Numerical Evaluation of Power Radiated and Dissipated by a Loaded Surface Coil at High Field

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ABSTRACT: The amount of power radiated and dissipated by a surface coil loaded with different samples at different frequencies was estimated using computer models. The radiation loss increases with the increase of frequency but is lower when the coil is loaded with dielectric materials.

INTRODUCTION: In theory, the radiation power of an antenna is proportional to the square of the antenna-length-to-wavelength ratio (1). The evaluation of radiation power loss by a RF coil has been an interest particularly for high field MRI engineering because the decrease of the wavelength may increase the radiation power loss of a coil to an significant degree. To assess the radiation power loss of a given RF coil theoretically or experimentally is difficult because of the complicated geometry and the near-field characteristics of the coil. In this report, we examine the radiation loss in a surface coil loaded with different samples at different frequencies using a computer modeling method.

METHODS: A 11 cm x 11 cm linear surface coil loaded with a head-size (18 cm diameter) spherical sample was modeled. Four capacitors in series placed symmetrically in each loop were modeled to tune the coil to the resonance frequency. Two kinds of samples were used: one having the electrical properties of average brain tissue and the other having electrical conductivity (σ) of average brain tissue but the relative electric permittivity (ε_r) of free space (ε_r=1). The boundary was set at least 85 cm away from the coil and the sample. The FDTD method (2) was used to find the steady state of RF fields and the radiation power was then calculated by integrating the time average Poynting vector over the surface of a box that enclosed the coil and the sample. The absorbed power in the sample was also calculated, using methods given elsewhere (3). All FDTD calculations were prepared and solved with the aid of xfdtd software (Remcom; State College, PA).

RESULTS AND DISCUSSION : The radiated and the absorbed power by the sample-coil system at 300 MHz, 385 MHz and 530 MHz are listed in Table 1. The percentage of radiation loss, which was calculated by taking the ratio of radiation power over the sum of radiated power and the power absorbed by the sample, is also given at each frequency in Table 1. For each frequency, two conditions are given to the sample. First, the sample is assigned to have the same conductivity and dielectric constant as the averaged brain gray matter and white matter at the given frequency. Previous computer modeling and experimental studies at 7.0 T demonstrated that this sample yielded a similar RF field distribution in the human brain at 300 MHz. Thus, its perturbation of the RF field should approximate that of the human head. As indicated by our result, the percentage of the input power lost to radiation increases with the increase of frequency as anticipated according to antenna theory. However, the percentage of the radiation loss remains small up to 530 MHz. Considering that the unshielded surface coil model is most susceptible to radiation loss among the RF coil designs for MRI because of its open structure, the radiation loss by other RF coil designs for MRI should be less significant at high fields available for human imaging. One important contribution for this is the high dielectric constant of the human sample. As indicated by the result when ε = 1, the radiation loss is significantly increased. Although the high dielectric constant is not directly involved in energy dissipation, it increases the RF field coupling with the sample so that more RF energy is absorbed and subsequently dissipated by resistive loss.

Table 1: The radiation power (P_r), the power absorbed in sample, P_{abs} and the percentage of the input power lost to radiation. The input power is the summation of radiated power and dissipated power.

Frequency	σ (S/m)	ε_r	P_r (mWatt)	P_{abs} (mWatt)	$\frac{P_r}{(P_r+P_{abs})}$ x100%
300 MHz	.657	1	1.2	22.8	5.00%
	.657	50.56	0.32	15.9	1.97%
385 MHz	.688	1	1.8	19.8	8.33%
	.688	48.12	0.54	14.3	3.64%
530 MHz	.744	1	2.1	9.6	18.0%
	.744	45.86	1.4	13.9	9.15%

CONCLUSIONS:

The radiation loss by the surface coil is relatively small in the frequency regime that corresponds to the field strength available for human imaging. The sample having ε_r of brain results in less radiation loss than does the sample having ε_r of free space at all these frequencies. The explanation is that the dielectric material helps the sample to absorb more energy, thus reducing the percentage of the input power lost to radiation.

REFERENCES

1) KF Lee, "Principles of Antenna Theory", John Wiley, (1984), p. 33
2) KS Yee, IEEE Trans. Ant. Propag. 14:302 (1966)
3) CM Collins and MB Smith, MRM 45:692 (2001)