



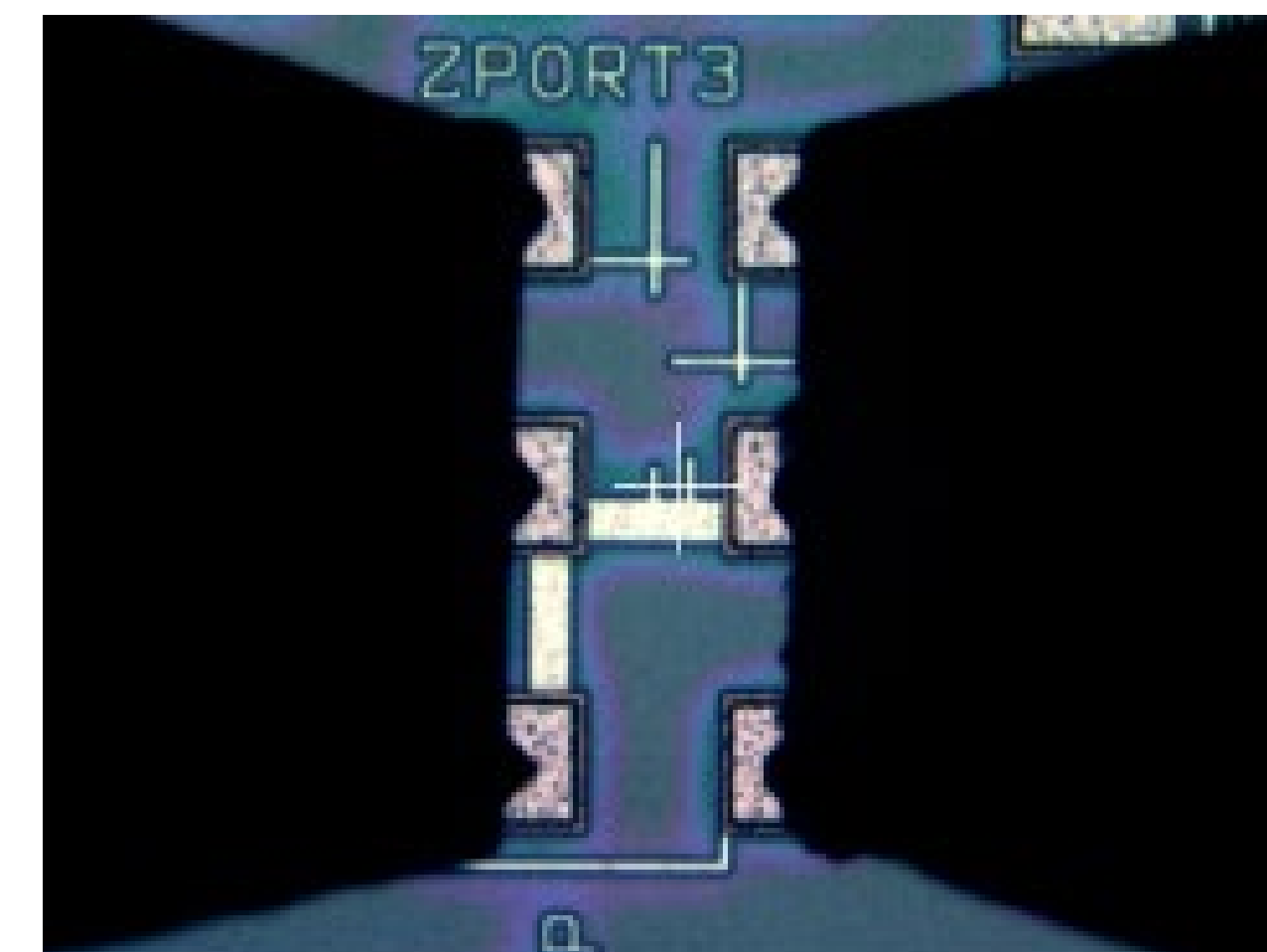
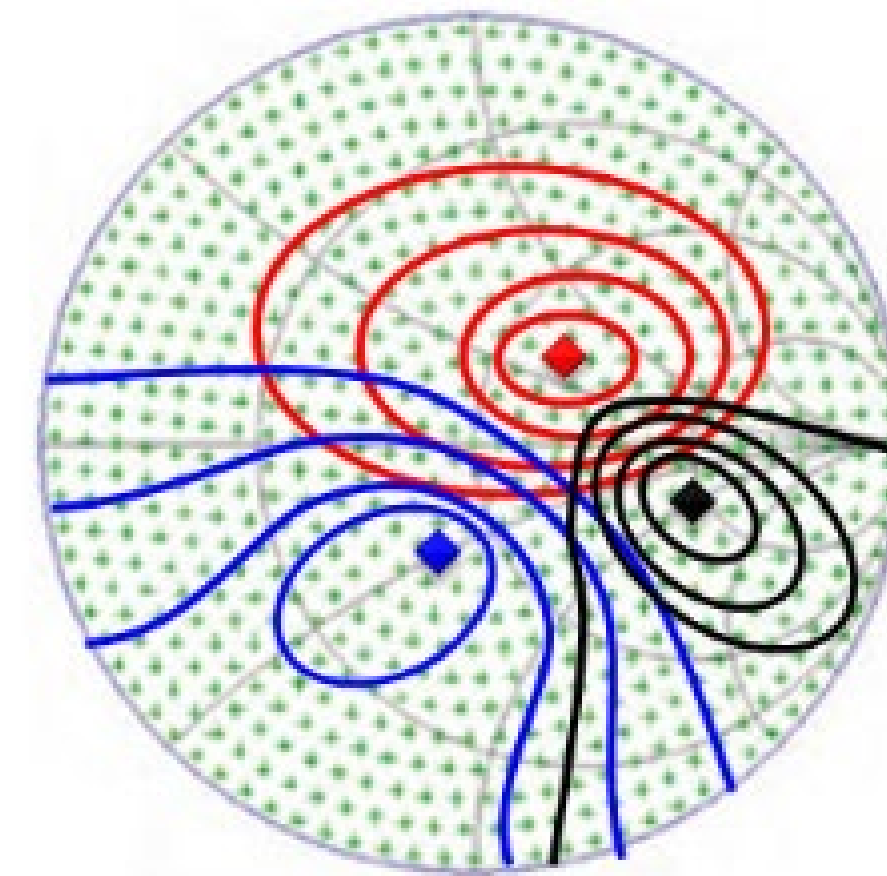
COMPASS
a FormFactor users' group conference

Load-pull Probe Station for Characterization of 5G Devices and Circuits at Wafer-Level

November 17, 2020

Challenges of mm-wave Load-pull

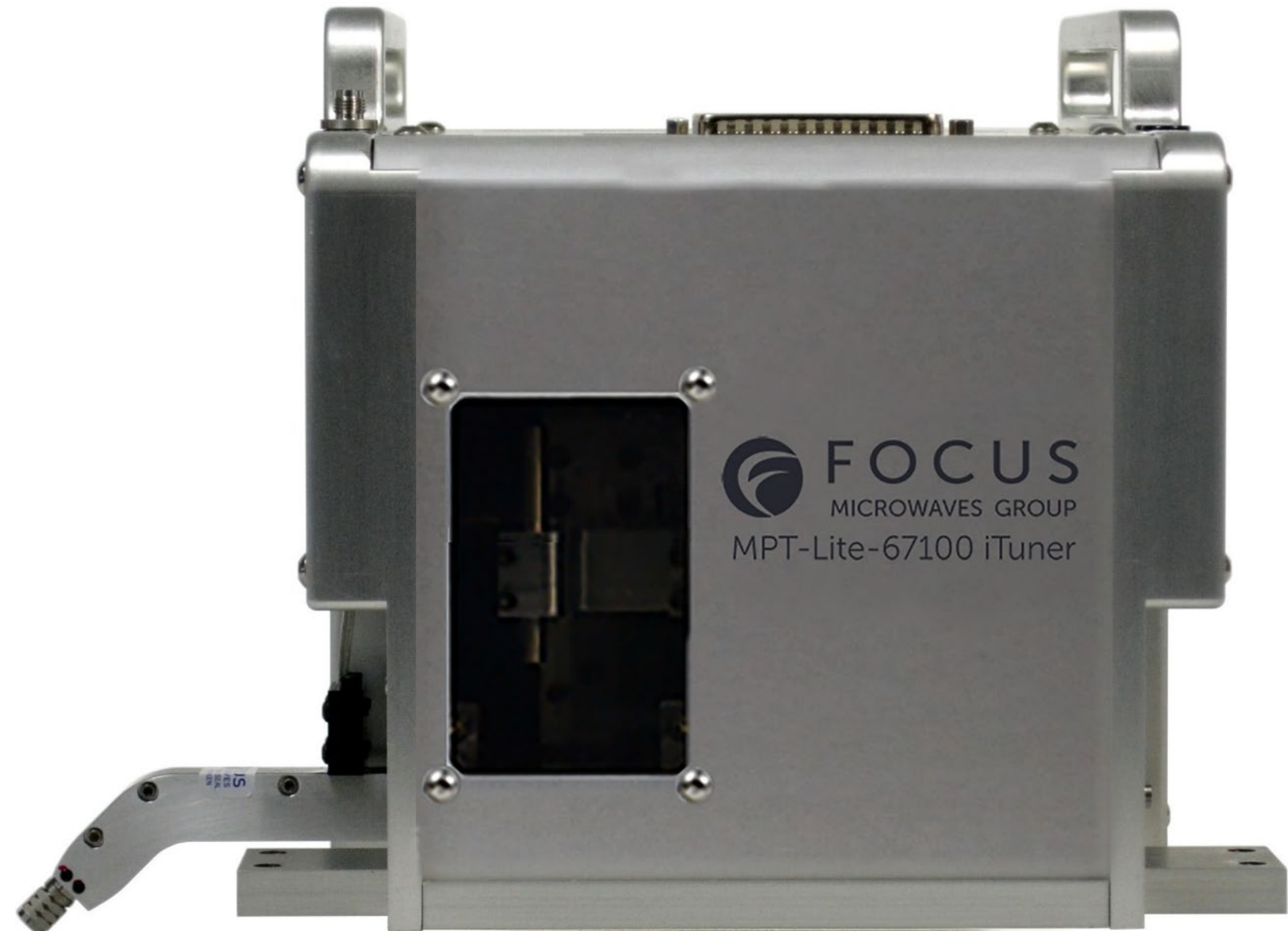
- Keeping the measurement channel insertion loss as small as possible to maximize Gamma
- In order maximize the tuning range over the Smith chart, insertion loss of the probe and integration needs to be as low as possible, but still provide usability
- Ability to measure over temperatures from -60 to 125degC
- An open system does not allow cold, EMI shielded or dark measurements
- A measurement enclosure is required for this
- Accurate probing of small pads
- In order to place probes on pads as small as 30 μ m, a high power microscopy system is required
- Stability during probing
- System used should have minimal vibration during tuning on same DUT for long periods



New Focus Microwave DELTA & Traditional Tuners



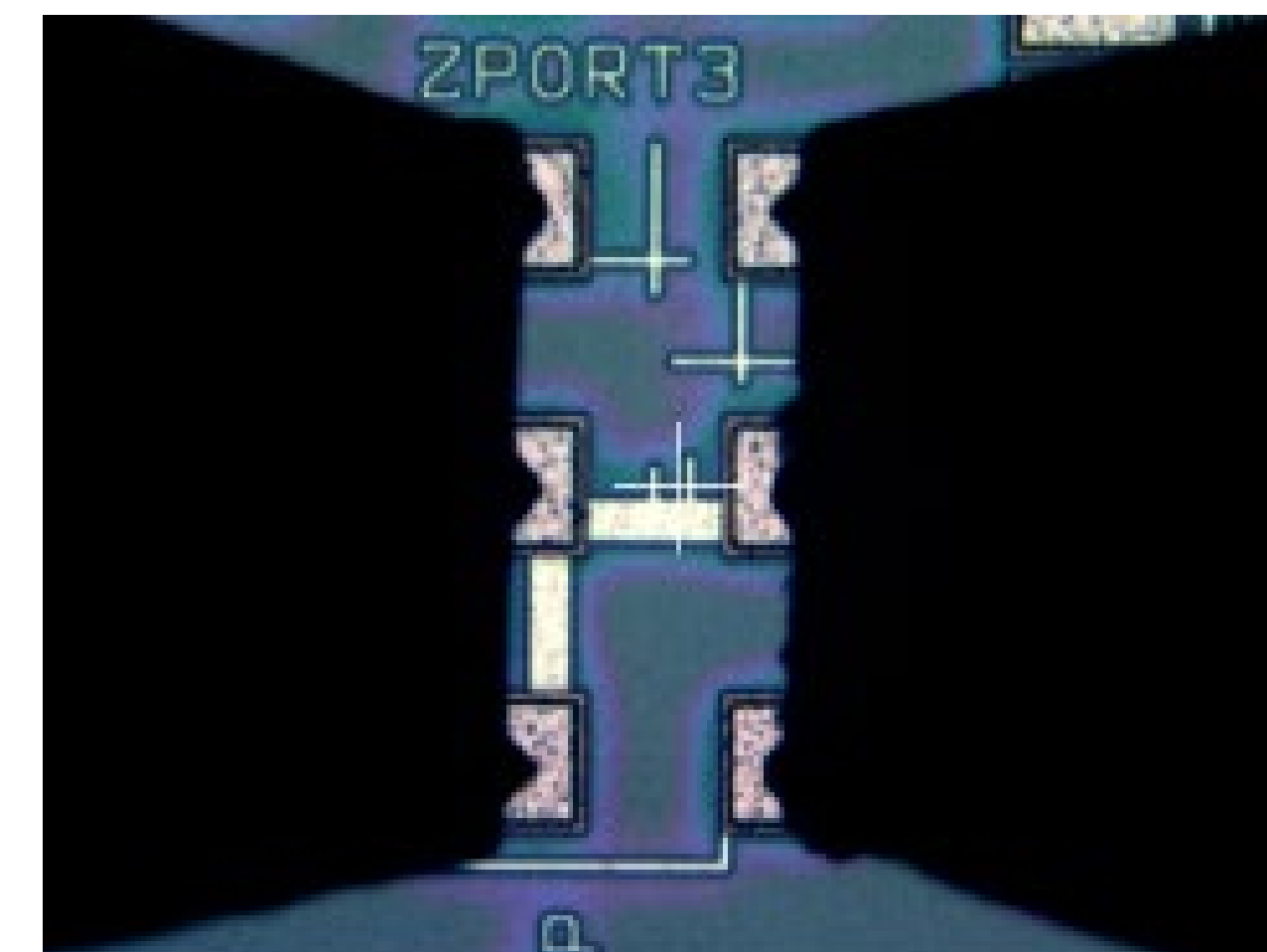
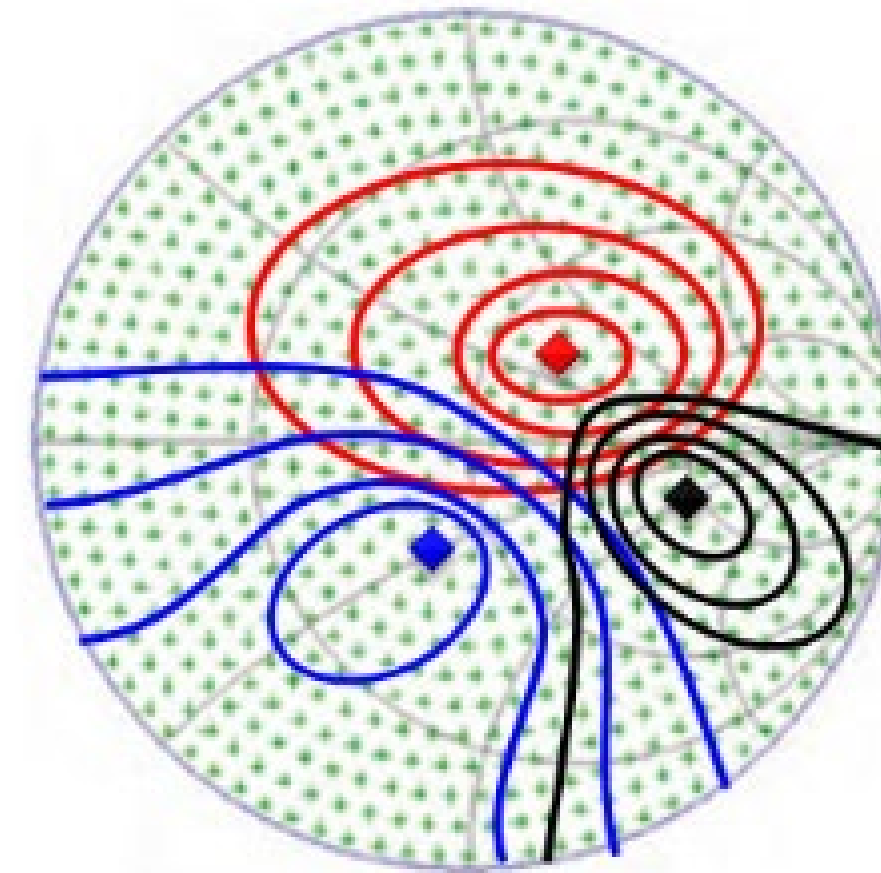
DELTA Tuner



Traditional Tuner

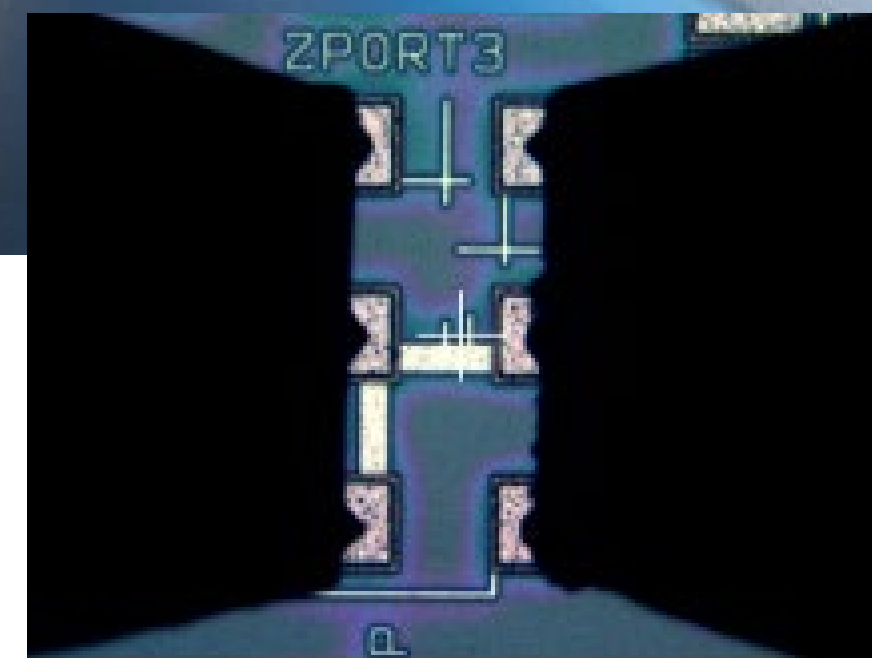
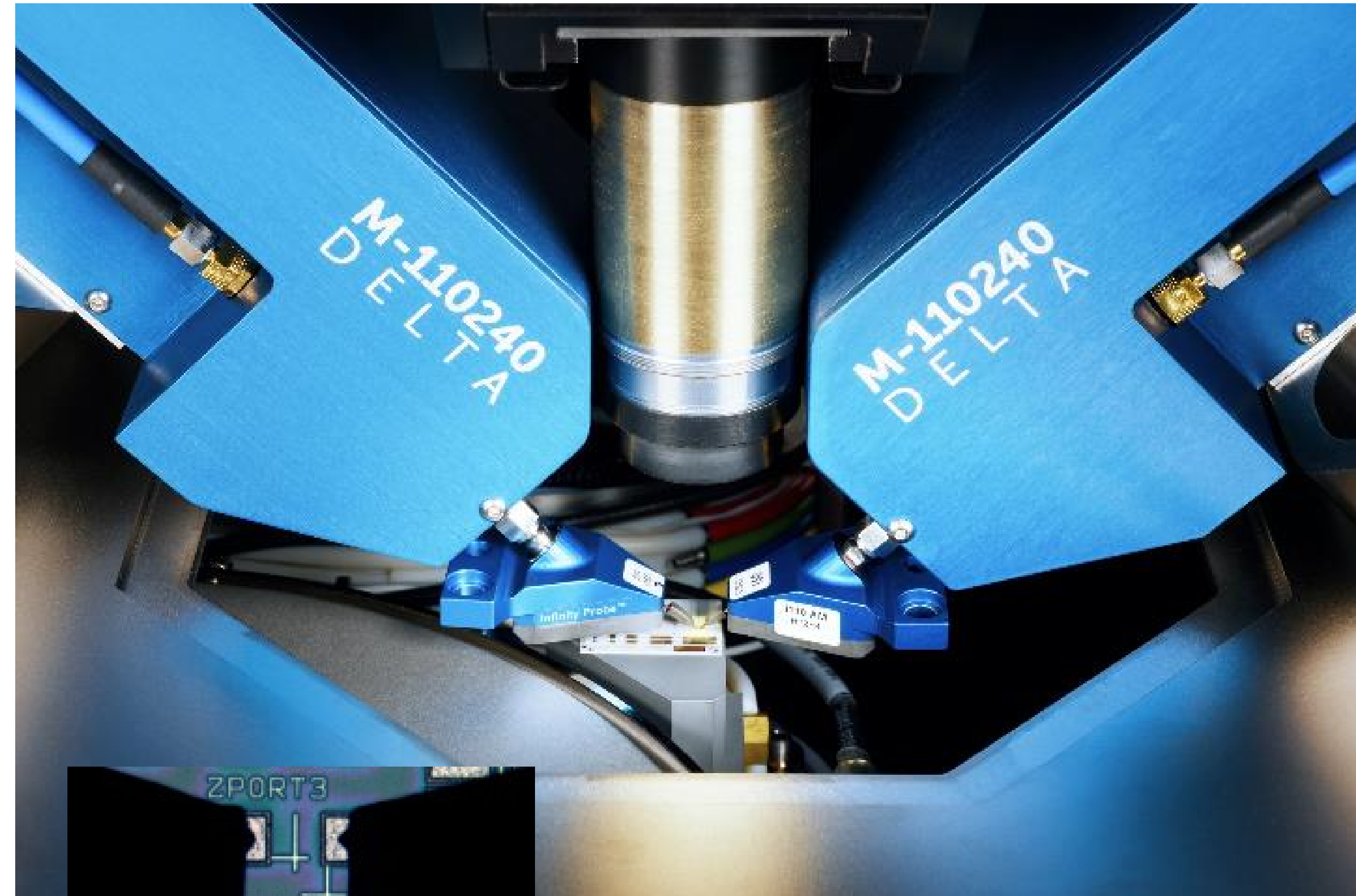
Challenges of mm-wave Load-pull

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Low Loss Integration with & without RF TopHat

- Probes connected directly with tuner for non-TopHat
- Minimizes insertion loss and maximizes Gamma (loss of cable removed)
- Does not compromise on compatibility with high power microscope objectives
- Contact pads as small as $30\mu\text{m}$ with micron level accuracy
- Probe tips can probe the smallest transistors with minimal probe-to-probe distance and calibrate on standards with small calibration structures
- Probes can come as close together as needed without hitting microscope
- Use standard LRRM calibration substrates



Optimized Integration of Load-pull Tuners

- Manual or programmable positioners
- On any FormFactor probe system
- Dark, EMI shielded and frost-free option
- Low temperature Measurements still possible
- Easy visibility of probe tips
- High performance digital microscopy compatibility
- With high resolving power (NA) objectives
- Low loss measurement channel
- Proven measurement performance
- Fast swap application arms for easy and safe set up

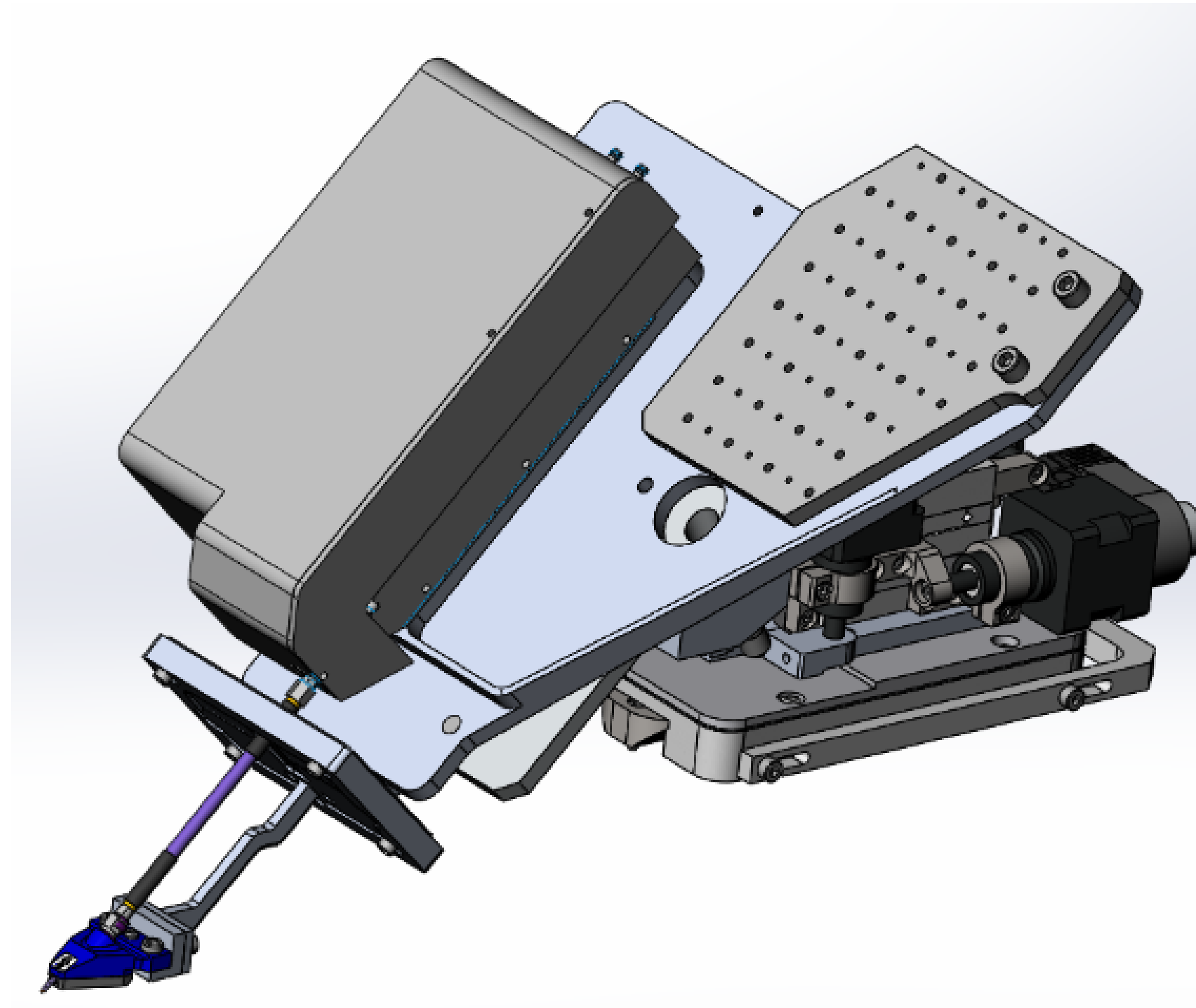


RF TopHat Configuration for Focus Delta Tuners

- Enables dark, EMI shielded and frost-free measurements, keeping additional insertion loss to a minimum
- Keeping maximum possible Gamma whilst allowing extra functionality
- Can be converted to non-TopHat set up for optimized Gamma
- FlexShield* to allow resistance-free probe positioning
- No stiction during probe movement
- Improved probe contact accuracy
- ProbeView* I.T.O. coated window to allow easy probe viewing
- Easy set up and probe tracking
- Always shielded, always frost free
- Cover for dark measurements

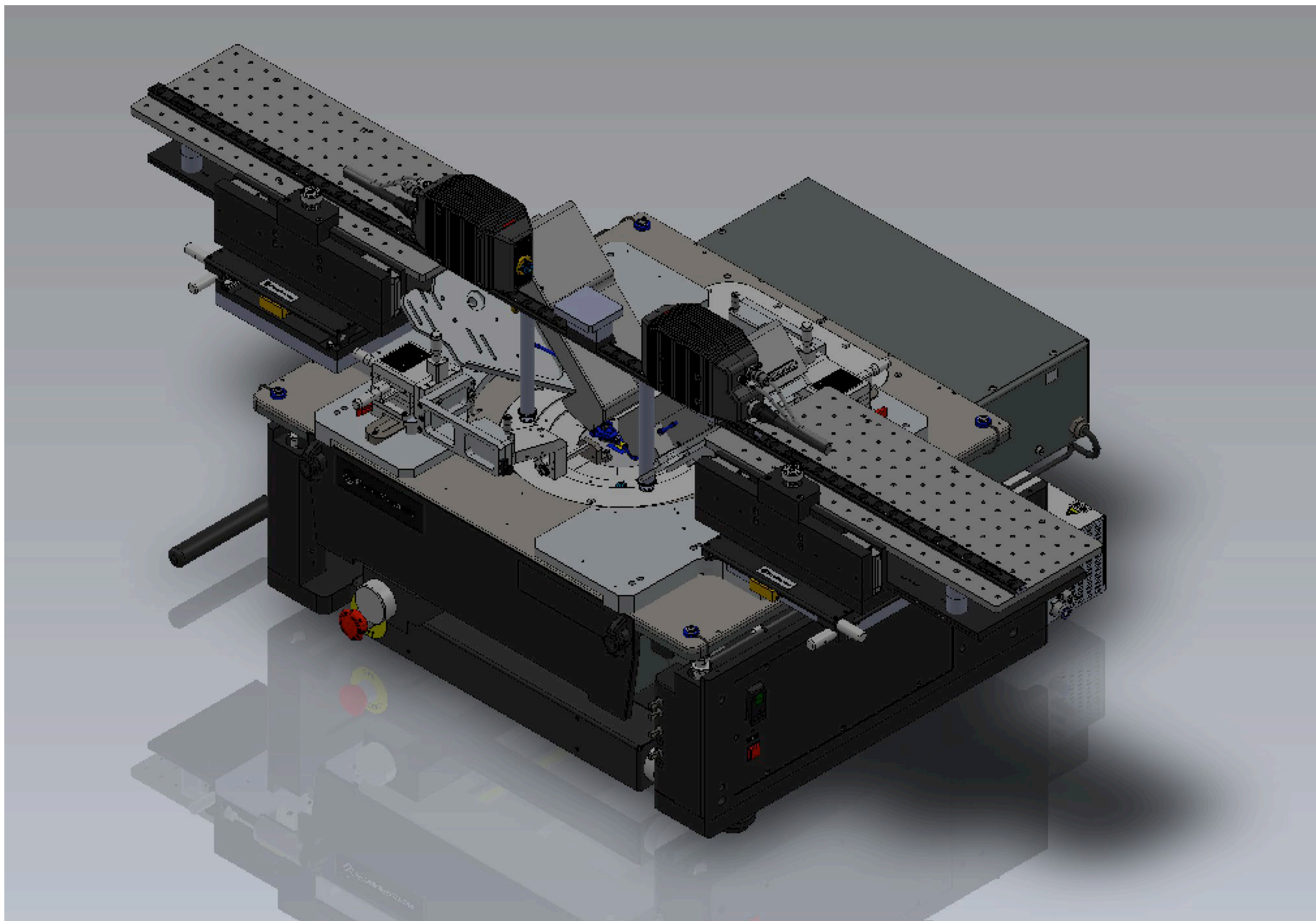


Expanding setup for components other than extender



- Components other than the frequency extender often required like :-
 - Power meters
 - Couplers
 - Amplifiers
 - Bias tees
- Mounting of these items facilitated using standard breadboard or customised mounting plates
- Extender is often only mounted closely for the tuner calibration

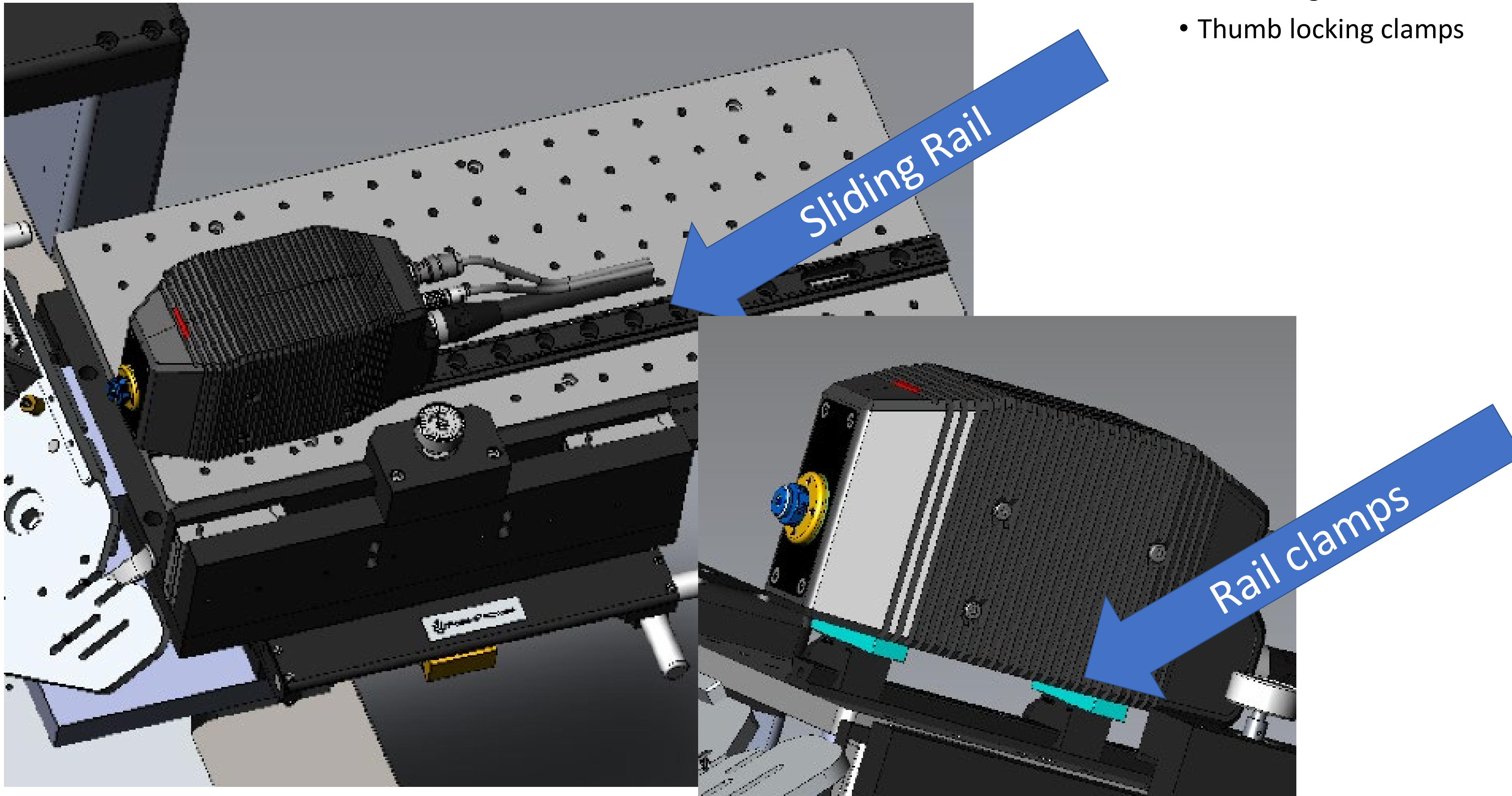
More complex arrangements



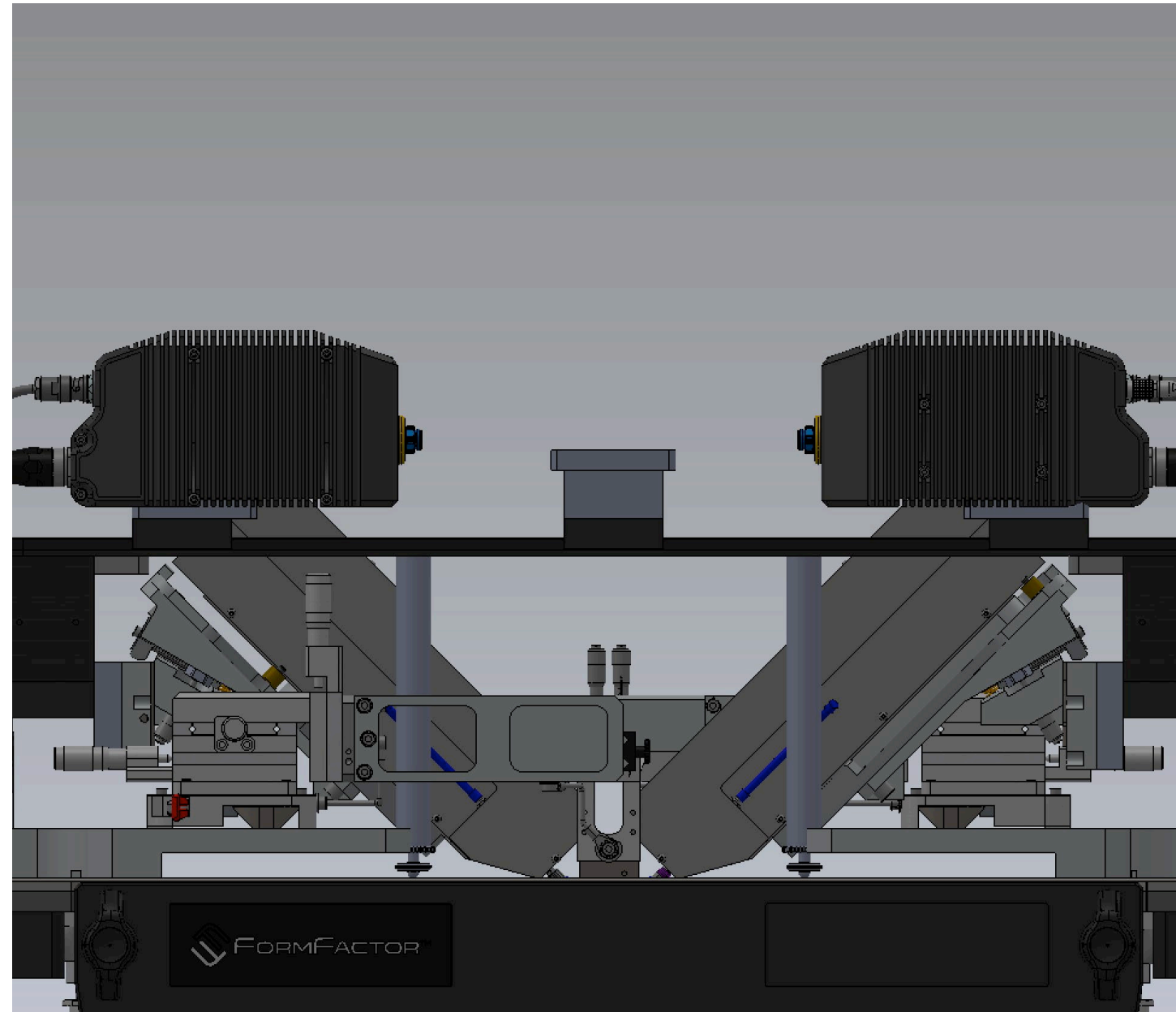
- Solution developed for more complicated scenarios requiring large real estate or heavy components
- N5291 sliding rail kit used to manipulate extenders
- Uses standard tuner RFA arms and standard large area positioners

N5291A Sliding Rail Kit

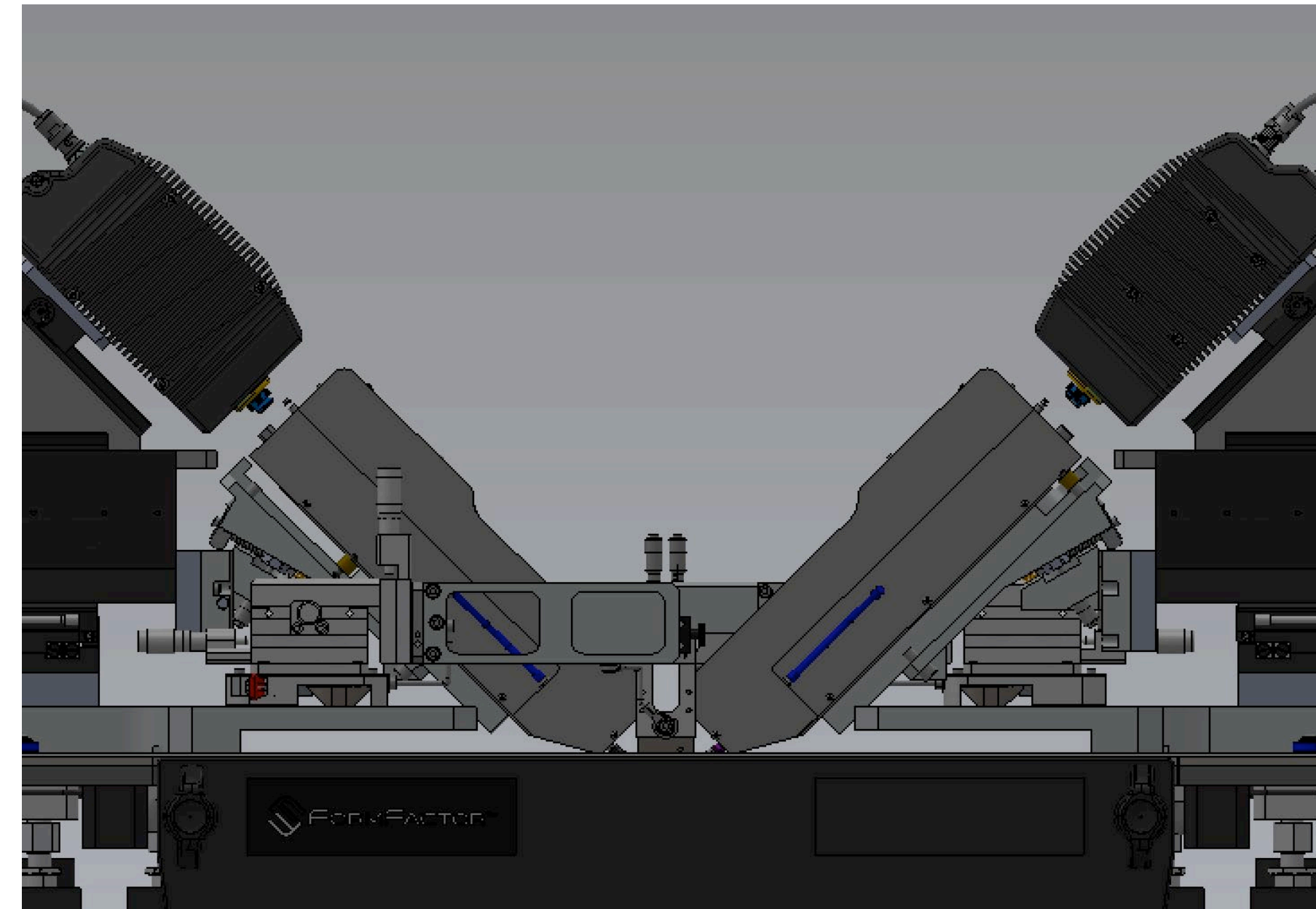
- Wide range of travel
- Thumb locking clamps



Calibrations Arrangements

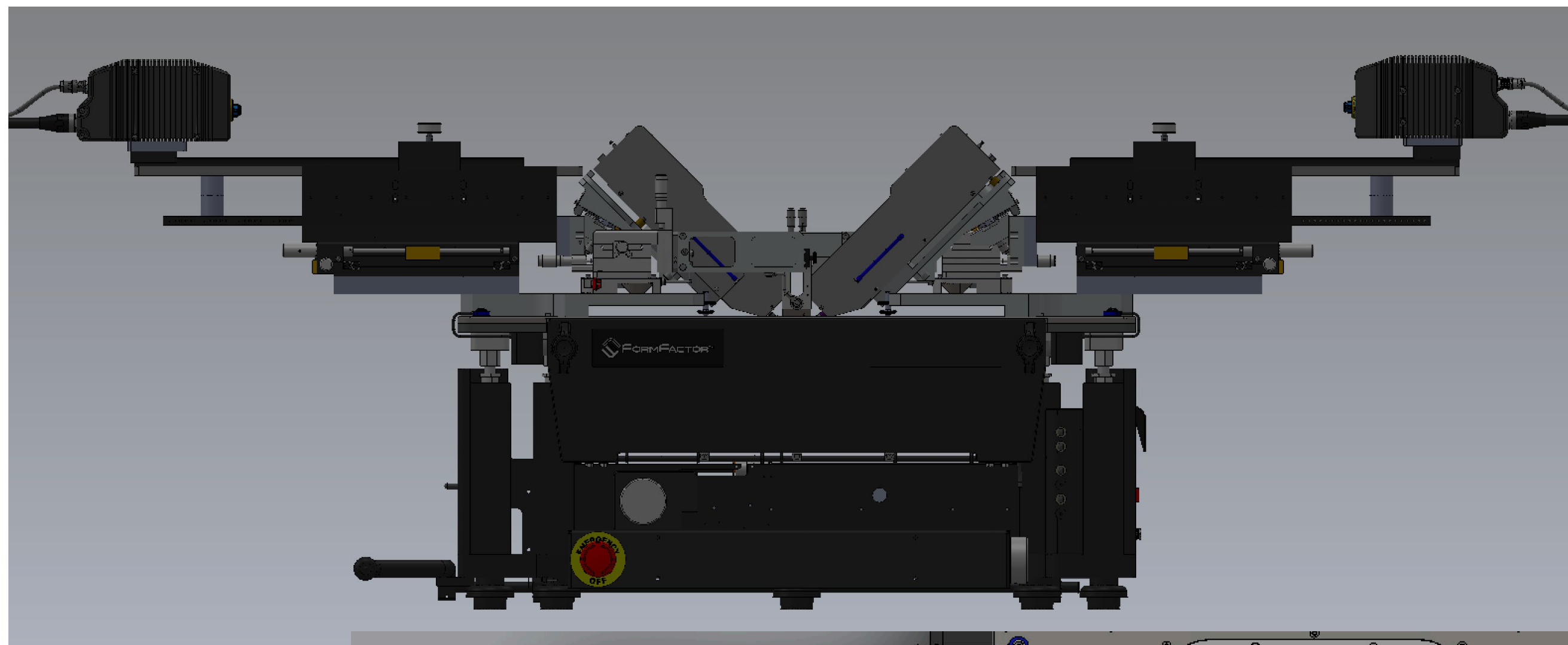


- Step 1 – Coaxial Cal
 - Straight cables
 - Coax standard support
 - Sliding rails
 - Removable bridge

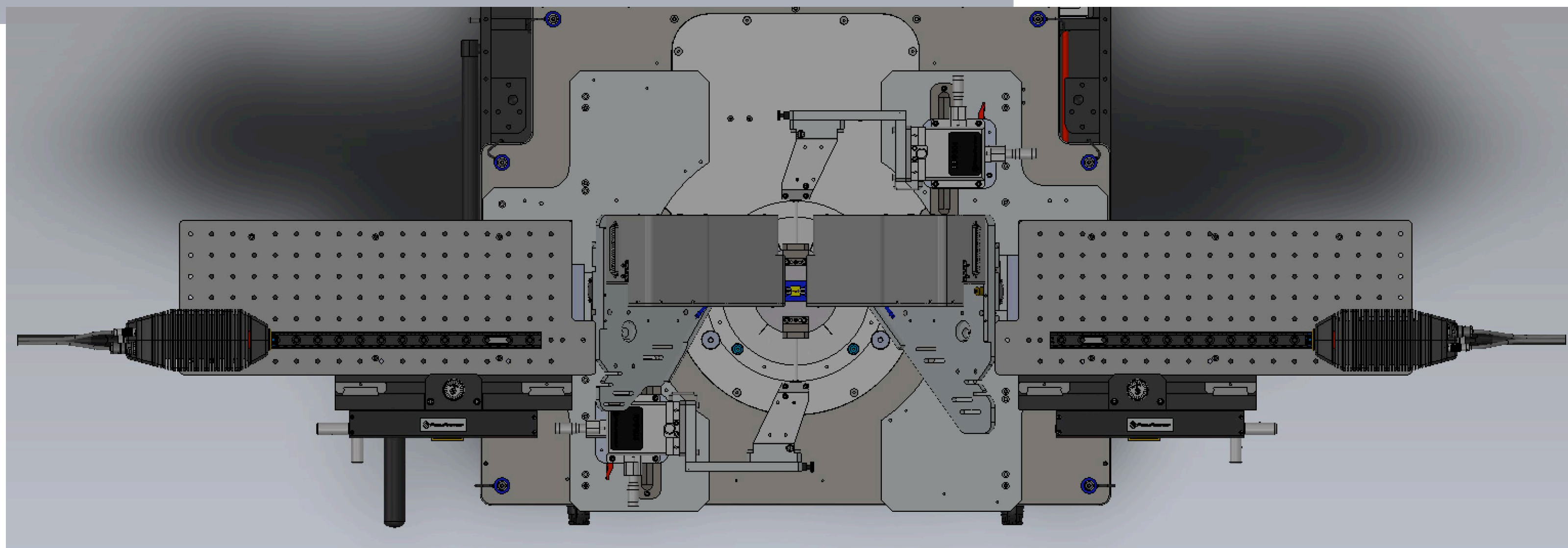


- Step 2 – Tuner Cal
 - Straight cables
 - Sliding 45deg rails
 - Removable wedges

DUT Testing

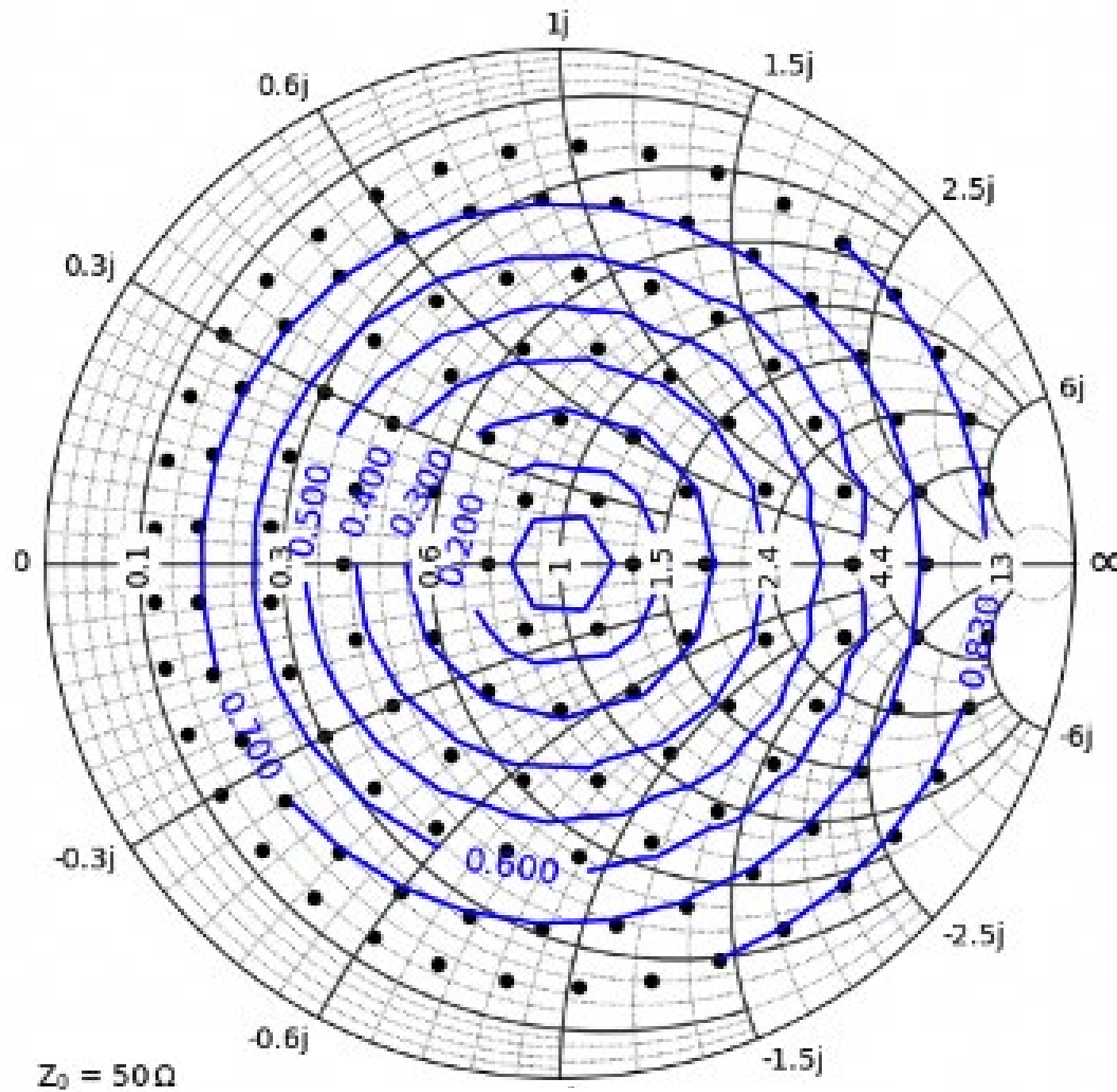


- Extenders can be as far apart as needed or removed
- Easy to move on optical rails
- Lots of available space on breadboard for components



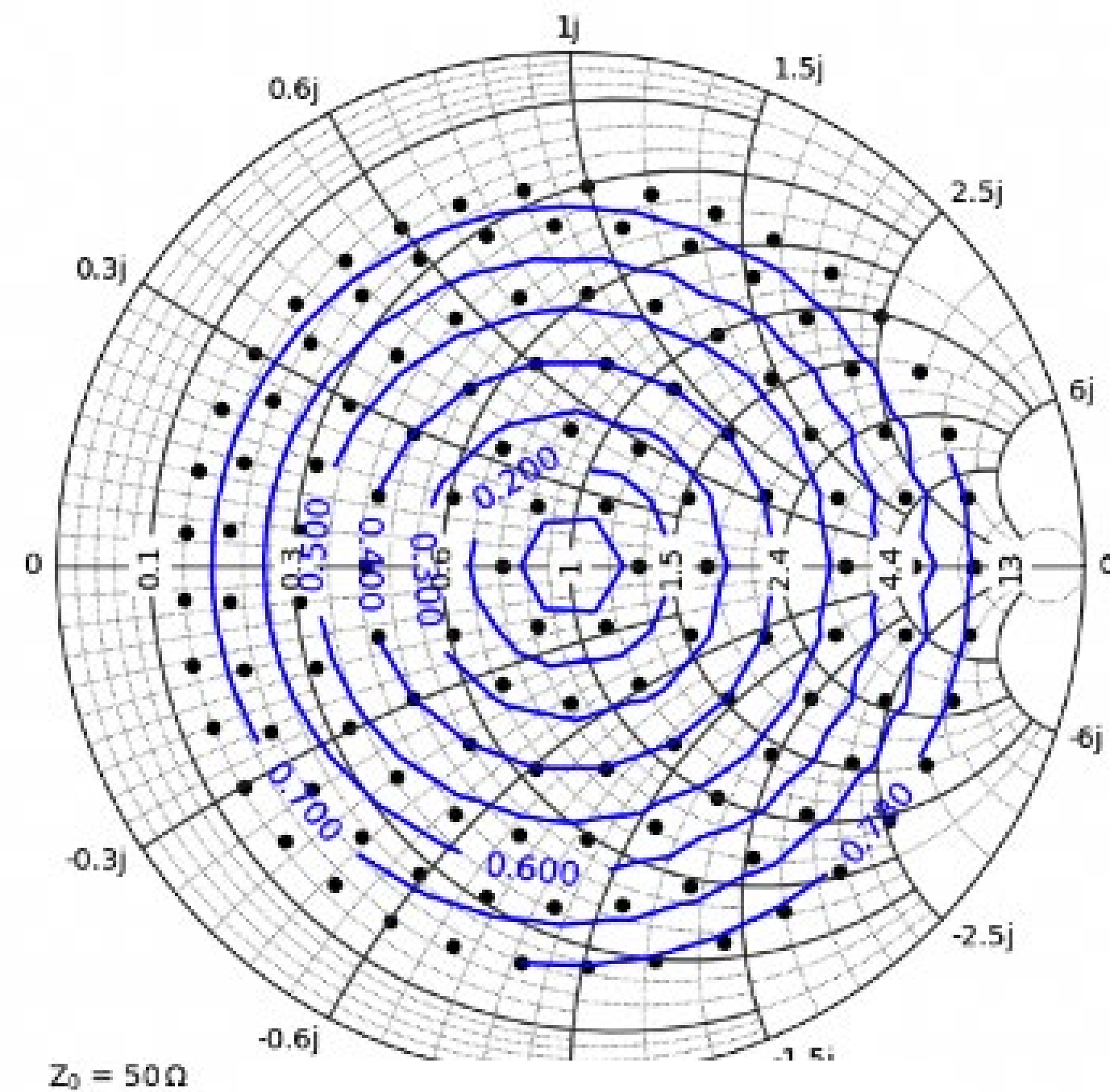
Proven Solution Performance – Tuning Range Directly connected

- Qualified Results – Optimized gamma and functionality



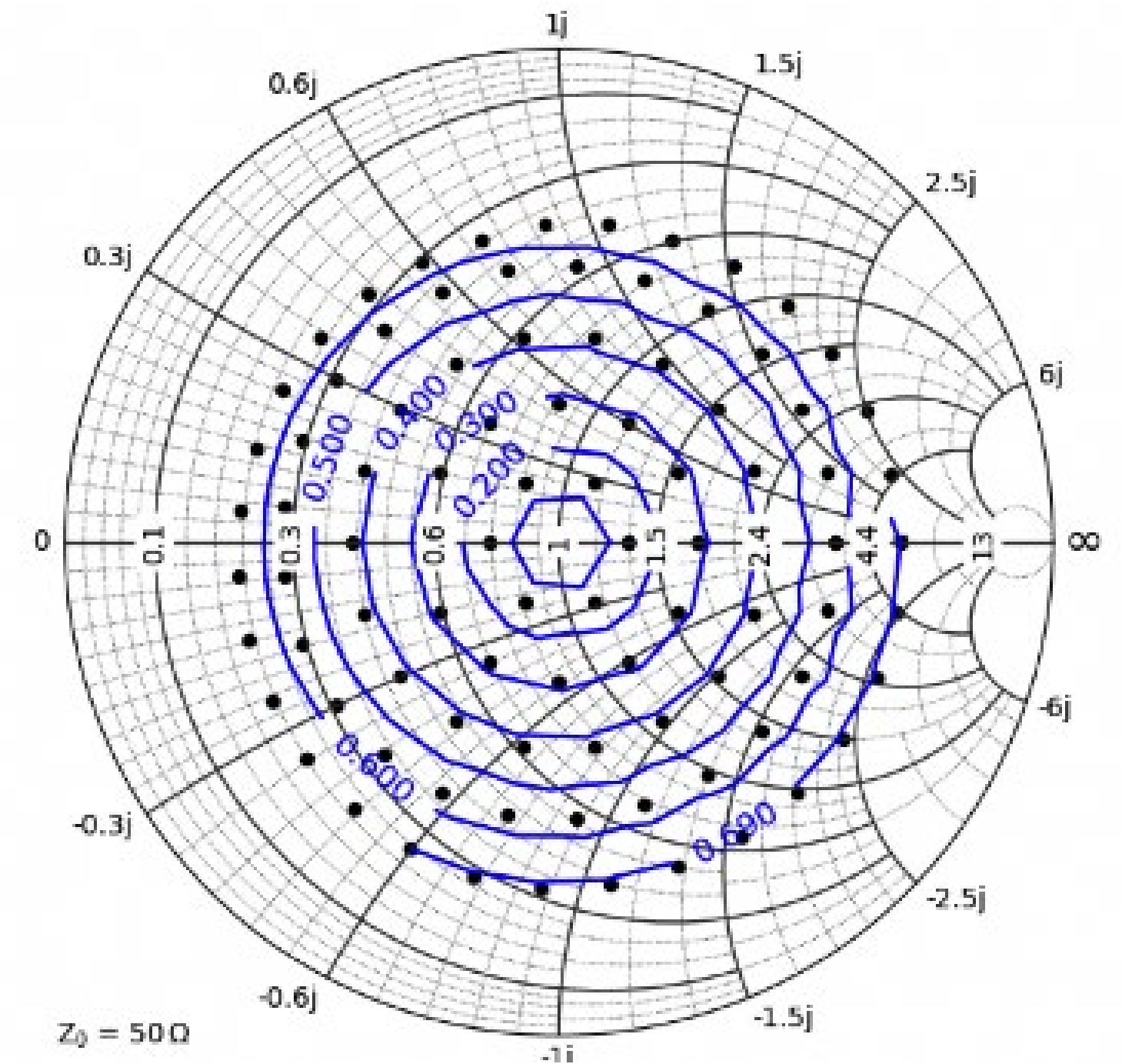
$$\Gamma_{\text{max}} = 0.84$$
$$\Gamma_{\text{max_360deg}} = 0.79$$

28GHz



$$\Gamma_{\text{max}} = 0.79$$
$$\Gamma_{\text{max_360deg}} = 0.74$$

50GHz

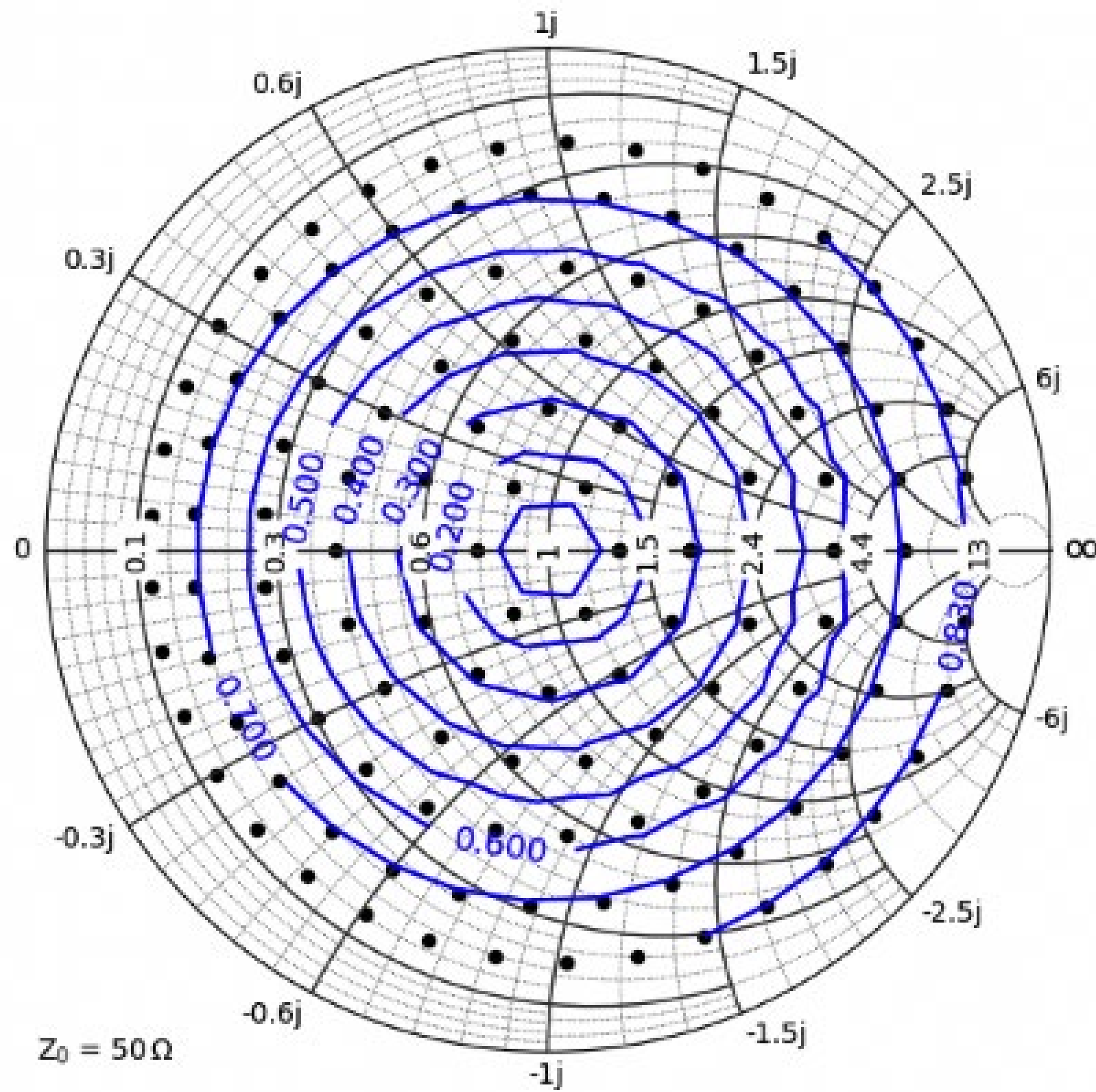


$$\Gamma_{\text{max}} = 0.7$$
$$\Gamma_{\text{max_360deg}} = 0.63$$

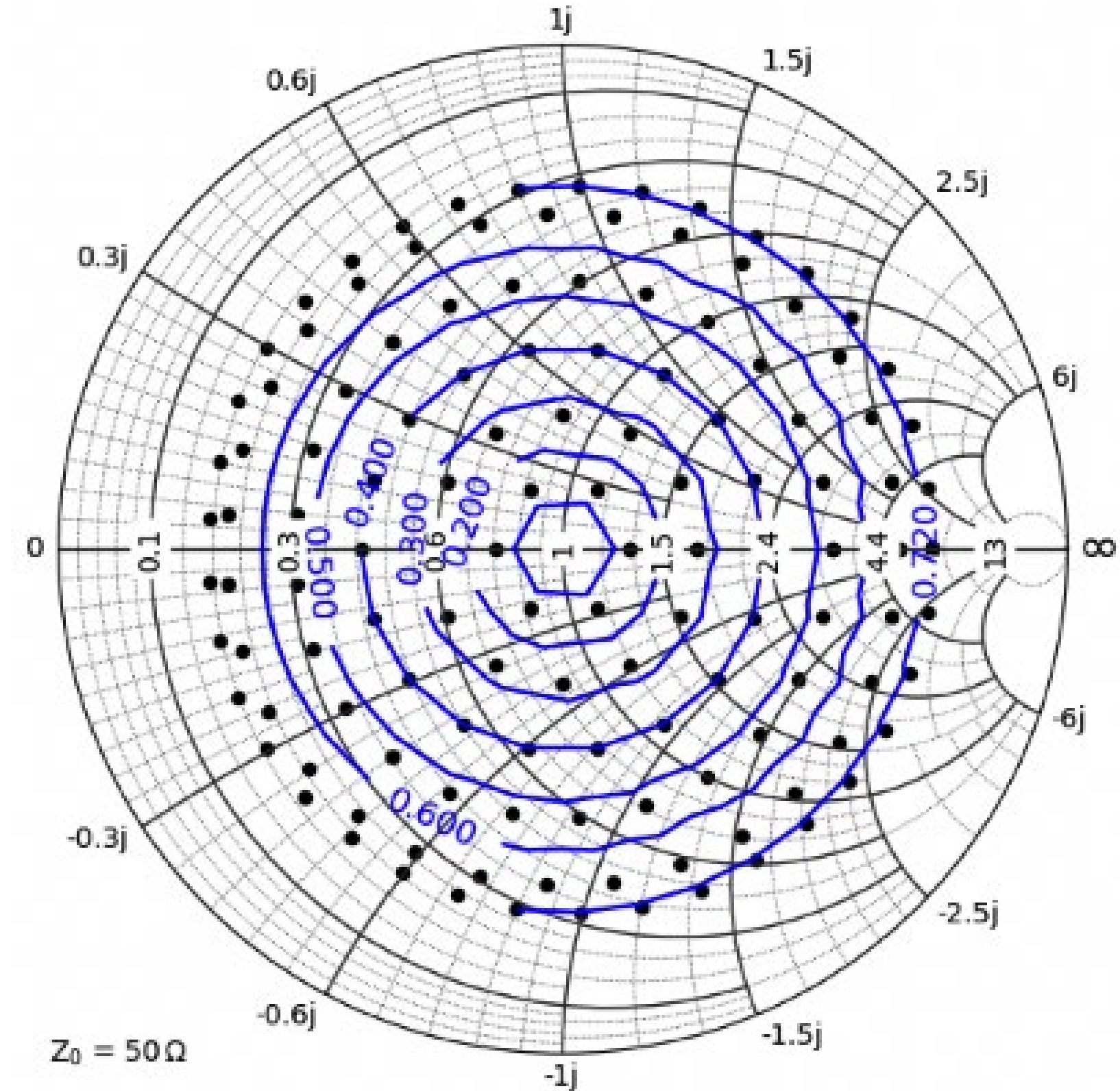
96GHz

Impact on Gamma – non-TopHat vs TopHat

• @ 28GHz



$$\Gamma_{\max} = 0.84$$
$$\Gamma_{\max_360\text{deg}} = 0.79$$



$$\Gamma_{\max} = 0.74$$
$$\Gamma_{\max_360\text{deg}} = 0.7$$

Focus Delta Load-pull Solution Summary

OPTIMIZED PERFORMANCE AND USABILITY

- Direct connect probes for optimized Gamma
- Optional RF TopHat for shielded functionality
 - EMI shielded, dark and frost free
 - Trade off is ~ 0.15 Gamma tuning range depending on frequency and other factors
- High power microscope compatibility for probing small pads and accurate calibrations
- Easy to perform coaxial and on-wafer calibrations
- Fast and easy to swap RFA arms for different measurement disciplines
- Fits on all FormFactor platforms





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THANK YOU