

[54] **FREQUENCY AGILE-BASEBAND SIDELobe CANCELLER**

[75] Inventors: **Joseph F. Len**, Skaneateles; **Peter M. Rankin**, Syracuse, both of N.Y.

[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

[22] Filed: **Mar. 12, 1974**

[21] Appl. No.: **450,543**

[52] U.S. Cl. **343/18 E; 325/367; 325/371; 343/100 CL; 343/100 LE**

[51] Int. Cl. **G01s 7/36**

[58] Field of Search **343/18 E, 100 CL, 100 LE; 325/367, 369, 371**

[56] References Cited

UNITED STATES PATENTS

3,167,761 1/1965 LeParquier 343/100 LE X
3,177,489 4/1965 Saltzberg 343/100 LE

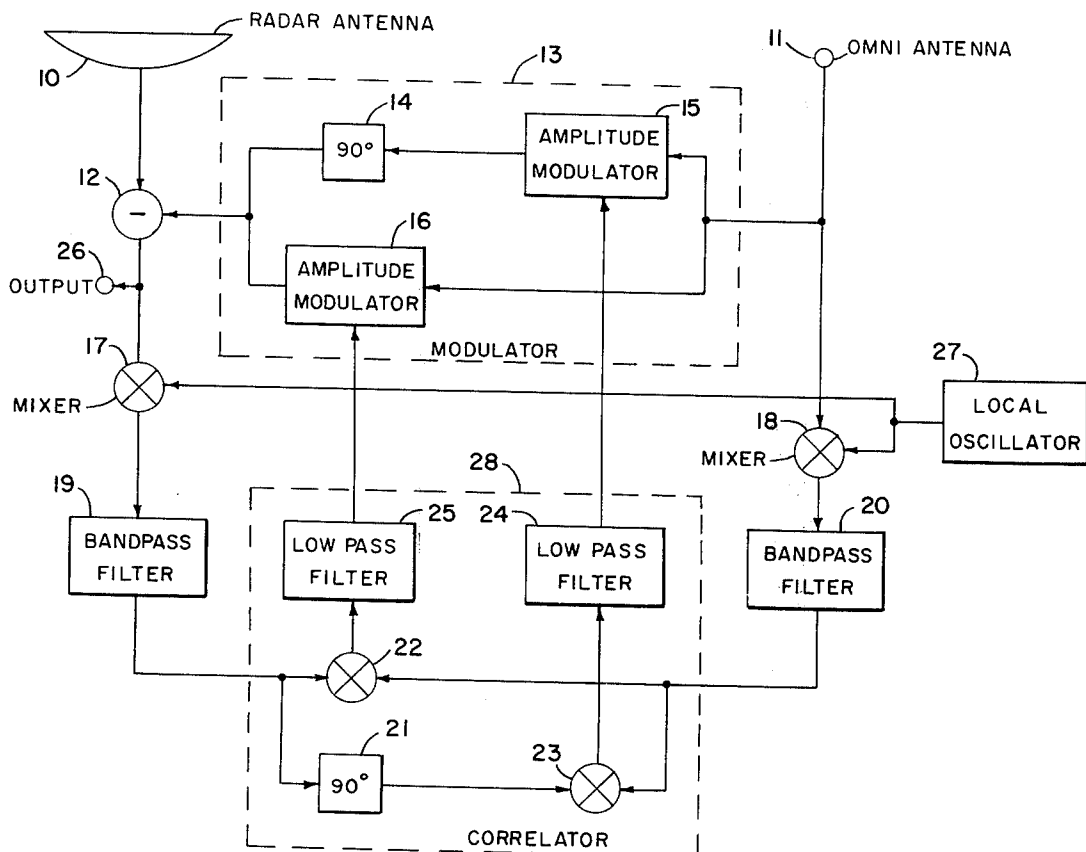
3,202,990 8/1965 Howells 343/100 LE
3,290,684 12/1966 Renn et al. 343/100 CL

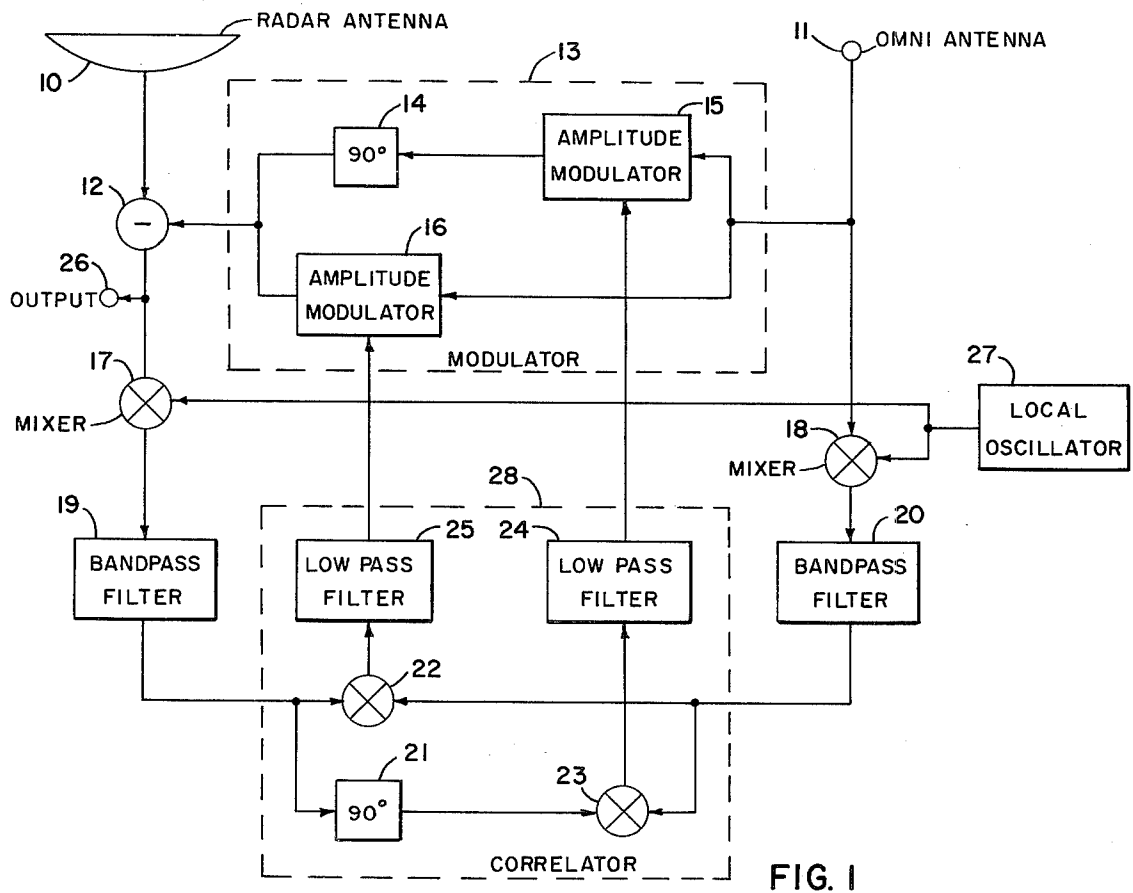
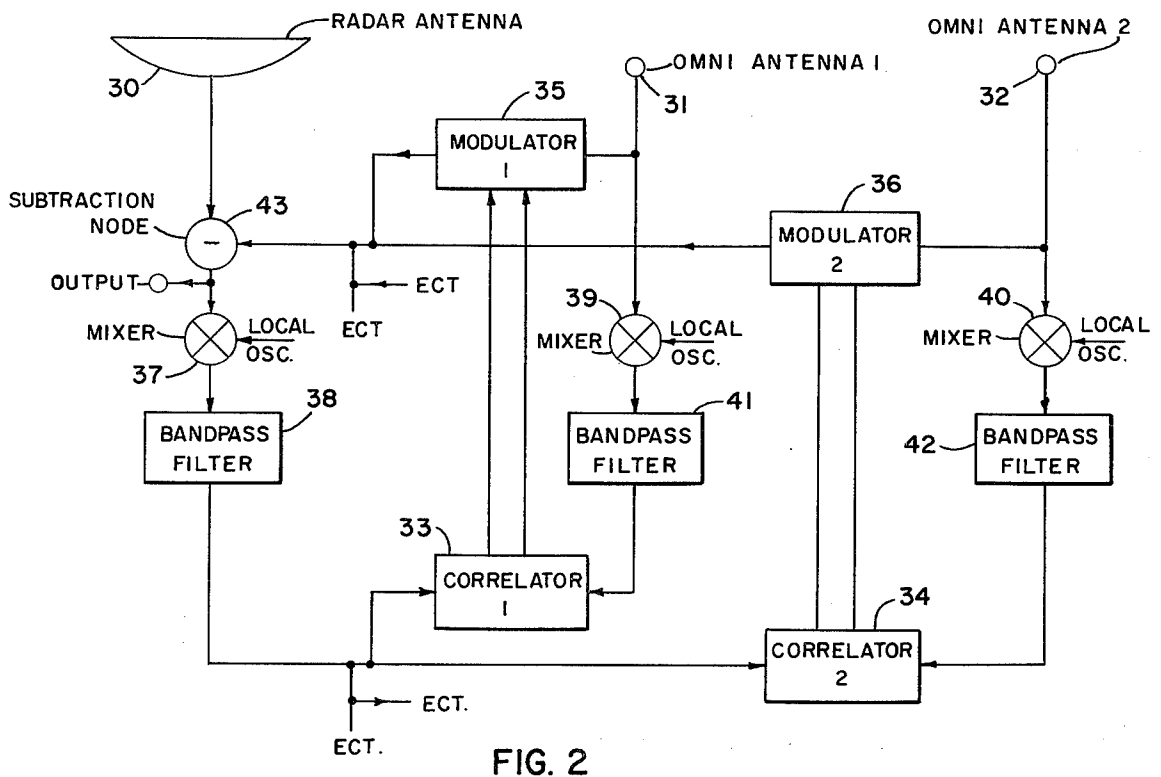
Primary Examiner—T. H. Tubbesing
Attorney, Agent, or Firm—Lawrence A. Neureither;
Joseph H. Beumer; Robert C. Sims

[57] ABSTRACT

Undesirable sidelobe signals are cancelled from the returns of a main radar by the use of an omni antenna which will receive the undesired signal. The signals from the main antenna and the omni antenna are mixed together in a correlator which detects phase and amplitude difference therebetween. The correlator feeds its output to a modulator which amplitude modulates a signal from the omni antenna and feeds it to a signal subtraction circuit which is in series with the main antenna's output. The correlator and the modulator are broken down into two parallel units which are 90° out of phase with each other.

4 Claims, 2 Drawing Figures





FREQUENCY AGILE-BASEBAND SIDELOBE CANCELLER

BACKGROUND OF THE INVENTION

This invention is related to the field of radar processing. More particularly the invention is related to the provision for countering anti-radar devices. U.S. Pat. No. 3,202,990 to P. W. Howells, patented in Aug. 24, 1965, shows an example of the prior art in this field. The patent to Howells suffers in many respects due to its transposing to an intermediate frequency before cancellation, and a need exist for a device which overcomes the limitations inherent in the Howells patent.

SUMMARY OF THE INVENTION

The phase and amplitude modulation of the omni directional antenna signal is performed by the use of two amplitude modulators which operate in parallel circuits which have a 90° phase shift between them at the carrier frequency. The difference signal between the main antenna and that subtracted from it by a subtraction circuit connected in the main radar antenna's receiving network is transposed into an intermediate frequency by the use of mixers, local oscillators, and bandpass filters. The same is done for the omni antenna received signals. The intermediate frequency of these two transposed signals are the same, and the bandpass filters in each channel are the same. These signals are then mixed together in two parallel baseband balanced mixers. One of the two parallel mixer circuits has a 90° phase shift at the intermediate frequency. The outputs of the mixers are low pass filtered and applied as the control signals for the two amplitude modulators in the two parallel circuits. The signal received in the omni directional antenna is distributed to these modulators. One of the parallel circuits contains a 90° phase shifter. The two parallel circuits are linearly summed to produce one output for the overall modulator. This output is fed to the subtraction circuit so as to provide a cancellation of undesired sidelobes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing a preferred embodiment of the invention; and

FIG. 2 is a block diagram of another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Sidelobe cancellation is a process by which interfering signals (such as produced by jammers) received through the sidelobe of an antenna are eliminated. The present invention uses omni directional antennas located near the principal antenna which also receives the undesired interfering signal. Optimum amplitude and phase modulations are applied to this signal which is then subtracted from the principal antenna signals. By having the proper phase and amplitude modulation applied, cancellation of the undesirable signals is achieved. The modulation values are derived by correlating the principal antenna output after subtraction of the modulated omni antenna signals with the direct omni antenna signals. These values are applied in a feedback loop such that the cancellation process is continuous and automatic.

The amplitude modulation of the omni directional antenna signals and the subtraction of the modulated

omni directional antenna signal from the main antenna is performed at the radio carrier frequency of the received signals. No transposing to an intermediate frequency by the use of mixers, local oscillators, and bandpass filters of the received signal before the cancellation mode is required or used. The phase and amplitude modulation of the omni directional antenna signal antenna is performed by the use of two amplitude modulators which operate in two parallel circuits which have a 90° phase shift between them at the carrier frequency. These two channels are referred to as the in-phase (I) and quadrature-phase (Q) channels.

Referring to the diagram of FIG. 1, the signals received in an omni directional antenna 11 are distributed to the modulator 13 and the mixer 18. The signal applied to the modulator is distributed to two parallel circuits each of which contain an amplitude modulator 15 or 16. One circuit contains a 90° phase shifter 14. The two parallel circuits are linearly summed to produce one output for the modulator. A summing circuit could be connected to the outputs of modulator 16 and phase shifter 14.

The output of modulator 13 is subtracted from the directional radar antenna 10 signals at the subtraction node 12. This is the cancellation node. The difference between the radar antenna signals and the modulated omni directional antenna signals is distributed to mixer 17 and to the sidelobe canceller output port 26. The output of local oscillator 27 is applied to mixers 17 and 18. The output signals of the mixers are filtered by the bandpass filters 19 and 20. These filters are identical in center frequency, bandwidth, and bandpass characteristics.

The outputs of the filters 19 and 20 are mixed together in the baseband mixers 22 and 23. The center frequency of the signals passed through filters 19 and 20 is the same; therefore the difference frequency components are base banded. The mixers are balanced such that one input signal from one filter cannot by itself produce a base banded output.

The mixer 23 is in a circuit which contains a 90° phase shift; therefore the unmodulated omni directional antenna signal (transposed to an intermediate frequency) is mixed with the main antenna/modulated omni directional antenna difference signal (transposed to the same intermediate frequency after it has been phase shifted 90°). The base banded difference signals desired from mixers 22 and 23 are low pass filtered by low pass filters 25 and 24 and applied as control signals for the amplitude modulators 16 and 15 respectively. Although not shown, linear amplifiers are employed at various points in the circuit with gains and dynamic ranges as are required by the specific application.

Since no frequency transposing or bandpass filtering is performed upon signals before the cancellation mode, channel match errors associated with mixing and band pass filtering are nonexistent in this circuit. The bandwidth over which signals are to be cancelled is not limited by frequency transposing or bandpass filtering processes. The bandwidth over which cancellation of signals will occur is only limited by the practical bandwidth of the modulator 13, circuitry of the cancellation node 12 and any linear amplifier which may be used in the circuits between the antennas and the cancellation node 12.

Desirable signals which are received in radar antenna 10 to be made available at output terminal 26 are not

required to pass through any mixers, bandpass filters, or other processes which would alter their characteristics in addition to that which is to be produced by the sidelobe canceller process itself. The output signals are available at the same carrier frequency and have not been required to pass through any bandpass filter. The center frequency and bandwidth for which the cancellation process is optimized is determined by signals which are applied to correlator 28. With the use of mixers 17 and 18, bandpass filters 19 and 20, and local oscillator 27, the center frequency and bandwidth of the antenna signals which are applied to the correlator 28 are selected.

With the use of base band feedback control signals, derived from the in-phase 22 and quadrature phase 23 mixers, flexibility of design is possible for the low pass filters 24 and 25. Multiple pole and zero filter designs are practical and sample and hold processes for the feedback control signals are possible.

The function of the circuit in FIG. 1 is to subtract from the main antenna output those signals that have been received by omni antenna 11 after they have been complex modulated; that is, after the phase and the amplitude of the omni antenna signals have been modulated. Modulator 13, therefore, is a complex modulator that achieves an equivalent phase and amplitude modulation by means of two amplitude modulators, which operate on the signal and on a 90° phase shifted sample of the signal. The remaining circuitry in FIG. 1 generates the decreased control signal from complex modulator 13. Correlator 28 is a complex correlator measuring the effective magnitude and phase angle of the correlator between the signals out of bandpass filters 19 and 20. Bandpass filters 19 and 20 determine the bandwidth of the signals to be correlated.

Mixers 17 and 18 together with local oscillator 27 allow the bandpass filtering function and the correlation process to take place at a carrier frequency independent of the carrier frequency at which the modulation and subtraction processes take place.

A feedback loop exists because the process of changing the modulator control signal changes the nature of the signal subtraction at 12, which changes the correlation of signals 19 and 20, and thus the control signal out of correlator 28. In the given configuration, the loop feedback drives the modulator so that the signal in output channel 26 is not correlated with the signal of bandpass filter 20, which was obtained from omni antenna 11. Thus the processor in FIG. 1 coherently subtracts signals out of the radar antenna output, which are correlated with signals received in omni antenna 11 automatically by means of a rapidly conveying feedback loop. The loop power gain is proportional to the power received by the omni antenna; therefore the loop will cancel jamming signals which have a high average power, while it is relatively insensitive to target returns which have low average power. In this way the system is able to discriminate between the two.

FIG. 2 is a block diagram of a multiple loop cancellation processor capable of processing and, therefore, cancelling a number of independent signals received in the radar antenna. The process is, in effect, a multiple processor of the type defined by FIG. 1, but which has a multiple dimensional capacity capable of processing as many different signals as there are cancellation loops. In general, signals are defined to be different

when they are received from widely separate angles of arrival.

The following example describes the operation of the multiple loop processor. Assume a quiescent state in which no signals are received in any of the antennas 30-32, the correlators 33 and 34 outputs are zero, and therefore, the modulators 35 and 36 are off. Allow an environment consisting of a number of signals arriving from widely separate angles to suddenly appear at the antenna outputs. Each correlator will start to generate an output that is representative of the correlation of the multiple signals received in its antenna (by way of mixers 39 and 40 and filters 41 and 42) and the multiple signals received in the radar antenna. Initially the modulators are off so that the unprocessed radar antenna signal will appear by way of mixer 37 and filter 38 at one input of each of the correlators. The initial value of the correlation output applied to the modulator will result in a relatively small reduction of the radar antenna waveform. The initial reduction is small because the initial value of the control voltages for each modulator were derived independently of the effect of the other modulators on reducing the waveform. The process is convergent however, and a relatively large reduction is achieved if the number of independent loops is equal to or greater than the number of independently received signals. In the converging process, the output of the subtraction node is continuously being correlated in each loop with the signals received in the loop's omni antenna. As long as some part of the subtraction node 43 output is correlated with a loop's omni antenna inputs, the loop's modulator is adjusted to subtract the signals, resulting in a further reduction or cancellation of the radar antenna signals.

As can be seen from FIG. 2 each omni antenna is connected in a separate cancellation loop. Each loop consists of the omni antenna, mixer, bandpass filter, correlator, and a modulator. If further omni antennas are to be used in the system shown in FIG. 2, further cancellation loops will be provided with the output of the modulator in each cancellation loop connected as indicated by "ECT," and the input to the further correlators would be fed from the bandpass filter 38 by way of connections indicated as ECT. In this way a plurality of additional cancellation loops connected in the same manner as that for the omni antenna 1 can be added to the system shown in FIG. 2 so as to provide cancellation of other undesired signals which may be received by radar antenna 30.

We claim:

1. A system comprising a main signal path containing therein a desired and an undesired signal; a second signal path containing therein primarily the undesired signal; cancellation means connected in the main signal path for substantially cancelling the undesired signal therein; correlator means connected to said main signal path and said second signal path so as to measure the amplitude and phase difference of the undesired signal in each of these paths; modulator means having inputs connected to outputs of said correlator means and said second signal path; an output of said modulator means being connected to said cancellation means so as to subtract the output signal of the modulator from the signals contained in said main signal path; said modulator means amplitude modulating the undesired signal in said second path such that the signal and its output is of the proper phase and amplitude to cancel in the can-

5

cellation means the undesired signal in said main signal path; said main signal path is connected to an output terminal; said cancellation means is connected between the main signal path and said output terminal; said correlator means and said modulator means each contain two parallel paths; one path containing a 90° phase shifting means therein; said correlator means contains first and second mixer means each having first and second inputs and an output; said first and second mixer means being connected in different ones of the two parallel paths of the correlator means; one input of the first mixer means is connected to the main signal path and the other input of the first mixer means is connected to said second signal path; one input of the second mixer means is connected through the 90° phase shifter to the main signal path, and the other input is connected to said second signal path; said modulator means containing first and second amplitude modulators in separate ones of the two parallel paths of the modulator means; said first and second modulators each having two inputs and an output; the output of the first mixer means being connected to one input of the first modulator; the other input of the first modulator being connected to said second signal path; the output of the second mixer means being connected to one input of said second modulator; the other input of the second modulator being connected to said second signal path; the output of said second modulator being connected through the

6

90° phase shifter to the input of said cancellation means; and the output of said first modulator being connected to the input of said cancellation means.

2. A system as set forth in claim 1 further comprising third and fourth mixer means each having first and second inputs and an output; a local oscillator having an output connected to one input of each of said third and fourth mixer means; the other input of said third mixer means being connected to said main signal path; the other input of said fourth mixer means being connected to said second signal path; first and second bandpass filters; the output of said third mixer means being connected through said first bandpass filter to the input of said first mixer means; and the output of said fourth mixer means being connected through said second bandpass filter to an input of said second mixer means.

3. A system as set forth in claim 2 further comprising a plurality of additional second signal paths each containing undesired signals which are to be found in said main signal path; and a plurality of additional correlators and modulators associated with the additional second signal paths and connected in the manner of said original second signal path.

4. A system as set forth in claim 3 wherein said main signal path is supplied by a directional radar antenna; and said plurality of second signal paths each being fed by one of a plurality of omni antenna.

* * * * *

30

35

40

45

50

55

60

65