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125 kHz Magnetic Field Attenuation Characteristics in Some of the Homogeneous Human Organs

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1. Introduction

Current capsular endoscopes use tiny battery cells, and these batteries have limited power supplying capability. The capsule transmits pictures to the outside world generally at the speed of 2 frames/sec. If we generate high frequency, and high magnetic field intensity inside the human body and if the capsule in the human body has magnetic coils to induce the electromotive force (emf) to generate DC power after rectification and regulation, the capsule with enough DC power can transmit the pictures faster than 5 frames/sec, which would allow the examining doctors to feel more convenient and to diagnose more accurately.

The high frequency current is driven along the coils wound on the vest of the patient for magnetic field excitation in the chest and abdomen. This technology also renders the capsule to do active operation in the intestinal organ and to do compound functions with sufficient DC power in the human body. The magnetic field to induce the emf by the coils inside the capsule should be of high frequency to give more power generation by electromagnetic induction law.

But if the field frequency is higher than about 100 kHz, it is known that the thermal absorption gets started in the human body [1], which would obviously be an energy loss factor. Below 100 kHz range, the known dominant effect by the induced current in the body is not thermal but nerve stimulation effect.

We calculated the magnetic field attenuation in the simulating homogeneous human organs at 125 kHz to check if we have to lower the magnetic field frequency to avoid thermal effect or if we can move the operating frequency to a higher band for better efficiency of power generation in the human body.

2. Computation of Magnetic Field Intensity in the Isotropic Human body

The capsule for endoscope is swallowed in the mouth, and goes through the esophagus, stomach, small intestine, and colon, and eventually it is excreted out of the anus. The magnetic field inside the human body should be calculated with a fine human model at the computation field frequency. We used a commercial simulation tool (Ansoft HFSS) for computation and that tool does not provide the whole human body model yet. Instead we surveyed the relative permittivity and conductivity of each important human organ at the computation frequency. In Table 1 the relative permittivities and conductivities of the important organs in the human body at 125 kHz are shown [2][3]. All of the organs in Table 1 are supposed to be non-magnetic materials. We calculated the magnetic field in the vacuum first for reference and calculated the H-field in the two homogeneous organs with extreme permittivity or conductivity in Table 1. The magnetic field is generated by one turn rectangular current loop of 240 mm × 300 mm laid on z = 0 plane in Figure 1. The simulating conducting source wire is 10 mm × 10 mm squared shape, and 1 Ampere peak current of 125 kHz flows along the wire.

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Table 1. Some dielectric constants and conductivities of human organs at 125 kHz.

Organ	Relative Permittivity	Conductivity [S/m]
Esophagus	2,710	0.537
Stomach	2,710	0.537
Wet Skin	13,117	0.080
Muscle	7,550	0.367
Small Intestine	13,030	0.600
Colon	3,518	0.249
Cerebral Spinal Fluid (CSF)	109	2.0

The geometry of the homogeneous organ is a rectangular parallelepiped 180 mm × 240 mm× 180 mm in Figure 1 for reasonably simulating the abdomen of the male adult. The volume of the computation box surrounded by perfect magnetic conductors is 1,440 mm × 1,800 mm × 1,080 mm.

The calculated H-fields in the homogenous organs were compared with the reference value in the vacuum.

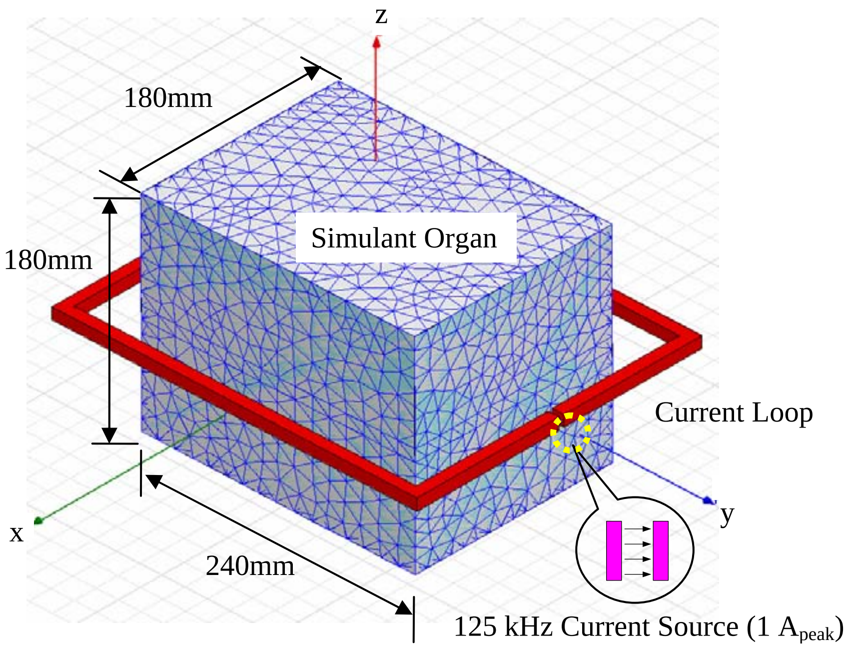

Figure 1. Computation geometry with a current source, a current loop, and a homogeneous tissue inside.

The H-field intensity in vacuum along y-axis is shown in Figure 2. The minimum value is 3.268 A/m at the origin point. This value is about the same as the analytic one. The magnitude of H in vacuum along z-axis is also shown in Figure 3 from the bottom organ plane to the top organ plane of Figure 1. The H-fields in wet skin or in CSF were computed to be mostly the same as the values at the corresponding points in the vacuum. The field curves of both the organs are not shown here because of the coincidences with Figure 2 or Figure 3.

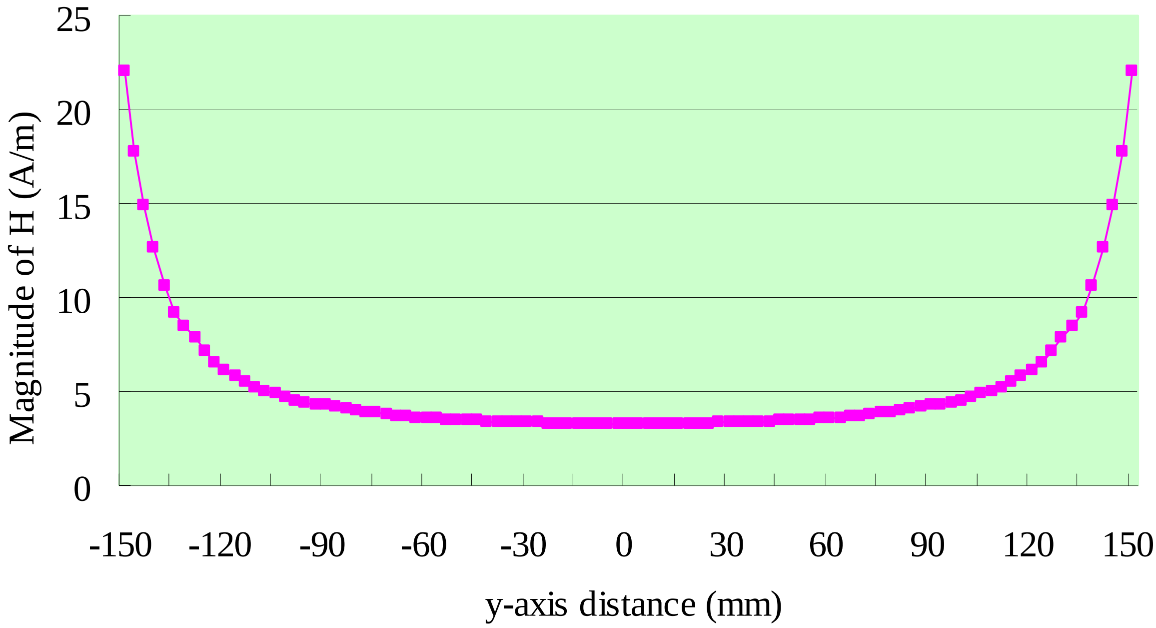

Figure 2 . H-field intensity variation in vacuum along y-axis of Figure 1.

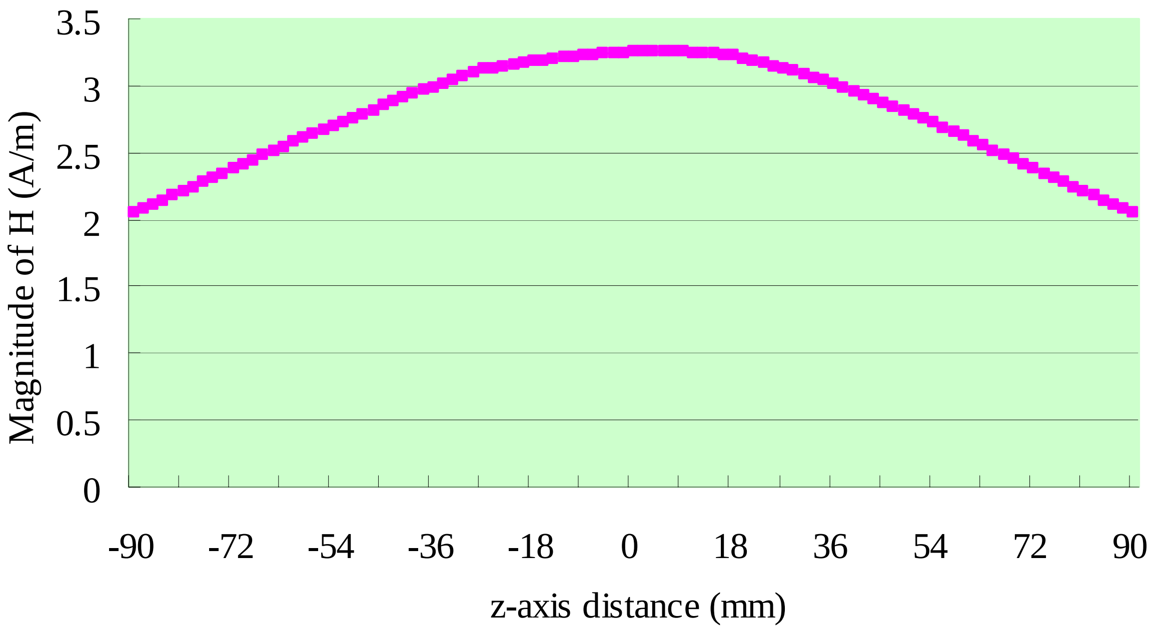

Figure 3. H-field intensity variation in vacuum along z-axis of Figure 1.

3. Conclusion

The magnetic fields in vacuum, wet skin, and CSF were excited by a 125 kHz unit current source of a single turn rectangular current loop surrounding the homogenous rectangular parallelepiped organs. The computed H-fields in the simulant organs showed extremely small differences ($< 10^{-3}$) from the field in the vacuum, which means 125 kHz magnetic field gives very little thermal effect in the organs of human. So we can use a higher frequency than 125 kHz for more efficient electric power generation of the electric devices in the human body.

Acknowledgments

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