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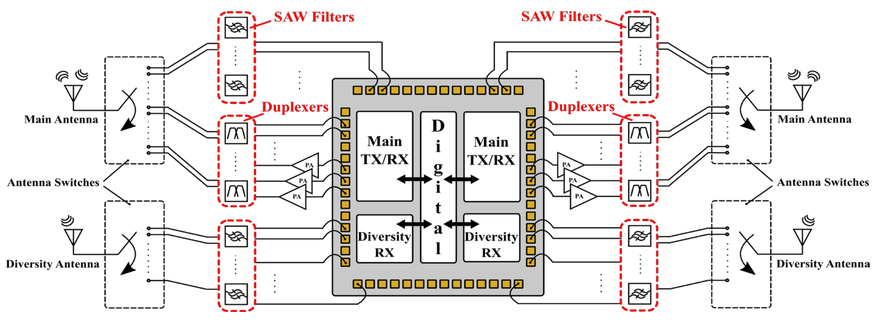
XXX Cycle - II year presentation

SAW-less digitally-assisted receivers

Typical modern multi-standard platform for smartphones



MIMO (Multi Input Multi Output) | **Large number RX-TX paths** | **Large number of bands**

Huge number of external components

The exponentially increasing complexity of modern wireless terminals, like smartphones, is due to the ever growing demand of performance, standard, modes of operations and bands to be supported. For each band, dedicated off-chip SAW filters are used to eliminate large out-of-band blockers, keeping the receiver linearity requirements feasible.

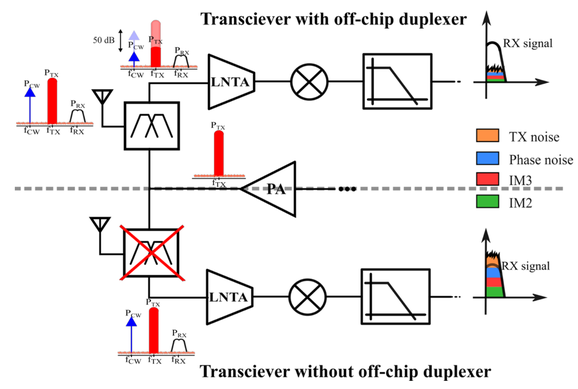
In FDD applications, in which the main transmitter and receiver share the same antenna, SAW-based duplexers are used to provide sufficient Tx-Rx isolation.

However, this highly selective RF filters have many drawbacks:

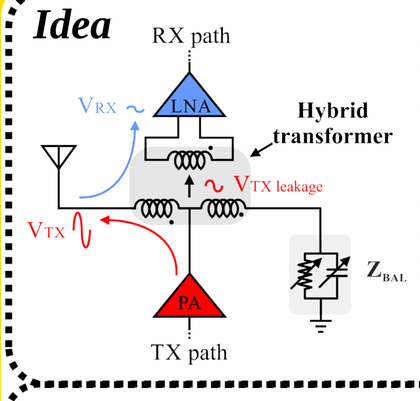
- **high costs**
- **lack of tunability**
- **bulky structures (area)**

Project aim

Finding equivalent integrable solutions



Idea



A hybrid transformer is a four-ports circuits with a biconjugacy between alternate sets of ports.

In balancing condition, it can realize an integrable and reconfigurable duplexer, ensuring a good isolation level between TX and RX.

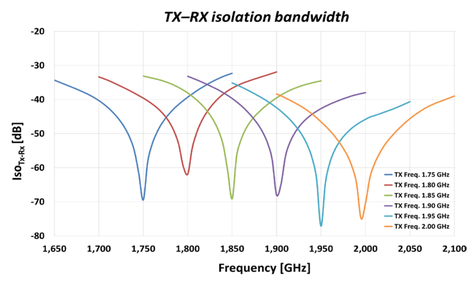
60 dB peak isolation
over 45dB across 14 MHz bandwidth

Issue

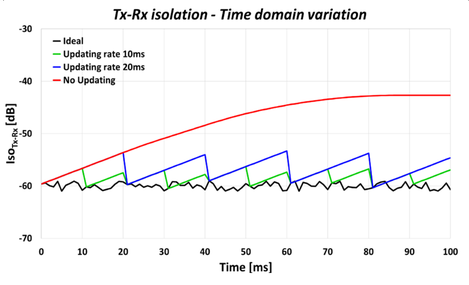
Sensitivity of the Tx–Rx isolation of the matching between the antenna impedance (e.g. PIFA) and a suitably designed balancing impedance (e.g. programmable R-C parallel network)

$$ISO_{Tx-Rx} = \frac{V_{LNA}}{V_{Tx}} \propto \left(\frac{Z_{ANT} - Z_{BAL}}{Z_{ANT} + Z_{BAL}} \right)$$

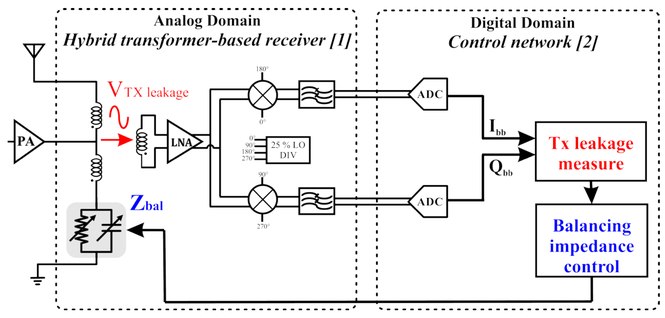
Strongly frequency dependent

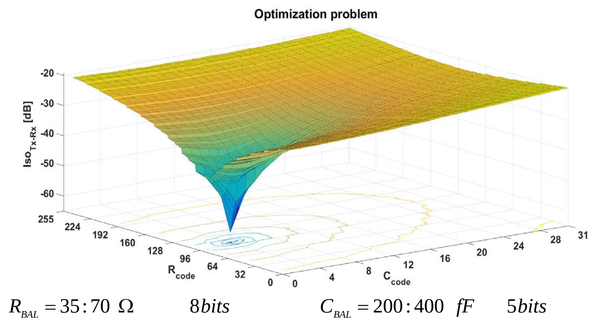


Time variant
(interactions with external environment)



Control network design





$R_{BAL} = 35:70\ \Omega$ 8*bits* $C_{BAL} = 200:400\ fF$ 5*bits*

Digital algorithm description

Main goal: low-power low-area hardware implementation

1) Optimization phase

Finding the initial optimal balancing conditions

$$P_{TxL}\left(\mathbf{Z}_{BAL}\right) \qquad \mathbf{Z}_{BAL} = [R_{BAL}, C_{BAL}]$$

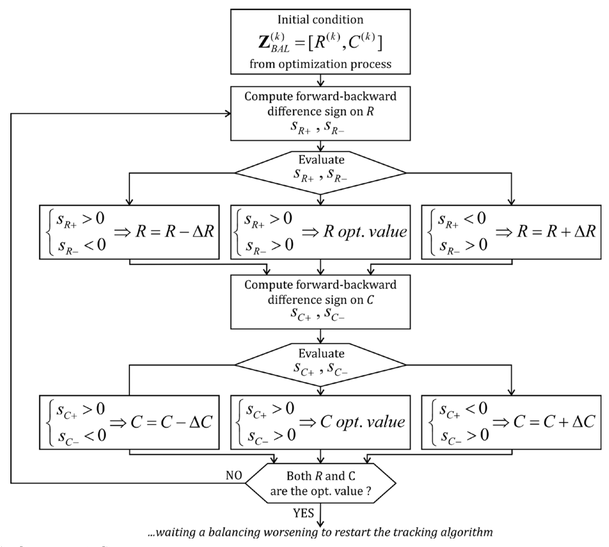
$$\mathbf{Z}_{BAL}^{(n+1)} = \mathbf{Z}_{BAL}^{(n)} - \boldsymbol{\gamma}^{(n)} \operatorname{sgn}\left(\nabla P_{TxL}\left(\mathbf{Z}_{BAL}^{(n)}\right)\right)$$

$$\boldsymbol{\gamma}^{(n)} = [\gamma_1^{(n)}, \gamma_2^{(n)}] = [2^{N_1 - n - 2}\Delta R_{BAL}, 2^{N_2 - n - 2}\Delta C_{BAL}]$$

- The Tx leakage minimization is resolved applying a customized gradient descent method;
- The sign of the gradient components are estimated through real-time Tx leakage measurements, exploiting finite difference approximations;
- The step size is chosen like in a binary search method.

2) Tracking phase

Tracking the variations during normal functioning of the system



...waiting a balancing worsening to restart the tracking algorithm

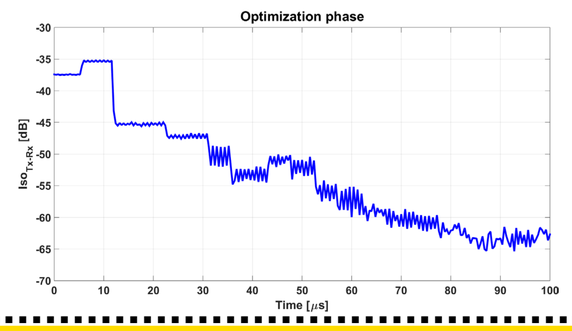
[1] M. Ramella, I. Fabiano, D. Manstretta, and R. Castello, "A 1.7-2.1GHz +23dBm TX Power Compatible Blocker Tolerant FDD Receiver with Integrated Duplexer in 28nm CMOS", Proc. of IEEE ASSCC, Nov 2015

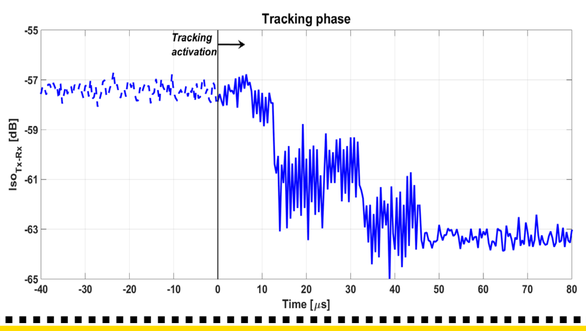
[2] G. Castellano, D. De Caro, A. G. M. Strollo, D. Manstretta, "A Low Power Control System for Real-Time Tuning of a Hybrid Transformer-based Receiver", 2016 IEEE International Conference on Electronics Circuits and Systems (to be presented)

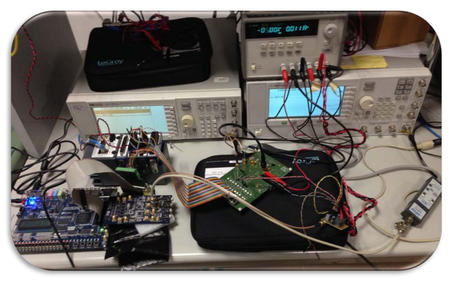
Experimental setup and results

In a real environment, relevant variations occur on a time scale of a few milliseconds:

- optimization process is performed in a sufficiently small time to ensure static conditions;
- tracking process, after a slight balancing condition change, restores the optimal value.







VLSI Group

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MINISTERO DELL' ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA

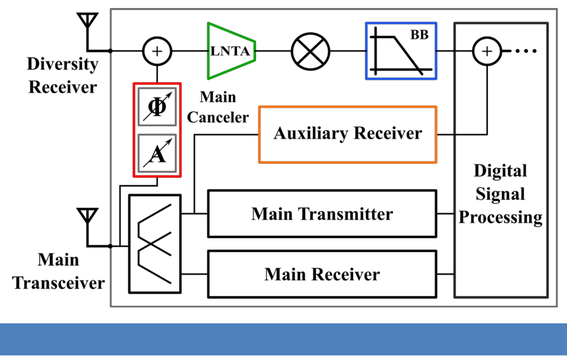
Advanced Nanometer IC Technologies for Next Generation Transceivers "ANIThiNG"

PRIN Project 2015

Ongoing and future research activity

A typical mobile communication system is made of a main transceiver and one or more diversity receivers (*MIMO* structure). Usually, the main transmitter and receiver share the same antenna through a SAW-based duplexer, while the diversity receiver has a dedicated antenna. To avoid desensitization of the diversity receiver, an off-chip SAW filter is commonly used to filter out the self-interference component as well as out-of-band interferers.

That we will propose is a fully integrated mixed-signal system for SAW-less transceivers.



Key points

- A main tunable canceler is used to reduce the Tx leakage power at the beginning of the receiving chain;
- A highly linear receiver allows to reduce out-of-band blocker effects;
- An auxiliary receiving chain, combined with a digital equalizer, allows to reduce the Tx noise in Rx band.