Investigating the SAR due to the Rectangular Power-Bus Structure's Impedance and Orientations

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***Abstract*— This paper conducts a study on the effect of the radiated emission from a rectangular Power-Bus Structure(PBS) on the human head in terms of the specific absorption rate(SAR) . Though numerical, the experiment with a standard head-phantom enlightens us on how the emanating fields due to the PBS affect depending upon the PBS impedance VS frequency and orientations relative to the human head.**

Key words: Power-Bus Structure, SAR, Head phantom.

I. INTRODUCTION

The Printed Circuit Board(PCB) in electronic equipment consists of multiple layers to which the Power-Bus Structure(PBS) belongs. The PBS's metal planes play the ground and the DC-voltage supplying medium, respectively. Simultaneously, they will cause electric noise due to the geometrical resonance and unstable grounding at certain frequencies. So it is crucial to know and predict the occurrence of the resonance of the PBS from the stand point of the impedance or electromagnetic fields.

Regarding the characterization of the PBS, research activities have been carried out to find out the impedance behavior and radiated fields of the geometry for years[1]-[7]. In particular, references [1]-[6] elaborated the cause of the highest values of the PBS impedance in relation to the resonance modes and suggested the ways to lower the impedance using the surface loading or differential signals. Reference [7] linked the radiated emission to the resonance frequencies of the PBS. However, there has been no open literature that deals with the PBS's radiation effect on the human body.

In this paper, we investigate the influence of the radiated field due to the rectangular PBS on the human head replaced by a head phantom in terms of the SAR. In more detail, assuming the PBS as part of a wireless device, the head phantom is exposed in the near-field for the standard SAR estimation with a variety of the PBS's orientations. Besides, we compare the SAR values between the PBS with and without slot loadings which introduce the change in the impedance levels for the resonance modes of interest here.

II. PBS IMPEDANCE AND RESONANCE

A. Impedance of the reference PBS

In the first place, we are supposed to get the impedance profile of the reference rectangular PBS which is illustrated in the following figure where the upper and lower rectangular metal plates have the FR4 substrate right in between and the two plates are connected by a metal wire at a corner corresponding to the coordinates' origin, which provides the electric signal.

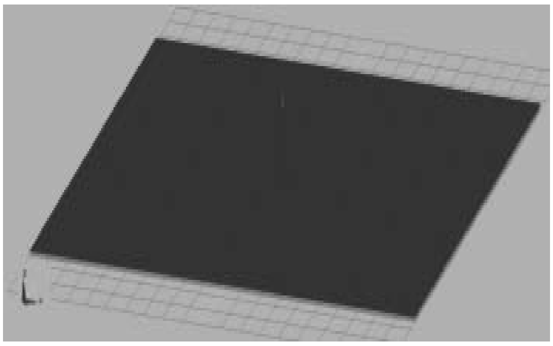


Fig. 1 Rectangular PBS as the reference geometry

In Fig. 1, each plane is 250 mm by 200 mm and the substrate is 1.5 mm thick. The FDTD solver SEMCAD is used to compute the impedance profile, though the modal analysis solver of our own making is available, since the presently adopted tool is handy enough to provide the SAR estimation in one frame of calculation. As a result of the computational work, the following impedance profile is obtained.

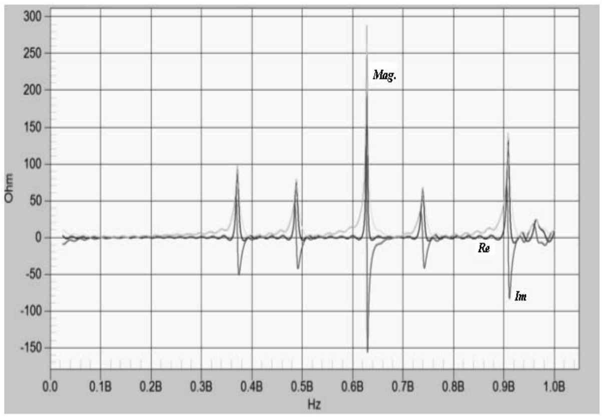


Fig. 2 Impedance(Re, Im, and Mag) of the reference PBS

Fig. 2 has three curves that are blue, red, and green meaning the real part, imaginary part and magnitude of the impedance, respectively. Later we will take a closer look at the first two resonance modes around 100 ΩdB for which we will consider the radiated fields. However, the far-zone field at the first resonance mode will be given in the next section. And then we will move on to the field in the near-zone for the SAR computation.

B. Radiation field in the far-field

There goes one thing that always be checked about the radiated field level for the resonance frequency that shows the local peak in the impedance. It is the Radiated Emission(RE) in accordance with the resonance mode. This is different from the SAR in that the RE is measured or predicted as the far-zone concept.

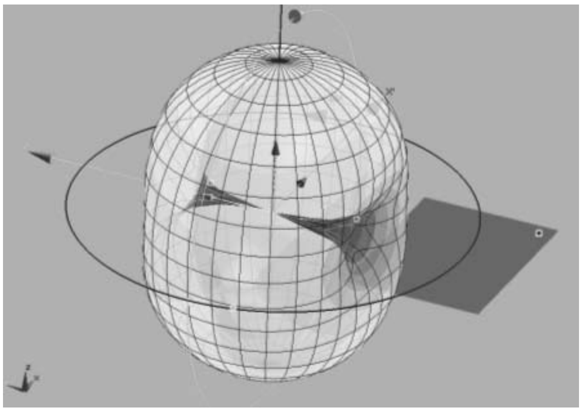


Fig. 3 Far-field from the reference PBS at the first resonance mode.

The 3D-far-field is computed for 370 MHz and presents the PBS will be a radiator such as an antenna that is not intended.

III. Estimating the SAR due to the PBS

In this section, we discuss the near-zone field's effect of the PBS. Especially, instead of evaluating just the field in the near zone air, we would like to focus on the interaction between the human head and the electromagnetic field due to the PBS's resonance mode. The following head-phantom is substituted for the real human head.

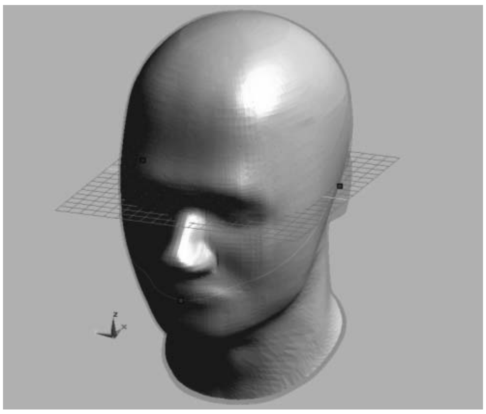
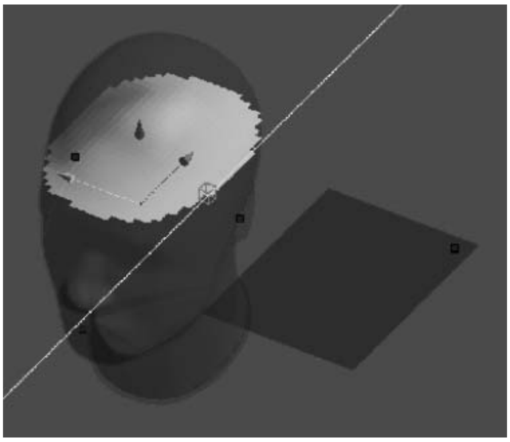


Fig. 4 Head-phantom to check the SAR due to the PBS

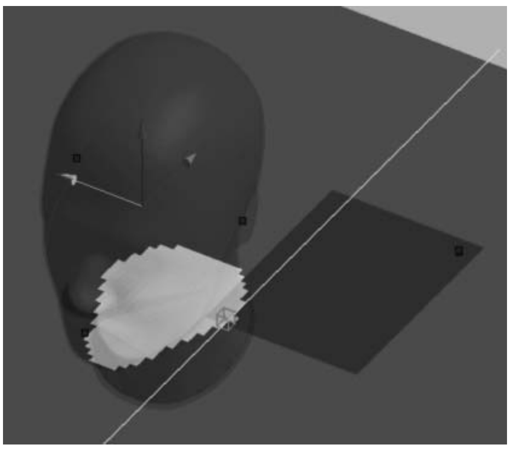
The head phantom consists of a dielectric shell and a filling liquid. The dielectric shell has relative permittivity of 3.7 and relative permeability of 1. The liquid is given 41.5 and 0.97 as the relative permittivity and electrical conductivity in order. Their frequency dependence is ignored. The volume of the head model is around 164 mm by 164 mm by 300 mm. As far as the SAR is concerned about the hand-held set, the surface of the device is usually attached on the head. However, in our test, we will not be so strict about the distance as recommended the standard SAR measurement. Instead, the PBS as the radiation source will be placed approximately 15 mm away from the nearby surface of the human phantom. Along with these settings for the simulations, four cases of orientations, say, 'horizontal broad side', 'horizontal narrow side', 'vertical broadside' and 'vertical narrow side' will be taken into consideration. For each orientation, the first two resonance modes(370 MHz and 480 MHz) will be dealt with..

A. Horizontal broadside case(cases 1.1 and 1.2)

This case specifies the orientation such that the PBS planes lie on the transverse plane(namely, xy-plane) and one broadside of the PBS is parallel with the sides of the head phantom.



(a) SAR at a near-zone due to the PBS at the first resonance mode



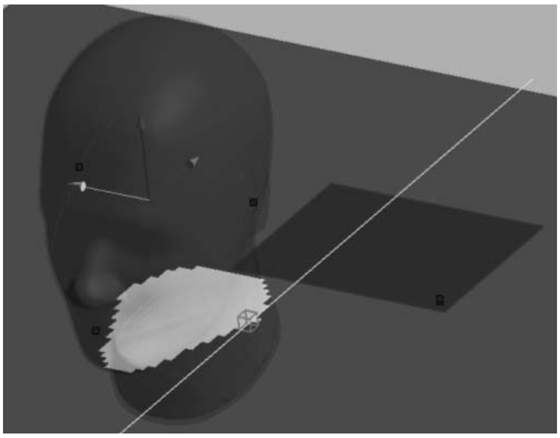
(b) SAR at a near-zone due to the PBS at the second resonance mode

Fig. 5 Near-field distribution(including the SAR & hot-spot) due to the PBS with horizontal broadside orientation at the first two resonance modes

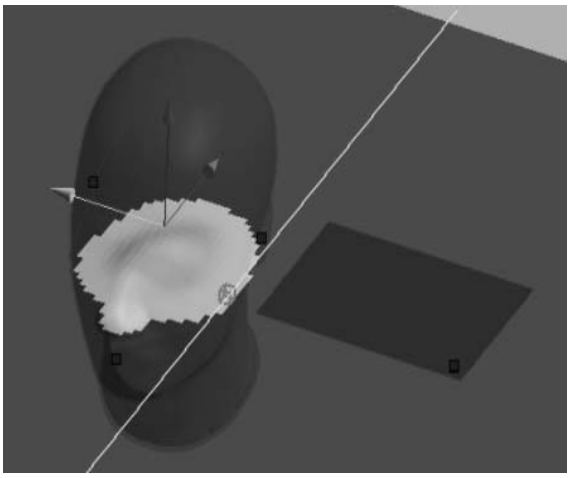
Fig. 5 shows the near-electric-field distribution on the horizontal layer of the head model which includes the highest intensity and its related SAR. Particularly, Fig. 5(a) presents the hot spot created on the forehead-cut at 370 MHz(case 1.1). On the other hand, when the near-zone electric field is investigated throughout the head phantom with the frequency of 480 MHz(case 1.2), the chin-cut plane is observed to have the hottest spot. Different resonant frequencies mean the geometrical difference between the field behaviors.

B. Horizontal narrow side case(cases 2.1 and 2.2)

This case has the PBS orientation described as the metal planes lie on the transverse plane(namely, xy-plane) and one narrow side of the PBS is parallel with the sides of the head phantom.



(a) SAR at a near-zone due to the PBS at the first resonance mode



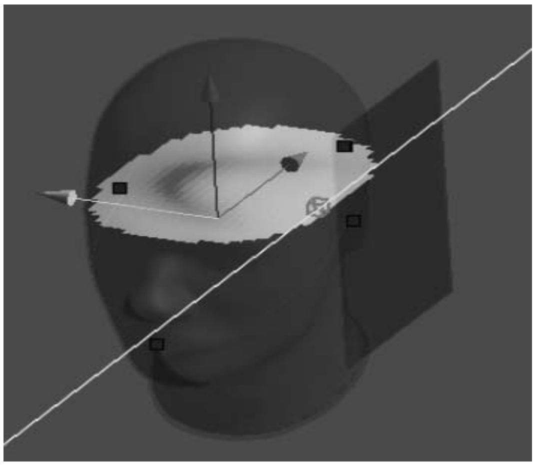
(b) SAR at a near-zone due to the PBS at the second resonance mode

Fig. 6 Near-field distribution(including the SAR & hot-spot) due to the PBS with horizontal narrow side orientation at the first two resonance modes

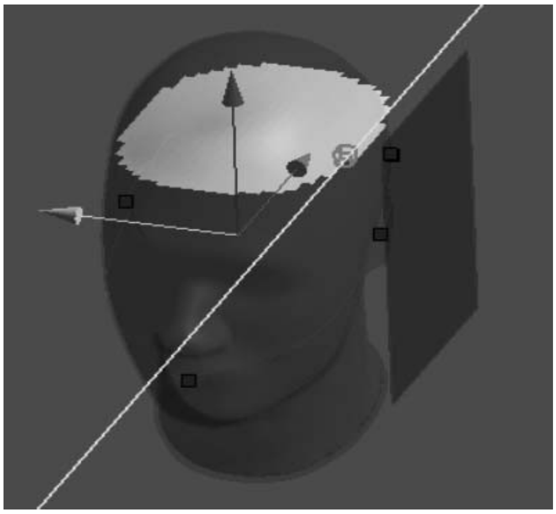
In Fig. 6, the near-electric-field distribution on the horizontal layer of the head model is shown to include the highest intensity and its related SAR. Most of all, Fig. 6(a) presents the hot spot created on the chin-cut at 370 MHz(case 2.1). On the contrary, when the near-zone electric field is investigated throughout the head phantom with the frequency of 480 MHz(case 2.2), the eye-cut plane is observed to have the hottest spot. Both cases of experiments imply that the high field is widespread over the layers and the area closest to the immediate side of the PBS has the hottest spot except that in case 2.2 the field seems to be influenced by the head's pseuso-cavity resonance.

C. Vertical broadside case(cases 3.1 and 3.2)

This particular case designates the orientation such that the PBS planes lie on a z-directed plane(namely, xz-plane) and one broadside of the PBS is parallel with the z-axis.



(a) SAR at a near-zone due to the PBS at the first resonance mode



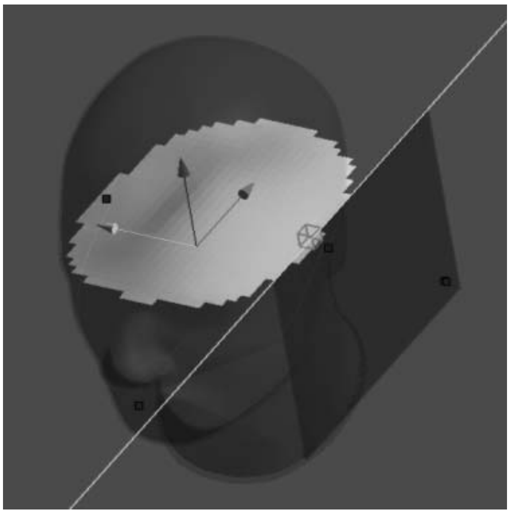
(b) SAR at a near-zone due to the PBS at the second resonance mode

Fig. 7 Near-field distribution(including the SAR & hot-spot) due to the PBS with vertical broadside orientation at the first two resonance modes

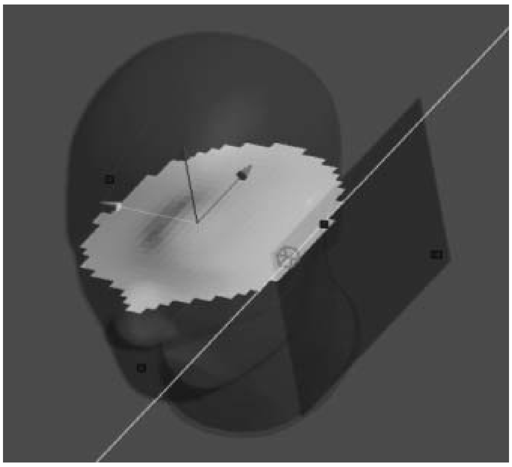
Fig. 7 gives us the near-electric-field distribution on the horizontal layer of the head model which includes the highest intensity and its related SAR. Particularly, Fig. 7(a) presents the hot spot created on the eye-above-cut at 370 MHz(case 3.1). In this plot, similar to Fig. 6(b), the field distribution seems to be correlated with the head's pseudo-cavity resonance. On the other hand, when the near-zone electric field is investigated throughout the head phantom with the frequency of 480 MHz(case 3.2), the forehead-cut plane is observed to have the hottest spot.

D. Vertical narrow side case(cases 4.1 and 4.2)

This particular case sets the orientation such that the PBS planes lie on a z-directed plane(namely, xz-plane) and the narrow sides of the PBS coincide with the z-axis.



(a) SAR at a near-zone due to the PBS at the first resonance mode



(b) SAR at a near-zone due to the PBS at the second resonance mode
Fig. 8 Near-field distribution(including the SAR & hot-spot) due to the PBS with vertical narrow side orientation at the first two resonance modes

Fig. 8 (a) presents the hot spot created on the forehead-below-cut at 370 MHz(case 4.1).In this simulation, in the vicinity of the PBS, the field is strong, and farther from the left ear, the field is getting weaker. On the other hand, when the near-zone electric field is investigated on the eye-cut of the head phantom with the frequency of 480 MHz(case 4.2), similar to Fig. 6(b), the field distribution seems to be correlated with the head's pseudo-cavity resonance.

IV. Conclusion

In this paper, we examined the field distributions with the hottest spots in the near zone from the PBS at the resonance frequencies where the impedance profile has local peaks. The experiment was carried out with numerous orientations of the PBS and giving the information how far and with what direction the PBS should be placed from the head phantom..

Acknowledgments

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