Amateur Microwave Communications

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Introduction

- Microwaves are the frequencies above 1000 MHz
  - More than 99% of the radio amateur frequency allocation is in the microwave bands….
- Amateur frequencies
  - 23 cm, 13 cm, 9 cm, 6 cm, 3 cm (= 10 GHz), 1.2 cm (= 24 GHz)
  - 47 & 76 GHz,...
- Presentation: Primarily aimed at 10 and 24 GHz

Wideband FM

- 1950s -1960s
  - Transmitter
    - modulated Klystron oscillator
    - Seldom any power amplifier
      - travelling wave tubes costly, complex power supplies
    - Tens or hundreds of milliwatts output
  - Receiver
    - Same Klystron used as local oscillator
    - No RF amplifier
    - Direct injection to mixer diode (10 dB NF)
    - IF typically 30 MHz
  - Waveguide feed

Wideband FM

- 1950s / 1960s
  - – 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

Commercial

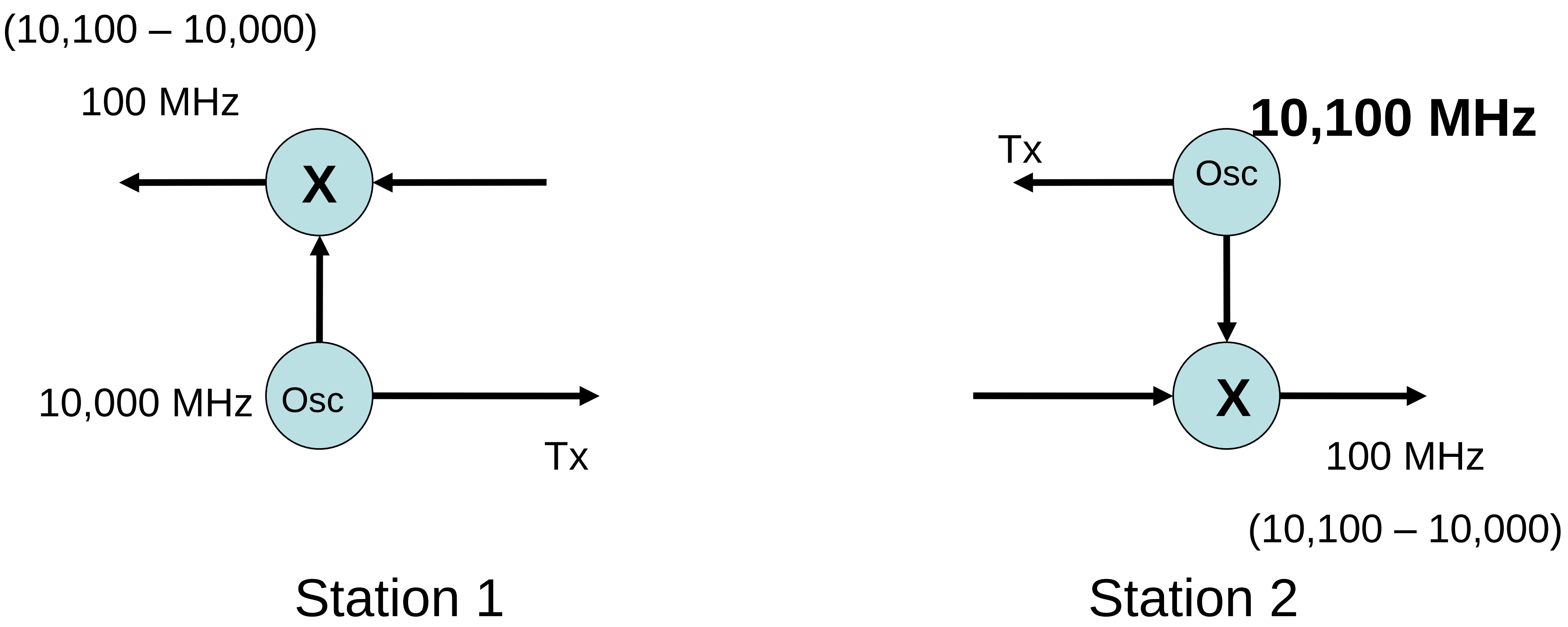
- Tellurometer
  - Available surplus 20+ years ago
  - Surveying instrument with communications capability
    - same technology as homebrew
  - 10 GHz plus other bands available
  - 100 km path worked by VE3ASO (sk) from Foymount to Gatineau Park

Wideband FM

- 1970s
  - Gunn diode replaces klystron
  - 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

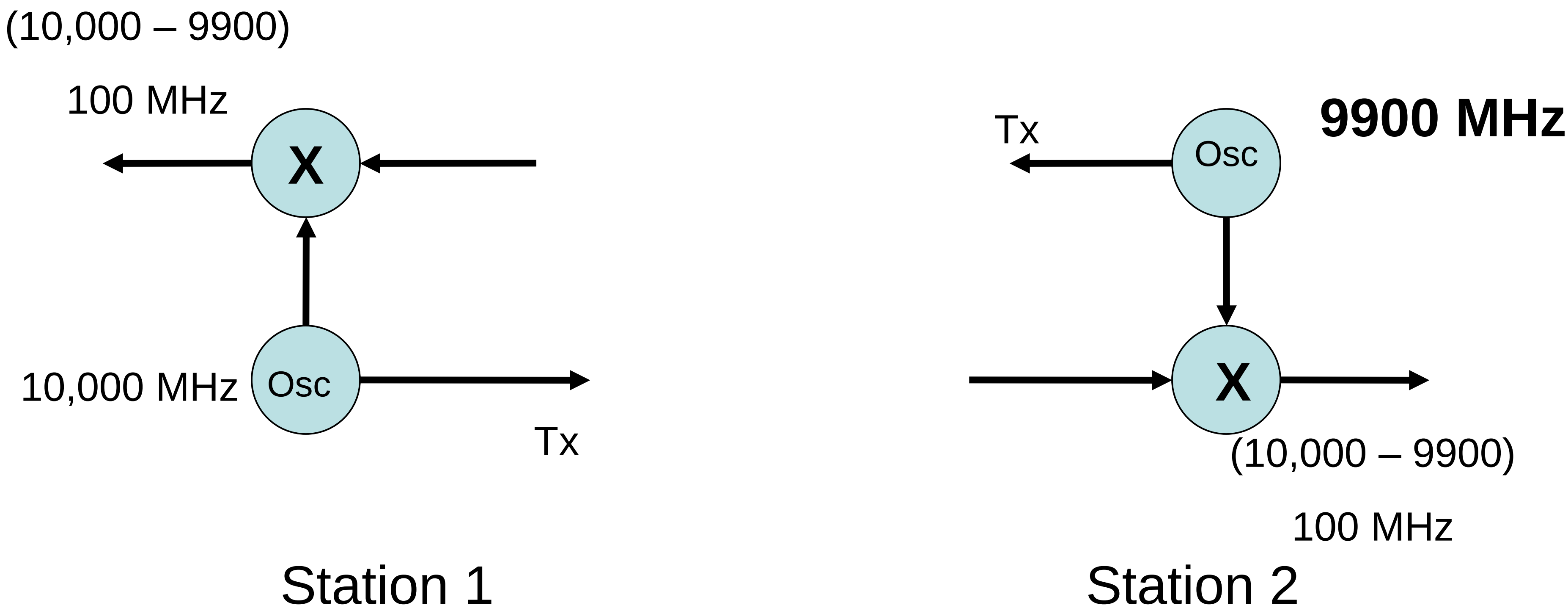
Gunnplexer

Wideband FM Communications



Each station has IF of 100 MHz

Wideband FM Communications



Each station has IF of 100 MHz

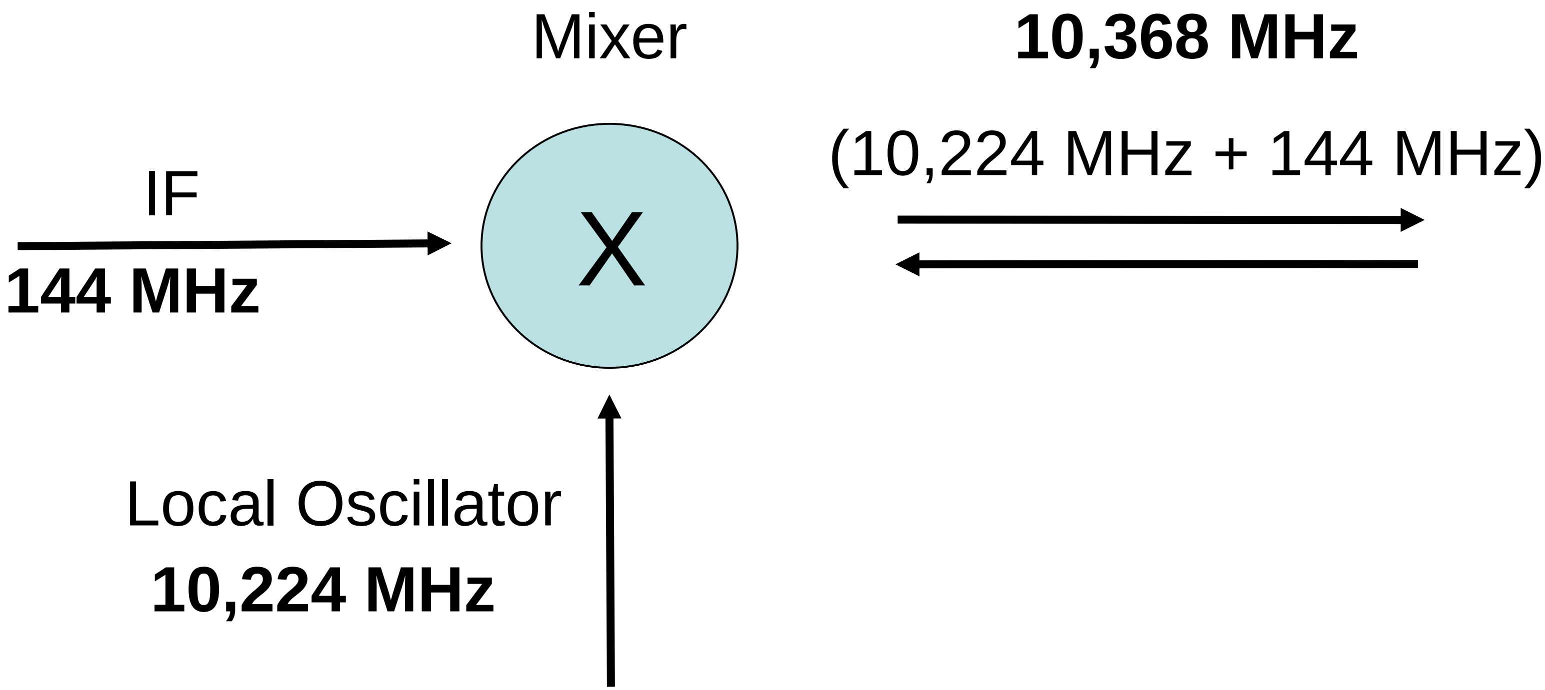
Narrowband

- 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

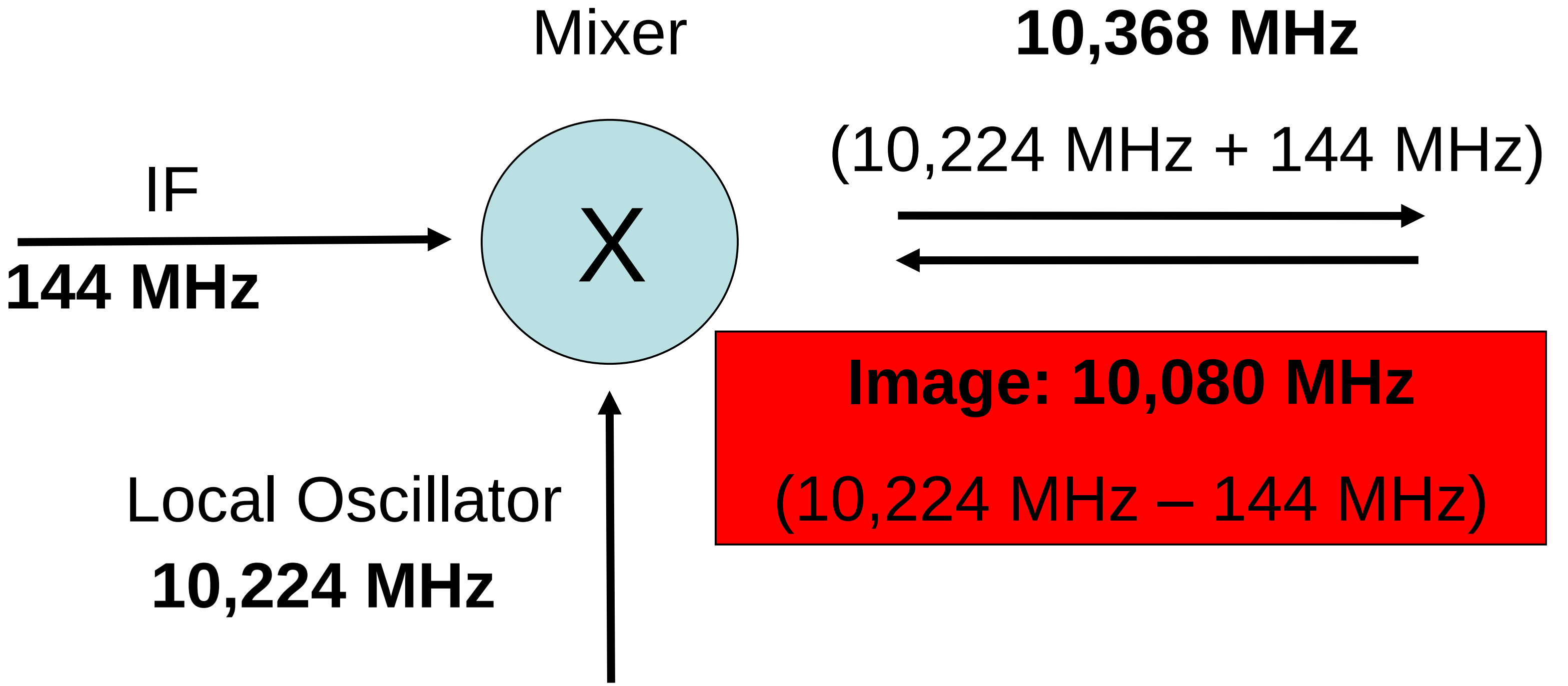
- Transverter
  - Transmitting / Receiving converter
  - Transmit
    - VHF / UHF IF source (typically 144 or 432 MHz) mixed with LO to produce microwave signal
    - usually power amplifier
  - Receive
    - microwave received signal mixed with LO to produce VHF / UHF output
    - usually RF amplifier

Narrowband



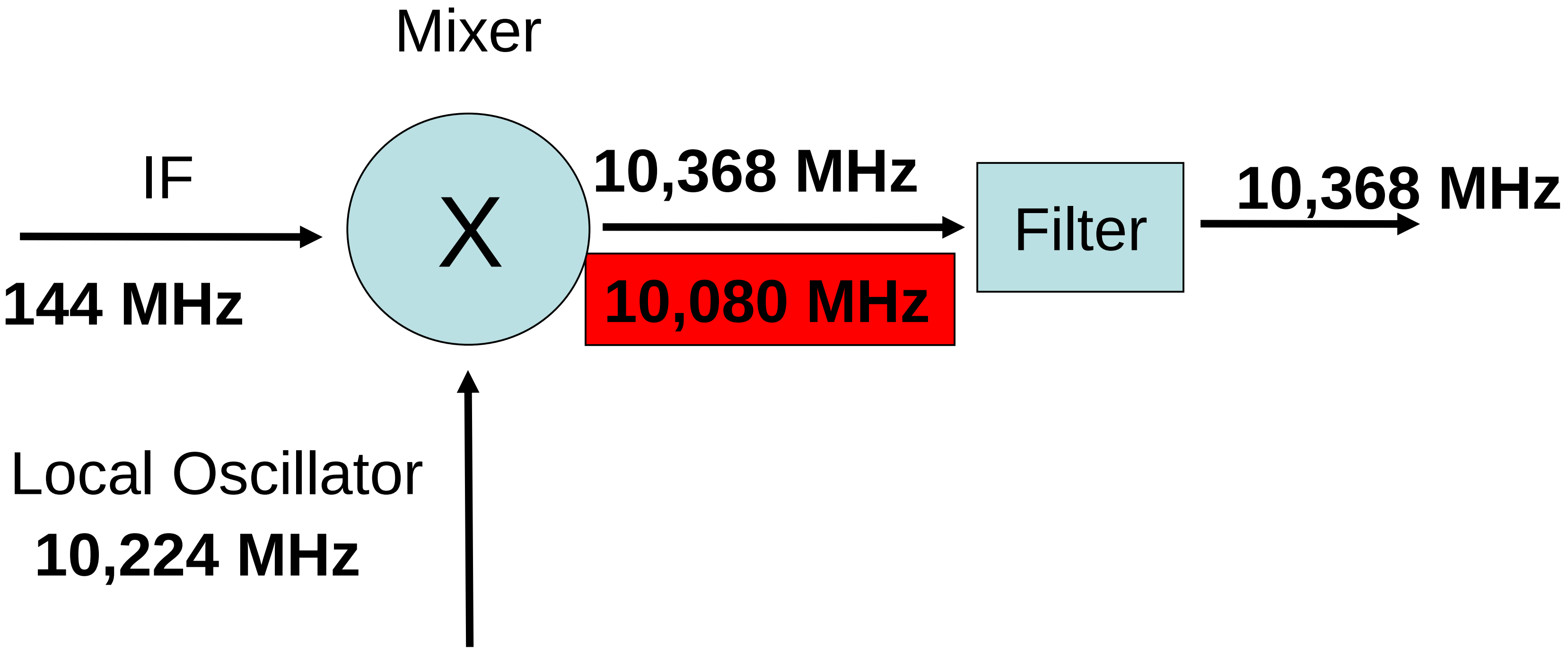
Simple Transverter: 10,368 MHz

Narrowband



Simple Transverter: 10,368 MHz

Narrowband



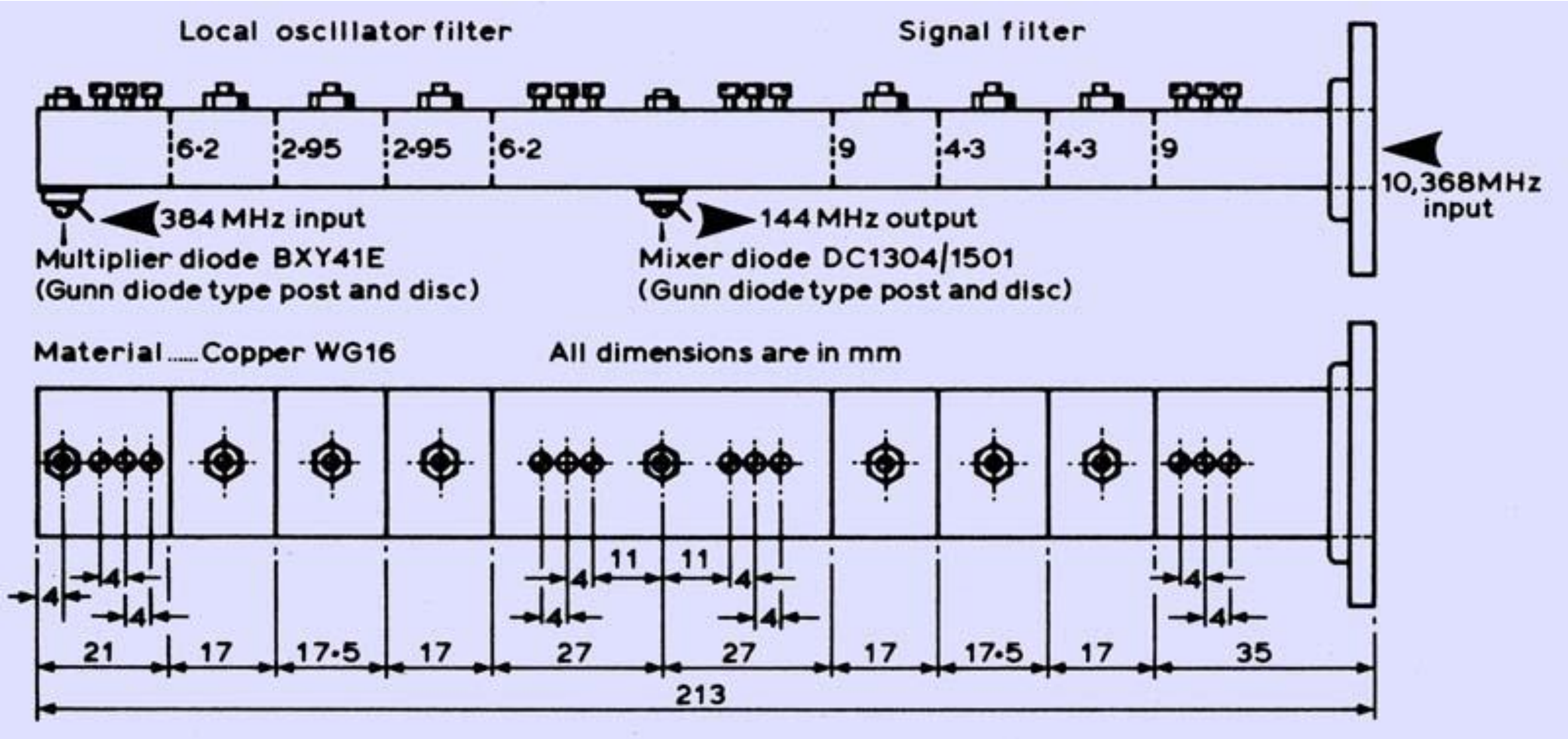
Simple Transverter + Image Filter: 10,368 MHz

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



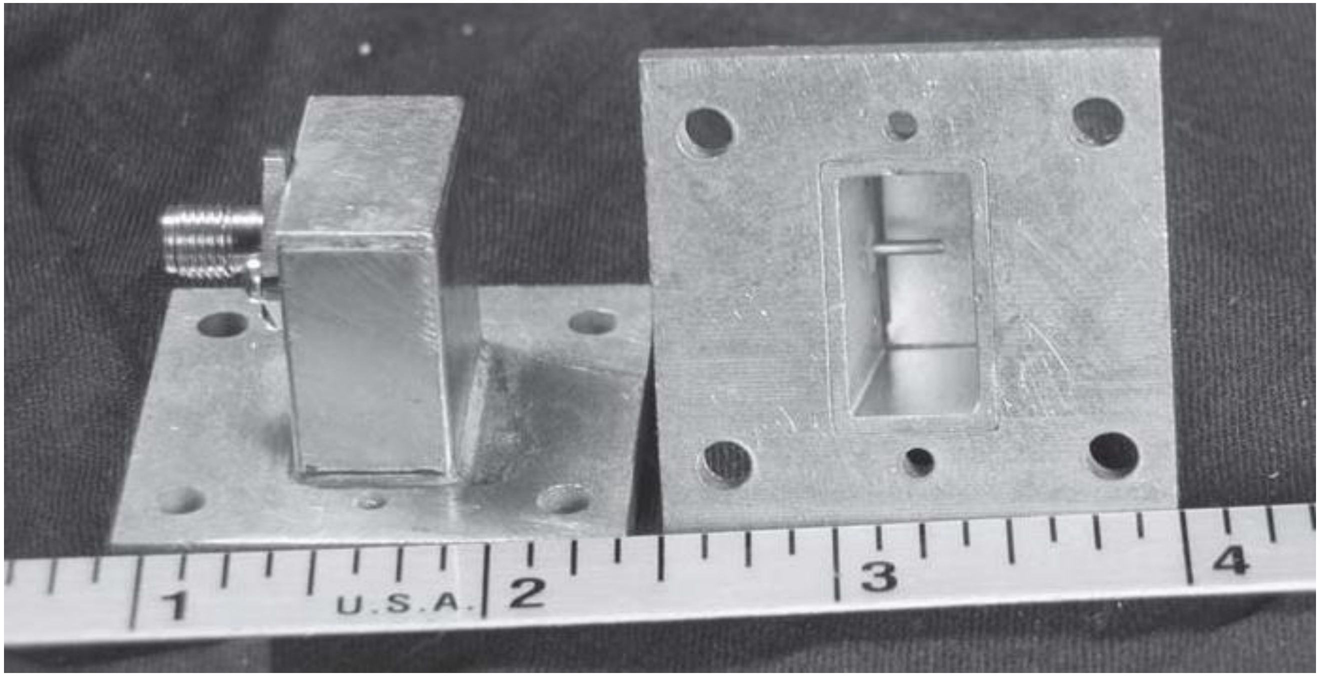
10 GHz & Up

- 1980s Technologies
  - 10 GHz Transistors available
    - Low-noise RF amplifiers
    - Power transistors
  - PC board construction and semi-rigid coax
    - Reduce need for waveguide
  - Equipment source: homebrew

10 GHz and Up

- Current Technologies
  - RF power amplifiers (Class A)
    - 10 GHz amp up to 50 W output available (25% efficient)
    - 24 GHz amp up to 10 Watts output (10% efficient)
    - Expensive!!
      - 10 GHz, $100 per Watt
      - 24 GHz, $1,000 per Watt
  - Low-noise RF amplifiers
    - 10 GHz: 0.8 dB NF available
    - 24 GHz: 1.6 dB NF available

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)

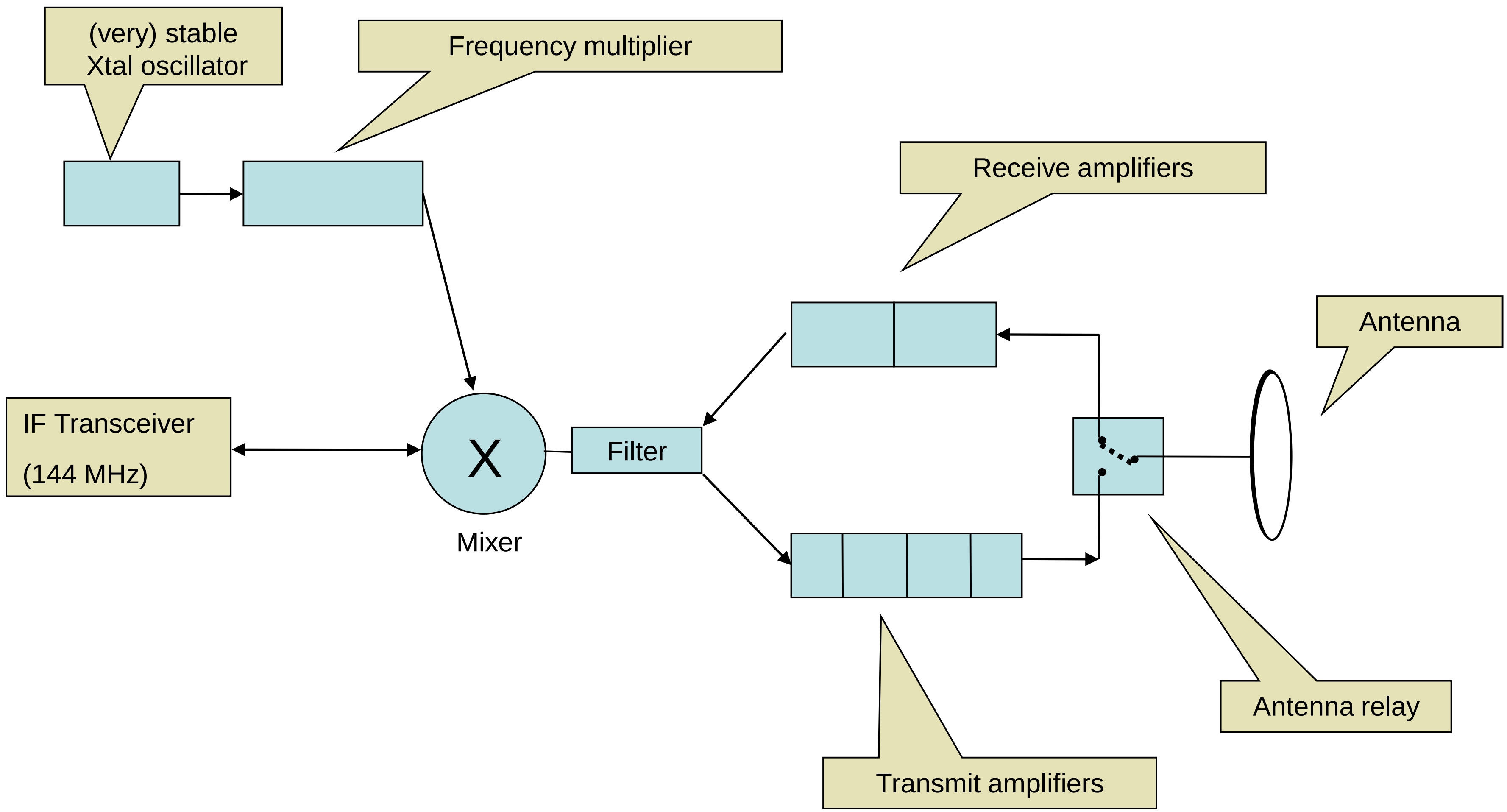
Design Challenges

- 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!

Design Challenges

- Local Oscillator frequency accuracy and drift
  - An LO 100 Hz off frequency or producing 100 Hz drift at 144 MHz would produce frequency error or drift of:
    - 7.2 kHz at 10 GHz; and
    - 16.8 kHz at 24 GHz
  - Current Crystal LOs
    - Clean LO (100 MHz region) plus multipliers
      - low phase noise (also multiplied)
    - Crystal heater typically used to reduce frequency error and drift.
    - Some lock (PLL) to external oscillator
      - Oven or GPS disciplined.

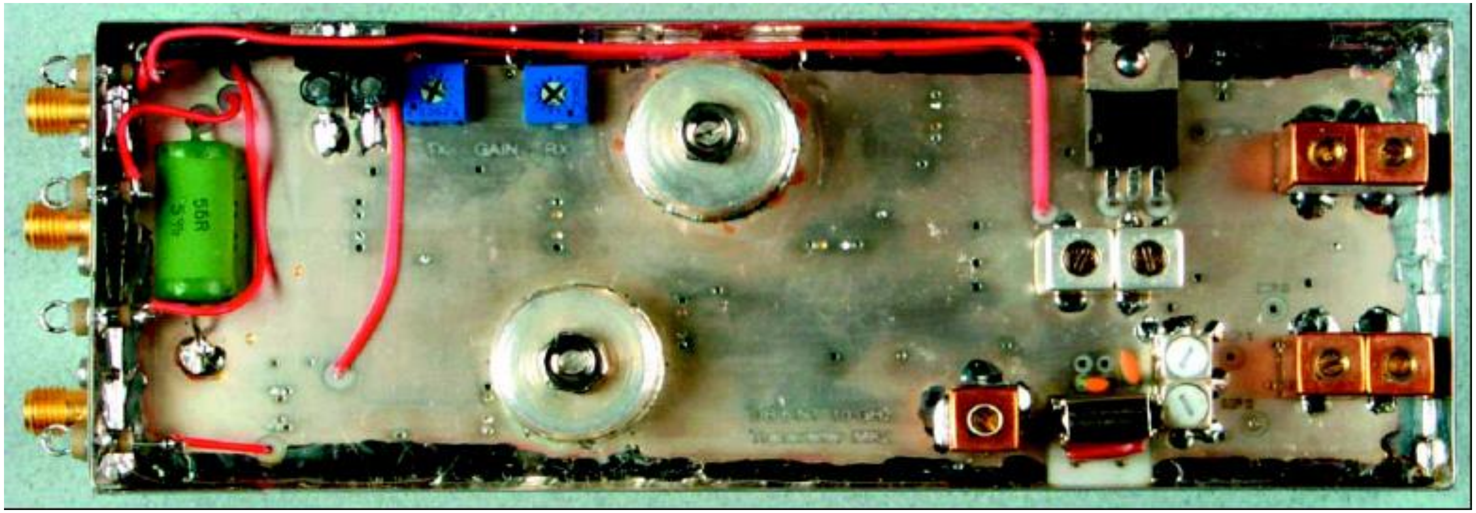
Microwave Transverter

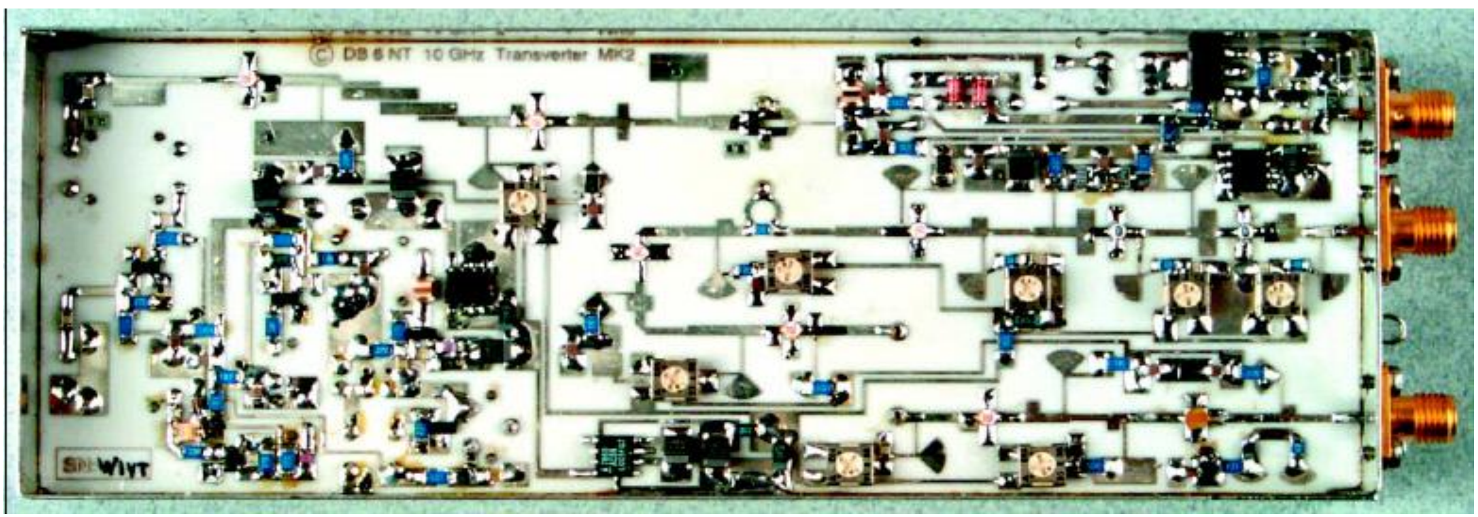


Sources of Equipment

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

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

1.2 dB NF, 200 mW out

DB6NT Pre-amp

0.8 dB NF

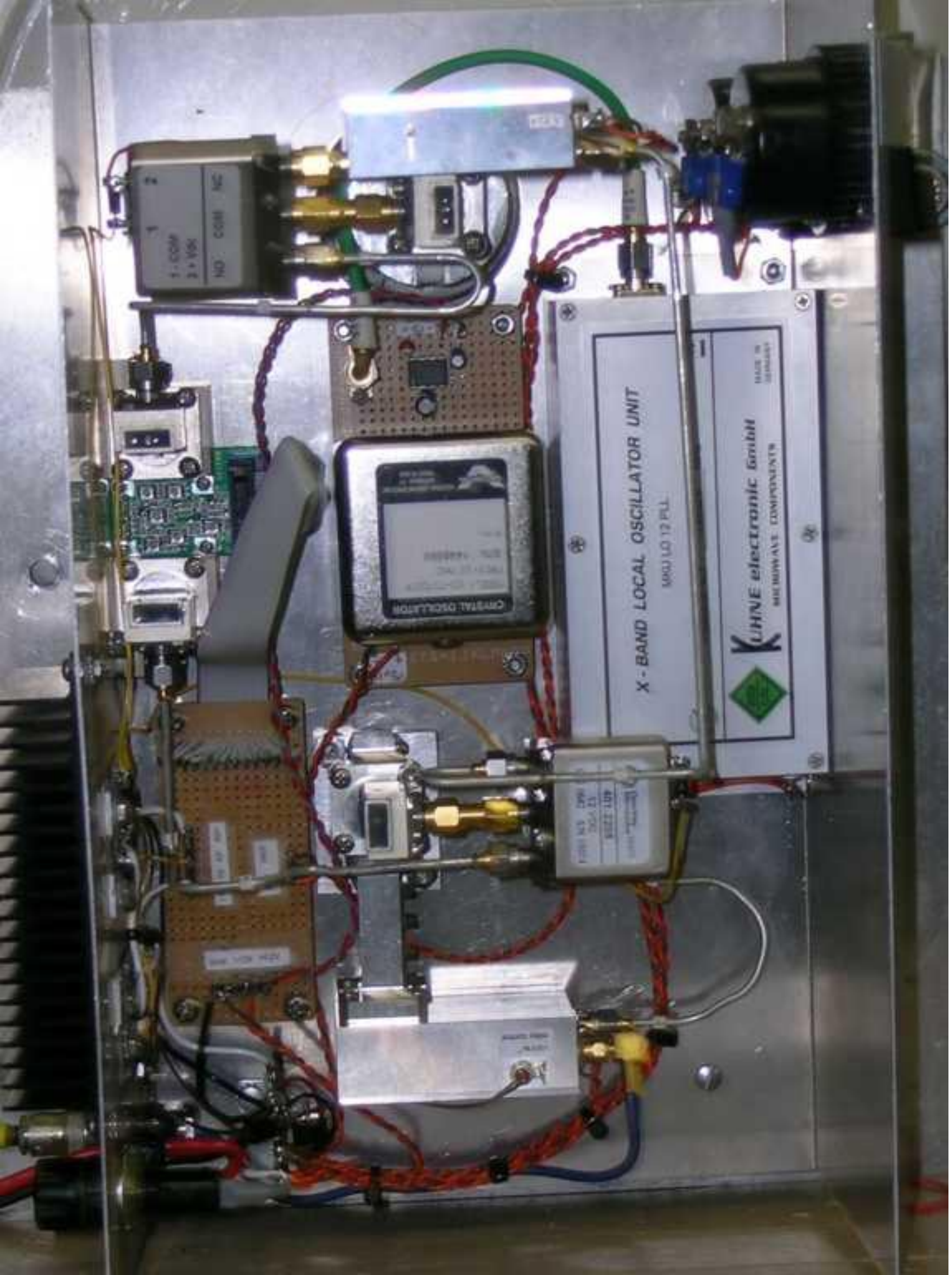
DL2AM amplifier

12 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
- 200 microwatts output
- 8 dB NF

Waveguide Image Filter

DB6NT Pre-amp 1.6 dB NF

Toshiba Power Amp: 1 Watt

18” Dish

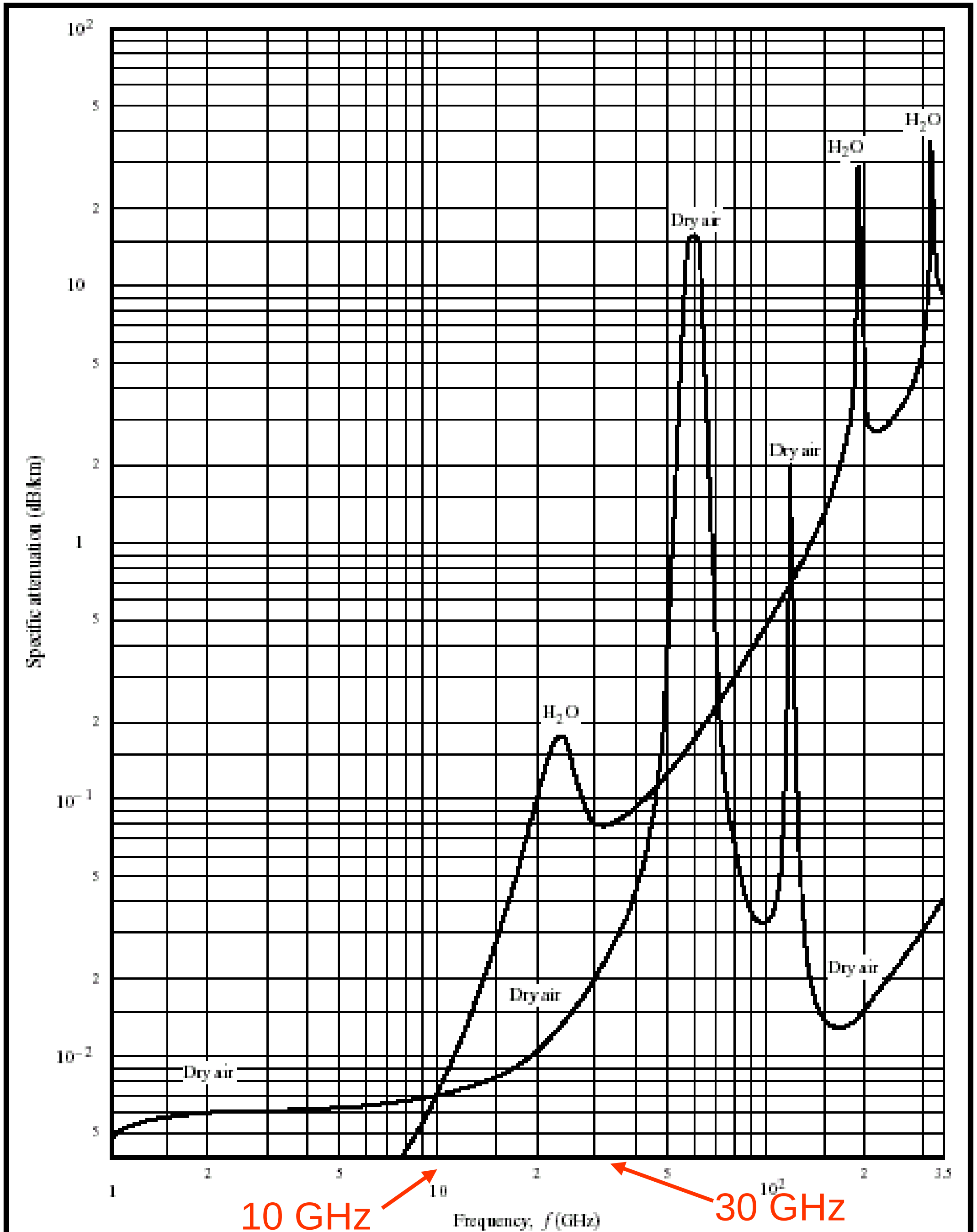
Microwave Attenuators

- Free-space loss
  - Increases with frequency
- Local obstructions
  - Hills, buildings, etc.
    - Increases with frequency
  - Tree leaves
    - Some attenuation at UHF
    - Attenuation increases with frequency and is substantial at 10 GHz and above

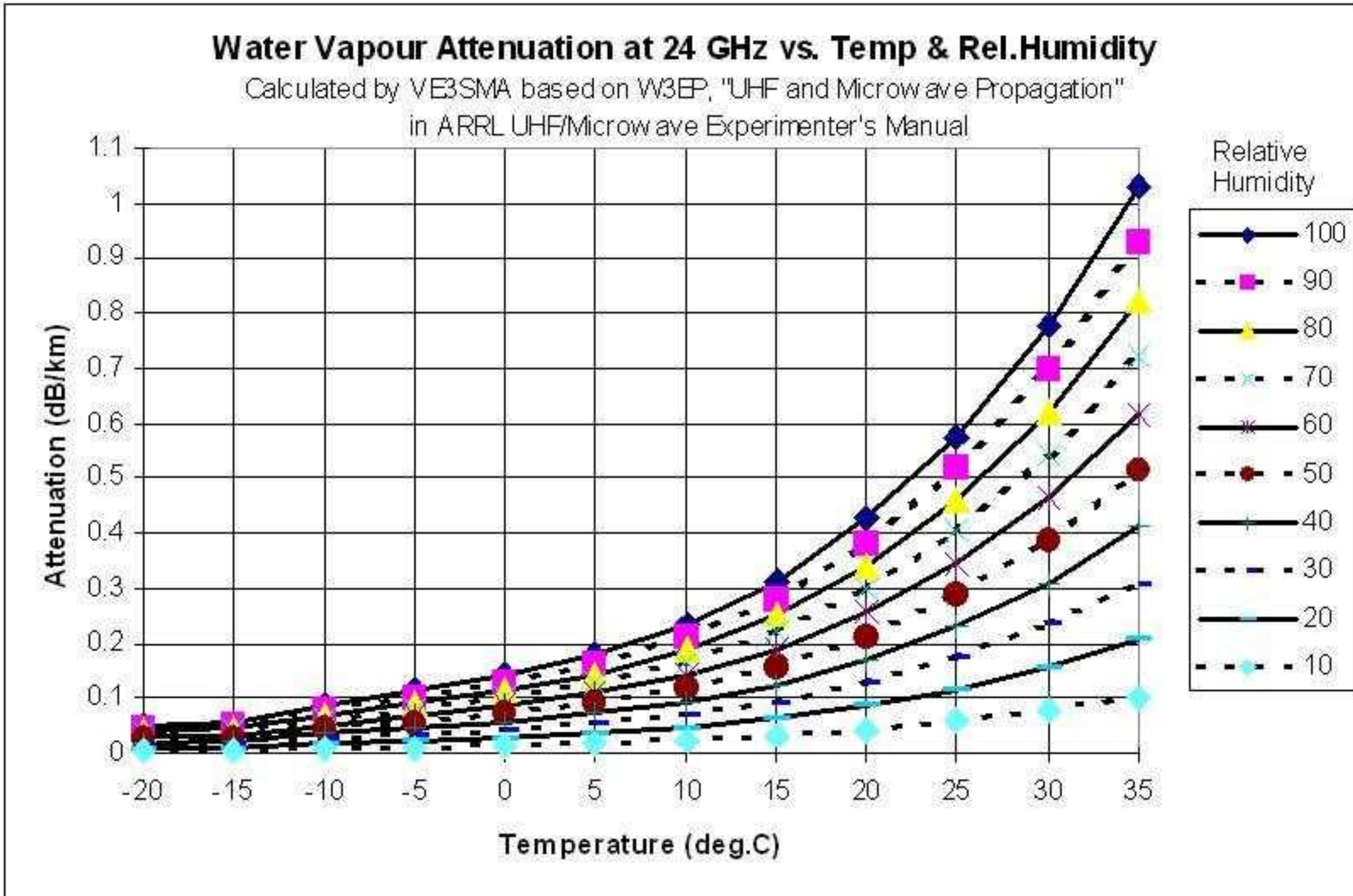
Microwave Attenuators

- Tropospheric scatter and diffraction loss
  - Typically long-haul non optical (line of sight) paths
  - Loss increases with frequency

Atmospheric absorption



- <10GHz absorption is neglect-able
- >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

Microwave Propagation

- Troposphere
  - Ducting or temperature inversion
    - especially over water
      - Over 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
  - Diffraction on non line-of-sight paths
    - Can be enhanced by ducting
  - Scatter (refraction) at greater distances

Microwave Propagation

- Tropospehere
  - Tropospheric turbulence may “break up” or distort Morse or SSB signal
    - A dash could become 2 dots
    - Doppler shift can spread signal
  - Tropospheric enhancement usually best:
    - in summer and fall
    - early morning or evening / night
    - but usually bad for 24 GHz and up (water vapour)

Microwave Propagation

- Good location is a big advantage
  - High altitude & “clear horizon”
    - Tree leaves and other blockages are significant attenuators
    - Tropo diffraction and scatter losses mount quickly
  - Low “take-off” angle
    - Over water can work well

Microwave Propagation

- 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’.

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
- Numogate, Ontario (FN14xw)
  - Only 550 feet ASL, but clear horizon

10 GHz: Personal Achievements

- From Gatineau Park
  - 385 km to Mount Washington, NH (SSB)
  - 403 km to Hamilton, ON
  - 588 km to Block Island, RI
- From Mont Tremblant
  - 620 km to Martha’s Vineyard (Mass. coast)
- From Foymount
  - 490 km to Mount Washington, NH (SSB)
- From Numogate
  - 383 km to Mount Washington, NH (SSB, Rain Scatter)

24 GHz: Personal Achievements

- From Mont Tremblant
  - 234 km to Mount Mansfield, Vt. (SSB)

QSO Techniques

- Antenna beam width very narrow
  - Roughly 3 degrees or less
    - Azimuth <u>and Elevation</u>!
  - 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 callsigns plus grid.

Any Questions ???