Tunable Microstrip Bandpass Filters Based on Planar Split Ring Resonators

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Introduction

Most satellite communication systems use multiple filters for different communication bandwidth.

Tunable filters

Current filter technology: waveguide, dielectric resonators, cavity resonators.

Microstrip Tunable Filters

- Integratable
- Robust
- Low-cost
Tuning Methods

Fig. 8: SEM of a two-resonator, surface-micromachined, HF micromechanical filter with a measured frequency characteristic [29]

Nguyen et al 86, IEEE 1998

Ishikawa et al 1, MTT 1990

a) Mechanically tunable filter

b) Magnetically tunable filter
Smaller, Faster, Cheaper …

- The mechanically tunable filter designed using MEMS have low insertion loss but their tuning speed is slow (Nguyen).
- The ferromagnetic tunable filters are achieved magnetically altering the property of yttrium-iron-garnet (YIG) element (Ishikawa). **Difficult.**

- Difficult to fabricate.
- Hard to miniaturize.
- Bulky, costly and complex.

Split Ring Resonators (SRR)

- Artificial materials - also called left handed materials.
- An example of a metamaterial is composed of conducting split ring resonators (SRRs) and wires on a thin circuit board material.

A SRR

- Operates at quasi-TEM mode
- Resonates with a size smaller than operational wavelength – Small!
Proposed Tuning Method

- Use Split Ring Resonators (SRR) to build tunable filter.
- The resonant frequency of split ring resonator depends on the capacitance between inner and outer rings.
- SRR is loaded with varactor to tune the resonate frequency.
- Guarantee a size reduction!
Basic Cell of the Proposed Filter

- A tuning diode BB833, manufactured by Infenion Technology, is connected between concentric rings of a SRR as varactor.
- These tuning silicon diodes have high capacitance ratio, or tunability.
- The tuning diode changes junction capacitance with respect to DC biasing voltage applied between its ports.
- Input impedance is set to 50 ohm to minimize reflection from the ports—it is matched.

Schematic of varactor loaded SRR tuning block. Metal regions are depicted in gray. $w_1=10$, $w_2=2.9$, $w_3=1$, $w_4=0.5$, $w_5=8$, $d_1=1.5$, $d_2=8$. All the dimensions are in mm
Equivalent Circuit Model

Equivalent lumped element circuit model for single tuning block.

\[ f_0 = \frac{1}{2\pi \sqrt{(C_g + C_s + C_d)L_s}} \]

Junction capacitance \((C_d)\) can be tuned from 9.75 pF until 0.75 pF by changing biasing DC voltage from 25 V to 0 V.
Simulation– Basic Cell

Response of tunable cell for various varactor capacitance

The tunable filter module with a passband located at 2.8 GHz is designed and simulated using Agilent Momentum.
The module is fabricated with the LPKF circuit board milling machine; Rogers RO4003 high frequency laminates (dielectric constant= 3.38, substrate thickness= 1.27 mm) is chosen as the substrate; DC bias voltage is applied between ports of the tuning diode by probes with voltage supply.
Measurements– Basic Cell

The measured transmission parameters (S12) of the tunable single block using Vector Network Analyzer (VNA)
Multi-Stage Filter Implementation

- Higher order filter implementation is designed to have more selective filter response.
- The feed-line is directly connected to the corners of the resonators R1 and R3. The resonator R2 is excited with electric field created by R2.
- For simplification purpose, the coupling between R1 and R2, between R3 and R2 are set to the same.
- The coupling is controlled by the spacing of resonators.

A third order bandpass filter with single transmission zero located on the right side of passband.
Final Implementation

![Diagram with frequency and dB plot](image)

- S12-Cd=27 pF
- S11-Cd=27 pF
- S12-Cd=3.6 pF
- S22-Cd=3.6 pF
- S12-Cd=0.8 pF
- S22-Cd=0.8 pF

![Image of implementation](image)
A miniaturized, integratable, tunable filter using varactor loaded split ring resonators is designed and tested. Basic tunable SRR module is fabricated and measured using VNA. In order to have more selective filter response, a 3\textsuperscript{rd} order filter is designed and simulated. The measured response of the filter agrees well with the simulated response. The design can be easily implemented in Ka band. A close collaboration with a refined fabrication facility is favorable.
Questions?

Thank you!