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IN REPLY REFER TO:

Attorney Docket No. 84702
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Attorney Docket No. 84702
Customer No. 23523

OMNI-AZIMUTHAL PATTERN GENERATOR
FOR VLF AND LF COMMUNICATION

TO ALL WHOM IT MAY CONCERN

BE IT KNOWN THAT DAVID A. TONN, employee of the United States Government, citizen of the United States of America, and resident of Charlestown, County of Washington, State of Rhode Island, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

JEAN-PAUL A. NASSER, Esq.
Reg. No. 53372

Attorney Docket No. 84702

OMNI-AZIMUTHAL PATTERN GENERATOR FOR VLF AND LF COMMUNICATION

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

CROSS REFERENCE TO OTHER RELATED APPLICATIONS

Not applicable.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to antennas, and more specifically to the elimination of the null along the axis coincident with the dipole moment of an antenna.

(2) Description of the Prior Art

Electrically small antennas possess a pattern in azimuth that has a null along an axis coincident with the dipole moment of the antenna. This null renders the antenna "blind" along that axis. If two antennas are used and the signals are combined, a null occurs along an axis between the two dipole moments. An ideal antenna system would be one capable of rendering equally good reception from all azimuth angles without a null in the antenna pattern(s).

It is possible to remove the null in the azimuthal response of a pair of identical orthogonal antennas by combining the two signals together ninety degrees out of phase. Adding the two signals in phase only causes the null in the azimuth pattern to shift to a position midway between the dipole moments of the two antennas.

In the past, it has been quite easy to introduce a 90-degree phase shift, at only a single frequency, by the use of a simple, single-pole electrical network. The disadvantage is that over a broad range of frequencies the user has to retune the circuit every time the frequency of operation changes. The challenge is to accomplish a ninety degree phase shift between two identical orthogonal antenna signals and be able to do so over a broad range of frequencies for example from 10 kHz to 200 kHz without exceeding a 3dB pattern deformation.

SUMMARY OF THE INVENTION

It is a general purpose and object of the present invention to generate an antenna pattern that does not change as a function of azimuth angle, but has equally good reception from all azimuth angles.

It is an additional purpose to generate such an omniazimuthal antenna pattern over a broad range of frequencies in a manner that does not require manual retuning or adjustment.

These objects are accomplished through the introduction of a "relative" phase shift in a pair of identical orthogonally mounted loop antennas whereby operational-amplifier circuits in a network within the antenna system are all single pole circuits, with the pole frequency of the single pole circuits being adjustable by means of a potentiometer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an equivalent representation of two orthogonally mounted antennas;

FIG. 2 is a block diagram of the circuit stages of the omni-azimuthal pattern generator;

FIG. 3 is a circuit diagram of the differential driver stage of the omni-azimuthal pattern generator;

FIG. 4 is a circuit diagram of a single building block circuit of the all-pass network;

FIG. 5 is a circuit diagram of the entire all-pass network stage of the omni-azimuthal pattern generator;

FIG. 6 is a circuit diagram of the combiner stage of the omni-azimuthal pattern generator;

FIG. 7 is a circuit diagram of the drive stage of the omni-azimuthal pattern generator.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The omni-azimuthal pattern generator is designed to work with the AN/BRA-34 (V) and OE-538/BRC VLF/LF loop antennas. It is not, however, limited as such and can be scaled and applied to other frequency ranges of interest. Inside each of these antennas are two identical orthogonally mounted loop antennas, called the "Fore/Aft" (F/A) and "Athwart" (ATH) loops. Referring now to FIG. 1 the equivalent representation of the identical orthogonal antennas F/A and ATH is illustrated. The outputs of each of these antennas is amplified in the antenna housing and presented as a balanced twisted pair transmission line.

Referring now to FIG. 2, there is illustrated a block diagram of the four stages of the omni-azimuthal pattern generator 10. The first stage is the differential driver stage 12. The two balanced twisted pair transmission lines from the orthogonal antennas F/A and ATH enter the omni-azimuthal pattern generator 10 at the differential driver stage 12 at the points denoted "F/A HI", "F/A LO", "ATH HI", "ATH LO". The next stage is the all-pass network 14, so called because it has approximately unity gain over a wide frequency range. The all-pass network introduces a relative phase shift of 90 degrees between the two antenna signals. The signals are then combined in the combiner stage 16. In the final stage, the drive stage 18, the combined signal is amplified. The resulting output of the omni-azimuthal pattern generator 10 is an "OMNI HI" signal and an "OMNI LO" signal.

Referring now to FIG. 3, there is illustrated a circuit diagram of the differential driver stage 12. Operational amplifiers 20 and 22 and associated resistors serve as isolation amplifiers and to convert the balanced input into an unbalanced signal for subsequent conditioning.

Referring now to FIG. 4 and FIG. 5, there is illustrated in FIG. 4 a single building block circuit 30 of the active all-pass network 14 consisting of an operational amplifier 24 a potentiometer R_2, a resistor R_1, a capacitor C_1 and other circuit elements. In FIG. 5 there is illustrated the entire all-pass network 14 consisting of two parallel sets of three of the single building block circuits 30 in series labeled B1 to B6. As stated above, the active all-pass network 14 introduces a relative phase shift of 90 degrees between the F/A leg of the circuit along the top three building block circuits B2, B4, B6, and the ATH leg of the circuit along the bottom three building block circuits B1, B3, and B5. A relative rather than absolute phase shift is sufficient since the absolute phases of the signals are unimportant. The building block circuits B1 to B6 in the all-pass network 14 are all single pole circuits, with the pole frequency being adjustable by means of a potentiometer R_2.

The transfer function H(jω) of this network can be shown to be:

$$H(j\omega) = \frac{1 - j\omega R_{E1} C_1}{1 + j\omega R_{E1} C_1}, R_{E1} = R_1 + R_2 \quad (1)$$

By cascading the several building block circuits 30, the phase shift from input to output of each leg of the all-pass network 14 can be derived as follows:

$$\phi\,(F/A) = -2 \arctan(\omega/p2) - 2 \arctan(\omega/p4) - 2 \arctan(\omega/p6) \quad (2)$$

$$\phi\,(ATH) = -2 \arctan(\omega/p1) - 2 \arctan(\omega/p3) - 2 \arctan(\omega/p5) \quad (3)$$

Here, the "pN" represent the pole frequencies of each of the six building block circuits B1 to B6 of the all-pass network. The pole frequencies in these equations are expressed as angular frequencies. When the two signals are subtracted the resulting phase difference between the F/A and ATH legs of the all-pass network 14 will be:

$$\Delta\phi = 2\,[-\arctan(\omega/p1) + \arctan(\omega/p2) - \arctan(\omega/p3) + \arctan(\omega/p4) - \arctan(\omega/p5) + \arctan(\omega/p6)] \quad (4)$$

By proper selection of the pole frequencies of each of the building block circuits B1 to B6, it is possible to tailor this response to provide a value of $\Delta\phi$ that is close to 90 degrees over the frequency band of interest.

The required pole frequencies that drive the all-pass network 14 are shown in Table 1 below:

Building Block Circuit#	**p/2π (Hz)**
1	1687
2	7335
3	22,915
4	69,824
5	218,143
6	948,000

Potentiometers R_2 are utilized in B1 through B6 to calibrate the all-pass network 14 before it is used. This is critical to ensure that the pole frequencies are correctly set so that proper operation of the circuit over the VLF/LF band is maintained. The test points TP1 to TP6 in FIG. 5 allow a dual channel digitizing oscilloscope (not shown) to be connected in order to set the pole frequencies precisely by means of the potentiometers R_2 in B1 to B6.

Referring to FIG. 6 there is illustrated the circuit diagram for the combiner stage 16. The operational amplifier 26 combines the outputs from the all-pass network 14.

Referring to FIG. 7 there is illustrated the circuit diagram for the drive stage 18. The driver 28 and associated components provide a balanced 50-Ohm output in the form of an OMNI HI and OMNI LO signal.

The advantages of the present invention over the prior art are that the current invention is more lightweight. It is more compact than prior art devices. It does not require elaborate external drive circuitry. It uses no moving parts and requires no user intervention to operate.

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ABSTRACT OF THE DISCLOSURE

A relative phase shift is induced in the signals of a pair of identical orthogonal antennas such that when the signals are combined the signals are 90 degrees out of phase. This is done in order to eliminate the null along the axis between the two dipole moments of the antennas such that the system has equally good reception from all azimuth angles over a broad range of frequencies. The phase shift is accomplished with the use of single pole operational amplifier circuits whose pole frequencies are adjusted by means of a potentiometer prior to implementation of the antenna system.

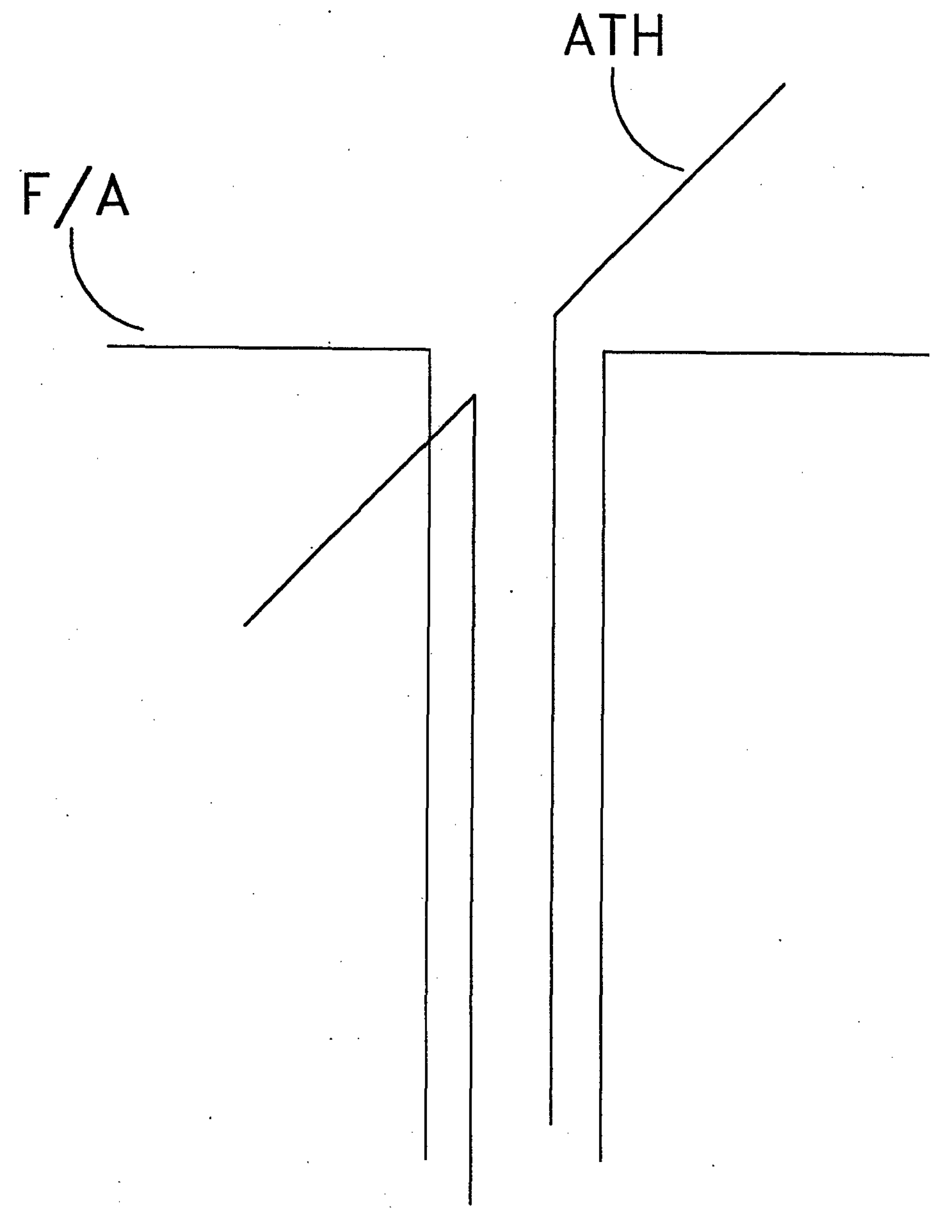

FIG. 1

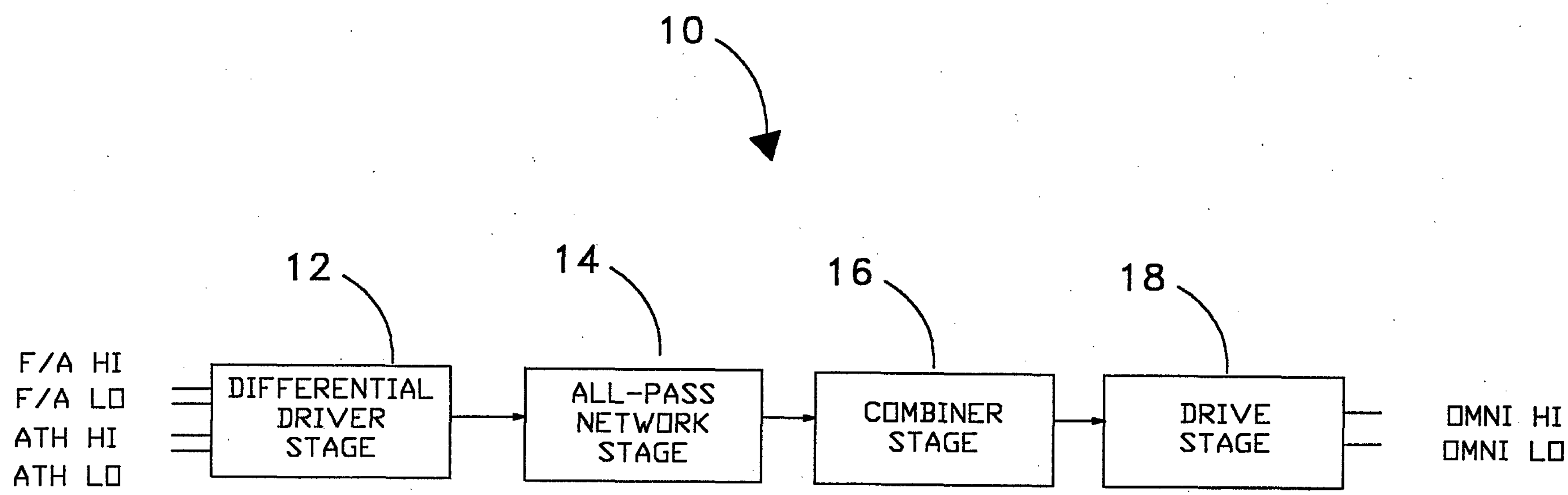
10
12
14
16
18
F/A HI
F/A LO
ATH HI
ATH LO
DIFFERENTIAL DRIVER STAGE
ALL-PASS NETWORK STAGE
COMBINER STAGE
DRIVE STAGE
OMNI HI
OMNI LO

FIG. 2

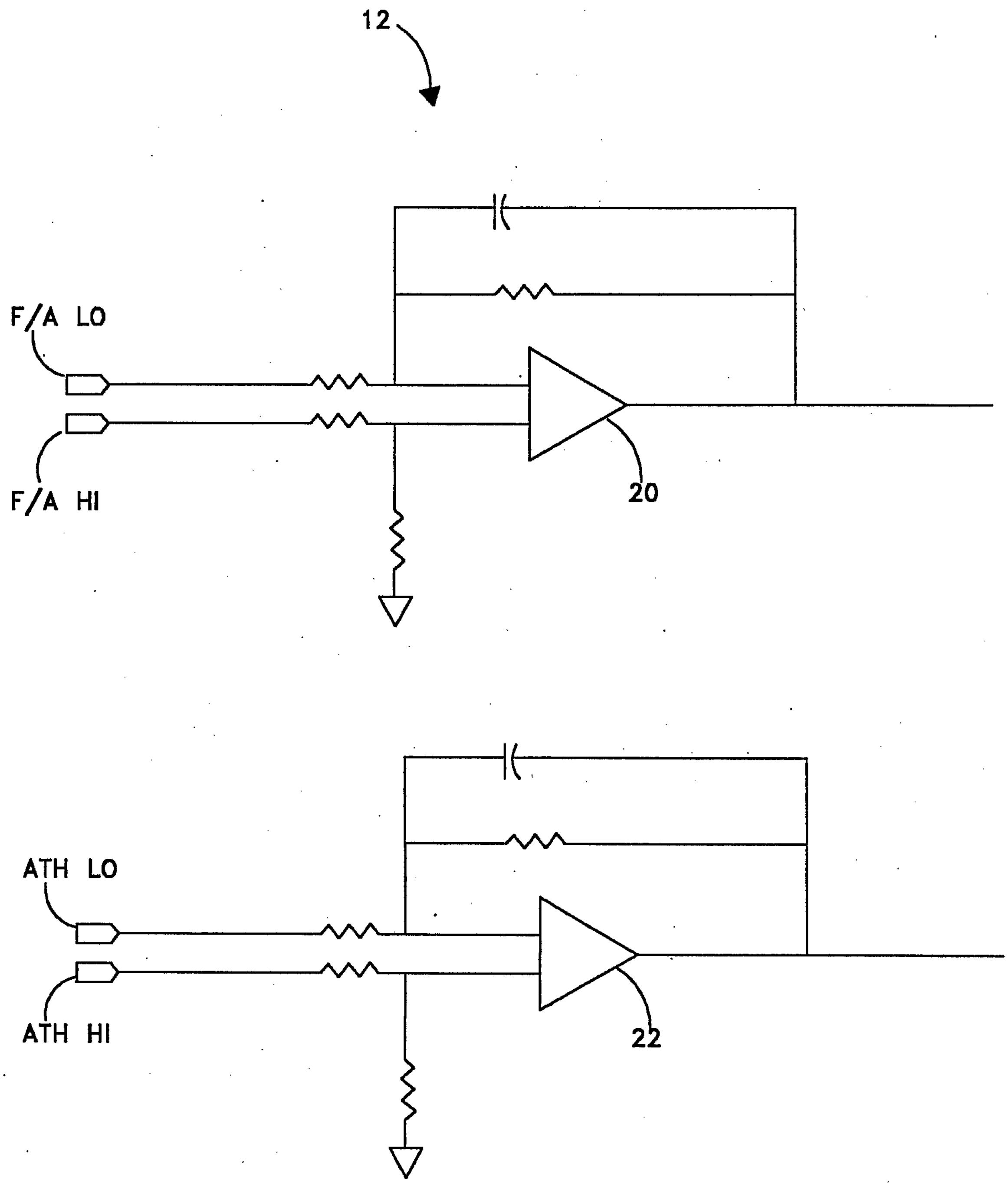

FIG. 3

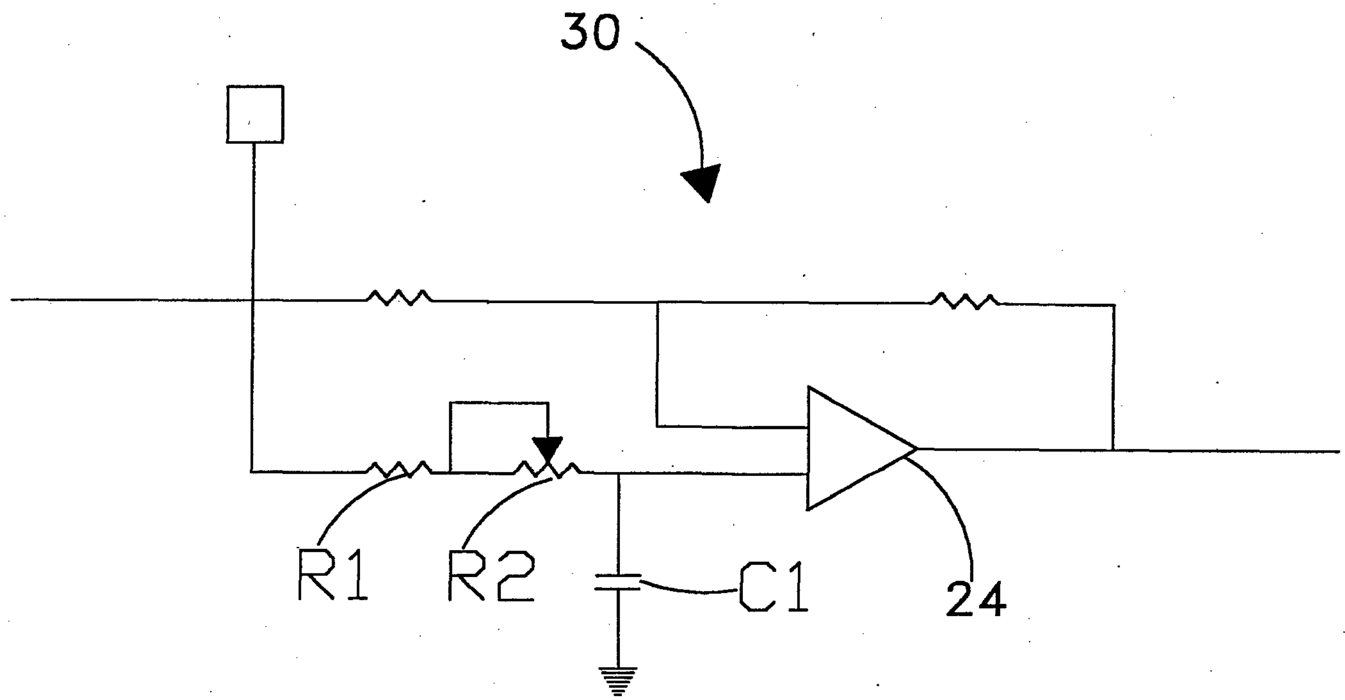

FIG. 4

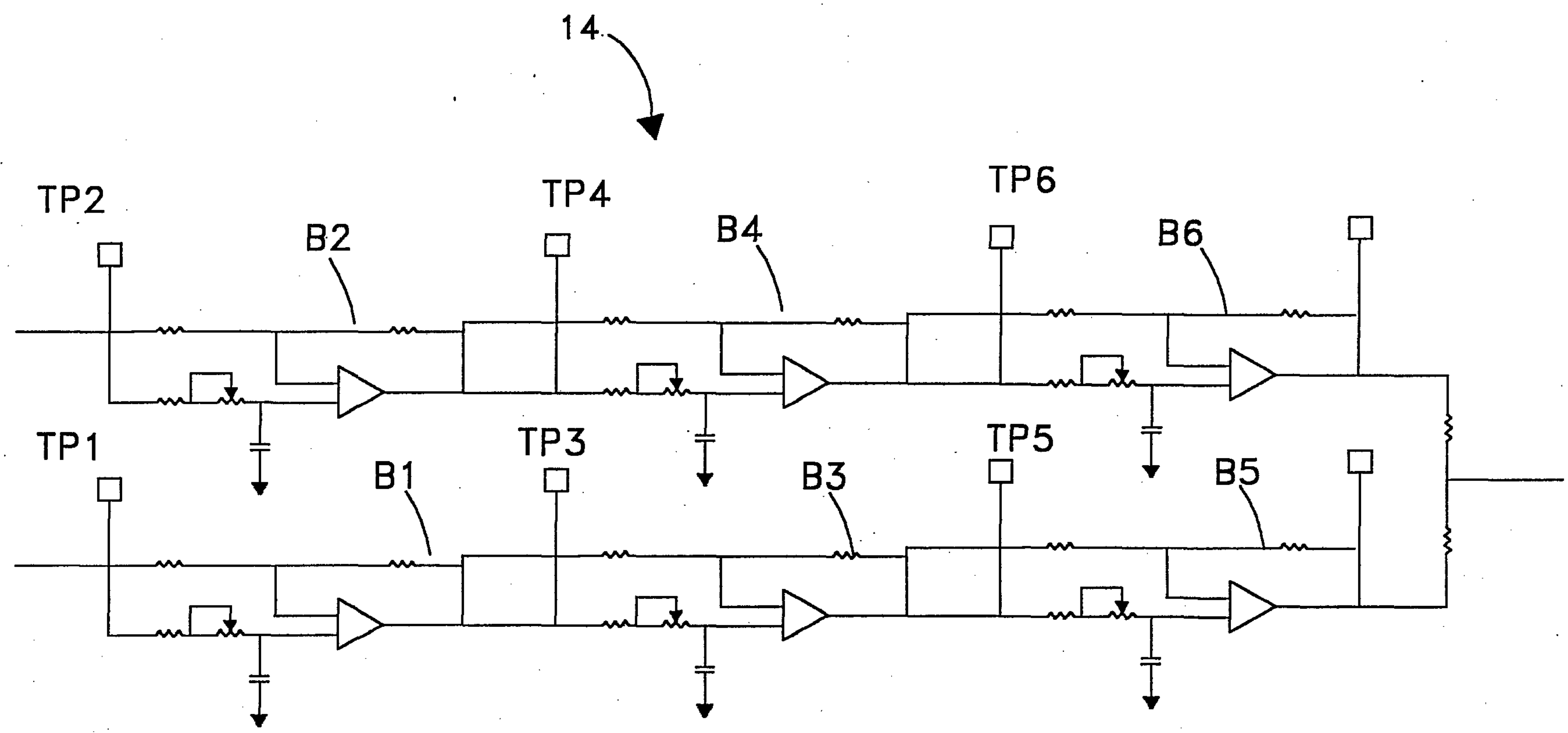

FIG. 5

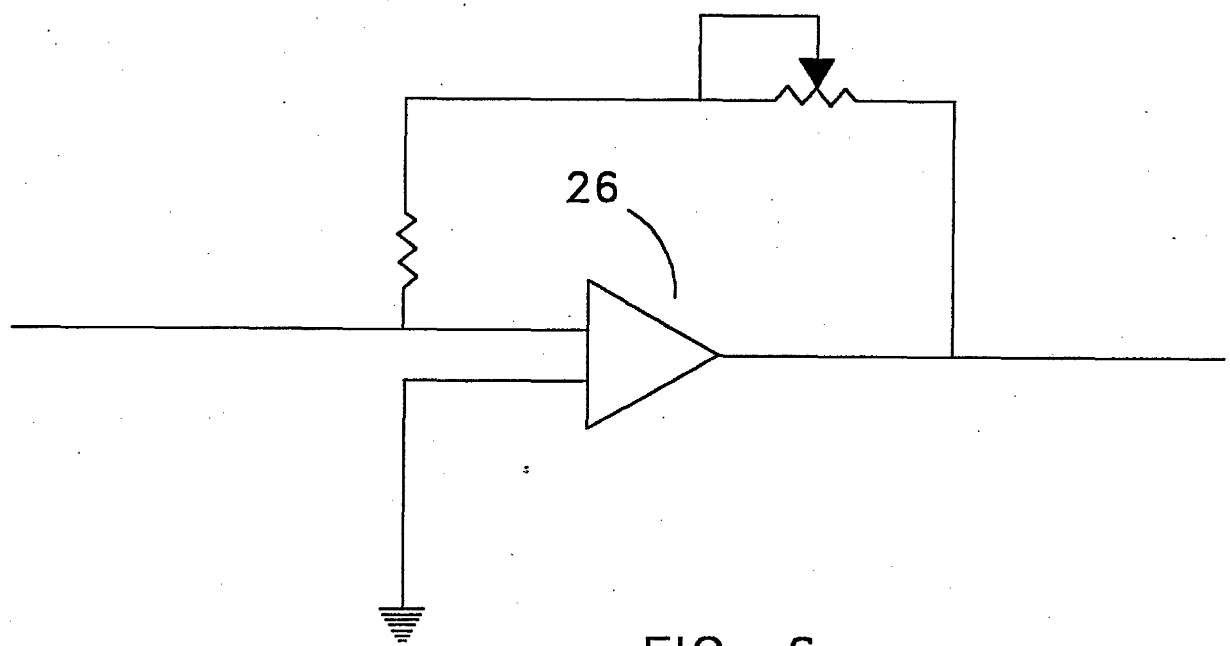

FIG. 6

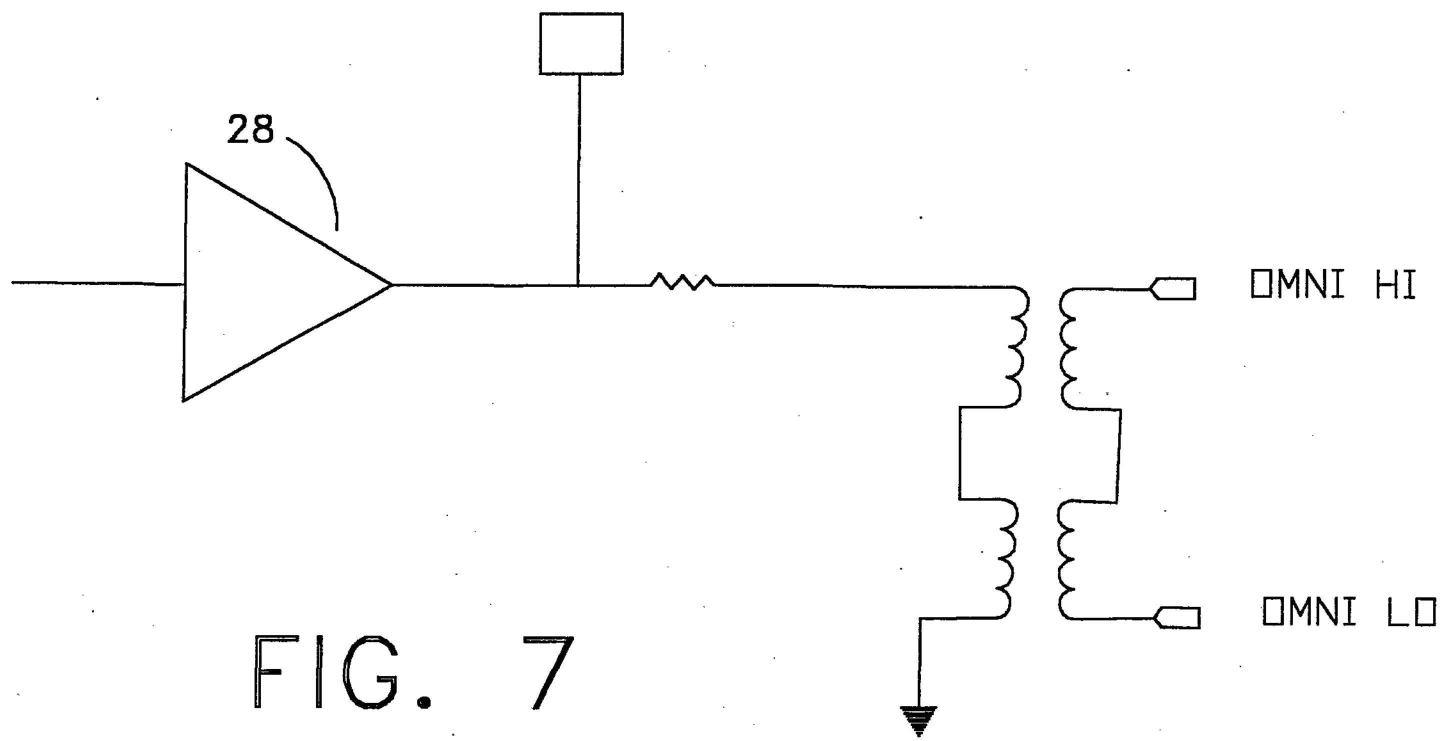

FIG. 7