TU4C-3

# Waveguide Multimode Directional Coupler for Harvesting Harmonic Power from the Output of Traveling-Wave Tube Amplifiers

Rainee N. Simons and Edwin G. Wintucky
NASA Glenn Research Center
Cleveland, OH 44135, USA
Email: Rainee.N.Simons@nasa.gov

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# Outline

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- Benefits & Challenges
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  - Coupler Characterization
- Conclusions
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# Introduction – Motivation

- Growing user community
  - Congestion in the traditional Ku, K, and Ka frequency bands designated for space-to-ground data communications
- Next available bands above Ka-band are the Q-band (37-42 GHz) and E-band (71-76 GHz)

# Benefits of Migrating to Higher Frequencies

- Allocated bandwidth at Q-band & E-band is in excess of 4 GHz, which can enhance throughput by 10X or higher
  - Competitive with terrestrial fiber optic & wireless service in terms of cost per transmitted bit
- Narrower beam width & smaller spot size
- Greater frequency reuse & spectral efficiency

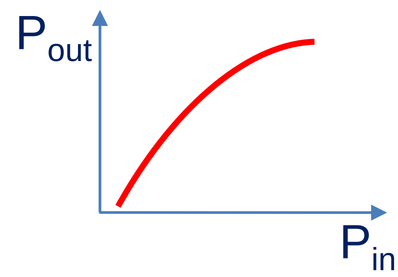
# Challenges

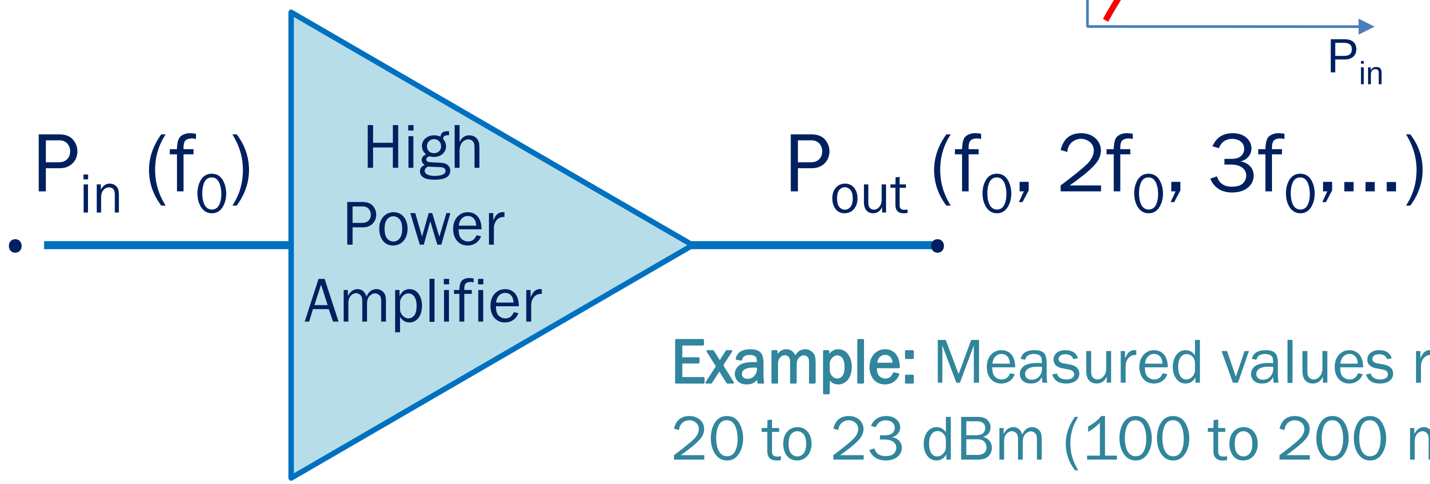
- Lack of rigorous studies to understand atmospheric effects on radio wave propagation at Q-band & E-band
  - These studies are essential for the design of a robust system for deployment in space

# Challenges
## (continued)

- A wide band beacon transmitter has to be deployed on a satellite
  - Ground receivers have to be dispersed over climate zones of interest
  - Statistical data on rain attenuation, fading, change in refractive index, scintillation, de-polarization effects, etc., have to be acquired for a period of 3 to 5 years

# High Power Amplifier Harmonics

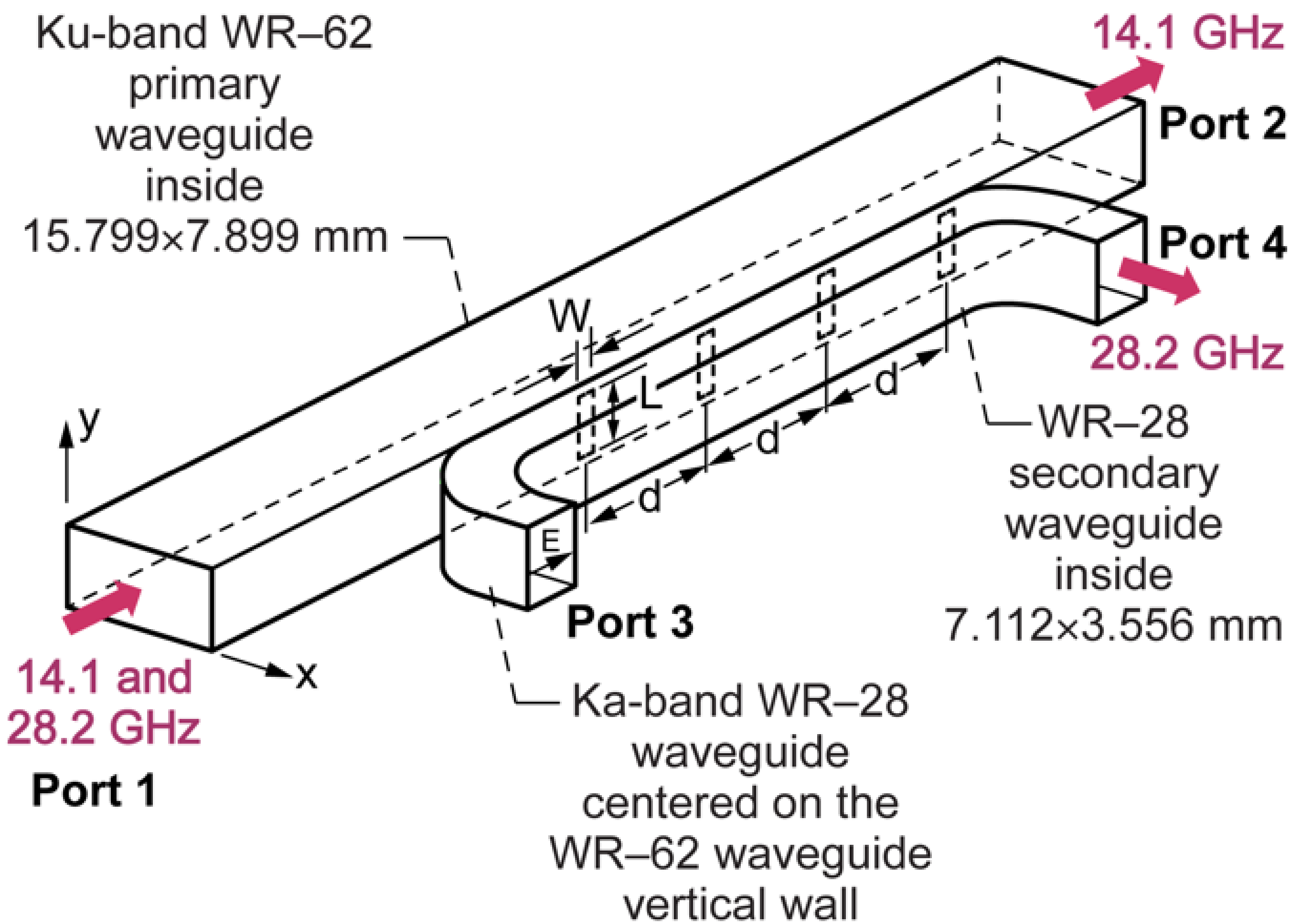


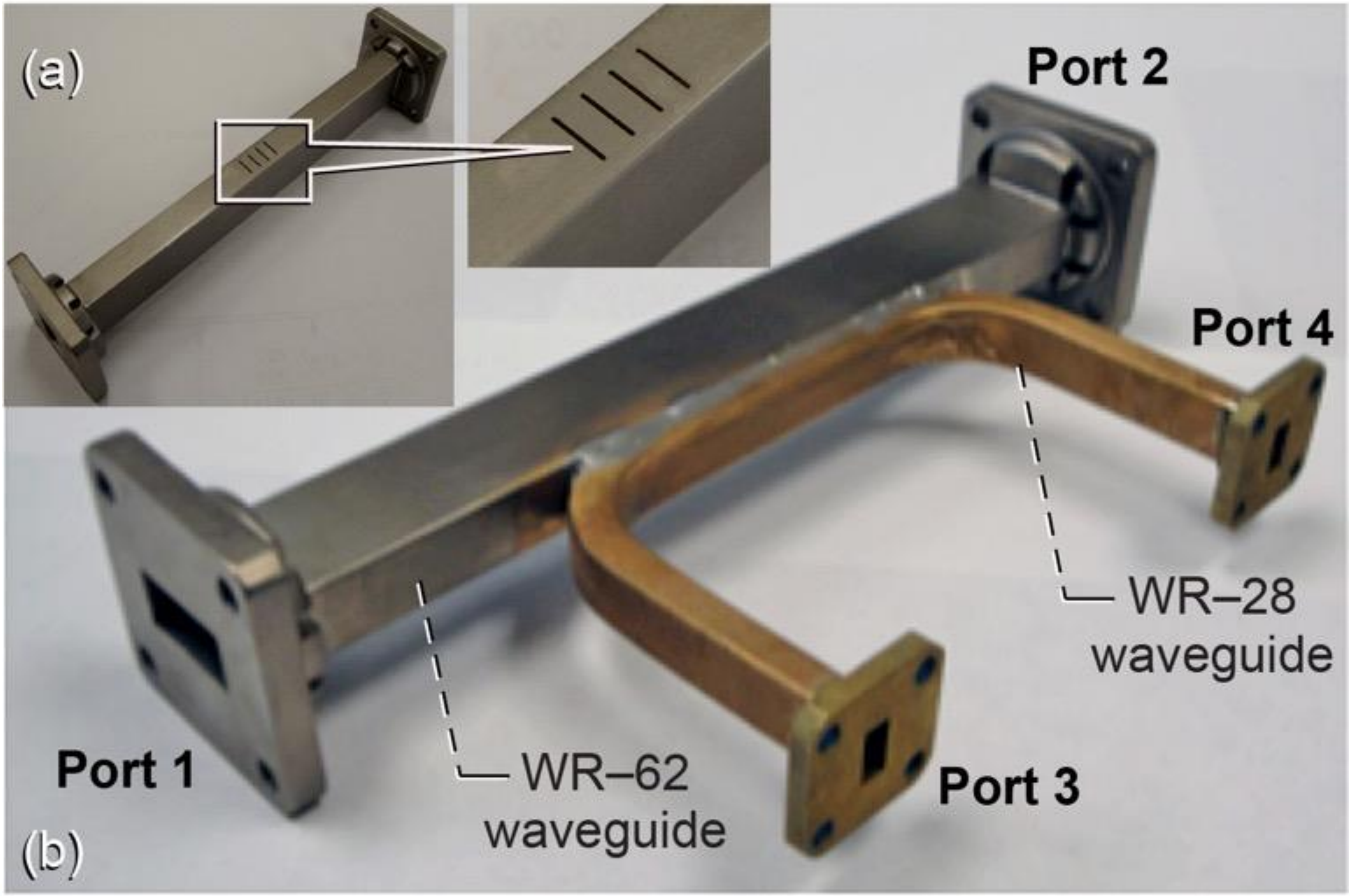

**Example:** Measured values range from 20 to 23 dBm (100 to 200 mW) for the 40 W K-band TWTA

TWTAs on board satellites for data transmission operate with constant envelope type waveform (for e.g. QPSK) and at saturation for peak efficiency

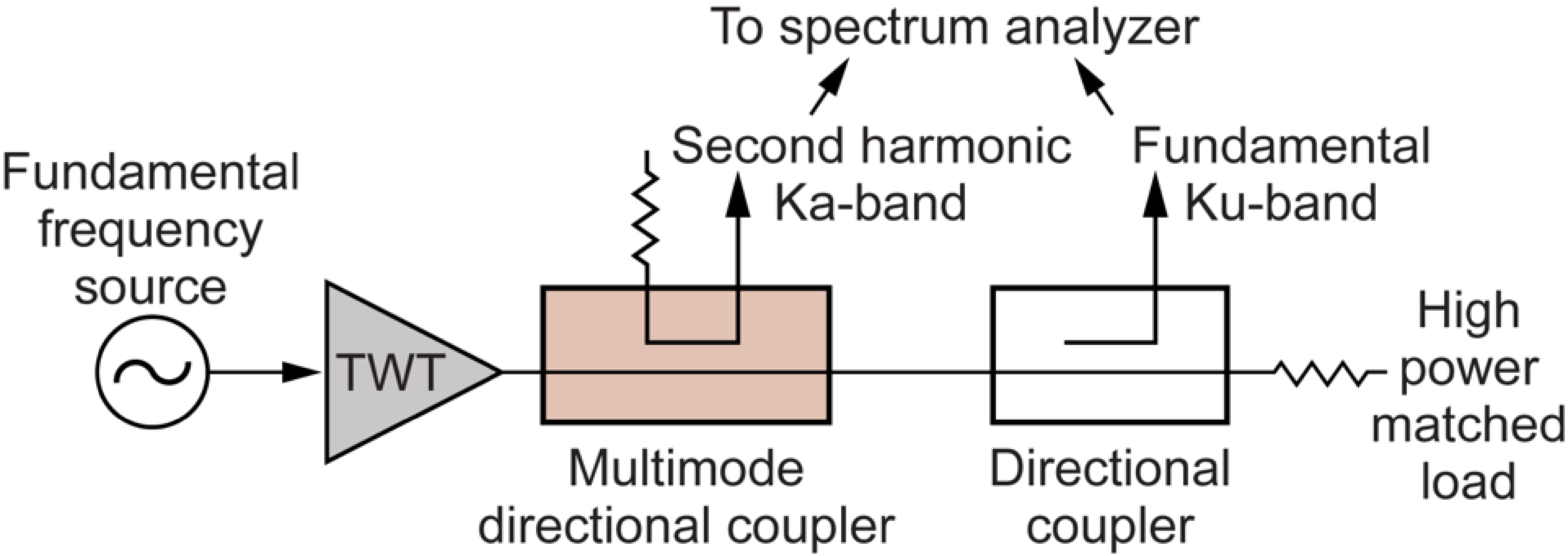
# Waveguide Multimode Directional Coupler (MDC)



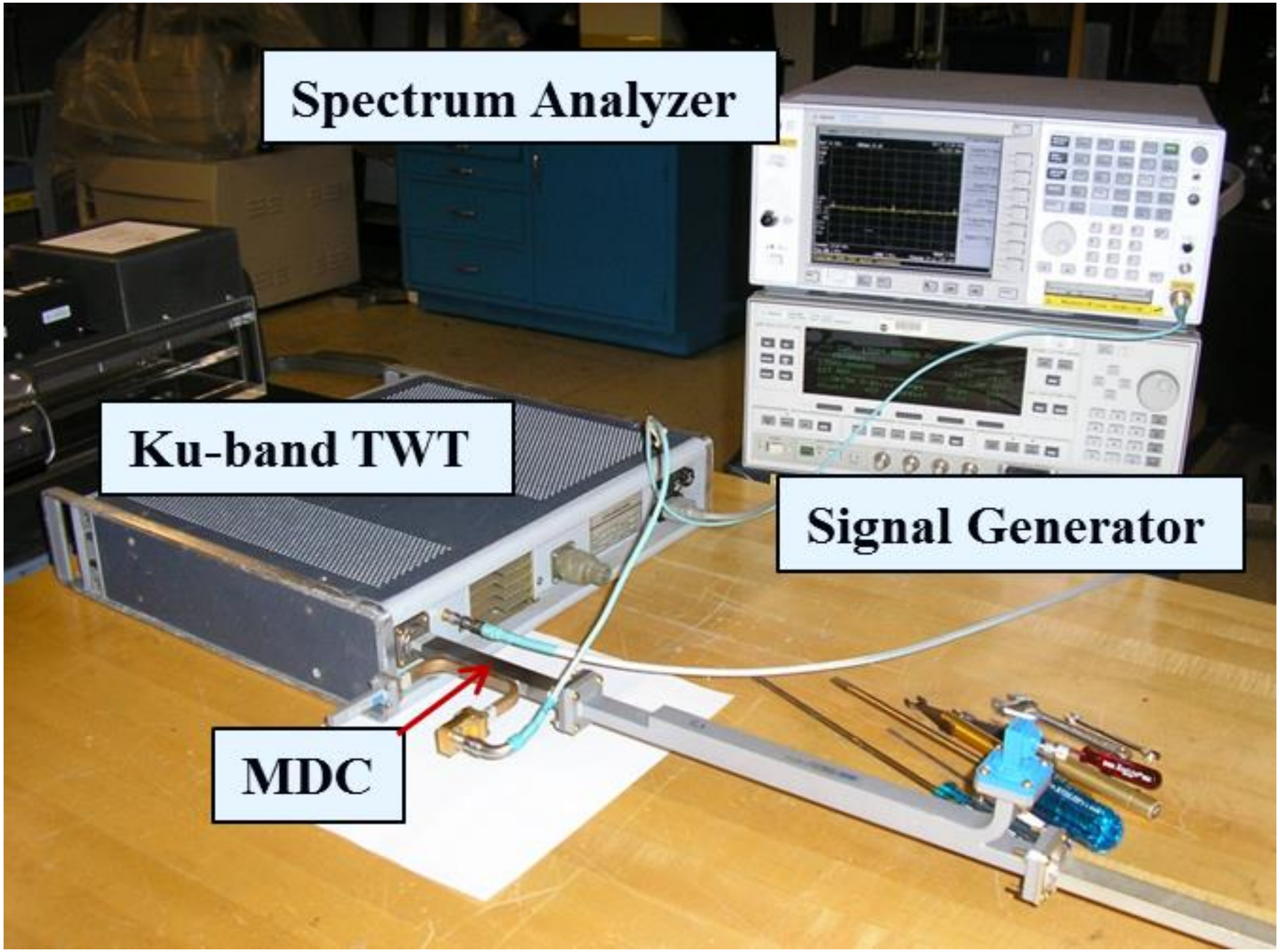
# Fabricated Ku-Band/Ka-Band Waveguide MDC



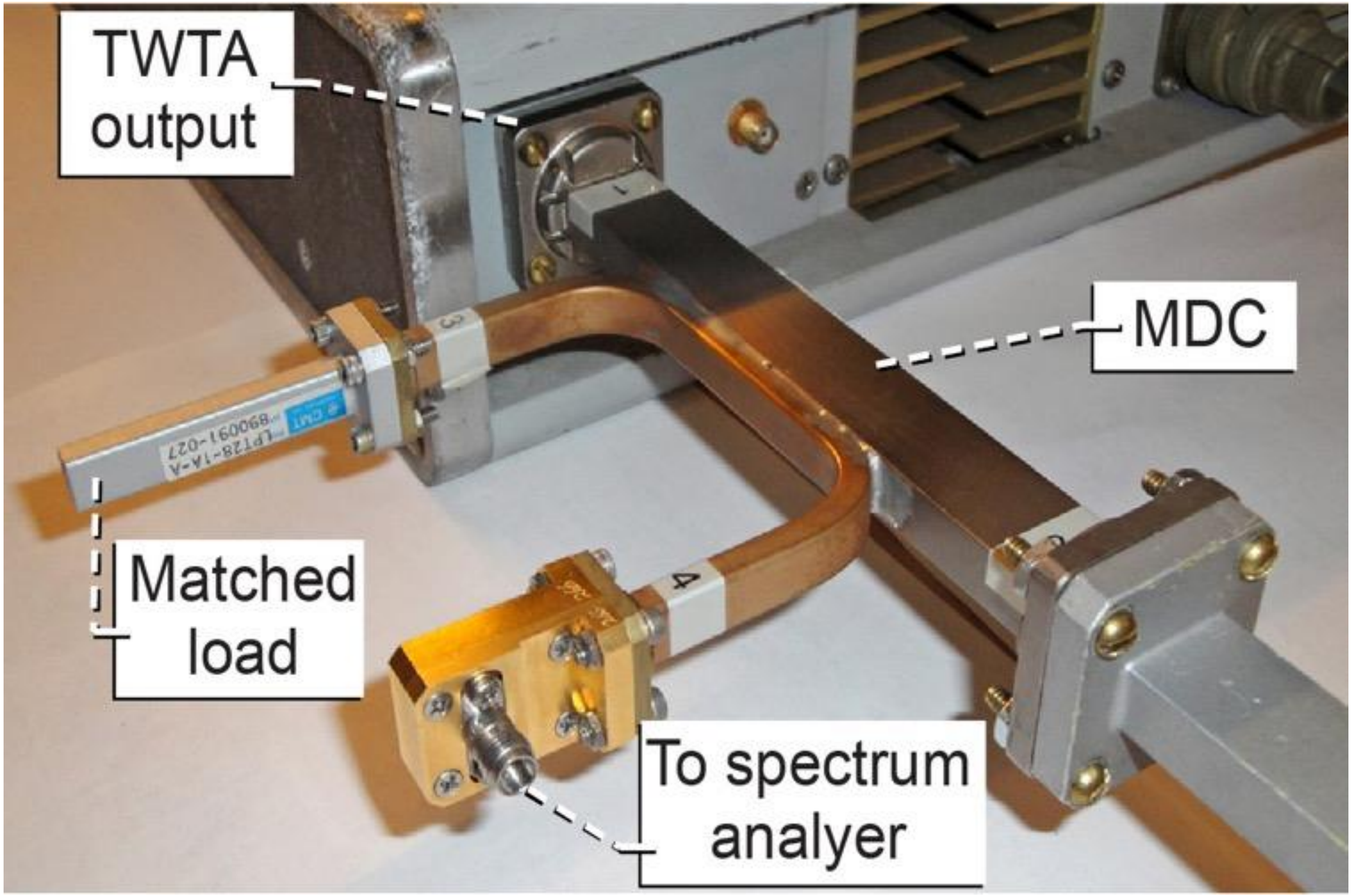
# Test Circuit for Measurement of Power at Fundamental ($f_0$) & Second Harmonic ($2f_0$)



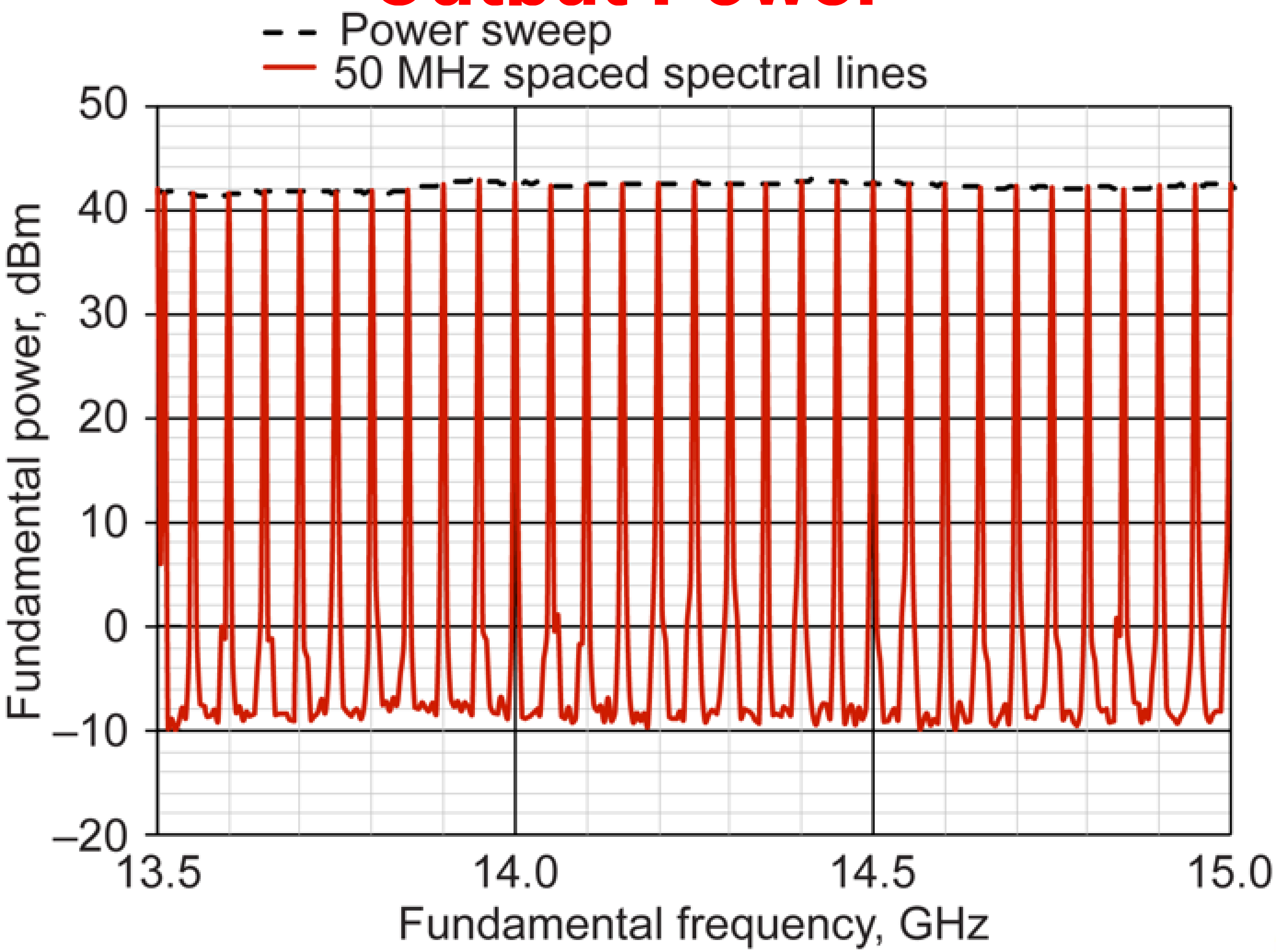
# Experimental Setup - Ku-Band/Ka-Band MDC Tests



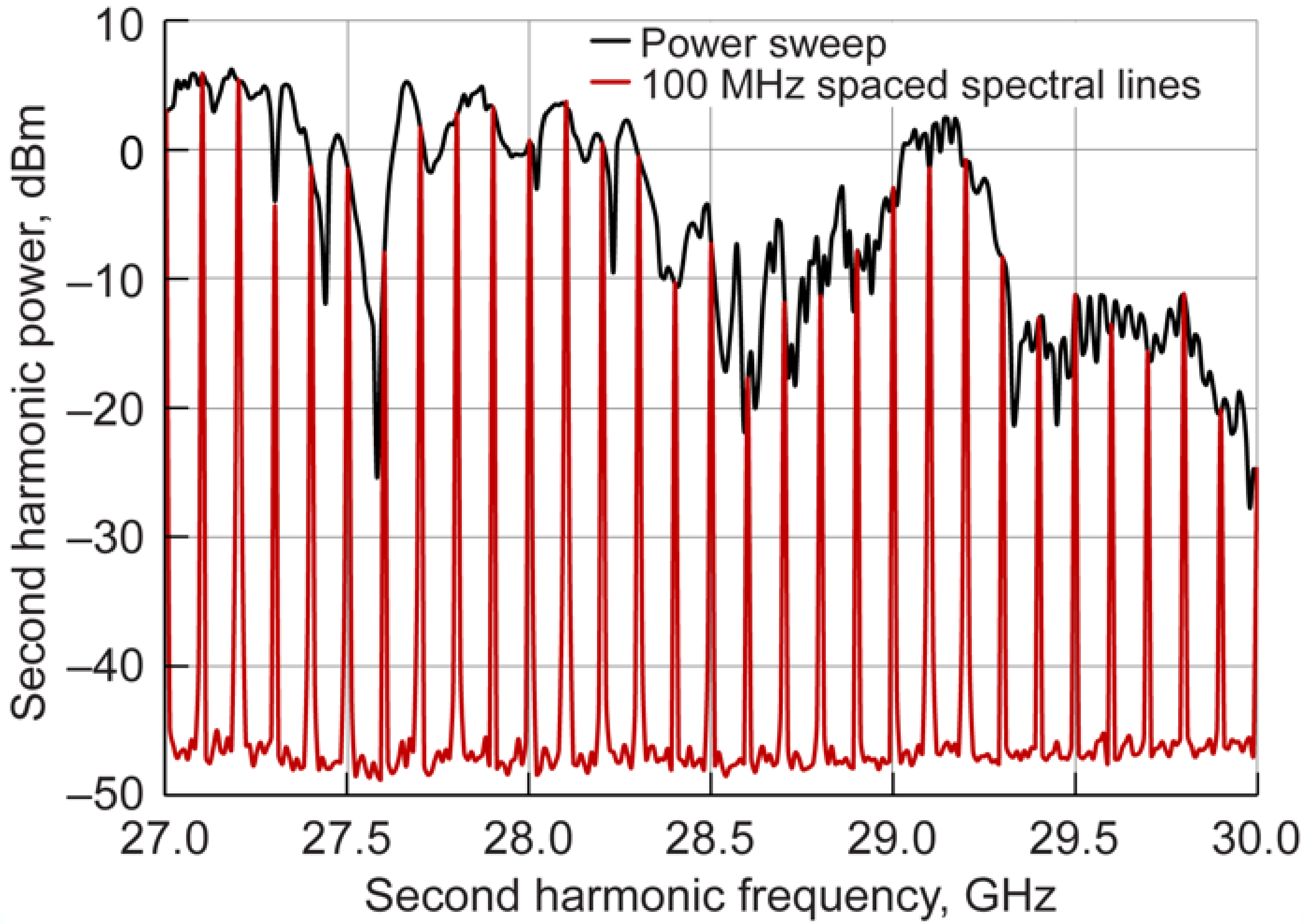
# MDC at Output Port of Ku-Band TWTA



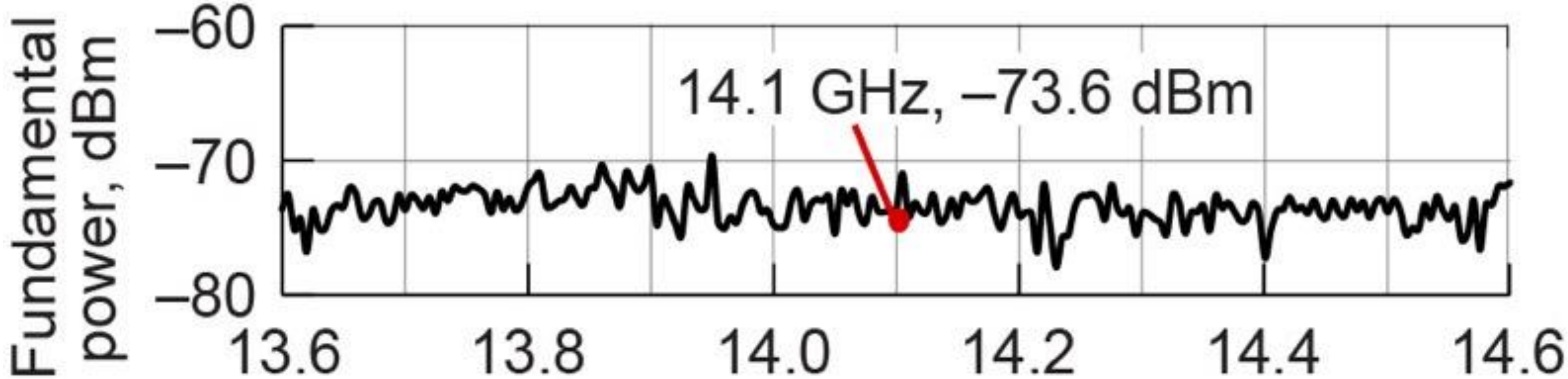
# Measured TWT Fundamental ($f_0$) Saturated Output Power



# Measured Second Harmonic ($2f_0$) Power at Port 4 of MDC



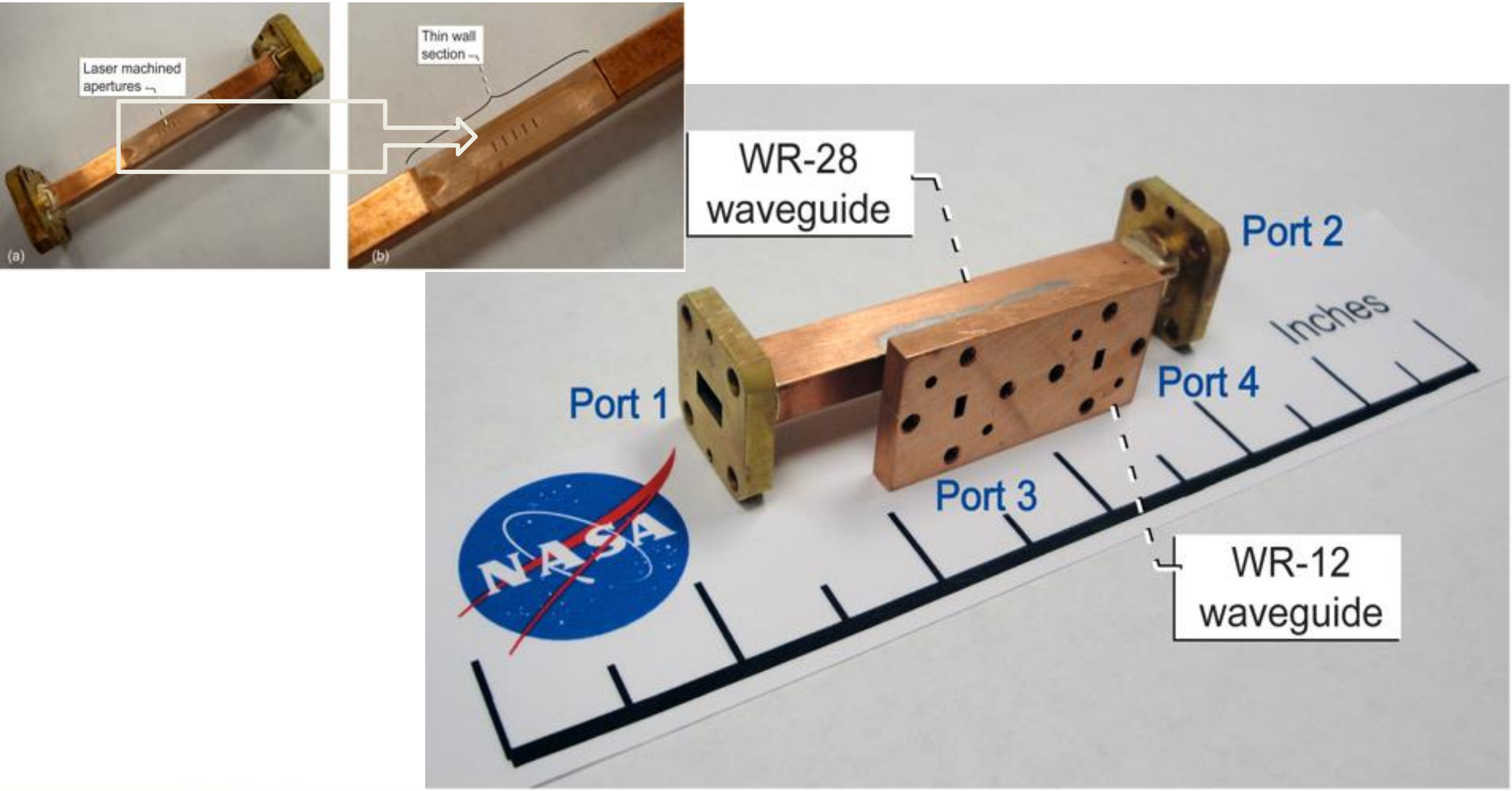
# Measured $f_0$ Power at the MDC Port 4 & Measured Insertion Loss Between Port 1 & Port 2



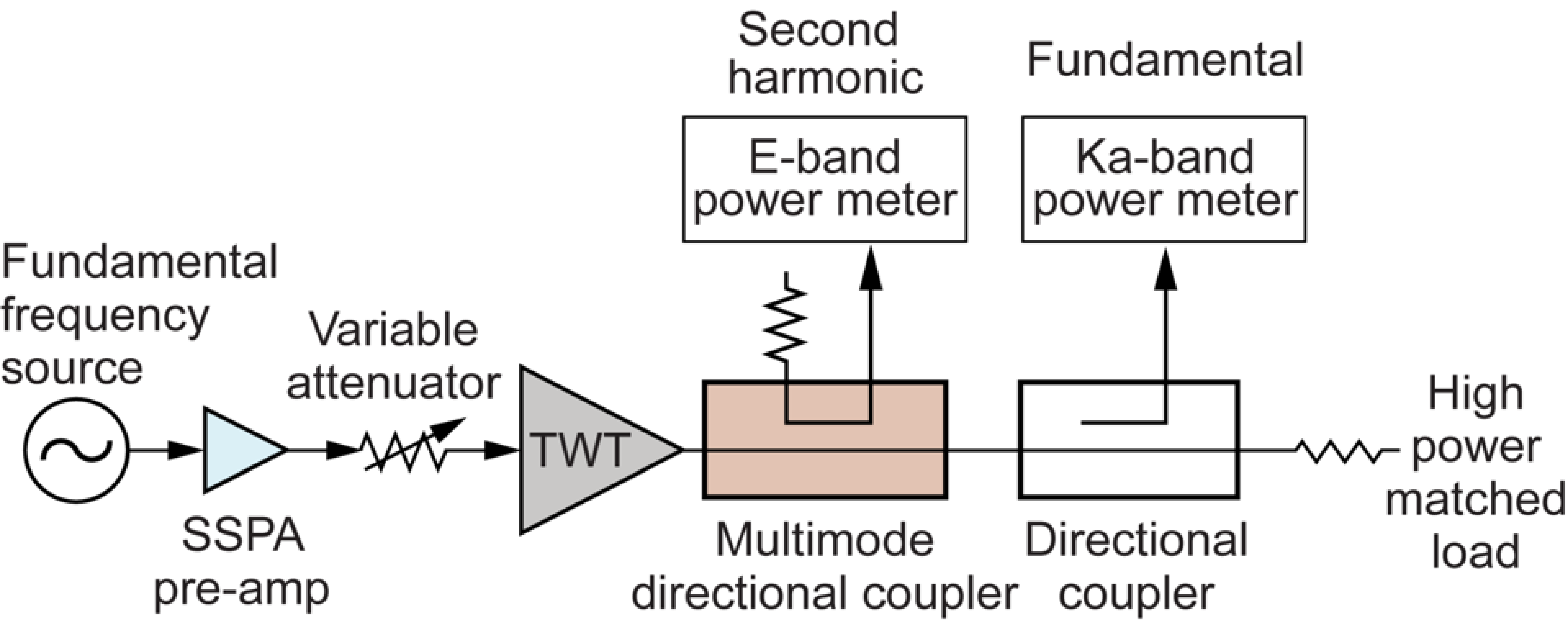

(a)


(b)

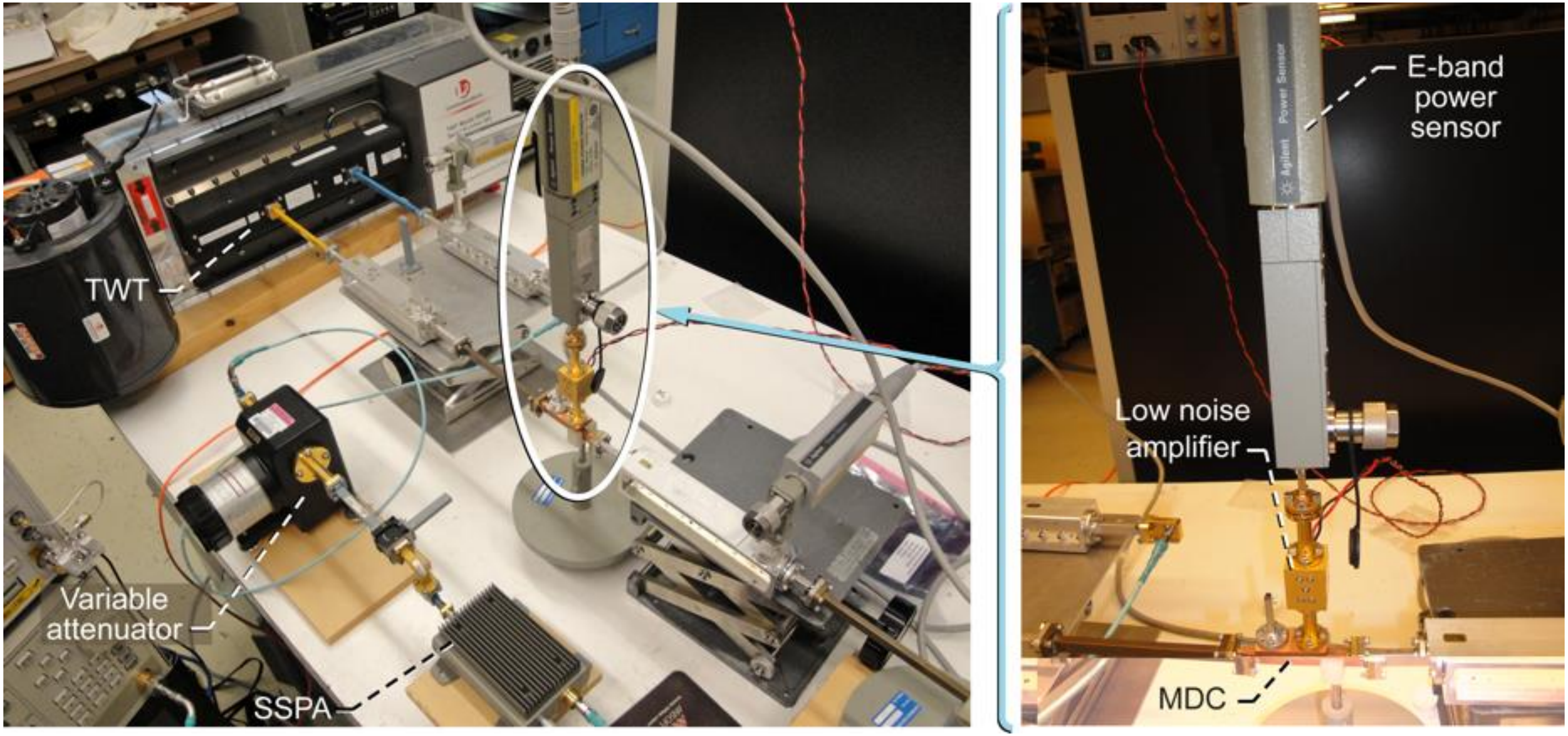
# Fabricated Ka-Band/E-Band Waveguide MDC



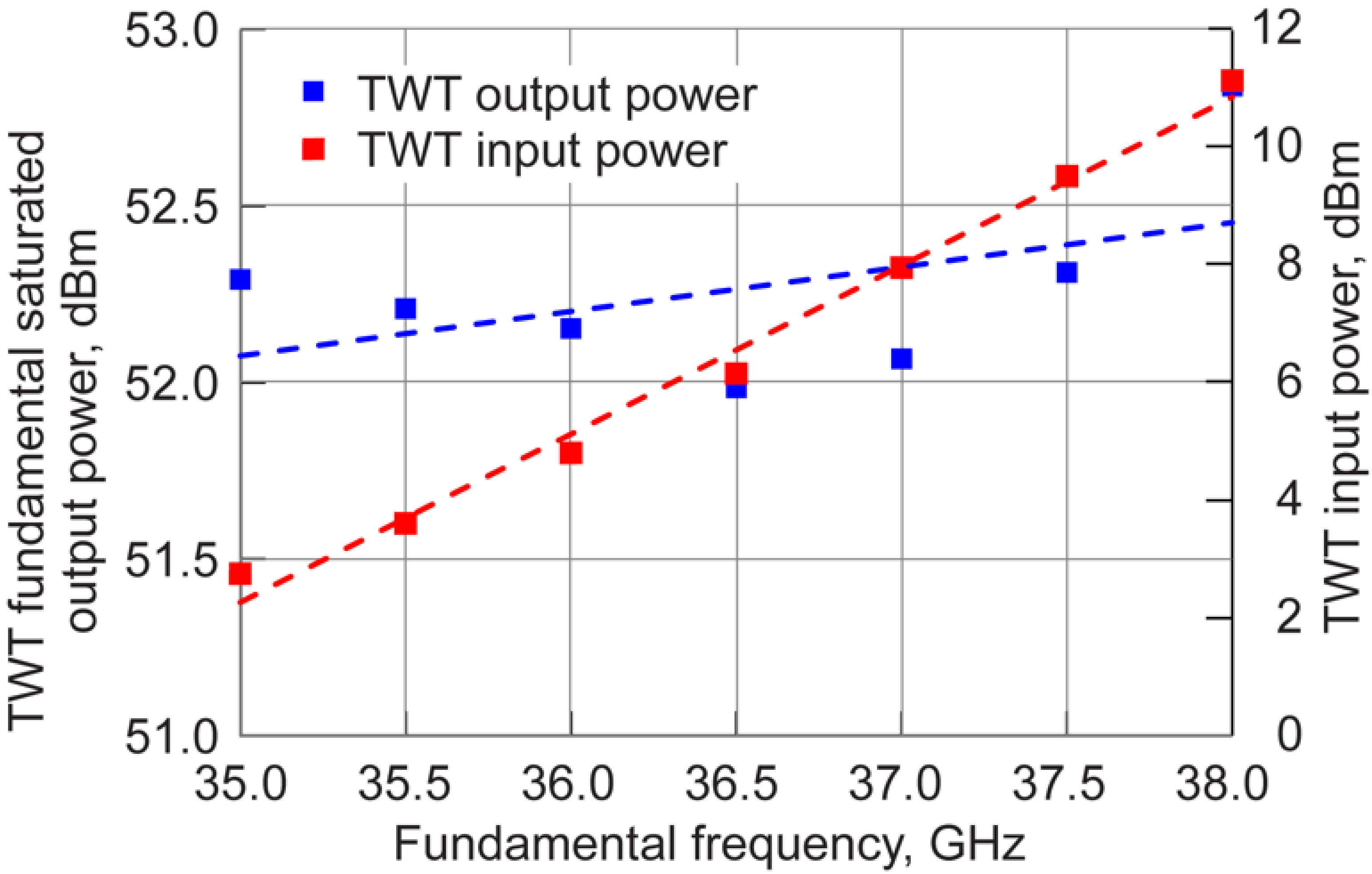
# Test Circuit for Measurement of Power at Fundamental ($f_0$) & Second Harmonic ($2f_0$)



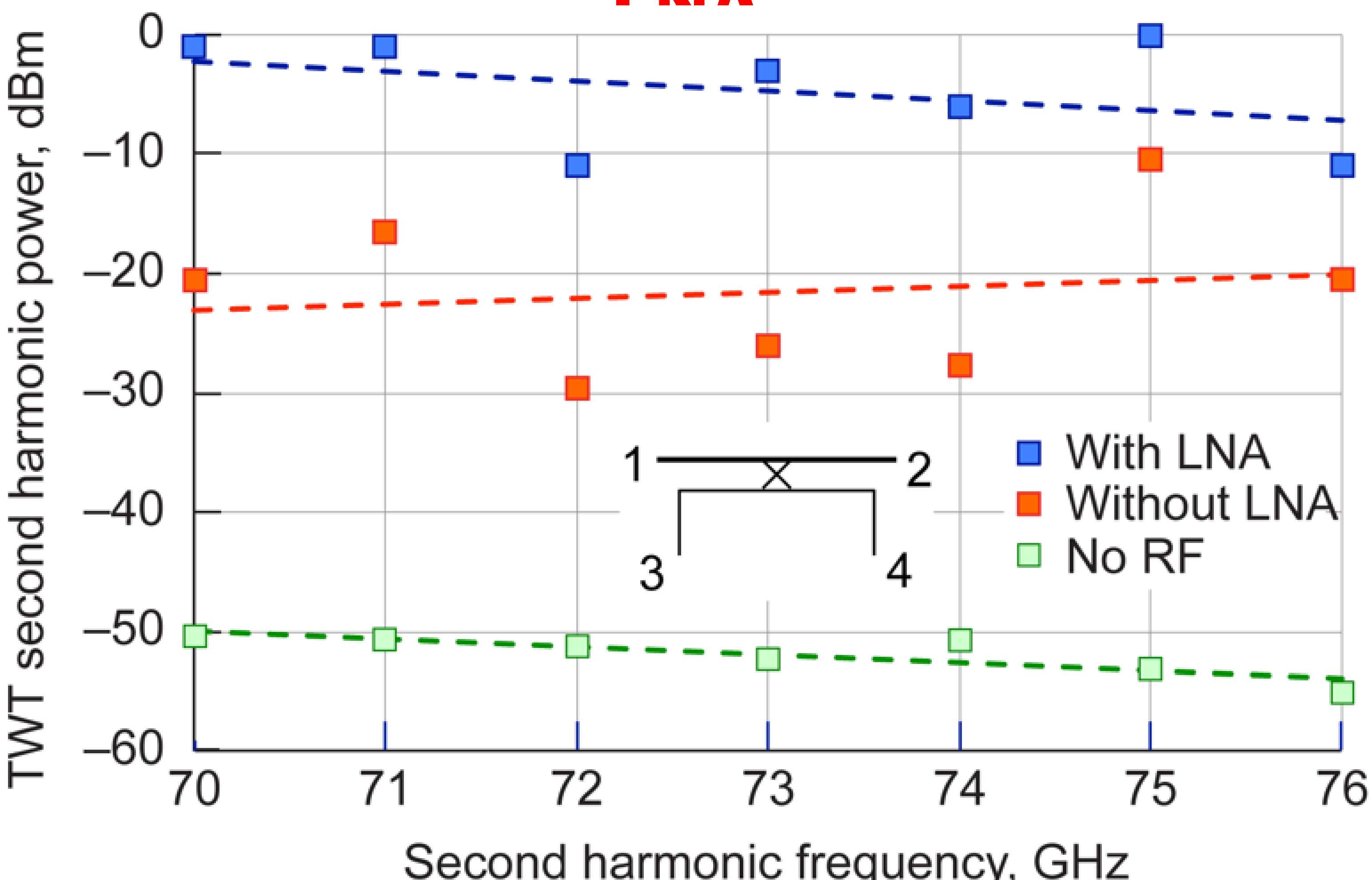
# Experimental Setup - Ku-Band/Ka-Band MDC Tests



# Measured TWT Fundamental ($f_0$) Saturated Output Power



# Measured Second Harmonic ($2f_0$) Power at Port 4 of MDC With & Without the LNA



# Conclusions

- Design, fabrication and test results are presented for a Ku-Band/Ka-Band & Ka-Band/E-Band MDCs
- The MDC can be connected directly to the output port of a TWTA with negligible loss of fundamental power – an advantage over harmonic filters and diplexers
- Test results demonstrate sufficient power in the 2$^{nd}$ harmonic for potential space borne beacon source for atmospheric studies