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Cappucci

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[54] SIGNAL SPLITTING NETWORK WHEREIN AN OUTPUT FROM SECOND COUPLER IS FED BACK TO ISOLATED PART OF FIRST COUPLER

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[63] Continuation of Ser. No. 866,632, Oct. 15, 1969, abandoned.

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[51] **Int. Cl.** **H01p 1/20**

[58] **Field of Search** .....333/10, 11, 73 R, 73 C, 73 S, 333/73 W

[56] **References Cited**

UNITED STATES PATENTS

3,074,033	1/1963	Smith	333/10
3,514,722	5/1970	Cappucci	333/10

OTHER PUBLICATIONS

Shelton, Wolfe, Van Wagoner, Tandem Couplers and Phase Shifters for Multi-Octave Bandwidth in Microwaves, April 1965; pp. 14–19.

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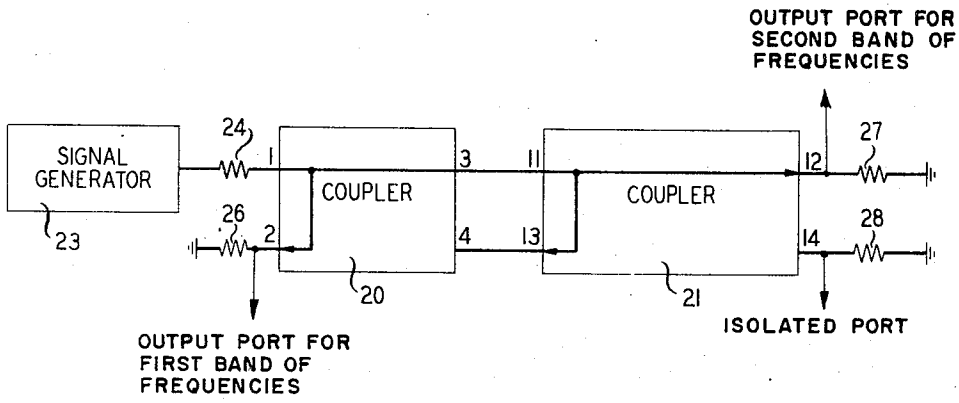
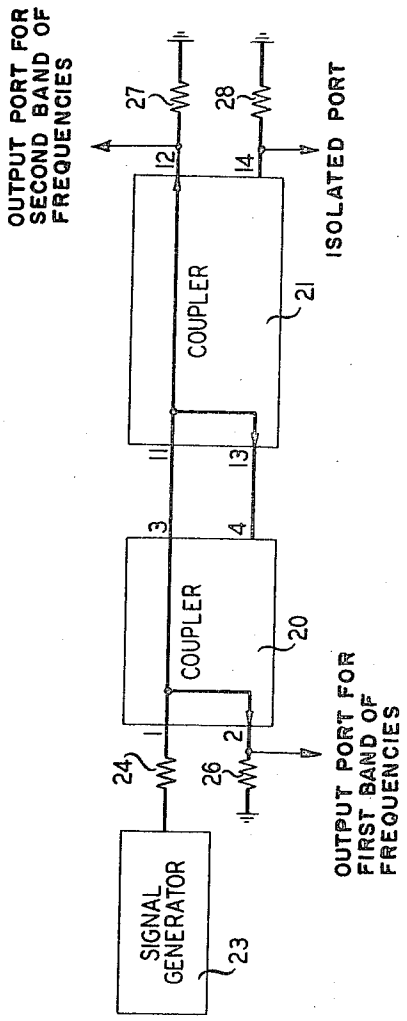
[57] **ABSTRACT**

A composite coupler is disclosed formed by a pair of analogous quadrature couplers. Energy passed from the first coupler to the second is fed back to the first initiating a recirculating effect which provides composite coupling characteristics described by a higher order differential equation than describes the original pair of couplers.

6 Claims, 1 Drawing Figure





INVENTOR
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SIGNAL SPLITTING NETWORK WHEREIN AN OUTPUT FROM SECOND COUPLER IS FED BACK TO ISOLATED PART OF FIRST COUPLER

This is a continuation of my copending application Ser. No. 866,632 filed Oct. 15, 1969, and entitled SIGNAL SPLITTING NETWORKS FORMED FROM DIRECTIONAL COUPLERS, now abandoned.

FIELD OF THE INVENTION

This invention relates to a signal splitting network formed by a plurality of directional couplers and particularly to such a signal splitting network having transfer characteristics described by differential equations of the second order or higher.

BACKGROUND OF THE INVENTION

A directional quadrature coupler is a four-port microwave device which exhibits a prescribed set of characteristics. When properly driven, a signal applied to one of the four ports induces a signal at two of the other ports and none at the fourth port. The two induced signals are in phase quadrature with one another. In a basic quadrature coupler, the transfer characteristic between the driven port and one of the two ports at which a signal is induced is essentially inductive while the transfer characteristic between the driven port and the second of the two ports is essentially capacitive.

Quadrature couplers can, therefore, be used to transfer energy above a prescribed frequency to one port and below the prescribed frequency to a second port. Since the transfer characteristics from the driven port to each of the two ports are only of the first order, signal frequency selectivity is not sharp. My copending patent application Ser. No. 742,052, filed July 2, 1968, and entitled "Networks Using Cascaded Quadrature Couplers, Each Coupler Having a Different Center Operating Frequency," now U.S. Pat. No. 3,514,722, teaches that quadrature couplers can be cascaded by prescribed interconnection to provide complementary band pass and band suppression transfer characteristics in resulting composite quadrature couplers. The characteristics of this arrangement is also first order functions of the signal frequency. Accordingly, the arrangement exhibits poor frequency separation.

Because a quadrature coupler is a bisymmetric device, any of the four ports can be employed as the driven port. As each port is driven, a different two of the remaining ports will have signals induced thereon and a unique port will be isolated therefrom. In my above-mentioned copending application particular care was taken in interconnecting the couplers to insure that recirculating signals were not set up in the composite couplers.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with this invention a sharp cutoff signal splitting network is provided by specific interconnection of a pair of analogous directional couplers each of which has corresponding first, second, third and fourth ports. When each of the four ports are properly terminated, the second and third ports of each coupler provides an output signal when a signal is applied to the respective first port from which the respective fourth ports are isolated.

The third port of the first coupler is connected to the first port of the second coupler so that the output signal appearing on the third port of the first coupler in response to a signal applied to the first port thereof is employed as an input signal to the second coupler.

The third port of the second coupler is connected back to drive the fourth port of the first coupler. Since the fourth port of the first coupler is isolated from the first port thereof, and the coupler is bisymmetric, energy will circulate between the couplers without causing an input mismatch.

In one embodiment a sharp cutoff signal splitting network of this invention is provided by interconnecting a pair of analogous first order directional couplers in which the signal

provided at the second ports thereof in response to a signal applied to the respective first ports is a first order function thereof; and the signal provided at the respective third ports in response to the applied signal is a second first order function of the applied signal. The first and second first order functions are duals of each other.

The resulting network when properly terminated will provide a first, second order transfer characteristic between the first port of the first coupler and the second port of the second coupler and a second, second order transfer characteristic between the first and second ports of the first coupler. The first and second, second order transfer characteristics will be duals of each other so that the network will function to separate a band of frequencies with sharp cutoff characteristics.

DESCRIPTION OF THE DRAWING

The sole FIGURE is a block diagram showing the interconnection of bisymmetrical quadrature couplers in accordance with the teaching of this invention.

DETAILED DESCRIPTION

In the FIGURE there is seen a pair of analogous bisymmetrical quadrature couplers **20** and **21**. Each of the couplers **20** and **21** have four ports designated **1**, **2**, **3** and **4** and **11**, **12**, **13** and **14**, respectively. The ports **1**, **2**, **3** and **4** of the coupler **20** are analogous to the ports **11**, **12**, **13** and **14** of the coupler **21**. Each of the couplers **20** and **21** are of the type that will respond to a signal applied to one of its ports by providing a pair of transfer signals at two of the other ports and will be isolated from the port diagonally thereacross in the FIGURE. The pair of transfer signals will be time dependent functions of the applied signal which will be duals of each other inherently showing that the circuit paths between the port the signal is applied to and each of the signal providing ports are duals.

In this example the transfer function between ports **1** and **3** and **11** and **13** have an inductive characteristic therefore being functions of the same physical property (i.e. inductance) and having the same mathematical form while the transfer function between ports **1** and **2** and **11** and **12** have a capacitive characteristic therefore being functions of the same physical property (i.e. capacitance) and having the same mathematical form. In this example the transfer characteristic of coupler **20** is characterized by an inductance L_1, a capacitance C_1 and an impedance $Z_o = \sqrt{L_1/C_1}$ while the coupler **21** is characterized by an inductance L_2, a capacitance C_2 and the impedance Z_o which is also equal to $\sqrt{L_2/C_2}$.

A broadband signal generator **23** is connected by an impedance **24** having a value of Z_o to port **1**. The impedance **24** usually includes a length of transmission line. Ports **2**, **12** and **14** are terminated in impedances **26**, **27** and **28** each having a value of Z_o. Port **3** is connected to port **11** and port **4** is connected to port **13**. From the inherent properties of quadrature couplers as disclosed, for example, in my above-mentioned patent, the interconnected ports **3**, **11**, **4** and **13** will terminate the ports **11**, **3**, **13** and **4** respectively with the characteristic impedance Z_o without the need for adding an external physical impedance.

An analysis of the above-described coupler arrangement will show that the scattering parameters are:

$$S_{1,1}=0$$

$$S_{1,2}=\frac{i\left[wC_1z_o-\frac{4Z_o}{wL_2}\right]}{2+j\left[wC_1z_o-\frac{4Z_o}{wL_2}\right]}$$

$$S_{1,12}=\frac{2}{2+j\left[\frac{wL_1}{Z_o}-\frac{4}{wC_2z_0}\right]}$$

This result can be most easily obtained by an even mode-odd mode bisection analysis. An example of this type of analysis can be seen in my above-mentioned patent application.

An examination of the scattering parameters shows that a pair of first order couplers **20** and **21** have been interconnected to provide second order transfer characteristics. The transfer characteristics between ports **1** and **12** are characterized by a series resonant circuit having the components L_1 and $C_2/4$. The transfer characteristic between ports **1** and **2** are characterized by a paralleled resonant circuit having the components C_1 and $L_2/4$.

The reason the characteristic of the second coupler **21** is seen in the transfer characteristics between ports **1** and **2** of coupler **20** is that energy from the signal generator **23** is transferred from port **1** to port **3**. Port **3** drives port **11** which provides energy to port **13**. Port **13** being connected to port **4** which is isolated from port **1** drives energy back into coupler **20**. This energy results in the reflection of characteristics between couplers.

It should be noted that analogous bisymmetric couplers having characteristics described by other than simple first order differential equations can be interconnected as above to provide a composite coupler having characteristics described by higher order equations than those describing the original couplers.

It should be clear that other embodiments representing the applications of the principles of the invention can readily be devised by those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. A combination comprising:

first and second bisymmetric directional couplers each having first, second, third and fourth ports, each of said couplers being responsive to a time varying signal applied to the first port thereof through an impedance of a predetermined value for providing first and second transfer signals at the second and third port thereof respectively;

said fourth port being isolated from said first port when each of the second, third and fourth ports thereof are terminated by an impedance of said predetermined value;

said first and second transfer signals being respectively first and second time dependent functions of said time variable signal applied to said first port, said respective first and second time dependent functions of said first and second couplers being representative of the same physical properties and having the same mathematical form; and

said first and second time dependent functions of each of said respective first and second couplers being dual showing that the circuit paths between said respective first and second and first and third of said ports are dual; said combination characterized by: means for connecting said third and fourth ports of said first coupler to said first and third ports of said second coupler respectively so that if said first port of said first coupler is employed as an input port, said second port of said first coupler and said second port of said second coupler will serve as output ports and said fourth port of said second coupler will be isolated from said first port of said first coupler.

2. The combination as defined in claim **1** in which:

said first and second time dependent functions of said first and second couplers are described by differential equations of the first order so that one of said dependent functions is representative of a capacitive characteristic while a second of said time dependent functions is representative of an inductive characteristic.

3. The combination as defined in claim **1** also including:

a signal generator; and

means for connecting said signal generator to said first port of said first coupler.

4. A combination as defined in claim **3** also including:

means for terminating said second port of said first coupler and said second and fourth ports of said second coupler with impedances of said predetermined value.

5. The combination as defined in claim **4** in which said first time dependent function is a function of inductance and said second time dependent function is a function of capacitance.

6. A combination comprising:

first and second bisymmetric directional couplers each having first, second, third and fourth ports, each of said couplers being responsive to a time varying signal applied to the first port thereof through an impedance of a predetermined value for providing first and second transfer signals at the second and third port thereof respectively;

said fourth port being isolated from said first port when each of the second, third and fourth ports thereof are terminated by an impedance of said predetermined value; and

said first and second transfer signals being respectively first and second time dependent functions of said first and second couplers being representative of the same physical properties and having the same mathematical form; said combination characterized by:

said first and second time dependent functions of each of said respective first and second couplers being dual showing that the circuit paths between said respective first and second and first and third of said ports are dual;

means for applying said second transfer signal from said first coupler to said first port of said second coupler to render said second transfer signal from said second coupler a function of both said first time dependent functions of said first and second couplers; and

means for applying said second transfer signal of said second coupler back to drive said fourth port of said first coupler creating a recirculating signal which reflects the characteristics between said first and third ports of said second coupler to alter the characteristics between said first and second ports of said first coupler without causing mismatch at the first port of said first coupler so that if said first port of said first coupler is employed as an input port, said second port of said first coupler and said second port of said second coupler will serve as output ports and said fourth port of said second coupler will be isolated from said first port of said first coupler.

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