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(54) Title: DUPLEXER OR QUADPLEXER HAVING IMPEDANCE MATCHING FOR CARRIER AGGREGATION

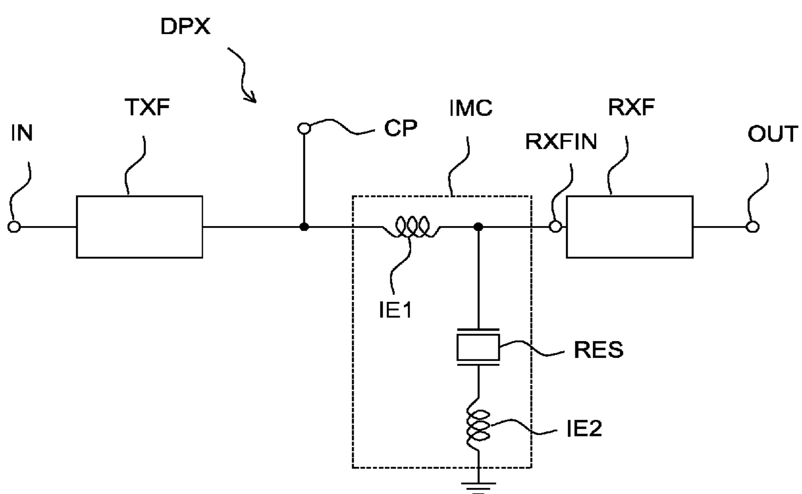

Fig. 2

(57) Abstract: A duplexer topology with improved electrical properties and compatible with carrier aggregation modes is provided. The duplexer comprises a transmission filter between an input port and a common port and a reception filter between the common port and an output port. An impedance matching circuit is connected between the reception filter, the transmission filter and the common port. At the common port a matched impedance is provided for transmission signals and reception signals of a first transmission frequency band and an open circuit impedance is presented for transmission signals and for reception signals of a second transmission frequency band. The impedance matching circuit (IMC) comprises a first inductance element (IE1), a second inductance element (IE2) and a resonator (RES), - the first inductance element (I E1) is connected in series between the common port (CP) and the input port (RXFIN) of the reception filter (RXF), - the resonator (RES) is connected in a shunt path between the input port of the reception filter (RXFIN) and ground, - the second inductive element (IE2) is connected in the shunt path between the resonator (RES) and ground.

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[Continued on next page]

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Description

DUPLEXER OR QUADPLEXER HAVING IMPEDANCE MATCHING FOR CARRIER AGGREGATION

The present invention refers to duplexers, i.e. to duplexer topologies, to duplexer components, to quadplexers, i.e. to quadplexer topologies and to quadplexer components.

Wireless communication devices should be able to work with an increasing number of frequency bands and data transmission rates should increase, too. To separate transmit signals and receive signals from one another and from other transmit or receive signals of different frequency bands multiplexer such as duplexers or quadplexers are employed in such devices. Carrier aggregation (CA) is a means for increasing data rates by using more than one transmission frequency and/or more than one reception frequency simultaneously.

Known duplexers use an impedance matching circuit between a transmission filter and a reception filter to decouple the filters from one another.

However, especially when neighbouring frequency bands are only separated by a narrow frequency gap, insertion loss and skirt steepness in the carrier aggregation mode may be dete-riorated.

Thus, a duplexer with improved electrical properties that is compatible with a carrier aggregation mode and that is com-patible with frequency bands that are arranged close together is desired.

Further desired is a quadplexer which intrinsically allows simultaneous data transmission in different frequency bands.

To that end a duplexer, a duplexer component, a quadplexer and a quadplexer component according to the claims are provided. Dependent claims provide preferred embodiments.

The duplexer that is compatible with carrier aggregation modes comprises an input port, an output port and a common port. Further, the duplexer comprises a transmission filter between the input port and the common port. Further, the duplexer comprises a reception filter between the output port and the common port. The reception filter has an input port. Further, the duplexer comprises an impedance matching circuit between the reception filter, the transmission filter and the common port. The duplexer provides a matched impedance at a common port for transmission signals of a first transmission frequency band. Further, the duplexer provides a matched impedance at the common port for reception signals of the first transmission frequency band. Further, the duplexer provides an open circuit impedance at the common port for transmission signals of a second transmission frequency band and the duplexer provides an open circuit impedance at the common port for reception signals of the second transmission frequency band.

Thus, a duplexer for carrier aggregation is provided. The input port may be used to receive RF signals from an external circuit environment. The output port can be used to provide RF signals to an external circuit environment. The common port may be used to simultaneously transmit and receive signals via an antenna. The transmission filter and the reception filter may be bandpass filters. By providing an open circuit impedance at the common port for transmission signals and for reception signals of a second transmission frequency band while providing a matched impedance at the common port for transmission signals and for reception signals of the first transmission frequency band, the duplexer is well suited for carrier aggregation. In this context, a matched impedance is an impedance that is matched to commonly used impedances such as 25 ohm, 50 ohm, 100 ohm and similar values. The provided impedance does not necessarily have to be exactly 25 ohm, 50 ohm and so on but the matched impedance is for the necessary frequency range within an allowed limit.

Correspondingly, the provided open circuit impedance does not necessarily mean an infinite impedance. The open circuit impedance is an impedance that results in a sufficiently high reflection factor for unwanted signals.

Thus, wanted signals of the first transmission band can propagate from the input port to the common port. Wanted signals from the first transmission band can propagate from the common port to the output port. However, unwanted signals such as signals from the second frequency band will see an open circuit-like configuration at the common port and do not disturb the proper working of the duplexer in the first frequency band.

It is possible that the transmission filter and/or the reception filter are electro acoustic filters.

Electro acoustic filters such as pass band filters comprise electro acoustic resonators. Electro acoustic resonators, e.g. SAW-resonators (SAW = surface acoustic wave), GBAW-resonators (GBAW = guided bulk acoustic waves), and BAW-resonators (BAW = bulk acoustic wave) utilize the piezoelectric effect of a piezoelectric material to converter between RF signals and acoustic waves.

The filters have a ladder-type like topology or a DMS (DMS = double mode SAW) topology. In a ladder-type like topology series resonators are electrically connected in series in a signal path. Parallel resonators arranged in shunt paths electrically connect the signal path to ground. In a DMS structure several electro acoustic transducers are arranged between electro acoustic reflectors and more than one acoustic wave mode can propagate in this structure.

In SAW-resonators interdigitated electrode structures are arranged on a piezoelectric substrate. In a BAW-resonator a piezoelectric material is sandwiched between a bottom electrode and a top electrode. A BAW-resonator can be an SMR-type resonator (SMR = solidly mounted resonator) or an FBAR-resonator (FBAR = film bulk acoustic resonator). In a BAW-resonator of the SMR-type an electro acoustic mirror is arranged below the sandwich structure. In a BAW resonator of the FBAR type a cavity is arranged between the bottom electrode to decouple the sandwich structure from its environment.

It is possible that the impedance matching circuit comprises a first inductance element and a second inductance element.

The first inductance element can be a series inductance element electrically connected in series between the common port and the input port of the reception filter. The second inductance element can be a parallel inductance element arranged in a shunt path that electrically connects the signal path between the common port and the output port to ground.

In particular, the shunt path can electrically connect the input port of the reception filter to ground.

It is possible that the impedance matching circuit comprises a resonator.

The resonator can be an electro acoustic resonator.

The resonator can be in a shunt path electrically connecting the signal path between the common port and the output port to ground. The shunt path of the resonator can be the same shunt path in which the second inductance element is arranged. Then, the resonator can be electrically connected between the signal path and the second inductance element. Thus, the second inductance element electrically connects the resonator to ground.

Correspondingly, it is possible that the impedance matching circuit comprises the first inductance element, the second inductance element and the resonator. The first inductance element is connected in series between the common port and the input port of the reception filter. The resonator is connected in the shunt path between the input port of the reception filter and ground and the second inductive element is connected in the shunt path between the resonator and ground.

Such a configuration of the impedance matching circuit is well-suited for carrier aggregation mode because matched impedances for wanted transmission and reception signals and open circuit impedances for unwanted signals of the parallel data transmission in the second frequency band can easily be provided with values fulfilling necessary requirements.

It is possible that the first transmission band is the Band 26 transmission band. The first reception band is the Band 26 reception band. The second transmission band is selected from the Band 12 transmission band and the Band 28A transmission band. The second reception band is selected from the Band 12 reception band and the Band 28A reception band.

Thus, the presented duplexer works well with frequencies of Band 26. This duplexer can easily be used in a carrier aggregation mode in a mobile communication device where simultaneously a parallel data transmission and/or reception in frequencies of Band 12 or Band 28 takes place.

Thus, the presented duplexer together with a duplexer for Band 12 or Band 28 signals can easily be combined to form a quadplexer.

It is possible that all circuit constituents of the duplexer are monolithically integrated in a multilayer component.

In a multilayer component dielectric layers and metallization layers can be stacked. Via connections in a vertical direction can electrically connect metallization structures created within the metallization layers. Passive circuit elements such as capacitive elements, inductive elements or resistive elements can be created by structuring metallizations of the metallization layers. The filters can be created as filter chips and the filter chips can be embedded within the multilayer stack construction.

Correspondingly, it is possible that a quadplexer comprises two duplexers. One duplexer has a circuit topology as described above. The second duplexer can be a similar duplexer or another duplexer.

In particular, the first duplexer can be as described above and be used for data transmission in Band 26. The second duplexer can be a Band 12 duplexer or a Band 28A duplexer.

The frequencies of Bands 26 and 28A and the frequency of Band 26 and Band 12 are such that only narrow frequency gaps between different pass bands make it nearly impossible for conventional duplexers or quadplexers to work in a carrier aggregation mode. However, the presented duplexer allows carrier aggregation mode even for the critical Band 26/Band 28A and for the Band 26/Band 12 combinations.

It is possible that a quadplexer component comprises the above-presented quadplexer where all circuits constituents of the quadplexer are monolithically integrated in a multilayer component as described above.

Especially the trend towards miniaturization makes it difficult to obtain good electrical values such as low insertion losses, high isolation levels and high separation levels when the circuit’s constituents and signal paths are packed close together, what is necessary to obtain a component with small spatial dimensions complying with trend towards miniaturization.

The following bands can be provide preferred band pairs for combination: Band 8 and band 20, band 26 and band 12, band 26 and band 28A, band 26 and band 29.

Transmission frequencies of band 8 are 800 MHz to 915 MHz. Reception frequencies of band 8 are 925 MHz to 960 MHz. Correspondingly, the bandgap has a width of 10 MHz.

Transmission frequencies of band 26 are 814 MHz to 849 MHz. Reception frequencies of band 26 are 859 MHz to 894 MHz. Correspondingly, the bandgap has a width of 10 MHz.

The mentioned bands refer to the generally known standard valid at the filing date of the present application.

Central aspects of the duplexer, the quadplexer, the duplexer component and the quadplexer component and details of preferred embodiments are shown in the accompanying schematic figures:

Fig. 1 shows circuit elements of an equivalent circuit diagram of the duplexer.

Fig. 2 shows circuit elements of a preferred embodiment of the impedance matching circuit.

Fig. 3 illustrates the ports of a quadplexer.

Fig. 4 illustrates a possible integration of circuit elements and circuit constituents in a monolithically integrated component.

Fig. 5 illustrates impedance values for wanted matched impedances and for open circuit impedances that can be provided utilizing the topology as described above and that fulfils necessary requirements for a proper duplexer operation in a carrier aggregation mode.

Fig. 6 illustrates non-optimal impedance values that are provided by a conventional duplexer topology.

Fig. 7 shows insertion losses for a duplexer and a quadplexer as described above for frequencies of a Band 26/Band 28A combination.

Fig. 8 shows insertion losses for a duplexer and a quadplexer as described above for frequencies of the band combination Band 26/Band 12.

Fig. 9 shows insertion losses for a duplexer and a quadplexer according to conventional duplexer topologies for frequencies of the combination Band 26/Band 28A.

Fig. 10 shows insertion losses for a duplexer and for a quadplexer utilizing conventional topologies for frequencies of the band combination Band 26/Band 12.

Fig. 1 shows circuit elements of an equivalent circuit diagram of a duplexer DPX as described above. The duplexer DPX has an input port IN, an output port OUT and a common port CP. Between the input port IN and the common port CP a transmission filter TXF is arranged. Between the common port CP and the output port OUT a reception filter RXF is arranged. Further, the duplexer comprises an impedance matching circuit IMC arranged between the common port CP and the reception filter RXF. The impedance matching circuit IMC is provided such that the duplexer DPX provides at its common port CP a matched impedance for transmission signals and for reception signals of the first frequency band. Further, the impedance matching circuit IMC provides a nearly infinite impedance for unwanted signals such as transmission and reception signals of the second frequency band.

Thus, the duplexer DPX is well-suited to work with frequencies of the first frequency band while it is suited to work in a carrier aggregation mode where data transmission and/reception takes place simultaneously in the second frequency band.

The common port may be connected to an antenna of a mobile communication device.

Correspondingly, the mobile communication device further comprises one or more duplexers or the presented duplexer is a part of a quadplexer topology.

Of course, higher degrees of multiplexers such as hexaplexers are also possible.

Fig. 2 shows a preferred embodiment of the impedance matching circuit IMC comprising a first inductive element IE1, a second inductive element IE2 and a resonator RES.

The first inductive element IE1 is electrically connected in series between the common port and the output port OUT, in particular between the common port CP and an input port RXFIN of the reception filter RXF. The second inductive element IE2 is electrically connected in a shunt path between the signal path and ground. In particular, the shunt path is electrically connected between the input port RXFIN of the reception filter RXF and ground. The resonator RES is electrically connected between the input port RXFIN of the reception filter RXF and the second inductive element IE2.

Fig. 3 illustrates the ports of a quadplexer QPX. The quadplexer QPX has a common port CP that may be connected antenna. Further, the quadplexer QPX has a first input port IN1 and a second port IN2. Further, the quadplexer QPX has a first output port OUT1 and a second output port OUT2. The first input port IN1 and the first output port OUT1 can be used according to a regular use of the quadplexer QPX similar to the use of a duplexer. Additionally, the second input port IN2 and/or the second output port OUT2 can be used to transmit and/or receive further RF signals, e.g. to establish a carrier aggregation mode.

Fig. 4 illustrates a possible integration of filters such as one or more transmission filters TXF or one or more reception filters RXF and/or one or more resonators RES within the monolithically integrated component. Correspondingly, a cross-section of a duplexer component DPXC or a cross-section of a quadplexer component QPXC is shown. Via connection 3 can be used to vertically connect different metallization layers through dielectric layers DL. Capacitive elements CE and inductive elements IE can be created as structured metallizations in metallization layers between the dielectric layers.

Connection pads at the bottom side or at the top side of the component can be used to electrically and/or mechanically connect the component to an external circuit environment, i.e. a frontend circuit of a mobile communication device.

Fig. 5 illustrates simulated frequency-dependent impedances at a common port of a duplexer according to the above-described topology. The duplexer is provided to work in Band 26. Correspondingly, for transmission frequencies (B26TX) and reception frequencies (B26 RX) frequencies and matched impedance in the centre of the Smith chart are obtained. Further, for frequencies of a second frequency band, in this case of Band 12, impedances for transmission frequencies (B12TX) and reception frequencies (B12RX) are near the open circuit. Thus, the duplexer topology is well-suited to work with Band 26 signals while simultaneously a communication device works in a carrier aggregation mode transmitting or receiving signals in Band 12.

In contrast, Fig. 6 illustrates simulated frequency-dependent impedance values obtained for a conventional duplexer topology. Although impedance values for transmission and reception frequencies of Band 26 are well-matched, impedance values of transmission and reception signals of Band 26 signals are far away from an open circuit impedance. Especially for Band 26 reception signals (B26RX) a nearly short circuit impedance configuration would be obtained. Correspondingly, it would be possible that energy of Band 12 reception signals would be drained and the energy would be missing in the parallel data transmission system. Thus, Band 12 transmission signals would disturb operation of the Band 26 duplexer and the Band 26 duplexer may disturb reception of reception signals of the Band 12 duplexer.

Fig. 7 shows simulated insertion losses for a duplexer (DPX) and for a quadplexer (QPX) utilizing the above-described topology. For the Band 28A transmission frequencies, for the Band 28A reception frequencies, for the Band 26 transmission frequencies and for the Band 26 reception frequencies the requirements concerning insertion loss are fulfilled for the duplexer and for a corresponding quadplexer comprising the topology of the described duplexer. Thus, the topology of the duplexer is well-suited to be used when simultaneous data transmission should take place in Band 28A when the duplexer works in Band 26 frequencies.

Correspondingly, Figure 8 shows the situation of the frequency band combination Band 26 and Band 12. Insertion losses for the duplexer and for the quadplexer comprising such a described duplexer topology are well within required ranges thus, the duplexer can be used for Band 26 signals and simultaneously data transmission and reception can take place in Band 12 frequencies.

In contrast, the insertion losses are provided for the same scenario but with the use of a conventional duplexer design. Especially the edges of Band 26 reception frequencies critical insertion losses would be obtained. Further, the necessary requirements concerning insertion loss of Band 28A signals cannot be complied with. Insertion loss for reception signals is too high. Insertion loss for transmission signals of Band 28A are still higher for the quadplexer.

Fig. 10 shows the corresponding scenario for a Band 26/Band 12 combination. At the lower reception frequencies of Band 26 the insertion loss for the Band 26 duplexer becomes critical for the duplexer and for the quadplexer.

For the quadplexer configuration insertion losses for Band 12 reception frequencies are inadmissibly high. For transmission signals the insertion loss is still higher.

The duplexer topology, the duplexer component, the quadplexer topology and the quadplexer component are not limited to the technical features described above and shown in the figures. Duplexers and quadplexers can comprise further circuit elements and corresponding components can comprise further constituents, dielectric layers, metallization layers and electrical connections.

List of Reference Signs

CE:	capacitive element
CP:	common port
DL:	dielectric layer
DPX:	duplexer
DPXC:	duplexer component
IE1:	first inductive element
OUT1, OUT2:	first, second output port of the quadplexer
IMC:	impedance matching circuit
IE:	inductive element
IN:	input port
RXFIN:	input port of the reception filter
IN1, IN2:	input ports of a quadplexer
OUT:	output port
QPX:	quadplexer
QPXC:	quadplexer component
RXF:	reception filter
B12RX:	reception frequencies of Band 12
B26RX:	reception frequencies of Band 26
B28ARX:	reception frequencies of Band 28A
RES:	resonator
IE2:	second inductive element
TXF:	transmission filter
B12TX:	transmission frequencies of Band 12
B26TX:	transmission frequencies of Band 26
B28ATX:	transmission frequencies of Band 28A
V:	via connection

Claims

1. A duplexer (DPX) for carrier aggregation, the duplexer comprising
- an input port (IN), an output port (OUT), and a common port (CP),
- a transmission filter (TXF) between the input port (IN) and the common port (CP),
- a reception filter (RXF) between the output port (OUT) and the common port (CP), the reception filter (RXF) having an input port,
- an impedance matching circuit (IMC) between the reception filter (RXF), the transmission filter (TXF), and the common port (CP),

where
- the duplexer (DPX) provides a matched impedance at the common port (CP) for transmission signals of a first transmission frequency band,
- the duplexer (DPX) provides a matched impedance at the common port (CP) for reception signals of the first transmission frequency band,
- the duplexer (DPX) provides an open circuit impedance at the common port (CP) for transmission signals of a second transmission frequency band,
- the duplexer (DPX) provides an open circuit impedance at the common port (CP) for reception signals of the second transmission frequency band.

2. The duplexer of the previous claim, where the transmission filter (TXF) and/or the reception filter (RXF) are electro acoustic filters.

3. The duplexer of one of the previous claims, where the impedance matching circuit (IMC) comprises a first inductance element (IE1) and a second inductance element (IE2).

4. The duplexer of one of the previous claims, where the impedance matching circuit (IMC) comprises a resonator (RES).

5. The duplexer of the previous claim, where the resonator (RES) is an electro acoustic resonator.

6. The duplexer of one of the previous claims, where
- the impedance matching circuit (IMC) comprises a first inductance element (IE1), a second inductance element (IE2) and a resonator (RES),
- the first inductance element (IE1) is connected in series between the common port (CP) and the input port (RXFIN) of the reception filter (RXF),
- the resonator (RES) is connected in a shunt path between the input port of the reception filter (RXFIN) and ground,
- the second inductive element (IE2) is connected in the shunt path between the resonator (RES) and ground.

7. The duplexer of one of the previous claims, where
- the first transmission band is the band 26 transmission band,
- the first reception band is the band 26 reception band,
- the second transmission band is selected from the band 12 transmission band and the band 28A transmission band,
- the second reception band is selected from the band 12 reception band and the band 28A reception band.

8. A duplexer component (DPXC) comprising a duplexer (DPX) of one of the previous claims, where all circuit constituents of

the duplexer are monolithically integrated in a multilayer component.

9. A quadplexer (QPX), comprising a duplexer (DPX) of one of claims 1 to 7 and one additional duplexer (DPX).

10. A quadplexer component (QPXC), comprising the quadplexer (QPX) of the previous claims where all circuit constituents of the quadplexer (QPX) are monolithically integrated in a multilayer component.

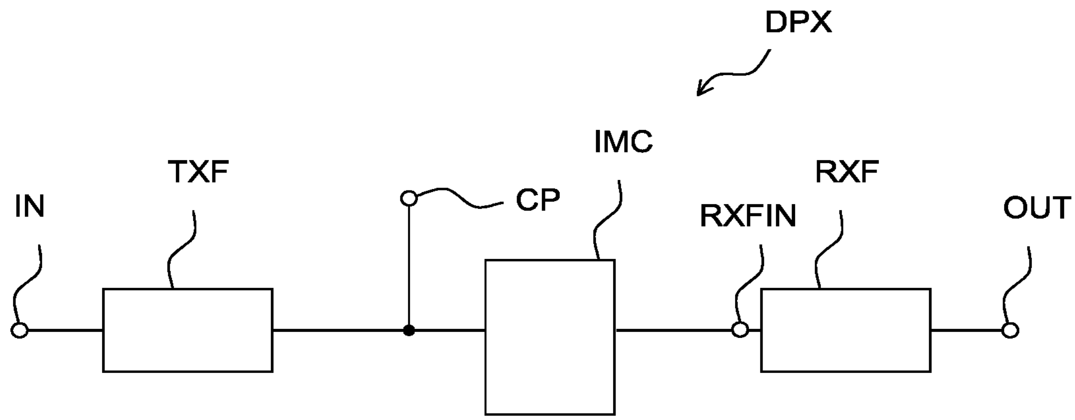
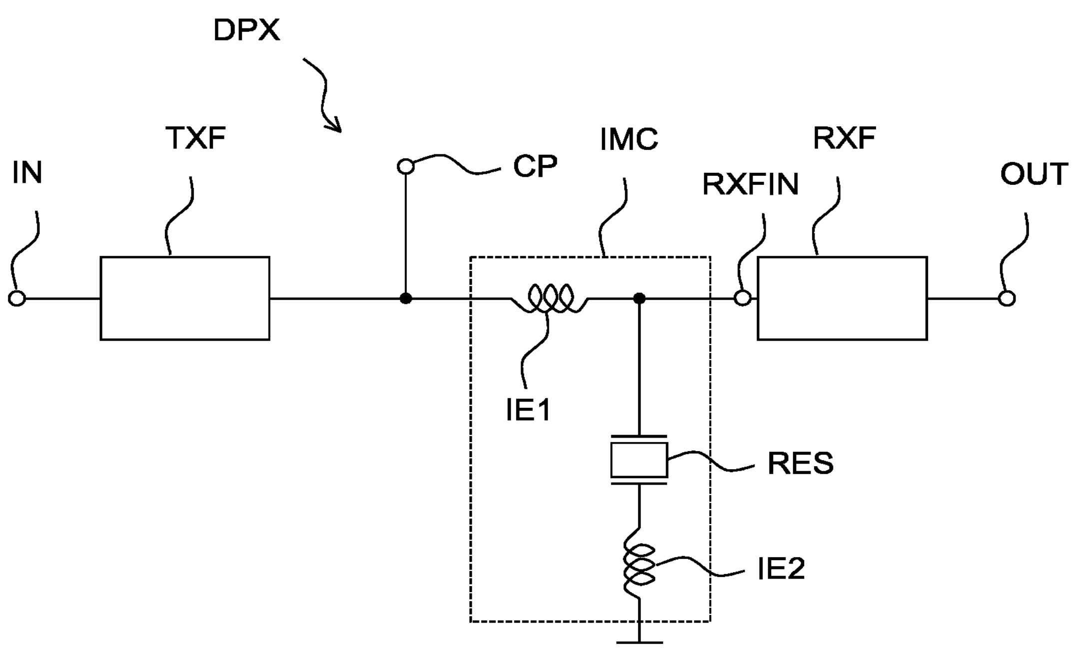

DPX
IMC
TXF
RXF
IN
CP
RXFIN
OUT

Fig. 1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IMC
RXF
IN
CP
RXFIN
OUT
IE1
RES
IE2

Fig. 2

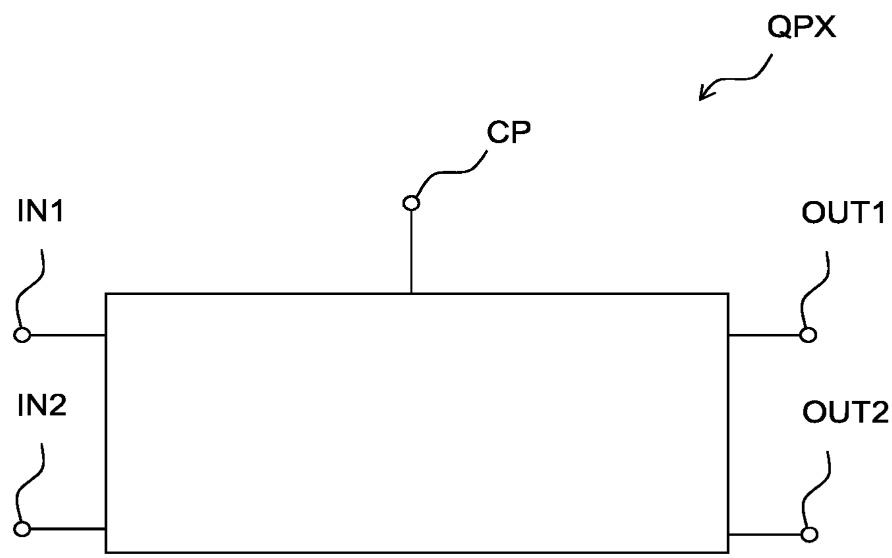


Fig. 3

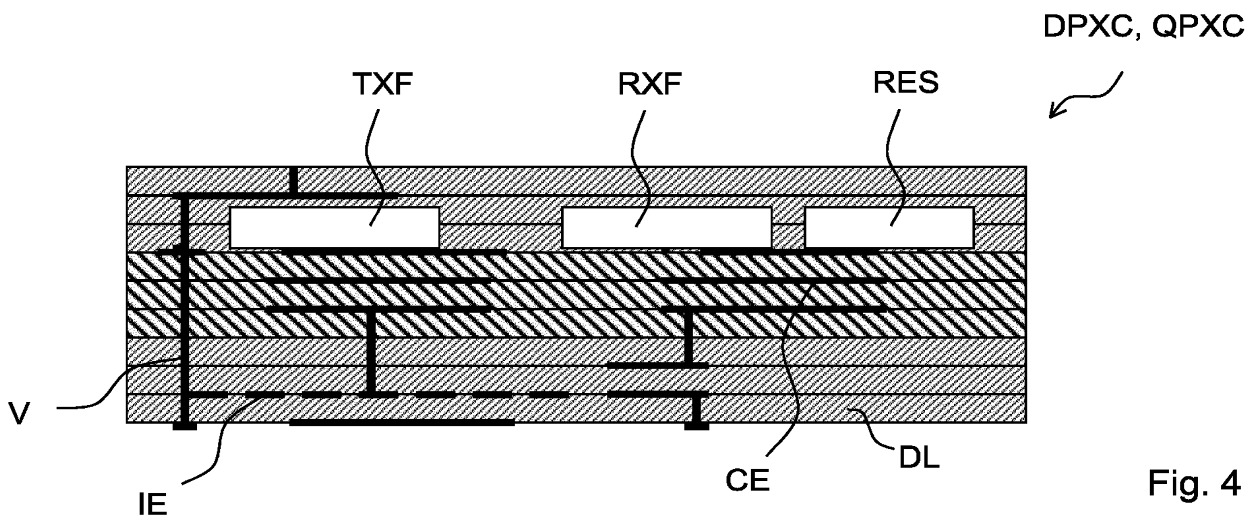
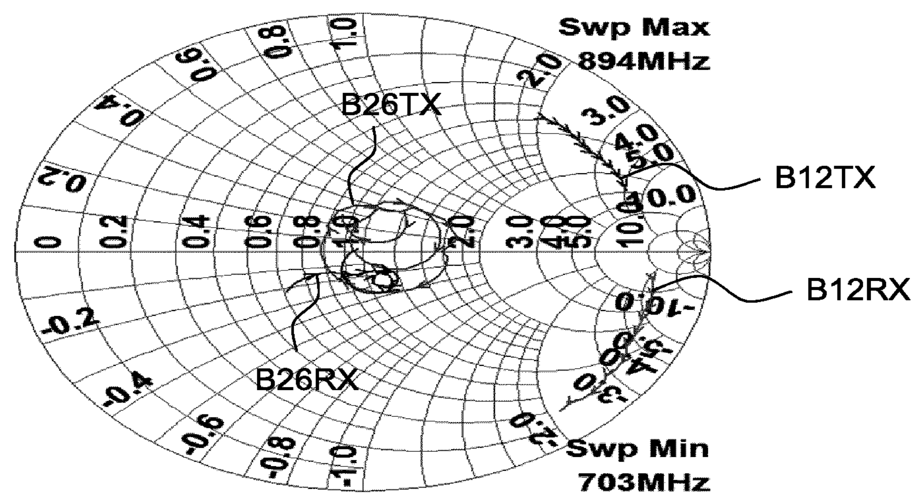


Fig. 4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894MHz
B26TX
B12TX
B12RX
B26RX
Swp Min
703MHz

Fig. 5

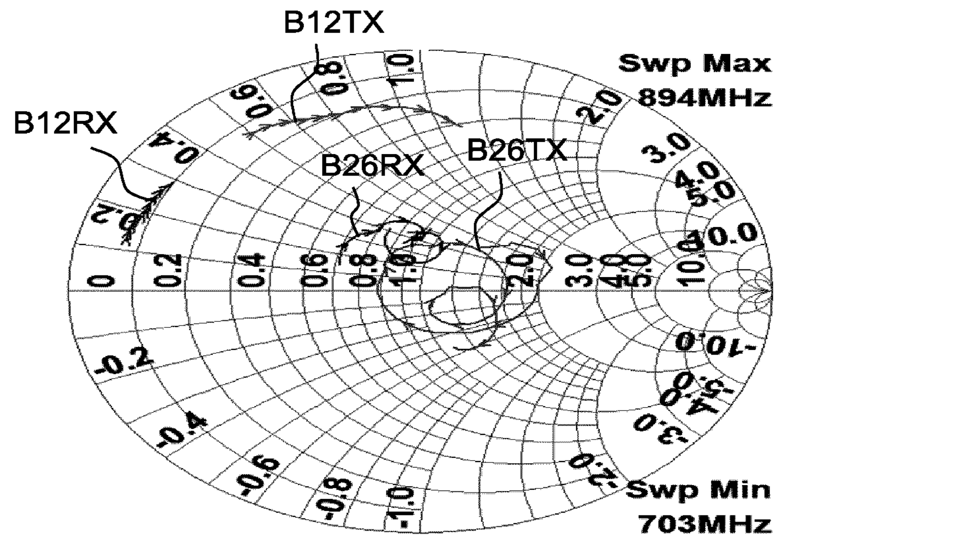
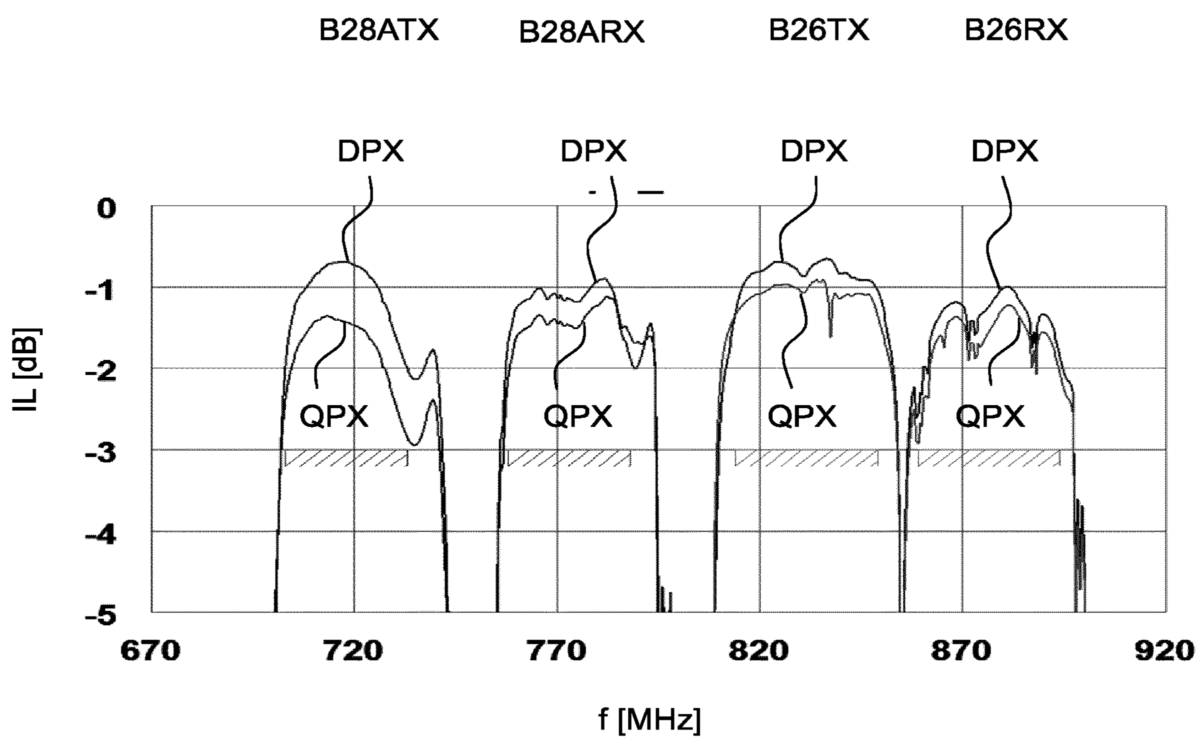

B12TX
B12RX
B26RX
B26TX
Swp Max
894MHz
Swp Min
703MHz

Fig. 6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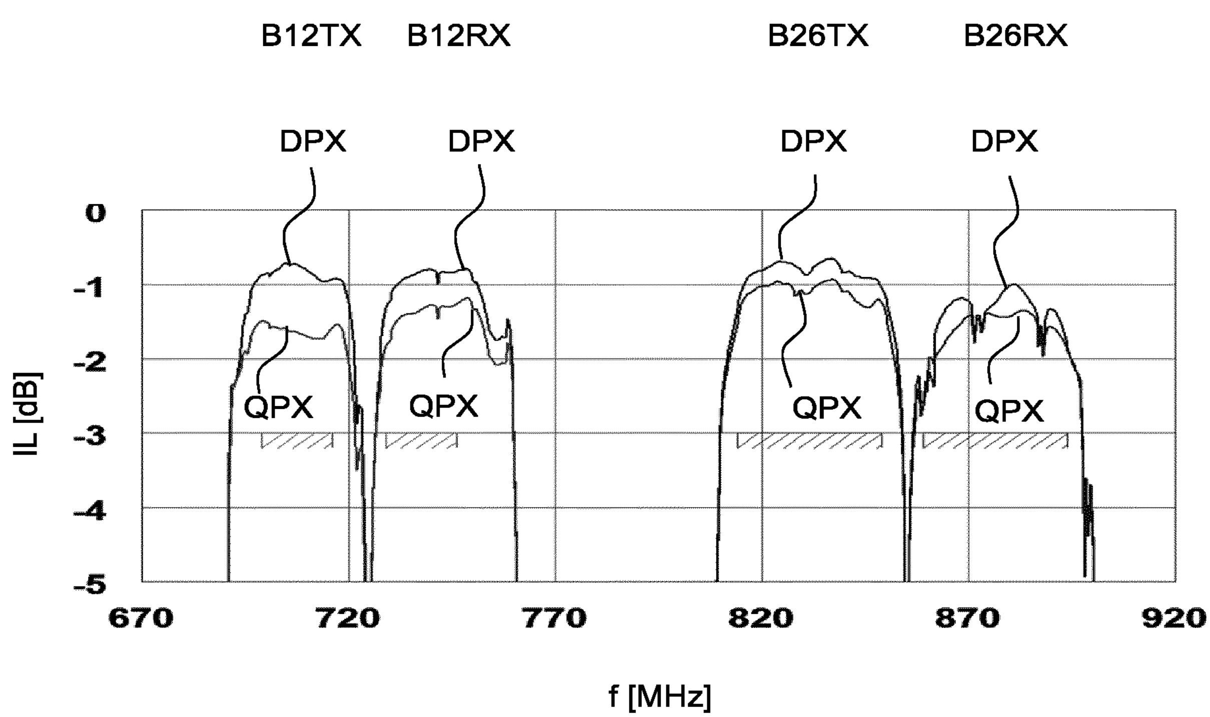
B28ARX
B26TX
B26RX
DPX
DPX
DPX
DPX
QPX
QPX
QPX
QPX
0
-1
-2
-3
-4
-5
IL [dB]
670
720
770
820
870
920
f [MHz]

Fig. 7


B12TX
B12RX
B26TX
B26RX
DPX
DPX
DPX
DPX
QPX
QPX
QPX
QPX
0
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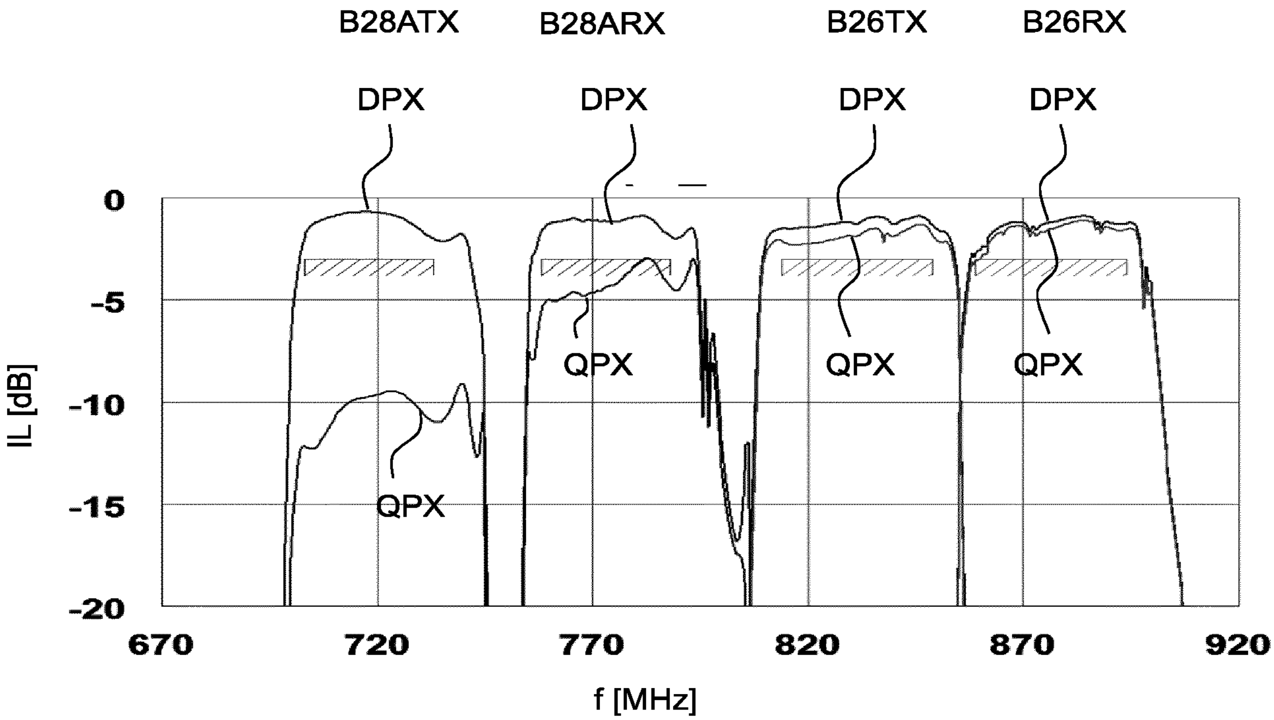
-2
-3
-4
-5
IL [dB]
670
720
770
820
870
920
f [MHz]

Fig. 8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-5
-10
-15
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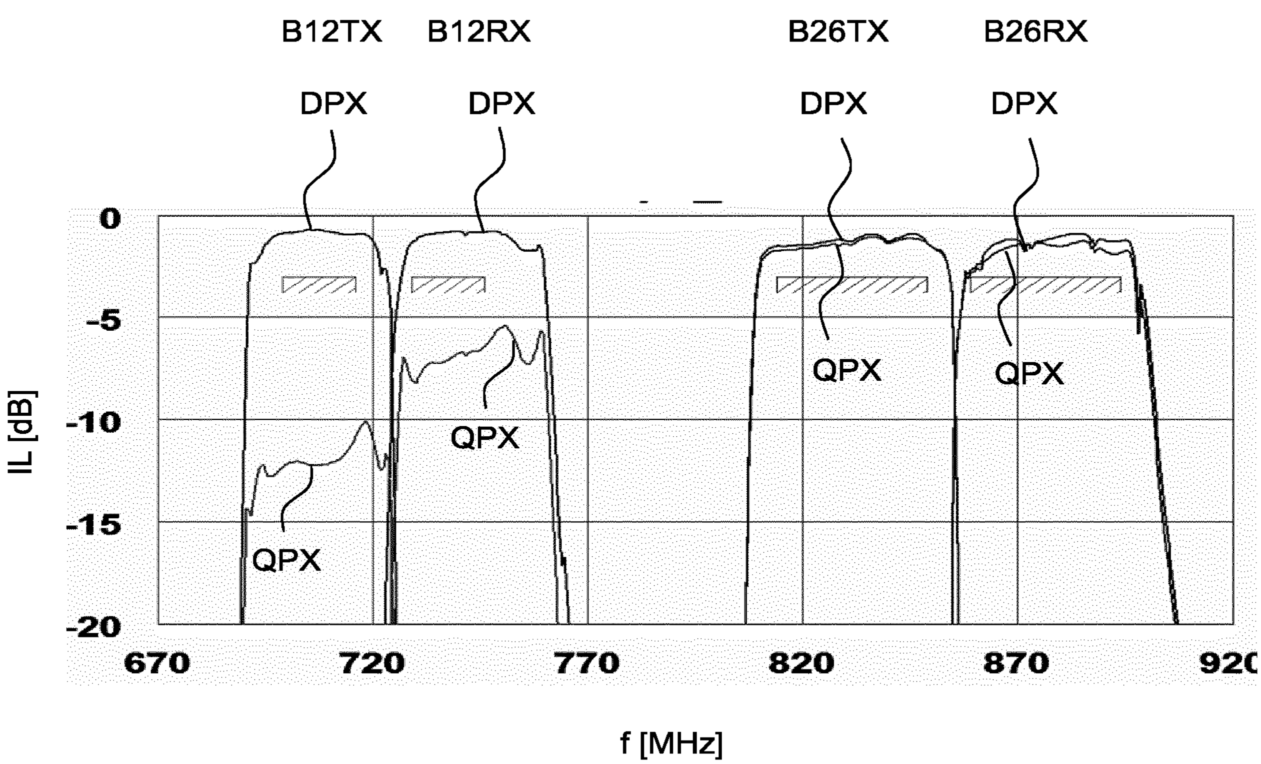
QPX
QPX
QPX
QPX
670
720
770
820
870
920
f [MHz]

Fig. 9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0
-5
-10
-15
-20
IL [dB]
QPX
QPX
QPX
QPX
670
720
770
820
870
920
f [MHz]

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/070183

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03H7/01 H03H9/00 H03H9/70 H03H9/72 H03H7/38
ADD. H04B1/00 H04B1/18

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H03H H04B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2017/170865 A1 (CHEON SEONG JONG [KR]) 15 June 2017 (2017-06-15) paragraphs [0061], [0062]; figure 2 -----	1-3,7-10 6
X A	WO 2016/177617 A1 (EPCOS AG [DE]) 10 November 2016 (2016-11-10) figures 8-12 & US 2018/138929 A1 (ELLÄ JUHA [FI] ET AL) 17 May 2018 (2018-05-17) paragraph [0096] -----	1-4,7-10 6
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search

12 October 2018

Date of mailing of the international search report

24/10/2018

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	DE 10 2017 101602 A1 (AVAGO TECH GENERAL IP PTE LTD [SG]) 3 August 2017 (2017-08-03) figure 4 -----	1-6

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