Waveguide Cross-guide Directional Couplers

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Waveguide

- Just metal and air – dimensions defined
- Lower loss than coax
- More power than amateurs can generate
- 10 GHz – ubiquitous
- Below 10 GHz – big and heavy
- Above 10 GHz
  - Essential
  - Rare and expensive for higher mm bands

New DB6NT 47 GHz

DB6NT 47 GHz

- 30 milliwatts output = not QRP
- NF ~ 5 dB
- WR-19 waveguide
  - None in junkbox
- Separate TX and RX
  - No waveguide relay
- 2 months until 10 GHz and Up contest
  - *What to do?*

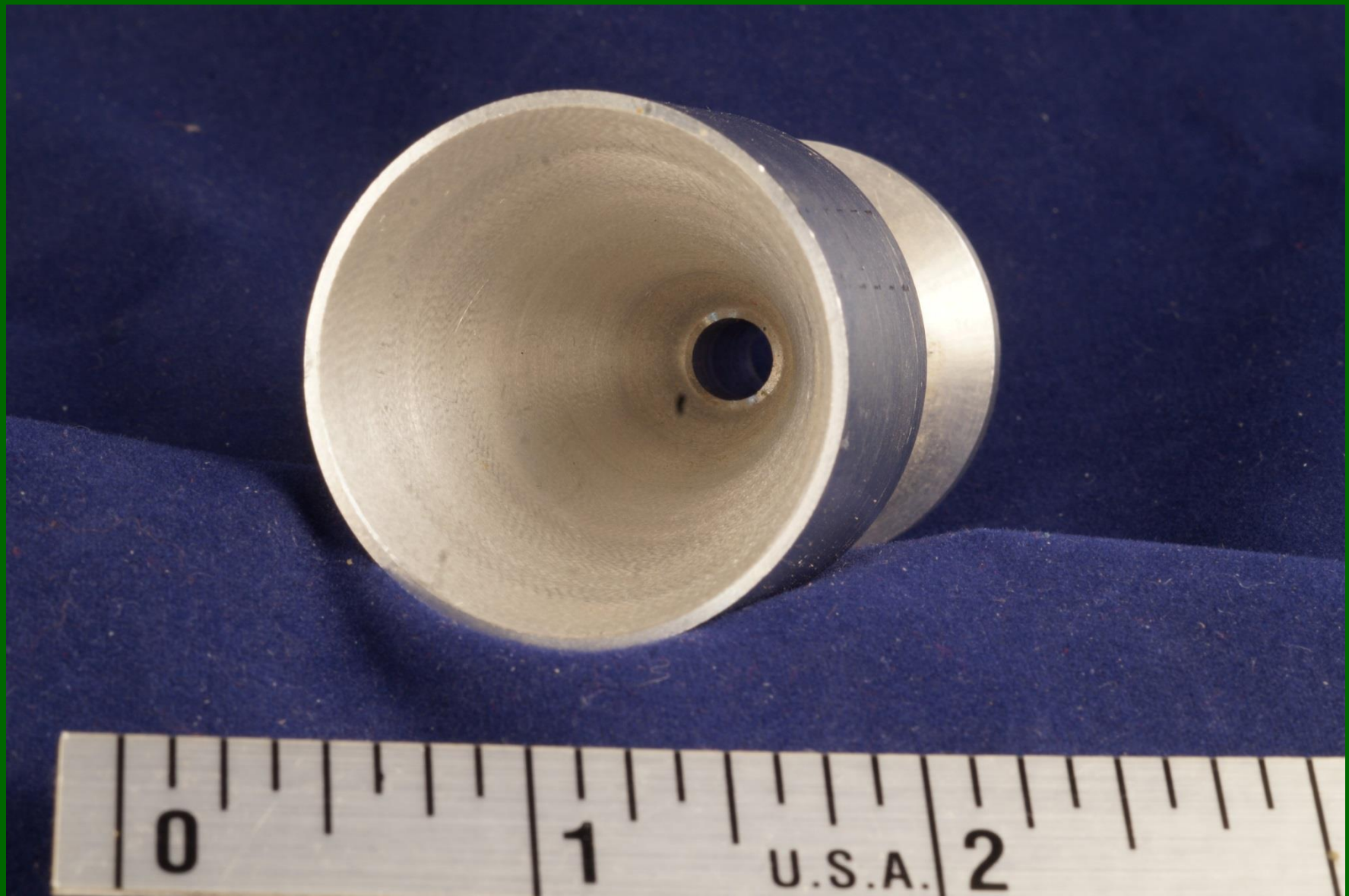
DB6NT 47 GHz

- Maybe separate antennas for TX and RX
- Two horns?
- Skobolev Dual-Mode horn
  - 6λ diameter would fit
  - Scrap aluminum available
  - ~23 dB gain
  - Accurate machining?

Makerspace – The Foundry VT

CNC Lathe

23 dBi Horn



23 dBi Horn

47 GHz Breadboard

47 GHz Measurement

- Return Loss or VSWR
  - Directional Coupler
  - Slotted Line
  - VNA ($$$$$$$$$$$$$$$$$)
- Power
  - HP432A waveguide head
  - Directional Coupler
- Frequency
  - Synthesizer with multiplier

Directional Coupler

- For measuring power
  - Forward
  - Reflected
  - Phase (impedance)
- Coupling
  - Steals a small part of signal
  - Ratio of transmitted power to coupled power
  - In dB
  - ex: -30 dB coupling has coupled output 30 dB below transmitted power

Basic Directional Coupler

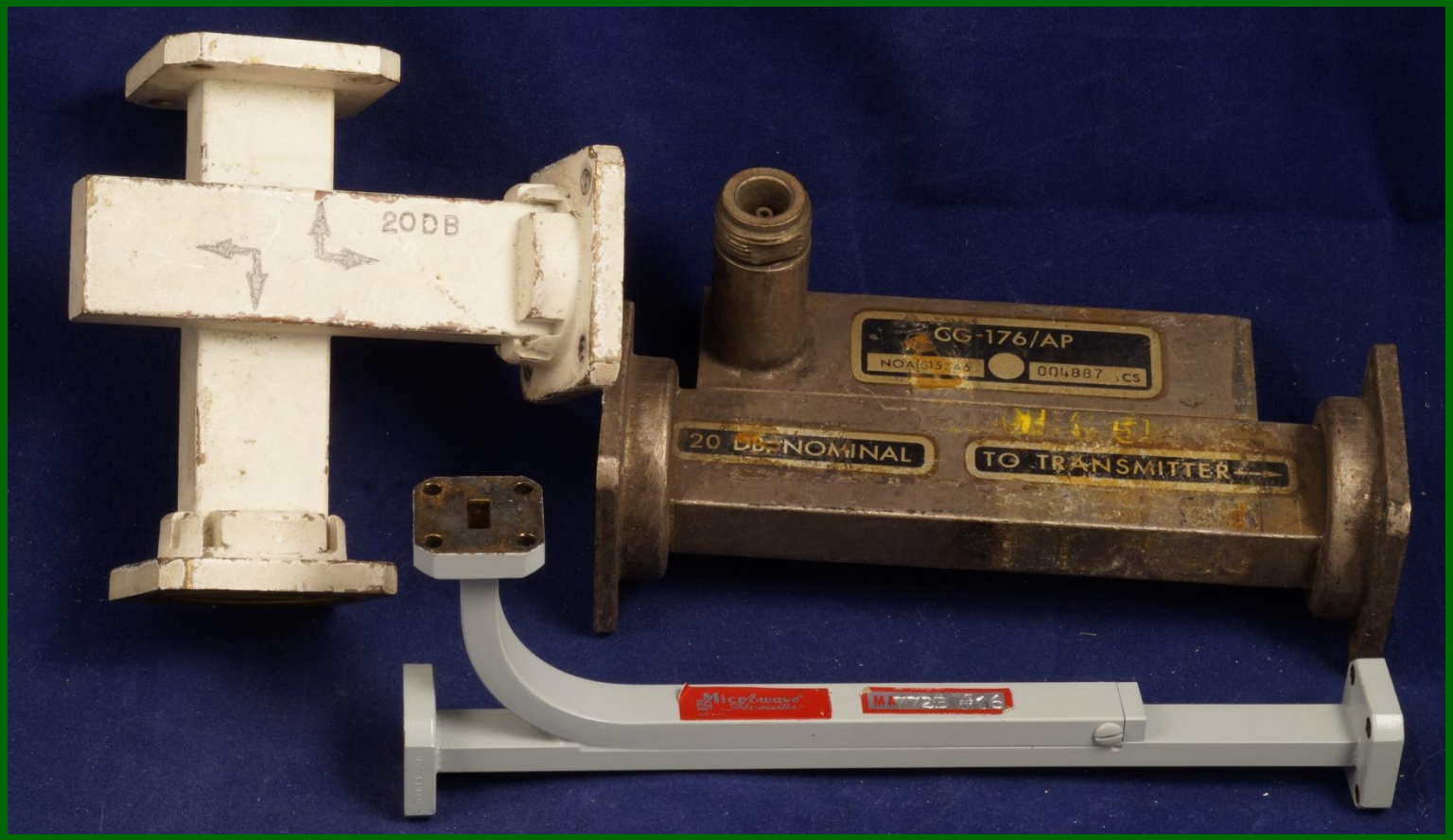
Directivity

- = Leakage into reflected port
- 12 dB directivity = -12 dB reflected power with perfect termination
- Can add or subtract depending on phase
- Poor directivity gives false VSWR or RL
- Limits accurate Return Loss or VSWR measurement
- Can only measure Return Loss less than directivity
- Tuning with low directivity => false results

Directivity vs VSWR

Directivity	Minimum VSWR
15	1.43
20	1.22
25	1.12
30	1.065
35	1.036
40	1.02

Waveguide Directional Coupler



- Cross-Guide
- Side wall
- Broad wall

HP 752 Directional Coupler

- 10, 20, 30, or 40 dB Coupling
- Excellent – 40 dB Directivity

- *Hard to find in small waveguide*

What can I make?

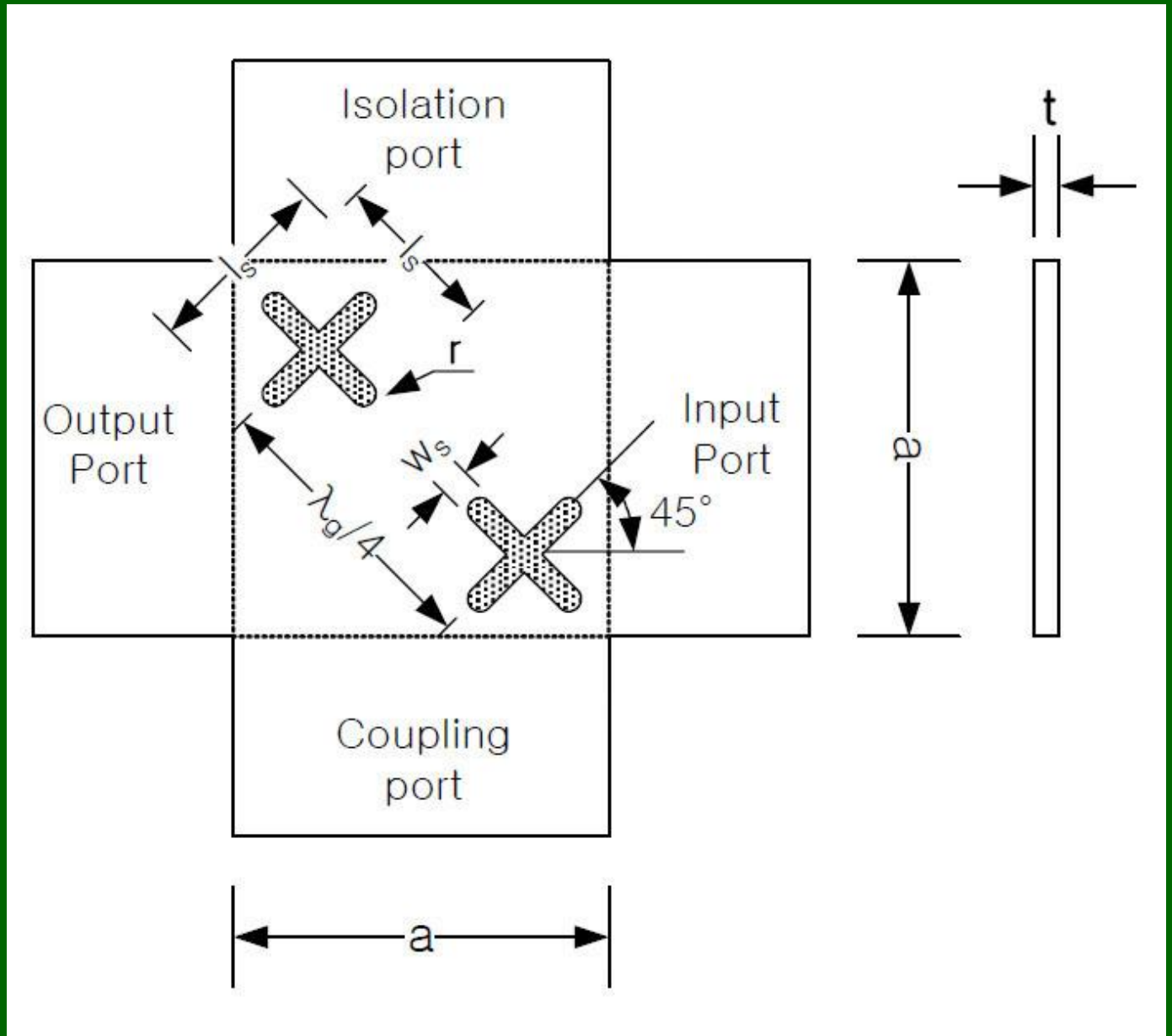
- CNC Machinery available at Makerspace
- Broadwall and sidewall need waveguide bend - more difficult
- Cross-guide has straight waveguides

CNC Milling Machine

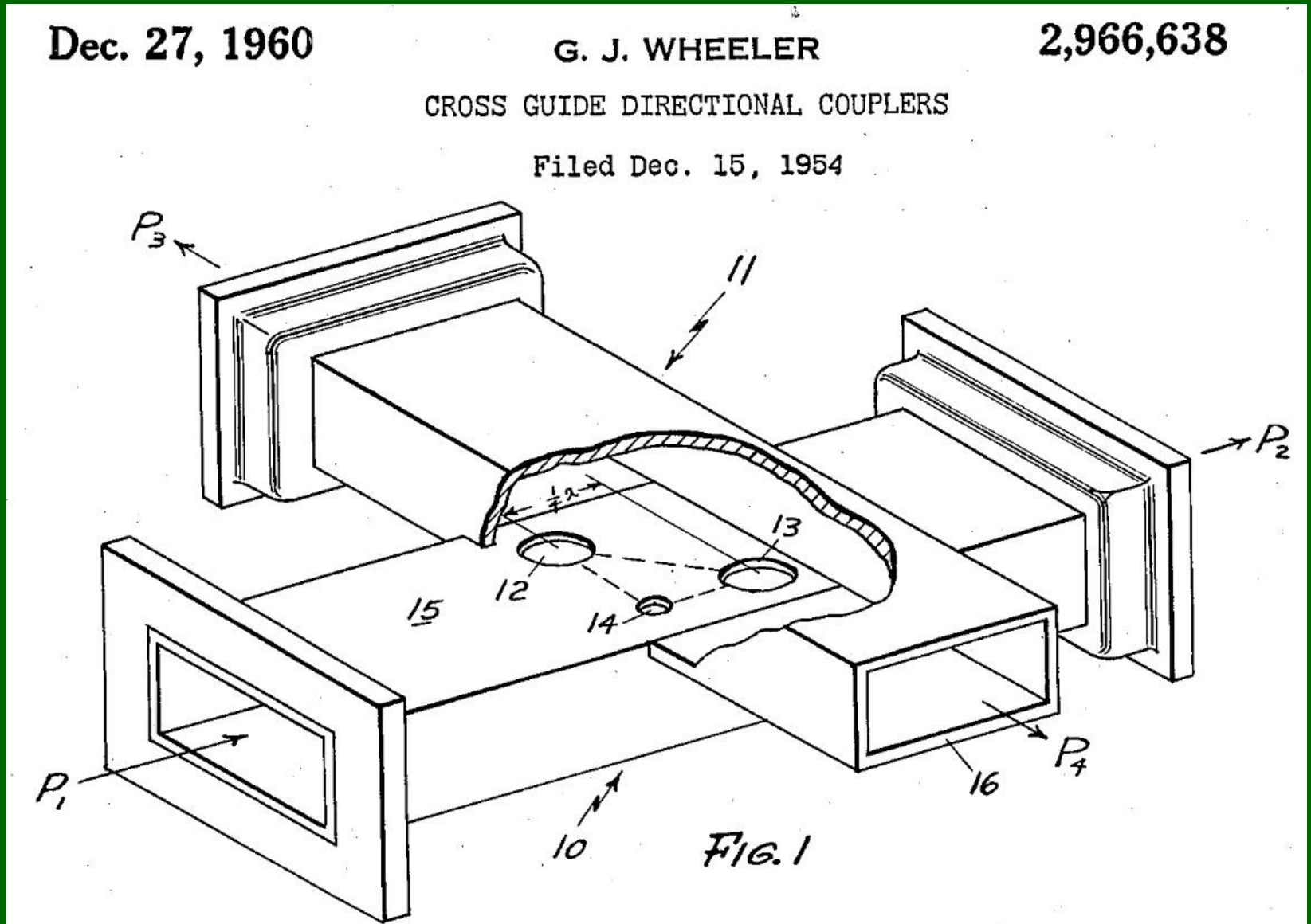
Cross-guide Couplers

- Moreno – X-shaped holes
  - Too small at 47 GHz
- Round hole coupler
  - Round holes are easy

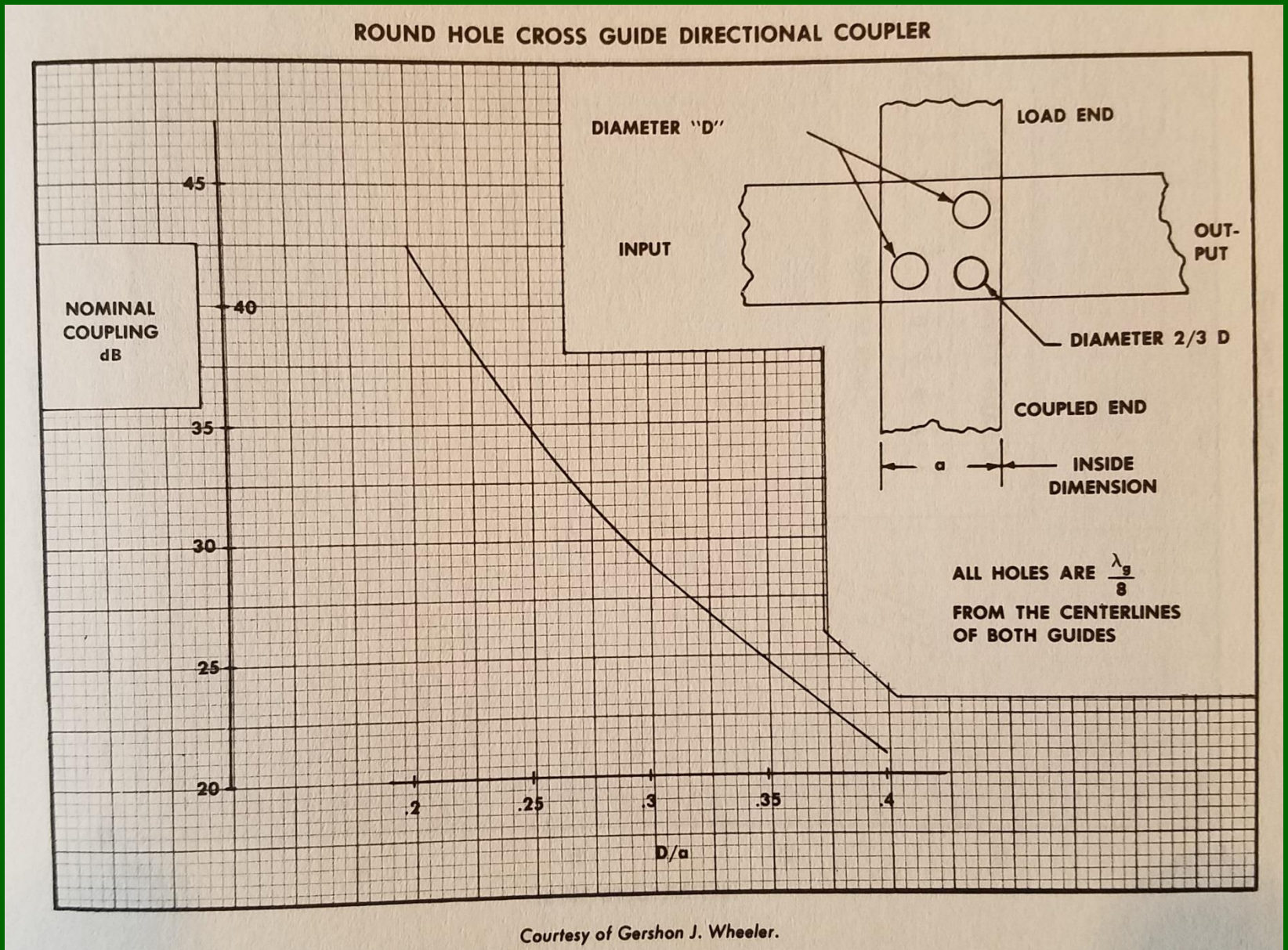
Moreno Cross-guide Coupler



Three-hole Cross-guide Coupler

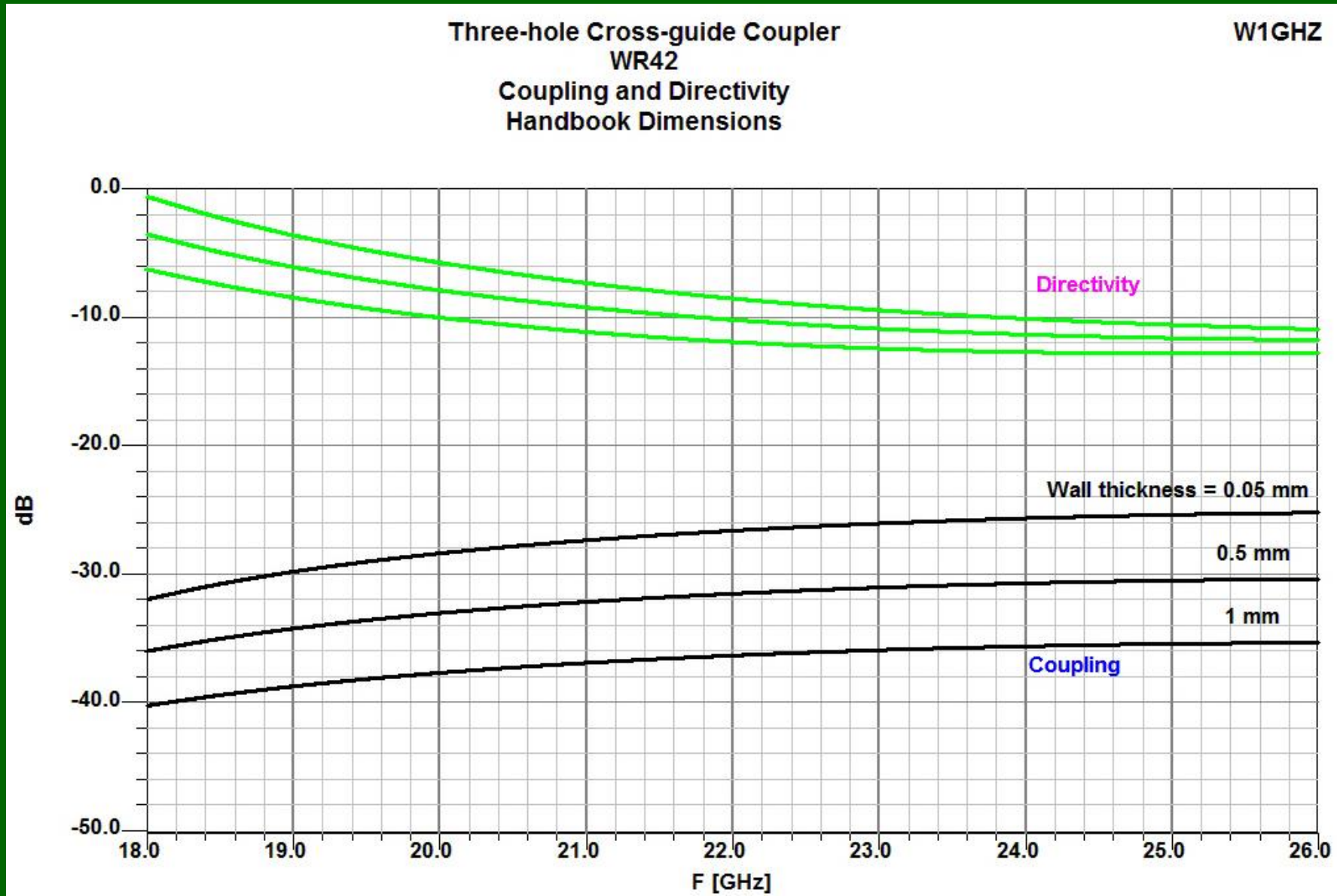


Round-hole Design graph



Courtesy of Gershon J. Wheeler.

Simulate 30dB Round-hole Design



Simulation Results

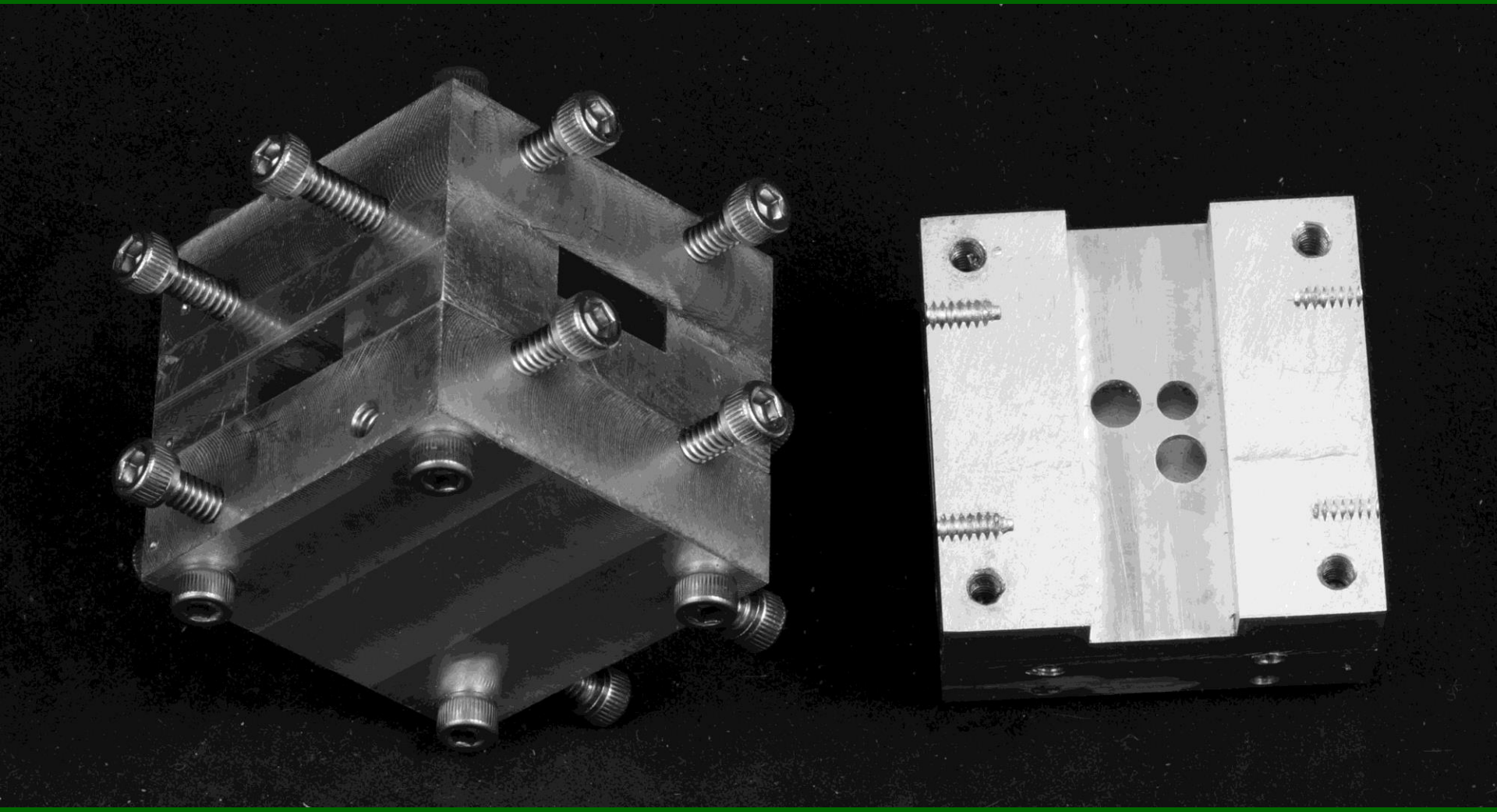
- Coupling close to 30 dB
  - With wall thickness scaled to WR-90
- Coupling stronger with thinner wall
- Directivity poor

- Conclude: coupling graph fairly accurate

Can Directivity be improved?

- Trial and error in simulation
- Enlarge small holes
- Directivity is only narrow band
  - Fine for ham bands
- Adjust hole spacing to move frequency

Trial coupler in WR-42 (better measurement capability)

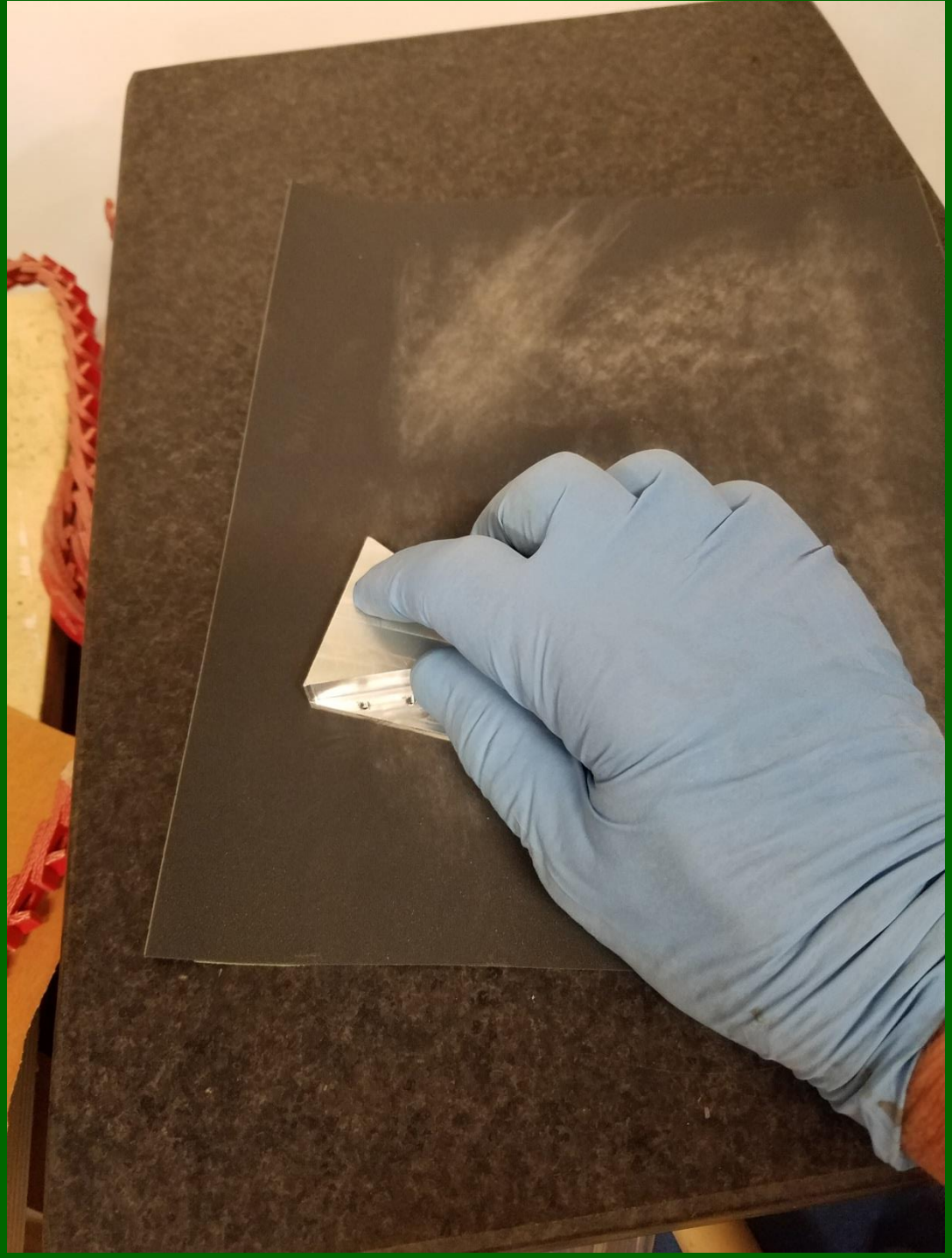


Three-piece Construction

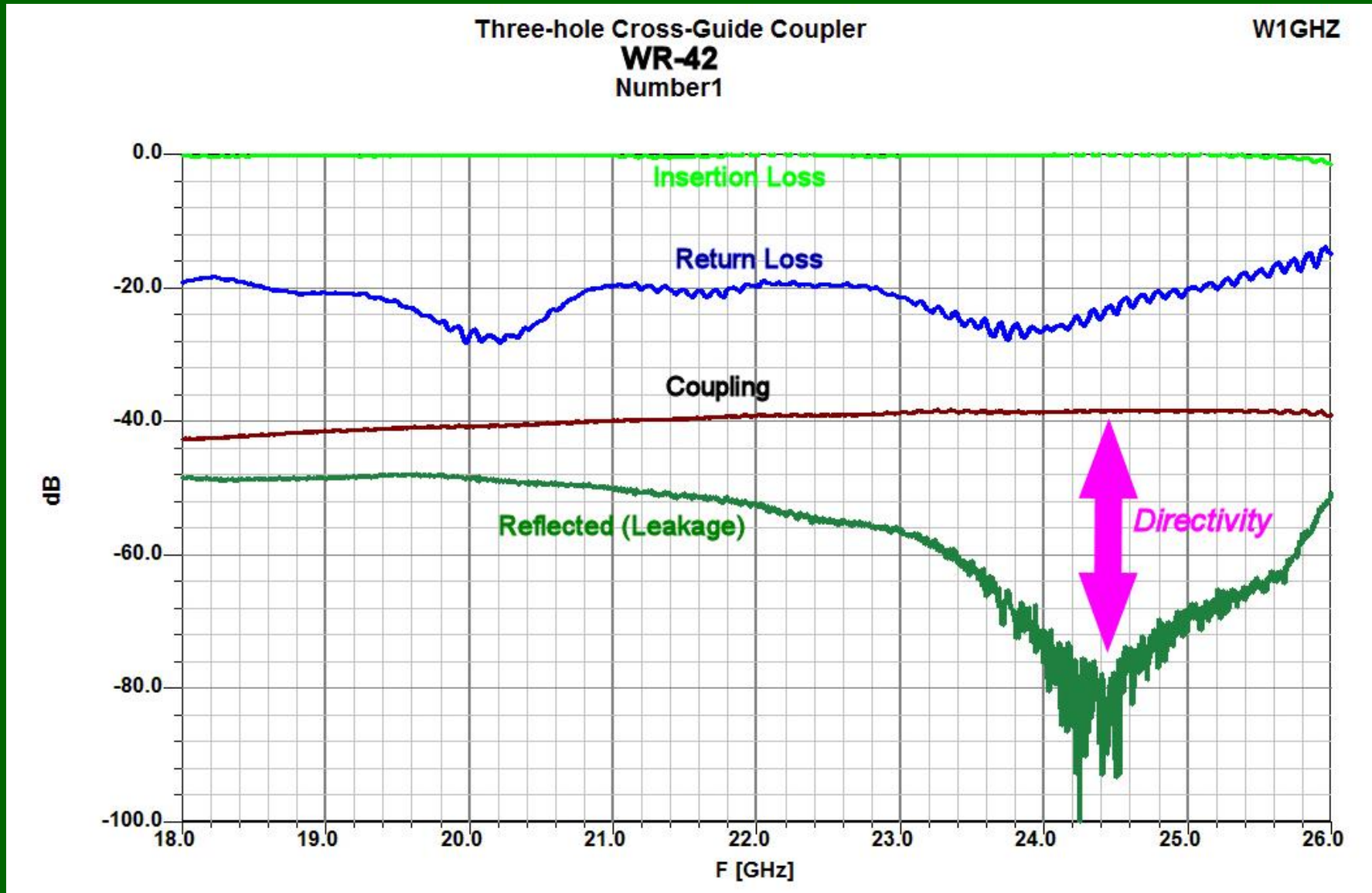
- Center block with crossed waveguides and wall with coupling holes
- Wall thickness = 0.5 mm at 47 GHz
  - scaled to 1 mm at 24 GHz
- CNC machining for accurate waveguides and hole placement
- Holes sized with gauge pins
- Top and bottom pieces are 4^{th} wall of waveguides and hole flange screws
- 20 tapped holes

Tapping Threads

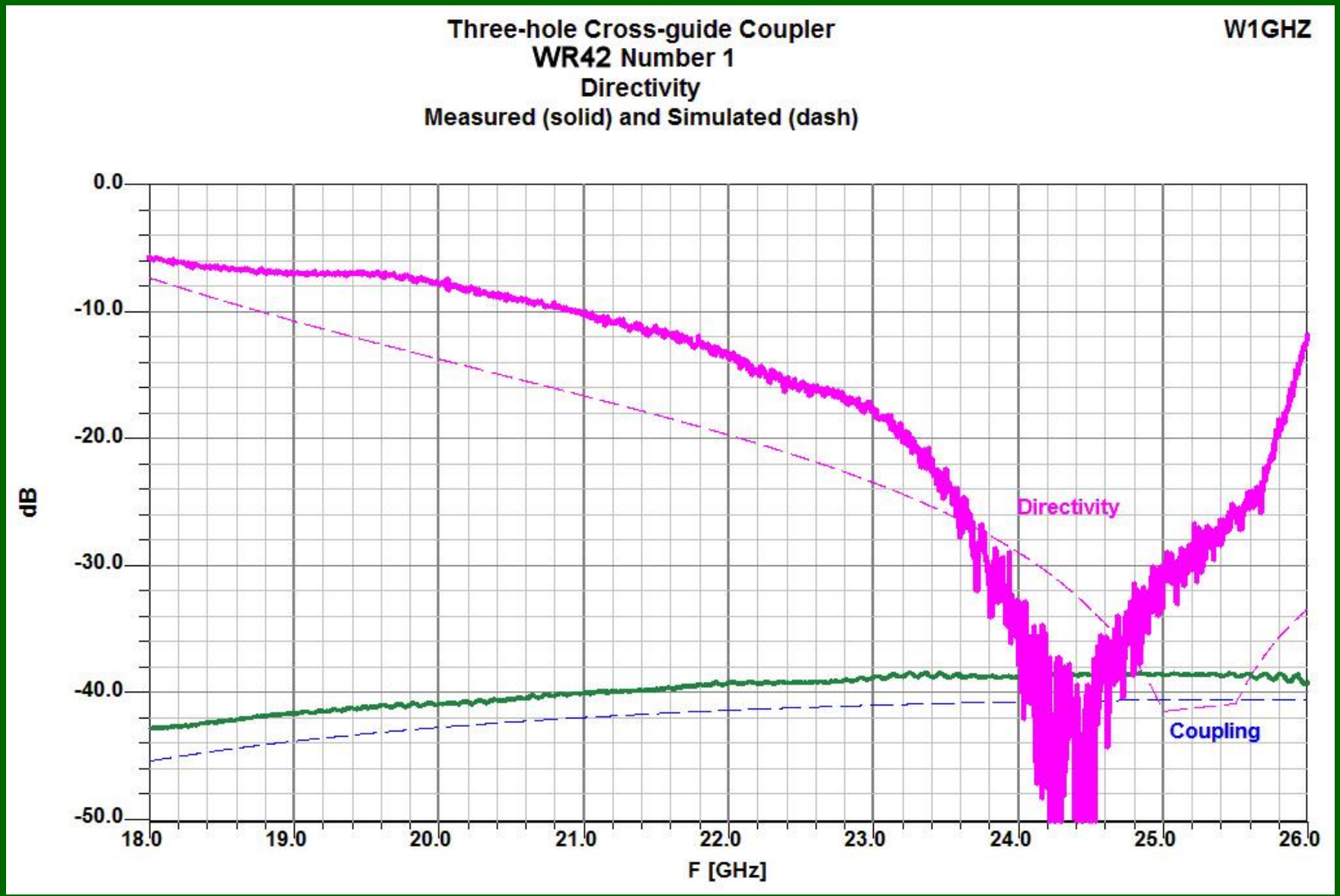
Sanding and Polishing



30 dB coupler in WR-42



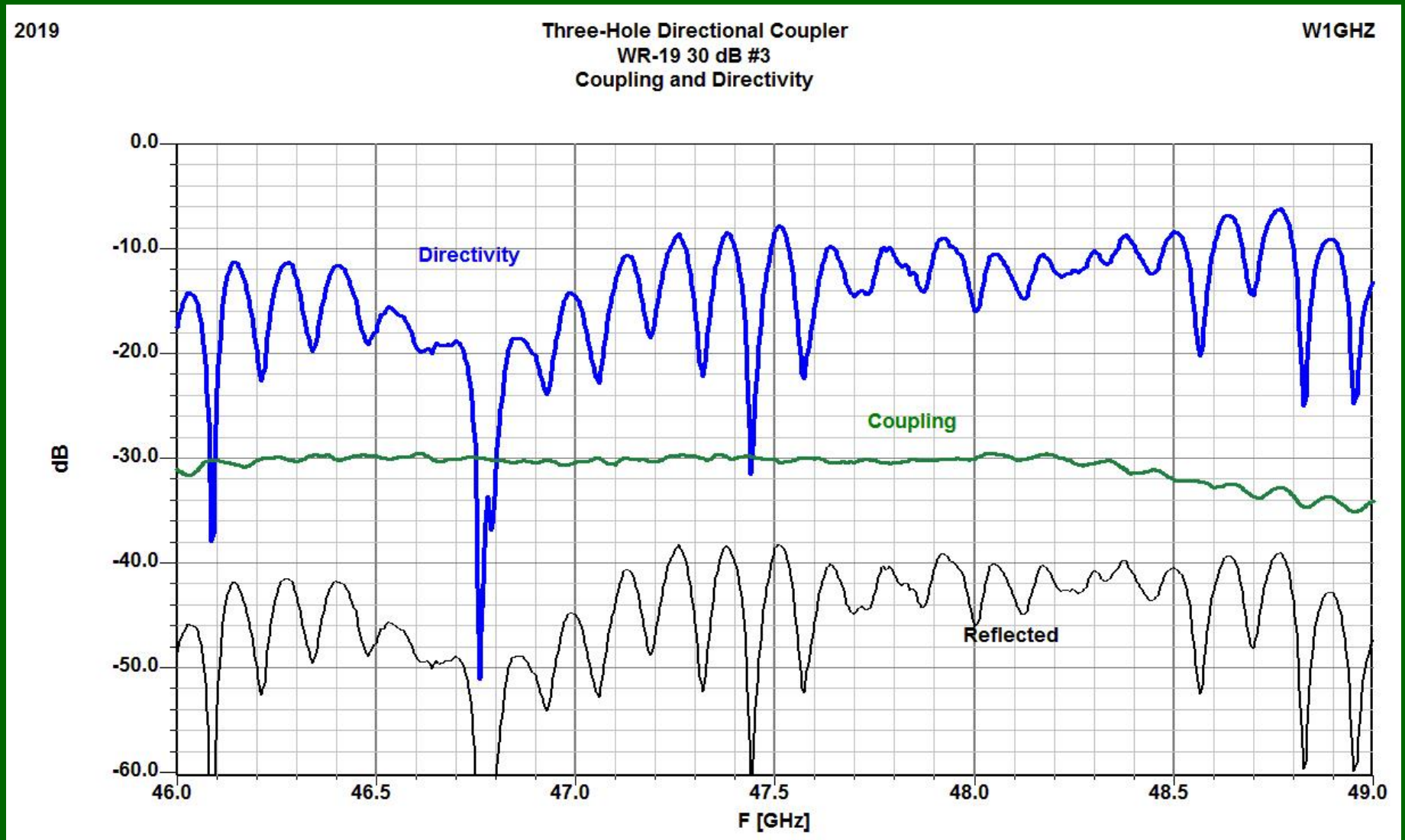
Measurement vs Simulation



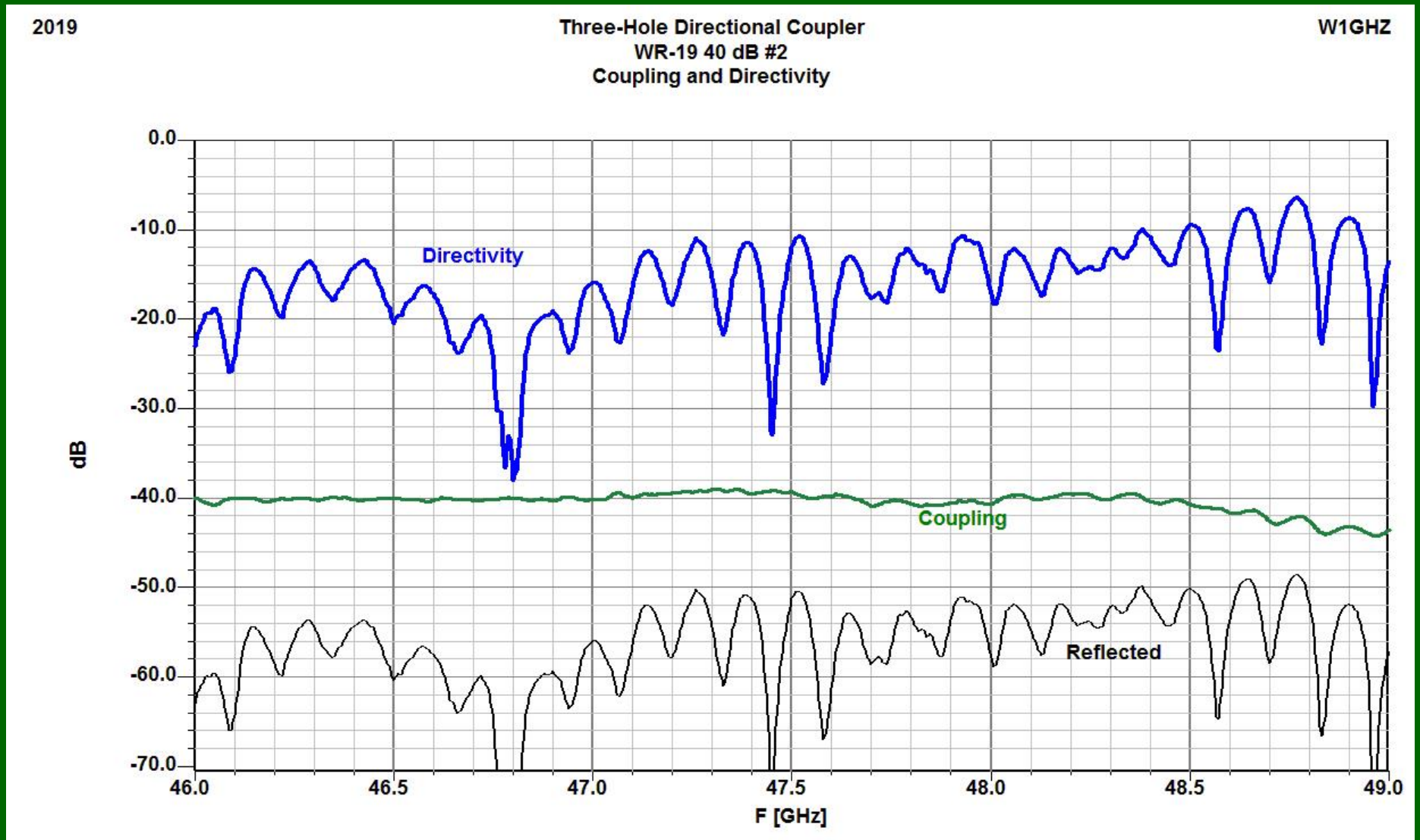
47 GHz

- WR-19 waveguide
- Machine 30 and 40 dB couplers
- Three-piece construction
- Rectangular flanges
  - Round flange holes land on joints

WR-19 30 dB coupler



WR-19 40 dB coupler

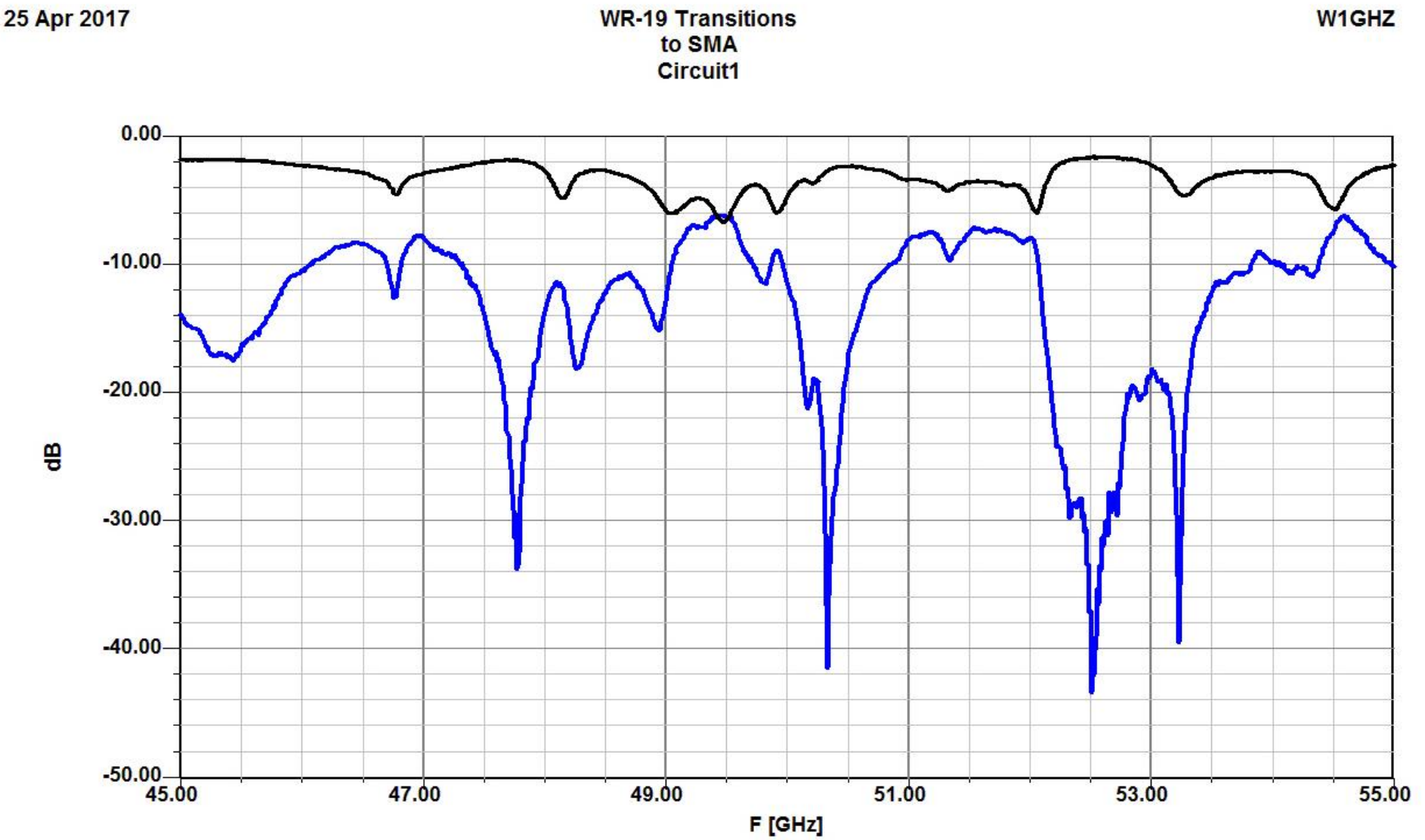


WR-19 Cross-guide couplers

- Coupling reasonably close to 30 & 40 dB
- Directivity best slightly lower than 47 GHz
- Measurement accuracy limited by homebrew SMA transitions

- I don’t have enough power to detect 30 dB down (DB6NT makes 1 watt amplifier)

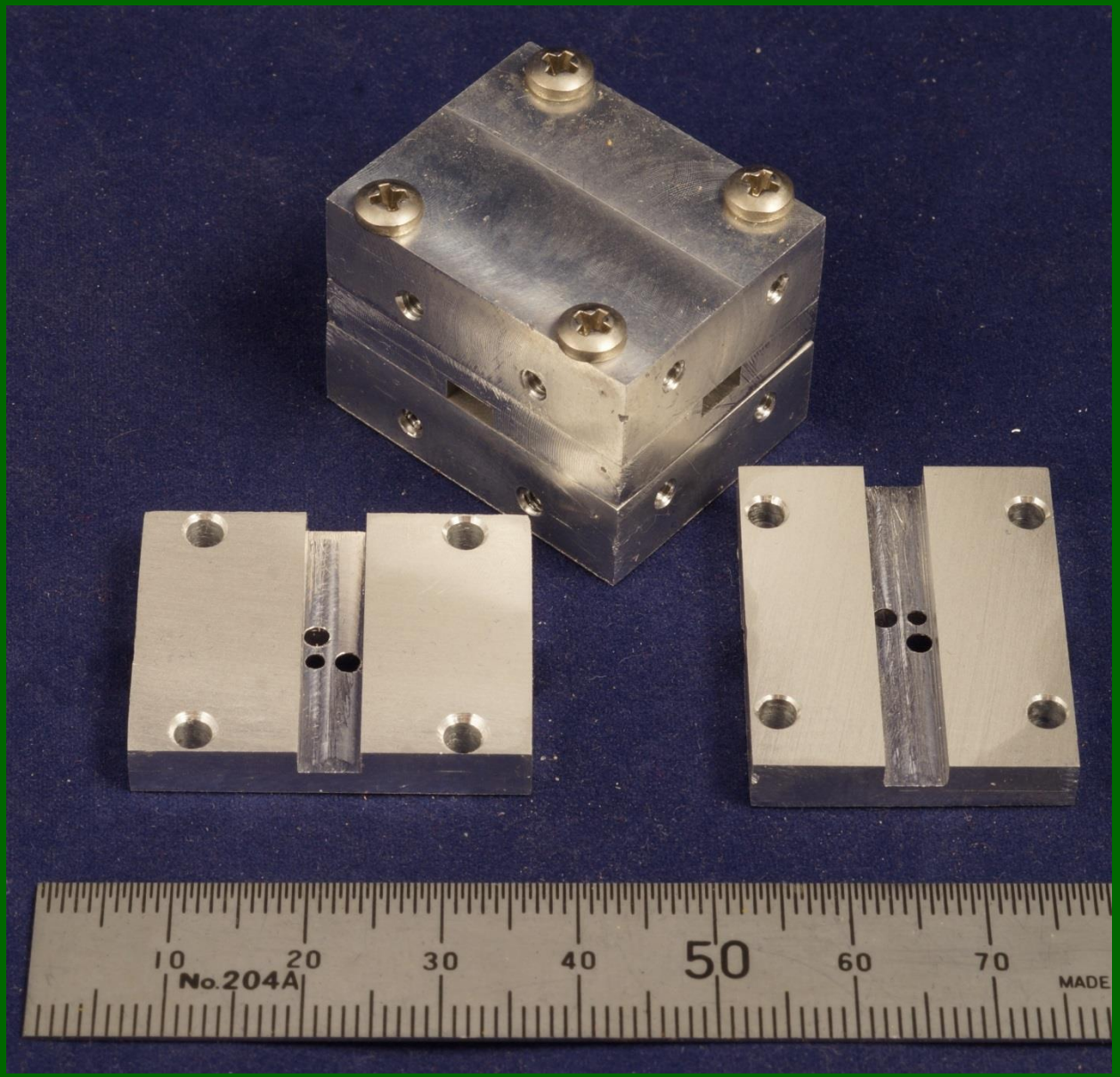
Two Transitions – back to back



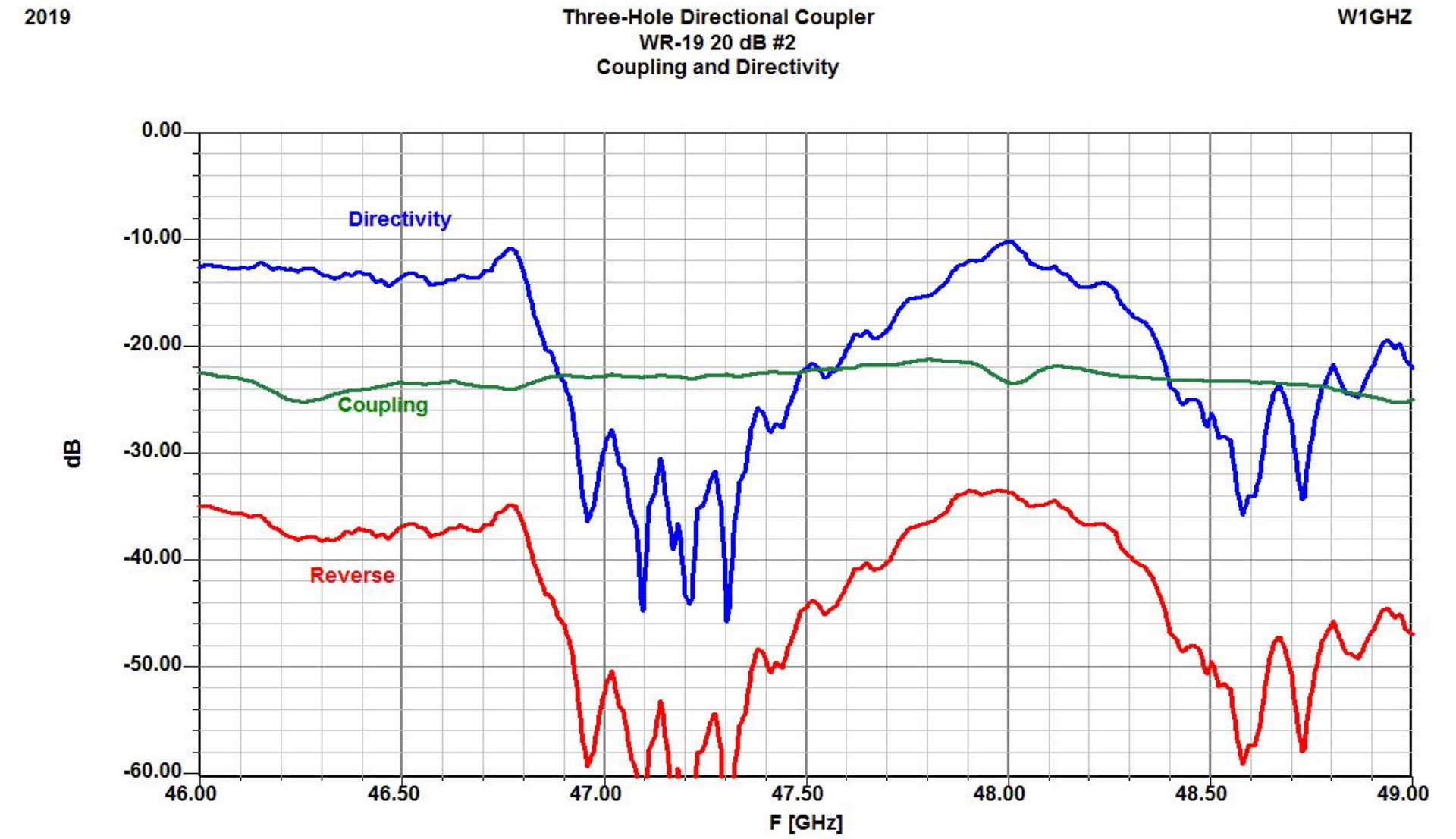
WR-19 20 dB coupler

- Simulation – max coupling ~23 dB before holes meet waveguide side walls
- Measured coupling slightly stronger than simulation
- Thinner wall increases coupling

WR-19 ~20 dB coupler



WR-19 20 dB coupler measurement

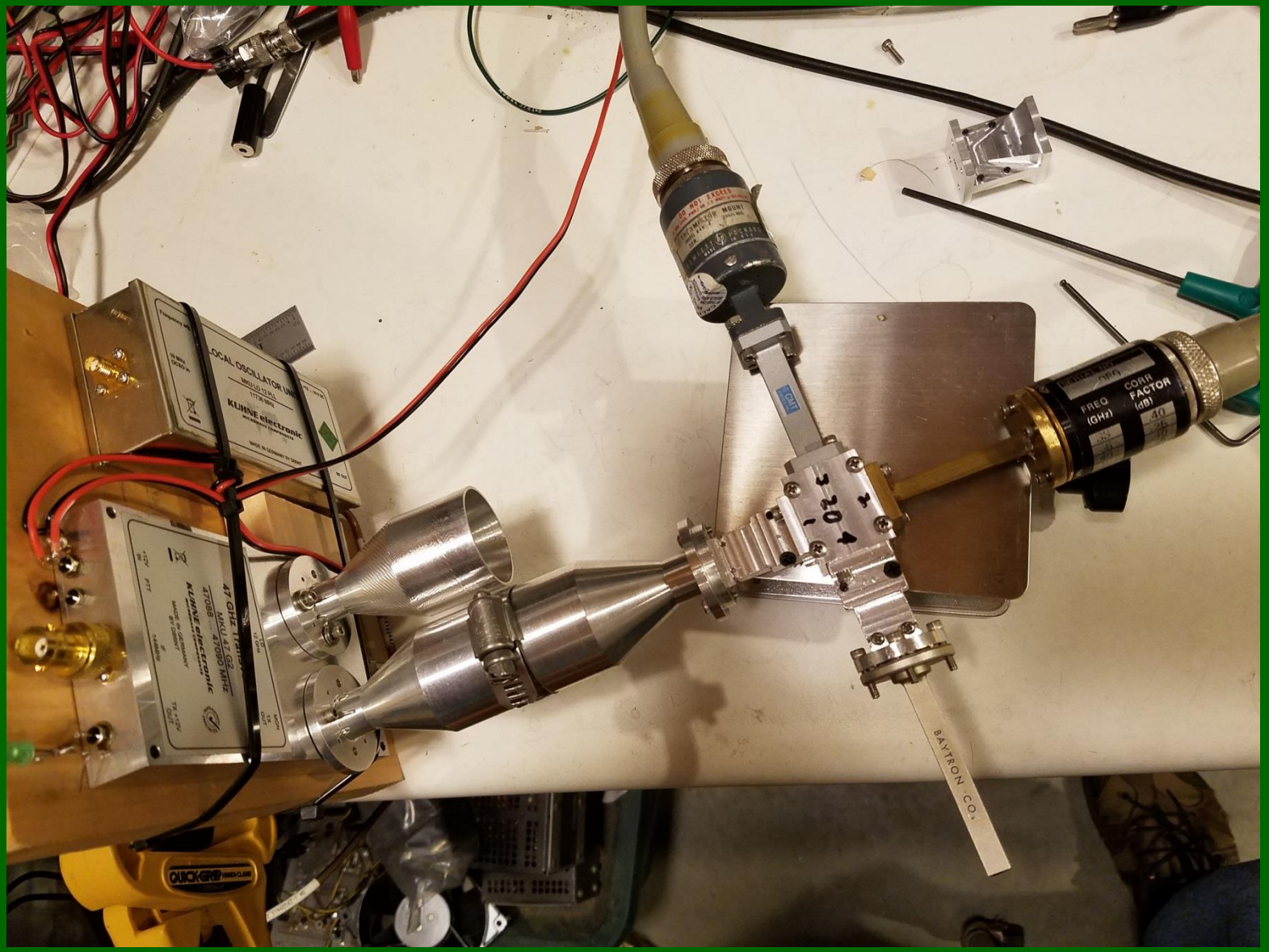


WR-19 ~20 dB coupler

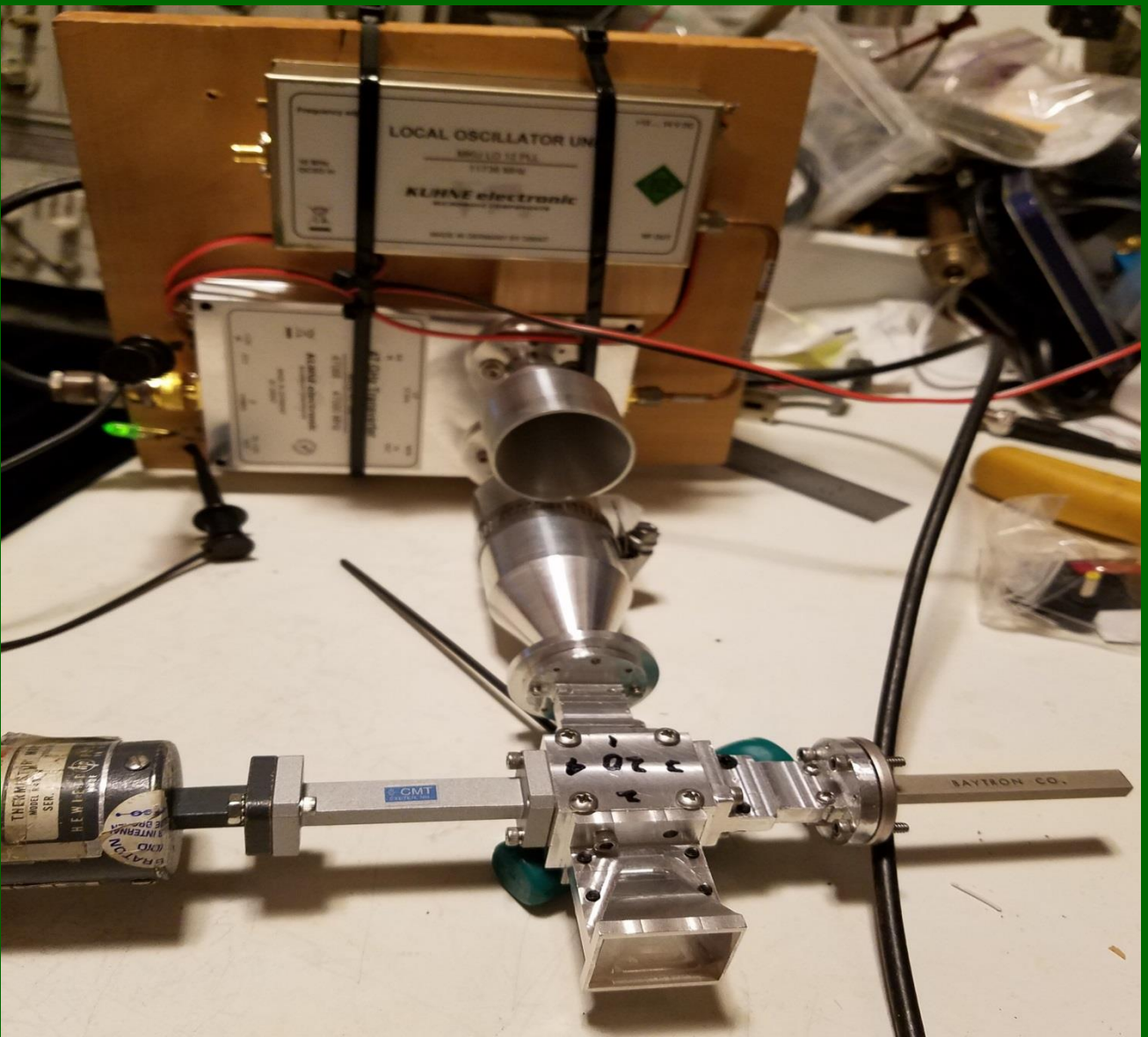
- Coupling ~22 dB (± coax transition loss)
- Directivity >30 dB
- Good for Return Loss measurement

- *Now I have some measurement capability*

Initial Test

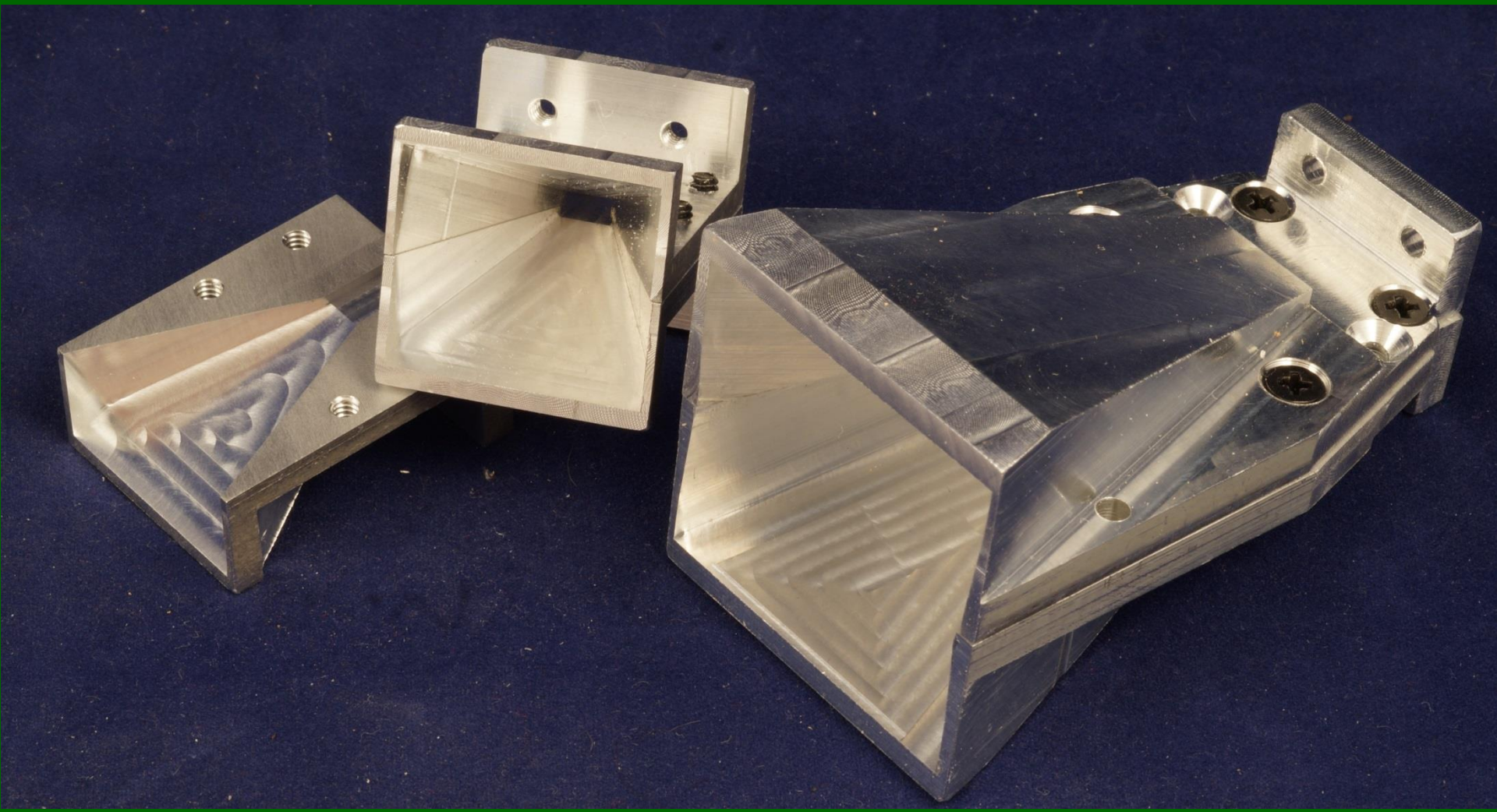


Measure Return Loss



Horn >25 dB
Open waveguide ~12dB

47 GHz Rectangular Horns



10 GHz

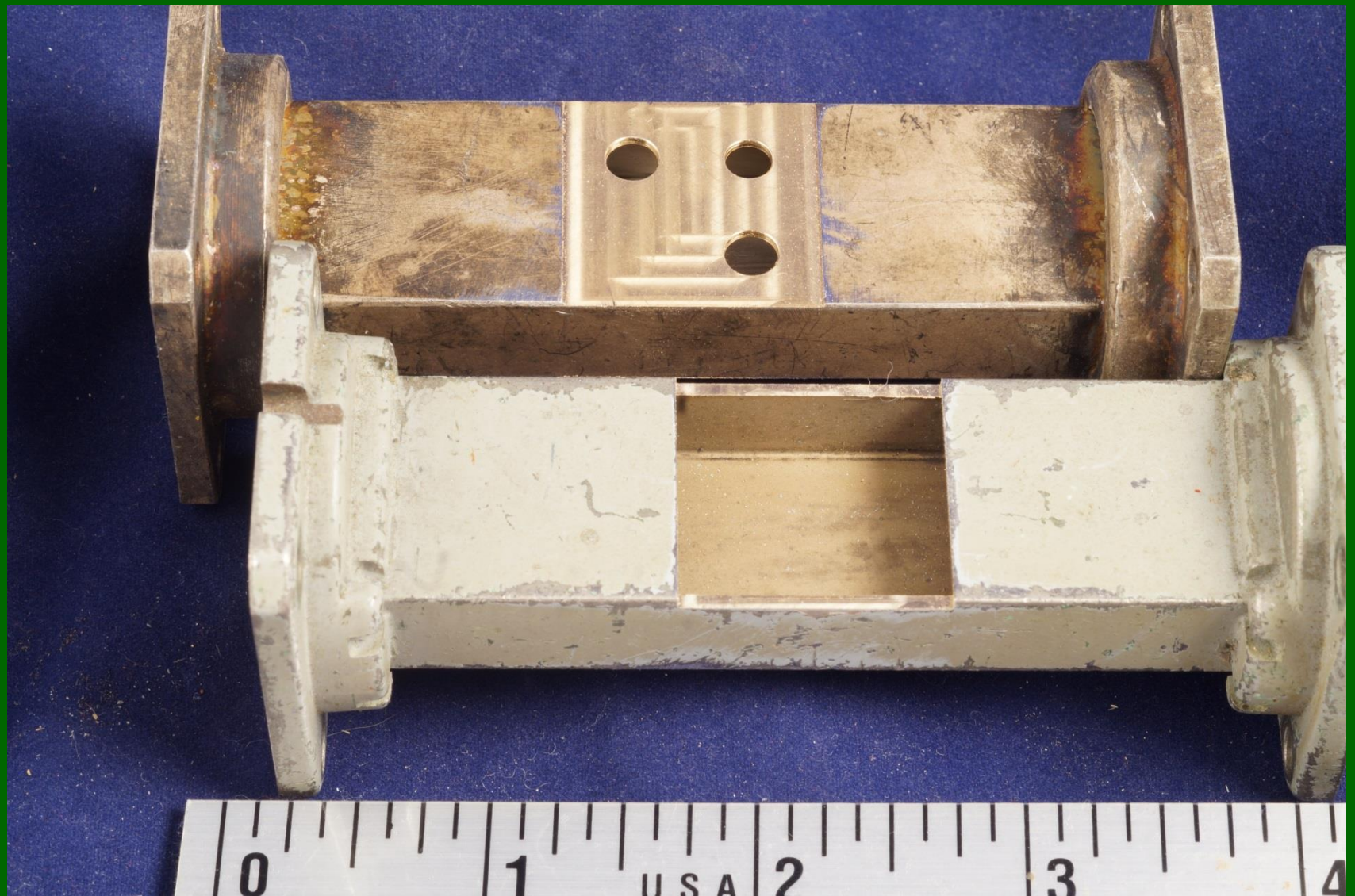
- Serious EME stations run QRO
- Waveguide
- SMA only good for <50 watts
- 40+ dB coupler needed to measure power

10 GHz Waveguide couplers

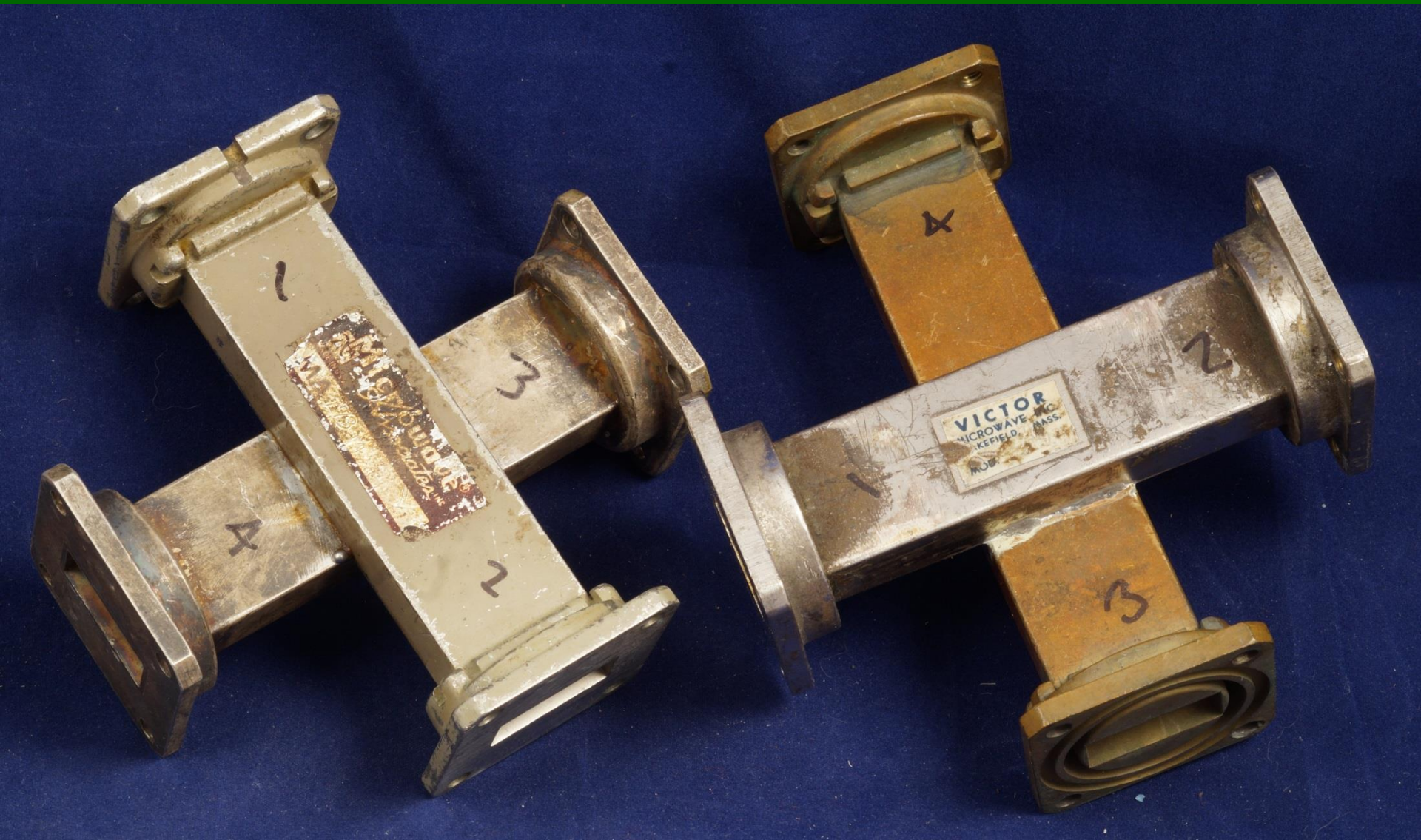
- 40 and 50 dB target
- WR-90 waveguide
- Machine in surplus waveguide pieces
- Cut away one wall
- Solder together

- CNC not required

WR-90 Waveguide couplers



WR-90 40 & 50 dB couplers



WR-90 coupler results

- 40 dB target = 37.3 dB
- 50 dB target = 46.3 dB
- Directivity <20 dB
  - Limited by homebrew coax transitions, noise floor
- Good for power measurement
  - 10 milliwatts + 46.3 dB = 426 Watts max.
  - (Waveguide limit ~250 kW)

Summary

- Waveguide Directional Couplers with good directivity
- Useful for measuring Return Loss or QRO power
- Machine at Makerspace
- Dimensions in paper

Can you do this?

- Makerspace near you
- Home Shop Machinist
- Entrepreneur
- Drawings available to share

- *What do you have to trade?*

More Details

- www.w1ghz.org