

# Amateur Microwave Communications 10 GHz and Up

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# Introduction

- Microwaves are usually considered to be the frequencies above 1000 MHz
  - More than 99% of the radio amateur frequency allocation is in the microwave bands.
- Frequency bands:
  - 1.2 GHz (23 cm), 2.3 GHz (13 cm), 3.3 GHz (9 cm), 5.6 GHz (6 cm), 10 GHz (3 cm), 24 GHz (1.2 cm), 47 GHz (6 mm), 75 GHz (3 mm) .....

# Introduction

- Amateur microwave frequencies (SSB/CW)
  - 1296 MHz, 2304 MHz, 3456 MHz, 5760 MHz, 10.368 GHz, 24.192 GHz, 47.088 GHz, .....
  - Note: 1152 MHz is key to determining weak-signal (SSB/CW) frequencies
    - $1296 = 1152 + 144$
    - other bands are usually whole multiples of 1152
- Presentation aimed at 10 GHz and up.

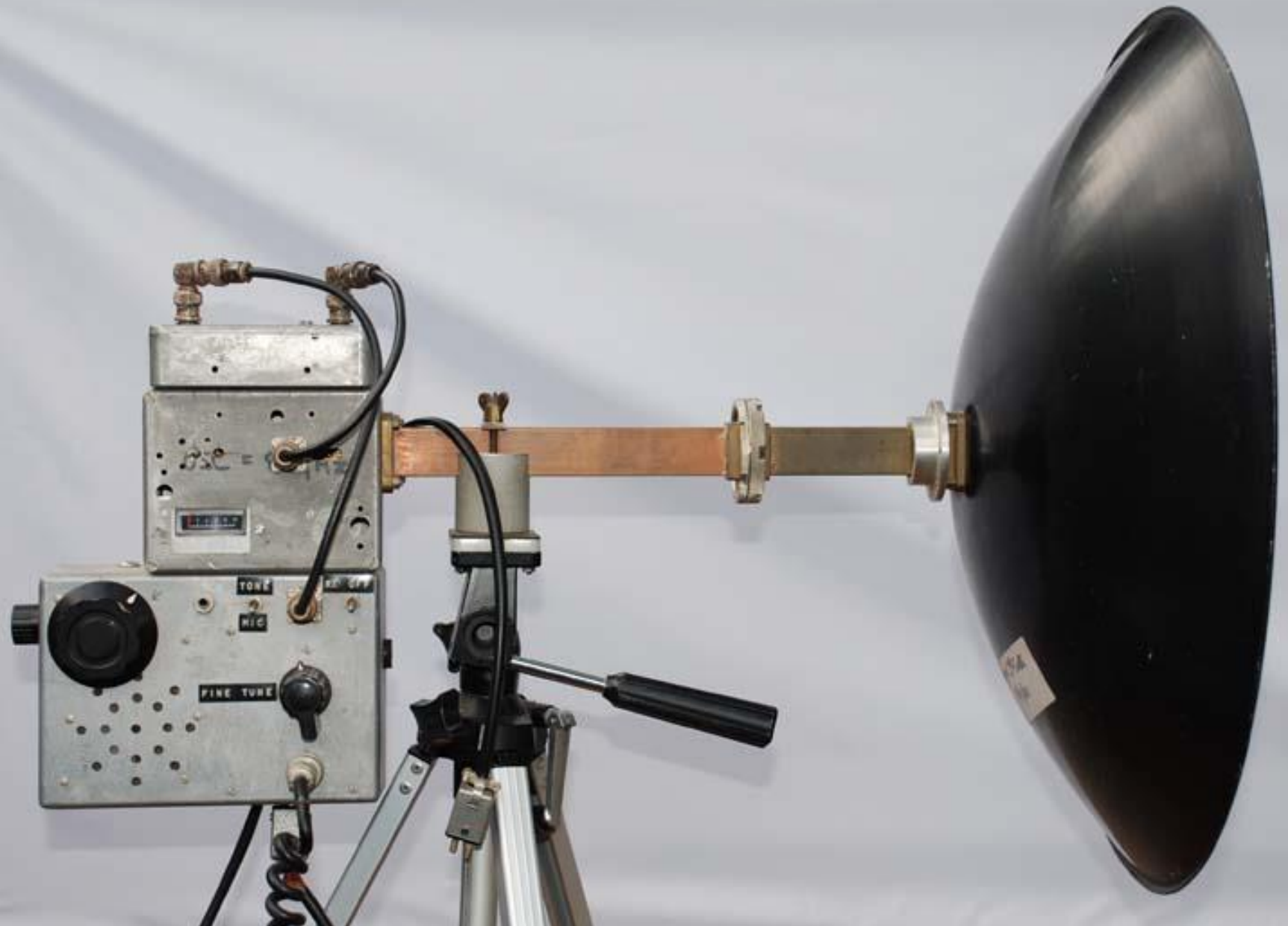
# Wideband FM: 1950s, 60s

- Transmitter
  - modulated Klystron oscillator
  - Seldom any power amplifier
    - travelling wave tubes costly, complex power supplies
  - tens or hundreds of milliwatts output typical
- Receiver
  - Same Klystron used as local oscillator
  - No RF amplifier
  - Direct injection to mixer diode (10 dB NF)
  - IF typically 30 MHz
- Waveguide

# Wideband FM: 1950s, 60s

- Line of sight paths only
  - Theoretical range few hundred km
  - In practice, max 50 – 100 km over land
  - DX possible by ducting, especially over water and along coast
- Source of equipment
  - Homebrew
  - Later -- surplus commercial equipment

# 1950s - 60s Homebrew Wideband FM Transceiver



# 1950s - 60s Commercial

- Tellurometer
  - Available surplus 30+ years ago
  - Surveying instrument with communications capability
    - same technology as homebrew
  - 10 GHz plus other bands available
  - 110 km path worked by VE3ASO (sk) from Foymount to Gatineau Park

# Modified Tellurometer





# Wideband FM 1970s

- Gunn diode replaces klystron (Gunnplexer)
- Otherwise, similar technologies
  - No preamp or power amp
- Max range still typically 50 – 100 km over land
- Source of equipment:
  - Modified burglar alarm
  - Commercial from ARR
    - produced station complete with IF radio and horn antenna

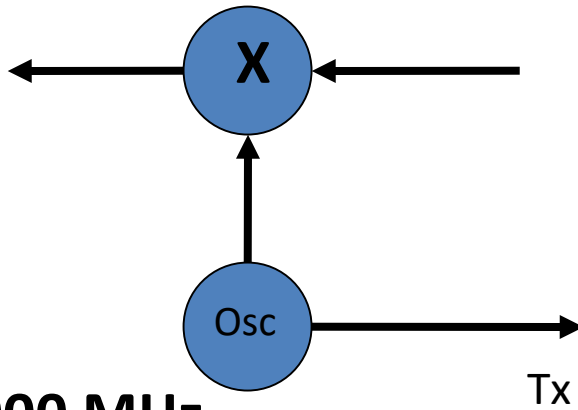
# Gunnplexer



# Wideband FM Communications

(10,100 – 10,000)

100 MHz

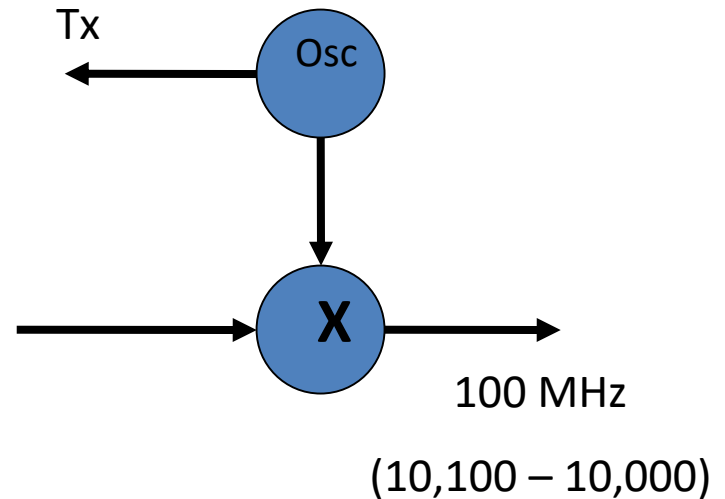


10,000 MHz

Tx

Station 1

10,100 MHz



Tx

Osc

X

100 MHz

(10,100 – 10,000)

Station 2

Each station has IF of 100 MHz

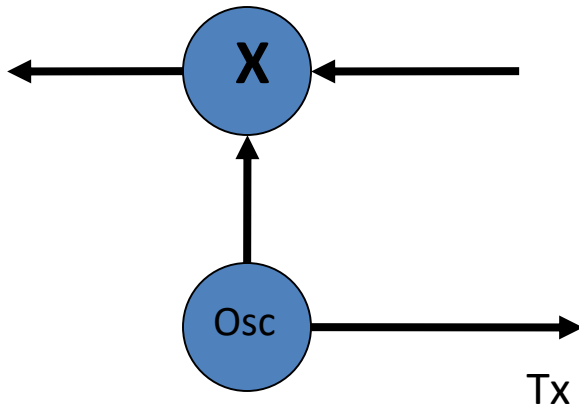
# Wideband FM Communications

(10,100 MHz)

**9900 MHz**

(10,000 – 9900)

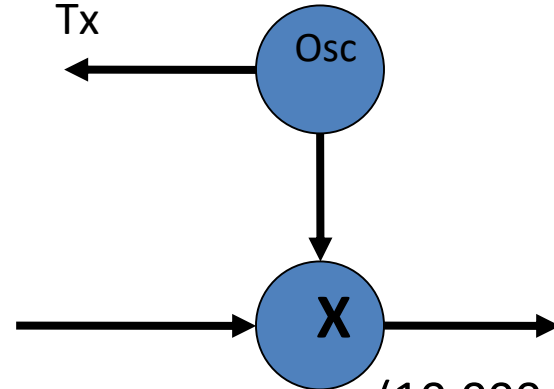
100 MHz



**10,000 MHz**

Station 1

Tx



(10,000 – 9900)

100 MHz

Station 2

Each station has IF of 100 MHz

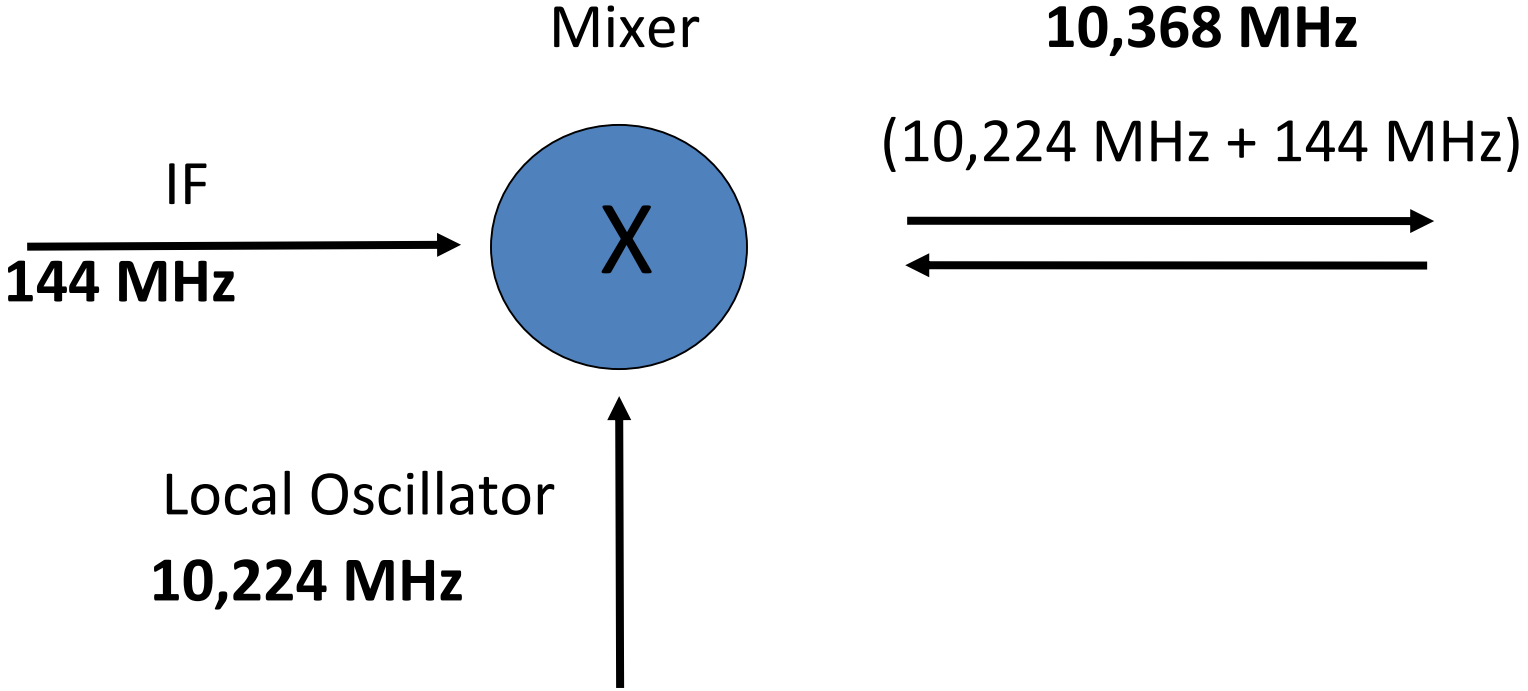
# Narrowband

- Why Narrowband (CW/SSB)??
  - For very weak signals, SSB has roughly 30 dB advantage over wideband FM
  - But:
    - More complex circuitry
    - must have very stable oscillators and accurate frequency indication.

# Narrowband

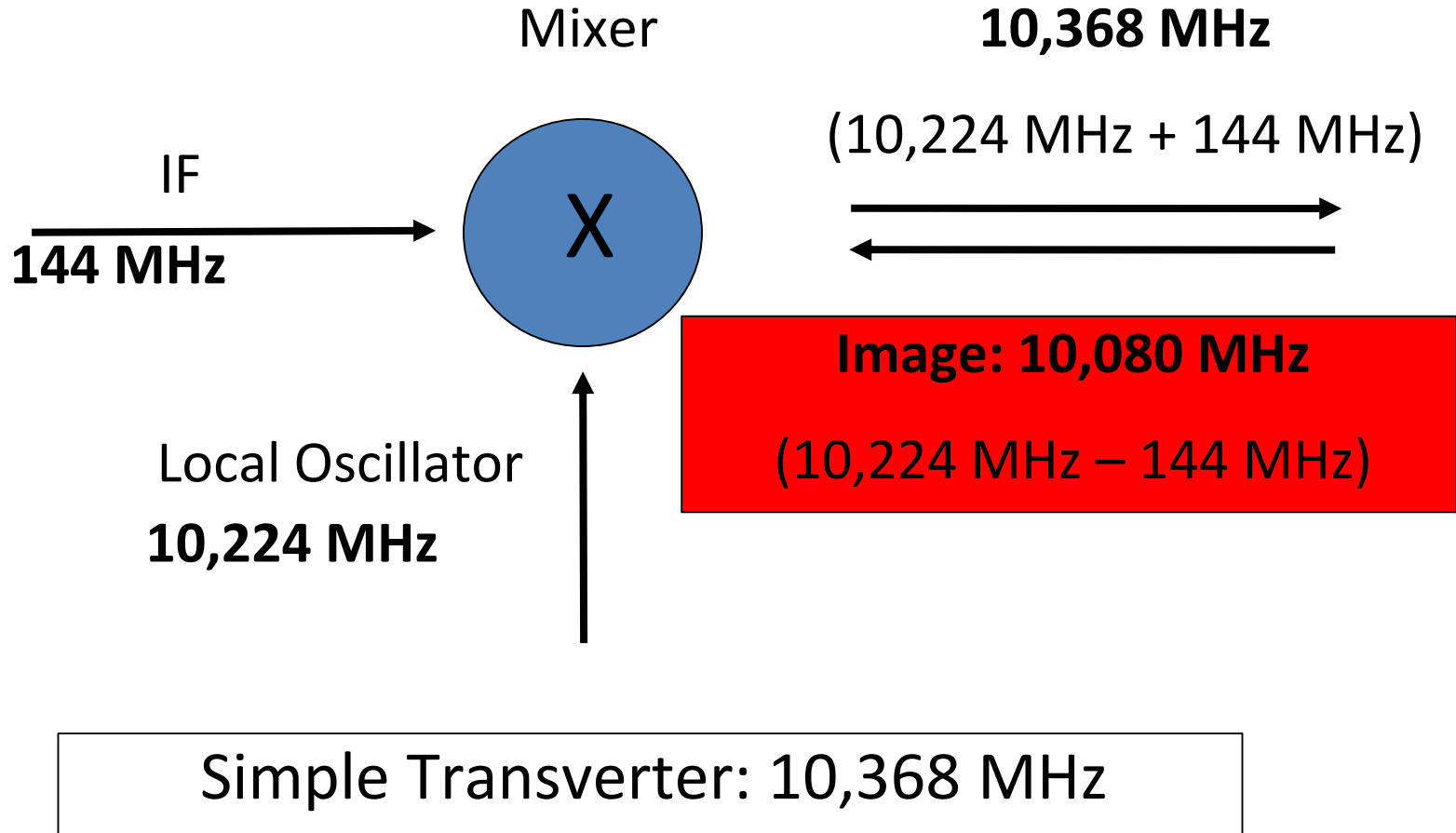
- Transverter
  - Transmitting / Receiving converter
  - Transmit
    - VHF / UHF IF source (typically 144 or 432 MHz) mixed with LO to produce microwave signal
    - usually power amplifier
  - Receive
    - microwave received signal mixed with LO to produce VHF / UHF output
    - usually RF amplifier
  - Usually image filter

# Narrowband



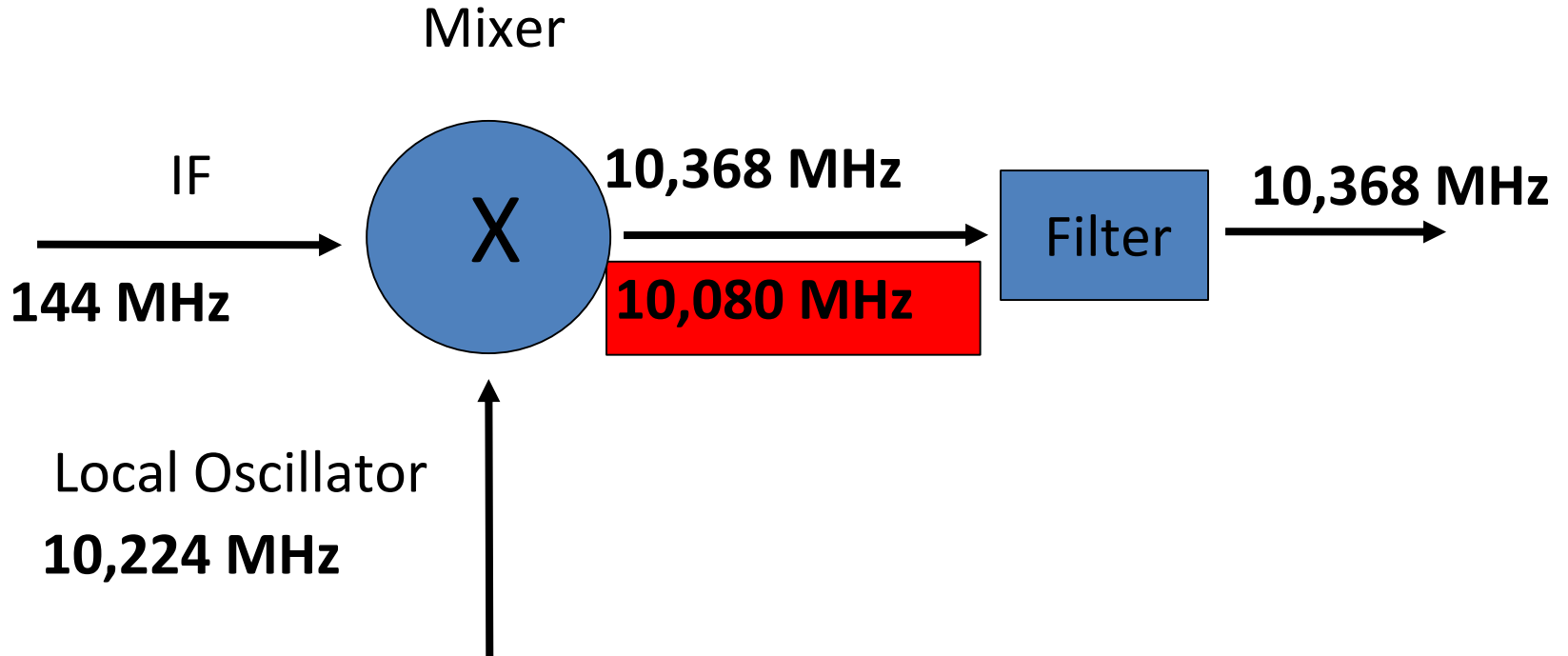
Simple Transverter: 10,368 MHz

# Narrowband





# Narrowband



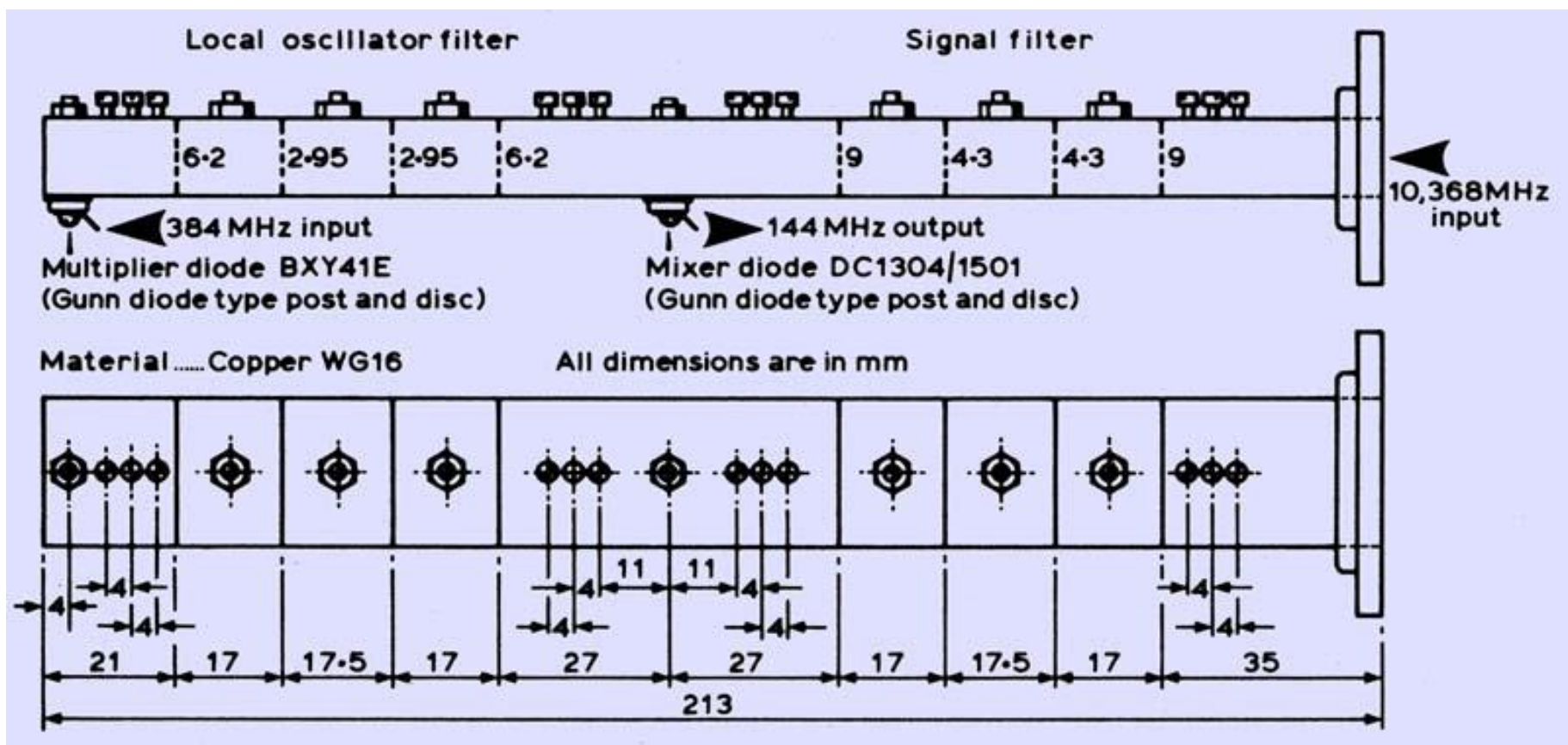
Simple Transverter + Image Filter: 10,368 MHz

# Narrowband

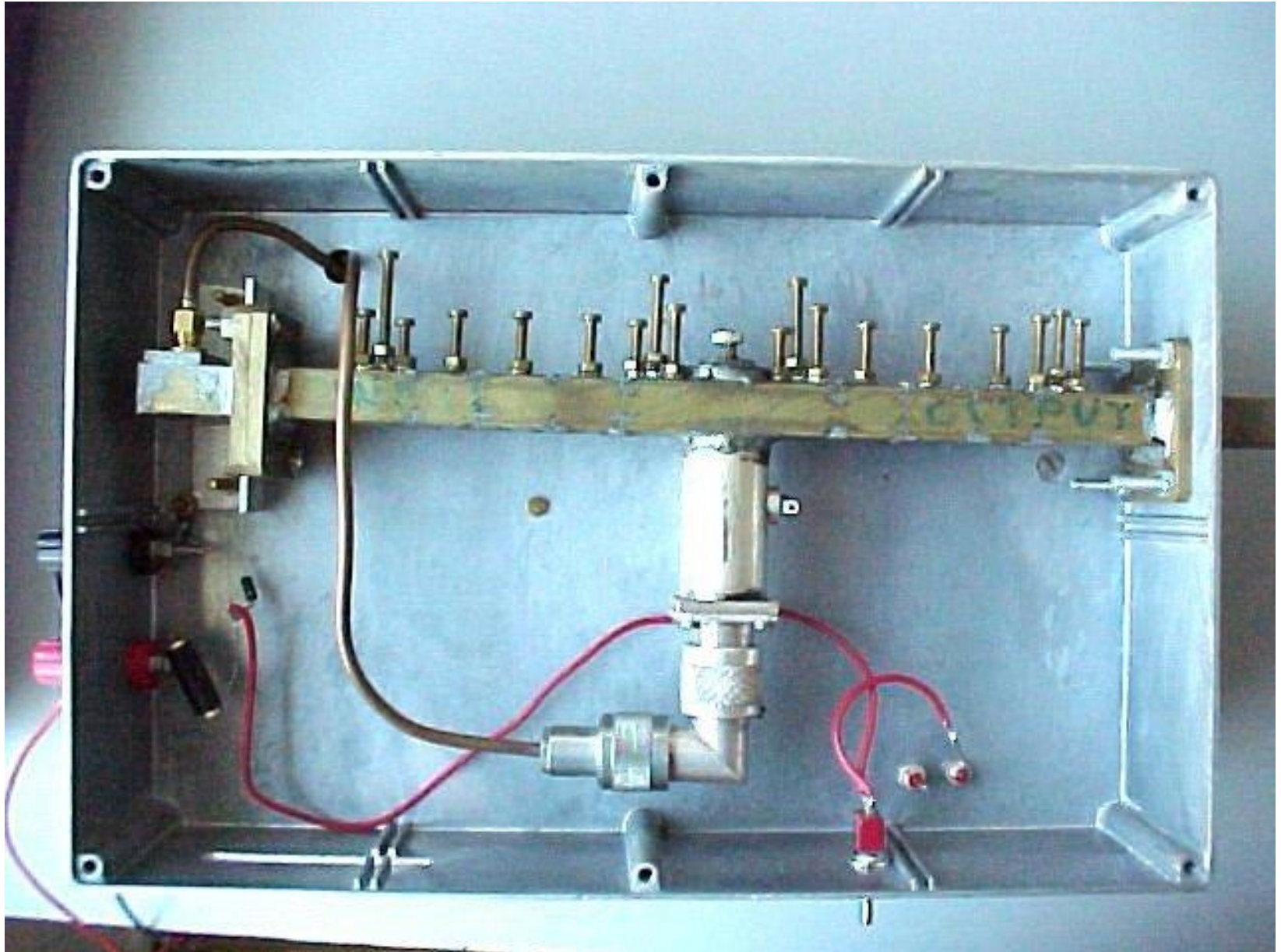
- 1979: G3JVL waveguide 10 GHz transverter
  - Tuned circuits in waveguide
  - 378.666 MHz LO input to harmonic generator
  - 10,224 MHz harmonic of LO selected by waveguide filter and fed to diode mixer
    - Tx: Mixed with 144 MHz and filtered  $\square$  10,368 MHz
    - Rx: 10,368 MHz Rx filtered and mixed  $\square$  144 MHz
  - Tx output about 1 mW
  - Rx about 7 dB NF
  - Not limited to Line of sight
    - SSB has 30 dB advantage over wideband FM

# G3JVL 10 GHz Waveguide Transverter

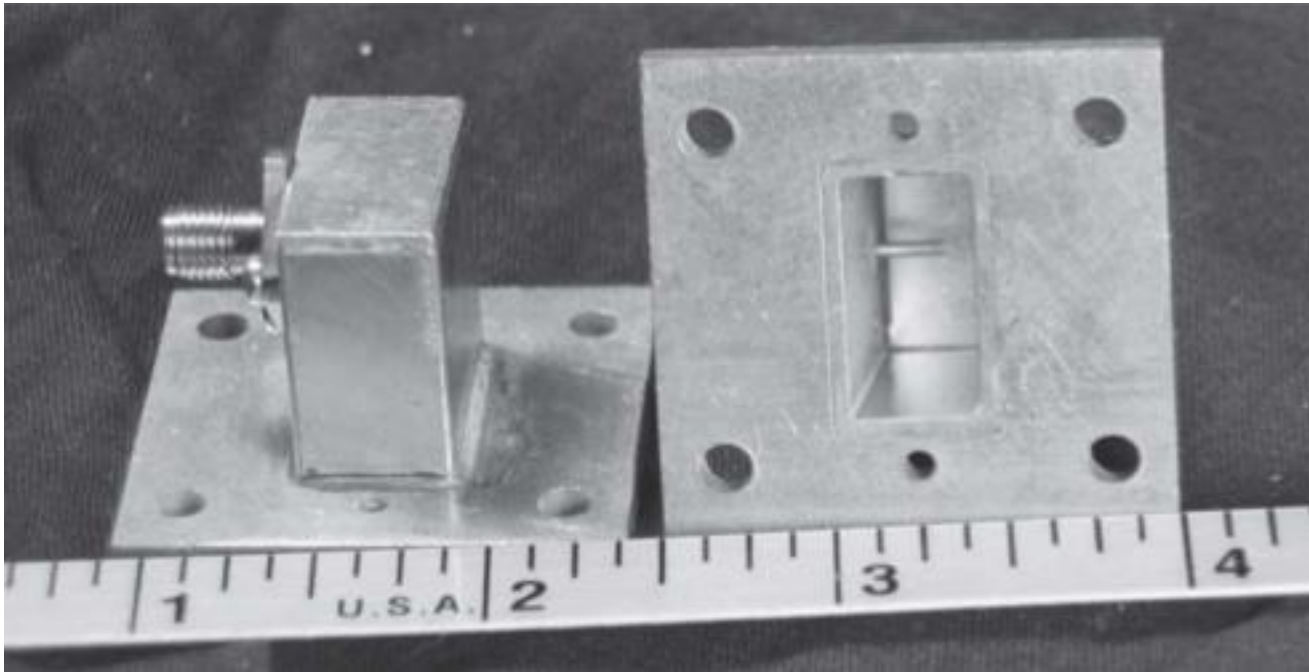
January 1979



# G3JVL 10 GHz Waveguide Transverter



# Key Components



Waveguide to Coax Transition: 10 GHz

# Key Components



## Semi-rigid Coax with SMA Connectors

UT-141: 0.5 dB / Foot @ 10 GHz (approx.)

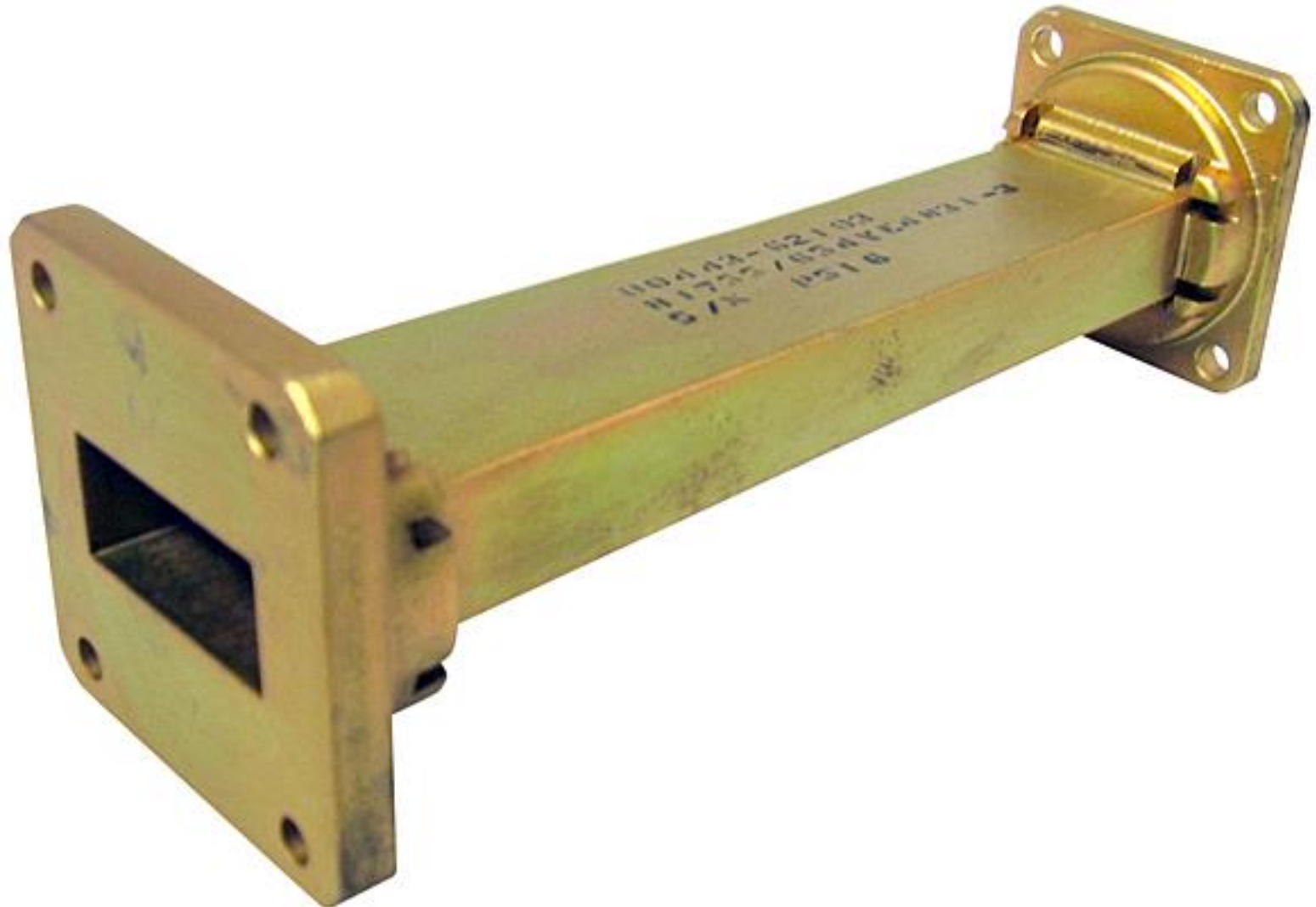
UT-085: 1.2 dB / Foot @ 24 GHz (approx.)

# Key Components



SMA Microwave Switch (Relay)

# Waveguide





Waveguide Switch



# 10 GHz and Up

## Current Technologies

- Low-noise and power RF transistors
- PC board construction
- Semi-rigid coax
  - Reduce need for waveguide at 24 GHz and below
- Equipment: commercial and homebrew

# 10 GHz and Up

## Current Technologies

- Commercial Ham RF power amplifiers
  - 10 GHz up to 50 W output (25% efficient)
    - cost approx. \$100 per Watt
  - 24 GHz up to 10 W output (10% efficient)
    - cost approx. \$500 - \$1,000 per Watt
  - 47 GHz: 1 Watt newly available
  - 78 GHz: 250 milliWatts newly available

# 10 GHz and Up

## Current Technologies

- Ham Commercial low-noise RF amplifiers
  - 10 GHz: 0.8 dB NF available
  - 24 GHz: 1.6 dB NF available
  - 47 GHz, 78 GHz: 5 dB NF available

# Design Challenges

- Context
  - 10 GHz and 24 GHz bands are 72<sup>nd</sup> and 168<sup>th</sup> harmonics of 144 MHz respectively
  - Wavelengths
    - 10 GHz: 3 cm
      - ¼ inch is roughly ¼ wavelength!
    - 24 GHz: 1.2 cm
      - ½ inch is roughly 1 wavelength!

# Local Oscillator Frequency Accuracy and Drift

- An LO 100 Hz off frequency or having 100 Hz drift at 144 MHz would produce frequency error or drift of:
  - 7.2 kHz at 10 GHz
  - 16.8 kHz at 24 GHz
  - 32.7 kHz at 47 GHz
  - 54.3 kHz at 78 GHz !!

# Local Oscillator

## Frequency Accuracy and Drift

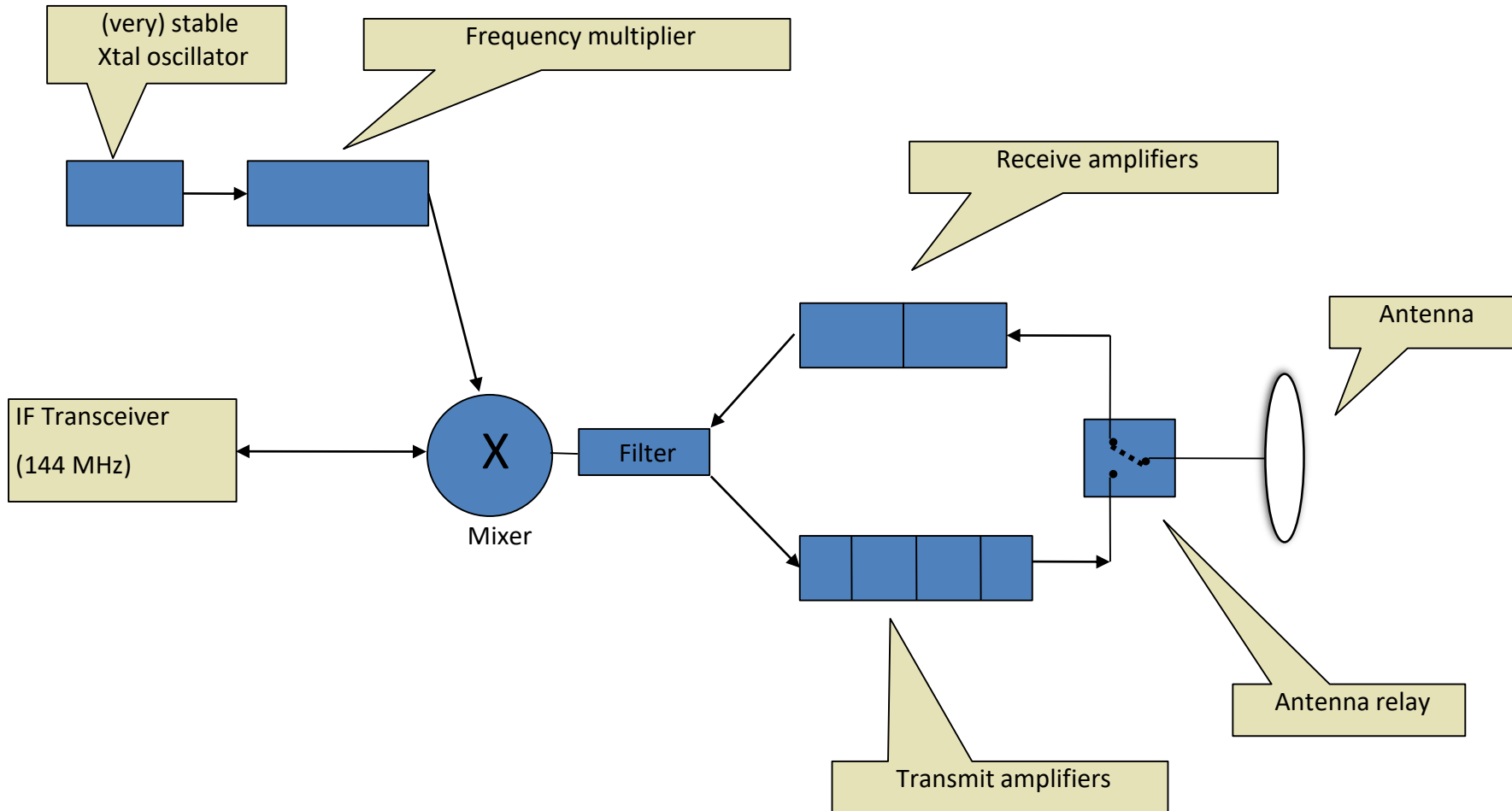
- Crystal Local Oscillators
  - Clean LO (100 MHz region) plus multipliers to microwave frequency
    - low phase noise (also multiplied)
  - Crystal heater or oven typically used to reduce frequency error and drift.
  - Some lock (PLL) to external oscillator
    - Oven or GPS disciplined.

# Sources of Equipment

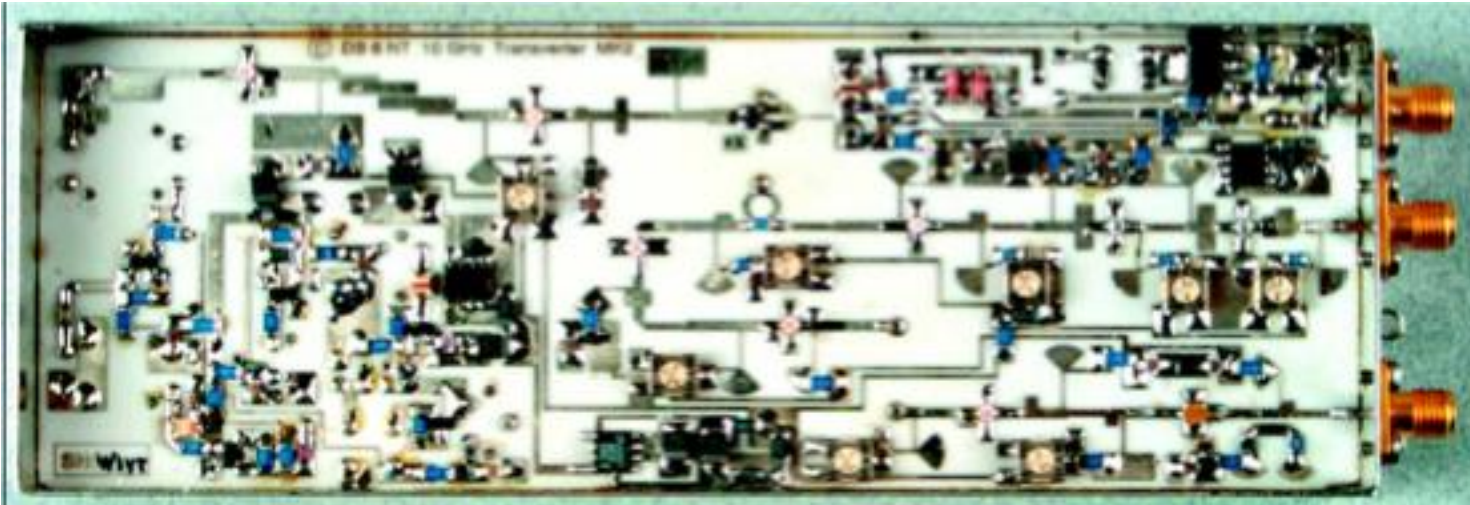
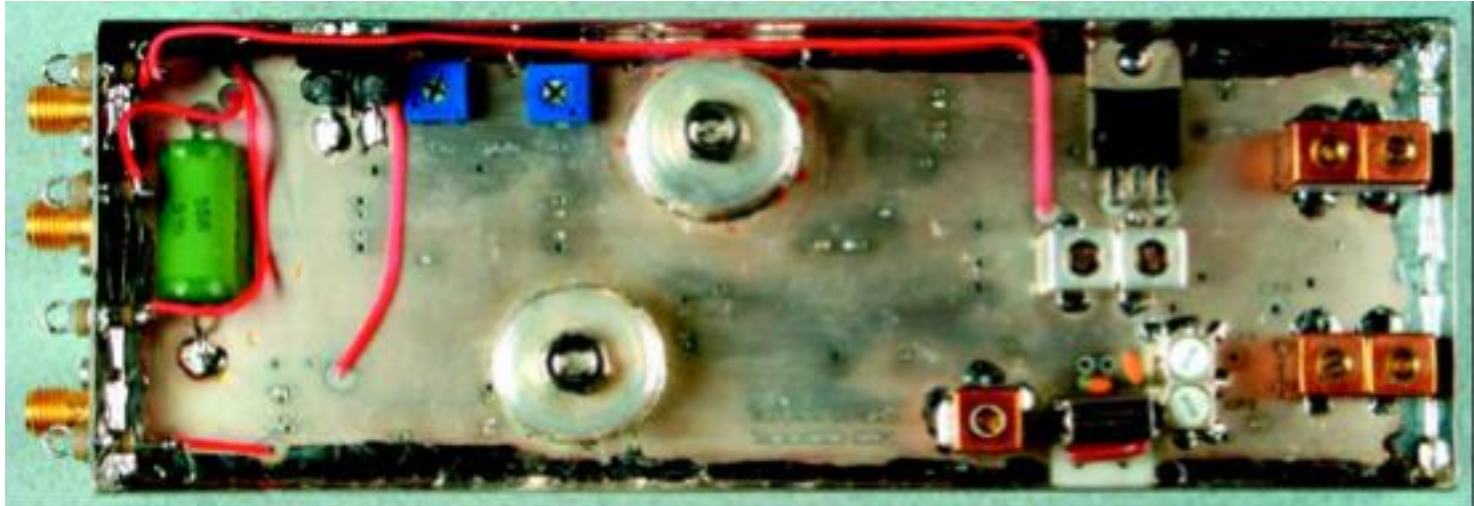
- Surplus amplifiers
- Modify surplus commercial equipment (e.g. “White Box”)
- Commercial ham transverters, power amps, pre-amps available (DB6NT, DL2AM, I3OPW, DEMI)
- Homebrew



# Microwave Transverter

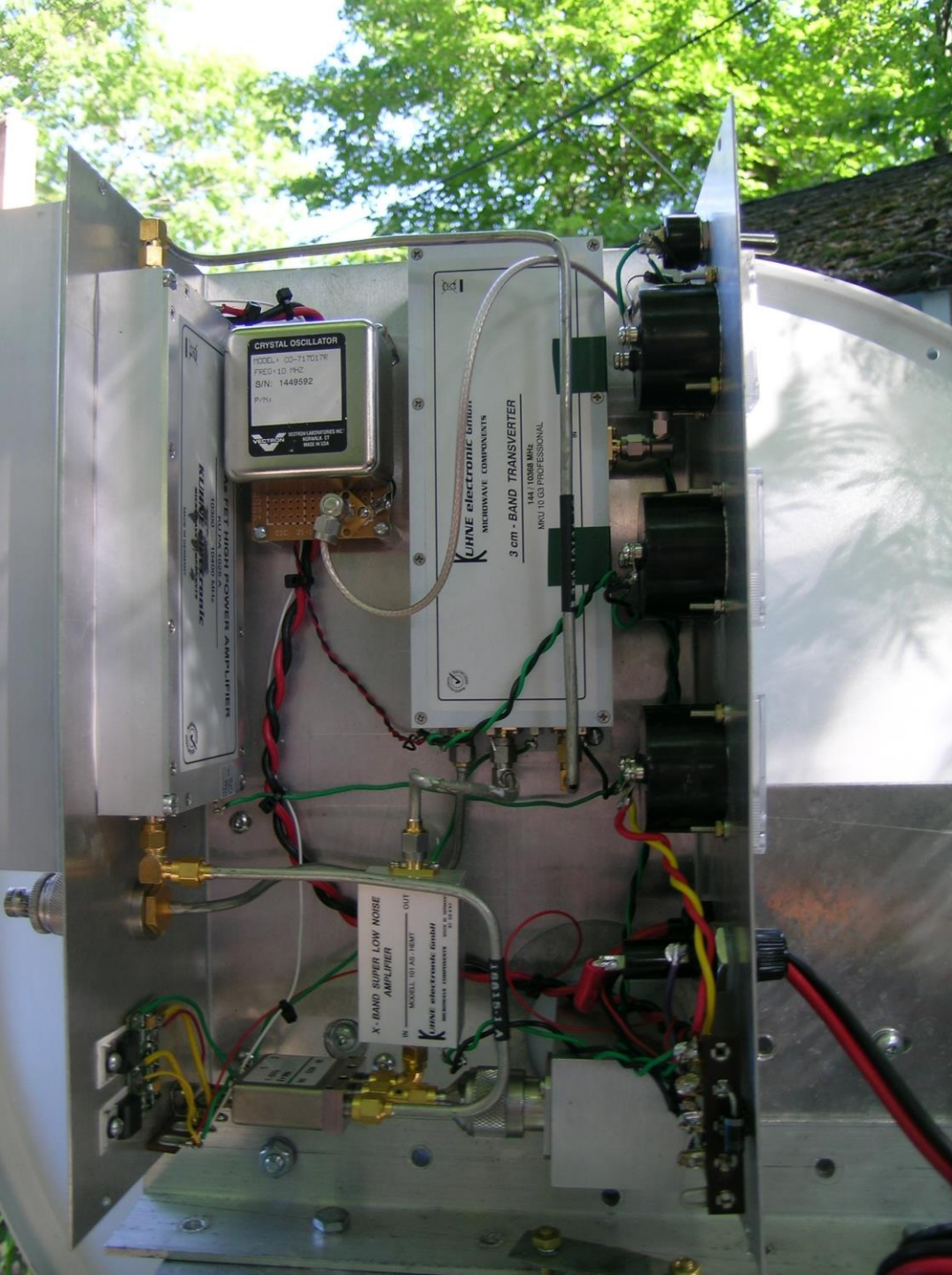


# DB6NT 10 GHz Transverter



LO, Mixer, Tx/Rx control, Image filters, 10 GHz Rx and Tx amplifiers in one package

1.2 dB NF Rx, 200 milliwatts Tx



# 10 GHz

DB6NT Transverter

LO, Mixer, Filter, Rx & Tx  
amplifiers in one box

LO phase-locked to 10 MHz OCXO

1.2 dB NF, 200 mW out

DB6NT Pre-amp

0.8 dB NF

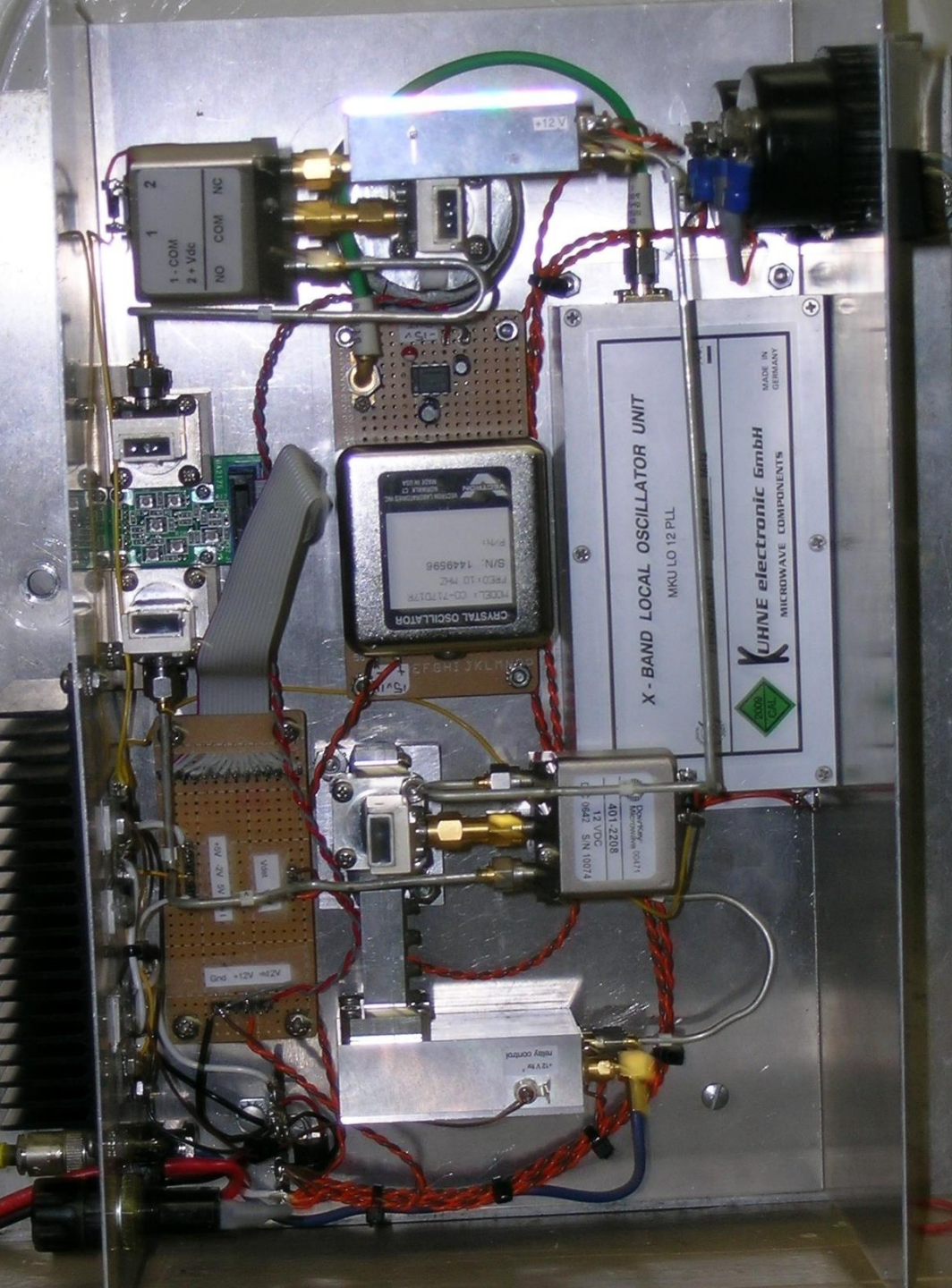
DB6NT amplifier

25 Watts out

Sequencer

T/R Relay

2 foot dish



## 24 GHz

DB6NT Local Oscillator

12024 MHz

PLL locked to 10 MHz Oven Osc.

DB6NT Mixer

Doubles LO freq to 24048 MHz

Mixes with 144 MHz → 24192 MHz

400 microwatts output

8 dB NF

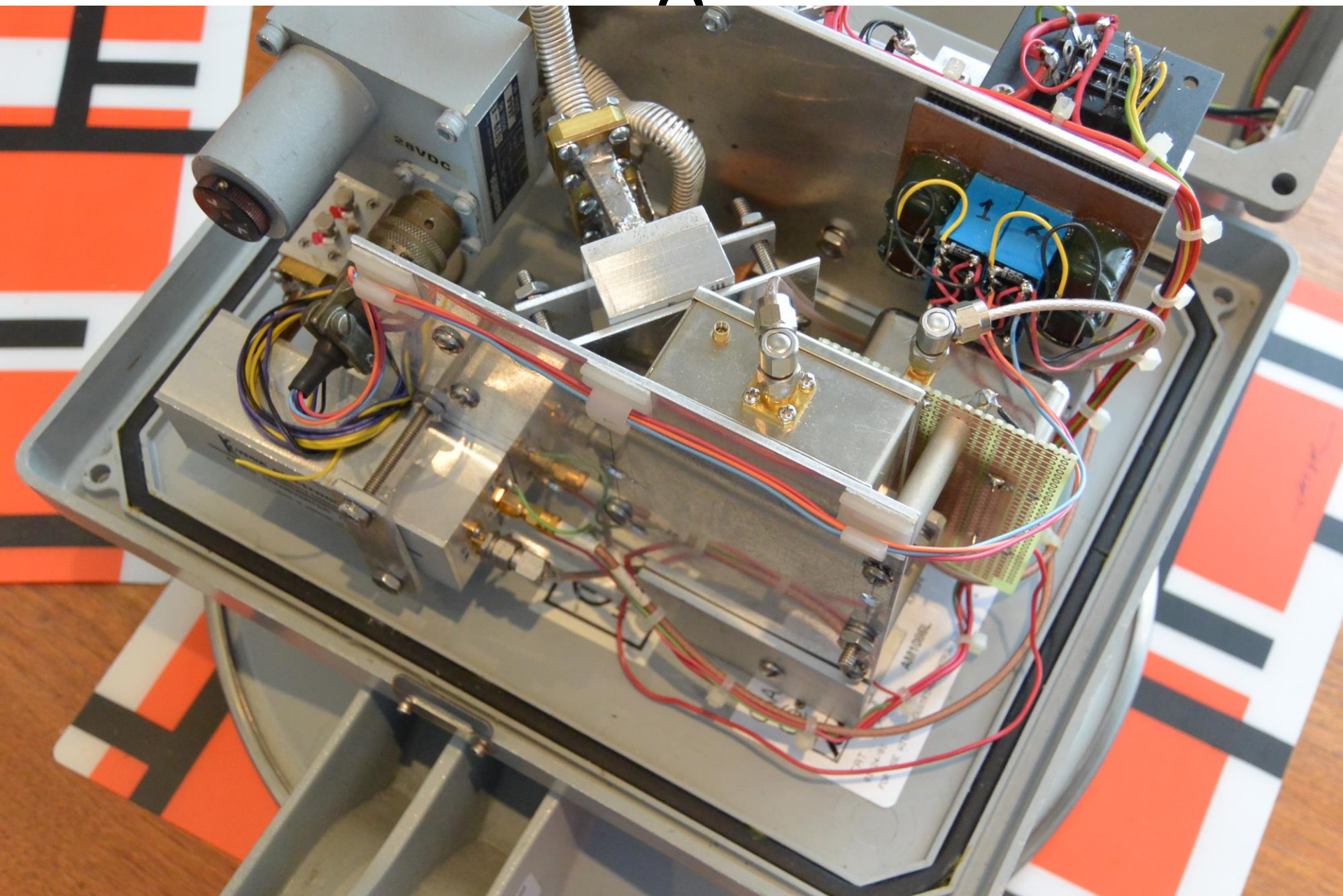
Waveguide Image Filter

DB6NT Pre-amp: 1.6 dB NF

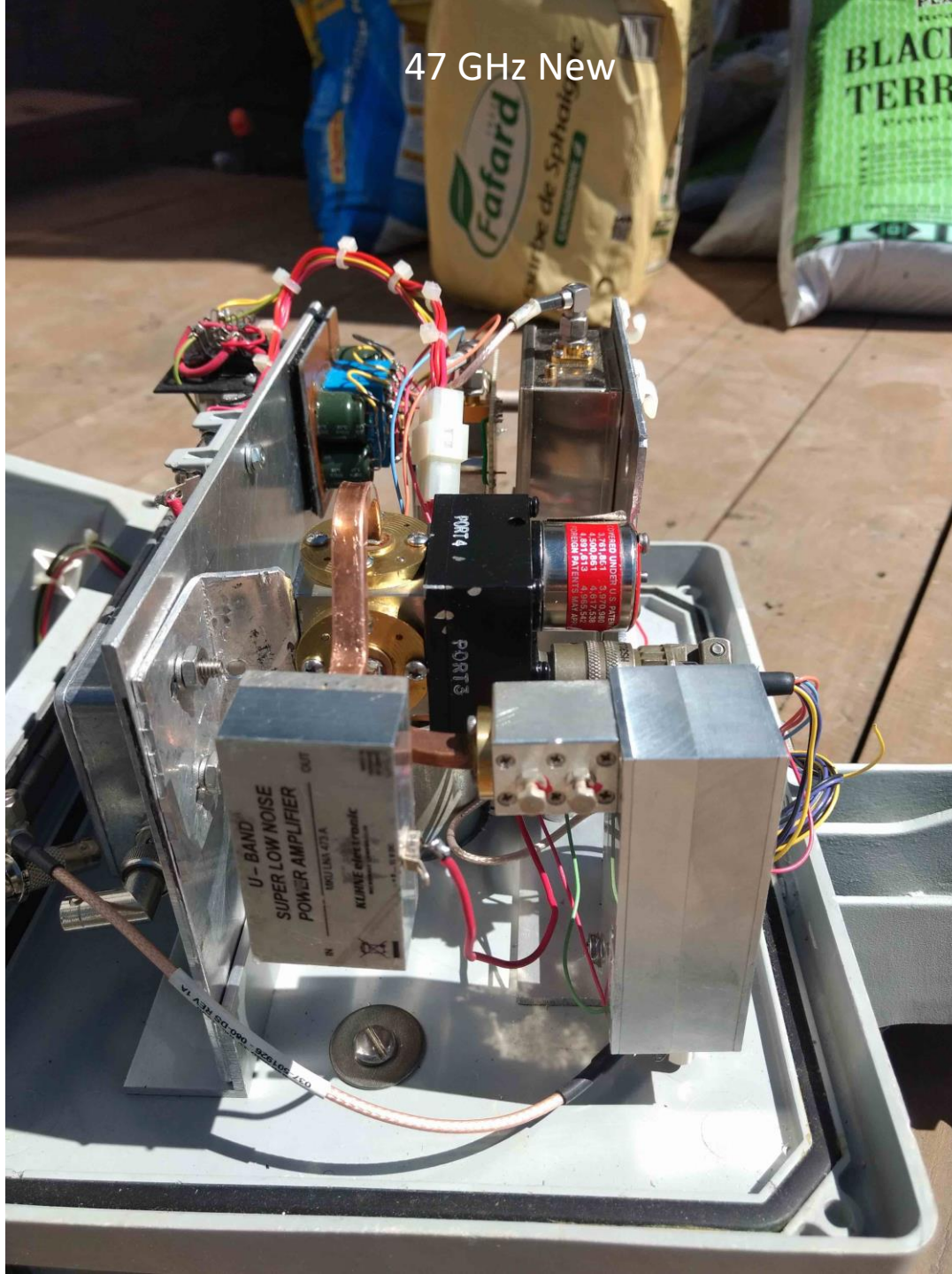
Toshiba Power Amp: 1 Watt

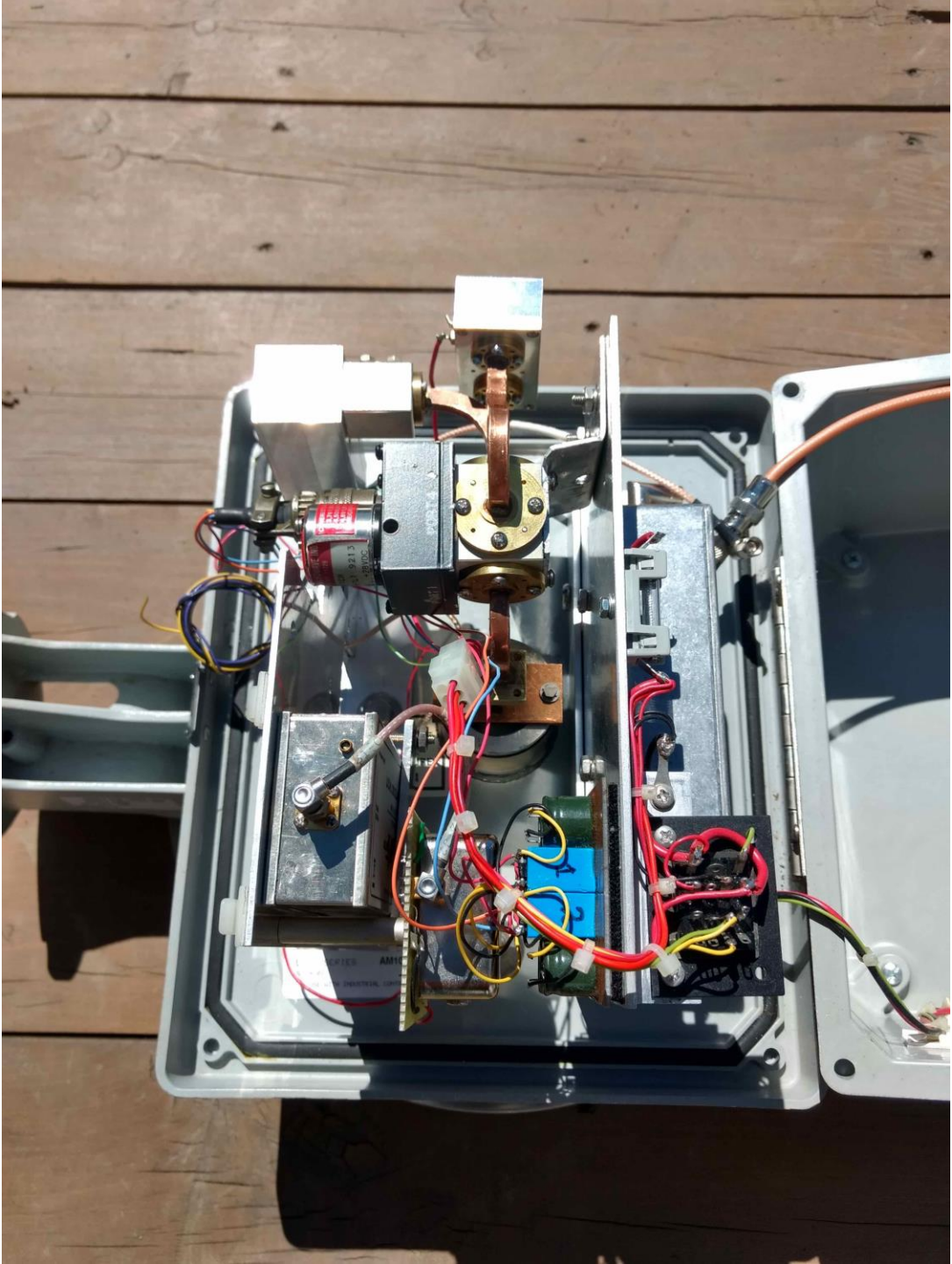
18" Dish

# 47 GHz Original



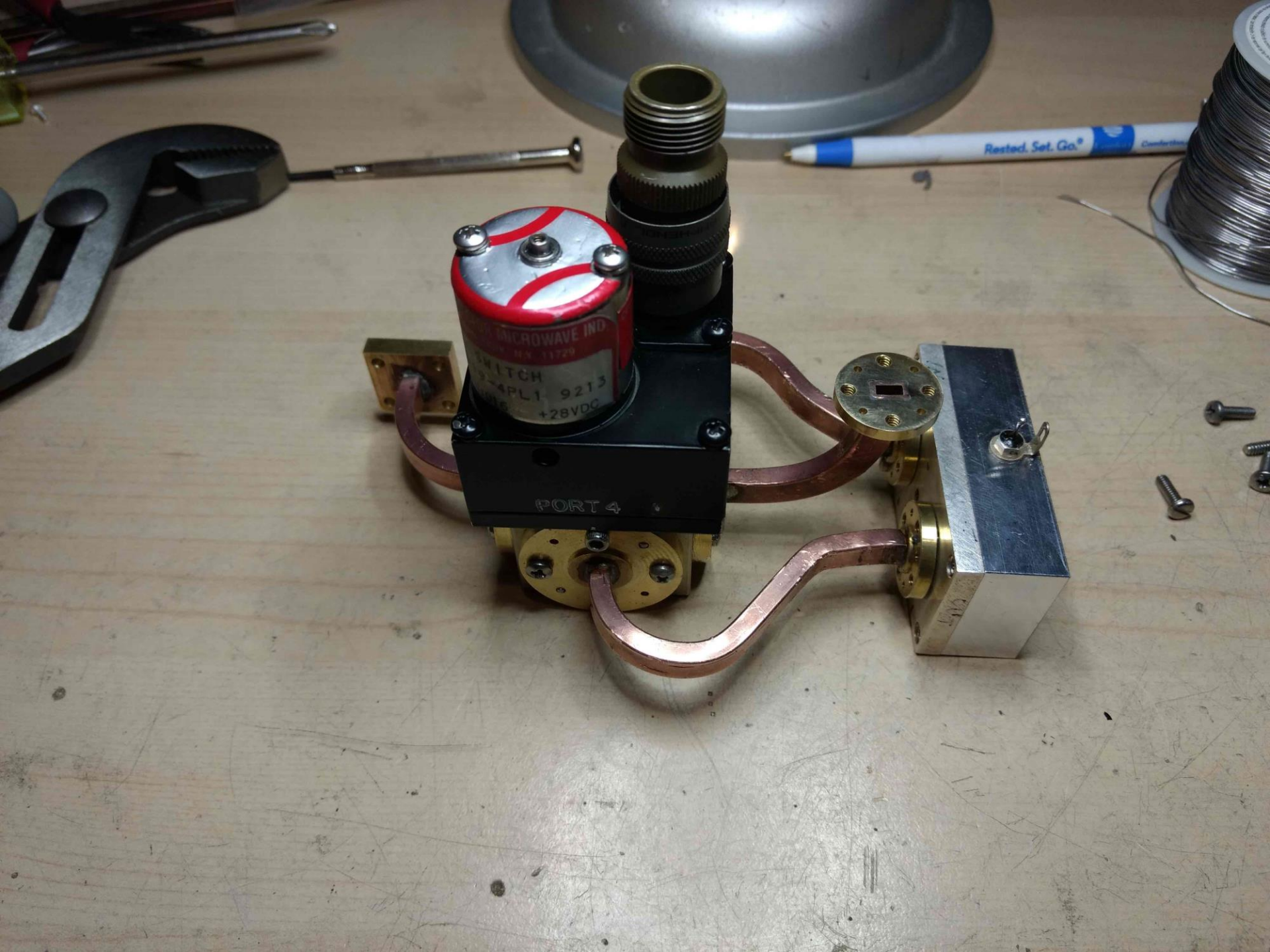
47 GHz New







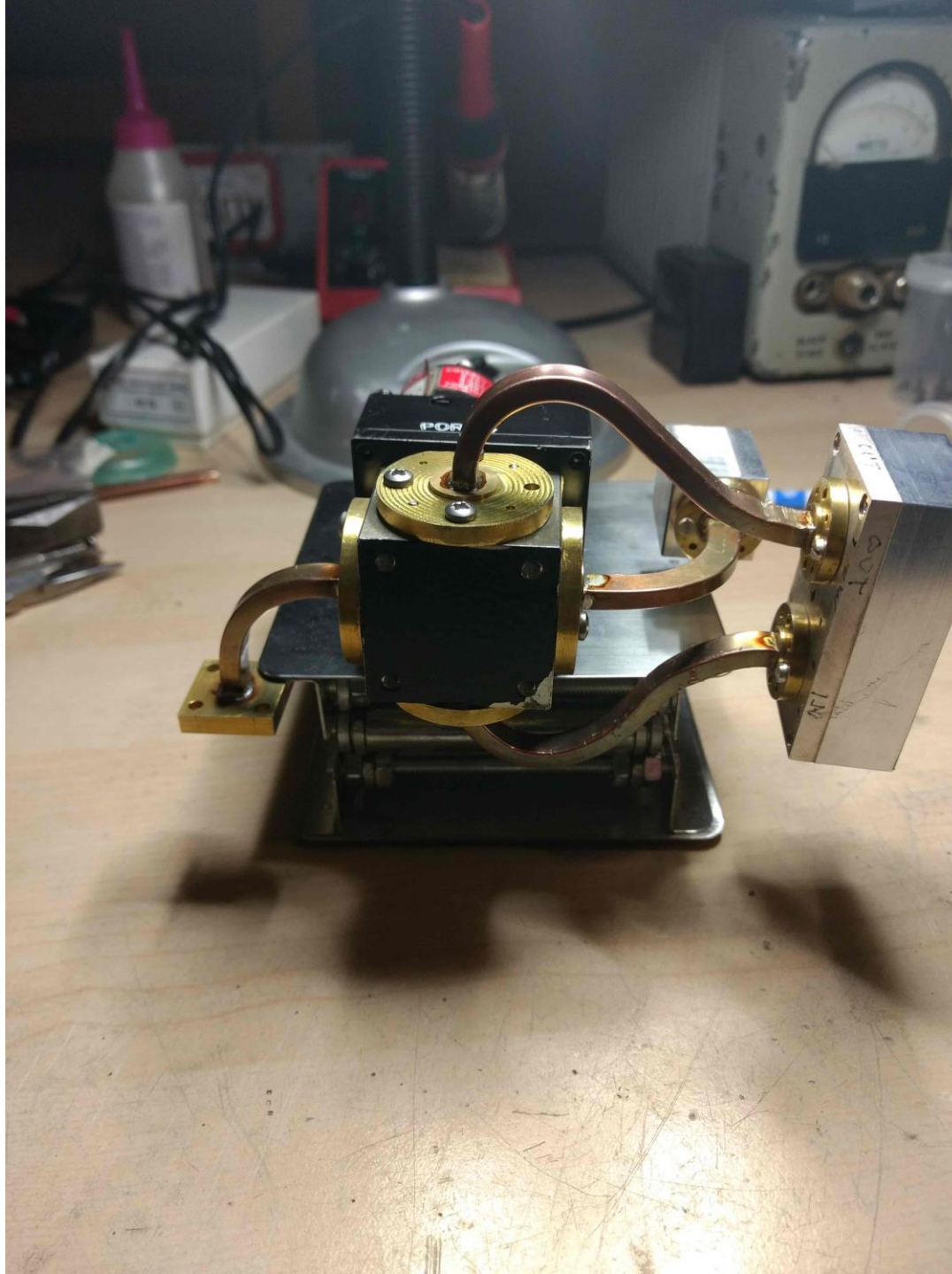


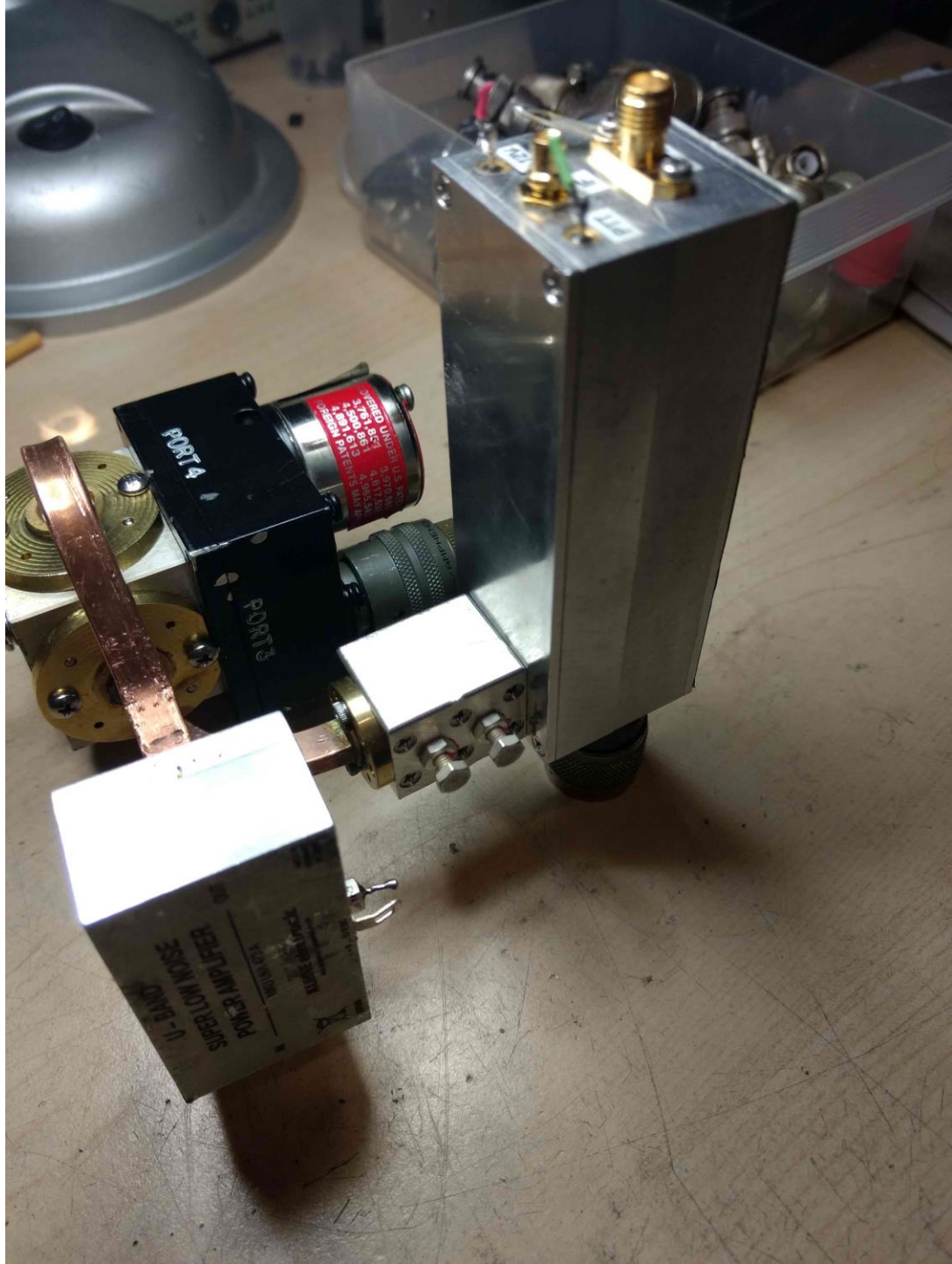


MICROWAVE IND  
SWITCH  
APL1 9213  
+28VDC

PORT 4

Rested. Set. Go.®



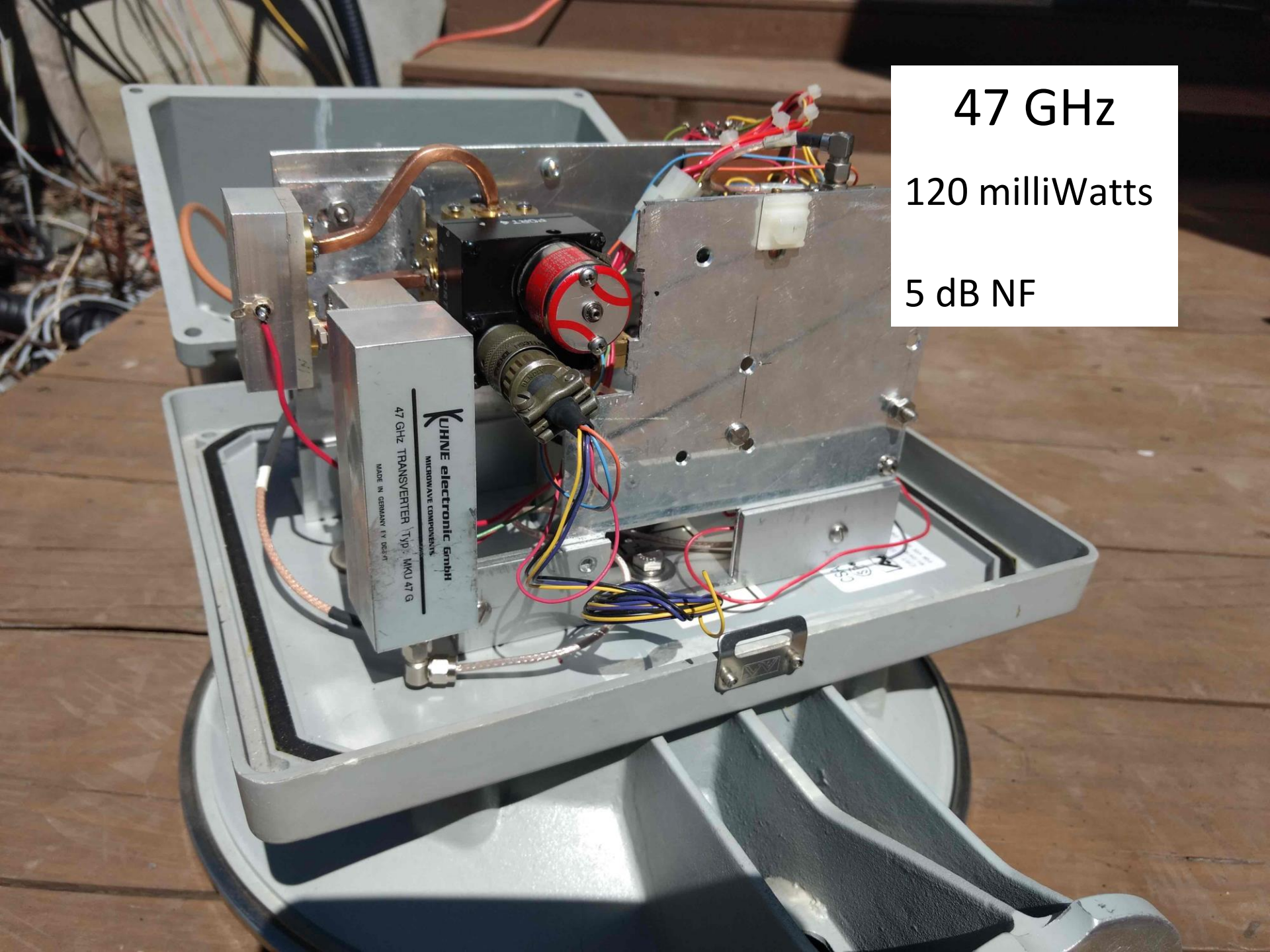


47 GHz

120 milliWatts

5 dB NF

**KUHNE electronic GmbH**  
MICROWAVE COMPONENTS  
47 GHz TRANSVERTER Typ: MKU 47 G  
MADE IN GERMANY 1 V 0624/17



78 GHz

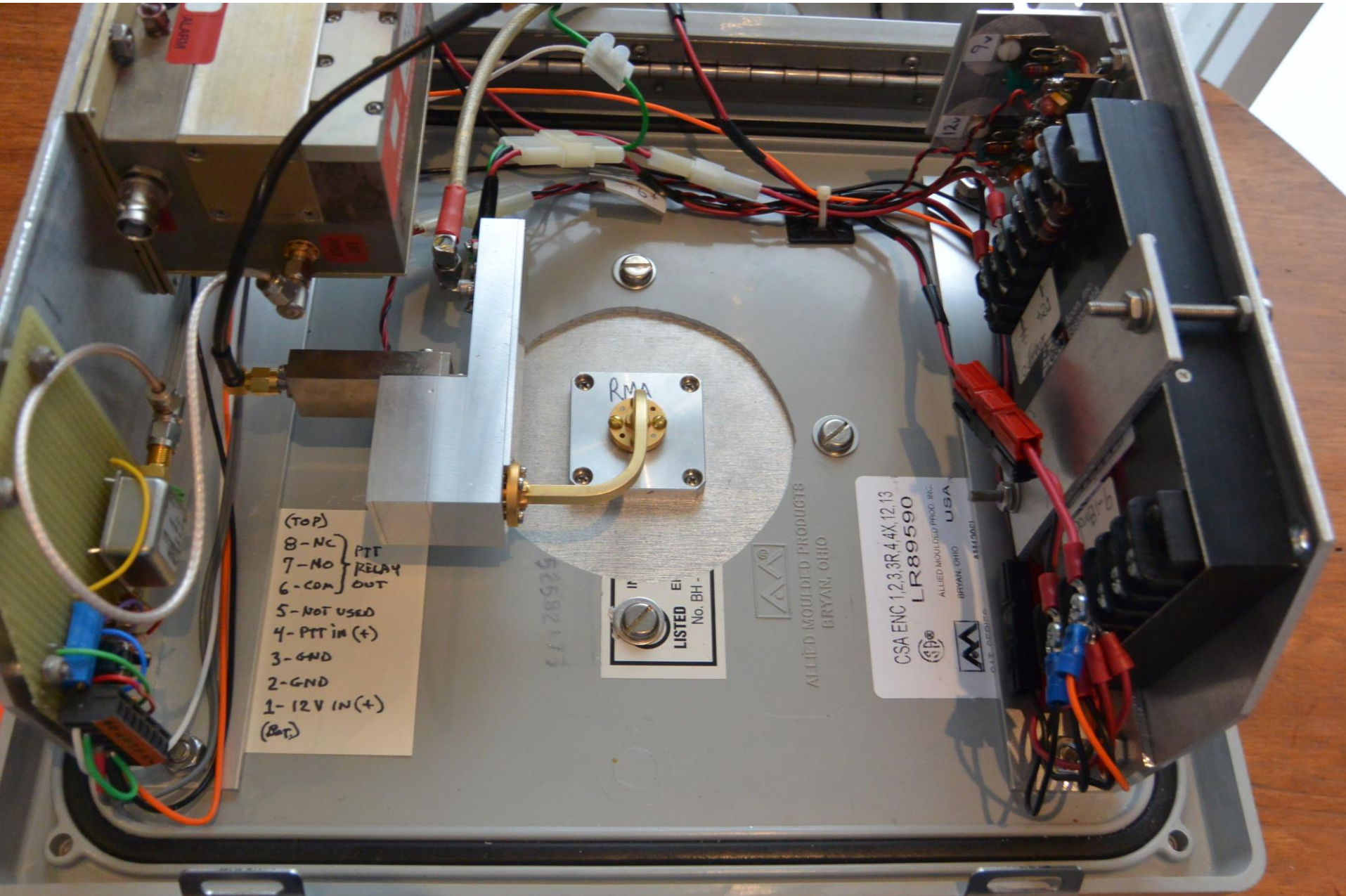
Mixer only

10 microWatts

78GHz@10 $\mu$ w  
\$630<sup>00</sup>



78 GHz



# Propagation Modes

- Line of sight
  - free-space loss + atmospheric losses
- Diffraction
- Tropospheric scatter
- Rain scatter
- Bounce off large object
- No ionospheric impact at microwave frequencies





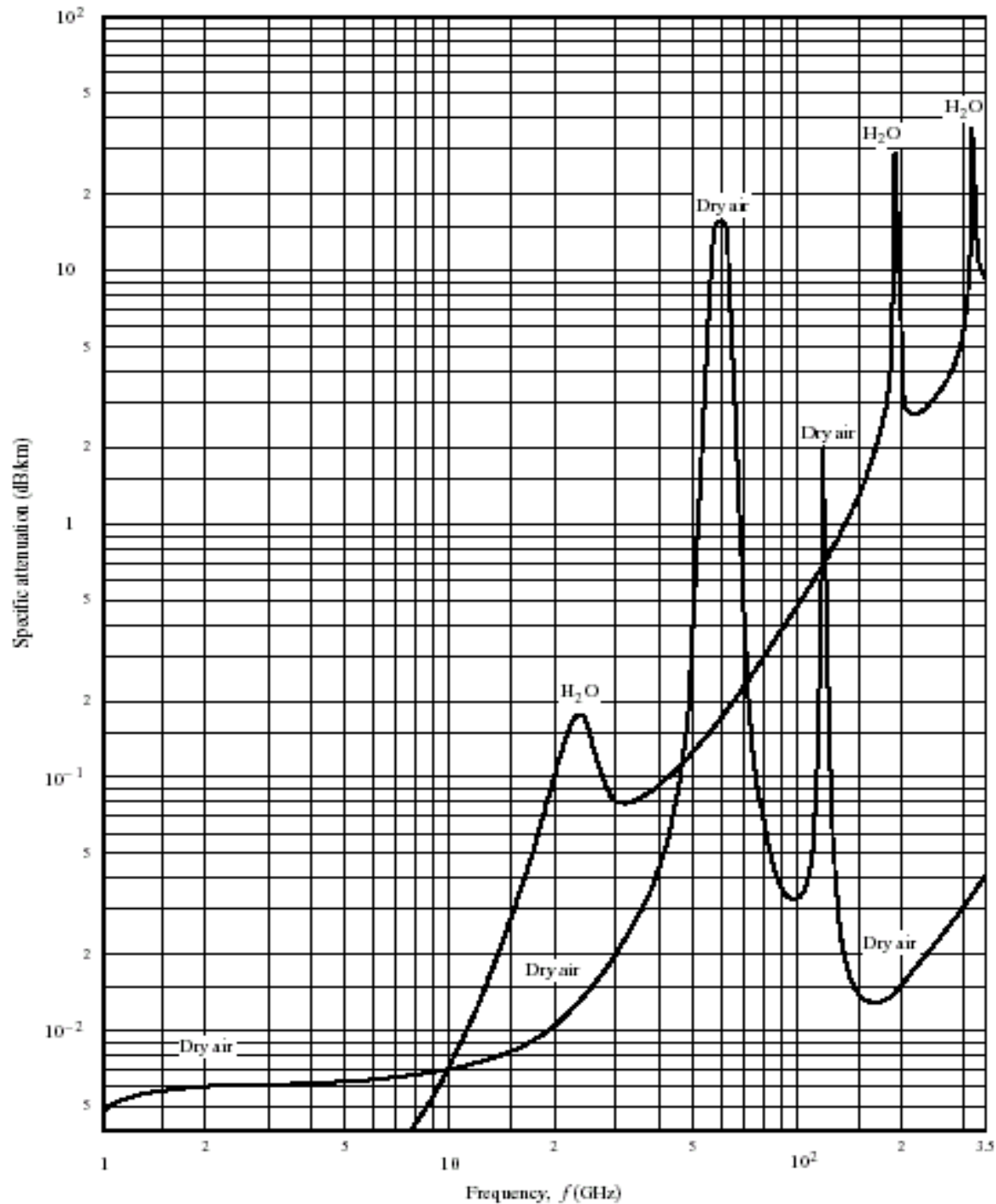
# Propagation Attenuators

- Free-space, diffraction and tropo scatter losses all increase with frequency
- Tropospheric turbulence may “break up” or distort Morse or SSB signal
  - A dash could become 2 dots
  - Doppler shift can spread signal

# Propagation Attenuators

- Local obstructions
  - Hills, buildings, etc
    - Loss increases with frequency
  - Tree leaves
    - Some attenuation at UHF
    - Attenuation increases with frequency and is substantial at 10 GHz and above
  - Water vapour (24 GHz and up)
  - Oxygen

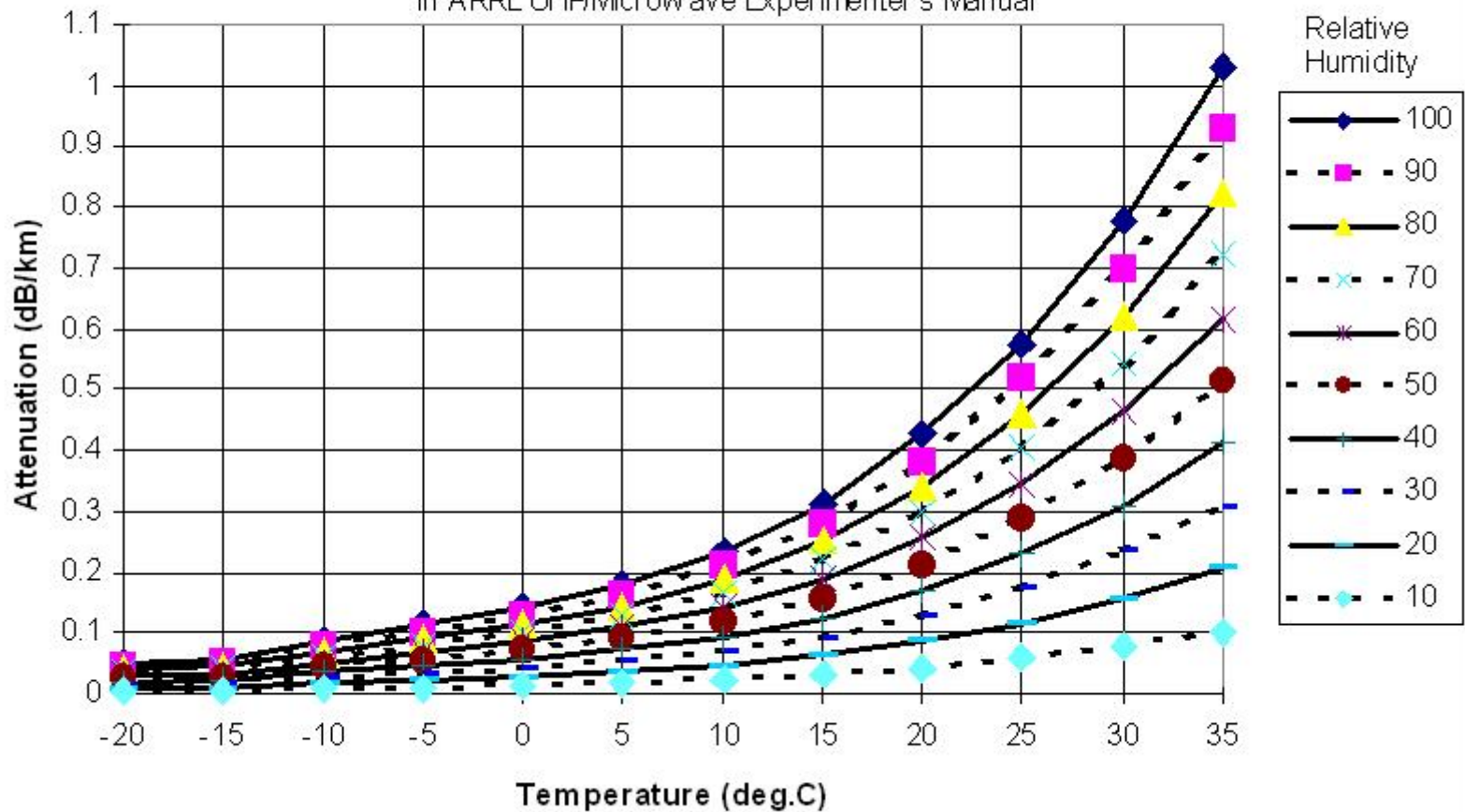
# Atmospheric Absorption



- <10GHz absorption is negligible
- >10GHz absorption becomes significant

## Water Vapour Attenuation at 24 GHz vs. Temp & Rel.Humidity

Calculated by VE3SMA based on W3EP, "UHF and Microwave Propagation"  
in ARRL UHF/Microwave Experimenter's Manual



# Propagation Enhancements

- Temperature inversion and ducting
  - Enhancement usually best:
    - in summer and fall
    - early morning or evening / night
    - can be bad for 24 GHz and up (water vapour)
  - Especially over water
    - Great Lakes and along ocean coast
    - More than 1000 km worked along east and west coast on 10 GHz
  - Small low ducts over water may propagate microwave frequencies, but not 144 MHz

# Propagation Enhancements

- Rain scatter
  - Antennas become efficient when their dimensions are in the same range as the wavelength
  - Water is polarized
  - Raindrop dimensions are typical 2-3mm
  - At 10 GHz raindrops are (small) antennas which reflect the incoming signals
    - Weather radar
  - Doppler shift
    - Caused by random (wind) movement of the 'antennas'.

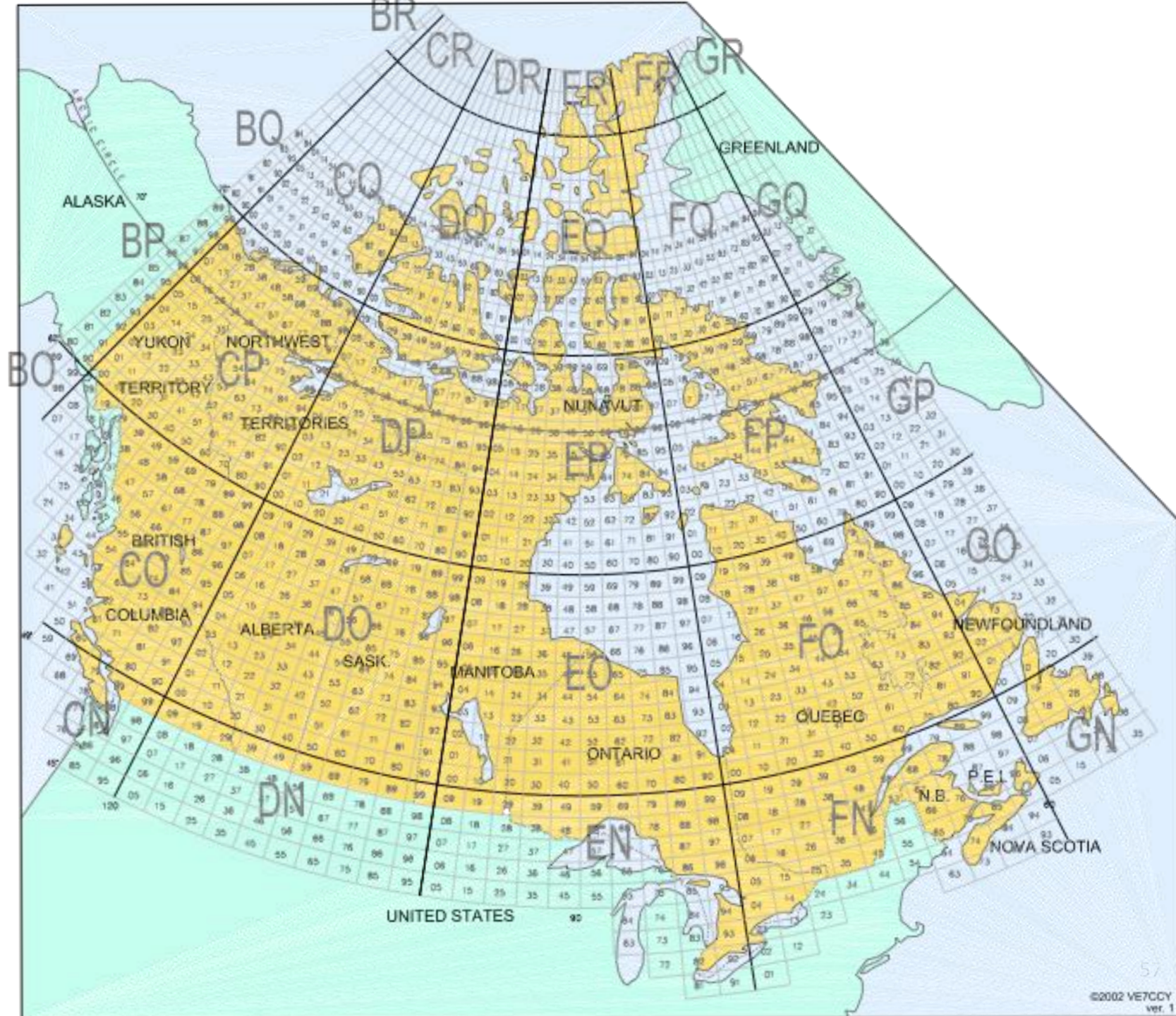
# Microwave Propagation

- Good location is a big advantage
  - High altitude & “clear horizon”
    - Tree leaves and other blockages are significant attenuators
    - diffraction and scatter losses mount quickly
  - Low “take-off” angle
    - Over water can work well (ducting)
  - Low humidity for frequencies above 10 GHz
    - Best DX in colder weather (low dew point)

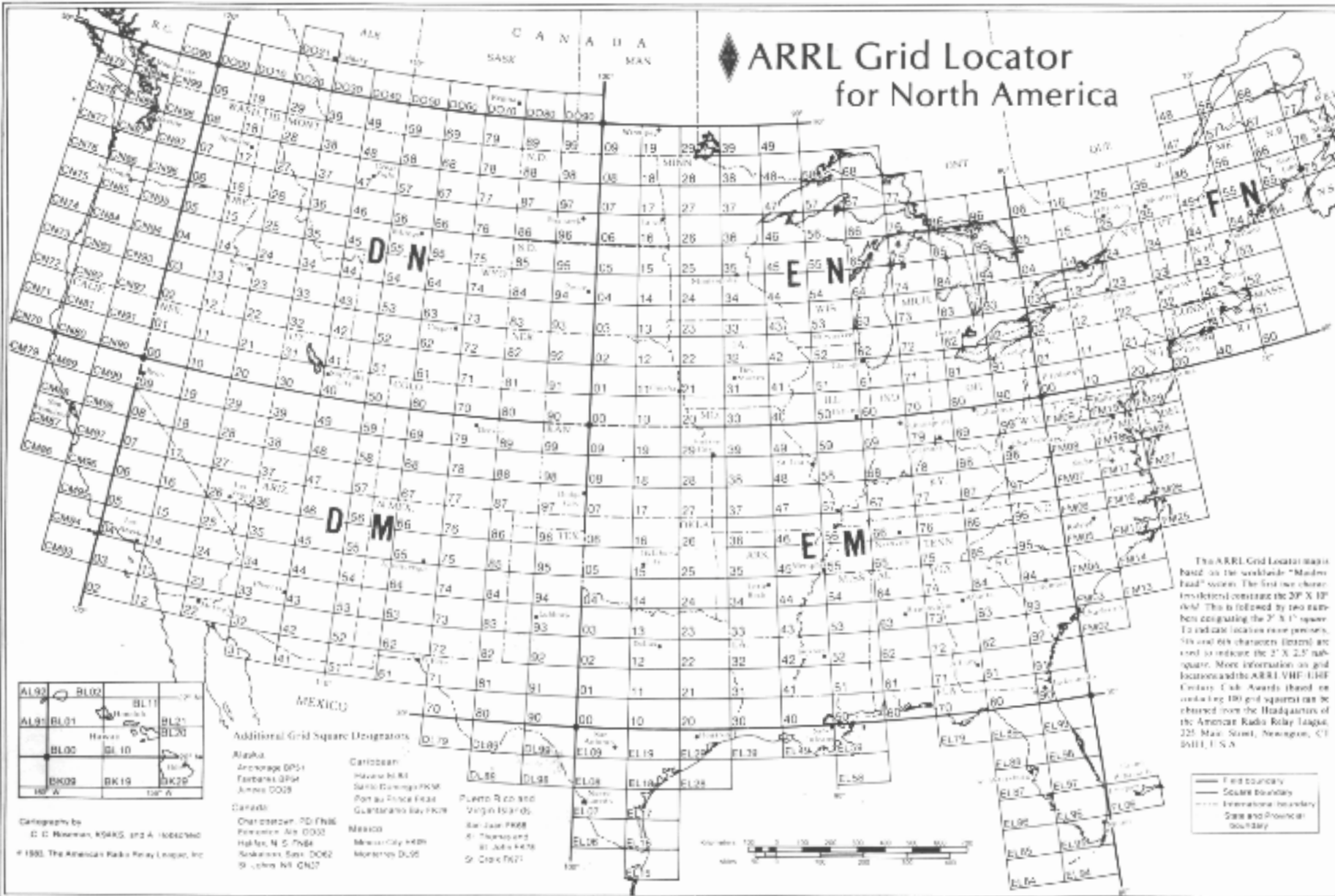
# Maidenhead Grid System

- World divided into grids:
  - 2 degrees E-W by 1 degree N-S
  - A “square” at 45 degrees N / S
- Unique reference by 2 letters & 2 numbers
  - e.g. FN25
- Further subdivided by additional 2 letters
  - e.g. FN25dk





# ARRL Grid Locator for North America



AL92	BL02	BL11
AL91	BL01	BL10
BL00	BL10	BL20
BK09	BK19	BK29

- Additional Grid Square Designations**
- Alaska**  
Anchorage GP51  
Fairbanks 3PM  
Juneau DO9
  - Canada**  
Charlottetown 7D FN6  
Halifax NS DO3  
Montreal QC 06  
Ottawa ON 07
  - Caribbean**  
Havana HI 81  
San Juan PR 8M  
Port au Prince HA 8A  
Guantanamo Bay HA 8B
  - Mexico**  
Mexico City 8M  
Monterrey DL 06
  - Puerto Rico and Virgin Islands**  
San Juan PR 8B  
St. Thomas VI 8A  
St. John VI 8B  
St. John VI 8C

The ARRL Grid Locator maps based on the worldwide "Maidenhead" system. The first two characters indicate constants of 20° X 10° grid. This is followed by two numbers comprising the 2° X 1° square. To indicate location more precisely, the last six characters (letters) are used to indicate the 2° X 2.5' sub-square. More information on grid locations and the ARRL VHF-UHF Century Club Awards (based on covering 100 grid squares) can be obtained from the Headquarters of the American Radio Relay League, 221 Main Street, Newington, CT 06111, U.S.A.

- Field boundary
- Square boundary
- - - International boundary
- State and Provincial boundary

Cartography by  
D. C. Newman, K9ARS, 372 A 10662760  
© 1980, The American Radio Relay League, Inc.



# Beacons

- A few 10 GHz and up beacons
- Closest VE2TWO on Rigaud Mountain
- Others on Mt. Mansfield VT, Mt. Washington NH, etc.

# QSO Techniques

- Antenna beam width very narrow
  - Roughly 3 degrees or less
    - Azimuth and Elevation!
  - Calling CQ futile except for very local
- Usually first contact on 144 MHz SSB
  - Identify exact location (6 digit Maidenhead grid square – e.g. FN25bl)
  - Confirm antenna bearings

# QSO Techniques

- One station sends continuous dashes
- Other station tunes (freq. errors)
- When found, peaks antenna and reports success on 144 MHz liaison
- Second station may then send dashes or start QSO by sending calls plus grid

# Local Sites

- Gatineau Park, Quebec (FN25bl, FN25bm)
  - Brule, Champlain outlooks
    - blocked to East and SE
  - King Mountain trail
    - Clear from East to West through South
  - Both 1150 feet ASL
- Mont Tremblant, Quebec (FN26rf)
  - 2850 feet ASL
- Foymount, Ontario (FN15ik)
  - 1750 feet ASL

# Local Sites

- Mont Ste. Marie, Quebec (FN25bw)
  - 1800 feet ASL
  - clear horizon



**Gatineau Park**

**King Mountain Trail**



# Mont Tremblant



Mont Tremblant





**Foymount: East (telephoto)**

**Foymount South**



# Mont Ste Marie





Mont Ste Marie

# Mont Ste Marie



# Personal Achievements

- 10 GHz
  - 600 km
- 24 GHz
  - 234 km
- 47 GHz
  - 215 km
- 78 GHz
  - 28 km



# Ottawa & Montreal Stations

Ray VE3FN

Luc VE3JGL

Dean VA3CDD

Rene VE2UG

Jimmy VE2JWH







**Any Questions ???**