DESIGN OF CIRCULAR PATCH ANTENNA INTEGRATED INTO THE ASPHALT SURFACE OF THE ROAD

David Wolanský

Doctoral Degree Programme (1), FEEC BUT

E-mail: xwolan00@stud.feec.vutbr.cz

Supervised by: Zbyněk Raida

E-mail: raida@feec.vutbr.cz

Abstract: This paper deals with the design of circular patch antenna with two shorting pins for the purpose of transmission information about road temperature to the receiver. Antenna works at the frequency 868 MHz and it is placed 20 mm under the asphalt surface of a road. Next, the influence of the asphalt background material on the antenna gain and radiation patterns is discussed as well.

Keywords: circular patch antenna, shorting pins, asphalt surface

1. INTRODUCTION

Information boards often appear along the roads providing the road temperature information. Temperature sensors are placed in the road and temperature information is transmitted via cable to the receiver on the board. The receiver is situated 50 to 100 m far from the antenna and 3 m above the road surface. The cable is led under the road surface. This solution is very simple, but economically inconvenient. Therefore, a hole is drilled into the road and the temperature sensor supplied by battery is placed inside. Temperature information is transmitted then through wireless communication by means of the antenna placed into the hole. This antenna is designed and simulated in HFSS.

2. CIRCULAR PATCH ANTENNA WITH TWO SHORTING PINS

In order to place the antenna under the road surface a hole in the road is needed. The maximum hole diameter is 40 mm. The patch antenna has to be designed small enough to fit the hole. Accordingly, the antenna has to be 40 mm in diameter. Since the transmission works at the frequency 868 MHz, the antenna diameter will be approximately 90 mm if commercially available 9 mm thick FR4 substrate (ε_r = 4.2) is used (the 9 mm thick substrate was chosen in order to maximally reduce the size of the antenna and on the other hand to broaden bandwidth). That is why an electrically small antenna has to be developed using available techniques.

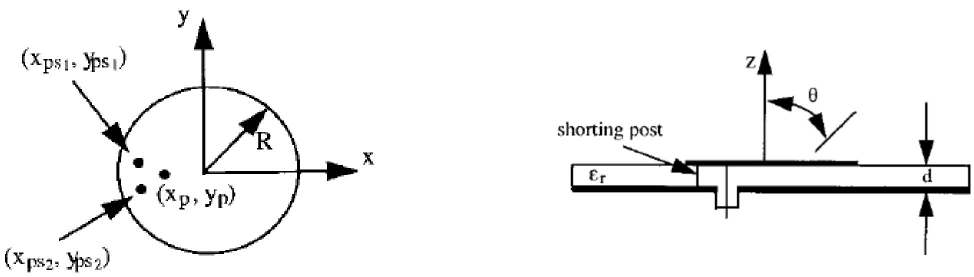
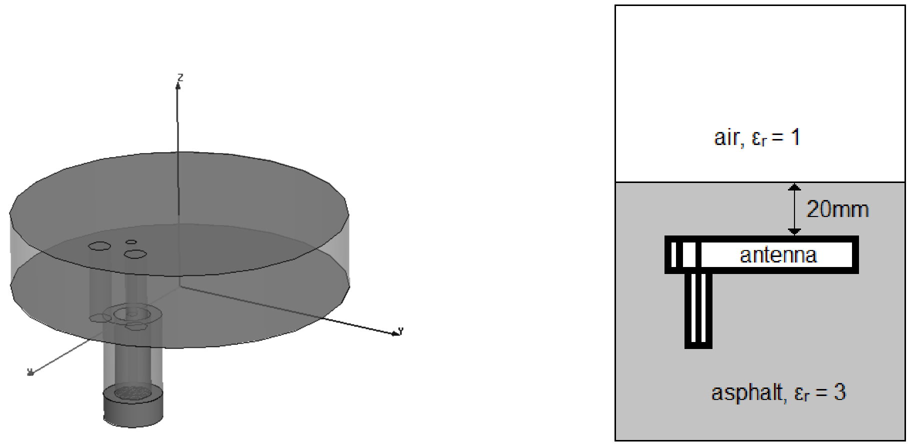


Figure 1: Schematic of probe-fed patches incorporating two shorting pins [1]

Fig. 1 shows the concept of a circular patch antenna with two shorting pins. The antenna is fed by a probe at the point x_p, y_p. Shorting pins are situated at the point x_{ps1}, y_{ps1} and x_{ps2}, y_{ps2} [1]. The zero mode of the unloaded circular patch is crucial for the existence of a resonance mode below the lowest operation frequency of the unloaded circular patch. In an equivalent circuit picture, this new resonance mode can be viewed as resulting from an inductance (due to the shorting pin) in series with the static capacitance of the patch configuration. The shorting pin raises the zero eigenvalue of the unloaded patch [2]. It results in the fact that shorting pins enable the minimization of overall dimensions of the patch antenna.

The usage of two shorting pins instead of one has its own purpose. In a case of one shorting pin, the resonant frequency of the antenna is dramatically changing even with the slight change of the distance of the shorting pin from the center of the antenna. This might be a problem in the case of an inaccurate production of the antenna. If two shorting pins are used, the production inaccuracy is not so dominant because the antenna reacts less sensitively on the distance deviation of two shorting pins from the center of the antenna. This antenna was designed and simulated in HFSS. The antenna model is depicted in Fig. 2a. The background material is asphalt with relative permittivity ε_r = 3. The antenna is located 20 mm under the interface of vacuum and asphalt (Fig. 2b). The antenna is fed by 50-ohm SMA connector. Table 1 shows the antenna dimensions. Return loss characteristics as a function of frequency is shown in Fig. 3. The 10-dB return loss bandwidth is about 1.6%. The narrow band of the proposed antenna is typical for electrical short antennas.

The radiation patterns are shown in Fig. 4. If we consider that the receiver is situated 50 to 100 m far from the antenna and 3 m above the road surface, it is important to know the extent of the antenna radiation in horizontal direction. The radiation pattern clearly shows that the electromagnetic wave reflects from the air-asphalt interface towards the antenna. It means that the antenna radiates to the ground. The antenna gain is shown in Tab. 2.



a) b)

Figure 2: Antenna model in HFSS: a) antenna, b) antenna with background materials

Parameter	Dimension
Patch diameter	40 mm
Substrate thickness	9.15 mm
Substrate relative permittivity	4.2
Substrate diameter	40 mm
Shorting pin diameter	2.6 mm
Pins position from the center	x_{ps1} = 13.5 mm, y_{ps1} = 2.5 mm x_{ps2} = 13.5 mm, y_{ps2} = –2.5 mm
Feed position from the center	x_p = 10.5 mm, y_p = 0 mm

Table 1: Antenna dimensions

Phi [deg]	GainTotal [dB]	
	Theta = -90deg	Theta = 90deg
0	0.181	-0.774
90	-1.231	-1.249

Table 2: Antenna gain (antenna is placed into the asphalt)

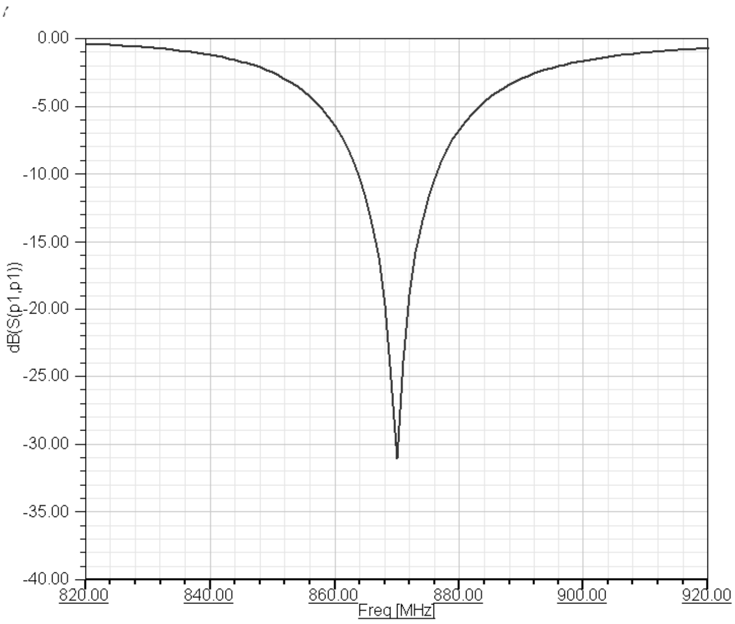


Figure 3: Return loss characteristics as a function of frequency (antenna is placed into the asphalt)

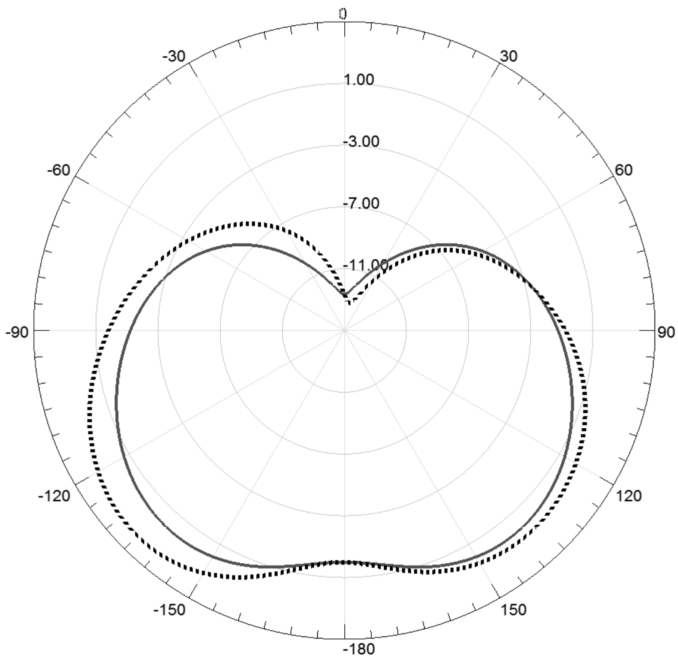


Figure 4: Radiation patterns (antenna is placed into the asphalt): phi = 0° (dashed line) and phi = 90° (GainTotal [dB])

In order to examine the antenna radiation patterns in more realistic conditions, the antenna is placed into the 200 mm deep vacuum hole. This situation is depicted in Fig. 5. The antenna dimensions are tuned such a way that the antenna resonates at the required frequency. The bandwidth remains almost equal. The antenna radiation characteristics are shown in Fig. 6. These characteristics clearly show that the antenna radiates even more into the ground. The antenna gain in the horizontal direction is given in Tab. 3.

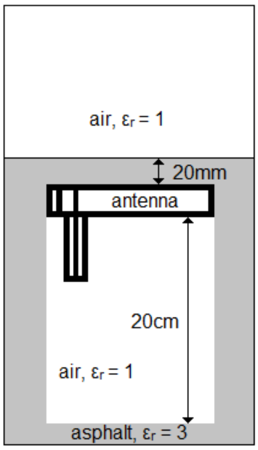


Figure 5: Antenna placed into the vacuum hole

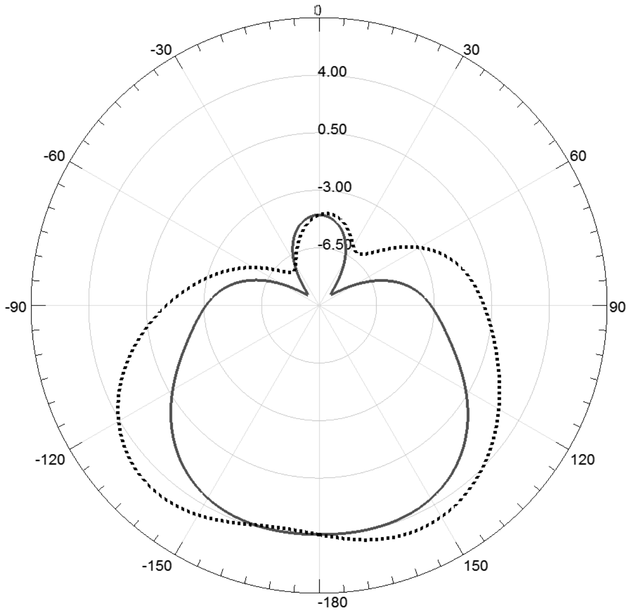


Figure 6: Radiation patterns for antenna placed in vacuum hole: phi = 0° (dashed line) and phi = 90° (GainTotal [dB])

Phi [deg]	GainTotal [dB]	
	Theta = -90deg	Theta = 90deg
0	-0.727	0.02
90	-2.963	-3.209

Table 3: Antenna gain (vacuum hole)

3. CONCLUSION

According to the radiation patterns, both antennas have low gain in the horizontal direction. This is caused by a very small ground plane of the antenna. It is necessary to investigate how to enhance the antenna gain in horizontal direction. In order to check whether the antenna gain is sufficient enough for the data transmission for the distance of 100 m, measurements in real conditions have to be performed. It is also important to thoroughly study the influence of weather conditions (snow, water on the road etc.) on antenna radiation. All these influences including the investigation how to enhance the antenna gain in horizontal direction will be the subject of further investigation.

ACKNOWLEDGEMENT

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REFERENCES

[1] WATERHOUSE, B. R., TARGONSKI, D. S., KOKOTOFF, M. D. Design and performance of small printed antennas. *IEEE Transactions on Antennas and Propagation*, 1998, vol. 46, no. 11, p. 1629–1633.

[2] PORATH, R. Theory of Miniaturized Shorting-Post Microstrip Antennas. *IEEE Transactions on Antennas and Propagation*, 2000, vol. 48, no. 1, 41-47.