

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 828 306 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

11.03.1998 Bulletin 1998/11(51) Int Cl.⁶: **H01P 1/213**(21) Application number: **97306729.1**(22) Date of filing: **02.09.1997**

(84) Designated Contracting States:

**AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC
NL PT SE**(30) Priority: **03.09.1996 FI 963446****03.09.1996 FI 963445**(71) Applicant: **LK-PRODUCTS OY****SF-90440 Kempele (FI)**

(72) Inventors:

- **Hagstrom, Panu**
90230 Oulu (FI)
- **Yrjola, Seppo**
90460 Oulunsalo (FI)

(74) Representative: **Potter, Julian Mark et al**

Nokia Mobile Phones (UK) Ltd
St. Georges Court
St. Georges Road
Camberley, Surrey GU15 3QZ (GB)

(54) A matched impedance filter

(57) In a radiofrequency filter (34; 35; 36) there is a port (34a; 34b; 34c) by means of which it is connected to an external component (14; 17; 21) and the impedance of which is adjusted by internal filter circuits so as to correspond to the impedance of the external compo-

nent (Z_{ant} ; Z_{RX} ; Z_{TX}) at the operating frequency. The filter may for example be a duplex filter (34), in which case the internal impedance matching may be employed at the antenna port (34a), at the reception port (34b) and/or at the transmission port (34c).

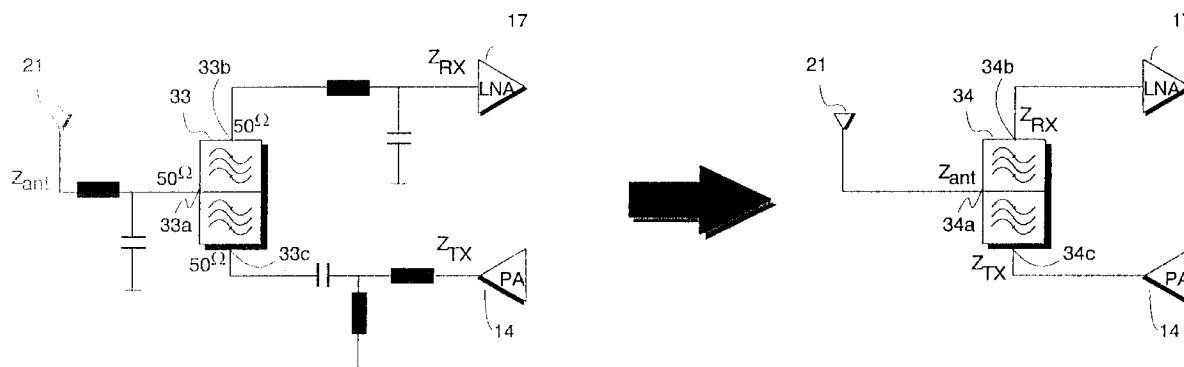


Fig. 3

Description

The invention relates in general to the design of a radio transmitter/receiver and in particular to application of filter technology to increased integration of the radio transmitter/receiver and reduction of its physical size.

The radio set according to the prior art, having bilateral action and employing time division duplex (TDD) or frequency division duplex (FDD), contains a number of RF- and intermediate frequency filters on both the transmission side and the receiving side. Figure 1 shows a TDD radio 10 according to the prior art, which contains a duplex filter 33 connected to the antenna 21, for separation of the transmitted and received signals one from the other. The output port of the duplex filter is connected to a low-noise amplifier (LNA) 17 via an impedance matching network 12. The LNA amplifies the received radio signal. It is followed by a band-pass filter 18, which further filters the received signal. Also, between the LNA and the band-pass filter 18 there is an impedance-matching circuit 16. All impedance-matching circuits in the Figure have been shown as specific combinations of inductive and capacitive components, but to men skilled in the art it will be clear that the use of other types of impedance-matching network is possible. The output port of the filter 18 is connected to a mixer 11, in which the received signal is mixed with the first injection signal coming from a synthesizer 22. The intermediate frequency signal (IF) obtained as a result of mixing is conveyed to the RF circuit for demodulation and further processing.

The transmitter portion of the radio 10 comprises a second local oscillator signal (LO) 26, which is brought in by the forward stage (not illustrated) of the transmitter and is mixed in a mixer 30 with the first injection signal. The output of the mixer 30 is carried to a band-pass filter 13, which is usually situated upstream from the power amplifier 14 of the transmitter. The output of the power amplifier 14 is connected to the input of a duplex filter 15 via an impedance-matching circuit 19. A further, similar impedance-matching network 20 is found between the power amplifier 14 and the band-pass filter 13. Between the power amplifier 14 and the duplex filter there is frequently a directional coupler (not shown), with which it is possible to measure the power level of the signal going to the antenna. The antenna port of the duplex filter 33 is connected to the antenna of the transmitter/receiver via an impedance-matching circuit 23.

Figure 2 shows a similar radio set according to the prior art, in which in place of a duplex filter use is made of an antenna coupler 25, a band-pass filter 27 and a low-pass filter 28. On both sides of filters 27 and 28 impedance-matching networks 12a, 12b, 19a, 19b are required.

The standard impedance at the junctions between the discrete components and the filters has been established as 50 Ω . Filter and semiconductor manufacturers adjust the input and output impedances of their products

to a standard value in order to facilitate modular design. The input and output impedances of RF circuits would often benefit from being smaller or greater, for example the input impedance of the LNA 17 could, as it is, be approximately 100 Ω . Adjustment to the standard value has to be done by a matching circuit, which is built from independent components or which the semiconductor manufacturer integrates into an RF circuit. The matching circuits required for the standard impedance take up space, increase interference and attenuation and raise manufacturing costs. In order for the size of the radio set and its manufacturing costs to be substantially reduced from current values, it is necessary to develop a transceiver filtering solution which permits easier integration of the said blocks.

Impedance matching may also be viewed from the standpoint of the antenna and the associated antenna filtering solution. In data transmission networks use is generally made of time division multiple access (TDMA), in which transmission and reception occur in different time intervals. If the transmission and reception frequency are the same, the mobile telephone comprises an antenna coupler used for separation of the signals, which connects the antenna in turn to the transmission or reception branch of the set. If transmission and reception occur in different frequency bands, a filter similar to the duplex filter used in analog telephones may be employed as a separating unit. The latter alternative is also involved in systems applying frequency division multiple access (FDMA).

In a digital mobile telephone employing frequency division duplex (FDD), filters are also required in addition to the RF coupler circuit described, since there must be selectivity at the receiver input and it must protect the low-noise pre-amplifier. At the transmitter output the harmonic multiples of the transmission frequency and other spurious emissions such as image frequencies must be attenuated. In addition, the filters remove noise generated by the transmitter chain to the receiver band. Also, the lower frequencies of the transmission band must be attenuated by a separate filter. In a system employing time duplex, such as the DECT (Digital European Cordless Telephone) system, in addition to the above different arrangements must be employed to ensure that, during signal transmission, spurious emissions towards the antenna generated in the receiver are adequately attenuated.

Regardless of whether the radio set employs an antenna coupling or simply frequency-selective filtering for separation of the transmitted and received signal, the impedance of the antenna must be matched to the connected coupler or filter block. The standard 50 junction impedance again necessitates at least one impedance-matching circuit, which in Figures 1 and 2 is marked by reference number 23. The same observations concerning loss, interference and costs apply to this circuit as were presented above in relation to circuits 12, 16, 19 and 20.

An aim of this present invention is to provide a filtering solution for a transmitter/receiver, which increases the degree of integration of the set while removing and/or reducing the drawbacks of the prior art as described above. Another aim of the invention is also to present a radio set of small design which is reasonable in terms of its manufacturing costs and which with regard to its operating frequencies and other specifications is readily applicable to differing systems.

The aims of this invention are endeavoured to be attained by designing the radiofrequency filters of the transmission and reception chains in such a way that the impedances of their input and output ports correspond to the natural impedances of the components connected to them. In this way, other components may be attached to the filters without separate matching networks.

The characteristic feature of the matched impedance filter according to this invention, which has a certain operating frequency and which comprises at least one port for connection to an external component, is that the impedance of the port at the operating frequency is so adjusted by internal circuits of the filter that it is essentially the same as the impedance of the external component attached to it.

The invention is also concerned with a radio set which comprises at least one radiofrequency filter and an active component connected to its input or output port. Characteristic of the radio set according to the invention is that impedance matching between the radiofrequency filter and the active component is provided for by internal circuits of the filter without an external impedance-matching network.

The invention is founded on the belief that the opportunities offered by filter technology should be used as a basis for design of the radio structure. A modern radiofrequency filter is formed from transmission line resonators, possible discrete components, transmission lines connecting these and a framework, which is most commonly a low-interference substrate, a dielectric (most commonly ceramic) frame block or a combination of these. The filter-entity is surrounded by an electrically conductive casing. In accordance with the invention, the transmission lines and any discrete components inside the filter in connection with the input and output ports of the filter are so dimensioned that the impedance of the port corresponds to the impedance of the antenna or active component connected thereto without the need for matching networks. The filter together with its internal matching structures forms a single component on the circuit board of a mobile telephone or other radio set, which economizes on space and accelerates assembly of the radio set. What is important with regard to the electrical functioning is the elimination of parasitic elements due to external impedance-matching networks, which results in an acceleration of electrical functioning and a decrease in overall power losses.

The invention will now be described in greater detail with reference to a favourable embodiment presented by way of example and to the attached drawings, where

- 5 Figure 1 represents a particular radio set in accordance with the prior art,
- Figure 2 represents a second radio set in accordance with the prior art,
- 10 Figure 3 shows a duplex filter solution according to the invention compared with a duplex filter solution in accordance with the prior art,
- 15 Figure 4 represents a radio set in which there are a number of matched impedance filters in accordance with the invention.
- Figure 5 shows a radio set comprising an integrated filtering unit in accordance with an embodiment of the invention; and
- 20 Figure 6 shows in outline the design of the integrated filtering unit shown in Figure 5.

25 In the above description of the prior art reference is made to Figures 1 and 2, and so in the following account of the invention and of favourable embodiments thereof reference will chiefly be made to Figures 3 and 4. In the drawings, the same reference numbers are employed for parts which correspond to each other

30 In the left part of Figure 3 is a duplex filter solution according to the prior art, in which the impedance of all three ports 33a, 33b, 33c of the filter 33 at the operating frequency is 50 ohm. The input impedance Z_{RX} of the low-noise pre-amplifier (LNA) 17 is not 50 ohm, so that an impedance-matching network is required between the LNA and the duplex filter. There is also a matching network between the antenna 21 and the duplex filter 33 and between the transmission chain power amplifier (PA) 14 and the duplex filter 33. The duplex filter 34 according to the invention, which is shown in the right half of Figure 3, includes an antenna port 34a, a reception port 34b and a transmission port 34c, the impedance of each of which at the operating frequency is so adjusted that it is the same as the impedance of the component connected to the port. The impedance of the antenna port is designated Z_{ant} , the impedance of the reception port is designated Z_{RX} and the impedance of the transmission port is designated Z_{TX} . No separate impedance-matching networks are required between the filter and the components connected thereto.

35 Selection of the impedance value of the filter port is in itself a known technique. Owing to the 50 ohm requirement according to the prior art, there are many filters commercially available where the chosen impedance value of the ports is 50 ohm. By varying the dimensions of the parts belonging to these filters it is possible by

experiment to seek almost any suitable impedance value. Variable parts include, for example, the transmission lines and capacitive and inductive discrete components inside the filter.

Figure 4 shows a radio set in which there is a duplex filter 34 in accordance with the invention between the antenna 21, the LNA 17 and the PA 14. Also in the set between the LNA 17 and the mixer 11 there is a first band-pass filter 35 according to the invention, and between the mixer 30 and the PA 14 there is a second band-pass filter 36 according to the invention. The band-pass filters 35 and 36 conform to the invention by virtue of the fact that their ports are adjusted to correspond in impedance to the impedances of the components which are connected to them. Consequently, there is no need for separate impedance-matching networks for the filter ports.

Figure 5 shows a block diagram of a radio set in which there is an integrated filtering unit 25 in accordance with the invention. The central part of the transmission and reception chains of the radio set is this integrated filtering unit 25, which contains a duplex filter, made up of two filter branches 25a and 25b, and two band-pass filters 25c and 25d. In the reception branch 25b of the duplex filter and in the first band-pass filter 25c there are ports for connection of a low-noise amplifier 17 in such a way that the input thereof is connected to the duplex filter and the output thereof is connected to the band-pass filter. Correspondingly, in the second band-pass filter 25d and in the transmitter branch 25a of the duplex filter there are ports for connection of a power amplifier 14 in such a way that its input is connected to the band-pass filter and its output is connected to the duplex filter. In addition, in the first band-pass filter 25c there is a port for conducting the signal to a mixer 11 and in the second band-pass filter 25d there is a port for conducting the signal from mixer 30. In the duplex filter there is a port for connection of the antenna 21.

The above-mentioned ports in the filtering unit 25 each have a certain impedance level. The impedance level of the ports connected to the low-noise amplifier 17 is in Figure 5 designated Z_{RX} and the impedance level of the ports connected to the power amplifier 14 is designated Z_{TX} . The impedance level of the input port and the output port of a certain amplifier is not necessarily the same, in which case the levels in the filtering unit also have to be adjusted differently, but for clarity only one designation is used for each amplifier. The impedance level of the ports connected to the mixers 11 and 30 is designated Z_{mix} and the impedance level of the port connected to the antenna 21 is designated Z_{ant} .

An embodiment of the invention which is favourable in respect of the filter structure relates to a filter in which, for transmission line resonators, use is made of dielectric resonators which are known as such and in which the necessary transmission lines and soldering pads for the internal discrete components of the filter are formed on the surface of a dielectric frame block and/or of a

substrate attached thereto. The structure is protected by a protective casing. An example of such a structure is shown in Figure 6.

The framework is made up of a low-interference substrate 40 and a ceramic frame block 41 connected to each other, in the latter of which resonator apertures 42 are formed in a way which is in itself familiar. In that surface of the ceramic frame block which faces the substrate 40 and which cannot therefore be seen in the drawing, it is possible to form conductive patterns for connection to the resonator apertures 42. On the surface of the substrate are formed transmission lines 43 and circuit lands 44; the former of these provide the internal connections of the structure, while the components attached to the latter affect the electrical characteristics of the structure. The ports by means of which the integrated filtering unit 25 is connected to the antenna, to the amplifiers and to the mixers take the form of conductor strips 45 extending to the edge of the substrate. The structure includes a protective cover 46 made from a thin metal plate or other electrically conductive material.

In one version of the structure shown in Figure 6, not all resonators are contained in the same ceramic frame block, but the filter contains a number of discrete blocks. As a result of these discrete blocks, the resonators may easily be of differing lengths, which in a single-block filter would necessitate a dielectric block which was stepped in respect of the other end face. In addition, resonator groups between which no electromagnetic connection is to occur may be easily insulated one from another by arranging between them the metallized surface of two blocks. On the other hand, as the number of blocks increases, so too does the number of stages in the filter manufacturing process.

The invention is not restricted to the internal structure of the filter. As resonators use may be made not only of dielectric resonators but also of helical, stripline or coaxial resonators, for example. The best framework for a structure based on helical resonators is a circuit board on one edge of which are digitate projections to which the cylindrical coil conductors of the helical resonators are attached. The same circuit board acts also as the substrate for transmission lines and discrete components. The electrically conductive protective casing is divided into a number of compartments for the helical resonators, the resonators being separated by partitions in which there may be window couplers. The fundamental structure of the filter based on helical resonators is as such well known in the field.

Mobile telephones are currently the most important area of application of portable radio technology. Since there are many different mobile telephone systems in operation throughout the world, it must be assumed that so-called dual-mode telephones, that is, telephones which operate in different systems at the user's discretion according to circumstances, will become generalized. Alternative systems may use very different fre-

quencies. For example, dual-mode telephones for the GSM and DECT systems have to incorporate both 900 MHz and 1900 MHz radiofrequency components. In the dual-mode application according to the present invention all the transmission and reception-frequency passive filter components of the different systems, or at least a significant proportion of them, have been combined in an integrated filtering unit, thus avoiding as many as ten separate impedance-matching networks and many separate filter components. Active components operating at radiofrequencies in different systems may further be realized as a single GaAs circuit or as a multichip module, which is connected to an integrated filtering unit via signal ports of matching impedance, in which case the structure becomes particularly small and compact in character.

The application of the invention is not limited to any particular radio design, but may be used at all junctions between radiofrequency filters and components connected thereto.

Claims

1. A radiofrequency filter (34; 35; 36), which has a certain operating frequency and which comprises at least one port (34a, 34b, 34c) for connection to an external component, which external component has a certain impedance (Z_{ant} , Z_{RX} , Z_{TX}) at the operating frequency, characterized in that the impedance of the port at the operating frequency is so adjusted by internal circuits of the filter as to be essentially the same as the impedance of the external component connected to the port.
2. A radiofrequency filter in accordance with Claim 1, characterized in that it is a duplex filter (34) comprising an antenna port (34a), a reception port (34b) and a transmission port (34c), and
 - the impedance of said antenna port is so adjusted by internal circuits of the filter as to be essentially the same as the impedance of the antenna (21) connected to the antenna port,
 - the impedance of said reception port is so adjusted by internal circuits of the filter as to be essentially the same as the input impedance of the low-noise pre-amplifier (17) connected to the reception port, and
 - the impedance of said transmission port is so adjusted by internal circuits of the filter as to be essentially the same as the output impedance of the transmission chain power amplifier (14) connected to the port.
3. A radiofrequency filter in accordance with Claim 1, characterized in that it is a band-pass filter (35; 36).
4. A radiofrequency filter in accordance with Claim 1, characterized in that it is a dielectric filter comprising dielectric transmission line resonators.
5. A radiofrequency filter in accordance with Claim 1, characterized in that it is a helical filter comprising helical resonators.
6. A radio set which comprises a radiofrequency filter (34; 35; 36) and an external active component (11; 14; 17; 21; 30) connected thereto, characterized in that impedance matching between the radiofrequency filter and the active component is arranged by internal circuits of the filter without an external impedance-matching network.
7. A radio set in accordance with Claim 6, characterized in that the radiofrequency filter is a duplex filter (34) and the active component is an amplifier (17; 14) connected thereto.
8. A radio set in accordance with Claim 6, characterized in that the radiofrequency filter is a band-pass filter (35; 36) and the active component is an amplifier (17; 14) connected thereto.
9. A radio set in accordance with Claim 6, characterized in that the radiofrequency filter is a band-pass filter (35; 36) and the active component is a mixer (11; 30) connected thereto.
10. A filter structure (25) for the filtering of radiofrequency signals in a radio transmitter and/or receiver, which comprises a first active radiofrequency component (17), characterized in that the filter structure comprises, in an integrated filtering unit,
 - a first filter (25b) as claimed in claim 1 for filtering of a signal before it is conducted outside the filtering unit to the first active radiofrequency component and
 - a second filter (25c) as claimed in claim 1 for filtering of said signal after it is conducted through the first active radiofrequency component.

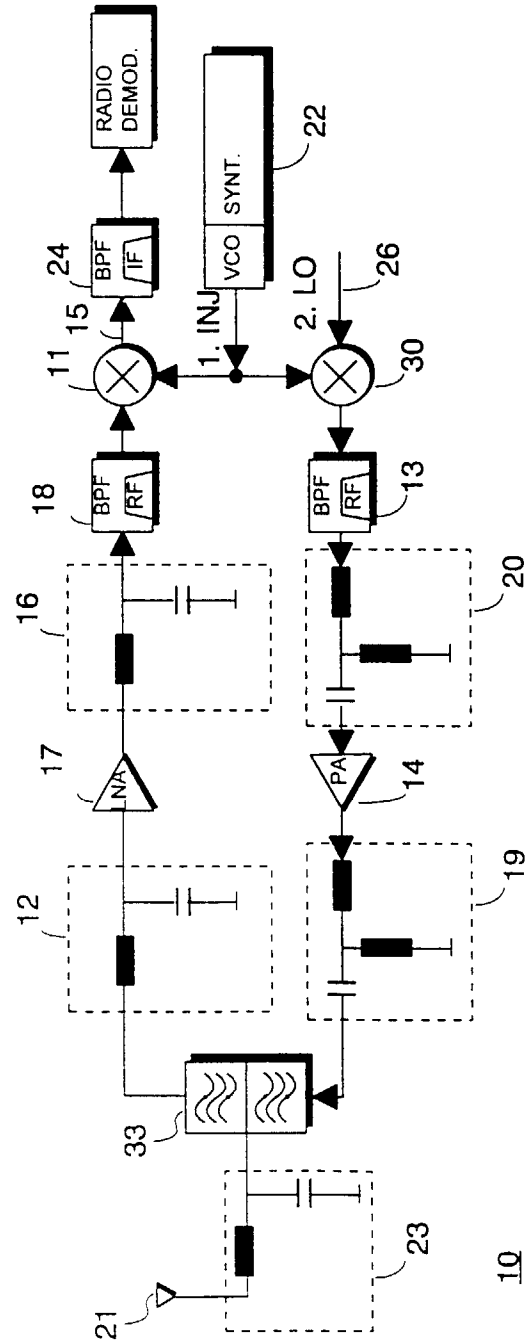


Fig. 1

PRIOR ART

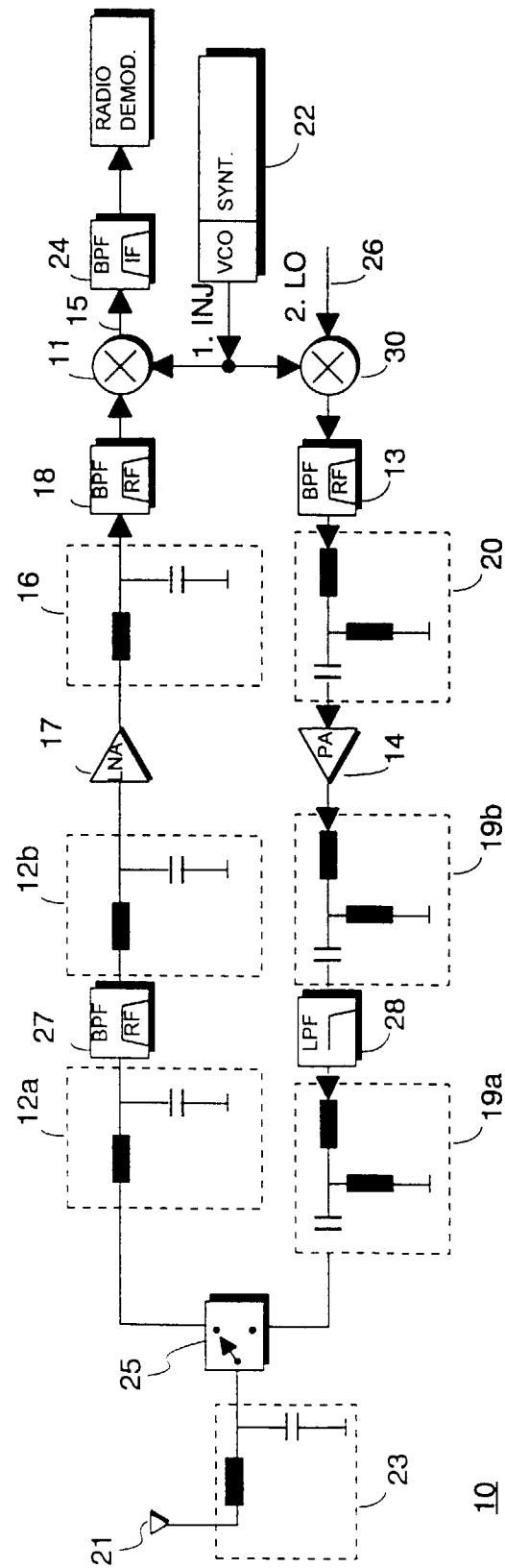


Fig. 2
PRIOR ART

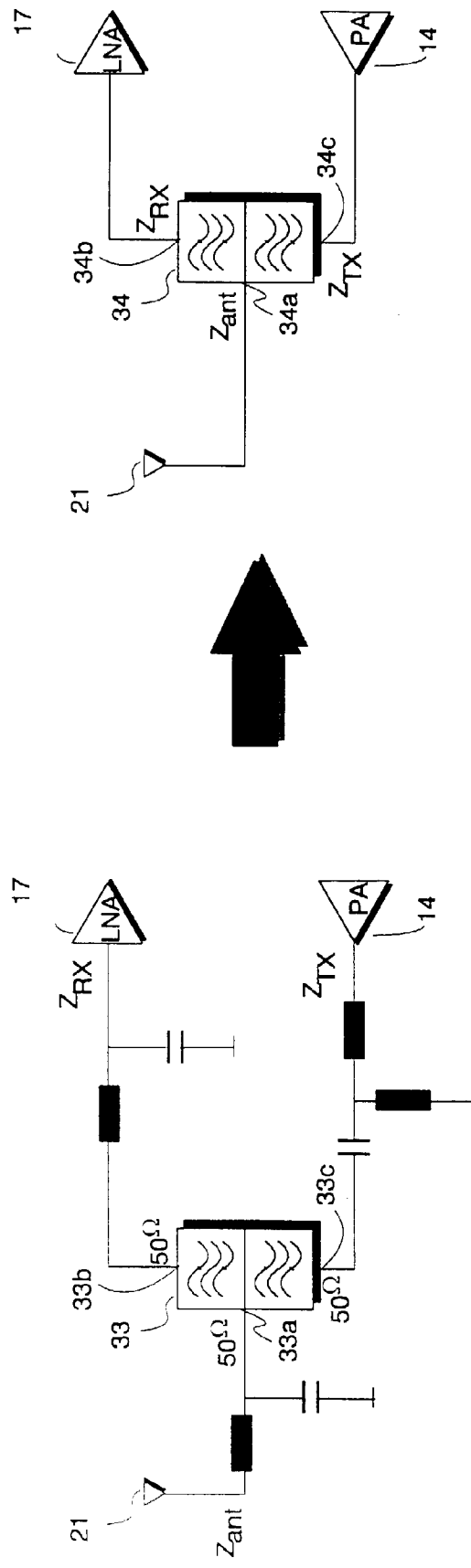


Fig. 3

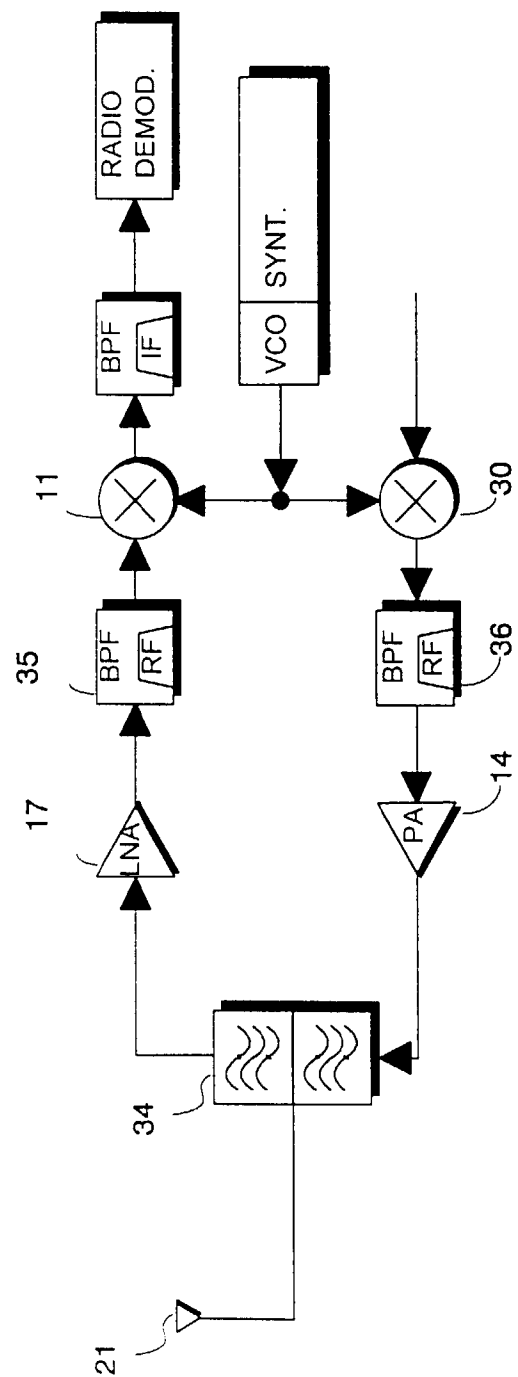


Fig. 4

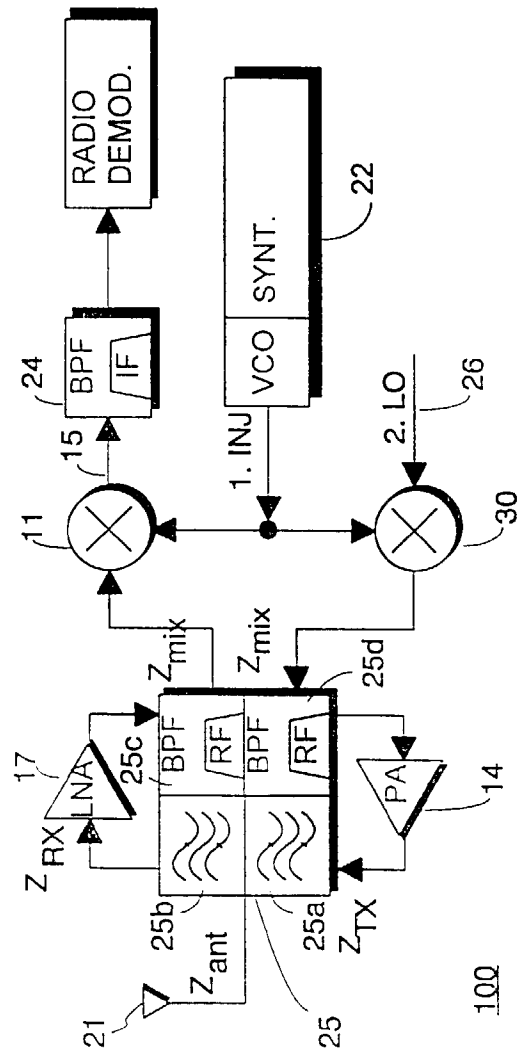


Fig. 5

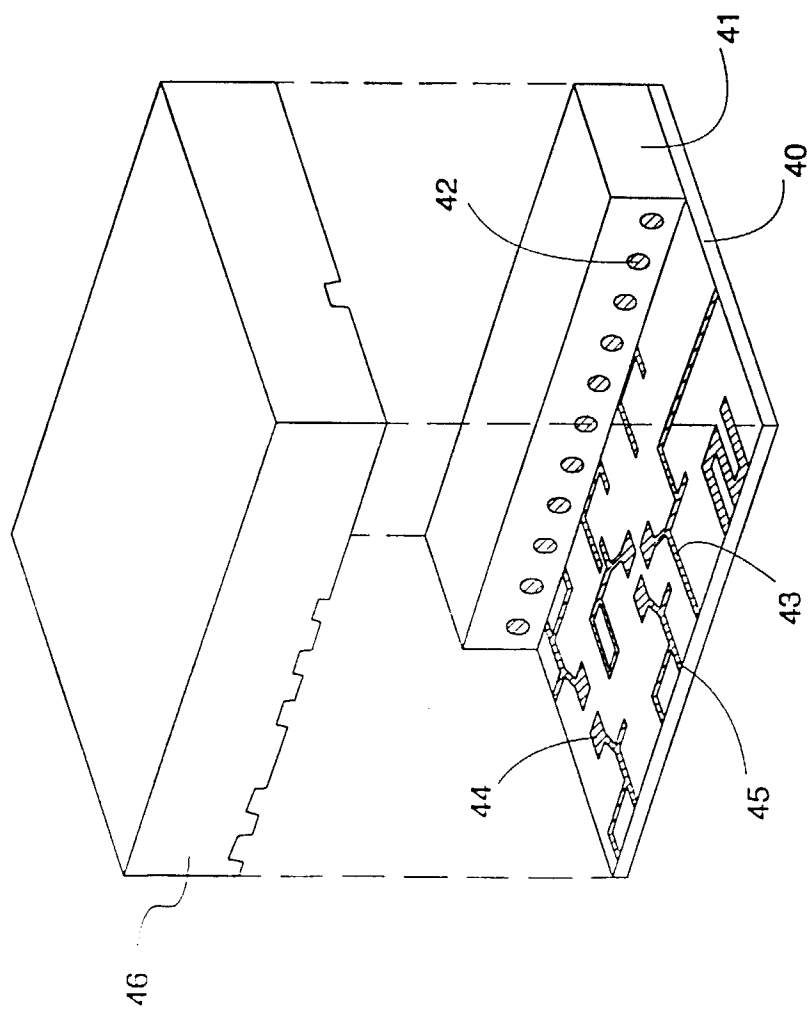


Fig. 6