

PATENT SPECIFICATION

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(54) RADAR SYSTEMS

(71) We, JAMES SCOTT (ELECTRONIC ENGINEERING) LIMITED, a British company of Carntyne Industrial Estate, Glasgow G32 6AB, Scotland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to radar systems, and more particularly to continuous wave Doppler radar systems.

According to Claim 1 of our Patent No. 1,289,496 a continuous wave Doppler radar system includes a microwave frequency generator comprising a Gunn effect device mounted in a resonant cavity, two mixer diodes to which in operation received signals are supplied, the diodes also having supplied thereto local oscillator signals derived from said generator, the phase of one local oscillator signal being displaced by 90° relative to the other, and means to derive from the signals supplied by the diodes an indication of the velocity and direction of motion of a target.

According to the present invention there is provided a continuous wave Doppler radar system including a microwave frequency generator comprising a Gunn effect device mounted in a resonant cavity, two mixer diodes to which in operation received signals are supplied, the diodes also having supplied thereto local oscillator signals derived from said generator, the positioning of the diodes relative to one another and to the Gunn effect device being such that at the diodes the phase of one local oscillator signal is displaced by 90° relative to the other and the received signals are in phase, and means to derive from the signals supplied by the diodes an indication of the direction of motion of a target.

Preferably the cavity is a tunable waveguide cavity, and is coupled directly to a transmitting and receiving aerial, which may be a horn antenna. Said diodes may be positioned in a first resonant cavity with said Gunn effect device positioned in a second resonant cavity which is coupled to the first cavity.

As compared with the embodiment des-

cribed in the complete specification of our above-mentioned patent therefore, embodiments of the present invention are substantially simplified because they do not need a non-reciprocal phase shifter for causing said relative phase displacement of the local oscillator signals.

Two radar systems in accordance with the present invention will now be described by way of example with reference to the accompanying drawing, in which:

Figure 1 shows a part of a first radar system diagrammatically,

Figure 2 shows diagrammatically how the positions of some elements of the first system are calculated, and

Figure 3 shows a part of a second radar system diagrammatically.

The first radar system to be described is a miniature continuous wave Doppler radar system in which a Gunn effect device is used as the microwave frequency generating element and preferably solid state circuitry is used for the data recovery circuits. The operation is such that both the velocity and the direction of motion of a target can be determined.

The Gunn effect device is based on the effect that periodic fluctuations occur in the current passing through a thin wafer of n-type gallium arsenide when the applied electric field exceeds a threshold value in the region of 3000 volts/cm. By suitable choice of wafer thickness the frequency of oscillation can be made to lie in the microwave region, and the microwave output from the device becomes fully coherent if it is inserted in a resonant cavity. When this is done the oscillation frequency can be tuned over a wide frequency range by altering the size of the resonant cavity.

Referring now to Figure 1, the first radar system comprises a transmitting and receiving aerial 1 formed by a standard horn antenna which is coupled to a tunable waveguide cavity 2 of rectangular cross-section, the Q of which may be approximately 50. Mounted in the cavity 2 is a Gunn effect device 3 having an input terminal 4, and insulation 5 to insulate it from the wall of the cavity 2. The cavity

2 is tunable by a variable short circuit 6 and two tuning screws 7.

Axially spaced apart in the cavity 2 so as to be one each side of the Gunn effect device 3 are two similar mixer diodes 8 and 9 having output terminals 10 and 11 respectively, and insulation 12 and 13 to insulate them from the wall of the cavity 2. Preferably the diodes 8 and 9 are Schottky diodes.

The system operates on the homodyne principle. The Gunn effect device 3 generates a continuous wave signal of 13.6 GHz which provides both the transmitted signal of some 5mW, and a local oscillator signal for each of the diodes 8 and 9. The positioning of the diodes 8 and 9 relative to one another and to the Gunn effect device 3 is such that local oscillator signals supplied to the diodes 8 and 9. The positioning of the diodes 8 and 9 relative to one another and to the Gunn effect device 3 is such that local oscillator signals supplied to the diodes 8 and 9 and 90° out of phase relative to one another, and the received signals supplied to the diodes 8 and 9 are in phase.

Referring to Figure 2, the positions are as follows. The distance from the Gunn effect device 3 to the short circuit 6 is $n\lambda/2$, where n is an integer and λ the wavelength of the continuous wave signal. For the local oscillator signals to be 90° out of phase at the diodes 8 and 9: $R_1 - R_2 = \lambda/4$ whilst for the received signals supplied to the diodes 8 and 9 to be in phase: $R_1 + R_2 = m\lambda$ where m is an integer. If: $m = 1$ $R_1 = 5\lambda/8$ and $R_2 = 3\lambda/8$.

The incoming echo signal mixes with the local oscillator signals and the result is that each of the diodes 8 and 9 supplies a Doppler signal, which falls in the range 10 Hz to 30 KHz approximately for most targets. Both of these signals derived from the terminals 10 and 11 can be processed as described in the complete specification of our Patent No. 1,254,443 to provide an indication of the velocity of the target.

In addition, the described system enables the direction of motion of the target, that is to say approaching or receding, to be determined as explained theoretically on Page 82 *et seq* of "Introduction to Radar Systems" by M. I. Skolnik. From that theoretical discussion it will be seen that the direction of motion of the target can be determined by ascertaining whether the signal supplied by the diode 8 leads or lags the signal supplied by the diode 9. A convenient way of doing this is the electronic method described at Page 83 *et seq* of "Introduction to Radar Systems" by M. I. Skolnik.

Any other known method of determining the direction of motion of the target from the signals supplied by the diodes 8 and 9 can be used. For example the signals derived from the terminals 10 and 11 may be amplified and applied to a synchronous two-phase motor.

The sense in which the motor rotates then indicates the direction of motion of the target. A simple indicator coupled to the rotor of the motor therefore provides the required indication.

The second radar system, which is shown in Figure 3 to which reference is now made, is similar in form to and the same in operation as the first radar system. The same reference numerals are used where possible.

The differences between the two systems are that in the second only the diodes 8 and 9 are positioned in the cavity 2, the Gunn effect device 3 being in a separate cavity 14 attached to the cavity 2 between the diodes 8 and 9, and coupled to the cavity 2 by an H or E plane junction. The cavity 14 is tunable by a variable short circuit 15 and two tuning screws 16. The variable short circuit 6 can be replaced by a matched load.

The relative distances between the Gunn effect device 3 and the diodes 8 and 9 are calculated as described above for the first radar system.

The systems provide in simple and readily portable form a radar which gives indications both of the velocity and direction of motion of a target, and is thus suitable for many purposes for example in the industrial, research and traffic engineering fields.

Various modifications can of course be made without departing from the invention as defined by the appended claims. For example, in some applications only the directional information may be required, and not the velocity, and for such applications the velocity-determining circuits can be omitted.

WHAT WE CLAIM IS:—

1. A continuous wave Doppler radar system including a microwave frequency generator comprising a Gunn effect device mounted in a resonant cavity, two mixer diodes to which in operation received signals are supplied, the diodes also having supplied thereto local oscillator signals derived from said generator, the positioning of the diodes relative to one another and to the Gunn effect device being such that at the diodes the phase of one local oscillator signal is displaced by 90° relative to the other and the received signals are in phase, and means to derive from the signals supplied by the diodes an indication of the direction of motion of a target.

2. A system according to claim 1 including means to derive from the signals supplied by the diodes an indication of the velocity and direction of motion of a target.

3. A system according to claim 1 or claim 2 wherein said resonant cavity is a tunable waveguide cavity.

4. A system according to claim 1, claim 2 or claim 3 wherein said cavity is coupled directly to a transmitting and receiving aerial.

2 is tunable by a variable short circuit 6 and two tuning screws 7.

Axially spaced apart in the cavity 2 so as to be one each side of the Gunn effect device 3 are two similar mixer diodes 8 and 9 having output terminals 10 and 11 respectively, and insulation 12 and 13 to insulate them from the wall of the cavity 2. Preferably the diodes 8 and 9 are Schottky diodes.

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In addition, the described system enables the direction of motion of the target, that is to say approaching or receding, to be determined as explained theoretically on Page 82 *et seq* of "Introduction to Radar Systems" by M. I. Skolnik. From that theoretical discussion it will be seen that the direction of motion of the target can be determined by ascertaining whether the signal supplied by the diode 8 leads or lags the signal supplied by the diode 9. A convenient way of doing this is the electronic method described at Page 83 *et seq* of "Introduction to Radar Systems" by M. I. Skolnik.

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The sense in which the motor rotates then indicates the direction of motion of the target. A simple indicator coupled to the rotor of the motor therefore provides the required indication.

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Various modifications can of course be made without departing from the invention as defined by the appended claims. For example, in some applications only the directional information may be required, and not the velocity, and for such applications the velocity-determining circuits can be omitted.

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2. A system according to claim 1 including means to derive from the signals supplied by the diodes an indication of the velocity and direction of motion of a target.

3. A system according to claim 1 or claim 2 wherein said resonant cavity is a tunable waveguide cavity.

4. A system according to claim 1, claim 2 or claim 3 wherein said cavity is coupled directly to a transmitting and receiving aerial.



5. A system according to claim 4 wherein said aerial is a horn antenna.

6. A system according to any one of the preceding claims wherein said diodes are Schottky diodes.

7. A system according to claim 2 or any one of claims 3 to 6 as dependent on claim 2, comprising electronic means to derive said indication of the velocity and direction of motion of a target.

8. A system according to any one of claims 1 to 6 comprising a synchronous two-phase electric motor to which the signals supplied by the diodes are applied to derive said indication of the direction of motion of a target.

9. A system according to any one of the preceding claims wherein said diodes are positioned in a first resonant cavity and said Gunn

effect device is positioned in a second resonant cavity which is coupled to the first cavity.

10. A continuous wave Doppler radar system substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawing.

11. A continuous wave Doppler radar system substantially as hereinbefore described with reference to Figure 3 of the accompanying drawing.

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