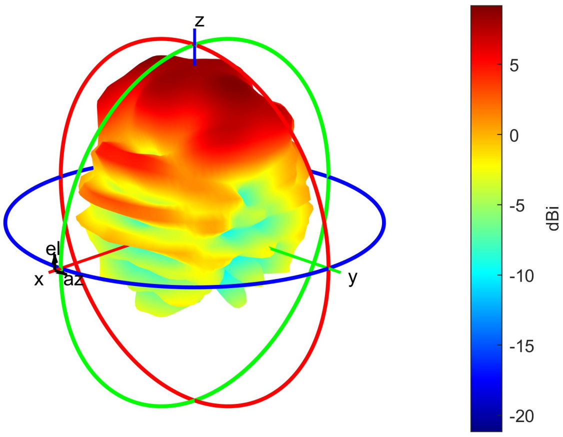

Fig. 25. Radiation pattern of optimized antenna with 2 objectives formulation 3.5 GHz

6. Conclusions

An original revisitation of classical optimization theory made it possible to propose a customized method for the optimal design of Vivaldi's antenna. The main elements of novelty can be summarized as follows:

– at the design level, a concept of coupling the Vivaldi antenna with a corner reflector for improving the radiation performance;
– at the methodological level, a combination of minimax formulation of design criteria against frequency and a Pareto-like tradeoff of solutions driven by evolutionary computing.

Specifically, the Frequency Domain Method of Moments combined with the Genetic Algorithm optimization technique, has proven to be an effective tool for optimizing the antenna-reflector system: the optimized design achieved significant improvements in back-lobe suppression and the VSWR, making it a promising candidate for 5G wireless communication applications.

Based on the antenna simulations obtained using three-criteria optimization, it can be stated that extending the Vivaldi antenna with a corner reflector improves its directional properties. It is possible to limit back radiation in this way (FBR = 17 dB) while maintaining the typical value of maximum gain (G_f = 8 dBi). The antenna developed in this way is characterized by slightly worse impedance matching (VSWR < 2.8), however, in the case of using such an antenna in the receiving mode, this is not a disqualifying factor.

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