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(54) METHOD AND APPARATUS FOR DEFINING THE DIRECTION OF INCIDENCE OF ELECTROMAGNETIC WAVES

(71) We, C. PLATH GmbH NAUTISCH ELEKTRONISCHE TECHNIKM a German Company, of Gotenstrasse 18, 2000 Hamburg 1, Federal Republic of Germany 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:—

The invention relates to a method and apparatus for defining the direction of incidence of electromagnetic waves by using an antenna system adapted to supply six voltages and comprising three frames situated perpendicularly with respect to each other and disposed in the principle coordinate planes of a rectangular system of coordinates, and three dipoles disposed in the principal coordinate axes, in which system products are formed from any two antenna voltages and functions of the azimuth and/or the elevation angle are formed from the sum and/or differences of such products.

Such methods which achieve direction finding without polarization errors are already known (German patent specification 1 080 633, German patent specification 1 170 481 and German Offenlegungsschrift 1 798 346). More particularly, the associated antenna system comprising three dipoles which are oriented in accordance with the right-angled coordinate axes x, y and z of space and three frame antennae disposed in the coordinate planes, are illustrated in Figure 1 of the German patent specification 1 080 633.

In the known system a separate reception channel must be provided for each antenna and all six channels must provide precisely the same gain in terms of magnitude and phase and the same frequency translation. Accordingly, comprehensive calibration and regulating procedures and circuits are required in practical embodiments in order to ensure absolute synchronism of the reception channels and reliable direction finding values. Such calibrating steps which must be performed prior to the actual determination of the direction finding values are exceptionally time-consuming if they are carried out manually so that direction finding of brief signals is not possible. Furthermore, calibrations must also extend to the computer elements which are embodied in analog technology, a feature which results in a further delay of the actual direction finding operation. Automation of all calibrating procedures appears to be possible but this would still further increase the circuit complexity which is in any case substantial.

It is the object of the invention to eliminate the previously-mentioned disadvantages and to provide a method and systems which permit genuine short-period direction finding with comparative simple technological means in conjunction with the known spatially concentrated antenna system At the same time, the kind of computer programme which is also known is to ensure that correct direction finding results in terms of azimuth and elevation angle can be obtained even for waves with random elevation and/or polarization.

According to the invention the problem is solved in that the two antenna voltages which are to be combined into a product are selected successively in time from the antenna system and are multiplied with each other and the product formed thereby is separately stored in a coordinated memory and that after all required products are formed and stored the contents of the memory is interrogated in accordance with a computer programme by a computer and the direction of incidence is defined therefrom. According to the invention the multiplication of a plurality of voltages or voltage products hitherto carried out simultaneously is now carried out in time sequence, a procedure which can be performed very rapidly so that, as will be

evident from the description hereinbelow, the expenditure in terms of time as well as in terms of apparatus can be substantially reduced compared with that associated with the prior art.

According to one aspect of the invention there is provided a method for defining the direction of incidence of electromagnetic waves by using an antenna system adapted to supply six voltages and comprising three frames antennae situated perpendicularly with respect to each other and disposed in the principal coordinate planes of a rectangular system of coordinates, and three dipole antennae disposed in the principal coordinate axes, in which system products are formed from any two antenna voltages and functions of the azimuth and/or the elevation angle are formed from the sum and/or differences of such products, and wherein the two antenna voltages which are to be combined into a product are selected in time from the antenna system and are multiplied with other and the product formed thereby is separately stored in a memory and that after all required products are formed and stored the contents of the memory are interrogated in accordance with a computer programme by a computer and the direction of incidence is defined therefrom.

According to another aspect of the invention there is provided apparatus for performing the method hereinbefore described having an antenna system comprising three frame antennae disposed perpendicularly to each other and arranged in the principal coordinate planes of a system of rectangular coordinates and three dipole antennae disposed in the principal coordinate axes and a double channel receiver, and wherein two switches are provided which operate in synchronism and are adapted for successively connecting the two antennae, whose voltages are to be multiplied with each other, via double channel receiver to the two inputs of a multiplier stage the output of each of which can be connected by a switch actuated in synchronism with the input switches to one of a plurality of memories, the number of which corresponds to the number of products to be formed, and the outputs of the memories being connectable to a computer which processes the memory contents in accordance with a computer in order to define the direction of incidence.

A preferred embodiment of the invention provides that the products are digitalised and are stored in digital form. More particularly, within the scope of the invention it is also possible to store the calculated values of the direction finding direction so that even brief transmissions can be detected in terms of direction finding technology and can subsequently be evaluated.

One advantageous system for performing the method according to the invention comprises an antenna system comprising three frames disposed perpendicularly to each other and arranged in the principal coordinate planes of a system of rectangular coordinates and three dipoles disposed in the principal coordinate axes and a double channel receiver.

By contrast to known systems the invention consists of the provision of two switches operated in synchronism and adapted for successively connecting the two antennae, whose voltages are to be multiplied with each other, via the double channel receiver to the two inputs of a multiplier stage the output of each of which can be connected by a switch actuated in synchronism with the input switches to one of a plurality of memories the number of which corresponds to the number of products to be formed and the outputs of the memories can be connected to a computer which processes the memory contents in accordance with a computer programme in order to define the direction of incidence. Computer circuits of this kind are known, for example they are disclosed in the above-mentioned printed specifications. The computer result can be displayed either in known manner or as will be explained subsequently.

Compared with known systems the invention therefore permits the circuit and operating complexity to be substantially reduced. The double channel receiver in the prior art is intended to again amplify the variables produced at two outputs of a computer circuit before such variables are supplied to the two deflection systems of a cathode ray oscilloscope but in this case it is the function of the double channel receiver to raise the two relevant antenna voltages, the value of which is frequently sufficient for driving the multiplier stage, to a level which is adequate for performing multiplication. If the antenna voltages are sufficiently high this receiver can of course also be omitted.

A further embodiment of the system according to the invention provides that the multiplier stage comprises a multiplier, a low-pass filter and an integrator stage. To enable computation to be performed in digital form it is also provided that an analog-digital converter is connected between the output of the multiplier stage and the switch which follows the latter and the memories are constructed as digital memories. To enable brief direction finding results to be evaluated at leisure it is of course also possible with the invention to connect the output of the computer to a

device which stores the direction finding result.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawing in which:

Figure 1 shows a system for defining the azimuth angle and

Figure 2 a system for defining azimuth and elevation.

The underlying formulae for calculation are based primarily on the multiplication of two antenna voltages, for example as is already known from the German patent specification 1 170 481. According to the invention only the minimum number of two identical reception channels 9 and 10 is provided which are supplied by the two factors of the individual voltage products by means of the input switches 7 and 8 which switch rapidly from one antenna to the other. The number of switch positions which are successively picked off depends on the number of products to be formed and in Figure 1 this amounts to four, but in Figure 2 it amounts to six.

At the output of the two reception channels the products are actually formed at a suitable frequency in a multiplier 11 and, since the operation normally concerns the formation of products in the form $P=U_1 U_2 \cos \phi_{12}$, they are supplied in the course of the operation to a low-pass filter 12 and an integrating stage 13.

The products must be stored for further computation and for this reason are supplied via the analog-digital converter 14 and the switch 15 to the digital memories 16. The number of contact places of the switch 15 and the number of memories 16 corresponds to the number of contact places of the switches 7 and 8 and corresponds to the number of products which are to be formed. The switches, advantageously constructed as electronic switches, operate in synchronism. The switching frequency of 20 is supplied with a delay, adjustable at 21, to the two groups of switches. The delay corresponds approximately to the signal transit time through the circuit parts 9 to 14.

The contents of the memory 16 are interrogated by the programme-controlled digital computer 17. To this end it is possible to form the product combinations disclosed in the German patent specification 1 170 481, i.e.

$$P_x = U_{RZ} \cdot U_{DY} - U_{RY} \cdot U_{DZ}$$
$$P_y = U_{RX} \cdot U_{DZ} - U_{RZ} \cdot U_{DX}$$
$$P_z = U_{RY} \cdot U_{DX} - U_{RX} \cdot U_{DY}$$

and furthermore to define the values of

$$\text{azimuth } \alpha = \arctan\left(\frac{P_x}{P_y}\right) \text{ and of}$$

$$\text{elevation } \varepsilon = \arctan\left(\frac{P_z}{\sqrt{P_x^2 + P_y^2}}\right)$$

for registering in the final store 18. The said store 18 cooperates with one or more digital or analog display units 19, 19'.

It will be readily obvious that it is also possible to connect the contacts of the switches 7 and 8 to the antenna in a modified manner, for example in order to form the products mentioned in the German patent specification 1 080 633.

The dipoles 1, 2 and 3 as well as the frames 3, 4 and 5 will then correspond to the dipoles D_x, D_y and D_z and to the frames R_x, R_y and R_z in the two abovementioned printed specification.

WHAT WE CLAIM IS:—

1. A method for defining the direction of incidence of electromagnetic waves by using an antenna system adapted to supply six voltages and comprising three frame antennae situated perpendicularly with respect to each other and disposed in the principal coordinate planes of a rectangular system of coordinates, and three dipole antennae disposed in the principal coordinate axes, in which method products are formed from any two antenna voltages and functions of the azimuth and/or the elevation angle are formed from the sum and/or differences of such products, and wherein the two antenna voltages which are to be combined into a product are selected in time from the antenna system and are multiplied with each other and the product formed thereby is separately stored in a memory and after all required products are formed and stored the contents of the memory are interrogated in accordance with a computer programme by a computer and the direction of incidence is defined therefrom.

2. A method according to Claim 1, wherein the products are digitalised and are stored in digital form.

3. A method according to Claim 1 or 2, wherein the calculated values of the direction of incidence are stored.

4. Apparatus for performing the method according to any preceding claim having an antenna system comprising three frame antennae disposed perpendicularly to each other and arranged in the principal coordinate planes of a system of rectangular coordinates and three dipole antennae disposed in the principal coordinate axes and a double channel receiver, and wherein two switches are provided which operate in

synchronism and are adapted for successively connecting the two antennae, whose voltages are to be multiplied with each other, via a double channel receiver to the two inputs of a multiplier stage the output of each of which can be connected by a switch actuated in synchronism with the input switches to one of a plurality of memories the number of which corresponds to the number of products to be formed, and the outputs of the memories being connectable to a computer which processes the memory contents in accordance with a computer programme in order to define the direction of incidence.

5. Apparatus according to Claim 4, wherein the multiplier stage comprises a multiplier, a low-pass filter and an integrating stage.

6. Apparatus according to Claim 4 or 5, wherein an analog-digital converter is connected between the output of the multiplier stage and the switch which follows the latter and the memories are digital memories.

7. Apparatus according to any one of Claims 4 to 6, wherein the output of the computer is connected to a device which stores the direction finding result.

8. A method for defining the direction of incidence of electromagnetic waves substantially as hereinbefore described with reference to the drawings.

9. Apparatus for defining the direction of incidence of electromagnetic waves substantially as hereinbefore described with reference to the drawings.

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2 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 1

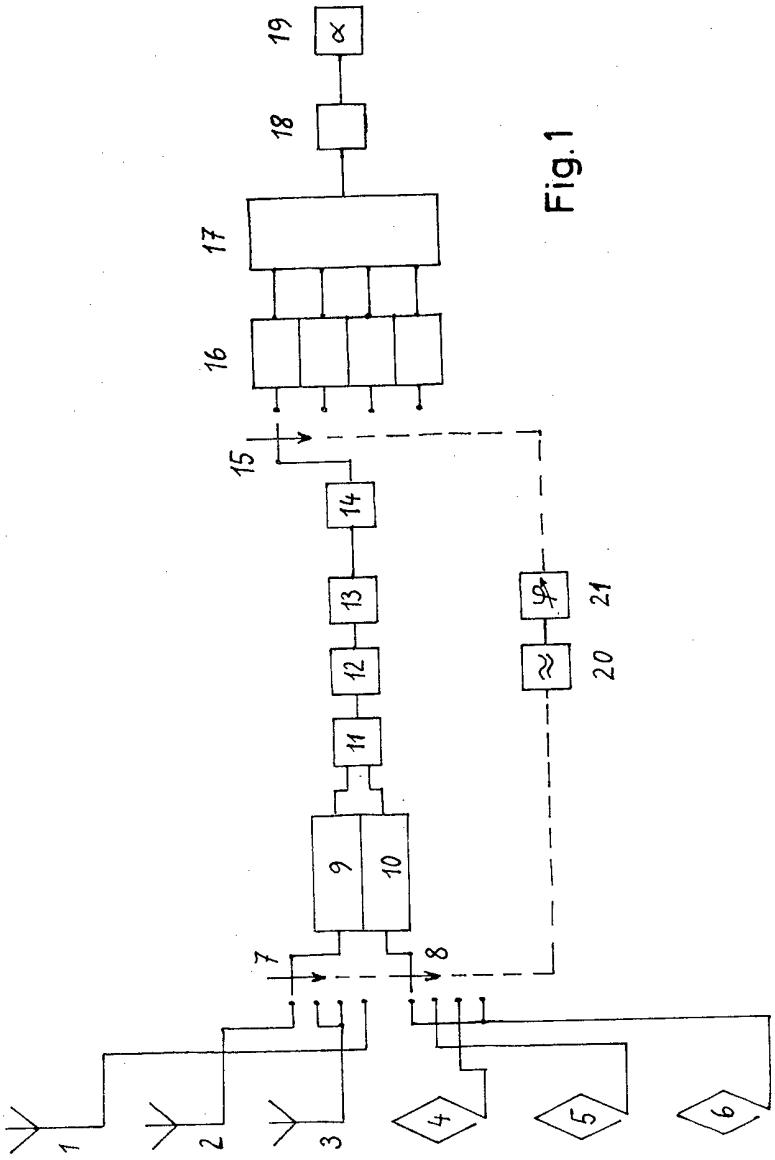

Fig.1

1595092 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

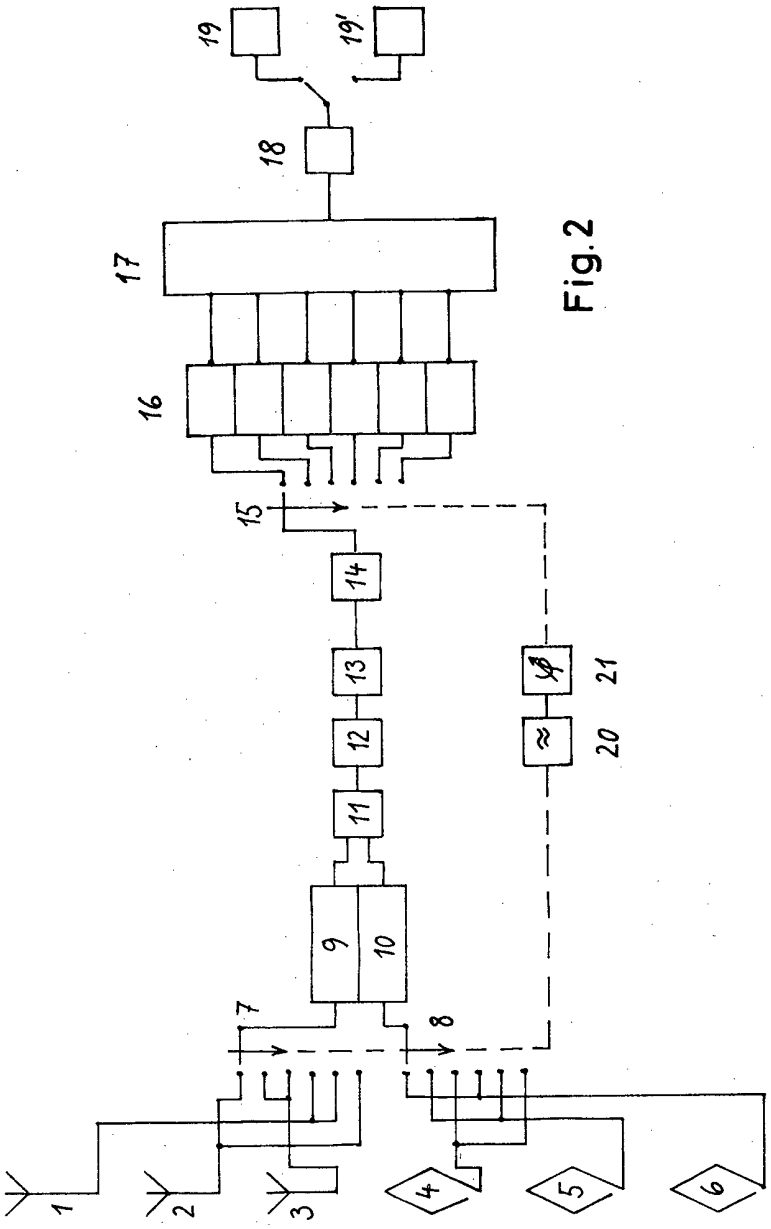

Fig.2