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;

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

a frequency tunable resonator; and

a primary 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 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.

4. The variable filter of claim 1 or 2, wherein the controller is programmed to selectively Q-spoil or Q-enhance one or more frequency tunable resonators toward a desired frequency response.

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

6. The variable filter of any one of claims 1 - 5, 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.

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

8. The variable filter of any one of claims 1 - 5, 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 variable filter.

9. The variable filter of any one of claims 1 – 7, further comprising a sensor that measures 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.

10. The variable filter of claim 8, further comprising a sensor that measures the 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.

11. 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 – 10.

12. The multistage analog filter circuit of claim 11, wherein two or more filter elements are in parallel or in series.