**Vaclav RUZEK, Jiri DRINOVSKY, Jiri ZACHAR**

Brno University of Technology ,

# Novel probe position for WBFC measurement method

***Abstract**. PCB with mounted IC can produce wide spectrum of harmful signals. One of the way, how to measure this disturbance is WBFC measurement method. This paper deals with numerical simulation of this method, especially about geometrical orientation of the measurement probe, and its influence to the measurement results with same conditions. The effect of changed boundary conditions and comparison between simulation in free space and closed Faraday cage is also simulated there.*

***Streszczenie.** W artykule opisano zastosowanie metody WBFC (Workenbach Faraday Cage) do pomiaru zakłóceń wysokoczęstotliwościowych. (**Analiza pozycji sondy w metodzie WBFC do badań elektrokompatybilności**)*

**Keywords:** WBFC, Worbench Faraday Cage, EMC, EMI
**Słowa kluczowe:** klatka Faradaya, elektrokompatybilnosć.

## Introduction

All nowadays electronic equipment is exposed to many sources of electromagnetic disturbances. There are no differences between desired signals (useful for TV, radio and mobile devices), or disturbing signals (which could not be removed due to economically or realisation reasons), each of them can cause outage of useful function of the arrangement. In the other hand all electronic equipment can produce many harmful signals. One of the significant sources of disturbance is printed circuit boards (PCB) with mounted integrated circuits (IC).

The scale of this dangerous feature is given by amount of installed integrated circuits, its operational frequency, IC design and optimization from EMC point of view and PCB layout. There are many operative and scientific methods, how to measure disturbance caused by PCB let us say IC. One of the significant methods is Workbench Faraday Cage.

The standard WBFC measurement method primarily derives from EIC 61000-4-6. This method assumes that supply and signal cables are connected to electrically small PCB with dimensions x ≤ λ / 2, for example 0,15 m at 1000 MHz. The connected cables become the dominant antennas, so RF emission takes place via these antennas.

The connected cables are functions such as supply, data and other signal interfaces. These cables are usually not geometrically oriented in the same plane like the other cables. The common – mode impedance the of antenna has been normalised to 150 Ω with tolerances in the various frequency bands, see Table 1.

Table 1. WBFC field of aplication. [1]

| Frequency range | 0.15 to 26 MHz | 26 to 1000 MHz |
|---|---|---|
| Impedance | 150 Ω ± 20 Ω | 150 Ω +60 (-40) Ω |

## Workbench principle

Measurements used in original method EIC 61000-4-6 take place above a metalic reference plane. With common-mode impedances defined, relations between measured voltage and the RF emission can be approximed.

In case of Workbench method, a small Faraday cage is used. Generally, coupling and decoupling is similar to the EIC 61000-4-6, but this method implemented discrete resistors connected to the several common-mode ports of the PCB under test. The decoupling of supply and other input / output wires is performed via inductances built on ferite cores, representing impedances >> 150 Ω at the nominal frequencies. The feed-trough filters are installed trough the wall of the cage also. All set – up is presented in Fig. 1.

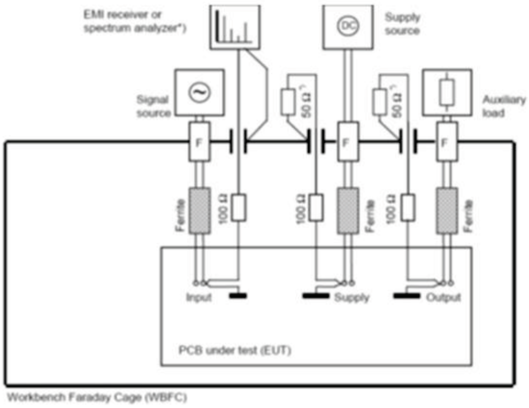

Fig. 1. Workbench Faraday cage measurement principle [1]

PCB under test is placed on the middle of the Faraday cage inner place; mounting height is set to 30 mm. Positions of the measurement or supply wires are not strictly defined, they are depending on design of terminals on the PCB. However, this work is focused on dependency between geometrical orientation of the probe (wire down, wire straight and wire straight with air gap).

## Calculation aspects

Simulations were done in a metal box without internal absorbers. According to the theory, we can expect resonancy inside the box. The metal box behaves like a Helmholz resonator which enables using simple formula for computing of the resonance frequency (1)

$$f_{res} = \frac{3.10e^8}{2} . \sqrt{\left(\frac{m}{x}\right)^2 + \left(\frac{n}{y}\right)^2 + \left(\frac{p}{z}\right)^2} \tag{1}$$

where: m,n,p – modes, x,y,z – resonator dimensions.

Table 2a. Computed resonant frequencies in the Faraday cage (standard dimensions).

| FARADAY CAGE 500 x 350 x 150 mm | | | |
|---|---|---|---|
| m | n | p | frequency [MHz] |
| 1 | 1 | 0 | 516,3 |
| 2 | 1 | 0 | 727,7 |
| 1 | 2 | 0 | 896,3 |

Computed frequencies are shown in Table 2a for cage with standard dimensions, or 2b for cage with non – standard, but frequently used dimensions. It is obvious, that the resonance frequency at the same modes grows up with decreasing dimensions of the cage, if changes of dimensions occur.

Table 2b. Computed resonant frequencies in the Faraday cage (different dimensions).

| FARADAY CAGE 450 x 300 x 160 mm | | | |
|---|---|---|---|
| m | n | p | frequency [MHz] |
| 1 | 1 | 0 | 593,0 |
| 2 | 1 | 0 | 822,5 |
| 1 | 2 | 0 | 1040,3 |

## Model and computation method

FDTD computing method is based on infomations about E and H field in the primary cell. Graphic user interface, developed at Aalborg university allows creating these primary cells in groups like wires, rectangles, blocks and etc. Computing model of tested PCB is created just from these parts. According to the smallest size of the primary cell are dimensions slightly modificated. Thickness of the PCB is 1mm (real FR4 has thickness 1.6 mm ), width of microstrips on the board is rounded also.

PCB under test has these dimensions: 150 x 100 x 1.6 mm. Base material is FR4 with both sides plated. There are 3 microstrips wires, each of them is supplied from generator over SMA connector mounted on the board and terminated by 50 Ω SMD resistor whitch is connected to the ground plane in the opposite side of the PCB. Ground plane covers all surface on bottom layer with exception of short interuption under wire number 3. Top layer with microstrip wires is shown at the (Fig. 2).

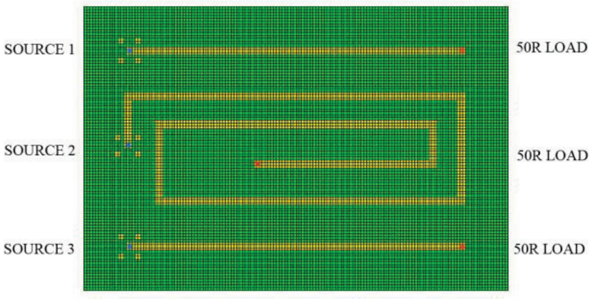

Fig. 2. PCB under virtual test layout[2].

Generally, we use 4 places for virtual measurements but with different orientation of the coaxial wire (Fig. 3).

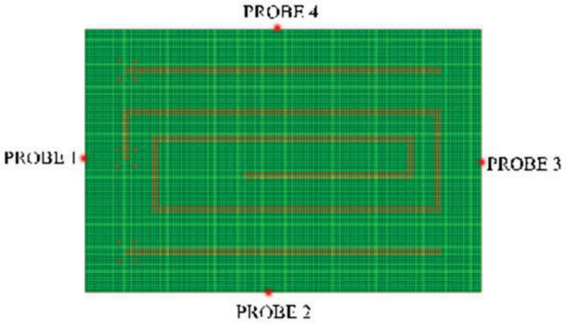

Fig. 3. Measurement probes lay-out [2].

Measurements for simulation purposes are ensured by virtual electric field probes connected serially with 50 Ω and 100 Ω resistors.

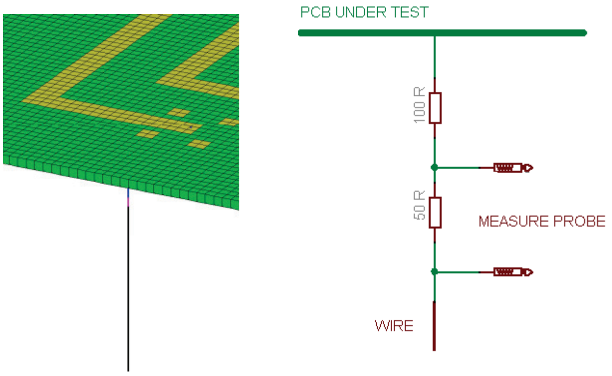

Fig. 4. Measurement probe connection method. Left figure shows substitution diagram, right shows connection in simulation[2].

Experimental simulations were prepared for 3 alternative connections of the probe:

1) wire down,
2) wire straight,
3) wire straight with air gap.

Detail explanation to all types of connection is given on beginning of next chapter. We can assume, that geometrical orientation of the probe can not affect measured magnitudes significatly. Basic boundary conditions are invariable for all simulations – model of closed Faraday cage is used. Virtual boards are placed 30 mm above the floor plate of the Cage.

## Simulation setup

### Wiredown

This connection method is the nearest to method mentioned in standards. The measurement probe and couple of resistors are connected to bottom layer of the PCB, how was described in previous chapter. The end of wire is directly connected to the bottom wall of the Cage. See (Fig.5) bellow.

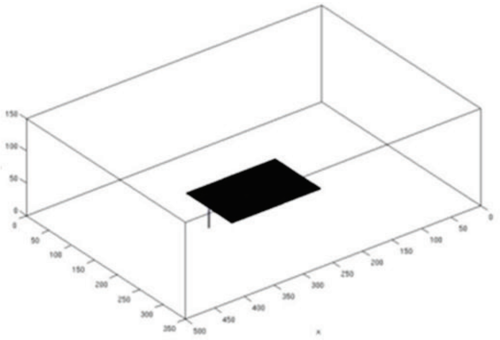

Fig. 5. Wire down simulation setup

Simulations have been done for all sources: we have got a results from probes 1, 2, 3, 4. Traces for all probes are in one figure, each figure shows results for single source. The most interesting is curve of coupled power $P_{OUT}/P_{IN}[dB]$. Frequency range is set between 30 MHz and 1000 MHz. We can expect resonancies at computed frequencies: 593 and 822 MHz. (see Tab.1)

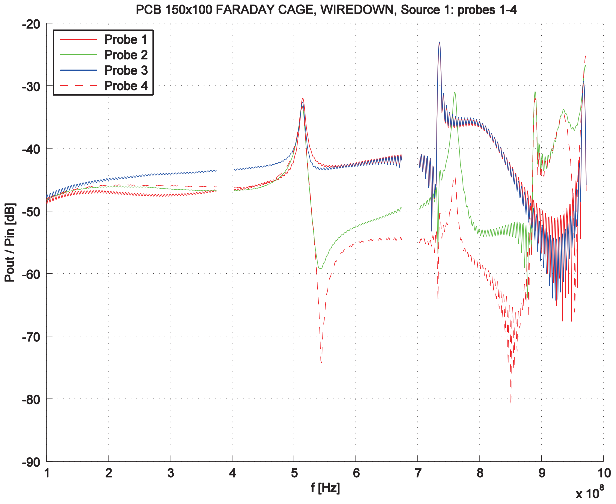

Fig. 6. Influence of probe position to harmful signal strength - source 1.

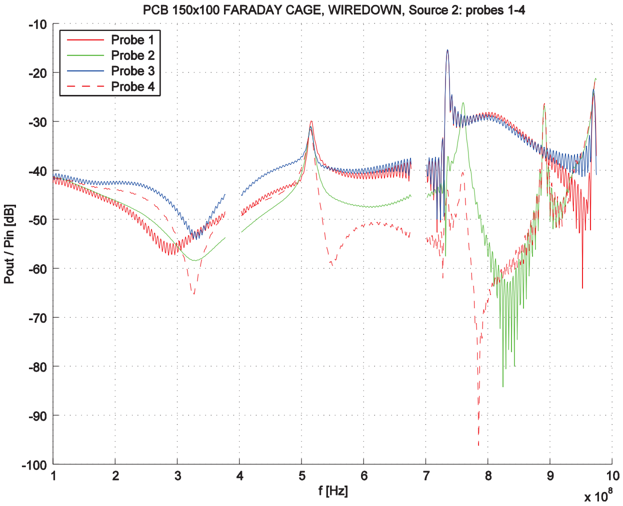

Fig. 7. Influence of probe position to harmful signal strength - source 2.

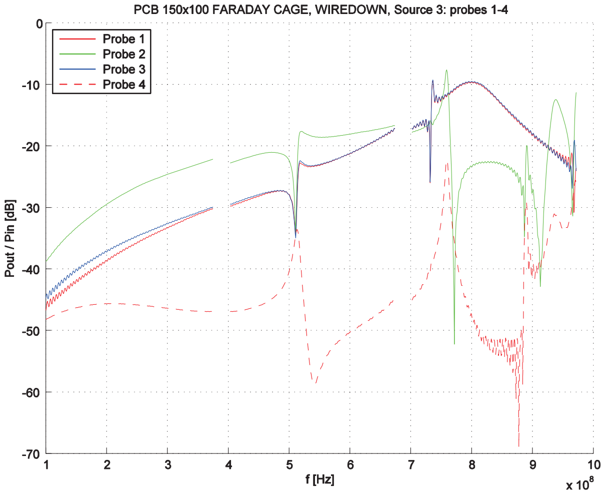

Fig. 8. Influence of probe position to harmful signal strength- source 3.

## Wire straight

This connection method is diferent especially in length of wire and connection point, unlike previous method. The end of wire is directly connected to the side wall of the cage.

The measurement probe and couple of resistors are connected to bottom layer of the PCB, as well as previuous type of the simulation. This situation is shown in Fig. 9.

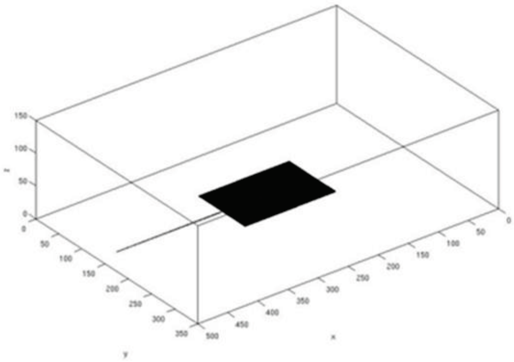

Fig. 9. Wire straight simulation setup

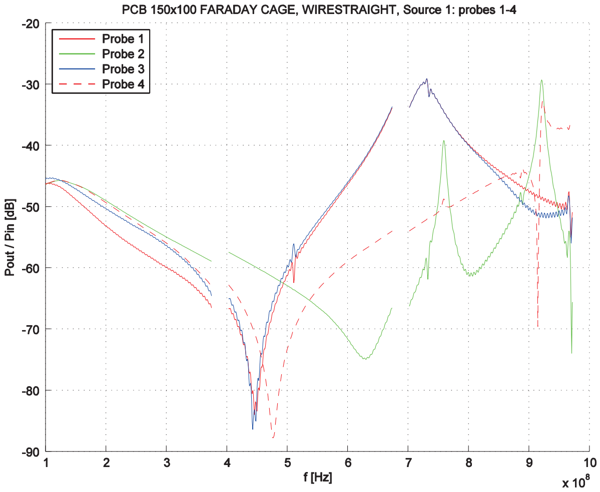

Fig. 10. Influence of probe position to harmful signal strength - source 1

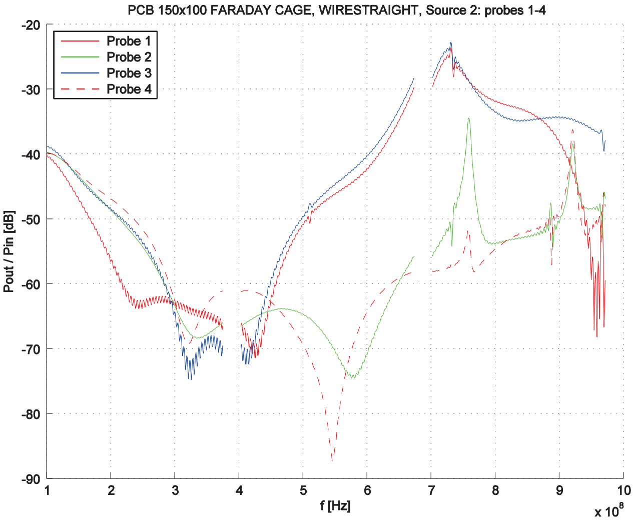

Fig. 11. Influence of probe position to harmful signal strength - source 2

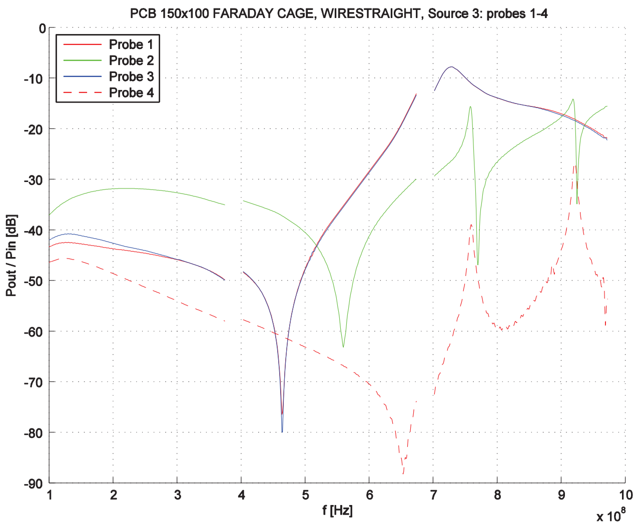

Fig. 12. Influence of probe position to harmful signal strength - source 3

### Wire straight – air gap

This connection method is completely experimental. The end of the wire with resistors and measurement probe is not is directly connected to the PCB. There is an air gap, 1 cell sized. The wire is directly connected to side wall of the faraday cage at the opposite end. See (Fig. 13) bellow.

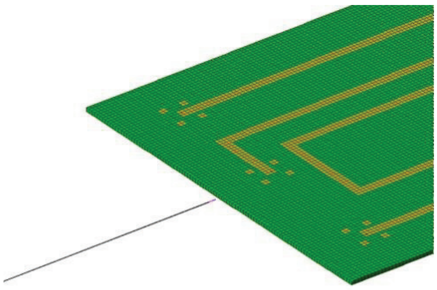

Fig. 13. Wire straight - air gap simulation setup

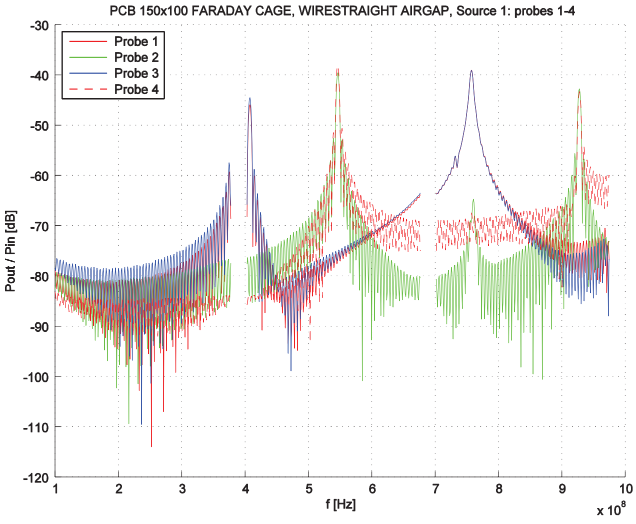

Fig. 14. Influence of probe position to harmful signal strength - source 1

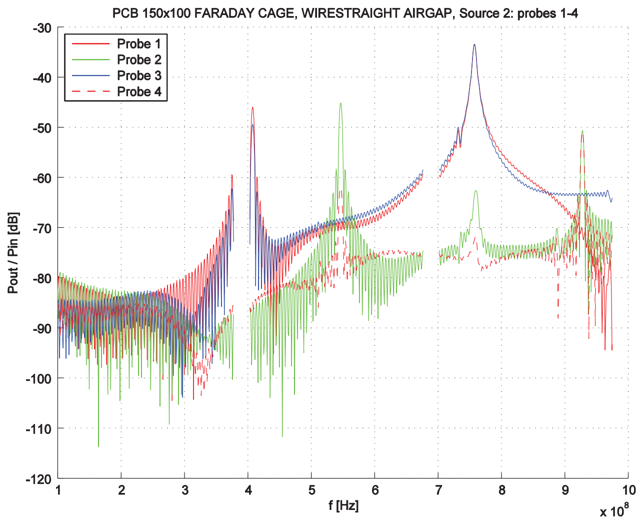

Fig. 15. Influence of probe position to harmful signal strength - source 2

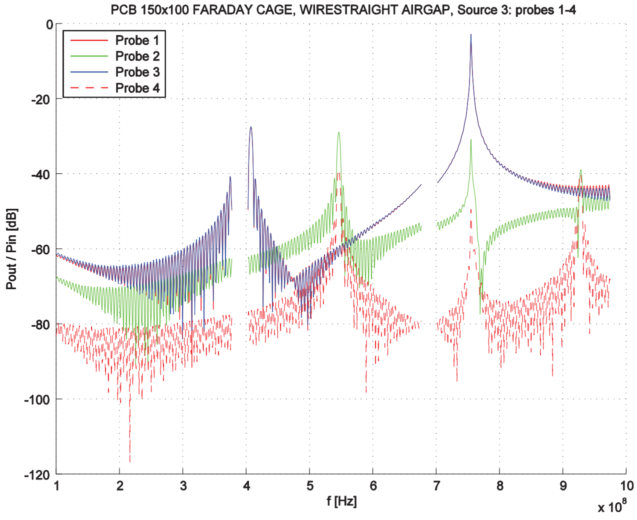

Fig. 16. Influence of probe position to harmful signal strength - source 3

### Conclusion

The optimal geometrically position of the experimental measurement probe for the Workbench Faraday Cage method is explored in this paper. 3 sources of harmful signal were independently measured by 4 variously placed virtual probes.

Simulations in the Faraday cage showing resonant frequencies (Tab.1) according to formula (1). The traces for sources 1 and 2 are very similar and especially up to 500 MHz have a non fluctuating character. There is an agreement among all probes up to the second resonance frequency.

The curve for source 3 is not so similar to the others and we can see big distinctions among single probes. Probe 4 has a much lower course and resonances are manifested in the opposite way than other curves.

From the results, it is evident that probes placed on the axis of the measured trace can extend reciprocal results due to linear trace.

The completely different traces between wire down and wire straight traces were find out. The changes of impedance parameters are the main source of difference, as we supposed. Experiment with unconnected probe (wire straight with air gap) shows non-conductive way of coupling clearly. But trace for all probes are quite linear (except resonation peaks) and could be used for next experiments.

Generally, we can say, that probe orientation could affect the results of measurement using WBFC measurement method significantly. Each company should set its own standard for this method for probes (cables) tracing especially. The reproducibility could not be preserved without clear rule set by internal standard.

## Acknowledgement

*This paper has been prepared as the part of the solution of the grant no. 102/09/P215 "Advanced EMI filters Insertion Loss Performance Analyses in System with Uncertain Impedance Termination" of the Czech Science Foundation and grant No. 102/09/P215, by the Czech Ministry of Education by the research program MSM 0021630513 and specific research project FEKT-S-11-13 Innovative approaches for designing systems of communication chain.*

## REFERENCES

[1] EIC 61967-5:2003: Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 5: Measurement of conducted emissions – Workbench Faraday Cage method, Apr. 2003. IEC organization.

[2] RŮŽEK, V.; DŘÍNOVSKÝ, J.; KEJÍK, Z.; ZACHAR, J. Influence of the Probe Position to Disturbance Measurement in the Workbench Faraday Cage. In *Proceedings of 21st International Conference Radioelektronika 2011.* BUT, 2011. s. 251-254. ISBN: 978-1-61284-322- 3.

[3] WILLIAMS, T. , *EMC for Product Designers*, (2nd Edition), Newnes, Oxford, 1996

[4] SVAČINA, J., *Electromagnetic Compatibility, electronic textbook*, Brno, Brno University of Technology, Faculty of electrical engineering and communication, Jan. 2004.

[5] CISPR 16-4-2: Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modeling – Uncertainty in EMC measurement, Nov. 2003

---

***Authors**: Ing. Vaclav Ruzek, Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Radio Electronics. Purkynova 118, 612 00 Brno, Czech Republic. E-mail: xruzek00@stud.feec.vutbr.cz.*

*Ing. Jiri Drinovsky, Ph.D., Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Radio Electronics. Purkynova 118, 612 00 Brno, Czech Republic. E-mail: drino@feec.vutbr.cz.*

*Ing. Jiri Zachar, Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Radio Electronics. Purkynova 118, 612 00 Brno, Czech Republic. E-mail: xzacha00@stud.feec.vutbr.cz.*