Reduction of Absorption Power in Human Head near Cellular Phone with Director

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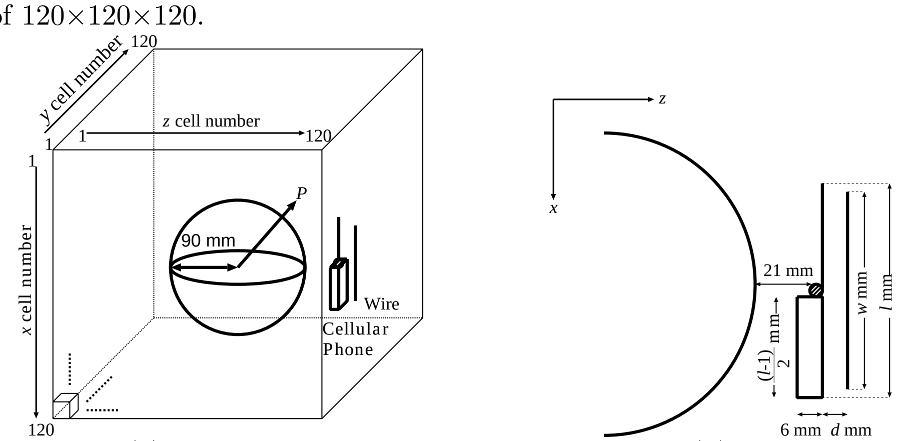
1 Introduction

Since the science and technology has advanced rapidly, a lot of devices generating the electromagnetic field are widespread to our environment. Especially, compact and convenient cellular phones have been remarkably popularized, and they have been already indispensable in our life. Human health hazard from a cellular phone and the reduction of radiation efficiency is, however, concerned because it is used in the vicinity of human head.

Recently, the designing of a directional antenna[1][2], and the method arranging a magnetic material plate near the feeding point[3] have been reported as a technique improved radiation efficiency. Tay[2] has reported that the director has no effect to the improvement of radiation efficiency in the frequency of 900 MHz. This study investigates the reduction of absorption power when a metallic wire is placed outside of the transmission device as a director.

2 Analysis Model and Antenna Configuration

Fig. 1 shows analysis model and antenna configuration in this study. A human head is approximated to a spherical model. Calculation space in FDTD analysis is composed using cubic cell of 120×120×120.



(a) calculation space (b) xz plane

Fig. 1: Analysis model and antenna configuration

The calculation conditions are shown as follows.

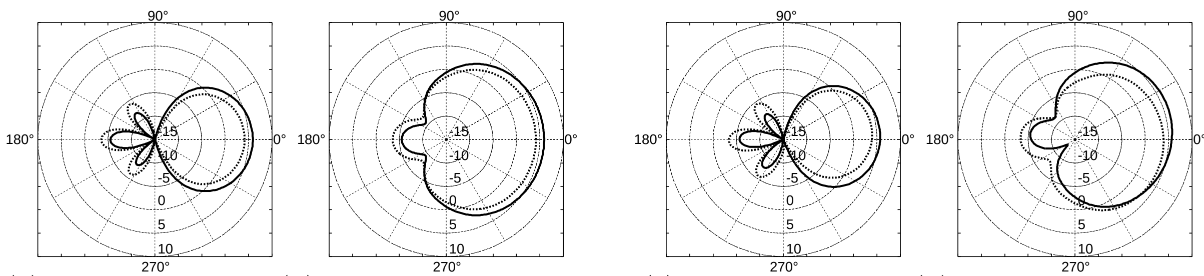
- Frequency is 1.5 GHz (and 900 MHz).
- Two types transmitters, a half-wavelength dipole and a cellular phone model, are used.
- The cell size of main grid is 3 mm. Subgrid with cell size of 1 mm is partially used for transmitter and wire.
- Radius of a spherical model is 90 mm, and the distance between surface of sphere and the feed point of transmitter is 21 mm(constant).
- Conductivity σ and permittivity ε_r of a spherical model are 0.82 S/m and 36.58, respectively, at 1.5 GHz. (σ = 0.65 S/m and ε_r = 37.30 at 900 MHz.)
- The length of transmitters l is 99 mm at 1.5 GHz (and 165 mm at 900 MHz). The length of metallic wire is 3 types, that is, $l-6$ mm, $l-4$ mm, and $l-2$ mm. The separation between transmitter and metallic wire d is from 1 mm to 12 mm in steps of 1 mm.

- Transmitter components and metallic wire are perfect conductor.
- The length of body of cellular phone model is $(l-1)/2$ mm, the thickness is 6 mm, and the width is 24 mm.

3 Results

3.1 Radiation Pattern

Fig. 2 shows radiation patterns. The axis of a radius direction denotes the radiation gain in dB unit. From the center, it is -15, -10, -5, 0, +5, +10 dB. Fig. 2(a) and (b) are vertical pattern and horizontal one, respectively, of a half-wavelength dipole. Fig. 2(c) and (d) are radiation patterns of cellular phone model. Solid line and dotted line is that with metallic wire and without wire, respectively. Fig. 2 is calculated under the condition that the length of the wire l is 95 mm (0.48λ), the separation d between transmitter and wire is 6 mm in the frequency of 1.5 GHz.



(a) dipole – vertical (b) dipole – horizontal (c) phone – vertical (d) phone – horizontal

Fig. 2: Radiation pattern

According to Fig. 2, radiation power is reduced at $\theta = 180°$(the side of sphere model) and increased at $\theta = 0°$(the one of metallic wire). In Figs. 2(a) and (b), concretely, electric field is reduced by 1.95 dB at $\theta = 180°$, and increased by 1.76 dB at $\theta = 0°$. Figs. 2(c) and (d), it is reduced by 2.28 dB at $\theta = 180°$, and increased by 1.75 dB at $\theta = 0°$. Comparing (a)(b) and (c)(d), respectively, (c) and (d) are unsymmetric because of the shape of cellular phone model.

3.2 Specific Absorption Rate

Table 1 shows each SAR in the case of metallic wire is added to transmitter, or not added. Table 1 shows each reduction rate of each SAR also. The unit is W/kg, and it is assumed that input power is 1.0 W. The length of the wire l is 95 mm(0.48λ), the separation d between transmitter and wire is 6 mm in the frequency of 1.5 GHz.

Table 1: SAR and reduction rate for each transmitter

SAR	half-wavelength dipole		reduction rate	cellular phone model		reduction rate
	no wire	with wire		no wire	with wire	
peak SAR	7.93	1.44	1/5.51	8.24	2.70	1/3.05
1g average SAR	6.62	1.07	1/6.19	6.91	2.11	1/3.27
10g average SAR	4.59	0.64	1/7.17	4.84	1.29	1/3.75
average SAR	0.12	0.03	1/4.00	0.13	0.04	1/3.25

According to Table 1, reducion rate of half-wavelength dipole is about 1/6, cellular phone model about 1/3 on the whole. Comparing two reducion rates, they have a few difference due to the shape of cellular phone model. The almost same results are obtained about average SAR and its reduction rate.

3.3 Antenna Impedance

Though the reduction effect is obtained by adding a metallic wire to transmitter, antenna impedance changes significantly. Table 2 shows their characteristics. The length of the wire l is 95 mm(0.48λ), the separation d between transmitter and wire is 6 mm in the frequency of 1.5 GHz.

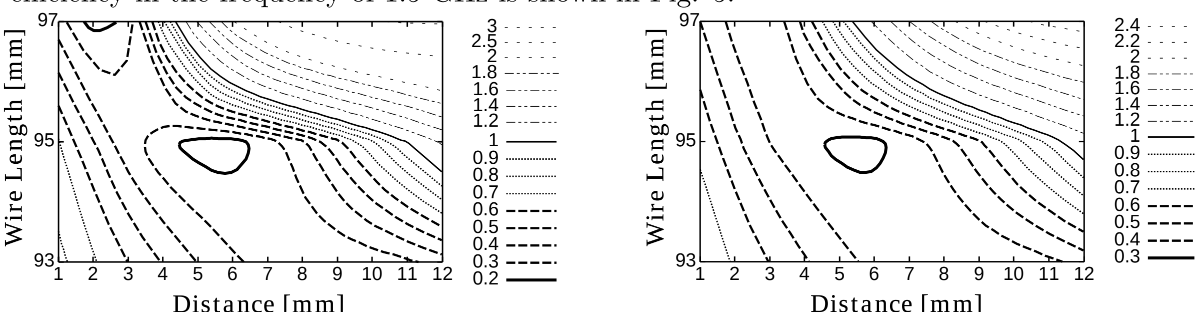
Table 2 shows that impedance added metallic wire to transmitter becomes less than 1/10, comparing to one not added. Also, separation d between transmitter and metallic wire is proportional to antenna impedance. It is necessary to investigate the problem of low antenna impedance to realization.

Table 2: Change of antenna impedance

	half-wavelength dipole	cellular phone model
no wire	58.29+j59.07	73.96+j66.61
$d = 1$ mm	4.25−j15.11	4.71−j13.83
$d = 2$ mm	5.72−j14.82	6.96−j11.75
$d = 3$ mm	5.76−j11.93	7.60−j7.16
$d = 4$ mm	5.55−j8.42	7.80−j2.18
$d = 5$ mm	5.33−j4.76	7.86+j2.76
$d = 6$ mm	5.19−j1.11	7.87+j7.51
$d = 7$ mm	5.13+j2.46	7.88+j12.07
$d = 8$ mm	5.14+j5.92	7.92+j16.44
$d = 9$ mm	5.21+j9.27	7.98+j20.62
$d = 10$ mm	5.35+j12.51	8.10+j24.65
$d = 11$ mm	5.54+j15.64	8.29+j28.53
$d = 12$ mm	5.77+j18.66	8.55+j32.27

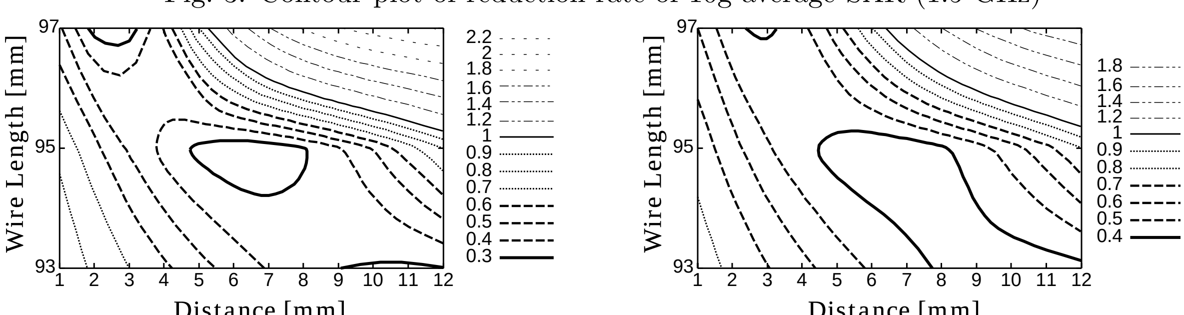
3.4 Characteristics for Wire Parameters

Contour plot of reduction rate of 10g average SAR and average SAR as index of absorption power is shown in Figs. 3 and 4 in the frequency of 1.5 GHz. Moreover, contour plot of radiation efficiency in the frequency of 1.5 GHz is shown in Fig. 5.



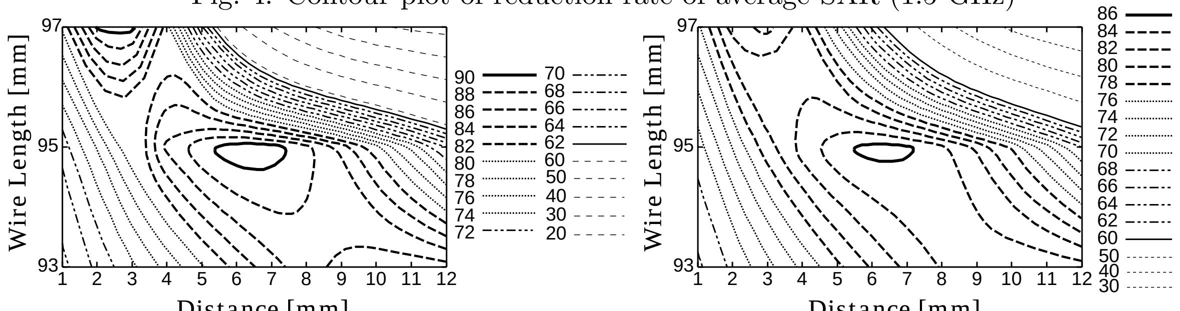
(a) half-wavelength dipole (b) cellular phone model

Fig. 3: Contour plot of reduction rate of 10g average SAR (1.5 GHz)



(a) half-wavelength dipole (b) cellular phone model

Fig. 4: Contour plot of reduction rate of average SAR (1.5 GHz)

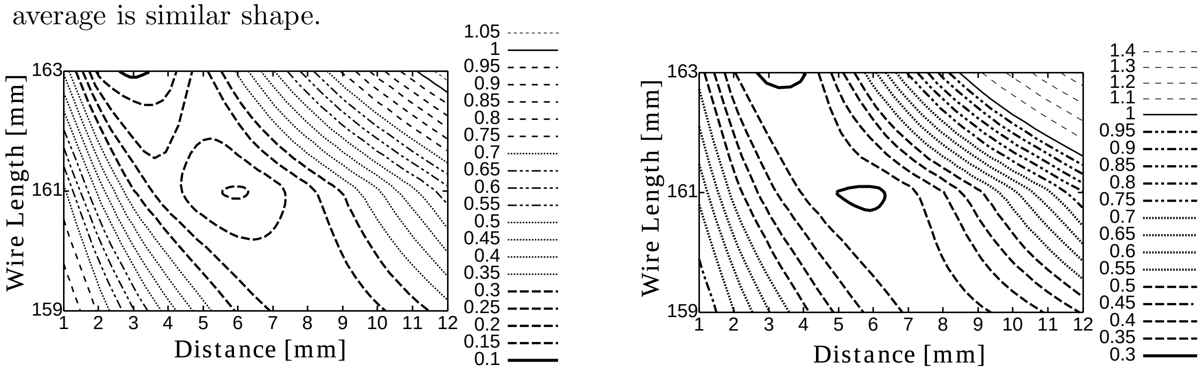


(a) half-wavelength dipole (b) cellular phone model

Fig. 5: Contour plot of radiation efficiency (1.5 GHz)

According to Figs. 3, 4 and 5, higher effect points are that separation between transmitter and wire d is from 9 mm to 11 mm at l = 93 mm(0.47λ), d is from 5 mm to 7 mm at l = 95 mm(0.48λ), d is from 2 mm to 3 mm at l = 97 mm(0.49λ). Each parameter characteristics are same shape.

Fig. 6 shows contour plot of reduction rate of 10g SAR average in the frequency of 900 MHz. In the same way, the frequency of 1.5 GHz, contour plot of reduction rate of 10g SAR average is similar shape.



(a) half-wavelength dipole (b) cellular phone model

Fig. 6: Contour plot of reduction rate of 10g average SAR (900 MHz)

According to Fig. 6, higher effect points are that separation between transmitter and metallic wire d is from 9 mm to 11 mm at 159 mm(0.48λ), d is from 5 mm to 7 mm at 161 mm(0.49λ), d is from 2 mm to 3 mm at 163 mm(0.495λ). We confirm that each parameter characteristics are same shape.

4 Conclusion

We analyzed that metallic wire is added to transmitters in outside as director in this study. Human head is approximated to spherical model, frequencies are two kinds of 1.5 GHz and 900 MHz. It is found that director has reduction effect of absorption power, that is, improvement effect of radiation efficiency in contradiction to Tay's report[2].

In radiation pattern, radiation power is reduced at the side of head model, and is increased at the side of metallic wire. Radiation power is concretely reduced by about 2 dB at $\theta = 180°$, and increased by about 1.75 dB at $\theta = 0°$. It is found that the reduction rate of each SAR is 1/3 or less.

However, it has a problem about antenna impedance, when antenna added metallic wire to transmitter cause higher reduction effect of SAR. Its value become less than 1/10 comparing to one without wire. It is necessary to investigate the problem of low antenna impedance to realization.

References

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