# On the SNR Gain for Copper and Superconductor Cryogenic Coils

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**Introduction**

The study of SNR improvement via implementation of cryogenic array coils is motivated by recent developments towards implementing parallel imaging techniques with RF array coils using a large number of elements(1). Significant SNR gain over room temperature SNR values is obtained through noise reduction by either cooling down normal copper coils or by using HTS coils(2). The current trend of array fabrication with an increased number of array elements results in a decreased size for each element in a given field of view. As the size of the individual coils is reduced, a cross over point is reached at which the coil noise exceeds the body noise(3). At this point there will be additional noticeable benefits from the application of cryogenic coils(4). However, it is not clear where this cross point lies for both cooled copper and HTS coils in different experimental configurations. Thus far, there has been no systematic discussion of these questions related to cryogenic coil designs. The purpose of this work is to determine the SNR improvement that can be achieved by using both the cooled copper and the HTS coil arrays with different sizes of coil elements and for operation at different frequencies.

**Method and results**

A simplified theoretical model is built to study the general trends of SNR gains depending on the coil radius, r, and at different operating frequencies, f. The coil noise reduction can be estimated by introducing a parameter α (the ratio of coil to body temperature) and β (coil resistance ratio at 77K over 300K). The SNR gain due to the use of a 77K Cu or an HTS coil can be derived from Eq. 1 for the same signal in the same experimental set up:

$$SNRG(f,r)=\sqrt{\frac{R_{body}+R_{coil}}{R_{body}+\alpha\beta R_{coil}}}=\sqrt{\frac{1+\delta(f,r)}{1+\alpha\beta\delta(f,r)}}\qquad where\qquad \delta(f,r)=\frac{R_{coil}(f,r)}{R_{body}(f,r)}\qquad (1)$$

Usually, the SNR improvement due to the use of cryogenic coils is determined experimentally by the square root of the Q ratio. In this work, we consider the effect of both the coil noise and the body noise on the Q values. Measurements are completed at 300K and 77K for an unloaded copper coil, a loaded copper coil, and an HTS coil. The resulting six Q values are used in Eq 2 to determine the SNR gains for both cooled copper and HTS coils.

$$SNRG_{Cu77K/Cu300K}=\sqrt{1+\frac{0.25(Q_0^{300K}/Q_0^{HTS})}{A}}\qquad SNRG_{HTS/Cu300K}=\sqrt{(\frac{Q_0^{HTS}}{Q_0^{300K}})\frac{1+A}{0.25+(\frac{1+A}{Q_0^{300K}/Q_L^{300K}}\frac{Q_0^{HTS}}{Q_L^{HTS}}-1)}}\qquad (2)$$

$$where\qquad A=\frac{Q_L^{300K}/Q_L^{77K}-Q_0^{300K}/Q_0^{77K}}{1-Q_L^{300K}/Q_L^{77K}}$$

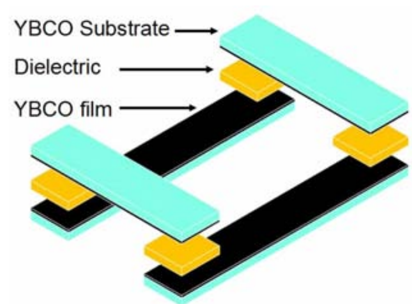


**Fig 1: Example of HTS coil design**

The Q measurements were performed at a distance of 5 mm from the coil on a flat phantom with a conductivity simulating that of a real person. The frequency tuning for each HTS coil is accomplished by adjusting the thickness of the dielectric layer between YBCO films (Fig. 1). The experimental results for the Cu cooled coils (Fig 2) and for the HTS coils (Fig. 3) are plotted together with the corresponding SNR gain simulation results from Eq. 1.

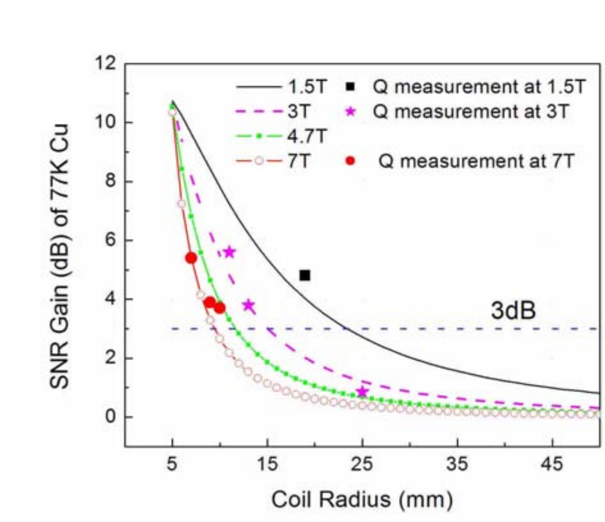


**Fig 2: SNR Gain of cooled Cu coil**

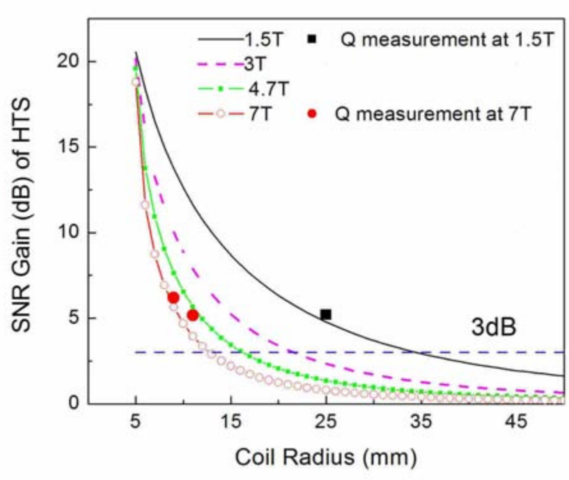


**Fig 3: SNR Gain of HTS coil**

**Discussion and conclusions**

The SNR gain values were derived from the experimental Q values with significantly improved accuracy. These experimentally verified results of SNR gains are in excellent agreement with the theoretically predicted trends of the SNR gain versus coil element size at different frequencies. The results in Figs 2 and 3 identify the maximum size of coil elements at various frequencies at which the SNR gain (over 300K values) is still sufficient (3dB) for both cooled copper and HTS coils. The significance of these results clearly demonstrates the advantages of HTS coils over cooled Cu coils in selected operation regimes. Successful HTS coil designs are based on a novel tuning technology.

**References**

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