

The development of the RF-pulse for the low level SAR used by the MRI.

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Abstract. The Magnetic Resonance Imaging (MRI) is important diagnostic image equipment as a medical instrument which does not use the radiation. The signal acquisition of the MRI irradiates human body with electromagnetic wave (radio frequency : RF-pulse), and it collects MR signal of the human body. The safety of RF-pulse used by MRI has been defined at specific absorption ratio (SAR) [Watt/Kg]. Recently, there was a case in which the SAR became high-level by a diversity of the imaging sequence for the MRI in the selection of the imaging procedure. The effect of the electromagnetic wave on human body had to be considered, when the SAR became high-level, and there was the necessity of the development of the RF-pulse for the low level SAR. We produced the RF-pulse of the SAR for the low level experimentally. The trial manufacture RF-pulse carried out the imaging test by MRI equipment used by the clinic actually. The radiofrequency pulse used in SAR type sequence for low level produced original functional type radiofrequency pulse based on the Fourier cosine development experimentally. Evaluation method of original functional type radiofrequency pulse were frequency characteristics and slice profile characteristics required by the numerical simulation analysis using Bloch equation. In the clinical equipment, the following were carried out. Slice thickness adjustment and optimization of the power condition degree of 90-180. Low SAR type pulse sequence using original functional type RF-pulse reduced RF-watt [KW] to 25.6%. And, contrast lowering in the multi-slice imaging was suppressed at 12.5%. The improvement was able to realize SAR reduction and picture quality on imaging pulse sequence using the low SAR type RF-pulse.

KEYWORDS: *RF-pulse*, MRI, SAR

1. Introduction

A safety-relevant effect of magnetic resonance(MR) examinations is the deposition of energy in the patient due to the transmission of radiofrequency (RF)excitation pulses[1]. A dosimetric measure which has been widely adopted to quantify RF exposure to the patient is the specific absorption rate (SAR)[2]. This is defined as the energy dissipated in the body per unit of mass and time(W/kg). MR sequences can be employed in clinical practice for which SAR levels exceed the defined IEC limits[3]. Particular emphasis has been placed on determining SAR of the human body when subjected to different MR pulse sequences[4]. Also, the area of frequency domain (the integration value of the function that obtained by Fourier transformation of the RF pulse within its frequency range) is an important element to determine a relation between the 90°and the 180°RF pulses.

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2. Method

The relation between the time-averaged maximum allowable power deposition (P_{LIM} [W]) and MR pulse sequences is given by Eq.(1) [5]. The relation between the SAR limit (SAR_{LIM}) and P_{LIM} is given by Eq.(2). Equations (1) and Eq.(2) exhibits that SAR limit depends on the waveform of RF pulses when the repeat count of the RF pulses and the repetition time (TR) are fixed. The strength of the RF pulse per unit area depends on the area of frequency domain, and also it sets the relation between the 90° and the 180° RF pulses. We consider that the reduction of the SAR can be achieved by improving the waveform of the RF pulse and reducing the area of frequency domain.

$$P_{LIM} = (R/TR) \sum_{n=1}^N \sum_{m=1}^M f_{(n,m)} \tau_{(n,m)} P_{(n,m)} \quad (1)$$

P_{LIM}	:RF pulse maximum power [W]	R	:RF pulse repeated time
TR	:repetition time [msec]	$f_{(n,m)}$	:RF pulse form function
$\tau_{(n,m)}$	:RF pulse duration time [msec]	$P_{(n,m)}$	:RF pulse mean power [W]

$$SAR_{LIM} = \frac{P_{LIM}}{mass} \quad (2)$$

P_{LIM}	: RF pulse maximum power [W]	$mass$	:The volume of tissue mass [kg]
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2.1. Computer Simulation

We make functions for the RF pulse that can reduce SAR and have the same (or better) frequency characteristic as (or than one of) the $\pm 2\pi \text{sinc}$ function. We give functions based on the Fourier cosine transform (original function:OF) multiplied by a correctional function.

$$\text{original function(OF)} = A \cos(\omega t/4) + B \cos(3\omega t/4) + C \cos(5\omega t/4) \quad (3)$$

We perform the Fourier transformation of our functions and obtain the area of frequency domain and rectangle ratios of the frequency characteristics (Fig.1). We also try to improve the contrast-to-noise ratio (CNR) in the Multi slice (MS) imaging by reducing the RF power. For each RF pulse, the impressed time is 3.0 ms and the period of the phase (converted into the original sinc function) is $\pm 2\pi$.

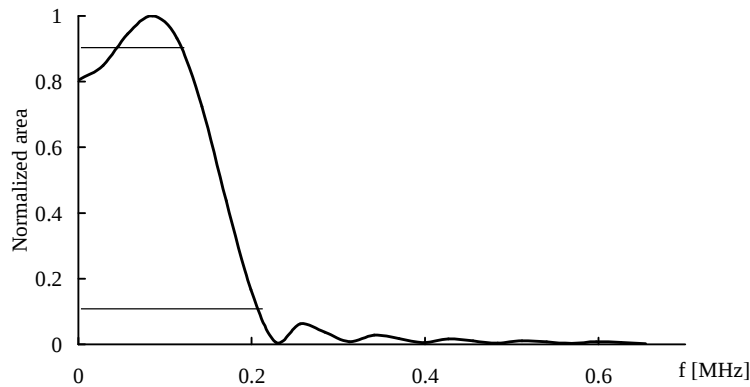


Figure 1: We perform the Fourier transformation of our functions and obtain the area of frequency domain and rectangle ratios of the frequency characteristics

2.3. Phantom and volunteer study

The slice thickness and signal-to-noise ratios (SNR) of the NEMA phantom images obtained by using our RF pulses. We also take the Single slice(SS) and Multi slice(MS) Bran images of normal volunteer. We measure the RF power directly through the RF amplifier in taking the images. We obtain the decreasing rates of CNR from the Bran image in SS and MS from the gray matter(GM) part and the white matter(HM) part .

Data was collected with a SE T1-weighted pulse, TR/TE=400/12ms, slice thickness of 5mm, 256x256 matrix, FOV=250mm. All experiments were performed on a 1.5 Tesla Toshiba EXCELART/XGS Scanner using a BR QD coil. We obtained the informed consent of the volunteer in advance.

3. Results

Figure 2 shows the effect of the difference of the coefficient of the OF on the frequency domain. The frequency domain characteristics changed, that each value of the correction factor changed. In OF, the FWHM(full width at half maximum) increases by 14.8% compared to $\pm 2\pi\text{sinc}$ function, but the rectangle ratio of their frequency characteristic also decreases by 12.2% compared to $\pm 2\pi\text{sinc}$ function. The rectangle nature of the slice is important in MRI. The area of frequency domain of the OF is 118% of $\pm 2\pi\text{sinc}$, and so we can reduce the RF power by 18 % compared to $\pm 2\pi\text{sinc}$ (Fig.3).

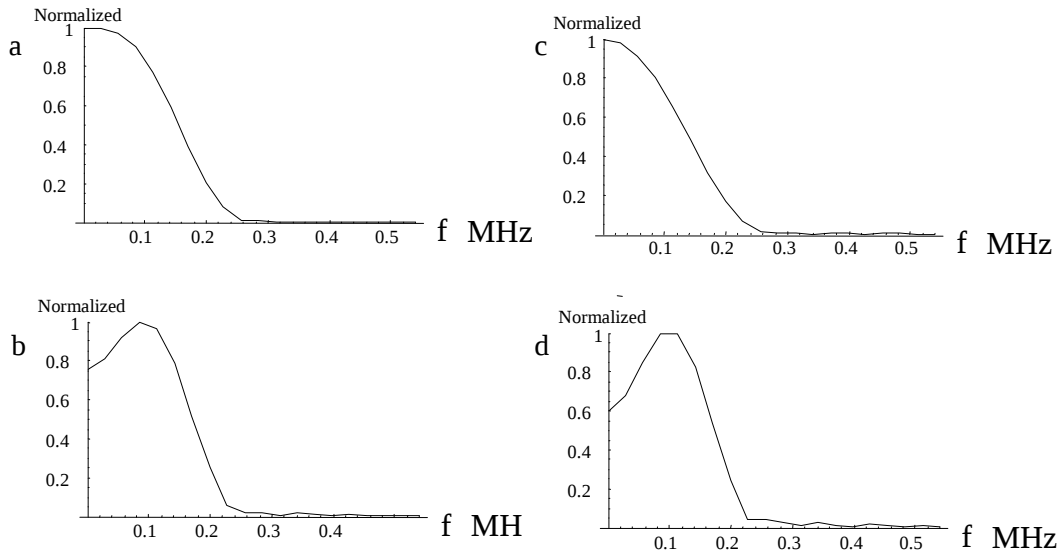


Figure 2: The effect of the difference of each coefficient of the original function on the frequency domain. a ($A=0.2, B=0$), b ($A=0, B=0.2$), c ($A=0.4, B=0$), d ($A=0, B=0.4$)

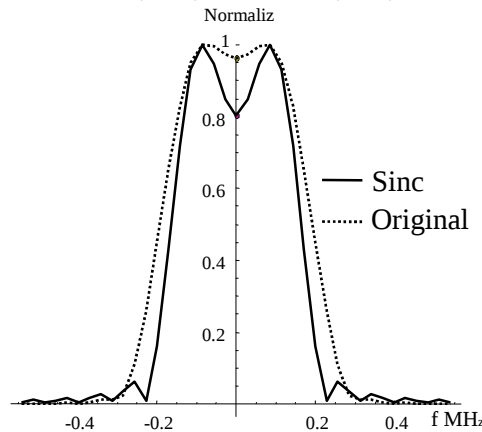


Figure 3: Frequency characteristic comparison between $\pm 2\pi\text{sinc}$ function and the OF function.

Figure 4 show the NEMA phantom images obtained by using our RF pulses. The slice thickness for the sinc and the OF are 5.3mm and 5.1mm. SNR for the sinc and the OF are 15.1 and 13.9, respectively. Both of slice thicknesses are almost same, but SNR for the OF decreases by 8.0 % compared to the sinc. Figure 5 shows the Brain image of the normal volunteer. The RF power for the OF measured by the RF amplifier decreases by 25.6% compared to the sinc. For the sinc, CNR in MS decreases by 29.2% compared to one in SS. Compared to this, for the OF the decrement of CNR in MS is 16.7% and drastical improvement can be achieved. This is due to the reduction of the RF power.

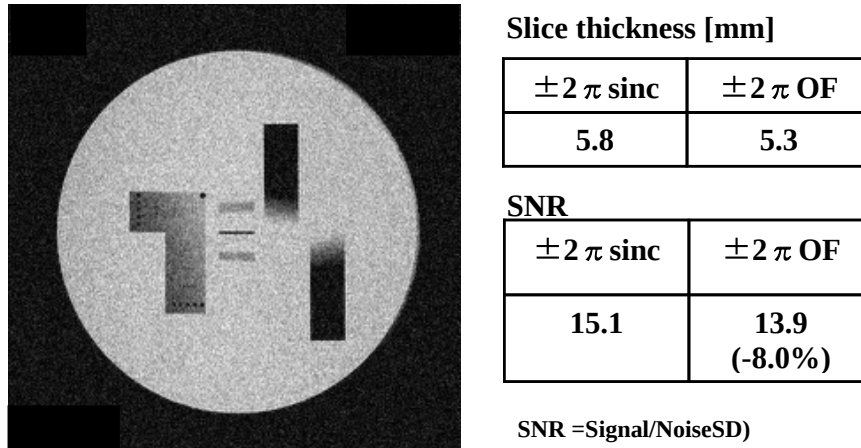
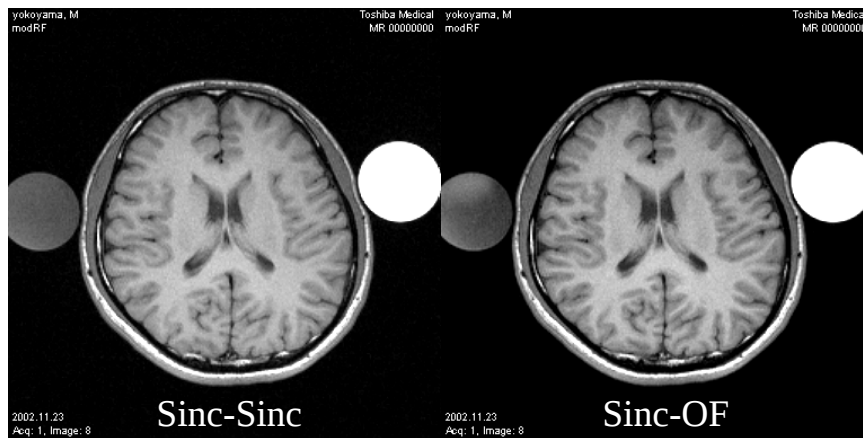


Figure 4: The NEMA phantom images obtained by using two different RF pulse.

Figure 5 shows the Brain image of the normal volunteer. The RF power for the OF measured by the RF amplifier decreases by 25.6 % compared to the sinc. For the sinc, CNR in MS decreases by 29.5 % compared to one in SS. Compared to this, for OF the decrement of CNR in MS is 16.7% and drastical improvement can be achieved. This is due to the reduction of the RF power



	single slice	multi slice	
	90(sinc)-180(OF)	90(sinc)-180(sinc)	90(sinc)-180(OF)
CNR	20.96	14.84 (-29.2)	17.47 (-16.7)
RF power [KW]	-	4.3	3.2 (-25.6%)

Fig.5: A set of transverse slice of brain images showing the same slice with two different RF pulse.

4. DISCUSSION

We make the OF function for RF pulses that is obtained by multiplying a correctional function to the product of the sinc function and the Fourier cosine function. The rectangle ratio of the frequency characteristics of our RF pulses is equivalent to one of the sinc function, and the area of frequency domain of our RF pulses increases by 18% compared to the sinc function. From this improvement, the RF power can reduce by about 25.6 %. It can be known that the area of frequency domain plays a important role to determine the relation between the 90° and the 180° RF pulses. By reducing the RF power, the reduction of the magnetization transfer contrast can be achieved in MS[7]. Nowadays there is a tendency to relax the SAR limits from the reason that the effects of the human body by the dissipated energy through the RF pulses is low[3]. By cogitating the waveform of the RF pulses, however, we can achieve the reduction of SAR and the improvement of SNR in MS of the T1-W at the same time.

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