# Anomalous Results with Recent Flex Antennas

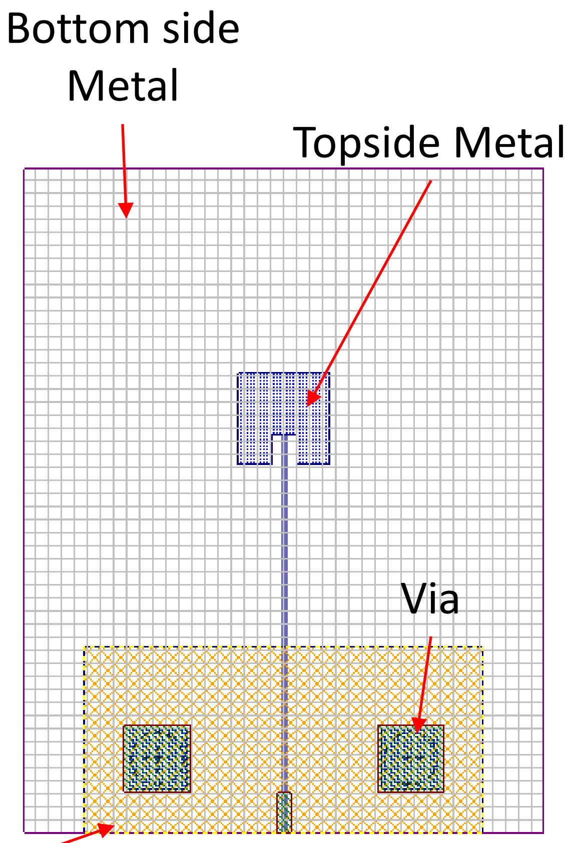
# Summary

- 3 Fab runs done all on the same substrate
  - Dupont Pyralux AP9151R
    - (35um) copper / (125um) Polyimide / (35um) copper
    - Specific datasheet attached along with a more comprehensive Polyimide datasheet
- All the runs have a test coupon with an antenna structure to measure
  - Idea being, changes in the substrate or fabrication tolerances will affect the antenna's resonant frequency. Something easy to track over time
- First 2 fab runs measured as expected, compared to Cadence's Microwave Office
  - I didn't adjust my models to achieve a good first order fit between measured and simulated data
  - Will present the modeling and measured data
- Third fab run measured quite different than expected
  - Same fab process as before, same measurement setup as before
  - I had to adjust the dielectric constant within my models from the nominal 3.4 (as the datasheet suggests) to 4.4 in order for my models to more closely match my measurements
- Before I ask my vendor if something changed I wanted to make sure I didn't miss anything on my end

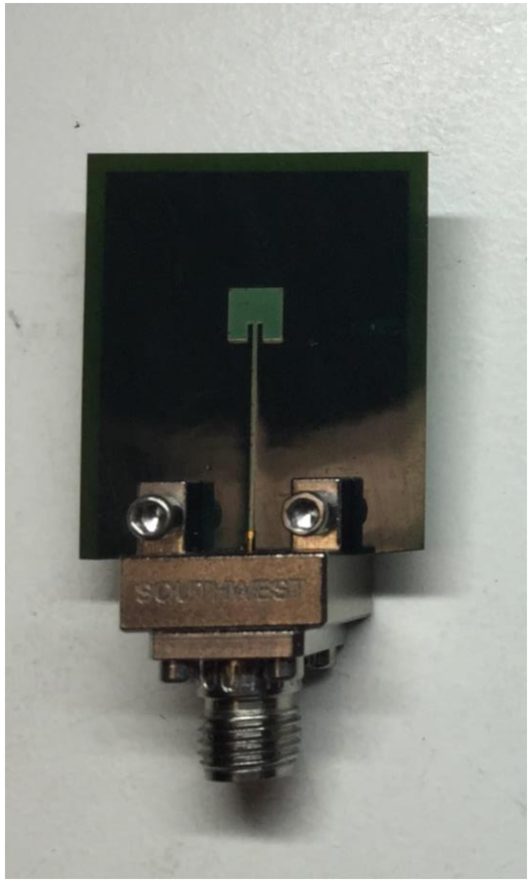
# First Fab Run, 24GHz Test coupon

- Patch Antenna tuned to 24 GHz
- Modeled 2 ways
  - Infinite ground plane
  - Finite ground plane as fabricated
- Dielectric properties below
  - Taken from datasheet of material
  - Used real conductivity for copper
  - Problem setup as Cadence recommends

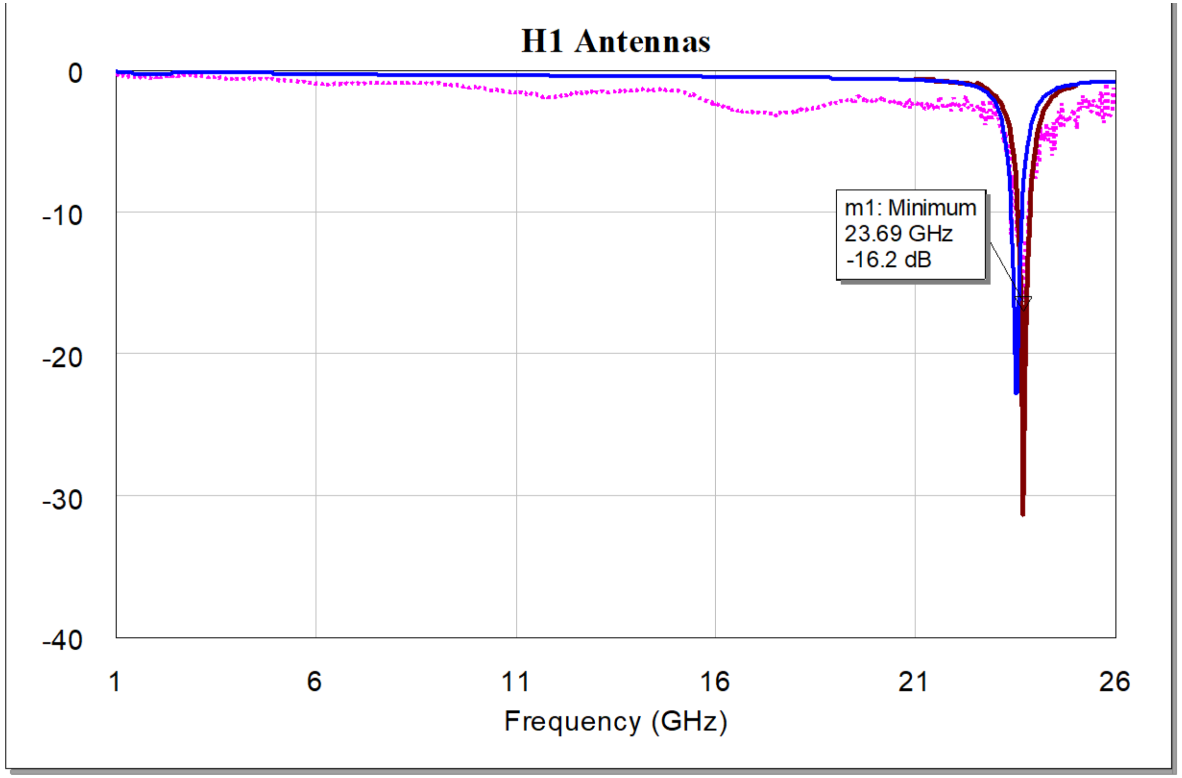
| Name | Er | TanD | Color | Advanced Properties |
|---|---|---|---|---|
| Polyimide | 3.4 | 0.003 | | Advanced: Er=3.4, TanD=0.003, Sigma=0, Ur=1, TanM=0 |




Orange layer is the backside solder mask, not used in EM simulation. Only the top side metal, bottom side metal, and vias are used



# Comparing measured and simulated results for 24 GHz test coupon

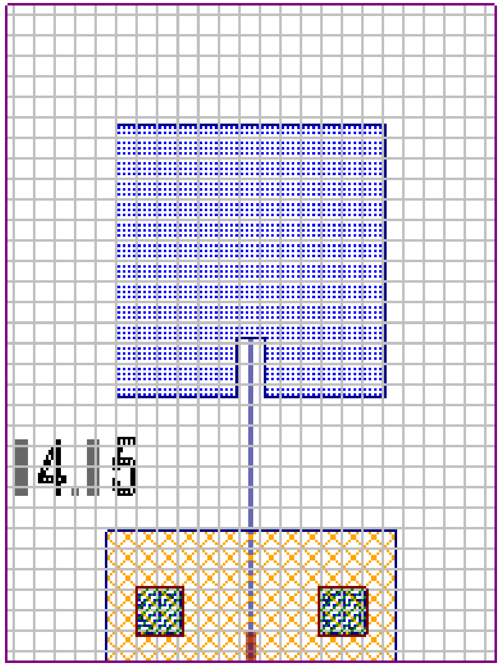


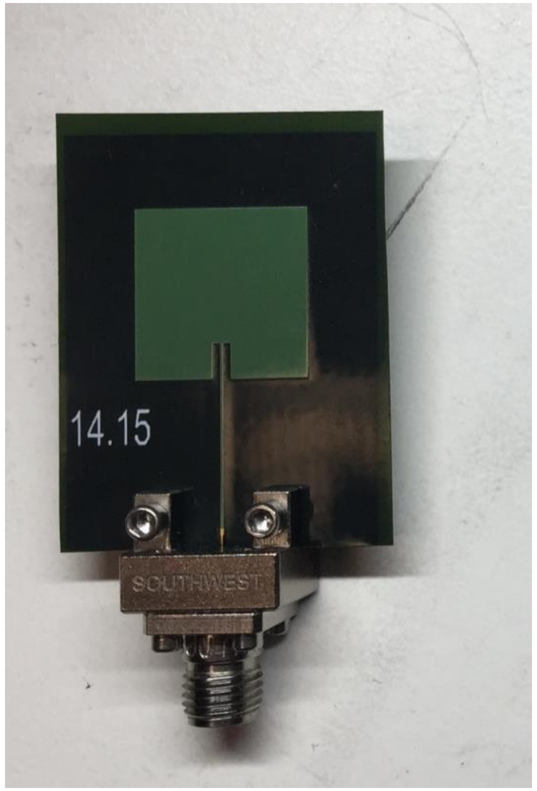

- Measured data purple dots
- Infinite ground plane simulation
- Finite ground plane, as fabricated
  - Didn't simulated full band due to the physical size of the model and simulated data
- Aside from higher frequency loss, the resonant frequency of the test structure is quite close to both predicted values.
  - High frequency loss is due to the use of a SMA end launch connector and a dietetic loss tangent that increases with frequency (see page 12 of supplement data sheet)
  - Slight variations in the resonant frequency are a combination of fabrication tolerance and the varying dialectic constant as a function of frequency (See page 14 of supplement data sheet).

# Second Fab Run, 5.8 GHz Test coupon

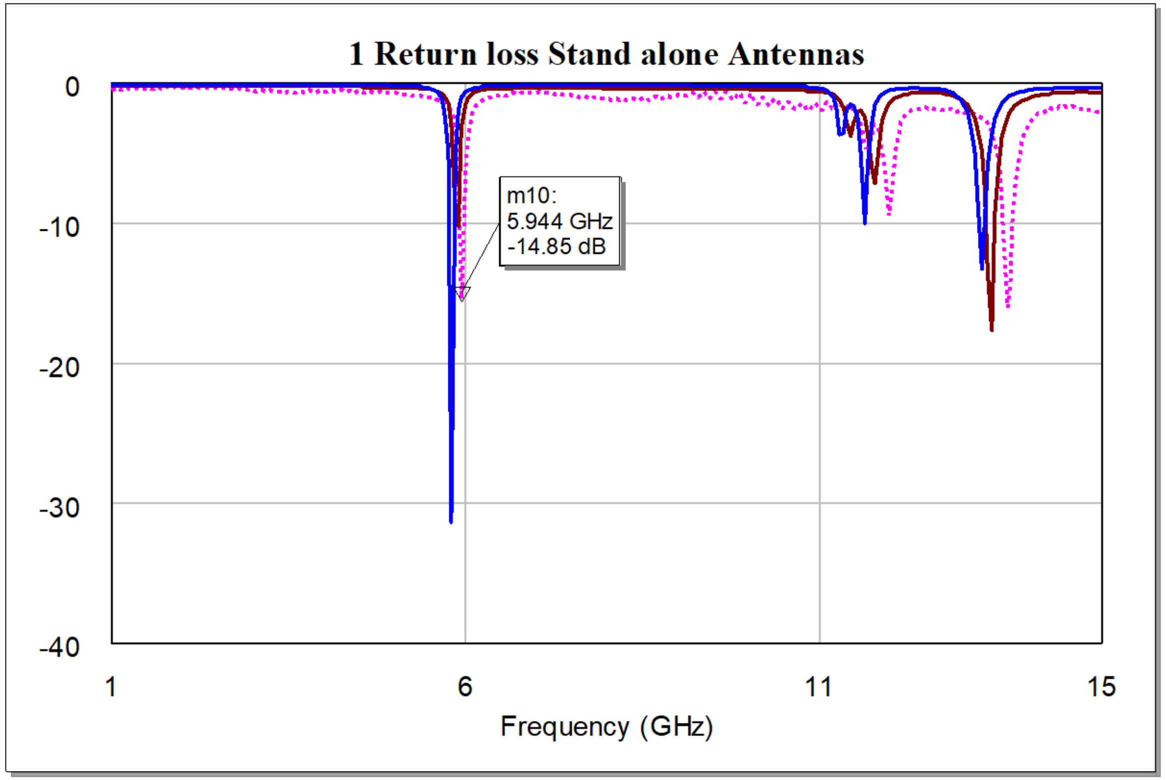
- Patch Antenna tuned to 5.8 GHz
- Modeled 2 ways
  - Infinite ground plane
  - Finite ground plane as fabricated
- All parameters the same as before, only the geometry of the antenna changed

| Name | Er | TanD | Color | Advanced Properties |
|---|---|---|---|---|
| Polyimide | 3.4 | 0.003 | | Advanced: Er=3.4, TanD=0.003, Sigma=0, Ur=1, TanM=0 |



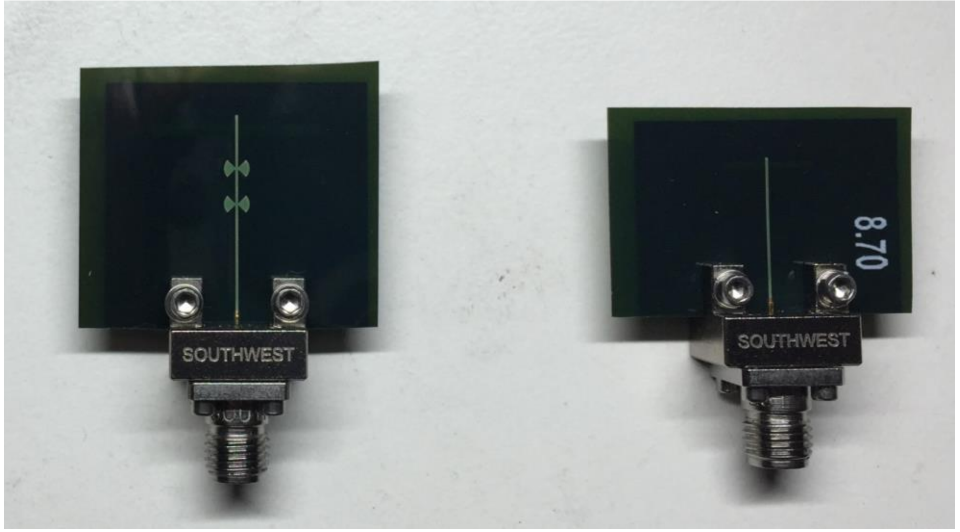
# Comparing measured and simulated results for 5.8 GHz test coupon

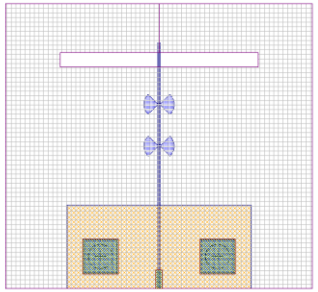


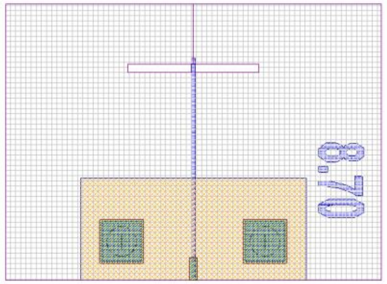

- Measured data purple dots
- Infinite ground plane simulation
- Finite ground plane, as fabbed
- Aside from higher frequency loss, the resonant frequency of the test structure is quite close to both predicted values.
  - High frequency loss is due to the use of a SMA end launch connector and a dietetic loss tangent that increases with frequency (see page 12 of supplement data sheet)
  - Slight variations in the resonant frequency are a combination of fabrication tolerance and the varying dialectic constant as a function of frequency (See page 14 of supplement data sheet).

# Third Fab Run, 5.8 and 11.3 GHz Test coupons

- 2 Microstrip fed slot antennas (slot in ground plane is hard to see in the top photos, apologies)
  - 5.8 GHz center frequency with LPF (top left)
  - 11.3 GHz center frequency (top right)
- Modeled 1 way
  - Finite ground plane as fabricated
  - Not possible to model infinite ground plane with cutout but both methods have shown comparable results
- All parameters the same as before, only the geometry of the antenna changed

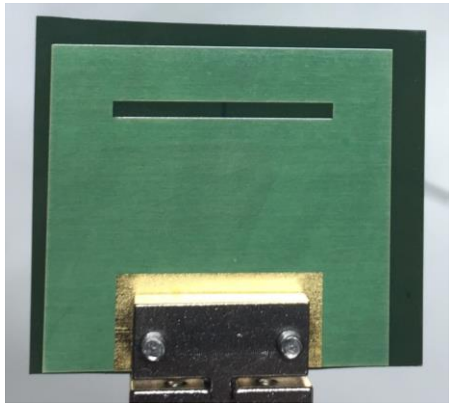





| Name | Er | TanD | Color | Advanced Properties |
|---|---|---|---|---|
| Polyimide | 3.4 | 0.003 | | Advanced: Er=3.4, TanD=0.003, Sigma=0, Ur=1, TanM=0 |

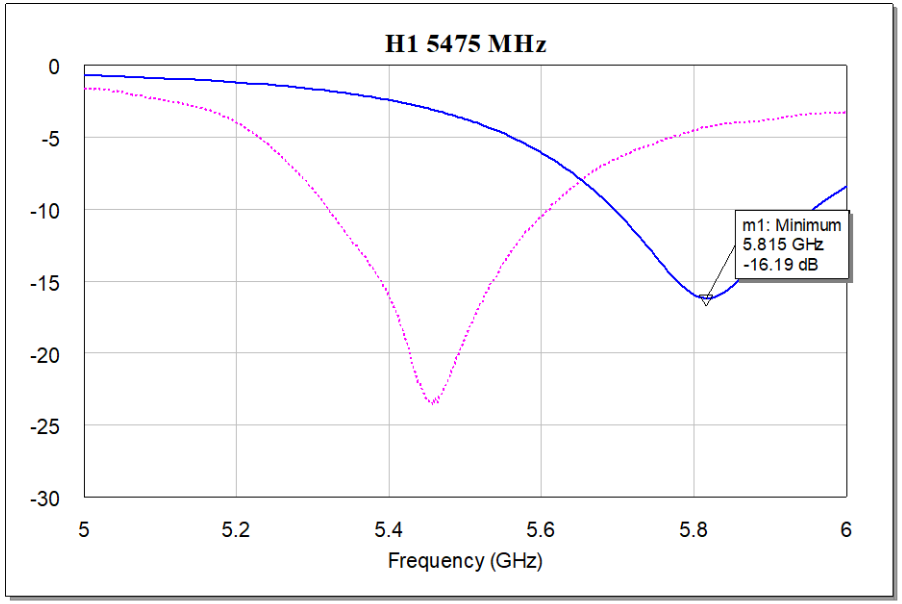

Front of 5.8 GHz Antenna

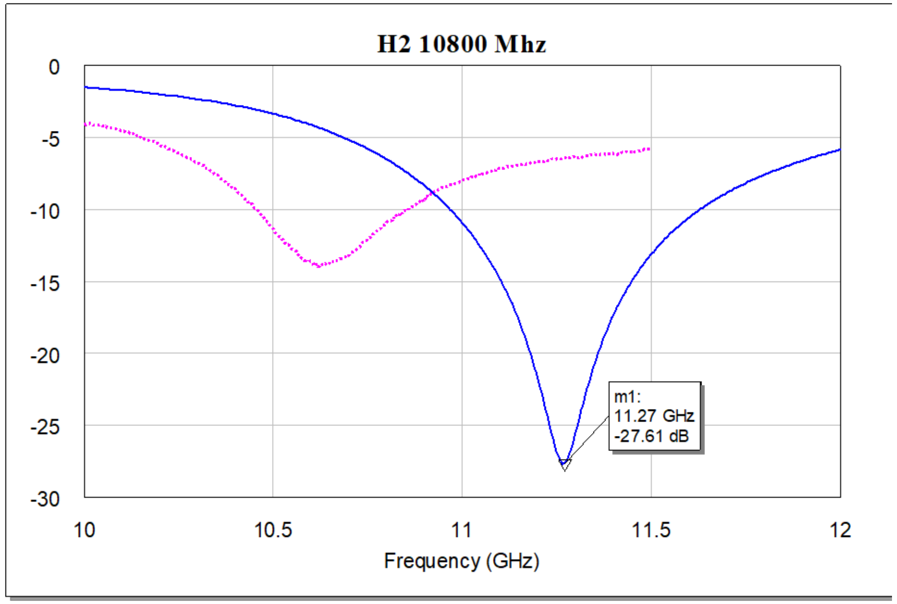


Back of 5.8 GHz Antenna

# Comparing measured and simulated results for both coupons

- Measured data purple dots
- Finite ground plane simulation



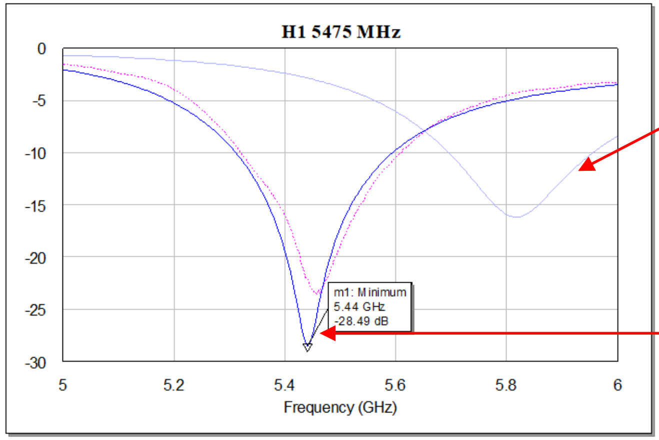

- Since I am forced to model the entire geometry for a finite ground plane, the bandwidth of the plots is limited
- In all prior work, simulated and measured data were never off by more than 100 MHz; which could be explained by slight variations in fabrication and the material. The measured differences above are quite large as compared to differences seen before.

# Simple, yet odd, explanation

Dielectric Definitions: (use for dielectric layers)

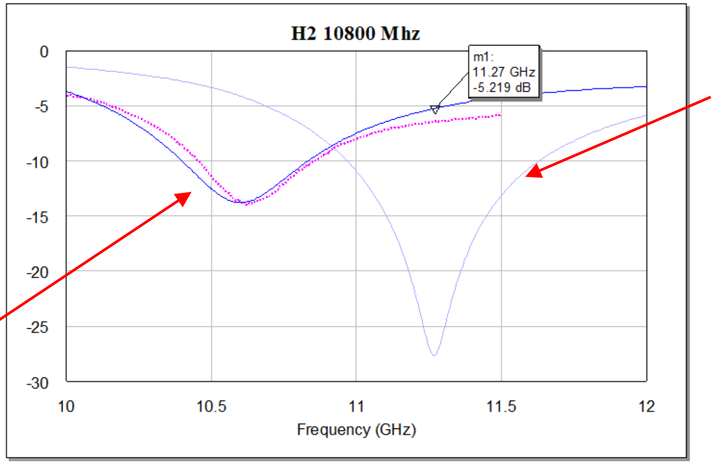
| Name | Er | TanD | Color | Advanced Properties |
|---|---|---|---|---|
| Polyimide | 4.4 | 0.003 | | Advanced: Er=4.4, TanD=0.003, Sigma=0, Ur=1, TanM=0 |

- I only made one change; I adjusted the relative dietetic quite high, 4.4. This number seems unreasonable for the material, but both antenna models matched the measured results with this adjustment to the dielectric constant.
- Page 12 of the supplemental data sheet plots the relative dietetic as a function of relative humidity (RH). The material can posses a $e_r$ of ~3.8 at 100% RH. As a sanity check, and to rule out humidity, I recently remeasured the 24 GHz patch test coupon and 5.8 GHz patch test coupon and got similar results to before.




$e_r$ = 3.4

$e_r$ = 4.4




$e_r$ = 3.4

- Measured data purple dots
- Finite ground plane simulation

# Conclusions

- All things being equal, the substrate for the most recent fabrication run seems to have a different dielectric constant than past runs. I wish I had more test structures to measure and verify.
- That doesn't necessarily imply the vendor used a different substrate, other than the Dupont Pyralux AP9151R. Perhaps it was a bad batch from DuPont?
    - Perhaps some different processing step was used which altered the material?
- Also, I don't posses a real accurate way of double checking the physical circuit/metal line dimensions. But the changes needed to the physical size of the antennas to reach the measured discrepancies are on the order of 1.5 mm. Too large to be fabrication tolerance issues
- Not sure how to move forward. I've used a lot of different RF materials in the past, and I've had pretty decent success. In addition, my first two runs with this flex material worked as expected. So given everything, am I right to contact my vendor and ask if something might be wrong on their end? I really want to make sure I am not missing something before doing so.

# Note about the measurement setup


- VNA is a Keysight 26 GHz Fieldfox
- We use 3.5mm SOL cal standards
- Antennas connected at the calibrated refence plane

# Thanks for taking the time!