Claims

1. A variable filter for an analog electromagnetic signal, comprising:

a secondary signal loop comprising a secondary signal path and a secondary feedback path connected between a signal input and a signal output, the secondary signal loop comprising a plurality of primary signal loops in the secondary signal path and a secondary adjustable scaling block ~~in the secondary feedback path that applies a gain factor, the gain factor of the secondary adjustable scaling block being adjustable in a range between a positive gain that is greater than zero and a negative gain that is less than zero~~;

each of the plurality of primary signal loops comprising a primary signal path ~~and~~, a primary feedback path, ~~wherein:~~ and a plurality of circuit elements connected in the respective primary signal ~~path comprises~~ loop, the plurality of circuit elements comprising:

a frequency tunable resonator; and

~~the primary feedback path comprises~~ a primary adjustable scaling block that applies a gain factor, the gain factor ~~of the primary adjustable scaling block~~ being adjustable in a range ~~between~~that comprises a positive gain ~~that is greater than zero~~ and a negative gain ~~that is less than zero~~; and

a controller connected to tune each frequency tunable resonator and to adjust the gain factor of each of the primary adjustable scaling blocks and the secondary adjustable scaling block between a negative gain factor and a positive gain factor.

2. The variable filter of claim 1, wherein the plurality of primary signal loops comprise two or more primary signal loops connected in series.

3. The variable filter of claim 1 or 2, wherein the controller is connected to independently adjust the secondary adjustable scaling block and one or more adjustable primary scaling blocks toward a desired frequency response.

~~3.~~4. The variable filter of any one of ~~claim~~claims 1 - 3, wherein the controller is programmed to selectively Q-spoil or Q-enhance one or more ~~of the~~ frequency tunable resonators toward a desired frequency response.

5. The variable filter of any one of claims 1 - 4, wherein the controller comprises

instructions to maintain stability of a frequency response of the filter when adjusting at least the gain factor of the primary adjustable scaling blocks and the secondary adjustable scaling block, the instructions comprising a look up table of control values.

6. The variable filter of claim 5, wherein the control values in the look up table are determined based on a calibration procedure applied to the filter.

7. The variable filter of any one of claims 1 - 4, wherein the controller comprises instructions to iteratively adjust the gain factor of one or more of the primary adjustable scaling blocks and the secondary adjustable scaling block toward a desired frequency response of the filter, the gain factor being adjusted based on a measure of the frequency response of the variable filter and to maintain stability of a frequency response of the filter.

~~4.~~8. The variable filter of ~~claim 1~~ any one of claims 1 – 7, further comprising a sensor that measures ~~the~~a frequency response at the signal output, the sensor being in communication with the controller, wherein the controller is programmed to tune each of the frequency tunable resonators and control the gain factor of each of the primary adjustable scaling blocks and the secondary adjustable scaling block in response to the measured frequency response toward a desired frequency response.

~~5. The variable filter of claim 1, wherein the controller is connected to independently adjust the secondary adjustable scaling block and one or more primary scaling blocks toward a desired frequency response.~~

~~6. The variable filter of claim 1, wherein the controller comprises instructions to selectively Q-spoil one or more frequency tunable resonators toward a desired frequency response.~~

~~7.~~9. A method of filtering an analog electromagnetic signal, comprising ~~the steps of~~:

providing a filter comprising:

a signal loop ~~defined~~comprising a signal path and a feedback path between a signal input and a signal output;

a plurality of circuit elements connected in the signal loop, the plurality of circuit elements comprising:

a frequency tunable resonator; and

an adjustable scaling block that applies a gain factor that is adjustable in a range that comprises a positive gain and a negative gain; and

a controller connected to tune the frequency tunable resonator and control the gain factor of the adjustable scaling block; and

adjusting the filter by tuning the frequency tunable resonator and adjusting the gain factor of the adjustable scaling block~~, the filter being adjusted to Q-spoil the frequency tunable resonator and~~ to achieve a desired frequency response in the filter~~.~~;

wherein:

adjusting the filter comprises Q-spoiling the frequency tunable resonator.

~~8.~~10. The method of claim ~~7~~9, wherein:

the signal loop comprises a plurality of ~~frequency tunable resonators~~primary signal loops in the signal path of the signal loop, each primary signal loop comprising a primary signal path, a primary feedback path, a frequency tunable resonator~~ being connected to~~, and a primary adjustable scaling block~~ to form a plurality of primary loops, the plurality of primary~~, the primary signal loops being connected in series between the signal input and the signal output; ~~the adjustable scaling block comprises a secondary scaling block that is connected between the signal input and the signal output;~~ and

adjusting the filter ~~comprising~~comprises tuning each frequency tunable resonator and adjusting the gain factor of each of the primary adjustable scaling blocks and the ~~secondary~~ scaling block, wherein the filter is adjusted such that at least one of the plurality of frequency tunable resonators is Q-spoiled.

~~9.~~11. The method of claim ~~8~~10, wherein adjusting the filter comprises independently tuning two or more frequency tunable resonators.

~~10.~~12. The method of claim ~~8~~10 or 11, wherein adjusting the filter~~ further~~ comprises Q-enhancing at least one frequency tunable resonator that is not Q-spoiled.

~~11.~~13. The method of ~~claim 7~~any one of claims 10 - 12, further comprising~~ the step of~~ measuring the frequency response of the signal loop, and using the controller to tune the

frequency tunable ~~resonator~~resonators and adjust the gain factor of the adjustable scaling ~~block~~blocks in response to the measured frequency response toward the desired frequency response.

~~12.~~14. The method of ~~claim 8~~any of claims 10 - 13, further comprising ~~the step of~~ transmitting an analog communication signal through the filter.

~~13.~~15. A variable analog filter for an analog electromagnetic signal, comprising:

a signal loop ~~defined~~ comprising a signal path and a feedback path connected between a signal input and a signal output;

a plurality of circuit elements connected in the signal loop, the plurality of circuit elements comprising:

a frequency tunable resonator; and

an adjustable scaling block that applies a gain factor, the gain factor being adjustable in a range that comprises a positive gain and a negative gain; and

a controller connected to the frequency tunable resonator and the adjustable scaling block,

wherein

the controller ~~comprising~~comprises instructions to Q-spoil the frequency tunable resonator by adjusting at least the gain factor.

~~14.~~16. The variable analog filter of claim ~~13~~15, wherein the signal loop comprises a plurality of ~~frequency tunable resonators, each frequency tunable resonator being connected to a primary adjustable scaling block to form primary~~ primary signal loops~~, the primary loops being~~ connected in series between the signal input and the signal output~~; and~~

~~the adjustable scaling block comprises a secondary scaling block that is connected between the signal input and the~~ , each primary signal ~~output; and~~

loop comprising a frequency tunable resonator and a primary adjustable scaling block and wherein the controller further comprises instructions to tune each frequency tunable resonator and adjust the gain factor of each of the primary adjustable scaling blocks and the adjustable scaling block, at least one of the plurality of frequency tunable resonators being Q-spoiled.

~~15.~~17. The variable analog filter of claim ~~13~~16, further comprising a sensor that measures ~~the~~a frequency response at the signal output, the sensor being in communication with the controller, wherein the controller is programmed to tune the frequency tunable resonator and the adjustable scaling ~~block~~blocks in response to the measured frequency response toward a desired frequency response.

~~16.~~18. The variable analog filter of claim ~~14~~17, wherein the controller Q-enhances at least one frequency tunable resonator that is not Q-spoiled.

~~17.~~19. A variable analog filter, comprising:

a signal loop comprising a signal path and a feedback path connected between a signal input and a signal output; and

a plurality of circuit elements connected in the signal loop, the plurality of circuit elements comprising:

a plurality of frequency tunable resonators ~~connected in series within the signal loop~~; and

an adjustable scaling block that applies a gain factor that is adjustable in a range that comprises a positive gain and a negative gain; and

a controller connected to tune each frequency tunable resonator and to adjust the gain factor of the adjustable scaling block toward a desired frequency response.

~~18.~~20. The variable analog filter of claim ~~17~~19, wherein the frequency tunable resonators and the adjustable scaling block are connected in series in the signal path of the signal loop.

~~19.~~21. The variable analog filter of claim ~~17,~~19 or 20 wherein the controller ~~adjusts~~controls a phase shift within the signal loop by adjusting the frequency tunable resonators ~~to achieve a desired phase shift in the signal loop.~~ .

22. The variable analog filter of claim 21, wherein the phase shift is controlled by detuning the frequency tunable resonators from a central frequency of the filter.

~~20.~~23. The variable analog filter of claim ~~17~~19, wherein two or more frequency tunable resonators are connected in primary signal loops, the primary signal loops being connected in

series within the signal loop, each primary signal loop comprising a primary adjustable scaling block that is controlled by the controller between a negative gain factor and a positive gain factor.

~~21. The variable analog filter of claim 17, wherein the controller is programmed to selectively Q-spoil or Q-enhance one or more frequency tunable resonators toward the desired frequency response.~~

~~22. The variable analog filter of claim 21, wherein the controller is programmed to Q-spoil the one or more frequency tunable resonators by applying a negative gain factor, and Q-enhance the one or more frequency tunable resonators by applying a non-negative gain factor.~~

~~23. A multipole filter comprising a plurality of variable analog filters of claim 17 connected in series, in parallel, or combinations thereof.~~

24. A method of filtering an analog electromagnetic signal, the method comprising ~~the steps of~~:

providing a filter comprising:

a signal loop comprising a signal path and a feedback path connected between a signal input and a signal output; and

a plurality of circuit elements connected in the signal loop, the plurality of circuit elements comprising:

a plurality of frequency tunable resonators ~~connected in series within the signal loop~~; and

an adjustable scaling block that applies a gain factor that is adjustable in a range that comprises a positive gain and a negative gain; and

tuning the frequency tunable resonators and adjusting the gain factor of the adjustable scaling block toward a desired frequency response.

25. The method of claim 24, further comprising ~~the step of~~ controlling a phase shift within the signal loop by adjusting the frequency tunable resonators.

26. The method of claim 25, wherein controlling the phase shift comprises detuning the

frequency tunable resonators from a central frequency of the filter.

~~27. The method of claim 24, wherein the frequency tunable resonators and the adjustable scaling block are connected in series in the signal path of the signal loop.~~

~~28. The method of claim 24, wherein two or more frequency tunable resonators are connected in primary signal loops, the primary signal loops being connected in series within the signal loop, each primary signal loop comprising a primary adjustable scaling block that is adjusted between a negative gain factor and a positive gain factor.~~

~~29. The method of claim 24, wherein the frequency tunable resonators are selectively Q-spoiled or Q-enhanced toward the desired frequency response.~~

~~30. The method of claim 29, wherein the frequency tunable resonators are Q-spoiled by applying a negative gain factor or Q-enhanced by applying a non-negative gain factor.~~

27. A multistage analog filter circuit, comprising:

a plurality of filter elements, wherein the plurality of filter elements comprises a variable filter as defined in any one of claims 1 – 8 and 15 - 23.

28. The multistage analog filter circuit of claim 27, wherein two or more filter elements are in parallel or in series.