

Wideband MRI: A New Dimension of MR Image Acceleration

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Abstract

We propose a new paradigm of MRI acceleration using the frequency multiplexing technique in modern communication technology; we name it "Wideband MRI". A major component of wideband MRI is frequency multiplexing of MR signals. Using simultaneous multi-slice RF excitation pulses centered at different frequencies followed by simultaneous multi-slice acquisition during readout, the total scan time of a subject can be significantly reduced using existing hardware. Mathematical model and experimental results explain Wideband MRI image quality and serves as a criterion to evaluate the tradeoff between imaging speed and image quality in future applications.

Introduction

Faster MRI acquisition has always been an unceasing pursuit of all MRI practitioners. From Multi-Slice Multi-Echo to parallel imaging, acceleration methods of MRI have exploited in both temporal and spatial domains. However, the usage of signal bandwidth in MRI equipments remains to be highly inefficient compared to its radio-frequency sibling in communication, which has a speed improvement of 1000 folds within the last few decades. Previous attempts using multiple bandwidths such as simultaneous multi-slice acquisition [1,2,3] have failed. Not only do they leave the image quality an unsolved issue, but more importantly lack the comprehension of acceleration in the frequency domain. Possessing the knowledge of modern digital communication, we summarize the whole topic from a more generic perspective - the concept of wideband multiple-input multiple-output (MIMO). Another mission is to reason the image quality scientifically with the equation and experiments we have derived.

Material and method

RF pulses in Wideband MRI contains several bands, we define the number of bands as "Wideband multi-slice/slab factor W ". It is the excitation/acquisition of this wideband signal that provides additional information that makes acceleration possible. Also with the additional separation gradient, voxels experience a shear along the direction of spatial encoding where separation gradient is added. By identifying the true mechanism of this effect, the relation between blurred pixels and separation gradient strength is established. It is an explicit statement that, for fixed in-plane resolution and readout gradient strength, the number of blurred pixel is proportional to the product of slice thickness and separation gradient strength. Two sets of experiments were designed to prove that image thickness and separation gradient strength is the two factors that determine image quality of Wideband MRI. The first set of experiment observes the equation by adjusting slice thickness and separation gradient strength with a phantom. After the equation is observed, we apply this imaging criterion on applications such as phantom, human knee and brain.

Results

Sets of 2D Wideband MRI are taken, The phantom images shows linearity between blurred pixels slice thickness or separation gradient strength, proving our theory and calculations to be correct. Several fine 2D *in vivo* images were taken with W greater or equal to 2 with fine image quality. These images are shown in Fig. 2&3. Scan time for each setting is reduced more than 50% compared to conventional sequences with the use of wideband MRI. The same wideband acceleration concept is also implemented on 3D MR imaging, exciting/acquiring multiple slab simultaneously. Shown in Fig. 4, excellent image quality of whole brain with fine contrast and details is acquired in only 1/4 the original acquisition time.

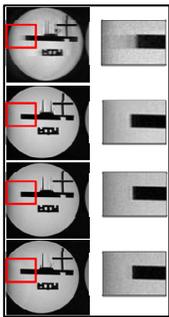


Fig. 1 linearity of slice thickness v.s. blur. 6,3,2,1 pixel blurs from top to bottom.

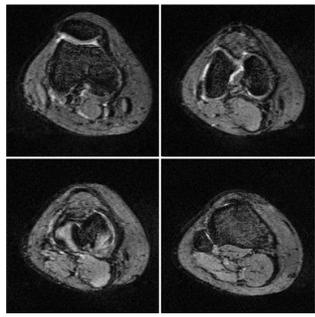


Fig.2 $W=3$ 2D192x192x192 knee image, scan time=6 min8sec, 3X reduction from 18min.

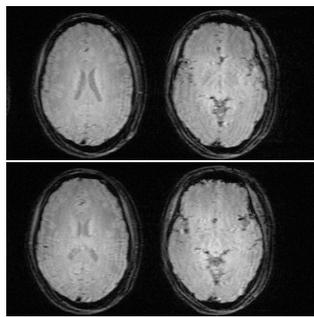


Fig.3 $W=2$ 2D192x192x128 whole brain anatomy image, scan time=6min8sec, 2X reduction from 13min

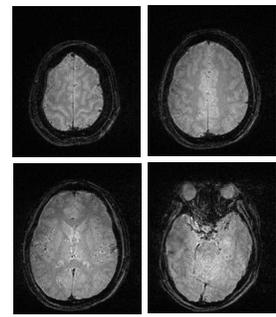


Fig.4 $W=4$ 3D 256x256x256 brain image scan time=8min11sec, a 4X reduction from 32min45sec.

Discussion & Conclusion

We have shown that imaging time is directly divided by Wideband multi-slice/slab factor (W), because more information is captured with the increase of signal bandwidth. Also by proving equation 1., the tradeoff between number of blurred pixels and acquisition settings is lucid. This equation serves as a guideline for future attempts to use Wideband MRI acceleration. MR practitioners are able to determine the optimal combination of acceleration and image quality according to this rule. The optimal 2D Wideband multi-slice factor (W) is 3 on our current MR system for subject the size of human head, it may be higher for machines with stronger gradients (wider bandwidth) and able to excite thinner slices accurately. Wideband 3D imaging sequence is a highly efficient method to reduce slice thickness by simply adding more steps of encoding along slice direction. From our results at least 4 times acceleration can be achieved on our human system with Wideband 3D MRI, even 8~10 times can be obtained depending on the subject's geometry. According to its characteristics, wideband MRI is most ideal for applications obtaining large coverage such as whole human body screening. Finally, what makes Wideband MRI so exciting is that it is accelerated on a dimension orthogonal to MSME and parallel imaging, meaning that one can gain unthinkable speed with the combination of these methods altogether. Moreover, Wideband MRI is compatible to almost every existing MR sequence. It allows a direct speedup to these sequences, and the world of MRI as well.

References

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