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UHF FRACTAL ANTENNAS: SOLUTIONS FOR RADIO LINKS USING MATLAB SIMULATIONS

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Abstract: *The paper proposes the use of MATLAB simulations as a first step in identifying proper antennas to be used in specific ultra-high frequency (UHF) communication links. Giving that fractal antennas provide interesting features, we aimed at comparing a few of their significant parameters with those of a monopole antenna so as to ensure signal coverage between two real sites situated at 5.82 km distance in a mixture of urban and flat – open terrain conditions. We started from the requirements imposed to the return loss of the antenna and to the link margin, we established their desired thresholds and then computed solutions regarding which antenna type in the set provide the highest received power and on which frequency sub-bands can be successfully used. The studied fractal antenna set were from the series Koch, Koch loop and Sierpinski. The chosen radio link refers to a real situation on the map. Generally, different narrow bands were provided by each antenna regardless of its type, but still, comparing them with the monopole, better solutions could be identified.*

Keywords: fractal antennas, UHF radio link, multi-band antennas, usable band, resilient link

1. Introduction and Objective

The use of fractal antennas for communication in the ultra-high frequency (UHF) range is not very new [1]-[5], but the interest for these field continues due to specific needs [6]-[8]. These antennas present a complex, convoluted form, they have a self-similar structure and are specifically recognized as multi-band antennas. Generally, they don't represent a significant competitor for classical antennas, but there are situations when they respond much better to specific needs.

Present work aimed to identify pros and cons on using one or another antenna model in conditions of deploying a point-to-point UHF radio-link between two sites situated at 5.8 km distance.

Simulations offer a rapid solution so that we used MATLAB to analyse radio-link capability starting from the analysis of antennas parameters. As a kind of reference we used a monopole antenna, largely used in UHF range. Other six types of fractal antennas were investigated to check for better solutions in particular cases.

2. Materials and Methods

Antenna Toolbox of MATLAB software [9] was the computational environment in the present approach. The simulated fractal antennas are presented in Figure 1. The types (a total of six) were: Koch dipoles (2 and 3 iterations), Koch loops (2 and 3 iterations) and Sierpinski gaskets (2 and 3 iterations). They will be noted from now on as Koch 2, Koch 3, etc. and similarly. Separately, a monopole antenna was also designed and analysed. All the fractal antennas were prepared on a substrate of

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epoxy FR4fiberglass sheet of 20x20 cm^2 area and a thickness of 1.5 mm. The length of the antennas was 15 cm and the width of all the antennas was 0.2 cm. The antennas response was analysed in the whole range from 300 MHz to 3 GHz, following: a) radiation pattern; b) return loss; c) impedance. The frequency step applied in the simulations was either 50 MHz or 10 MHz, depending on the interest sub-band. The computations were based on Method of Moments which is implemented in the Antenna Toolbox.

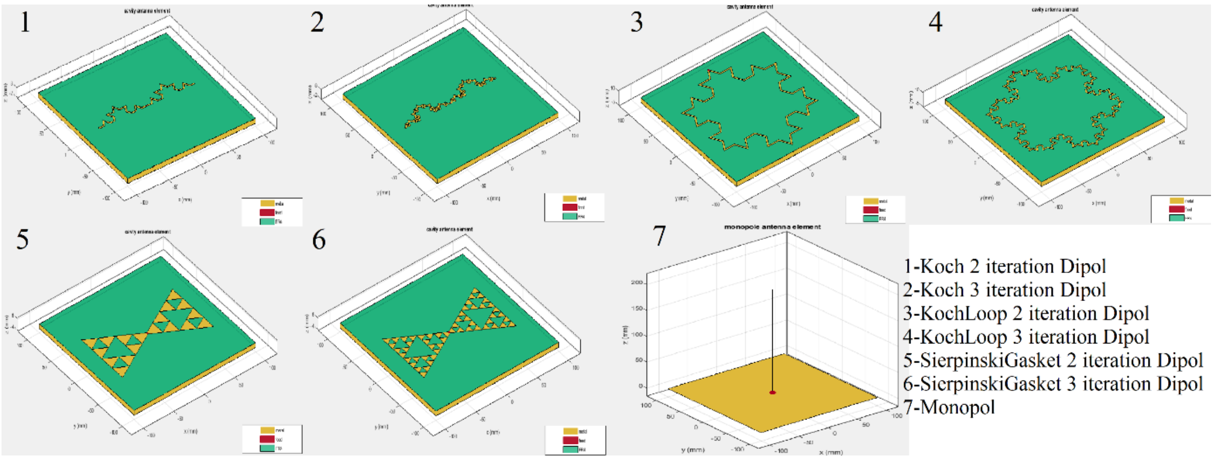

Figure 1: The set of seven antenna models used in simulations: six fractal antennas and one monopole

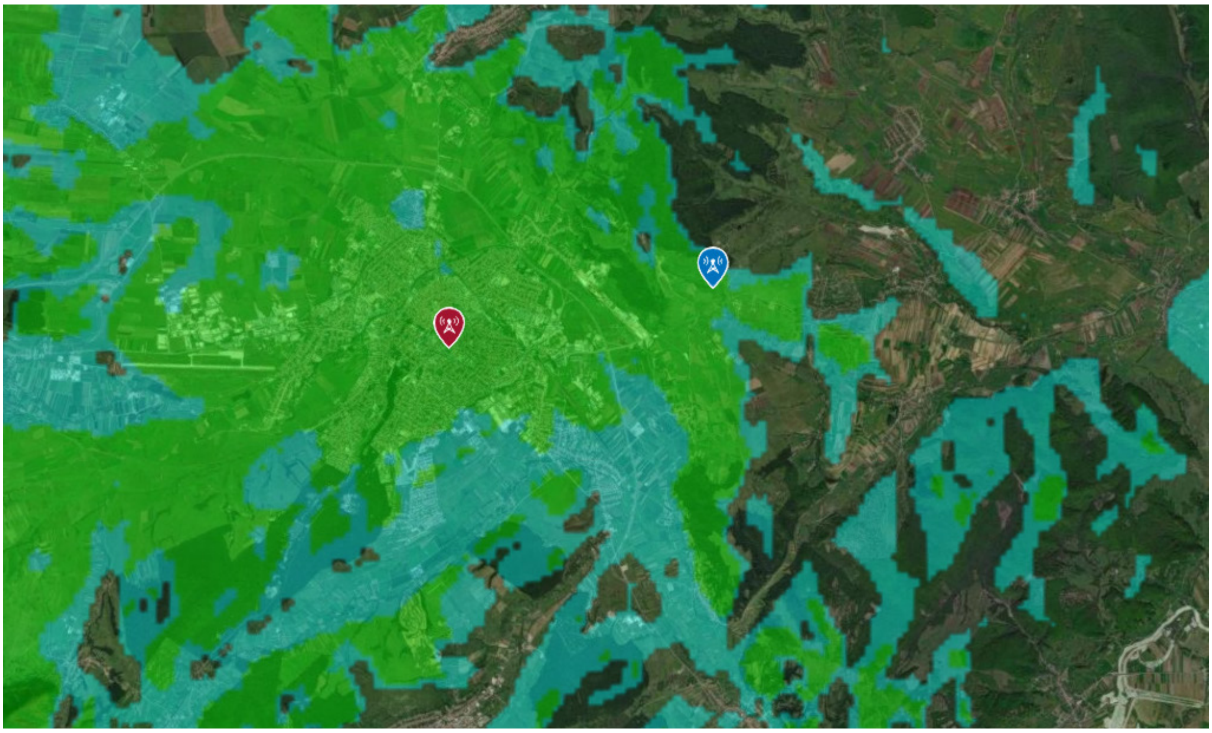

Figure 2: The locations of the the tx site (Sibiu, red) and rx site (Daia, blue) and the signal coverage area in the case: frequency = 300 MHz, antenna types=Koch 2; green coverage = -75 dBm; blue-green coverage = -90 dBm

After designed antennas analysis, a radio link was projected between Sibiu city – the location of the authors institution, and a remote location situated at 5813.9 m away (Figure 2). The link always made use of pairs of the same antenna model both at the transmission point (tx) and at the receiving point (rx). The transmitted power, P_tx in all cases was set to 33 dBm. At rx position, we assumed to have a receiver with a sensitivity S = -100 dBm.

Studying the antennas radiation patterns enabled us to orient them in the simulation step with the azimuthal direction of maximum radiation (gain) exactly one to the other with antenna polarization = horizontal.

Path loss was computed based on Longley–Rice propagation model with ground conductivity = 0.005 S/m, ground relative permittivity = 15 and atmospheric refractivity = 301.

For the link reliability we imposed two conditions of the UHF communication: a) the antennas return loss to be higher than 16 dB (reflected power <2.5 %); b) the link margin (which equals the difference between P_rx and S) to exceed 10 dB. These two thresholds imposed simultaneously over the entire UHF band will be visualised in Figure 3 as horizontal lines intersecting the graphs.

With these data we then computed the frequency sub-bands for each pair of antenna links, which provided the reliable link. In this way multi-band response tailored to our concrete situation was defined. At the end we computed also the values of the received powers for the most resilient situations and sub-bands.

3. Results and Discussion

Figure 3 depicts variations of the return loss of each antenna and the link margin in case of using pairs of such antennas during UHF communication. By applying the established values of level thresholds (horizontal lines), we were able to select the sub-bands in which each antenna couple provided the resilient link. It is obvious that fractal antennas have multi-band features, with very narrow bands allowed for proper linking.

Figure 4a summarizes the situation by indicating the received power level for each resilient sub-band and each antenna type. The received power P_rx was computed for the maximum return loss of the respective antenna and frequency. Figure 4b indicates the bandwidths of each antenna and the variations of the received power in such a narrow band. The bandwidths and the position in the spectrum are visible in Figure 4b. One can observe that: a) the widest available bands were obtained with Koch loop 2 (60 MHz) and Koch 2 (50 MHz) antennas; b) a maximum of four bands can be used only with Koch 2, Koch 3 and Koch loop 2 fractal antennas; c) the highest signal strength could be obtained with Koch 2 antenna, P_rx_max = -57 dBm and its frequency band was of 40 MHz, in the 340-380 MHz range. By comparison, the monopole antenna provides solutions in just three narrower bands situated in the upper region of UHF, with the largest bandwidth of 20 MHz. Sierpinski antennas don’t represent a possible solution for this link.

Figure 5 depicts the 3D radiation patterns of Koch 2 fractal at 360 MHz and Koch loop 2 at 1670 MHz. These two frequencies correspond to the bands estimated to fulfil the imposed threshold condition for a resilient link and are also indicated by two small arrows in Figure 4b. If directivity is needed, then Koch loop 2 antenna responds better.

Figure 6 shows the azimuth and elevation planar radiation patterns of Koch 2, Koch 3, Koch loop 2 and monopole antennas at six frequencies between 560 MHz and 2.42 GHz. To be noted that all three fractal antennas in this figure generally present higher gains in azimuth than that of the monopole antenna.

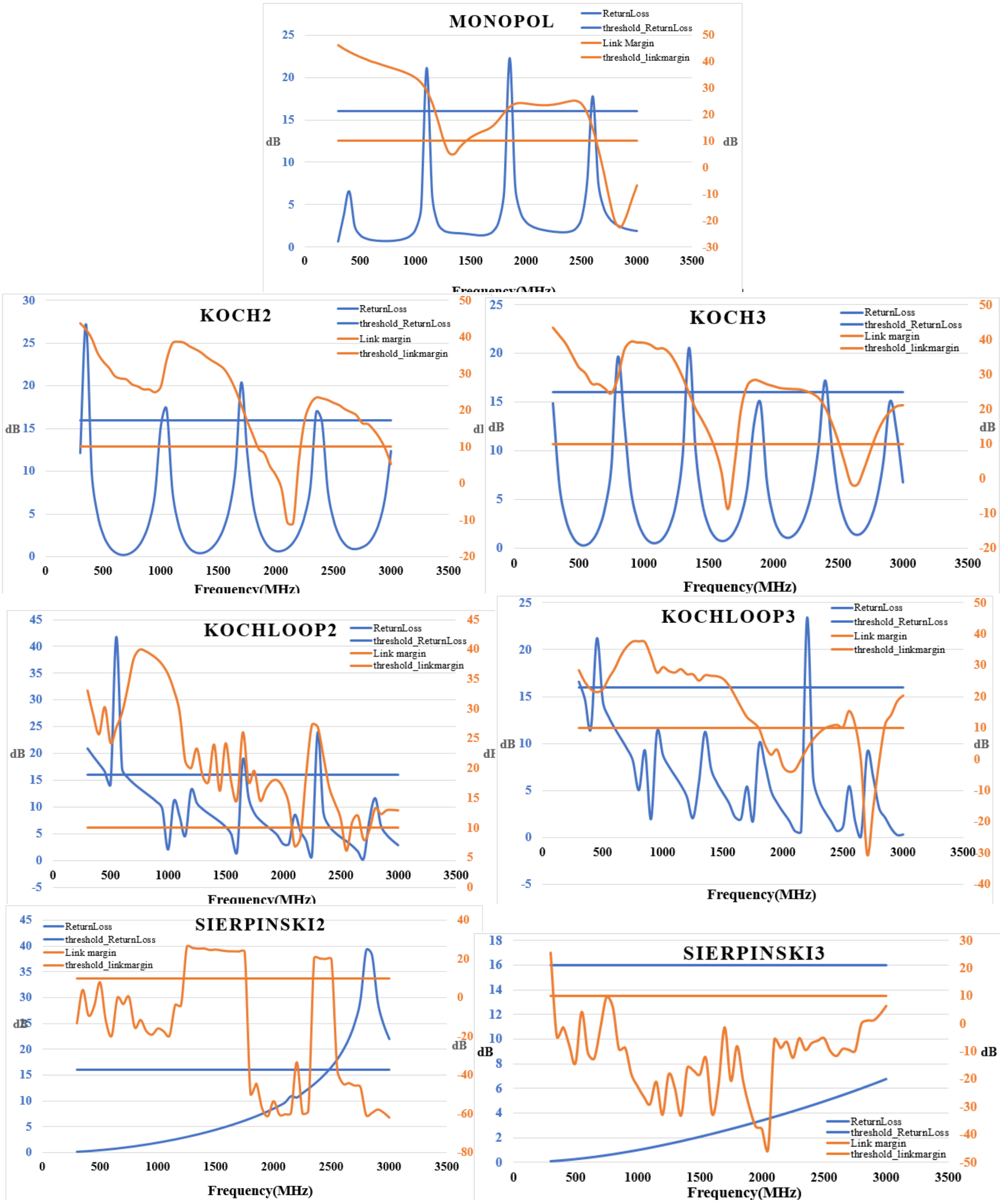

Figure 3: Dependencies on frequency of return loss of antennas (blue curves) and of link margin (orange curves) with superimposed thresholds condition (horizontal lines) for a resilient link

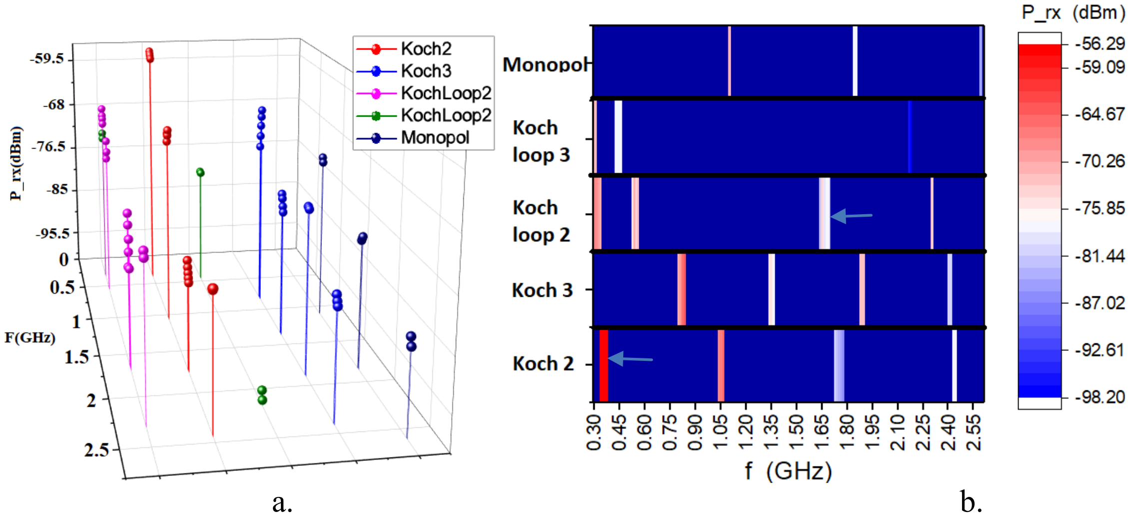

Figure 4: a. Received power levels for resilient links solutions obtained with fractal antennas versus monopole antenna for a transmitted power of 33 dBm over a distance of 5.82 km from Sibiu city; b. Frequency bands and widths to be used for a resilient link with various antennas and the respective received powers, when the transmitted signal power was 33 dBm

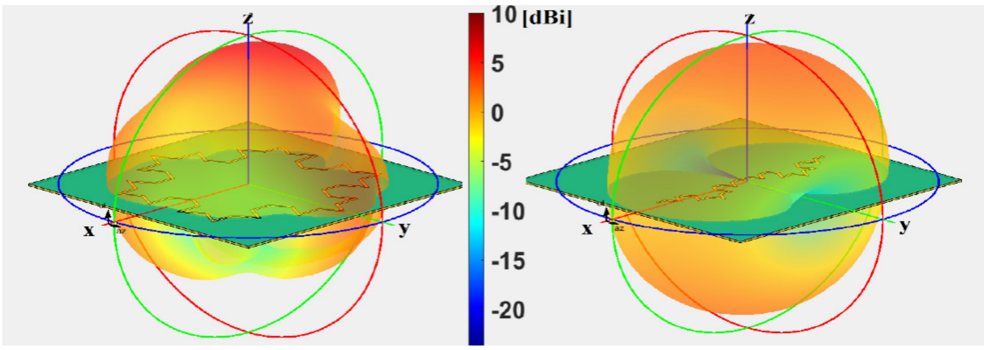

Figure 5: 3D Radiation patterns of fractal antenna Koch loop 2 at 1670 MHz and Koch 2 at 360 MHz

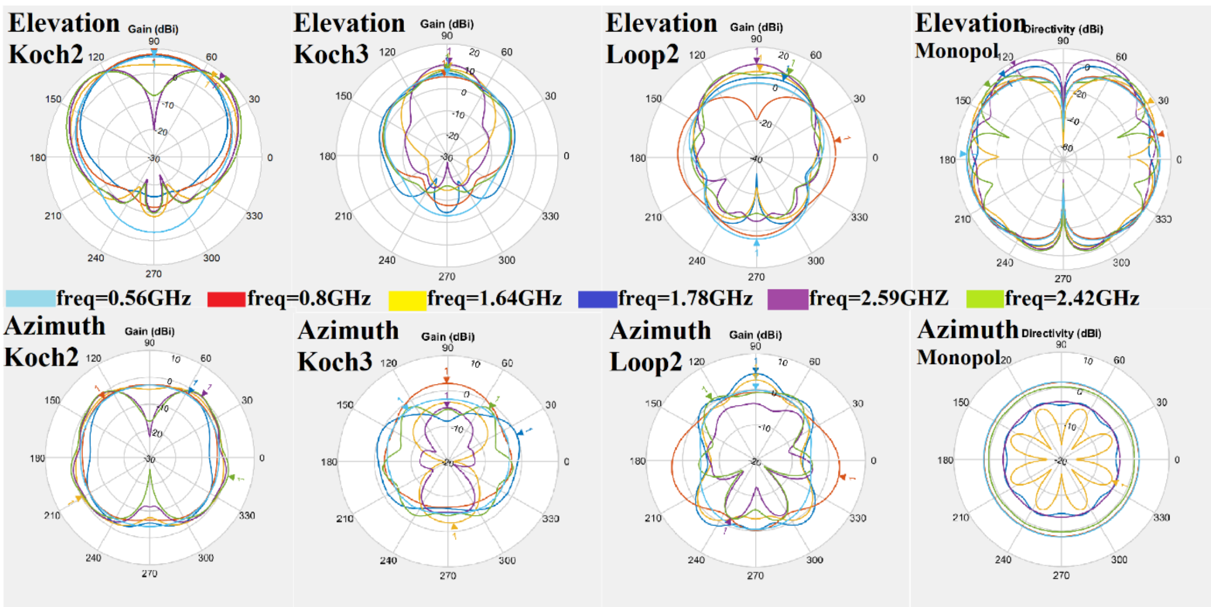

Figure 6: Azimuth and elevation plane patterns of fractal antennas versus monopole at six frequencies

4. Conclusions

Fractal antennas provide interesting solutions in case of narrow and multi-band UHF linking requirements. Bandwidths of the order of up to 60 MHz could be achieved in restricted spectrum positions and with one specific fractal antenna type in the present work.

Transmitted powers as low as 33 dBm proved to be received at 5.8 km distance, in propagation conditions mixing urban and flat – open terrain conditions, at a level of -57 dBm when the sensitivity of the receiver was set to -100 dBm. Link margin was considered 10 dB for a satisfactory link.

From the seven types and dimensions of fractal antennas analysed here, it resulted that two types, namely Koch loop 2 antenna and Koch 2, provide bandwidths 2-2.5 times larger than the monopole and their gain also exceed with few dB that of the monopole's. Both fractal antennas and the monopole present properties specific to multi- and narrow-band antennas in the UHF range. Four bandwidths were identified to ensure a resilient link for Koch 2 and Koch loop 2 antennas in the practical situation we had to treat, while the monopole offered just three and narrower bandwidths. Sierprinski gasket did not prove to offer a proper solution for the desired radio link.

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