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(54) Branching network for the separation of very high frequency signals in double polarization.

(57) Branching network for the separation of very high frequency signals in double polarization, with compact structure, reduced loss due to insertion and with a high degree of selectivity for frequencies and polarizations to be used essentially in the field of terrestrial stations for satellite communications.

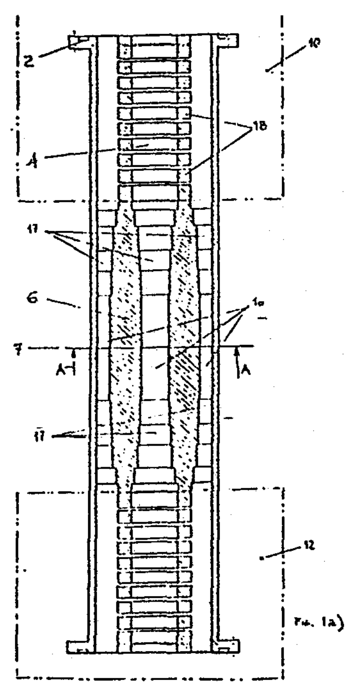

FIG. 1

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Croydon Printing Company Ltd

BRANCHING NETWORK FOR THE SEPARATION OF VERY HIGH FREQUENCY SIGNALS IN DOUBLE POLARIZATION

This application is related to the copending application Ser. No. 469,141 filed 23 February 1983 by me and Enzo Cavalieri D'Oro.

The present invention relates to a branching network for the separation of signals with a very high frequency in double polarization and, more particularly, to a signal separator for microwaves which comprises two "3dB"-type couplers with reject-band type filters inserted between them, the filters reflecting the signals coming from the first 3dB-type coupler in one of the frequency bands and allowing the transit of the other band. The filters are such as not to alter the amplitude and phase relationships in the signals pertaining to each of the two frequency bands.

Branching or separation networks of the type with which the present invention is concerned have utility in the telecommunication field, more particularly to the field of satellite telecommunications. The device can form an element of the illumination system ("FEED") for terrestrial antennas, since frequency recovery is generally required for this type of communications, given the high cost of duplicating antennas of large dimensions.

While this description will refer repeatedly to linearly polarized signals, it should be understood that the principles involved can also be applied to telecommunication systems operating with circular polarization.

A linearly polarized signal can be transformed into a circularly polarized signal or vice versa, by means of a 90° differential phase shifter (polarizer) with its differential phase-shift axis located at 45° with respect to the linearly polarized signal.

It is also known that in the waveguide connected to the antenna for signal transmission and extraction, four channel groups are present, namely, two transmission channel groups which are isofrequential and differ from one another by their polarization, and two reception channel groups which are isofrequential but in a frequency band different from that of the transmission channels, and also differing from each other by their polarization.

In order to separate the transmission channels from the reception channels it is necessary to use frequency separation. This separation can be based on polarization and can be effected by using orthogonal-mode transducers (OMT) or others known to those skilled in the art.

In satellite telecommunications systems, devices such as "OdB" type couplers, besides separating the two bands by their frequencies, extract and supply to different outputs the channels of one of the two bands, separated according to their polarization.

A double OdB coupler consists of a central waveguide (having a circular or square cross-section) wherein both the frequencies with both polarizations can propagate and of four lateral waveguides symmetrically arranged with respect to the central waveguide, connected thereto by a plurality of coupling waveguides, arranged so as to allow the transit of the signals present on one of the polarization planes.

The signals present in the central waveguide are thus separated according to their polarization. One pair of lateral guides symmetrically arranged with respect to the central guide, receives the vertically polarized signals, and the other pair of lateral guides receives the horizontally polarized signals. In a more general sense, one pair of lateral guides receives the signals present in one plane of polarization, while the other pair receives the signals present in a polarization plane perpendicular to the first.

Each coupling guide allows the transfer into the lateral guides of a fraction of the energy of the signals present in the central guide, which can propagate into the coupling guide. By suitably dimensioning the couplers, the complete transfer of the mentioned energy from the central guide to the selected lateral guides can be achieved. Based on the reciprocity principle, the above-mentioned coupler can also accommodate dual mode operation: the delivery to one of the pairs of opposite lateral guides of two signals with equal amplitudes and phases, these being totally transferred to the central guide, where they are summed.

The coupling waveguides can be dimensioned as high-pass filters of poor efficiency. If the reception band is sufficiently remote from the transmission band, it is possible to separate the two bands by dimensioning the coupling waveguides so that only the band with the highest frequency can propagate (for instance the transmission band) while the other band propagates undisturbed in the central waveguide.

Mention should also be made of the circuit for the separation of two frequency bands for very high frequency signals in double polarization" (Italian patent application No. 22821 A/81, 9/7/81, CAVALIERI D'ORO) which describes OdB couplers capable of separating the reception band from the transmission band, even when the two bands are close to each other.

The frequency selectivity which allows the use of the OdB coupler in only one of the two bands, is achieved due to the rejection cavities located in one wall of each of the lateral guides and facing the coupling guides, but the rejection cavities are capable of operating only when acting upon very narrow frequency bands, which limits the use of this device, because when very wide frequency bands must be rejected, the cavities will produce a different phase relationship in the lateral guides, departing from the synchronism principle to the point where these couplers cannot be useful.

The copending application relates to a circuit for the separation of two frequency bands for signals of very high frequency in double polarization" (see also Italian patent application No. 19845 A/82, 25/2/82, CAVALIERI D'ORO- VITA). This circuit arrangement uses bandpass filters inserted between 3dB type couplers to separate the reception band from the transmission band. Here the filters with lamellar structure make the construction of this device complicated.

In addition, when the reception band is very close to the transmission band, the desired selectivity cannot be achieved. Thus it may be said that prior art separators have the following disadvantages:

major insertion losses, due to the maximum rejectivity required in the filters;

large and cumbersome construction and weight;

a very complex construction; and

difficulties is use of the device for wide and close frequency bands.

It is the principal object of this invention to provide a microwave branching network for the separation of polarized high-frequency signals whereby the disadvantages of earlier systems are obviated.

Another object of this invention is to provide a separator connectible to a terrestrial antenna of a satellite communications system for separating transmitting and receiving bands with respective polarizations so that the insertion losses are negligible and the device is of simple construction, small size and little weight.

These objects and others which will become apparent hereinafter for the separation of very high frequency microwave signals in double polarization are achieved with a device which comprises a central waveguide permitting propagation of the signals of both bands with respective polarizations and four lateral waveguides connected symmetrically to the central waveguides by respective coupling waveguides allowing transit of the signals of the two bands having the same polarization.

Respective reject-band or high-pass filtering means is connected to the control waveguide and to the four lateral waveguides to permit transit of only one frequency band each, the filtering means being symmetrical with respect to both polarization planes.

Connected to these filtering means is a second double 3dB coupler with central waveguide, drom lateral waveguides and respective coupling waveguides as described.

The device of the present invention has been found to be capable of overcoming the disadvantages of the earlier devices, with the following results:

negligible insertion losses ($\leq$0.20 dB in the band 10.7 + 14.5 GHz);

less cumbersome construction and a lower weight, due to its particular configuration, which will be further described below;

simple construction;

agreement between the controlling elements;

optimum reproducibility;

utility of the device even with wide frequency bands close to each other.

More specifically the device of the invention consists of a double coupler of the OdB-type, comprising in turn two identical sections in the form of double couplers of the 3dB-type with filtering elements of the reject-band or the high-pass type inserted between them and capable of separating two frequency bands even if they are very wide or close to each other.

The circuit according to the invention for the separation of two frequency bands for very high frequency signals in double polarization comprises:

a first double coupler of the 3dB type including a central waveguide, capable of permitting the propagation of signals from both bands, according to each of the two polarizations (V and H as described below to represent vertical and horizontal polarizations, respectively) and four lateral waveguides, disposed symmetrically with respect to the central waveguide, being connected thereto by a multiplicity of coupling waveguides capable of allowing the transit of signals from both bands having the same polarization;

filtering structures of the reject-band type or the high-pass type received in the square-cross section central guide with square cross-section, allowing the transit of signals of only one of the frequency bands;

a second 3dB coupler analogous to the first.

The invention is now going to be described with respect to one of its preferred embodiments which is given as an illustrative, but nonlimiting, example, with reference to the accompanying drawing in which:

FIG. 1a is an axial (longitudinal) section through a device according to the invention;

FIG. 1b is a section taken along the line Ib-Ib of FIG. 1a;

FIG. 1c is an end view of the device;

FIG. 2 is a block diagram illustrating the principles for single plane polarization;

FIG. 3 is a similar diagram for a transit mode of the filters; and

FIG. 4 is another diagram showing the principles of operation in a mode in which the filters are rejecting.

FIG. 1 shows the configuration of the device in one of its possible embodiments and in which the device comprises a flange 1 having connection bores 2 for connecting the separator with the remaining parts of the antenna illuminator. Within the device is a set of lateral rectangular guides 3, a central guide 4, and a supporting structure 5 of polygonal shape (so as to reduce the weight of the device). The filtering structures with cut-off guides in the reception band (high-pass filters) are represented at 6.

In the block diagram of FIG. 2, the circuit arrangement for a single polarization (V or indeed H) comprises a reception end or port 8, a common guide 9 for transmission/reception, the first 3dB coupler 10, the high-pass filters 11, a second coupler 12, the transmission end or port 13 and a terminal 14 for high frequency.

It is to be noted that a double 3dB coupler can also have a dual mode of operation, i.e. the energy of a field applied to the inputs of a pair of lateral guides can be distributed over the lateral guides and the central guide.

The present device is a circuit for the separation of signals by their frequencies and polarization. In the embodiment shown in FIG. 2, the ends or ports 8 and 13, respectively the reception and transmission ports, are uncoupled. While the signals coming from the port 13 in the band TX are sent to the antenna 15, the signals received by the antenna 15 in the band RX are inserted into the reception port 8.

This diagram refers to only one of the polarizations (for instance polarization in the V-plane polarization of FIG. 1b) and is completely separate (isolation >35dB) from the other polarization plane (H of FIG. 1b). These features are a result of the symmetry of its structure. The mode of operation of the structure with the frequency accepted by the filters is shown in FIG. 3.

FIG. 4 refers, as already mentioned, to the signals present in the band rejected by the filters.

In order to achieve greater graphic and descriptive clarity, the attenuation and the phase shift introduced by the double 3dB couplers and the filtering sections 17 have been considered zero, as well as the angle of reflection (the reflected signal has the same amplitude and phase as the incident angle); in practice, the couplers, as well as the filtering sections, may modify the amplitude and/or the phase of the transitting signals and/or of the reflected signals.

With reference to FIG. 3, a unitary amplitude signal applied in B will generate at the outputs C and C' of the first coupler 10 two signals of an amplitude $1/\sqrt{2}$, phase-shifted with respect to each other by $\pi/2$ (the signal in C anticipates the one in C') these signals pass through the filtering sections (which have been omitted being transparent to the passed signal) and reach the inputs D and D' of the second coupler 12.

By application of the overlapping effect it can easily be seen that the entire signal applied in B is available at the exit of the lateral guide E', while at the exit E of the central guide 4 there is no signal.

With reference to Fig. 1a, the two isofrequential signals comprised in the band passing through the filtering sections can still be extracted, in accordance with their polarization, at the output of the two pairs of lateral guides of the second coupler 12.

In the diagram of FIG. 4 the filtering sections have been substituted by short circuits, since the filters work in the rejection band. A signal of unitary amplitude applied in B will generate at the outputs C and C' of the first coupler 10 two signals with an amplitude of $1/\sqrt{2}$ phase-shifted with respect to each other by $\pi/2$.

The signals will be reflected by the short circuit towards the first coupler (as mentioned before, the signals have not been phase-shifted).

By applying the overlapping effect, it can be easily seen that the entire signal applied in B is available at the output B'.

The device according to the invention separates the transmission band from the reception band, respectively in the two polarizations perpendicular to four rectangular guides.

The high-pass filter section are constructed with stretches of cut-off waveguides 16 for the lower frequency band of sufficient length to achieve the desired degree of selectivity or rejection, these stretches being preceded by adapter sections 17 for the high frequency band.

CLAIMS

1. A branching network for the separation of very high frequency microwave signals in double polarization, comprising in an elongated waveguide body the following elements arranged in series:

a first double 3dB-type coupler consisting of a central waveguide permitting propagation of signals of both bands according to each of two polarizations and of four lateral waveguides symmetrically arranged with respect to the central waveguide to which they are connected by a plurality of coupling waveguides, capable of allowing the transit of signals of both bands having the same polarization;

high-pass type filtering sections connected to the central waveguide and to the four lateral waveguides, which allow the transit of signals of only one frequency band, said filtering sections being symmetrical with respect to both polarization planes and having the same electrical characteristics in the central guide and in the lateral guides for the signals present in respective pass and reject bands; and

a second double 3dB coupler corresponding to said first coupler and connected to said filtering sections.

2. The branching network defined in claim 1 wherein the high-pass filter sections are constructed with stretches of cut-off waveguides for the lower frequency band, of sufficient length to achieve selectivity, said stretches being preceded by adapter sections for the high-frequency band.

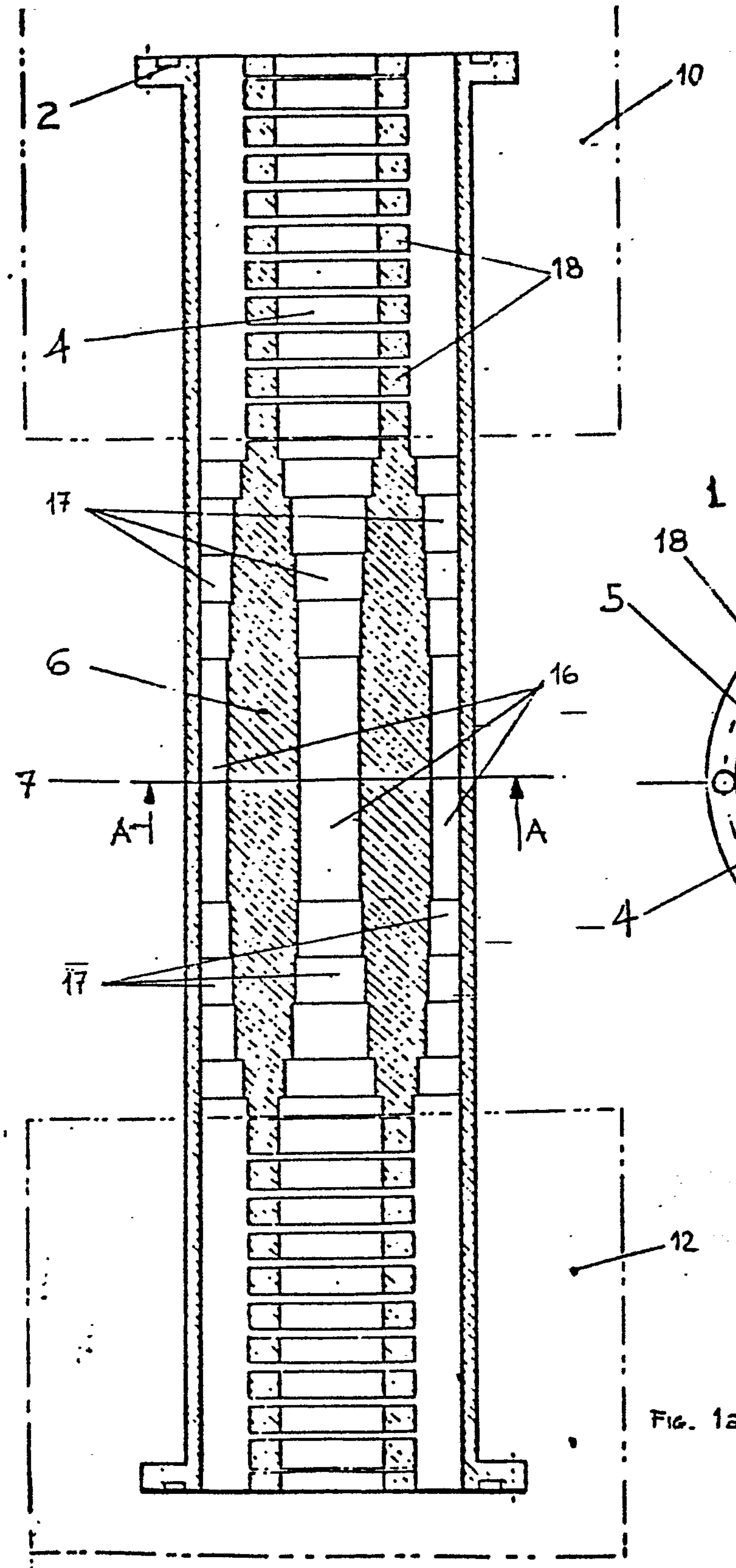

Fig. 1a)

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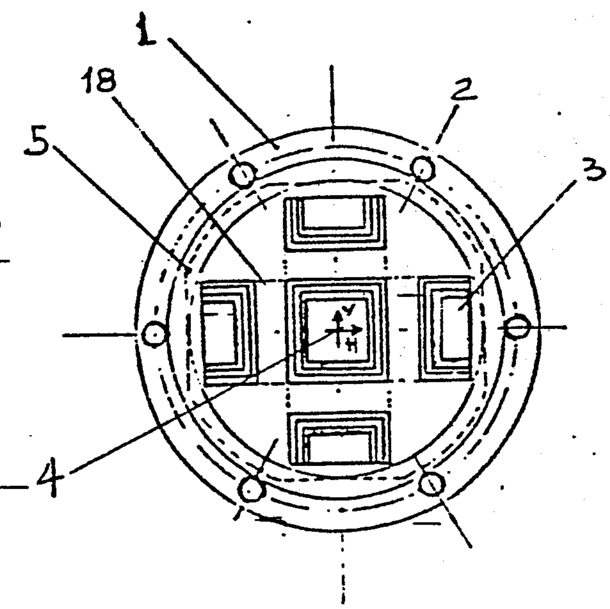

Fig. 1b)

FIG. 1

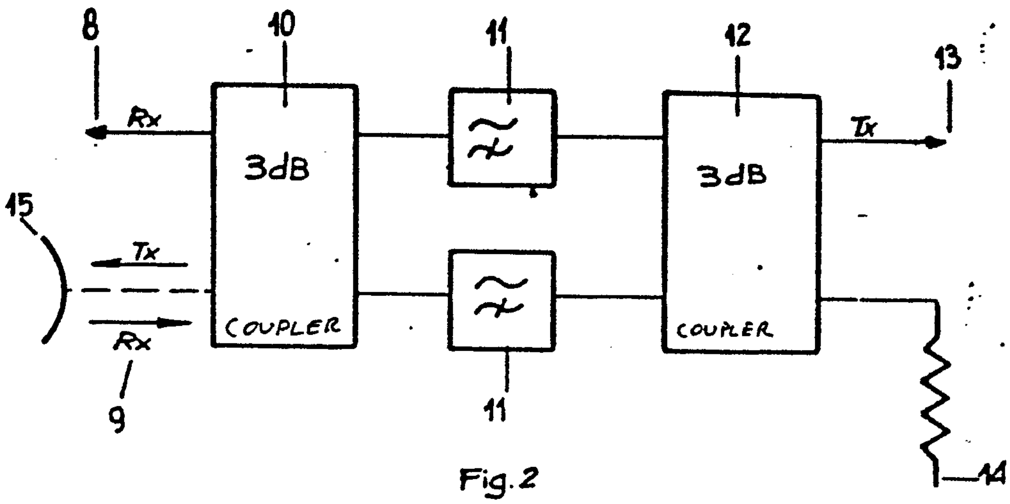

Fig. 2

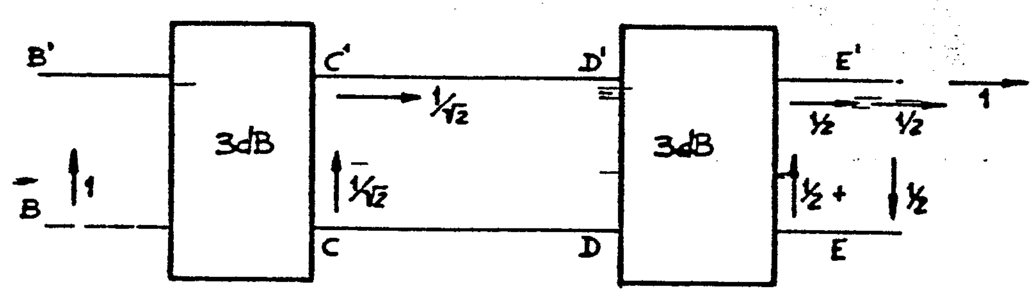

Fig. 3

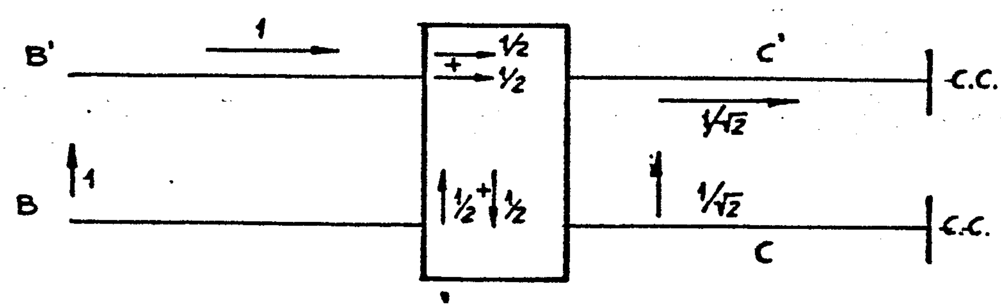

Fig. 4