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[54] **METHOD OF AND DEVICE FOR AIMING BARRELS OF CANNONS INSTALLED IN TERRAIN FROM A REMOTE AIMING STATION**

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[51] **Int. Cl.**..**G01s 1/08**

[58] **Field of Search**................343/102, 105, 113; 89/41 SW, 89/41 AA

[56] **References Cited**

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[57] **ABSTRACT**

A method of and an apparatus for the training of pieces of artillery on to a target from a remote control station. At the control station is a transmitting antenna array for sending beat signals to a receiving antenna array at the piece of artillery to be trained. By measuring the phase shift of the signals received by the receiving array the angle between a base line at the control station and a reference line from the station to the artillery piece can be determined and from this a second base line at the artillery piece can be established for the purpose of laying the piece on to the target.

6 Claims, 3 Drawing Figures

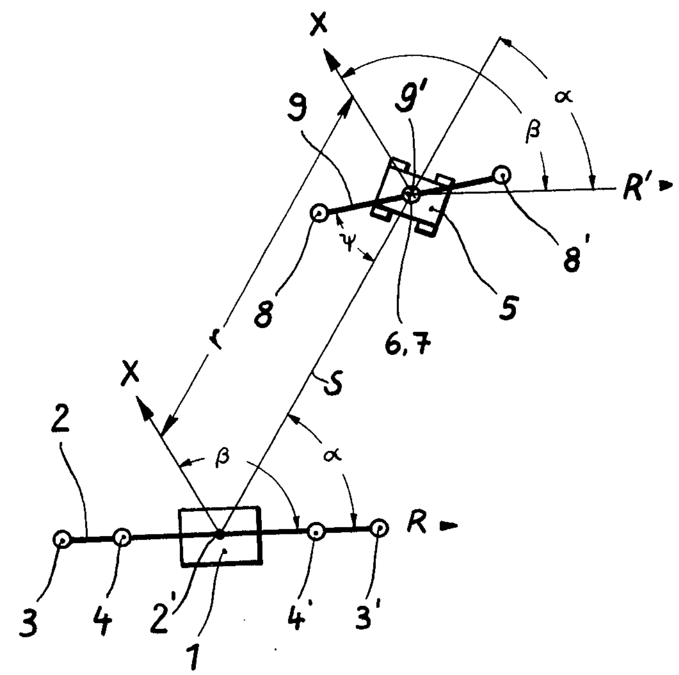

Fig. 1

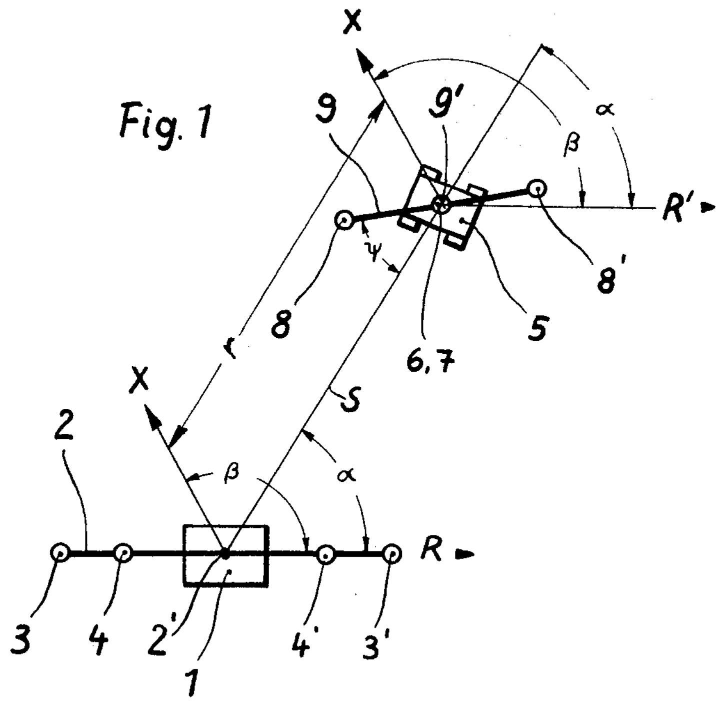

Fig. 3

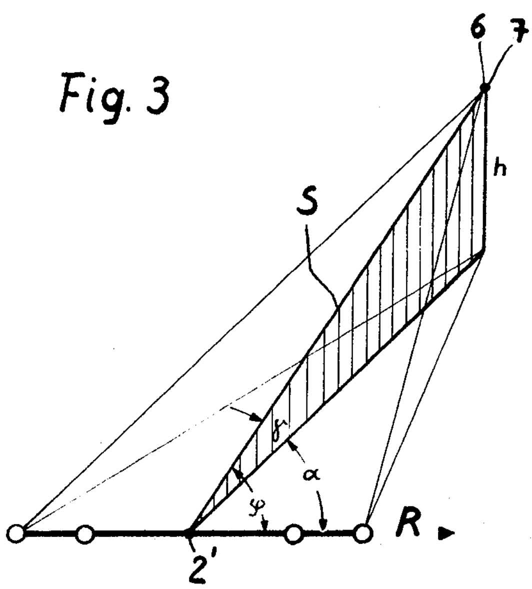

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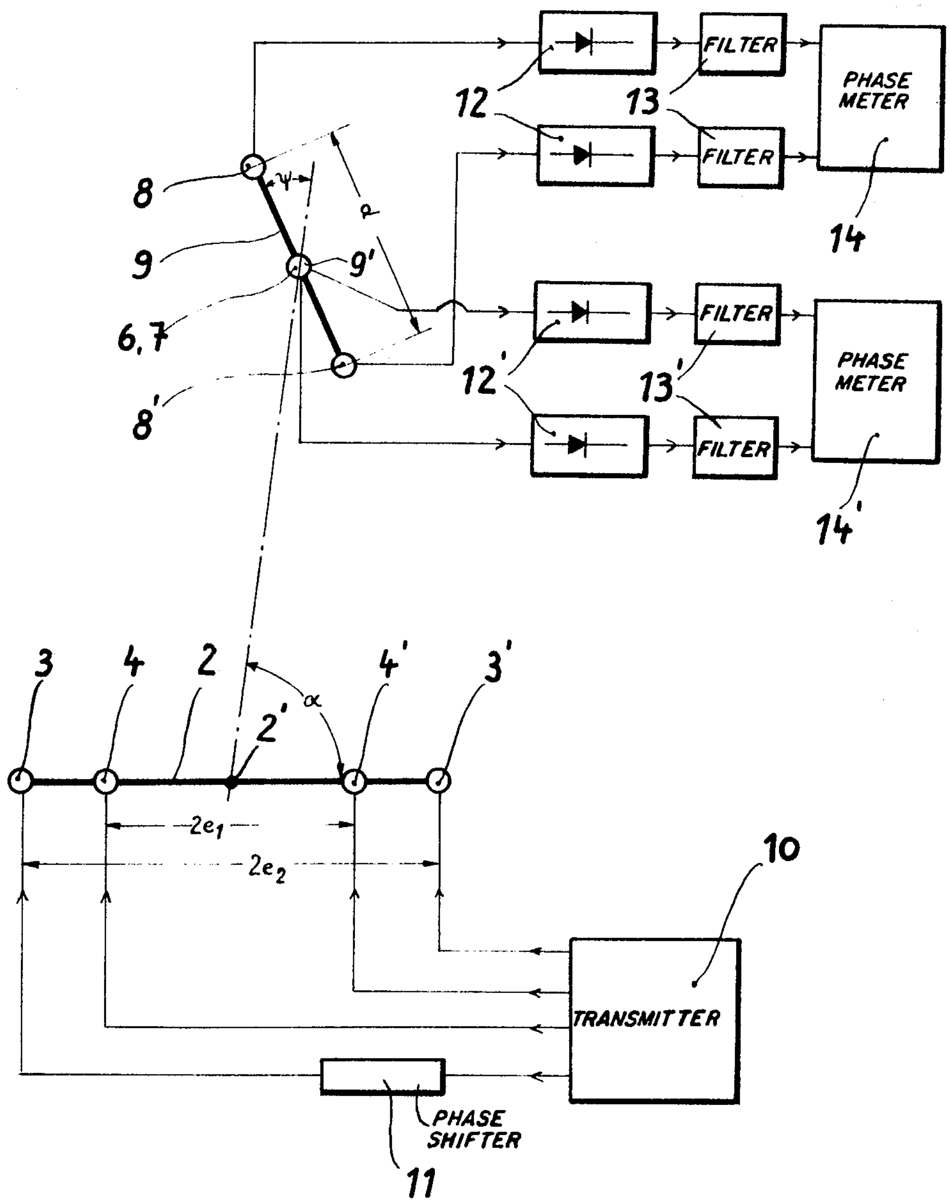
Fig. 2



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METHOD OF AND DEVICE FOR AIMING BARRELS OF CANNONS INSTALLED IN TERRAIN FROM A REMOTE AIMING STATION

BACKGROUND OF THE INVENTION

The present invention relates to a method of and an apparatus for aiming pieces of artillery from a remote control station.

It has previously been proposed to employ optical methods and apparatus for aiming pieces of artillery from a remote control station, the method involving the laying of each gun separately and this is a time consuming process. Moreover, a direct line-of-sight path is required between the guns and the control station, so that a free choice of sites for both guns and control station is not always possible. Moreover, the choice of site can be limited by atmospheric conditions which may affect the line-of-sight path.

It has also been proposed to overcome the disadvantages of visual methods by employing radio techniques derived from radio navigation systems. The techniques employed entail the use of rotatable directional antennae and do not provide a sufficient degree of accuracy. Futhermore, with some techniques each gun must again be dealt with separately although it is possible to overcome this disadvantage by the use of directional modulated carriers which enables all the guns to be dealt with simultaneously.

In addition to the absence of a sufficient degree of accuracy, there is the disadvantage that the requisite transmitter and receiver systems are complicated and impose extra burdens on power supplies. The fault rate is frequently high and this is another disadvantage.

OBJECTS OF THE INVENTION

It is one object of the present invention to provide a method of aiming a piece of artillery from a remote control station which comprises the steps of

i. transmitting from a transmitting antenna array at the control station electromagnetic beat fields of relatively greater frequency spacing but of relatively low beat frequency,

ii. receiving such fields by a rotatable receiving antenna array at the piece and measuring the phase shifts thereof,

iii. establishing a reference line between the transmitting and receiving arrays, and a first base line at the control station,

iv. determining, from the measured phase shifts, the angle between the reference line and the first base line,

v. aligning the receiver array in a known orientation with respect to the reference line, and,

vi. thereby, establishing at the weapon, a second base line parallel with the first base line.

Preferably, the electromagnetic fields are derived from a crystal-controlled oscillator.

The outputs of the receiver array may be non-linearly rectified and applied in pairs to instruments for indicating the phase difference.

Where there is a difference in elevation between the control station and the piece of artillery controlled thereby, further antenna arrays are provided to determine the respective angles of elevation.

Apparatus for carrying out the method of the invention comprises, at the control station, a transmitting antenna array including at least two pairs of radiators on a first supporting arm, the radiators of each pair being disposed symmetrically with respect to its rotary axis of the arm, and, at the weapon, a receiving antenna array rotatable about a vertical axis and having at least two receiving antennae on a second supporting arm, the two receiving antennae being disposed symmetrically with respect to the vertical axis of rotation of the second arm, the receiving array also having a further two receiving antennae disposed vertically one above the other on the said axis of rotation. The outputs of the receiving antennae are applied to phase shift measuring instruments, which may be digital phase meters.

The transmitting array is energized from the said crystal-controlled oscillator and included in one feeder to one of the radiators of the transmitting array is a phase shifter.

With this and other objects in view, which will become apparent in the following detailed description, the present invention, which is shown by example only, will be clearly understood in connection with the accompanying drawings, in which:

FIG. 1 is a schematic arrangement of the device and the factors which are important for the method;

FIG. 2 is in symbolic form the circuit of the transmitter and receiver portion for measuring the angle between the radiator beam direction and the reference line as well as the direction of the antenna beam to the aiming station in the horizontal plane; and

FIG. 3 shows the geometric relations in case of a level difference between the aiming station and one of the cannons.

DETAILED DESCRIPTION OF A PREFERRED FORM OF THE PRESENT INVENTION

Referring first to the drawings and in particular to FIG. 1, there is shown a remote control station 1 from which each of a number of pieces of artillery are to be aimed. The station 1 has a transmitting antenna array comprising an arm 2 on which are mounted pairs of radiators 3, 3', and 4, 4' disposed symmetrically about the center 2' of the arm 2.

FIG. 1 also shows a single piece only of artillery although it is to be understood that there will usually be several such pieces. The single piece is shown schematically by block 5, it being understood that the type and construction of weapon forms no part of the present invention. Mounted upon the weapon is a receiving antenna array comprising antennae 6 and 7, mounted vertically one above the other at the vertical axis of rotation 9' of an arm 9, at whose ends further receiving antennae 8,8' are mounted. Antenna 8,8' are symmetrically disposed with respect to the rotary axis 9'. FIG. 1 also shows an arrow X indicating the direction in which weapon 5 is to be trained under the control of station 1.

The longitudinal axis of the arm 2 defines a direction R which makes an angle β with the direction X through its center 2'.

Joining rotary axis 9' with the mid-point 2' of arm 2 is a reference line 5 with which arm 9 makes some arbitrary angle ψ. The angle between line S and direction R is shown as α. As will be shown later, the arm 9 will be rotated about its vertical axis 9' until the arm lies along a direction R' parallel to the direction R and the weapon will then be layed-of through angle β whose value is transmitted to the weapon from the control station by radio or in some other suitable manner.

Referring now to FIG. 2, the radiators 3,3',4,4' at the remote control station are connected by feeders to a transmitter indicated by block 10. The transmitter is preferably crystal-controlled but is otherwise of conventional, known form. Included in the feeder from the transmitter 10 to radiator 3 is a phase shifter of conventional form represented by block 11. Radiators 3 and 3' are each spaced by a distance e_2 from the center 2' of the arm 2, while radiators 4 and 4' are spaced by a distance e_1 from the center 2'.

Receiving antennae 6, 7 stacked vertically one above the other on the arm 9 are joined as shown by feeders to rectifiers 12' whose output is applied via filters 13' to a digital phase meter 14'. Similarly, antennae 8 and 8' are joined by feeders to rectifiers 12 whose output is applied via filters 13 to a digital phase meter 14. Antenna 8, 8' are spaced apart along the arm 9 by a distance d.

Transmitter 10 is adapted to feed radiators 3 and 3' with signals of frequencies f_2 and $f_2 + \Delta f$ respectively, and radiators 4 and 4' are fed with signals of frequencies f_1 and $f_1 + \Delta f$. Frequencies f_1 and f_2 are relatively widely spaced — the frequency gap being in the Megahertz range. Δf is relatively small, typically 100 Hertz. By superposing the frequencies, beat frequencies of the same low value are obtained. Because f_1 and f_2 are relatively widely spaced, it is possible to limit the frequency band passed by each antenna **6**, **7**, **8**, **8'** to either of them by providing appropriate circuits in the channel to rectifiers **10**. Since the frequency Δf is so small with respect to frequencies f_1 and f_2, for sake of simplicity the beat fields are assumed to have said frequencies while in fact they are between f_1 and $f_1 + \Delta f$, and between f_2 and $f_2 + \Delta f$, respectively. The tuning of the antenna channels is such that antenna **6** is tuned to f_1, antenna **7** is tuned to f_2, and antennae **8** and **8'** are tuned to the same frequency f_1 or f_2, and for the purpose of this specification it will be assumed that both antennae **8** and **8'** pass but the frequency f_2. Thus, there is fed to the pairs of digital phase meters **14**,**14'** four beat voltages $U_1 \ldots U_4$ of frequency Δf, the phases thereof being compared in the phase meters.

Beat voltages U_1 and U_2 at the output of filters **13'** are determined by

$$U_1 \sim \cos\left(2\pi\Delta f + \frac{4\pi}{\lambda_1} e_1 \cos\alpha + \delta_1\right)$$

$$U_2 \sim \cos\left(2\pi\Delta f + \frac{4\pi}{\lambda_2} e_2 \cos\alpha + \delta_2\right)$$

wherein λ_1 and λ_2 are the wave lengths, e_1 and e_2 being the radiator distances as shown, and δ_1 and δ_2 the unknown start phases of the beat fields. By means of the phase shifter **11**, the difference $/\delta_1 - \delta_2/$ is made zero, so that the phase difference $\Delta\Phi_{1,2}$ of the beat voltages U_1 and U_2 becomes equal to

$$\Delta\Phi_{1,2} = 4\pi\left(\frac{e_2}{\lambda_2} - \frac{e_1}{\lambda_1}\right) \cos\alpha$$

Thus, by measuring the phase difference $\Delta\Phi_{1,2}$ by means of the phase meter **14'** the angle α may be determined.

The phase difference $\Delta\Phi_{3,4}$ between the beat voltages U_3 and U_4 is given by

$$\Delta\Phi_{3,4} \sim \frac{4\pi}{\lambda_2} e_2 \left[\cos\left(d\,\frac{\sin\psi}{r} + \alpha\right) - \cos\alpha\right]$$

d being the distance between the two antennae **8** and **8'** and r the distance between the axis **9'** and the axis **2'** of the arm **2**. The arm **9** is then turned until the angle ψ has the value 0° or 180° and thus $\Delta\Phi_{3,4} = 0$, too. In case of $\psi = 0°$ or $\psi = 180°$, respectively, the arm **9** will extend accurately in the direction of the reference line S. The antenna arm **9** being so adjusted, standard direction R' will be obtained by applying the angle α, R' thereby becoming parallel to the radiator arm direction R. Application of the angle β at R' will then permit the training of the weapon on the desired direction X.

In order to increase the aiming accuracy, there may be provided an additional radiator pair which radiates at the frequencies f_3, $f_3 + \Delta f$, and corresponding antennae at the weapon. Thereby, in addition to a coarse adjustment with respect to 360°, a fine adjustment will also be obtained.

Referring now to FIG. **3**, it will be seen that in case of a difference h in elevation between the location of station **1** and the weapon, instead of the angle α in the horizontal plane the angle ψ in the inclined plane is considered. Thereby aiming errors result with respect to the horizontal plane, such errors may be eliminated by additional determination of a quadrant elevation angle γ.

The equation $\cos\alpha = \cos\Phi / \cos\gamma$ may be derived from the diagram, the equation permitting the determination of the horizontal angle α by measuring the angles Φ and γ. The angle Φ is measured as described hereinabove. For measuring the elevation angle γ, an additional radiator system is used orthogonally disposed in the vertical plane with respect to that which is provided for determination of angles Φ, or α respectively. The two radiator pairs necessary for this purpose radiate frequencies f_4, $f_4 + \Delta f$ and f_5, $f_5 + \Delta f$, said frequencies being different from $f_1, f_1 + \Delta f, f_2, f_2 + \Delta f, f_3, f_3 + \Delta f$. The angle γ is obtained from the measured phase shift $\Delta\Phi_{4,5}$ by means of the relation

$$\sin\gamma = \frac{\Delta\Phi_{4,5}}{4\pi\left(\frac{e_5}{\lambda_5} - \frac{e_4}{\lambda_4}\right)}$$

wherein λ_4, and λ_5 are the wave lengths and e_4, e_5, the radiator spacing corresponding with e_1 and e_2 above.

While we have disclosed several embodiments of the present invention, it is to be understood that these embodiments are given by example only and not in a limiting sense.

We claim:

1. A method of aiming a piece of artillery from a remote control station comprising the steps of

i. transmitting from a transmitting antenna array at said control station electromagnetic beat fields of relatively greater frequency spacing but of relatively low beat frequency,

ii. receiving said fields by a rotatable receiving antenna array at the piece and measuring the phase shifts thereof,

iii. establishing a reference line between said transmitting and receiving arrays, and a first base line at the control station,

iv. determining from said measured phase shifts, the angle between said reference line and said first base line,

v. aligning said receiver array in a known orientation with respect to said reference line, and

vi. thereby, establishing at the weapon, a second base line parallel with said first base line.

2. The method, as set forth in claim **1**, which includes the steps of

supplying said beat fields from a single, quartz-controlled oscillator, and

subjecting the outputs of the antennae of said receiving array to non-linear rectification prior to the combining of the outputs into pairs for the measurement of the phase difference.

3. The method, as set forth in claim **2**, which further includes the steps of

determining, in the case that the control station and the piece of artillery are at different heights relative to sea level, the angle of elevation between them by means of further transmitting and receiving antennae arrays disposed orthogonally with respect to said first mentioned transmitter, and receiving arrays, respectively.

4. An apparatus for aiming a piece of artillery from a remote control station, comprising in combination,

at the control station, a transmitting antennae array including at least two pairs of radiators on a first support arm,

said radiators of each pair being disposed symmetrically with respect to the axis of said first arm, and,

at the weapon, a receiving antennae array rotatable about a vertical axis and having at least two receiving antennae on a second supporting arm,

said two receiving antennae being disposed symmetrically, about the vertical axis of said second arm,

said receiving array also having further two receiving antennae disposed vertically one above the other on said axis of rotation, and

the outputs of the antennae of said receiving array being connected to phase shift measuring instruments.

5. The apparatus, as set forth in claim **4**, further comprising phase shifting means for shifting the phase of the signals fed to one radiator of one of said pairs of radiators.

6. The apparatus, as set forth in claim **4**, wherein said phase shift measuring instruments comprise digital counters.

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