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SYSTEMS

Superior Imaging with HTS RF Coil

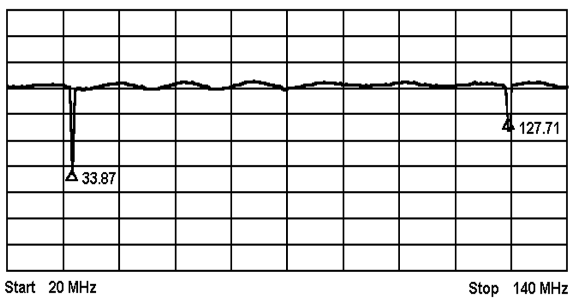
For the past 30 years, a major focus for new MRI technology and products has been in the development of higher field strength magnets. The rational for this is - the higher the field strength, the better the Signal-to-Noise (SNR) of the MR image. This trend comes to an end as the field strength reaches 3Telsa (T), the highest field permitted for clinical use by FDA, CE and other regulatory agencies. Clearly, alternative solutions are needed to further improve the SNR without increasing field strength.

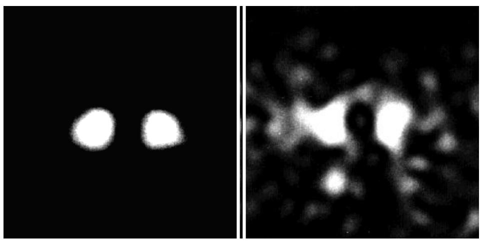
Recently, the major commercial MR vendors have shifted their focus to the parallel imaging area using RF surface coil arrays. 16-32 channel array coils are now commercially available for head, orthopedic, and breast imaging while 96-128 channel arrays are being developed in the R&D labs for head and body imaging.

Array coils are known to improve SNR up to 200% and reduce imaging time. It has been well demonstrated that the greater the number of coil elements in an array, the better the improvement in SNR. Today, the coil elements are made of Copper (Cu) surface loops ranging in 2-4 inch sizes. With such small coil sizes, the dominant noise in MRI no longer arises from the body sample but rather from the coils themselves. Therefore, the challenge arises - how to reduce the coil noise. The best solution is to change the Cu material with a material with lower resistance/noise characteristics. For this reason, High Temperature Superconductor material (HTS) becomes an ideal material of choice.

HTS MRI Coil technology was initially developed by the research team at Columbia University in late 1990s. The engineering team, led by Prof Q. Y. Ma specialized in the use of superconductor electronic devices for RF and sensing applications.

The first phase of HTS MRI coil development was focused on small (approx one inch size) surface coils for phantom and animal imaging in late 1990s. The first HTS coil was designed for Na imaging at 3T. Numerous tests with Na phantom imaging showed the SNR gains of 5-10 times using the HTS coil, relative to comparable Cu Coils [Fig 1].

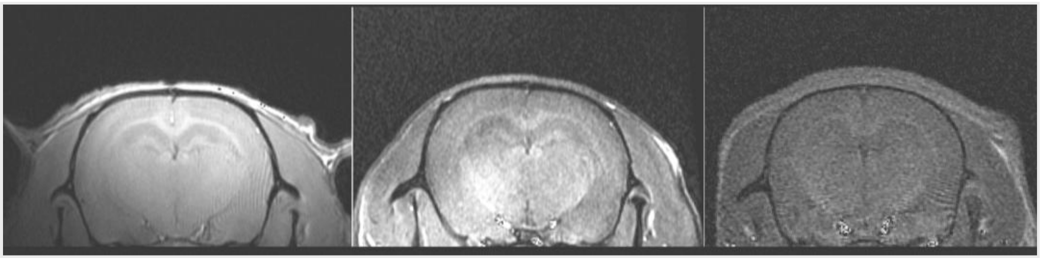




(a) HTS coil (b) Cu coil

Fig 1: Dual frequency HTS coil spectrum for H and Na (left), 3T Na phantom images by HTS coil (a) and Cu coil (b).

Similar small surface coils were developed for proton (H) imaging of animals at higher field. In collaboration with NIH Center for In Vivo microscopic imaging at Duke University, the team performed high resolution imaging experiments on rat brains with a 2T animal MRI system. The HTS coil results showed an improvement of 300 - 400% in SNR over conventional Cu coil. This significant SNR improvement was used to improve the resolution in small animal brain imaging. Using a 2T MRI system for In Vivo micro imaging, a record 50 um image resolution was achieved [Fig. 2 & 3]. Even today, without HTS, similar resolution MR micro-imaging can only be achieved using animal MR systems with magnetic fields above 11T. Such systems are very expensive and due to the exceptional high field, are not likely to be approved for larger animals and human studies. The team also performed experiments to demonstrate the benefits of HTS coils on the reduction of imaging time. With the HTS improved SNR, the imaging time was reduced by a factor 2-3 in animal imaging studies. Between 1996-1999, the Columbia team filed several patent applications covering the design and construction of HTS MRI coils, as well as additional multiple frequency coils for H, Na, P, ... resonance studies.



(a) HTS coil (b) Cu surface coil (c) Cu Volume coil

Fig 2: 2T rat brain in vivo images by HTS surface coil (a), Cu surface coil (b), and Cu volume coil. The SNR ratio for (a) (b) (c) is 8:4:1 respectively

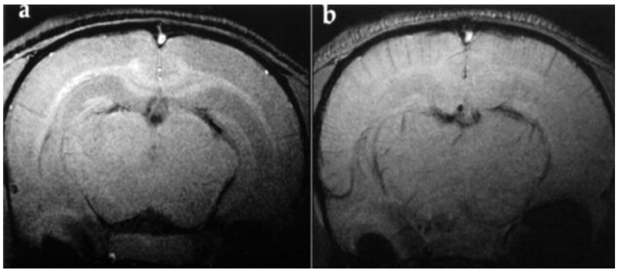


Fig 3: In vivo high resolution rat brain image at 2T acquired by HTS surface coil showing resolution of 50 um.

In addition to the HTS MRI coil technology, the team had also developed special cryogenic probes which permit the operation of HTS coils inside MRI systems. The cryo probes were made mainly of non-magnetic and non-metallic materials which performed well at very low temperature (20-30K) with Liquid Helium as the cryogen. After numerous experiments with various materials and designs, the team successfully built stable cryo probes which were capable of continuous operation inside high field magnetic environments.

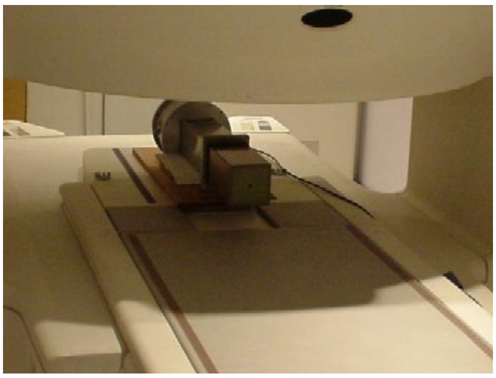


Fig 4: The first phase cryo probe with liquid helium flow. The probe was placed in an open MRI system for imaging.

The second phase of the HTS coil development focused on the larger surface coil designs suitable for human imaging applications (approx. 2-4 inch for film coils and 6-9 inch for tape coil loops). The work was done by teams at University of Hong Kong MRI center and Harvard Medical Center in the early 2000s using clinical low field MRI systems. Successful MRI studies were performed in anatomical regions including the eye, TMJ, partial brain, as well as orthopedic joints with a GE 0.2T Profile MRI system using HTS coils and comparing the results to commercial Cu Coils. Results showed 300-400% SNR gains by HTS film coils (200-300% by HTS tape coil) in human imaging at 0.2T [Fig. 5]. The cryogenic probe developed during the second phase was a simpler Liquid Nitrogen (LN2) probe for use at higher temperatures. Initial designs permitted imaging operation for limited operation times (approx. 30-60 mins).

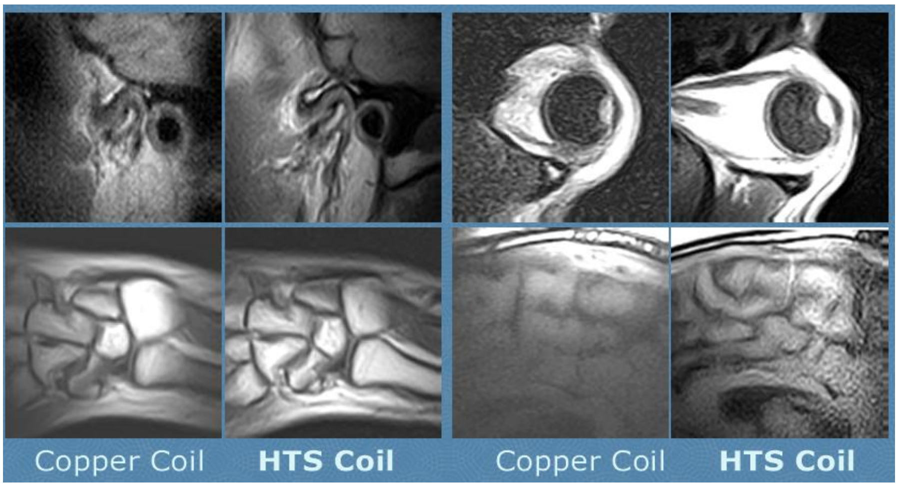
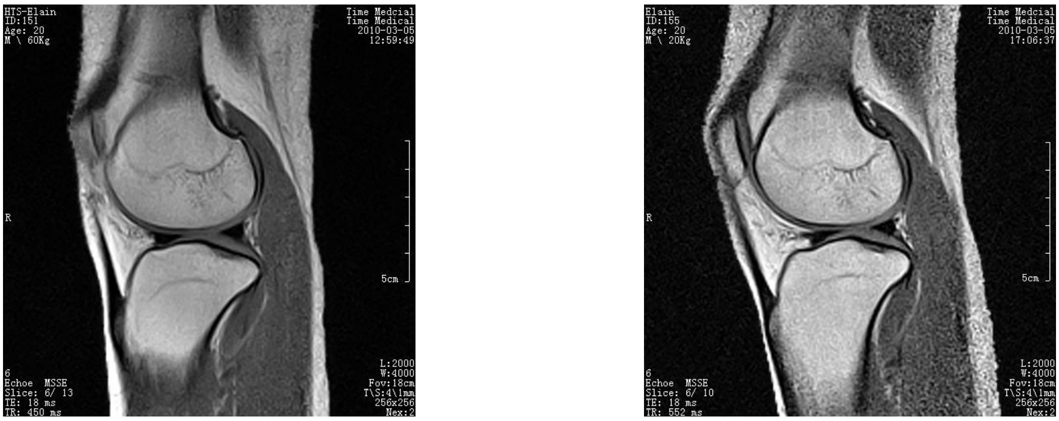


Fig 5: Comparison images made by Cu coil (left) and HTS coil (right) showing clockwise - TMJ, Eye, partial brain and wrist. Images were done with GE Profile 0.2T system.

The commercialization of HTS MR coils arrived during the third phase development of HTS development with the inception of Time Medical Inc. The team left academia and set up the corporation in 2006 with the initial focus on the development of open MRI systems –PICA (Whole body 0.35T) and MONA (Orthopedic 0.2T). The HTS coil development program continued with strong focus on new clinical surface coil products. Key challenges included the development of LN2-based cryogenic probes which were stable and sufficiently robust for routine use in MRI clinics. With many prototypes and evaluations, the team developed the first cryo probe product for orthopedic MR imaging in 2009 and consequently received US FDA clearance in Nov '09. The new LN2 probe has been tested in our low field systems, as well as in 3T clinical MRI systems. The probe is stable and can be operated continuously in MRI magnets and requires minimal attention by the MR technologists. A key reason for many of the positional benefits of the new HTS coil design is that they only require cooling to 80K and are no longer immersed into LN2.

Fig 6: Third phase cryo probe structure with Liquid nitrogen reservoir (left) and the probe in operation in a 3T system.

The first orthopedic HTS coil and cryo probe product has been tested in PICA 0.35T system and result shows the SNR gains of 200-300% over the Cu coil for human imaging [Fig. 7]. This coil will soon be commercially available and is suitable for all low field systems. The modification of the orthopedic HTS coil for 1.5T MRI is currently underway. Such probes will follow in Q3 2010.



SNR = 192 SNR = 57

Fig 7: Orthopedic images taken by HTS coil (left) and Cu coil (right) from Time Medical's PICA system.

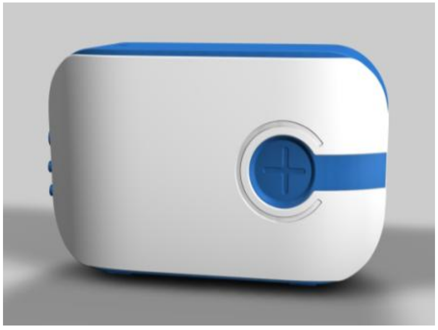


Fig 8: First HTS orthopedic coil probe

The following product pipeline for HTS coils is in development:

- Spine and breast coil by Q4 '10 for both low field and 1.5T MRI systems
- Head coil array by Q2 '11 for 1.5T MRI [Fig. 9]
- Large coil array for body by Q4 '11 for both low field and 1.5T MRI
- Large coil array for body by Q2 '12 for 3T MRI system

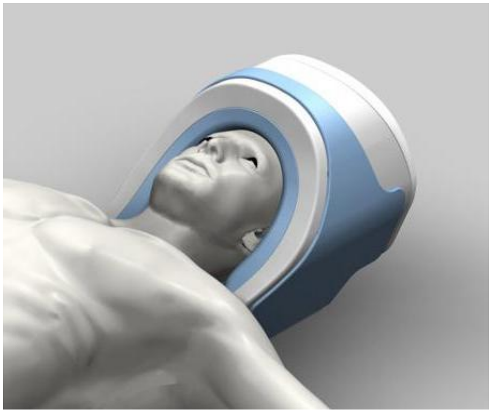


Fig 9: HTS Head coil design

The information regarding this technology is preliminary and in development. Commercial specifications and future availability cannot be ensured. Contact: sales@time-medical.com or visit website www.time-medical.com
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