

[72] Inventor **John P. Curtis**
Reading, Mass.
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[73] Assignee **Adams-Russell Co., Inc.**
Waltham, Mass.

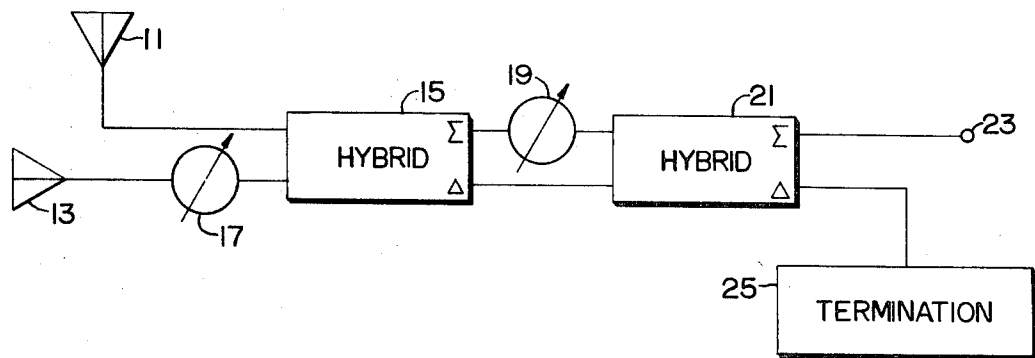
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Primary Examiner—Robert L. Griffin
Assistant Examiner—James A. Brodsky
Attorney—Kenway, Jenney & Hildreth

[54] **HYBRID COUPLER RECEIVER FOR LOSSLESS
SIGNAL COMBINATION**
1 Claim, 3 Drawing Figs.

[52] U.S. Cl. **325/369,**
333/11
[51] Int. Cl. **H04b 1/06,**
H01p 5/12
[50] Field of Search **325/365,**
369, 366, 305; 333/11; 343/853, 854

ABSTRACT: The apparatus disclosed herein is operative to combine a pair of input signals having arbitrary amplitude and phase relationships in such a way as to provide a single output signal equal in power to the sum of the available power of the two input signals. The apparatus employs hybrid couplers to obtain certain intermediate signals and phase shifters to obtain necessary phase relationships.



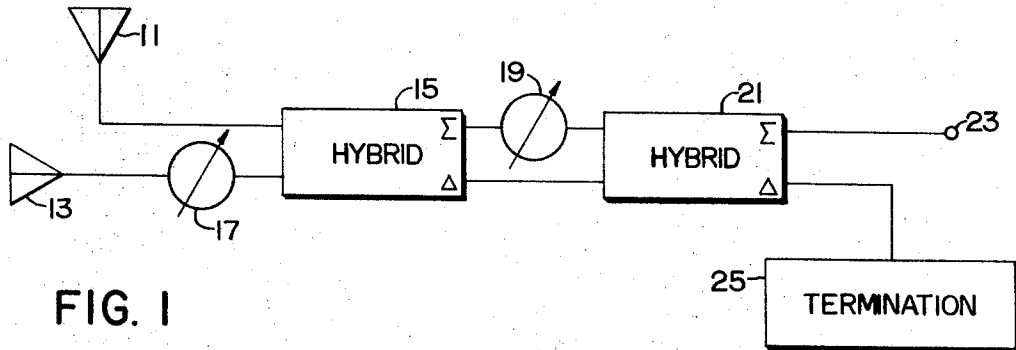


FIG. 1

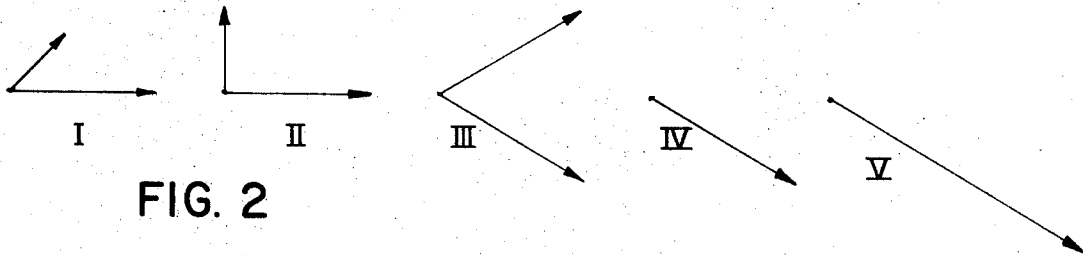


FIG. 2

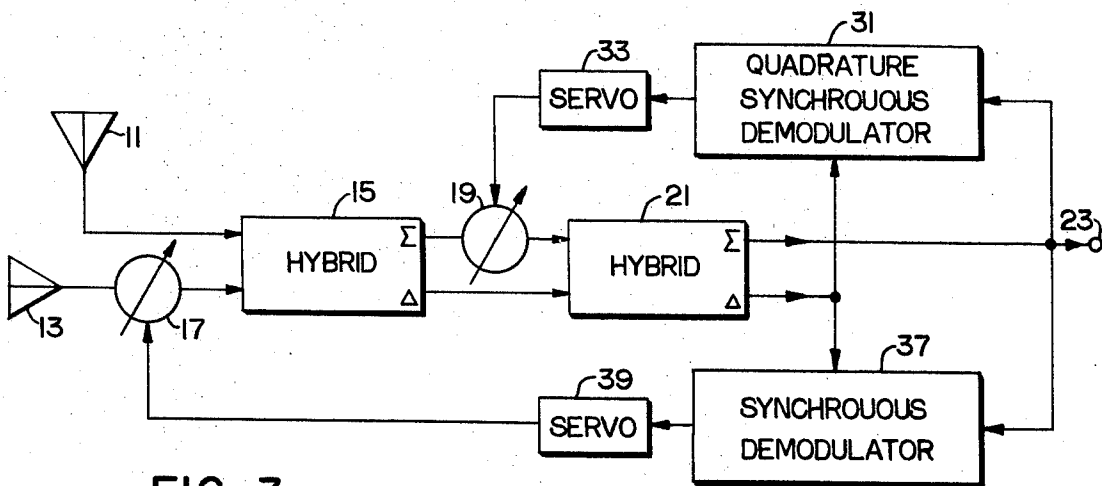


FIG. 3

INVENTOR.
JOHN P. CURTIS

BY
Kenway, Jenney + Hildebreth
ATTORNEYS

HYBRID COUPLER RECEIVER FOR LOSSLESS SIGNAL COMBINATION

BACKGROUND OF THE INVENTION

In various situations it is desired to combine into a single signal, the available power of a pair of coherent signals which have arbitrary phase and amplitude relationships. For example, if a radio frequency wave front impinges upon a pair of antenna elements which are vertically and horizontally polarized, each antenna element will provide a signal containing a portion of the total energy abstracted from the wave. A favorable signal-to-noise ratio can be obtained if the power which is initially divided between the two signals can be efficiently consolidated in a single signal. However, as is understood by those skilled in the art the amplitude and phase relationships of the two signals will depend on the polarization characteristics and the angle of incidence of the impinging radio frequency wave and thus will be essentially arbitrary.

Among the several objects of the present invention may be noted the provision of apparatus which will efficiently combine a pair of input signals; the provision of such apparatus which will combine signals having arbitrary phase and amplitude relationships; the provision of such apparatus which is essentially lossless; the provision of such apparatus which is reciprocal; the provision of such apparatus in which the input terminals are isolated; and the provision of such apparatus which is relatively simple and inexpensive. Other objects and features will be in part apparent and in part pointed out hereinafter.

SUMMARY OF THE INVENTION

Briefly, apparatus according to the present invention is operative to efficiently combine a pair of input signals which are of the same frequency but which are of arbitrary amplitude and phase relationship. The apparatus includes a first phase shifter which shifts the phase of one of the input signals to bring the one into quadrature relationship with the other. The quadrature related signals are combined in a first hybrid coupler thereby to obtain pair of equal amplitude signals. The phase of one of the equal amplitude signals is then shifted by a second phase shifter to bring the one equal amplitude signal into phase with the other. The inphase equal amplitude signals are then combined in a second hybrid coupler thereby to provide a single output signal which is substantially equal in power to the sum of the powers of the two input signals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a signal processor of this invention;

FIG. 2 is a series of phasor diagrams representing the phase relationships of various pairs of signals occurring in the apparatus of FIG. 1; and

FIG. 3 is a block diagram of a signal processor of this invention employing servo control of various phase shifting elements incorporated therein.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, a pair of antenna elements are indicated at 11 and 13, these elements being vertically and horizontally polarized respectively. The signal obtained from the antenna element 11 is applied directly to one of the inputs of a conventional hybrid coupler 15 while the signal obtained from the antenna 13 is applied to the other input of hybrid coupler 15 through a reciprocal phase shifter 17 which is operative to provide an adjustable amount of phase shift or signal delay. At relatively high frequencies, phase shifter 17 may be constituted by an adjustable delay line or a variable ferrite phase shifter as is known in the art. As is understood, such components can be constructed so as to be essentially lossless.

Hybrid coupler 15 is operative, when connected to matched source and load impedances, to provide a pair of output signals one of which is proportional to the complex sum of the input signals applied to the hybrid coupler and the other of which is proportional to the complex difference of the input signals applied to the hybrid coupler. The sum output is indicated at Σ and the difference output is indicated at Δ . Further, such a coupler is essentially lossless and is reciprocal, that is, the outputs can function as the inputs with the inputs then acting as outputs.

The sum output signal from the hybrid coupler 15 is applied, through a reciprocal phase shifter 19 which provides an adjustable amount of phase shift or signal delay, to one of the inputs of a second hybrid coupler 21. The difference signal from hybrid coupler 15 is applied directly to the other input of the hybrid coupler 21.

The sum output signal from hybrid coupler 21 is applied to an output terminal 23 which is adapted to be connected to a suitable utilization device, e.g. a receiver which presents a load impedance which is matched to the source impedance of the antenna elements 11 and 13. The difference output signal from the hybrid coupler 21 is applied to an appropriate termination as indicated at 25, the impedance of termination 25 being likewise matched to the source impedance of the antenna elements 11 and 13.

The operation of the apparatus of FIG. 1 may be understood with reference to the phasor diagrams of FIG. 2. It is assumed that the antenna elements 11 and 13 provide signals having arbitrary amplitude and phase relationships as represented at I in FIG. 2. The phase shifter 17 is adjusted so that the signal from antenna element 13 is brought into quadrature with the signal from the antenna element 11 as represented at II.

As is understood by those skilled in the art, the complex sum and difference signals provided by the hybrid coupler 15 will be complex conjugates of one another when the input signals applied to the coupler are in quadrature. Such complex conjugates are represented at III in FIG. 2. As is also understood, these signals are of equal absolute amplitude.

The phase shifter 19 is adjusted so that the sum signal provided by hybrid coupler 15 is brought into phase with the difference signal as represented at IV. Given a pair of inphase equal amplitude signals, the hybrid coupler 21 combines these signals so that the sum output signal contains substantially twice the power present in either of the respective input signals while the difference signal is substantially equal to zero. Since the components of the apparatus of FIG. 1 are essentially lossless and no power is dissipated in the termination 25, it can be seen that the single output signal is substantially equal in power to the sum of the powers of the two original input signals, i.e. the signals provided by the antenna elements 11 and 13.

Since each of the elements comprising the apparatus of FIG. 1 is essentially lossless and is reciprocal, it can be seen that the overall system is also essentially lossless and reciprocal. Thus, if the apparatus of FIG. 1 is first adjusted to provided optimum combination of the antenna signals provided by a particular received wave and then a RF signal source, such as a transmitter, is connected to the terminal 23, the antenna elements 11 and 13 will be caused to radiate a wave with polarization characteristics which are similar to those of the received wave.

If desired, the phase shifters 17 and 19 can be automatically adjusted by respective servo controls as illustrated in FIG. 3. From the phasor diagrams of FIG. 2, it can be seen that small variations in the adjustment of phase shifter 19 will cause a correspondingly small signal component to appear at the difference output of hybrid coupler 21 and that this signal component will be substantially in quadrature with the sum signal provided to the output terminal 23. As the polarity or phase of this quadrature difference component will reverse as the sense or direction of deviation of setting of the phase shifter 19 varies from the desired setting, it will be seen by those skilled in the art that the amplitude of this quadrature component is appropriate for use as an error signal in controlling the setting of phase shifter 19.

In the apparatus of FIG. 3, this quadrature difference component is detected by a quadrature synchronous demodulator 31 which is synchronized or timed by the sum signal from hybrid 21. The detected component then drives a conventional servomechanism as indicated at 33 which controls the setting of phase shifter 19 in a sense tending to minimize the quadrature difference component.

From the phasor diagrams of FIG. 2, it can be seen that small deviations in the adjustment of phase shifter 17 will cause the signals represented at III in FIG. 2 to be of slightly different amplitudes. Assuming that the servosystem 33 maintains the quadrature difference component from hybrid coupler 21 substantially equal to zero, as described above, any differences in the amplitudes of the signals represented at III in FIG. 2 will cause the hybrid coupler 21 to produce a difference output signal component which is substantially inphase with the sum signal provided to the terminal 23.

In the apparatus of FIG. 3 this inphase component of the difference from hybrid coupler 21 is synchronously demodulated as indicated at 37 and the detected inphase difference component is employed as an error signal to control a servomechanism 39 which adjusts the phase shifter 17 in a sense tending to minimize the inphase component. Thus, this outer feedback servo control loop will automatically maintain the setting of phase shifter 17 at the desired point so long as the inner servocontrol loop maintains the phase shifter 19 at the desired setting. As will be understood, the quadrature and inphase components detected by demodulators 31 and 37, respectively could also be applied to visual indicators which would then serve to facilitate manual adjustment of the phase shifters 17 and 19.

It will be understood also that in some applications the efficient utilization of available signal strength may not be of prime importance but it may be desired to determine the polarization characteristics of an incident wave. As will be apparent to those skilled in the art, the settings of phase shifters 17 and 18 which produce a maximum sum output and a minimum difference output from hybrid coupler 21 provide

information from which the amplitude and phase relationships of the input signals and thus the desired polarization characteristics may be determined.

In view of the foregoing, it can be seen that the several objects of the invention have been achieved and other advantageous results have been obtained. As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained herein or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Apparatus for efficiently combining a pair of input signals which are of the same frequency and have arbitrary amplitude and phase relationships, said apparatus comprising:

- 15 a first adjustable phase shifter for shifting the phase of one of said input signals;
- a first hybrid coupler for combining the phase shifted signal and the other input signal thereby to provide a pair of intermediate signals;
- 20 a second adjustable phase shifter for shifting the phase of one of said intermediate signals;
- a second hybrid coupler for combining the phase shifted intermediate signal and the other intermediate signal thereby to provide a sum output signal and a difference output signal;
- 25 means for detecting the component of said difference output signal which is in quadrature with said sum output signal thereby to provide a first error signal;
- servo means responsive to said first error signal for adjusting said second phase shifter to minimize said quadrature component;
- 30 means for detecting the component of said difference output signal which is inphase with said sum output signal thereby to provide a second error signal; and
- 35 servo means responsive to said second error signal for adjusting said first phase shifter to minimize said inphase component.

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