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(54) **Switchable RF-path and frequency splitter for wide range multiband applications**

(57) A switchable FR-path (P1, P2, P3) and a frequency splitter comprising n RF-paths (P1, P2, P3), for use in a multiband and/or multistandard module comprising an RF-input port and an RF-output port, and at least one RF-block (Sb1, Sb2, Sb3), each RF-block (Sb1, Sb2, Sb3) consisting of a quarter-wave line section (QW1, QW2, QW3) shunt connected at its output side to a switching element (S1, S2, S3) which is connected to ground on an output side, whereby each quarter-wave line section (QW1, QW2, QW3) is directly connected in series with the corresponding switching element (S1, S2, S3), wherein for each RF-block (Sb1, Sb2, Sb3) a predetermined frequency band is selected and the length of said quarter-wave line section is matched to said selected frequency band. The inventive frequency splitter enables switching more than two frequency bands and/or a frequency band to more than two ports and also for switching frequencies which are located within a wide frequency range.

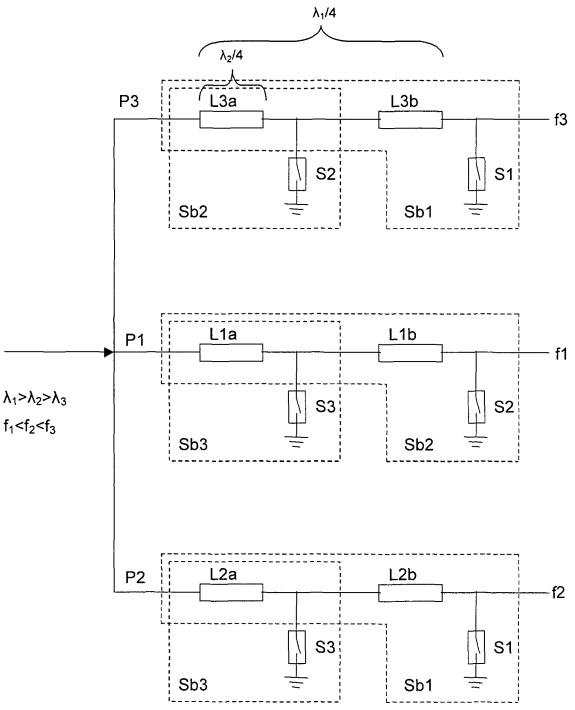


Fig. 5

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Description

[0001] A switchable RF-path with RF-blocks each comprising a quarter-wave line section shunt connected at its output side to the input of a switching element, which is itself ground connected at its output side is known from US2007 0155345 A1. US2007 0155345 A1 also discloses a frequency splitter with RF-paths as described above.

Background of the invention

[0002] Switching RF signals become more and more challenging, if power and frequency increases. Three main limiting factors are the power handling capability, the linearity and parasitic effects caused by the package of the switching element or the switching component itself.

[0003] Switching RF signals is conventionally realized with series switching elements. By switching ON or OFF said switch, the signal path is physically disconnected. In ON state, the entire power passes the switching element. Those switches have to withstand the whole passing power. Since available switches as MEMS or PIN diodes are able to handle RF power up to e.g. 10 Watts, usability is limited to low or medium power applications only. Further problems of series switching elements are unwanted parasitic effects and non-linearities caused by the switching elements used in series configuration.

[0004] The RF-block known from US2007 0155345 A1 uses a switching element as a shunt element instead of a series element. Such RF-blocks are used in RF circuits where lines have to be switched on or off without affecting linearity e.g. for switching different paths frequency related. It provides a possibility of line on- and off-switching without the need to use switching elements in series configuration, which improves the power handling capability, and reduces the impact of unwanted parasitic and nonlinearity effects.

[0005] In US 2007 0155345 A1 the switching element is connected to ground and in series with a capacitor which acts as necessary DC-block for biasing of the PIN diodes which are used as switching element. However with the usage of other switching elements, which are already including a suitable biasing possibility, the performance of the known RF-Block can be diminished by the capacitor.

[0006] The switching principle known from US2007 0155345 A1 enables switching an input signal adaptively and frequency dependent to two narrowband ports in an inexpensive and efficient manner. For the known switching principle switchable/blockable frequencies and thus number of ports are limited. For switching more than two frequencies over a wider frequency range, enhanced switching principles are required.

Object of the invention

[0007] It is an object of the invention to suggest a switchable RF-path with a simplified structure which can be used more efficiently for a multitude of switching elements.

[0008] It is a further object of the invention to suggest a frequency splitter which enables switching more than two frequency bands and/or which enables switching a frequency band to more than two ports and also for switching frequencies which are located within a wide frequency range.

Short description of the invention

[0009] These objects are achieved by a switchable RF-path according to claim 1, a frequency splitter according to claim 3 and a switching module according to claim 6.

[0010] The inventive switchable RF-path can be used in a multiband and/or multistandard module. It comprises an RF input port and an RF output port, wherein the RF input port and the RF output port limit the RF-path, and at least one RF-block, each RF-block consisting of a quarter-wave line section shunt connected at its output side to a a switching element which is connected to ground on an output side, whereby each quarter-wave line section is directly connected in series with the corresponding switching element, and wherein for each RF-block a predetermined frequency band is selected and the length of said quarter-wave line section is matched to said selected frequency band in order to block incoming signals in said selected frequency band if the switching element of the corresponding RF-block is switched on. Each RF-block, which follows at least one other RF-block within an RF-path, comprises a quarter-wave line section consisting of the quarter-wave line section of all preceding RF-blocks within said RF-path and a further line segment. The length of said further line segment is calculated with respect to frequency to be blocked taking into account the length of line segments of all preceding RF-blocks. Thus the frequencies to be blocked by RF-blocks within a switchable RF-path decrease with the distance of the particular RF-block from the input port.

[0011] The inventive switchable RF-path comprises at least one conventional switching element which is used as shunt element and at least one quarter-wave line section in order to transform the shunt open/short into a series short/open for an intended frequency. The biasing point of the switching elements of the inventive switchable RF-path has to

be adjustable. The switching element is provided with a suitable configuration for bias-adjustment. Thus in contrast to the known switchable RF-block no capacitor is needed. The switching element is connected directly to the quarter-wave line section. A multitude of switchable RF-blocks can be used for the inventive switchable RF-path while the impact of the above described limiting factors is reduced by using switching elements as shunt instead of series elements. The quarter-wave line section is used to transform the shunt short or open into the aimed series open or short. Therewith the demand for higher power handling capability can be met by the inventive switching principle. Further effective parasitic effects, insertion loss and effects on linearity can be reduced. The inventive switchable RF-path enables effective frequency selective switching and a choice of a wide range of switching elements.

[0012] In a preferred embodiment of the inventive switchable RF-path the RF-blocks are arranged symmetrically between input port and output port for bidirectional use. Possibly existing preceding quarter-wave line sections need to be taken into account for the quarter-wave line section of each RF-block.

[0013] The invention further relates to an RF frequency splitter for switching n frequency bands, comprising n inventive switchable RF-paths as described above.

[0014] In a preferred embodiment of the inventive RF frequency splitter each RF-path comprises n-1 RF blocks, whereby each of the n-1 RF-blocks within one of the RF-paths are matched to different frequencies, in order to block n-1 frequency bands and to let pass one frequency band in each RF-path. The frequency splitter allows switching any number of input frequencies to any number of output ports over a wide frequency range. Therefore a bandwidth enhancement and increase of number of switchable output ports can be achieved.

[0015] The number of frequency bands to be switched is preferably ≥ 2.

[0016] The invention further relates to a switching module comprising an inventive switchable RF-path.

[0017] It is preferred that the inventive switching module comprises an inventive RF frequency splitter arrangement as described above. The inventive switching module may further comprise for example amplifier stages or filter elements.

[0018] Such switching modules can be used with a transmitter for mobile communication which is preferably part of a base station.

[0019] The invention can be used with adaptive multiband/multistandard RF modules/systems in general, e.g. power amplifier modules, antenna modules, adaptive filter modules and adaptive circulator modules.

[0020] Further characteristics and advantages of the invention are provided in the following description of exemplary embodiments of the invention, with reference to the figures of the drawing, which shows details that are significant in the context of the invention and in the claims. The individual characteristics can be implemented individually by themselves, or several of them can be implemented in any desired combination in a variant of the invention.

Drawing

[0021] The invention is shown in the drawing.

Fig. 1 shows an unidirectional switchable RF-path according to the invention;

Fig. 2 shows a serial switch according to the state of the art;

Fig. 3 shows a bidirectional symmetrical switchable RF-path according to the invention;

Fig. 4 shows a frequency splitter according to the state of the art;

Fig. 5 shows a frequency splitter according to the invention; and

Fig. 6 shows a multiband filter module with frequency splitters according to the invention.

[0022] Conventional switches are mainly used as series elements as shown in **figure 2.** In ON state, the entire RF power passes the switch. Since the maximum rated power of e.g. available RF relays, RF MEMS (Micro-Electro-Mechanical-Systems) or PIN diodes is limited to around 10 Watts, switching higher power levels as e.g. in case of power amplifier is not possible.

[0023] The inventive switchable RF-path reduces the power limitation described above and additionally reduces the impact of the non-linearities and the adverse parasitic effects of the switching element. The improved RF switching principle is realized as follows.

[0024] The inventive switchable RF-path is shown in **figure 1.** At least one quarter-wave line section **QW3** is terminated with at least one conventional shunt switching element **S3** (e.g. RF relay, RF MEMS or PIN diode), whereby the quarter-wave line section QW3 is shunt connected at its output side to the input of a switching element S3, which is itself ground connected at its output side The quarter-wave line section QW3 transforms the shunt short/open into an open/short at

position← for a specific frequency. The switching element S3 in OFF state acts as open which is transformed into a short at position← for the same specific frequency. Thus the RF signal is passed to the output. The switching element S3 in ON state acts as short and is transformed into an open acting at the input of the circuit for the specific frequency. Due to the open, the input power is blocked and not passed to the output at position↑ for the specific, quarter wave line section related frequency.

[0025] Since the inventive principle is in ON state as long as the switching element S3 itself is switched OFF, the power passing the switching element S3 is determined by the off impedance of the switching element S3 and thus significantly reduced compared to serial switches shown in figure 2. Due to that, the power handling capability of the RF-block Sb3 itself increases and the principle enables switching higher power compared to maximum rated power of the switching element S3.

[0026] Due to the impedance transformation a series switching behavior as described in figure 2 is generated. Since the quarter-wave transformation is limited to only a dedicated frequency or a small frequency range also the switching principle is limited to those frequencies. To increase the frequency range additional optional line sections which are part of further RF-blocks Sb1, Sb2 with further quarter-wave line sections **QW1, QW2** and shunt switching elements **S1, S2** can be added (dotted lines in figure 1) to the inventive switchable RF-path. Possibly existing preceding quarter-wave sections need to be taken into account for the quarter-wave line sections of each RF-block, as indicated by the quarter-wave line sections QW1, QW2 in figure1.

[0027] An important difference compared to the conventional serial switch is, that the switchable RF-path shown in figure 1 works only unidirectional, that means, that the ON/OFF state of the circuit works only one-way, due to the required impedance transformation using quarter-wave transmission lines. If bidirectional working is required, the circuit has to be extended symmetrically as shown in **figure 3** by adding the corresponding quarter-wave line section(s) also to the second port. Related to the symmetry axis, the symmetrical line segments have to be of the same length, each (La = La, Lb = Lb in figure 3)

[0028] **Figure 4** shows a frequency splitter known from the state of the art which switches an input signal to an output port of a first RF-path **P1,** by blocking the input signal for every other RF-path **P2, P3** at a common input node **A.** Blocking is realized by RF-blocks **Sb', Sb'', Sb'''** each comprising a quarter-wave line section **QW', QW'', QW'''** and a switching element **S', S'', S'''.** Since said blocking is realized by quarter-wave transformation, the principle is frequency dependent. If an input signal at particular frequency f1 is switched for example to the output port of the first RF-path P1, the output ports of the other RF-paths P2, P3 have to block the input frequency f1 at input node A. In a second mode, the input signal at particular frequency f2 is switched for example to the output port of the second RF-path P2. In this case, the output ports of the first and third RF-path P1, P3 have to block the input frequency f2. In this case, the output port of the third RF-path P3 has to block frequency f2 and in the first exemplary case frequency f1. Since the blocking in each RF-path P1, P2, P3 is realized by a single quarter-wave line section QW', QW'', QW''', e.g. the third quarter-wave line section QW''' in the third RF-path P3, said frequency splitter is frequency dependent and works only satisfactorily if frequency f1 and frequency f2 are close together or in case of only two output ports.

[0029] To increase the bandwidth capability and the number of output ports, the present invention extends the switching principle explained above, as it is exemplarily shown for three ports of the wideband frequency splitter in **figure 5.** In this case, every of the three RF-paths P1, P2, P3 is provided with two different RF-blocks **Sb1, Sb2, Sb3,** blocking different frequencies **f1, f2, f3** with f1 < f2< f3 . Due to that, every RF-path P1, P2, P3 can block the two different frequency bands of the respective two other output ports. Due to that, e.g. an input signal of frequency f1 can be switched to the output port of the first RF-path P1 by switching on both switching blocks Sb1 in the second RF-path P2 and in the third RF-path P3, while all other switching blocks Sb2, Sb3 are switched off.

[0030] Using this principle, in general n frequency bands can be switched to n ports using n-1 RF-blocks at each of n RF-paths (P1, P2, P3).

[0031] An additional necessary benefit of the inventive configuration as shown in figure 5 is the reduced circuit effort. This is achieved by reusing a line segment **L1a, L2a, L3a** required for quarter-wave transformation for any following RF-block of the same RF-path. E.g. Length of line segment L3a is calculated with respect to frequency f2 respective wavelength λ2. Instead of adding an additional quarter-wavelength line for blocking frequency f1 only the difference in wavelength between ¼ of the larger wavelength λ1 and ¼ of the smaller wavelength λ2 is added with line segment **L3b.** Likewise the length of line segments **L1b, L2b** is chosen.

[0032] The inventive frequency splitter is cheap, flexible and easy to integrate and allows frequency switching, which supports improved frequency band selection and thus e.g. improved matching of single band transistors, realization of multiband filter bank and of multiband circulator bank.

[0033] E.g. multiband/multistandard power amplifier modules for a very wide frequency range (e.g. 800 MHz - 2.7 GHz) and for more than two frequency bands can be realized, among other things by common use of pre- and driver amplifier stages as well as improved matching of final transistors, resulting in improved efficiency and gain characteristic.

[0034] An inventive multiband filter module for example comprises an inventive frequency splitter FS1 which is adapted to receive signals at different specific frequencies or within frequency bands (related to the frequencies which are

addressed by the switch) and transfer said received signals to one of at least two RF-paths and at least one of the RF-paths being connected to a filter. **Figure 6** shows an inventive multiband filter module with two inventive frequency splitters FS1, FS2 , three RF-paths P1, P2, P3, whereby each of the RF-paths P1, P2, P3 is connected to a filter **Fi1, Fi2,** Fi3. The RF-paths P1, P2, P3 merge in the second frequency splitter FS2, which directs the signal to the single output port of the filter module.

Reference signs

[0035]

L1a, L2a, L3a, L1b, L2b, L3b	line segment
P1, P2, P3	RF-path
QW', QW'', QW''', QW1, QW2, QW3	quarter-wave line section
Sb' Sb'', Sb''', Sb1, Sb2, Sb3	RF-block
S', S'', S''', S1, S2, S3,	switching element
Fi1, Fi2, Fi3	filter
FS1, FS2	frequency splitter

Claims

1. A switchable RF-path (P1, P2, P3), for use in a multiband and/or multistandard module comprising
an RF input port and an RF output port, wherein the RF input port and the RF output port limit a RF-path, and
at least one RF block (Sb1, Sb2, Sb3), each RF-block (Sb1, Sb2, Sb3) consisting of a quarter-wave line section (QW1, QW2, QW3) shunt connected at its output side to a switching element (S1, S2, S3) which is connected to ground on an output side, whereby each quarter-wave line section (QW1, QW2, QW3) is directly connected in series with the corresponding switching element (S1, S2, S3),
wherein for each RF-block (Sb1, Sb2, Sb3) a predetermined frequency band is selected and the length of said quarter-wave line section is matched to said selected frequency band in order to block incoming signals in said selected frequency band if the switching element (S1, S2, S3) of the corresponding RF-block (Sb1, Sb2, Sb3) is switched on.

2. A switchable RF-path (P1, P2, P3) according to claim 1, **characterized in that** for bidirectional use the RF-blocks are arranged symmetrically between input port and output port.

3. An RF frequency splitter for switching n frequency bands, comprising n switchable RF-paths according to claim 1.

4. An RF frequency splitter according to claim 3, **characterized in that** each RF-path (P1, P2, P3) comprises n-1 RF blocks (Sb_i), whereby each of the n-1 RF-blocks within one of the RF-paths (P1, P2, P3) are matched to different frequencies, in order to block n-1 frequency bands (f_i) and to let pass one frequency band (f_j) in RF-path (P1, P2, P3), with i,j=1...n and $i \neq j$.

5. RF frequency splitter according to claim 3, **characterized in that** $n \geq 2$.

6. A switching module comprising a switchable RF-path (P1, P2, P3) according to claim 1.

7. A switching module according to claim 6 comprising at least one RF frequency splitter according to claim 2.

8. A transmitter for mobile communication comprising a switching module according to claims 6

9. A base station comprising a transmitter according to claim 8.

Amended claims in accordance with Rule 137(2) EPC.

1. A switchable RF-path (P1, P2, P3), for use in a multiband and/or multistandard module comprising
an RF input port and an RF output port, wherein the RF input port and the RF output port limit a RF-path, and
at least one RF block (Sb1, Sb2, Sb3), each RF-block (Sb1, Sb2, Sb3) consisting of a quarter-wave line section (QW1, QW2, QW3) shunt connected at its output side to a switching element (S1, S2, S3) which is connected to ground on an output side, whereby each quarter-wave line section (QW1, QW2, QW3) is directly connected in series with the corresponding switching element (S1, S2, S3),
wherein for each RF-block (Sb1, Sb2, Sb3) a predetermined frequency band is selected and the length of said quarter-wave line section is matched to said selected frequency band in order to block incoming signals in said selected frequency band if the switching element (S1, S2, S3) of the corresponding RF-block (Sb1, Sb2, Sb3) is switched one,
wherein for bidirectionla use the RF-blocks are arranged symmetrically between input port and output port.

2. An RF frequency splitter for switching n frequency bands, comprising n switchable RF-paths according to claim 1.

3. An RF frequency splitter according to claim 2, **characterized in that** each RF-path (P1, P2, P3) comprises **n-1** RF blocks (Sb_i), whereby each of the n-1 RF-blocks within one of the RF-paths (P1, P2, P3) are matched to different frequencies, in order to block **n-1** frequency bands (f_i) and to let pass one frequency band (f_j) in RF-path (P1, P2, P3), with i,j=1...n and i≠j.

4. RF frequency splitter according to claim 2, **characterized in that** n≥2.

5. A switching module comprising a switchable RF-path (P1, P2, P3) according to claim 1.

6. A switching module according to claim 6 comprising at least one RF frequency splitter according to claim 1.

7. A transmitter for mobile communication comprising a switching module according to claims 5.

8. A base station comprising a transmitter according to claim 7.

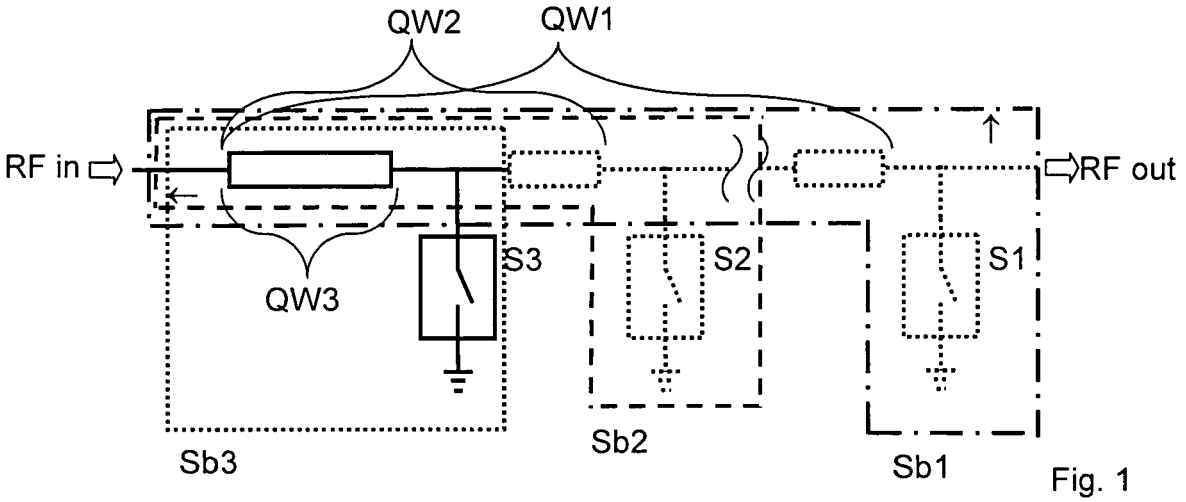


Fig. 1

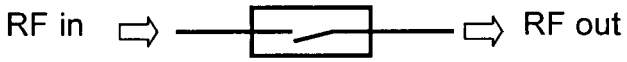


Fig. 2

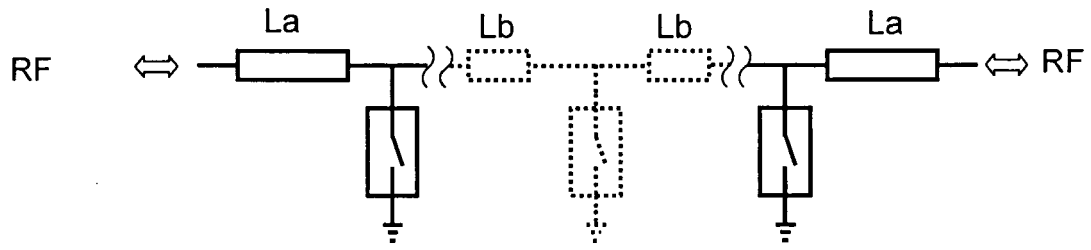


Fig. 3

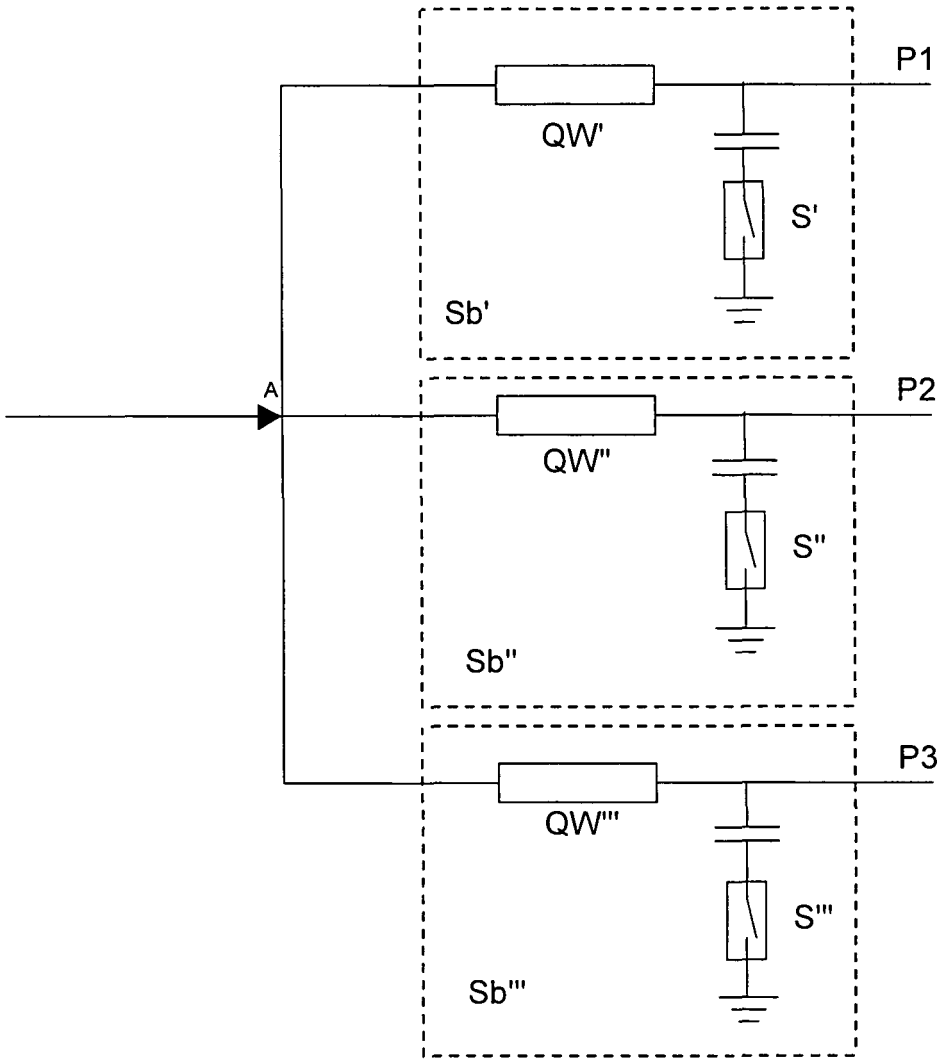


Fig. 4

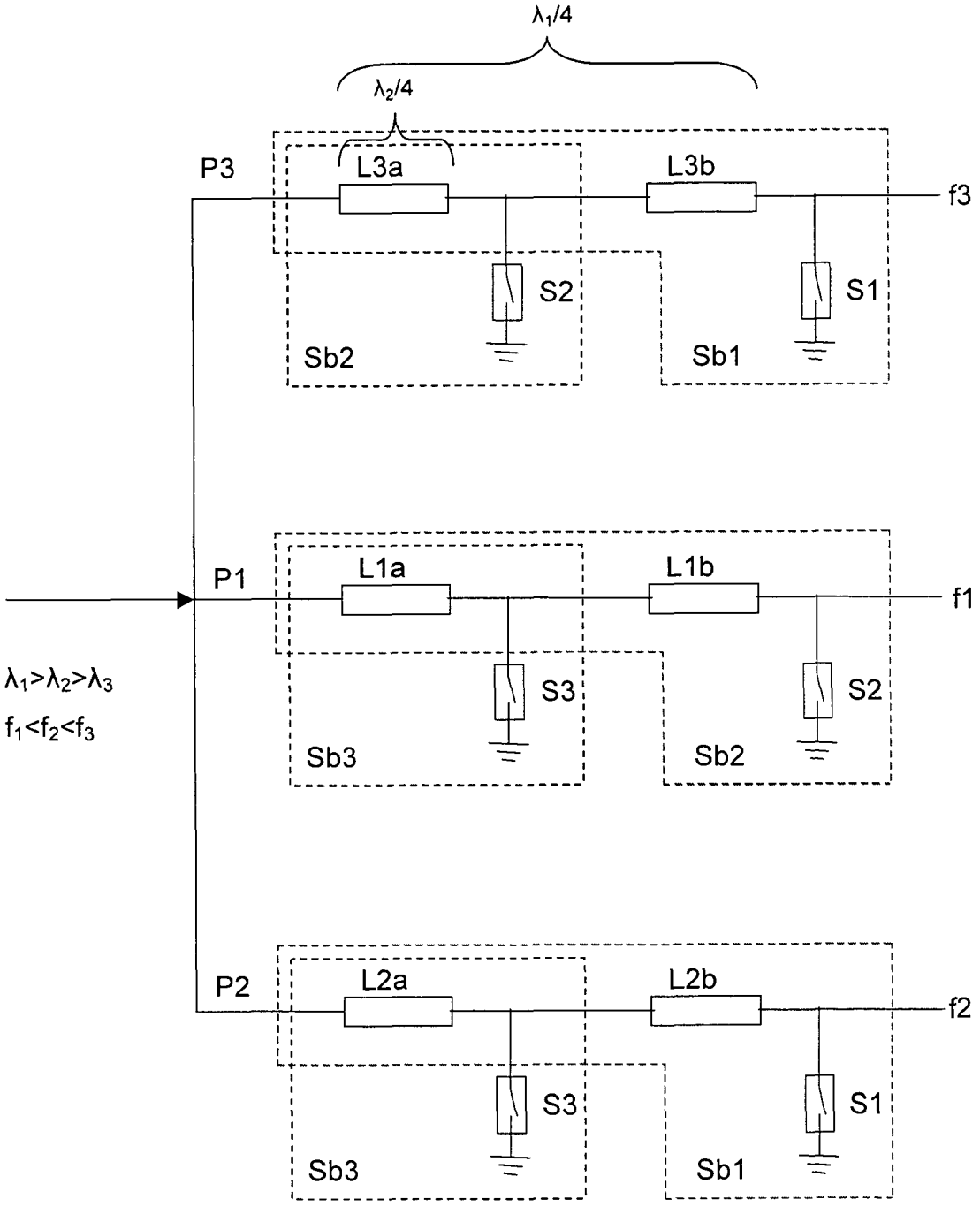

λ1/4
λ2/4
P3
L3a
L3b
f3
S2
S1
Sb2
Sb1
P1
L1a
L1b
f1
λ1>λ2>λ3
f1<f2<f3
S3
S2
Sb3
Sb2
P2
L2a
L2b
f2
S3
S1
Sb3
Sb1

Fig. 5

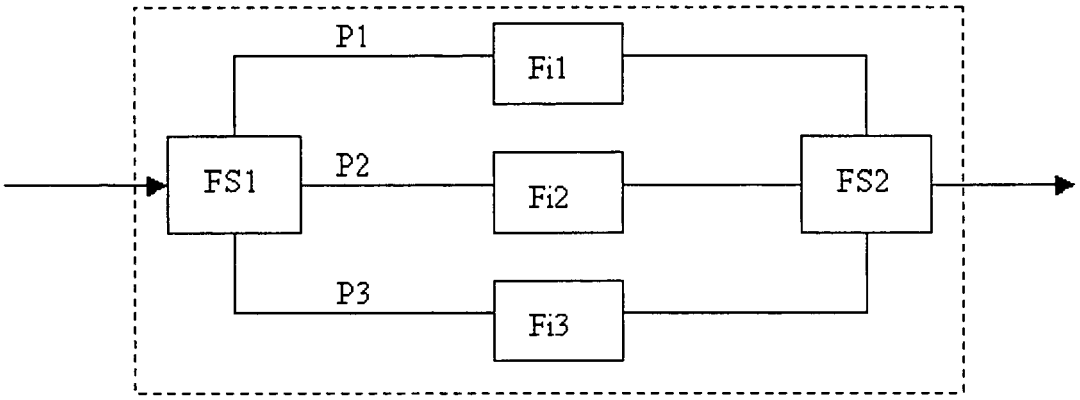


Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 07 29 1104

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	21 February 2008	PASTOR JIMENEZ, J

CATEGORY OF CITED DOCUMENTS

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