Design of Ultra-Wideband Filter with Embedded RF-MEMS based Reconfigurable Notched Band

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Abstract. This paper presents the design of a compact ultra-wideband (UWB) bandpass planar filter with a tunable notched band within the bandwidth. The filter can be used for wireless communications within the unlicensed UWB range (3.1-10.6 GHz). The UWB filter is based on external interdigitated quarter-wavelength microstrip resonators and a central half-wave microstrip resonator embedding a reconfigurable open-circuited stub. The stub introduces a narrow rejection band inside the UWB filter bandwidth. The frequency tuning of the notched band is obtained by sequentially activating three RF MEMS ohmic switches placed in series along the embedded stub. HFSS® simulations of a 5th order UWB filter show very low return (>13dB) and insertion losses (<0.3dB) in all stub states and good selectivity performance of the notched bands (up to -18dB of rejection). The device is being fabricating at FBK on quartz substrate; experimental results will be available soon.

1. Introduction

Since 2002, when the Federal Communication Commission (FCC) authorized the unlicensed use of the frequency band from 3.1 to 10.6 GHz for commercial communication applications [1], considerable research efforts have been put into ultra-wideband (UWB) radio technology worldwide. For the indoor use, the UWB frequency band of 3.1 to 10.6 GHz may be interfered by the wireless local area network radio signals. So, a communication system working in this UWB frequency band requires a bandpass filter with tunable notched bands to avoid being interfered by the WLAN radio signals.

In recent years several techniques have been introduced to generate a single or multi notched bands into UWB bandpass filters. In [2] an asymmetric parallel-coupled line structure is developed in a multi-mode resonator UWB filter and in

[3] an asymmetric dual-line coupling structure is employed for multiple-notch implementation in UWB filters. In [4] and in [5] stepped-impedance resonators are coupled to the UWB filter to achieve a narrow notched band. In [6] open stubs are embedded in a microstrip-to-SIW transitions to generate the frequency notch in a UWB filter realized combining the responses of a highpass filter in Substrate Integrated Waveguide (SIW) technology and a step-impedance lowpass filter. Embedded open-circuited stubs have been proposed to introduce a fixed notched band in a UWB filtering response, such as in [7], [8], [9].

In this paper, a UWB 5th order bandpass filter with an embedded RF-MEMS based reconfigurable notched band is presented. The UWB filter is composed by external interdigitated quarter wavelength microstrip resonators and a central half-wave microstrip resonator [2], embedding a MEMS-reconfigurable open stub. Such a solution allows for lower loss contribution and narrower rejection bandwidth if it is compared to other solutions developed so far which employ pin diodes [10].

Moreover, the MEMS-based open-circuited stub yielding the tunable notched bands is embedded in the 5th order filter thus unchanging the filter footprint and achieving a very compact structure (2×35 mm).

2. Filter Design

The layout of the UWB filter is shown in Fig. 1. At both extremities, three λ/4 (at 6.5 GHz central frequency) open-circuited lines are parallel-coupled in an interdigitated configuration producing four filtering function poles. The additional pole of the filter is due to the central λ/2 resonator. The UWB filter structure is characterized by the presence of a length-reconfigurable open-circuited stub that is directly embedded within the central λ/2 resonator (Fig. 2).

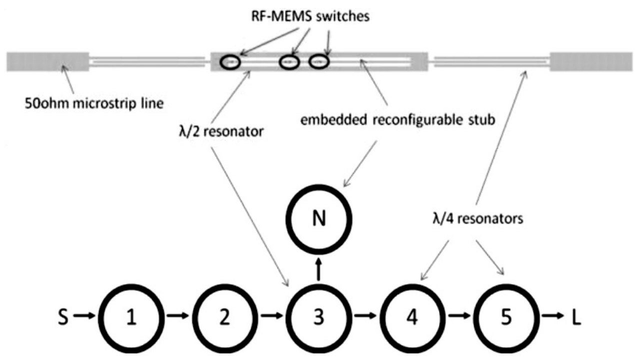

Fig. 1. Layout and scheme of the UWB bandpass 5th order filter.

Three RF-MEMS cantilever switches are placed in series along the open-circuited stub to vary its length L_{notch} and consequently tune the notch frequency.

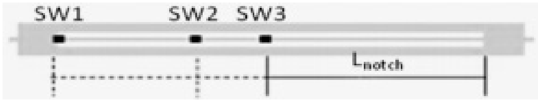

Fig. 2. Reconfigurable open-circuited stub with three RF-MEMS switches embedded in the UWB filter central resonator.

The cantilever MEMS switch consists of a gold membrane suspended above the interrupted microstrip stub and anchored at one end. The membrane has a size of 110µm×170µm and an air gap of 2.7µm (Fig. 3). In the off-state the switch provides very high wide-band isolation from DC up to high frequencies, virtually realizing an ideal open-circuit. In the on-state, on the contrary, the cantilever is lowered by electrostatic forces applied on the actuation pad and contacts the interrupted signal line.

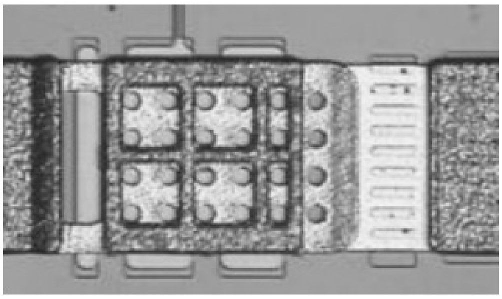

Fig. 3. Photo of the series ohmic cantilever switch used as building block of the filter.

Similar switches in coplanar or microstrip technology have already been manufactured at FBK (Fondazione Bruno Kessler) on high resistivity silicon substrate showing equivalent on-state resistance of 0.9Ohm and off-state capacitance of about 10fF [11], [12].

3. Simulated Results

Fig. 4 shows the Ansoft HFSS® model of the MEMS-based 5th order UWB filter. Each MEMS switch has been modeled as a series capacitance of 10fF or a series resistance of 1Ohm for the cantilever in up (off-state) or down position (on-state) respectively. The filter footprint is 2×35 mm.

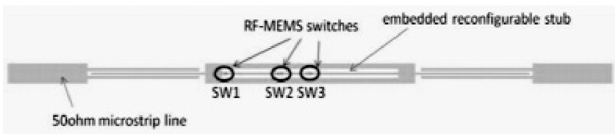

Fig. 4. HFSS® model of the MEMS-based 5th order UWB filter.

When all switches are activated (on-state), the line is uninterrupted and no selective stop band is visible. Fig 5 shows the full wave simulated results via Ansoft HFSS® [13] for this configuration. As can be seen, return loss and insertion loss better than 20 dB and 0.25 dB have been obtained from 3.5 GHz to 9.5 GHz.

When switch #1 is deactivated and the other ones are in the on-state, the embedded line is interrupted introducing the notch stop-band response at 4.3 GHz. When also switch #2 is deactivated, the length of the stub is reduced so as to produce a rejected band exactly at the center of the filter band, *i.e. at* 6.5GHz. Similarly when switch #3 is deactivated as well, the notched band is moved to the upper bandwidth, *i.e*. at 8.5GHz.

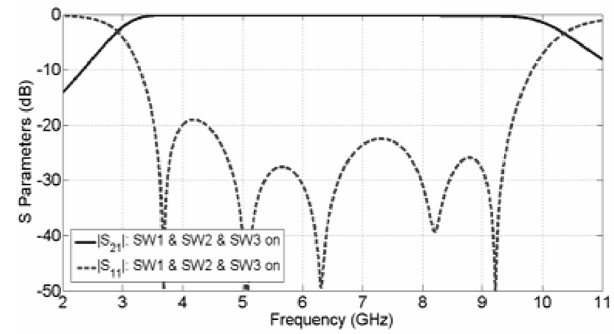

Fig. 5. Full wave HFSS® simulated performance of the UWB filter with no rejected band: |S21| (solid blue line) and |S11| (dashed red line).

Fig. 6 shows the comparison in terms of insertion loss in these three configurations. As can be seen, the 3dB rejection bandwidth is very narrow (5-6% depending on the stub state) because of the very low coupling between the central resonator and the embedded stub [9].

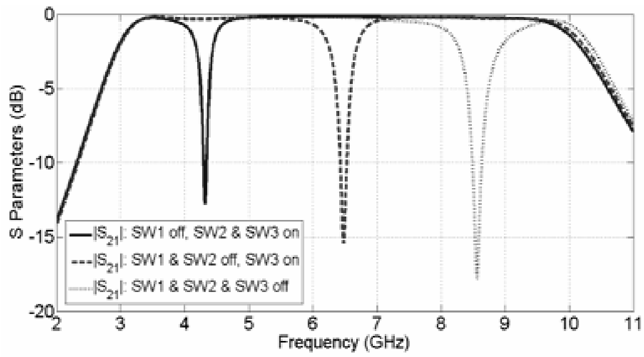

Fig. 6. Comparison among the UWB filter |S21| responses of the three different stub configurations (HFSS®).

The rejection ranges from -13dB up to -18dB depending on the stub configuration. The insertion loss of the UWB filter is insensitive to the embedded stub state and is below 0.3dB in all cases. Fig. 7 shows the filter responses in terms of return loss for different states of the embedded stub. The stub introduces a small degradation of the filter matching: the return loss is however better than 13 dB over the whole filter bandwidth in all cases.

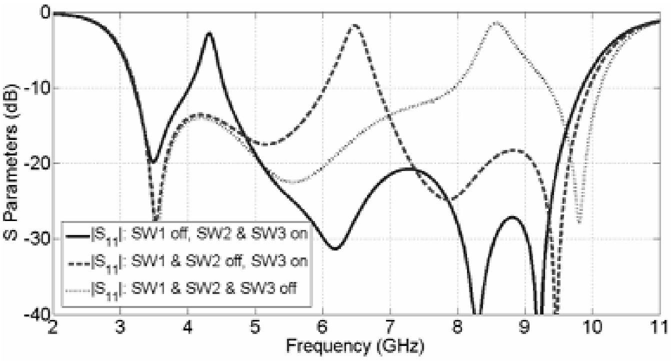

Fig. 7. Comparison among the UWB filter |S11| responses of the three different stub configurations (HFSS®).

The device is being fabricated on quartz substrate by using the 8-mask MEMS process developed by FBK in Trento [11]. RF performance and reliability tests will be carried out for a complete characterization. The experimental results will be available soon.

4. Conclusions

The design of a compact UWB 5th order bandpass filter with a tunable notched band has been presented. A variable length λ/4 open stub is embedded in the central λ/2 resonator of the UWB filter. Three RF-MEMS cantilever switches have been placed in series to the open stub allowing for selecting four possible filter states: no notch, notch in the lower bandwidth, notch at centre frequency, notch in the higher bandwidth. The Ansoft HFSS® filter simulations show very good return loss (>13 dB), insertion loss (<0.3dB) in the entire bandwidth and rejection of notched band up to -18dB in all configurations. The presented device is being fabricated at FBK.

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