# Bandpass Filters for D-band Application

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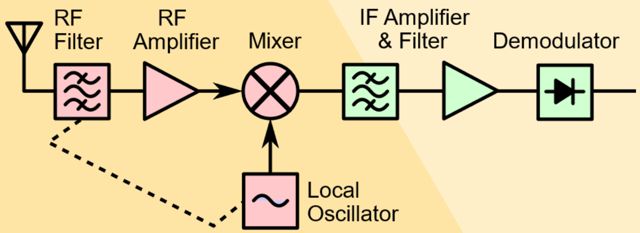
# RF Filters

## Role and Requirement for RF Filter

Requirements for high performance RF filters for RF Front-End

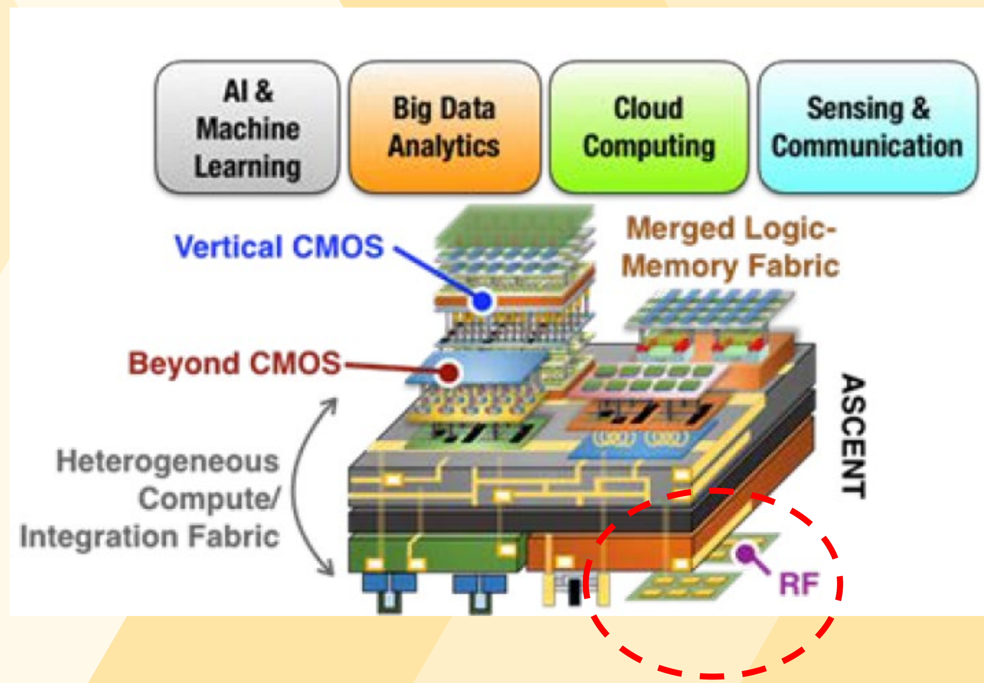



**Shortcomings of traditional filter**

- Cannot meet the demand for higher integration
- Cannot meet the demand for higher frequency

**Our Objectives:**

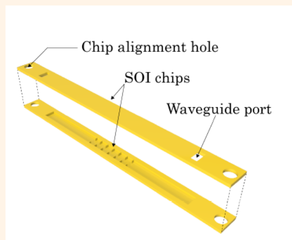
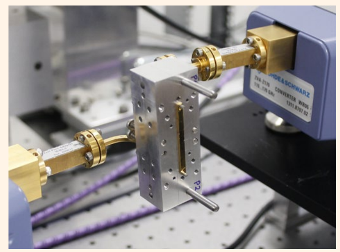
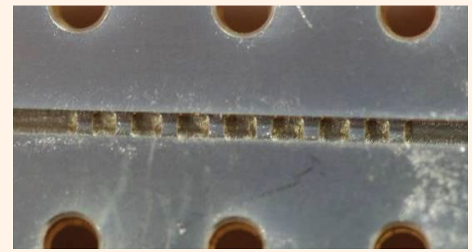
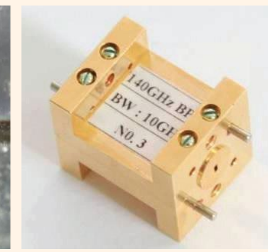
- Look for new high-performance platforms for RF filters in D band.
- Design Passive Filter with lower insertion loss and sharper roll-off.
- Further integrate passive RF Filters into package




The ASCENT Vision

# D-band Bandpass Filter : Related Work

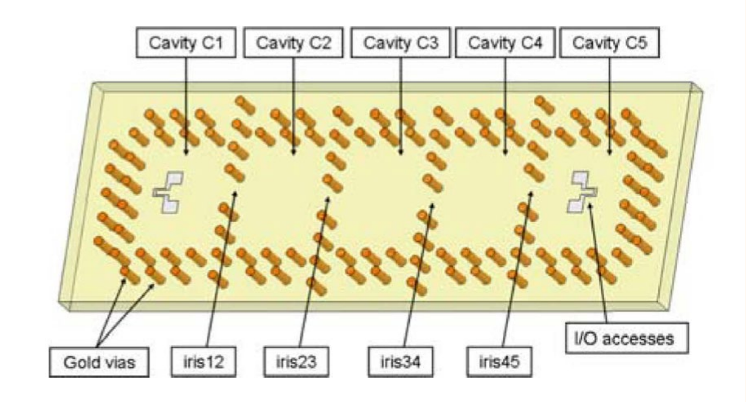
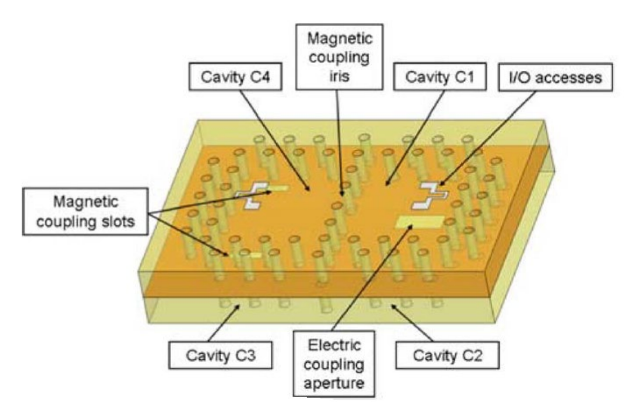
## High performance Rectangular Waveguide Bandpass Filter

| | [1] | [2] |
|---|---|---|
| Technology | Silicon micromachined technology | High speed CNC milling fabrication |
| Topology |    |   |
| Center frequency | 144.75 GHz | 139.2GHz |
| FBW | 5.2% ( 7.5 GHz) | 8.3% ( 11.6 GHz) |
| Insertion Loss | Average of 0.5 dB at passband | Minimum insertion loss -1.0dB |

[1] Campion, James, et al. "An ultra low-loss silicon-micromachined waveguide filter for D-band telecommunication applications." 2018 IEEE/MTT-S International Microwave Symposium-IMS. IEEE, 2018.
[2] Cheng, Wang, et al. "140GHz waveguide H ladder bandpass filter." 2012 International Conference on Microwave and Millimeter Wave Technology (ICMMT). Vol. 2. IEEE, 2012.

# D-band Bandpass Filter : Related Work

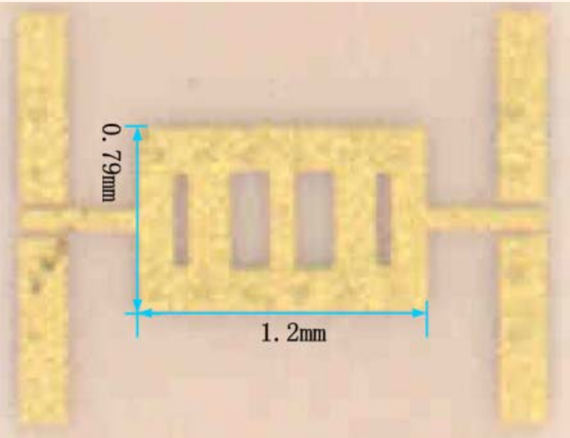
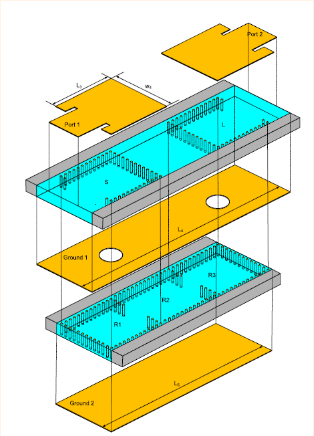
## Substrate Integrated Wave (SIW) Guide Bandpass Filter

| | [1] | |
|---|---|---|
| Technology | Ferro A6M LTCC | Ferro A6M LTCC |
| Topology |  |  |
| Center frequency | 151.175 GHz | 149.7 GHz |
| FBW | 1.31% ( 7.5 GHz) | 1.35 % ( 2.02 GHz) |
| Insertion Loss | 8.4dB at 151.175 GHz | 5.5dB at 149.7 GHz |

[1] Khalil, Ali H., et al. "Quasi-elliptic and Chebyshev compact LTCC multi-pole filters functioning in the submillimetric wave region at 150 GHz." IEEE Transactions on Microwave Theory and Techniques 58.12 (2010): 3925-3935.

# D-band Bandpass Filter : Related Work

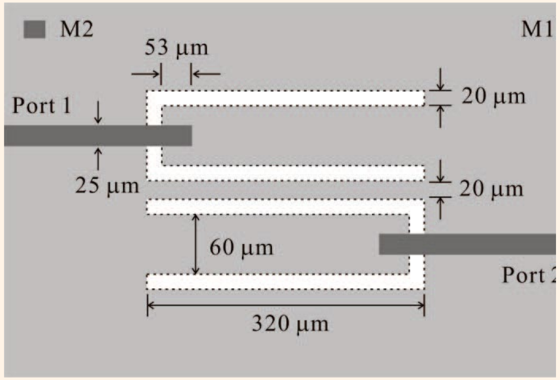
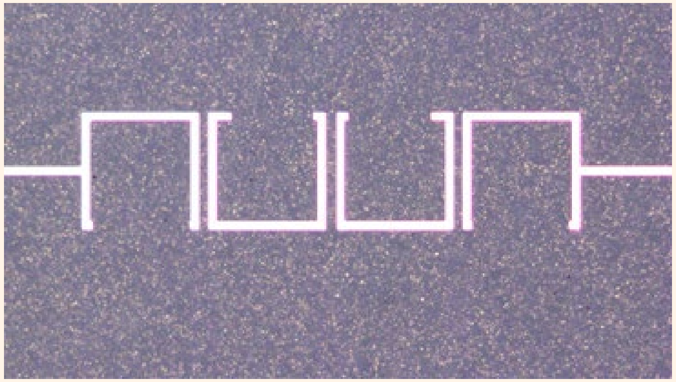
## Substrate Integrated Wave (SIW) Guide Bandpass Filter

| | [2] | [3] |
|---|---|---|
| Technology | single-circuit layer using LTCC technology | BCB and Glass dielectric cavity etched on the traditional low-resistivity silicon (LRSi) with through dielectric via (TDV) |
| Topology |  |  |
| Center frequency | 140 GHz | 159.69 GHz (Simulation) |
| FBW | 13.03% ( 18.3GHz) | 12.5% ( 20 GHz) (Simulation) |
| Insertion Loss | 1.913 dB at 140GHz | 1.5 dB (Simulation) |

[2] Wong, Sai Wai, et al. "Electric coupling structure of substrate integrated waveguide (SIW) for the application of 140-GHz bandpass filter on LTCC." IEEE Transactions on Components, Packaging and Manufacturing Technology 4.2 (2013): 316-322..
[3] Liu, Xiaoxian, et al. "Wideband Substrate Integrated Waveguide Bandpass Filter Based on 3-D ICs." IEEE Transactions on Components, Packaging and Manufacturing Technology 9.4 (2018): 728-735.

# D-band Bandpass Filter : Related Work

## Microstrip structure

| | [1] | [2] |
|---|---|---|
| Technology | Suspended BCB membrane structure | Thin BCB dielectric layer deposited on the Si substrate |
| Topology |   |  |
| Center frequency | 126.8 GHz | 140 GHz |
| FBW | 13.9 % ( 17.63 GHz) | 6% ( 8.4 GHz) |
| Insertion Loss | 4 dB at mid-band | 4.3 dB |

[1] Li, Rui, et al. "A 135GHz slotline bandpass filter using silicon/membrane technology." 2012 IEEE 14th Electronics Packaging Technology Conference (EPTC). IEEE, 2012.
[2] Shi, Shengqi, et al. "Design of 140GHz Narrow Band-pass Planar Filters Based on Open Loop Resonators." 2019 International Conference on IC Design and Technology (ICICDT). IEEE, 2019.

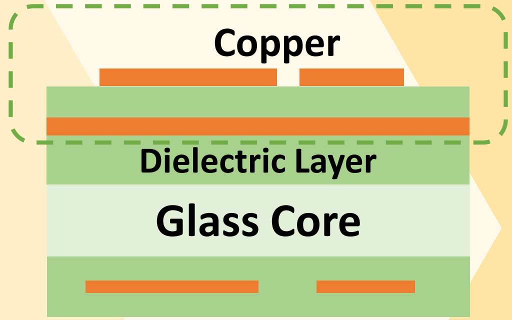
# Integration for RF Microstrip Filter

## Thin Dielectric Layer Microstrip Structure

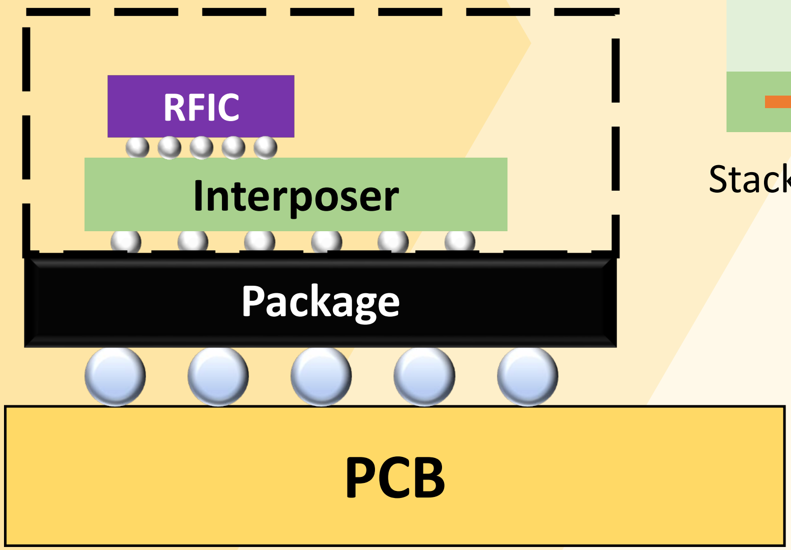
Basic idea of System-on-Package for RF Filters:

**Further miniaturize the RF filter in the package**

Thin Dielectric Layer Microstrip Structure




Stack up for RF components

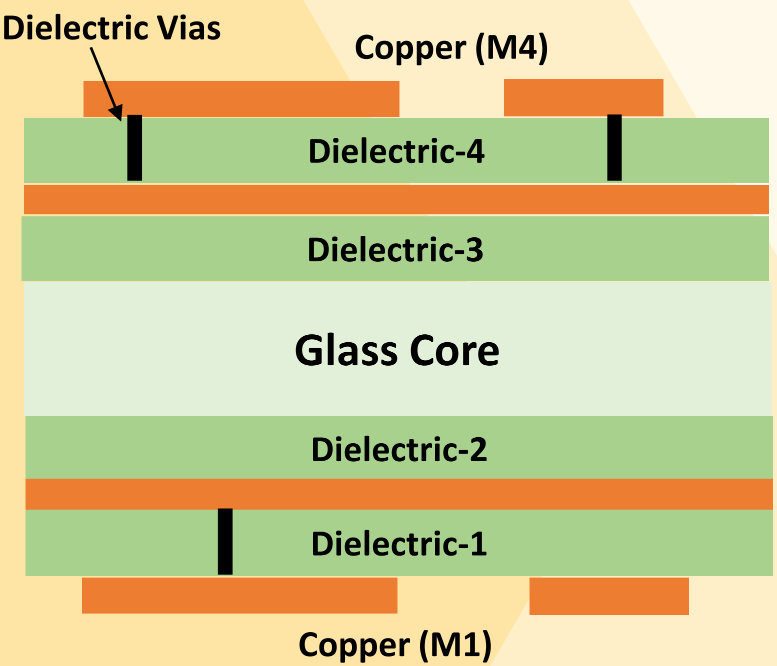



System on Package structure

**Benefits** for Microstrip Structure

- Can be realized in thin dielectric layer
- Cost less areas to realized
- Lots of existed theories for RF microstrip filter design in lower frequency

# Stack-up for Test Vehicle

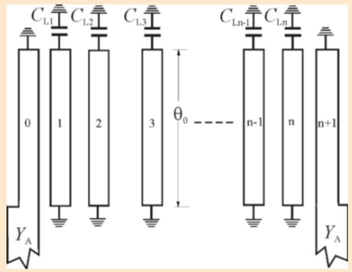
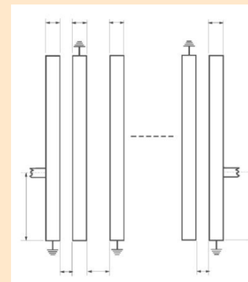
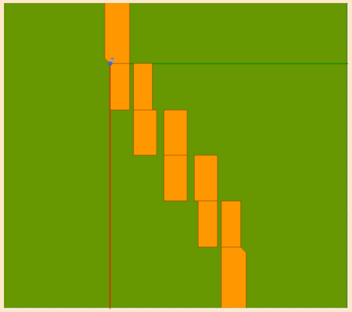
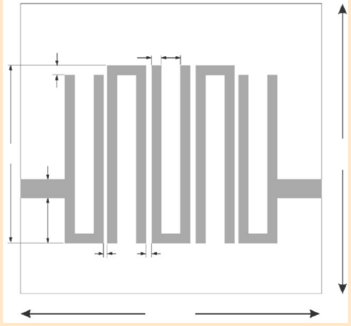



| Layer | Details |
|---|---|
| M4 (Top) | Microstrip Passive Components (8um) |
| Dielectric-4 | Taiyo Zaristo (28+28+15=71-µm) |
| M3 | GND, Via Antipads, Dicing Clearance |
| Dielectric-3 | Taiyo Zaristo (15-µm) |
| Core-Glass | AGC EN-A1 (100-µm), TGVs |
| Dielectric-2 | Taiyo Zaristo (15-µm) |
| M2 | GND, Via Antipads, Dicing Clearance |
| Dielectric-1 | Taiyo Zaristo (28+28+15=71-µm) |
| M1 (Bottom) | Microstrip Passive Components |

| Feature | Dimensions (µm) |
|---|---|
| Min. L/S | 25/25 |
| Copper Thickness | 8-10 |
| Via-in-Via Dia. | 100 |

| Material | Dk | Df |
|---|---|---|
| Glass (AGC EN-A1) | 5.4 | 0.005 |
| Polymer (Ajinomoto ABF GL102) | 3.3 | 0.0044 |
| Polymer (Taiyo Zaristo) | 3.3 | 0.0025 |

# Common Topologies for Microstrip BPF

| | Combine filter | Interdigital BPF | Coupled line BPF | Hairpin BPF |
|---|---|---|---|---|
| Common choices for Microstrip BPF |  |  |  |  |

## Specifications of Microstrip BPF

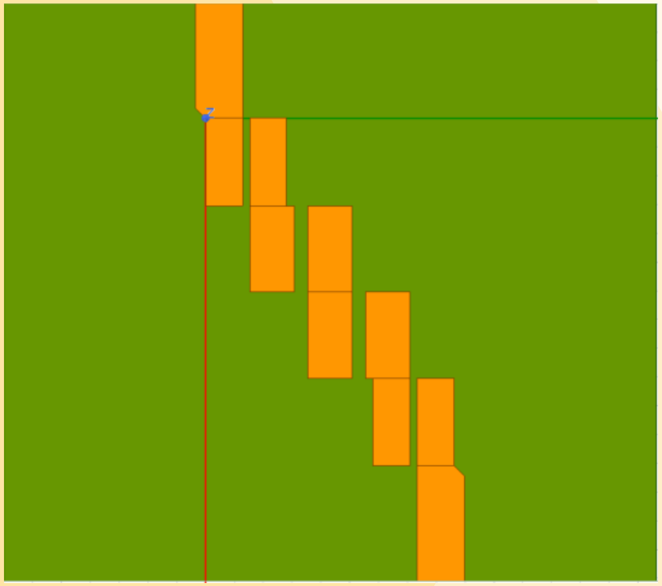
| | |
|---|---|
| Center Frequency | 140GHz |
| BW-3dB | 14GHz (10% 133-147GHz) |
| Insertion Loss | <4dB |
| Roll-off ($BW_{20dB}/BW_{3dB}$) | <3 (BW20dB from 120-160GHz) |

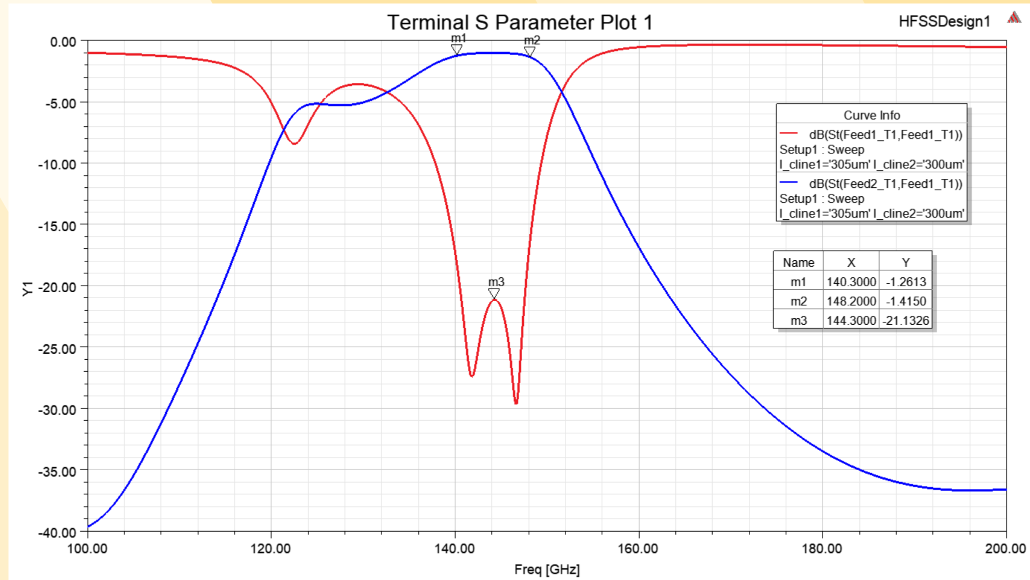
## Considerations for Choosing Topology

- Lumped capacitor is not available in such a high frequency range
- Vias will have significant radiate effect in this frequency
- Unwanted coupling is easier to appear in such high frequency range
- There will be more loss for microstrip line than lower frequency

# Simulation Result of Dielectric Microstrip BPF

## Coupled Line Bandpass Filter and Frequency Response






Based on the considerations mentioned before, this work choose simple coupled line BPF as a staring point.

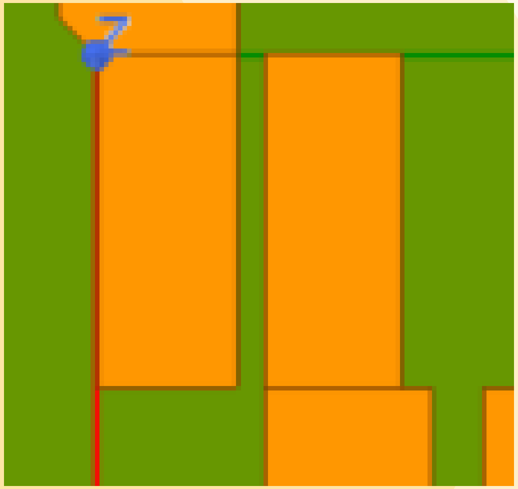
Performance:

- This BPF shows low insertion loss (-1.2dB minimum) and high return loss (under -20dB at passband.

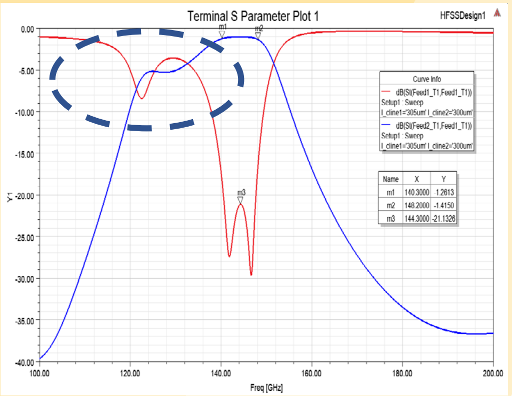
Problems unsolved yet:

- Impedance mismatches at about 120 GHz

# Challenges



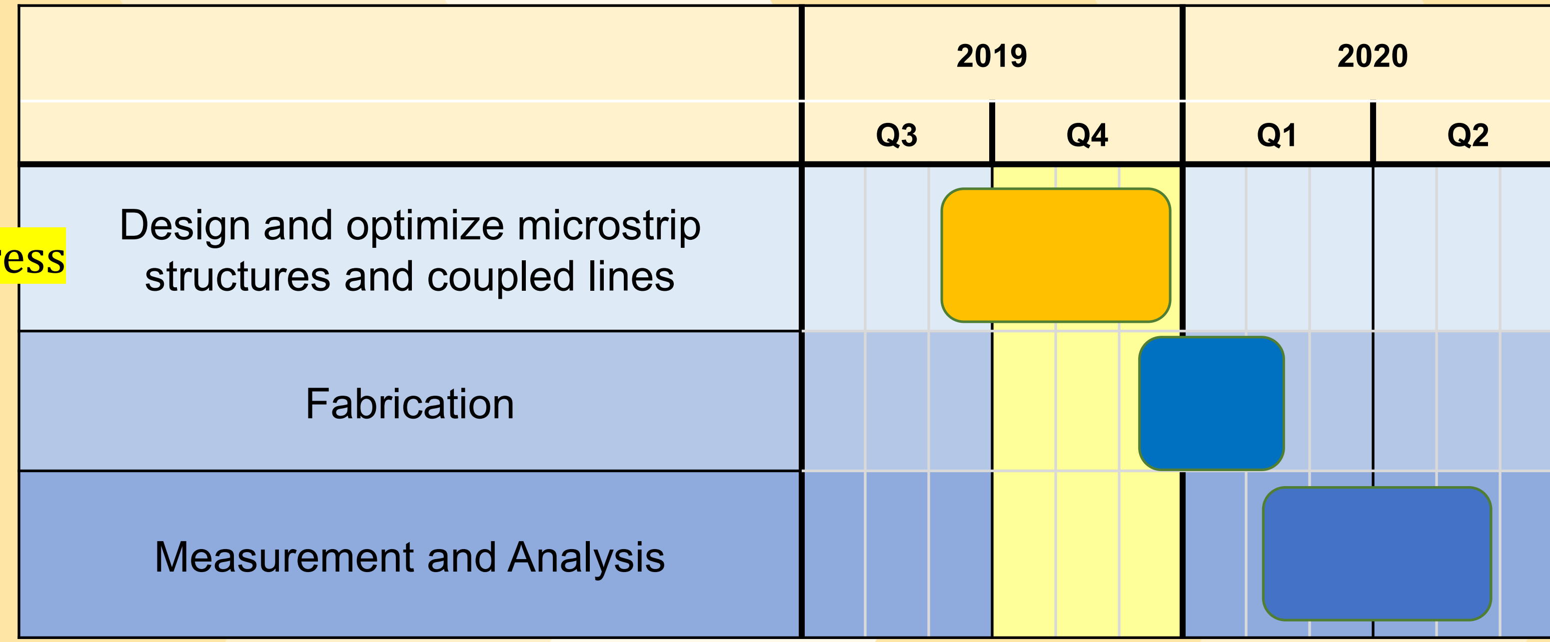
Limited by resolution, it’s difficult to fabrication smaller spaces between lines.




Impedance mismatches at about 120GHz, which needs further optimization

# Timeline

In progress




<u>Light Yellow:</u> Current time window

# Acknowledgements

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**Liaisons**

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