9.6-11.7 GHz Analogically Tuned Band Stop Filter Based on RF-MEMS Varactors

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Abstract. Tunable 9.6 GHz to 11.7 GHz bandstop filters are presented. Tuning is done using RF MEMS structure with analogical capacitance variation, from 25 fF to 225 fF [1]. Filter is designed with ring resonators coupled on a 50 Ohms micro-strip transmission line. To optimize microwave performances, a 2 pole is presented with a half-wave line arranged between two resonators with a zero refection mode. This configuration permits to enhanced rejection and minimizes the out of band losses. The measured performances are -35 dB of rejection at 9.6 GHz, shifting to -42 dB at 11.7 GHz. The losses below the rejected band are less than -1 dB. This device has also been measured under variable RF power and has shown handling at 6 W.

1. Introduction

MEMS technology is an attractive solution for microwave component switching and tuning. For instance, micro-electromechanical analog tunable capacitors enable wide tuning ranges and high quality factors, compared to the existing solid state varactors, which typically have small tuning ratios, high resistive losses and low self-resonances. Due to their superior RF performance (low loss, low power and low intermodulation distorsion), RF MEMS have been used in different RF circuit applications: tunable microwave filters [2], tunable phase shifters [3] and tunable antennas. One type of tunable filter that is very important in RF receivers for communication and radar systems is the bandstop filter.

In this work, RF MEMS are used as analog varactors, to change the operating frequency of a band reject filter. MEMS based tunable split ring resonator can be easily tuned using a variable capacitor since the arms of the ring are in opposite phase. Using 2 pole filters, the performances at the working frequency can be improved, with the 2 pole tuned at the same frequency. Also, the filtered can be widened, by appropriate separate tuning of the resonators. For band stop filter applications, the use of ring resonators designs also permits to improve the filter performances along with tuning, as the electromagnetic energy can be coupled using a magnetic field coupling inside the ring. This device has also been measured under variable RF power.

2. Tunable Band Stop Filter

The band stop filter developed is designed on 50 Ohms micro-strip waveguide, on a 530 µm fused silica substrate with a 400 nm AlN dielectric insulating layer. The design of this filter is shown on Fig. 1.

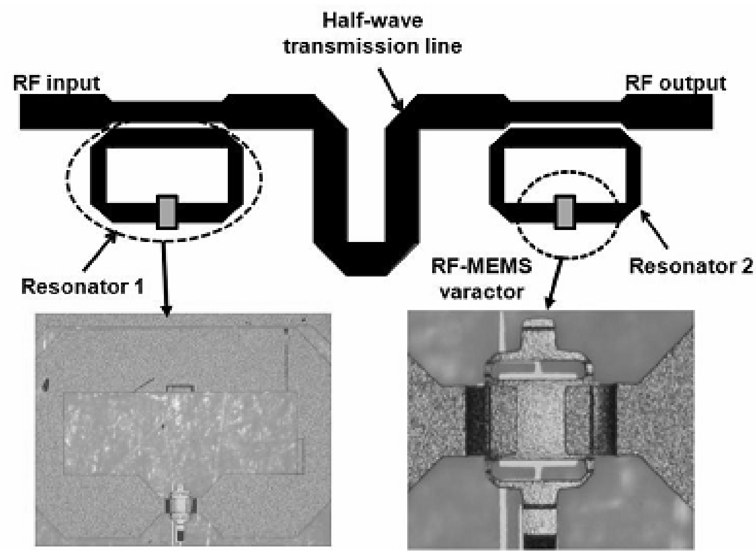

Fig. 1. Design of the 2 pole tunable X-band rejecter filter based on RF-MEMS varactor.

The filter rejection is made with ring resonators. There are two of these as the filter operates with 2 pole. The operating frequency of these resonators without loading is 12 GHz, changed by the charged impedance presented by the RF-MEMS varactors. The RF-MEMS used is based on a technology development already presented in [1]. It is composed of an electroplated gold bridge raised above an actuation electrode made in chromium, and an aluminum nitride dielectric layer. The microwave input and output are standing above the bridge, with an air gap between both. The varactor corresponds to two capacitance in series located at the RF input of the bridge (metal-air-metal capacitance), and the same with the output. These two capacitances will decrease by applying bias, which reduce the bridge height, and increase the distance with microwave inputs.

These tuning devices are located at the opposite of the micro-strip line (on the rings), where the accumulated EM field is maximum. This permits to maximize the effect of tuning devices on the filter. The two rings are arranged in series with a half-wave line between them (9 GHz). This disposition is used to create two reflections zero, which reduces losses outside of the rejected band. A second zero reflection point exists for the frequency of 12 GHz, due to combination of this half-wave line with the resonators.

Two types of application on this filter can be considered. On the one hand, the two pole are working at the same frequency, and so, the rejected performance is enhanced with high selectivity. On the other hand, the two poles can be adjusted on near frequencies, so the rejection bandwidth is improved.

This design had been simulated under ADS MOMENTUM software, and compared with measurement, for each pole centered at 10.95 GHz, on Fig. 2.

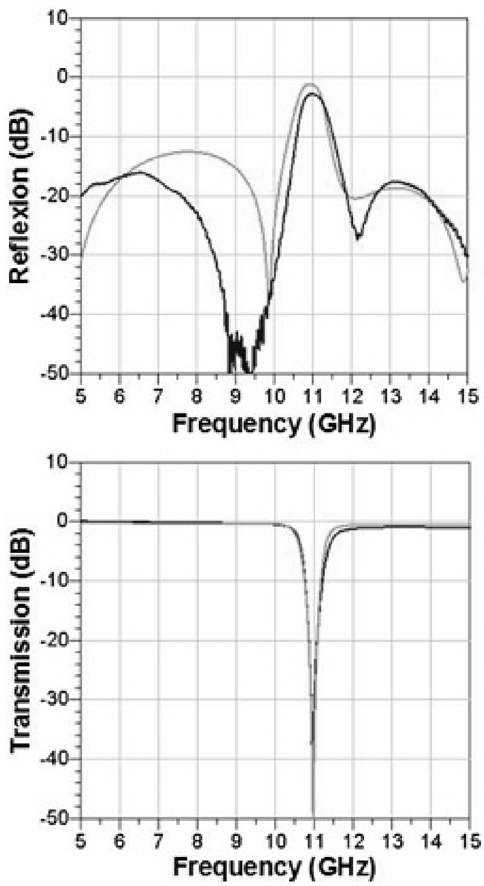

Fig. 2. Microwave simulation of the filter (red) and measurement (blue).

Thus, this design of filter shows potential rejection performances better than -50 dB rejected at 11 GHz. The measurements show rejection of -42 dB.

3. Measurements

The filter has been realized, and measured with the 2 pole working at the same frequency. A picture of the filter in its package is shown on Fig. 3.

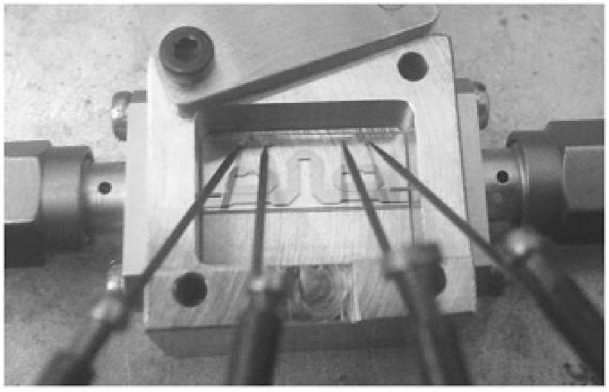

Fig. 3. Photography of the filter set in case with SMA connection accesses.

The microwave signal is brought with two SMA connectors, and the bias is applied with external pads on the filter. On the picture, two bias signals are applied using DC probes on the two varactors. In the final development of this device, bias will be applied using a specific plug system. Reflection and transmission performances are shown on Fig. 4.

We can see the influence of the two zero reflection points at 9.5 GHz and 12 GHz. The first of these permits to enhance the return loss with increasing working frequency, up to -30 dB at 9.6 GHz (with rejection set at 10.8 GHz). The 12 GHz zero reflection point permits to have return loss under -16 dB between 12 GHz and 12.5 GHz.

In transmission, this filter shows tunability on X-band between 9.6 GHz to 11.7 GHz. This tunability allows rejecting all possible frequencies in this frequency band, since the matching devices (RF-MEMS varactors) are analogically actuated. The isolation due to rejection are from -35 dB at 9.6 GHz, improved to -42 dB at 11.7 GHz. Performances are better for higher frequencies because the resonator are design at 12 GHz (considering no bridges), also measured at 12.2 GHz. The bandwidth measured for -20 dB rejection increases from 50 MHz at 9.6 GHz, to 250 MHz rejected at 11.7 GHz operating frequency.

Another essential point on this design concerns insertion losses outside the rejected band. Using the two zero reflection points seen before, these are limited to low values. This is presented in Fig. 5.

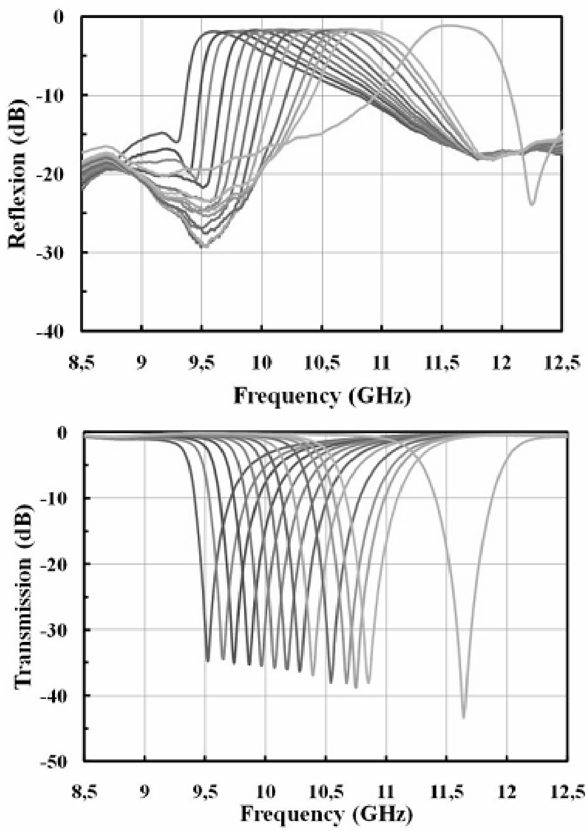

Fig. 4. Microwave performances of the filter, on top the reflection, and down the transmission. The measurements are realized for different applied voltages, from 0 V to 90 V on the two varactors.

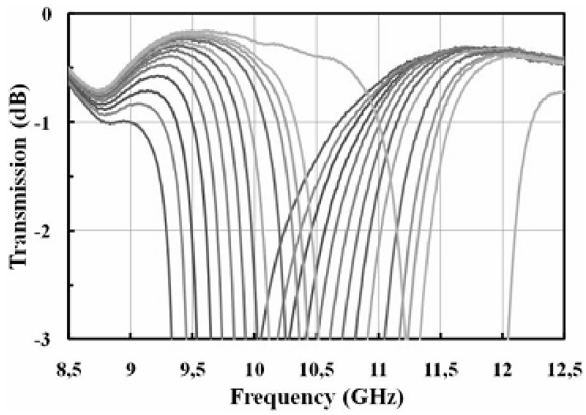

Fig. 5. Expanded view on transmission. Insertion losses are low outside of the rejected band.

Moreover, this filter has been caracterized in response of a power effect.

Sensivity to radio-frequency power provokes drifts of the resonant frequencies of each pole. This drift is depending of the electromagnetic energy located between MEMS bridges and RF electrodes. Thus, capacitance values are changed by power effect, and then will increase with higher power applied, due to the inverted electromechanical principle of the actuators. Capacitance variations can be compensated thanks to several volts of applied voltage added on the actuators. This is shown on Fig. 6 with different values of power, between 100 mW and 250 mW. With 1.5 V added on the first pole and 9 V added on the second pole, drift of the RF power variation from 100 mW to 250 mW is cancelled.

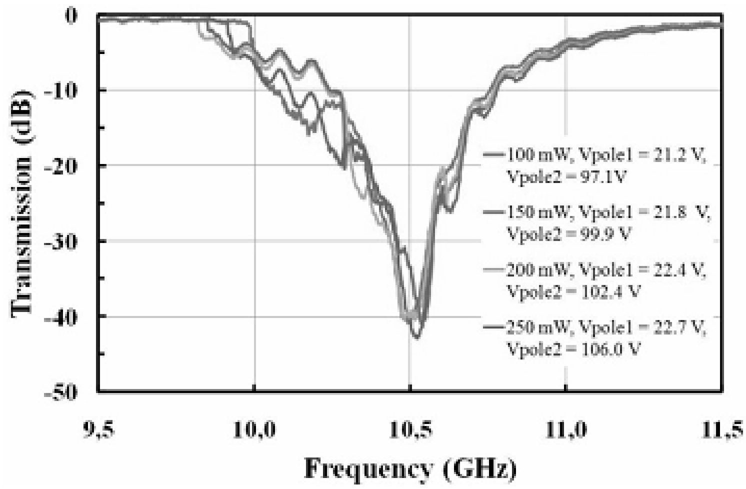

Fig. 6. Compensated power effect on the device to obtain fixed 10.5 GHz resonant frequency.

Futhermore, this device has been tested at highest resonant frequency, with variable RF power. In this case, applied power will have the lowest influence on the filter stability because MEMS bridges are contacting on the ALN dielectric. This has been measured, and shown on Fig. 7.

Thus, with all RF MEMS in the down state, the resonant frequency of the two pole filter is 11.65 GHz, also with 100 mW RF power applied. Then, the transmission response is measured for variable power until 6 W, with inchanged bias. At 1 W power applied, disturbances are low on the filter, and at 2 W applied, we can see that these disturbances are found by drift of the resonance frequency of almost 500 MHz. More, we can see that the rejection at 11.65 GHz is still strong with -30 dB of transmission at 6 W of power applied.

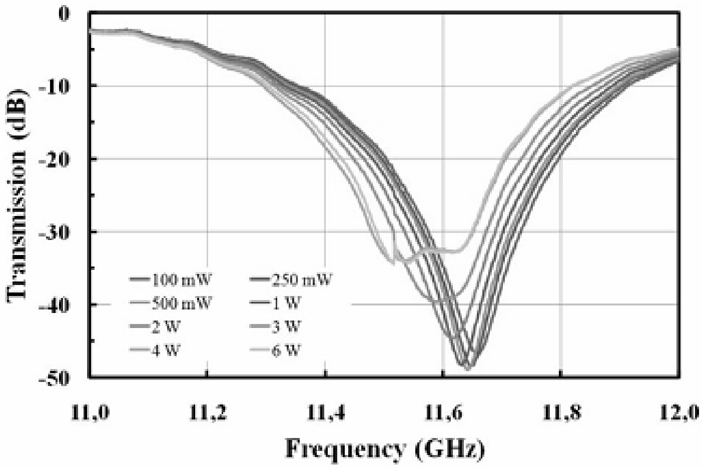

Fig. 7. Influence of RF power on rejection when RF MEMS are in the down state.

4. Conclusion

A high performance tunable X-band bandstop filter for interference management applications is presented. RF-MEMS are used as tuning devices for their interests in microwave performances, with high Q factor. Here we used analog RF-MEMS varactors which present low values of capacitance (25 fF to 225 fF), in order to tune the center frequency of two ring resonators coupled to a micro-strip line. Measurements have shown that tuning effect operate between 9.6 GHz to 11.7 GHz with rejection about -35 dB to -42 dB. Furthermore, this bandstop filter has shown power handling performances under 6 W with disturbances compensation possibility.

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