IEC 62604-2

Edition 3.0 2022-09
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Surface acoustic wave (SAW) and bulk acoustic wave (BAW) duplexers of assessed quality –
Part 2: Guidelines for the use

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FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62604-2:2017. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62604-2 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection. It is an International Standard.

This third edition cancels and replaces the second edition published in 2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the term "cross-isolation" has been added to Clause 3;

b) multiplexers are described.

NOTE In this document, SAW and BAW duplexers are treated simultaneously because both duplexers are used in the same manner, especially in mobile phone systems and have the same requirements of characteristics, test method and so on.

The text of this International Standard is based on the following documents:

Draft	Report on voting
49/1361/CDV	49/1376/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62604 series, published under the general title *Surface acoustic wave (SAW) and bulk acoustic wave (BAW) duplexers of assessed quality*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

While in 2G systems mainly dielectric duplexers have been used, the ongoing miniaturization in 3G and 4G mobile communication systems promoted the development and application of acoustic wave duplexers due to their small size, light weight and good electrical performance. While standard surface acoustic wave (SAW) duplexers have been employed for applications with moderate requirements regarding the steepness of individual filters, applications with narrow duplex gap (e.g. Bands 2, 3, 8, 25), i.e., the frequency gap between receiving and transmitting bands, require the application of temperature-compensated (TC) SAW or bulk acoustic wave (BAW) technology, because of their better temperature characteristics and resonator Q-factors.

Standard specifications, such as those of IEC, of which these guidelines form a part, and national specifications or detail specifications issued by manufacturers will define the available combinations of centre frequency, pass bandwidth and insertion attenuation for each sort of transmitting and receiving filters and the isolation level between transmitter and receiver ports, etc. These specifications are compiled to include a wide range of SAW and BAW duplexers with standardized performances. It cannot be over-emphasized that the user should, wherever possible, select his duplexers from these specifications, when available, even if it can lead to making small modifications to his circuit to enable the use of standard duplexers. This applies particularly to the selection of the nominal frequency band.

SURFACE ACOUSTIC WAVE (SAW) AND BULK ACOUSTIC WAVE (BAW) DUPLEXERS OF ASSESSED QUALITY –

Part 2: Guidelines for the use

1 Scope

This part of IEC 62604 ~~concerns~~ applies to duplexers which can separate receiving signals from transmitting signals and are key components for two-way radio communications, and which are generally used in mobile phone systems compliant with CDMA systems such as N-CDMA in second generation mobile telecommunication systems (2G), W-CDMA / UMTS (3G) or LTE (4G). ~~While in 2G systems mainly dielectric duplexers have been used, the ongoing miniaturization in 3G and 4G mobile communication systems promoted the development and application of acoustic wave duplexers due to their small size, light weight and good electrical performance. While standard surface acoustic wave (SAW) duplexers have been employed for applications with moderate requirements regarding the steepness of individual filters, applications with narrow duplex gap (e.g. Bands 2, 3, 8, 25), i.e. the frequency gap between receiving and transmitting bands, require the application of temperature-compensated (TC) SAW or bulk acoustic wave (BAW) technology, because of their better temperature characteristics and resonator Q-factors.~~

~~It is neither the aim of these guidelines to explain theory, nor to attempt to cover all the eventualities which may arise in practical circumstances.~~ These guidelines draw attention to some ~~of the more~~ fundamental questions about the theory of SAW and BAW duplexers and how to use them, which ~~should~~ will be considered by the user before he places an order for SAW and BAW duplexers for a new application. Such a procedure will be the user's insurance against unsatisfactory performance. Because SAW and BAW duplexers have very similar performance for the usage, it is useful and convenient for users that both duplexers are described in one standard.

~~Standard specifications, such as those of IEC, of which these guidelines form a part, and national specifications or detail specifications issued by manufacturers will define the available combinations of centre frequency, pass bandwidth and insertion attenuation for each sort of transmitting and receiving filters and the isolation level between transmitter and receiver ports, etc. These specifications are compiled to include a wide range of SAW and BAW duplexers with standardized performances. It cannot be over-emphasized that the user should, wherever possible, select his duplexers from these specifications, when available, even if it may lead to making small modifications to his circuit to enable the use of standard duplexers. This applies particularly to the selection of the nominal frequency band.~~

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60862-1~~:2015~~, *Surface acoustic wave (SAW) filters of assessed quality – Part 1: Generic specification*

IEC 62575-1~~:2015~~, *Radio frequency (RF) bulk acoustic wave (BAW) filters of assessed quality – Part 1: Generic specification*

3 Terms and definitions

~~No terms and definitions are listed in this document.~~

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Response characteristics related terms

3.1.1
guard band
unused part of the radio spectrum between radio bands, for the purpose of preventing interference

3.1.2
cross-isolation
leakage power ratio from one of the TX ports to one of the RX ports from another nominal frequency band in a multiplexer

3.2 SAW and BAW duplexers related terms

3.2.1
phase shifter
device which changes the phase of signals, not the frequency of them

Note 1 to entry: This is a basic part of a duplexer.

3.2.2
void
vacancy in the IDT electrode caused by stress migration resulting from diffusing and/or transfer of metal atoms forming part of the electrode

3.2.3
hillock
projection on the side or upper surface of the electrode caused by stress migration resulting from diffusing and/or transfer of metal atoms forming part of the electrode

4 Technical considerations

It is of prime interest to a user that the duplexer characteristics should satisfy particular specifications. The selection of the front-end circuits in user equipment and SAW and BAW duplexers to meet such specifications should be a matter of agreement between the user and the manufacturer.

Duplexer characteristics are usually expressed in terms of centre frequency, pass bandwidth and insertion attenuation for each of transmitting and receiving filter parts in the duplexer and isolation level between the transmitter and receiver ports. Since the SAW and BAW duplexer is used in RF front-end of the user equipment, lower insertion attenuation, higher isolation/rejection level, stronger power durability and smaller/thinner package dimensions are strictly required.

5 Fundamentals of SAW and BAW duplexers

5.1 Basic function

5.1.1 General

Duplexers are necessary for frequency division duplex (FDD) equipment to receive and transmit signals simultaneously. Duplexers are 3-port devices which consist of an antenna port, a transmitter port (TX port) and a receiver port (RX port), as shown in Figure 1. The duplexer has three basic functions:

- to transfer the transmitting signal from the TX port to the antenna port;
- to transfer the receiving signal from the antenna port to the RX port;
- to prevent transfer of the transmitting signal and noise from the TX port to the RX port.

The transmitting and the receiving frequencies are determined corresponding to each mobile communication system. For example, Table 1 shows typical allocated frequency bands for ~~UMTS~~ LTE.

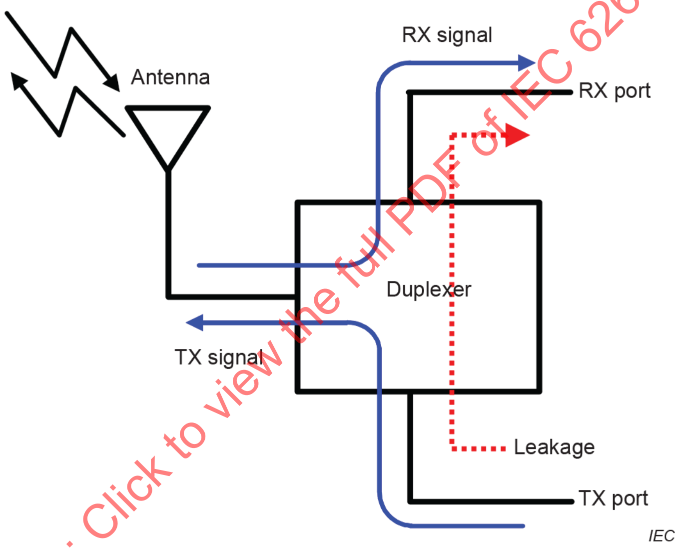


Figure 1 – Basic duplexer configuration

Table 1 – Frequency allocation for typical LTE frequency division duplex (FDD) bands

Band	Uplink frequency (MHz)	Downlink frequency (MHz)	Band	Uplink frequency (MHz)	Downlink frequency (MHz)
1	1 920 – 1 980	2 110 – 2 170	16	2 010 – 2 025	2 585 – 2 600
2	1 850 – 1 910	1 930 – 1 990	17	704 – 716	734 – 746
3	1 710 – 1 785	1 805 – 1 880	18	815 – 830	860 – 875
4	1 710 – 1 755	2 110 – 2 155	19	830 – 845	875 – 890
5	824 – 849	869 – 894	20	832 – 862	791 – 821
6	830 – 840	875 – 885	21	1 447,9 – 1 462,9	1 495,9 – 1 510,9
7	2 500 – 2 570	2 620 – 2 690	22	3 410 – 3 490	3 510 – 3 590
8	880 – 915	925 – 960	23	2 000 – 2 020	2 180 – 2 200
9	1 749,9 – 1 784,9	1 844,9 – 1 879,9	24	1 626,5 – 1 660,5	1 525 – 1 559
10	1 710 – 1 770	2 110 – 2 170	25	1 850 – 1 915	1 930 – 1 995
11	1 427,9 – 1 447,9	1 475,9 – 1 495,9	26	814 – 849	859 – 894
12	699 – 716	729 – 746	27	807 – 824	852 – 869
13	777 – 787	746 – 756	28	703 – 748	758 – 803
14	788 – 798	758 – 768	30	2 305 – 2 315	2 350 – 2 360
15	1 900 – 1 920	2 600 – 2 620	31	452,5 – 457,5	462,5 – 467,5

NOTE For a user equipment, uplink frequency means transmitting frequency and downlink frequency means receiving frequency respectively.

5.1.2 TX filter response (filter response from TX port to antenna port)

Figure 2 shows an example of frequency characteristics of the TX filter. The required frequency characteristics are low insertion attenuation in the transmitting frequency band (f_T), high insertion attenuation in the receiving frequency band (f_R) and good impedance matching.

5.1.3 RX filter response (filter response from antenna port to RX port)

Figure 3 shows an example of frequency characteristics of the RX filter. The required frequency characteristics are low insertion attenuation in the receiving band (f_R) and high insertion attenuation in the transmitting frequency band (f_T).

5.1.4 Isolation (isolation from TX port to RX port)

Figure 4 shows an example of isolation characteristics. One of the important functions for duplexers is isolation characteristics, which show the frequency dependence of the leakage power from the TX port to the RX port.

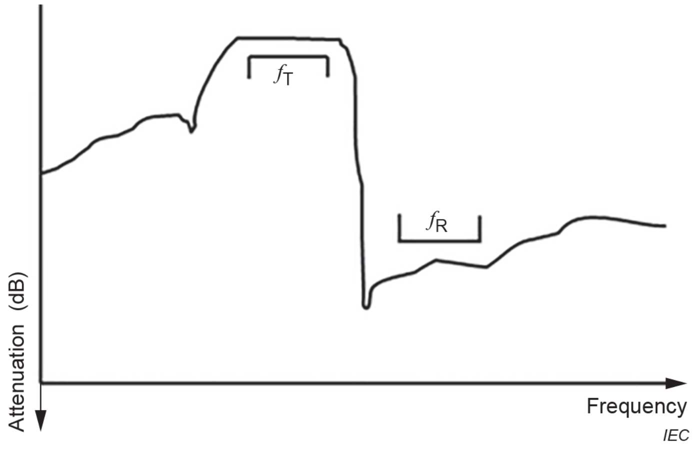


Figure 2 – Basic TX filter response example of SAW and BAW duplexers

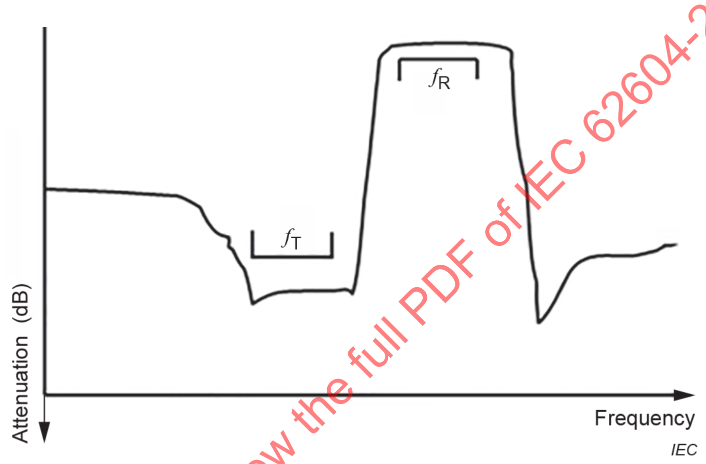


Figure 3 – Basic RX filter response example of SAW and BAW duplexers

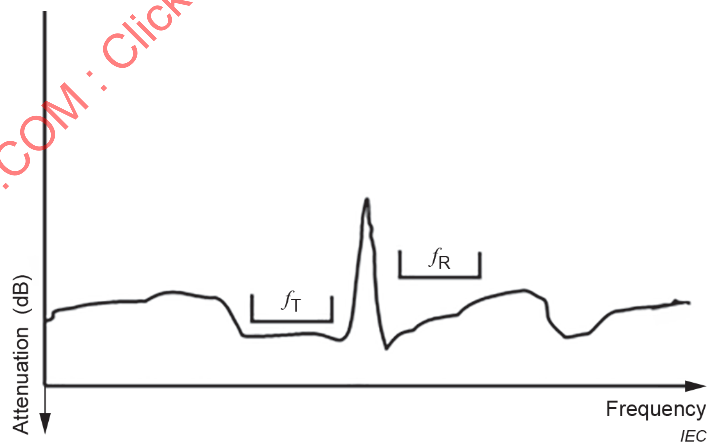


Figure 4 – Basic isolation characteristics example of SAW and BAW duplexers

5.2 Basic structure

Duplexers are 3-port devices/modules, which enable to transmit and receive signals simultaneously through a common antenna. A basic structure of duplexers is shown in Figure 5. SAW and BAW duplexers consist of a transmitter (TX) part and a receiver (RX) part. These two parts, which ~~may~~ can add a phase shifter, are connected to an antenna port. The phase shifter is utilized to prevent the interaction between the filters. In Figure 5, Z_t and Z_r correspond to the impedance of the TX and RX part at the antenna port side, whereas Z_o is the impedance of the antenna port. The following conditions shall be fulfilled to achieve the duplexer functions.

~~$Z_o \cong Z_t$ and $|Z_o|$ << $|Z_r|$ in the TX pass band~~

~~$Z_o \cong Z_r$ and $|Z_o|$ << $|Z_t|$ in the RX pass band~~

$Z_t \cong Z_o$ and $|Z_r|$ >> $|Z_o|$ in the TX pass band

$Z_r \cong Z_o$ and $|Z_t|$ >> $|Z_o|$ in the RX pass band

DMS (double mode SAW) type filters which are also known as LCRF (longitudinally coupled resonator filters)[1], ladder type SAW[2] and BAW filters and other type of SAW filters such as interdigitated interdigital transducer (IIDT) resonator filters[3] can be adopted as TX and RX filters. High power durability is required in the TX filters.

5.3 Principle of operation

In the TX pass band, the impedance of the TX part in the antenna port side (Z_t) is almost the same as that of antenna (Z_o), while that of the RX part (Z_r) is much higher, which means that at the antenna port, the RX part has large reflection coefficient in this band.

~~$Z_o \cong Z_t$ and $|Z_o|$ << $|Z_r|$ in the TX pass band~~

$Z_t \cong Z_o$ and $|Z_r|$ >> $|Z_o|$ in the TX pass band

On the other hand, in the RX pass band, the impedance of the RX part at the antenna port side (Z_r) is almost the same as that of antenna (Z_o), while that of the TX part (Z_t) is much higher. This also means the TX part has large reflection coefficient in this band.

~~$Z_o \cong Z_r$ and $|Z_o|$ << $|Z_t|$ in the RX pass band~~

$Z_r \cong Z_o$ and $|Z_t|$ >> $|Z_o|$ in the RX pass band

[1] See IEC 60862-2:2012, 5.3.

[2] See IEC 60862-2:2012, 5.2.

[3] See IEC 60862-2:2012, 5.4.

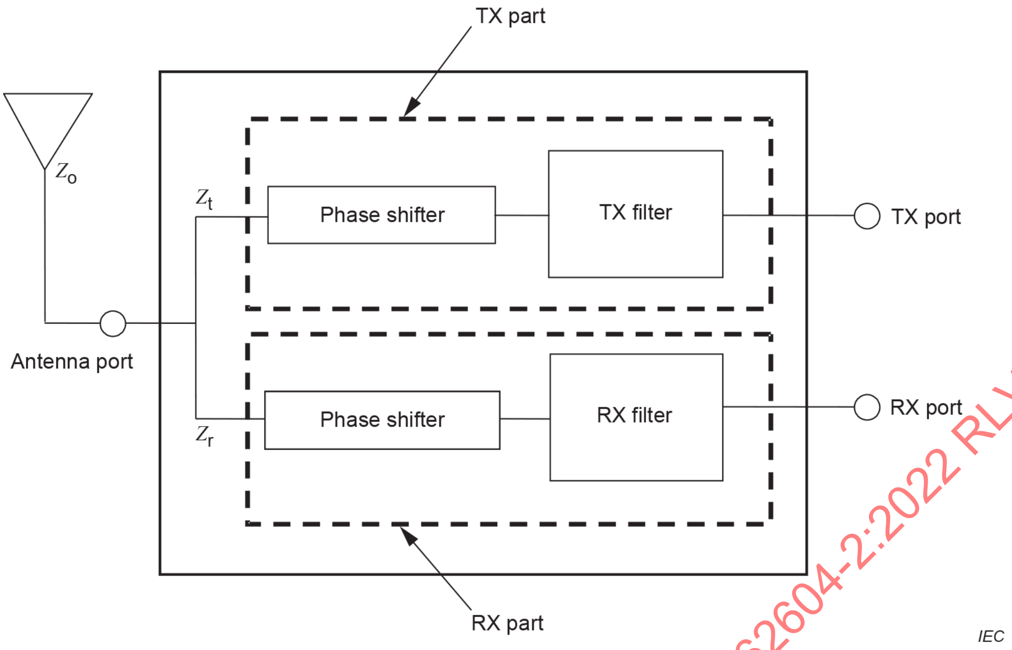
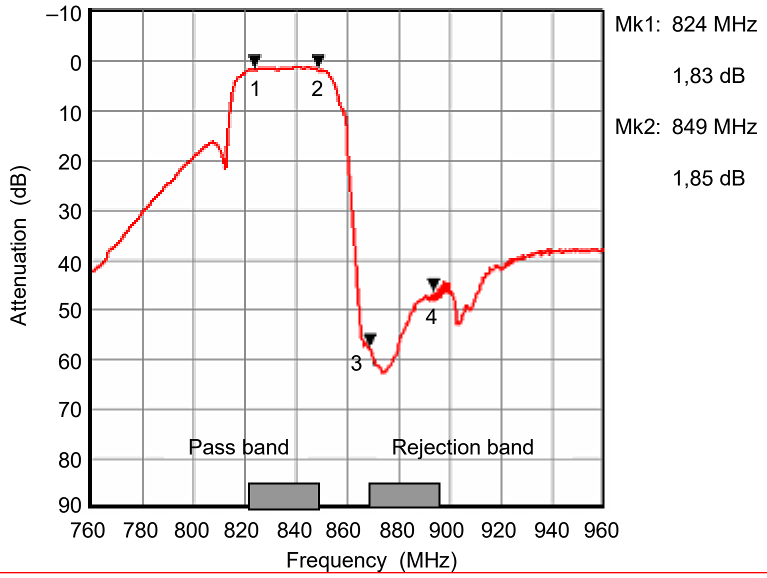
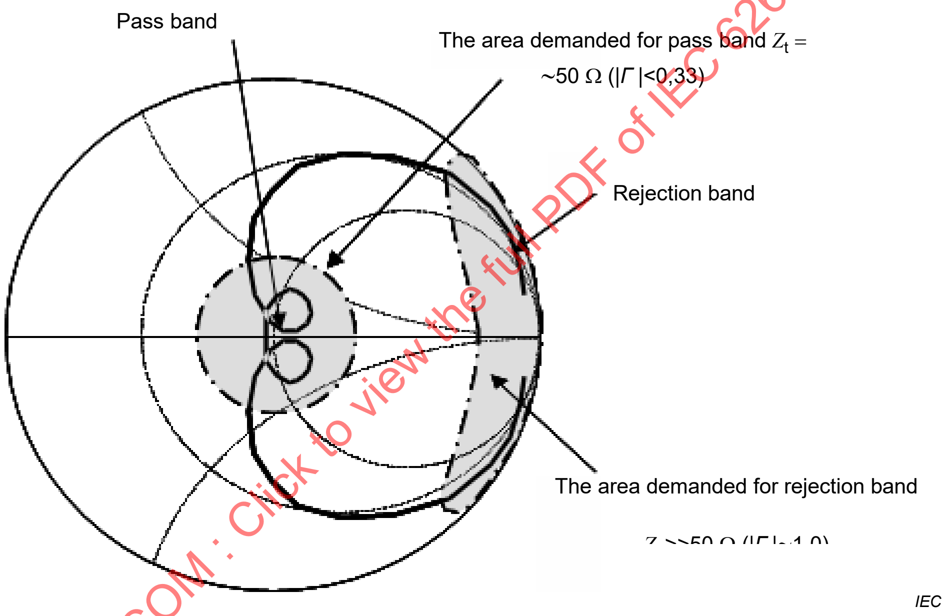


Figure 5 – The block diagram of a duplexer

The transmitting signal applied to the TX port passes through the TX filter and then flows to the antenna port, not the RX filter. The received signal from the antenna port does not flow to the TX filter, but to the RX filter. As a result, the TX part and the RX part can share the common antenna port. In the following explanation, the impedance of the antenna (Z_o) is assumed to be 50 Ω. The S_{11} curve of the TX part at the antenna port side shall satisfy the demanded condition indicated in Figure 6. The impedance of its pass band shall be around 50 Ω. In the rejection band, the impedance shall be sufficiently larger than 50 Ω. In the actual duplexer, the S_{11} trace in the Smith chart of the TX filter is rotated to its optimum state by a phase shifter, as shown in Figure 7. On the other hand, the frequency characteristics of the amplitude of S_{21} remains the same as that without phase shifter. Figure 8 shows the S_{21} frequency characteristics and S_{11} demanded condition of the RX part.


Attenuation (dB)
–10
0
10
20
30
40
50
60
70
80
90
760 780 800 820 840 860 880 900 920 940 960
Frequency (MHz)
1
2
3
4
Pass band
Rejection band
Mk1: 824 MHz
1,83 dB
Mk2: 849 MHz
1,85 dB


Pass band
The area demanded for pass band Z_t =
~50 Ω (|Γ|<0,33)
Rejection band
The area demanded for rejection band
IEC

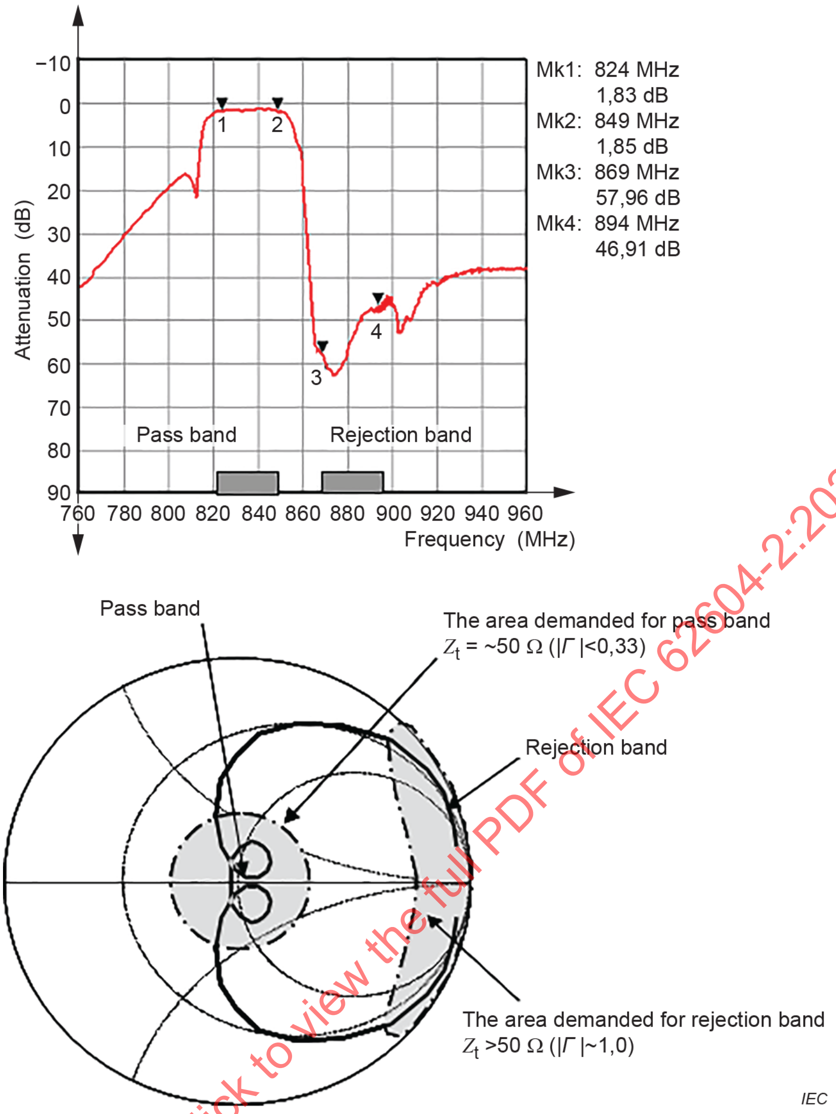


Figure 6 – Demanded condition of TX part for duplexers

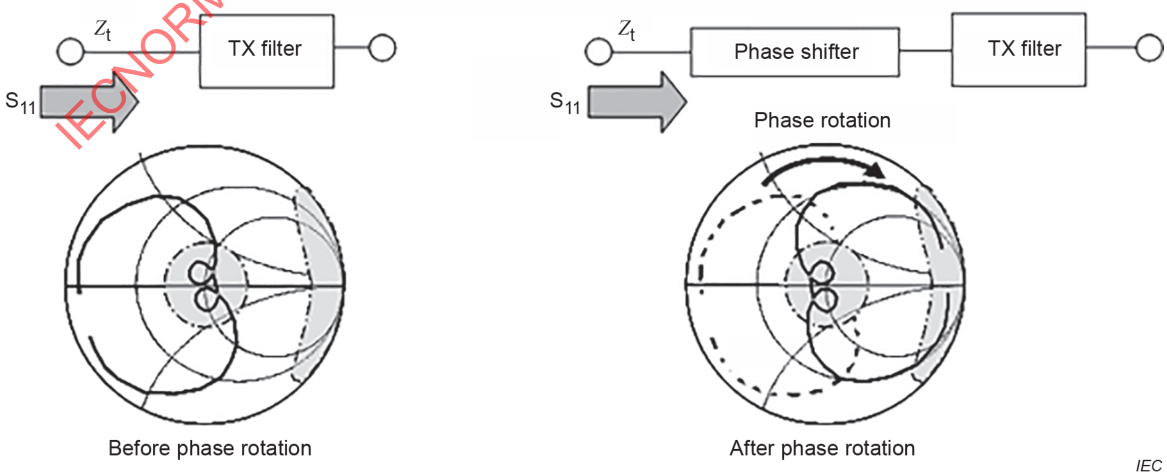
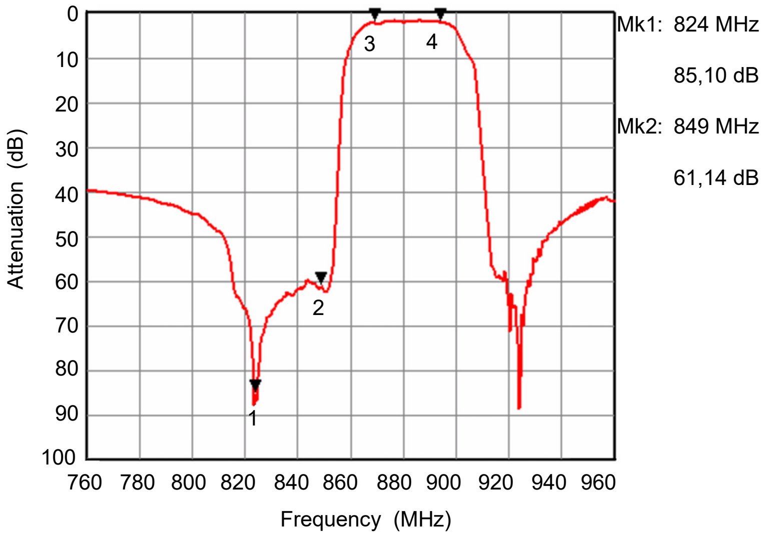
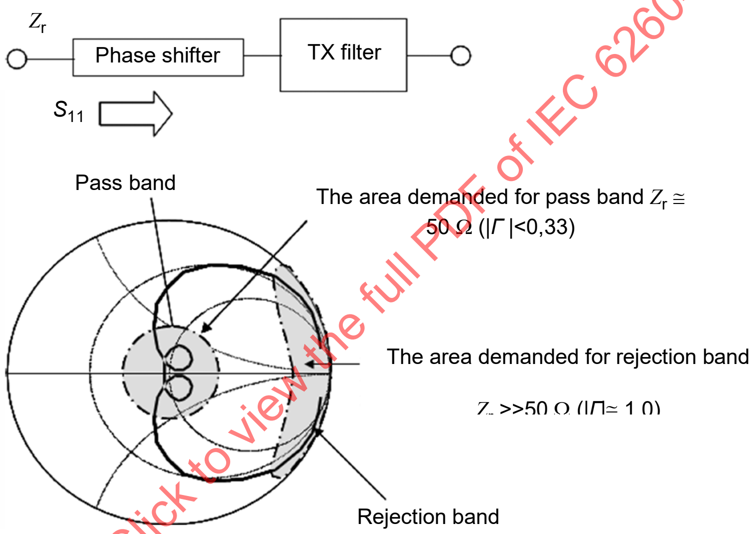


Figure 7 – Phase rotation in TX part


Attenuation (dB)
0
10
20
30
40
50
60
70
80
90
100
760 780 800 820 840 860 880 900 920 940 960
Frequency (MHz)
1
2
3
4
Mk1: 824 MHz
85,10 dB
Mk2: 849 MHz
61,14 dB


Zr
Phase shifter
TX filter
S11
Pass band
The area demanded for pass band Zr ≅ 50 Ω (|Γ|<0,33)
The area demanded for rejection band
Zr >>50 Ω (|Γ|≅ 1,0)
Rejection band

IEC

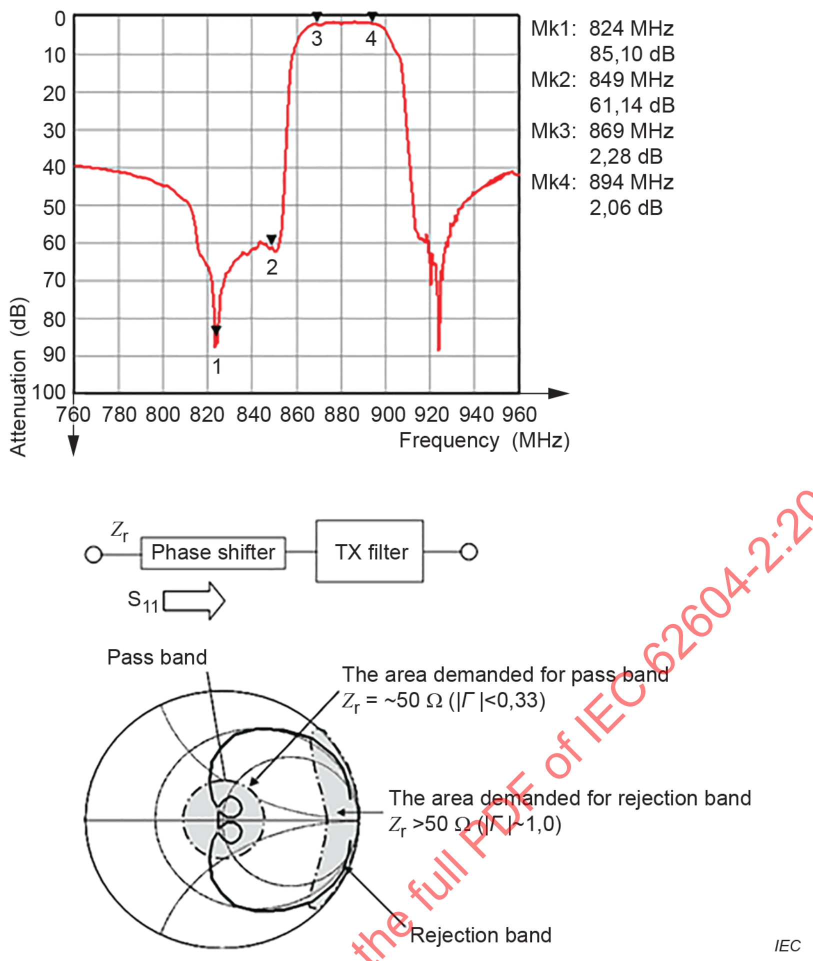


Figure 8 – Demanded condition of RX part for duplexers

5.4 Diplexer

Diplexers combine different frequency domains as shown in Figure 9. They have a structure and an operation principle very similar to those of duplexers.

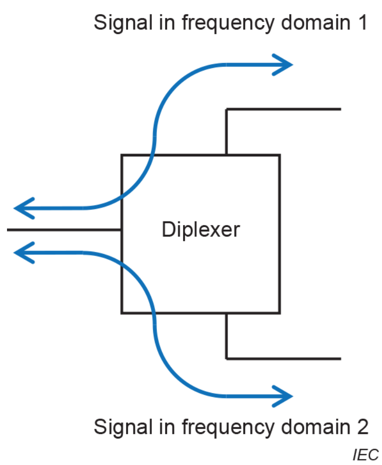
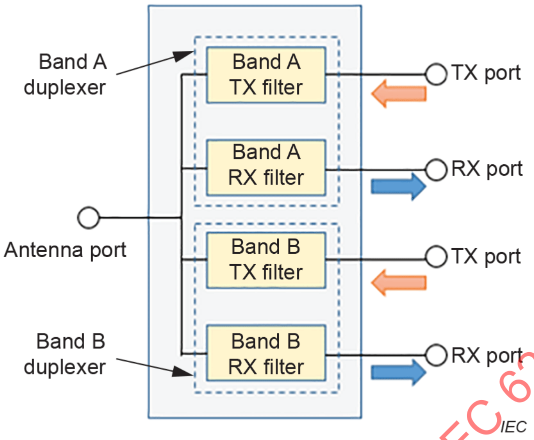


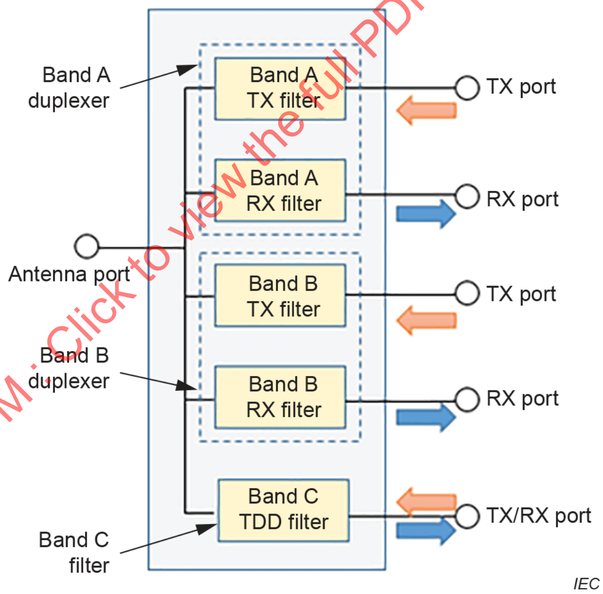
Figure 9 – Basic diplexer configuration

5.5 Multiplexer

Multiplexers combine a duplexer with other duplexers or filters which are used in respective nominal frequency bands. As shown in Figure 10, every duplexer and filter is connected to the common antenna port. In the case of Figure 10 b), a TDD (time division duplex) filter is added to the two duplexers. They have a structure and an operation principle very similar to those of duplexers.



a) Two duplexers combined



b) Two duplexers and one filter combined

Figure 10 – Basic multiplexer configuration

6 SAW and BAW duplexer characteristics

6.1 General conditions for SAW and BAW duplexers

The TX filter, RX filter and phase shifter, which compose SAW and BAW duplexers, as shown in 5.2, are described in Clause 6. The duplexer assembly configuration is also explained here.

– TX filter

The TX filter of the duplexers needs high power durability against the transmitting signal. To ensure the durability against high power, e.g., 1 W, a ladder filter or lattice filter is used for the TX filter because of their higher power durability among several types of SAW and BAW filters. SAW ladder and lattice filters are described in 5.2 of IEC 60862-2:2012 and BAW ladder filters are described in 4.4 of IEC 62575-2:2012.

Besides low insertion attenuation in the TX band (f_T) and high insertion attenuation in the RX band (f_R) described in 5.1, the high attenuation in the second harmonic ($2f_T$) and the third harmonic ($3f_T$) is also important. The attenuation in spurious frequency (f_{SP}) suppresses the inter-modulation signal at $f_R = 2f_T - f_{SP}$. The typical frequency response is shown in Figure 11.

– RX filter

Transmitting power passes through the TX filter and attacks the antenna port side of the RX filter. Filter types used for the TX filter can be adopted for the RX filter, but DMS (double mode SAW) type filters which are also known as LCRF (longitudinally coupled resonator filters) have the possibility of adoption with trap elements to block the transmitting power.

Besides low insertion attenuation in the RX band (f_R) and high insertion attenuation in the TX band (f_T) described in 5.1, a heterodyne receiver with the intermediate frequency (f_{IF}) demands high attenuation in the local oscillation frequency (f_{LO}) and the image frequency ($f_{IM} = f_{LO} + f_{IF}$ for upper local system). The inter-modulation signal in f_R can be reduced by high attenuation in the ~~duplex image frequency ($f_{DIM} = 2f_T - f_R$)~~ frequency of e.g., $2f_T + f_R$, $2f_T - f_R$, $f_R + f_T$ and $f_R - f_T$. The typical frequency response is shown in Figure 12.

– Phase shifter

There are various types of phase shifters according to duplexer configurations and the out-of-band complex impedance of TX and RX filters. To construct the phase shifter of a delay line with the desired electrical length, a stripline is located between the inside layers of a package, or a microstrip line is located on the surface of a package as shown in Figure 13. Figure 14 shows a lumped element phase shifter. A suitable number of lumped elements is not fixed at three. In some cases no phase shifter is necessary.

– Duplexer configuration

Figure 15 shows two types of duplexer configurations. They have merits and demerits with regard to characteristics, size, cost and other items.

Figure 15 a) shows a module type, which mounts SAW and BAW filters and other components on a substrate, such as a printed board. Figure 15 b) shows a device type, which seals the package after mounting SAW and BAW filter bare chips on a package, such as multi-layered ceramics. In those two types, the TX and RX filters/chips are separated from each other, and there is the possibility of a single filter/chip solution.

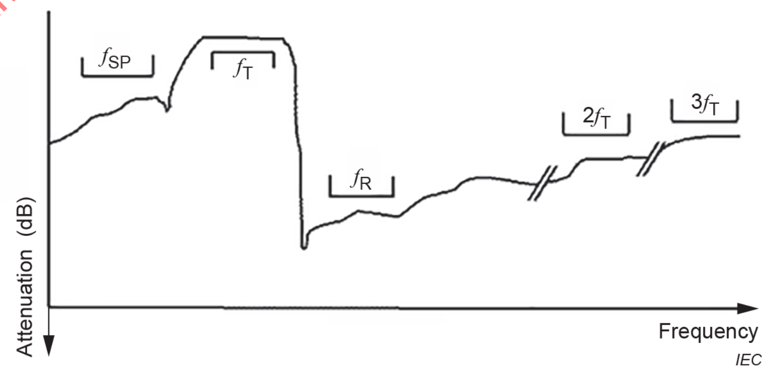
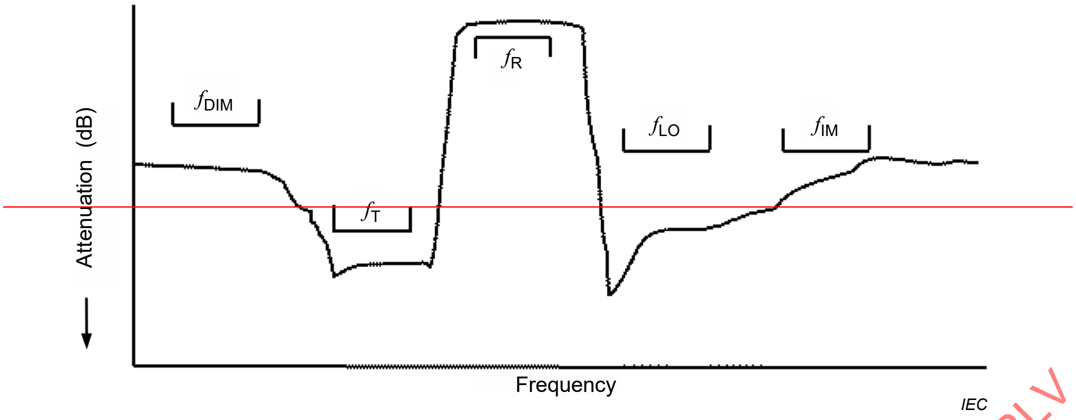


Figure 11 – Typical wide range frequency response of TX filter



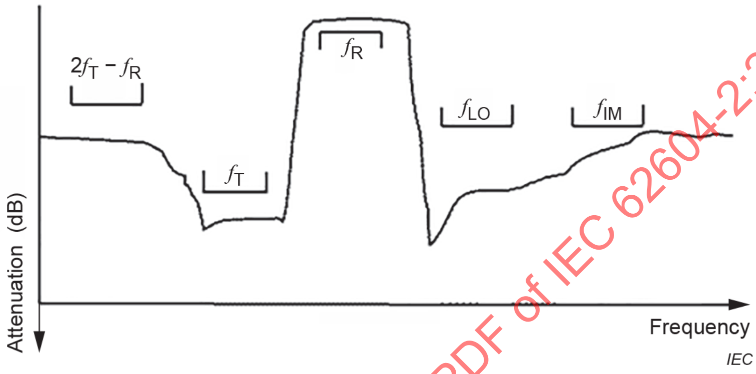


Figure 12 – Typical wide range frequency response of RX filter for upper local system

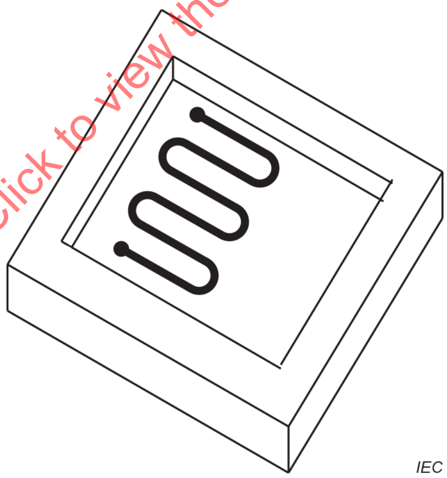


Figure 13 – Phase shifter by microstrip line on the surface of a ceramic package

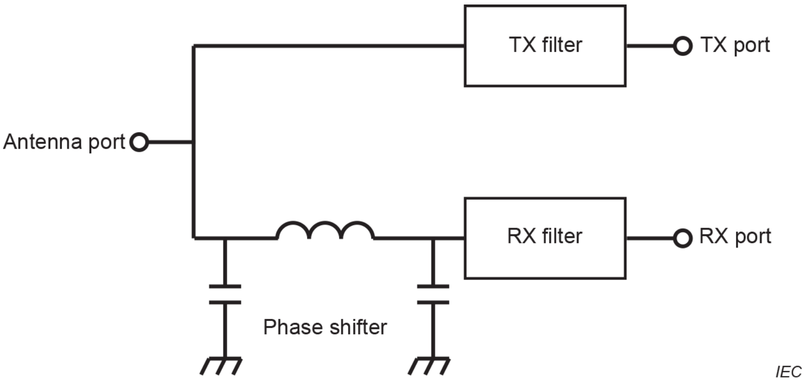
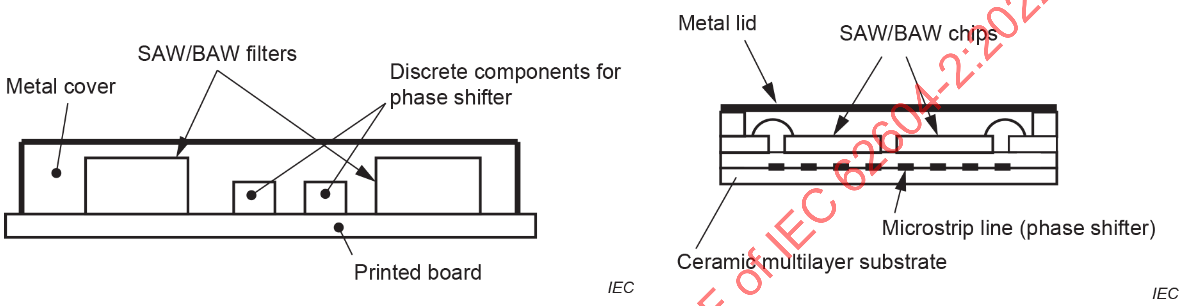


Figure 14 – Lumped element phase shifter



a) Module type b) Device type

Figure 15 – Duplexer configuration

6.2 Typical characteristics of SAW and BAW duplexers

6.2.1 UMTS duplexer

As an example of a duplexer for a UMTS system, a SAW duplexer for UMTS Band 1 is shown in ~~6.2~~ Figure 16. The frequency regulation of Band 1 is provided by a third generation partnership project (3GPP). The transmitter and receiver pass bands in the handset are 1 920 MHz to 1 980 MHz and 2 110 MHz to 2 170 MHz, respectively. Both frequency bands are indicated by f_T and f_R in Figure 16. The size of this duplexer is typically 4,9 mm × 4,9 mm × 1,7 mm. A 41° rotated Y cut X propagated $LiNbO_3$ crystal is used as substrate. The structure of the filter is a ladder (see 5.2 of IEC 60862-2:2012), and the electrode material is made by Al-Ti alloy for high power durability.

Frequency characteristics of this SAW duplexer for UMTS Band 1 are shown in Figure 16. The typical insertion attenuation from the TX port to the antenna port and that from the antenna port to the RX port are 1,4 dB and 2,3 dB, respectively. The isolation values between transmitter and receiver ports are typically 48 dB for the TX band and 40 dB for the RX band.

6.2.2 US CDMA duplexer

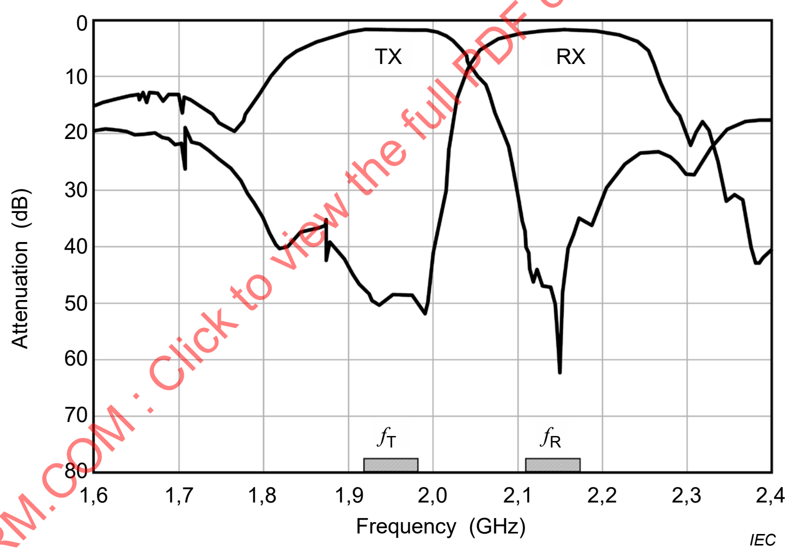
The frequency characteristics example of US CDMA duplexer is shown in Figure 17. This type of duplexer is also applicable to UMTS Band 5. The TX passband frequency is 824 MHz to 849 MHz, while RX passband frequency is 869 MHz to 894 MHz. Both frequency bands are indicated by f_T and f_R in the Figure 17. The dimension of this duplexer is typically 3,8 mm × 3,8 mm × 1,6 mm. Y cut X propagated $LiTaO_3$ with a rotation angle optimized around 36° is used as a substrate. The ladder type SAW filters are used for both TX and RX parts. Typical insertion attenuation is 1,8 dB from TX port to antenna port. And 2,5 dB typical insertion attenuation is from antenna port to RX port. The isolation between TX port and RX port is typically 60 dB for the TX band and 47 dB for the RX band.

6.2.3 PCS CDMA duplexer

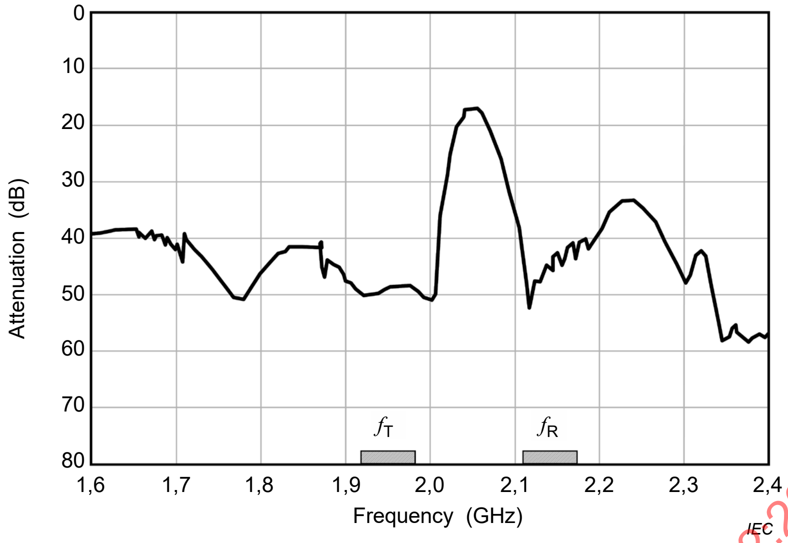
According to Table 1, the guard band or a gap distance between the transmitting and receiving frequencies for UMTS band 2 or PCS band is relatively narrow, and high Q characteristics or a sharp filter response in the transition band is required. From this requirement, BAW duplexers which are composed of film bulk acoustic resonators (FBAR) or solidly mounted resonators (SMR) are mainly used for PCS CDMA duplexers. The frequency characteristics example of a PCS CDMA duplexer using FBAR is shown in Figure 18. The TX passband frequency is 1 850 MHz to 1 910 MHz, while the RX passband frequency is 1 930 MHz to 1 990 MHz. This duplexer can comply with the specified maximum insertion attenuation of 3,5 dB for the TX band and 4,0 dB for the RX band, with excellent transition band responses between the TX and RX bands. Also, the specified minimum isolation values between the transmitter and receiver ports are 54 dB for the TX band and 43 dB for the RX band.

6.2.4 LTE Band 1 + Band 3 multiplexer

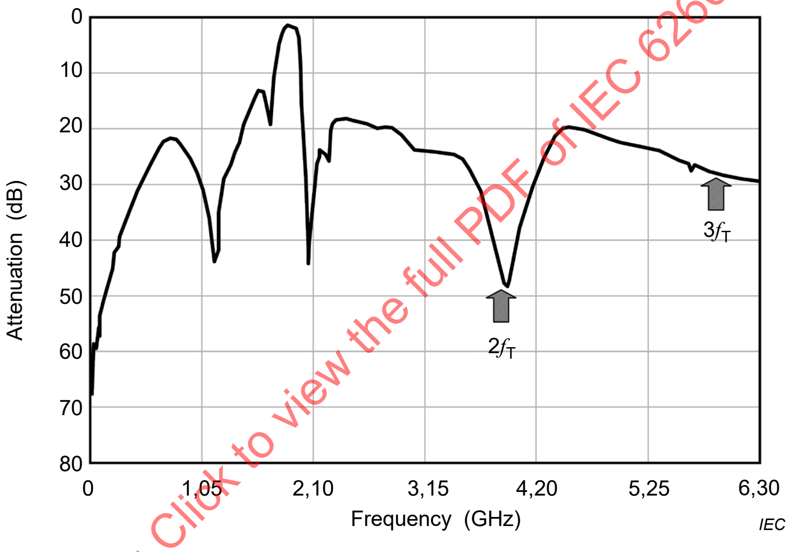
The frequency characteristics example of Band 1 + Band 3 multiplexer using SAW is shown in Figure 19. The frequency regulations of them are shown in Table 1. Cross-isolation is inherent in multiplexer and one of the important functions for the multiplexer. At this example, the cross-isolation values from the Band 1 TX port to the Band 3 Rx port are 59 dB both for the Band 1 TX band and the Band 3 RX band, and the other cross-isolation from the Band 3 TX port to the Band 1 Rx port are 59 dB for the Band 3 TX band and 60 dB for the Band 1 RX band.



a) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (near pass band)

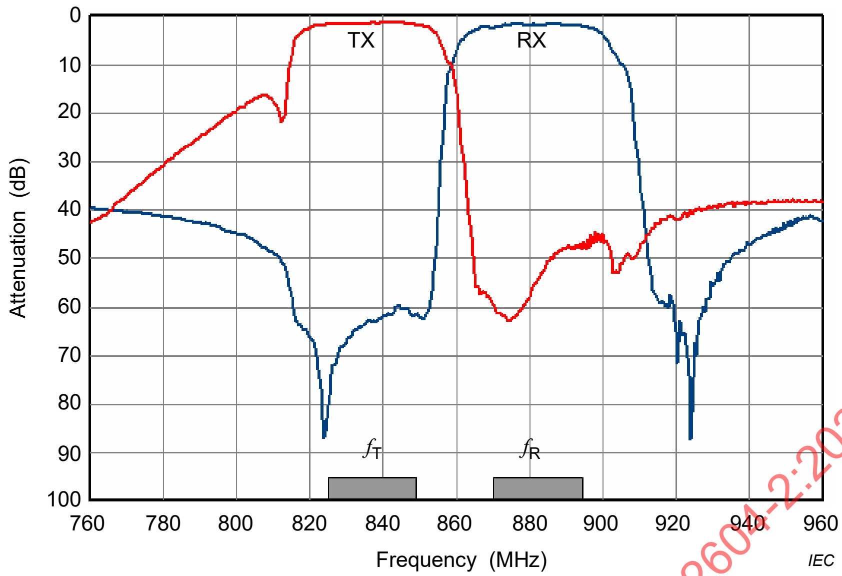


b) Isolation characteristics of the duplexer between RX port and TX port

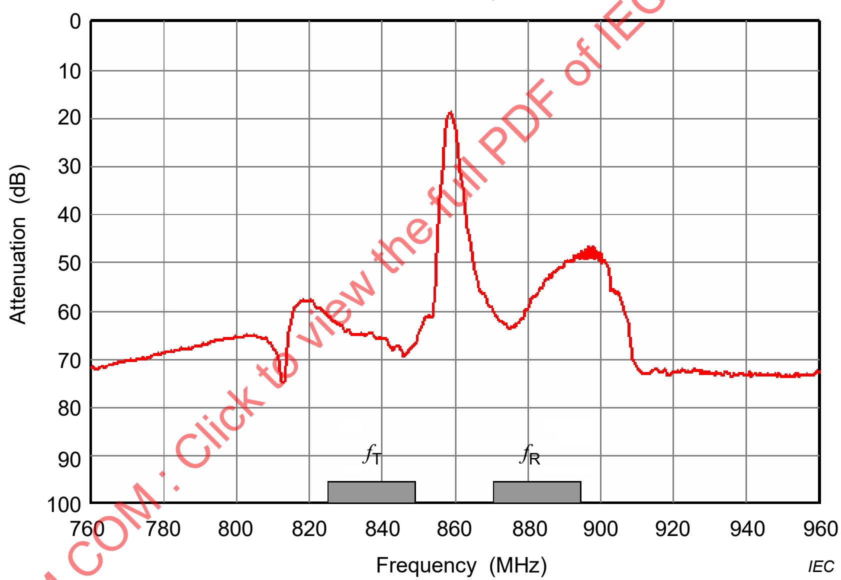


c) Amplitude response of the duplexer from TX port to antenna port (DC to 6 GHz)

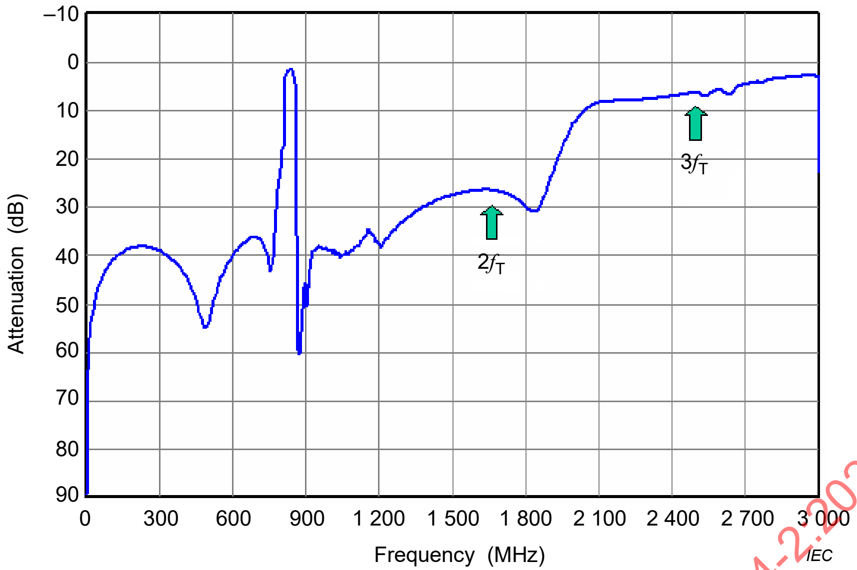
Figure 16 – Frequency characteristics of SAW duplexer for UMTS Band 1 system



a) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (near pass band)

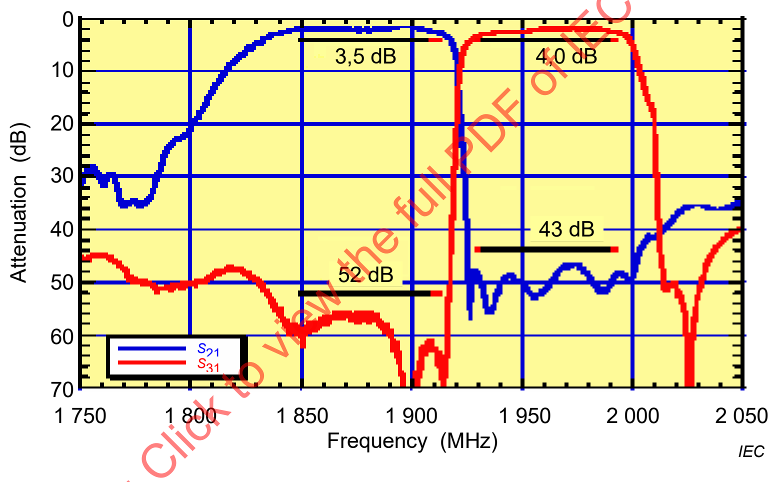


b) Isolation characteristics of the duplexer between RX port and TX port

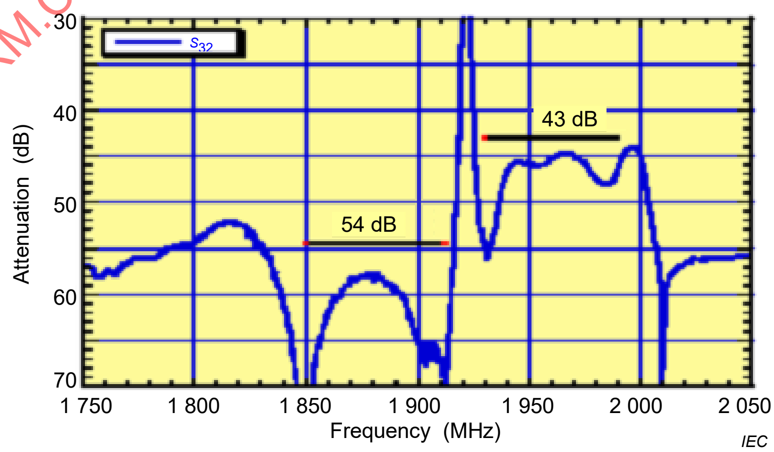


c) Amplitude response of the duplexer from TX port to antenna port (DC to 3 GHz)

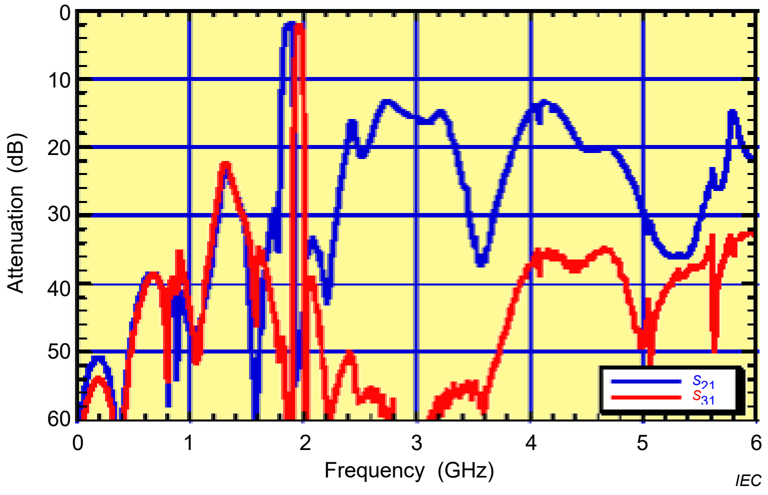
Figure 17 – Frequency characteristics of a SAW duplexer for US CDMA system



a) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (near pass band)



b) Isolation characteristics of the duplexer between RX port and TX port



c) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (DC to 6 GHz)

SOURCE: Reproduced from P.Bradley et al.: *A 6-port Film Bulk Acoustic Resonator (FBAR) Multiplexer For U.S. CDMA Handsets Permitting use of PCS, U.S. CDMA and GPS with a single Antenna*, Proc. IEEE Ultrasonics Symp., pp.325-328, 2006, with the permission of the IEEE.

Figure 18 – Frequency characteristics of BAW duplexer for PCS CDMA system

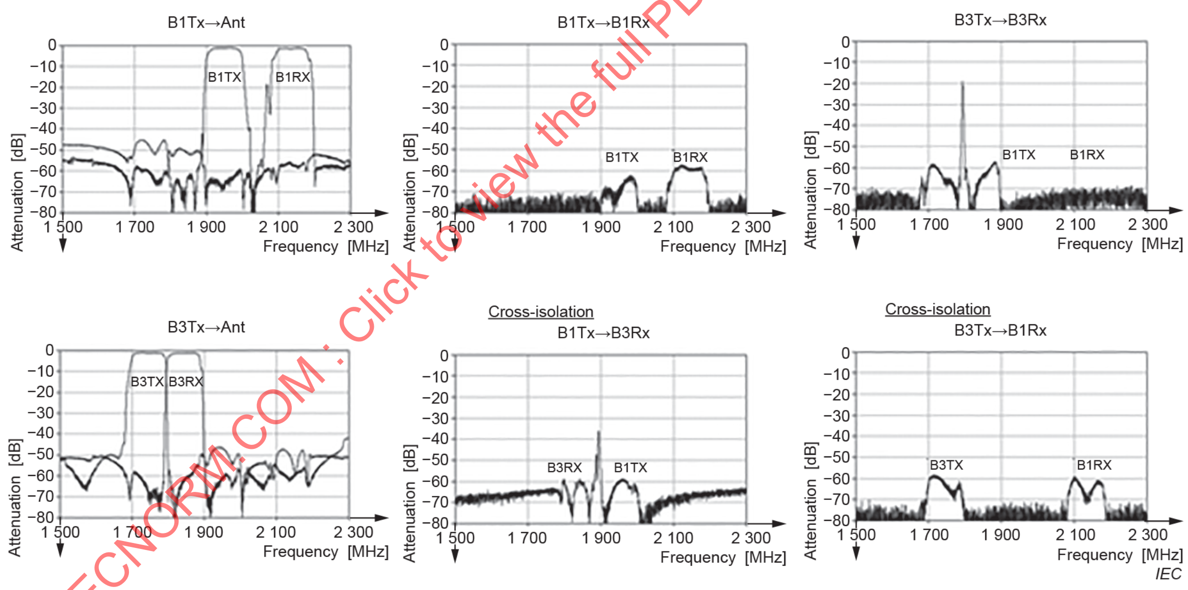


Figure 19 – Frequency characteristics of SAW Band 1 + Band 3 multiplexer for LTE

7 Application guidelines

7.1 Power durability

High power durability of about 1 W is necessary for SAW and BAW duplexers. There are two modes of damage caused by power beyond the durability and the situation is severer for a SAW duplexer than for a BAW duplexer.

The first mode is breakdown. High voltage momentarily destroys SAW electrodes. Input power should be considered to prevent their breakdown.

The second mode is stress migration. The excessive repeated mechanical stress can induce electrode deteriorations, such as voids and hillocks. They cause frequency shift and insertion attenuation degradation of the SAW duplexer.

In order to protect the SAW duplexer from such deteriorations, and to keep the duplexer working for a sufficient amount of time, the drive level shall be less than 1 W. Various technologies of high power durability in SAW devices intended to extend their lifetime have been studied; these are described in 5.5 of IEC 61019-2:2005.

In the case of a BAW duplexer, it is said that its durability is stronger than that of a SAW. However, consideration of the drive level is necessary also for a BAW duplexer. More detailed studies and reports are required technically.

7.2 Harmonics and inter-modulation distortion

Nonlinearity of SAW and BAW duplexers loaded in high power can cause harmonics, which generates unwanted output signals in stop band areas, as shown by Figure 11 and Figure 12. In addition inter-modulation distortion also occurs both in stop band and pass band areas. Detailed technical information is described in 8.5.7 of IEC 60862-1:2015.

7.3 Measurement method for the duplexer

The measurement method shall basically be performed in accordance with the measurement method of IEC 60862-1~~:2015~~ and IEC 62575-1~~:2015~~. However, in the evaluation of the duplexer, the instructions given by the application notes from a vendor should be considered. Because the duplexer is a three-port device, it is recommended to use multi-port-type network analyzers. Figure 20 shows a schematic diagram of the measurement method for a duplexer with a four-port-type network analyzer, as an example.

However, a conventional two-port-type network analyzer can also be used for measuring the characteristics between any two ports chosen from three ports of the duplexer with 50 Ω termination of the unchosen port. ~~A vector voltmeter or other filter test equipment can be also applicable in the same way instead of the network analyzer.~~

If the multiplexer has 5 ports or more, it can be measured in the same way as described above. In other words, the unchosen ports should be connected to 50 Ω termination. It is also convenient to use multi-port-type network analyzers that support more than 5 ports.

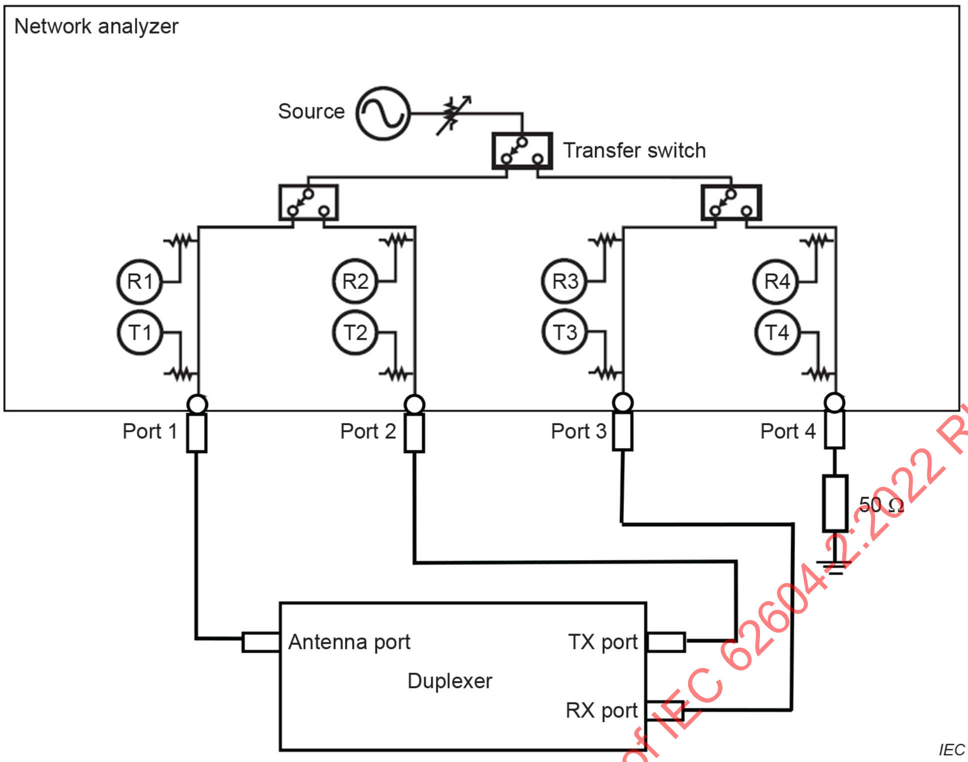


Figure 20 – Four-port-type network analyzer for duplexer measurement

Adopting a balanced connection filter[4] to the RX filter, a duplexer with a balanced RX port will be realized. It can also be evaluated using four-port-type network analyzer as shown in Figure 21.

[4] See IEC 60862-2:2012, 5.3.5.

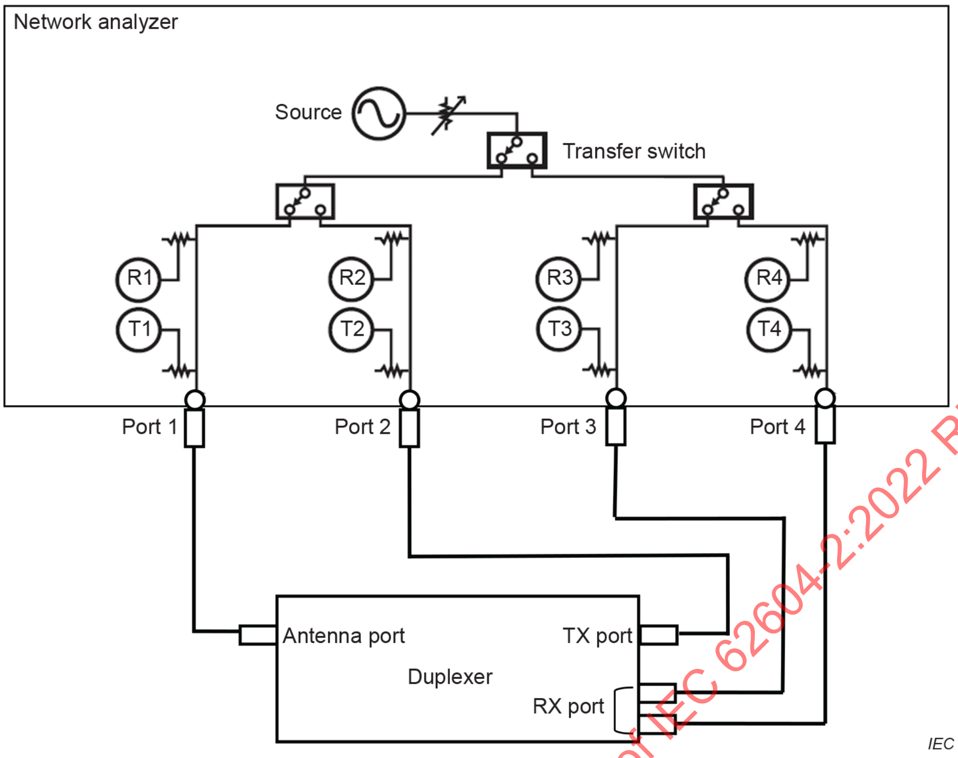


Figure 21 – Four-port-type network analyzer for measurement of a balanced RX port duplexer

7.4 Electrostatic voltage protection

Since the duplexers are used in the front-end of the user equipment, electrostatic overstress (discharge) can easily affect the device's antenna port, and a countermeasure against the static electricity is generally required, particularly for SAW duplexers. As the electrode gap of IDT in the SAW duplexer is very narrow, especially for the high frequency range, and it might be a cause of degradation or destruction to apply static electricity to a SAW duplexer, it is necessary to be careful not to apply static electricity or excessive voltage while transporting, assembling and measuring.

If the piezoelectric material of duplexers has large pyro-electricity, excessive voltage can occur during rapid temperature changes. In order to prevent such an occurrence, it is necessary to take care not to add any thermal shock. In the soldering process, adequate preheating is effective.

Bibliography

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IEC 61019-1:2004, *Surface acoustic wave (SAW) resonators – Part 1: Generic specification*

IEC 61019-2:2005, *Surface acoustic wave (SAW) resonators – Part 2: Guide to the use*

IEC 62047-7:2011, *Semiconductor devices – Micro-electromechanical devices – Part 7: MEMS BAW filter and duplexer for radio frequency control and selection*

IEC 62575-2:2012, *Radio frequency (RF) bulk acoustic wave (BAW) filters of assessed quality – Part 2: Guidelines for the use*

IEC 62604-1, *Surface acoustic wave (SAW) and bulk acoustic wave (BAW) duplexers of assessed quality – Part 1: Generic specification*

P. Bradley et al.: "A 6-port Film Bulk Acoustic Resonator (FBAR) Multiplexer For U.S. CDMA Handsets Permitting use of PCS, U.S. CDMA and GPS with a single Antenna", Proc. IEEE Ultrasonics Symp., pp.325-328, 2006.

IEC 62604-2

Edition 3.0 2022-09

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Surface acoustic wave (SAW) and bulk acoustic wave (BAW) duplexers of assessed quality –
Part 2: Guidelines for the use

Duplexeurs à ondes acoustiques de surface (OAS) et à ondes acoustiques de volume (OAV) sous assurance de la qualité –
Partie 2: Lignes directrices d'utilisation

IEC 62604-2:2022-09(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SURFACE ACOUSTIC WAVE (SAW) AND BULK ACOUSTIC WAVE (BAW) DUPLEXERS OF ASSESSED QUALITY –

Part 2: Guidelines for the use

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62604-2 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection. It is an International Standard.

This third edition cancels and replaces the second edition published in 2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the term "cross-isolation" has been added to Clause 3;
b) multiplexers are described.

NOTE In this document, SAW and BAW duplexers are treated simultaneously because both duplexers are used in the same manner, especially in mobile phone systems and have the same requirements of characteristics, test method and so on.

The text of this International Standard is based on the following documents:

Draft	Report on voting
49/1361/CDV	49/1376/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62604 series, published under the general title *Surface acoustic wave (SAW) and bulk acoustic wave (BAW) duplexers of assessed quality*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

While in 2G systems mainly dielectric duplexers have been used, the ongoing miniaturization in 3G and 4G mobile communication systems promoted the development and application of acoustic wave duplexers due to their small size, light weight and good electrical performance. While standard surface acoustic wave (SAW) duplexers have been employed for applications with moderate requirements regarding the steepness of individual filters, applications with narrow duplex gap (e.g. Bands 2, 3, 8, 25), i.e., the frequency gap between receiving and transmitting bands, require the application of temperature-compensated (TC) SAW or bulk acoustic wave (BAW) technology, because of their better temperature characteristics and resonator Q-factors.

Standard specifications, such as those of IEC, of which these guidelines form a part, and national specifications or detail specifications issued by manufacturers will define the available combinations of centre frequency, pass bandwidth and insertion attenuation for each sort of transmitting and receiving filters and the isolation level between transmitter and receiver ports, etc. These specifications are compiled to include a wide range of SAW and BAW duplexers with standardized performances. It cannot be over-emphasized that the user should, wherever possible, select his duplexers from these specifications, when available, even if it can lead to making small modifications to his circuit to enable the use of standard duplexers. This applies particularly to the selection of the nominal frequency band.

SURFACE ACOUSTIC WAVE (SAW) AND BULK ACOUSTIC WAVE (BAW) DUPLEXERS OF ASSESSED QUALITY –

Part 2: Guidelines for the use

1 Scope

This part of IEC 62604 applies to duplexers which can separate receiving signals from transmitting signals and are key components for two-way radio communications, and which are generally used in mobile phone systems compliant with CDMA systems such as N-CDMA in second generation mobile telecommunication systems (2G), W-CDMA / UMTS (3G) or LTE (4G).

These guidelines draw attention to some fundamental questions about the theory of SAW and BAW duplexers and how to use them, which will be considered by the user before he places an order for SAW and BAW duplexers for a new application. Such a procedure will be the user's insurance against unsatisfactory performance. Because SAW and BAW duplexers have very similar performance for the usage, it is useful and convenient for users that both duplexers are described in one standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60862-1, *Surface acoustic wave (SAW) filters of assessed quality – Part 1: Generic specification*

IEC 62575-1, *Radio frequency (RF) bulk acoustic wave (BAW) filters of assessed quality – Part 1: Generic specification*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Response characteristics related terms

3.1.1
guard band
unused part of the radio spectrum between radio bands, for the purpose of preventing interference

3.1.2
cross-isolation
leakage power ratio from one of the TX ports to one of the RX ports from another nominal frequency band in a multiplexer

3.2 SAW and BAW duplexers related terms

3.2.1
phase shifter
device which changes the phase of signals, not the frequency of them

Note 1 to entry: This is a basic part of a duplexer.

3.2.2
void
vacancy in the IDT electrode caused by stress migration resulting from diffusing and/or transfer of metal atoms forming part of the electrode

3.2.3
hillock
projection on the side or upper surface of the electrode caused by stress migration resulting from diffusing and/or transfer of metal atoms forming part of the electrode

4 Technical considerations

It is of prime interest to a user that the duplexer characteristics should satisfy particular specifications. The selection of the front-end circuits in user equipment and SAW and BAW duplexers to meet such specifications should be a matter of agreement between the user and the manufacturer.

Duplexer characteristics are usually expressed in terms of centre frequency, pass bandwidth and insertion attenuation for each of transmitting and receiving filter parts in the duplexer and isolation level between the transmitter and receiver ports. Since the SAW and BAW duplexer is used in RF front-end of the user equipment, lower insertion attenuation, higher isolation/rejection level, stronger power durability and smaller/thinner package dimensions are strictly required.

5 Fundamentals of SAW and BAW duplexers

5.1 Basic function

5.1.1 General

Duplexers are necessary for frequency division duplex (FDD) equipment to receive and transmit signals simultaneously. Duplexers are 3-port devices which consist of an antenna port, a transmitter port (TX port) and a receiver port (RX port), as shown in Figure 1. The duplexer has three basic functions:

- to transfer the transmitting signal from the TX port to the antenna port;
- to transfer the receiving signal from the antenna port to the RX port;
- to prevent transfer of the transmitting signal and noise from the TX port to the RX port.

The transmitting and the receiving frequencies are determined corresponding to each mobile communication system. For example, Table 1 shows typical allocated frequency bands for LTE.

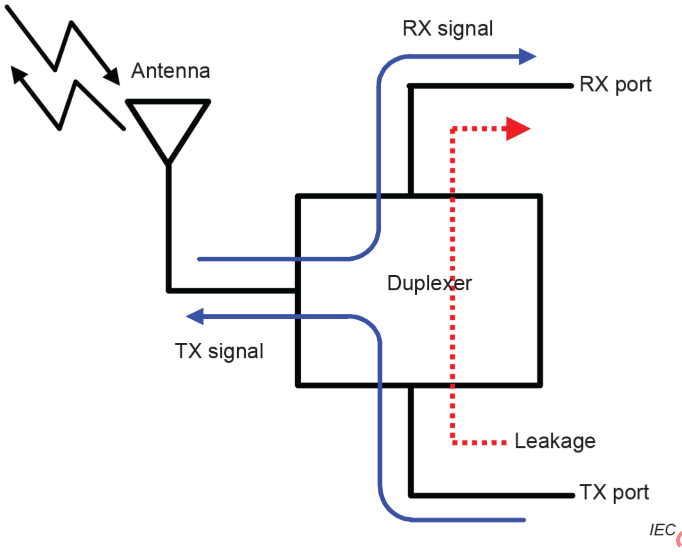


Figure 1 – Basic duplexer configuration

Table 1 – Frequency allocation for typical LTE frequency division duplex (FDD) bands

Band	Uplink frequency (MHz)	Downlink frequency (MHz)	Band	Uplink frequency (MHz)	Downlink frequency (MHz)
1	1 920 – 1 980	2 110 – 2 170	16	2 010 – 2 025	2 585 – 2 600
2	1 850 – 1 910	1 930 – 1 990	17	704 – 716	734 – 746
3	1 710 – 1 785	1 805 – 1 880	18	815 – 830	860 – 875
4	1 710 – 1 755	2 110 – 2 155	19	830 – 845	875 – 890
5	824 – 849	869 – 894	20	832 – 862	791 – 821
6	830 – 840	875 – 885	21	1 447,9 – 1 462,9	1 495,5 – 1 510,9
7	2 500 – 2 570	2 620 – 2 690	22	3 410 – 3 490	3 510 – 3 590
8	880 – 915	925 – 960	23	2 000 – 2 020	2 180 – 2 200
9	1 749,9 – 1 784,9	1 844,9 – 1 879,9	24	1 626,5 – 1 660,5	1 525 – 1 559
10	1 710 – 1 770	2 110 – 2 170	25	1 850 – 1 915	1 930 – 1 995
11	1 427,9 – 1 447,9	1 475,9 – 1 495,9	26	814 – 849	859 – 894
12	699 – 716	729 – 746	27	807 – 824	852 – 869
13	777 – 787	746 – 756	28	703 – 748	758 – 803
14	788 – 798	758 – 768	30	2 305 – 2 315	2 350 – 2 360
15	1 900 – 1 920	2 600 – 2 620	31	452,5 – 457,5	462,5 – 467,5

NOTE For a user equipment, uplink frequency means transmitting frequency and downlink frequency means receiving frequency respectively.

5.1.2 TX filter response (filter response from TX port to antenna port)

Figure 2 shows an example of frequency characteristics of the TX filter. The required frequency characteristics are low insertion attenuation in the transmitting frequency band (f_T), high insertion attenuation in the receiving frequency band (f_R) and good impedance matching.

5.1.3 RX filter response (filter response from antenna port to RX port)

Figure 3 shows an example of frequency characteristics of the RX filter. The required frequency characteristics are low insertion attenuation in the receiving band (f_R) and high insertion attenuation in the transmitting frequency band (f_T).

5.1.4 Isolation (isolation from TX port to RX port)

Figure 4 shows an example of isolation characteristics. One of the important functions for duplexers is isolation characteristics, which show the frequency dependence of the leakage power from the TX port to the RX port.

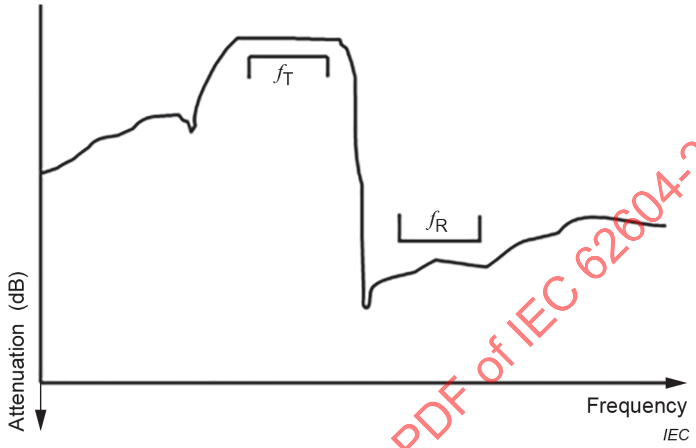


Figure 2 – Basic TX filter response example of SAW and BAW duplexers

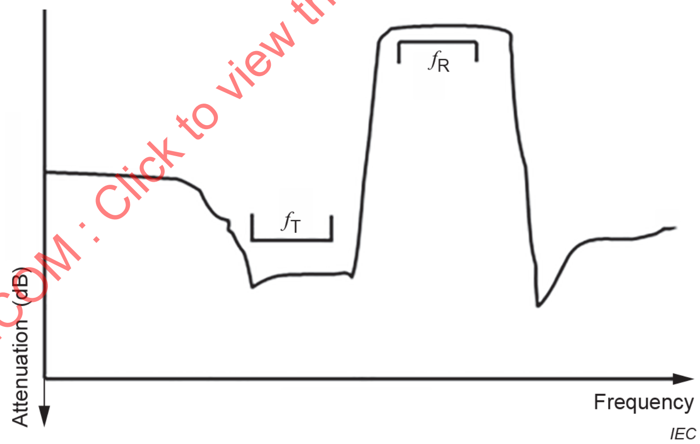


Figure 3 – Basic RX filter response example of SAW and BAW duplexers

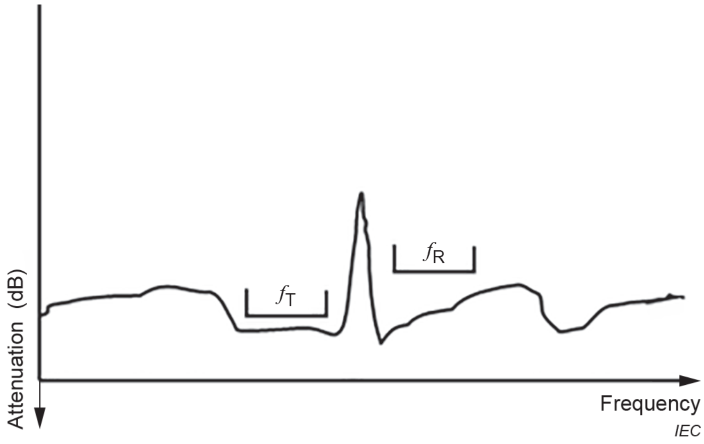


Figure 4 – Basic isolation characteristics example of SAW and BAW duplexers

5.2 Basic structure

Duplexers are 3-port devices/modules, which enable to transmit and receive signals simultaneously through a common antenna. A basic structure of duplexers is shown in Figure 5. SAW and BAW duplexers consist of a transmitter (TX) part and a receiver (RX) part. These two parts, which can add a phase shifter, are connected to an antenna port. The phase shifter is utilized to prevent the interaction between the filters. In Figure 5, Z_t and Z_r correspond to the impedance of the TX and RX part at the antenna port side, whereas Z_o is the impedance of the antenna port. The following conditions shall be fulfilled to achieve the duplexer functions.

$$Z_t \cong Z_o \text{ and } |Z_r| >> |Z_o| \quad \text{in the TX pass band}$$

$$Z_r \cong Z_o \text{ and } |Z_t| >> |Z_o| \quad \text{in the RX pass band}$$

DMS (double mode SAW) type filters which are also known as LCRF (longitudinally coupled resonator filters)[1], ladder type SAW[2] and BAW filters and other type of SAW filters such as interdigitated interdigital transducer (IIDT) resonator filters[3] can be adopted as TX and RX filters. High power durability is required in the TX filters.

5.3 Principle of operation

In the TX pass band, the impedance of the TX part in the antenna port side (Z_t) is almost the same as that of antenna (Z_o), while that of the RX part (Z_r) is much higher, which means that at the antenna port, the RX part has large reflection coefficient in this band.

$$Z_t \cong Z_o \text{ and } |Z_r| >> |Z_o| \quad \text{in the TX pass band}$$

On the other hand, in the RX pass band, the impedance of the RX part at the antenna port side (Z_r) is almost the same as that of antenna (Z_o), while that of the TX part (Z_t) is much higher. This also means the TX part has large reflection coefficient in this band.

1) See IEC 60862-2:2012, 5.3.

2) See IEC 60862-2:2012, 5.2.

3) See IEC 60862-2:2012, 5.4.

$Z_r \cong Z_o$ and $|Z_t| >> |Z_o|$ in the RX pass band

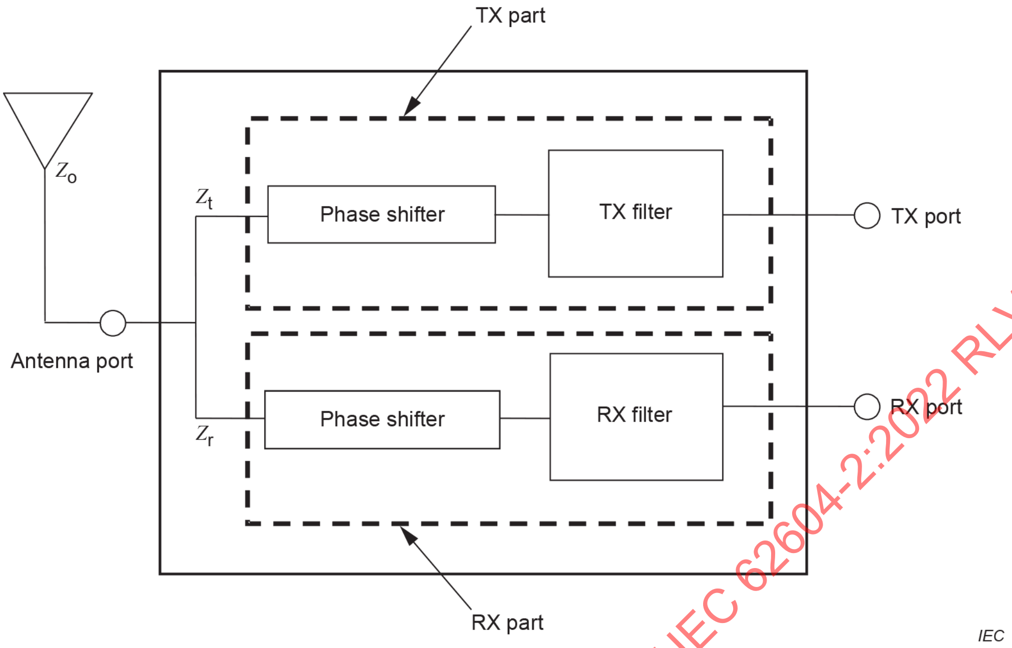


Figure 5 – The block diagram of a duplexer

The transmitting signal applied to the TX port passes through the TX filter and then flows to the antenna port, not the RX filter. The received signal from the antenna port does not flow to the TX filter, but to the RX filter. As a result, the TX part and the RX part can share the common antenna port. In the following explanation, the impedance of the antenna (Z_o) is assumed to be 50 Ω. The S_{11} curve of the TX part at the antenna port side shall satisfy the demanded condition indicated in Figure 6. The impedance of its pass band shall be around 50 Ω. In the rejection band, the impedance shall be sufficiently larger than 50 Ω. In the actual duplexer, the S_{11} trace in the Smith chart of the TX filter is rotated to its optimum state by a phase shifter, as shown in Figure 7. On the other hand, the frequency characteristics of the amplitude of S_{21} remains the same as that without phase shifter. Figure 8 shows the S_{21} frequency characteristics and S_{11} demanded condition of the RX part.

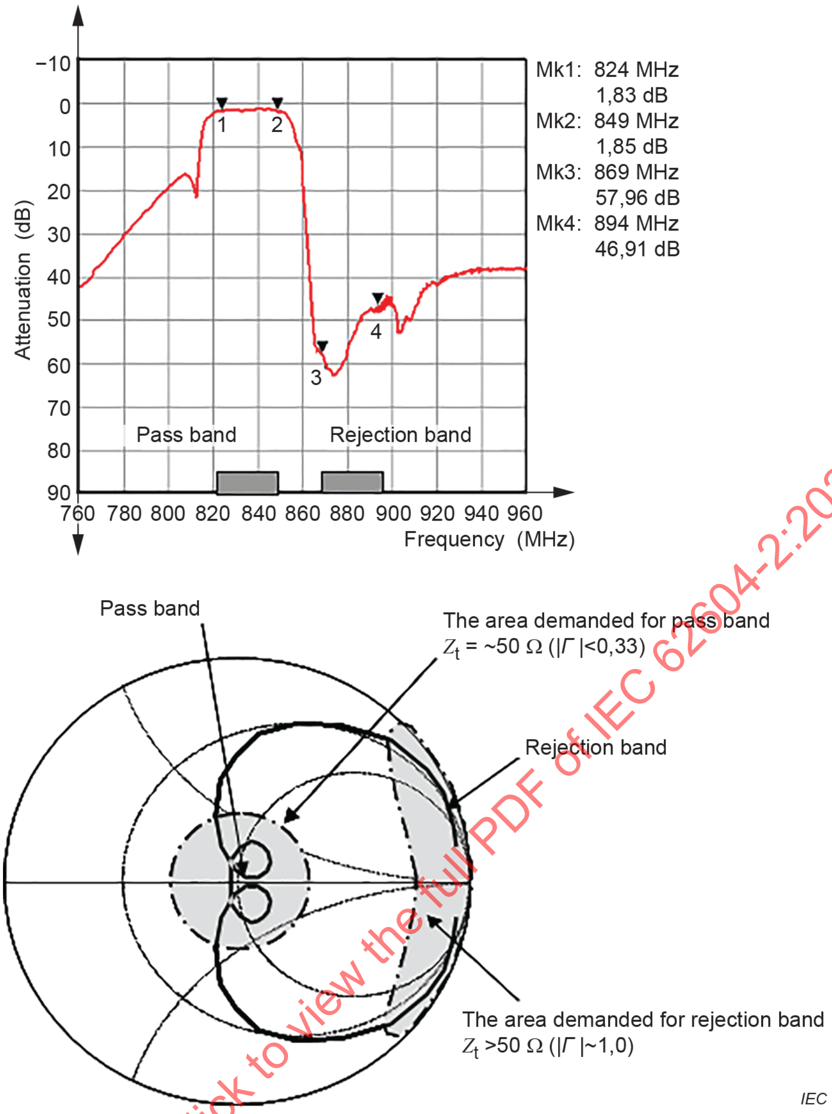


Figure 6 – Demanded condition of TX part for duplexers

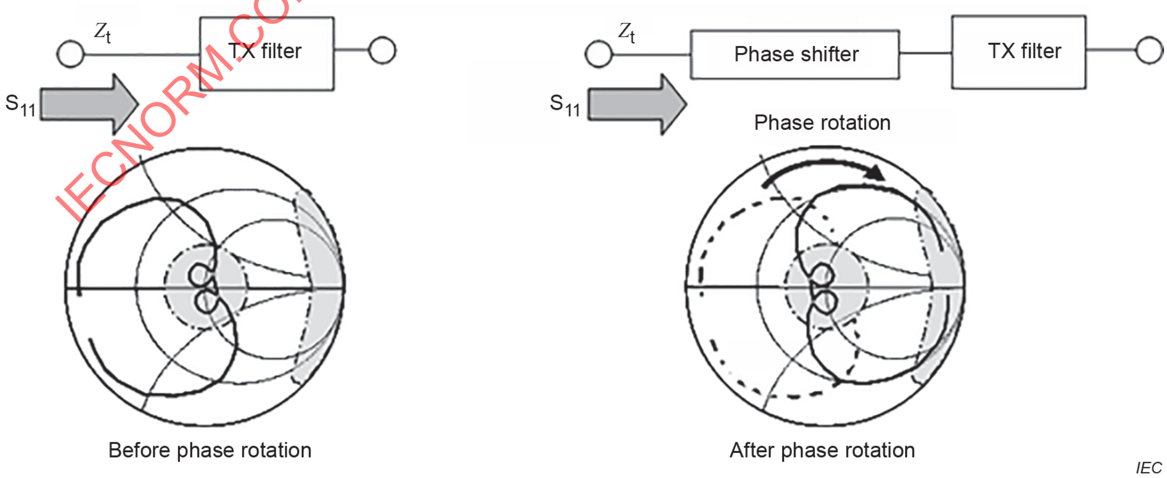


Figure 7 – Phase rotation in TX part

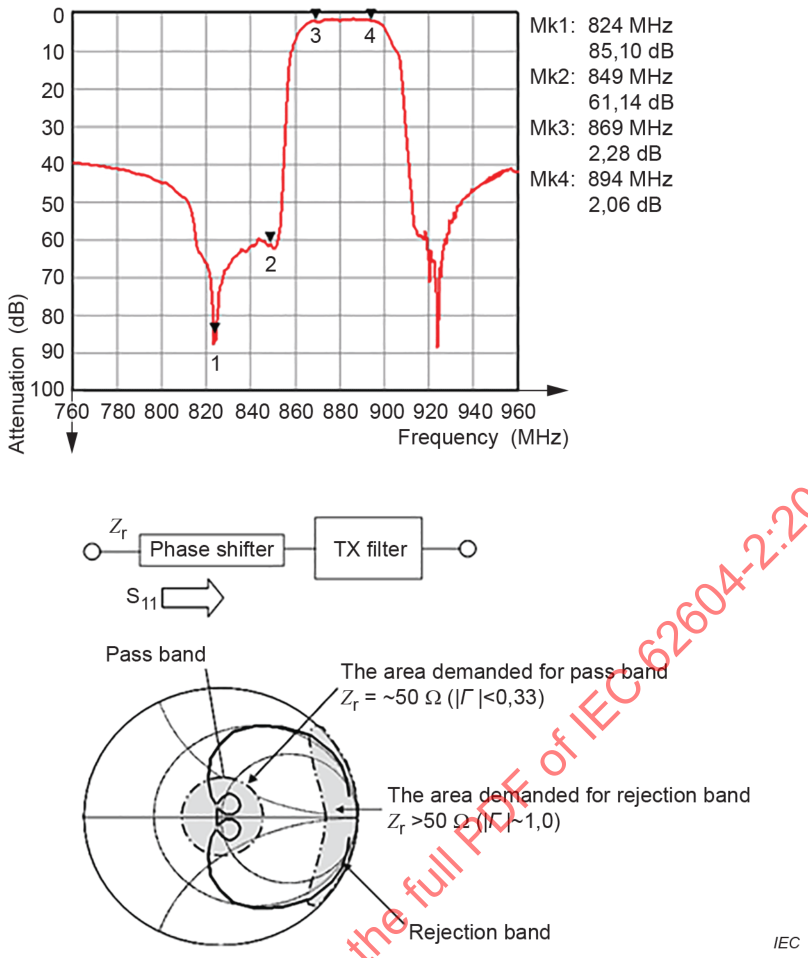


Figure 8 – Demanded condition of RX part for duplexers

5.4 Diplexer

Diplexers combine different frequency domains as shown in Figure 9. They have a structure and an operation principle very similar to those of duplexers.

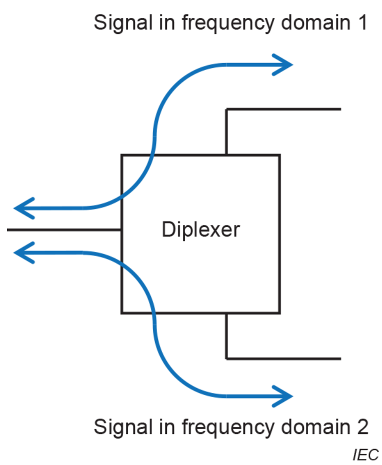
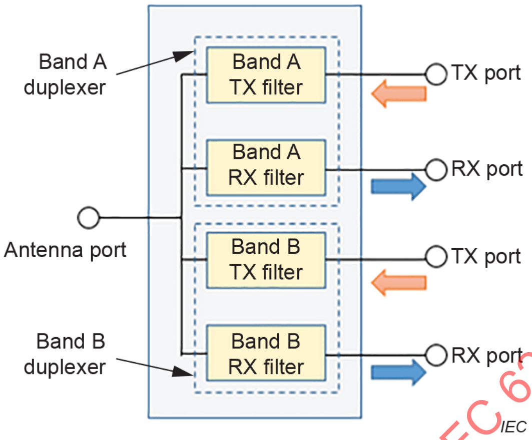


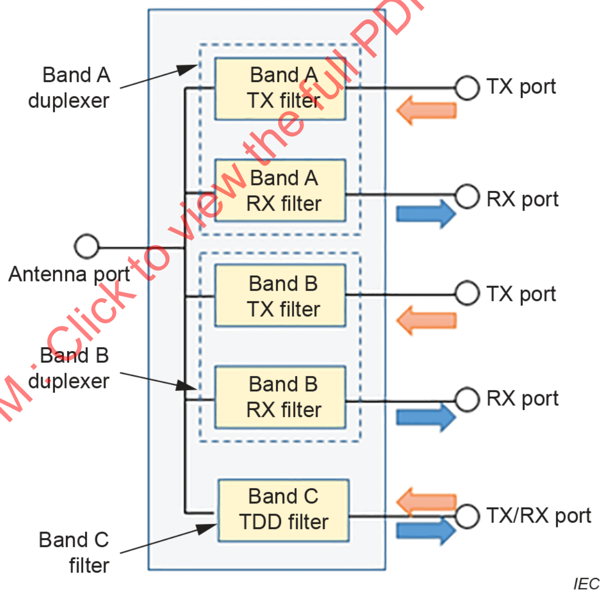
Figure 9 – Basic diplexer configuration

5.5 Multiplexer

Multiplexers combine a duplexer with other duplexers or filters which are used in respective nominal frequency bands. As shown in Figure 10, every duplexer and filter is connected to the common antenna port. In the case of Figure 10 b), a TDD (time division duplex) filter is added to the two duplexers. They have a structure and an operation principle very similar to those of duplexers.



a) Two duplexers combined



b) Two duplexers and one filter combined

Figure 10 – Basic multiplexer configuration

6 SAW and BAW duplexer characteristics

6.1 General conditions for SAW and BAW duplexers

The TX filter, RX filter and phase shifter, which compose SAW and BAW duplexers, as shown in 5.2, are described in Clause 6. The duplexer assembly configuration is also explained here.

– TX filter

The TX filter of the duplexers needs high power durability against the transmitting signal. To ensure the durability against high power, e.g., 1 W, a ladder filter or lattice filter is used for the TX filter because of their higher power durability among several types of SAW and BAW filters. SAW ladder and lattice filters are described in 5.2 of IEC 60862-2:2012 and BAW ladder filters are described in 4.4 of IEC 62575-2:2012.

Besides low insertion attenuation in the TX band (f_T) and high insertion attenuation in the RX band (f_R) described in 5.1, the high attenuation in the second harmonic ($2f_T$) and the third harmonic ($3f_T$) is also important. The attenuation in spurious frequency (f_{SP}) suppresses the inter-modulation signal at $f_R = 2f_T - f_{SP}$. The typical frequency response is shown in Figure 11.

– RX filter

Transmitting power passes through the TX filter and attacks the antenna port side of the RX filter. Filter types used for the TX filter can be adopted for the RX filter, but DMS (double mode SAW) type filters which are also known as LCRF (longitudinally coupled resonator filters) have the possibility of adoption with trap elements to block the transmitting power.

Besides low insertion attenuation in the RX band (f_R) and high insertion attenuation in the TX band (f_T) described in 5.1, a heterodyne receiver with the intermediate frequency (f_{IF}) demands high attenuation in the local oscillation frequency (f_{LO}) and the image frequency ($f_{IM} = f_{LO} + f_{IF}$ for upper local system). The inter-modulation signal in f_R can be reduced by high attenuation in the frequency of e.g., $2f_T + f_R$, $2f_T - f_R$, $f_R + f_T$ and $f_R - f_T$. The typical frequency response is shown in Figure 12.

– Phase shifter

There are various types of phase shifters according to duplexer configurations and the out-of-band complex impedance of TX and RX filters. To construct the phase shifter of a delay line with the desired electrical length, a stripline is located between the inside layers of a package, or a microstrip line is located on the surface of a package as shown in Figure 13. Figure 14 shows a lumped element phase shifter. A suitable number of lumped elements is not fixed at three. In some cases no phase shifter is necessary.

– Duplexer configuration

Figure 15 shows two types of duplexer configurations. They have merits and demerits with regard to characteristics, size, cost and other items.

Figure 15 a) shows a module type, which mounts SAW and BAW filters and other components on a substrate, such as a printed board. Figure 15 b) shows a device type, which seals the package after mounting SAW and BAW filter bare chips on a package, such as multi-layered ceramics. In those two types, the TX and RX filters/chips are separated from each other, and there is the possibility of a single filter/chip solution.

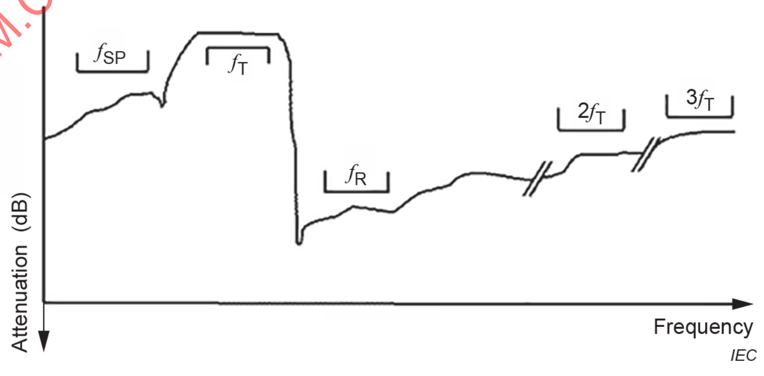


Figure 11 – Typical wide range frequency response of TX filter

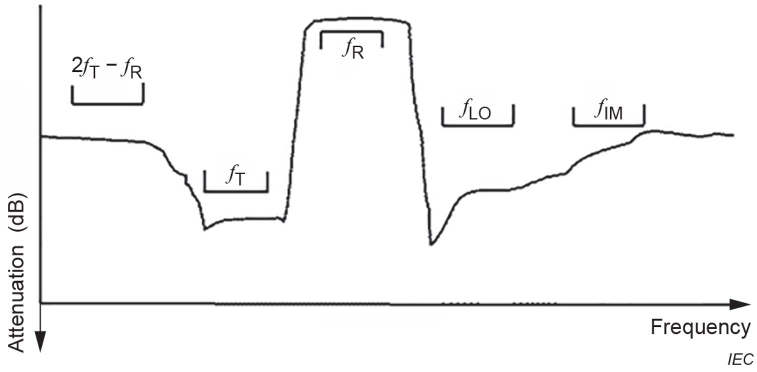


Figure 12 – Typical wide range frequency response of RX filter for upper local system

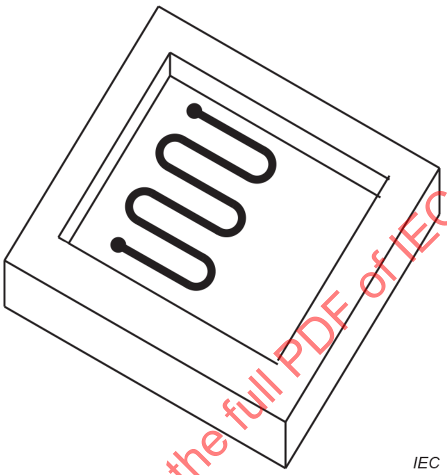


Figure 13 – Phase shifter by microstrip line on the surface of a ceramic package

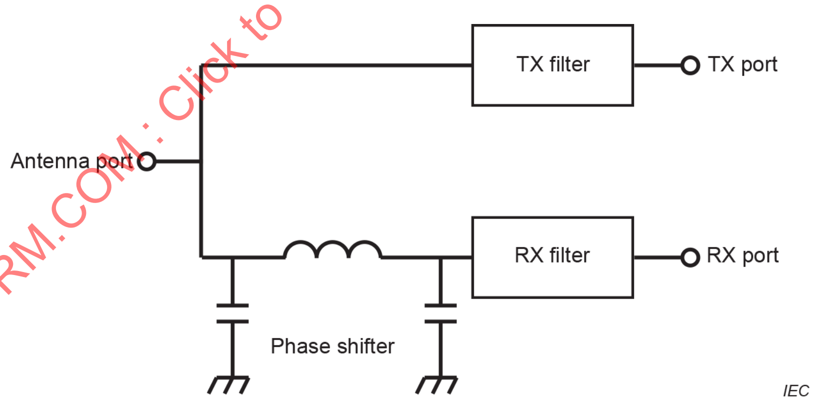
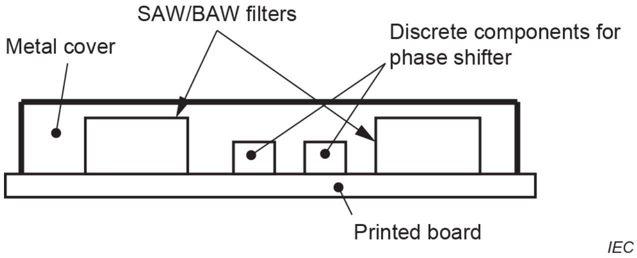
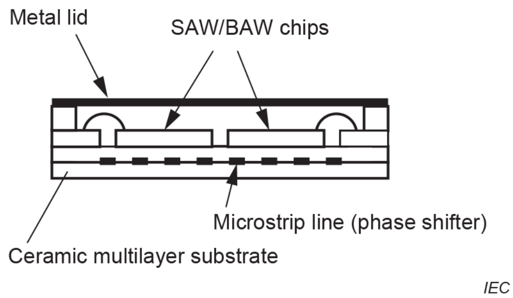


Figure 14 – Lumped element phase shifter



a) Module type



b) Device type

Figure 15 – Duplexer configuration

6.2 Typical characteristics of SAW and BAW duplexers

6.2.1 UMTS duplexer

As an example of a duplexer for a UMTS system, a SAW duplexer for UMTS Band 1 is shown in Figure 16. The frequency regulation of Band 1 is provided by a third generation partnership project (3GPP). The transmitter and receiver pass bands in the handset are 1 920 MHz to 1 980 MHz and 2 110 MHz to 2 170 MHz, respectively. Both frequency bands are indicated by f_T and f_R in Figure 16. The size of this duplexer is typically 4,9 mm × 4,9 mm × 1,7 mm. A 41° rotated Y cut X propagated $LiNbO_3$ crystal is used as substrate. The structure of the filter is a ladder (see 5.2 of IEC 60862-2:2012), and the electrode material is made by Al-Ti alloy for high power durability.

Frequency characteristics of this SAW duplexer for UMTS Band 1 are shown in Figure 16. The typical insertion attenuation from the TX port to the antenna port and that from the antenna port to the RX port are 1,4 dB and 2,3 dB, respectively. The isolation values between transmitter and receiver ports are typically 48 dB for the TX band and 40 dB for the RX band.

6.2.2 US CDMA duplexer

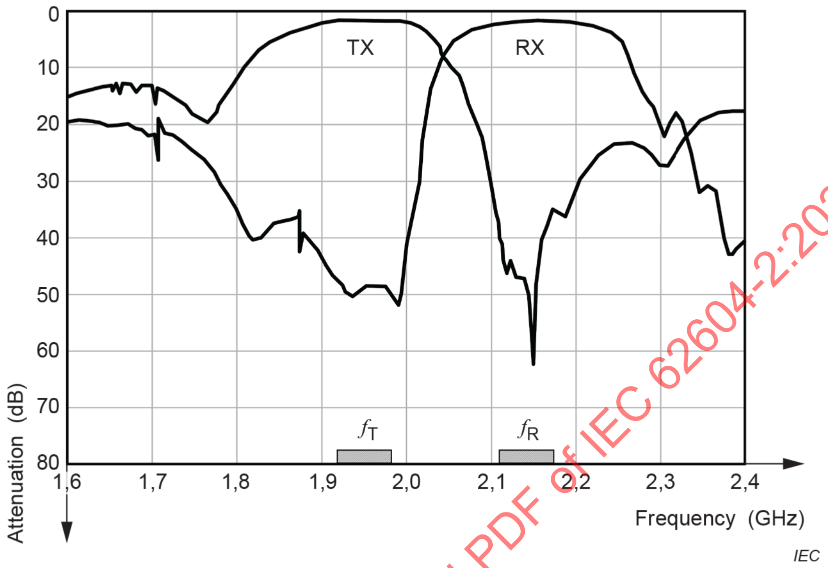
The frequency characteristics example of US CDMA duplexer is shown in Figure 17. This type of duplexer is also applicable to UMTS Band 5. The TX passband frequency is 824 MHz to 849 MHz, while RX passband frequency is 869 MHz to 894 MHz. Both frequency bands are indicated by f_T and f_R in the Figure 17. The dimension of this duplexer is typically 3,8 mm × 3,8 mm × 1,6 mm. Y cut X propagated $LiTaO_3$ with a rotation angle optimized around 36° is used as a substrate. The ladder type SAW filters are used for both TX and RX parts. Typical insertion attenuation is 1,8 dB from TX port to antenna port. And 2,5 dB typical insertion attenuation is from antenna port to RX port. The isolation between TX port and RX port is typically 60 dB for the TX band and 47 dB for the RX band.

6.2.3 PCS CDMA duplexer

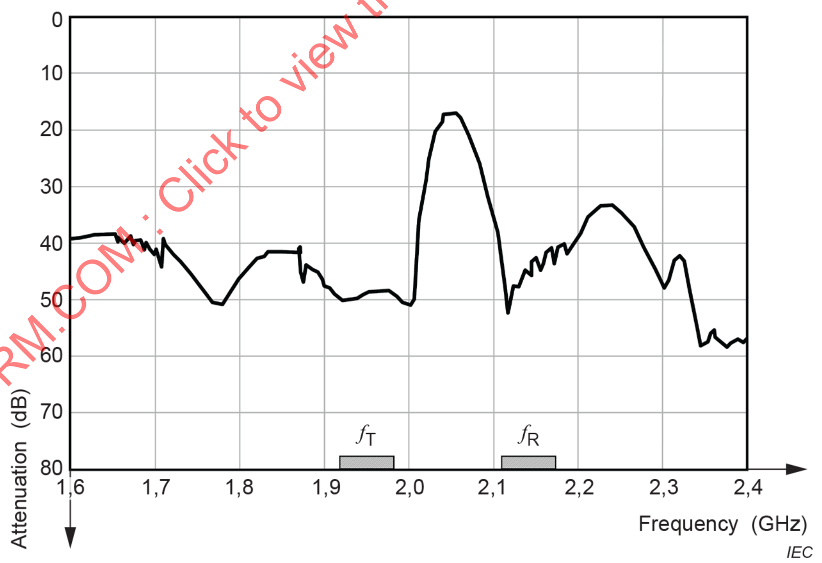
According to Table 1, the guard band or a gap distance between the transmitting and receiving frequencies for UMTS band 2 or PCS band is relatively narrow, and high Q characteristics or a sharp filter response in the transition band is required. From this requirement, BAW duplexers which are composed of film bulk acoustic resonators (FBAR) or solidly mounted resonators (SMR) are mainly used for PCS CDMA duplexers. The frequency characteristics example of a PCS CDMA duplexer using FBAR is shown in Figure 18. The TX passband frequency is 1 850 MHz to 1 910 MHz, while the RX passband frequency is 1 930 MHz to 1 990 MHz. This duplexer can comply with the specified maximum insertion attenuation of 3,5 dB for the TX band and 4,0 dB for the RX band, with excellent transition band responses between the TX and RX bands. Also, the specified minimum isolation values between the transmitter and receiver ports are 54 dB for the TX band and 43 dB for the RX band.

6.2.4 LTE Band 1 + Band 3 multiplexer

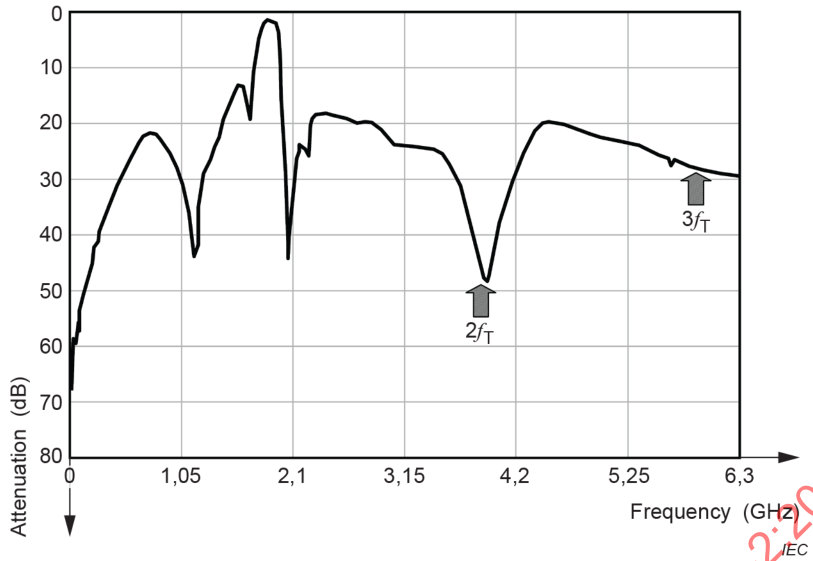
The frequency characteristics example of Band 1 + Band 3 multiplexer using SAW is shown in Figure 19. The frequency regulations of them are shown in Table 1. Cross-isolation is inherent in multiplexer and one of the important functions for the multiplexer. At this example, the cross-isolation values from the Band 1 TX port to the Band 3 Rx port are 59 dB both for the Band 1 TX band and the Band 3 RX band, and the other cross-isolation from the Band 3 TX port to the Band 1 Rx port are 59 dB for the Band 3 TX band and 60 dB for the Band 1 RX band.



a) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (near pass band)

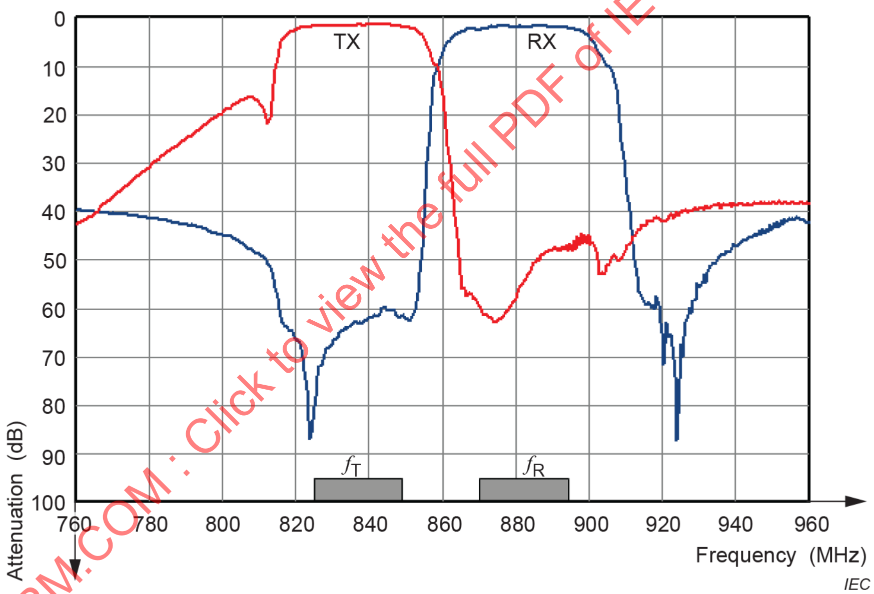


b) Isolation characteristics of the duplexer between RX port and TX port

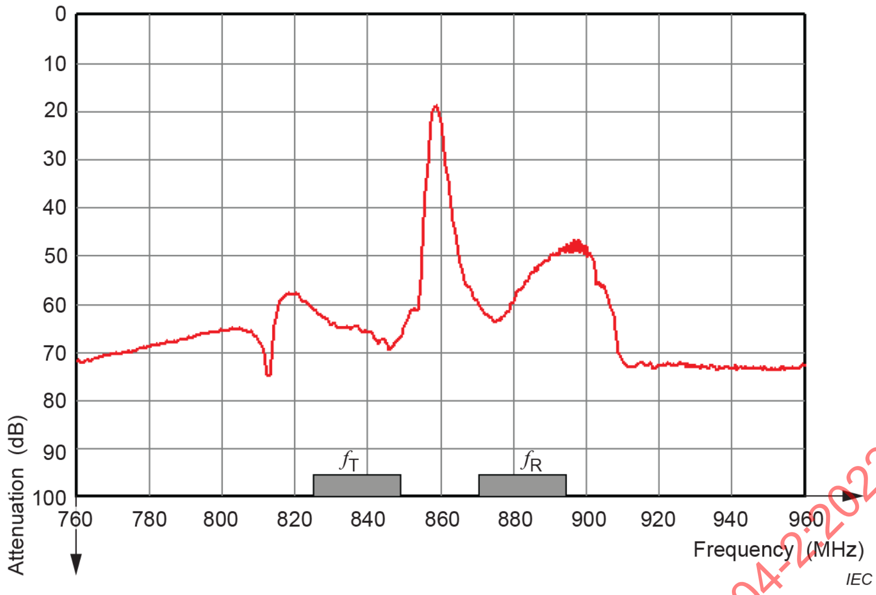


c) Amplitude response of the duplexer from TX port to antenna port (DC to 6 GHz)

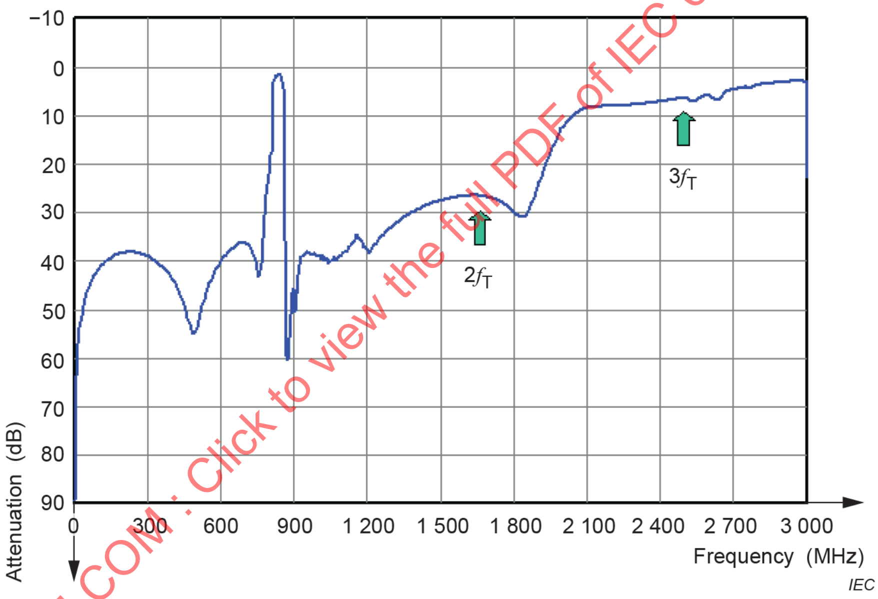
Figure 16 – Frequency characteristics of SAW duplexer for UMTS Band 1 system



a) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (near pass band)

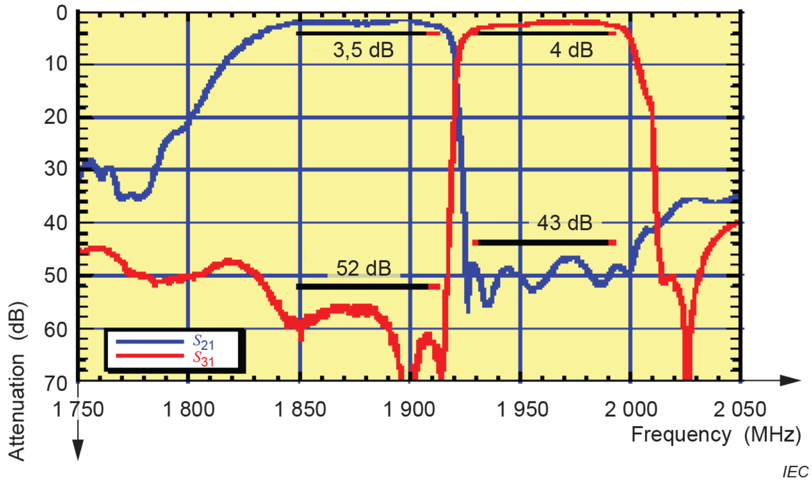


b) Isolation characteristics of the duplexer between RX port and TX port

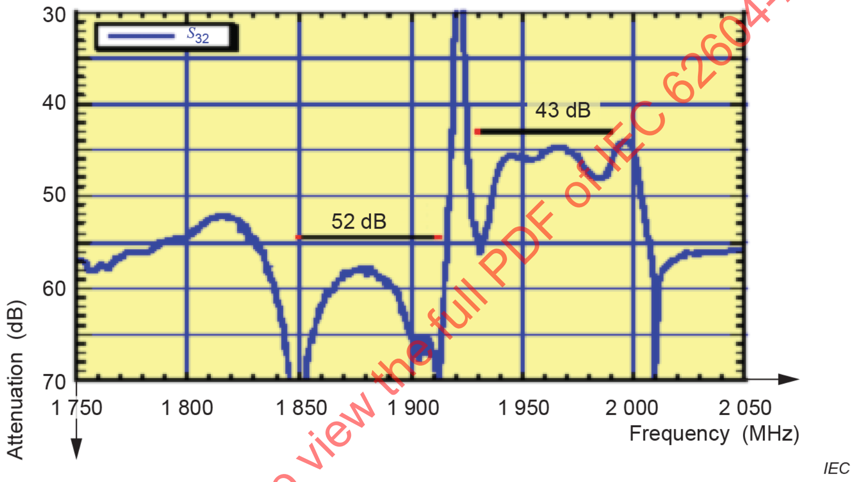


c) Amplitude response of the duplexer from TX port to antenna port (DC to 3 GHz)

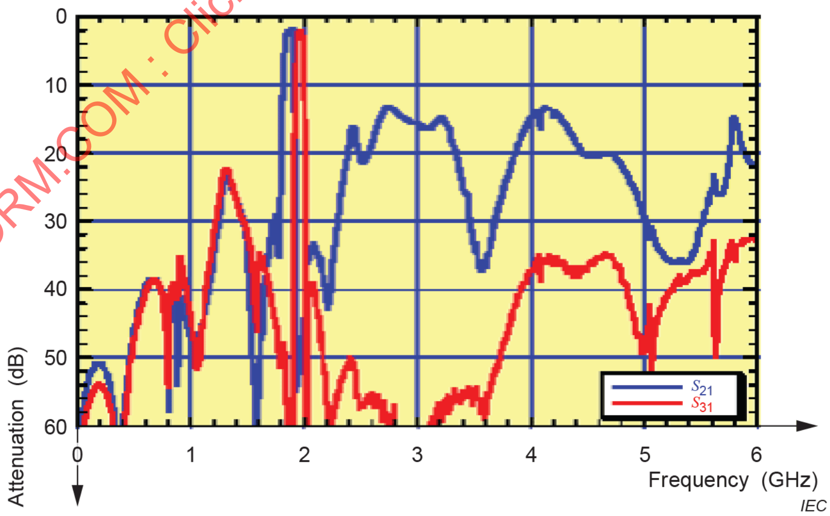
Figure 17 – Frequency characteristics of a SAW duplexer for US CDMA system



a) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (near pass band)



b) Isolation characteristics of the duplexer between RX port and TX port



c) Amplitude responses of the duplexer from TX port to antenna port and from antenna port to RX port (DC to 6 GHz)

SOURCE: Reproduced from P.Bradley et al.: *A 6-port Film Bulk Acoustic Resonator (FBAR) Multiplexer For U.S. CDMA Handsets Permitting use of PCS, U.S. CDMA and GPS with a single Antenna*, Proc. IEEE Ultrasonics Symp., pp.325-328, 2006, with the permission of the IEEE.

Figure 18 – Frequency characteristics of BAW duplexer for PCS CDMA system

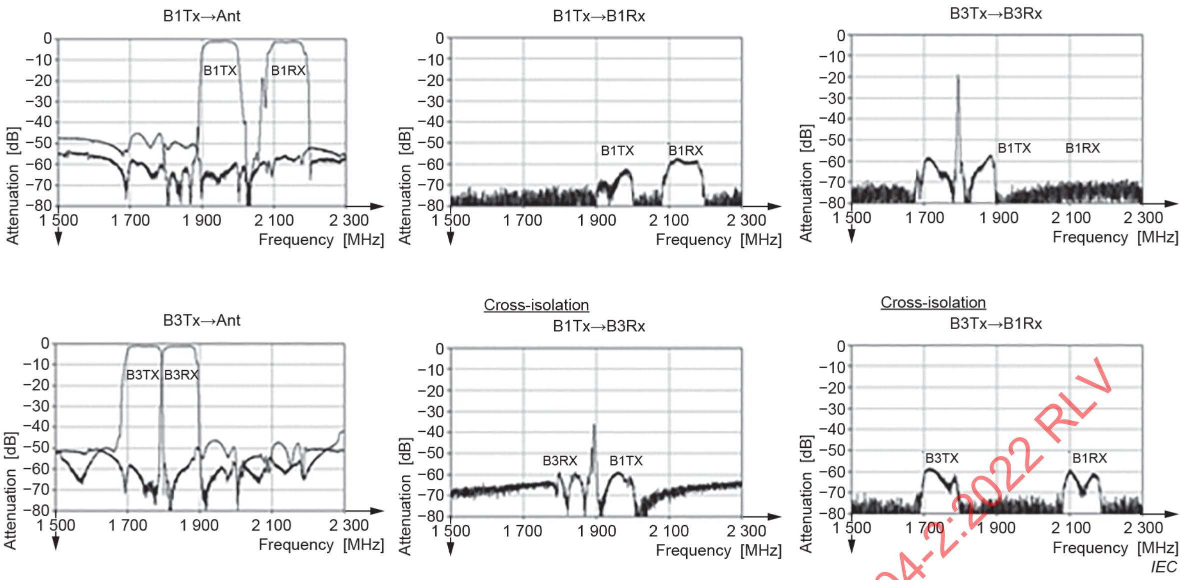


Figure 19 – Frequency characteristics of SAW Band 1 + Band 3 multiplexer for LTE

7 Application guidelines

7.1 Power durability

High power durability of about 1 W is necessary for SAW and BAW duplexers. There are two modes of damage caused by power beyond the durability and the situation is severer for a SAW duplexer than for a BAW duplexer.

The first mode is breakdown. High voltage momentarily destroys SAW electrodes. Input power should be considered to prevent their breakdown.

The second mode is stress migration. The excessive repeated mechanical stress can induce electrode deteriorations, such as voids and hillocks. They cause frequency shift and insertion attenuation degradation of the SAW duplexer.

In order to protect the SAW duplexer from such deteriorations, and to keep the duplexer working for a sufficient amount of time, the drive level shall be less than 1 W. Various technologies of high power durability in SAW devices intended to extend their lifetime have been studied; these are described in 5.5 of IEC 61019-2:2005.

In the case of a BAW duplexer, it is said that its durability is stronger than that of a SAW. However, consideration of the drive level is necessary also for a BAW duplexer. More detailed studies and reports are required technically.

7.2 Harmonics and inter-modulation distortion

Nonlinearity of SAW and BAW duplexers loaded in high power can cause harmonics, which generates unwanted output signals in stop band areas, as shown by Figure 11 and Figure 12. In addition inter-modulation distortion also occurs both in stop band and pass band areas. Detailed technical information is described in 8.5.7 of IEC 60862-1:2015.

7.3 Measurement method for the duplexer

The measurement method shall basically be performed in accordance with the measurement method of IEC 60862-1 and IEC 62575-1. However, in the evaluation of the duplexer, the instructions given by the application notes from a vendor should be considered. Because the duplexer is a three-port device, it is recommended to use multi-port-type network analyzers.

Figure 20 shows a schematic diagram of the measurement method for a duplexer with a four-port-type network analyzer, as an example.

However, a conventional two-port-type network analyzer can also be used for measuring the characteristics between any two ports chosen from three ports of the duplexer with 50 Ω termination of the unchosen port.

If the multiplexer has 5 ports or more, it can be measured in the same way as described above. In other words, the unchosen ports should be connected to 50 Ω termination. It is also convenient to use multi-port-type network analyzers that support more than 5 ports.

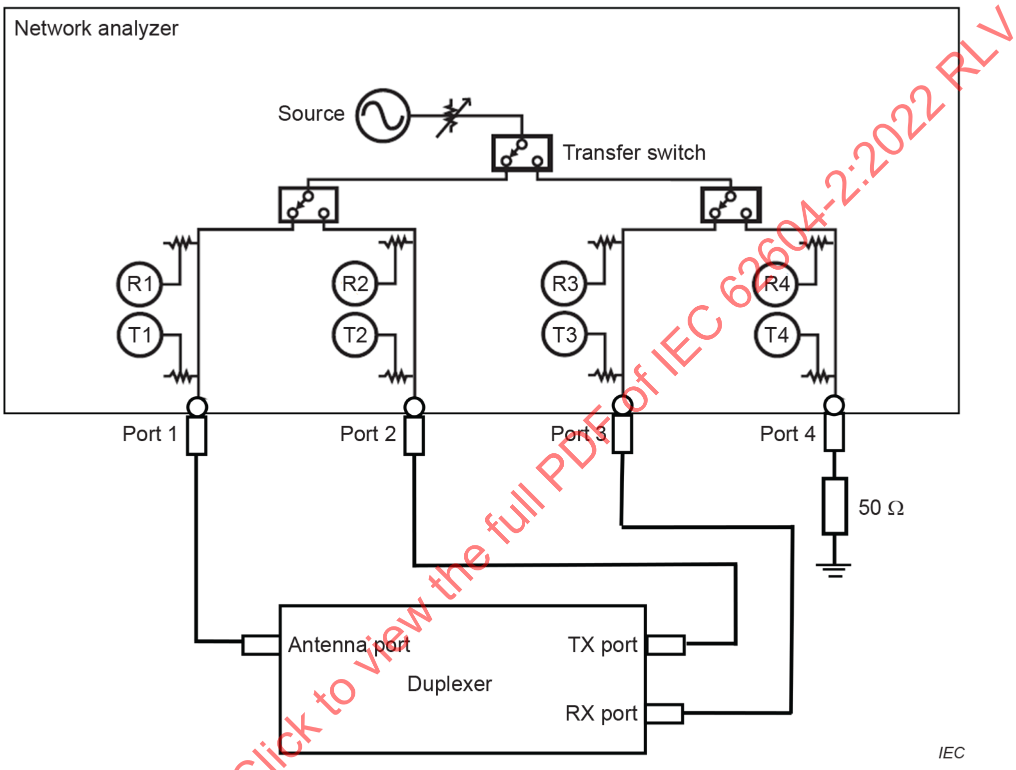


Figure 20 – Four-port-type network analyzer for duplexer measurement

Adopting a balanced connection filter[4)] to the RX filter, a duplexer with a balanced RX port will be realized. It can also be evaluated using four-port-type network analyzer as shown in Figure 21.

4) See IEC 60862-2:2012, 5.3.5.

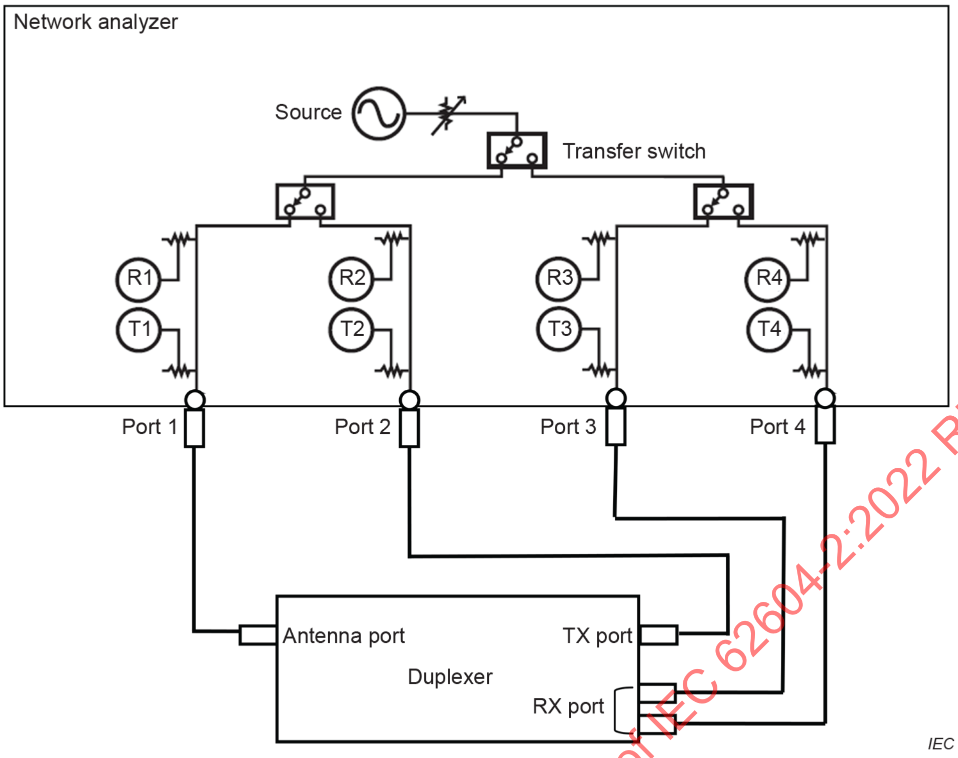


Figure 21 – Four-port-type network analyzer for measurement of a balanced RX port duplexer

7.4 Electrostatic voltage protection

Since the duplexers are used in the front-end of the user equipment, electrostatic overstress (discharge) can easily affect the device's antenna port, and a countermeasure against the static electricity is generally required, particularly for SAW duplexers. As the electrode gap of IDT in the SAW duplexer is very narrow, especially for the high frequency range, and it might be a cause of degradation or destruction to apply static electricity to a SAW duplexer, it is necessary to be careful not to apply static electricity or excessive voltage while transporting, assembling and measuring.

If the piezoelectric material of duplexers has large pyro-electricity, excessive voltage can occur during rapid temperature changes. In order to prevent such an occurrence, it is necessary to take care not to add any thermal shock. In the soldering process, adequate preheating is effective.

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SOMMAIRE

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Partie 2: Lignes directrices d'utilisation

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L'IEC 62604-2 a été établie par le comité d'études 49 de l'IEC: Dispositifs piézoélectriques, diélectriques et électrostatiques et matériaux associés pour la détection, le choix et la commande de la fréquence. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la seconde édition parue en 2017. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) ajout du terme "isolation de polarisation croisée" à l'Article 3;
b) description des multiplexeurs.

NOTE Dans le présent document, les duplexeurs à OAS et à OAV sont traités simultanément car ces deux duplexeurs sont utilisés de la même manière, en particulier dans les systèmes de téléphonie mobile; ils ont en outre les mêmes exigences de caractéristiques, de méthode d'essai, etc.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
49/1361/CDV	49/1376/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Une liste de toutes les parties de la série IEC 62604, publiées sous le titre général *Duplexeurs à ondes acoustiques de surface (OAS) et à ondes acoustiques de volume (OAV) sous assurance de la qualité*, se trouve sur le site web de l'IEC.

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INTRODUCTION

Alors que pour les systèmes 2G, les duplexeurs diélectriques sont majoritairement utilisés, la miniaturisation actuelle des systèmes de communication mobile 3G et 4G a encouragé le développement et l'application de duplexeurs à ondes acoustiques, en raison de leurs petites dimensions, de leur faible poids et de leurs bonnes performances électriques. Tandis que les duplexeurs à ondes acoustiques de surface (OAS) courants sont employés pour des applications dont les exigences sont modérées quant à l'inclinaison des filtres individuels, les applications dont l'écart de duplex est étroit (bandes 2, 3, 8, 25, par exemple), c'est-à-dire l'intervalle de fréquences entre les bandes de réception et d'émission, exigent l'application de technologies OAS ou OAV avec compensation de la température en raison de leurs meilleures caractéristiques de température et de meilleurs facteurs Q de résonateur.

Les spécifications comme celles de l'IEC dont les présentes lignes directrices font partie, les spécifications nationales ou les spécifications particulières des fabricants définissent les combinaisons disponibles de fréquence centrale, de largeur de bande passante et d'affaiblissement d'insertion pour chaque type de filtre d'émission et de réception ainsi que le niveau d'isolation entre les accès d'émission et les accès de réception, etc. Ces spécifications sont compilées afin d'intégrer une large plage de duplexeurs à OAS et à OAV présentant des performances normalisées. Il convient de ce fait de bien conseiller à l'utilisateur de choisir ses duplexeurs, dans la mesure du possible, à l'aide de ces spécifications lorsqu'elles sont disponibles même si cela peut impliquer des modifications mineures de son circuit pour permettre l'utilisation de duplexeurs normalisés. Ceci s'applique en particulier à la sélection de la bande de fréquence nominale.

DUPLEXEURS À ONDES ACOUSTIQUES DE SURFACE (OAS) ET À ONDES ACOUSTIQUES DE VOLUME (OAV) SOUS ASSURANCE DE LA QUALITÉ –

Partie 2: Lignes directrices d'utilisation

1 Domaine d'application

La présente partie de l'IEC 62604 s'applique aux duplexeurs qui peuvent séparer les signaux en réception des signaux en émission et constituent des composants essentiels pour les radiocommunications bilatérales. Ils sont généralement utilisés dans les systèmes de téléphonie mobile conformes aux systèmes d'accès multiple par répartition en code (AMRC) comme les systèmes N-CDMA des systèmes de télécommunication mobile de seconde génération (2G), les systèmes W-CDMA/UMTS (3G) ou les systèmes LTE (4G).

Les présentes lignes directrices attirent l'attention sur certaines des questions fondamentales concernant la théorie des duplexeurs à OAS et à OAV, et leurs modalités d'utilisation, qui sont à prendre en considération par l'utilisateur avant de commander un duplexeur à OAS ou à OAV pour une nouvelle application. Ainsi, l'utilisateur évite d'être confronté à des performances non satisfaisantes. Dans la mesure où les duplexeurs à OAS et à OAV présentent des performances très similaires dans leur utilisation, il est utile et pratique pour les utilisateurs que les deux types soient décrits dans une seule norme.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60862-1, *Filtres à ondes acoustiques de surface (OAS) sous assurance de la qualité – Partie 1: Spécification générique*

IEC 62575-1, *Filtres radiofréquences (RF) à ondes acoustiques de volume (OAV) sous assurance de la qualité – Partie 1: Spécification générique*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1 Termes relatifs aux caractéristiques de réponse

3.1.1
bande de garde
partie non utilisée du spectre radio entre les bandes radio, à des fins d'évitement des interférences

3.1.2
isolation de polarisation croisée
dans un multiplexeur, taux de puissance de fuite depuis l'un des accès TX vers l'un des accès RX sur une autre bande de fréquences nominale

3.2 Termes relatifs aux duplexeurs à OAS et à OAV

3.2.1
déphaseur
dispositif qui change la phase des signaux, pas leur fréquence

Note 1 à l'article: Il constitue une partie élémentaire d'un duplexeur.

3.2.2
vide
vacance dans l'électrode IDT induite par la migration de contrainte provoquée par la diffusion et/ou le transfert d'atomes de métal qui font partie de l'électrode

3.2.3
monticule
projection sur la surface latérale ou supérieure de l'électrode induite par la migration de contrainte provoquée par la diffusion et/ou le transfert d'atomes de métal qui font partie de l'électrode

4 Aspects techniques

Il convient en priorité pour l'utilisateur que les caractéristiques du duplexeur soient conformes aux spécifications particulières. Il convient que la sélection des circuits frontaux dans l'appareil utilisateur et les duplexeurs à OAS et à OAV pour satisfaire à de telles spécifications fasse l'objet d'un accord entre l'utilisateur et le fabricant.

Les caractéristiques des duplexeurs sont généralement exprimées en fonction de la fréquence centrale, de la largeur de bande passante et de l'affaiblissement d'insertion pour chaque partie des filtres d'émission et de réception dans le duplexeur et selon le niveau d'isolation entre les accès d'émission et de réception. Dans la mesure où les duplexeurs à OAS et à OAV sont utilisés dans les circuits frontaux RF de l'appareil utilisateur, les caractéristiques suivantes font l'objet d'exigences strictes; un faible affaiblissement d'insertion, un niveau d'isolation/de réjection élevé, une tenue en puissance élevée et de faibles dimensions en taille et épaisseur des boîtiers sont strictement exigés.

5 Aspects fondamentaux des duplexeurs à OAS et à OAV

5.1 Fonction de base

5.1.1 Généralités

Les duplexeurs sont nécessaires pour que les appareils de duplexage par répartition en fréquence (FDD, frequency division duplex) reçoivent et émettent des signaux simultanément. Les duplexeurs sont des dispositifs à trois accès à savoir un accès d'antenne, un accès pour l'émission (accès TX) et un accès pour la réception (accès RX) comme représentés à la Figure 1. Ils assurent trois fonctions de base:

– transférer le signal d'émission de l'accès TX à l'accès d'antenne;
– transférer le signal de réception de l'accès d'antenne à l'accès RX;
– empêcher le transfert du signal d'émission et de bruit de l'accès TX à l'accès RX.

La fréquence d'émission et celle de réception sont déterminées en fonction de chaque système de communication mobile. Par exemple, le Tableau 1 présente les bandes de fréquences généralement attribuées dans le cas des systèmes LTE.

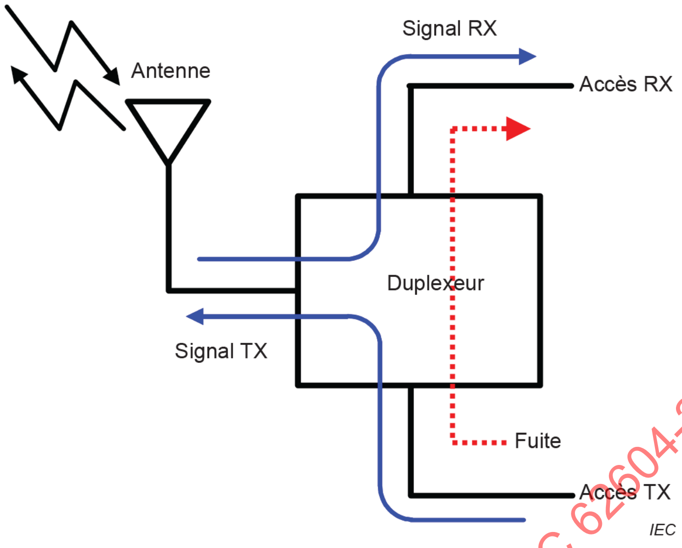

Figure 1 – Configuration de base d'un duplexeur

Tableau 1 – Attribution des fréquences pour les bandes de duplexage par répartition en fréquence (FDD) des systèmes LTE types

Bande	Fréquence de liaison montante (MHz)	Fréquence de liaison descendante (MHz)	Bande	Fréquence de liaison montante (MHz)	Fréquence de liaison descendante (MHz)
1	1 920 – 1 980	2 110 – 2 170	16	2 010 – 2 025	2 585 – 2 600
2	1 850 – 1 910	1 930 – 1 990	17	704 – 716	734 – 746
3	1 710 – 1 785	1 805 – 1 880	18	815 – 830	860 – 875
4	1 710 – 1 755	2 110 – 2 155	19	830 – 845	875 – 890
5	824 – 849	869 – 894	20	832 – 862	791 – 821
6	830 – 840	875 – 885	21	1 447,9 – 1 462,9	1 495,5 – 1 510,9
7	2 500 – 2 570	2 620 – 2 690	22	3 410 – 3 490	3 510 – 3 590
8	880 – 915	925 – 960	23	2 000 – 2 020	2 180 – 2 200
9	1 749,9 – 1 784,9	1 844,9 – 1 879,9	24	1 626,5 – 1 660,5	1 525 – 1 559
10	1 710 – 1 770	2 110 – 2 170	25	1 850 – 1 915	1 930 – 1 995
11	1 427,9 – 1 447,9	1 475,9 – 1 495,9	26	814 – 849	859 – 894
12	699 – 716	729 – 746	27	807 – 824	852 – 869
13	777 – 787	746 – 756	28	703 – 748	758 – 803
14	788 – 798	758 – 768	30	2 305 – 2 315	2 350 – 2 360
15	1 900 – 1 920	2 600 – 2 620	31	452,5 – 457,5	462,5 – 467,5

NOTE Pour un appareil utilisateur, la fréquence de liaison montante signifie la fréquence d'émission et la fréquence de liaison descendante signifie la fréquence de réception, respectivement.

5.1.2 Réponse du filtre TX (réponse du filtre entre l'accès TX et l'accès d'antenne)

La Figure 2 représente un exemple de caractéristiques de fréquence du filtre TX. Les caractéristiques de fréquence exigées sont un faible affaiblissement d'insertion dans la bande de fréquences d'émission (f_T), un affaiblissement d'insertion élevé dans la bande de fréquences de réception (f_R) et une bonne adaptation d'impédance.

5.1.3 Réponse du filtre RX (réponse du filtre entre l'accès d'antenne et l'accès RX)

La Figure 3 représente un exemple de caractéristiques de fréquence du filtre RX. Les caractéristiques de fréquence exigées sont un faible affaiblissement d'insertion dans la bande de fréquences de réception (f_R) et un affaiblissement d'insertion élevé dans la bande de fréquences d'émission (f_T).

5.1.4 Isolation (isolation entre l'accès TX et l'accès RX)

La Figure 4 représente un exemple de caractéristiques d'isolation. Une des fonctions importantes des duplexeurs concerne leur caractéristique d'isolation, qui indique la puissance de fuite entre l'accès TX et l'accès RX en fonction de la fréquence.

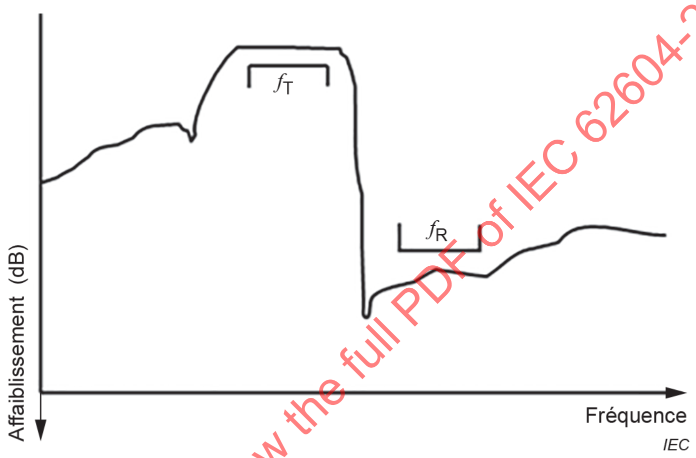

Figure 2 – Exemple de réponse de base du filtre TX des duplexeurs à OAS et à OAV

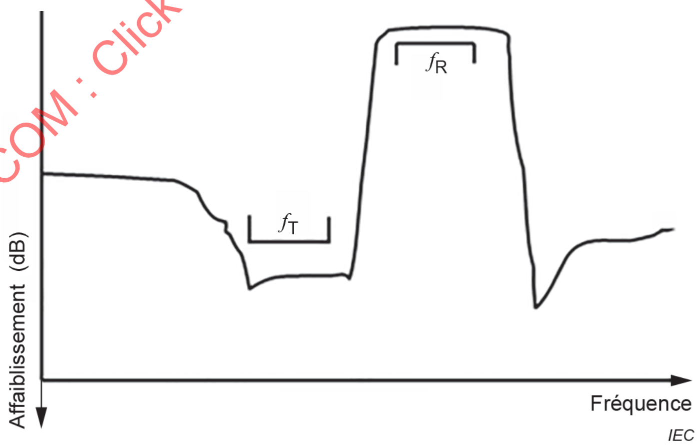

Figure 3 – Exemple de réponse de base du filtre RX des duplexeurs à OAS et à OAV

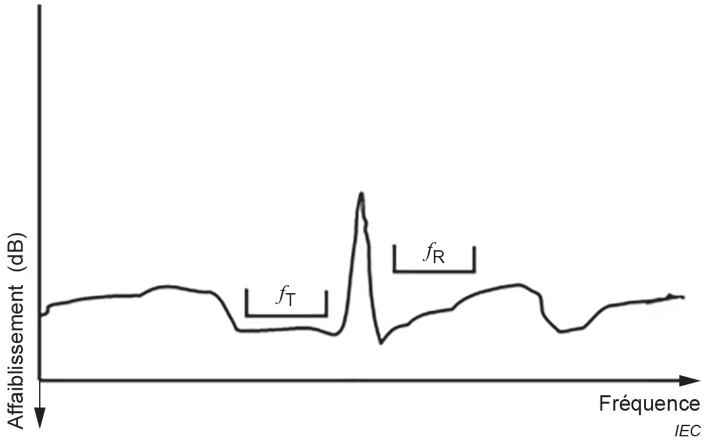

Figure 4 – Exemple de caractéristiques d'isolation principale des duplexeurs à OAS et à OAV

5.2 Structure de base

Les duplexeurs sont des dispositifs/des modules à 3 accès, qui permettent d'émettre et de recevoir des signaux simultanément au moyen d'une antenne commune. Une structure de base des duplexeurs est représentée à la Figure 5. Les duplexeurs à OAS et à OAV comprennent une partie émission (TX) et une partie réception (RX). Ces deux parties, avec éventuellement un déphaseur, sont reliées à un accès d'antenne. Le déphaseur est utilisé pour empêcher l'interaction entre les filtres. A la Figure 5, Z_t et Z_r correspondent à l'impédance de la partie TX et de la partie RX du côté de l'accès d'antenne tandis que Z_o est l'impédance de l'accès d'antenne. Les conditions suivantes doivent être satisfaites pour que le duplexeur remplisse ses fonctions.

$$Z_t \cong Z_o \text{ et } |Z_r| >> |Z_o| \qquad \text{dans la bande passante TX}$$

$$Z_r \cong Z_o \text{ et } |Z_t| >> |Z_o| \qquad \text{dans la bande passante RX}$$

Les filtres de type DMS (OAS mode double), également appelés filtres à résonateurs couplés longitudinalement (LCRF, longitudinally coupled resonator filters)[1], les filtres OAS et OAV de type en échelle[2] et les autres types de filtres OAS tels que les filtres à résonateurs à transducteurs interdigités imbriqués (TIDI)[3] peuvent être adoptés comme filtres TX et RX. Une tenue en puissance élevée est exigée pour les filtres TX.

5.3 Principe de fonctionnement

Dans la bande passante TX, l'impédance de la partie TX du côté accès d'antenne (Z_t) est presque la même que celle de l'antenne (Z_o), tandis que celle de la partie RX (Z_r) est bien supérieure, ce qui signifie qu'à l'accès d'antenne, la partie RX a un coefficient de réflexion élevé dans cette bande.

$$Z_t \cong Z_o \text{ et } |Z_r| >> |Z_o| \qquad \text{dans la bande passante TX}$$

1) Voir l'IEC 60862-2:2012, 5.3.

2) Voir l'IEC 60862-2:2012, 5.2.

3) Voir l'IEC 60862-2:2012, 5.4.

Par ailleurs, dans la bande passante RX, l'impédance de la partie RX du côté accès d'antenne (Z_r) est presque la même que celle de l'antenne (Z_o), tandis que celle de la partie TX (Z_t) est bien plus élevée. Ceci signifie aussi que la partie TX a un coefficient de réflexion élevé dans cette bande.

$$Z_r \cong Z_o \text{ et } |Z_t| >> |Z_o| \quad \text{dans la bande passante RX}$$

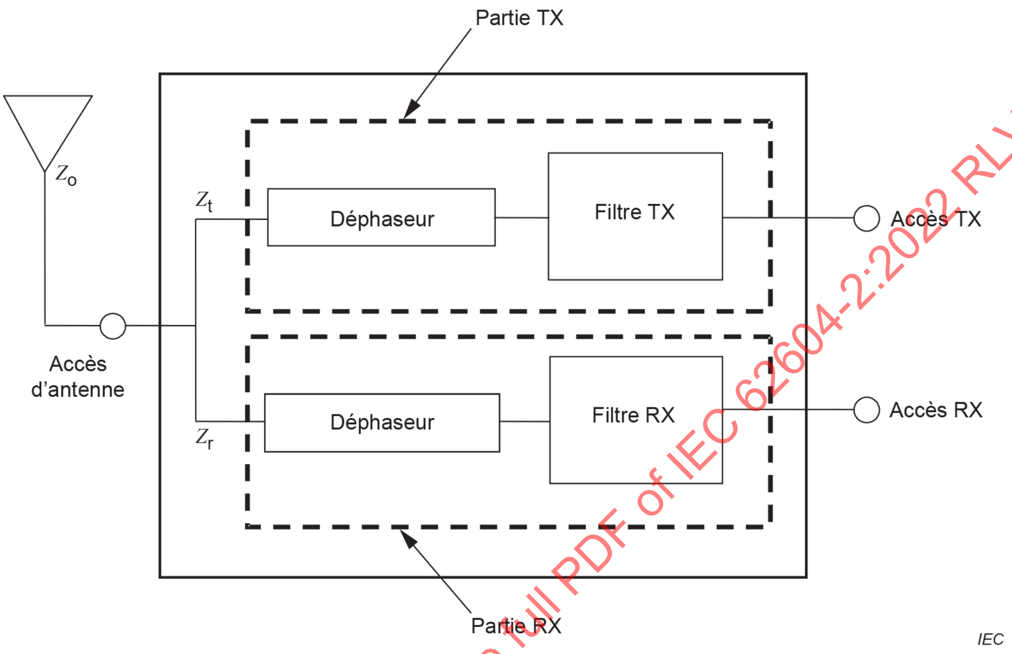

Figure 5 – Schéma fonctionnel d'un duplexeur

Le signal d'émission appliqué à l'accès TX passe à travers le filtre TX et s'écoule ensuite à l'accès d'antenne et non au filtre RX. Le signal reçu de l'accès d'antenne ne s'écoule pas au filtre TX mais au filtre RX. Il en résulte que la partie TX et la partie RX peuvent partager l'accès d'antenne commun. Dans l'explication suivante, l'impédance de l'antenne (Z_o) est par hypothèse de 50 Ω. La courbe S_{11} de la partie TX du côté accès d'antenne doit satisfaire à la condition demandée indiquée à la Figure 6. L'impédance de sa bande passante doit être égale à environ 50 Ω. Dans la bande de réjection, l'impédance doit avoir une valeur suffisamment supérieure à 50 Ω. Dans le duplexeur réel, le tracé S_{11} dans l'abaque de Smith du filtre TX subit une rotation par un déphaseur pour être dans son état optimal, comme cela est représenté à la Figure 7. Par ailleurs, les caractéristiques de fréquence de l'amplitude de S_{21} restent les mêmes que celles sans déphaseur. La Figure 8 représente les caractéristiques de fréquence de S_{21} et la condition demandée de S_{11} de la partie RX.