SNR Gain of Cooled/Superconductor Array

L. Xue[1], L-M. Xie[2], M. Kamel[1], J. Wosik[1]

[1]Texas Center for superconductivity and Advanced Material and Department of Electrical Engineering, University of Houston, Houston, TX, United States, [2]Texas Center for Superconductivity, University of Houston, Houston, TX, United States

Abstract.

It is well recognized that cryogenically cooled normal metal or high critical-temperature superconducting (HTS) surface probes can be used to significantly improve SNR when coil noise dominates in MRI system [1]. However, it is not clear what is the maximum size of the probe at any given frequency where either cooled cooper or HTS still can be used. Because of recent developments in parallel imaging techniques and increasing importance of SNR of coil arrays in parallel imaging, we have calculated potential SNR gain *vs.* number of elements in the array, which can be achieved, for the same field of view, by replacing normal metal array with either cooled to 77K copper or HTS material. We consider 3 dB gain (equal body and coil resistances), as the lowest limit of the gain worth considering for using a superconductor. For such gain we have found that maximum size of the HTS array elements are: ~2", 1.7", 1.2" and 1" at 64, 128, 200 and 300 MHz, respectively.

Introduction

In recent years, the design of phased arrays for parallel acquisition in MRI application has become the subject of a great deal of research. The drive for faster and faster acquisition rates calls for arrays with a larger number of receiving elements. In this work, we discuss the advantages of using HTS materials for SNR improvement of large number of elements arrays required by parallel imaging techniques [2]. HTS thin films are very attractive for use as surface receiver coils because at 77 K they exhibit an extremely low surface resistance, several orders of magnitude lower than that of copper [3]. The number of elements and optimal size of each element at four MRI frequencies will be discussed.

Methods and results

A cylindrical phantom model was used to analyze the relation between SNR and the number of coils in the array. SNR was calculated for a voxel placed inside a cylindrical loss body at a distance Zv from the body surface (Fig. 1). The rectangular coil/array was placed at Z_p distance from the body. In the calculations presented here we have assumed that the body is 5 mm away from the array of coils. It corresponds to the average coil/array-body distance in a cryostat, which has to be used for cooling. At frequencies 64 MHz and 128 MHz, the size of the array, and body size were assumed to be 8" by 2" and 10" by 6", respectively. For two other frequencies the size of the array and body were equal to 2" by 1" and 6.5" by 2.5". Conductivity was assumed to be σ= 0.8S/m. An example of calculations at 200 MHz relative SNR distribution for normal metal and HTS arrays is shown in Fig.2. Results of calculated SNR gain, which can be achieved by replacing copper either with 77 K cooper or HTS material, *vs.* number of array elements are presented in Fig. 3. We see that with increasing coil numbers and decreasing individual coil size, not much gain can be obtained by cooling copper. However, for the same configuration, there is considerable gain from using HTS array.

Conclusions

Fig. 3 shows very clearly that with increasing the number of elements in the array and decreasing individual coil size, HTS arrays are superior to cooled cooper arrays. It can be explained by the fact that for small coils most of the system loss is due to coil resistance, which is reduced almost entirely by HTS material. Also from this Figure we can see that to achieve 3dB SNR gain by using HTS material, the maximum coil size in the array should not exceed 2" at 64MHz, 1.75" at 128 MHZ, 1.25" at 200 MHZ and 1" at 300 MHz. The potential SNR gain using large arrays increases with the number of elements.

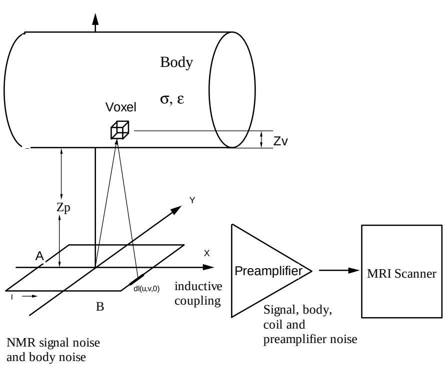

Fig.1 The SNR was calculated for a voxel placed inside a cylindrical loss body at a distance Z_v from the body surface. Z_p indicates the distance from the rectangular coil to the body.

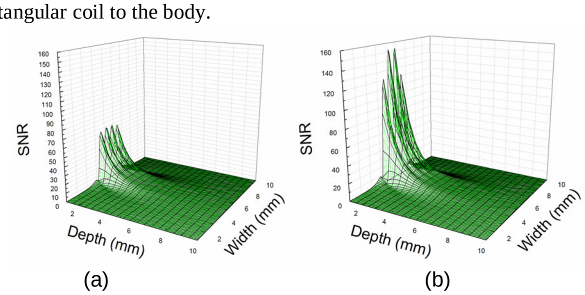

Fig. 2. Relative SNR calculated at 200 MHz for four 1" by 0.5" normal metal (a) and HTS (b) coils (see SNR gain equal to 8 dB in Fig. 3c).

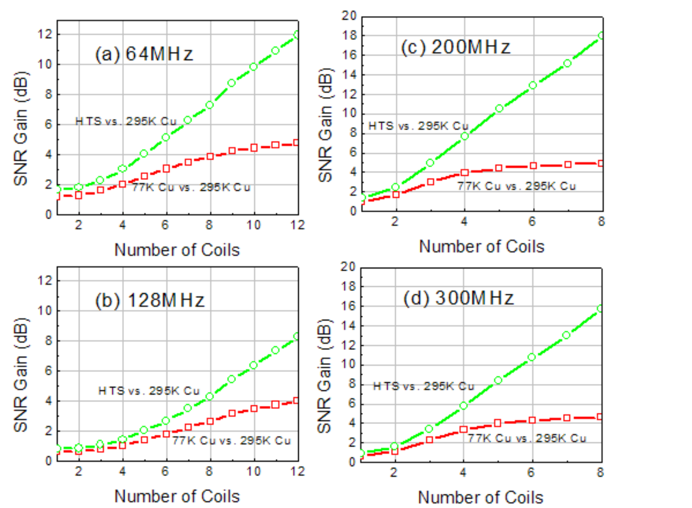

Fig 3. Calculated SNR gain of replacing in array normal metal by cooled normal metal and/or by HTS material *vs.* number of elements in the array. 64 MHz (a), 128 MHz (b), 200 MHz (c), and 300 MHz (d). Field of view was 8" by 2" at 64 MHz and 128 MHz and 2" by 1" at 200 MHz and 300 MHz.

References.

[1] R. D. Black, et al., *Science*, 259, (1993): 793-795; Q. Y. Ma, *IEEE Tr. on Applied Supercon.*, 9, pp. 3565-3568, 1999.

[2] K. P. Prussman et al., *Magn. Reson. Med.* v.42, pp. 952-962,1999.

[3] Z.-H. Shen, "*High-Temperature Microwave Circuits*," Artech House, Boston London, 1994.