# ELEC-E4440 - Microwave Engineering Workshop

# *A 1.5 GHz Doppler Radar*

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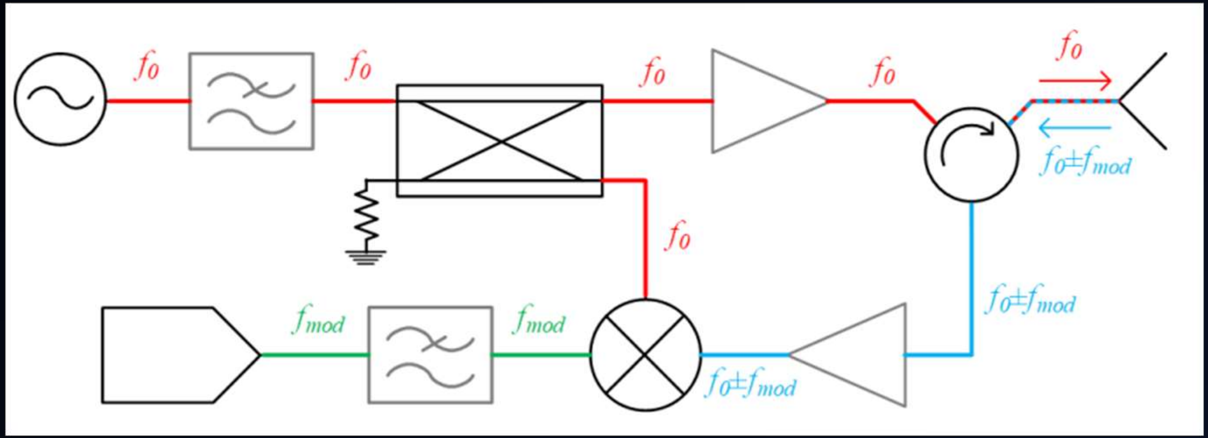
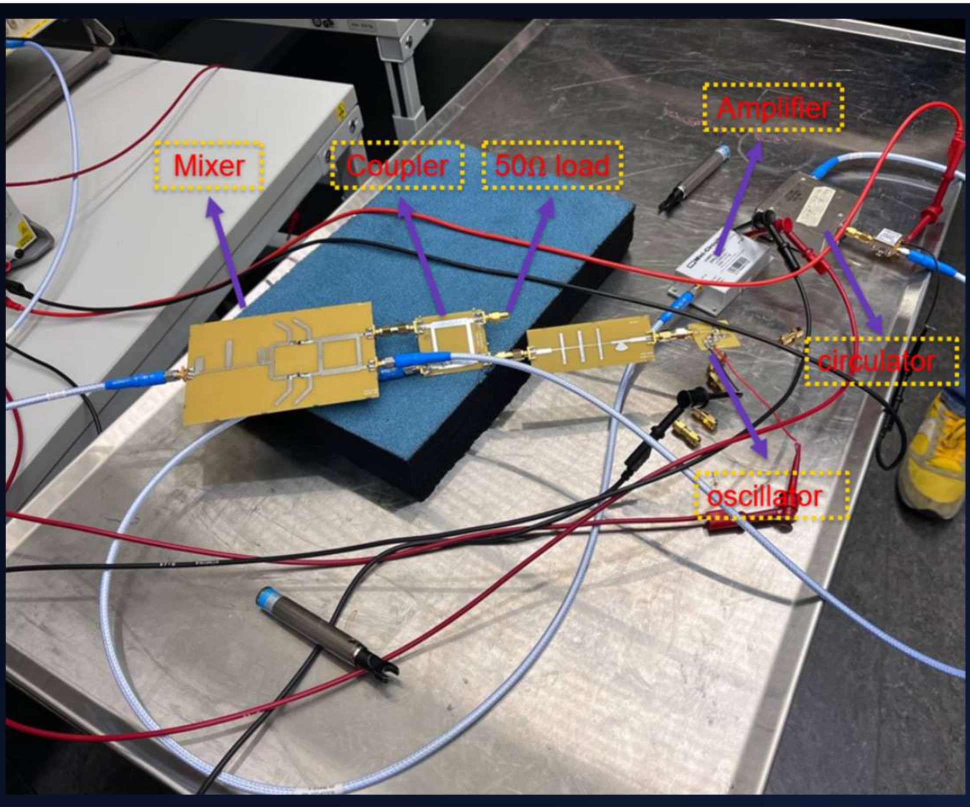
# Work Division

- Sihan: LPFs, Coupler, Mixer
- Yifan: Oscillator, *Amplifier*

Our presentation will roughly follow the order in which the signal flows



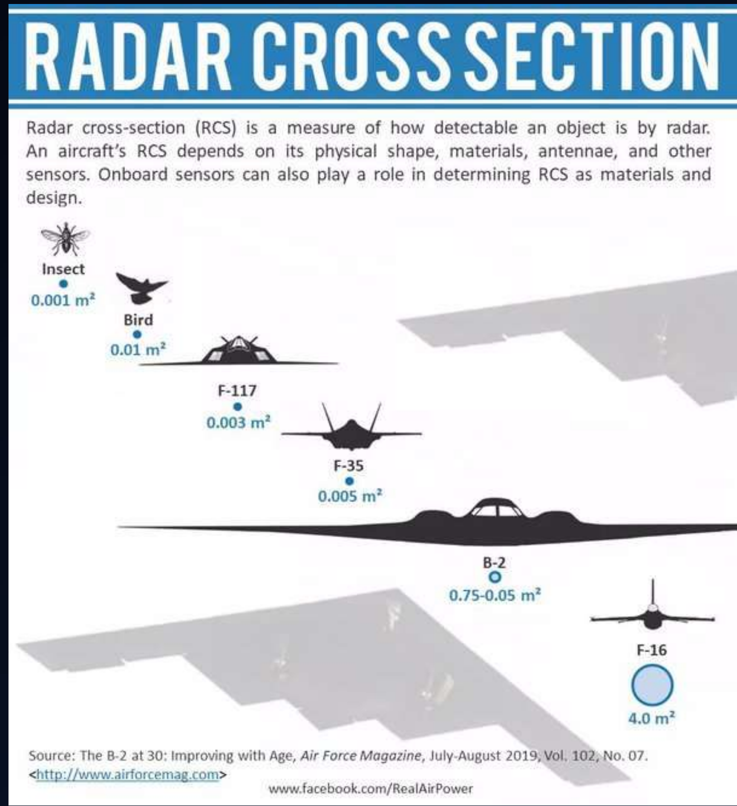
# Results

| Calculated | Measured |
|---|---|
| 1.75m | 1.32m |

- Oscillator output power: 5 dBm
- Cable insertion loss: 1 dB (estimate)
- LPF insertion loss: 0.69 dB
- PA gain: 24 dB
- Coupler insertion loss: 3.6 dB
- Circulator insertion loss: 0.5 dB
- Total transmitted power: 23.21 dBm (209 mW)

$$\left(\frac{Pt\, G\, G\, \sigma\, \lambda^2}{(4\,\pi)^3\, Smin}\right)^{1/4}$$

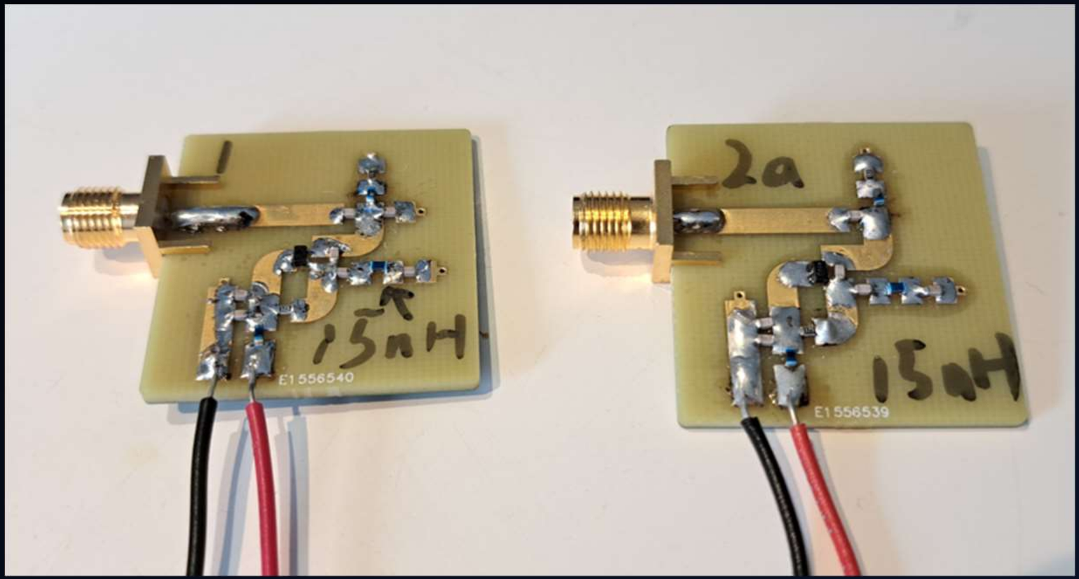
1.74733

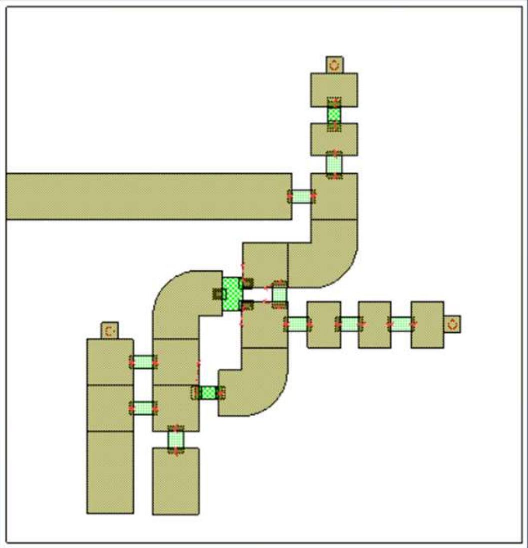


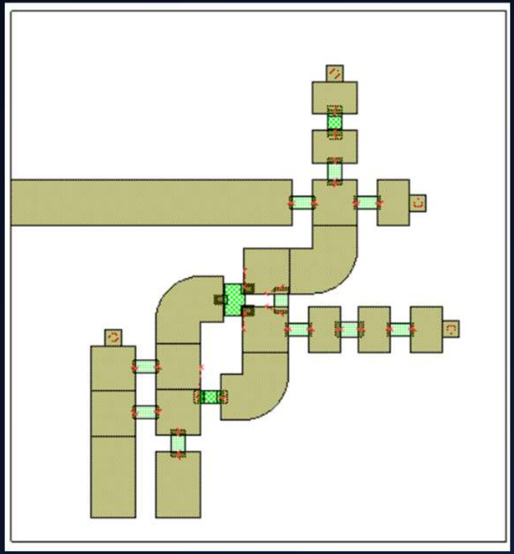

- Antenna Gain: 9 dBi (7.94)
- Radar cross section: 0.035 m^2
- Wavelength: 0.2 m
- Noise floor: -60 dBm (Smin = 1 uW)

# Oscillator (two versions)

- Left: Version 1, Original Clapp oscillator
- Right: Version 2, "Degenerated Clapp" achieving higher output power

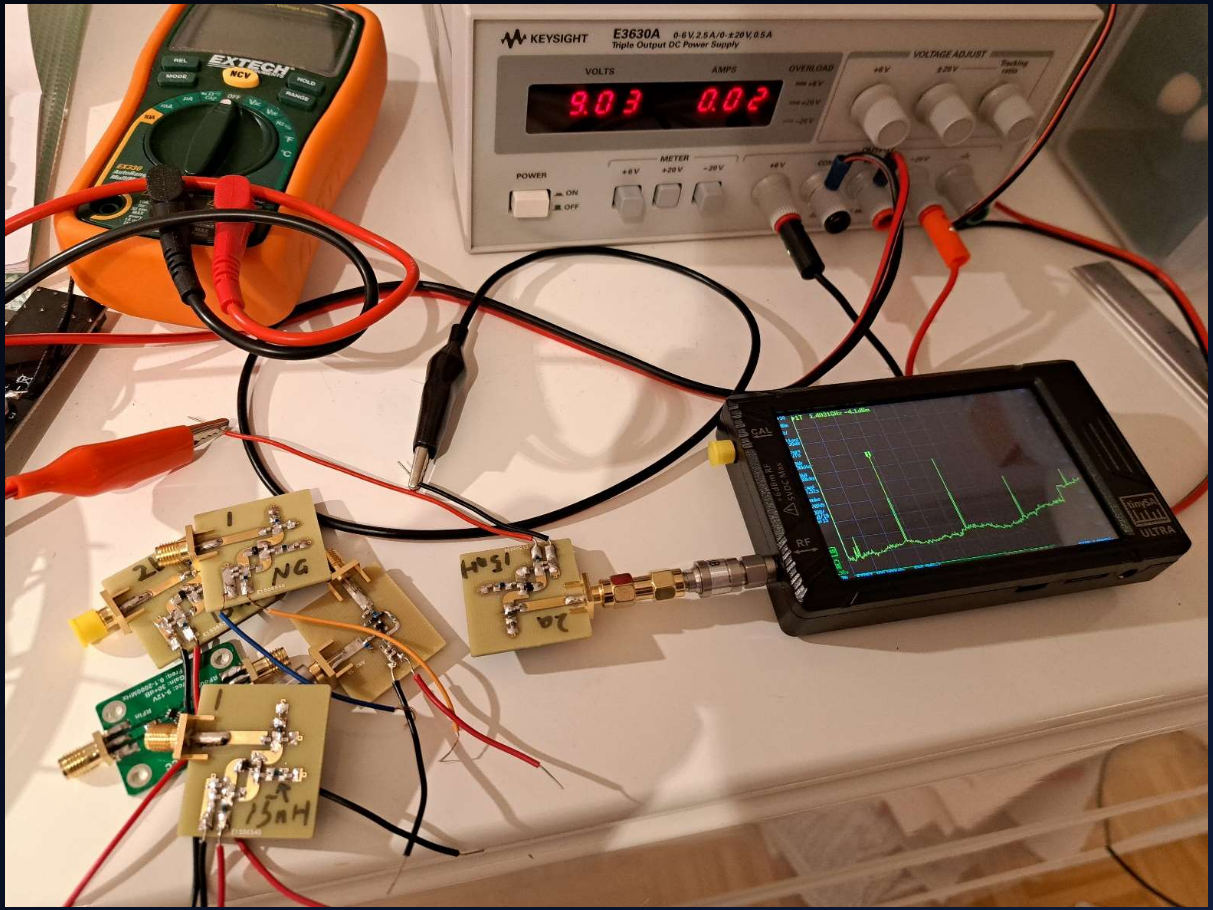


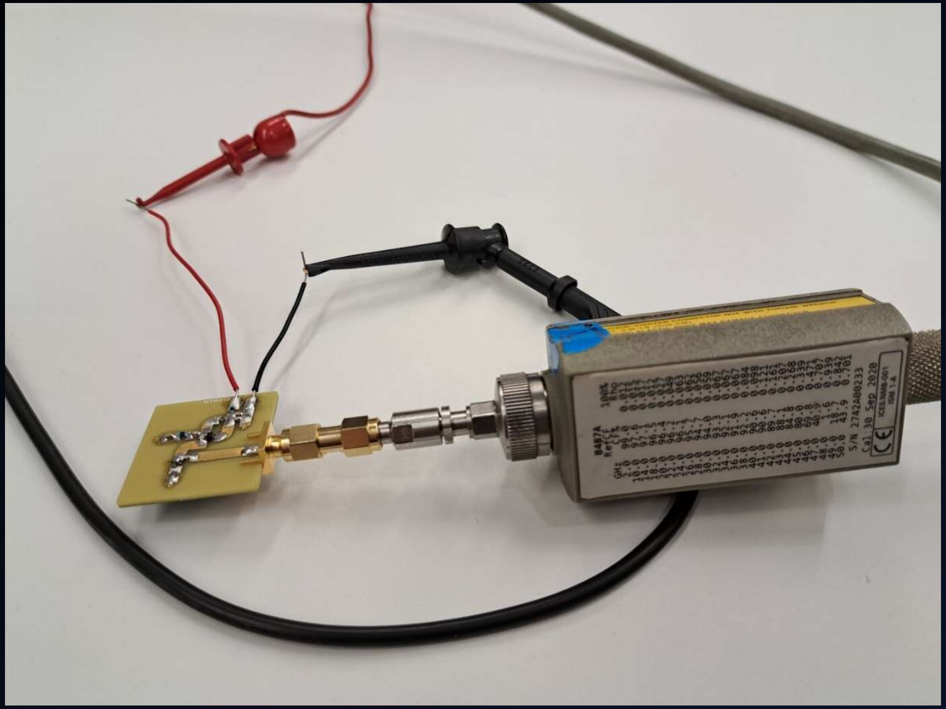


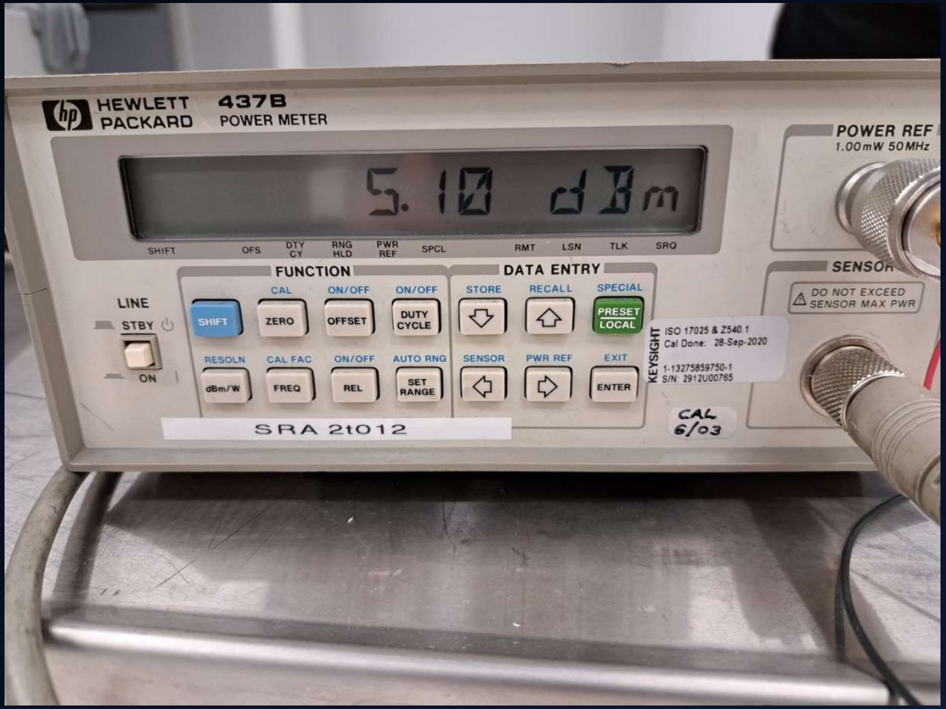
# Measurement Setup

- Supply voltage: 9V
- tinySA Ultra: 0 to 6 GHz
- External 10 dB attenuator (tinySA input max. 6 dBm)



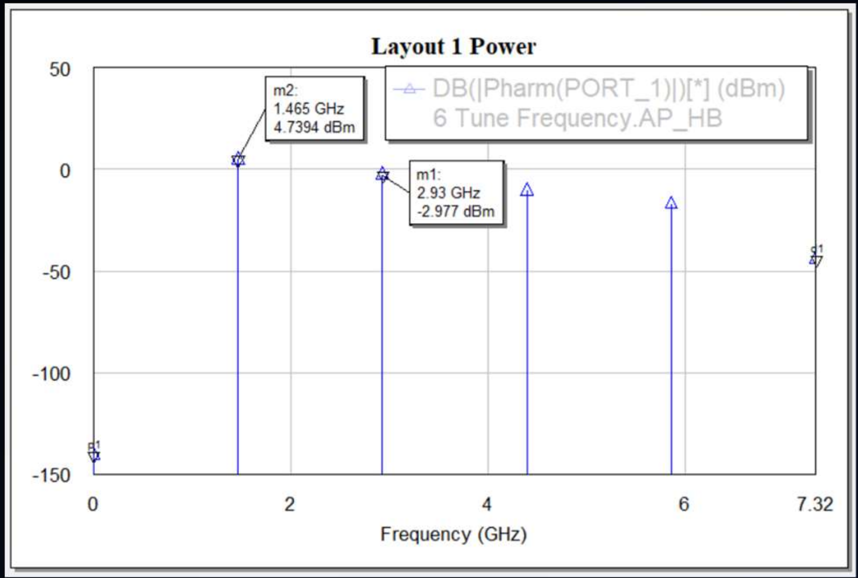
# Measurement Setup (Version 2 only)





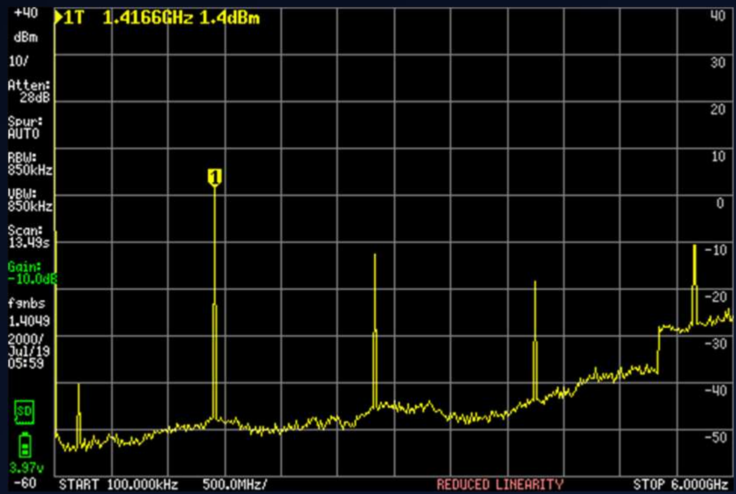

Measured Total Output Power: 5.1 dBm

# Output Power: Original Clapp



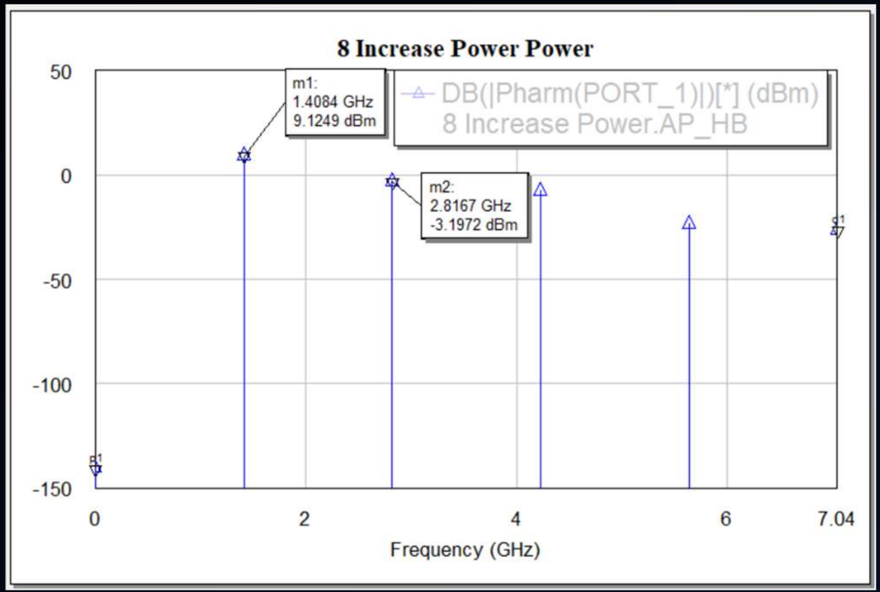


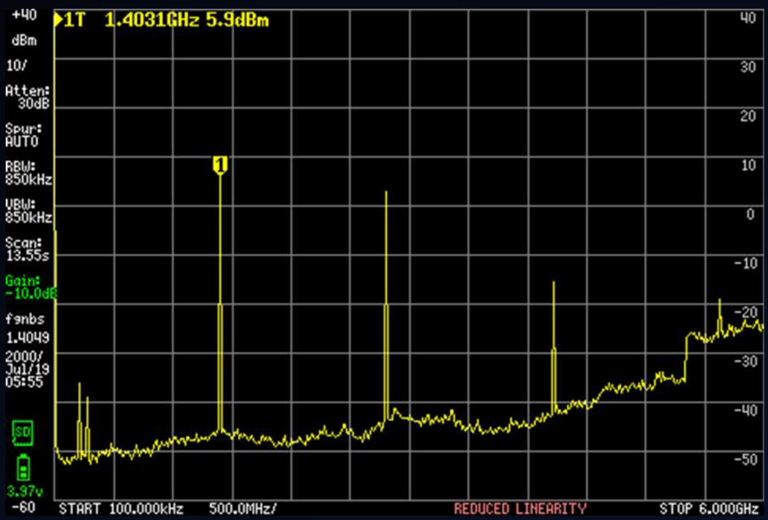
Power reduces as the transistor heats up



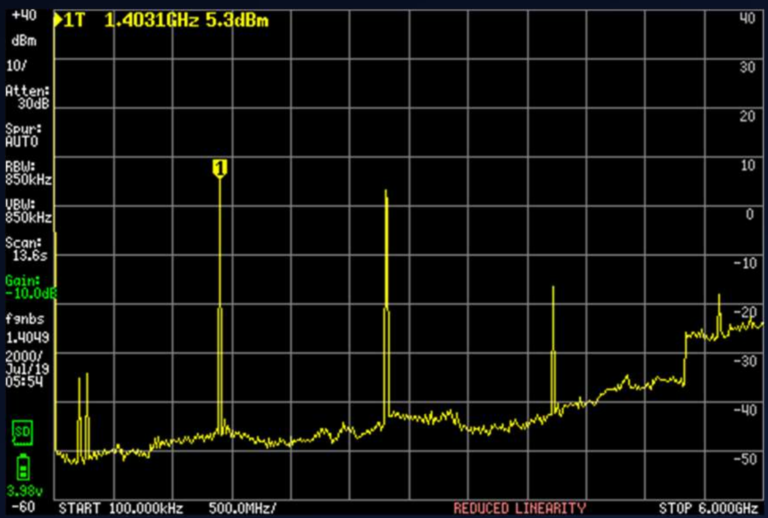

- Simulated Output Power: 4.7 dBm at 1.47 GHz
- Measured Output Power: 1.4 dBm at 1.42 GHz

# Output Power: Improved Design




Power reduces as the transistor heats up




- Simulated Output Power: 9.1 dBm at 1.41 GHz
- Measured Output Power: 5.3 dBm at 1.4 GHz

# Filter Design

## LOW-PASS FILTER AFTER OSCILLATOR

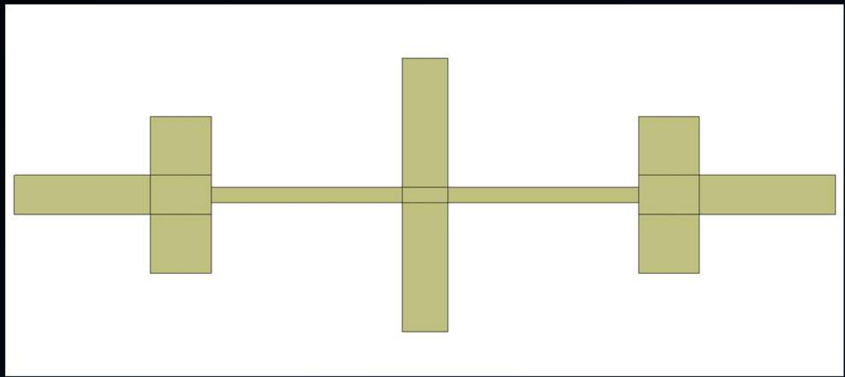
- The oscillator generates a signal at around 1.5GHz
- Harmonic signals such as 3GHz and 4.5 GHz should be eliminated

## LOW-PASS FILTER AFTER MIXER

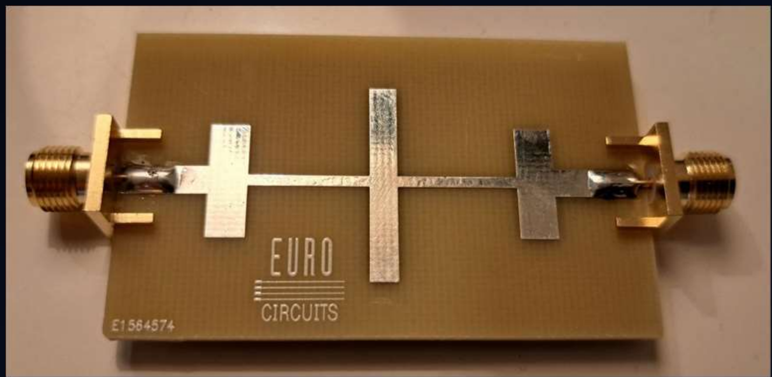
- The mixing process generates various frequencies, and the desired frequency is about a few MHz
- Harmonic signals such as 1,5 GHz to 6 GHz should be eliminated

# Filter Design

## LOW-PASS FILTER AFTER OSCILLATOR

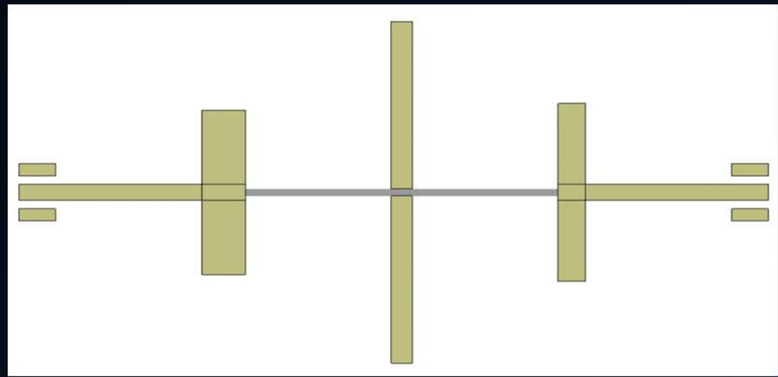


a) Layout 1st of Low-pass filter on AWR

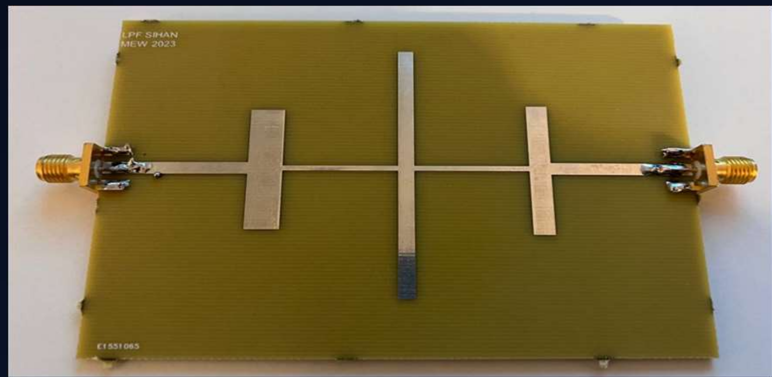



c) Prototypes of Manufactured LPF

## LOW-PASS FILTER AFTER MIXER



b) Layout of 2nd Low-pass filter on AWR

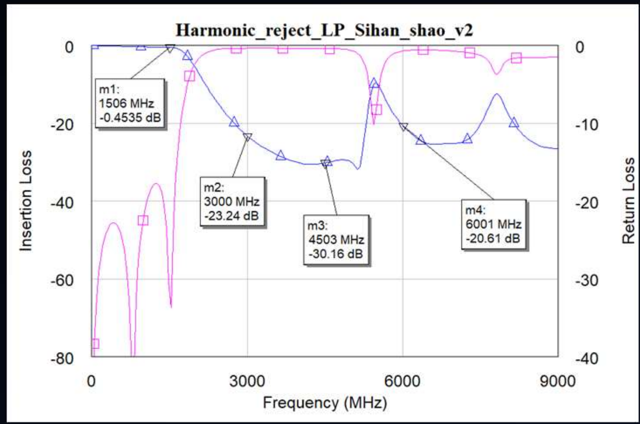


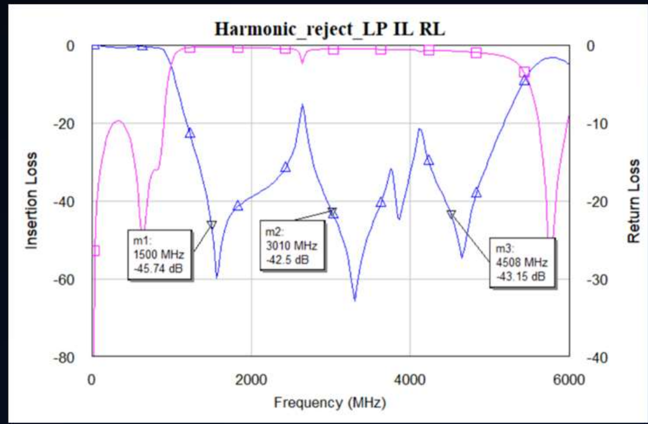

d) Prototypes of Manufactured LPF

# Filter results

## HARMONIC REJECT FILTERS

- Effectively targets specific frequency points
- Removes undesired frequency components



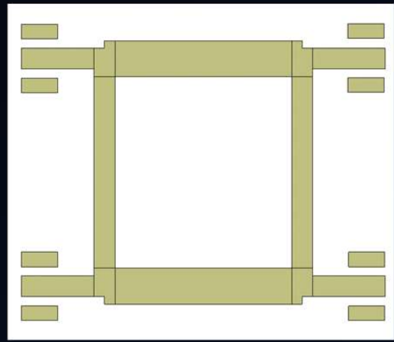


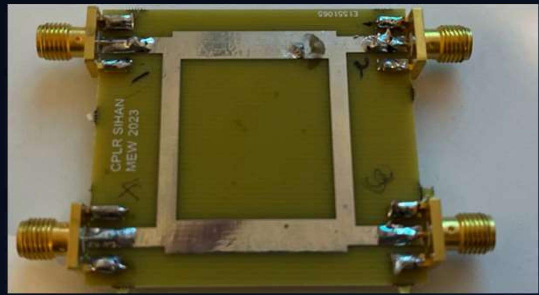

a) Low-pass filter after oscillator

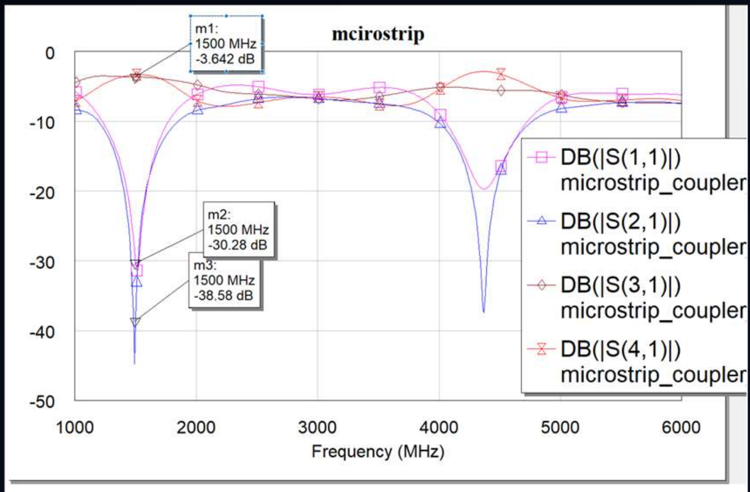
b) Low-pass filter after mixer

# Hybrid Coupler

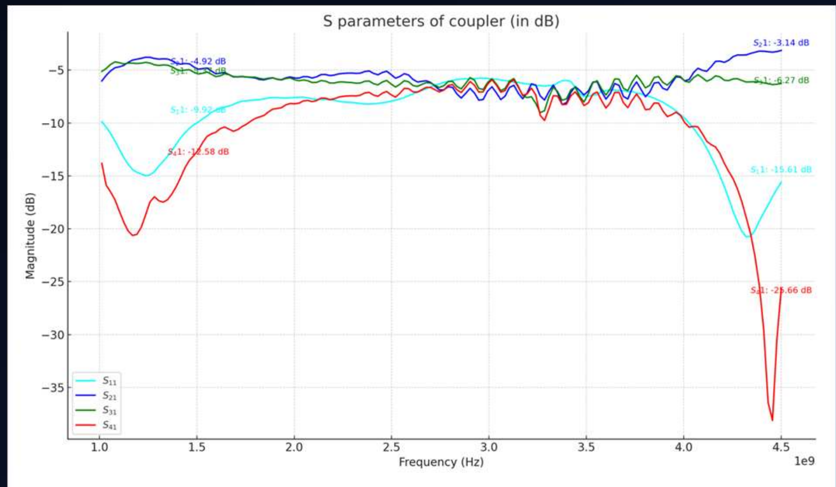
- **FUNCTION**
  - Splits or combines signals while maintaining phase relationship
- **PERFORMANCE**
  - Transmission coefficients (S21, S31) close to simulated values (-4.92dB, 5.37dB vs. -3.642dB)
  - Power distribution is nearly equal, showing strong performance






(a) Simulated S-parameter on AWR

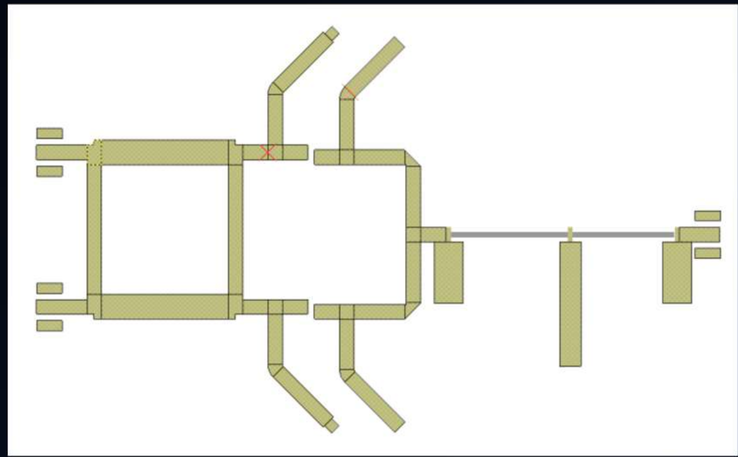



(b) Measured S-parameter

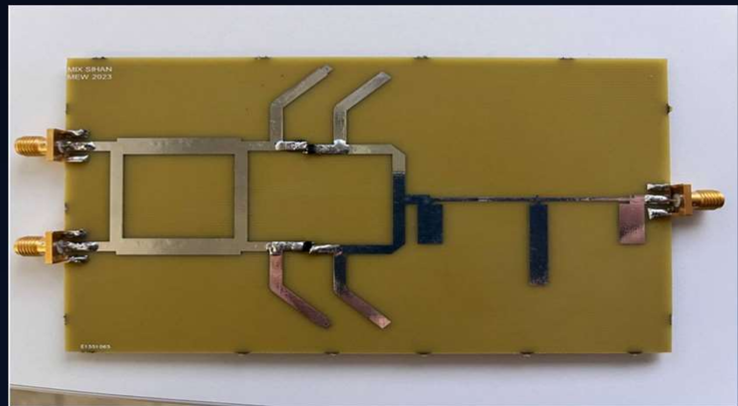
# Mixer Design

- **DESIGN CONSIDERATIONS**
  - Ground-end microstrip lines as inductors, accounting for parasitic effects and limited choices
  - Open-ended microstrip lines as capacitors for impedance control
  - Microstrip lines introduces less lossy comparing with lumped elements

- **OUTPUT HANDLING**
  - Mixer produces various frequency products
  - Design of a specialized low-pass filter to reject RF, LO, and harmonic signals simultaneously

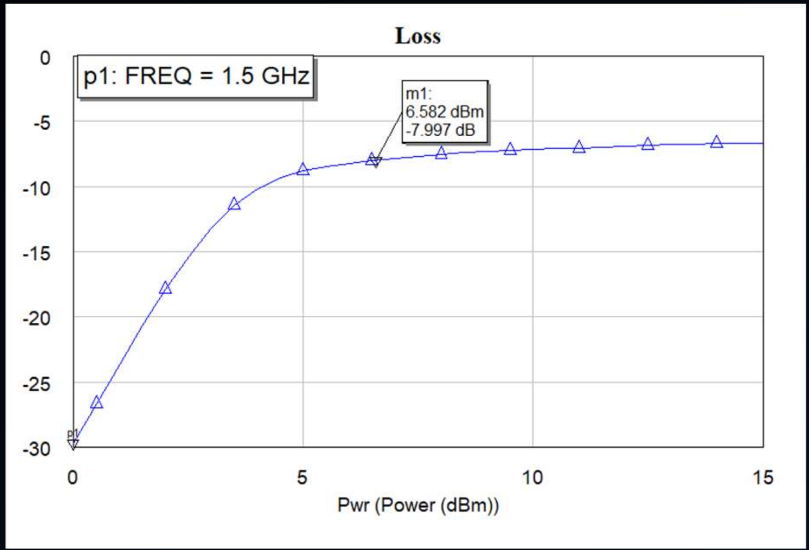


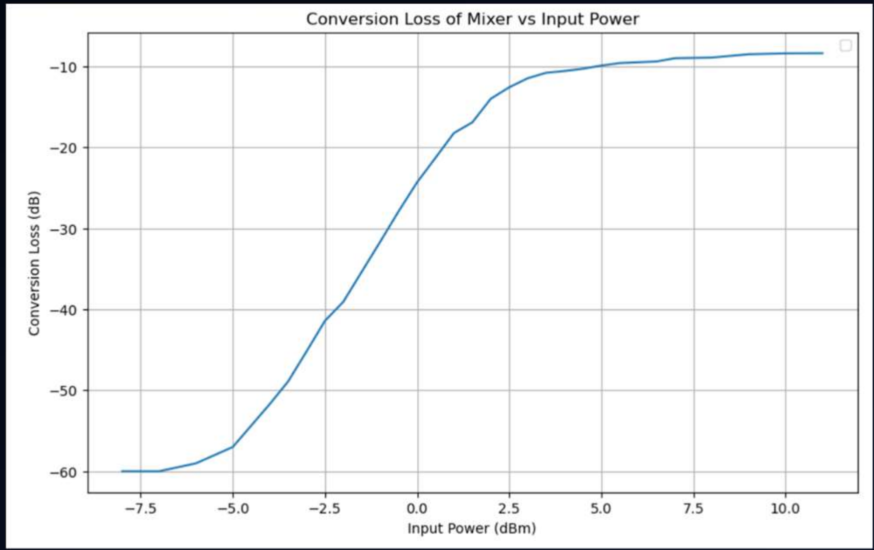
a) Layout of Mixer on AWR



b) Prototypes of Manufactured Mixer

# Mixer Results




a) Simulated Conversion Loss on AWR

b) Measured Conversion Loss

Comparing the practical and simulated results between 0dB and 15dB, we observe a very similar overall trend, which indicates the good performance of our mixer.

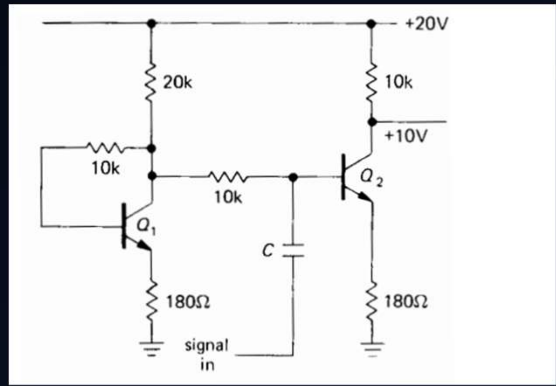
# Problems and Future Optimizations

## 1. Optimization of Oscillator:

- Output power instability
- Frequency sensitivity
- Harmonics reduction

- Use transmission lines instead of discrete LC components to construct the resonant circuit
- Use temperature-compensated bias network
- Add shielding?

a) hot air significantly decreases the output power




b) one possible temperature-compensated bias network

## 2. Optimization of passive components:

- miniaturization of components can reduce the lossy of our system

# Thanks for your Attention !