COMPARISON OF MICROSTRIP PATCH ANTENNAS OPERATED ON 2.45GHZ

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ABSTRACT

Nowadays we are living in the ages of innovations. The expansions of communication systems is unbelievable. Many of devices recent are based on database and cloud systems. They need to be connected with other devices and services provider. Well known types of transmission are radio frequency (RF) and optical systems. They use different access for communication. In case of RF systems is need in/out device proposed to receiving/sending of signals. Now are available the many of types of antennas. They are divided by purpose, shape, material, value of radiated power, gain and price. For each purpose is appropriate different type of antenna. The low cost type of antenna is microstrip patch antenna. They are represented by different shapes and materials. Microstrip patch antenna contains the layer of substrate placed between two conduct layers. Parameters of antenna could be affected by change of relative permittivity of substrate. Nowadays are available many of high frequency materials with low value of relative permittivity. The point of this paper is comparison of two types of microstrip patch antennas witch different shapes of radiation patch.

Keywords: *Ansoft HFSS, microstrip antenna, radiation*

1. INTRODUCTION

Microstrip patch antennas in recent years expanded in many of different areas. This type of antennas is very popular because their implementation costs are too low in comparison with other antennas. They are characterized by wide angle of radiation, low level of gain and difficulty of impedance matching for case of using microstrip array. The challenge in design is correct impedance matching and modification of conduct layer used as radiation patch. Appropriate impedance matching combine with implementation cut out of patch allow increase gain of antenna. The key parameter of this type of antenna is also used material. The dielectric constant of substrate also dominantly affect parameters of microstrip patch antenna. This paper is focused on impact of cut out of patch antenna in U shape [1-3].

2. DESIGN OF REFERENCE PATCH ANTENNA

On the base of theoretical knowledge was designed reference microstrip patch antenna which is used as base for next optimisation process. The width of patch *Wp* is defined by equation (1). Where *c* is speed of light, f_0 is operating frequency and ε_r is dielectric constant.

$$Wp = \frac{c}{2 \cdot f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

For determination of length of substrate we have to define effective value of dielectric constant ε_{reff} in (2)

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2}, \tag{2}$$

where *h* is thickness of substrate and substrate width *W*. Then the effective length L_{eff} is defined as

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}}. \tag{3}$$

Using effective length from (3) could be defined value length of edging ΔL

$$\Delta L = 0{,}412h \frac{\left(\varepsilon_{reff} + 0{,}3\right)\left(\frac{W}{h} + 0{,}264\right)}{\left(\varepsilon_{reff} - 0{,}258\right)\left(\frac{W}{h} - 0{,}8\right)}, \tag{4}$$

where *h* represents height of substrate. Finally the length of patch is defined by (5).

$$Lp = L_{eff} - 2\Delta L \tag{5}$$

On the base on equations (1-5) were obtained of reference microstrip patch antenna. These parameters are defined in Table 1. Material of dielectric substrate is from Rogers Company denote as RO4350 with smaller value of dielectric constant in comparison with standard PCB (Printed Circuit Board) material FR04 [4-7].

Table 1 Parameters of designed microstrip patch antenna

Parameter	Describe
Frequency	2.45GHz
Substrate	Rogers RO4350
Relative permittivity	$\varepsilon_r = 3.66$
Dimension of substrate	100x90x6mm
Dimension of patch	40x30x0.07mm

Dimensions of substrate are in format "W x L x H" (Width x Length x Height) and dimensions of patch are in format "Wp x Lp x Hp" (Width x Length x Height). Dimensions of designed reference microstrip patch antenna are in the Fig. 1. Input port is used SMA connector which

connect two conduct layer placed on both sides of substrate [8-10].

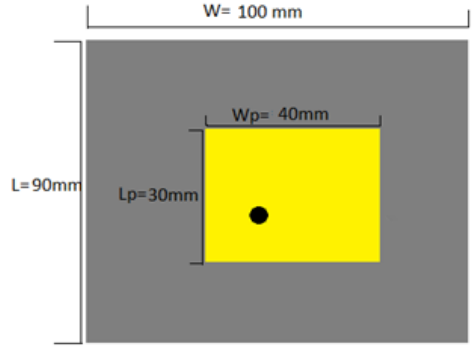

Fig. 1 Dimensions of microstrip patch antenna

In the Fig. 2 could be seen the designed model in development environment of Ansys HFSS software. The boundaries of antenna are represented by semi-transparent block.

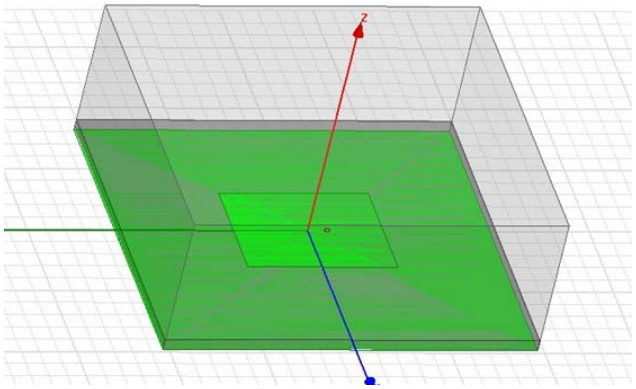

Fig. 2 Designed reference antenna in HFSS Ansys

The main parameter which represents impedance matching and resonance on operating frequency is $S_{1,1}$ parameter. $S_{1,1}$ parameter represents amount of radiated power on operating frequency. This parameter obtained through simulation of reference microstrip patch antenna without cut out is in the Fig. 3.

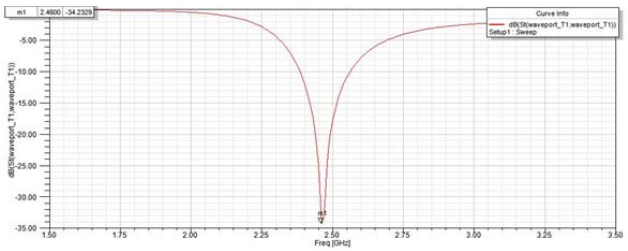

Fig. 3 $S_{1,1}$ parameter of designed reference antenna in Ansys

The $S_{1,1}$ parameter from Fig. 3 could be determine value of these parameter which correspond with -34,2329dB on operating frequency 2.45GHz.

Total radiation pattern of designed reference antenna placed in 3D shown on operating frequency 2.45GHz could be seen in the Fig. 4. The area with high level of saturation represents the area of maximal radiation.

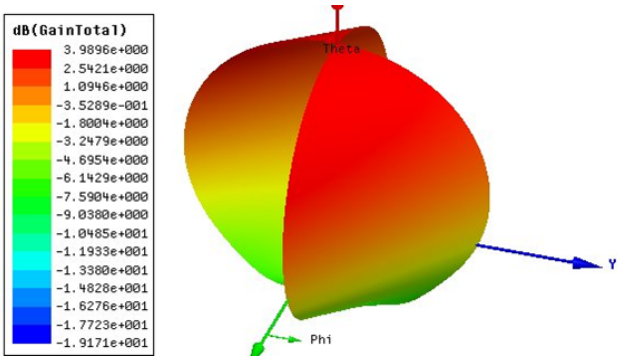

Fig. 4 Radiation pattern of designed reference patch antenna in HFSS Ansys

The radiation pattern of reference antenna in E plane cut which represents cut of electrical plane could be seen in the Fig. 5.

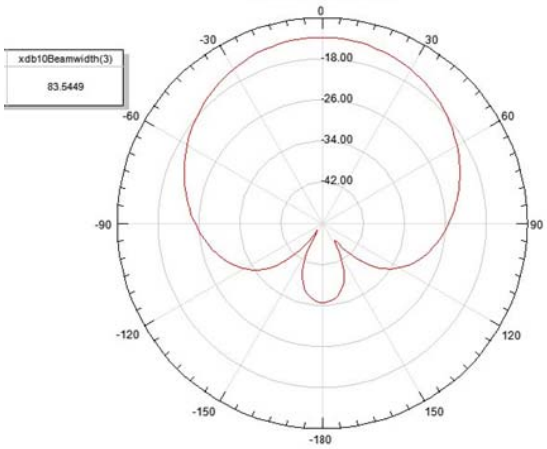

Fig. 5 Angle of radiation in polar coordinates realized for E plane cut

The radiation pattern of reference antenna in H plane cut which represents cut of electrical plane could be seen in the Fig. 6.

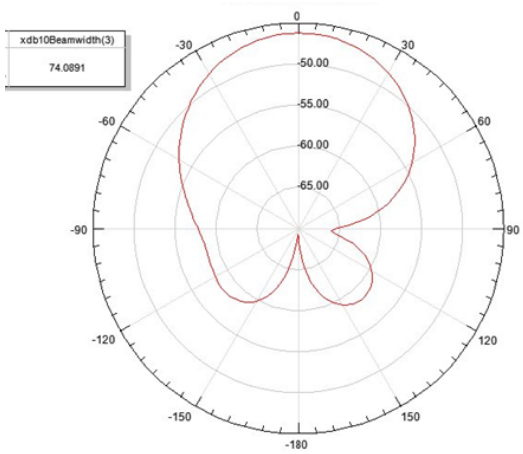

Fig. 6 Angle of radiation in polar coordinates realized for H plane cut

The parameter which represent maximum value of radiation is radiated power. The obtained value of radiated power from simulation of reference microstrip patch antenna is 1.003mW on operating frequency 2.45GHz.

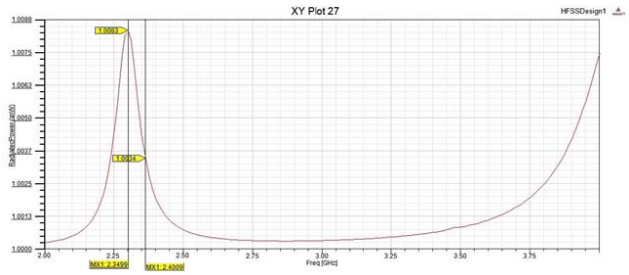

Fig. 7 Maximal radiated power of reference antenna

3. MICROSTRIP PATCH ANTENNA WITH U-SHAPE CUT

In this section is realized design of cut out of patch. The dimensions of patch were obtained through optimisation process. These parameters of modified microstrip patch antenna with regards on ensure same operating frequency as reference antenna are in the Table 2 [11-13].

Table 2 Parameters of designed microstrip patch antenna

Parameter	Describe
Frequency	2.45GHz
Substrate	Rogers RO4350
Relative permittivity	$\varepsilon_r = 3.66$
Dimension of substrate	100x90x6mm
Dimension of patch	40x30x0.07mm

Dimensions of substrate are in format "W x L x H" (Width x Length x Height) and dimensions of patch are in format "Wp x Lp x Hp" (Width x Length x Height).

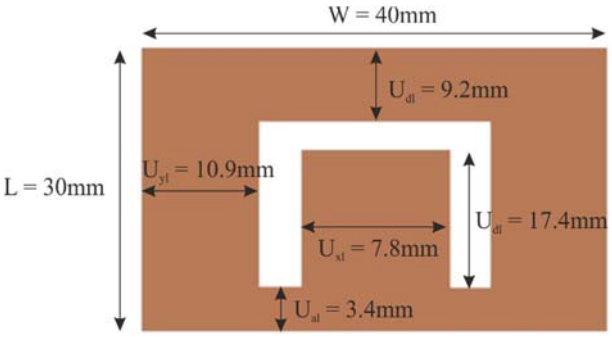

Fig. 8 Dimensions of U-shape cut out of radiation plane of patch

In the Fig. 8 could be seen parameters of patch. The cut out is U shape for increasing the value of gain and expand the radiation angle for ensure the cover of widely area in comparison with reference microstrip patch antenna.

In the Fig. 9 could be seen the designed model in development environment of Ansys HFSS software. The boundaries of antenna are represented by semi-transparent block. The patch is placed on dielectric substrate and under substrate on the bottom layer is conduct grounding layer.

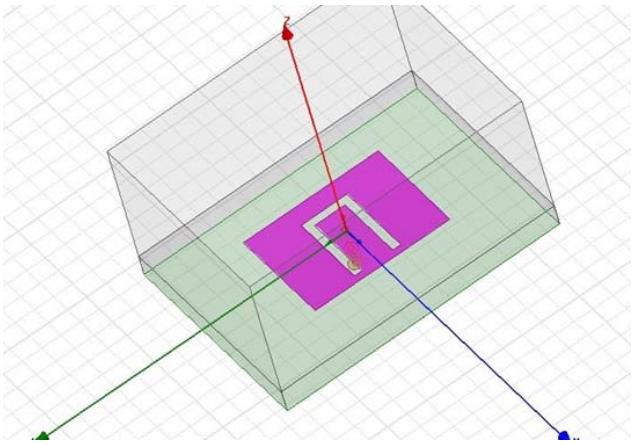

Fig. 9 Design of microstrip patch antenna with U-shape cut out in HFSS Ansys

The $S_{1,1}$ parameter from Fig. 10 could be determine value of these parameter which correspond with -33,1316dB on operating frequency 2.45GHz.

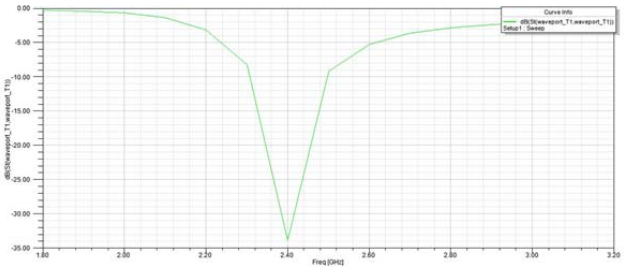

Fig. 10 $S_{1,1}$ parameter of antenna with U-shape cut out in Ansys

Total radiation pattern of designed modified antenna placed in 3D shown on operating frequency 2.45GHz could be seen in the Fig. 11.

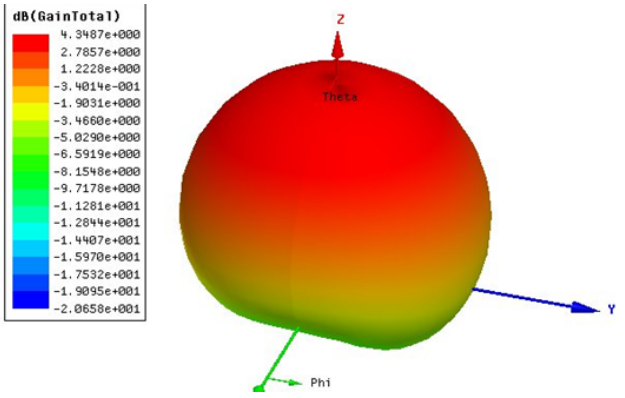

Fig. 11 Radiation pattern of patch antenna with U-shape cut out in HFSS Ansys

The radiation pattern of modified antenna in E plane cut which represents cut of electrical plane could be seen in the Fig. 12.

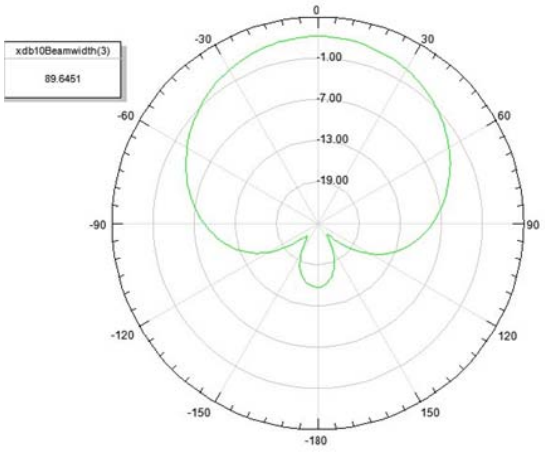

Fig. 12 Angle of radiation in polar coordinates realized for E plane cut out

The radiation pattern of modified antenna in H plane cut which represents cut of electrical plane could be seen in the Fig. 13.

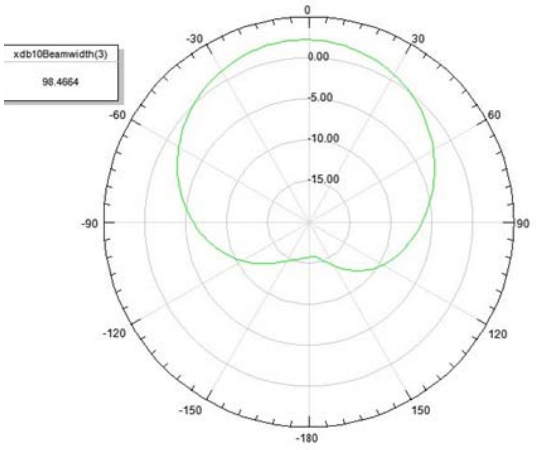

Fig. 13 Angle of radiation in polar coordinates realized for H plane cut out

The obtained value of radiated power from simulation of reference microstrip patch antenna is 1.003mW on operating frequency.

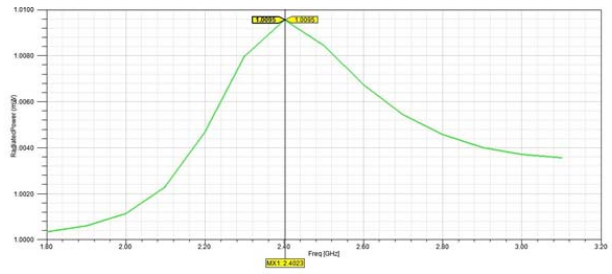

Fig. 14 Maximal radiated power of modified U-shape antenna

In the Fig. 14 could be seen distribution of radiation power which is maximal on operating frequency. The trend line show minimisation of unwanted side radiation which can cause attenuation of other services which operating on frequencies nearby operating frequency of modified antenna.

4. COMPARISON OF ANTENNAS

The comparison of these two antennas could be seen in the Table 3. In this table is realized comparison of values of maximal radiated power, total gain, radiation angle in two different cuts.

Table 3 Comparison of reference patch antenna with modified patch antenna

Parameter	Reference patch antenna	Patch antenna with U-shape cut
Frequency	2.45GHz	2.45GHz
Gain	3.99dBi	4.35dBi
Radiation angle (horizontal cut)	74.09°	89.65°
Radiation angle (vertical cut)	83.54°	98.47°
Radiated power	1.003mW	1.003mW

5. CONCLUSIONS

The comparison realized in the Table 3 clearly show the differences in parameters of each of antennas. The impact of appropriate implementation of cut out of patch show increasing of parameters of antenna. Total gain of reference antenna obtained 3.99 and total gain of modified antenna obtained 4.35. The modified antenna reach increasing about 0.36dBi. This increasing is not significantly but can be the base step for next optimisation. Higher difference between antennas is in value of radiation angle. The value of angle of radiation of reference antenna in E plane cut reach 74.09° and modified antenna obtained 89.65°. Modified antenna reach increasing of radiation angle about 15.61° in E plane cut. The value of angle of radiation of reference antenna in H plane cut reach 83.54° and modified antenna obtained 98.47°. Modified antenna reach increasing of radiation angle about 14.93° in H plane cut.

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Jakub Urbanský (Ing.) was born in 1991. In 2017 graduated (MSc) at the Department of Electrical Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. At present is a Ph.D. student in the Department of Electrical Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. He received a master degree in electric power engineering on subject of the integration of electric vehicle into the electrical power distribution, using the vehicles-to-grid (V2G) technology. His scientific research is mainly focused on research of renewable energy sources.

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