Tu4B-5

Miniaturized IPD Filter with Flexibly Controllable Transmission Zeros for 5G Application

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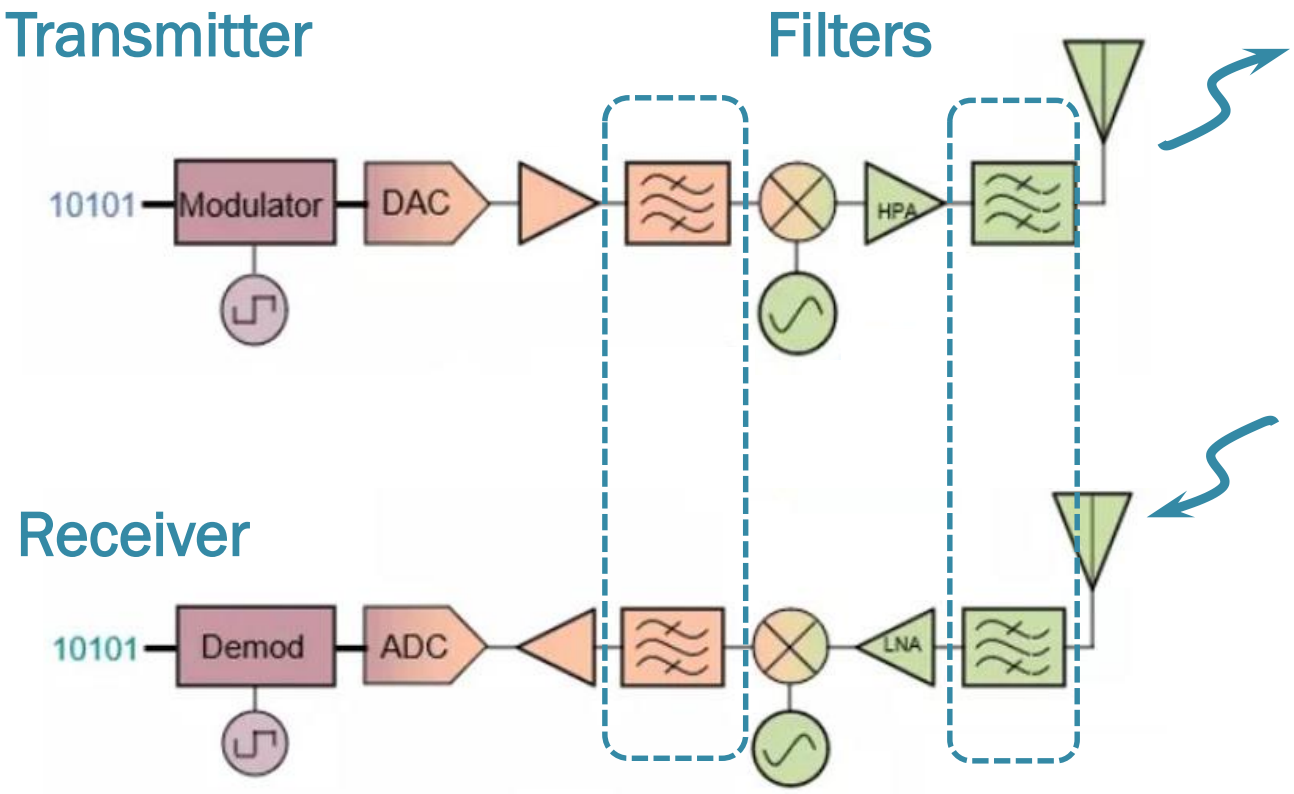
Outline

- Introduction & Motivation
- Filter Configuration & Working Principle
- Simualtion & Measurement
- Conclusion

IPD: integrated passive device

Introduction & Motivation

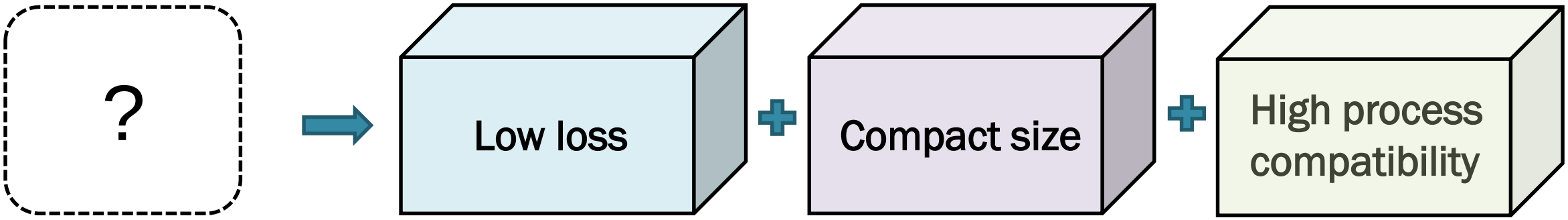
- On-chip filter in transceivers



- Conventional transceivers with modular filters
  - High cost
  - Large and bulky at low frequency
- Transceivers with on-chip filters
  - Compact size
  - An attracting solution for high-density and low-cost system integration

Introduction & Motivation

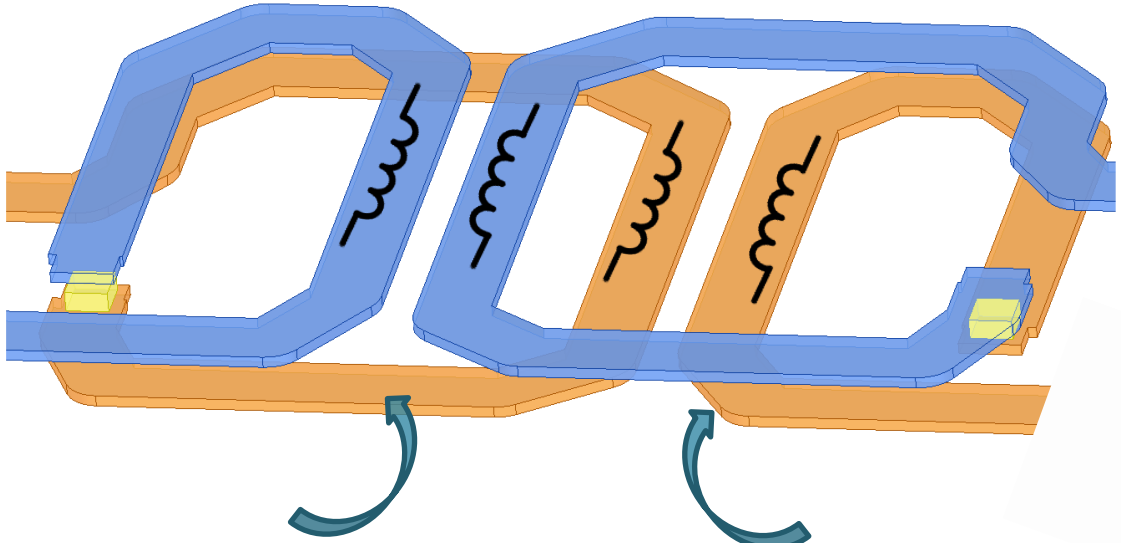
- Desired on-chip filter



- System in Package (SiP) and System-on-a-Chip (SoC) *integration possible*
- Low dielectric loss and metal loss
- Allows stacking of passive devices that *consume area* in active circuits

Filter Configuration

- Inductors in this work



Technology： GaAs IPD

◆ Multi-path coupling

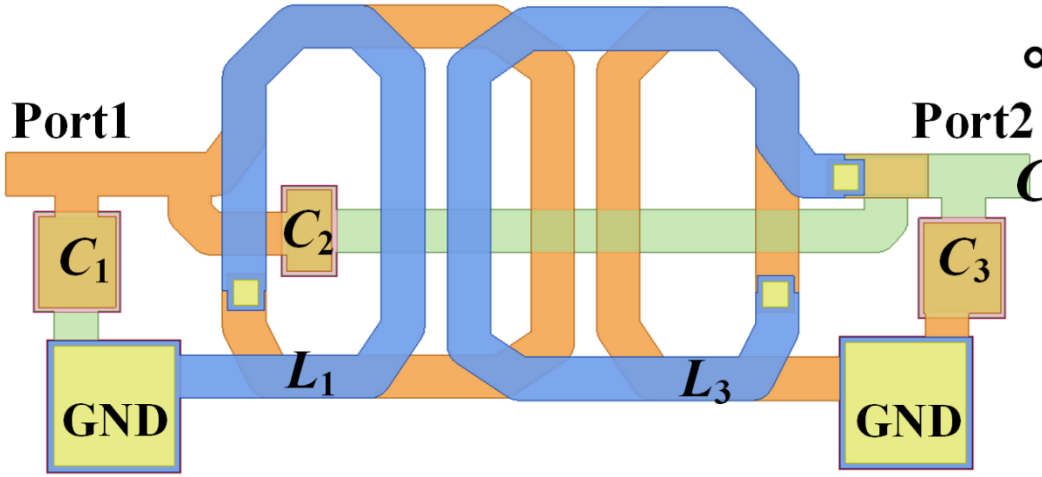
- Horizontal direction
- Vertical direction

◆ Compact structure

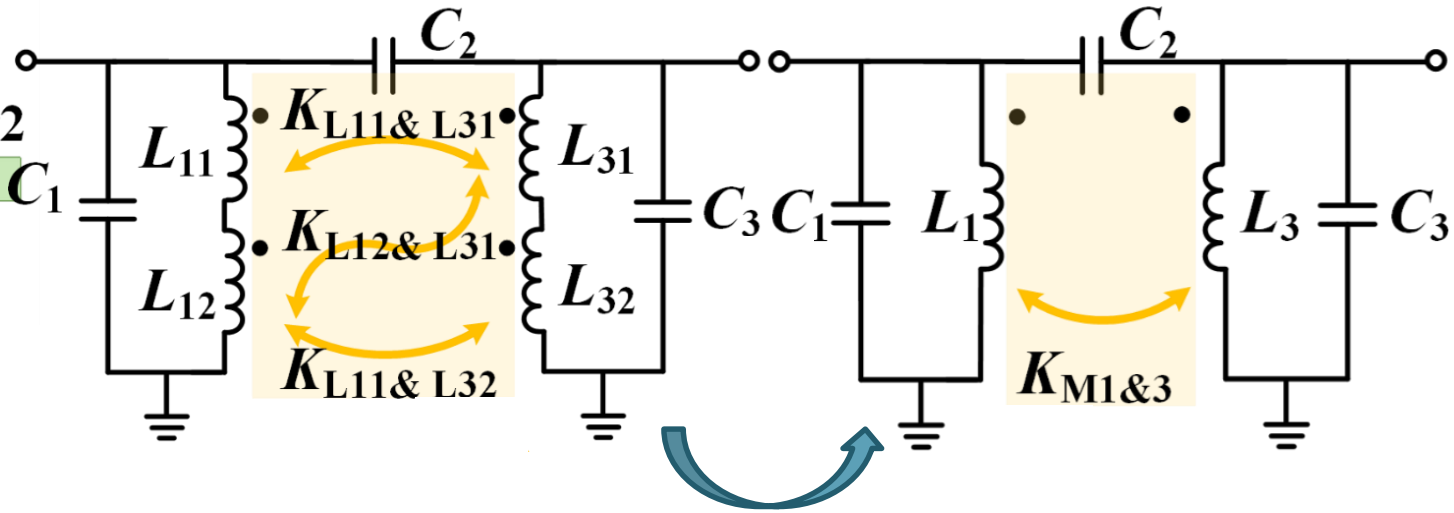
- By winding metal wires in series on metal layers M2 and M3
- Horizontal overlap between two inductors

Filter Configuration

- Filtering unit



Structure of the filtering unit

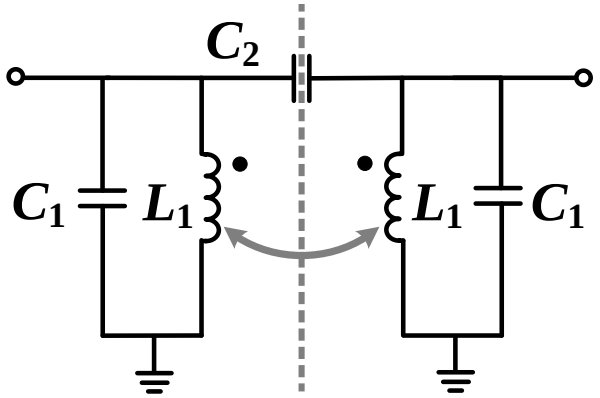


Equivalent circuit model

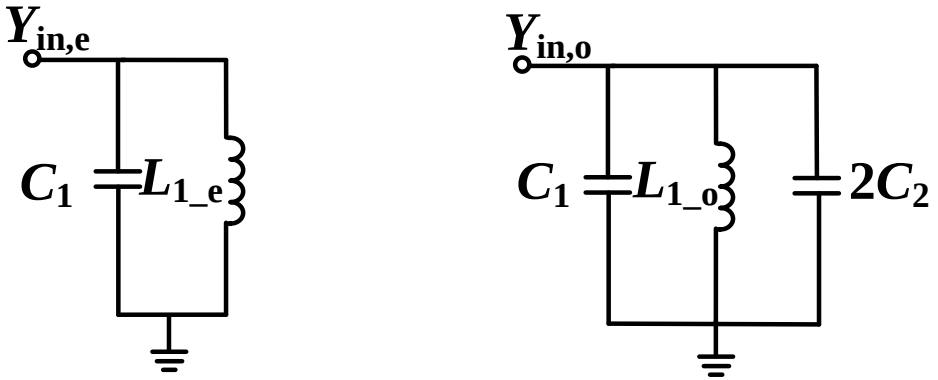
- Reduced chip size
  - *Using transformer* reduces the number of total inductors require
  - A capacitor is embedded inside a inductor
  - *Non-inverting coupling* method was used

Working principle

- Even- and odd-mode features



Equivalent circuit of the filtering unit



Even- and odd-mode equivalent circuits

$$Y_{in,e} = j\omega C_1 + \frac{1}{j\omega L_{1\_e}}$$

$$Y_{in,o} = j\omega (C_1 + 2C_2) + \frac{1}{j\omega L_{1\_o}}$$

$$L_{1\_e}^{'} = L + K_{Mi\&j}\sqrt{L_i L_j}$$

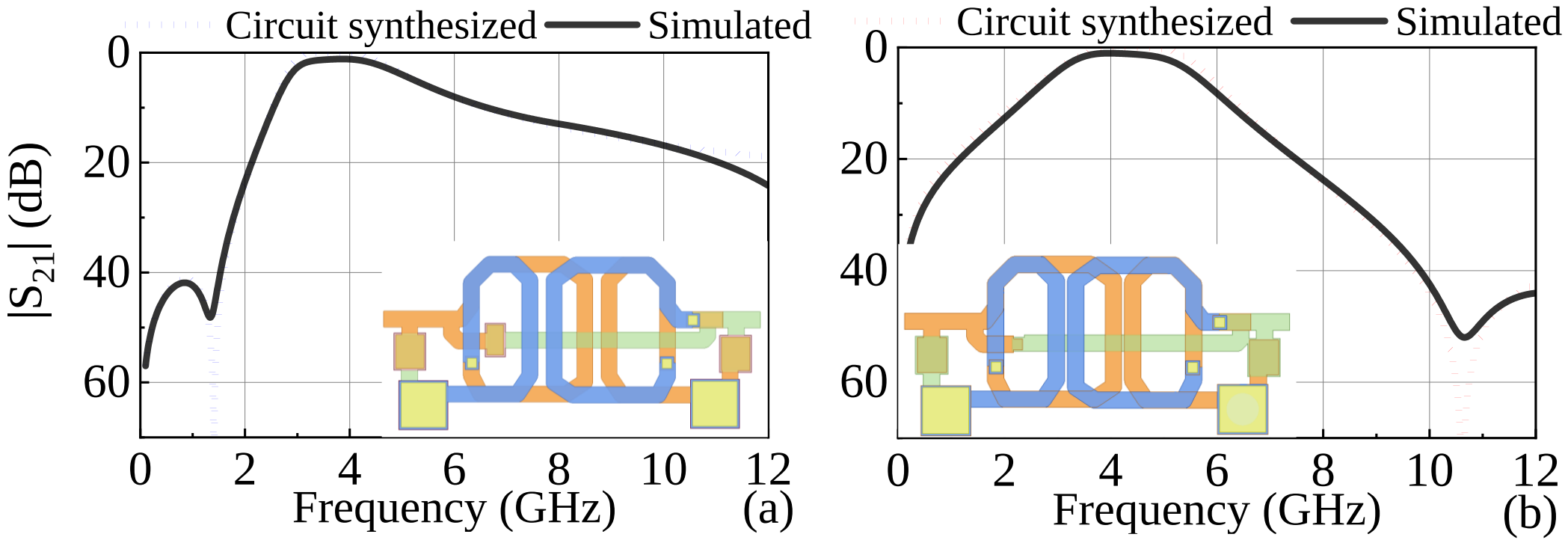
$$L_{1\_o}^{'} = L - K_{Mi\&j}\sqrt{L_i L_j}$$

$$K = \frac{\mathrm{Im}[Y_{in,e(\omega_0)} - Y_{in,o(\omega_0)}]}{\omega_0 \dfrac{\partial \mathrm{Im}\left[\dfrac{(Y_{in,e} + Y_{in,o})}{2}\right]}{\partial w}\Big|_{\omega=\omega_0}}$$

$$\frac{1}{j\omega(L + K_{Mi\&j}L)} = 2j\omega C_2 + \frac{1}{j\omega(L - K_{Mi\&j}L)}$$

Working principle

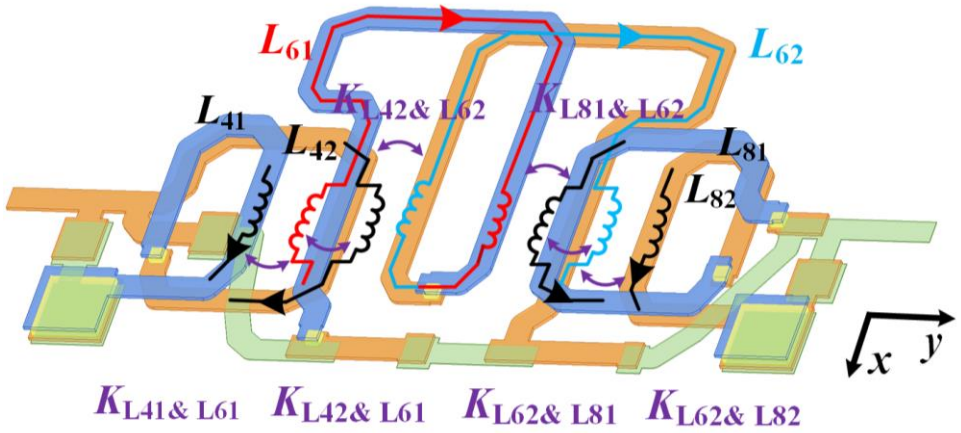
- Response characteristics of the filtering unit



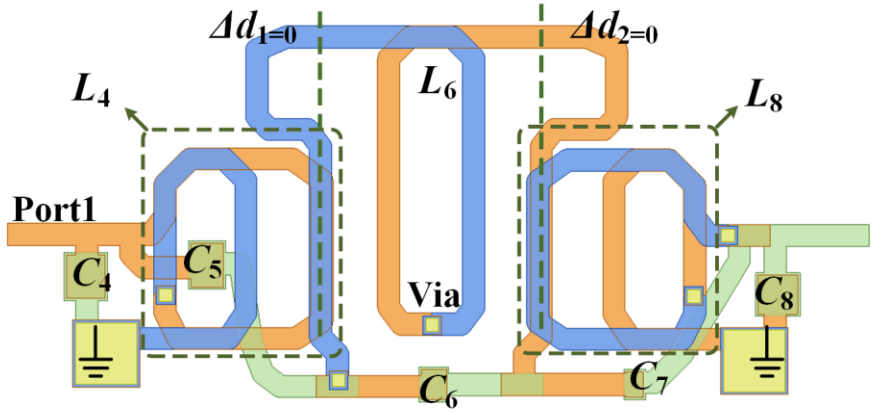
- Flexible transmission zero (TZ)
  - Controlled by the *series capacitance and the strength of the coupling*

Filter Configuration

- Third-order bandpass filter



Perspective view of the structure



Top view of the structure

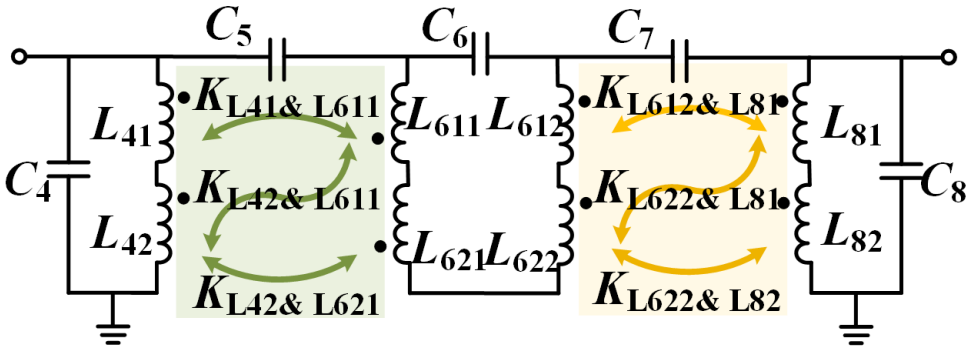
Technology: GaAs IPD

◆ Structural features

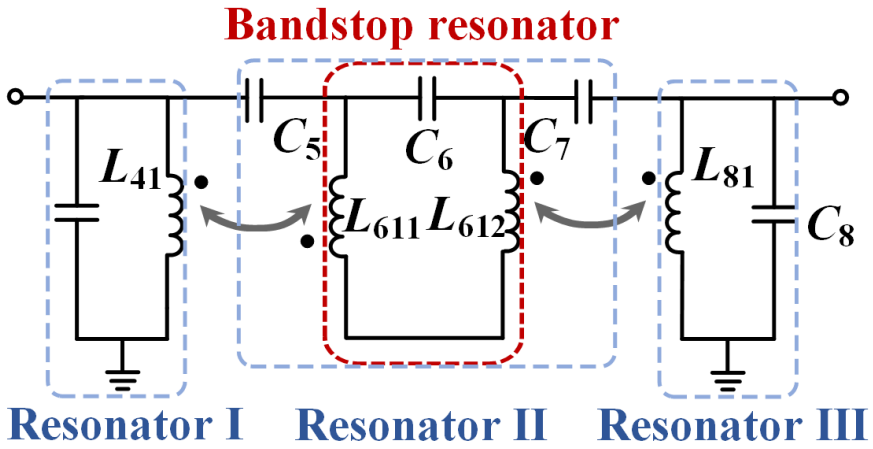
- L_6 is drawn in a *particular configuration* to facilitate coupling with resonator 1 and 3
- L_4 and L_8 are two symmetrical inductors about the origin
- The inductors L_4 and L_8 are still arranged in series as L_{41} and L_{42}, L_{81} and L_{82}, respectively
- Capacitor C_5 is embedded inside a inductor for *compact size*

Working principle

●Equivalent circuit



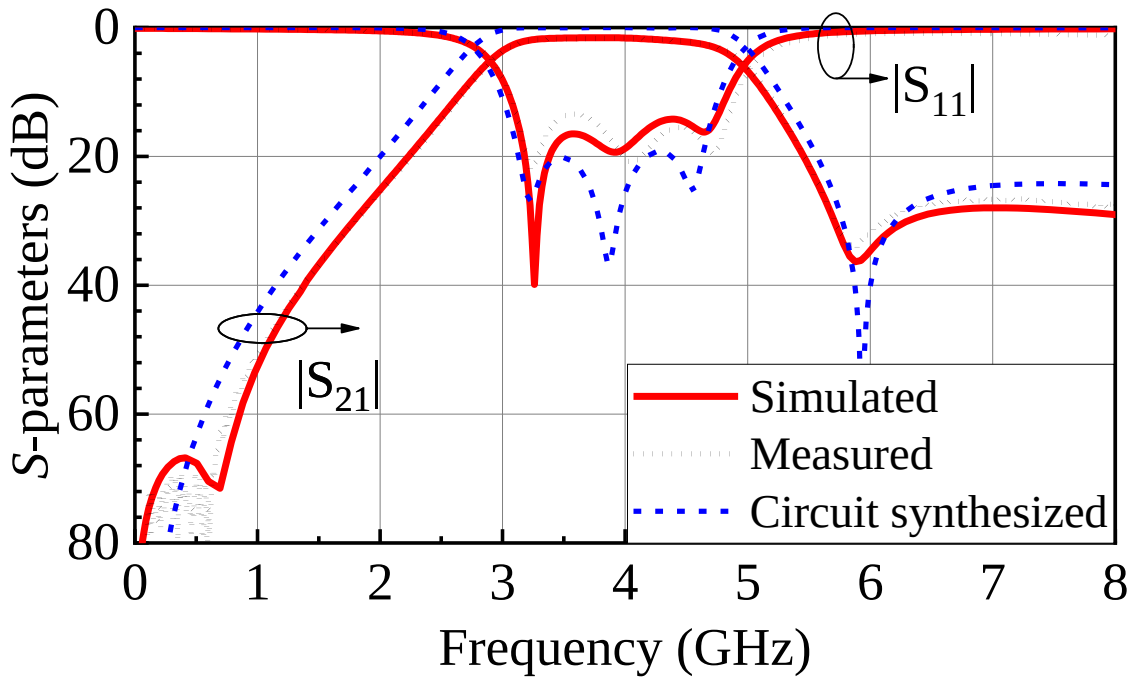
With different coupling

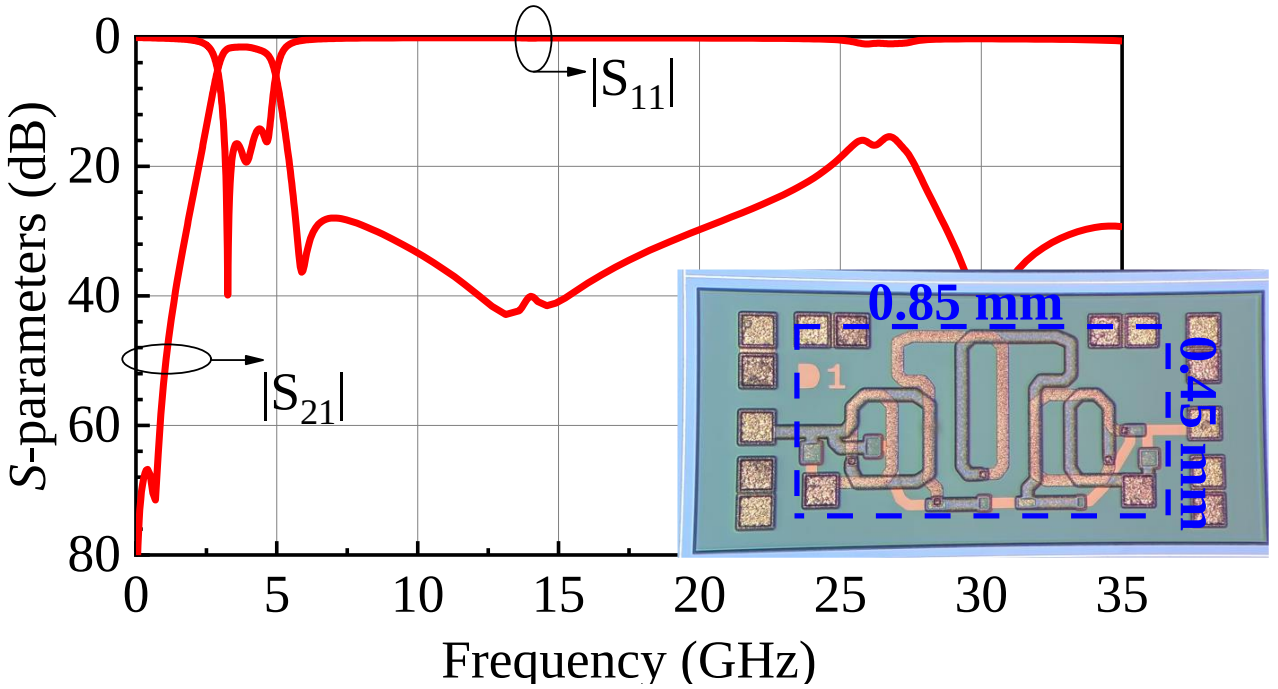


In resonator format

- Equivalent circuit with different coupling
  - The inductive coupling between inductors L_4 and L_6 can be characterized by the joint action of $K_{41\&61}$, $K_{42\&61}$ and $K_{42\&62}$
  - This design employs *two types of coupling* aiming for size reduction and easier control of the coupling
- Equivalent circuit in resonator format
  - The combination of C_5 and C_7 serves a series resonator
  - Inductor L_6 is part of both *bandpass and bandstop resonators*

Simulation & Measurement





- Insertion Loss:1.63 dB
- Size: 0.85mm*0.45mm
- Harmonic Suppression: 6.34 f_0
- 3-dB fractional bandwidth:43.3%
- Measured via on-wafer G-S-G probes, using a vector network analyser (VNA)

Conclusion

- The filtering devices using *non-inverting coupling and inverting coupling theory* was analyzed.
- Special inductor winding method for *compact size, high-quality factor and easier control of the coupling* is used.
- Equivalent circuits from different perspectives *(coupling types and resonator format)* are used to analyze the structure.
- The proposed *N77 band filter* exhibits the merits of *large bandwidth, size reduction and wide band*.

Thank You !

Questions ?

Further discussion is welcome at:

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