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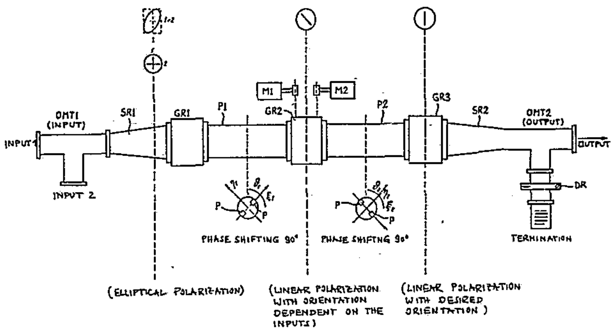
(54) Device for the combination without r.f. power loss of two or more microwave transmitters running in parallel and without any power ratio.

(57) The invention relates to a device for the combination without r.f. power loss of two or more microwave transmitters running in parallel and with any power ratio, comprising as basic components in cascade connection and with the interposition of rotative joints and, where necessary, of transition connections with the rotative joints, a first orthogonal mode input transducer (OMT1), a first rotative polarizer (P1) which can receive at the input an elliptically polarized field and supply at the output a linearly polarized field, a second rotative polarizer (P2) which can receive at the input a linearly polarized field and supply at the output a linearly polarized field which, however, in an intermediate part has got a transformation into a circular polarization, a second orthogonal mode output transducer (OMT2) and two motors (M1, M2) commanding the rotational motions of said two polarizers (P1, P2) and being controlled by a computer which gets monitoring data from a detector diode (DR) connected with the transversal branch of said output transducer.



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Device for the combination without r.f. power loss of two or more microwave transmitters running in parallel and with any power ratio

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Description

The invention relates to a device for the combination without r.f. power loss of two or more microwave transmitters running in parallel and with any power ratio.

It is known that often it is required to add the power of two r.f. amplifiers fed by the same source of energy, e.g. in order to feed an antenna. If, according to the prior art, the power values of both amplifiers are known and if e.g. these values are equal, the two output powers of the amplifiers are fed to a summing network - a hybrid - which generally has two outputs, and the parameters of the hybrid are set by means of construction such that the whole power is at one output and a zero power is at the other output. Usually, at the undersired output a load is applied in order to absorb the possibly present power which could attain to it for some unbalance reason. If, however, this unbalance varies in an uncontrolled manner, e.g. because of the variation of the amplificator characteristics or of the phase variation owing to different thermal expansions of the wave-guides or owing to other reaons, the whole undesired power absorbed by the load and therefore not utilized increases in an unendurable measure.

It is an object of the invention to realize a device for combining or adding the outputs of two or more microwave amplifiers which automatically adapts or can manually be adapted to the powers and phases generated by the two transmitters.

The summing network according to the invention comprises a variable coupler the structure of which will be explained by means of the drawing.

The theory of said summing network is as follows. First of all it should be considered that the coupling between two wave-guides has to be made in parallel with a total coupling factor $C = ce^{j\Psi}$, in which the coefficient c may vary between zero and the unit value and the phase Ψ may have any value. The structure can be considered having four gates numbered as usual. With such a device, the powers available at the two input gates 1 and 4 are added such that their sum is available at one of the two output gates whereas the other output is zero so that - presuming that the ohmic losses of the device are negligible - the combination of the two powers is obtained without matching losses.

In order to achieve such a result, the variation of phase Ψ of one of the signals and the coupling coefficient c have to be set appropriately as a function of the input amplitudes and of the relative input phases.

It may be supposed that

$$S \equiv \begin{vmatrix} 0 & t & jc & 0 \\ t & 0 & 0 & jc \\ jc & 0 & 0 & t \\ 0 & jc & t & 0 \end{vmatrix}$$

is the diffusion matrix of the coupler (which is considered without any loss), wherein $0 \leq c \leq 1$ is, as already stated, the coupling coefficient and $t = \sqrt{1 - c^2}$ is the transmission coefficient.

Other diffusion matrices could be imagined but those can all be reduced to the above expressed form by suitably choosing the reference sections input - output.

If to the gates 1 and 4 are fed the signals $\overrightarrow{V_1}$ and $\overrightarrow{V_4}$ (while $\overrightarrow{V_2} = \overrightarrow{V_3} = 0$) and all gates are closed with appropriate terminations, the diffused signals are:

$$\begin{aligned} \overleftarrow{V_1} &= 0 \\ \overleftarrow{V_2} &= t\overrightarrow{V_1} + jc\overrightarrow{V_4} \\ \overleftarrow{V_3} &= jc\overrightarrow{V_1} + t\overrightarrow{V_4} \\ \overleftarrow{V_4} &= 0. \end{aligned}$$

If the whole power is to be obtained, i.e. in practice the sum power, $\overleftarrow{V_3}$ at the output 2 has to be zero:

$$\overleftarrow{V_3} = jc\overrightarrow{V_1} + \sqrt{1 - c^2}\ \overrightarrow{V_4} = 0$$

thence

$$\frac{\overrightarrow{V_4}}{\overrightarrow{V_1}} = -j\,\frac{c}{\sqrt{1-c^2}}\,.$$

This requires that $\overrightarrow{V_4}$ is shifted 90^0 out of phase from $\overrightarrow{V_1}$. This result can be obtained by suitably choosing the value of ψ which is a first degree of freedom.

After this first step we get:

$$\frac{\overrightarrow{V_4}^2}{\overrightarrow{V_1}^2} = \frac{c^2}{1-c^2}$$

and thence:

$$0 \leq c = \frac{|\overrightarrow{V_4}| / |\overrightarrow{V_1}|}{\sqrt{1+|\overrightarrow{V_4}|^2/|\overrightarrow{V_1}|^2}} \leq 1.$$

The appropriate choosing of the values for ψ and c, which represents a second degree of freedom, can be effected by monitoring the signal amplitude at the output 3 and by setting the values for ψ and c such that said signal may be kept at the minimum, ideally zero.

The principle of the present invention is to substitute the two mutually coupled wave-guides to which the above explained theory refers by a single structure having a circular section and behaving as in realty it were two guides, i.e. it permits the independent propagation of two polarized fields in two mutually orthogonal axes. As, for the objects of the invention, these two modes of propagation have to be coupled, i.e. a power exchange between both of them must be possible, the guide in question which is structurally unique but functionally double has to be provided with coupling members. These coupling members consist of diametral asymmetries, e.g. P protuberances called irisses, or continuous or discontinuous projections. These diametral asymmetries may be realized by a continuous deformation of the guide section which would assume e.g. an elliptical shape. Said wave-guides in the following will be called polarizers.

The presence of said asymmetries works such that the two fields are no longer independent. In fact, the field component ξ propagating in the direction which unites the irisses propagates with a speed (i.e. has a certain phase constant) which is different from the propagation speed of the component η orthogonal to it (and which propagates with a different phase constant), so that after a time the two field components get out of phase. Acting on this phase difference said two orthogonal fields are coupled and consequently power is trasmitted from one to the other. The phase difference is set by varying the angle θ which the irisses uniting diametral plane includes with the input direction of said two fields. To each rotation angle corresponds a certain coupling degree.

Having realized in this way a regulation possibility, i.e. a degree of freedom, the present invention makes use of a second guide-wave segment with P asymmetries in order to analogously obtain a second regulation possibility and consequently a second degree of freedom.

This theory in practice is accomplished by a device as illustrated in the annexed figure which will now be explained in detail.

The device comprises in combination successively a first section consisting of an orthogonal mode transducer (orthomode transducer) OMT 1, possibly a connection section SR 1 having a circular exit, a first rotative joint GR 1, a first polarizer P1 which can be rotated by means of a motor M1, a second rotative joint GR 2, a second polarizer P 2 which can be rotated by means of a motor M2, a third rotative joint GR 3, possibly a second connecting section SR 2 having a circular input, a second section consisting of an orthomode transducer OMT 2, a detector diode DR connected with an output of said second section OMT 2 in order to detect the undesired field component and to send monitoring data to a computer (not shown) which controls the rotation of said motors M1 and M2. The segment incorporating said diode DR is closed by a convenient terminal.

Such a device is a variable means which by a computerized control circuit automatically matches to the power and to the phase of said two transmitters. There are two adjustable parameters corresponding to the amplitude and to the phase or to the amplitude in phase and to the amplitude in quadrature of the two field components. The structure is aperiodic and therefore has wide band and low losses. In fact, compared with a coupling between two separate wave-guides which has coupling bores or the like, the coupling realized in asymmetry as a rotative structure is much better, owing to the lack of sliding contacts, to the small surface extension of the structure and to the lack of resonance effects.

The two segments P1 and P2 have been determined polarizers because they actually behave as polarizers. In fact, looking e.g. at the first of them and supposing that its length is such that there is a phase difference of 90^0 between the component η_1 and the component ξ_1 of the field and that the input field is linearly polarized, it can be ascertained that, varying the angle θ_1 e.g. from 0^0 through 45^0 to 90^0, the field will assume a polarization that varies from linear to elliptic (for $0 < \theta_2 < 45^0$) and then to circular (for $\theta_1 = 45^0$) and subsequently becomes elliptical again (for $45^0 < \theta_1 < 90^0$) and finally again linear (for $\theta_1 = 90^0$). In other words, starting from a linear polarization and adjusting the angle θ_1, all elliptic and particularly circular polarizations can be obtained.

Vice versa, the very same means to the input of which an elliptically polarized field is applied can supply at the output a linearly polarized field.

In further explaining the functional principles of the device according to the invention, it can be seen that, using a first polarizer which at the input accepts an elliptically polarized field the axes ratio and the ellipse orientation of which depend on the amplitudes and relative phases of the input fields, a rotation angle of the polarizer can be found at which the output field has a linear polarization, though unknown.

In order to obtain at the output a field that not only has a linear polarization but also is oriented in a desired mode, the first polarizer P1 is followed by a second polarizer P2 the length of which is twice the length of the first polarizer P1 such that, if the first polarizer supplies a phase difference of 90^o, the second polarizer supplies a phase difference cf 180^o.

In said second polarizer P2, in practice the field components η_2 will have a phase difference which is 180^o more than that of the components ξ_2. The second polarizer P2 can be considered a union cf two polarizers having a phase difference of 90^o, i.e. a first segment receiving the linearly polarized field supplied by the first polarizer P1 and supplying at the output a circularly polarized field, and a second segment receiving at the input the circularly polarized field and supplying at the output a linearly polarized field. Said second polarizer P2 can be rotated at any angle in order to align the direction of the output field polarization with any desired direction. In practice, such a polarization of double length at the cutput has always a linear field, however turned by an angle which is twice the angle by which said polarizer is turned.

From the structural point of view it can be seen that two transmitters are applied to both inputs 1 and 2 of an OMT1 input device. This device has an already known structure and generally has a square section so that a segment is provided having a transition from a square shape to a circular shape in order to connect the OMT 1 device with the rotative joint GR 1 having the same circular section. The same is true for the connection means between the third rotative joint GR 3 and the OMT 2 output device. It is therefore obvious that the connection segments SR 1 and SR 2 are not necessary if the OMT 1 and OMT 2 devices have circular sections.

As already said, in order to determine the two rotations θ_1 and θ_2 which are both unknown, the undersired component of the output field is monitored by means of a diode DR connected in the transversal branch of the OMT 2 output transducer and the reading executed by the diode DR is sent to a computer which, for subsequent attempts and by actuating the motors M1 and M2, individualizes the two rotations θ_1 and θ_2 which minimize and eventually nullify said undersired component. Of course, this solution does not exclude the search by manual instead of automatic rotation. Here it should be noted that the sensitivity of the regulation system is very high because it is based on the detection of a zero power at the non used output and on the detection of the maximum power at the used output.

Obviously, the system can be extended to more than two transmitters, combining the added output of the first two transmitters with that of the third one and so on.

In the foregoing a preferred example of the invention has been described, but it is obvious that those skilled in the art can accomplish various modifications without leaving the spirit of the invention.

Claims

1. Device for the combination without r.f. power loss of two microwave transmitters running in parallel and with any power ratio, comprising in combination in series a first orthogonal mode input transducer (orthomode transducer) (OMT 1), a first rotative joint (GR 1), a first polarizer (P1) which effects a 90^{0} phase difference and can be rotated by means of a first motor (M1), a second rotative joint (GR 2), a second polarizer (P2) which effects a 90^{0} phase difference and can be rotated by a second motor (M2), a third rotative joint (GR 3), a second orthogonal mode output transducer (OMT 2), a detector diode (DR) connected with the transversal branch of said second transducer (OMT 2) in order to detect the undersired field component and to supply monitoring data for controlling the rotation of said motors (M1, M2).

2. Device as claimed in claim 1, wherein said polarizers (P1, P2) are realized as circular wave-guides which can sustain the propagation of two mutually orthogonal fields and which have incorporated means joining said two fields.

3. Device as claimed in claim 2 wherein said joining means are asymmetries realized by discrete or continuous projections provided in diametral opposite positions within the wave-guide.

4. Device as claimed in claim 3 wherein said asymmetries are realized by an elliptic deformation of the wave-guide which remains circular only at the ends mounted in the rotative joints.

5. Device as claimed in anyone of the preceding claims wherein the orthogonal mode transducers have a square shaped section and wherein segments are provided having a transition from a square shape to a circular shape section for the connection with the rotative joints.

6. Device as claimed in claim 1, wherein the monitoring signals of said detector diode (DR) are sent to a computer which controls the rotational motions of said motors (M1, M2).

7. Device as claimed in anyone of claims 1 to 4, wherein said second polarizer (P2) has the identical structure of the first polarizer (P1) but twice the length.

8. Device as claimed in claim 1, wherein the transversal branch of said second orthogonal mode transducer (OMT 2) incorporating the detector diode (DR) is closed by a suitable termination.

9. Device for the combination without r.f. power loss of two or more microwave transmitters running in parallel and with any power ratio as claimed in anyone of the preceding claims and substantially as described and illustrated.

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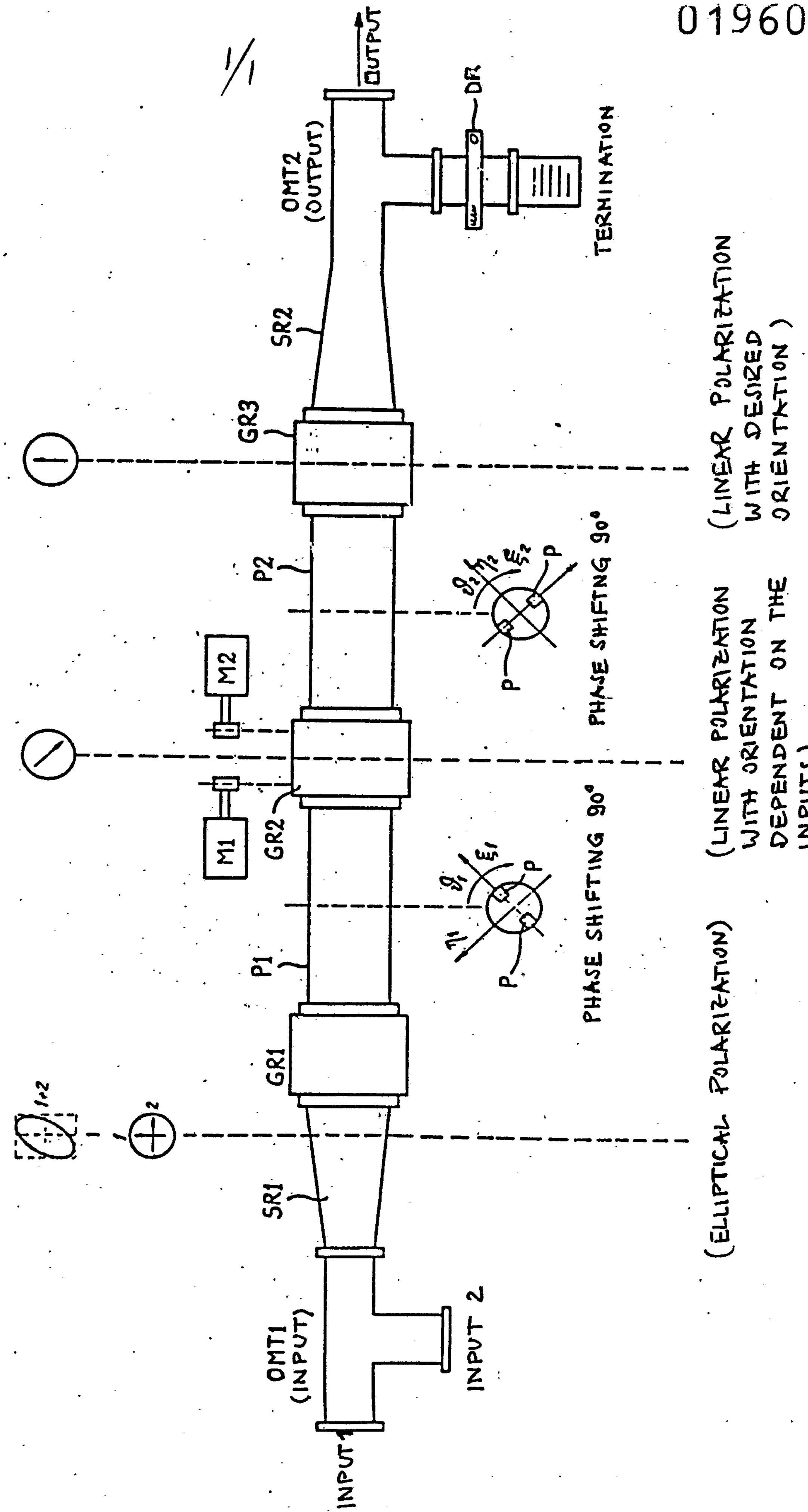
OUTPUT
DR
OMT2
(OUTPUT)
TERMINATION
SR2
GR3
(LINEAR POLARIZATION
WITH DESIRED
ORIENTATION)
P2
PHASE SHIFTNG 90°
M2
M1
GR2
(LINEAR POLARIZATION
WITH ORIENTATION
DEPENDENT ON THE
INPUTS)
PHASE SHIFTING 90°
P1
GR1
(ELLIPTICAL POLARIZATION)
SR1
OMT1
(INPUT)
INPUT 2
INPUT 1