Simple 122 GHz Radios

SiliconRadar TRX120
122 GHz ISM band
short range sensor

An update: What’s new since MUD 2017?

Mike Lavelle, K6ML
Andrew Anderson, VK3CV
MUD 2019, Dallas, TX
Ham Designs Using TRX120 @ 122 GHz

At least two of us are working on SiRadar based designs:

• MUD 2017: I showed a simple 122 GHz radio
  – Original TRX_120_001 chip
  – 2 km (2017): bare chip to bare chip (on chip 9 dBi antennas)
  – 25 km (2/19): 60cm offset dish (50 dBi) to bare chip (9 dBi); last winter here

• Dubus 2019/3: Andrew (VK3CV) described another 122 GHz radio
  – Newer TRA_120_002 chip
  – 60 km (7/19): 60 cm dish to 60 cm dish; winter Down Under
  – Tim, vk2xax@skybase.net, is putting together a group build of Andrew’s radio
    • Tim’s taking orders for assembled PCB & machined horns for another week or so.
    • Details announced on vk-microwave@yahoogroups.com.

• MUD 2019: I’m bringing up 2nd gen radio
  – TRX_120_001 & TRX_024_006
  – Dual band 122 & 24 GHz

Rumors of other SiRadar based designs out there
SiRadar TRX_120 Family

- **SiGe Technology**
  - For short range sensing applications

- **Tunable 120 GHz Local Oscillator**

- **div64 PLL prescaler**
  - 1.9 GHz to PLL
  - Can lock VCO to a stable reference

- **Tx PA**
  - 0.5 mW typ
  - Always on (FMCW)
  - Can’t do AM/SSB; use FM/FSK

- **Rx LNA**
  - ~9 dB DSB NF

- **Phased IQ mixers**
  - DC-200 MHz IF out
  - Could use IQ to reject image noise
Initial TRX_120_001 Packaging

- 8x8mm QFN56 package includes internal Tx and Rx antennas

- Each is an array of 4 patch antennas
  - Each about 2.5 mm x 2.5 mm area
  - About 3.1 mm apart
  - Each about 9 dBi gain
  - Open window for antennas

- This means no wires at 122 GHz
  - Highest freq. on PCB is LO/64 (~2 GHz)

- Antenna pattern is OK to feed an offset dish
  - ~80 degrees dish illumination, ~0.6 f/D
K6ML 122 GHz Front End (2017)
Add PLL, IF Amp and Regulators
1.9”x2.5” FR4 PCB

ADF4159 PLL
Loop Filter

1.9 GHz
Phase Locked Loop
~2 GHz/V

TX Enable
(T/R, CW keying)

120 GHz
VCO

PA
(-3 dBm)

IF Amps
(I & Q)
0-2.5 MHz

I/Q Mixer

LNA
(~10 dB DSB NF)

TRX120
Complete Radio

• **Tx**
  – Arduino Trinket controller
    • FSK keying for beacon
    • Tuning switch: 16 channels; 160 MHz steps
  – 10.000000 MHz ovenized crystal oscillator
  – Use the TRX120 10 dBi in-package antennas
    -3 dBm PA + 9 dBi antenna = +6 dBm EIRP

• **Rx**
  – Same hardware plus a FT-817 or similar as 2.5 MHz IF
    -174 dBm + 12 dB (NF) + 35 dB (3 kHz) -9 dBi (ant) = -136 dBm MDS

• **System Gain** = 142 dB (in 3 kHz) without dishes
Atmospheric Loss

can be 1 – 2 “S” units every 10 km

strongly depends on water vapor plus relatively constant oxygen

For example, a 100 km LOS path at 122 GHz (68°F, 50%RH, sea level)

FSPL = 173 dB (1/r^2)
ATML = 80 dB (1/r)
Total = 253 dB

...equal to EME path loss at 144 MHz
Roughly Equivalent Antennas

150 foot Stanford Big Dish, operating at around 1 GHz

18” TV satellite dish, operating at 122 GHz

Both have over 50 dB gain (and both have less than ½ degree beam) Because both are about 200 wavelengths in diameter
Dish Antenna Beam Skew

• TRX_120_001 TX and RX antenna sites are offset by:
  ~ 3 mm vertically and ~ 0.7 mm horizontally

• With **high gain** (long focal length)
  – We get serious parallax between TX and RX beams

• Example: estimated beam shift is **half a degree**
  – But -3 dB half beam width is about **an eighth of a degree**
  – Tx beam is in the **first null or side lobes** of Rx pattern!!!

• I hear you, but you don’t hear me

3 mm 0.49 degrees

3 mm FL (60 cm f/D 0.59)
Solving Tx/Rx Beam Skew

At least two ways to skin this cat ...

- **K6ML**: Reposition feed on every “over”
  - Use micro linear actuators to slide PCB & chip to focal point
  - Supports band switching, too
  - Firmware calibrates, remembers and applies feed X-Y offsets when band or T/R switching

- **VK3CV**: Combine Tx/Rx antennas into one feed
  - Designed & machined a waveguide combiner
  - Fits over TRA_120_002 5x5mm QFN package
  - Single circular WG out to feed horn
  - Designed & machined a teensy Chaparral horn
Newer TRA_120_002 Packaging

• Smaller 5x5mm QFN32 package with internal Tx and Rx antennas
  – Cost Reduction

• Each is an on-die dipole
  – About 1.7 mm apart (closer)
  – WG Combiner fits over smaller chip
  – Sealed inside package

• Again, no wires at 122 GHz

• Lower gain, broader antenna pattern
  – Not great for feeding a dish directly
  – But WG combiner drives separate common feed
K6ML 24/122 Dual Band Rig

- Use motorized X-Y stage to move desired feed to focus
- Add a 24 GHz front end that shares the dish & IF Rx
  - Make a copy of TRX_120 design using the TRX_024 chip
  - Use the X-Y stage to focus on 1 of 4 feeds (24/122, Tx/Rx)
- Extra ‘pilot’ band has several operational advantages:
  - Higher power & lower NF at 24 GHz using TRX_024
  - Much lower water vapor loss (and no O₂ loss) at 24 GHz
    - 24 GHz link budget is 50-60 dB better at 100 km
  - Dish pointing is 5x easier in both azimuth and elevation at 24
  - 5x easier to find operating frequency at 24 GHz
    - Can scale up freq. ref. error to 122, so ‘spot on’
  - Find ‘em on 24 & QSY up to 122 GHz
Motorized X-Y Stage for Feed Positioning uses linear slide bearings

Assembled stage w/backlash springs on adjustable feed arm insert

Building the feed positioner
K6ML 122/24
Dual Band Radio
(2.5” x 3.8” PCB)

- TRX 120
- TRX 024

Itsy Bitsy Arduino
- Tunes PLL
- Drives X, Y Motors
Motorized Dish Mount

Dish arm on see saw pivot & lazy susan rotor
Linear Actuators for El & Az (+/- 5 deg, ~0.02 deg res)
I²C bus links radio, dish & hand controller

Hand controller menus:
• Pointing the dish
• Tuning the radio
• Calibrating feed offsets
• Radio settings
PLL and motor status display
Finding Focus (metallized duct tape)
In Focus
on PCB, centered stage

First test target was perf board, but too much sun, switched to an Aluminum plate
122 GHz Antenna Testing ain’t easy...
A 2 ft dish is $250\lambda$ – wants > 0.3 km (far field)
Only 0.5 mW power & high path loss
plus multipath clutter and air current QSB
makes for several dB or more of flutter
300m Far Field Range
# Comparing Radios

Similar, but Different ...

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<th>Feature</th>
<th>K6ML 122/24</th>
<th>VK3CV 122</th>
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<td>TRA_120_002 5x5mm</td>
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<tr>
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<td>Patch array in _001 chip</td>
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<td>144.4 MHz</td>
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<td>Modes (right now)</td>
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<td>Availability</td>
<td>gen2 testing; design files:</td>
<td>Full design files in Dropbox;</td>
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<tr>
<td></td>
<td>gen1 now, gen2 someday</td>
<td>Group buy <strong>now</strong>:</td>
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<td>A&amp;T PCBs &amp; machined horns</td>
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For more info on VK3CV radio, see my 9/24 post to the mw list “122 GHz for All”
Thank You