Faster Dixon Fat-Water imaging with Multiplex RF pulses

K. J. Lee[1]

[1]Academic Radiology, University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Introduction: Phase sensitive imaging for fat-water separation was first proposed by Dixon [1]. For each slice, two or more images are acquired at different echo times with fat and water magnetization vectors at different relative phases e.g. (0, π, 2π) [2]. These are then combined to separate water and fat. The need to acquire each slice at different echo times increases the minimum imaging time (T_{min}). In a multiecho Dixon sequence, although T_{min} can be reduced by decreasing the separation between echo times, there needs to be a minimum interval for adequate phase evolution [3]. However, if the interval between the echoes from one slice is used to sample another slice, T_{min} would be halved. This work describes how this may be achieved with multiplex RF pulses [4]. A multiplex pulse combines several component pulses into a single pulse with the duration of a single component pulse. Each component pulse simultaneously excites a different slice which is rephased with a different slice gradient refocusing lobe. This avoids aliasing because applying the rephasing condition for one slice dephases the others. By alternately rephasing and dephasing slices in a multiecho sequence, echoes from one slice can be interleaved with those from the other.

Method: A 4 ms two-slice multiplex pulse, the slices of which are rephased by -0.30 and -0.75 of the slice select lobe, was designed using the method described in Ref [5]. The slices were 1kHz in width, and located at ± 6.25 kHz. This was used in a 3-point Dixon multiecho spin-echo sequence on a 1.5T scanner (Philips Infinion). The sequence diagram (not to scale) is shown in Fig. 1. An amplitude-modulated π pulse was used for multiband slice-selective refocusing. The readout lobes were separated by 1.1 ms. With the first lobe located at the in-phase time for the first slice, the positive lobes acquire (0, π, 2π) echoes for slice 1. Initial experiments performed with fat and water phantoms determined that the in-phase echo time for the second slice was 1.6 ms later. Therefore, the echoes for the second slice are not exactly (0, π, 2π), but were assumed to be so during post-processing for this proof-of-principle work. During processing, where necessary, 2D phase unwrapping was performed manually. Slice thickness = 3.2 mm, and was limited by the the slice gradient slew rate, which was 72 mT/m/s. Other parameters were: Matrix = 256×256, TR/TE = 800/30 ms, number of averages = 1, number of interleaves = 3.

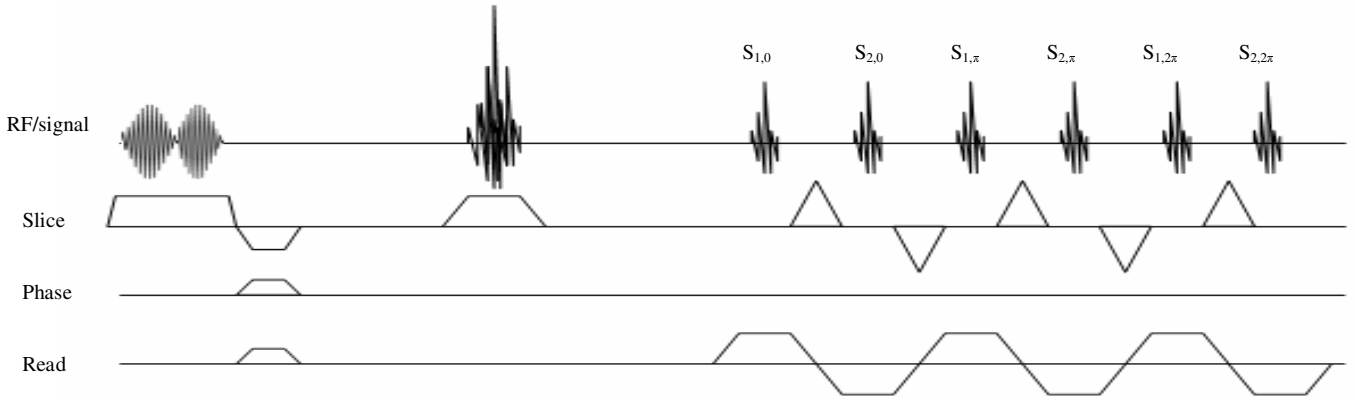

Figure 1. Pulse sequence schematic. Signals are labeled $S_{a,b}$ where a = slice number, and b = fat-water phase in radians (approximate for slice 2).

Results: Figure 2 shows the fat-water separated images from an in-vivo exam of a normal volunteer. The middle interleaf was located over the knee, with the other two interleaves located on either side. Fat-water separation has been achieved, although some crosstalk is visible, indicating that dephasing from other slice is not complete.

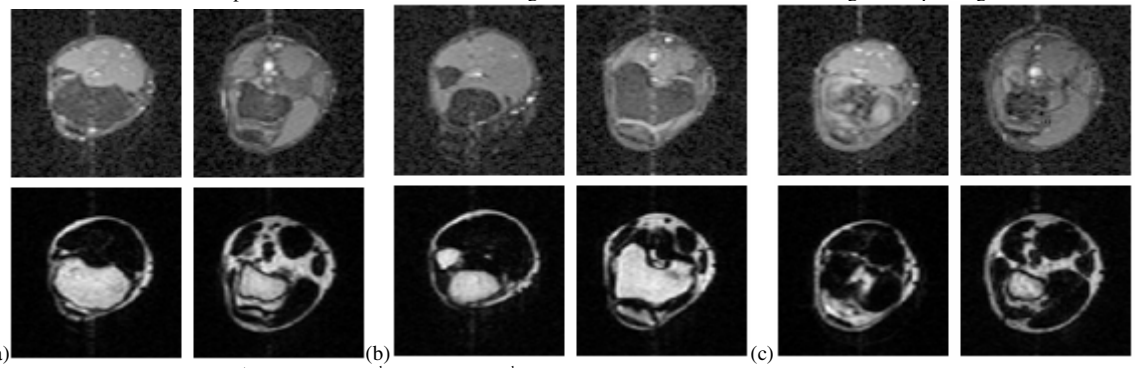

Figure 2. Axial images from a normal leg (a) 1st interleaf (b) 2nd interleaf (c) 3rd interleaf. In each interleaf, column 1 = slice 1, column 2 = slice 2, with water images on top row and fat images below. Water image levels have been re-windowed to show crosstalk more clearly.

Discussion: The need to acquire two or more echoes lengthens the minimum imaging time considerably for the Dixon method. These echoes cannot be too close to each other, otherwise there will be insufficient phase evolution [3]. This work attempts to use the "dead time" in between echoes from one slice to collect signal from another slice, thus halving the minimum scan time required to cover a volume with a given phase evolution. The results demonstrate that this is feasible. Another advantage of this method is that the signal from a particular slice is obtained with gradients of the same polarity. Therefore, no correction for phase or distortion from gradient switching is required. Some crosstalk from incomplete dephasing is visible, most likely due to gradients from susceptibility differences, which can be reduced by using thinner slices [4]. Other disadvantages are: increased SAR from the multiband slice-selective refocusing pulse, and reduced SNR because the sampling time for one slice is reduced in order to fit in the other slice. Note that the slices have different in-phase echo times. This means that as the multiplex pulse is played out, the transverse magnetization is formed at different times for different component pulses. Therefore, the relative in-phase echo times may be adjusted simply by shortening or lengthening the existing pulse. This may be useful when adapting a sequence for use on scanners of different field strengths. Adjustment will also be necessary for other variants of Dixon imaging requiring different fat-water shifts e.g. the IDEAL method (-π/6, π/2, 7π/6) [6], or the 2-point POP (0, 135°) [7].

Conclusion: The feasibility of multiplex pulses to halve the minimum scan time for Dixon fat-water imaging has been demonstrated. In future, it is hoped to implement multiplex fat-water imaging with gradient-echo, FSE, and possibly even SSFP sequences, although the latter will require very fast gradients. Multiplex Dixon may be particularly suited for fat suppression at low fields, where the relatively long interval between in- and out-of-phase echoes may be used to fit in more slices with multiplex pulses. Crosstalk due to susceptibility gradients will also be reduced at low fields. The method can also be used with other parallel imaging methods such as SENSE to provide even more acceleration.

References: [1] Dixon W. Radiology. 1984; 153: 189-194 [2] Glover GH. JMRI. 1991; 1: 521-530 [3] Pineda AR *et al.* MRM 2005 ; 54: 625-635 [4] Lee KJ *et al.* MRM. 2005; 54: 755-760 [5] Lee KJ *et al*. JMR. 2006; 182: 133-142. [6] Reeder SB *et al.* MRM. 2005; 54: 636-644 [7] Xiang QS. MRM. 2006; 56:572-584.

Acknowledgments: Support from EPSRC First Grant Scheme (EP/C537491/1).