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Inner filled constructive material effect on shielding effectiveness of screened electronics in resonance mode

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Abstract. In this paper, the results of an investigation of the resonance regime of shielding of cylindrical conducting enclosure as unmanned aerial vehicle hull model with an inner filling of common constructive components are presented. Calculations of the hull shielding effectiveness so as the induced currents in the inner placed transmission line were done in FEKO on the basis of the confirmed accuracy of the simulation. It was found that the increasing the level of the hull inner filling would result in a shift of the shielding effectiveness resonances to lower frequencies. The difference between the shielding effectiveness of the hollow hull and 90%-filled can be of 50-100 dB.

1. Introduction

The resonance process of UAV conducting hull can cause both in the uprising of electromagnetic (EM) field penetration through UAV hull and an increase of the induced currents in the inner signal circuits [1,2]. It is therefore of interest to predict the reaction of UAV to EM impact in the resonance regime. The actual UAV consists of the variety of electronics including onboard flight management systems, radio receivers and transmitters, functional systems for monitoring etc. that can be susceptible to microwave EM exposure. The inner filled constructive materials (device housing, supporting frame) will result in a redistribution of the penetrated EM field within the hull. EM fields inside the filled and the hollow hull can differ significantly. Thus, it is of concern to investigate how the level of hull filling will effect on its shielding properties in the resonant regime.

The problem of the resonance determination in the shielding enclosure (e.g., box) with metal filling like boards, plates in EM field irradiation (microwaves) has widely been considered in literature (e.g. [3,4]). The purpose of this study is to determine the effect of UAV hull filling consisting of cylindrical metal blocks on its shielding effectiveness (SE) and the induced currents in two-wire transmission line placed inside the hull. On the basis of the high accuracy of FEKO simulation confirmed by the results of the pattern experiments the hull SE and the induced current will be investigated.

The paper is organized as follows. In section II, the results of the pattern experiments so as the brief functionality of FEKO simulation tool are outlined. In section III, the description of UAV hull model with filling for calculating SE and the induced currents in the two-wire transmission line is presented. In section IV, the results of FEKO simulation so as the analysis and discussion are given. The conclusions are in section V.

2. Results of pattern experiments

It was demonstrated in [1] that the measured SE of UAV hull model within the frequency range 100-1000 MHz agrees with FEKO simulation accurately. In addition, FEKO is capable of simulating the currents induced in the ohmic loads of the electric circuits [5]. In order to verify this simulation process the pattern experiment of the induced currents in two-wire transmission line under microwave irradiation was conducted. The measurement setup is shown in figure 1.

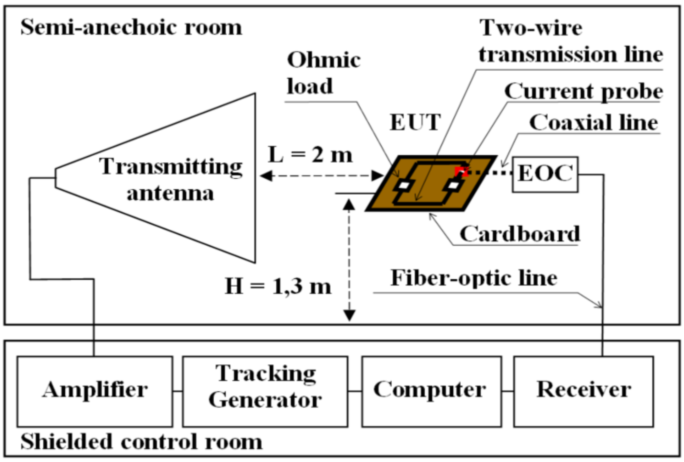

Figure 1. The measurement setup.

The equipment under test (EUT) was two-wire transmission line made of two unshielded one-core wires 0.35 mm^2 connected with two ohmic loads (r = 1 Ohm, R - variable) placed on the dielectric basement (cardboard). The wires were stretched out at full length (200 mm) and separated in parallel at 35 mm. The equipment typical for the measurement of the induced currents in microwave irradiation including the transmitting antenna, a current probe placed in the vicinity of the load, coaxial line, electrical-optical converter (EOC), fiber-optic line, receiver, computer, tracking generator and amplifier are also shown in figure 1. The results of the experiments and simulation are presented in figure 2. The analysis indicates that the measured data are consistent with the simulation within the frequency range 100-1000 MHz with high accuracy.

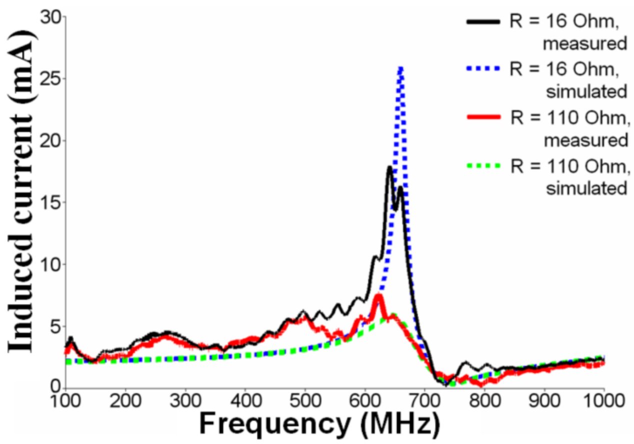

Figure 2. The measured and simulated induced currents in the two-wire transmission line for R = 16 Ohm and 110 Ohm.

Based on high reliability of FEKO simulation of the pattern UAV hull SE and the currents induced in two-wire transmission line it is adequate to simulate these parameters for new untested objects with

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similar constructive parameters in considered frequency range. In addition, it is sufficient to study in detail UAV hull inner filled constructive materials effect on SE and the induced currents in the two-wire transmission line using FEKO.

3. Simulation of hull with filling

UAV hull model was a hollow metallic cylinder with a height d = 632 mm, radius ρ = 171 mm. The through hole of radius ρhole = 10 mm was located on the underside end face (see figure 3). The thickness of the cylinder walls was 1 mm. The volume inside the cylinder was modeled as air medium.

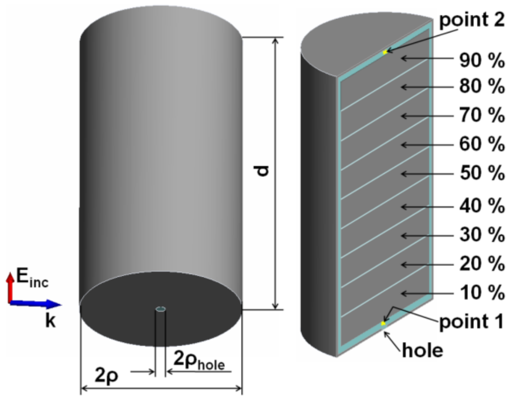

Figure 3. UAV hull model (left) and the view of the cut with filling (right).

The filling was a solid cylindrical block made of metal with a radius 160 mm and a variable height. It was situated coaxial with the hull main cylindrical axis (see figure 3 right). The height of the block was chosen so that the certain space inside the hull was occupied. For example, when modeling a 10% filling of the entire internal volume of the hull the block height was approximately 67 mm, 20% - 2×67 mm, 30% - 3×67 mm etc. The plane electromagnetic wave of 100-1000 MHz frequency range was incident on the hull with the electric intensity vector E_{inc} parallel to the hull axis (see figure 3 left). The shielding effectiveness in the form SE = 20 lg (E_{inc}/E_{point}) was calculated at two points on the axes of the hull. Point 1 and point 2 were put at a distance of 15 mm from the inner surface of the ends on the bottom and the top of the hull, respectively. Point 1 was located, thus, closer to the hole, and point 2 was further from it.

The investigation of the induced currents was provided by adding two-wire transmission line modeled as the rectangular line of a length l = 230 mm and a separation 20 mm to the previous geometry (see figure 4).

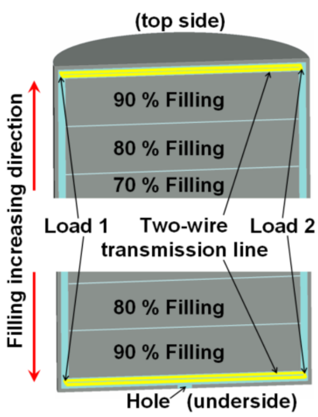

Figure 4. The model of two-wire transmission line inside the hull with different level of filling.

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The line was placed in series in two planes with point 1 and point 2 parallel to the end faces of the cylindrical hull. The ports with ohmic loads R_{Load1} = 1 Ohm and R_{Load2} = 100 Ohm were placed in the middle of the narrow sides of the rectangular line. The induced currents in the ports ILoad1 and ILoad2 were calculated and presented for convenience as reduced to the incident electric intensity in the form $I_{reduced} = 20 \lg [(I_{Load} \cdot Z)/(E_{inc} \cdot l)]$, where Z = 377 Ohm is the wave impedance. The increasing of the filling level was modeled from the top down for the line on the underside (in the point 1 plane). On the contrary, the filling increasing direction for the line on the top side (in the point 2 plane) was modeled from the bottom up (see figure 4).

4. Results

The results of the simulation of the hull with different level of filling are shown in figures 5-7.

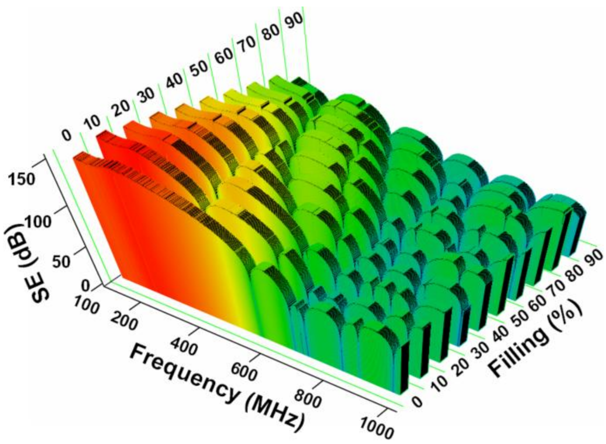

Figure 5. The 3-D bar plot of the simulated SE of the hull with different level of filling in point 2.

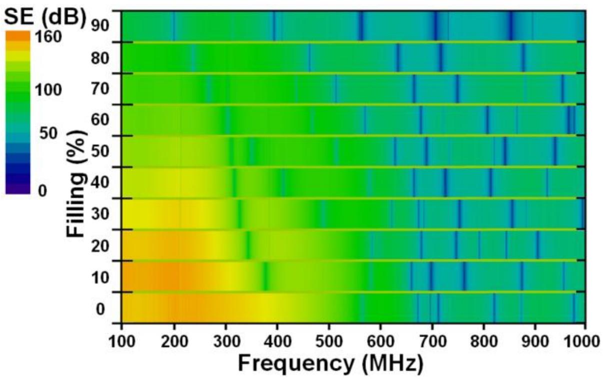

Figure 6. The contour plot of the simulated SE of the hull with various level of filling in point 2.

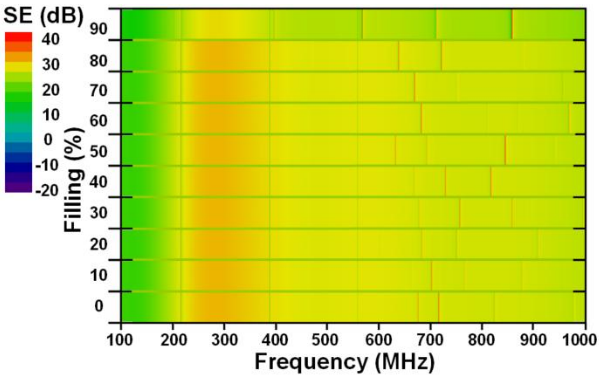

Figure 7. The contour plot of the simulated SE of the hull with different level of filling in point 1.

It follows from the data in figures 5 and 6 that the sequential increasing of the filling level from 0% to 90% will result in shifting the first SE resonance minimum to a lower frequency range for point 2. When the space inside the hull is decreasing EM field will be forced out to free air medium so the higher EM intensity in left space will be produced. Increasing the level of the filling will result in SE decreasing from 50-100 dB to 0 dB at one certain frequency. SE in point 1 will not change significantly if the filling level is increasing (see figure 7). It can be explained by the proximity of the hole that is constant reradiating antenna inside the hull so the resonance modes cannot be adequately excited in its vicinity.

The results of the simulation of the induced currents in two-wire transmission line placed on the top side and underside of the hull with different level of filling are shown in figure 8.

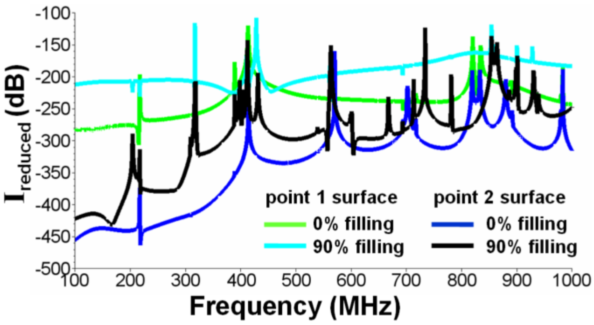

Figure 8. The simulated reduced current in 1 Ohm load of two-wire transmission line placed inside the hull with different filling level.

It is evident from figure 8 that the filling increasing will result in the rising of the currents induced in loads of the wire. By analogy with SE resonance minimum the currents maximum will be shifted to the lower frequency range. The currents maximum at 90% hull filling can be 50-100 dB greater than ones for the hollow hull (0% filling). Furthermore, when comparing two lines it is significant that the proximity to the hole produces the currents in the underside line to be on average higher than ones in the top side line. However, it can be seen that above 500 MHz the currents induced in the top side line placed far from the hole can exceed ones in the underside line at resonance peaks.

5. Conclusions

In this paper, the results of an investigation of the shielding effectiveness of cylindrical conducting enclosure as UAV hull model with an inner filling of typical constructive components like devices housing, supporting frame at the beginning of the resonance regime have been presented. On the basis of the high accuracy of FEKO simulation the hull SE and the induced currents in transmission line placed inside the hull were studied. It was found that SE minimum so as the current maximum induced in a two-wire transmission line would be shifted to the lower frequency range if increasing the level of the hull filling. SE difference between the hollow hull (0% filling) and 90% hull metal filling can be of 50-100 dB. The difference of about 100 dB will be for the currents induced in the inner placed line. The induced currents in the line and EM intensity within the vicinity of the hole inside the hull can on average be higher than ones in the far from the hole where resonance modes will effectively be excited. However, at resonance peaks the currents induced in the line placed far from the hole can exceed ones in the line close to the hole.

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