Exploring the Millimeter Wave Bands

Design & Construction of
78 and 122 GHz Transverters

Mark Lewis N0IO   n0io823<at>gmail.com

Grand Junction, CO

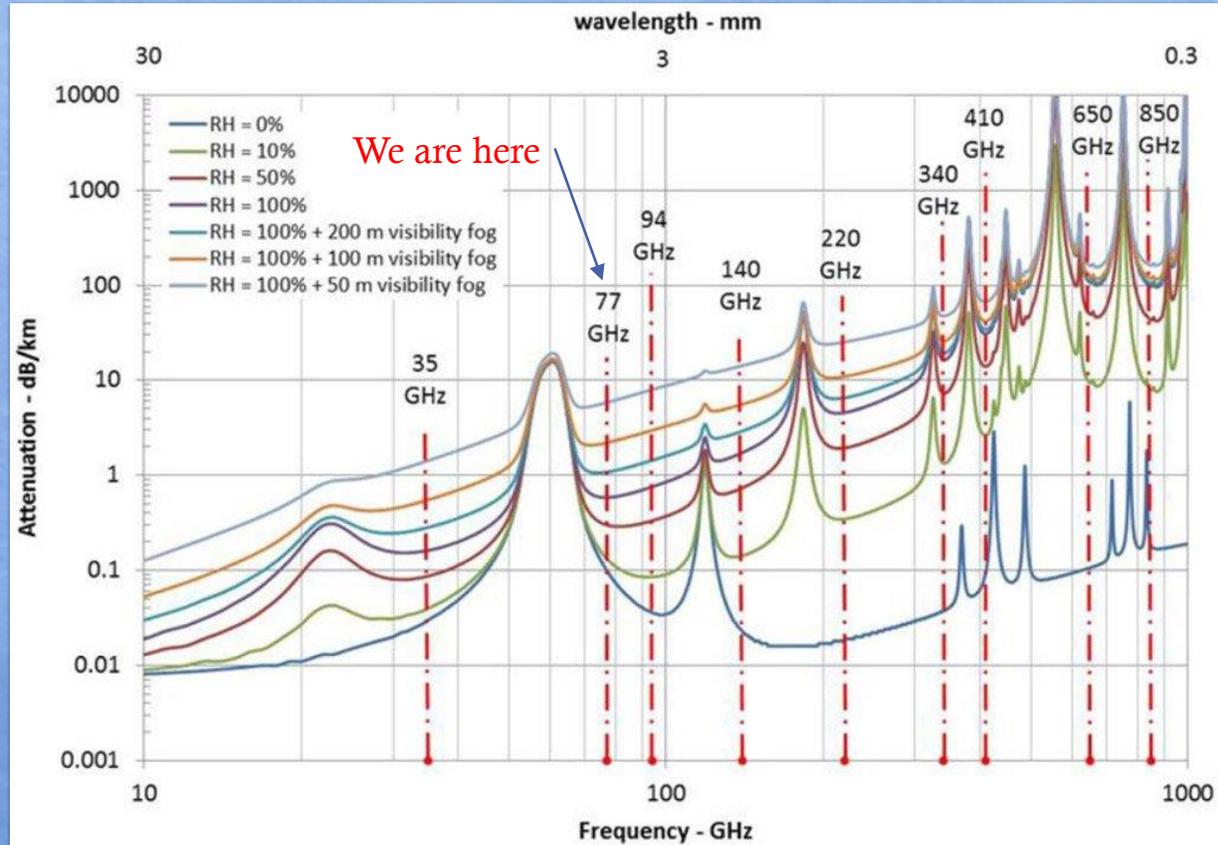NM TechFest 2020   NMVHF

Genesis

- ◈ Advanced Receiver Research

- ◈ 10 GHz Gunnplexer

- ◈ WBFM

NM TechFest 2020

NMVHF

78 GHz Path Losses

◈ Free space path loss = $20 \log (4 \pi D / \lambda)$

◈ For D = 300 km, λ = 3.8 mm, Free space loss = 180 dB

◈ Plus oxygen and water vapor loss

Atmospheric Losses

Calculated Atmospheric Loss @ 76 GHz

Path Loss Charts. This path loss is ONLY the part due to atmospheric attenuation/absorption. Based on Lieb formulations Prepared by Brian Justin WA1ZMS.   Calculated for Sea Level (standard pressure).

76GHz Loss vs Dew Point

Path Losses @ 78 GHz

◈ Free space path loss = $20 \log (4 \pi D / \lambda)$

◈ For D = 300 km, λ = 3.8 mm, Free space loss = 180 dB

◈ From Brian's table @ 5 ° Dew Point, additional loss of 0.18 dB/km

◈ Atmospheric loss 300 km x 0.18 dB/km = 54 dB

◈ Total path loss = 180 + 54 = 234 dB

NM TechFest 2020

NMVHF

Receiver Noise Floor @ 78 GHz

- Noise Floor (dBm) = 10 log (k x To x 1000) + NF + 10 log BW

- For To = 290 kelvin, system NF = 6 dB and a 1000 Hz bandwidth

- Noise Floor = -174 + 6 + 30

- Noise Floor = - 138 dBm

Power at the Receiver

◈ Maximum transmit power per FCC regulation = + 55 dBm EIRP

◈ Gain of decent 12 " dish on receiver end = 45 dB

◈ Received signal level = (55 + 45) – (234 path loss) = -134 dBm

◈ Signal 138 – 134 = around 4dB out of the noise

NM TechFest 2020

NMVHF

Design Criteria

◈ Transmit power + 55 dBm

◈ Receiver dish gain 45 dB

◈ System noise figure 6dB max

◈ And…..

NM TechFest 2020

NMVHF

Design Criteria

◈ Transmit power + 55 dBm

◈ Receiver dish gain 45 dB

◈ System noise figure 6dB max

◈ And….

◈ Two mountain tops at least 300 km apart with a dew point of less than 5 degrees

NM TechFest 2020

NMVHF
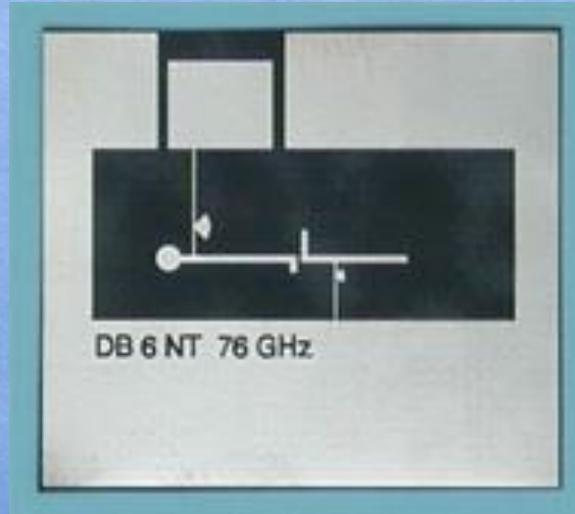
Simplest Transverter

- IF radio
- LO source
- Antenna
- Mixer

LO

IF   MIXER   ANTENNA

FT 818 and TM 255 IF Rigs

NM TechFest 2020

NMVHF

DB6NT Mixer Boards
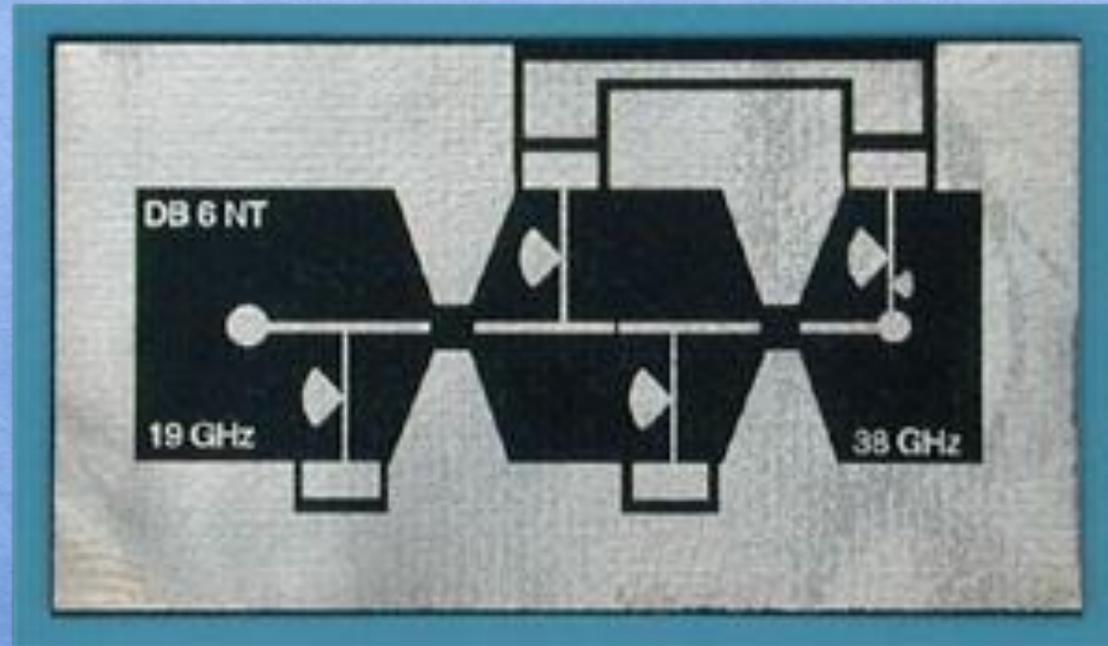

DB 6 NT 76 GHz

DB 6 NT
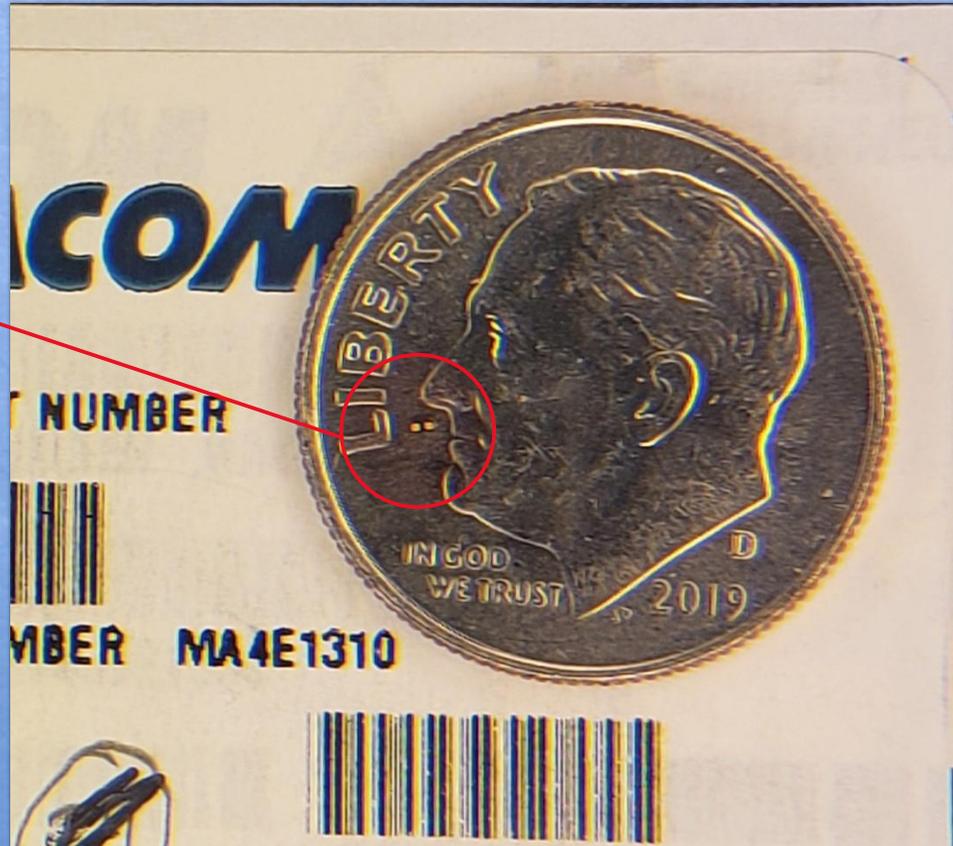76 GHz/2

NM TechFest 2020

NMVHF
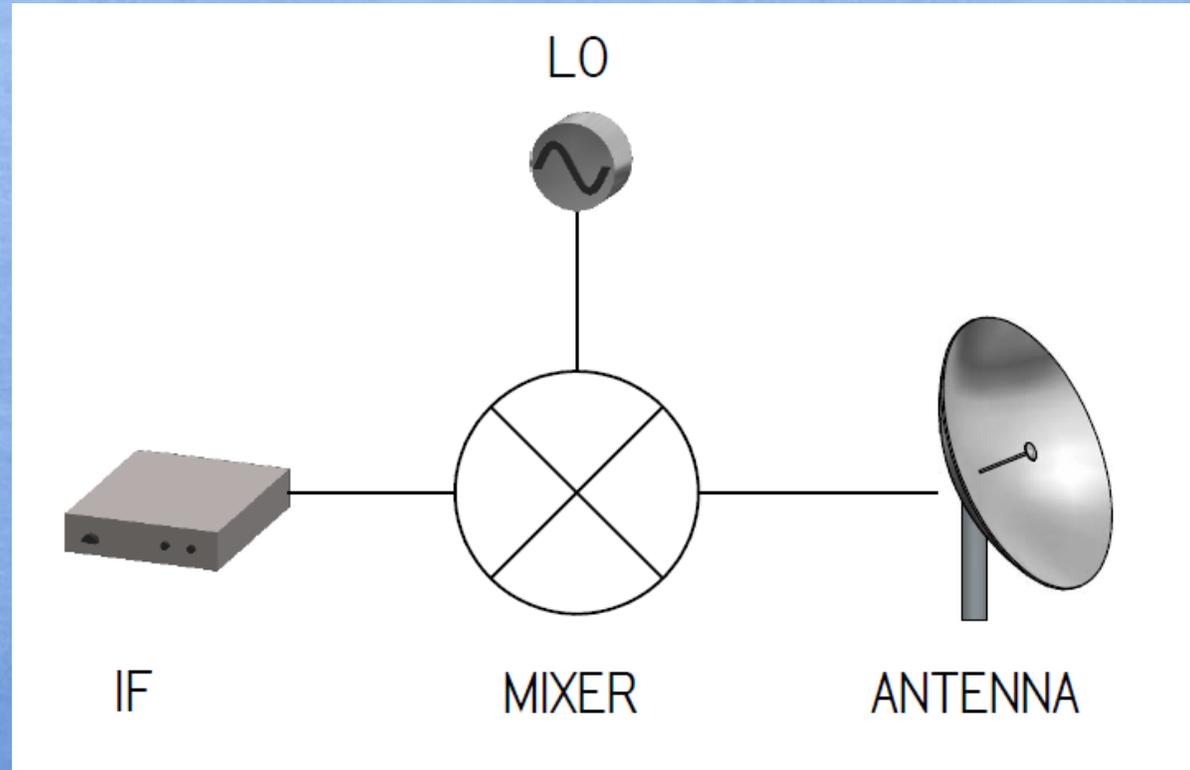
Surplus Frequency Multipliers
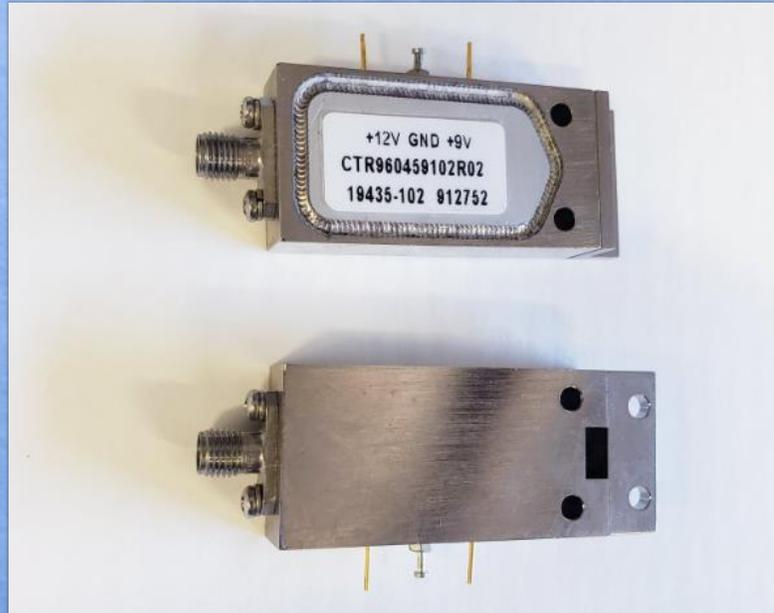
DB6NT 38 GHz Doubler

Mixer Diode

Diode

Homebrew Mixer

NMVHF
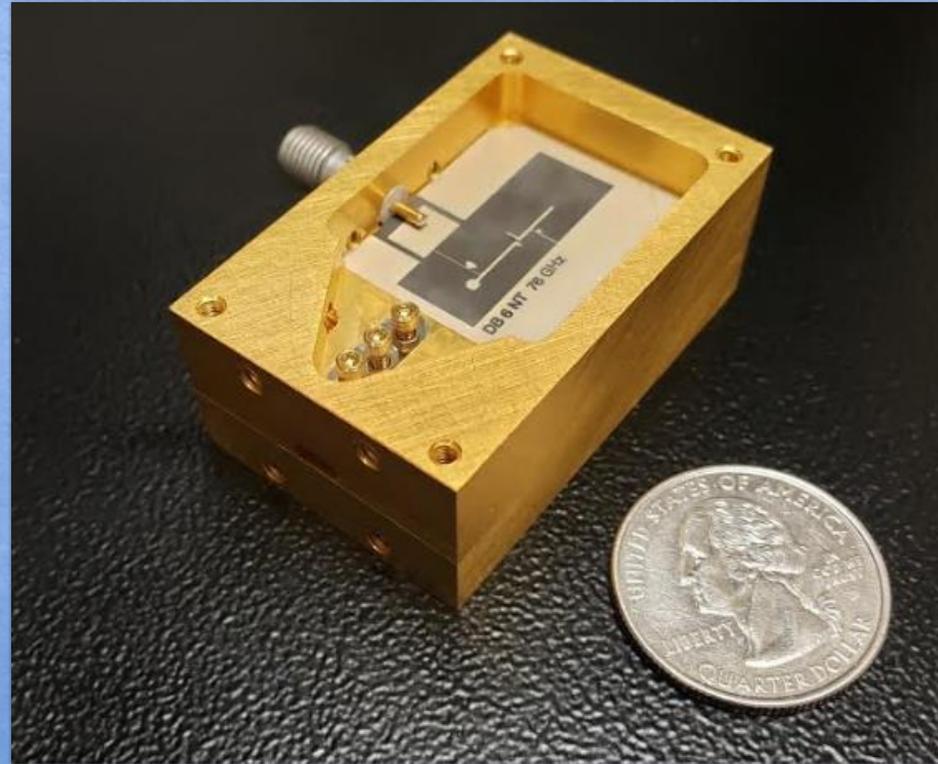
Surplus 12" Dish
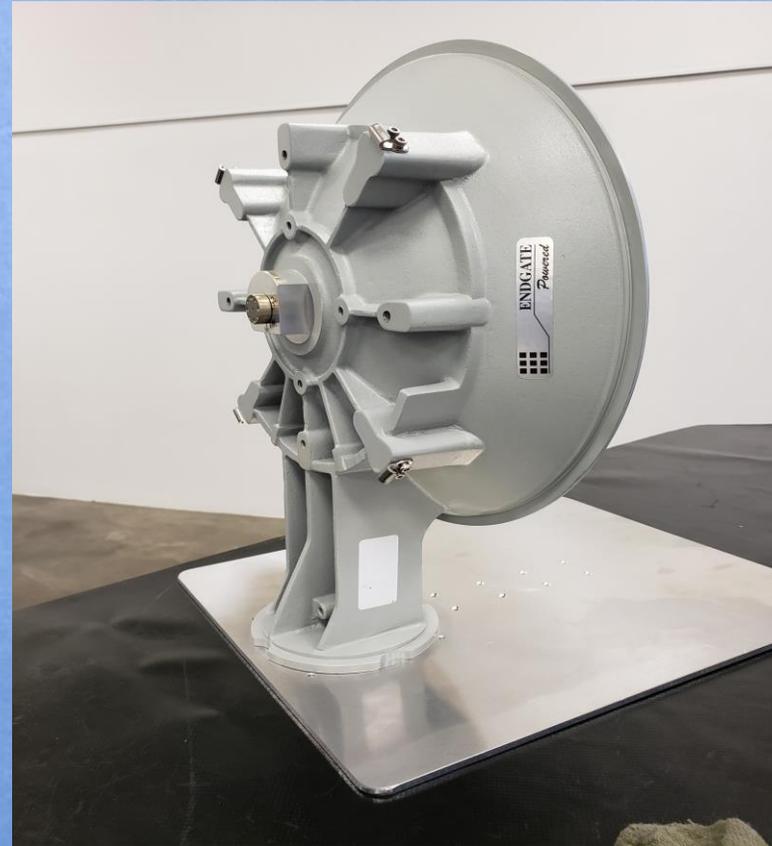
Edmunds Scientific Dish

NM TechFest 2020

NMVHF

W1GHZ Online Antenna Book
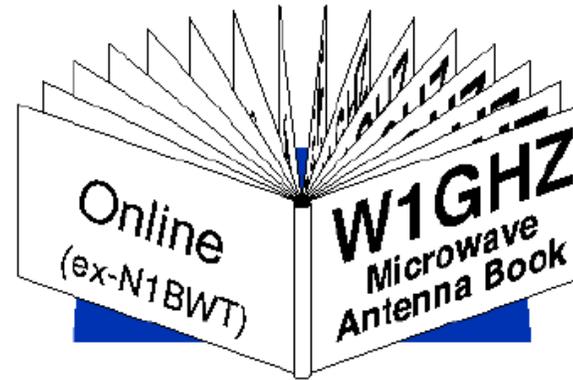
The W1GHZ Online Microwave Antenna Book
Paul Wade W1GHZ (ex N1BWT) © 1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2005,2006

Table of Contents

Preface -30 September 1999

Part 1 — Practical Antennas

1. Antenna Basics - *25 September 1998*
2. Electromagnetic Horn Antennas - *March 1998*

W1GHZ Cassegrain Calculator

M² 6 wavelength 432 Yagi

SPECIFICATIONS:

Model	432-6WL
Frequency Range	420 To 440 MHz
*Gain	18.04 dBi
Front to back	23 dB Typical
Beamwidth	E=22° H=24°
Feed type	Folded Dipole
Feed Impedance.	50 Ohms Unbalanced
Maximum VSWR	1.2:1 Typical
Input Connector	"N" Female
Power Handling	1 kW
Boom Length / Dia	14' 6"' / 1"
Maximum Element Length	13-7/8"
Turning Radius:	96"
Stacking Distance	65" High & 65" Wide
Mast Size	2" Nom.
Wind area / Survival	0.85 Sq. Ft. / 100 MPH
Weight / Ship Wt	4.6 Lbs. / 7 Lbs.

45 dB of gain with M² 432-6WL Yagis

◈ 1 antenna = 18 dB of gain

◈ To get to 45 dB of gain, 45 – 18 = 27 dB improvement

◈ 3 dB of gain for every doubling of array

◈ 27 / 3 = 9

◈ So you would need an array of 2 ^ 9 or 512 antennas

27 dB Horn Antenna

NM TechFest 2020

NMVHF
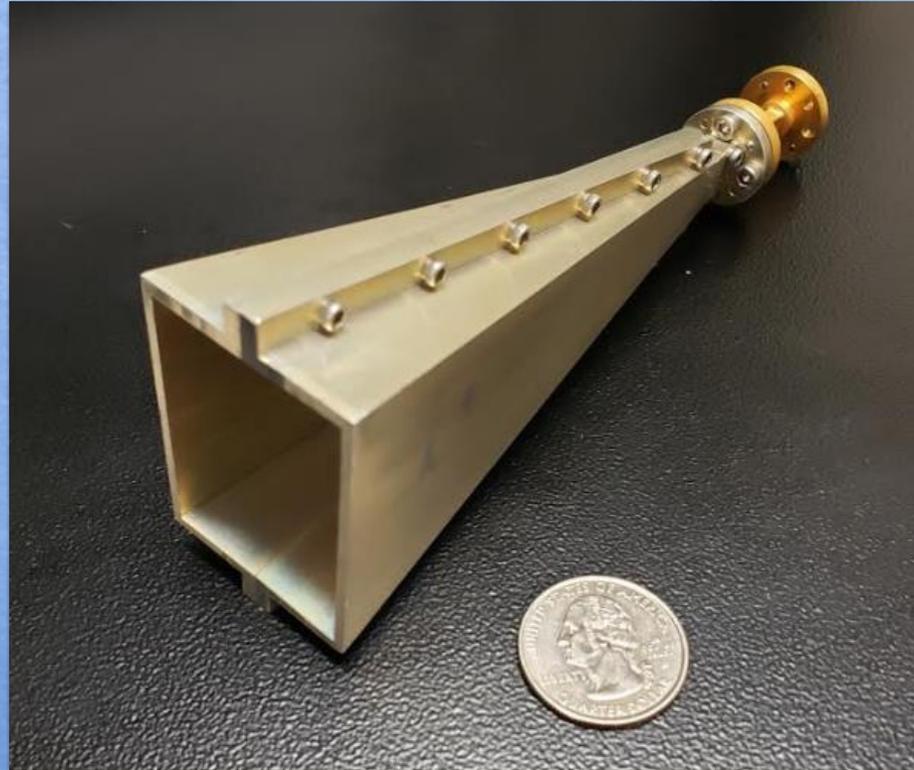
WA1MBA 78 GHz Preamp
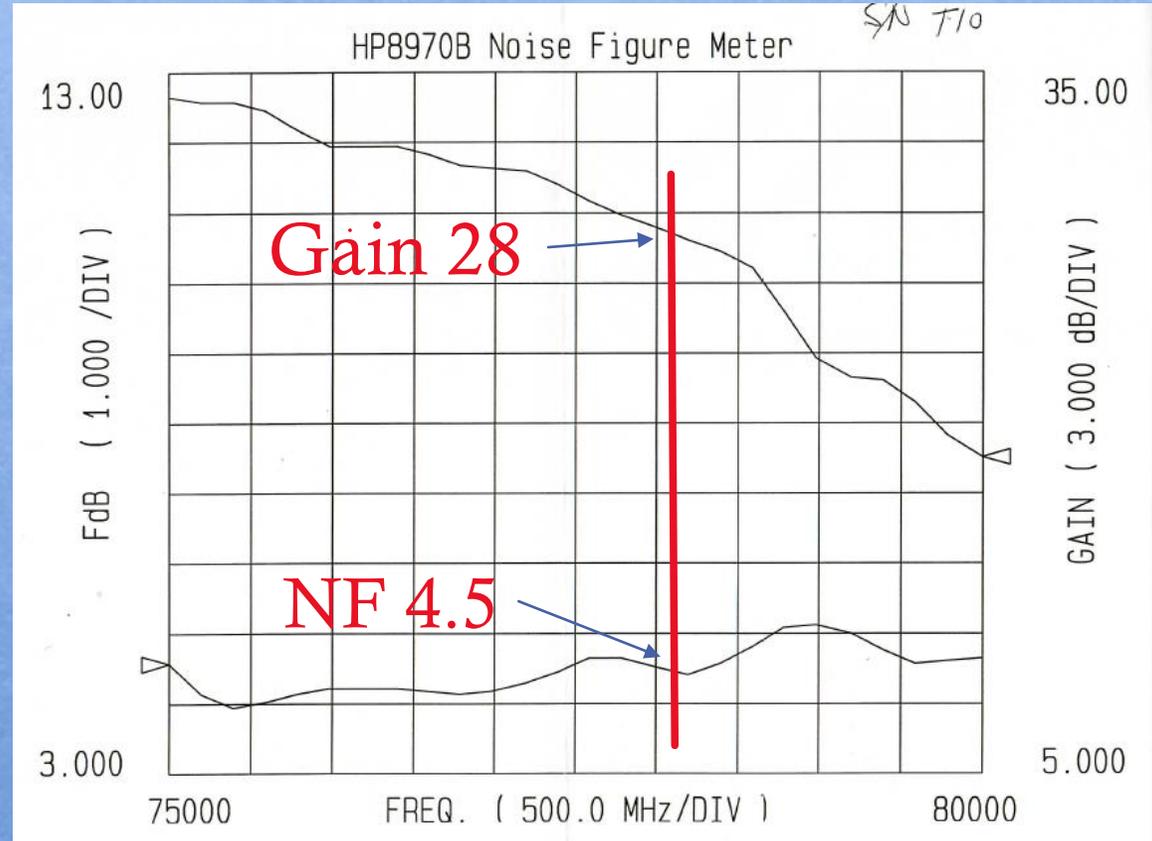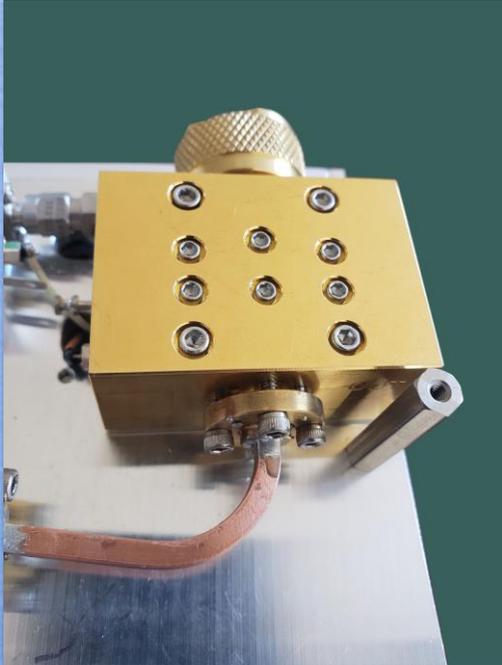
Sage Millimeter 75 GHz PA

Mixer output @ 78 with 432 MHz IF

- LO 5 dB greater than USB

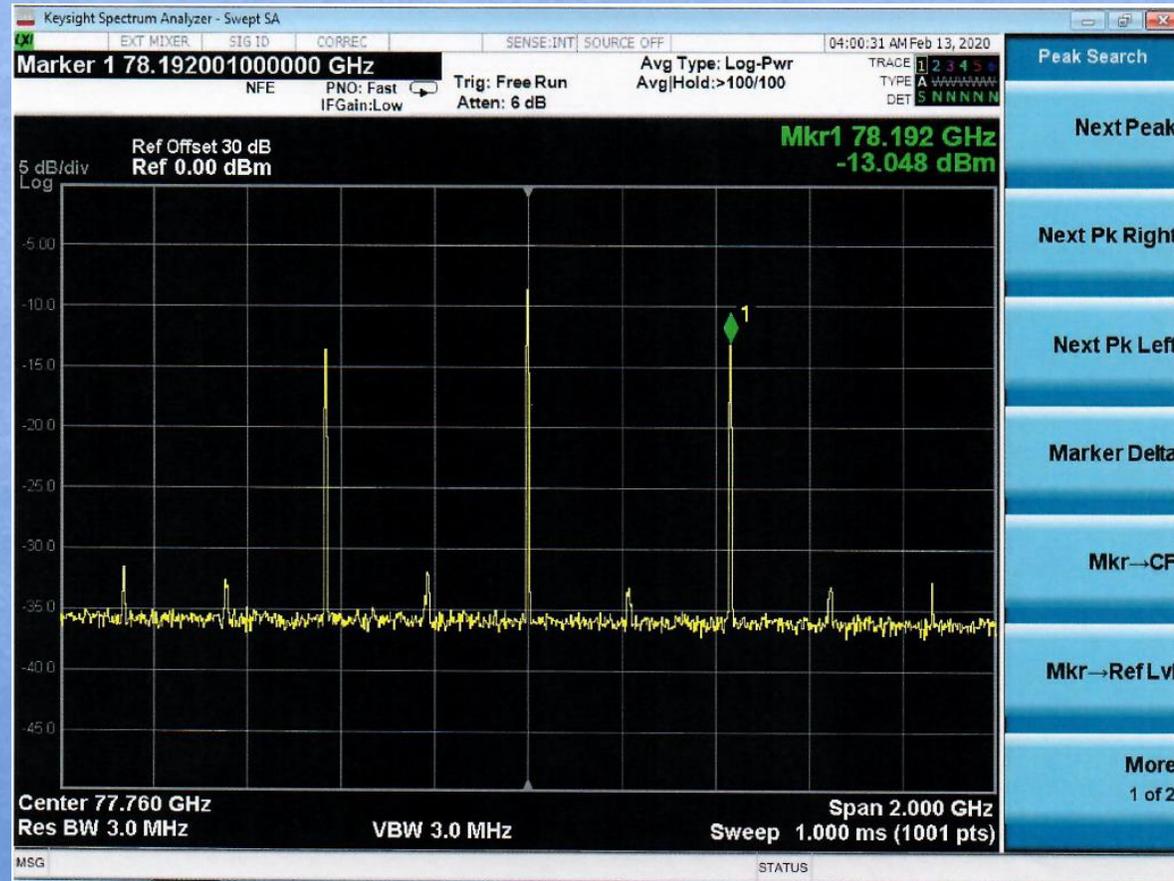- Don't want LSB at all

WGFIL Example


```
          Waveguide Filter Systhesis Program
          copyright (C) 1989  Dennis Sweeney WA4LPR
                    Version 1.1


Filter type:    Butterworth  : 1
                Chebyshev     : 2
                Equal Element : 3
      Enter # of desired type : 3

Filter structure :    Post  : 1
                      Iris  : 2
      Enter # of desired type : 1

Enter waveguide width (inches) .1240

Enter # of elements : 3

Center frequency in MHz = 78192
Bandwidth in MHz = 1000_
```

```
Post Coupled Filter    Center: 78190.401 MHz    BW:  1000.000 MHz
                       Fractional BW   1.28 %   Guide BW   2.03 %
                       Equal element minloss


Post diameter      Cavity length
  0.0163"
                   0.1008"
  0.0313                                  Caution:  D/a > 0.25
                   0.1112"
  0.0313                                  Caution:  D/a > 0.25
                   0.1008"
  0.0163

Do you wish another design (y/n)? _
```
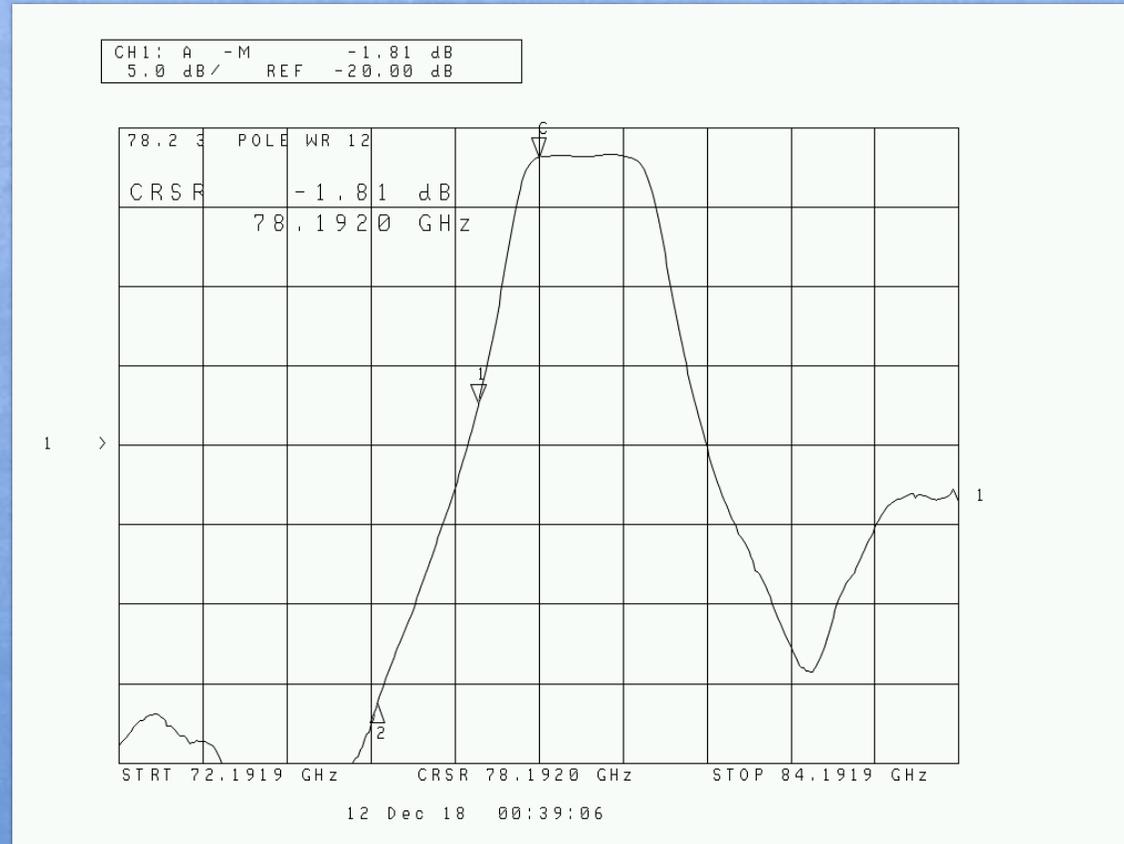
NM TechFest 2020

NMVHF

78 GHz 3 pole Band Pass Filter

Marker 0 @ 78,192 (reference)

Marker 1 @ 77,760   -14 dB

Marker 2 @ 77,328   -34 dB

Not very good for 432 IF

CH1: A -M   -1.81 dB
5.0 dB/   REF -20.00 dB

78.2 3   POLE WR 12

CRSR   -1.81 dB
         78.1920 GHz

STRT 72.1919 GHz   CRSR 78.1920 GHz   STOP 84.1919 GHz
12 Dec 18   00:39:06

Final 78 GHz 4 Pole Filter

- Marker 0 @ RF 78,192
- Marker 1 @ LO 75,888
- More than 30 dB down

CH1: A -M   -1.00 dB
5.0 dB/   REF   0.00 dB

78.2 4 POLE

CRSR   -1.00 dB
         78.1999 GHz

STRT 71.9999 GHz   CRSR 78.1999 GHz   STOP 82.0000 GHz

17 Dec 18 12:00:40

NM TechFest 2020

NMVHF
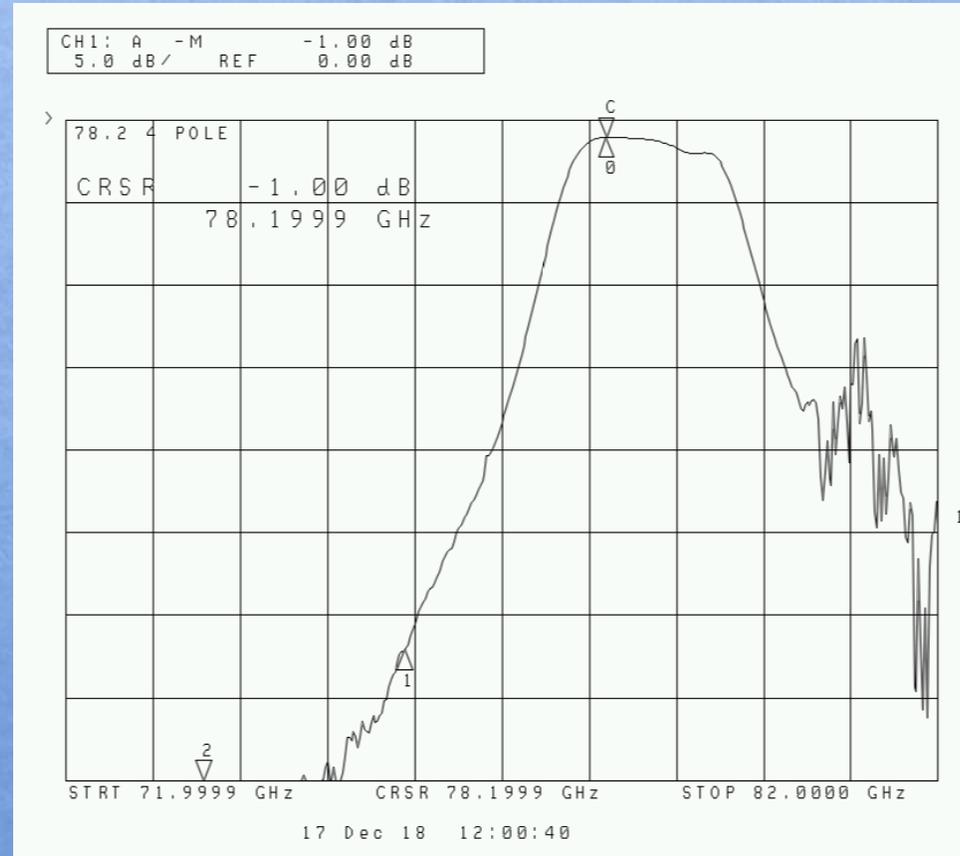
Mixer output @ 78 with 2304 MHz IF
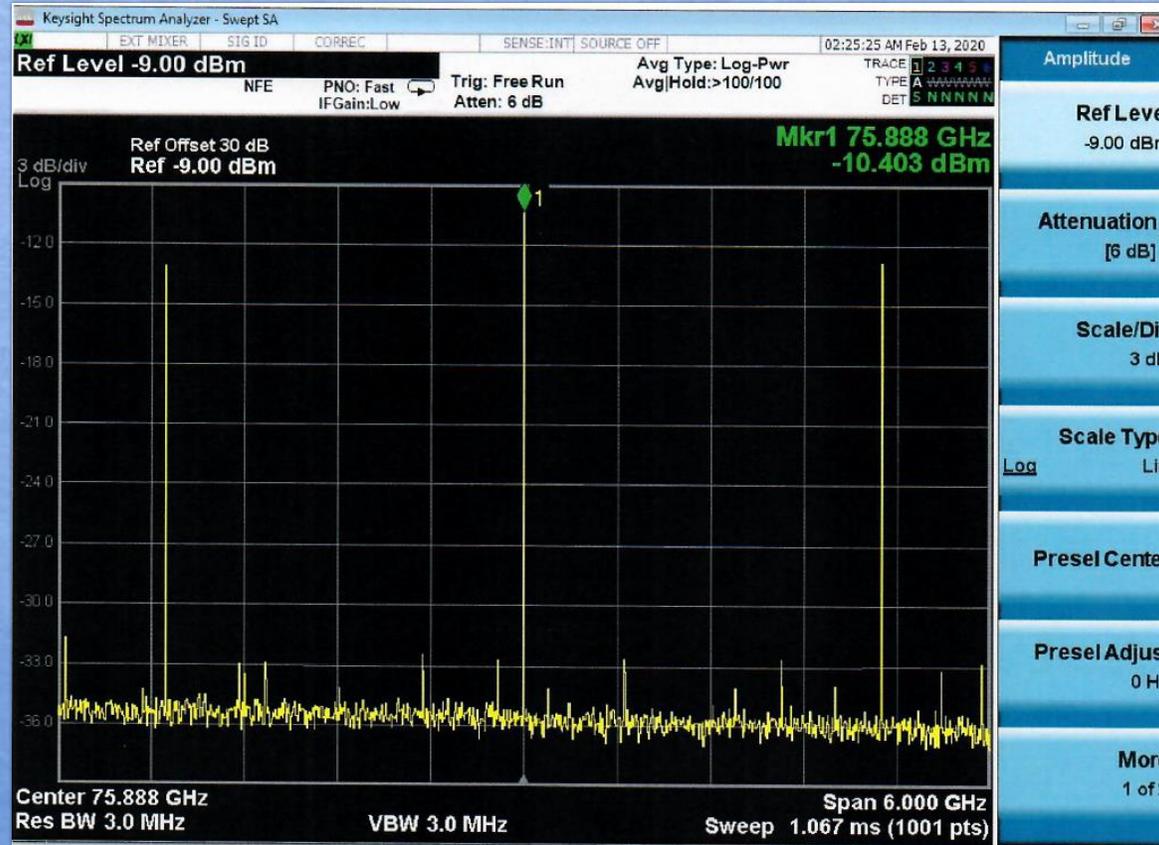
Mixer output @ 78 after Filter

Close in view

NM TechFest 2020

NMVHF

WR12 Circulator

NM TechFest 2020

NMVHF
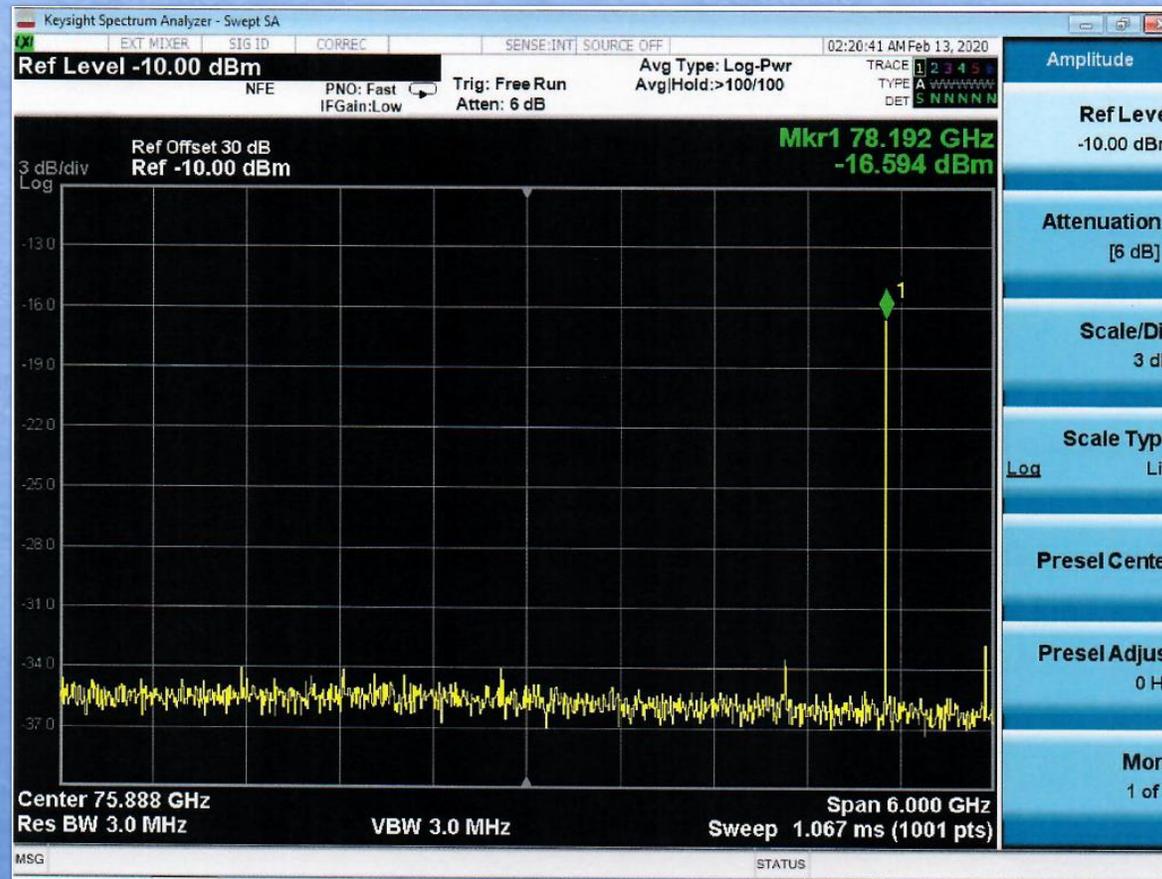
78 GHz Ver 1 Block Diagram

NM TechFest 2020

NMVHF
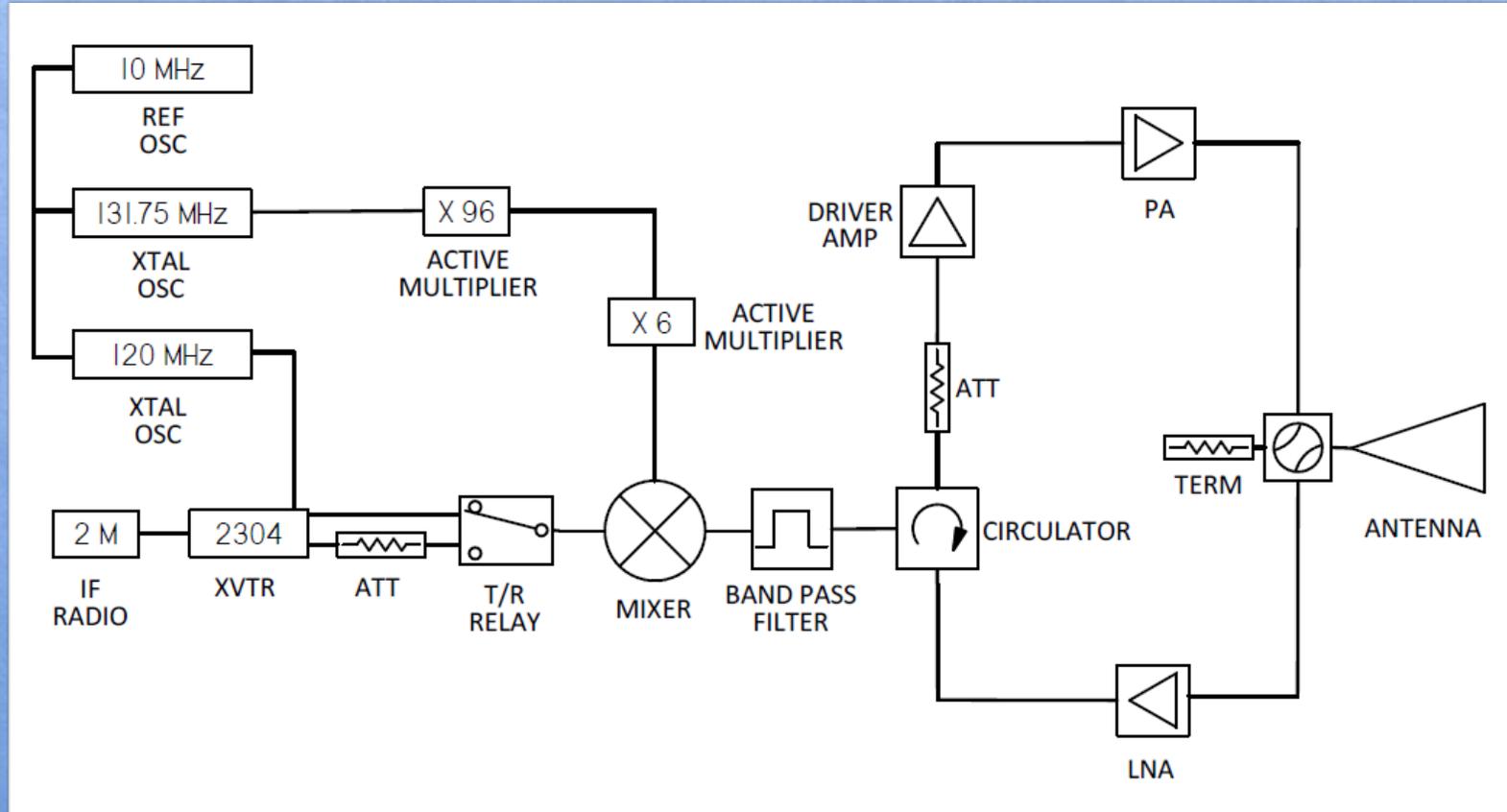
78 GHz Ver 2 rig in Arizona

NM TechFest 2020

NMVHF

W7QQ 78GHz Ver 1 rig 207 km path

78 GHz Ver 3 Block Diagram
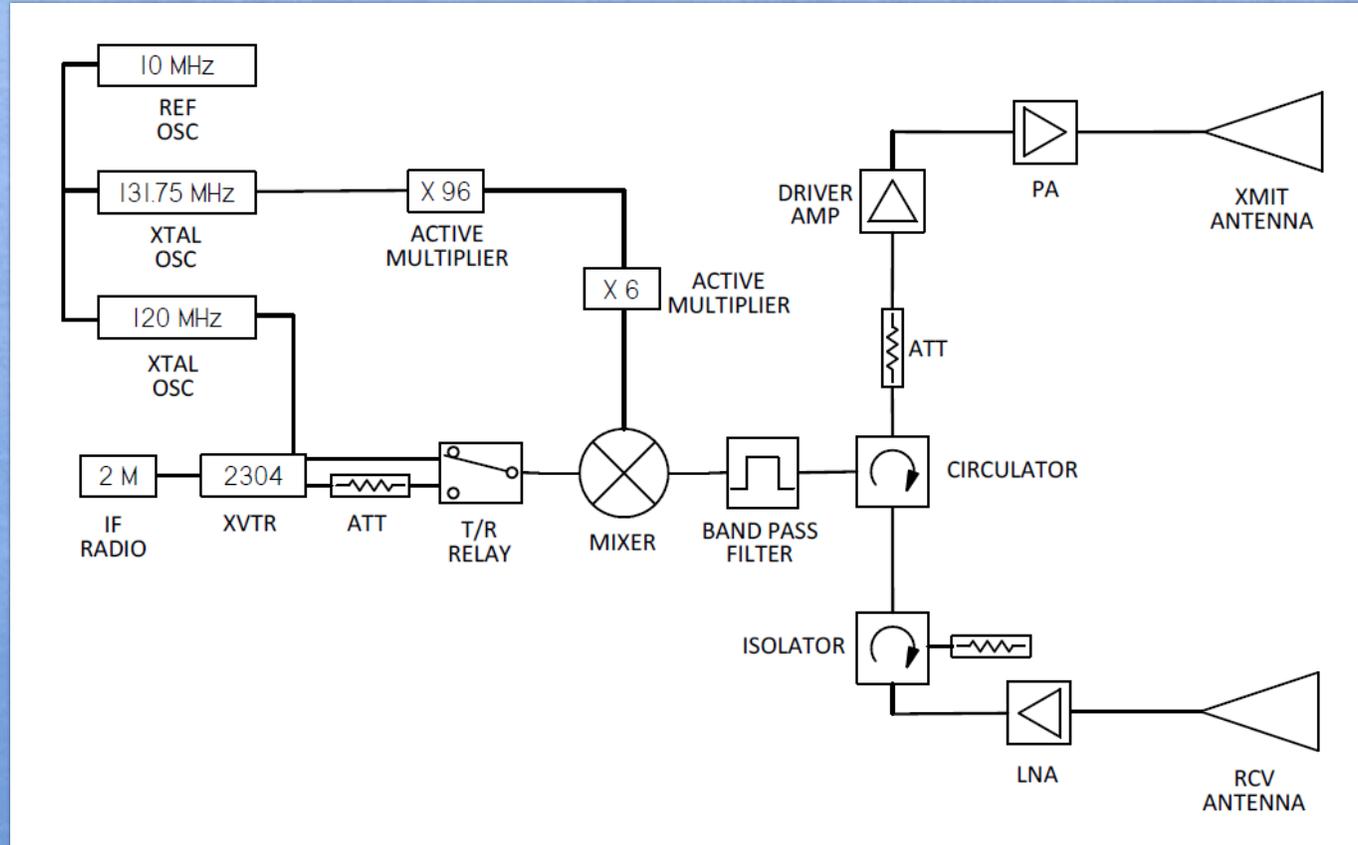
78 GHz Ver 3 rig ready to go

NM TechFest 2020

NMVHF

Mixer for 122/134

◈ **Model SFB-08-N1** is an F-Band balanced mixer that utilizes high performance GaAs Schottky beam-lead diodes and a balanced circuit configuration to offer superior RF performance. The mixer supports the full waveguide band operation for both LO and RF frequencies from 90 to 140 GHz with an extremely broad IF output from DC to 40 GHz. The mixer offers a conversion loss of 12 dB typical and a high RF to LO port isolation of 30 dB.

WR06 Waveguide Cutoff

**Rectangular Waveguide Sizes**

Waveguide name			Recommended frequency	Cutoff frequency lowest order mode	Cutoff frequency next mode	Inner dimensions of waveguide opening	
EIA	RCSC *	IEC				A inch[mm]	B inch[mm]
WR6	WG29	R1400	110 to 170 GHz	90.791 GHz	181.583 GHz	0.065 [1.651]	0.0325 [0.8255]

Cutoff

NM TechFest 2020   NMVHF

122 GHz LO and LSB Filtering

- WR06 Cutoff 91 GHz
- Natural High Pass Filter
- LO and LSB under cutoff

81,990 GHz

LO

40,266 GHz ——— IF

RF ——— USB 122,256 GHz
LSB 41,724 GHz

NM TechFest 2020

NMVHF
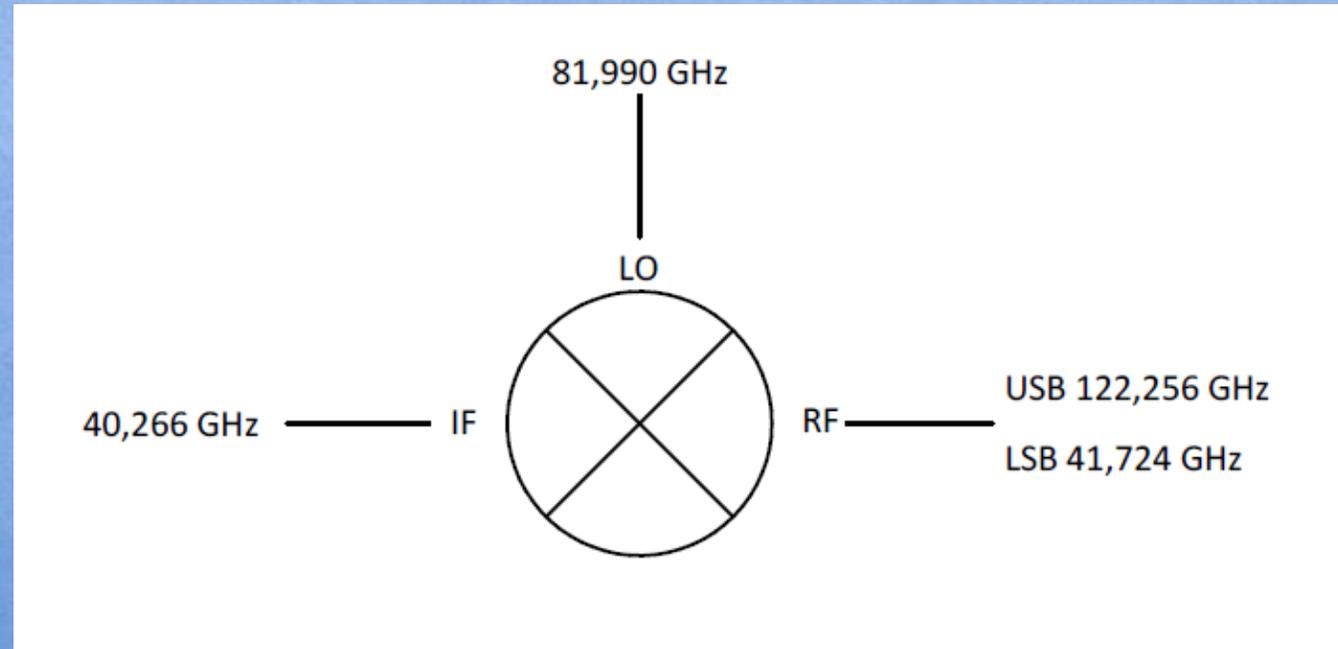
DigiLo Synthesizer Board

NM TechFest 2020

NMVHF
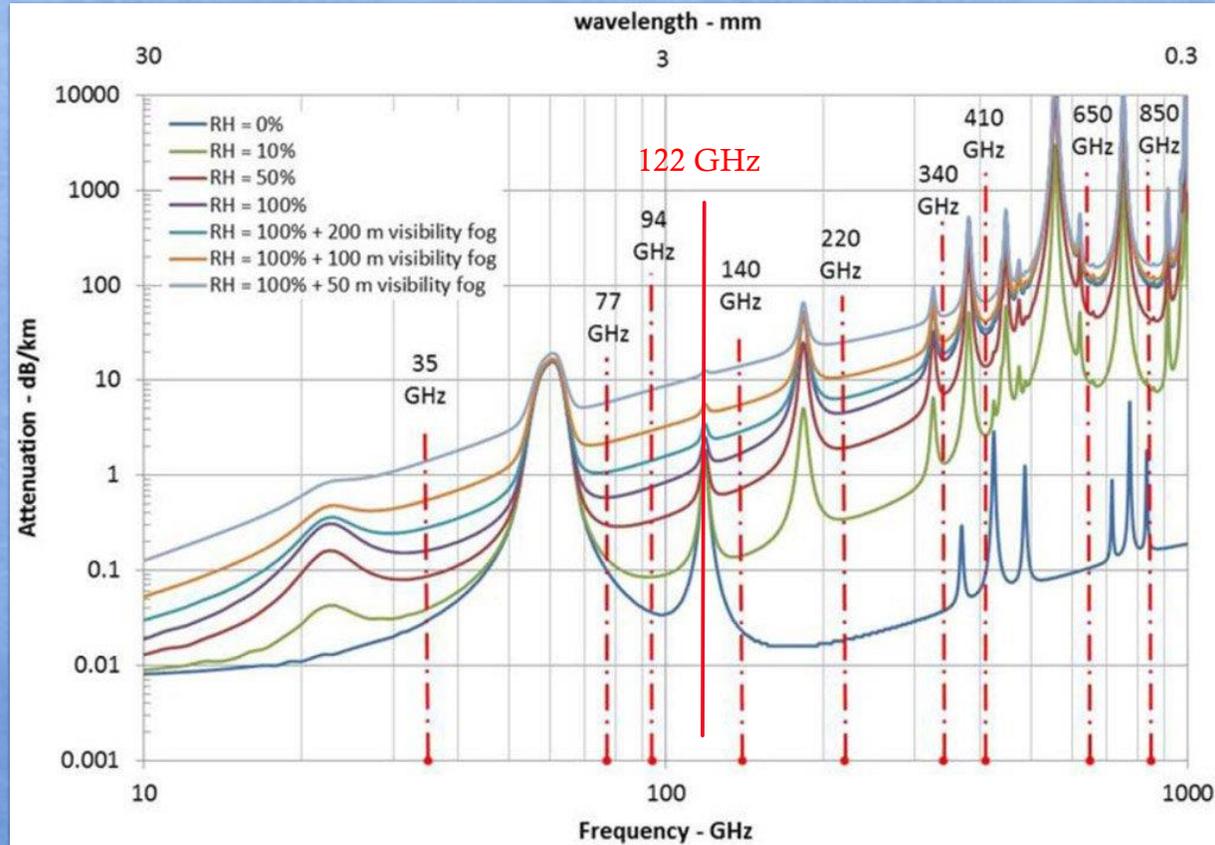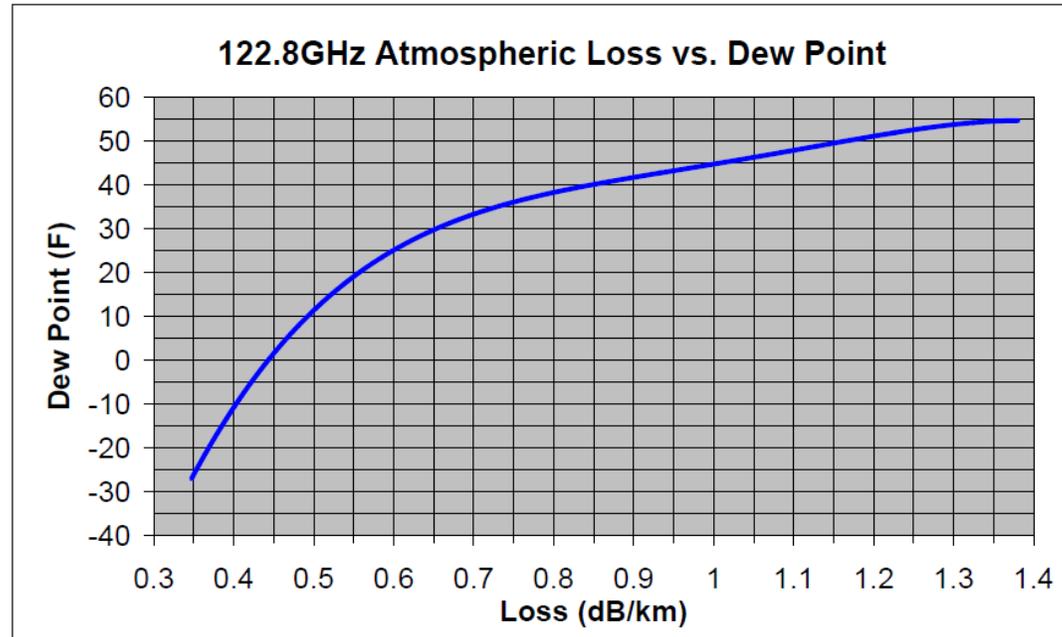
122/134 GHz Ver 1 Block Diagram
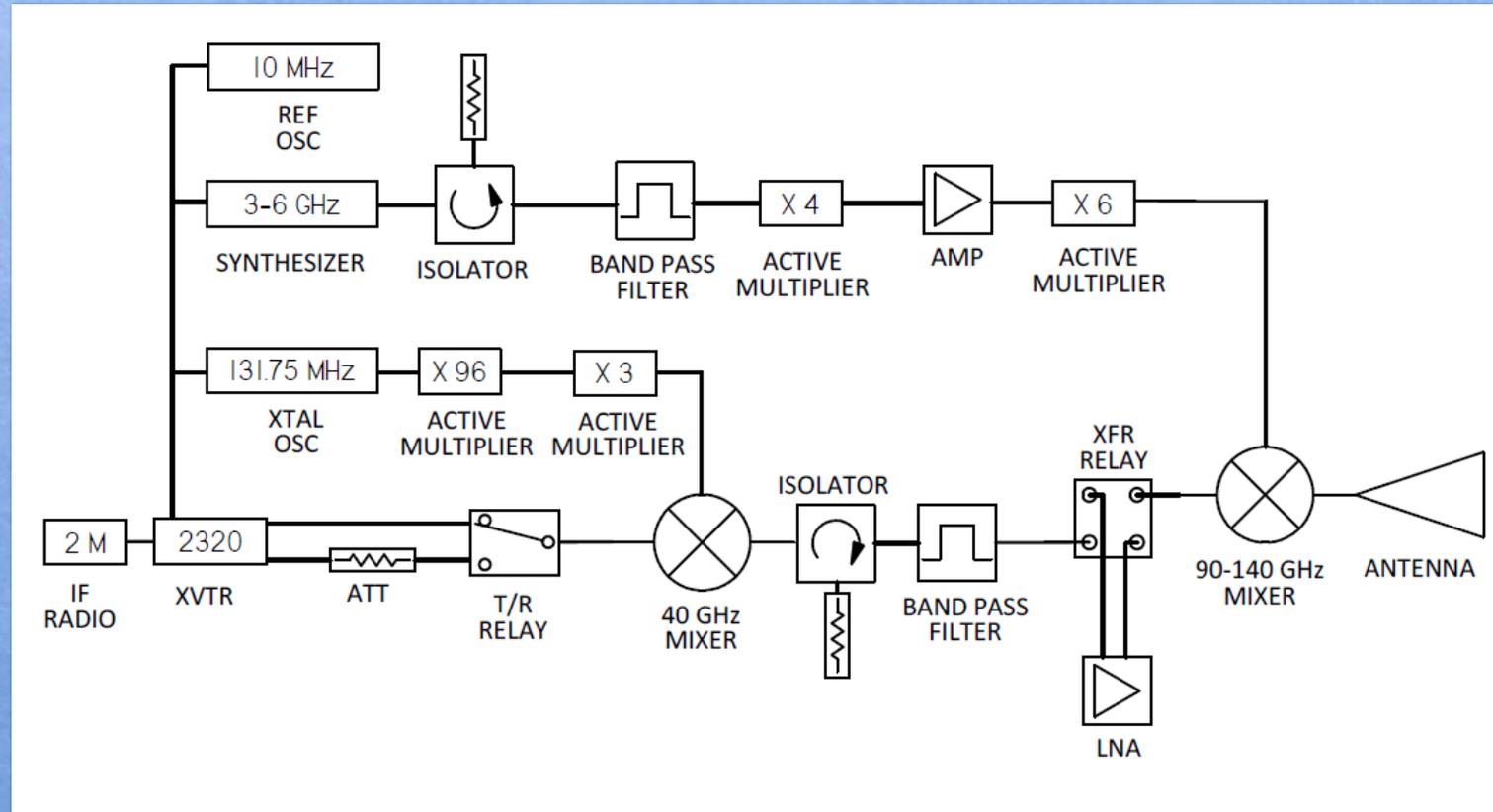
Atmospheric Losses

Calculated Atmospheric loss @ 122 GHz

Path Loss Charts. This path loss is ONLY the part due to atmospheric attenuation/absorption. Based on Lieb formulations Prepared by Brian Justin WA1ZMS.   Calculated for Sea Level (standard pressure).

122.8GHz Atmospheric Loss vs. Dew Point

Path Losses @ 122 GHz

◈ Free space path loss = 20 log (4 π D / λ)

◈ For D = 100 km, λ = 2.5 mm, Free space loss = 174 dB

◈ From Brian's table @ 0 ° Dew Point, additional loss of 0.45 dB/km

◈ Atmospheric loss 100 km x 0.45 dB/km = 45 dB

◈ Total path loss = 178 + 45 = 223 dB

NM TechFest 2020

NMVHF

122 GHz Power at the Receiver

◈ Mixer output − 6 dBm + 49 dB dish gain = 43 dBm

◈ 12 " dish on receiver end = 49 dB

◈ Received signal level = (43 + 49) − 223 = -131 dBm

NM TechFest 2020   NMVHF

Receiver Noise Floor @ 122 GHz

- Noise Floor (dBm) = 10 log (k x To x 1000) + NF + 10 log BW

- For To = 290 kelvin, system NF = 11 dB and a 1000 Hz bandwidth

- Noise Floor = -174 + 11 + 30

- Noise Floor = - 133 dBm

NM TechFest 2020

NMVHF

Received Signal on 122 GHz

- Noise Floor = -133 dBm

- Received power = -131 dBm

- S/N = 133 – 131 = 2 dB , MDS on CW for a good operator

- Probably need to find a day with dew less than - 5° for 100 km path

NM TechFest 2020

NMVHF

Just Buy It

- Kuhne MKU 76 G2
- Kuhne MKU LO 8-13

- Just add waveguide switch and antenna to be on the air

References

◈ Kuhne Electronics: https://shop.kuhne-electronic.com/kuhne/en/shop/amateur-radio/

◈ W1GHZ Online Antenna Book: http://www.w1ghz.org/antbook/contents.htm

◈ WA1MBA microwave pages: http://www.wa1mba.org/

◈ digiLO Q5 Signal: http://q5signal.com/index.php?route=product/product&product_id=67

◈ Sage Millimeter: https://www.sagemillimeter.com/

Questions ?

NM TechFest 2020

NMVHF