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ANTENNA SIDE LOBE SUPPRESSION SYSTEM

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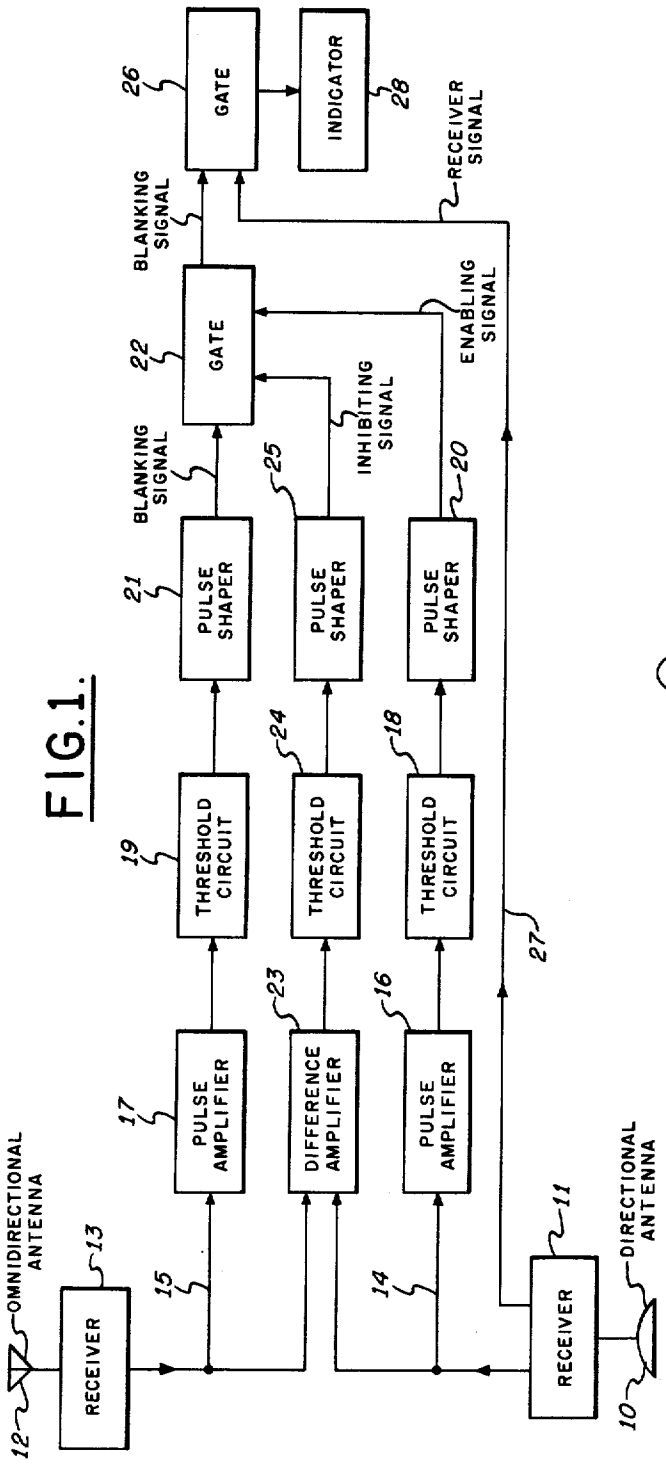


FIG. 1.

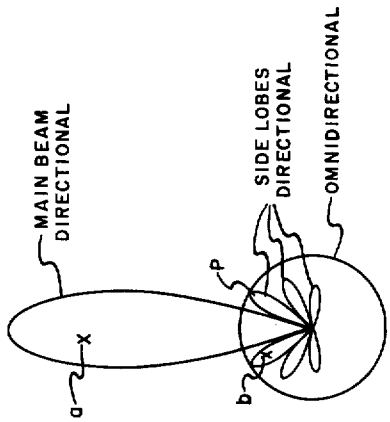


FIG. 2.

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ANTENNA SIDE LOBE SUPPRESSION SYSTEM

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This invention relates to receiving systems associated with electromagnetic wave directional antennas and, more particularly, to means for suppressing undesirable signals received in the side lobes of the directional antenna pattern.

In radar systems and quite often in commercial communications systems, electromagnetic energy is radiated and received by antennas which have highly directional patterns. These directional antenna patterns are characterized by a main beam in which most of the energy is radiated and received. The antenna patterns also include several minor lobes located on each side of the main beam and oriented at different angles to the main beam. In a receiving directional antenna system, electromagnetic energy not received in the main beam may be received in a side lobe. This may result when the receiving antenna is located in a congested area, or may result from intentional efforts to interfere with the reception of signals in the main beam. The reception of signals in the side lobes of a radar system gives rise to the presentation of false targets, or jamming, and in a communications system causes interfering cross-talk in the received signal.

It is an object of this invention to eliminate signals received in the side lobes of a directional antenna pattern whenever corresponding signals are not also received in the main beam of the antenna pattern.

Another object of this invention is to blank the indication of undesirable signals received in the side lobes but not in the main beam of a directional antenna pattern.

A further object of this invention is to derive signals corresponding to electromagnetic waves received in the main beam of a directional antenna and to eliminate signals corresponding to electromagnetic waves received in the side lobes of the antenna pattern but not simultaneously received in the main beam of the antenna pattern.

Still another object of this invention is to indicate the reception of energy in the main beam of such a directive antenna system at power levels below those heretofore usable with this type of device.

These and other objects and advantages of the invention, which will become more apparent from the specification and claims below, are accomplished in a receiving system having a directional antenna by also providing an omnidirectional receiving antenna and associated receiver means at the receiving location. The signal gain of the antenna-receiver combination of the omnidirectional antenna is made substantially equal to the principal side lobe signal gain of the antenna-receiver combination of the directional antenna. Because of this, the magnitude of a received signal received from the principal side lobe but not in the main beam of the directional antenna will be substantially equal to the magnitude of the corresponding received signal simultaneously received from the omnidirectional antenna. A signal received in the main beam of the antenna, however, will be greater in magnitude than the corresponding signal simultaneously received in the omnidirectional antenna since the main beam directional antenna gain is considerably greater than the side lobe directional antenna gain. Signals corresponding to electromagnetic waves received by each antenna are respectively coupled to two input terminals of a gating means. A third signal is produced proportional to the difference in the magnitudes of the respective signals from the directional antenna and omnidirectional antenna (when the directional signal is greater than the omnidirectional signal) and also is coupled to said gating means.

The signal from the omnidirectional antenna comprises a blanking signal when passed by the gate, and the signal from the directional antenna comprises an enabling signal to enable said gate when only said blanking and enabling signals occur simultaneously. The above-mentioned difference signal comprises an inhibiting signal which inhibits the gate and blocks the blanking signal whenever the inhibit signal is present. The output of the gate is coupled to an indicator and operates to block the presentation of I.F. signals from the directional antenna when no signal is received in the main beam of the directional antenna, that is, when a difference, or inhibit, signal is not produced. However, when an inhibit signal is produced, the gate is disabled and prevents the formation of a blanking signal, thus allowing the indicator to display the presence of a signal received in the main beam of the directional antenna.

The present invention will be explained in connection with the accompanying drawings, wherein:

FIG. 1 is a block diagram of the side lobe blanking system of the present invention; and

FIG. 2 is an illustration of the antenna patterns which are characteristic of the directional and omnidirectional antennas employed in the present invention.

Referring now in more detail to the drawings, a directional antenna **10** is coupled to receiver **11** which produces video signals in response to R.F. signals received by directional antenna **10**. For the sake of an example in this discussion it will be assumed that received signals will be in the form of pulses of electromagnetic energy, such as radar echo pulses reflected from a remotely located object. Directional antenna **10** has a radiation pattern as illustrated in FIG. 2, comprised of a main beam and a plurality of side lobes which decrease in magnitude as a function of their angular separation from the main beam.

The system illustrated in FIG. 1 also includes an omnidirectional antenna **12** and an associated receiver **13**. Omnidirectional antenna **12** has a pattern as illustrated in FIG. 2. The signal gain of the omnidirectional antenna 12-receiver **13** combination is chosen to be substantially equal to the principal side lobe "*p*" signal gain of the directional antenna 10-receiver **11** combination. As a result of this, an R.F. signal received only in the principal side lobe "*p*" of the directional antenna **10** and by the omnidirectional antenna **13**, but not in the main beam of directional antenna **10**, will result in substantially equal video signals being produced at the outputs of the respective receivers **11** and **13**. A signal received in the main beam of the directional antenna **10** and by omnidirectional antenna **12**, however, will result in a video signal from receiver **11** being greater in magnitude than the corresponding video signal from receiver **13**.

The video signals from receivers **11** and **13** are coupled over respective leads **14** and **15** to respective pulse amplifiers **16** and **17**. From pulse amplifiers **16** and **17** the respective signals are coupled to threshold circuits **18** and **19**. These circuits are substantially identical and operate to pass signals which exceed a predetermined magnitude, this magnitude being chosen to exceed the noise level of the signals, therefore to separate the signals from the noise. The respective signals which exceed the threshold level then are coupled to pulse shapers **20**, **21**, and then to gate **22**.

The video signals from receivers **11** and **13** also are coupled to a difference amplifier **23** which produces an output signal whose amplitude is a function of the difference in magnitude between the two signals simultaneously applied to its input terminals. This difference signal then is coupled to threshold circuit **24** which is similar to the

previously described threshold circuits **18**, **19** and operates to separate the difference signal from the noise. Threshold circuit **24** also performs the selective function of passing a difference signal when, and only when, the magnitude of the directional antenna video signal exceeds by a predetermined amount the magnitude of the omnidirectional antenna video signal. The output of threshold circuit **24** is passed through pulse shaper **25** to an input terminal of gate **22**.

Gate **22** may be a logical AND circuit which produces an output signal when and only when every input is in a prescribed state. In this instance, the prescribed states for the respective input signals are as follows: a signal from omnidirectional antenna **13**, a signal from directional antenna **10** and no difference signal from threshold circuit **24**. When these conditions are present a signal will be passed through gate **22** to a second gate **26**. These prescribed conditions arise only when signals are received in the omnidirectional antenna **12** and in side lobes but not the main beam of directional antenna **10**.

For convenience in the following discussion, a received omnidirectional antenna signal coupled into gate **22** will be called a blanking signal, a received signal from directional antenna **10** coupled into gate **22** will be called an enabling signal, and a difference signal coupled from difference amplifier **23** and threshold circuit **24** into gate **22** will be called an inhibiting signal.

The directional antenna video signal from receiver **11** also is coupled over lead **27** into gate **26**, and is passed through said gate to indicator **28** to present an indication of detected targets only when a blanking signal from gate **22** is not simultaneously present.

In discussing the operation of the blanking system of this invention it first will be assumed that a reflected or radiated energy source is located in the main beam of the directional antenna, as at "*a*" in FIG. 2, so that signals are received in the main beam by the directional antenna **10**, as well as by the omnidirectional antenna **12**. Receivers **11** and **13** respond to the received signals to produce corresponding video signals which are coupled through respective pulse amplifiers **16** and **17**, through threshold circuits **18** and **19** where the signals are separated from the noise, and through pulse shapers **20** and **21** to produce respective enabling and blanking signals which are coupled to logical AND gate **22**.

The respective video signals from directional antenna receiver **11** and omnidirectional antenna receiver **13** are coupled to difference amplifier **23** and because the signal gain of the main beam directional antenna-receiver combination is greater than the signal gain of the omnidirectional antenna-receiver combination, the directional antenna video signal will be greater in magnitude than the corresponding simultaneously occurring omnidirectional antenna received signal, thus resulting in an output signal from difference amplifier **23**. This difference signal is coupled through threshold circuit **24** where it is separated from the noise, is coupled through pulse shaper **21** and then to gate **22** as an inhibit signal. This inhibit signal causes gate **22** to be in a blocked condition to prevent the passage of the blanking signal from omnidirectional antenna **12**. Therefore, because there is no blanking signal passed by gate **22** to the input to gate **26**, the directional antenna video signals coupled from receiver **11** over lead **27** to gate **26** will be passed by gate **26** to indicator **28** which will present an indication of the target in the main beam of the directional antenna pattern.

In contrast to the above-described mode of operation, consider next the operation of the system when a signal is received in the principal side lobe but not in the main beam of the directional antenna pattern, as at "*b*" in FIG. 2. A corresponding signal will be simultaneously received by the omnidirectional antenna **12**. Received video signals from directional antenna receiver **11** and omnidirectional antenna receiver **13** will be respectively coupled over leads **14** and **15**, through pulse amplifiers **16** and **17**, threshold circuits **18** and **19**, pulse shapers **20** and **21** in the manner previously explained, and corresponding enabling and blanking signals will be coupled to gate **22**. In this instance, the magnitudes of the directional antenna video signal and the corresponding omnidirectional antenna video signal will be substantially equal as a result of the two antenna-receiver gain characteristics being chosen as explained previously. Therefore, there will be no output signal from threshold circuit **24** and no inhibiting pulse will be coupled to gate **22**. Logical AND gate **22** therefore has its three input signals in the prescribed conditions and will pass the blanking pulse to gate **26**. This blanking pulse blocks gate **26** and prevents the directional antenna video signals on lead **27** from being coupled to indicator **28**. There therefore will be no indication of the signal which is received in the side lobe but not simultaneously received in the main beam of the directional antenna pattern.

Because difference amplifier **23** and threshold circuit **24** will produce an inhibit signal only when the directional antenna video signal is greater in magnitude than the omnidirectional antenna video signal, the system of this invention also will operate as just described to blank the indicator in the event that signals are received in the minor side lobes of the directional antenna but not in the main beam.

From the discussion of the operation of this invention it is apparent that the functioning of gates **22** and **26** in response to their respective input signals provides unambiguous operation of the system to blank the indicator whenever a signal is not received in the main beam of the directional antenna. One of the important features which provides the unambiguous operation of the system is the generation of the inhibit signal to block the blanking signal only when the magnitude of the directional antenna signal exceeds the magnitude of the omnidirectional antenna signal. Because of the parameters chosen for the system, this condition can occur only when a signal is received in the main beam of the directional antenna, and thus the indicator can display only these main beam directional antenna signals.

While the invention has been described in its preferred embodiments, it is understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. In a directional antenna system means for suppressing side-lobe signals comprising a directional receiving antenna having a directional pattern including a main beam and a side lobe, an omnidirectional receiving antenna, receiving means for deriving a signal in response to electromagnetic waves received by said directional antenna, receiving means for deriving a signal in response to electromagnetic waves received by said omnidirectional antenna, the signal gain of said omnidirectional antenna and receiver combination being substantially equal to the side lobe signal gain of said directional antenna and receiver combination, an indicator means for providing an indication of signals coupled thereto, separate means for coupling received signals from said directional antenna to said indicator means, normally closed switching means for coupling said received directional antenna signals to said indicator means, means for controlling said switching means, means for producing blanking signals in response to signals received from said omnidirectional antenna, means for producing enabling signals in response to signals received from said directional antenna, means for producing an inhibiting signal whenever the magnitude of signals from said directional antenna exceeds by a predetermined amount the magnitude of signals simultaneously received from said omnidirec-

tional antenna, means for coupling said blanking, enabling and inhibiting signals to said controlling means, said controlling means operating in response to said three last-named signals coupled thereto to block the passage of received signals from said directional antenna to said indicator means when only blanking and enabling signals occur simultaneously and operating to permit the coupling of said received signals from said directional antenna to said indicator means when an inhibiting signal occurs.

2. In a directional antenna system means for suppressing side-lobe signals comprising a directional receiving antenna having a directional pattern including a main beam and at least one side lobe, an omnidirectional receiving antenna, receiving means for deriving a signal in response to electromagnetic waves received by said directional antenna, receiving means for deriving a signal in response to electromagnetic waves received by said omnidirectional antenna, the signal gain of said omnidirectional antenna and receiver combination being substantially equal to said one side lobe signal gain of said directional antenna and receiver combination, an indicator means for providing an indication of signals coupled thereto, separate means for coupling signals received from said directional antenna to said indicator means for indication thereon, threshold means coupled to said omnidirectional antenna receiving means for providing blanking signals whenever the signals from the omnidirectional receiving means exceed a predetermined value, coupling means interconnecting said threshold means and said indicating means to blank said indicating means when said blanking signals are coupled thereto, control means for controlling the coupling of said blanking signals to said indicator means and including means for producing enabling signals in response to signals received from said directional antenna to permit said blanking signals to blank said indicator when only said blanking signal and said enabling signals simultaneously are present, said control means further including means producing an inhibiting signal whenever the magnitude of signals received from said directional antenna exceeds by a predetermined amount the magnitude of signals simultaneously received from said omnidirectional antenna, said control means operating in response to the occurrence of said inhibiting signals to block the passage to said indicator means of blanking signals occurring simultaneously therewith.

3. In a directional antenna system means for suppressing side-lobe signals comprising a directional receiving antenna having a directional pattern including a main beam and at least a principal side lobe, an omnidirectional receiving antenna, receiving means for deriving a signal in response to a signal received by said directional antenna, receiving means for deriving a signal in response to a signal received by said omnidirectional antenna, the signal gain of said omnidirectional antenna and receiver combination being substantially equal to the principal side-lobe signal gain of said directional antenna and receiver combination, an indicator means for providing an indication upon the occurrence of signals being coupled thereto, gating means having first and second input terminals and having an output terminal coupled to said indicator means, means for coupling signals received by said directional antenna to the first input terminal of said gating means, said gating means normally being in a state to pass said directional antenna signals but being adapted to block the passage therethrough of said directional antenna signals upon the presence of a blanking signal on its second input terminal, means for coupling signals received from said omnidirectional antenna to said gating means, said omnidirectional antenna signals constituting said blanking signals, means controlling the coupling of said blanking signals to said gating means, said controlling means including means for providing an enabling signal in response to signals from said directional antenna, said controlling means operating in response only to said blanking signals and said enabling signals to pass said blanking signals to said gating means, said controlling means further including means providing an inhibiting signal when the magnitude of a signal received by said directional antenna exceeds by a predetermined amount the magnitude of a corresponding signal simultaneously received by said omnidirectional antenna, said controlling means operating in response to said inhibiting signals to prevent the coupling of simultaneously occurring blanking signals to said gating means, whereby said indicator means is blanked upon the presence of signals in a side lobe but not the main beam of said directional antenna and is unblanked to receive signals from the directional antenna upon the presence of a signal in the main beam of said directional antenna.

4. In a directional antenna system means for suppressing side-lobe signals comprising a directional receiving antenna having a directional pattern including a main beam and at least a principal side lobe, an omnidirectional receiving antenna, receiving means for deriving a signal in response to a signal received by said directional antenna, receiving means for deriving a signal in response to a signal received by said omnidirectional antenna, the signal gain of said omnidirectional antenna and receiver combination being substantially equal to the principal side lobe signal gain of said directional antenna and receiver combination, means for producing a blanking signal in response to the received signal from said omnidirectional antenna receiver, means for producing an enabling signal in response to the received signal from said directional antenna receiver, a gating means coupled to receive said blanking signal and said enabling signal and adapted to pass said blanking signal if both said blanking signal and said enabling signal are present simultaneously, means for producing an inhibiting signal when and only when the magnitude of a received signal from said directional antenna receiver exceeds by a predetermined amount the magnitude of a simultaneously received signal from said omnidirectional antenna receiver, means for coupling said inhibiting signal to said gating means, said gating means operating to block the passage of said blanking signal when an inhibiting signal is coupled simultaneously thereto, a second gating means coupled to receive the output of said first gating means, means for coupling the received signals from said directional antenna to said second gating means, said second gating means being normally operative to pass the received signal from said directional antenna but being blocked to prevent passage of said received signals when a signal from said first gating means is coupled thereto, and an indicator means coupled to said second gating means for providing an indication of signals coupled thereto.

5. In a directional receiving system of the type in which a directional antenna has a primary radiation pattern in space and an omnidirectional antenna has an auxiliary radiation pattern in space, said primary radiation pattern being greater than said auxiliary radiation pattern in a desired directional region, said system further having individual receivers connected to each antenna, and a comparison circuit wherein the outputs of the two receivers are combined so as to produce an output signal when and only when a signal received in the directional antenna exceeds by a given amount the magnitude of a signal received simultaneously in the omnidirectional antenna, the improvement comprising means for producing a blanking signal when and only when the magnitude of a received signal from said omnidirectional antenna receiver exceeds a predetermined value, means for producing an enabling signal when and only when the magnitude of the received signal from the directional antenna receiver exceeds a predetermined value, a first gating means coupled to receive said blanking signal and said enabling signal and adapted to pass said blanking signal if both said blanking signal and said enabling signal appear simultaneously, a pulse shaper coupled to the out-

put of said comparison circuit and adapted to form an inhibiting pulse in response to the output signal of said comparison circuit, means for coupling said inhibiting signal to said first gating means, said first gating means operating to block the passage of said blanking signals when an inhibiting signal is coupled simultaneously thereto, a second gating means coupled to receive the output of said first gating means, separate means for coupling signals directly from said directional antenna receiver to said second gating means, said second gating means being normally operative to pass all signals from said directional

antenna receiver, but being blocked to prevent the passage of said received signals when a blanking signal from said first gating means is coupled thereto, and an indicator means coupled to said second gating means for providing indications of directional antenna receiver signals coupled therethrough.

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