MIMOSA

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WP4

- Deliverable Report-

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Deliverable Title:	**BAW resonators and filters-1st run**
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TABLE OF CONTENTS

INTRODUCTION

WP4 focuses on microsystems integration. It addresses on the one hand integration issues to serve the demands of other work packages, according to MIMOSA global scheme, and provides the technology for demonstrators of WP1, and on the other hand new developments. The latter are specifically the development of MEMS components starting from the existing IC platform technology, new material integration study to enlarge the platform capability, or new integration methods.
The main objective is to develop an advanced technology platform, built around piezoelectric aluminium nitride (AlN) thin films, for realizing the very high quality components needed by the new high performance wireless communication systems. This platform will be adapted to the production of many different components, such as high-Q resonators, filters, RF-MEMS, or even sensors, on the same wafer with a limited number of technology steps. The development of a generic technology around aluminium nitride thin films will provide with a powerful tool to create many different micro-systems by combining the different components at the design level.

The work presented in this report deals specifically with the design, layout, fabrication and characterisation of a BAW filter for a wake-up radio. A 'MIMOSA wake-up radio feasibility study and specifications' has been made in WP3A. The following specifications for the BAW filter came out of this study:

- Differential filter covering the whole ISM band from 2.4 to 2.48 GHz
- *Input impedance of 50 Ohms and output impedance of 200 Ohms*
- Insertion loss of 3 dB
- out-of-band and image rejection of 40 dB

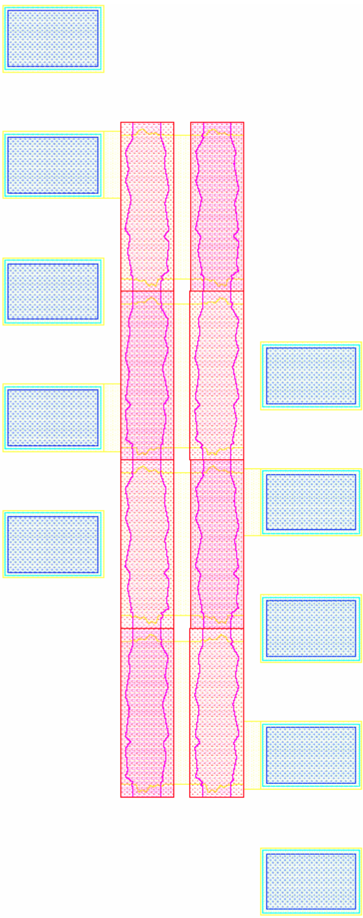
Though the impedance transformation is desirable, the first simulation work rapidly showed that the impedance transformation from 50 to 200 Ohm was too large and had as a consequence a large IL with a higher ripple. From the system point of view, a 100 to 100 Ohms filter was acceptable and the specification has been modified accordingly:

- Input impedance of 100 Ohms and output impedance of 100 Ohms

SIMULATION / LAYOUT

A differential filter being required, a lattice architecture has been chosen. In order to perform a simulation, various parameters are needed.

- Two are linked to the AlN layer. k^2_{eff} = 6% and dielectric losses of 0.2% have been taken.
- A third parameter is the quality factor of the resonators. Q_S = 800 has been taken for the simulation
- The other parameters, connection and electrodes resistances and parasitic capacitances, are linked to the layout. The layout shown below has been chosen.

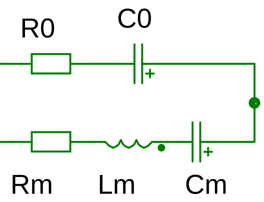


Layout of the 2 stage lattice filter.

The properties of the AlN layer and of the resonators were estimated from other works, in particular the European project MARTINA.
The aspect ratio of the resonators is mainly dictated by the pitch of the measurement pads. Pads are made with thick Aluminium (blue) and connected to the Al top electrode (yellow).

The 2 elongated, apodized pink shapes are the Pt (floating) bottom electrodes. The 4 darker pink rectangles represents the loaded resonators with a lower resonance frequency.

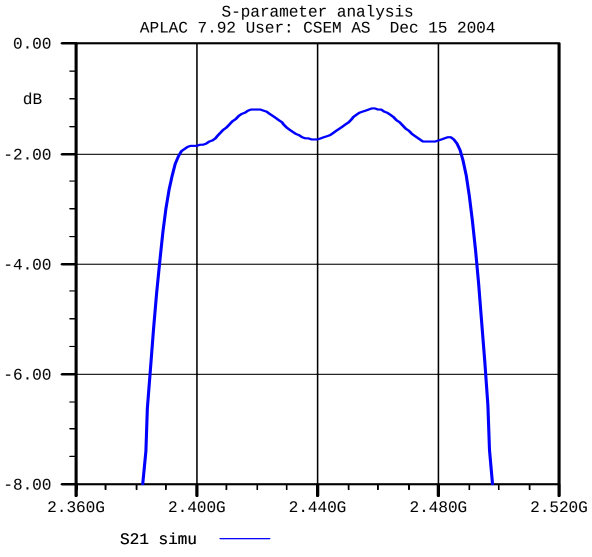
Simulations were performed using the APLAC software. Each resonator is represented by a an equivalent circuit of the following form:



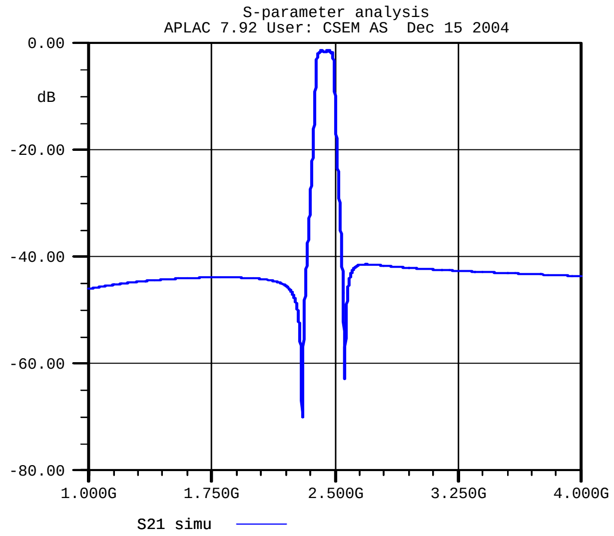
Equivalent circuit of a resonator

Apart from the resonators, resistances have been implemented into the software to account for the connection and electrode resistances. Additional capacitances representing the coupling between the neighbouring resonators have also been implemented. No other parasitic capacitances have been added. This corresponds approximatively to the deembedded case.

The result of the simulation work is presented on the 2 graphs here after. The specification of -3 dB insertion loss and -40 dB suppression level are fulfilled.



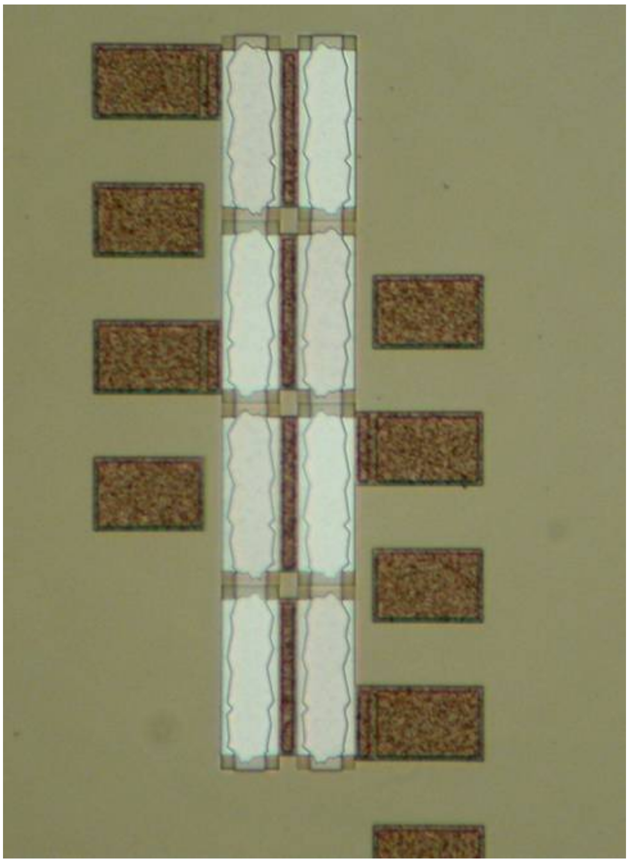
IL :Simulated S21 response of the lattice filter



Suppression: Simulated S21 response of the lattice filter

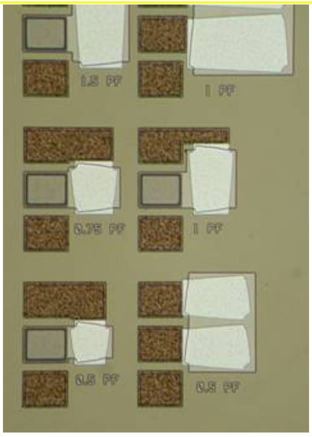
FABRICATION

The fabrication process starts with the Bragg mirror. Starting from the Si wafer, a 610 nm SiO2 layer is deposited, followed by a 1160 nm AlN layer. These 2 steps are repeated 3 more times and then an additional 610 nm SiO2 layer is deposited on top of the 8 other layer. Then the 200 nm Pt bottom electrode is deposited and structured. It is followed by the deposition of the 1190 nm thick AlN layer and the 200 nm thick Al top electrode. The top electrode is patterned and finally a 70 nm thick SiO2 loading layer is deposited and patterned. The resulting filter is shown on the picture below.

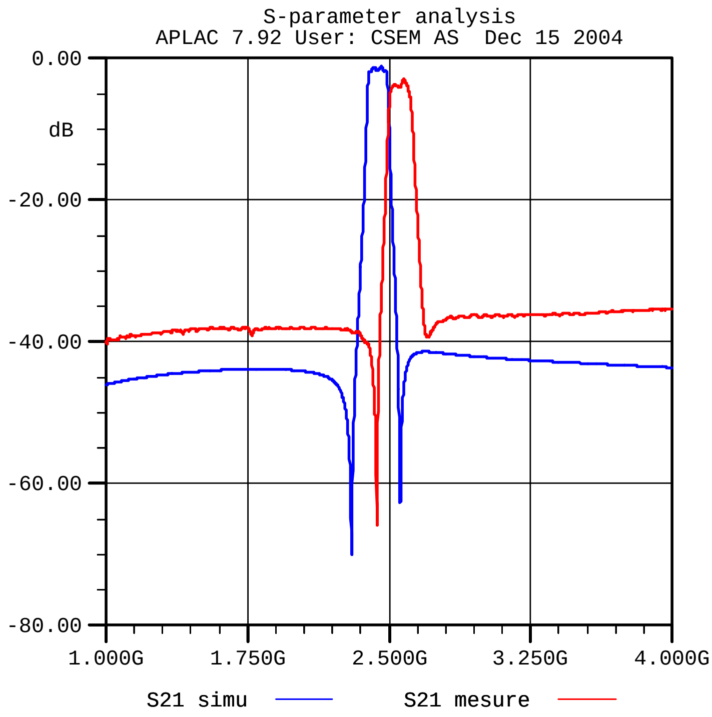


Picture of the fabricated lattice filter

Single resonators have also been fabricated. One aim was to extract parameters such as k^2_{eff} and Q_s. The second goal was to produce single resonators for VCO applications. Their size ranged between 0.5 and 1.5 pF. These resonators are shown on the picture here after.



Picture of the resonators for the VCO applications



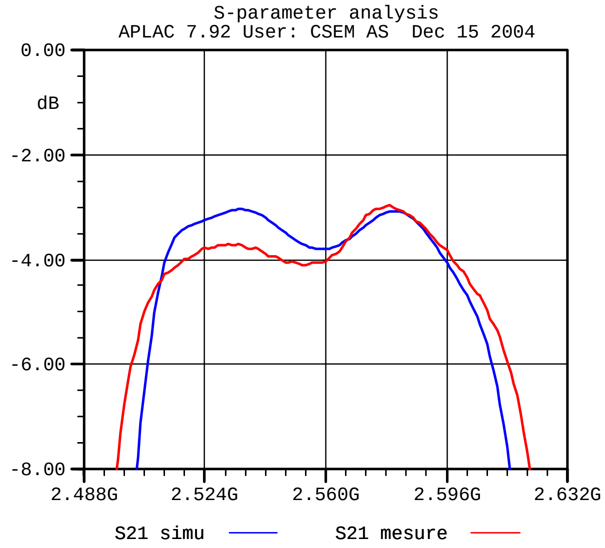
Measured (red) S21 response of the lattice filter compared to the original simulation (blue)

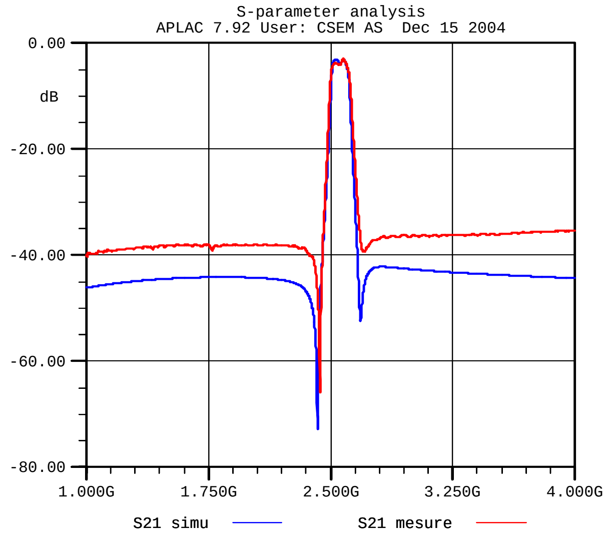
The red curve on the graph above shows the S_{21} response of the fabricated filter as compared to the simulated curve in blue. The frequency of the fabricated filter is slightly too high, by about 5% with the center of the pass band at 2.56 GHz instead of 2.44 GHz. A 5% error is acceptable for filters fabricated on a development tool not specially dedicated to BAW devices where the thickness control is a central point. The measured IL and suppression level are -4 dB and -36 dB respectively.

The insertion loss and the suppression level are not at the expected level. The explanation is as follow. The real k^2_{eff} , Q_s and losses have been extracted from the SMR resonators lying on the wafer. The following values have been found:

- k^2_{eff} = 5.6% (instead of 6%)
- losses= 8% (because the losses cover not only the 0.2% dielectric losses, but also other losses (acoustic, ...))
- Q_S= 500 (instead of 800)

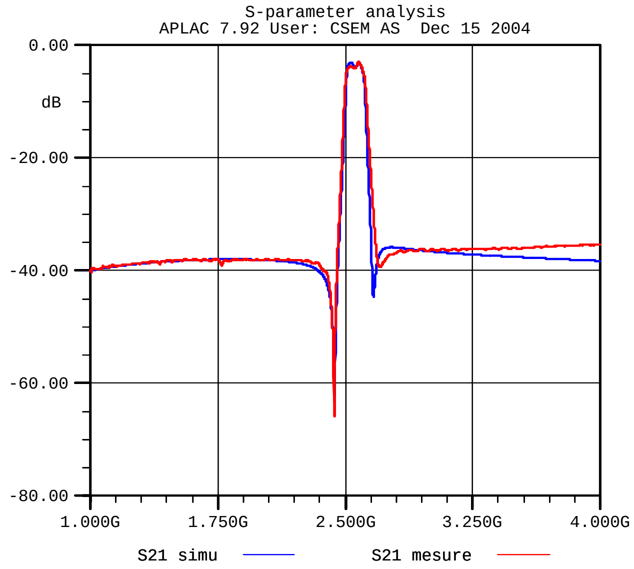
Using these values instead of the values used in the original simulation, and making the simulation at 2.56 GHz, the following result is obtained:





Measured (red) S21 response of the lattice filter compared to the simulation with the extracted parameters for the resonators (blue)

The measured insertion loss is now quite close to the simulated IL. However the suppression level is about 6 dB higher than simulated. The level of rejection out of band is mainly set by the parasitic capacitances. In the simulations presented previously only the parasitic capacitances between neighbouring resonators have been taken into account. The discrepancy between the simulated and measured curve can be reduced close to 0 by adding some extra parasitic capacitances in the order of 10-20 fF, as it is shown on the graph below where an additionnal 20 fF has been added between one of the input pad and one of the output pad. The presence of parasitic capacitances is not surprising and values in the 20 fF range are reasonable.



Measured (red) S21 response of the lattice filter compared to the simulation with the extracted parameters for the resonators and an additional 20 fF parasitic capacitance (blue).

CONCLUSIONS

- BAW resonators and filters have been designed, layouted and fabricated successfully.
- The APLAC simulation tool has proven to be an appropriate tool, specially when the material parameters are known precisely.
- The performance of the resonators with k^2_{eff} = 5.6% and Q_S= 500 are good.
- The characterization revealed a quite important fact that SMR resonators are subject to losses of different origins that sum up to about 8%.
- The fabricated filters, with an IL of -4dB, a bandwidth of 70 MHz and a rejection of -36dB show promising performances for Bluetooth applications.