CLAIMS

What is claimed is:

1. A magnetic imaging apparatus comprising:

a power source for providing a current; and

a ~~single-sided~~ gradient coil set for a single-sided magnetic imaging apparatus, the coil set being connected to the power source and ~~, the coil set~~ having an aperture,

wherein the coil set comprises ~~one or more~~a plurality of first spiral coils at a first position relative to the aperture and ~~one or more~~a plurality of second spiral coils at a second position relative to the aperture, the first position being different from the second position, and the first position being across from the second position with respect to the aperture, and

wherein the coil set is configured to receive a current ~~through the one or more first spiral coils and the one or more second spiral coils, thereby generating an~~ to generate a combined electromagnetic field gradient configured to project away from the coil set and into an imaging region of the magnetic imaging apparatus, and

wherein the one or more first spiral coils comprises a primary first spiral coil and a secondary first spiral coil, wherein the primary first spiral coil is configured to create a first large primary electromagnetic field gradient, and wherein the secondary first spiral coil is configured to create a first small secondary electromagnetic field gradient to provide adjustments to the combined electromagnetic field gradient.

2. The apparatus of claim 1, wherein the coil set is non-planar and oriented to partially surround the imaging region.

3. The apparatus of claim 1, wherein the ~~one or more~~plurality of first spiral coils and the ~~one or more~~plurality of second spiral coils are non-planar with respect to the aperture and mirror each other with respect to the aperture.

4. The apparatus of claim 1, wherein the electromagnetic field gradient is ~~substantially~~ uniform in the imaging region.

5. The apparatus of claim 1, wherein the electromagnetic field gradient is greater than 5 mT/m.

6. The apparatus of claim 1, wherein the electromagnetic field gradient has a rise time less than 10 µs.

7. The apparatus of claim 1, wherein the ~~one or more~~plurality of first spiral coils comprise at least two first spiral coils with at least two different diameters.

8. The apparatus of claim 7, wherein the ~~one or more~~plurality of second spiral coils comprise at least two second spiral coils with at least two different diameters.

9. The apparatus of claim 1, wherein the current is configured to flow through the primary first spiral coil and the secondary first spiral coil~~one or more first spiral coils~~ in alternating directions.

10. The apparatus of claim 9, wherein the current is configured to flow through the ~~one or more~~plurality of second spiral coils in alternating directions to minimize a rise time of the electromagnetic field gradient.

~~11. The apparatus of claim 1, wherein a primary first spiral coil of the one or more first spiral coils is configured to create a first large primary electromagnetic field gradient and a secondary first spiral coil of the one or more first spiral coils is configured to create a first small secondary electromagnetic field gradient to provide adjustments in the first large primary electromagnetic field gradient.~~

~~12~~11. The apparatus of claim ~~11~~1, wherein the plurality of second spiral coils comprises a primary second spiral coil and a secondary second spiral coil, wherein ~~a~~ the primary second spiral coil ~~of the one or more second spiral coils~~ is configured to create~~s~~ a second large primary electromagnetic field gradient and ~~a~~ the secondary second spiral coil ~~of the one or more second spiral coils~~ is configured to create a second small secondary electromagnetic field gradient to provide adjustments in the second large primary electromagnetic field gradient.

~~13~~12. The apparatus of claim 1, wherein a primary first spiral coil of the ~~one or more~~plurality of first spiral coils and a secondary first spiral coil of the ~~one or more~~plurality of first spiral coils adjacent to the primary first spiral coil have the current flowing through them in opposite directions.

~~14~~13. The apparatus of claim 1~~3~~, wherein a primary second spiral coil of the ~~one or more~~plurality of second spiral coils and a secondary second spiral coil of the ~~one or more~~plurality of second spiral coils adjacent to the primary second spiral coil have the current flowing through them in opposite directions.

~~15~~14. The apparatus of claim 12, wherein ~~a~~ the primary first spiral coil of the ~~one or more~~plurality of first spiral coils and ~~a~~ the secondary first spiral coil of the ~~one or more~~plurality of first spiral coils adjacent to the primary first spiral coil overlap up to 50% of respective coils to generate ~~a more parallel~~the first electromagnetic field gradient.

~~16~~15. The apparatus of claim ~~15~~13, wherein a primary second spiral coil of the ~~one or more~~plurality of second spiral coils and a secondary second spiral coil of the ~~one or more~~plurality of second spiral coils adjacent to the primary second spiral coil overlap up to 50% of respective coils to generate a ~~more parallel~~ second electromagnetic field gradient.

~~17~~16. The apparatus of claim 1, wherein the plurality of ~~one or more~~ first spiral coils and the ~~one or more~~plurality of second spiral coils are connected to form a single current loop.

~~18~~17. The apparatus of claim 1, wherein the ~~one or more~~plurality of first spiral coils and the plurality of ~~one or more~~ second spiral coils comprise different materials.

~~19~~18. The apparatus of claim 1, wherein the ~~one or more~~plurality of first spiral coils and the ~~one or more~~plurality of second spiral coils have diameters between about 10 µm to 10 m.

~~20~~19. The apparatus of claim 1, wherein the coil set further comprises one or more electronic components for tuning the electromagnetic field gradient.

~~21~~20. The apparatus of claim ~~20~~19, wherein the one or more electronic components include at least one of a PIN diode, a mechanical relay, a solid state relay, or a MEMS switch.

~~22~~21. The apparatus of claim ~~20~~19, wherein the one or more electronic components used for tuning includes at least one of dielectrics, conductive metals, metamaterials, or magnetic metals.

~~23~~22. The apparatus of claim ~~22~~21, wherein tuning the electromagnetic field gradient includes changing the current or changing physical locations of the one or more electronic components.

~~24~~23. The apparatus of claim 1, wherein the coil set is cryogenically cooled to reduce resistance and improve efficiency.

~~25~~24. The apparatus of claim 1, wherein the coil set ~~further comprises~~defines an opening ~~opposite~~ adjacent the aperture, wherein the region between the aperture and the opening defines a coil set region, and wherein the imaging region is at least partially disposed outside the coil set region in said opening.

~~26~~25. A method for using a magnetic imaging apparatus comprising:

providing a power source;

providing a ~~single-sided~~ gradient coil set for a single-sided magnetic imaging apparatus, the coil set being connected to the power source~~, the coil set~~ and having an aperture,

wherein the coil set comprises ~~one or more~~a plurality of first spiral coils at a first position relative to the aperture and ~~one or more~~a plurality of second spiral coils at a second position relative to the aperture, the first position being different from the second position, and the first position being across from the second position with respect to the aperture; and

turning on the power source so as to flow a current through the ~~one or more~~plurality of first spiral coils and the ~~one or more~~plurality of second spiral coils, thereby generating an electromagnetic field gradient that is projected away from the coil set and into an imaging region of the magnetic imaging apparatus.

wherein the plurality of first spiral coils comprises a primary first spiral coil and a secondary first spiral coil, wherein the primary first spiral coil is configured to create a first large primary electromagnetic field gradient, and wherein the secondary first spiral coil is configured to create a first small secondary electromagnetic field gradient to provide adjustments to the combined electromagnetic field gradient.

~~27~~26. The method of claim ~~26~~25, wherein the electromagnetic field gradient is greater than 5 mT/m.

~~28~~27. The method of claim ~~26~~25, wherein the electromagnetic field gradient has a rise time less than 10 µs.

~~29~~28. The method of claim ~~26~~25, wherein the coil set further comprises one or more electronic components from one of a PIN diode, a mechanical relay, a solid state relay, or a MEMS switch.

~~30~~29. The method of claim ~~29~~28, further comprising:

tuning the electromagnetic field gradient by changing the current or by changing one of physical properties or locations of the one or more electronic components.

~~31~~30. The method of claim ~~26~~25, wherein the coil set further ~~comprises~~ defines an opening ~~opposite~~ adjacent the aperture, wherein the region between the aperture and the opening defines a coil set region, and wherein the imaging region is at least partially disposed outside the coil set region in said opening.