Compensation of the Susceptibility Artifact in Temporal and Orbitofrontal Region in Brain using the Flat RF pulse

S. Oh[1], S. Yun[1], and H. Park[1,2]

[1]Department of Electrical Engineering, KAIST, Daejeon, Korea, Republic of, [2]fMRI Laboratory of Brain Research Center, KAIST, Daejeon, Korea, Republic of

Introduction

The susceptibility artifact in magnetic resonance (MR) image occurs by the variation in the magnetic field strength around the interface of substances having different magnetic susceptibility. Especially, this artifact has an effect on the signal loss on orbitofrontal and temporal regions of the brain. For the compensation of this artifact, we propose a new RF pulse having bilinear phase, and quadrature phase, which provides nearly constant signal intensity against the magnetic susceptibility.

Methods

The signal in a voxel is represented in equation (1) when assuming that the signal loss due to the magnetic susceptibility is happened by variation of the linear phase distribution of the spins only in the slice selection direction (z-direction). [1]

$$S = \sqrt{\left[\int_{-z/z_o}^{z/z_o} M_o \cos(P_{sus} z)\, dz\right]^2 + \left[\int_{-z/z_o}^{z/z_o} M_o \sin(P_{sus} z)\, dz\right]^2} = M_o z_o \left|\mathrm{sinc}\left(\frac{P_{sus}}{2} z_o\right)\right| = M_o z_o \left|\mathrm{sinc}\left(\frac{\gamma TEG_{sus}}{2} z_o\right)\right| \qquad (1)$$

where z_o is the slice thickness, M_o is the magnetization, γ is the gyromagnetic ratio, TE is the echo time, and G_{sus} is the field gradient caused by the magnetic susceptibility.

The proposed flat RF (F-RF) pulse is made by adding bilinear ($a_1|z|$) and quadrature ($a_2 z^2$) phase distributions along the slice selection direction in equation (2) for compensation of the phase dispersion due to the field variation induced by the magnetic susceptibility.

$$S = \sqrt{\left[\int_{-z/z_o}^{z/z_o} M_o \cos(a_1|z| + a_2 z^2 + P_{sus} z)\, dz\right]^2 + \left[\int_{-z/z_o}^{z/z_o} M_o \sin(a_1|z| + a_2 z^2 + P_{sus} z)\, dz\right]^2} \qquad (2)$$

We used a_1 ($=b\times\pi/z_o$) and a_2 ($=q\times 2\pi/z_o^2$), where $b(=0.001)$ and $q(=8)$ are parameters to modulate bilinear and quadrature phase distribution.

Results

Figure 1 shows the signal intensity with respect to the linear phase gradient (P_{sus}) in a voxel affected by the magnetic susceptibility. In the conventional slice selection RF pulse, *i.e.* Sinc RF pulse, the signal intensity sharply decreases as the P_{sus} increases. From this result, the Sinc RF pulse is affected strongly by the field inhomogeneity. In the case of the quadrature tailored RF pulse, where this has the quadrature phase distribution, the dependency of the signal loss on the field inhomogeneity was improved more than the Sinc RF pulse. However, the strong field inhomogeneity causes low intensity and the signal loss could happen in the severe field inhomogeneity like temporal or occipital lobe. We confirmed this condition from the in-vivo image in Fig. 2. On the other hand, the signal intensity by the F-RF pulse compensated the magnetic susceptibility effects more than that of other RF pulses.

We performed in-vivo experiments using 3T MR system for sinc, quadrature and F-RF pulses. In the experiments, TR was 600msec, the matrix size was 128×128, the slice thickness was 5mm and the imaging sequence was the gradient-echo multi-slice (GEMS). In addition, TE was 10 and 35msec. Figure 2 shows the obtained MR images. As TE increases from 10msece to 35msec, the susceptibility artifact is gradually severe in the case of the result of the Sinc RF pulse. Although this artifact from the quadrature tailored RF pulse is less than that of the Sinc RF, the susceptibility artifact is still remained in the orbitofrontal region in the brain. Moreover, there is the signal loss in the temporal region when TE is 35msec. In the case of the F-RF pulse, the signal of temporal region as well as orbitofrontal region was much improved in comparison with the other RF pulses. Therefore, the F-RF pulse shows better quality in the compensation of the signal intensity in orbitofrontal and temporal regions of the brain and could be used for the fMRI research about those regions.

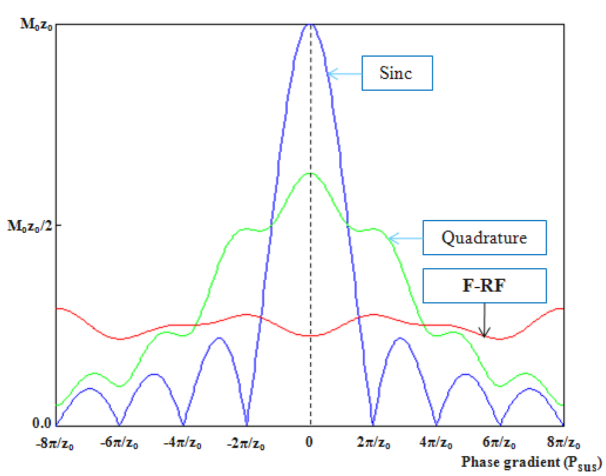

Fig. 1. Signal intensity distribution in the voxel, where z_o is the slice thickness.

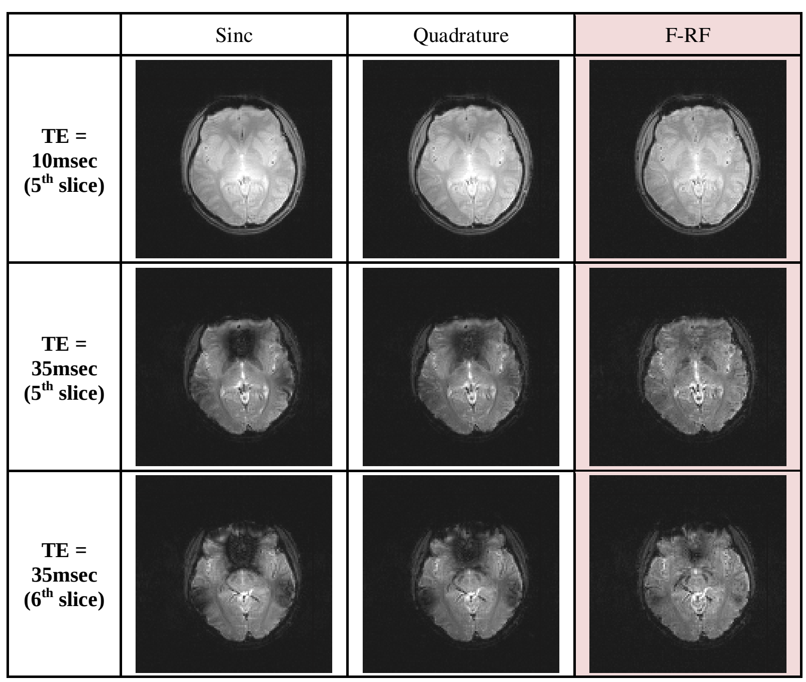

Fig. 2. MR images using various RF pulses

References

[1] Z.H. Cho and Y.M. Ro, Magnetic Resonance in Medicine **23**:193-200, 1992.

[2] Y.M. Ro and Z.H. Cho, Magnetic Resonance in Medicine **28**:237-248, 1992