Switchable bandpass filter for WiFi–UMTS reception standards

Z. Brito-Brito, I. Llamas-Garro, G. Navarro-Muñoz, J. Perruisseau-Carrier and L. Pradell

A reconfigurable bandpass filter able to switch between WiFi and UMTS reception standards is presented. The topology allows achievement of two accurate centre frequencies, each associated with a precisely defined bandwidth, using six *pin* diodes. The design carefully takes into account the external quality factor for both filter states to ensure a good impedance match at each band of operation. Coupling coefficients and resonator lengths produce the bandwidths and centre frequencies required by both standards definitions. Surface mount components were carefully modelled and included in simulations. Simulated and measured results show excellent agreement.

Introduction: The goal of this work is to design a switchable filter for a gateway involving WiFi and UMTS reception standards for vehicle to vehicle communications. The proposed filter is able to produce accurate centre frequency and bandwidth values for each application using *pin* diodes. The microstrip filter presented in this Letter consists of two switchable resonators. The centre frequency is controlled by adjusting resonator lengths using two switchable sections. These two sections give the freedom of independently controlling filter centre frequency and bandwidth, since precise values for these design parameters must be met. In addition, a good impedance match for each filter response is achieved by using switched input and output coupling sections to the filter. Previous works involving a reconfigurable centre frequency without accurate bandwidth control using MEMS tuning elements can be found in [1]. In [2] a reconfigurable filter with variable bandwidth using *pin* diodes is reported. Compared with these works, precise values of bandwidth for each centre frequency have been achieved using the proposed topology.

Filter design: The WiFi and UMTS reception standards are specified in Table 1. Each of the two filter states are defined by three design parameters: the external quality factor Q_e related to the input and output coupling to the filter, the coupling coefficient K between resonators and the resonator length [3]. The filter topology in Fig. 1 is based on the parallel coupled transmission line filter in [4], and consists of six transmission line extensions switched by *pin* diodes, used to precisely set the three design parameters required to produce the two filter states specified in Table 1. In this filter topology all *pin* diodes are reverse biased to produce the WiFi state, while all *pin* diodes are forward biased in the UMTS state, facilitating the biasing network of the circuit. The relation between external quality factor and filter bandwidth or overlapping distance Y (see Fig. 1) for the two filter states, considering a fixed spacing S_1 and a fixed input and output impedance step w, was obtained by full-wave simulations using ADS/MOMENTUM. The Q_e providing precise input and output coupling for each filter state corresponds to 10.04 and 15.19 mm overlapping distance Y for 80 and 110 MHz bandwidths, respectively. The two precise values of K are achieved by the use of resonator extensions A (see Fig. 1), which define the required filter bandwidth for each state. When D_3 and D_4 are in off state, the filter bandwidth is in the WiFi state; when D_3 and D_4 are 'on', the filter response corresponds to the UMTS state. The lengths of the resonator extensions A are selected to provide a precise K value for each filter state, considering a fixed inter-resonator separation S_2. The filter centre frequency is set by the overall lengths of the switchable resonators. However, since filter bandwidth should take precisely defined values, each resonator is arranged to have two resonator extensions. The relation between coupling coefficient and bandwidth or overlapping distance X (see Fig. 1) was computed using ADS/MOMENTUM. Extension A fixes the value of K for each state corresponding to 15.04 and 26.38 mm overlapping distance X for 80 and 110 MHz bandwidths, respectively; while resonator extension B is added to the resonators to define the UMTS centre frequency state. When both extensions are switched on (D_2, D_3, D_4, and D_5 are in on state), the filter passband is set to the UMTS standard, while the WiFi standard is achieved when these diodes are in off state. The two resonator extensions play the role of providing a controllable coupling between resonators in both states defined by a fixed inter-resonator spacing S_2, and resonator extension A. The resonator extension B defines the overall resonator length without increasing inter-resonator coupling, as desired for an independently controlled bandwidth and centre frequency. Input and output couplings to the filter are set by diodes D_1 and D_6. When these diodes are in on state, the input and output coupling to the filter is optimal for the UMTS state; and when these diodes are in off state, the input and output coupling to the filter is optimal for the WiFi state.

Table 1: Filter specifications

	Centre frequency (GHz)	Bandwidth (MHz)
WiFi	2.440	80
UMTS	2.165	110

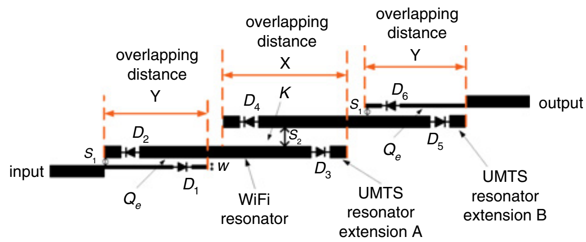

Fig. 1 *Switchable bandpass filter topology*

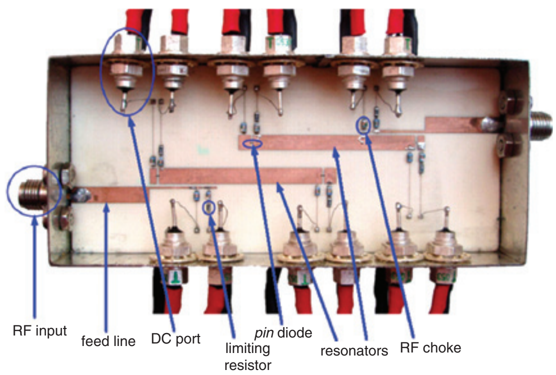

Fig. 2 *Photograph of switchable bandpass filter*

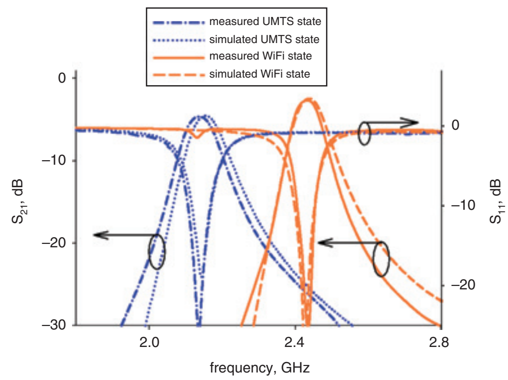

Fig. 3 *Simulated and measured results*

Results: Using the method described above, a bandpass filter was designed to switch between two filter states; one having a centre frequency of 2.165 GHz with a passband bandwidth of 110 MHz, the second state having a centre frequency of 2.440 GHz with a passband bandwidth of 80 MHz. These states correspond to the UMTS and WiFi reception standards, respectively, reported in Table 1. The filter was designed using a Rogers 1.524 mm-thick substrate ($\varepsilon_r = 3.55$, $\delta = 0.0021$) and HPND-4028 Avago Technologies *pin* diodes. The fabricated device is shown in Fig. 2. The bias network consists of a choke inductor to isolate the DC source and bias lines from the microwave circuit [5]. The current on each diode was limited to 10 mA by placing a 1 kΩ series resistor in the forward bias state; a voltage of -10 V was supplied in the reverse bias state. The filter topology included lumped element models extracted from measurements for the *pin* diodes and choke inductors are simulated in ADS/MOMENTUM, to precisely produce the two discrete states. This biasing method was also used in [6], where a filter topology for transmit standards using two diodes is reported. The measurements were taken using a N5242A PNA-X Agilent network analyser. Table 2 shows a comparison between simulated and measured results, where very good agreement in terms of centre frequency and bandwidth is observed for both filter states. Comparison between simulated and measured responses of the switchable bandpass filter for both states is shown in Fig. 3. The centre frequency deviation between simulations and measurements are 12 and 16 MHz for the WiFi and UMTS states, respectively. The simulated insertion loss is around 2.5 and 2.7 dB in measurements for the WiFi state, and 4.3 and 4.5 dB for the UMTS state. The simulated pass-band return loss is around 36 and 24 dB in measurements for the WiFi state, and 20 and 26 dB for the UMTS state. The difference between the simulated and measured bandwidth is 9 and 6 MHz for the WiFi and UMTS states, respectively. In summary, very good agreement between simulations and experiment is obtained for both filter states.

Table 2: Simulated and measured results

	Centre frequency (GHz)		Bandwidth (MHz)	
	WiFi	UMTS	WiFi	UMTS
Simulated	2.438	2.154	85	110
Measured	2.426	2.138	76	106

Conclusions: A switchable bandpass filter having two discrete states with precisely defined centre frequency and bandwidth has been demonstrated using *pin* diodes. The filter topology uses six switched sections to produce the filter response at each state defined by WiFi and UMTS reception standards. Very good agreement between simulations and measurements has been obtained.

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

Z. Brito-Brito, G. Navarro-Muñoz and L. Pradell (*Signal Theory and Communications Department, Technical University of Catalonia, Barcelona 08034, Spain*)

I. Llamas-Garro and J. Perruisseau-Carrier (*Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), Barcelona 08860, Spain*)

E-mail: llamasi@theiet.org

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