

The present invention has as an object a device for coupling energies which is able to be used in metric and decimetric waves.

Such devices are necessary in various cases: to arrange that, from one source, several amplifiers or preamplifiers function in an equipotential and equiphased manner, or else to add the powers delivered by a plurality of equipotential and equiphased preamplifiers so that, with the power obtained, the amplifiers are made to operate in an equipotential and equiphased manner, or else to add the powers delivered by a plurality of equipotential and equiphased amplifiers to supply the same user, generally composed of a transmission antenna.

In the case, for example, of amplifiers which are to be made to operate in an equipotential and equiphased manner, distribution boxes exist, having one input and n outputs, associated with impedance adaptation circuits by quarter wave length transformers, which correctly ensure this operation in so far as all the amplifiers deliver the same power; however, if one or more amplifiers break down, the disadaptations which result therefrom disturb appreciably the functioning of the whole of the assembly and it is necessary to protect the amplifiers by insulation devices. For this purpose, different solutions have been used:

- distribution boxes have been associated with insulating devices of the circulator type, using the gyromagnetic properties of ferrites. Theoretically, this solution is ideal but, in practice, it presents various disadvantages such as limitation in power, selectivity and relatively large losses in the circulators;
- hybrid junctions of the ring type, coupler of 3dB etc., have been mounted in cascade arrangement, the amplifiers being connected two by two on such a junction; an excellent

uncoupling is thus created between the amplifiers but, especially for a large number of amplifiers, this solution is cumbersome, owing to the number of hybrid junctions necessary and, in addition, the losses are great;

- distribution boxes have been associated with protection devices of the Wilkinson type; this is quite a good solution but the embodiment in decimetric band for a large number of amplifiers proves to be very difficult.

The present invention has the aim of obtaining the same advantages as those linked with the hybrid junction embodiments mounted in cascade arrangement, whilst minimising the disadvantages thereof.

This is obtained by associating in an adequate manner hybrid junctions and distribution boxes.

According to the invention, a device for coupling energies between m sources of energy, m being a whole positive number and n users, n being a whole positive number and $m+n$ being greater than 2, in which, for m greater than 1, the m sources are in phases and in which, for n greater than 1, the energies are supplied in phase to the n users, is characterised by a combination of m first hybrid circuits and n second hybrid circuits of 3 dB, at 90° , each having four entries, the first and the second entries and also the third and the fourth entries of each hybrid circuit forming interconnected entry pairs, of m and n balancing loads and a first and a second distribution box which are equipotential and equiphased having m inputs and n outputs, presenting the same input/output phase shift, φ_c , the combination being such that the m first circuits have their m first entries coupled respectively to the m sources, their m second entries connected respectively to the m loads, their m third entries connected respectively to the m inputs of the first box, their m fourth entries connected respectively to

the m inputs of the second box, that the n second circuits have their n first entries connected respectively to the n outputs of the first box, their n second entries connected respectively to the n outputs of the second box, their n third entries connected respectively to the n loads and their n fourth entries connected respectively to the n users.

Moreover, it is to be noted that it is known through the patent US-A-4 673 898 to create hybrid couplers at 90° which have a frequency band of wider use than a conventional coupler; they are composed of three conventional hybrid couplers at 90° , associated with circuits such as 0° or 180° dividers and 180° dephasers. By definition, even the hybrid couplers at 90° do not have their outputs in phase, as is sought in a device for coupling energies, but in phase quadrature. To transform such a coupler into a device for coupling energies, it would be possible to add to it, on one of its two outputs, a 90° dephaser; however, apart from the fact that the assembly thus obtained would not correspond to the device for coupling energies described in the preceding paragraph, it must be noted that the embodiment of broad band 90° dephasers is distinctly more difficult than that of 180° dephasers.

The present invention will be better understood and other characteristics will become apparent with the aid of the following description and the figures relating thereto, which show:

- Figure 1, a device for coupling between amplifiers and a user;
- Figure 2, a device for coupling between preamplifiers and the amplifiers of Figure 1;
- Figure 3, a device for coupling between a source and the

preamplifiers of Figure 2.

In the different figures, the corresponding elements are designated by the same reference numbers.

In the description which follows and also in the claims, hybrid junctions of 3 dB are concerned, at 90° , comprising two interconnected entry pairs. Interconnected entry pair of the junction is to be understood as two of the four entries of the junction such that, if adapted loads are connected thereto, there is practically no coupling between the other two entries of the circuit, the other two entries likewise constituting, furthermore, an interconnected entry pair; and, always when adapted loads are connected on one of the interconnected entry pairs, the power applied on one of the two interconnected entry pairs of the other pair results through the entries of the pair on which adapted loads are connected, with equal power but with waves in phase quadrature. In the diagrams, the interconnected entry pairs of the hybrid junctions of 3dB, at 90° , will be marked respectively 1-2 and 3-4; these junctions are directive couplers in the assemblies which have served as examples in the present description and these directive couplers of 3 dB, at 90° , will be designated hereinafter as "couplers of 3 dB", also "couplers"; however, it is to be noted that these junctions may, without departing from the scope of the invention, be constituted by any other equivalent junctions such as, for example, magic T's or hybrid rings associated with dephasing elements of suitable value.

Figure 1 shows the diagram of a coupling device allowing an antenna A to be supplied with the sum, except losses, of the energies supplied by n amplifiers, E1 to En (in the example described, n was equal to 8 and the amplifiers each had an output power of 1 kilowatt). The outputs of the amplifiers E1 to En are respectively connected to the entries 1 of n couplers of 3 dB, D1 to Dn. Between the entries 2 of the

couplers $D1$ to Dn and earth, balancing resistances $Rd1$ to Rdn are mounted, which constitute adapted loads. The entries 3 of the couplers $D1$ to Dn are respectively connected to the inputs 1 to n of a distribution box $C1$ of n inputs and one output; likewise the entries 4 of the couplers $D1$ to DN are respectively connected to the inputs 1 to n of a distribution box $C2$ of n inputs and one output; the boxes $C1$, $C2$ are equipotential and equiphased and have the same input/output phase shift. The outputs of the distribution boxes $C1$, $C2$ are respectively connected to the entries 1 and 2 of a coupler of 3 dB, B , the entry 3 of which is connected to earth by a balancing resistance Rb and the entry 4 of which is connected to the antenna A , the latter comprising an impedance adaptation circuit, not shown.

So that the functioning of the assembly according to Figure 1 is correct, the amplifiers $E1$ to En must deliver equipotential and equiphased signals; known assemblies exist to obtain this result but it is likewise possible, as will be seen with the aid of Figures 2 and 3, to reach this result with assemblies according to the invention, since it is a matter, each time, of distributing the power from one or more sources towards one or more users, these users becoming sources in the following amplifier stage; thus, the amplifiers of Figure 1, which are the users of the energy of preamplifiers in Figure 2, are also the sources of energy for the user which is the antenna A of Figure 1.

In normal operation, i.e. with the amplifiers $E1$ to En delivering equipotential equiphase signals, the power of the amplifier Ei (i : whole number being able to take any value from 1 to n) is divided into two equal parts but with an aperiodic phase shift of 90° , by the coupler Di :

- a part $U/\sqrt{2}$, which appears on the entry 3 of the coupler Di (U being the voltage corresponding to the power supplied by the

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- amplifier D_i which is, moreover, the same whatever the value taken by i from 1 to n);
- a part $U/\sqrt{2} \exp(-j\pi/2)$, in which $\exp(-j\pi/2)$ represents the exponential of $-j\pi/2$, with $j = \sqrt{-1}$;

all the power of the signals appearing on the entry 3 of the couplers D_1 to D_n is applied on the distribution box C_1 and all that appearing on the entry 4 of the couplers D_1 to D_n is applied on the distribution box C_2 . If φ_c is the phase change resulting from crossing the boxes C_1 and C_2 , the signals on the entries 1 and 2 of the coupler B are respectively of the form:

$$\begin{aligned} &U/\sqrt{2} \exp(j\varphi_c) \\ &U/\sqrt{2} \exp-j(\pi/2 - \varphi_c) \end{aligned}$$

which gives, respectively on the entries 3 and 4 of the coupler B

$U/2 \exp(j\varphi_c) + U/2 \exp-j(\pi - \varphi_c)$ signal zero
 $U/2 \exp-j(\pi/2 - \varphi_c) + U/2 \exp-j(\pi/2 - \varphi_c)$ signal
 representing the total recombined power.

Thus the unit formed by the couplers and the distribution boxes of Figure 1 constitutes a switching of the entries 1 of the couplers D_1 to D_n to the entry 4 of the coupler B when the entries 2 of the couplers D_1 to D_n and the entry 3 of the coupler B are perfectly decoupled. The assembly according to Figure 1 functions as power summation arrangement, the power on the entry 4 of the coupler B being the sum, except losses, of the powers delivered by the amplifiers E_1 to E_n . It is to be noted, in addition, that the assembly according to Figure 1 is reversible, except amplifiers E_1 to E_n .

But what is the insulation of the amplifiers E_1 to E_n with

respect to each other ? - The signal originating from an amplifier E_i (i : whole number, able to take any value from 1 to n) and arriving at the inputs i of the boxes C_1 and C_2 , is divided into three parts:

- a part transmitted to the entries 1 and 2 of the coupler B;
- a part reflected towards the amplifier E_i ;
- a part retransmitted towards the other amplifiers;

when all the signals delivered by the amplifiers E_1 to E_n are equipotential and equiphased, only the part transmitted towards the entries 1 and 2 of the coupler B exists, the other parts are zero; when this is not the case, owing to an imbalance of amplitude or of phase between the amplifiers or owing to a breakdown of one or more amplifiers, any signal originating from a defective amplifier E_i and reflected to the level of the boxes C_1 and C_2 or retransmitted towards the other amplifiers, recombines to appear on the entries 2 of the couplers D_1 to D_n where it is absorbed by the protection loads constituted by the balancing resistances R_{d1} to R_{dn} . The assembly according to Figure 1 therefore ensures a perfect protection of the amplifiers with respect to any imbalance and even with respect to any complete stoppage of one or more amplifiers. And the ratio of the total power normally available to the total power effectively available is, except losses of the system, as for an association of couplers in cascade arrangement:

$$n^2 / (n - n')^2$$

where n is the number of broken down amplifiers.

Figure 2 shows how the n amplifiers E_1 and E_n are supplied from m equipotential and equiphased amplifiers, J_1 to J_m . The assembly comprises the m preamplifiers followed by m couplers of 3dB, at 90° , H_1 to H_m , followed by 2 identical equipotential and equiphased distribution boxes G_1, G_2 of m

inputs and n outputs, followed by n couplers of 3dB, at 90° , $F1$ to F_n , followed by n amplifiers $E1$ to E_n . Between the entries 2 of the couplers $H1$ to H_m and earth, and also between the entries 3 of the couplers $F1$ to F_n and earth, balancing resistances R_{h1} to R_{hm} and R_{f1} to R_f are connected.

The part of the assembly of Figure 2 from the preamplifiers $J1$ to J_n to the inputs of the distribution boxes $G1$, $G2$ corresponds to the part of the assembly according to Figure 1 comprised between the amplifiers $E1$ to E_n and the inputs of the distribution boxes $C1$ and $C2$; the protection of the preamplifiers $J1$ to J_m against abnormal operation of one of them is thus ensured.

The part of the assembly of Figure 2 from the outputs of the distribution boxes $G1, G2$ to the inputs of the amplifiers $E1$ to E_n corresponds to the part of the assembly according to Figure 1 between the inputs of the distribution boxes $C1$ and $C2$ and the outputs of the amplifiers $E1$ to E_n , i.e. a part used in the reverse direction of its use according to Figure 1, taking advantage of its reversibility. This part of the assembly of Figure 2 permits an equipotential and equiphased supply of the amplifiers $E1$ to E_n .

Figure 3 shows how the preamplifiers $J1$ to J_m can be supplied in an equipotential and equiphased manner from a source represented by a single amplifier, N , on the input of which a signal S is applied. The assembly comprises the amplifier N followed by a coupler of 3dB, at 90° , M , followed by 2 identical equipotential and equiphased distribution boxes $L1, L2$, with one input and m outputs, followed by m couplers of 3dB, at 90° , $K1$ to K_m , followed by m preamplifiers $J1$ to J_m . Between the entry 2 of the coupler M and earth, and also between the entries 3 of the couplers $K1$ to K_m and earth, balancing resistances R and R_{k1} to R_{km} are connected.

The part of the assembly according to Figure 3 comprised between the output of the source N and the inputs of the preamplifiers J1 to Jm corresponds to the part of the assembly according to Figure 1 comprised between the antenna A and the outputs of the amplifiers E1 to En, and therefore used, owing to its reversibility, in the reverse direction of its use according to Figure 1. This assembly permits an equipotential and equiphased supply of the preamplifiers J1 to Jm.

The invention is not restricted to the examples described, it applies in a general manner to the equipotential and equiphased supply of n users by m sources of energy, with m and n being whole positive numbers and $m+n$ being greater than 2.



Claims

1. A device for coupling energies between m sources of energy (J_1 - J_m), m being a whole positive number, and n users (E_1 - E_n), n being a whole positive number and $m + n$ being greater than 2, in which, for m greater than 1, the m sources are in phases and in which, for n greater than 1, the energies are supplied in phase to the n users, characterised by a combination of m first hybrid circuits (H_1 - H_m) and n second hybrid circuits (F_1 - F_n) of 3dB, at 90° , each having four entries, the first and the second entries and also the third and the fourth entries of each hybrid circuit forming interconnected entry pairs, of m (R_{h1} - R_{hm}) and n (R_{f1} - R_{fn}) balancing loads and a first (G_1) and a second (G_2) distribution box which are equipotential and equiphased having m inputs and n outputs, presenting the same input/output phase shift, φ_c , the combination being such that the m first circuits (H_1 - H_m) have their m first entries coupled respectively to the m sources (J_1 - J_m), their m second entries connected respectively to the m loads (R_{h1} - R_{hm}), their m third entries connected respectively to the m inputs of the first box (G_1), their m fourth entries connected respectively to the m inputs of the second box (G_2), that the n second circuits (F_1 - F_n) have their n first entries connected respectively to the n outputs of the first box (G_1), their n second entries connected respectively to the n outputs of the second box (G_2), their n third entries connected respectively to the n loads (R_{f1} - R_{f2}) and their n fourth entries connected respectively to the n users (E_1 - E_n).