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Imoto

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[54] **ELECTRIC POWER DIVIDER HAVING FUNCTION OF IMPEDANCE TRANSFORMATION**

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[52] **U.S. Cl.** **333/9,** 333/10

[51] **Int. Cl.** **H01p 5/14**

[58] **Field of Search** 333/9, 10, 11, 35

[56] **References Cited**

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[57] **ABSTRACT**

A high frequency circuit arrangement having function of both impedance transformation and electric power division comprising first, second, third and fourth strip lines each having a length of a quarter of the wavelength of a transmitted signal which are connected in sequence to form a closed loop, and four branch lines each of which is connected to each of the junction points of the first, second, third and fourth strip lines, wherein the characteristic impedances of the first strip line and the branch lines connected to both ends of the first strip line are equal to each other, the characteristic impedances of the second and fourth strip lines are equal to each other, the characteristic impedances of the branch lines connected to both ends of the third strip line are equal to each other, and the characteristic impedances of the second and fourth strip lines are one half the square root of the characteristic impedance of the third strip line.

3 Claims, 2 Drawing Figures

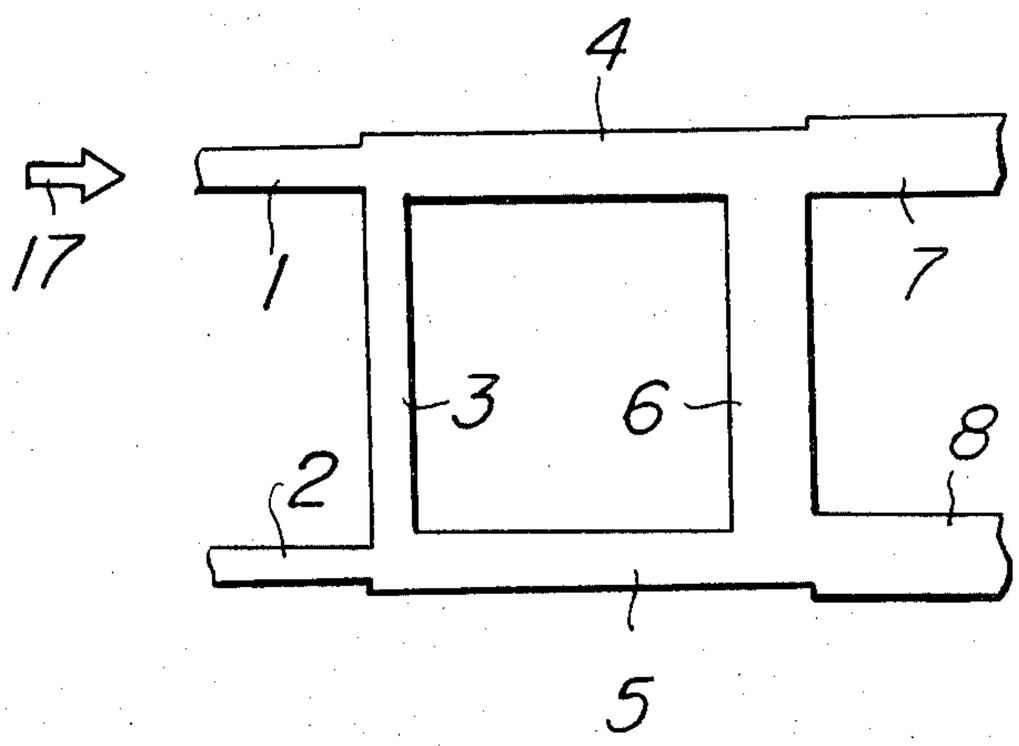


FIG. 1

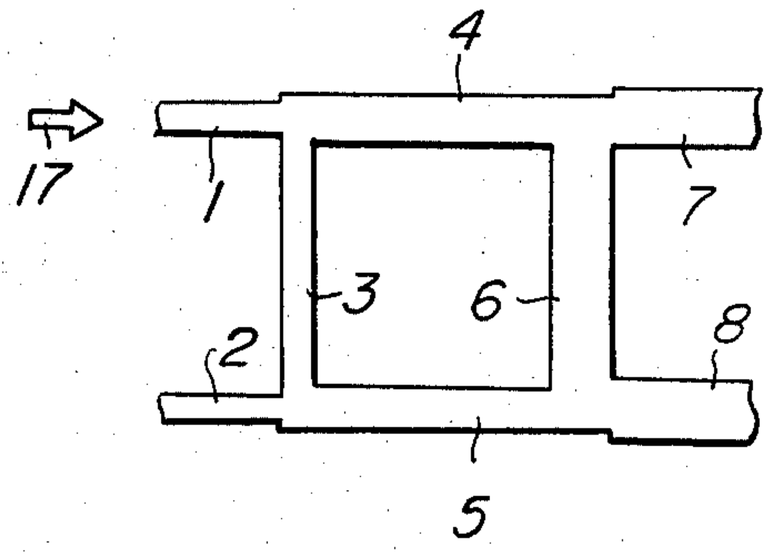
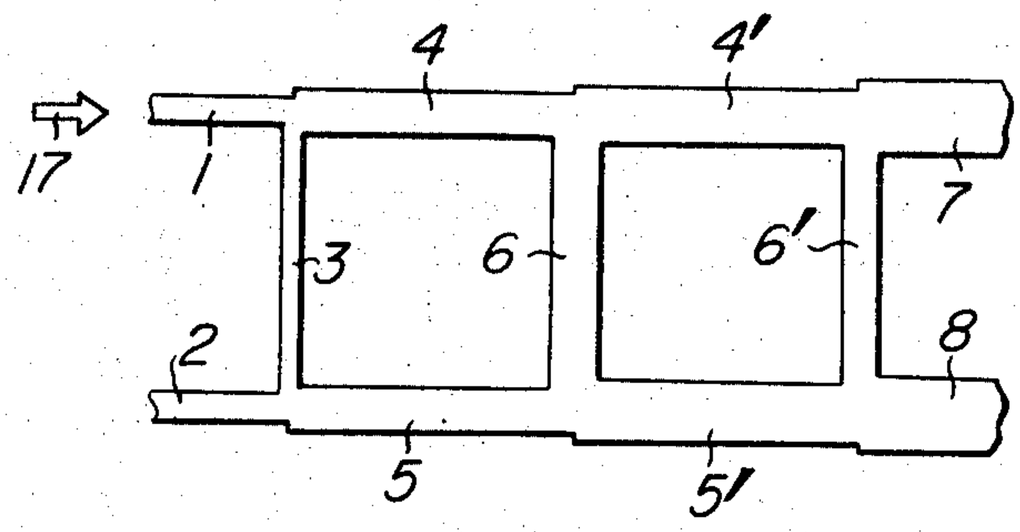


FIG. 2



ELECTRIC POWER DIVIDER HAVING FUNCTION OF IMPEDANCE TRANSFORMATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a microwave circuit, and more particularly to an electric power divider having functions of both impedance transformation and division of electric power.

2. Description of the Prior Art

In the past, when circuits having various functions were produced by coupling semiconductor elements such as transistors to a strip line to form a compound integrated circuit or to a coaxial line, it was necessary to provide the circuits with an impedance transformer and a matching circuit in order to match the impedance of the strip line or coaxial line with the arbitrary impedance characteristics of the semiconductor elements. In particular, when the output of the circuit is divided into two parts which are supplied to respective loads, it is necessary to provide special impedance transformers between the electric power divider and the loads.

Recently, miniaturization of r.f. circuits has been attempted by utilizing strip lines or the like. However, the provision of the impedance transformer prevents the miniaturization of the overall arrangement.

Furthermore, for ultra-high frequency circuits the impedance transformer increases the transmission line loss.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a circuit arrangement suitable for miniaturization of an r.f. circuit.

Another object of the present invention is to provide an r.f. circuit arrangement capable of performing both electric power division and impedance transformation.

In brief, for achieving the above-mentioned objects, the arrangement according to the present invention is constructed such that first, second, third, and fourth lines each having a length of a quarter of the wavelength of a signal to be transmitted are connected in sequence to form a closed loop and four branch lines are connected respectively to the junction points of the first, second, third and fourth lines, and that the characteristic impedances of the first line and the branch lines connected to both ends of the first line are equal to each other, the characteristic impedances of the second and fourth lines are equal to each other, the characteristic impedances of the branch lines connected to both ends of the third line are equal to each other, and the characteristic impedances of the second and fourth lines are one half the square root of the characteristic impedance of the third line.

According to this construction of the arrangement of the present invention the arrangement can be connected to a load having an arbitrary impedance in matched condition without the necessity of any intermediary impedance transformer and matching circuit, thereby miniaturizing the overall arrangement and reducing the transmission loss. In particular, this construction is very effective as an impedance transformation type 3 dB electric power divided suitable for a microwave integrated circuit.

The features, objects and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments of the present invention when taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIGS. **1** and **2** are diagrams of circuit arrangements embodying the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is an explanatory diagram of an embodiment of the impedance transformation type **3** dB electric power divider according to the present invention which is composed of micro strip lines. A first line **3**, a second line **4**, a third line **6** and a fourth line **5** are connected in sequence to form a closed loop. The lengths of the four lines **3**, **4**, **6** and **5** are all a quarter of the wavelength of a signal to be transmitted. Branch lines **1**, **7**, **8** and **2** are connected to the junction points of the four lines **3**, **4**, **6** and **5**, respectively. This arrangement per se is similar to the known branch line type directional coupler, but the present invention is characterized by the setting of the impedances of the component lines to provide the function of impedance transformation to the circuit arrangement.

Assume that the characteristic impedancs of the branch lines **1** and **2** are Zi, the characteristic impedances of the lines **3**, **4**, **5** and **6** and the branch lines **7** and **8** normalized with $Zi = 1$ are a, b, b, c, e and e, respectively, and the output voltages on the branch lines **1**, **7**, **8** and **2** are V_1, V_2, V_3 and V_4, respectively, when the input voltage **17** to the branch line **1** is 1. Then, the output voltages V_1, V_2, V_3 and V_4 corresponding to the central frequency of the input signal are expressed as

$$V_1=\frac{\left(\frac{b}{c}e+\frac{b}{a}\right)\left(\frac{b}{c}e-\frac{b}{a}\right)+\left(b+\frac{e}{b}-\frac{be}{ac}\right)\left(b-\frac{e}{b}+\frac{be}{ac}\right)}{\left(\frac{b}{c}e+\frac{b}{a}\right)^2+\left(b+\frac{e}{b}-\frac{be}{ac}\right)^2} \tag{1}$$

$$V_2=-j\frac{2e\left(b+\frac{e}{b}-\frac{be}{ac}\right)}{\left(\frac{b}{c}e+\frac{b}{a}\right)^2+\left(b+\frac{e}{b}-\frac{be}{ac}\right)^2} \tag{2}$$

$$V_3=-\frac{2e\left(\frac{b}{c}e+\frac{b}{a}\right)}{\left(\frac{b}{c}e+\frac{b}{a}\right)^2+\left(b+\frac{e}{b}-\frac{be}{ac}\right)^2} \tag{3}$$

$$V_4=-j\frac{\left(\frac{b}{c}e+\frac{b}{a}\right)\left(b-\frac{e}{b}+\frac{be}{ac}\right)-\left(b+\frac{e}{b}-\frac{be}{ac}\right)\left(\frac{b}{c}e-\frac{b}{a}\right)}{\left(\frac{b}{c}e+\frac{b}{a}\right)^2+\left(b+\frac{e}{b}-\frac{be}{ac}\right)^2} \tag{4}$$

Here, if assumed that

$$a = 1$$

$$c = e$$

$$b = \sqrt{e/2}$$

then

$$\left.\begin{aligned} V_1 &= V_4 = 0 \\ V_2 &= -j\sqrt{e/2} \\ V &= -\sqrt{e/2} \end{aligned}\right\} \quad (6)$$

Thus, this circuit arrangement functions as a 3 dB electric power divider. If further the characteristic impedance e is determined so that the condition

$$e > 1 \quad (7)$$

or $0 < e < 1$

is satisfied, the matching condition of the load impedance Z_L is satisfied with the result that an impedance transformation type 3 dB electric power divider which can be matched with an arbitrary circuit without employing any intermediary impedance transformer is provided. This construction of circuit arrangement can also be applied to a distributed constant circuit composed of coaxial lines as well as strip lines.

An example of the practical values of impedance transformation for the circuit of FIG. 1 is shown in Table I. Table I provides the characteristic impedances of an impedance transformation type 3 dB electric power divider according to the present invention for various load impedances.

TABLE I

Z_L	a	b	c	e
½	1	½	½	½
⅓	1	$1\sqrt{6}$	⅓	⅓
¼	1	$1/2\sqrt{2}$	¼	¼
3/2	1	$\sqrt{3/2}$	3/2	3/2
2	1	1	2	2

The above-described circuit is a single circuit showing a fundamental construction according to the present invention. It is evident that various impedance transformation type electric power dividing circuits can be produced by coupling a plurality of such single circuits as a multi-stage circuit. An example of the multi-stage circuit is shown in FIG. 2. The circuit of FIG. 2 is an impedance transformation type 3 dB electric power divider made into a two-stage cascade connection to broaden the pass band.

In the circuit of FIG. 2, lines 4′, 5′ and 6′ are individually a quarter of the wavelength in their transmission line lengths and b', b' and a' (normalized with $Zi = 1$),

respectively, in their characteristic impedances. An example of practical values for impedance transformation in the circuit of FIG. 2 is shown in Table II.

TABLE II

Z_L	a	b	c	b′	a′	e
$\frac{1}{2}$	$\frac{1}{\sqrt{2}-1}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	$\frac{1}{2(\sqrt{2}-1)}$	$\frac{1}{2}$
$\frac{1}{3}$	$\frac{1}{\sqrt{2}-1}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{6}}$	$\frac{1}{3(\sqrt{2}-1)}$	$\frac{1}{3}$
$\frac{1}{4}$	$\frac{1}{\sqrt{2}-1}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2\sqrt{2}}$	$\frac{1}{2(\sqrt{2}-1)}$	$\frac{1}{4}$
$\frac{3}{2}$	$\frac{1}{\sqrt{2}-1}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	$\frac{3}{2(\sqrt{2}-1)}$	$\frac{3}{2}$
2	$\frac{1}{\sqrt{2}-1}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	1	$\frac{2}{\sqrt{2}-1}$	2

In this manner, according to the present invention, even in case a plurality of circuits are cascade connected in order to give wide band pass characteristics thereto, a 3 dB electric power divider which can be matched with an arbitrary load impedance can be provided similarly to the case of a single circuit.

I claim:

1. An electric power divider having a function of impedance transformation comprising a first line, a second line, a third line and a fourth line connected in sequence to form a closed loop, each of said lines having a length of a quarter of the wavelength of a signal to be transmitted therethrough, and four branch lines each connected to each of the junction points of said closed loop, in which the characteristic impedance of said first line and the impedances of the branch lines connected to both ends of said second and fourth lines connected to both ends of said first line are equal to each other, the impedances of the branch lines connected to both ends of said third line are equal to each other, the impedances of said branch lines connected to both ends of said third line being different from the impedances of said branch lines connected to both ends of said first line, and the characteristic impedances of said second and fourth lines is the square root of one half of the characteristic impedance of said third line.

2. An electric power divider according to claim **1**, in which all of said lines are strip lines.

3. An impedance transformation type 3 dB electric power divider comprising an electric power divider according to claim **1** and another electric power divider also according to claim **1** coupled with each other in cascade fassion such that the third line of said electric power divider and the first line of said another electric power divider are superimposed on each other into a common line to both loops.

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