

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,182,724

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Date of Application (No. 12725/68) and filing Complete Specification: 15 March, 1968.

Application made in Netherlands (No. 6704219) on 22 March, 1967.

Complete Specification Published: 4 March, 1970.

Index at Acceptance:—H4 A (3M, 3W, 4A2S2, 4P2, 4X, 6D, 6G).

International Classification:—H 01 q 19/12.

COMPLETE SPECIFICATION

Combined Radar Antenna System

We, N.V. HOLLANDSE SIGNAALAPPARATEN, of 40, Zuidelijke Havenweg, Hengelo (Overijssel), The Netherlands, a company organized and existing under the laws of The Netherlands, 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 combined radar antenna system comprising a first antenna constituted by a substantially paraboloidally shaped reflector having unequal dimensions in width and height and a feed horn arranged at the focus of said reflector for producing, in co-operation with said reflector, a first directive antenna radiation pattern, and a second antenna constituted by the reflector of said first antenna and a plurality of individual radiating elements for producing a second antenna radiation pattern equidirectional to said first antenna radiation pattern. Such a combined radar antenna system is referred to as a combined radar antenna system of the kind set forth.

Combined antenna systems of the kind set forth are advantageous as compared with systems in which for the same purpose two separate antennas are employed, because a saving in space and weight is obtained and the sensitivity to wind is reduced. The substantially equal direction of the two antenna radiation patterns in the known combined antenna systems is achieved in that the individual radiating elements associated with the second antenna are constituted by two dipoles each provided with an auxiliary reflector and arranged each on one side of said feed horn at such a distance from each other that together they operate as a second primary radiation source at the focus of

the main reflector.

However, this known antenna configuration has the disadvantage that its parameters allow for little variation, thus greatly limiting the possibilities of use. The dimensions of the first antenna (reflector and feed horn), for example, are determined by the wavelength λ_1 of the signal applied to the feed horn and by the desired form of said first antenna radiation pattern. The angles of incidence of the second primary radiation source formed by the two dipoles are, however, practically determined by the wavelength λ_2 of the signal applied to said dipoles. Moreover, the wavelengths λ_1 and λ_2 must differ such that the distance between the dipoles as determined by $\frac{1}{2}\lambda_2$ permits the feed horn, whose minimum dimensions are determined by λ_1 , to be positioned between said dipoles. Generally this will lead to a compromise, in which a considerable amount of energy of the second primary source is spilled over the edge of the main reflector. This known antenna configuration becomes impracticable as soon as the rearward radiation resulting from said spill-over effect becomes inadmissibly high.

The present invention now provides a combined radar antenna system of the kind set forth wherein said individual radiating elements are supported by the reflector and are so spaced that in a projection of said radiating elements onto a plane at right angles to the axis of the paraboloid and taken in a direction parallel to said axis, the projections of adjacent ones of said elements are substantially equally spaced, said individual radiating elements being connected to transmission lines on the rear side of the reflector to be so fed that a plane wave front of uniform phase is obtained.

In order that the invention and the

[Price 5s. 0d.]

manner of carrying it into effect may be better understood a preferred embodiment thereof will now be described with reference to the accompanying drawings in which:

Figure 1 is a perspective front view of an embodiment of the antenna system according to the invention;

Figure 2 illustrates two antenna patterns;

Figure 3 is a side elevation of one of the radiating elements as used in the embodiment shown in Figure 1 with a sectional view of the supporting of a radiating element by the main reflector and the through-connection of the radiating element through the main reflector to a transmission line at the rear of the reflector;

Figures 4A and 4B show on an enlarged scale a detail of the sectional view of Figure 3;

Figures 5A and 5B illustrate an antenna diagram of the second antenna; and

Figure 6 shows diagrammatically one arrangement of the transmission lines obtained by strip-line technique.

In the combined radar antenna system shown in Figure 1 reference numeral 1 designates a paraboloidally shaped reflector having different dimensions in width and height. At the focus of this reflector a feed horn 2 is arranged so that it is held by rods 3 and 4. The feed horn 2 is connected to a waveguide 5, which extends to the rear in this embodiment and which is supported, together with the reflector 1, from a supporting frame 6. The reflector 1 and the feed 2 together form a first antenna for producing a first directive antenna radiation pattern, which is indicated in Figure 2 by *a*. The system comprises furthermore a second antenna formed by the reflector of said first antenna and a plurality of individual radiating elements such as indicated at 7 arranged generally in a line along the width of the reflector. This second antenna produces a second antenna radiation pattern indicated in Figure 2 by *b*. As shown, this second radiation pattern *b* has the same direction as said first radiation pattern

a. A particularly effective and advantageous combined radar antenna system is obtained if said plurality of individual radiating elements supported by the reflector 1 are so spaced that in a projection of said individual radiating elements onto a plane at right angles to the axis of the paraboloid and taken in a direction parallel to the paraboloid axis, the projections of adjacent ones of the radiating elements are substantially equally spaced. Furthermore the radiating elements are connected to transmission lines on the rear of the reflector, the electrical length of the transmission lines being so chosen that the radiating

elements are so fed that a plane wave front of uniform phase is obtained. The individual radiating elements may consist of dipole radiators. In the embodiment shown in Figure 1, however, said individual radiating elements are constituted by unipole radiators which are passed through the reflector 1 for establishing a connection to the transmission lines on the rear side of the reflector, and which in front of the reflector are each bent over at right angles so that a vertical polarisation is obtained. The use of unipoles as radiating elements has the important advantage that a "tri-plate" strip line may be used as transmission lines. This simplifies the construction, whilst, in addition, it saves weight. "Tri-plate" strip-line transmission lines are known and described, for example, in "IRE Transactions", volume MTT-3, Special Issue, March 1955/2, pages 21 and ff. so that it may suffice to state here that with tri-plate strip lines the electro-magnetic energy is conducted via a flat inner conductor through a dielectric medium located between two flat ground plates and that such a line can be readily manufactured by using printed-circuit techniques.

In the embodiment shown in Fig. 1 the unipole radiators are made of aluminium to save weight. As shown in Fig. 3 they are formed by a plate 8, which may be brazed in a recess at the end of a through-connection pin 9. The part of the plate 8 located above said through-connection pin has a length of $\frac{1}{2}\lambda$, where λ is the wavelength of the signal applied to the unipoles. The part of the plate 8 located below the through-connection pin has been proportioned so that the input impedance of the unipole has the appropriate value to produce maximum radiation. This method of adaptation has the important advantage that the plate 8 may be of slight thickness so that the antenna pattern of the first antenna (reflector plus feed horn), operating with horizontal polarisation, is not affected by the unipole radiators arranged in front of the reflector. In view of its small thickness plate 8 is shaped such that the width of the part located above the through-connection pin tapers down in the upward direction, so that this part is less readily caused to vibrate mechanically.

It will furthermore be apparent from Fig. 3 that the through-connection pin 9 is inserted in a tubular insulating piece 10, which is fitted in a distance piece 11 and associated retainer ring 12. The distance piece and the retainer ring are made of metal and are each provided with a flange. The assembly is inserted into a hole provided at the correct position in the reflector surface and fixed in place by means of a clamping ring 13, which clamps the two

flanges to each other and to the front of the reflector. At the place of said clamping ring the front of the reflector has a depression such that, when mounted, this clamping ring will be flush with the reflector surface.

The transmission lines constituted by the "tri-plate" strip line are indicated in Fig. 3 by 14. The strip line is fixed by means of screws 15 and a circular cover plate 16 to the rear of the distance piece 11. As shown more clearly in Figs. 4A and 4B, the strip line is constituted by two identical plates 17 and 18 of insulating material. Each of these plates is provided on the outer face with a very thin, conductive metal layer 19, 20. These layers are electrically connected to the reflector 1 via the screws 15 and the parts 11 and 12. The inner faces of these plates rest against each other and hold the inner conductor 21. Via this inner conductor 21 the energy is supplied in a given ratio to the various unipole radiators. Each one of these unipole radiators is connected for this purpose to a tapping of the inner conductor 21. The plate 18 has a circular recess 22 so that by means of a contact screw 23 a conductive connection can be established between a tapping of the inner conductor 21 and the through-connection pin 9.

The distance between the radiating elements varies preferably so that the projections of these radiating elements on a plane at right angles to the axis of the parabola and in a direction parallel to this axis have equal spacing of about $\frac{1}{2}\lambda_0$, where λ_0 is equal to the wavelength of the signal in free space. It follows that the maximum number of individual radiating elements of the second antenna is determined by the wavelength λ_0 and by the width of the reflector.

The wavelength λ_0 and the width of the reflector are also determinative of the width in azimuth of the antenna pattern produced by the second antenna. If the wavelength λ_0 is comparatively long and if the width of the reflector is comparatively small, the antenna pattern will be comparatively wide in azimuth, so that only a poor resolution in azimuth is obtainable. The antenna system described is favoured because it makes possible a considerable reduction of width in azimuth of the antenna pattern by the use of a method known from monopulse radar techniques. To this end the individual radiating elements are divided into two groups producing two overlapping beams, as is shown in Fig. 5A. These beams overlap in a point at about -3 dB. The beams are added (Σ) and subtracted (Δ) by means of, for example, a hybrid ring or a magic T. The sum pattern (Fig. 5B) shows the resultant for the whole array, this

being a single lobe with a maximum on the bore sight axis of the antenna. This sum pattern is used for transmission. The difference pattern for the whole array shows a double lobe with a minimum on the bore sight axis of the antenna. The sum pattern and the difference pattern are used on reception. The sum and difference signals appearing at the output of the hybrid ring or the magic T may be processed in the manner known in monopulse radar techniques. Said sum and difference beams may be obtained in a simple way by constructing the strip line transmission lines in the manner illustrated diagrammatically in Fig. 6. Reference numeral 24 designates a hybrid ring. The circumference of this hybrid ring is $1\frac{1}{2}\lambda$. At 25 the hybrid ring is connected to an output terminal for the difference signal Δ and at 26 it is connected to an output terminal for the sum signal Σ . Measured along the hybrid in clockwise direction, the distance between the terminals 26 and 25 is equal to one wavelength λ . The output terminal of the sum signal 26 serves at the same time as an input terminal for energy to be radiated. To this end two supply lines 27 and 28 are connected symmetrically to the hybrid ring at $\frac{1}{4}\lambda$ relative to the terminal 26, so that the applied energy is supplied, on the one hand to the tappings 29, 30, 31 and 32 and on the other hand to the tappings 29', 30', 31' and 32'. The path lengths α , β , γ and α' , β' and γ' are chosen so that the phase shift due to the fact that said tappings follow the parabola is corrected so that the beam formed by the radiators connected to the tappings 29, 30, 31 and 32 is at a squint angle $+\theta$ to the bore sight axis of the antenna, whereas the radiators connected to the tappings 29', 30', 31' and 32' form a beam which is at a squint angle $-\theta$ to the bore sight axis of the antenna. The energy received by the two antenna halves is added and subtracted in the hybrid ring so that a sum and a difference diagram respectively is obtained.

An advantage of the described antenna system is that the reflector of the first antenna, even with quite different dimensions of the system, prevents the radiating elements of the second antenna from producing an undesirable rearward radiation.

It will therefore, be clear that the invention is not at all restricted to the use of dipole or unipole radiators and that, (if it is desirable for the second antenna to operate with circular polarisation), dielectric rod radiators may be employed as individual radiating elements.

A further possible modification is obtained if the individual radiators are constituted by slot radiators. As is known, such a series of slot radiators may be

realized in a simple manner by utilizing a "tri-plate" embodiment arranged to be flush mounted in the supporting surface.

WHAT WE CLAIM IS:—

- 5 1. A combined radar antenna system comprising a first antenna constituted by a substantially paraboloidally shaped reflector having unequal dimensions in width and height and a feed horn arranged at
10 the focus of said reflector for producing, in cooperation with said reflector, a first directive antenna radiation pattern, and a second antenna constituted by the reflector of said first antenna and a plurality of
15 individual radiating elements for producing a second antenna radiation pattern equidirectional to said first antenna radiation pattern, wherein said individual radiating elements are supported by the reflector and
20 are so spaced that in a projection of said radiating elements onto a plane at right angles to the axis of the paraboloid and taken in a direction parallel to said axis, the projections of adjacent ones of said
25 elements are substantially equally spaced, said individual radiating elements being connected to transmission lines on the rear side of the reflector to be so fed that a plane wave front of uniform phase is
30 obtained.
2. A radar antenna system as claimed in claim 1, wherein said individual radiating elements are constituted by unipole radiators taken through the reflector for

establishing a connection to the trans- 35 mission lines on the rear side of the reflector, said elements being bent over each at right angles in front of the reflector so that a vertical polarisation is obtained.

3. A radar antenna system as claimed in claim 2, wherein said transmission lines are constituted by a "tri-plate" strip line.

4. A radar antenna system as claimed in claim 3, wherein the plurality of unipole radiators are divided symmetrically 45 into two groups and in that said strip line comprises a hybrid ring through which the two groups of radiators are fed and in which the signals received by means of the two groups are added and subtracted so 50 that the sum diagram shows a single lobe with a maximum along the bore sight axis of the antenna, whereas the difference diagram is formed by a double lobe having a minimum on the bore sight axis of the 55 antenna.

5. A radar combined radar antenna system substantially as hereinbefore described with reference to the accompanying drawings. 60

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