Electrical Properties Optimization of Stripline for EMC Testing of Automotive Parts

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Abstract – **This paper is focused on optimization of electrical properties of 50 ohm stripline which was described in international standard for the automotive industry ISO 11452-5. The standard shows the dimension of the stripline but information about impedance matching is missing – and this information is crucial for a power amplifier connection, especially in terms of VSWR parameter. In this paper connection possibilities between stripline feeders and an input / output coaxial connector are shown, simulations results describe dependencies of the VSWR to the dimensions and shapes of the stripline feeder in the point of connection to the connector.**

Keywords-EMC; simulation; stripline; automotive; electromagnetic susceptibility; ISO 11452; VSWR

I. INTRODUCTION

In this time, all electronics devices should comply with the electromagnetic compatibility (EMC) standards. The automotive industry is not excluded from standardization, but there are some differences to the industry or residential standards. These differences are caused by different topologies of individual parts in a car, especially in terms of cable harnesses – at the one point in a car all wires are placed – from communication buses to the power lines and the length of the parallel wires could be relatively long. Of course, between long parallel wires occurred interference. The electronic devices, which are connected to the harness, must comply with electromagnetic susceptibility (EMS) tests. These tests are designed to detect a possible undesirable behavior of electronic devices. The result of the EMS test is performance criterion which describes the behavior of the device under the test.

EMS tests for automotive components are defined in the international standard ISO 11452 which is composed of several parts. The first part ISO 11452-1 defines general principles and terminology [1]. Each subsequent part describes one test procedure; the part five (ISO 11452-5) is focused on testing by using stripline [2].

The area of using stripline is relatively wide – except automotive components testing [3-5] striplines are used for spread spectrum of tests in consumer electronics (audio-video products) [6], RF immunity of integrated circuits and small electronic devices [7-10], measurement of radiated emission [11] or gain measurement of miniaturized antenna [12].

II. ISO 11452-5

The frequency range for stripline testing is from 150 kHz to 400 MHz with unmodulated sine wave or sine wave amplitude is modulated by 1 kHz sine wave at 80 % [1].

Stripline is used for generating an electromagnetic field, where a relatively high intensity of the electromagnetic field is able to produce due to conventional generating by a radiation from an antenna (assuming the same value of an output power from an amplifier). The intensity of the electric field is given by equation [2]:

$$|E| = \frac{\sqrt{P \times Z}}{h} \text{ [V/m]}, \tag{1}$$

where P represents the input power to the stripline in watts, Z is characteristic impedance of the stripline in ohms and h is the height of the active conductor above a ground plane in meters.

The characteristic impedance of the stripline with larger width of the active conductor b than height h is:

$$Z = \frac{120\pi}{\frac{b}{h} + 2.42 - 0.44 \cdot \frac{b}{h} + \left(1 - \frac{b}{h}\right)^6} \text{ [}\Omega\text{]}. \tag{2}$$

The standard [2] describes two types of the stripline; 50 Ω and 90 Ω. Most RF power amplifiers have a 50 Ω output – for this reason is better use the 50 Ω stripline, when there is not necessary to connect impedance matching unit from 90 Ω to 50 Ω.

III. 50 Ω STRIPLINE ACCORDING TO ISO 11452-5

The dimensions of the 50 Ω stripline are shown in Figure 1.

N-type connectors are usually used for connections between the stripline and the RF power amplifier on the input side or there is a load at the output side. Connection of the load is the simplest way how to

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match the output – on the market is a lot of 50 Ω loads with a sufficient dissipation power. Ideally, the characteristic impedance of the stripline on the input (or output) connector is equals to 50 Ω.

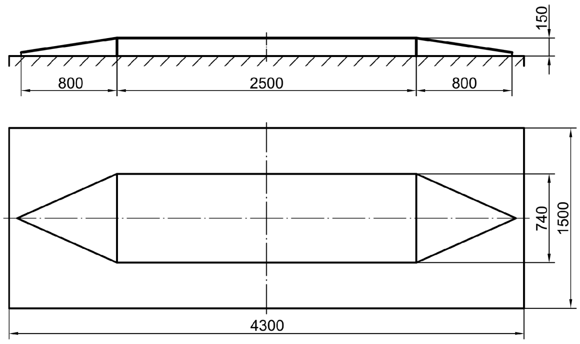


Figure 1. Dimensions of the stripline according to ISO 11452-5

The important parameter of the stripline is impedance matching in the input port – S11 parameter and transmission between input and output – S21 parameter. The voltage standing wave ratio VSWR is derived from S11:

$$\mathrm{VSWR} = \frac{1+|\mathrm{S11}|}{1-|\mathrm{S11}|}\ [-], \tag{3}$$

where $|S_{11}|$ represents the magnitude of S_{11}.

IV. NUMERICAL SIMULATIONS

The 50 Ω stripline was used for illustrative example in this paper. All simulations were performed in CST Microwave Studio 2015.

The dimension of the simulated model corresponds with Figure 1, but there were altered three types of connections between the active conductor and the connector – see Figure 2. The active and the ground conductor were approximated by aluminum sheets with thickness of 1 mm, the model contains two N-type connectors for connection to the RF amplifier by a coaxial cable and 50 Ω load. In the term of a mechanical durability, four galvanized hex bolts were used for connectors mounting to the ground plane.

The first connection is shown in Figure 2.a). There is the feeder directly soldered to the inner conductor of the connector. The second connection (Figure 2.b)) represents a square pad, where the inner conductor of the connector is soldered to the center of the pad. Figure 2.c) shows the last shape selected for the simulation, where the edges of the pad are rounded.

The impedance matching in the input connector S11 (S22 respectively) and the transmission between input and output connectors S21 (S12) were simulated for all models. Especially S11 parameter or VSWR (3) is crucial for real-world RF amplifier, where the reflection power from the unmatched stripline could cause the damage on the output of the amplifier. For this reason, simulations of dependencies of S11 to the shapes and different parameters were calculated.

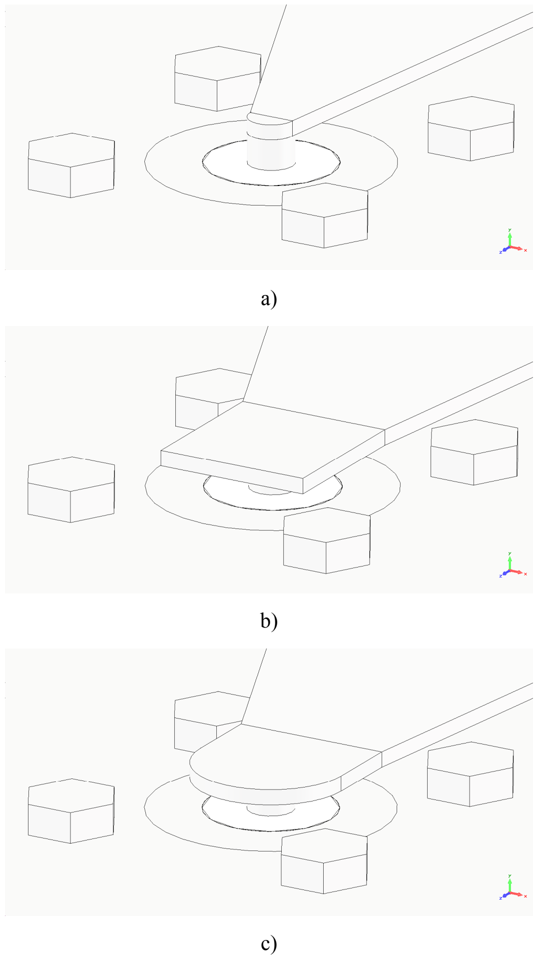
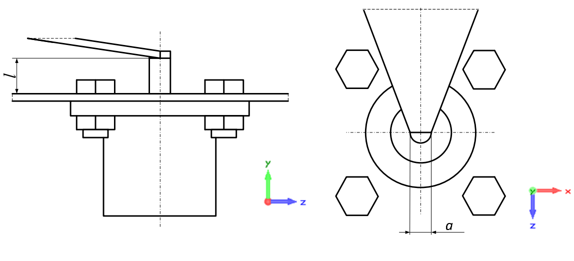


Figure 2. 3D views of connection of feeders to connectors. a) connection 1 (C1 in the following text), b) connection 2 (C2), c) connection 3 (C3)

For the optimization of electrical properties were selected following parameters:

- Height of the inner conductor of the N connector *l* (for the all three shapes C1 – C3, Figure 3 a)).
- Edge length *a* for the feeders for C1 from Figure 2 a) (Figure 3 b)).
- Edge length *b* for the feeders with square pads (C2) from Figure 2 b), (Figure 4 a)).
- Edge length *b* and radius *R* for the feeders with rounded edge pads (C3) from Figure 2 c), (Figure 4 b)).



a) b)

Figure 3. Dimension of the feeders connection / pads to the connector

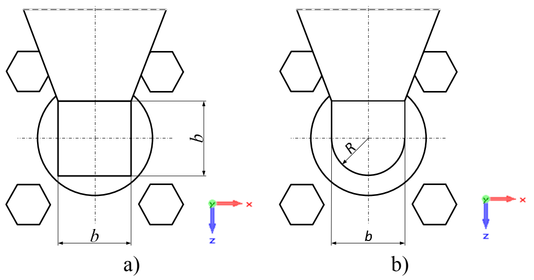


Figure 4. Dimension of the feeders connection / pads to the connector

All simulated parameters and values for simulations are shown in Table I.

TABLE I. SIMULATED PARAMETERS VALUES

Connection	Parameter	Dimension [mm]		
		From	To	Step
C1	*l*	2	10	1
	a	3	33	5
C2	*l*	2	10	1
	b	3	10	1
C3	*l*	2	10	1
	b	3	10	1
	2R	3	10	1

V. SIMULATIONS RESULTS

All simulations were performed in the frequency range from 150 kHz to 400 MHz according to ISO 11451-1. In the simulation, S11 and S21 parameters were calculated in the Time solver. There are shown just the most important results that could be important for construction of the stripline.

A. Connection 1

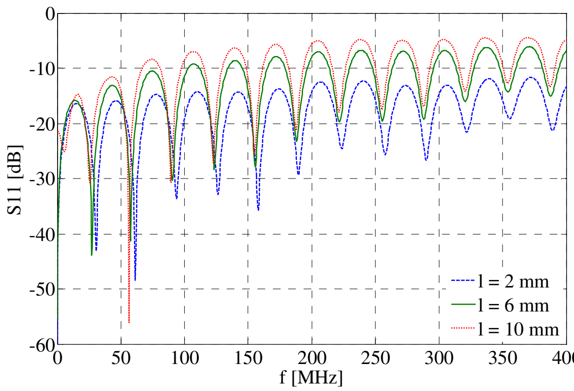


Figure 5. Connection 1: Dependence of S11 on the parameter *l*; *a* = 3 mm

Figure 5 represents the dependence of S11 on the length *l* of the connection between the active conductor and the connector, the dimension of the feeder by the connector is constant *a* = 3 mm. From the results, the best S11 is for the length *l* = 2 mm and it is increasing with the length and the frequency. For example, the difference of S11 is 0.38 dB at 16.81 MHz between the length *l* = 2 mm and *l* = 10 mm (the most favorable and the worst result). The difference at 371.6 MHz is already 7.17 dB.

Figure 6 shows the same result, but the S11 is transformed to the VSWR parameter by the equation (3). This view is probably preferable in term of parameters of the RF high power amplifier, where is preferred VSWR. In this figure the difference is better visible, the VSWR at 371.6 MHz equals to 1.707 for the length *l* = 2 mm and VSWR = 3.968 for *l* = 10 mm.

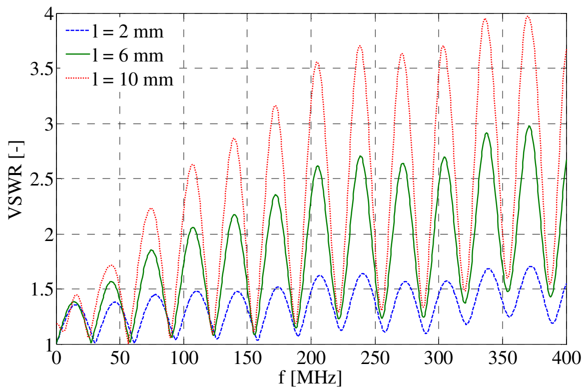


Figure 6. Connection 1: Dependence of VSWR on the parameter *l*; a = 3 mm

The dependences of the S21 parameter (transition from the input the output of the stripline) on the length *l* are shown in Figure 7. S21 represents the attenuation of the signal; the highest value (S21 = –5.65 dB) can be found at the frequency 371.6 MHz for the length l = 10 mm. For a comparison, the S21 is –3.14 dB for the length l = 2 mm, which represents almost a half attenuation at the same frequency.

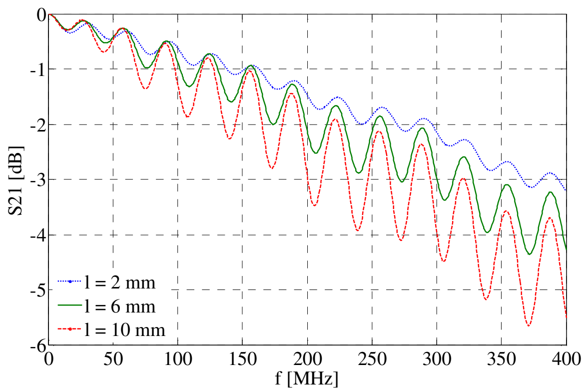


Figure 7. Connection 1: Dependence of S21 on the parameter *l*; *a* = 3 mm

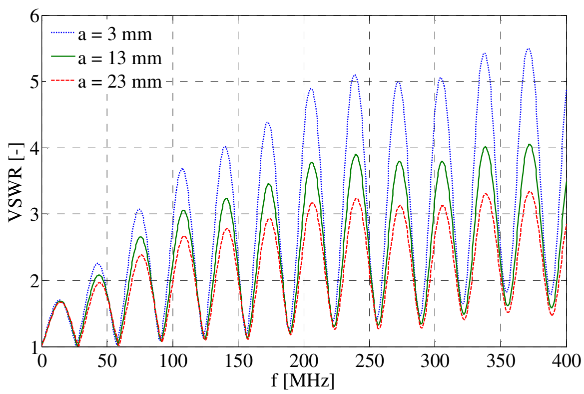


Figure 8. Connection 1: Dependence of VSWR on the parameter *a; l* = 2 mm

Figure 8 shows dependencies of VSWR on length *a* that represents a width of the feeder at the point of the connection to the connector.

B. Connection 2

The simulation result of the connection C2 (Figure 3b), 4a)) is very similar to the result of the connection C3 (Figure 3c), 4b)). Please see the next paragraph.

C. Connection 3

In these simulations the length and the roundness radius of the feeders pad were changed. The results are shown in Figure 9. There the dimension of the pad significantly influences the S11 in the whole frequency range.

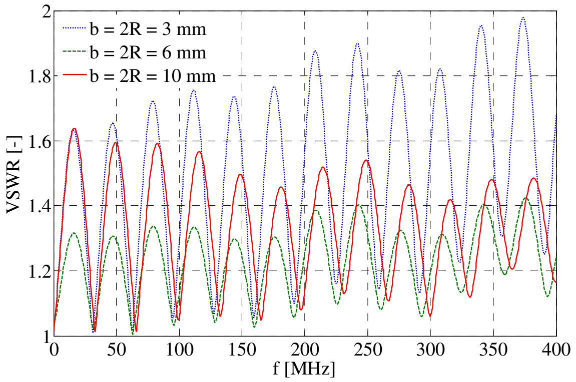


Figure 9. Connection 3: Dependence of VSWR on the parameter *b* and *R (b = 2R); l =* 2 mm

D. Connection comparison

The comparison of the simulation results for all three connections is presented in Figure 10. The dimension was set to $a = b = 2R = 2$ mm and $l = 2$ mm. There is a visible negligible difference between results.

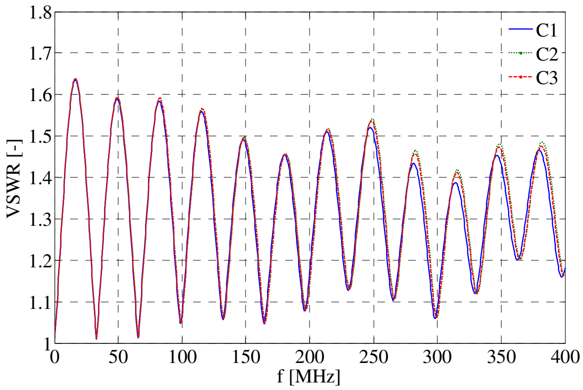


Figure 10. Dependence of VSWR on the connection C1 – C3; *a = b = 2R =10 mm, l = 2 mm*

VI. Conclusion

In this paper optimization results of the 50 Ω stripline for electromagnetic susceptibility testing (EMS) of automotive components according to ISO 11452-5 were presented.

The simulation outputs of the three connections of the feeder to the input and output N-type connectors show the most important results for the stripline design, for example the shape of the feeder pad do not influence the S11 (or VSWR), but the connection length between the active conductor and the connector or the dimension of the pad significantly influences the S11.

The future research will be focused on the design and the realization of the stripline, which will be used for testing in the ETL laboratory [13].

Acknowledgment

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