Visualing Microwaves

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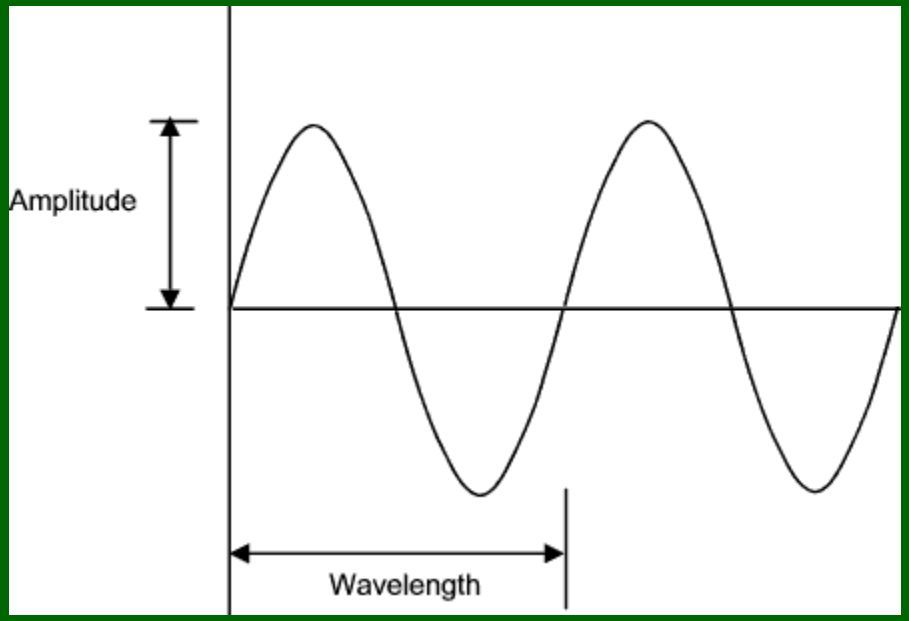
Visualizing Microwaves

- Invisible to eye
- Visible to RF detector
- On transmission line
- In Waveguide
- In space

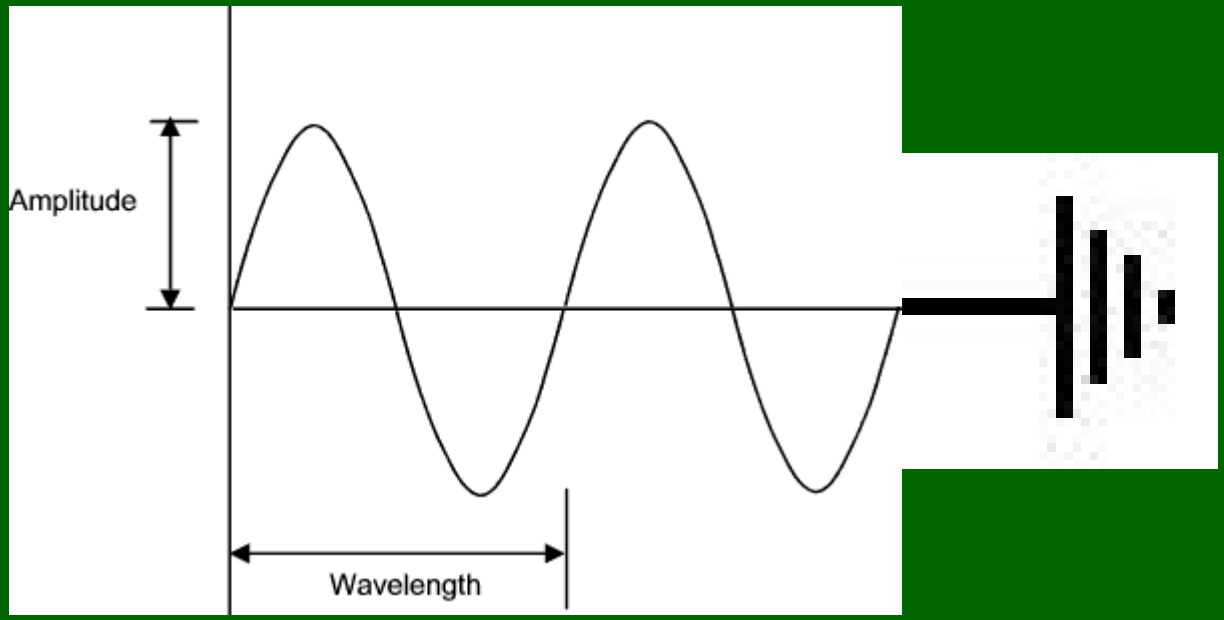
Microwaves



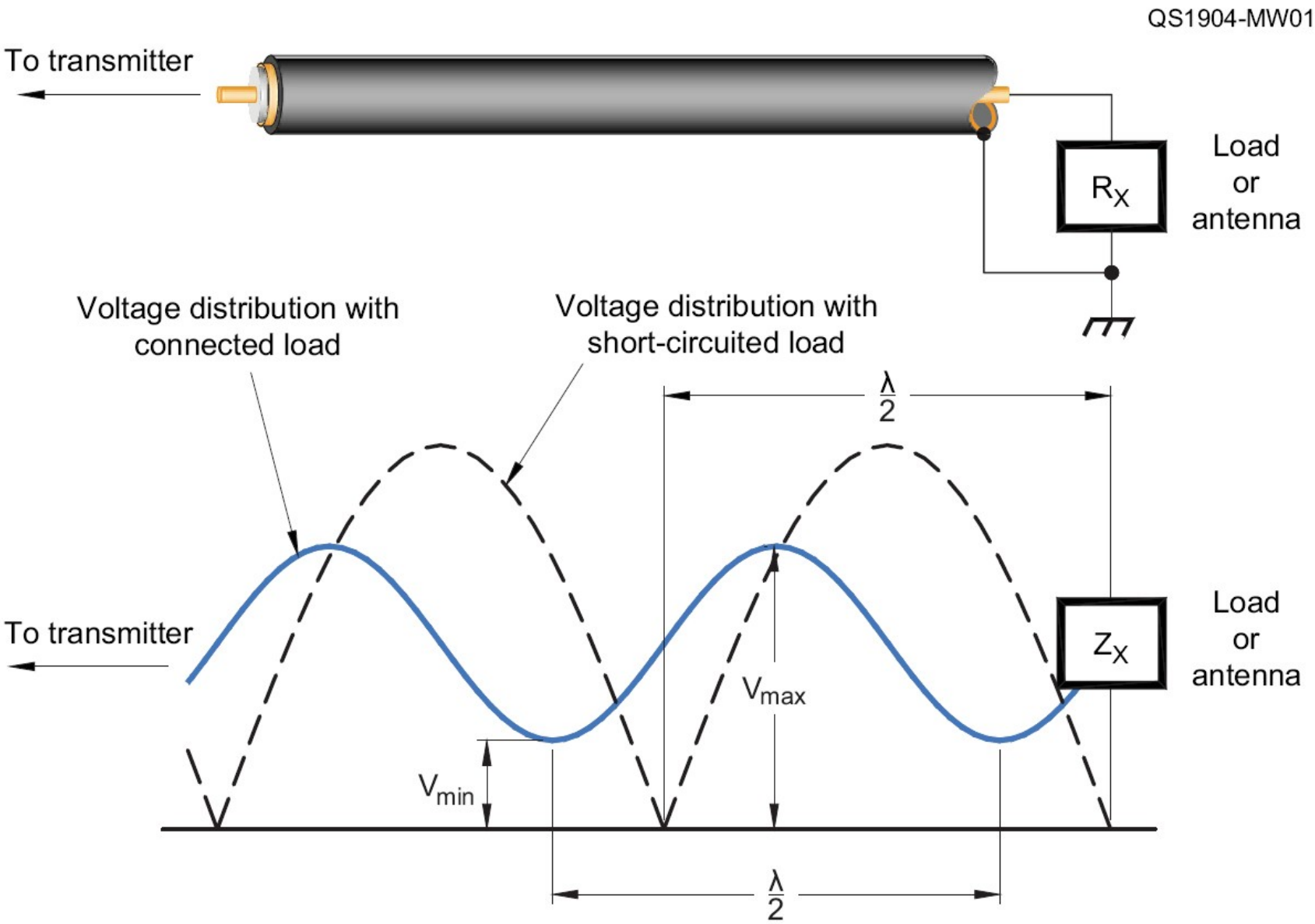
- Traveling at Speed of Light
- Hard to see
- $Wavelength = \frac{300000000\ m/sec}{1296000000\ cycles/sec}$ = 23 cm

Visualizing Microwaves

- Stop the sine wave – Short circuit
- Voltage must be ZERO at short circuit
- Wave stands still – Standing wave



Standing Waves on T-Line



Open Coaxial Line

Hobby Tubing

Center and 4 ground lines

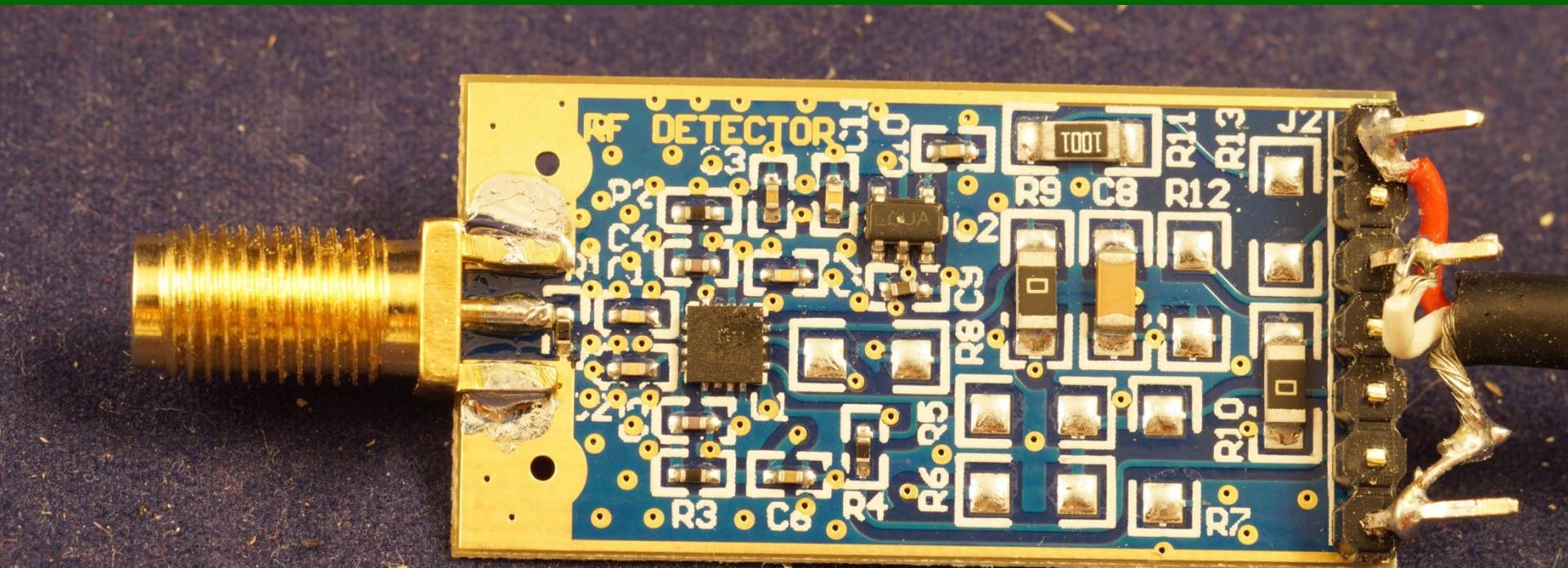


Sensitive RF Detector

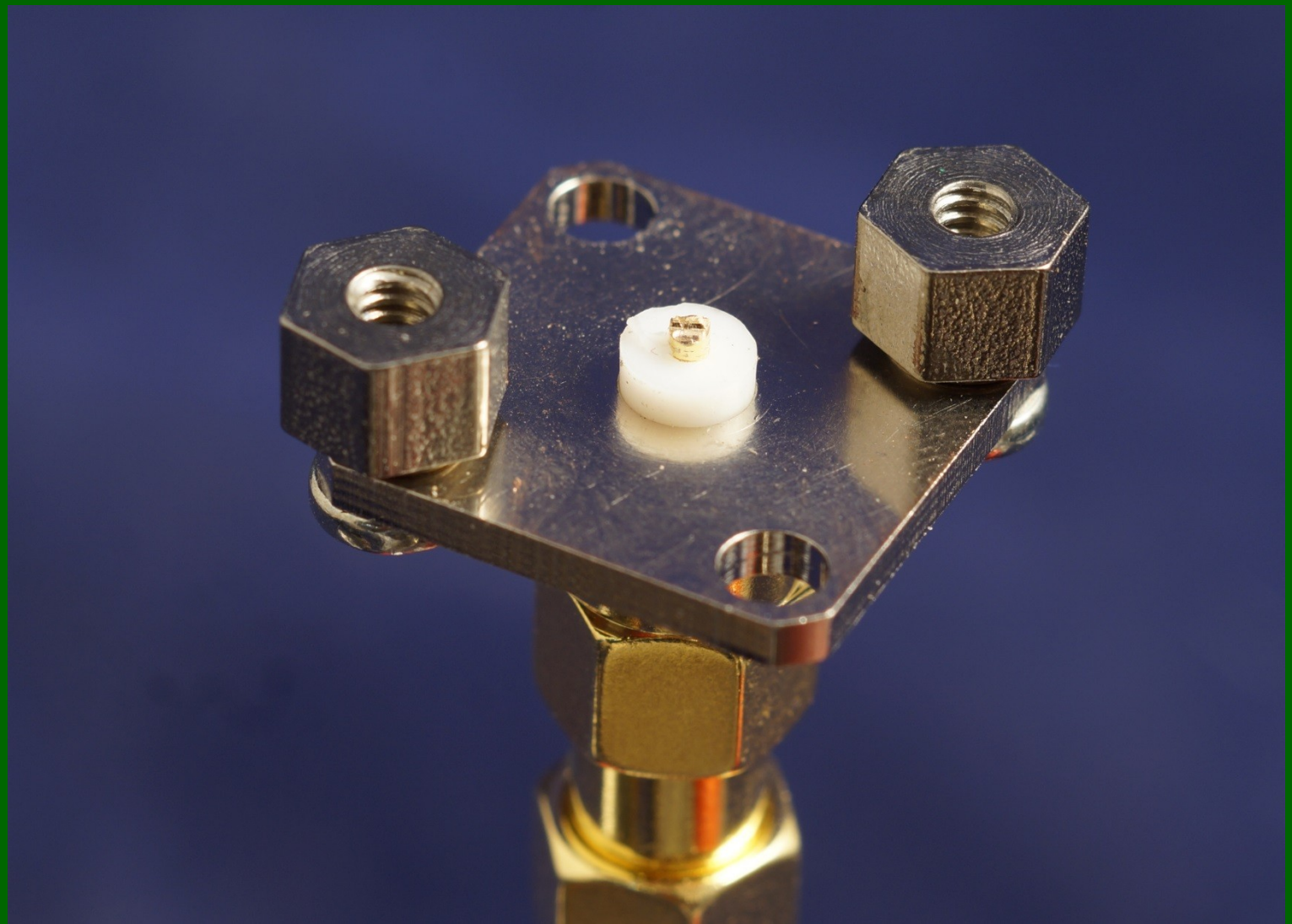
ADL5513 from SV1AFN

21 millivolts per dB

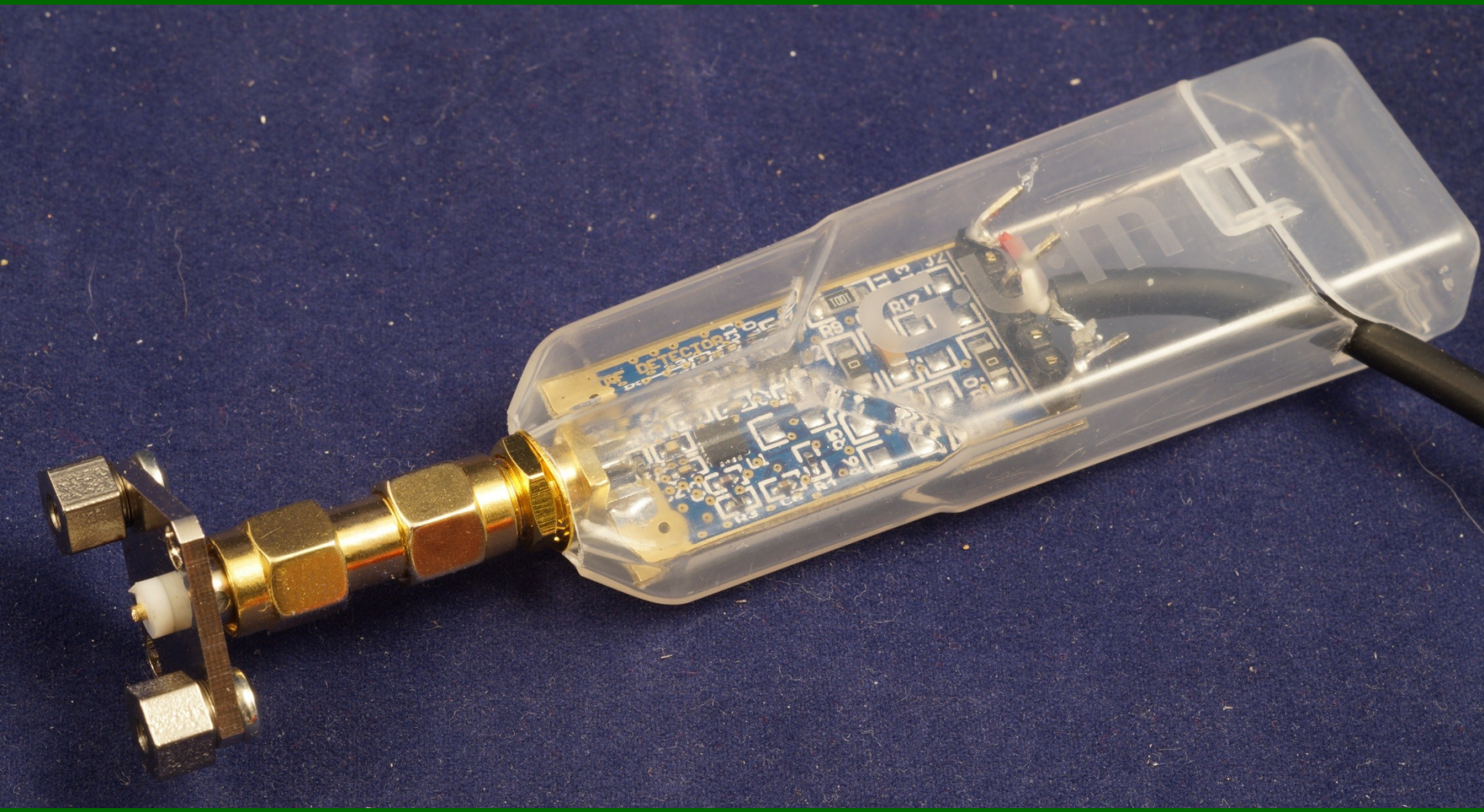
-50 dBm to -3 dBm



RF Probe

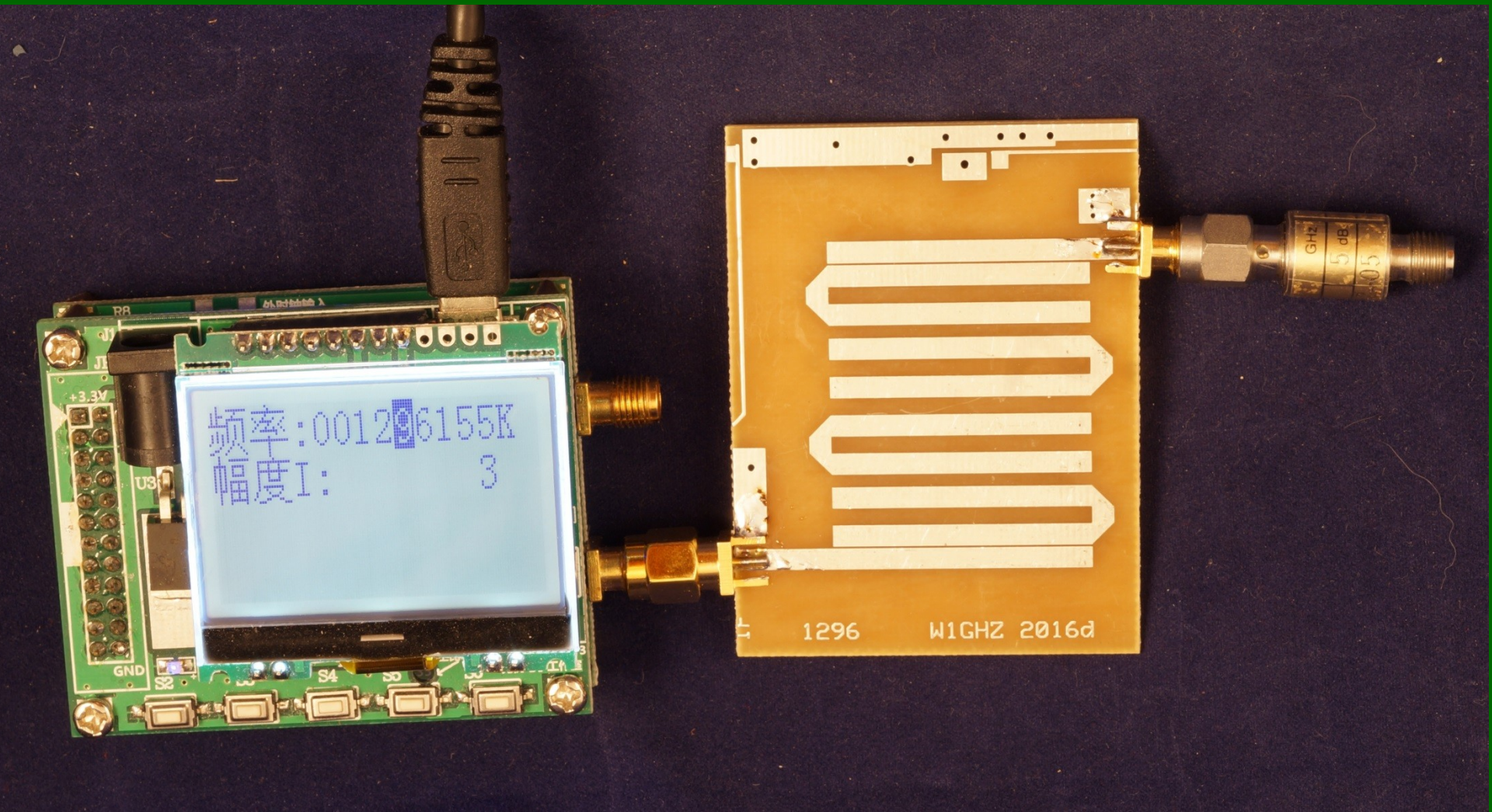


RF Probe & Detector

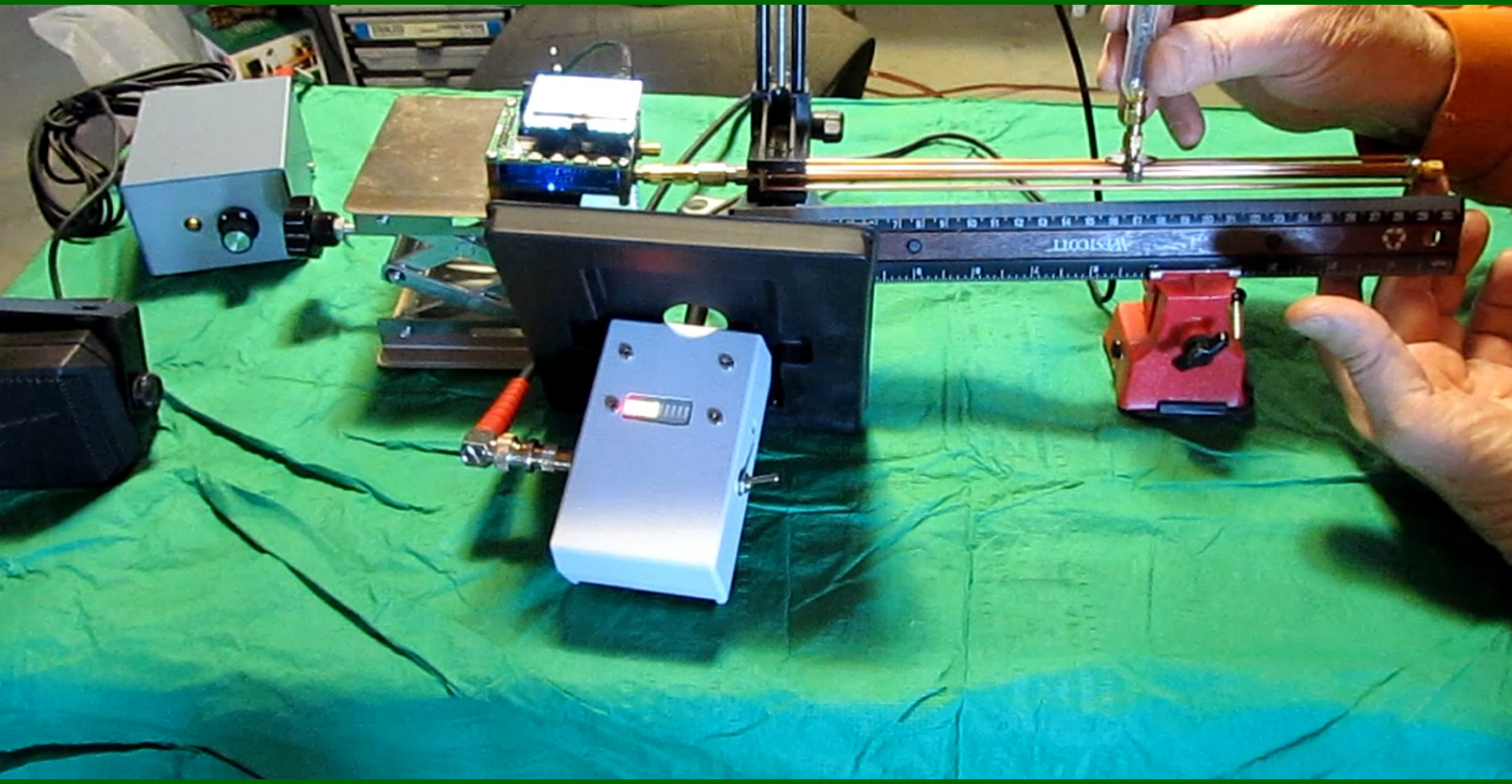


Signal Source

only a few milliwatts needed



Probe Standing Waves



Probe on Transmission Line

- Sensitive detector – very low power level
  - ~30 dBm max from probe
  - Low radiation levels = *SAFE*
- Indicators
  - Bargraph
  - Tonemeter
  - Digital Voltmeter for accurate dBm difference

Standing Wave Ratio

- Probe voltage along line
- $VSWR = \frac{V_{MAX}}{V_{MIN}}$
- Detector output in dB: 21 mV per dB
- Convert dB difference to Voltage Ratio

- Voltage symmetrical around coax

Short Circuit

- High VSWR
- Vmax to Vmin ~27 dB (Noise Floor limited)
- Voltage Ratio = VSWR >22

- Minimum at 5.5 and 17 cm
- Half-wavelength = 17 – 5.5 cm = 11.5 cm
- 1296 MHz -> 23 cm

Open Circuit

- High VSWR
- Minimum at 12 and 23.5 cm
- Half-wavelength = 23.5 – 12 cm = 11.5 cm

- Minimum and Maximum position reversed from Short Circuit

50 ohm Termination

- Low VSWR
- Vmax to Vmin 3.3 dB
- Voltage Ratio = VSWR = 1.5

- Transmission Line Zo NOT 50 ohms
  - Probably higher

100 ohm Termination

- Low VSWR
- Vmax to Vmin 8.6 dB
- Voltage Ratio = VSWR = 2.7

- Transmission Line Zo NOT 100 ohms
  - Probably lower

68 ohm Termination

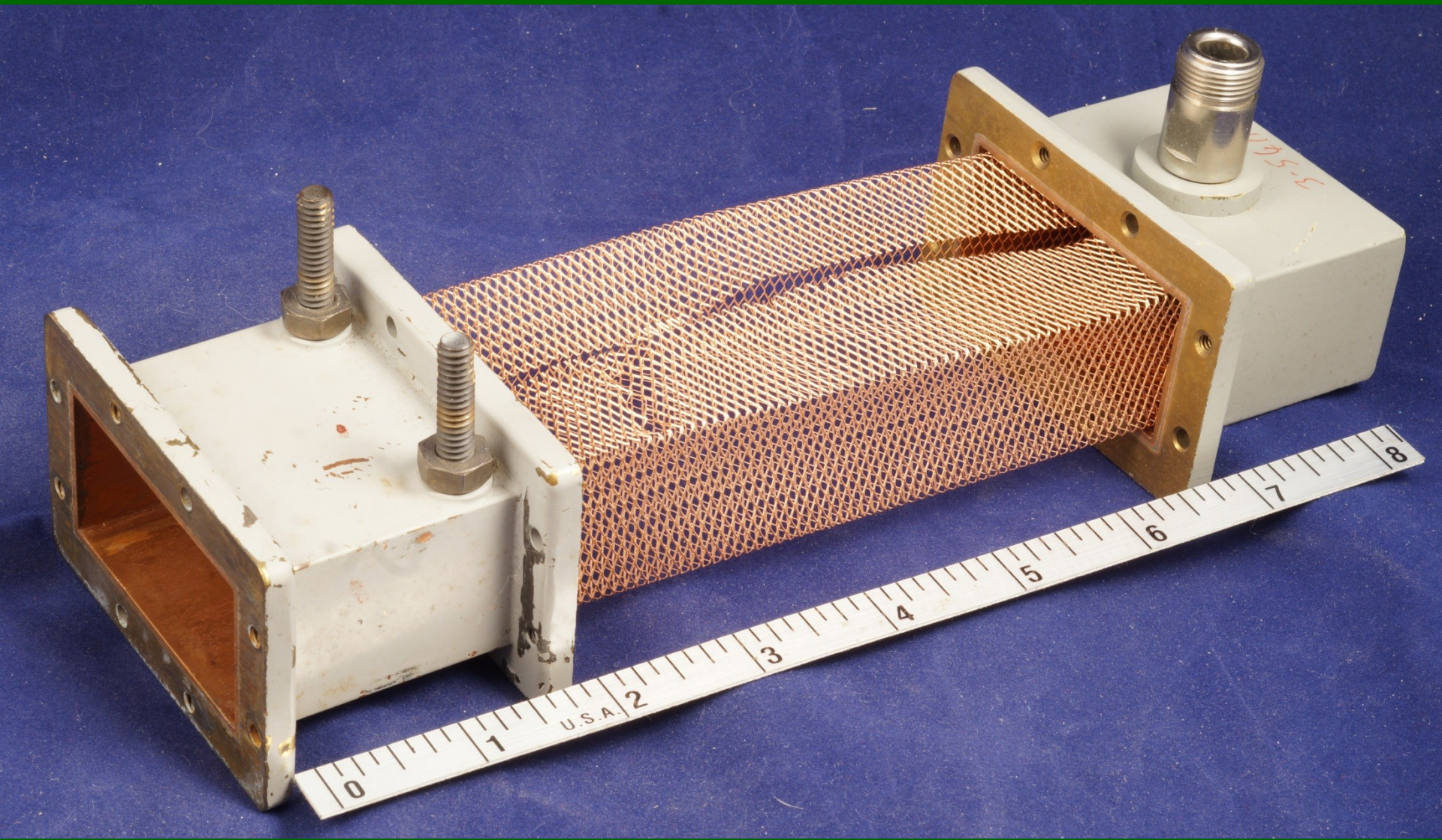
- Low VSWR
- Vmax to Vmin 3 dB
- Voltage Ratio = VSWR = 1.4

- Transmission Line Zo NOT 50 ohms
  - But has 50 ohm SMA connectors
  - Always some mismatch

68 ohm Termination



Waveguide
WR-229 at 3456 MHz



Probing Waveguide

- Waveguide = copper mesh
- Mesh inside waveguide – slightly smaller
- Slot in center of wide wall
- Probe thru mesh for other locations

- Same source and detector
- Slightly longer probe

Waveguide setup



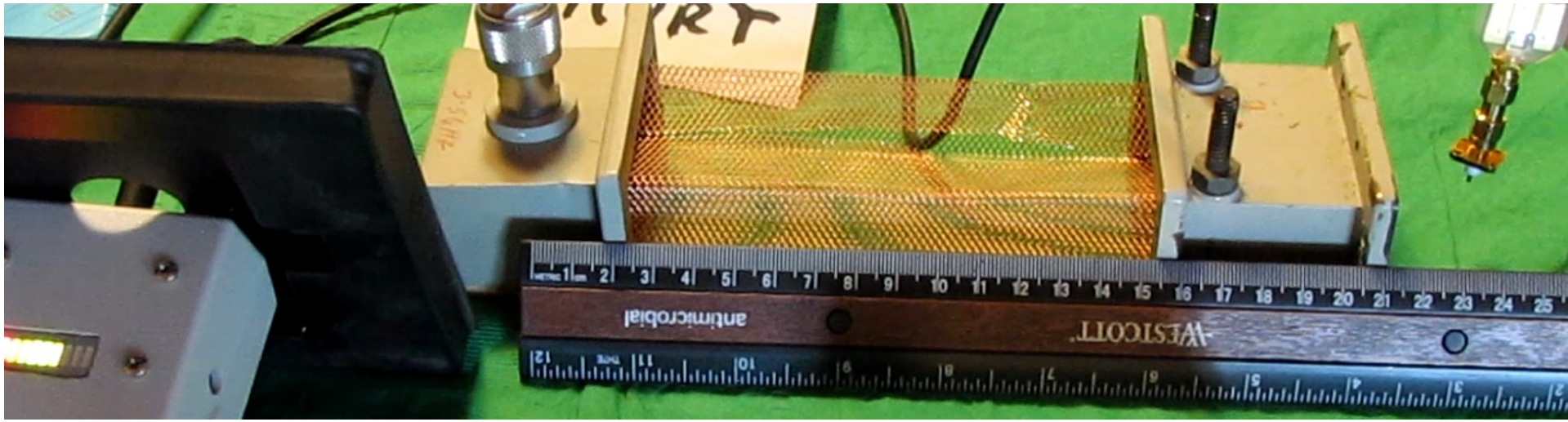
WR-229 Waveguide Short

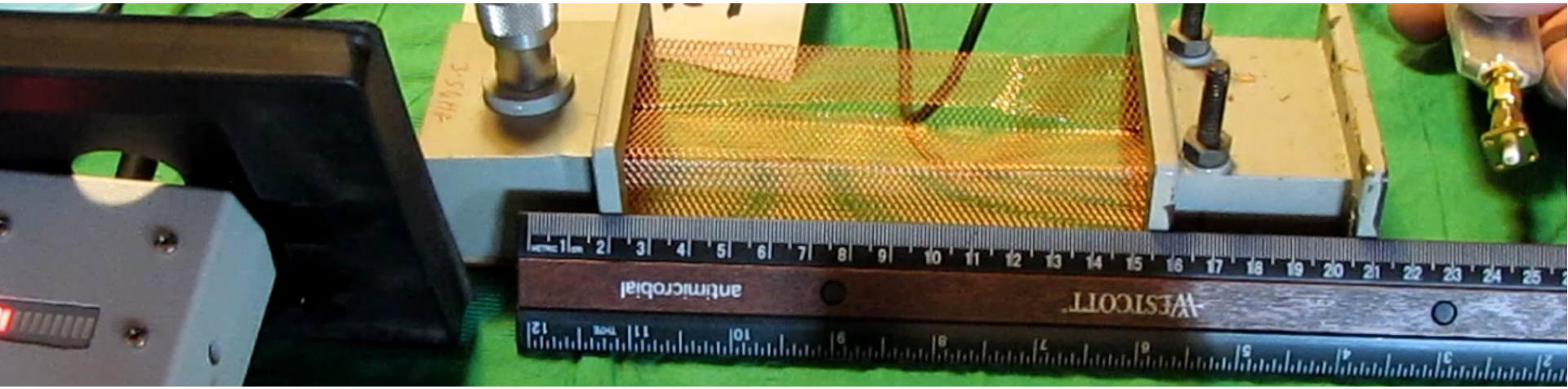
- High VSWR
- Vmin at 8.5 and 17 cm
- λguide ~ 17 cm
- λo = 8.7 cm
- λguide $> \lambda o$

Waveguide Open

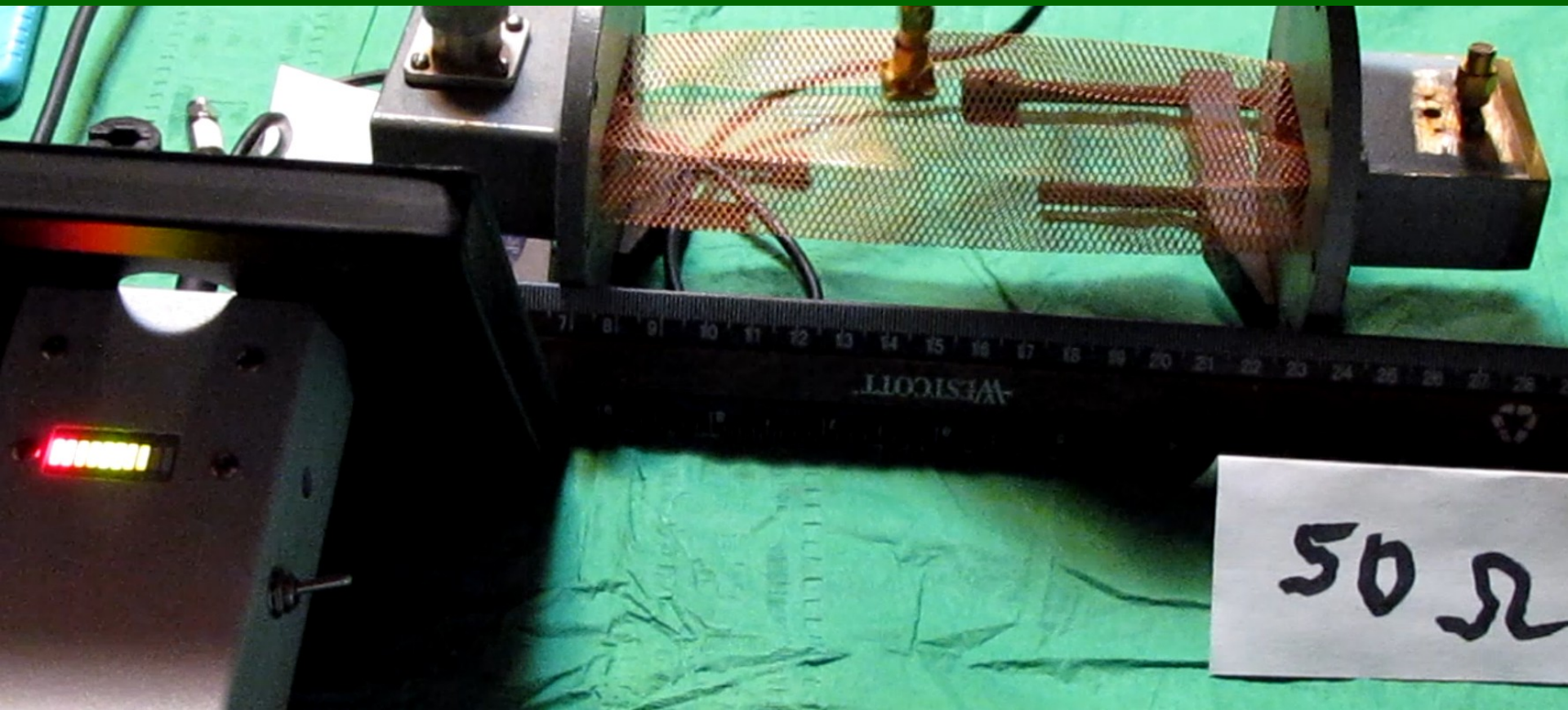
- Low VSWR
- Open waveguide radiates as antenna
- Polarized

Radiation and Polarization



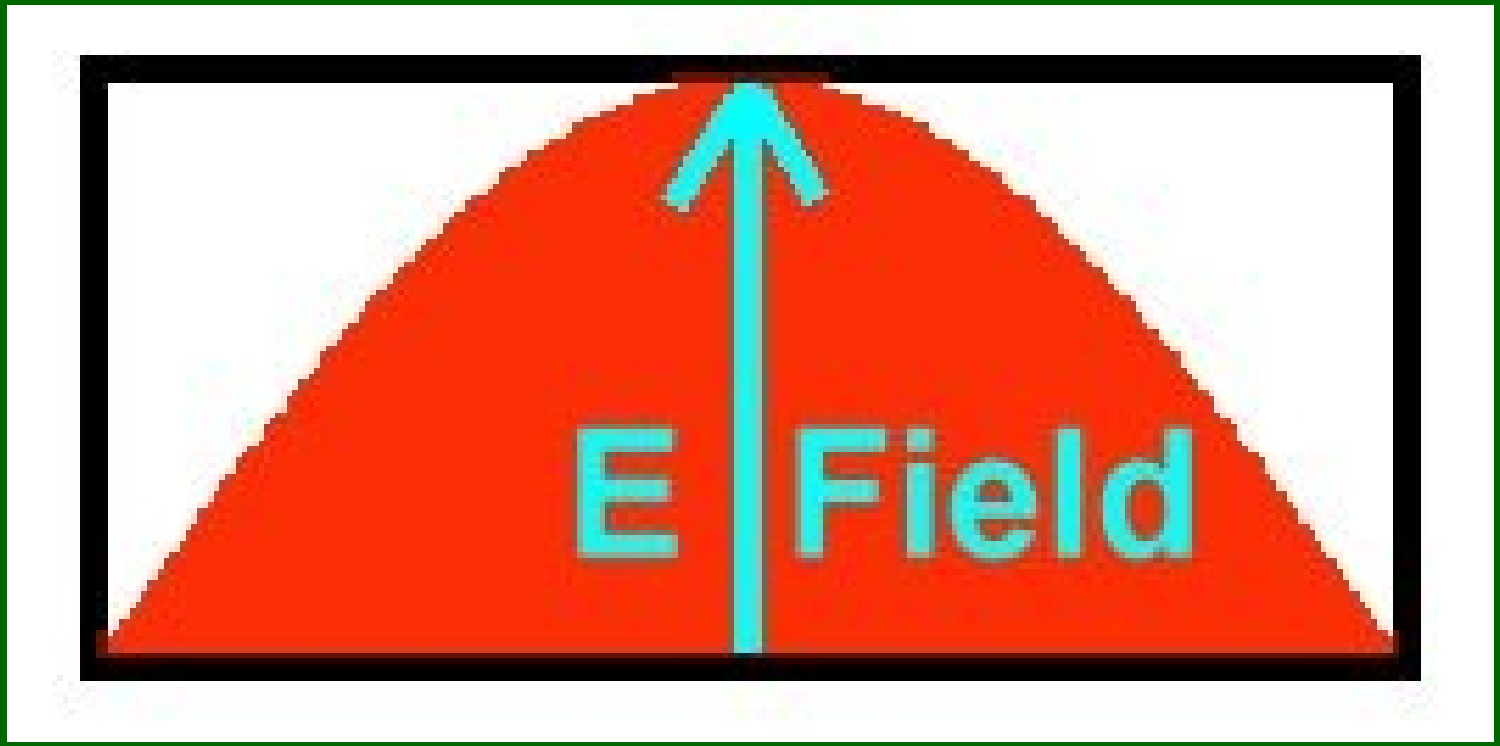


Waveguide Terminated
very low VSWR



Probe across Waveguide

probe thru mesh



WR-187 Waveguide

- Smaller guide very close to cutoff
- Vmin spacing longer than slot
- $\lambda_g >> \lambda_o$



Summary

- Open or mesh structures allow probing
- Sensitive detector for electric fields
  - Coax
  - Waveguide
  - Antennas
  - Leakage
  - Optical equivalents:
    - Reflection, refraction, diffraction, polarization

Heinrich Hertz 1887

- Experiments included open coax
- Spark gap source – high power
- Spark gap detector – very insensitive
- ~ 50 MHz
- Demonstrated optical equivalance:
- Electromagnetic waves

- MIT Museum Exhibit of replica apparatus

www.w1ghz.org

