Amateur Microwave Communications 10 GHz and Up

Ray Perrin VE3FN, VY0AAA

February 2019

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.

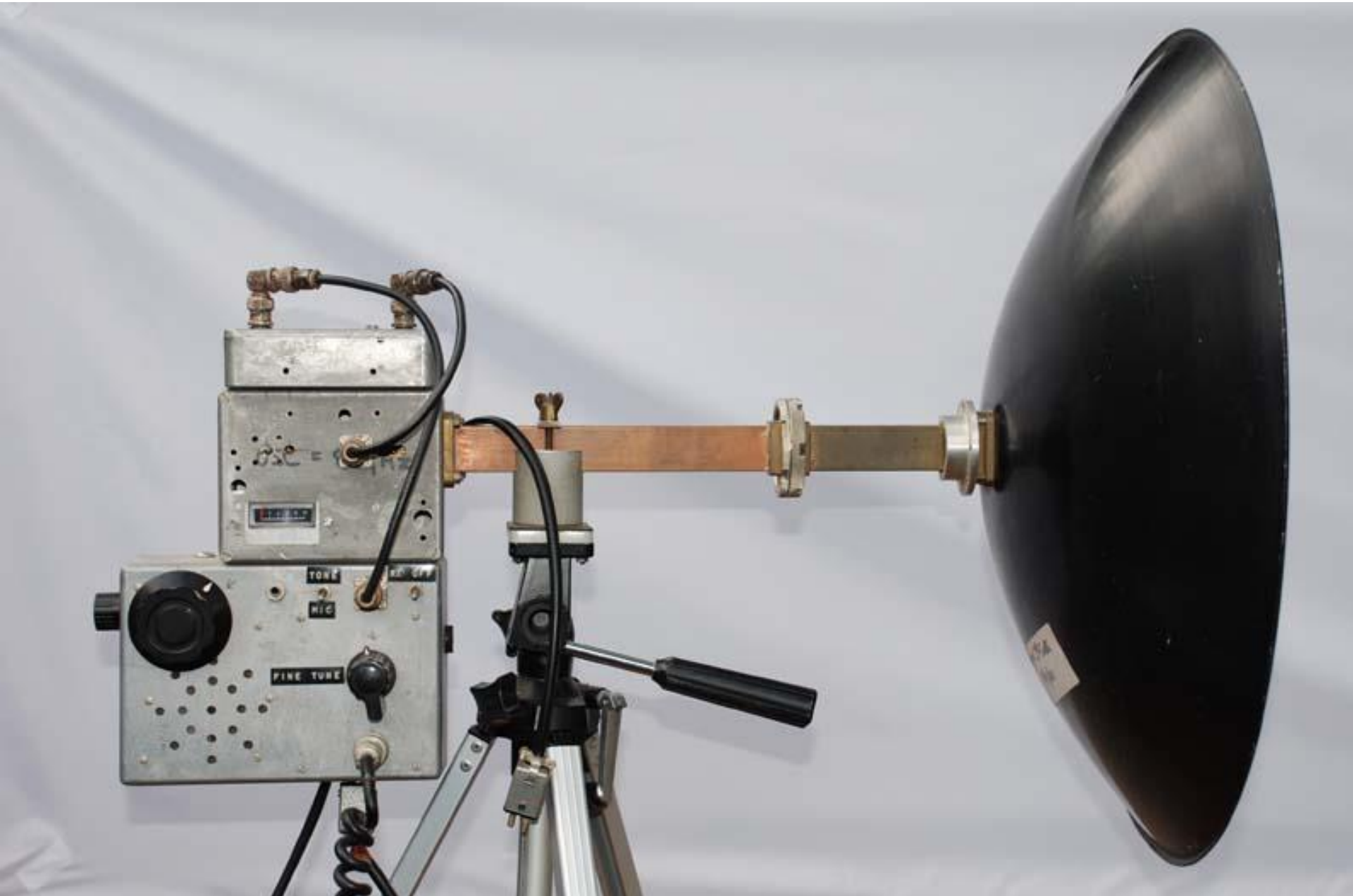
Wideband FM: 1950s, 60s

- 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

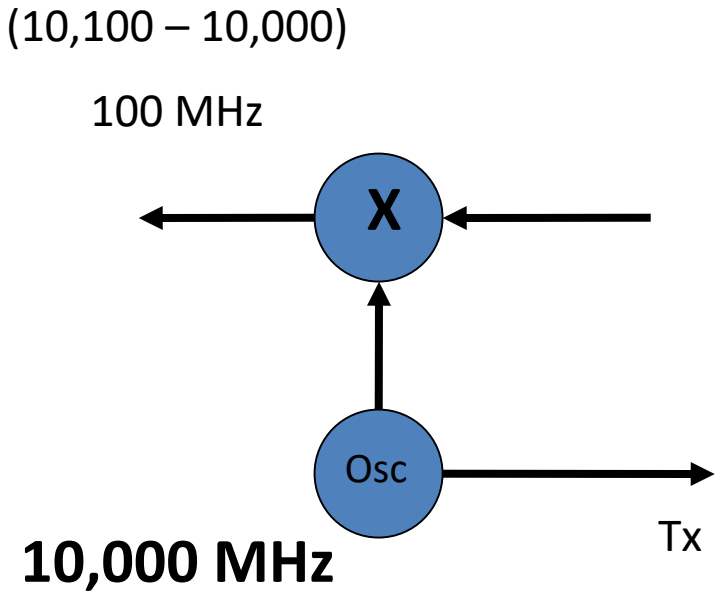
Modified Tellurometer

Wideband FM 1970s

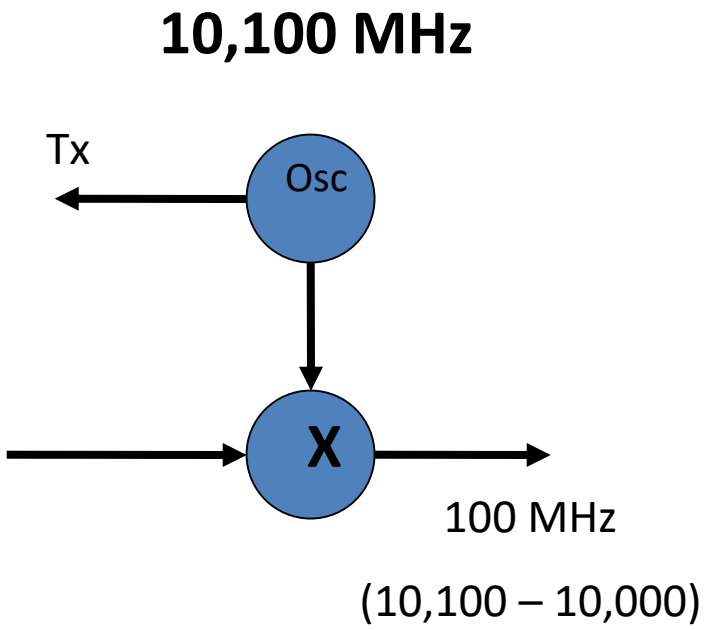
- Gunn diode replaces klystron (Gunnplexer)
- Otherwise, similar technologies
  - No preamp or power amp
- Max range still typically 50 – 100 km over land
- Source of equipment:
  - Modified burglar alarm
  - Commercial from ARR
    - produced station complete with IF radio and horn antenna

Gunnplexer

Wideband FM Communications



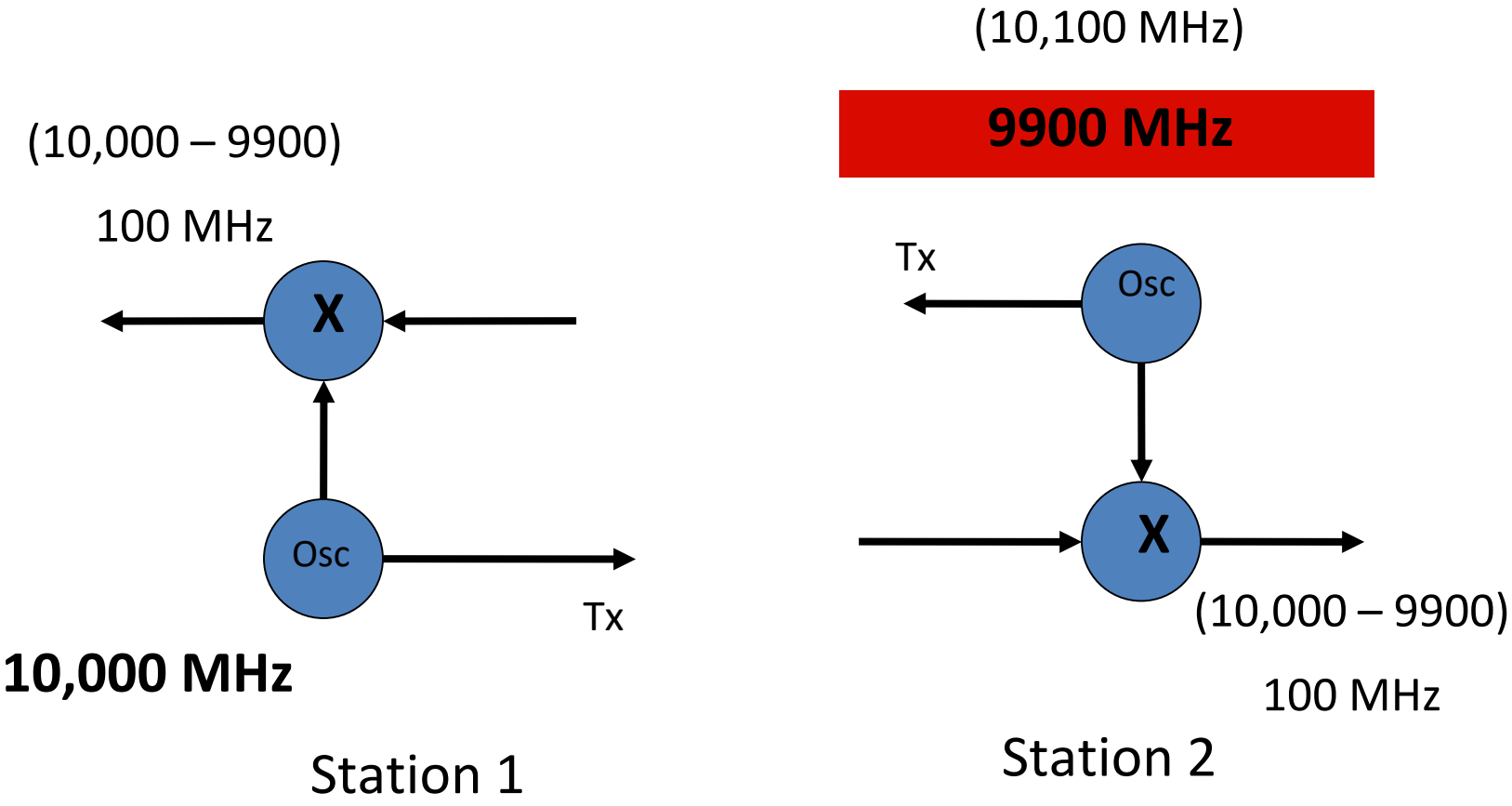
Station 1



Station 2

Each station has IF of 100 MHz

Wideband FM Communications



Each station has IF of 100 MHz

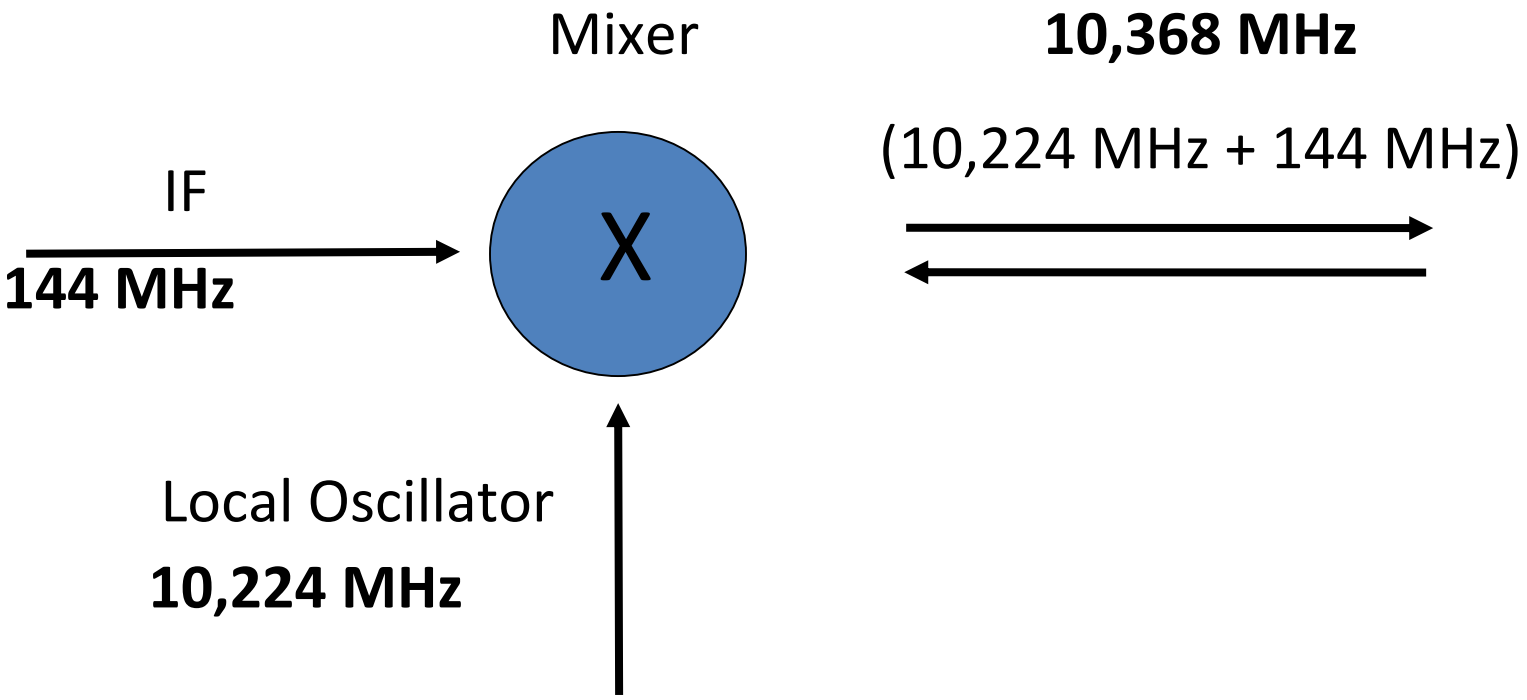
Narrowband

- 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

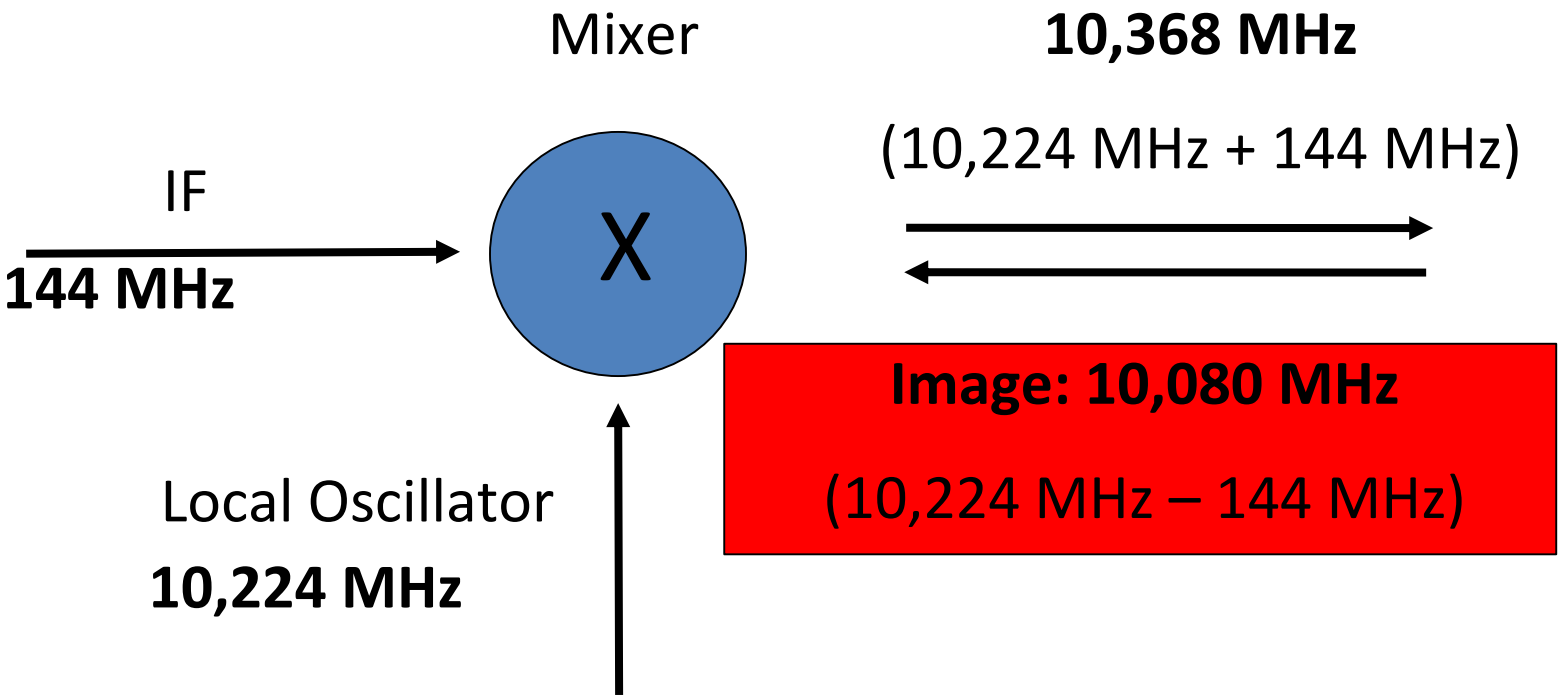
- Transverter
  - Transmitting / Receiving converter
  - Transmit
    - VHF / UHF IF source (typically 144 or 432 MHz) mixed with LO to produce microwave signal
    - usually power amplifier
  - Receive
    - microwave received signal mixed with LO to produce VHF / UHF output
    - usually RF amplifier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

Narrowband



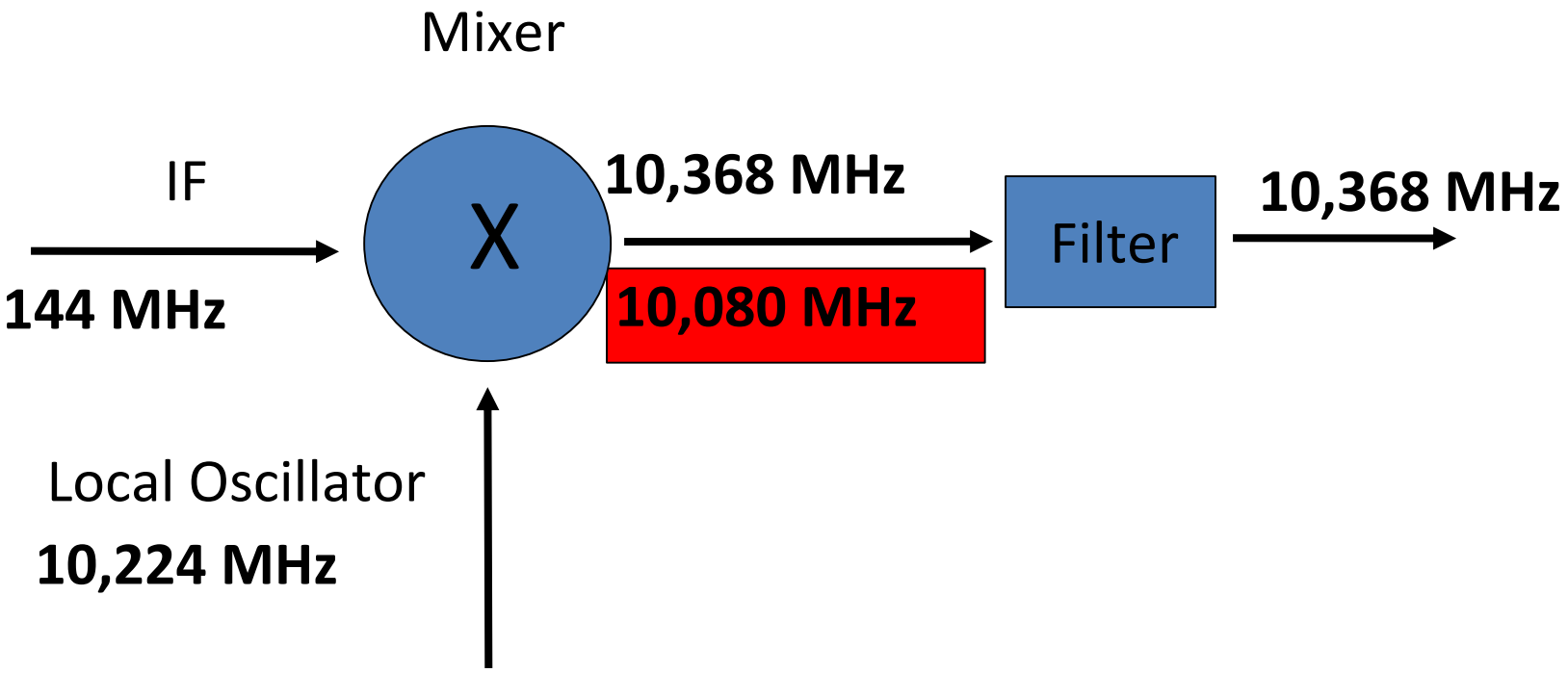
Simple Transverter: 10,368 MHz

Narrowband



Simple Transverter: 10,368 MHz

Narrowband



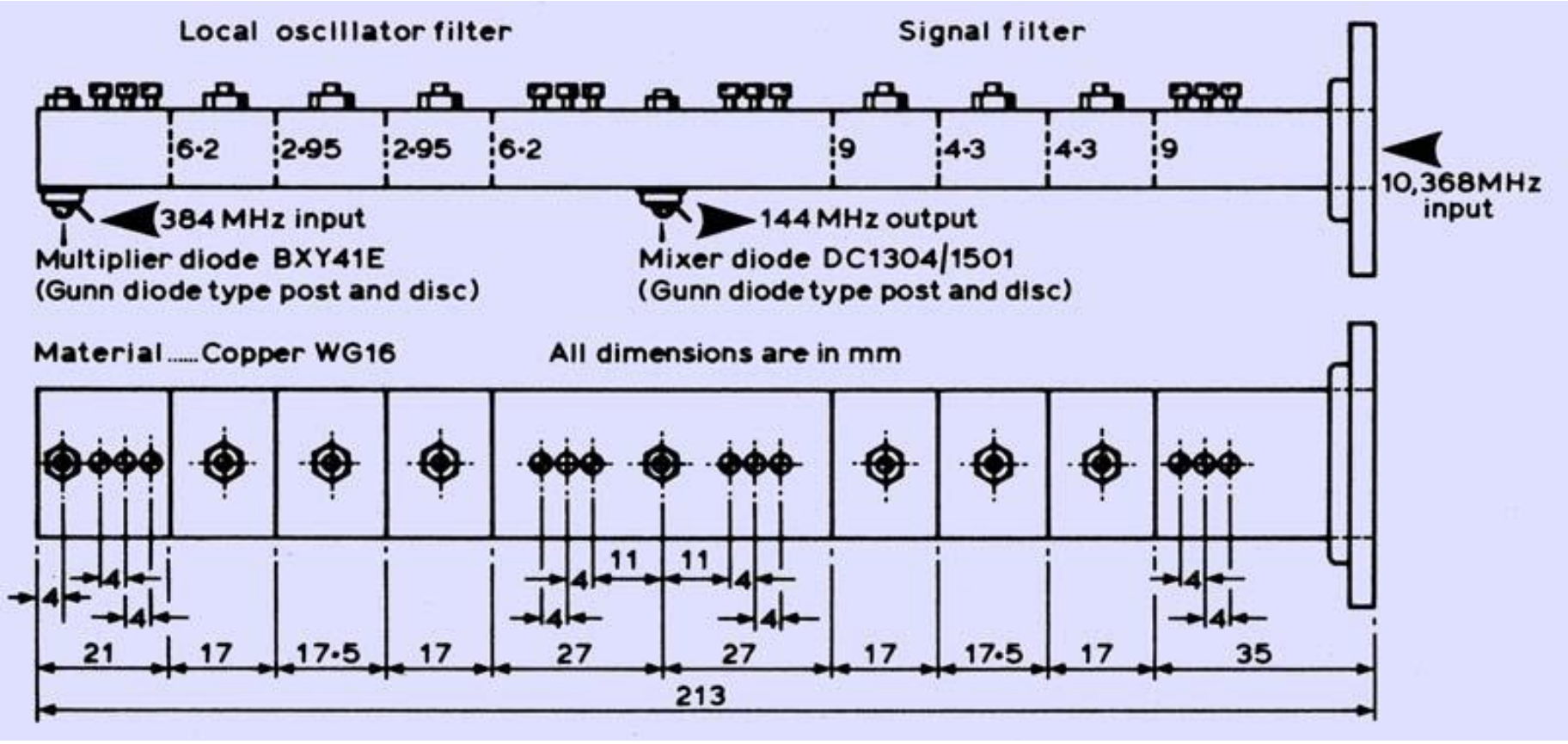
Simple Transverter + Image Filter: 10,368 MHz

Narrowband

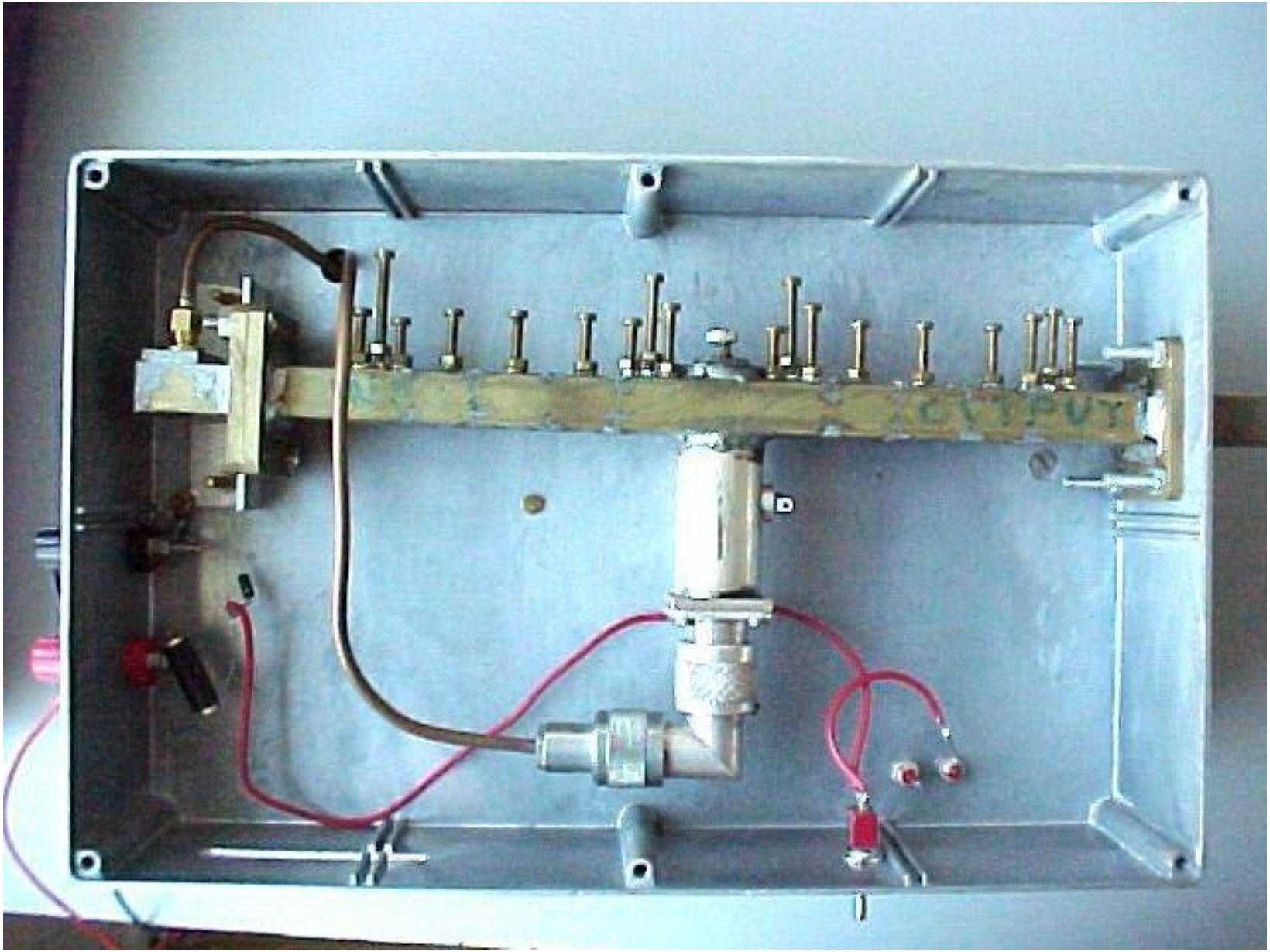
- 1979: G3JVL waveguide 10 GHz transverter
  - Tuned circuits in waveguide
  - 378.666 MHz LO input to harmonic generator
  - 10,224 MHz harmonic of LO selected by waveguide filter and fed to diode mixer
    - Tx: Mixed with 144 MHz and filtered 10,368 MHz
    - Rx: 10,368 MHz Rx filtered and mixed 144 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

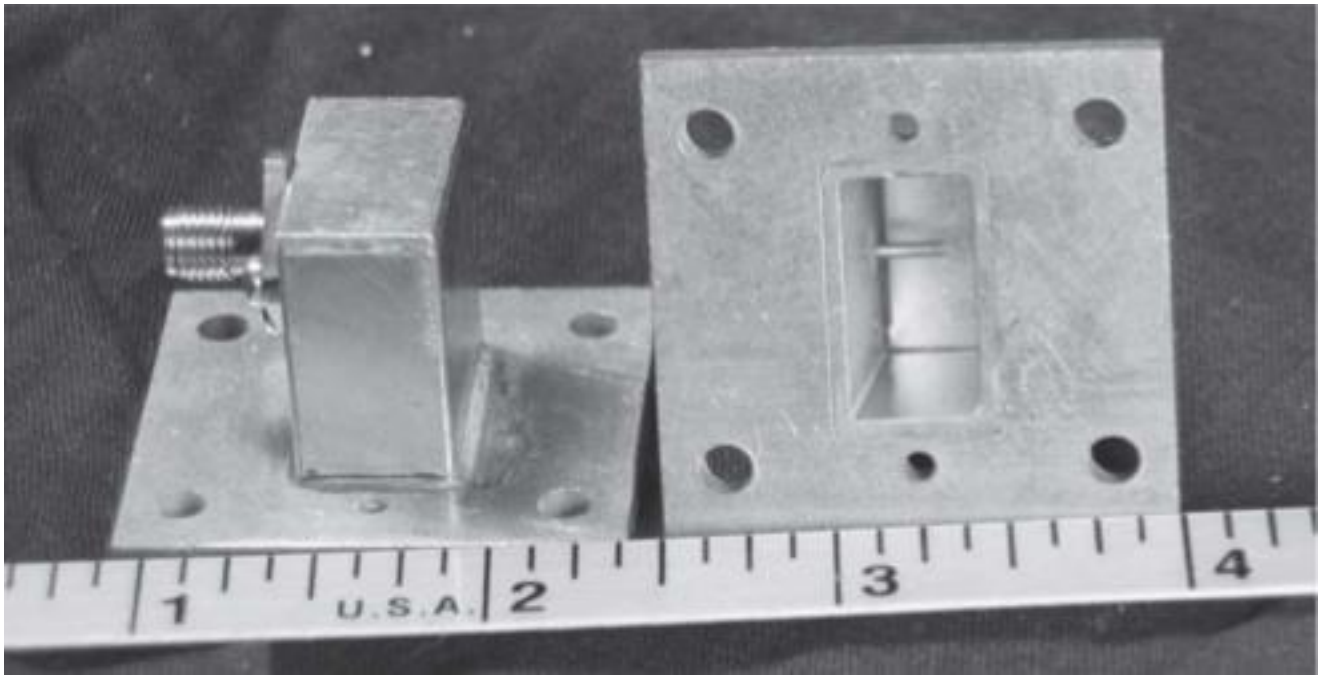
January 1979



G3JVL 10 GHz Waveguide Transverter



Key Components



Waveguide to Coax Transition: 10 GHz

Key Components

Semi-rigid Coax with SMA Connectors

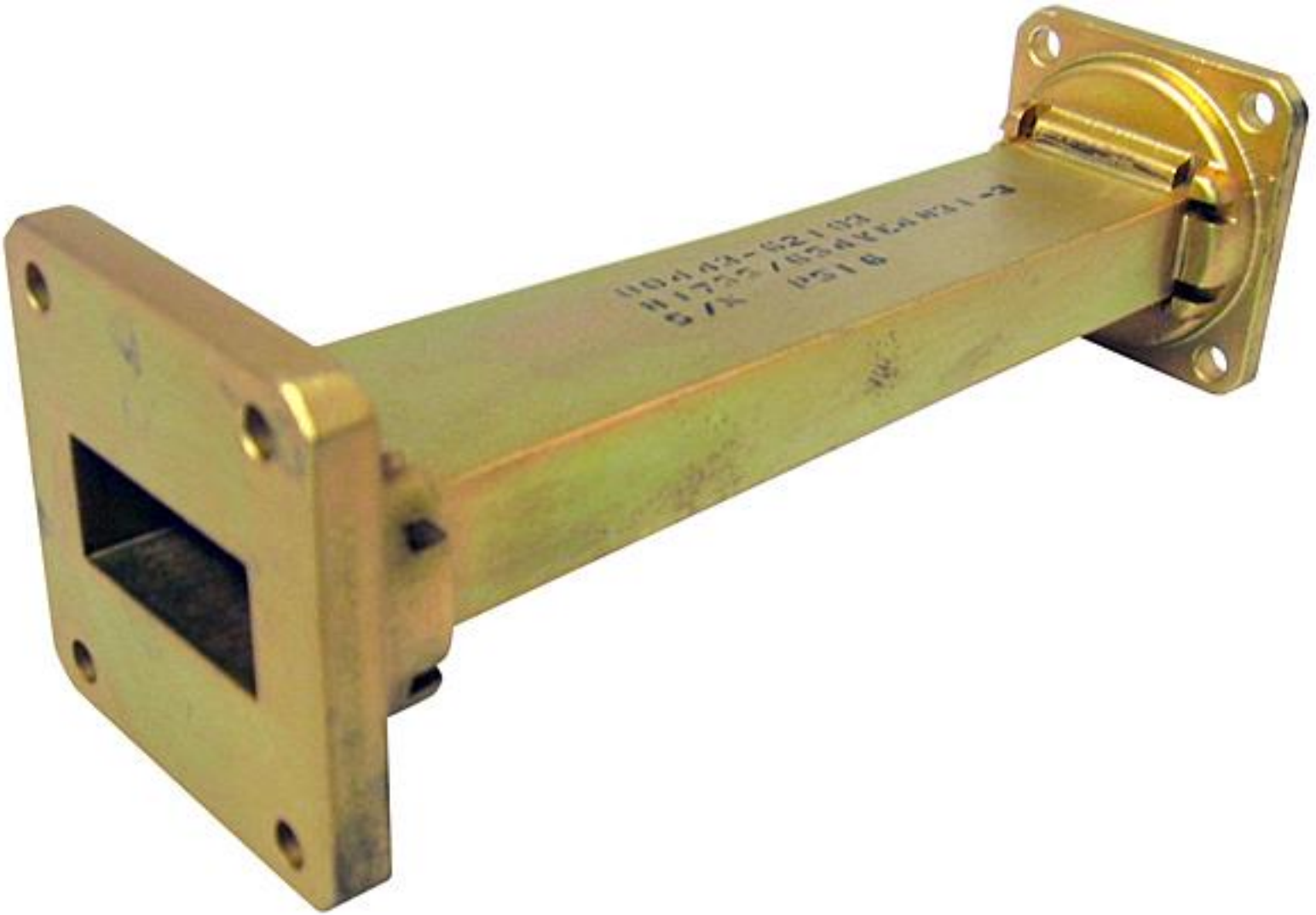
UT-141: 0.5 dB / Foot @ 10 GHz (approx.)

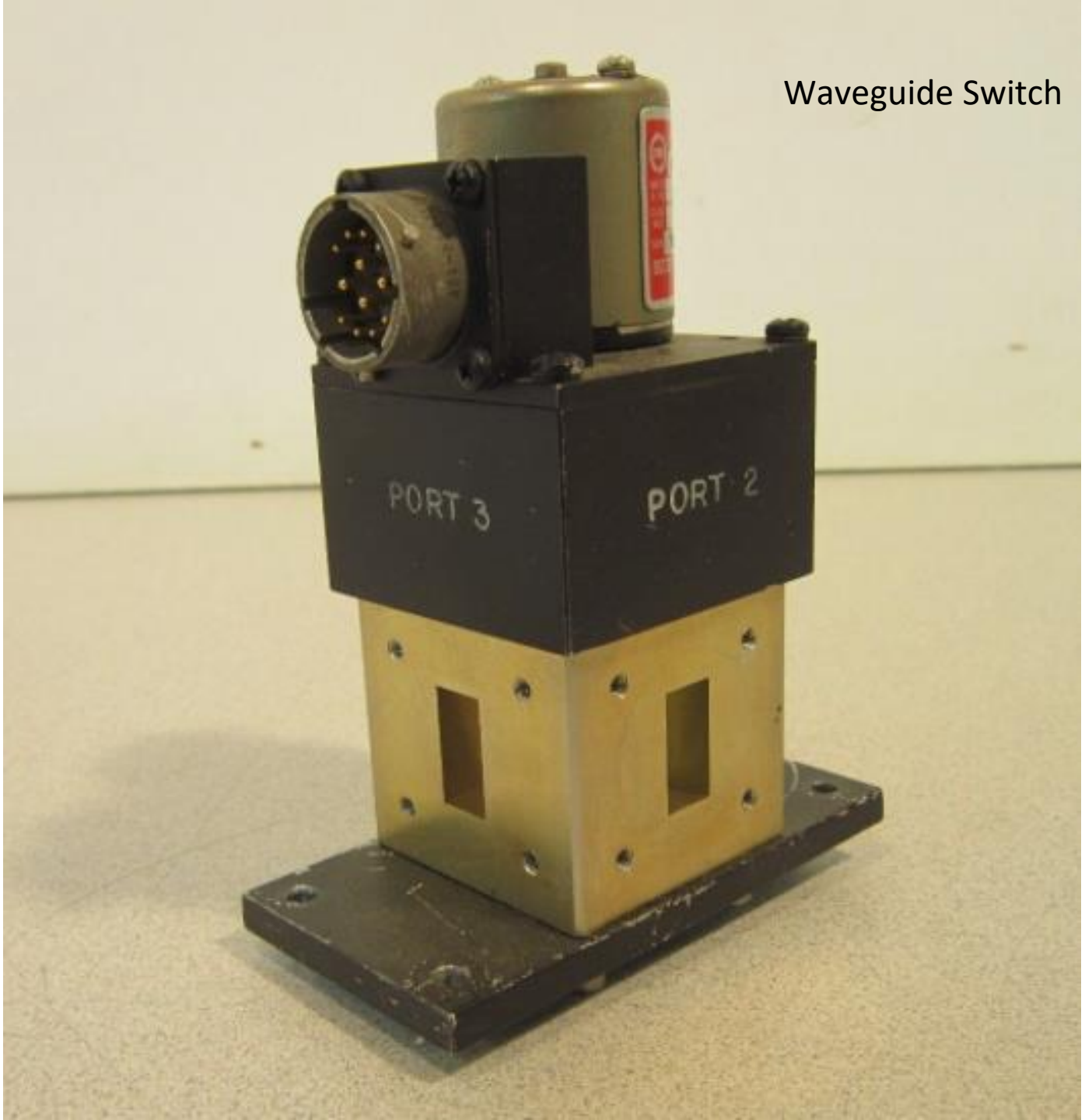
UT-085: 1.2 dB / Foot @ 24 GHz (approx.)

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 72nd and 168th 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 !!

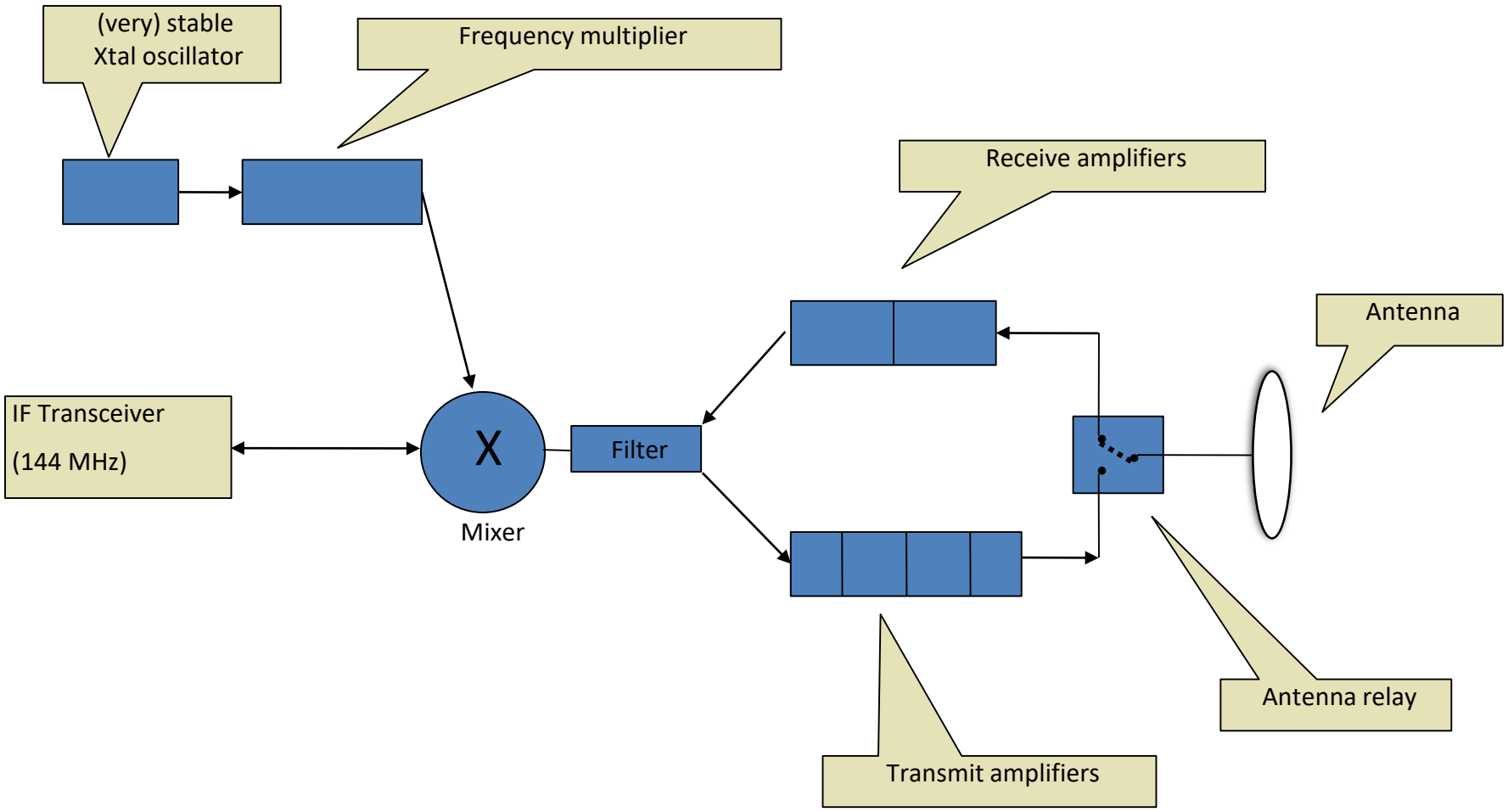
Local Oscillator Frequency Accuracy and Drift

- 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.

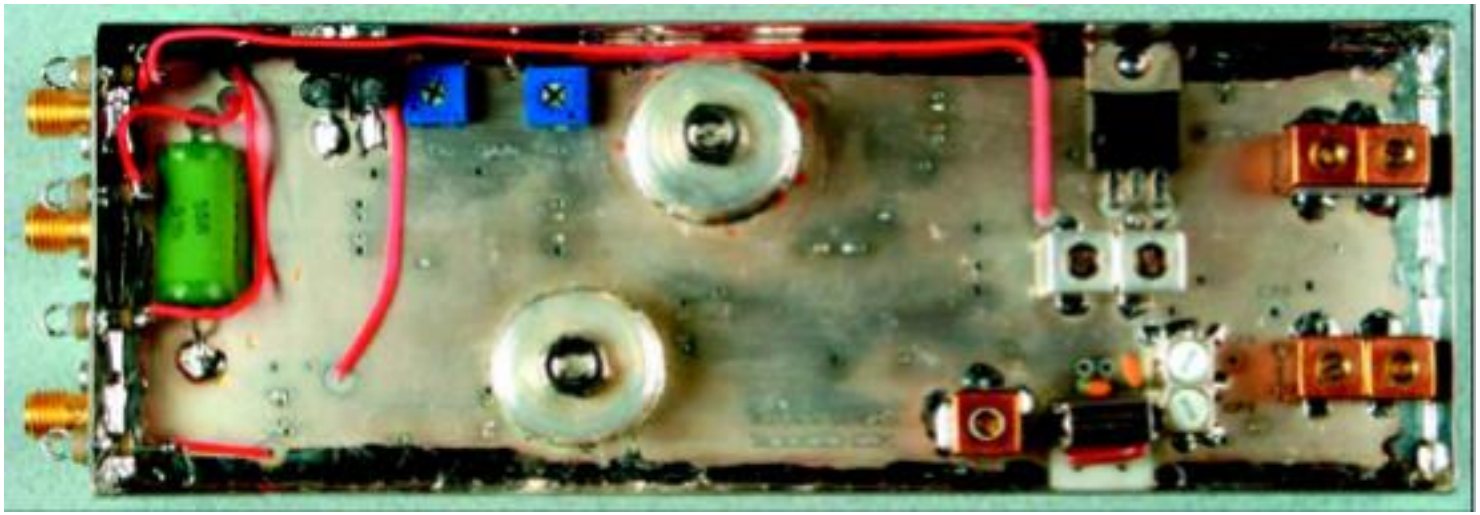
Sources of Equipment

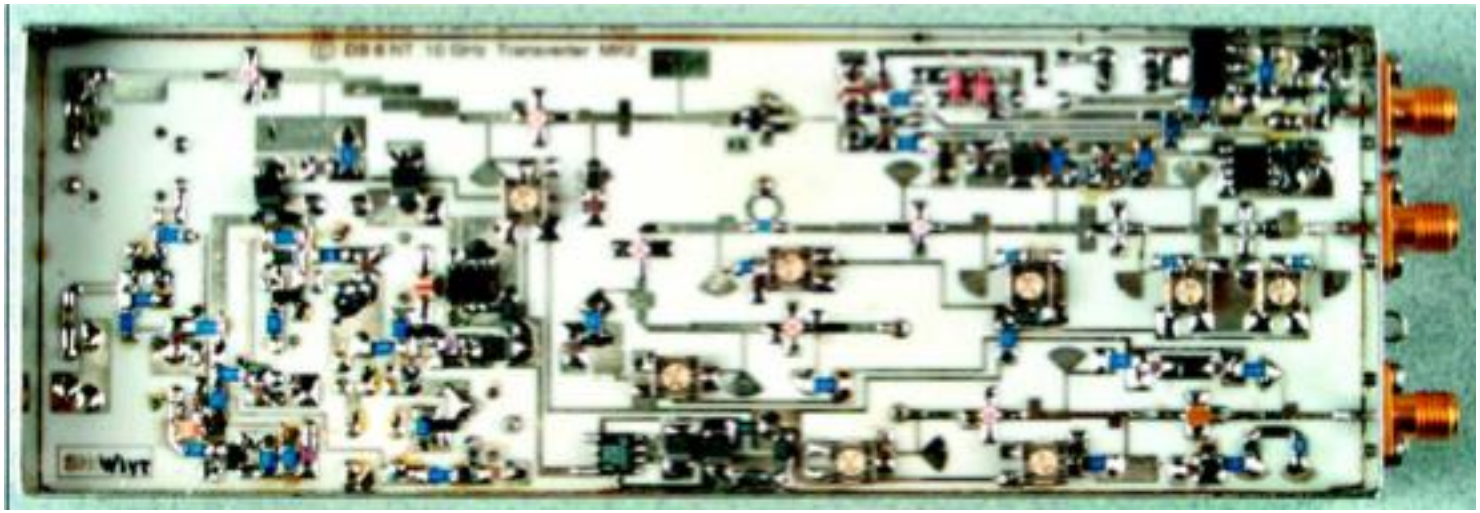
- Surplus amplifiers
- Modify surplus commercial equipment (e.g. “White Box”)
- Commercial ham transverters, power amps, pre-amps available (DB6NT, DL2AM, I3OPW, DEMI)
- Homebrew

Microwave Transverter



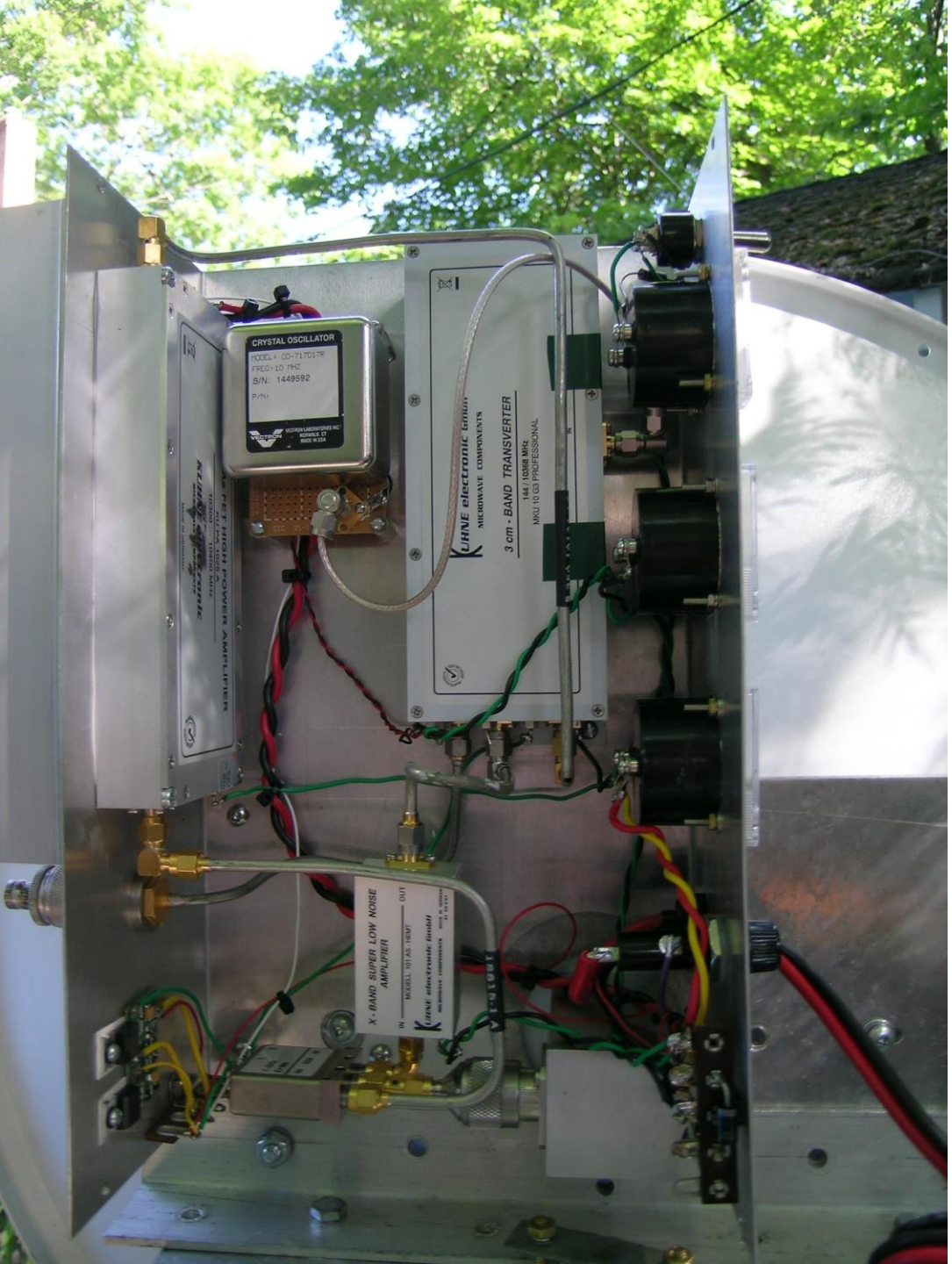
DB6NT 10 GHz Transverter





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

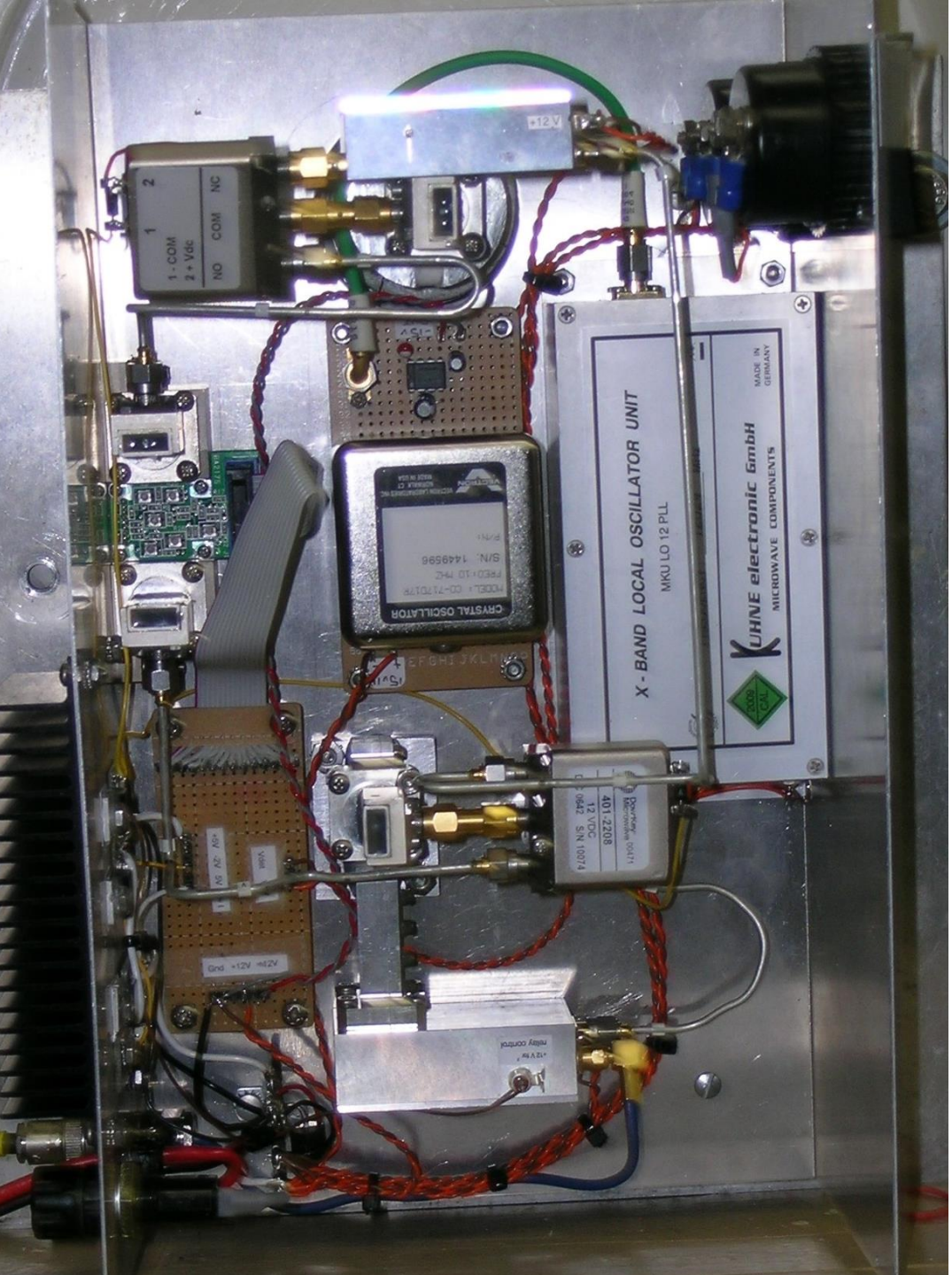
DB6NT amplifier

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

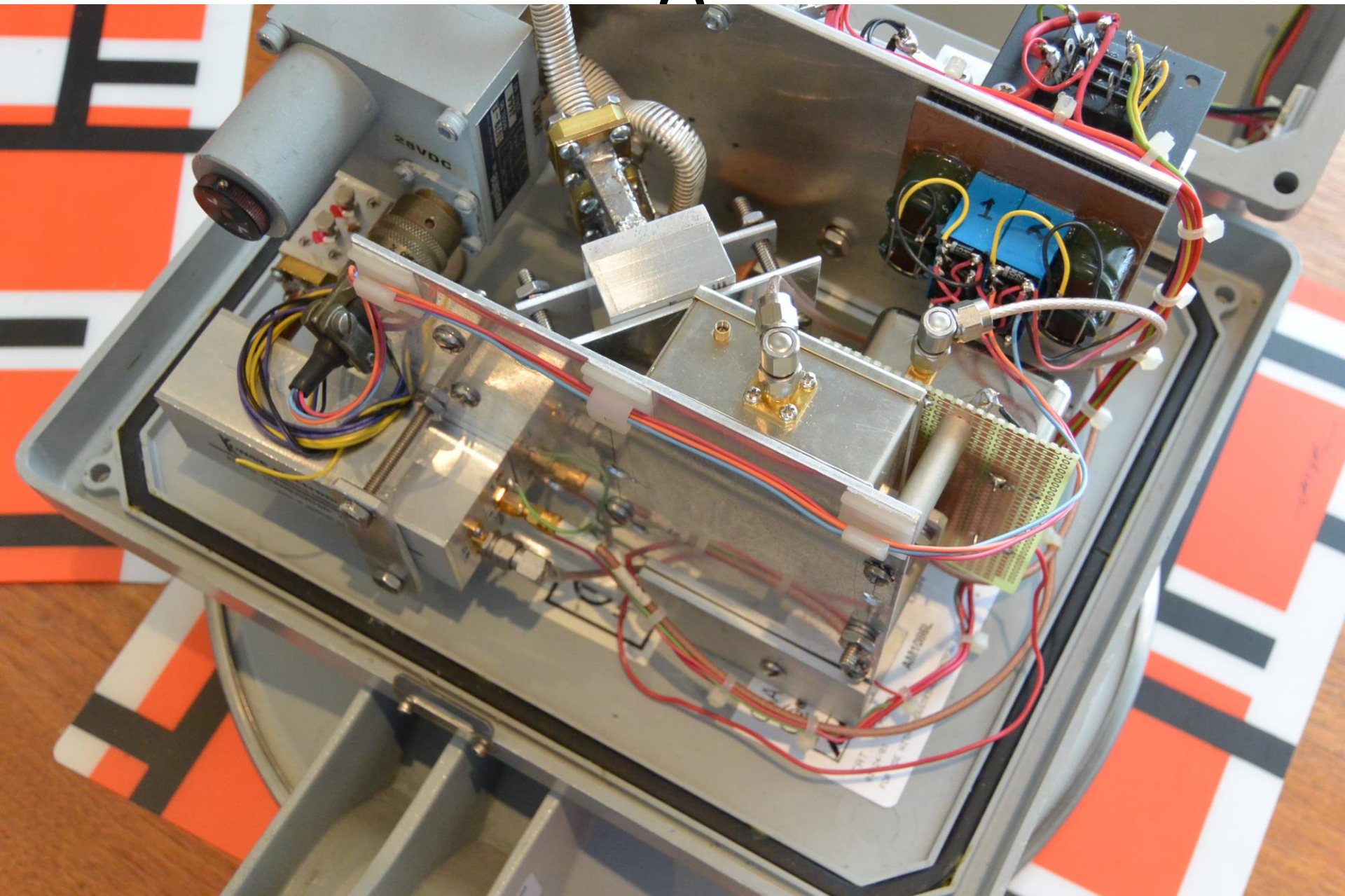
Waveguide Image Filter

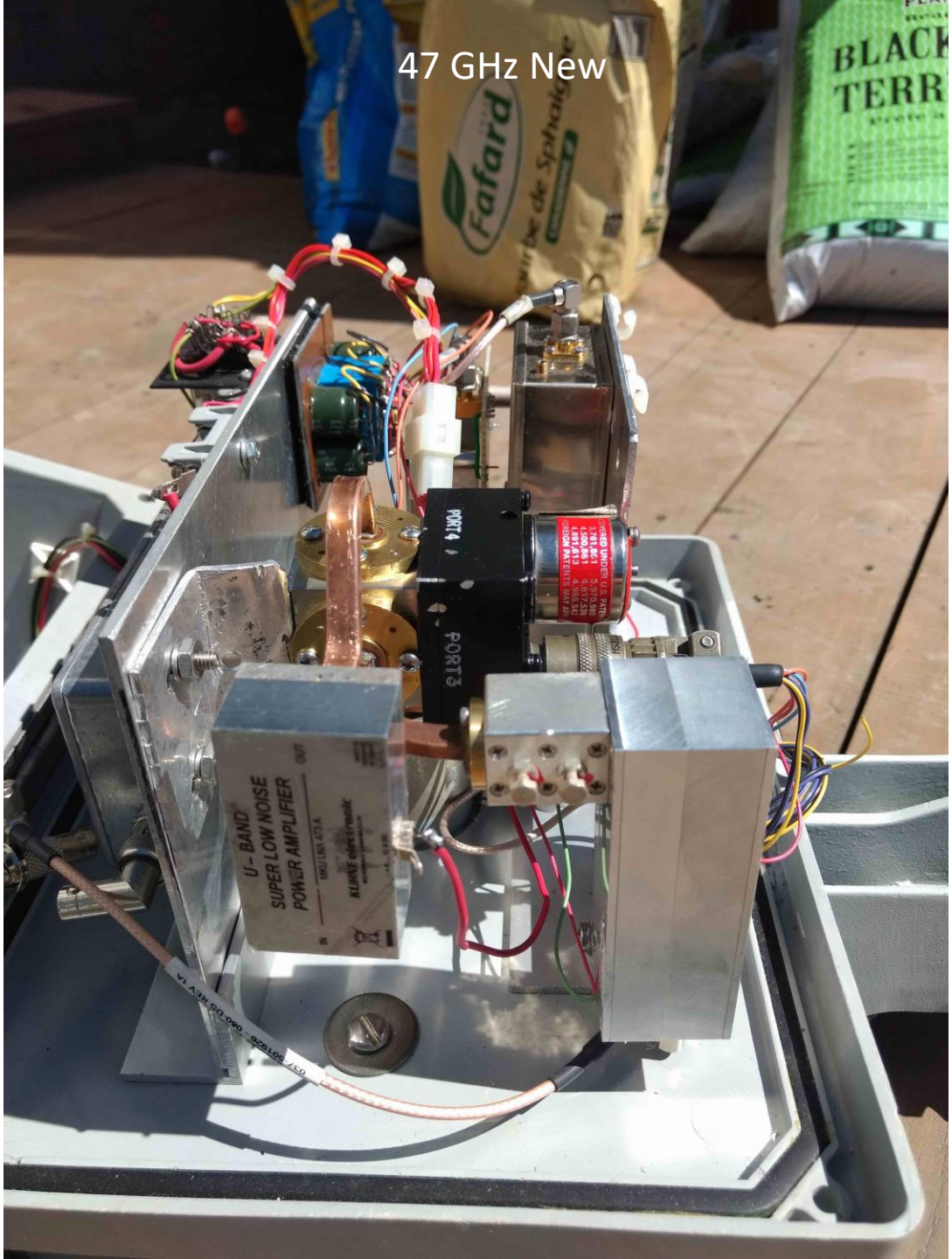
DB6NT Pre-amp: 1.6 dB NF

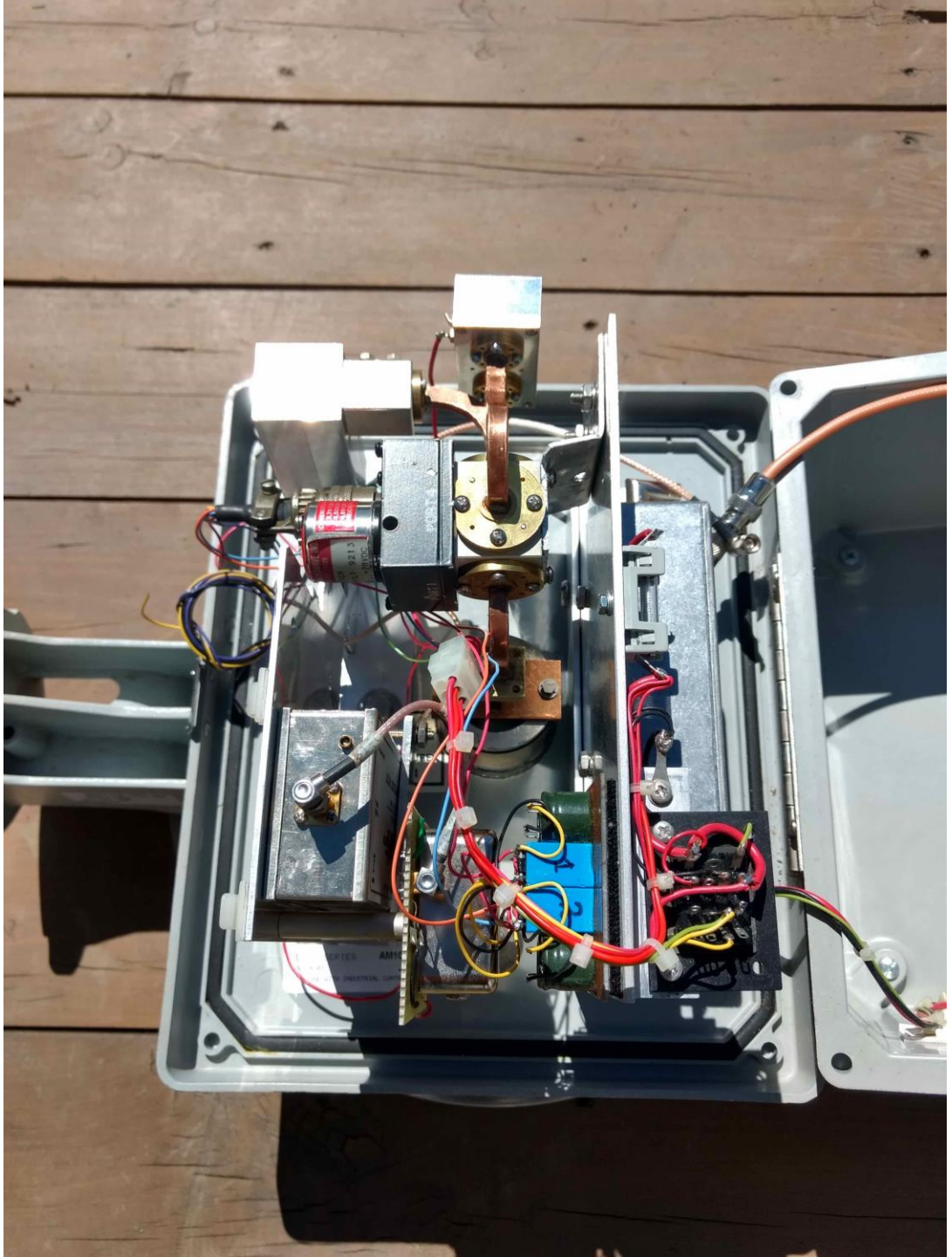
Toshiba Power Amp: 1 Watt

18” Dish

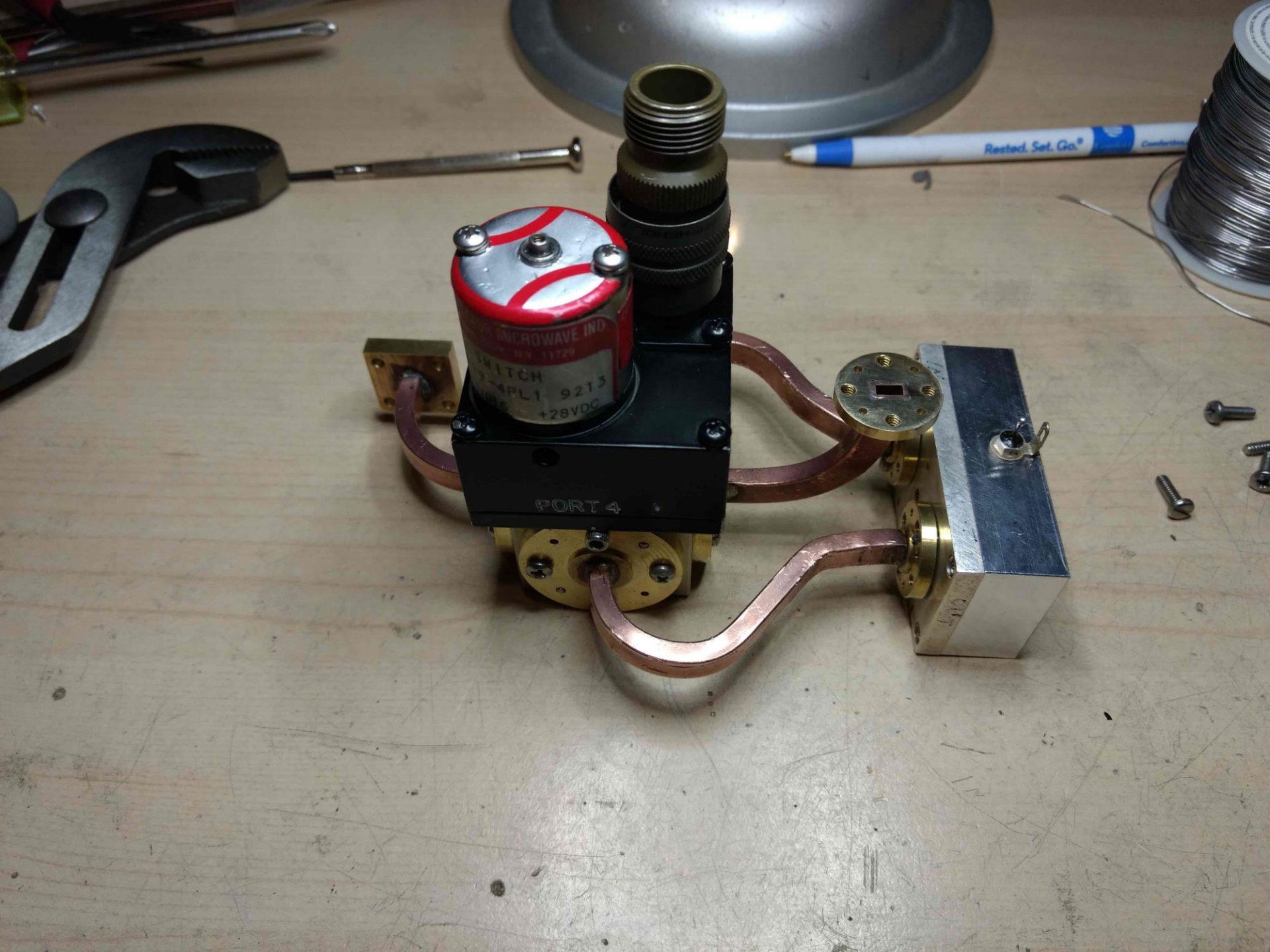
47 GHz Original

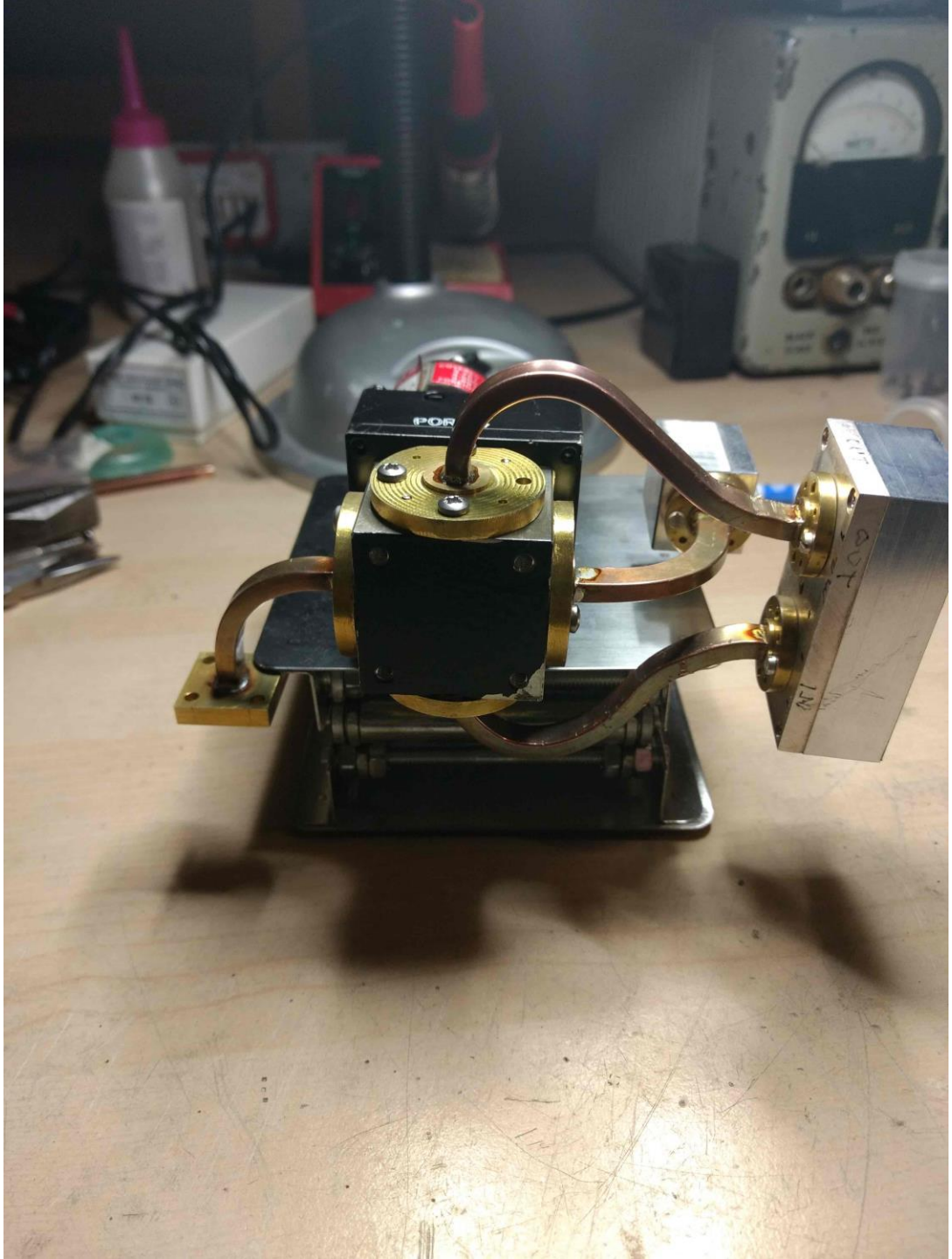


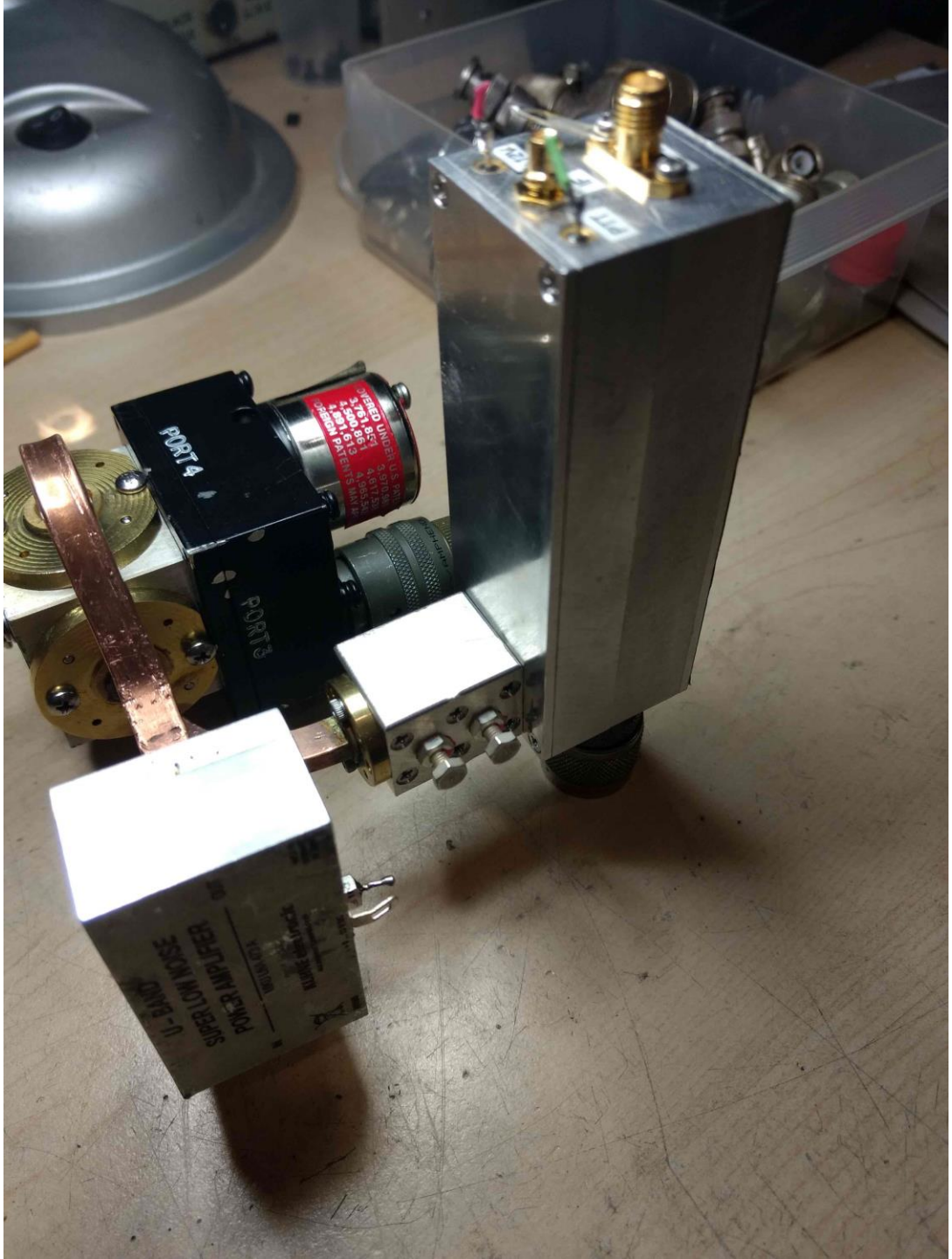

47 GHz New
Fafard
PORT 4
PORT 3
U- BAND
SUPER LOW NOISE
POWER AMPLIFIER

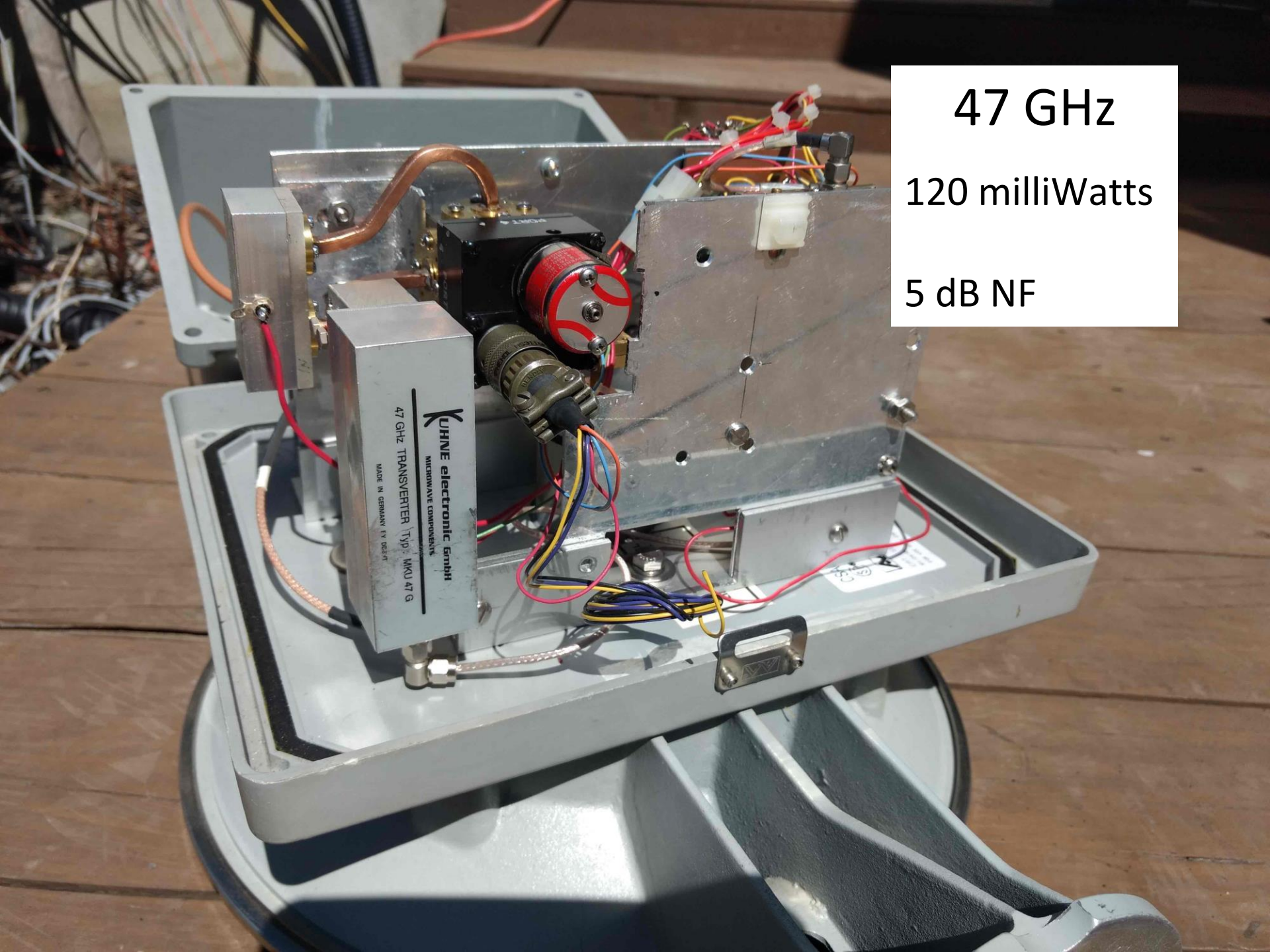



MODEL
HP-A1915B
300
400
120 VOLTS AC
750 WATTS
200
500
600
OFF
TYPE 1900
HOT PLATE


MICROWAVE IND
SWITCH
+28VDC
PORT 4

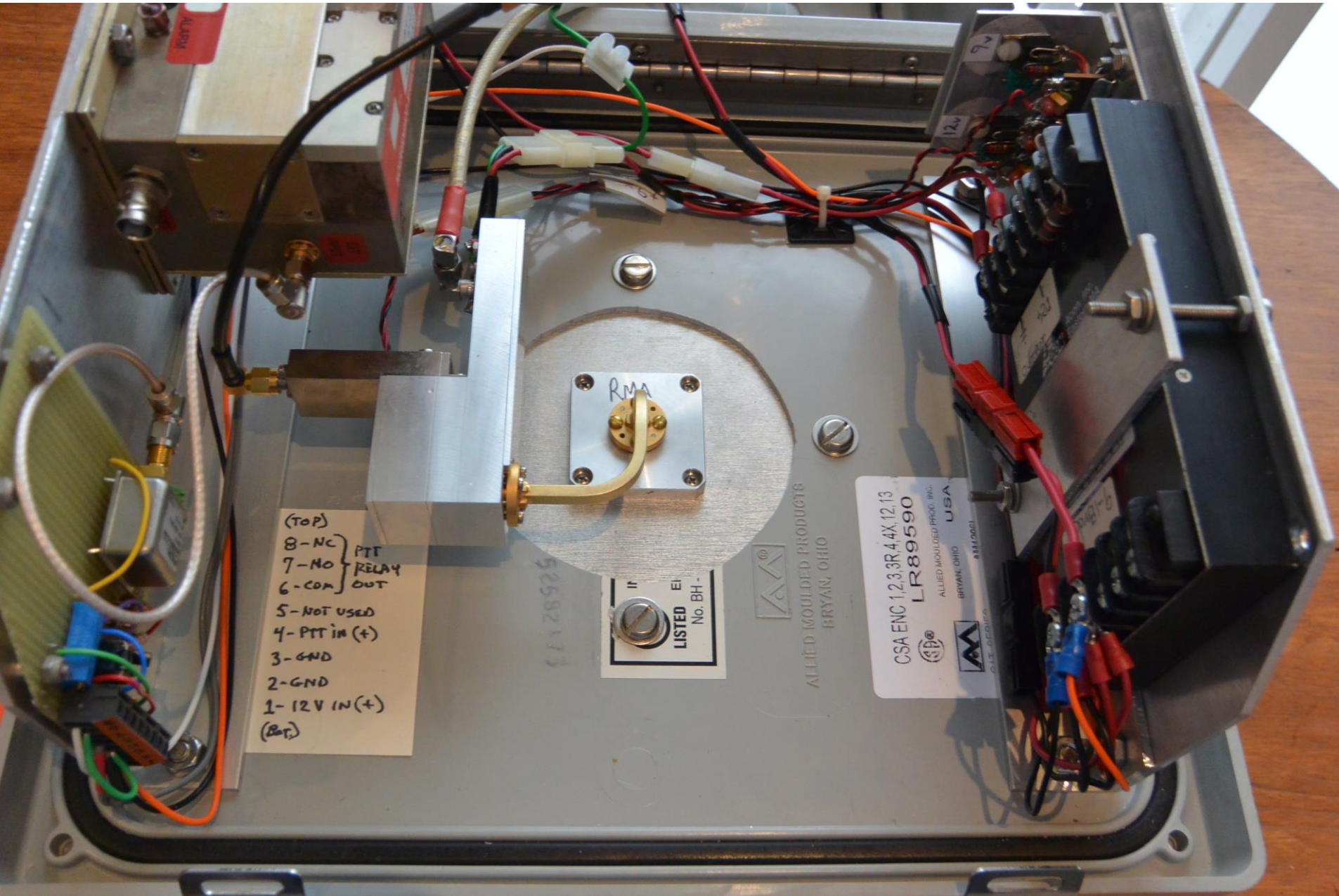



PORT 4
PORT 3
U-BAND
SUPERLOW NOISE
POWER AMPLIFIER


47 GHz
120 milliWatts
5 dB NF
KUHNE electronic GmbH
MICROWAVE COMPONENTS
47 GHz TRANSVERTER Typ: MKU 47 G
MADE IN GERMANY EV DG2.4T


78 GHz
Mixer only
10 microWatts
78GHz @ 10μw
#630

78 GHz


(TOP)
8-NC
7-NO
6-COM
PTT RELAY OUT
5-NOT USED
4-PTT IN (+)
3-GND
2-GND
1-12V IN (+)
(BAT)
LISTED
No. BH-
ALLIED MOULDED PRODUCTS
BRYAN, OHIO
CSA ENC 1,2,3,3R,4,4X,12,13
LR89590
ALLIED MOULDED PROD. INC.
BRYAN, OHIO
USA

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

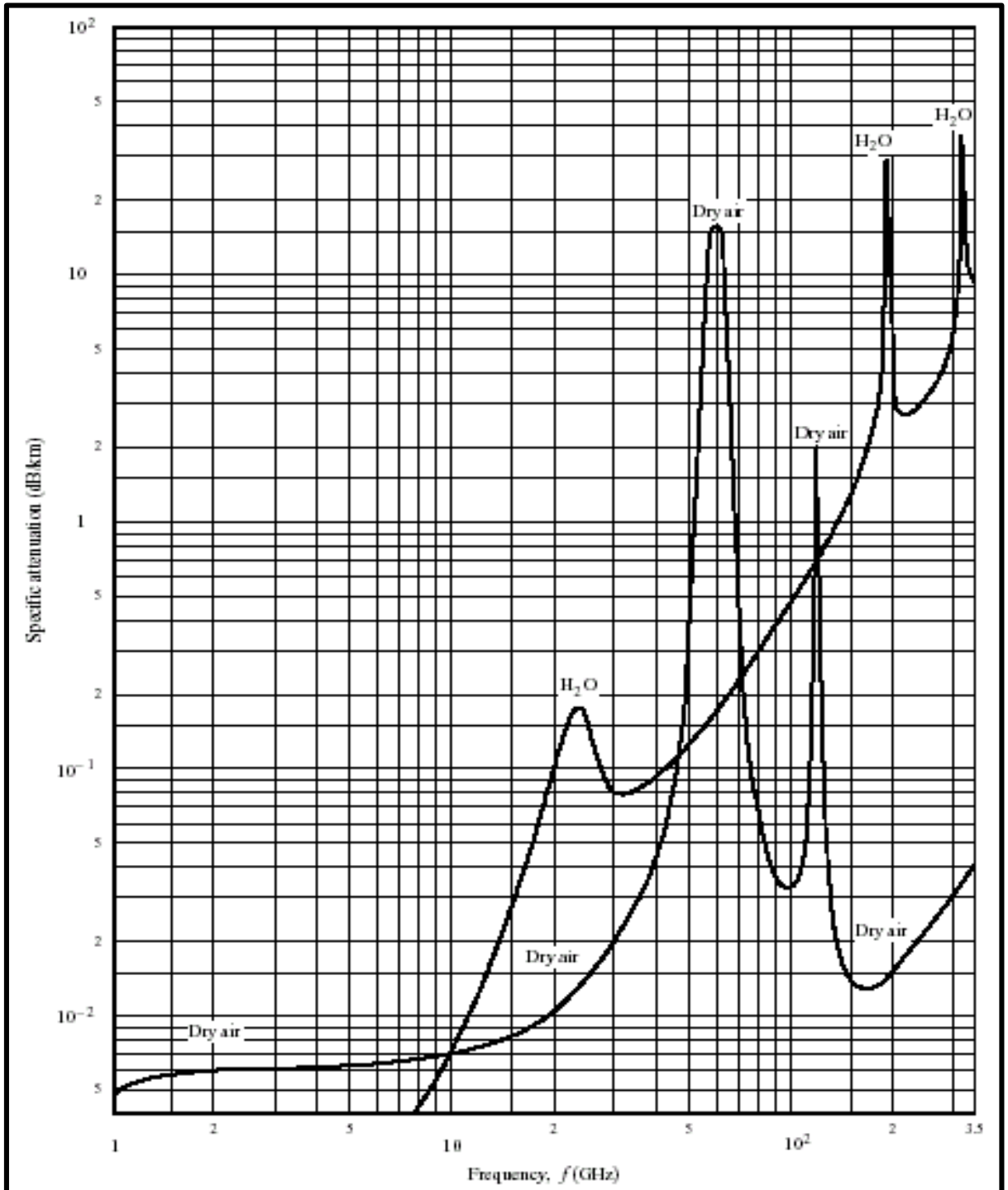
Propagation Attenuators

- 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

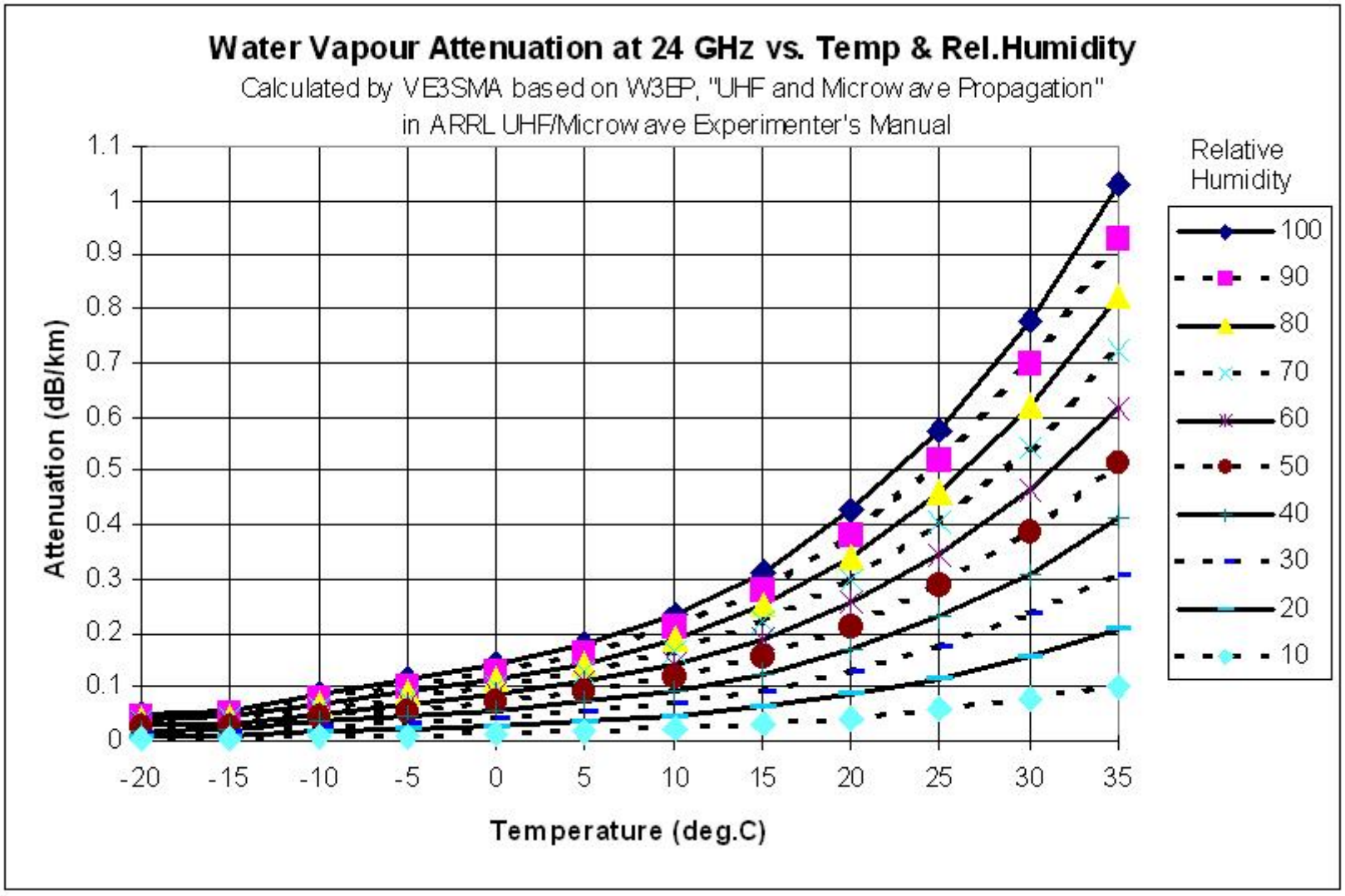
Propagation Attenuators

- 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
Attenuation (dB/km)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Temperature (deg.C)
Relative Humidity
100
90
80
70
60
50
40
30
20
10

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

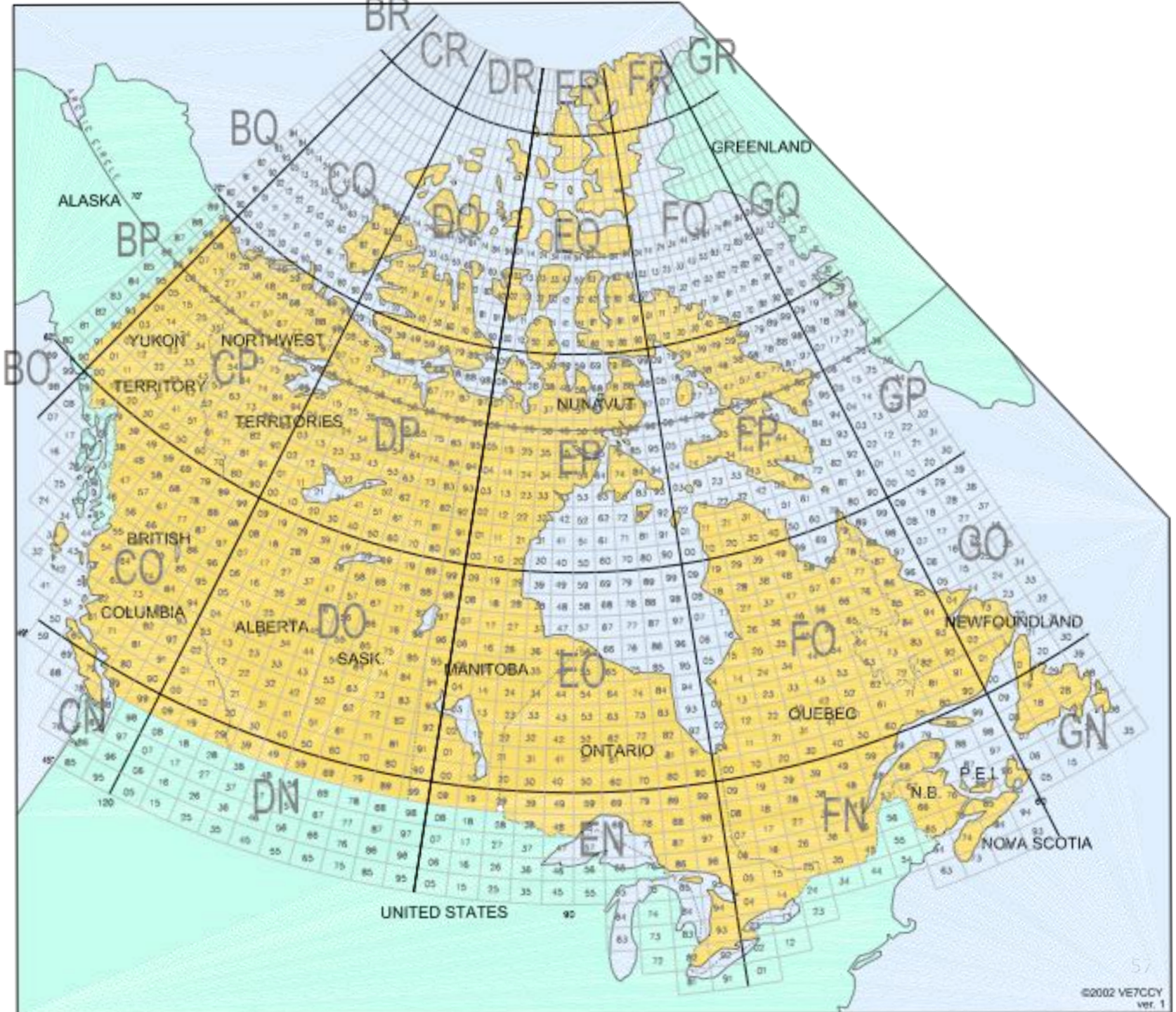
- Rain scatter
  - Antennas become efficient when their dimensions are in the same range as the wavelength
  - Water is polarized
  - Raindrop dimensions are typical 2-3mm
  - At 10 GHz raindrops are (small) antennas which reflect the incoming signals
    - Weather radar
  - Doppler shift
    - Caused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


BR
CR
DR
ER
FR
GR
BQ
CQ
DQ
EQ
FQ
GQ
BP
CP
DP
EP
FP
GP
BO
CO
DO
EO
FO
GO
BN
CN
DN
EN
FN
GN
ALASKA
GREENLAND
YUKON
TERRITORY
NORTHWEST
TERRITORIES
NUNAVUT
BRITISH
COLUMBIA
ALBERTA
SASK.
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
P.E.I
N.B.
NOVA SCOTIA
UNITED STATES
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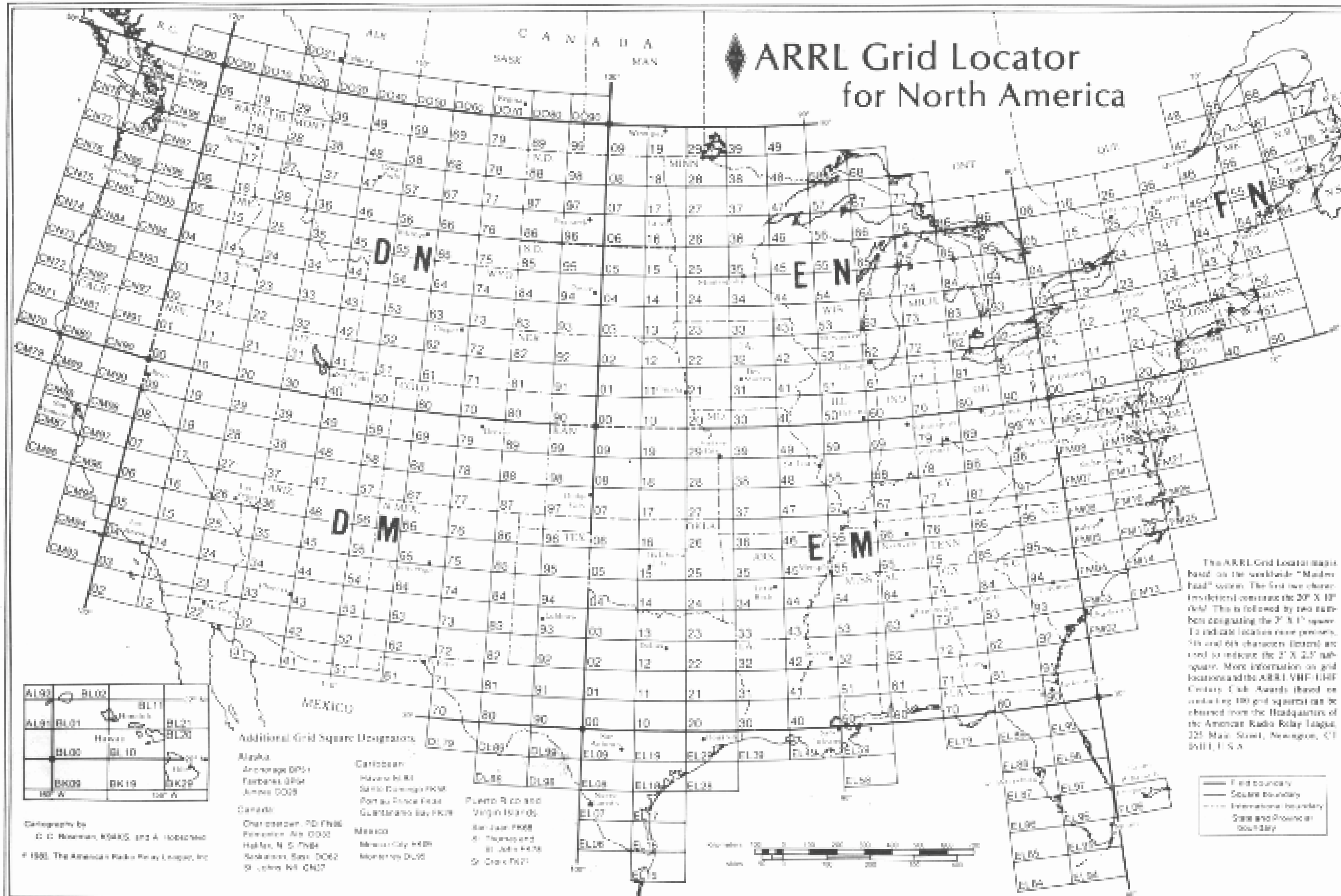
ARRL Grid Locator
for North America
C A N A D A
MEXICO
DN
DM
EN
EM
FN
Hawaii
Additional Grid Square Designators
Alaska
Anchorage BP51
Fairbanks BP64
Juneau CO28
Canada
Caribbean
Mexico
Puerto Rico and
Virgin Islands
Field boundary
Square boundary

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
Cansel

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


YAESU
ALTOIDS

Any Questions ???