

# Wide-band signal-interference duplexer with contiguous single/dual-band channels and its application to quasi-absorptive bandpass filters

Roberto Gómez-García<sup>✉</sup>, José-María Muñoz-Ferreras, Wenjie Feng and Dimitra Psychogiou

A type of wide-band signal-interference planar duplexer with single- and dual-band channels is presented. It exploits transversal-signal-interference-section-based channels with contiguous single- and dual-passband filtering transfer functions. Furthermore, by ending the dual-band channel in a reference-impedance resistor, a wide-band bandpass filter (BPF) with quasi-absorptive stopbands is realised. As experimental validation, microstrip prototypes of a duplexer and a two-stage quasi-absorptive BPF that operate in the 1.6–4.4 GHz range are built and tested.

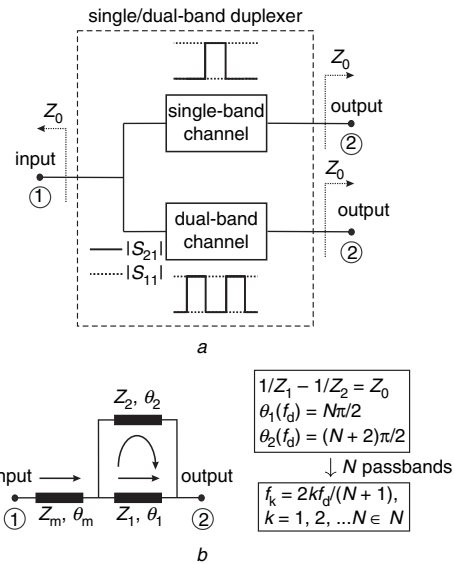
**Introduction:** RF/microwave signal-separation devices or multiplexers are fundamental circuits in the RF front-ends for a plurality of wireless applications. On the other hand, modern trends towards the development of higher-flexibility and multi-band wireless-communications and radar systems impose more stringent demands on their design [1]. This is the case of multiplexers composed of both single- and multi-band channelising filters. Furthermore, wide-band multiplexers with frequency-contiguous filtering channels are also desired.

Despite the previously referred interest, very few RF multiplexers exhibiting multi-band branches have been proposed. In [2, 3], a planar triplexer and a duplexer with dual-band channelising filters and static and reconfigurable characteristics, respectively, were described. These circuits, which are based on stub-loaded stepped-impedance resonators, are limited by narrow-band operation and their channels are not frequency contiguous. In [4], a 3D dual-band duplexer with spectrally adjacent dual-mode-cavity channels was presented. However, the bandwidths of the duplexer channels are very narrow. Hence, there is a current lack of RF multiplexer architectures with frequency-contiguous and sharp-rejection broad-band channels featuring both single- and multi-passband filtering responses.

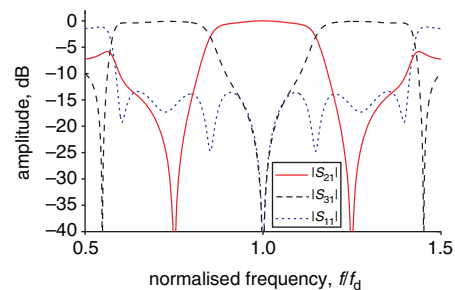
In this Letter, a class of wide-band duplexer with contiguous single- and dual-band channels is reported. It exploits transversal signal-interference filtering sections in its branches that exhibit sharp-rejection filtering responses with out-of-band transmission zeros. Moreover, the application of this duplexer to design bandpass filters (BPFs) with quasi-absorptive stopbands is shown. Note that these filters dissipate inside themselves the non-transmitted input-signal energy in their stopband regions [5]. For practical verification, two microstrip prototypes are manufactured and measured.

**Duplexer with single/dual-band channels:** The proposed wide-band duplexer concept with spectrally adjacent single- and dual-band bandpass channels is shown in Fig. 1a. The circuit detail of its building channel is given in Fig. 1b. It consists of a transversal signal-interference filtering section made up of two in-parallel transmission-line segments and an input matching line. Note that this type of filtering section was used in [6] to design multi-band BPFs. For this purpose, the design conditions detailed in Fig. 1b for the characteristic impedances  $Z_1$ ,  $Z_2$  and electrical lengths  $\theta_1$ ,  $\theta_2$  at the design frequency  $f_d$  of its constituent line segments must be met ( $Z_0$  is the reference impedance). Thus, a sharp-rejection transfer function with  $N$  passbands centred at the frequencies  $\{f_k\}$  as detailed in Fig. 1b within the spectral period  $[0, 2f_d]$  is realised. Furthermore, as it was demonstrated in [7], higher flexibility in the spectral positioning of these transmission bands is feasible by using stepped-impedance lines.

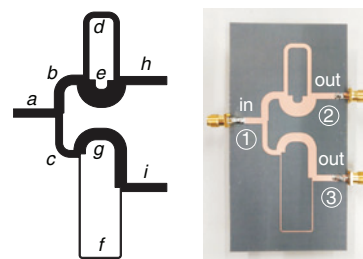
In this Letter, single- and two-band filtering sections (i.e.  $N = 1$  and 2) for the synthesis of a single/dual-band-channel duplexer are exploited. Note that the bandwidths of these channels can be adjusted to make them spectrally contiguous by means of the degree of freedom available from the characteristic-impedance design equation given in Fig. 1b. This is the case of the duplexer example theoretically synthesised in Fig. 2.



**Fig. 1** Proposed duplexer concept with contiguous single/dual-band channels  
a Architecture and operating principle  
b Constituent  $N$ -band channel based on a transversal signal-interference filtering section with input matching line



**Fig. 2** Power transmission ( $|S_{21}|$  and  $|S_{31}|$ ) and reflection ( $|S_{11}|$ ) parameters of theoretically synthesised duplexer example with single/dual-band channels (optimised design parameters of single-band channel:  $Z_1 = 0.52Z_0$ ,  $Z_2 = 1.24Z_0$ ,  $Z_m = 0.9Z_0$ ,  $\theta_1(f_d) = \pi/2$ ,  $\theta_2(f_d) = 3\pi/2$ , and  $\theta_m(f_d) = \pi/2$ ; optimised design parameters of dual-band channel:  $Z_1 = 0.78Z_0$ ,  $Z_2 = 2.56Z_0$ ,  $Z_m = 1.12Z_0$ ,  $\theta_1(f_d) = \pi$ ,  $\theta_2(f_d) = 2\pi$ , and  $\theta_m(f_d) = \pi/2$ )

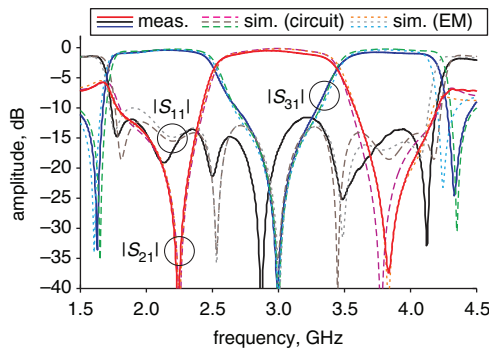


**Fig. 3** Layout and photograph of microstrip duplexer prototype with contiguous single/dual-band channels. Line widths ( $w$ ) and inner lengths ( $l$ ) in mm:  $w_a = 3$ ,  $l_a = 15$ ,  $w_b = 3.5$ ,  $l_b = 15$ ,  $w_c = 2.5$ ,  $l_c = 17.1$ ,  $w_d = 2$ ,  $l_d = 53$ ,  $w_e = 6.6$ ,  $l_e = 16.8$ ,  $w_f = 0.44$ ,  $l_f = 75$ ,  $w_g = 4.2$ ,  $l_g = 24.4$ ,  $w_h = 3$ ,  $l_h = 15$ ,  $w_i = 3$ , and  $l_i = 14.7$ . Rogers 5880 microstrip substrate: relative dielectric permittivity  $\epsilon_r = 2.2$ , dielectric thickness  $H = 1$  mm, metal thickness  $t = 35$   $\mu$ m, and dielectric loss tangent  $\tan \delta_D = 0.0009$

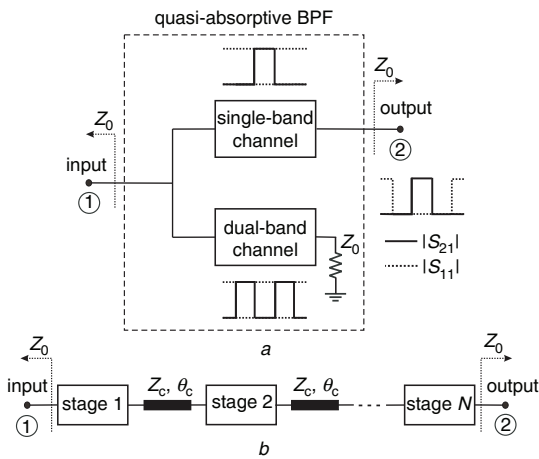
The layout and a photograph of the developed microstrip duplexer prototype corresponding to the previously synthesised example for  $Z_0 = 50 \Omega$  and  $f_d = 3$  GHz are shown in Fig. 3. Its simulated (with AWR Microwave Office and Ansys HFSS for circuit and electromagnetic (EM) simulations) and measured (with an Agilent E8361A network analyser) power transmission and input-reflection parameters are drawn in Fig. 4. Its main measured characteristics are:

- **Single-band channel:** centre frequency of 2.98 GHz, 3 dB absolute bandwidth of 930 MHz (i.e. 3 dB relative bandwidth of 31.3%), and minimum in-band insertion-loss level of 0.5 dB.

- **Dual-band channel:** lower-band centre frequency of 2.11 GHz, 3 dB absolute bandwidth of 797 MHz (i.e. 3 dB relative bandwidth of 37.8%), and minimum in-band insertion-loss level of 0.4 dB and upper-band centre frequency of 3.83 GHz, 3-dB absolute bandwidth of 778 MHz (i.e. 3 dB relative bandwidth of 20.3%), and minimum in-band insertion-loss level of 0.76 dB.



**Fig. 4** Simulated (circuit and EM) and measured power transmission ( $|S_{21}|$  and  $|S_{31}|$ ) and reflection ( $|S_{11}|$ ) parameters of microstrip duplexer prototype with contiguous single/dual-band channels

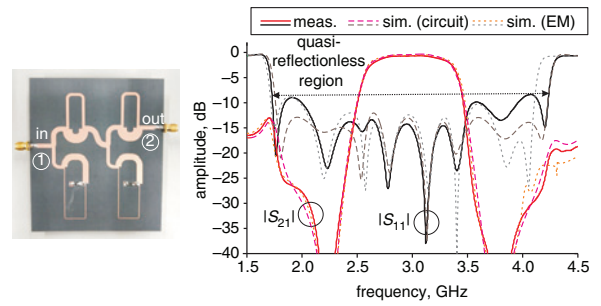


**Fig. 5** Proposed BPF with quasi-absorptive stopbands based on single/dual-band-channel duplexer

*a* Architecture and operating principle  
*b* *N*-stage BPF design

**Application to quasi-absorptive BPF design:** The proposed approach of wide-band duplexer with contiguous single/dual-band channels can be employed to design BPFs with quasi-absorptive stopbands at its input terminal. As shown in Fig. 5*a*, this is done by terminating the dual-band channel with a reference-impedance resistor and by taking as output terminal of the entire BPF the one of the other channel. Furthermore, as depicted in Fig. 5*b*, multi-stage designs can be realised through the in-series cascade of several replicas of the same duplexer-based quasi-absorptive BPF stage.

Based on this technique, a two-stage quasi-absorptive BPF prototype was realised by cascading two duplexer sections as the one in Fig. 3 by means of a quarter-wavelength-at-3 GHz transmission-line segment of 40  $\Omega$  impedance. Its photograph, simulated, and measured power transmission and input-reflection parameters are shown in Fig. 6. The main measured performance metrics of this circuit are as follows: centre frequency of 2.99 GHz, 3 dB absolute bandwidth of 800 MHz (i.e. 3 dB relative bandwidth of 26.9%), minimum in-band insertion-loss level of 0.64 dB, and minimum in-band input-power-matching levels of 13.4 and 8.3 dB within the filter 3 dB bandwidth and the frequency range 1.73–4.24 GHz (i.e. 2.45:1 ratio), respectively.



**Fig. 6** Photograph, simulated (circuit and EM), and measured power transmission ( $|S_{21}|$ ) and input-reflection ( $|S_{11}|$ ) parameters of microstrip BPF prototype with quasi-absorptive stopbands

**Conclusion:** A class of single/dual-band-channel duplexer that exploits signal-interference principles has been presented. The application of the engineered wide-band duplexer with single- and dual-band bandpass channels to quasi-absorptive BPF design has been verified. Moreover, for practical-demonstration purposes, two 1.6–4.4-GHz microstrip prototypes of the conceived duplexer and quasi-absorptive BPF approaches have been developed and measured.

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One or more of the Figures in this Letter are available in colour online.  
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