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(54) **SWITCHABLE BAND-PASS FILTER**

(75) Inventors: **Michael Schick**, Weissach im Tal (DE); **Norbert Kaste**, Backnang (DE)

(73) Assignee: **ROHDE & SCHWARZ GMBH & CO. KG**, Munich (DE)

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H01P 3/08	(2006.01)
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USPC 333/204, 205, 219, 235, 238, 246
See application file for complete search history.

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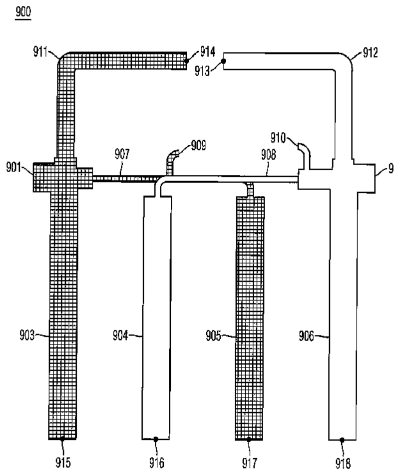
Primary Examiner — Stephen E Jones
Assistant Examiner — Rakesh Patel
(74) *Attorney, Agent, or Firm* — Ditthavong & Steiner, P.C.

(57) **ABSTRACT**

The invention relates to a switchable band-pass filter. In particular, the invention relates to a narrowband switchable band-pass filter over a broad frequency band with two filter elements (including microstripline technology, suitable for use as a cosite filter with a compact structure, which is particularly suitable for efficient mass production and robust in operation. The two filter elements in this context are coupled to one another, on the one hand via a switchable coupling device and, on the other hand, via a direct electromagnetic interaction.

9 Claims, 8 Drawing Sheets



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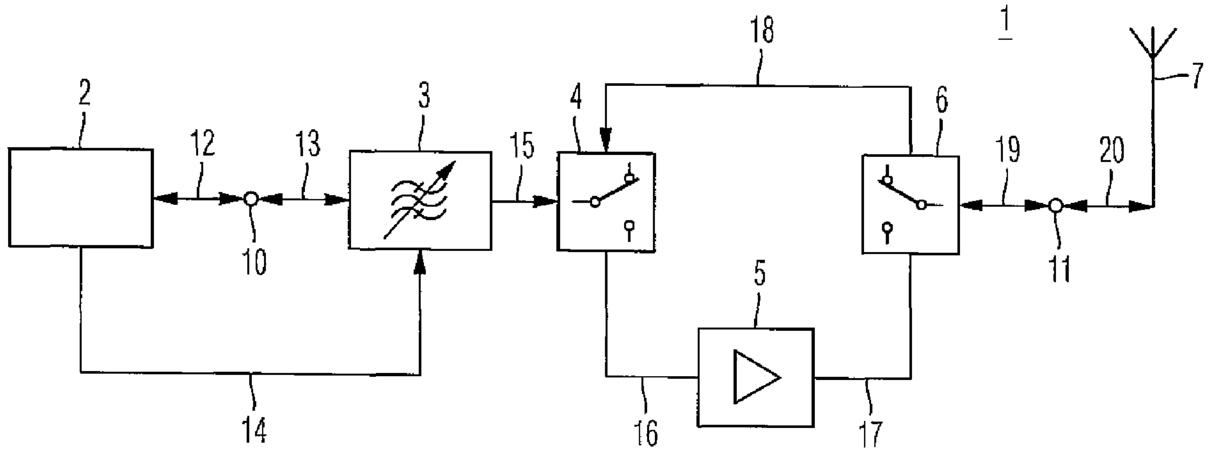
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Fig. 1

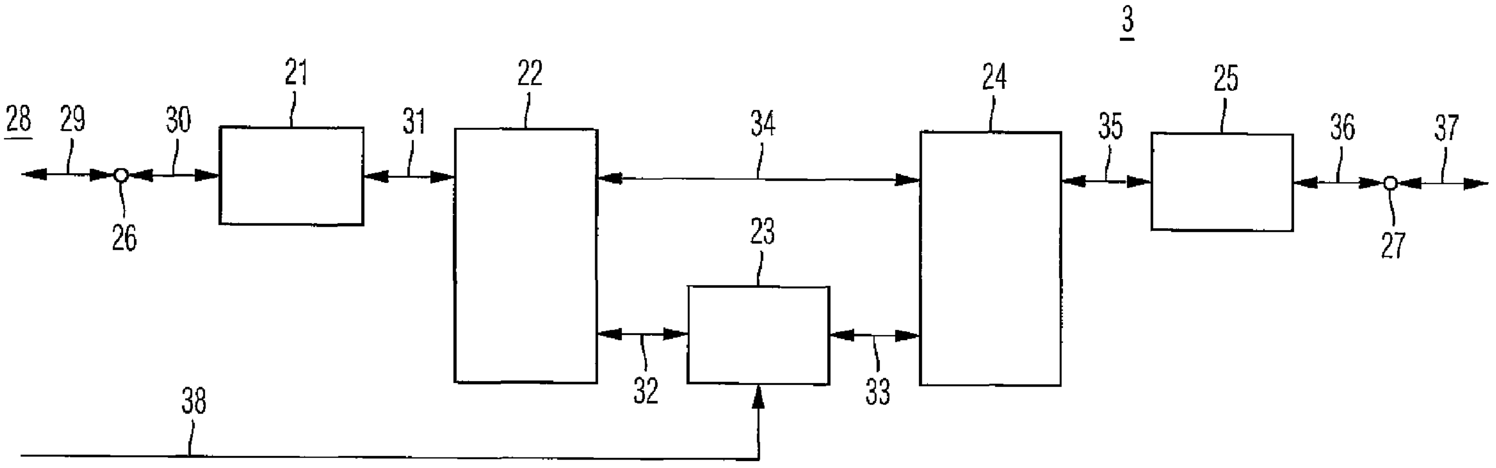
3
21
22
23
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Fig. 2

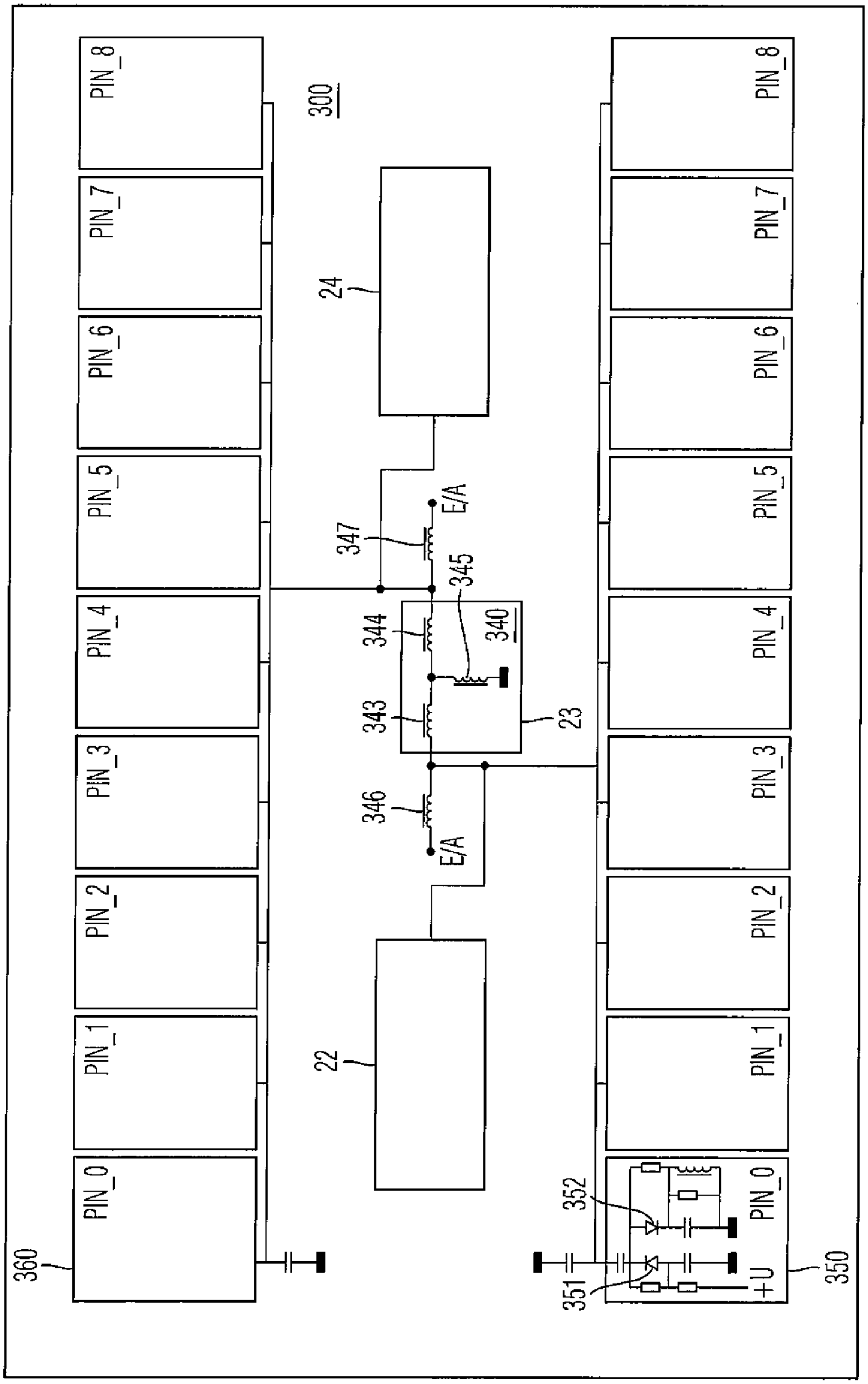
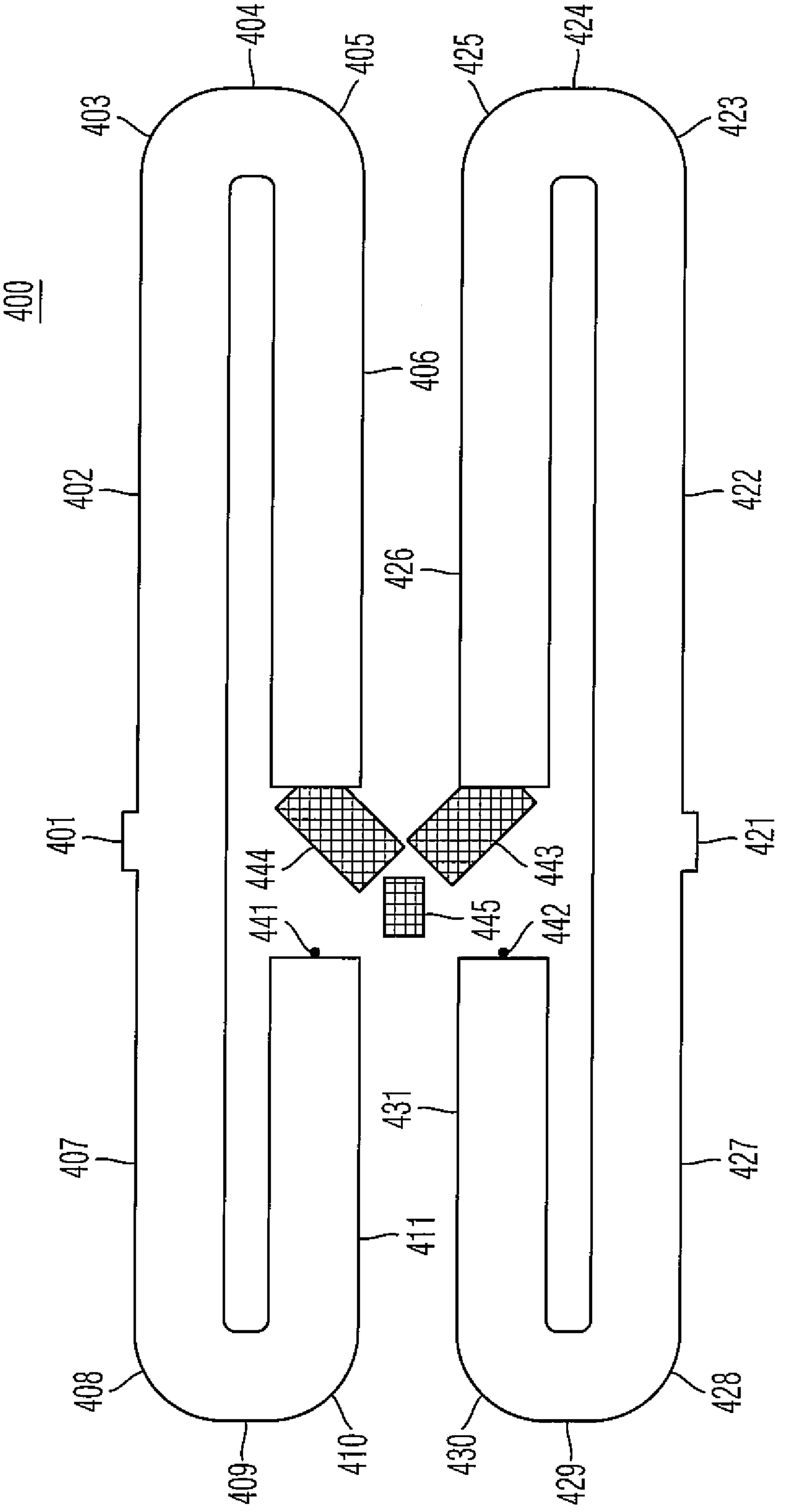

300
PIN_0
PIN_1
PIN_2
PIN_3
PIN_4
PIN_5
PIN_6
PIN_7
PIN_8
360
24
22
347
E/A
345
344
340
343
23
346
E/A
PIN_0
PIN_1
PIN_2
PIN_3
PIN_4
PIN_5
PIN_6
PIN_7
PIN_8
352
351
+U
350

Fig. 3


400
401
402
403
404
405
406
407
408
409
410
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421
422
423
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427
428
429
430
431
441
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443
444
445

Fig. 4

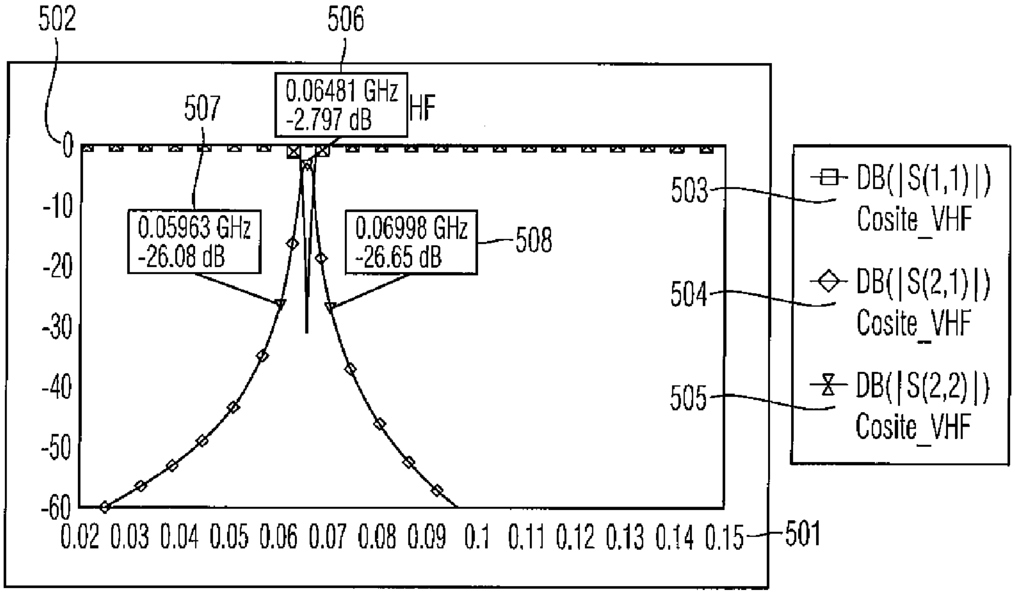

502
506
0.06481 GHz
-2.797 dB
HF
507
0
-10
-20
-30
-40
-50
-60
0.05963 GHz
-26.08 dB
0.06998 GHz
-26.65 dB
508
503
504
505
DB(|S(1,1)|)
Cosite_VHF
DB(|S(2,1)|)
Cosite_VHF
DB(|S(2,2)|)
Cosite_VHF
0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.15
501

Fig. 5

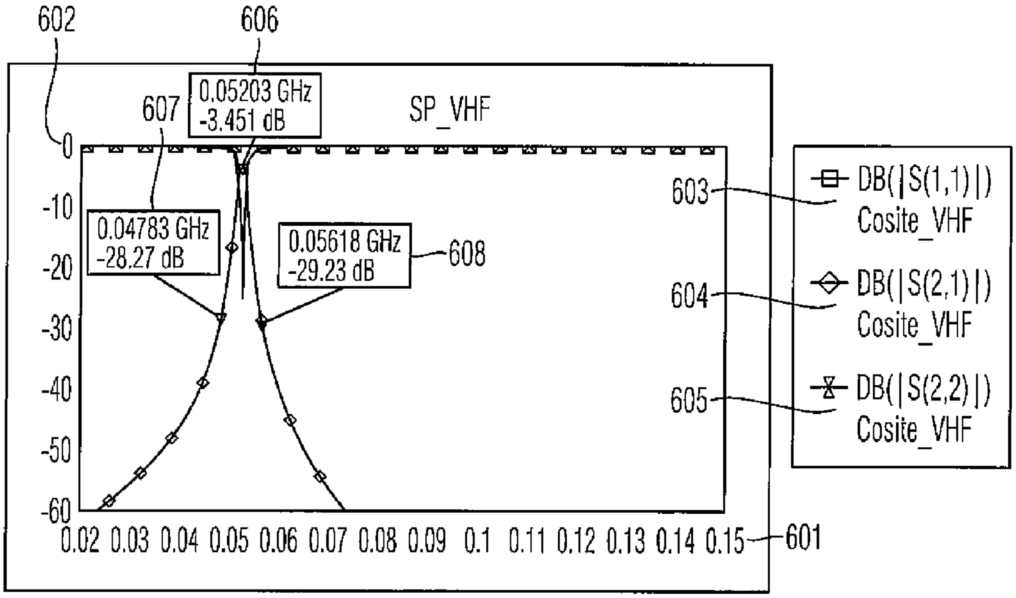

602
606
0.05203 GHz
-3.451 dB
607
SP_VHF
0
-10
-20
-30
-40
-50
-60
0.04783 GHz
-28.27 dB
0.05618 GHz
-29.23 dB
608
603
604
605
DB(|S(1,1)|)
Cosite_VHF
DB(|S(2,1)|)
Cosite_VHF
DB(|S(2,2)|)
Cosite_VHF
0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.15
601

Fig. 6

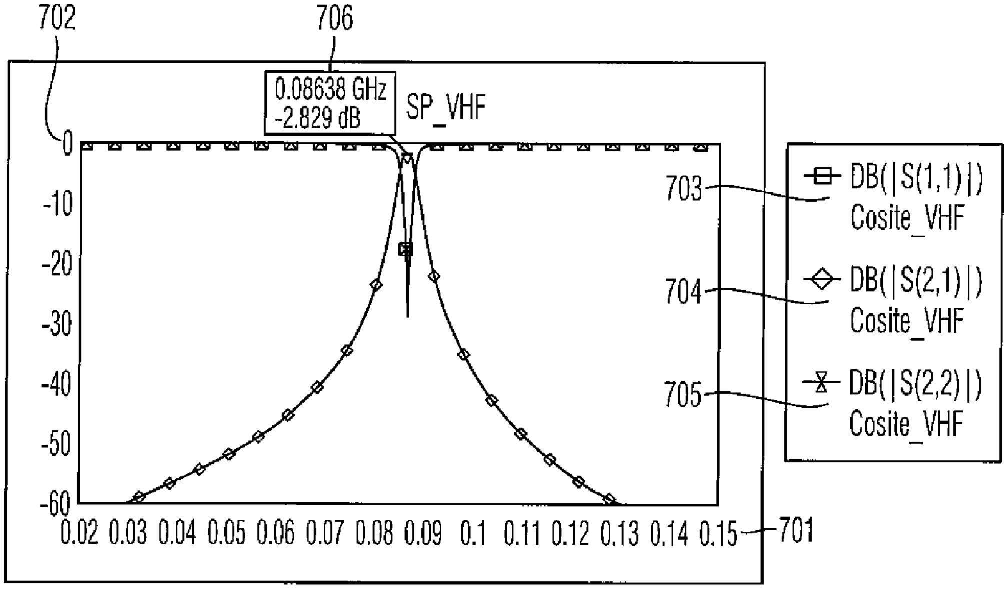

702
706
0.08638 GHz
-2.829 dB
SP_VHF
0
-10
-20
-30
-40
-50
-60
0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1 0.11 0.12 0.13 0.14 0.15
701
703
704
705
DB(|S(1,1)|)
Cosite_VHF
DB(|S(2,1)|)
Cosite_VHF
DB(|S(2,2)|)
Cosite_VHF

Fig. 7

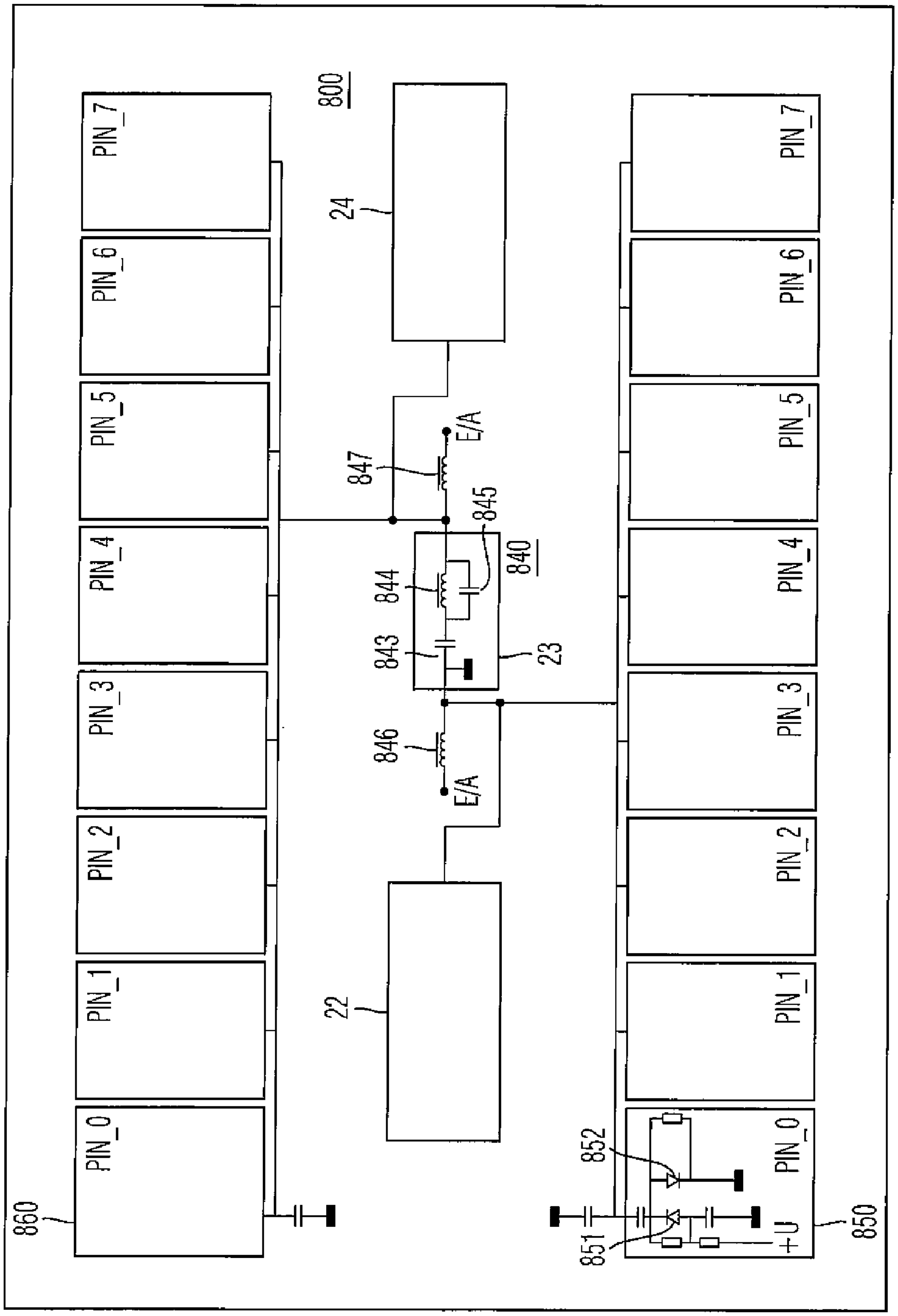
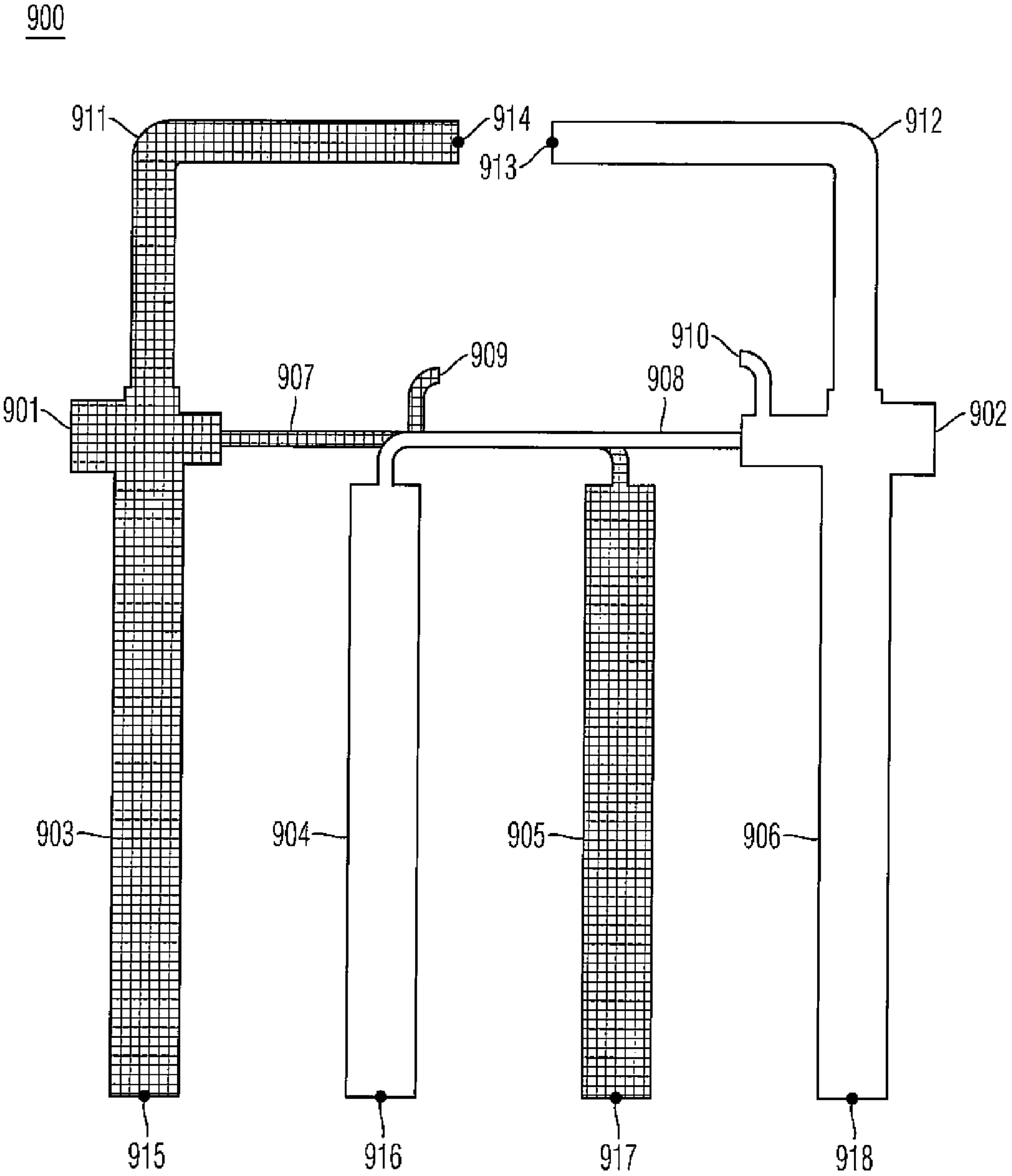

800
PIN_7
PIN_6
PIN_5
PIN_4
PIN_3
PIN_2
PIN_1
PIN_0
860
24
847
E/A
845
840
844
843
23
846
E/A
22
852
851
+U
850
PIN_7
PIN_6
PIN_5
PIN_4
PIN_3
PIN_2
PIN_1
PIN_0

Fig. 8


900
911
914
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908
901
902
903
904
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917
918

Fig. 9

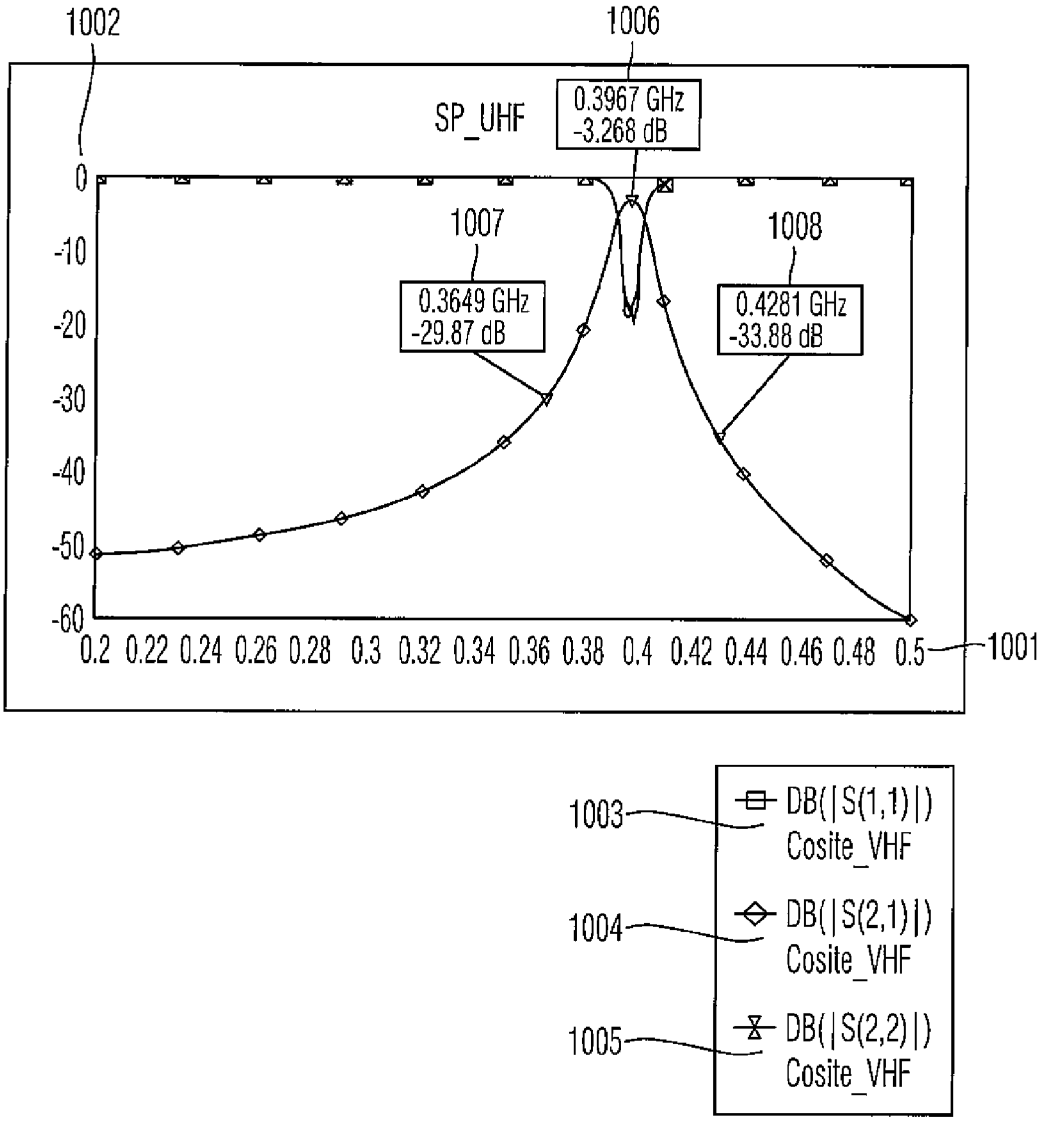
1002
1006
SP_UHF
0.3967 GHz
-3.268 dB
1007
0.3649 GHz
-29.87 dB
1008
0.4281 GHz
-33.88 dB
0
-10
-20
-30
-40
-50
-60
0.2
0.22
0.24
0.26
0.28
0.3
0.32
0.34
0.36
0.38
0.4
0.42
0.44
0.46
0.48
0.5
1001
1003
DB(|S(1,1)|)
Cosite_VHF
1004
DB(|S(2,1)|)
Cosite_VHF
1005
DB(|S(2,2)|)
Cosite_VHF

Fig. 10

SWITCHABLE BAND-PASS FILTER

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a national phase application of PCT Application No. PCT/EP2011/000201, filed on Jan. 19, 2011, and claims priority to German Patent Application No. DE 10 2010 008 483.2, filed on Feb. 18, 2010, the entire contents of which are herein incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a switchable band-pass filter. In particular, the invention relates to a narrowband band-pass filter switchable over a broad frequency band with two filter elements comprising microstripline technology, suitable for use as a so-called cosite filter with a compact structure which is particularly suitable for mass production and robust in operation.

Discussion of the Background

Frequency-hopping methods are used to an increasing extent in radio communications technology. Accordingly, the carrier frequency of the transmission link alternates in a rapid sequence known to the transmitter and receiver. For the transmitters and receivers used, the demand for narrowband filters which are adjustable in frequency over the relevant frequency ranges is derived from this. These filters must achieve a rapid adjustability of the mid-frequency and, if possible, a digital switching with a fine frequency resolution derived from the application.

Moreover, mobile communications devices provide transmission and reception component groups in close proximity. In addition to this, a plurality of communications devices is often active in the environment within the same frequency band at the same time. Accordingly, it is advantageous if the same filter can be used as a reception filter for selecting the desired reception signal and filtering out interference acting via the reception antenna, and also as a transmission filter for reducing undesirable radiation. Such a filter is referred to as a cosite filter and must be additionally capable of transmitting a corresponding transmission power with low insertion loss and, on the one hand, filtering signals in the forward direction from amplifier to antenna and, on the other hand, in the return direction from antenna to receiver.

The prior art is the realization of such filters as double-circuit resonator filters comprising two high-quality resonators coupled via a network of capacitors and/or inductances. The frequency tuning is implemented via connectable capacitors by means of semiconductor diodes. In this context, the resonators are generally high-quality coil resonators (especially air coils). The frequency adjustment is implemented by means of PIN diodes of connectable capacitors. The combination of the high-quality coil resonators and the use of PIN diodes allows the transmission of correspondingly high transmission powers.

However, the structure described provides a series of disadvantages. The use of two coil resonators leads to large mechanical dimensions, heavy mass, corresponding disadvantages in the robustness of the filter with regard to vibration stress, and large dimensions of the filter component group as a whole. A filter component group realized on this technical basis leads to correspondingly unfavourable requirements for integration in mobile devices. Moreover, a band-pass filter with two coil resonators is associated with further disadvantages during manufacture, calibration and operation. On the one hand, a corresponding filter structure for automated manufacture in production lines designed for surface-mounted components (English: surface mounted devices, abbreviation: SMD) and re-flow soldering methods (English: reflow soldering) is not possible in a fully automated manner, but also requires manual manufacturing steps. Additionally, both coil resonators must be matched exactly with one another in a difficult calibration step, in order to achieve a corresponding, constantly flat filter transmission function within the passband. A tuneable band-pass filter realized in this manner is cost intensive to manufacture and structured in a complex manner.

SUMMARY OF THE INVENTION

The invention advantageously a narrowband band-pass filter switchable over a broad frequency band for the UHF/VHF range, which avoids the named disadvantages of the prior art.

The switchable band-pass filter includes a first filter element and a second filter element which are connected to one another via a switchable coupling device. The band-pass filter is characterised in that the first and the second filter element comprise conductor structures formed in each case in a flat plane, and the first and the second filter element each comprise at least two line portions. In addition to the coupling via the switchable coupling device for the realization of the switchable band-pass filter, the first and the second filter element are disposed in electromagnetic interaction with one another.

This direct interaction of the first and second filter element ensures a small structural size of the overall band-pass filter and is achieved through the absence of further conductor elements, possibly connected to earth, between the first and the second filter element. The first and the second filter element are therefore structured directly adjacent to one another although at a distance. The realization of the first and the second filter element in the form of double-circuit resonator filters comprising microstripline technology allows the band-pass filter to be structured using multi-layer printed-circuit board technology and is therefore efficient and can be manufactured at low cost. In this context, the microstriplines are shorted at one end. The small overall mass of the band-pass filter and the distribution of the masses in the band-pass filter according to the invention are particularly suited for use in mobile communications devices. Similarly, the structure comprising microstripline technology allows a low-temperature coefficient without special temperature compensation or adjustment of the filter during operation over a wide temperature range from −30° C. to +80° C.

In particular, it is advantageous if the coupling device is realized as a network formed from capacitors and/or inductances and semiconductor diodes. In particular, PIN diodes are suitable for semiconductor diodes to be used as switch elements for the transmission of relatively high powers, however, varactor diodes can also be used with relatively low powers.

A space-saving realization of the band-pass filter on multi-layer printed-circuit boards is particularly preferred, wherein the first and the second filter element can be applied using microstripline technology to one or more layers of the printed-circuit board, and the coupling device is realized on one or more layers. The band-pass filter can also be structured in an appropriate manner so that the input connection of the band-pass filter is formed on an appropriately shaped portion of the first filter element, and the output connection is formed on an appropriately shaped portion of the second filter element. Moreover, in a preferred embodiment of the band-pass filter according to the invention, the coupling network can be formed in such a manner that the capacitors connectable to the first and second filter element are identical in size. This means that the filter can advantageously be operated with identical properties in the forward direction (transmission filter) and in the return direction (reception filter). This presupposes that the first and second filter elements are structured in a symmetrical manner relative to one another. The identity of the resonators can be guaranteed through the use of stripline technology.

The band-pass filter therefore provides a mutually symmetrical behaviour at the input and the output.

If the band-pass filter is realized in the form of line portions, it is favourable to guide the line portions of the first and the second filter element in such a manner relative to one another that, on the one hand, line portions are disposed parallel to one another in order to achieve a direct coupling between the first and the second filter element in parallel portions, and, furthermore, to keep the space requirement for the filter elements and the band-pass filter as a whole as small as possible.

In a further, particularly appropriate embodiment of the band-pass filter, the first and the second filter elements comprise mutually parallel line portions, which are arranged in alternation and connected to one another at one end in a conductive manner. It is particularly advantageous if the first and the second filter element are each connected to at least one further line portion, which is formed for the tuning of the respective filter element. Accordingly, an exact calibration of the first and second filter element with reference to their filter mid-frequency is therefore possible in a simple manner, if required. Optimum flatness of the filter transmission function within the passband can be achieved in this manner. A structure of the parallel line portions of the first filter element, on the one hand, and of the second filter element, on the other hand, on different layers of the printed-circuit board is particularly favourable in order to achieve a small space requirement of the band-pass filter and the direct electromagnetic interaction between the first filter element and the second filter element.

BRIEF DESCRIPTION OF THE DRAWINGS

The band-pass filter according to the invention is explained in greater detail below with reference to the drawings. The drawings are as follows:

FIG. **1** shows a block-circuit diagram of the high-frequency part of a communications system with frequency-hopping using a band-pass filter according to the invention;

FIG. **2** shows a simplified structure of a band-pass filter according to the present invention tuneable over a broad frequency range;

FIG. **3** shows a simple block-circuit diagram for a band-pass filter according to the invention for the VHF range;

FIG. **4** shows the structure and the arrangement according to the invention of the resonators for a band-pass filter for the VHF range;

FIG. **5** shows simulated S-parameters for a band-pass filter according to the invention for the VHF range for a deviation of the mid-frequency f_{ctr}=+/−8%, and PIN_**0**, PIN_**1**, PIN_**2**, PIN_**3**, PIN_**4** and PIN_**5** at "ON";

FIG. **6** shows simulated S-parameters for a band-pass filter according to the invention for the VHF range for a mid-frequency modified relative to FIG. **5** with a modified setting of the PIN diodes;

FIG. **7** shows simulated S-parameters for a band-pass filter according to the invention for the VHF range for a deviation from the mid-frequency f_{ctr}=+/−8%, and PIN_**0**, PIN_**1** at "ON";

FIG. **8** shows a simple block-circuit diagram of a switchable band-pass filter according to the invention for the UHF range;

FIG. **9** shows a structure and the arrangement according to the invention of the resonators for a band-pass filter according to the invention for the UHF range; and

FIG. **10** shows simulated S-parameters for a band-pass filter according to the invention for a deviation from the mid-frequency f_{ctr}=+/−8%, and PIN_**0**, PIN_**1**, PIN_**2** at "ON".

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE INVENTION

Before focusing on the structure of the switchable band-pass filter according to the invention, an appropriate application for the filter in a communications device **1** will first be described with reference to FIG. **1**. A transceiver **2** is connected via a switchable band-pass filter **3** to an antenna **7**. The mid-frequency for the signal **13**, **15** to be transmitted or to be received is specified to the switchable band-pass filter **3** via a digital signal **14**. The band-pass filter **3** is contained both in the transmission path **12**, **13**, **15**, **16**, **17**, **19**, **20** and also in the reception path **20**, **19**, **18**, **15**, **13**, **12** of the communications device. Within the transmission path, a power amplifier **5** is additionally connected into the transmission signal path via the switches **4**, **6** (realizable, for example, by circulators **4**, **6**). If the transceiver **2** is operated in frequency-hopping mode (English: frequency hopping), the mid-frequency of the band-pass filter, switched via the digital signal **14** from the transceiver **2**, for the transmission or reception frequency to be set, must follow sufficiently rapidly and with high precision. At the same time, the band-pass filter **3** must provide a good matching to the inputs and outputs for this application. In one embodiment of the filter **3**, values for the reflection factor at the input S_{11} and at the output S_{22} of less than −15 dB must be required for the matching. This corresponds to a standing wave ratio (VSWR: Voltage Standing Wave Ratio) less than 1.4. In the named embodiment, the band-pass filter **3** should provide the smallest possible insertion loss with good linearity of the filter transmission function over a broad power range, because both the transmission signal and also the reception signal are transmitted via the switchable band-pass filter **3**. For a characteristic exemplary embodiment, an insertion loss (insertion loss) of less than 4 dB should be aimed at. Moreover, an operation within the specified values for a wide temperature range from −30° C. to +80° C. is meaningful for mobile communications devices **2**. This requirement must therefore also be fulfilled by sub-component groups such as the switchable band-pass filter **3** according to the invention.

If the switchable band-pass filter **3** is operated as a so-called cosite filter for frequencies in the UHF band (Ultra High Frequency band), a frequency resolution of 8 bits is required in one embodiment for a switchable frequency bandwidth from 225 MHz to 400 MHz. If the switchable band-pass filter **3** is operated as a filter for frequencies in the VHF band (Very High Frequency band), a frequency resolution of 9 bits is required in one embodiment for a switchable frequency bandwidth from 30 MHz to 88 MHz.

FIG. **2** shows the structure of a preferred embodiment of the switchable band-pass filter **3** according to the present invention in a signal-flow diagram. The switchable band-pass filter **3** is structured in a symmetrical manner, that is to say, the band-pass filter **3** can be operated with a first connection **26** as the input and a second connection **27** as the output, or the band-pass filter can be operated with the second connection as the input and the first connection **26** as the output. The illustrated band-pass filter **3** shows broad-band matching networks **21**, **25** at the connections **26**, **27** for matching to the line surge impedance, typically 50 ohms, of the signal lines **28**, **37**. The band-pass filter **3** in this embodiment provides a first filter element **22** and a second filter element **24**. These filter elements **22**, **24** can be realized in the form of double-circuit resonator filters. The filter elements **22**, **24** are coupled to one another, on the one hand, via a coupling device **23**. On the other hand, the two filter elements **22**, **24** are additionally disposed in direct electromagnetic interaction **34** with one another. The adjustment of the filter mid-frequency is implemented via a digital switching signal **38**. The direct coupling **34** of the first filter element **22** and the second filter element **24** in addition to the coupling **32**, **33** via a coupling element **23** leads to a reduced structural size of the switchable band-pass filter **3** according to the invention, because a space-consuming and at the same time cost-intensive shielding between the first filter element **22** and the second filter element **24** can be dispensed with as a result of the targeted coupling.

FIG. **3** and FIG. **4** illustrate an exemplary embodiment of the switchable band-pass filter **3** for frequencies in the VHF range from 30 MHz to 88 MHz and a frequency resolution of approximately 116 kHz with 9 bits. The first filter element **22** and the second filter element **24** are realized as TEM resonators (Transversal Electro-Magnetic wave) using microstripline technology. The first filter element **22** comprises four coupled microstripline portions **402**, **406**, **407**, **411**. In the same manner, the second filter element comprises four further coupled microstripline portions **422**, **426**, **427**, **431**. The first filter element **22** and the second filter element **24** are arranged symmetrically to one another and disposed in the same plane, that is to say, on the same surfaces of a printed-circuit board. In addition to the existing direct coupling, the coupling between the first filter element **22** and the second filter element **24** is fine tuned via a coupling device in the form of a T-element, with the inductances **443**, **444**, **445** as an inductive current coupling. The frequency tuning capacitor network of the coupling device **23** is connected by means of PIN diodes at the high point of each of the two resonators as the first and respectively the second filter element **22**, **24**.

FIG. **3** illustrates the structure of the frequency-determining capacitor network **300** determining the switchable mid-frequency of the band-pass filter **3** switched via PIN diodes. The capacitor network **300** is structured symmetrically for the first filter element **22** and the second filter element **24**. The inputs and outputs of the band-pass filter marked with E/A are connected via matching-elements **346** and respectively **347** to the coupling device **23**. The matching-elements **346**, **347** can comprise a coil or any alternative reactance circuits, as illustrated. Dependent upon the value of the digital switching signal **38**, the capacitor network is connected symmetrically and in part to the first filter element **22** and the second filter element **24**. Moreover, the coupling device provides a T-element **340** comprising inductances **343**, **344**, **345** for the precise adjustment of the coupling as an inductive current coupling of the first filter element **22** and the second filter element **24**. A switching network **350** for the connection of capacitors is specified for the PIN diodes **351**, **352**. If the digital signal **38** provides the value PIN_**0**="ON", an additional capacitor is connected via this switching network **350** to the first filter element **22** and, symmetrically to this, a capacitor is connected via the switching network **360** to the second filter element **24**. The mid-frequency of the switchable, narrowband band-pass filter **3** is varied by connecting capacitors through the switching networks **350**, **360**. Appropriate control circuits, which are, however, per se known and have therefore not been explained in greater detail here or illustrated in FIG. **3**, should be additionally provided in order to control the PIN diodes of the illustrated exemplary embodiment.

FIG. **4** shows the structure and the arrangement according to the invention of the resonators of the switchable VHF band-pass filter **3**. As the first filter element **22**, the first resonator comprises a first microstripline portion **402** and a second microstripline portion **407**, which are disposed in a line, and a first connection of the switchable band-pass filter **3** is disposed at their connection point **401**, at which the first and the second microstripline portion **402**, **407** merge into one another. A first and respectively a second quarter-circle arc **403**, followed by a short straight-line portion **404** and respectively **409**, are connected at the end of the microstripline portions **402**, **407** disposed opposite to the connecting point **401**. The distance between the parallel-running microstripline portions **402**/**406**, **407**/**411** is adjusted by means of the straight-line portions **404**, **409**. This is followed in each case by a third and respectively a fourth quarter-circle arc **405** and respectively **410**. The third and respectively fourth quarter-circle arc **405**, **410** are followed in each case by the third and fourth microstripline portion **406** and **411**, wherein the fourth microstripline portion **411** is connected to earth via a through contact **441** at its end facing away from the fourth quarter-circle arc **410**. The third microstripline portion **406** and the fourth microstripline portion **411** in the illustrated exemplary embodiment are disposed on a common straight line.

The second filter element **24** is structured in a symmetrical manner relative to the first filter element.

The second filter element comprises a fifth microstripline portion **422** and a sixth microstripline portion **427**, which are disposed one after the other in a line. A second connection of the switchable band-pass filter **3** is disposed at their connecting point **421**. A fifth and respectively a sixth quarter-circle arc **423** and **428**, followed by a short straight-line portion **424** and respectively **429**, are connected at the end disposed opposite to the connecting point **421**. As in the case of the first filter element **22**, the straight-line portions **424**, **429** specify the distance between the parallel microstripline portions **422**/**426** and **427**/**431**. These are followed in each case by a seventh and respectively an eighth quarter-circle arc **425** and respectively **430**. The seventh and respectively eighth quarter-circle arc **425**, **430** are followed by a seventh and eighth microstripline portion **426** and **431**, wherein the eighth microstripline portion **431** is connected to earth at its end facing away from the other quarter-circle arc via a through contact **442**. The seventh microstripline portion **426** and the eighth microstripline portion **431** in the illustrated exemplary embodiment are disposed on a common straight line. In this context, the two filter elements **22**, **24** are arranged in such a manner that the microstripline portions **406**, **411** on one side and **426**, **431** on the other side, disposed in each case on a straight line, are arranged parallel and adjacent to one another. Accordingly, a direct electromagnetic coupling between the first and the second filter element **22**, **24** is achieved via the microstriplines **406**, **411**, **426**, **431**. The microstripline portions **406** and **426** and respectively **411** and **431** are directly adjacent, that is to say, no elements, especially no screening, is disposed between the microstripline portions over their entire respective longitudinal extension. Moreover, the coupling between the first filter element **22** and the second filter element **24** is finely adjusted via a T-element with the inductances **443**, **444**, **445** as an inductive current coupling. This T-element is arranged between the third microstripline portion **406** of the first filter element **22** and the third microstripline portion **426** of the second filter element **24**.

The arrangement of the microstripline portions **406**, **411** on the one side and directly adjacent on the other side **426**, **431** to form a direct electromagnetic coupling allows a corresponding structure with optimised structural-space of the switchable band-pass filter **3** according to the invention. Any screening between the adjacent microstriplines of the filter elements **22**, **24** is explicitly dispensed with. Additionally, the structure of the switchable band-pass filter **3** for the VHF range in the illustrated exemplary embodiment achieves good mechanical stability as a result of the structure using microstripline technology by comparison with a realization of the resonators for the first and the second filter elements **22**, **24** in the form of air coils. The symmetry of the structure ensures a substantial simplification of the calibration of the two filter elements. On the printed-circuit board for the band-pass filter, the microstriplines for the resonator structure of the two filter elements **22**, **24** is applied on one side (B-side), and the coupling element **23** with the capacitor/PIN diode network is applied to the other side (L-side). As a substrate for the printed-circuit board, a multi-layered printed-circuit board (for example, manufactured by Rogers, 10-layer ϵ_r=3.66) can be used. The components of the capacitor/PIN diode network can be fitted automatically (SMD-technology, surface-mounted device) and soldered using re-flow soldering methods. Manufacture and calibration of the band-pass filter **3** according to the invention are designed to be particularly efficient and cost-favourable. The entire volume for this embodiment of the band-pass filter according to the invention for the VHF range, including housing can accordingly be limited to less than 13 cm×7 cm×3 cm. The illustrated switchable VHF band-pass filter **3** can therefore be simply integrated into existing device designs. This is achieved through the selected design of the filter elements **22**, **24** and the direct electromagnetic coupling of the filter elements **22**, **24** according to the invention.

FIG. **5** shows a simulation of the scattering parameters (abbreviated as S-parameters) of the switchable VHF band-pass filter **3** according to FIG. **3** and FIG. **4** for a digital switching signal **38** with the settings PIN_**0**, PIN_**1**, PIN_**2**, PIN_**3**, PIN_**4**, PIN_**5** at "ON". On the horizontal axis **501**, the frequency is plotted in GHz. On the vertical axis **502**, the values for the scattering parameters are plotted in dB. The curve **503** represents the input-end matching of the switchable band-pass filter **3** in the form of the value of the input reflection factor $|S_{11}|$. The curve **505** represents the output-end matching of the switchable band-pass filter **3** in the form of the value of the output reflection factor $|S_{22}|$. The switchable band-pass filter **3** is matched for a mid-frequency f_{ctr} of 0.0641 GHz with values for $|S_{11}|$ and $|S_{22}|$ less than −30 dB. The selectivity of the switchable band-pass filter **3** is shown for the illustrated mid-frequency f_{ctr} and for frequencies which deviate from f_{ctr} by 8%. For a frequency f_{ctr}=0.06481 GHz, the value for the filter transmission function **506** and accordingly the insertion loss $|S_{21}|$=−2.797 dB. The loss of the band-pass filter **3** for a frequency of 0.05963 GHz is −26.06 dB **507**, and for a frequency of 0.06996 GHz is −26.65 dB **508**.

FIG. **6** shows a simulation of the scattering parameters (abbreviated as S-parameters) of the switchable VHF band-pass filter **3** according to FIG. **3** and FIG. **4** for a digital switching signal **38** with settings of the PIN diodes modified by comparison with FIG. **5**. The frequency is plotted on the horizontal axis **601** in GHz. On the vertical axis **602**, the values of the scattering parameter are plotted in dB. The curve **603** represents the input-end matching of the switchable band-pass filter **3** in the form of the value of the input reflection factor $|S_{11}|$. The curve **605** represents the output-end matching of the switchable band-pass filter **3** in the form of the value of the output reflection factor $|S_{22}|$. The switchable band-pass filter **3** is matched for a mid-frequency f_{ctr} of 0.05203 GHz with values for $|S_{11}|$ and $|S_{22}|$ less than −20 dB. The selectivity of the switchable band-pass filter **3** is shown for the illustrated mid-frequency f_{ctr} and for frequencies which deviate from f_{ctr} by 8%. For a frequency f_{ctr}=0.05203 GHz, the value of the filter transmission function **606** and accordingly the insertion loss $|S_{21}|$=−3.451 dB. The loss of the band-pass filter **3** for a frequency of 0.04783 GHz is −28.27 dB (display **607**) and for a frequency of 0.05618 GHz is −29.23 dB (display **608**).

FIG. **7** shows a simulation of the scattering parameters (abbreviated as S-parameters) of the switchable of VHF band-pass filter **3** according to FIG. **3** and FIG. **4** for a digital switching signal **38** with the settings PIN_**0**, PIN_**1** at ON. The frequency is plotted in GHz on the horizontal axis **701**. The values of the scattering parameters $|S_{11}|$, $|S_{22}|$ and $|S_{22}|$ are plotted in dB on the vertical axis **702**. The curve **703** represents the input-end matching of the switchable band-pass filter **3** in the form of the value of the input-reflection factor $|S_{11}|$. The curve **705** represents the output-end matching of the switchable band-pass filter **3** in the form of the value of the output-reflection factor $|S_{22}|$. The switchable band-pass filter **3** is matched for a mid-frequency f_{ctr} of 0.08638 GHz with values for $|S_{11}|$ and $|S_{22}|$ less than −25 dB. The selectivity of the switchable band-pass filter **3** is shown for the illustrated mid-frequency f_{ctr} with the display **706**. For a frequency f_{ctr}=0.08638 GHz, the value of the filter transmission function **704**, **706** and accordingly the insertion loss $|S_{21}|$=−2.829 dB.

In an exemplary embodiment for frequencies in the VHF range based on simulated S-parameters, FIG. **5**, FIG. **6** and FIG. **7** show a narrowband band-pass filter **3** capable of being switched over a broad frequency range with high selectivity and low insertion loss. In a further exemplary embodiment, a band-pass filter **3** according to the invention for the UHF range is presented.

FIG. **8** illustrates the structure of the capacitor network **800** as the coupling device **23** determining the frequency of the switchable mid-frequency of the UHF band-pass filter **3**, switched via PIN diodes. The capacitor network **800** is structured in a symmetrical manner for the first filter element **22** and the second filter element **24**. The inputs and outputs of the band-pass filter marked with reference letters E/A respectively are connected via matching-elements **846** and respectively **847** to the coupling device **23**. The matching-elements **846**, **847** can comprise a coil or any alternative reactance circuits, as illustrated. Dependent upon the value of the digital switching signal **38**, parts of the capacitor network are connected symmetrically and in part to the first filter element **22** and the second filter element **24**. Moreover, the coupling device **23** provides a coupling element **840** made up from inductances and capacitors for the fine tuning of the coupling of the first filter element **22** and of the second filter element **24**. A switching network **850** for the connection of capacitors is embodied with the PIN diodes **851**, **852**.

If the digital signal **38** provides the value, PIN_**0**="ON", an additional capacitor is connected via this switching network **850** to the first filter element **22** and, symmetrically to the latter, a capacitor is connected through the switching network **860** to the second filter element **24**. The mid-frequency of the switchable narrowband band-pass filter **3** is varied by connecting the capacitors through the switching network **850**, **860**. The use according to the invention of PIN diodes as the switching element allows the transmission of relatively large powers across the switchable band-pass filter **3** than could be achieved with the use of varactor diodes. Accordingly, the use of the band-pass filter **3** as a cosite filter is possible.

FIG. **9** shows the structure of the band-pass for an embodiment of the band-pass filter according to the invention for frequencies in the UHF range. The frequency resolution of the switchable band-pass filter **3** in this case is 8 bits, so that a step width for the mid-frequency of 700 kHz is attainable. The overall tuning range of the switchable band-pass filter in the UHF band in the present, second exemplary embodiment extends from 225 MHz to 400 MHz.

In FIG. **9**, the first filter element **22** comprises two parallel, straight microstripline portions **903**, **905**, which are connected to one another via a line portion **907**. The microstripline portions **903**, **905** are connected to earth at each end via a through contact **915**, **917**. At the end disposed opposite to the through contact **915**, **917**, the microstripline portions are connected to one another and to the first connection **901** via the straight-line conductor portion **907** at right angles to the lines **903**, **905**. Additionally, the first filter element **22** provides an L-shaped microstripline portion **911**, which is connected to the first connection **901** of the band-pass filter **3**. In the present embodiment, this L-shaped microstripline portion **911** is arranged as an extension of the microstripline portion **903** and, in the present case, is angled through 90° after a given length to form the L-shape. This microstripline portion **911** is used for the calibration of the first filter element. The coupling device **23** comprising a coupling network **23** of PIN diodes and capacitors is additionally connected to the filter element **22** via a line portion **909**, which branches off at right angles from the connecting line **907** of the two microstripline portions. The second filter element **24** of the band-pass **24** is structured in a comparable manner to the first filter element **22**. The second filter element **24** also comprises two parallel, straight-line microstripline portions **904**, **906**, which are each shorted at one end **916**, **918** and connected via a connecting line **908** formed at right angles to the microstriplines **904**, **906**. The second filter element **24** further provides an L-shaped microstripline portion **912**, which is connected to the output **902** of the band-pass filter **3**. This microstripline portion **912** in the present embodiment is arranged as an extension of the first microstripline portion **915** of the second filter element, and, in the present case also, is angled through 90° after a given length. This microstripline portion **912** is used for calibration of the second filter element **24**. The coupling device **23** comprising a coupling network **23** of PIN diodes and capacitors is additionally connected to the second filter element **24** via a line portion **910**, which branches off at right angles from the connecting line **908** of the two microstriplines **904**, **906**. The filter elements **22**, **24** are arranged with all microstripline portions **903**, **905**, **904**, **906** disposed parallel to one another on different layers of a multi-layered printed-circuit board, in such a manner that the short-circuited ends **915**, **916**, **917**, **918** point in the same direction and are disposed on a straight line perpendicular to the microstripline portions **903**, **904**, **905**, **906** and, at the same time, follow the microstripline portions **903**, **905** and **904**, **906** of the first and respectively second filter element **22**, **24** in alternation with one another. The illustrated arrangement at the same time guarantees a good symmetry of the switchable band-pass filter **3** with reference to the connections **901**, **902** and a good, direct electromagnetic coupling between the first filter element **22** and the second filter element **24**, at the same time as providing a minimal space requirement for the arrangement. The switchable band-pass filter **3** according to the invention therefore achieves a small structural size of approximately 45 mm×40 mm for the part of the band-pass filter **3** illustrated in FIG. **9** comprising the filter elements **22**, **24**. The arrangement of the elements on different planes of a multi-plane printed-circuit board is represented by different shading. However, it would also be sufficient to provide only the overlapping connecting lines **907**, **908** on different planes. For the housing of the component group of the switchable band-pass filter **3**, including the capacitor/PIN diode network **23**, overall dimensions of less than 6.6 cm×6 cm×3 cm can be achieved. Accordingly, the second exemplary embodiment of the switchable UHF band-pass filter **3** can be readily integrated into existing device designs, especially for mobile communications devices with small overall dimensions. This can be achieved with an embodiment according to the invention of the filter element **22** and **24** and the coupling according to the invention of the filter element **22**, **24**. Optimal symmetry of the switchable band-pass filter **3** is achieved by implementing the coupling device **23** determining the frequency by means of PIN diodes, in each case at the high point of the resonators which form the first filter element **22** and the second filter element **24**. The printed structure of the resonators of the first filter element **22** and of the second filter element **24** guarantees a good mechanical stability of the band-pass filter **3**, which is accordingly designed in a robust manner with regard to vibrations. Additional discrete capacitors C and inductances L in SMD format can be used to vary the coupling of the filter elements **22**, **24**. The overall component group can be structured on a multi-layer printed-circuit board (for example, 10-layer, manufactured by Rogers) as the substrate. The illustrated design of the band-pass filter **3** according to the invention allows efficient manufacture based on the automatic fitting of SMD technology and re-flow soldering techniques.

FIG. **10** shows a simulation of the scattering parameters (abbreviated as S-parameters) for the switchable UHF band-pass filter **3** as shown in FIG. **8** and FIG. **9** for a digital switching signal **38** with the settings PIN_**0**, PIN_**1**, PIN_**2**, at "ON". The frequency is plotted in GHz on the horizontal axis **1001**. The values of the scattering parameters are plotted in dB on the vertical axis **1002**. The curve **1003** represents the input-end matching of the switchable band-pass filter **3** in the form of the value of the input-reflection factor $|S_{11}|$. The curve **1005** represents the output-end matching of the switchable band-pass filter **3** in the form of the value of the output-reflection factor $|S_{22}|$. The switchable band-pass filter **3** is matched for a mid-frequency f_{ctr} of 0.3967 GHz with values for $|S_{11}|$ and $|S_{22}|$ smaller than −15 dB. The selectivity of the switchable band-pass filter **3** is shown for the illustrated mid-frequency f_{ctr} and for frequencies which deviate from f_{ctr}. For a frequency f_{ctr}=0.3967 GHz, the value of the filter transmission function **1006** and accordingly the insertion loss $|S_{21}|$=−3.266 dB. The loss of the band-pass filter **3** for a frequency of 0.3694 GHz is −29.87 dB **1007** and for a frequency of 0.4281 GHz is −33.88 dB **1008**.

The switchable band-pass filter according to the invention is not restricted to the embodiments illustrated. In this context, all of the features of the invention presented can be combined with one another in an appropriate form.

The invention claimed is:

1. A switchable band-pass filter for narrow band filtering over a large frequency band in a co-site filter application, said switchable band-pass filter comprising:

a first filter element and a second filter element, which are directly coupled to one another via a switchable coupling device,

wherein the first filter element includes a first connection and the second filter element includes a second connection, wherein the first connection is at least one of a band-pass filter input and a band-pass filter output and the second connection is at least a respective other one of the band-pass filter output and the band-pass filter input,

wherein the first and the second filter elements each provide a conductor structure formed in a flat plane, which includes respectively at least two line portions, the first and the second filter elements being in direct electromagnetic interaction with one another in at least a part of the at least two line portions extending in a straight line,

wherein the first and the second filter elements are microstrip lines and each is arranged on a different layer of at least one printed circuit board,

wherein the at least two line portions of the first and the second filter elements are arranged parallel to one another, such that each line portion of the at least two line portions of the first filter element alternates with each line portion of the at least two line portions of the second filter element,

wherein the at least two line portions of the first and the second filter elements respectively are each connected at one end in an electrically conductive manner, and

wherein each of the line portions of the first and the second filter elements is connected at another end with a short circuit to earth and the short circuits are disposed on a straight line which is perpendicular to the line portions.

2. The switchable band-pass filter according to claim **1**, wherein the switchable coupling device is realized as a network formed from semi-conductor diodes and capacitors and/or inductances.

3. The switchable band-pass filter according to claim **1**, wherein the switchable coupling device comprises varactor diodes or pin diodes.

4. The switchable band-pass filter according to claim **1**, wherein the switchable coupling device and control circuits are formed on one or more layers of the at least one printed-circuit board.

5. The switchable band-pass filter according to claim **1**, wherein the first and the second connections of the band-pass filter are formed on a part of the first filter element and the second filter element.

6. The switchable band-pass filter according to claim **1**, wherein the switchable coupling device is formed in such a manner that capacitors for connection to the first and the second filter elements have a same capacity for the first and the second filter elements.

7. The switchable band-pass filter according to claim **1**, wherein the first and the second filter elements are structured in a mutually symmetrical manner.

8. The switchable band-pass filter according to claim **1**, wherein the band-pass filter shows symmetrical electrical behavior with reference to the first and the second connections for being operated as a transmission filter and a reception filter, respectively, with identical properties.

9. The switchable band-pass filter according to claim **1**, wherein the at least two line portions of the first and the second filter elements each provide a further line portion suitable for tuning a frequency of the band-pass filter.

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