Multi arm Archimedean coil for high field MRI

S. Sanchez[1], S. S. Hidalgo[1], S. E. Solis[1], M. Rosas[1], and A. O. Rodriguez[1]
[1]CI3M, UAM Iztapalapa, Mexico, City, Mexico

Introduction

Spiral coils have been used for various MRI applications as single-channel coils and array coils. Archimedes introduced a special type of spiral [1] consisting of two arms or more as shown in Fig. 1. The Archimedean spiral geometry has not been studied for MRI applications according to the literature reported. Computer simulations of the magnetic field for different Archimedean spiral coil configurations were computed using a Finite Element Method. For comparison, the magnetic field of circular-shaped coil with similar dimensions was also performed.

Methods

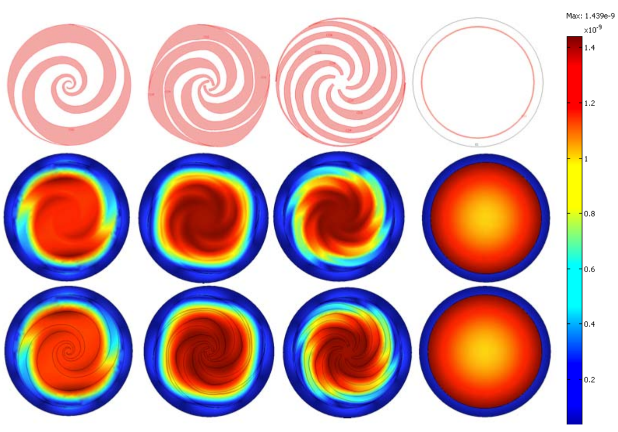
Archimedean spirals can be generally described by: $r = a + b\theta^{1/y}$ (1) where a (constant) and, b (controls the distance between successive turnings) are real numbers, θ is the angle between the arms of the coil and y is the position. The normal Archimedes spiral occurs when y=1. From Eq. (1), the corresponding expressions to determine the arm positions for different number of arms (2, 4 and 6) are:

$$y_{p1} = e^{a\theta} \;(2.a) \quad y_{p2} = e^{a(\theta-d)} \;(2.b) \quad y_{p3} = e^{a(\theta-2\pi/N)} \;(2.c) \quad y_{p4} = e^{a(\theta-d-2\pi/N)} \;(2.d)$$

where N is the number of arms. Eq. (2) was employed to plot the different Archimedean spirals as shown top row of Fig. 1. A set of Archimedean coil distributions with different number of wires with spiral geometry with a circular envelope was numerically studied by calculating the magnetic fields of the configurations. In this work, five types of spiral coils were studied to investigate the behaviour of the magnetic field as a function of the number of arms at high magnetic field. All numerical simulations were performed using COMSOL MULTIPHYSICS (V. 3.2, Comsol, Burlington, MA, USA) at 300 MHz (proton resonant frequency at 7T). It was assumed a 5m diameter for coil layouts.

Results and Discussion

Fig. 1 shows both the coil geometry and the numerical simulations of the magnetic flux density for various Archimedean spiral coils. To be able to accommodate more arms, the arm thickness was decreased. From Fig. 1 simulations can be observed that there is an increment in the field intensity as the number of arms and their thickness are incremented. To compare the behaviour of the Archimedean coil magnetic field, a comparison was computed and plotted in Fig. 2. It is clear from this plot (Fig. 2) that, the field intensity is greater than the circular coil one for configurations with two arms or more. However the region of interest is reduced for the all Archimedean coil layouts. This is a common pattern found: there is a tradeoff between the intensity and the uniformity. In addition, it is important to mention that the arm thickness also allows increasing the intensity of the magnetic field. Compared to the traditional circular coil, the spiral-Archimedean coils present a higher intensity (70%) of the produced magnetic field ensuring a higher SNR although the region of uniformity has been compromised. It still remains to investigate the experimental performance for single-channel coils and coil arrays normally used in parallel imaging. From the numerical point of view, this coil design may be a good candidate for MRI applications at high fields.



(a) (b) (c) (d)

Fig. 1. Magnetic flux density: columns (a) 2- (b) 4- (c) 6-arms Archimedean coils, and (d) circular coil.

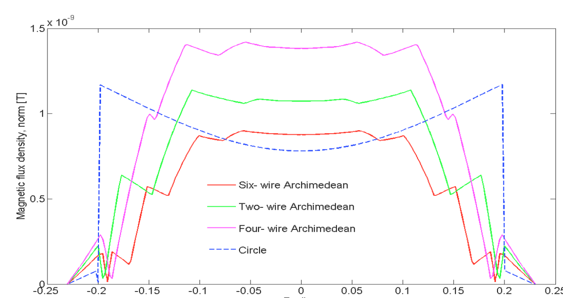


Fig. 2 Comparison profile plots of magnetic fields of Fig. 1 data.

Acknowledgments. S. S. thank the National Council of Science and Technology of Mexico (CONACyT) for Ph. D. scholarships. S. H. thanks UAM Iztapalapa for a posdoc stipend. Support from Inovamédica is gratefully acknowledged.

References

[1] Heath TL (Editor), The Works of Archimedes with the method of Archimedes, Dover, NY, p. 165, 1897.