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(54) **Electrically controlled aerial array with reduced side lobes.**

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US-A-3 193 830
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(73) Proprietor: **TELEFONAKTIEBOLAGET L M ERICSSON**
S-126 25 Stockholm (SE)

(72) Inventor: **Sjödin, Erik Staffan**
Rävekärrsgatan 205
S-431 33 Mölndal (SE)

(74) Representative: **Johnsson, Helge et al**
Telefonaktiebolaget L M Ericsson
S-126 25 Stockholm (SE)

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Description

Technical field

The present invention relates to an electrically controlled antenna array, i.e. an antenna with a main lobe which may be controlled by varying the phases in the included antenna elements. Such an antenna is used in radar reconnaissance equipment for example.

Background art

An antenna array of the kind intended here comprises a plurality of antenna elements configured as rectangular wave guides lying parallel. In particular, the radiation openings in the elements are formed as so-called broad side slits, i.e. longitudinal slits along the wider surface of each wave guide in the antenna array. It is already known to make the antenna lobe controllable in a plane at right angles to the longitudinal direction of the wave guides by placing phase shifters in the feed path to each guide, e.g. according to GB—B1.577.939. alternatingly above and below the centre line of the wave guides, the illumination function will be phase modulated along the antenna aperture, i.e. along the wave guides. This gives rise to large side lobe peaks in the antenna array radiation diagram.

It is known to solve this problem by using radiation openings and elements that reduce or eliminate the occurrence of periodical disturbances in the aperture. For example, edge slits may be used instead of broadside slits, see "Low-Sidelobe Radar Antennas" by H. E. Schrank from "Microwave Journal", July 1983 p 109 ff. Edge slits are difficult to master from the electrical design aspect, particularly due to the strong electromagnetic coupling between them, and it is therefore desirable to retain broadside slits to obtain good side lobe suppression.

A slot array antenna with slotted wave guides is previously known from US—A—4.423.421. This antenna is not provided with adjustable phase shifters to vary the phase of the electromagnetic field to the wave guides in the array. The spacing between the slots in one wave guide is different from that of another wave guide in order to produce a symmetrical pencil beam with maximized antenna gain and reduced sidelobes, but the pencil beam has a constant lobe direction.

Disclosure of invention

The object of the present invention is to achieve an electrically controlled antenna array of the kind mentioned in the introduction, using broadside slits as radiation elements, the antenna diagram of which shows substantially suppressed side lobes. The invention is characterized as will be seen from the characterizing portion of claim 1.

Brief description of drawings

The invention will now be described in detail, with reference to the accompanying drawings, where Figure 1 illustrates an antenna array with a construction known per se, but with further distinguishing features in accordance with the invention;

Figure 2 illustrates parts of two antenna elements included in the antenna of Figure 1;

Figure 3 is a cross section of an antenna element according to Figure 2; and

Figure 4 and 5 are radiation diagrams.

Best mode for carrying out the invention

The antenna array in Figure 1 comprises a plurality of antenna elements (4 elements in the Figure) in the form of rectangular wave guides V1, V2, V3 and V4 lying parallel along their respective long narrow sides. Feed wave guides M1 and M2—M4 (the latter three being concealed in the Figure) are each connected to one of the wave guides V1—V4. Each wave guide is provided with radiation openings in the form of longitudinal slits, S_{11}, S_{12}, . . . on the wave guide V1, S_{21}, S_{22} on the wave guide V2, S_{31}, S_{32}, . . . on the wave guide V3 and S_{41}, S_{42}, . . . on the wave guide V4. All the slits or slots shown are so-called broadside slits, i.e. uniformly wide slits or slots made in the wider face of the respective wave guide. The end portions of the feed wave guides M1—M4 which are attached to the wave guides V1—V4 have a feed opening (not illustrated in Figure 1) through which electromagnetic field energy, e.g. within the X band, is fed to each wave guide V1—V4. The other ends of the feed wave guides are connected via suitable input feed elements to the phase shifters F1—F4 (F3 and F4 being concealed in Figure 1) for controlling the phase of the field fed in, relative to a reference phase, e.g. the phase of the field to the wave guide VI.

The use of broadside slits or slots of the type shown in Figure 2 with uniform element spacing d ($d=d_1=d_2=$, . . .) gives rise to side lobe peaks in the antenna array radiation diagram, the height of the peaks depending on the directing angle. A radiation diagram is illustrated in Figure 4, in a plane parallel to the wave guides and through the lobe maximum when the direction is 20° from the direction of the normal. The side lobe peaks are so-called grating lobes whose periodicity correspond to the double element spacing 2d. If the slits S_{11}, S_{12}, . . . S_{21}, S_{22} . . . etc in the wave guides V1—V4 had mutually differing element spacing $d_1 \neq d_2 \neq$ . . . instead, the grid lobes from the individual wave guides V1—V4 would occur at different places in the radiation diagram and would not be added to each other to form the prominent peaks (S_1, S_2) in Figure 4. According to the invention, different element spacing is achieved by changing the wavelength of the individual wave guides.

Figure 2 illustrates a portion of the antenna array in Figure 1, portions of two wave guides being depicted. The slits S_{11}, S_{12}, and S_{13}, S_{14} in the wave guide V1 have the mutual spacing d_1 and the slits S_{21}, S_{22}, S_{23}, S_{24} etc in the wave guide V2 have the mutual spacing $d_2 \neq d_1$. To attain the intended reduction of the side lobe peaks in Figure 4, the wave guide wavelength λg varied such that λg is different for each of the guides

V1—V4. This is described below in connection with Figure 3. Different spacings d_1, d_2 between the slits of the different wave guides V1—V4 are obtained as a consequence.

Figure 3 is a cross section of a wave guide VI with the slits S_{11}, S_{12}, there also being shown a part of an adjacent wave guide V2. On its inner surface facing the slits S_{11}, S_{12} the wave guide VI is provided with a raised portion or ridge R1, situated symmetrically about the symmetrical axis C of the wave guide. The ridge has two side walls RV1 and RV2 extending at right angles to the inner surface Y of the wave guide in the longitudinal direction and entire length thereof. The side walls RV1 and RV2 are bridged by a wall RV3 at right angles to them. Both walls RV1 and RV2 have a height h_1 from the surface Y. The wave guide V1 is a so-called ridge wave guide wherein the wavelength λg for a given wave guide width *a* and height *b* may be varied within given limits by varying the ridge height h_1. The height h_1 is thus constant for a given wave guide in the group antenna, i.e. for the wave guide VI the height of the ridge R1 is equal to h_1, for the wave guide V2 the height of the ridge R2 is h_2 ($h_1 \neq h_2$) and so on. Since the slit spacing $d \approx \lambda g/2$, the grating lobes may be spread out over the lobe angle interval of the antenna, thereby reducing their effect on the side lobe level.

In Figure 5 is shown a radiation diagram for an antenna array with a ridge wave guide where this principle is utilised. The diagram in Figure 5 may be compared directly with the one in Figure 4, since apart from the ridges R1, R2 the antennas are otherwise entirely the same.

Broadside slits in antenna arrays of the type intended here have large advantages:

a) They have very low losses

b) They are simple and cheap to manufacture

c) Established and well functioning calculation methods are used.

The inventive antenna array retains the above-mentioned advantages due to the broadside slits, but with reduced side lobes.

The invention is not restricted to embrace wave guides V1—V4, where the wave guide wavelengths λg_1, λg_2, ... for the different wave guides have been varied by the measures described in connection with Figure 3. What is essential in the inventive concept is that the wavelengths λg_1, λg_2 ... have been made different, which results in that the mutual spacing d_1, d_2, ... must be dimensioned so that $d_1 \neq d_2$ etc. There is thus obtained variation in the positions of the grating lobes for the entire antenna array, which causes a reduction of the side lobe level.

Claim

An electrically controlled antenna array comprising at least two juxtaposed antenna elements and which gives a main lobe direction in dependence on the relative phase shift of the electrical signals applied to respective rectangular waveguides (V1, V2, ...) forming said juxtaposed antenna elements, one broadside surface of said waveguides being provided with a plurality of radiator openings in the form of slits or slots (S11, S12, ... S21, S22 ...) in the longitudinal direction thereof, the said waveguides being implemented such that the waveguide wavelength (λg) for at least some of the waveguides (V1, V2, ...) assumes mutually different values and the mutual spacing (d_1, d_2, ...) of the broadside slits or slots being different for selected waveguides characterized in that

a) said waveguides (V_1, V_2, ...) are of substantially equal length and width and

b) said different values of waveguide wavelengths (λg) are selected such as to spread the grating lobes pertaining to the individual antenna elements.

Patentanspruch

Elektronisch gesteuerte Gruppenantenne mit zumindest zwei nebeneinandergestellten Antennenelementen, die ein Hauptstrahlungskeulenrichtung in Abhängigkeit von der relativen Phasenverschiebung der elektrischen Signale ergibt, die den entsprechenden rechteckigen Wellenleitern (V1, V2, ...) zugeführt werden, die die nebeneinandergestellten Antennenelemente bilden, wobei eine Breitseitenoberfläche der Wellenleiter mit mehreren Strahleröffnungen in Form von Spalten oder Schlitzen (S11, S12, ... S21, S22, ...) in Längsrichtung ausgestattet sind, wobei die Wellenleiter derart implementiert sind, daß die Wellenleiterwellenlänge (λg) für zumindest einige der Wellenleiter (V1, V2, ...) wechselseitig unterschiedliche Werte annimmt und die wechselseitigen Abstände (d_1, d_2, ...) der Querseitenspalte oder -schlitze für ausgewählte Wellenleiter unterschiedlich sind, dadurch gekennzeichnet, daß

a) die Wellenleiter (V_1, V_2, ...) im wesentlichen die gleiche Länge und Breite aufweisen, und

b) die unterschiedlichen Werte der Wellenleiterwellenlängen (λg) derart ausgewählt sind, daß die Gitterstrahlungskeulen, die zu den einzelnen Antennenelementen gehören, gestreut werden.

Revendication

Réseau d'antennes commandé électriquement, comprenant au moins deux éléments d'antenne juxtaposés et établissant une direction de lobes principaux qui dépend du déphasage relatif des signaux électriques appliqués à des guides d'ondes rectangulaires respectifs (V1, V2, ...) formant lesdits éléments d'antenne juxtaposés, une surface de grande ouverture desdits guides d'ondes présentant plusieurs ouvertures de rayonnement sous la forme de fentes ou entailles (S11, S12, ... S21, S22 ...) dans leur direction longitudinale, lesdits guides d'ondes étant réalisés de façon que la longueur d'onde λg pour au moins certains des guides d'ondes (V1, V2, ...) prenne des valeurs mutuellement différentes et l'écartement mutuel (d_1, d_2, ...) des fentes ou entrailles de grande ouverture étant différent

pour des guides d'ondes choisis, caractérisé en ce que

a) lesdits guides d'ondes (V_1, V_2, ...) sont de longueurs et de largeurs sensiblement égales et,

b) lesdits différentes valeurs des longueurs d'ondes (λg) des guides d'ondes sont choisies de façon à étaler les lobes de treillis associés aux éléments d'antenne individuels.

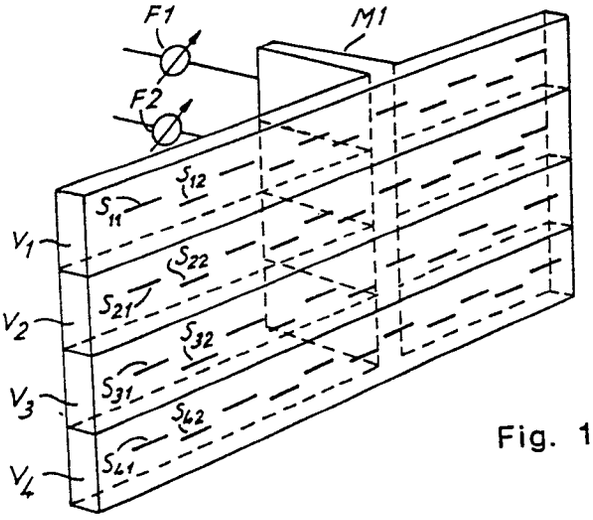

Fig. 1

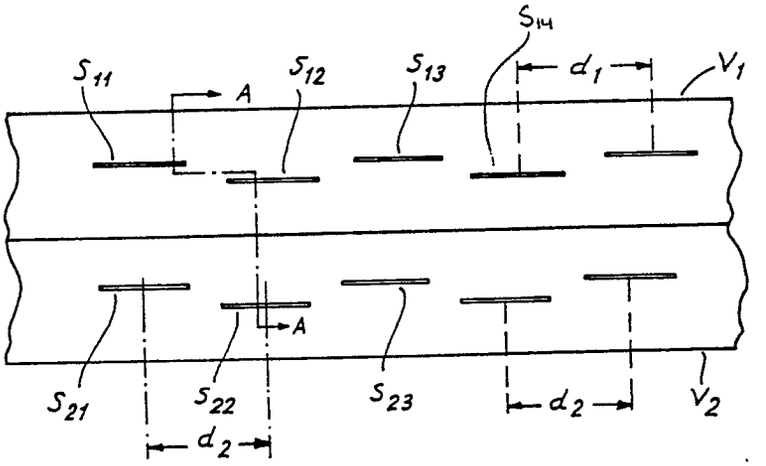

Fig. 2

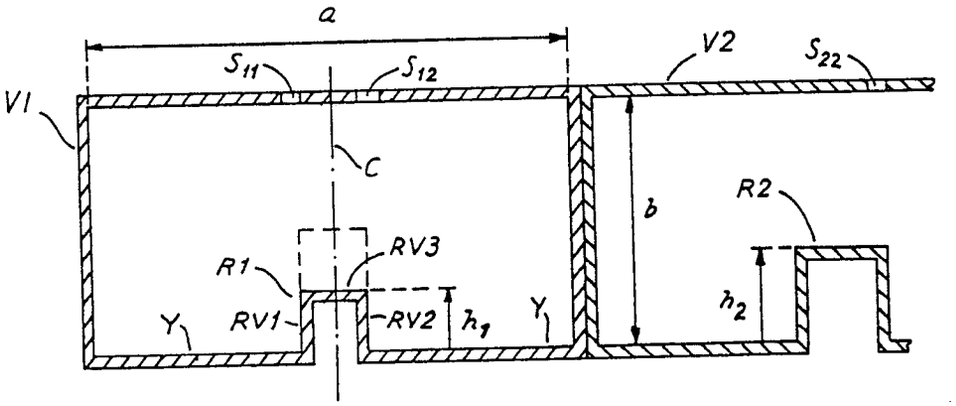

Fig. 3

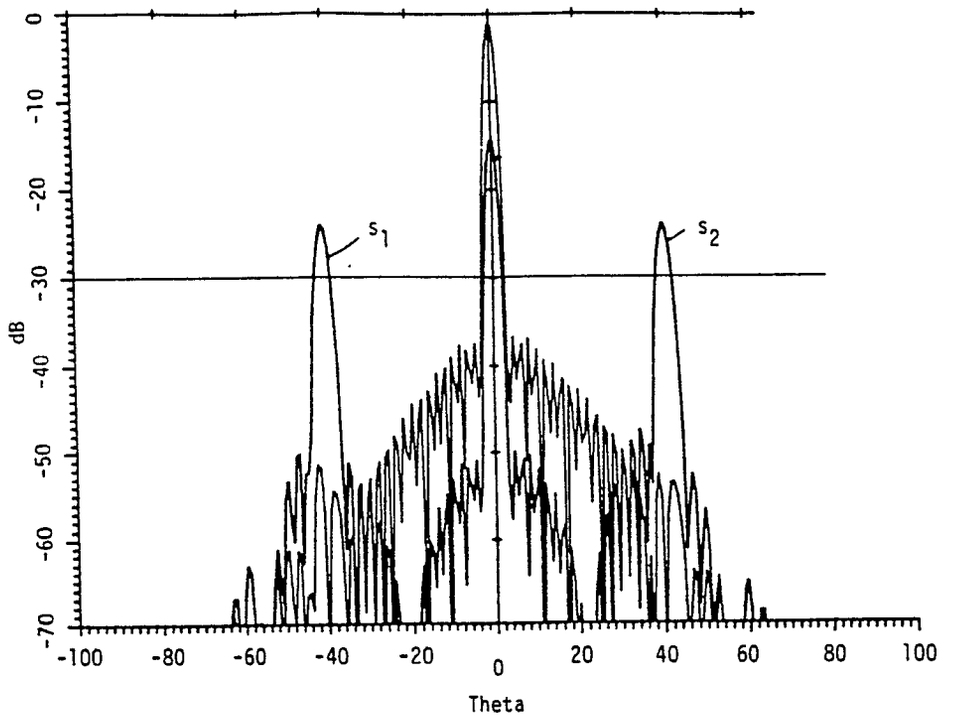
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Fig. 4

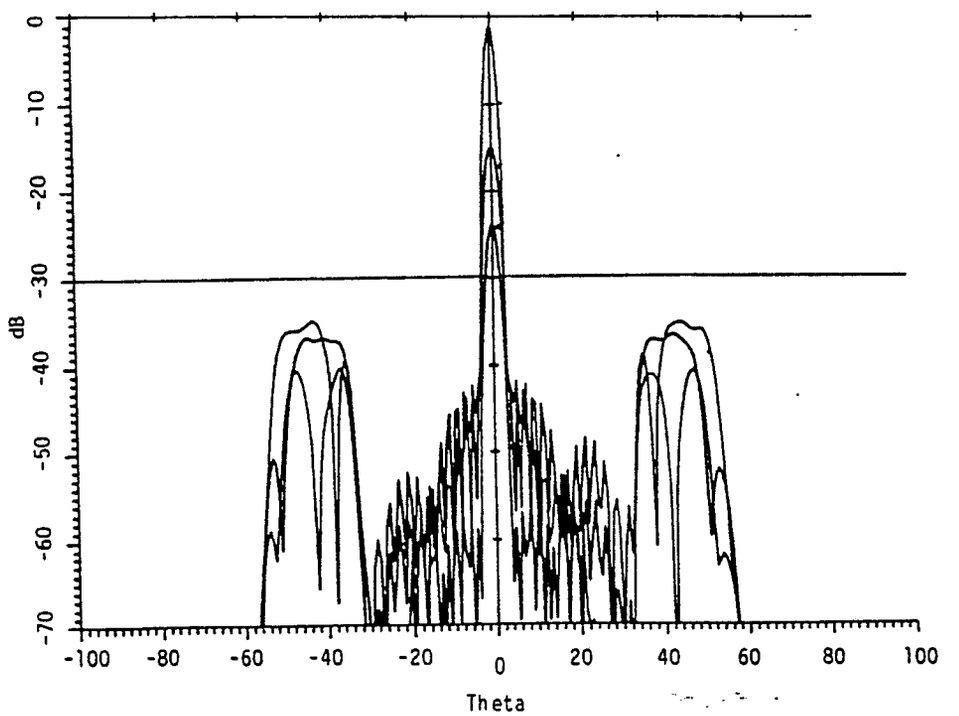
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Fig. 5