(12) UK Patent Application (19) GB (11) 2 094 089 A

(21) Application No **8106447**
(22) Date of filing **2 Mar 1981**
(43) Application published **8 Sep 1982**
(51) **INT CL³ G01S 13/86**
(52) Domestic classification **H4D** 300 348 349 369 399 508 512 535
(56) Documents cited **None**
(58) Field of search **H4D**
(71) Applicants
Decca Limited,
Decca House,
9 Albert Embankment,
London SE1 7SW.
(72) Inventors
Charles Freeman Robinson
(74) Agents
Boult, Wade and Tennant,
27 Furnival Street,
London EC4A 1PQ.

(54) Distant transmitter range measurement

(57) Apparatus for measuring the range R of a distant radio transmitter Tx has a directional receiver Rx which can receive signals both directly from the transmitter Tx and indirectly reflected off a reflecting object Ob. The time delay τ between the incoming signals yields the difference in path length $\delta = c\tau$ and from this and the angle between the signals θ the range R is determined:

$$R = r\frac{1 - (\delta/2r)}{1 - (r/\delta)(1 - \cos\theta)}$$

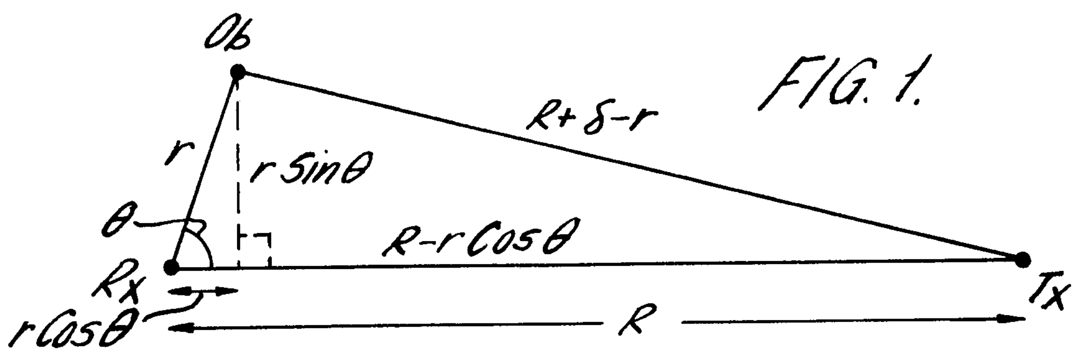


FIG. 1.

The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

GB 2 094 089 A

1/1

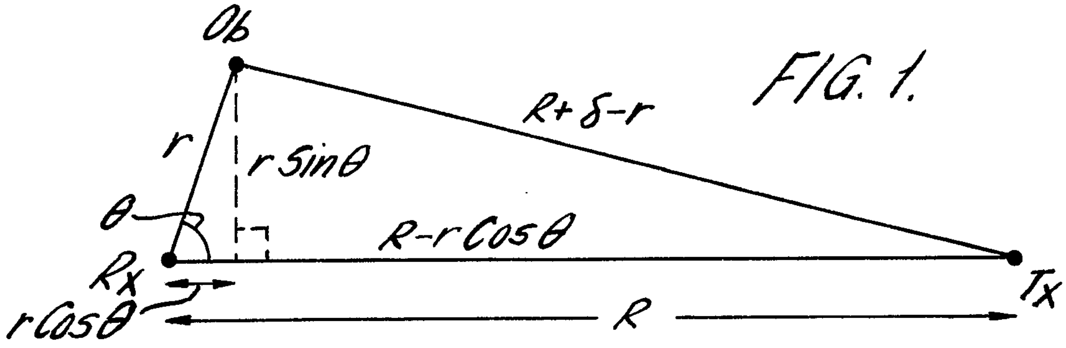
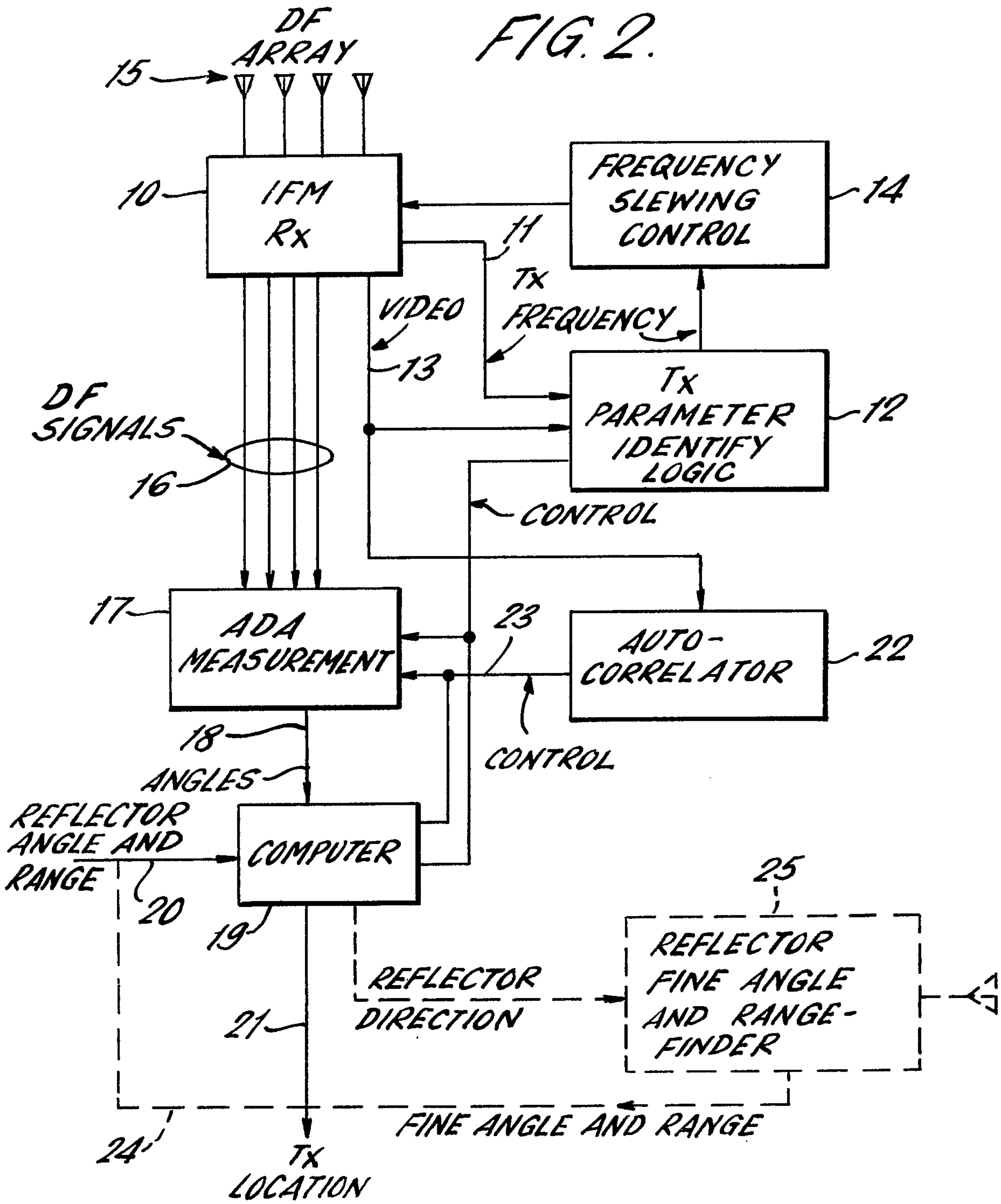

Ob
r
r Sinθ
R+δ-r
θ
R-r Cosθ
Rx
Tx
r Cosθ
R

FIG. 1.

FIG. 2.


DF ARRAY
15
10
IFM Rx
FREQUENCY SLEWING CONTROL
14
11
Tx FREQUENCY
VIDEO
13
Tx PARAMETER IDENTIFY LOGIC
12
DF SIGNALS
16
CONTROL
17
ADA MEASUREMENT
23
AUTO-CORRELATOR
22
18
ANGLES
CONTROL
REFLECTOR ANGLE AND RANGE
COMPUTER
20
19
25
REFLECTOR FINE ANGLE AND RANGE-FINDER
REFLECTOR DIRECTION
21
FINE ANGLE AND RANGE
24
Tx LOCATION

SPECIFICATION

Distant transmitter range measurement

The present invention relates to apparatus for and methods of measuring the range of distant radio transmitters. It is often desirable to locate the position of a distant radio transmitter, for example, a hostile radar or jamming transmitter. It is relatively straight forward to measure the bearing of the distant transmitter by radio direction finding techniques and it is also known to locate a distant transmitter by taking bearings from two or more spaced receiving stations and triangulating. However, it may also be desirable to be able to locate a distant radio transmitter from a single receiving site, for example, a ship at sea.

According to one aspect of the present invention, apparatus for measuring the range of a distant radio transmitter comprises a directional receiver capable of receiving radio signals both directly from the distant transmitter and indirectly reflected off a reflecting object at a determined range from the receiver and at an angle to the direct line from the transmitter, means to determine the difference between the angles of arrival at the receiver of the direct and indirect signals, means to measure the time delay of the received indirect signal relative to the received direct signal; and means to calculate from said determined range, said angle difference and said time delay the range of the transmitter from the receiver.

Operation of the present invention can best be understood by referring to Figure 1 of the accompanying drawings which is a geometrical representation of the distribution of a transmitter (TX), a receiver (RX) and a reflecting object (OB) in a single plane. The range of the transmitter relative to the receiver is R and the range of the reflecting object relative to the receiver is r. The range r of the object may be predetermined in that the receiver and object may be fixed relative to one another and the range known. However, in other arrangements the object may be movable relative to the receiver or, especially if the receiver is itself mobile, different objects may be employed as the reflecting object at different times. It is necessary only that the range of the object relative to the receiver can be accurately determined by existing range finding techniques, for example, either visual or radio. The apparatus of the present invention determines the angle θ between the radio signals received directly from the transmitter TX and those received reflected from the object OB. Assuming linear propagation of the radio signals, the angle θ is thus the angle between the lines joining the receiver and the transmitter and the receiver and the object respectively.

The apparatus also provides a figure for the time delay between the signals received directly and indirectly at the receiver. This provides directly a value δ ($= \tau c$) for the extra pathlength for radio signals travelling indirectly from the transmitter to the receiver and reflected by the object.

From simple trigonometry it is possible to derive the formula

$$r^2 \sin^2 \theta = (R+\delta-r)^2 - (R-r\cos\theta)^2.$$

Simple manuplilation of this formula produces

$$R = \frac{r\,1 - \frac{\delta}{2r}}{1 - \frac{r}{\delta}(1-\cos\theta)}$$

It can be seen therefore that the apparatus of invention can provide a value for R the range of the transmitter from the receiver.

Commonly, the receiver, transmitter and object are all in a horizontal plane. However, other arrangements are possible. For example the object may be elevated relative to the receiver and transmitter, e.g. a reflecting balloon tethered to a ship.

Preferably, the reflecting object should be approximately at 90° to the line to the transmitter.

In one arrangement, the apparatus includes a range finder to determine the range of the reflecting object from the receiver. This is especially useful when the reflecting object is a second ship for example. Then, said angle difference determining means may be operative to determine the angle of arrival relative to the receiver of at least the indirect signal and the range finder may be directional and arranged to be steered onto the direction of said determined angle of arrival. Conveniently, the range finder may be self-steering when locked onto a target and arranged to generate signals representing not only the determined range of the reflecting object but also the bearing and/or elevation of the object relative to the receiver, said means to calculate then receiving said range and bearing and/or elevation signals for use in calculating said transmitter range.

As mentioned before, in common arrangement the reflecting object is substantially at the same height as and horizontally spaced from the receiver. Then the directional receiver may be arranged to provide directional signals indicative of the angles of arrival in the horizontal plane of respective received radio signal pulses. When said time delay is greater than the pulse width of the transmitted signals, the directional receiver can provide successive signals indicative of the angles of arrival of direct and indirect signal pulses respectively.

Said time delay measuring means may include an auto correlator. Further, said means to calculate may include a programmed computer.

The invention also provides a method of measuring the range of a distant radio transmitter comprising determining the difference between the angles of arrival at a receiver of signals directly from the distant transmitter and signals indirectly reflected off a reflecting object at a predetermined range from the receiver and at an angle to the direct line from the receiver, measuring the time delay of the received indirect signal relative to the received direct signal, and calculating from said determined range, said angle difference and said time delay the range of the transmitter from the receiver.

An example of the present invention will now be described with reference to Figure 2 of the accompanying drawings which comprises a block schematic diagram of the major functional parts of the apparatus.

Referring to Figure 2, the receiver comprises an Instantaneous Frequency Measuring Receiver (IFM Rx)10. Such IFM receivers are well known in the art. They are broad band receivers sensitive to a range of transmitter frequencies which provide an output which is indicative of the frequency of any signals being received. This frequency output is provided on a line 11 to an Identification Unit 12. The amplitude characteristics of the received signal (i.e. the "video") is also provided by the receiver and fed to the identification unit 12 on a line 13. The identification unit 12 operates to compare the frequency and video characteristics of the received signal with stored characteristics and thereby provide an identification of the nature of the transmitter generating the signals being received. Identification units of this kind are also well known in this art.

The received frequency signal generated by the receiver 10 is also supplied via the unit 12 to a frequency slewing control unit 14. The receiver 10 is arranged so that it can be controlled by the unit 14 to become narrow band centered on the received signal frequency so as to cut out any extraneous signals at different frequencies once a distant transmitter has been identified. The identification unit 12 enables the receiver 10 to concentrate only on desired, typically hostile, transmitters. For example if the receiver 10 receives signals from a local or friendly transmitter which is identified as such in the unit 12, then the unit 12 prevents the slewing control unit 14 from concentrating the frequency response of the receiver 10 onto that known transmitter. Instead, the receiver can be concentrated automatically onto a hostile transmitter.

The receiver 10 is provided with an automatic direction finding antennae array 15. This array 15 may comprise at least 4 antennae pointing in the four orthogonal directions, in the horizontal plane. Once the receiver 10 is concentrated on the frequency of a "hostile" transmitter, the signals received in the four antennae 15 are fed, after suitable amplification, from the receiver 10 along lines 16 to an Angle of Arrival measuring unit 17. It will be appreciated that, when the receiver 10 is responsive to signals arriving at the antenn 15 from a single bearing, then the relative power levels or relative phases at any time of the signals in the lines 16 is indicative of the angle of arrival of the received signal. The AOA measuring unit 17 determines substantially instantaneously the angle of arrival of the received signals at any moment.

In the present invention, it will be appreciated that the signals being received at the receiver 10 are being received not only directly from the remote transmitter but also indirectly reflecting from a relatively nearby reflecting object. The signals received from the reflecting object are slightly delayed relative to the directly received signals. Where the signals from the remote transmitter are pulse signals, e.g. from a remote radar, and the pulses are sufficiently short, then the delay of the reflected signals can be greater than the pulse width of the received signals. The signals delivered along lines 16 to the AOA measuring unit 17 can then be seen as initially the received pulse directly from the remote transmitter, followed by the echo pulse received indirectly from the reflecting object. Normally the indirectly received signals are very much weaker than the directly received signals so that the two can be readily distinguished. The AOA measuring unit 17 can then provide on an output line 18 successive signals representing the angle of arrival of the direct pulses followed by the angle of arrival of the reflected pulses.

A computer 19 receives the arrival angles on line 18 and receives also signals indicating the time delay between the directly and indirectly received pulses. The computer is also fed with data defining the range of the reflecting object relative to the receiver and preferably also the bearing of the reflecting object on data lines 20. By employing the formula referred to above, the computer calculates and provides on an output line 21 data defining the range of the transmitter and conveniently also the bearing of the transmitter so that its location can be identified.

In order to measure the time delay between the indirectly and directly received signals, the received "video" is fed also from the receiver 10 to an auto-correlator 22.

The auto correlator works in a manner well known in the art to analyse the manner in which the received video varies with time and identify any periodicity. Thus, for example, for a pulsed received signal, the auto correlator provides a correlation peak corresponding to the pulse repetition frequency. When the receiver also receives signals via the reflecting object at a slight time delay, the auto correlator 22 provides also a second correlation pulse, usually at lower amplitude, corresponding to the delay between the directly and indirectly received pulses. The output pulses from the correlator 22 are supplied on a line 23 to the computer 19 to identify the required delay time.

It will be appreciated that the auto-correlator 22 can determine the delay between the directly and indirectly received signals even if the pulse length of the received signals is greater than the time delay. Indeed, provided the received signals have some modulation, the correlator is capable of determining the time delay even if the received signals are not on/off pulsed at all.

To distinguish the angles of arrival of directly and indirectly received signals when these overlap in time requires much greater sophistication than the simple arrangement described above but a microprocessor controlled data processing system can be envisaged which could perform this function. However, alternative apparatus can also be envisaged which would enable the angle of arrival of direct and indirect signals when these overlap in time to be determined more easily. For example, a directional antenna may be provided. Assuming the reflected indirectly received signals are much weaker than the direct signals, the approximate direction of the transmitter can readily be determined by existing direction finding techniques. Then using a narrow beam directional antenna, which discriminates against the reflected signals arriving from a different angle, the direction of the transmitter can be measured accurately.

The range and direction of the reflecting object may be determined by a range finder 23 which may comprise any known optical or radio range finder. The range finder preferably can provide an accurage bearing measurement of the reflecting object as well. The accurate bearing and range of the reflecting object may be supplied on a line 24 to the computer 19 as the range and bearing data.

Further, where the computer 19 is able to obtain a value from the unit 17 of the angle of arrival of the reflected signals, this data may be employed by the computer to control the steering of the range finder 23 which then provides more accurate bearing and the range information.

The range finding device may be a radar or laser range finder with, if necessary, a narrow conical or raster scanning beam for directional measurement in the horizontal and vertical directions.

With the above described arrangement, the range and bearing of a remote transmitter can be identified. With two ships moving in company at sea, one ship may have the receiver and apparatus illustrated in Figure 2, and the other ship may act as a reflecting object. Any method of determining the range and relative bearing of the two ships may be used. If several ships are present in convoy, then steps must be taken to discriminate against the several reflections by using a suitably directive receiving antenna.

The invention is not restricted to land or sea based receivers and reflecting objects. The receiver and apparatus may be contained on an aircraft which may use another aircraft or a land based object as the reflecting object.

On land, a geographical object may provide the reflecting object.

Where the receiver and apparatus is mobile, a typical arrangement would be for the apparatus to measure the direction of the transmitter as accurately as possible, discriminating angularly against any reflections, also measure the time delay of a selected relatively strong reflection and identifying the rough bearing or direction of the reflecting object from the reflected signal, and then employ a radar, laser or optical range finder to determine with accuracy the range and bearing of the likely reflector.

If several reflections are received simultaneously, several such measuring sequences could be performed to provide improved accuracy for the measurement of the transmitter range.

CLAIMS

1. Apparatus for measuring the range of a distant radio transmitter, comprising a directional receiver capable of receiving radio signals both directly from the distant transmitter and indirectly reflected off a reflecting object at a determined range from the receiver and at an angle to the direct line from the transmitter, means to determine the difference between the angles of arrival at the receiver of the direct and indirect signals, means to measure the time delay of the received indirect signal relative to the received direct signal, and means to calculate from said determined range, said angle difference and the said time delay the range of the transmitter from the receiver.

2. Apparatus as in claim 1 and including a range finder to determine the range of the reflecting object from the receiver.

3. Apparatus as claimed in claim 2 wherein said angle difference determining means is operative to determine the angle of arrival relative to the receiver of at least the indirect signal and the range finder is directional and arranged to be steered on to the direction of said determined angle of arrival.

4. Apparatus as claimed in claim 2 or claim 3 wherein the range finder is self-steering when locked on to a target and is arranged to generate signals representing not only the determined range of the reflecting object but also the bearing and/or elevation of the object relative to the receiver, said means to calculate receiving said range and bearing and/or elevation signals for use in calculating said transmitter range.

5. Apparatus as claimed in any preceding claim for an arrangement in which the reflecting object is substantially at the same height as and horizontally spaced from the receiver wherein the directional receiver is arranged to provide directional signals indicative of the angles of arrival in the horizontal plane of respective received radio signal pulses.

6. Apparatus as claimed in claim 5 wherein said time delay is greater than the pulse width of the transmitted signals so that the directional receiver provides successive signals indicative of the angles of arrival of direct and indirect signal pulses respectively.

7. Apparatus as claimed in any preceding claim wherein said time delay measuring means includes an auto-correlator.

8. Apparatus as claimed in any preceding claim wherein said means to calculate includes a programmed computer.

9. A method of measuring the range of a distant radio transmitter, comprising determining the difference between the angles of arrival at a receiver of signals directly from the distant transmitter and signals indirectly reflected off a reflecting object at a determined range from the receiver and at an angle to the direct line from the transmitter, measuring the time delay of the received indirect signal relative to the received direct signal, and calculating from said determined range, said angle difference and said time delay the range of the transmitter from the receiver.

10. Apparatus for measuring the range of a distant radio transmitter, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

11. A method of measuring the range of a distant radio transmitter substantially as hereinbefore described.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1982.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.