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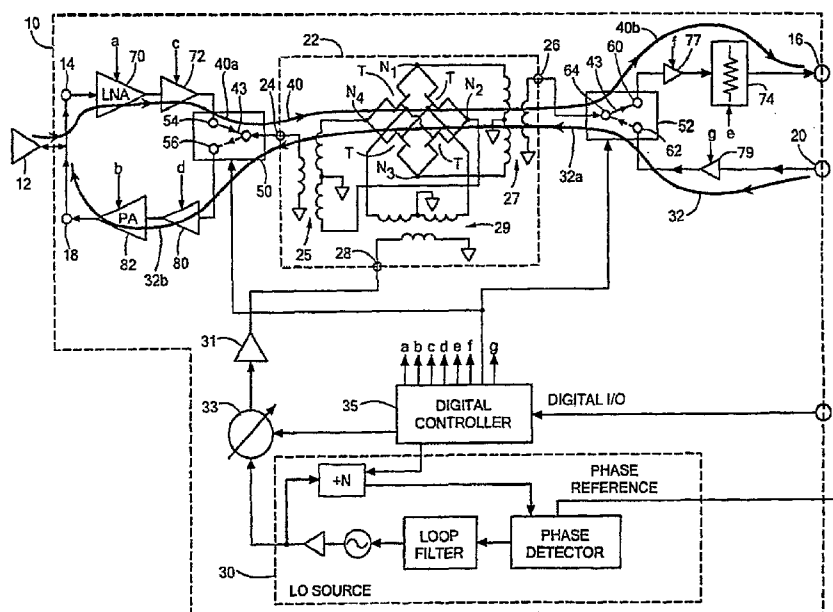
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
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(54) Title: TRANSMIT/RECEIVE MODULE HAVING BI-DIRECTIONAL FREQUENCY CONVERSION SECTION



(57) Abstract: A transmit/receive module having a frequency conversion circuit. The circuit includes a mixer having a pair of ports and a third port coupled to a local oscillator signal source. A transmit path transmits energy from the module and a receive path receives for the module. Both the receive path and the transmit path pass through the pair of ports of the mixer.

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TRANSMIT/RECEIVE MODULE HAVING BI-DIRECTIONAL FREQUENCY CONVERSION SECTION

TECHNICAL FIELD

This invention relates generally to transmit/receive modules and more
5 particularly to transmit/receive modules adapted for use in phased array radar system.

BACKGROUND

As is known in the art, microwave transmit/receive modules are used in beam
forming networks of phased array radar systems. More particularly, the beam forming
network is used to form beams of electromagnetic radiation. The shape of the beam is
10 related to the phase and amplitude distributions provided to signals received or
transmitted across an aperture of the apparatus. For example, in a phased array
antenna, the aperture includes a plurality of antenna elements. Each one of the
antenna elements is coupled to a feed structure through a corresponding one of a
plurality of variable phase shifter-variable gain modules. The feed structure may be a
15 corporate feed or may be through illuminations as in a space fed phased array system.
In any event, the modules are controlled by signals from a beam steering computer to
provide a collimated and directed beam of radiation. For example, for a broadside
(i.e., boresight) beam the phase shift of the signals emanating from each antenna
element is zero relative to some arbitrary reference. If the phase shift from element to
20 element differs by a fixed amount from zero, the direction of the main radiation lobe
is shifted from broadside accordingly.

As is also known in the art, phased array radars also require that each variable
phase shifter-variable gain module operate for both the transmit mode and the receive
mode. Further, it is known that heterodyne circuits to implement T/R modules are
25 preferred since they mitigate the need for microwave beam forming networks. As
noted above, such beamformers are typically used to provide the frequency and phase
reference to the array element. By providing one or more Local Oscillators (LO)
within the T/R element, it is possible to utilize lower Intermediate Frequencies (IF) as
the input and output signals to the array elements.

One such transmit/receive module is shown in FIG. 1. Here, a conventional frequency conversion circuit is shown having a separate transmit and receive path. Each path includes a mixer. The phase shifting is accomplished in the local oscillator (LO) path. The LO signal is provided by a phase locked loop. The loop contains a phase detector which synchronizes the LO signal to an injected clock. It is noted that in the conventional structure, each mixer must be fed from a buffer amplifier in the LO path. If a 2nd IF stage is used to provide yet a lower frequency output, then the mixers and the buffer amplifiers must be replicated in the 2nd IF. The buffer amplifiers are typically multistage structures to achieve the required gain. Therefore, they occupy space on the chip and consume power. A design is needed to mitigate this problem. The mixers also occupy space in the circuit.

SUMMARY

In accordance with the invention, a transmit/receive module is provided having a frequency conversion circuit. The circuit includes a mixer having a pair of ports and a third port coupled to a local oscillator signal source. A transmit path transmits energy from the module to a radiating element and a receive path receives energy from the radiating element. Both the receive path and the transmit path pass through the pair of ports of the mixer.

The arrangement reduces the number of amplifiers and mixers.

In one embodiment, the mixer has a pair of ports and a third port coupled to a local oscillator signal source. A transmit path has a first portion carrying signals having a first frequency. The first portion of the transmit path is coupled to a first one of the pair of ports and a second portion of the transmit path carries signals having a different frequency converted from the first frequency by the mixer responding to the local oscillator signal. The second portion of the transmit path carries signals having the different frequency from the -first one of the pair of ports of the mixer. A receive path has first portion carrying signals having the second frequency. The first portion of the receive path is coupled to the second one of the pair of ports. A second portion of the receive path carries signals having the first frequency converted from the second frequency by the mixer responding to the local oscillator signal. The second portion of the receive path carries signals having the first frequency from the first one of the pair of ports of the mixer.

In one embodiment, the module includes a pair of switches, a first one of such switches having a first port coupled to the first portion of the transmit path, a second port coupled to the second portion of the receive path and a third port coupled to the first port of the mixer; and the second one of the switches having a first port coupled to the first portion of the receive path, a second port coupled to the second portion of the transmit path and a third port coupled to the second port of the mixer

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram of a transmit/receive module according to the PRIOR ART;

FIG. 2 is a block diagram of a transmit/receive module according to the invention; and

FIG. 3 is a block diagram of a transmit/receive module according to another embodiment of the invention.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Referring now to FIG. 2 a transmit/receive module 10 is shown coupled to an antenna 12. The module 10 has radio frequency (RF) energy receive (RF Rx) port 14 and an intermediate frequency energy (IF) receive (IF Rx) port 16. The module 10 has radio frequency (RF) energy transmit (RF Tx) port 18 and an intermediate frequency energy (IF) transmit (IF Tx) port 20. The module 10 provides a frequency conversion circuit having a mixer 22.

The mixer 22 has a pair of ports 24, 26 and a third port 28 coupled to a local oscillator signal source 30 through an amplifier 31 and a digitally controlled phase shifter 33. The phase of the LO signal at port 28 is controlled by a digital controller 35 in response to digital control signals fed to the digital controller 35. Here the mixer 22 includes four field effect transistors T connected together in different branches of a bridge having four nodes N1-N4, with the source and drain of each one of the transistors being connected between a different pair of the nodes. Each one of the pair of ports 24 and 26 is connected to a corresponding one of a pair of primary

windings of a pair of transformers 25, 27, respectively. The secondary windings are connected to a corresponding one of a pair of the nodes; i.e., one secondary winding is connected to nodes N1 and N3 and the other secondary winding is connected to nodes N2 and N4. The gates of one pair of the transistors are connected together and to one
5 end of the secondary winding of a third transformer 29; and the gates of the other one pair of the transistors are connected together and to the other end of the secondary winding of the third transformer. The primary winding of the third transformer is connected to the port 28. As will be described in more detail below, the mixer 22 is a bi-directional mixer. It is noted that while transistors are used, the transistors are
10 unbiased and are functioning as variable resistors. Thus, since the transistors are unbiased they are passive devices. It should be understood that other types of passive devices, such as diodes and resistors may be used in the mixer 22.

A transmit path 32 is provided having a first portion 32a carrying signals having a first, intermediate frequency. The first portion 32a is coupled between a first
15 one of the pair of ports, here to port 26, and the intermediate frequency transmit port 20. The transmit path 32 has a second path 32b carrying signals having a different frequency, here a radio frequency, converted from the first frequency by the mixer 22 responding to the local oscillator (LO) from the LO signal source 30. Thus, the second portion 32b of the transmit path 32 is between port 24 of mixer 22 and the RF
20 transmit port 18. The second portion 32b of the transmit path 32 carries signals having the radio frequency energy from the second one of the pair of ports 24 of the mixer 22.

A receive path 40 is provided having a first portion 40a carrying radio frequency signals having the second frequency. The first portion 40a of the receive
25 path 40 is coupled between the RF receive port 14 and the second one of the pair of ports, here port 24. A second portion 40b of the receive path 40 carries signals having the first frequency radio frequency converted from the second intermediate frequency by the mixer 22 responding to the local oscillator (LO) signal from the LO signal source 30. The second portion 40b of the receive path 40 carries signals
30 having the first intermediate frequency from the first one of the pair of ports, here from port 24 of the mixer 22 to the RF receive port 16.

The transmit/receive module 10 includes a pair of switches 50, 52 here transmit/receive T/R switches. The switches are controlled by signals produced by the digital controller 35. When in the receive position, the poles 43 are in the positions shown in solid and when switched to the transmit mode, the poles 43 are in the positions indicated dotted. A first one of such switches, here switch 50 has a first
5 port 54 coupled to the first portion 40a of the receive path, a second port 56 coupled to the second portion 32b of the receive path 32 and a third port 58 coupled to the first port 24 of the mixer 22. The second one of the switches, here switch 52 has a first port 60 coupled to the second portion 40b of the receive path 40, a second port 62
10 coupled to the first portion 32a of the transmit path 32 and a third port 64 coupled to the second port 26 of the mixer 22.

A Low Noise Amplifier (LNA) is fed by the received RF signals at port 14. The output of the LNA 70 feeds the input of an amplifier 72, the gain being controlled by control signals fed thereto from the digital controller 35 on lines a and c,
15 respectively. The output of amplifier 72 is fed to port 54 of switch 50. A variable gain amplifier 77 is fed by the signals at port 60 and the then amplified signals are fed to a variable attenuator with the output being fed to the intermediate frequency receive port 16. The gain of the amplifier 77 and the attenuation of the attenuator 74 are controlled by control signals fed thereto from the digital controller 35 on lines f
20 and e, respectively.

A variable gain amplifier 79 is fed by the signals at IF transmit port 20 are fed to port 62 of switch 52. The gain of amplifier 79 is controlled by control signals fed thereto from the digital controller 35 on line g. A variable gain amplifier 80 is fed by the signals at RF signals at port 43 of switch 50 and the output is fed to an RF power
25 amplifier (PA) 82. The output of the power amplifier 82 is fed to the RF transmit port 18. The gains of amplifiers 80 and 82 are controlled by control signals fed thereto from the digital controller 35 on lines d and b, respectively.

Thus, with the arrangement described above in connection with FIG. 2, a transmit/receive module 10 is provided having a frequency conversion circuit,
30 comprising: a mixer 22 having a pair of ports 24, 26 and a third port 28 coupled to a local oscillator signal source 30. The circuit 10 includes a transmit path 32 for transmitting energy transmitted from the module 10; a receive path 40 for receiving

energy received by the module 10; and wherein both the receive path and the transmit path pass through the pair of ports 24, 26 of the mixer 22. The mixer 22 is thus a bi-directional mixer between ports 24 and 26. It should now be understood that the mixer 22 may use any type of available passive mixer topology (diode, resistive FET) to implement bidirectional mixer capable of both down-conversion in the Receive mode and up conversion in the Transmit mode. This allows significantly reducing number of components (mixers, amplifiers) in the T/R module block diagram.

The arrangement reduces the number of amplifiers and mixers. Transmit/Receive switches 50, 52 are placed in the mixer RF and IF pathways. The position of the switches is set by the on-board digital logic to allow re-use of the mixer during the transmit and receive states. The phase shifter 33 is set by the digital control logic and remains unchanged as the chip switches from transmit to receive. This allows for constancy of the beam direction.

Referring now to FIG. 3, an arrangement is shown which eliminates one of the amplifiers 72, 80 (FIG. 2) and replaces them with a single amplifier 94 through use of a switch 90. Likewise, one of the amplifiers 77, 79 and replaces them with a single amplifier 96 through the use of a switch 96. The switches 90 and 92 are controlled by control signals fed thereto from the digital controller 35. The gains of amplifiers 94 and 96 are controlled by control signals fed thereto from the digital controller 35 on lines c' and d', respectively. It is noted that both transmit signals and receive signals (i.e., both the transmit path and the receive path) pass through amplifiers 94 and 96.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A transmit/receive module, comprising:

a frequency conversion circuit, comprising:

5 a mixer having a pair of ports and a third port coupled to a local oscillator signal source;

a transmit path for transmitting energy transmitted from the module;

10 a receive path for receiving energy received by the module; and wherein both the receive path and the transmit path pass through the pair of ports of the mixer.

2. A transmit/receive module, comprising:

a frequency conversion circuit, comprising:

15 a mixer having a pair of ports and a third port coupled to a local oscillator signal source;

a transmit path comprising:

20 a first portion carrying signals having a first frequency, such first portion being coupled to a first one of the pair of ports; and

a second portion carrying signals having a different frequency converted from the first frequency by the mixer responding to the local oscillator signal, such second portion of the transmit path carrying signals having the different frequency from the second one of the pair of ports of the mixer;

25 a receive path comprising:

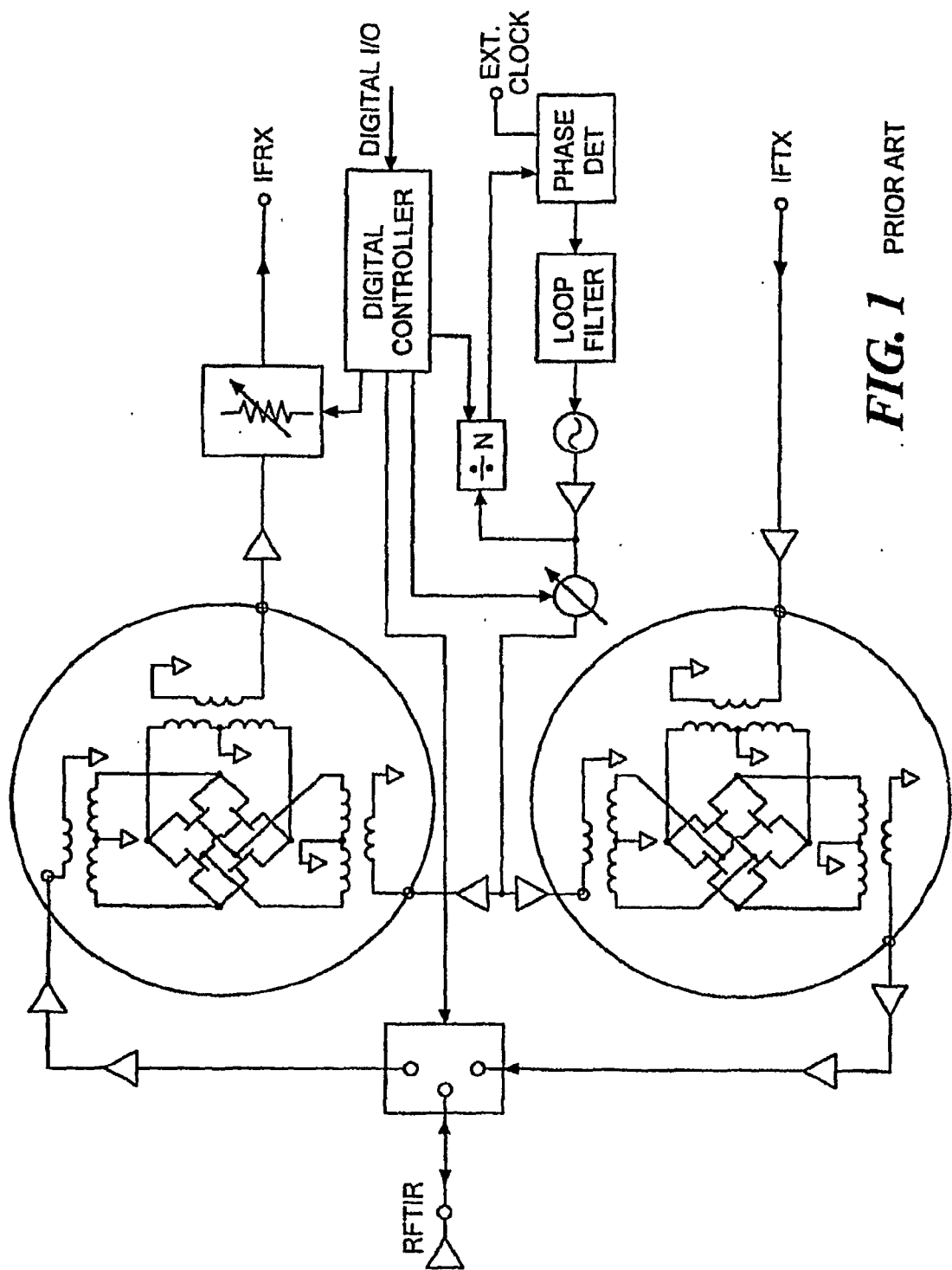
a first portion carrying signals having the second frequency, such first portion being coupled to the second one of the pair of ports; and

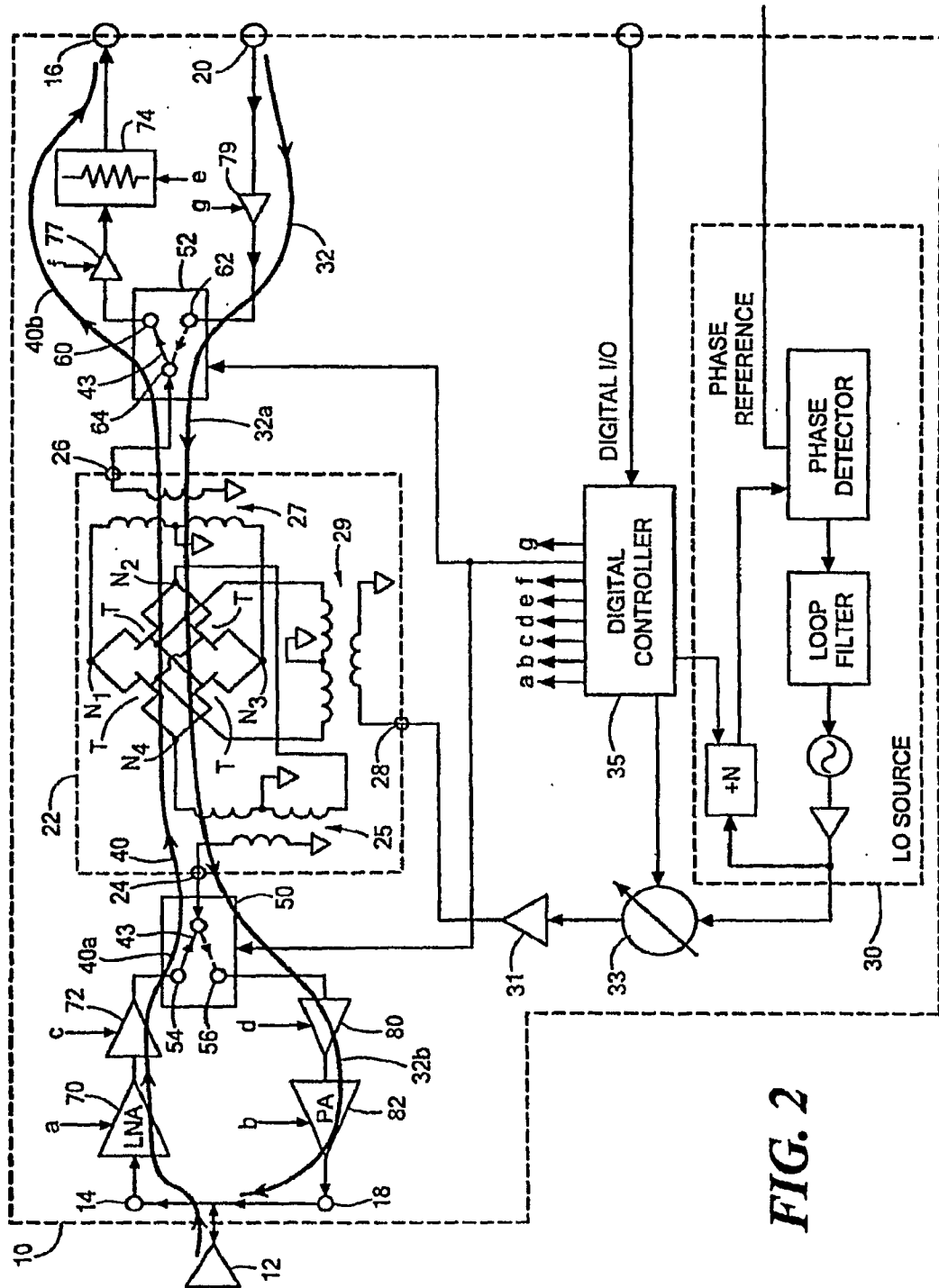
30 a second portion carrying signals having the first frequency converted from the second frequency by the mixer responding to the local oscillator signal, such second portion carrying

signals having the first frequency from the first one of the pair of ports of the mixer.

3. The transmit/receive module recited in claim 2 wherein such module includes a pair of switches, a first one of such switches having a first port coupled to the first portion of the transmit path, a second port coupled to the second portion of the receive path and a third port coupled to the first port of the mixer; and the second one of the switches having a first port coupled to the first portion of the receive path, a second port coupled to the second portion of the transmit path and a third port coupled to the second port of the mixer.
4. The transmit/receive module in claim 1 wherein the mixer includes interconnected passive devices.
5. The transmit/receive module in claim 4 wherein the passive devices are disposed in different branches of a bridge circuit.

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**FIG. 1** PRIOR ART



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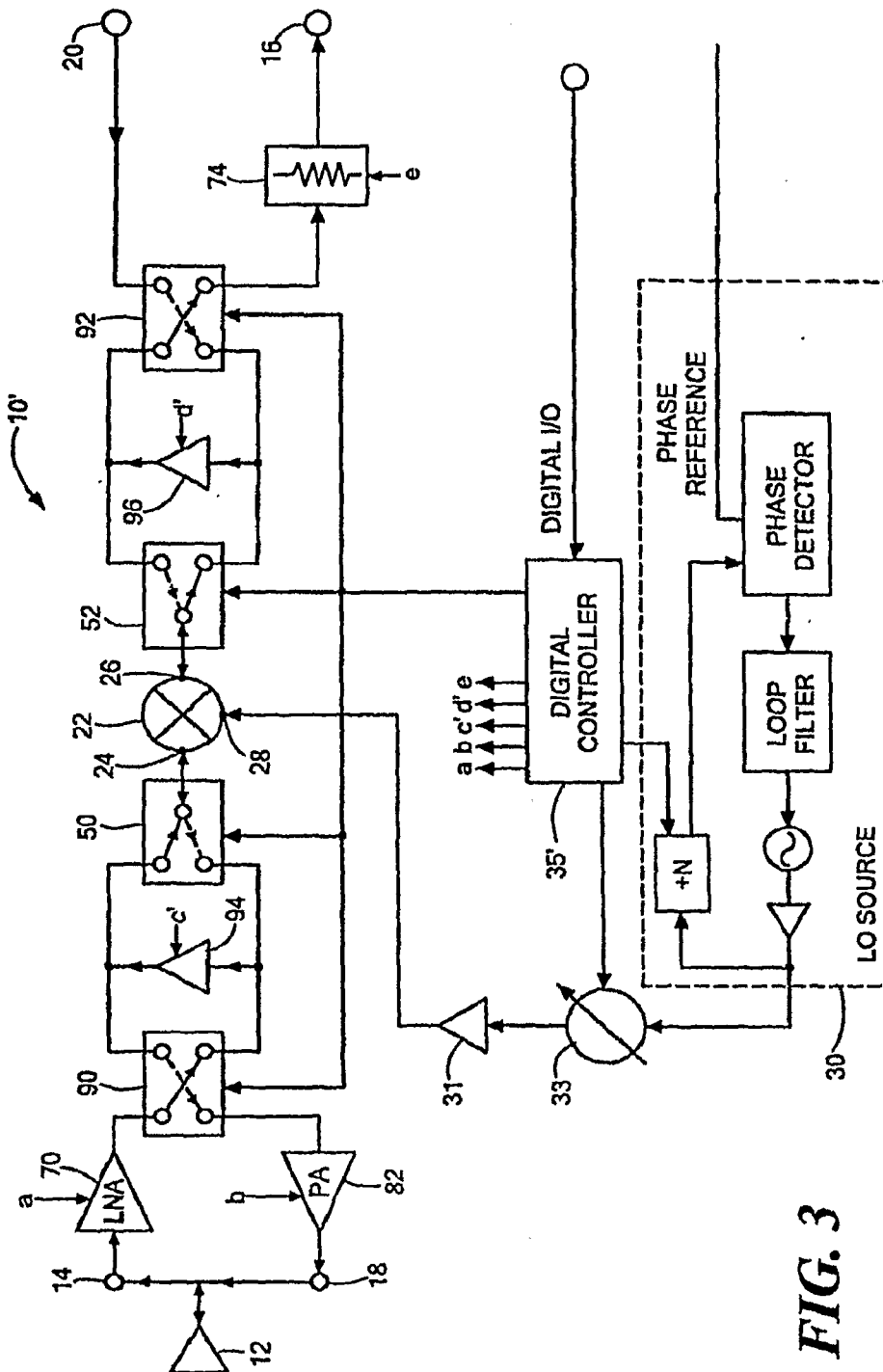


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/012586

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B1/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GERZELKA G: "9-MHZ-SSB-AUFBEREITER FUER AMATEUR-TRANSCEIVER" FUNK-TECHNIK, HUETHIG, HEIDELBERG, DE, vol. 31, no. 15, 1976, pages 471-474, XP000815833 ISSN: 0016-2825 page 471, column 1 - column 2; figures 1,3 -----	1-5
X	WYNS P: "6-METRE BAND TRANSVERTER" ELEKTOR ELECTRONICS, ELEKTOR ELECTRONICS, TUNBRIDGE WELLS, GB, vol. 17, no. 188, 1 April 1991 (1991-04-01), pages 38-43, XP000230068 ISSN: 0268-4519 page 38, column 2, line 22 - page 38, column 1, line 16; figures 1,2 ----- -/--	1-5

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"WORKING BOTH WAYS" ELECTRONICS & WIRELESS WORLD, REED BUSINESS PUBLISHING, SUTTON, SURREY, GB, vol. 92, no. 1610, December 1986 (1986-12), page 95, XP000815841	1-3
A	the whole document -----	4,5
X	WO 2006/020838 A (SHIELDTECH SYSTEMS LLC [US]; PLEASANT WAYNE [US]) 23 February 2006 (2006-02-23)	1-3
A	paragraph [0020] - paragraph [0027]; compound 1 -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2007/012586

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