

Technical Workshop

122 GHz

VK3CV

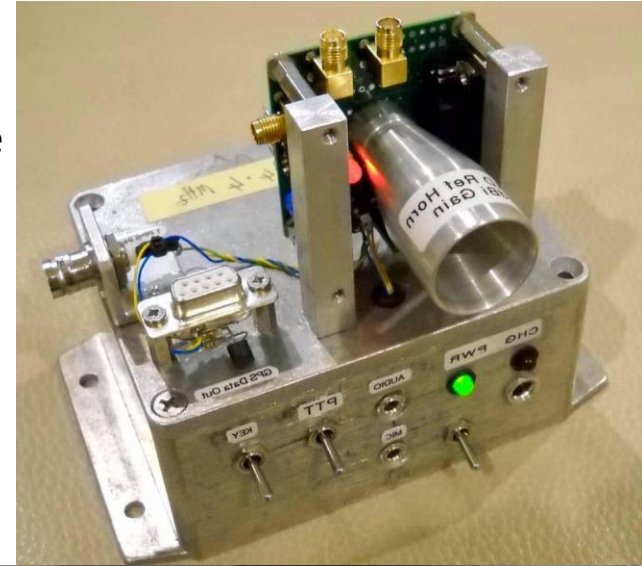
Transceivers

K6ML Intro, then Builders' Roundtable

July 2020

122 GHz Radar Transceivers

- Andrew's (VK3CV) design
- Tim's (VK2XAX) Group Build
 - Shipped ~300 late May-June 2020 to ~130 hams worldwide
- **Groups.io "The 122GProject"**
 - Message List
 - Wiki
 - Original DUBUS Article & Dropbox
 - Construction and Operation Notes
 - PCB & Control Schematics
- Facebook "122 GHz and mmwave activity"



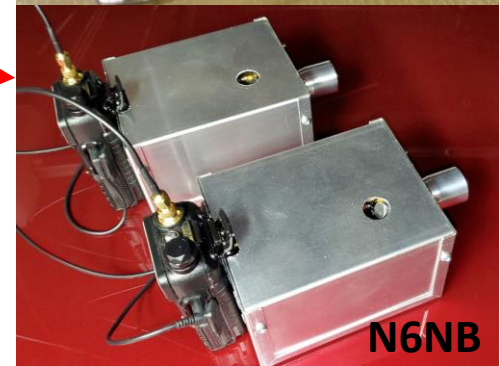
Mount + Ant + **Xcvr** + Ctrl + IF Rx

- VK3CV Transceiver
 - PCB = PLL + Complete Tx + Rx down converter + IF amp
 - Choice of feed horns: Chaparral or Conical
- Need to add:
 - IF receiver (2M SSB/FM/CW), **DISABLE TX (no mic, no key)**
 - Key, Mic and/or PC “Soundcard” for desired modes
 - Dish antenna & mount
 - Power supply
 - Mode & Channel Switches
 - 1PPS GPS (or External Reference)

Packaging & Partitioning

All That Stuff

- Feed & Control Boxes
 - Radio PCB
 - At feed point
 - Minimum beam obstruction
 - Power/Controls/IF Rx
 - Under/behind dish, convenient to Op
 - Interconnect cables & remote controls
- All – in – One Box
 - Dishless rig or beacon
 - FM Handie-Talkies
 - Or behind a PF or Cass dish
- Let's look at needed controls & I/Os...



Channel Pairs

Pair	Ch	Hex	8	4	2	A/B	Tx/Rx* Freq	Rx LO*	IF
0	A	0	O	O	O	O	122500.400	122356.000	+144.400
	B	1	O	O	O	X	122356.000	122500.400	-144.400
2	A	2	O	O	X	O	122250.0999	122394.2004	-144.1005
	B	3	O	O	X	X	122394.2004	122250.0999	+144.1005
4	A	4	O	X	O	O	122250.240	122394.4828	-144.2428
	B	5	O	X	O	X	122394.4828	122250.240	+144.2428
6	A	6	O	X	X	O	122400.000	122256.000	+144.000
	B	7	O	X	X	X	122256.000	122400.000	-144.000
8	A	8	X	O	O	O	122950.000	122805.600	+144.400
	B	9	X	O	O	X	122805.600	122950.000	-144.400
10	A	A	X	O	X	O	122500.400	122356.000	+144.400
	B	B	X	O	X	X	122356.000	122500.400	-144.400
12	A	C	X	X	O	O	122500.400	122356.000	+144.400
	B	D	X	X	O	X	122356.000	122500.400	-144.400
14	A	E	X	X	X	O	User defined pair (multiples of 0.4 MHz recommended)		
	B	F	X	X	X	X			

The original firmware has channel pairs 0 thru 6 as listed and pairs 8 thru 14 are just copies of pair 0.

* Tx & Rx on same freq and Rx LO at other half of pair, except for duplex mode (Rx LO = Tx freq; Rx Freq is other half of pair).

Channel 0A (pair 0, A/B = open or hex switch = 0) is the highest frequency (lowest O₂ loss) & recommended.

Andrew's new firmware supports RS-232 entry and EEPROM storage of a user defined frequencies in pair 14.

I'm also suggesting that pair 8 (a new standard pair at the top end of the band) be added (even lower O₂ loss).

Positive IF freq = low side LO & USB mixing; negative is reverse. This affects digital modes and image reject hybrids.

Might want to wire an 8 position rotary switch (0,2,4,..,14) plus A/B toggle switch to remote the hex switch; set hex = 0.

Operating Modes / Controls

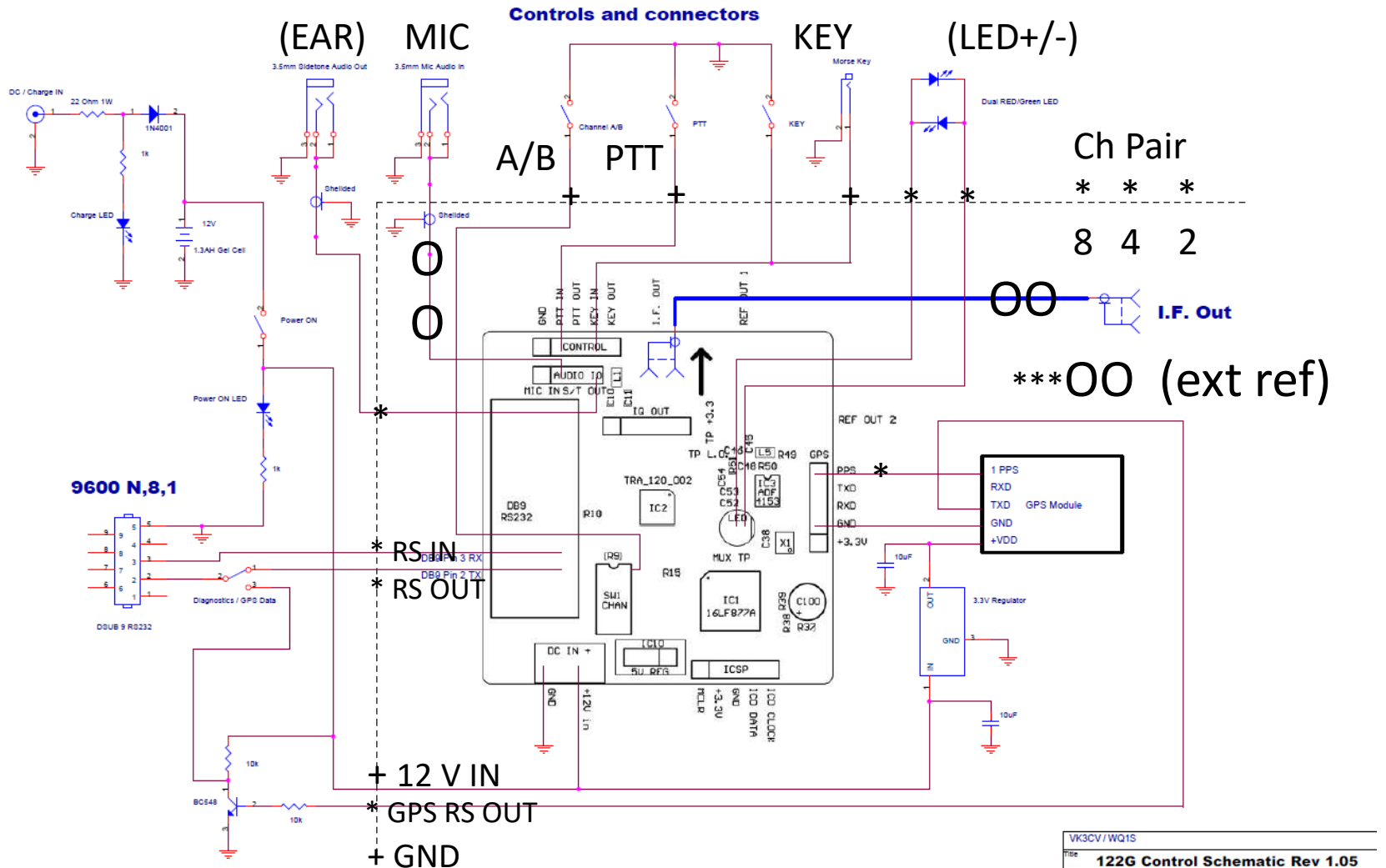
O = open, X = grounded

Mode	T/R	PTT_IN	KEY_IN	Chan A/B	IF Rx	I/O
OOK CW	Rx	O	O	O = A (both same channel)	CW	Full Break-in CW Ear = sidetone out Rx audio from IF Rx
	Tx	O	X			
FM Tone CW	Rx	O	O	X = B (both same channel)	FM	Full Break-in CW Ear = sidetone out Rx audio from IF Rx
	Tx	O	X			
FM Voice	Duplex	X	O	O = A (1st radio Tx A/Rx B) X = B (2nd radio Tx B/Rx A)	FM	Full Duplex Mic → Mic in Rx audio from IF Rx
	Rx	O	O	O = A or X = B (both same channel)	FM	Simplex (PTT) Mic → Mic in Rx audio from IF Rx
Tx	X	O				
Q&D Digital	Rx	O	O	O = A or X = B (both same channel)	USB	Simplex (PTT) PC sound out → Mic In Rx IF Audio → PC sound in
	Tx	X	O			
OOK CW Beacon	Tx	X	X	O = A	n/a	Beacon Tx (Ear = ID sidetone out)
FM Tone Beacon	Tx	X	X	X = B	n/a	Beacon Tx (Ear = ID sidetone out)

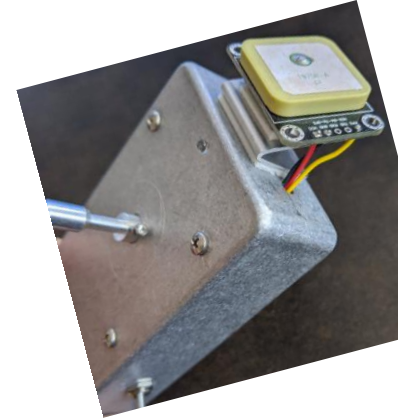
Except for FM Duplex, transmits & listens on same frequency

Control Wiring

(schematic from groups.io wiki)



Control Wiring Notes



- If two box partition (and GPS mounted at feed), how many wires?
 - Coax jack to IF Rx & shielded audio jack to mic
 - 5 minimum/essential wires: GND, +12V, A/B, PTT, KEY
 - 4 more likely wires: sidetone, ch8, ch4, ch2; really good idea to support remote chan switch
 - 2 more wires for LED (if not left to be seen on feed box)
 - 2 more if want RS-232 transceiver console (diagnostics, user def chan on the fly)
 - 1 more if want GPS RS-232 output
 - **A DB15 conn can handle all, most could fit in a DB9 conn**
- If GPS is used,
 - Need separate voltage regulator and 1 PPS, power & GND connected (RS-232 opt)
 - Good idea to have SPST switch on 1 PPS in: GPS out (use GPS) vs GND (don't use GPS)
- If Ext Ref is used instead of GPS,
 - Should wire GPS 1PPS to gnd (to prevent interrupt on noise)
 - Add a coax jack to bring in 10 MHz ext ref, and (maybe) audio jack to send out modulation
 - Want clean regulated supply for ext ref
- A battery power supply is a good idea (quieter)
 - Transceiver only draws about 90 mA as shipped (220 if sub linear reg for switcher)
 - Don't run below low voltage threshold (possible PIC loss of memory)
 - Don't charge while power is on (same PIC issue); chg & pwr on LEDs & power switch per schem

Top Side PCB

CONTROL (UR): PTT_IN, KEY_IN

AUDIO (UR): MIC/GND, EAR/GND

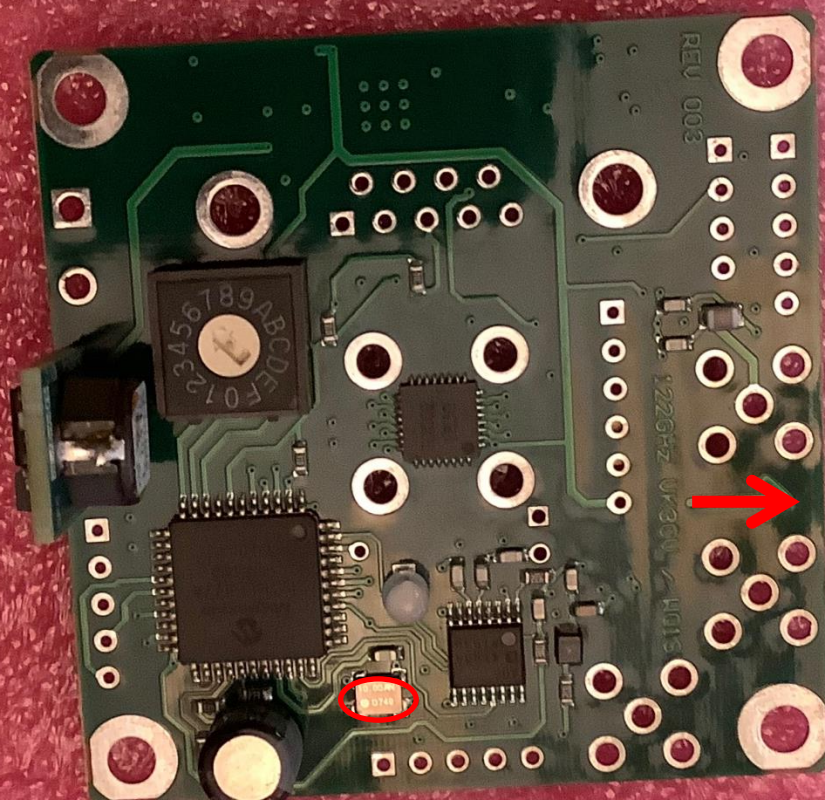
IF OUT (COAX, R): IF RX

REF OUT (COAX, LR): use as REF IN if ext ref mod

GPS: use PPS/GND if GPS; don't use PWR, RS232

DC IN: +12V & GND

CHAN PAIR, A/B: wire to back of switch, set switch to "0" (all open)



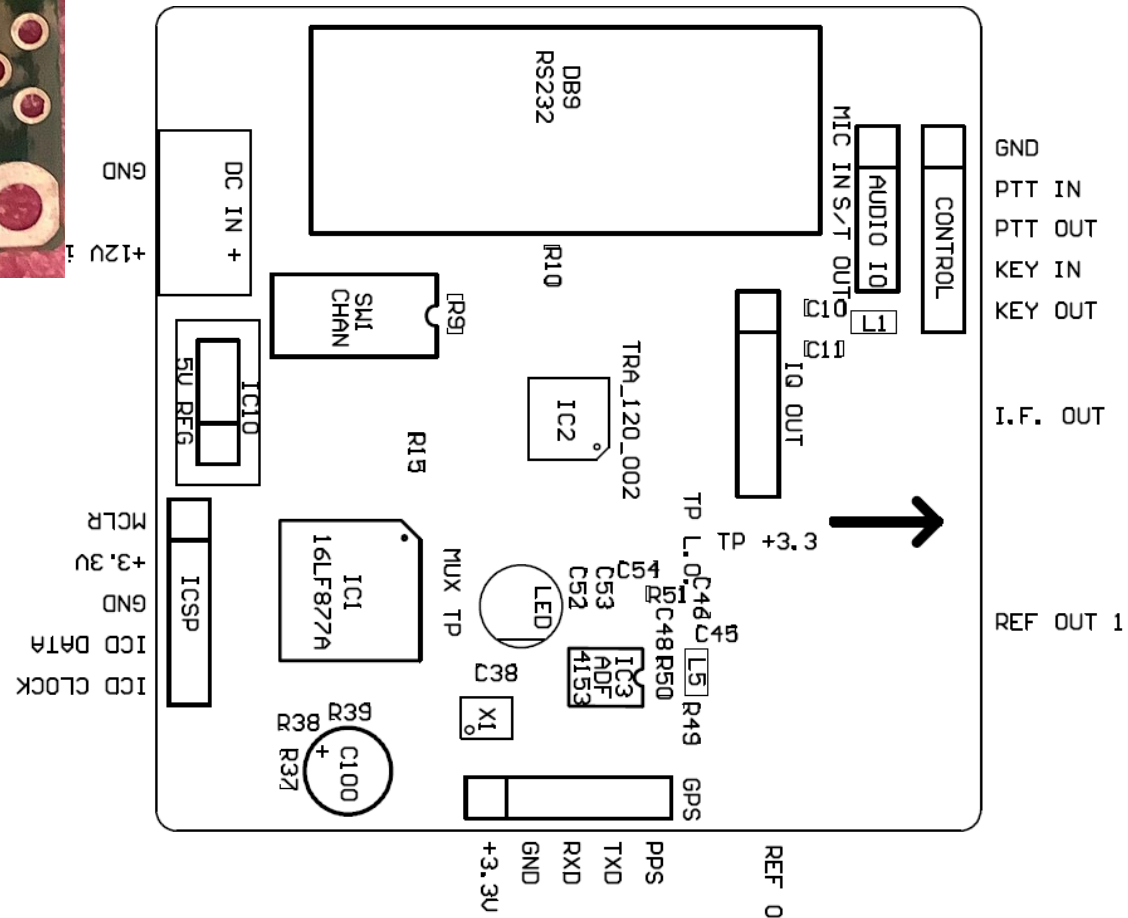
MAKE SURE ARROW IS HORIZONTAL for standard horizontal polarization!!!

MORE OPTIONS:

ICSP (LL): to program PIC FW

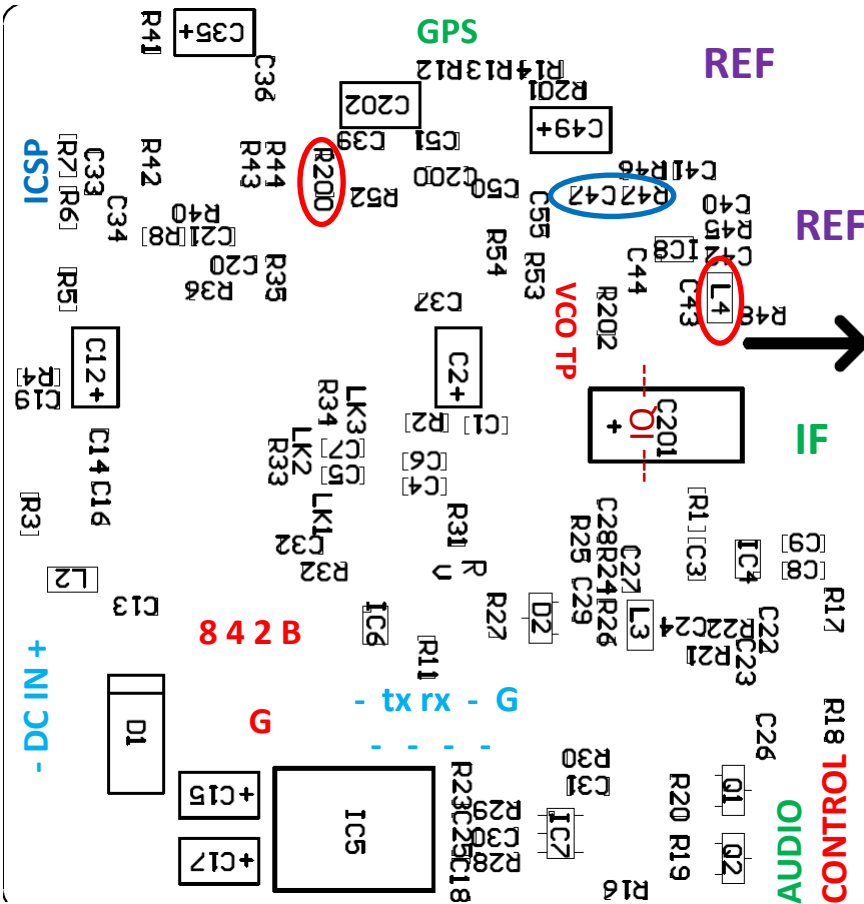
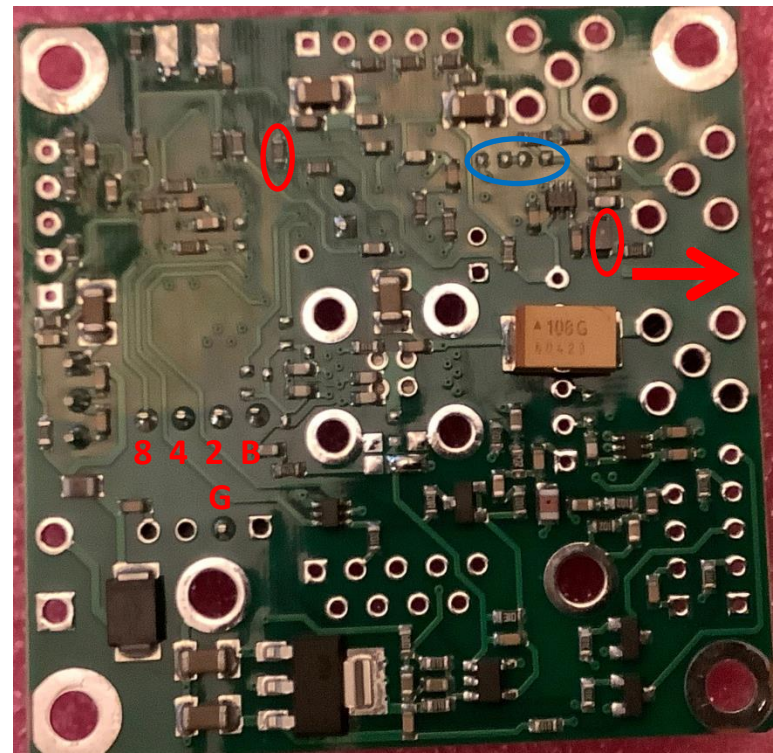
RS232 (TOP): TX, RX pins

IQ OUT (R): image reject mixer (3 dB more sensitive Rx) and/or different IF freq

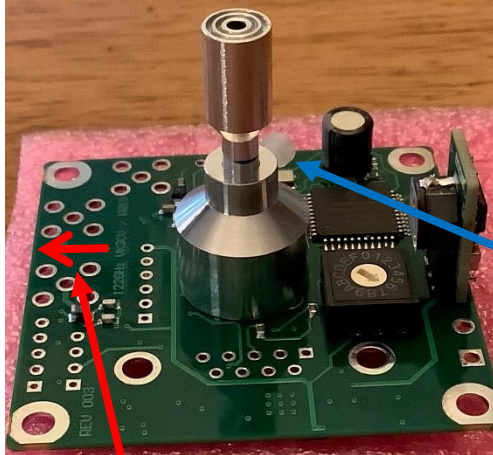


Bottom Side PCB

MAKE SURE ARROW IS HORIZONTAL!!!



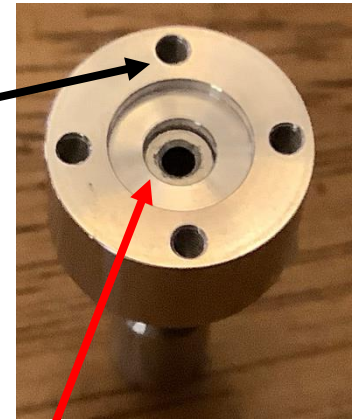
- ICSP: PIC firmware programming port
- GPS: -, GND, -, -, 1PPS
- SMA REF1 REF2: 2 copies ref out (or ref in if ext ref mod)
- VCO TP: VCO/64 test pt (phase noise, spurs, lockin)
- SMA IF OUT
- IQ -- (covered by C201): image reject mixer, other IF
- DC IN +/- 12V
- 8 4 2 B / G = chan pair, A/B/ gnd
(wire to remote switches; set hex = 0)
- DB9 : RS232 tx, rx, gnd
- AUDIO: G, mic, G, ear
- CONTROL: GND, PTT_IN, -, KEY_IN, -



Another key ingredient: the Antenna

Antenna Feeds

Needs 4 M2-6 screws
& one M2 set screw
to adjust feed WG depth in combiner



Oh, did I mention? ... MAKE SURE that ARROW IS HORIZONTAL!!!

Adjust feed WG depth in combiner 1.2-1.8 mm above chip (max Rx sig, 2 step cavity)

VK3CV / VK2XAX feeds:

- **Chaparral horn:** optimum dish $f/D \sim 0.5$ (70 deg HPBW)
 - Good for most dishes
- **Conical horn:** optimum dish $f/D \sim 2$ (8.5 deg HPBW)
 - Meant for **standalone (dishless) beacon (only 23 dBi gain)**
 - Not a good match for most dishes
 - One of us has a Cassegrain with the right subreflector shape



G4DBN custom feeds:

- **W2IMU horn:** optimum dish $f/D \sim 0.7$
 - Great for many offset dishes

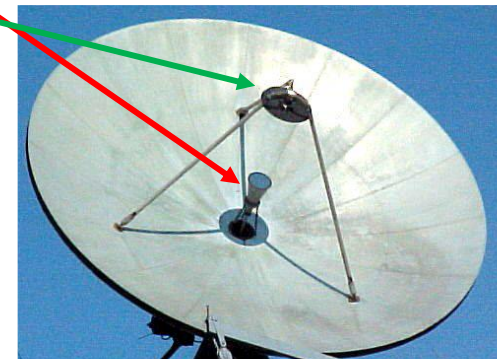


Dish Antennas

12" = 48/.55, 18" = 50/.35, 24" = 52/0.27 dBi/deg

Match feed to dish f/D

- **Prime Focus dishes usually 0.25 to 0.4 f/D** (SHF Micro is 0.6!)
 - **0.5 Chap** may slightly under illuminate, but **best choice** of above; some loss of gain
 - Might be able to make a lower f/D VE4MA/Kumar feed out of hobby tubing
 - Feed from front or thru waveguide from back
 - Mount radio for minimum dish blockage (2-3%):
 - 2-3" sq facing dish, long dimension parallel to beam
 - Note vertical vane, horizontal support beam (out of beam) in example
- **Offset (TV satellite) dishes usually 0.5 to 0.8 f/D** (Winegard is 0.59)
 - Choose **Chap or IMU**, depending on your dish; either will work well
 - Feed from front, feed arm support and most of radio well out of beam
 - Mount 2x2" radio at top edge of box, so less than 1x2" beam blockage (1%)
- **Cassegrain dishes have curved subreflector**
 - Fed from behind the dish (or just in front of a hole at dish vertex)
 - Subreflector "magnifies" horn illumination (reduces horn f/D)
 - **Desired feed f/D will vary depending on the subreflector design**
 - A suggestion:
 - Find one with a feed designed to match the two reflectors
 - If it is a lower band (39, 76-81 Ghz) dish, the waveguide will be too large...
 - Use telescoping metric hobby tubing to run from VK3CV combiner collar (4mmOD/2mmID) to an extender WG
 - Size extender WG OD to fit inside original WG, with a 2mm ID
 - Run the WG extension out to the original feed (maybe a lens/subreflector assembly)



Mounting & Pointing

*With 0.27-0.55 degree beam widths,
this is like mounting and pointing a telescope...*

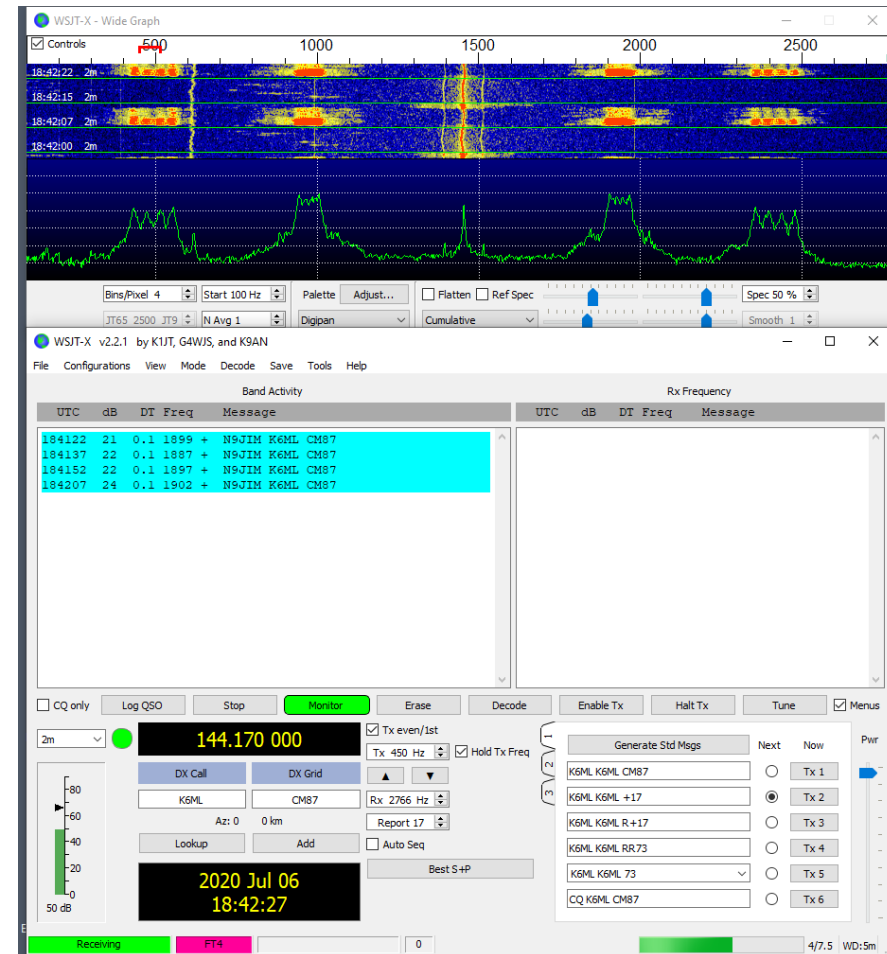
- Need a stable mount with smooth, repeatable, fine pointing
- Need a stable tripod, too
- Need an aligned spotting scope/landmarks to point
 - Rifle scope, Peak Finder app, heywhatsthat.com
- An aligned lower band radio helps a lot...
 - Example: 24 GHz is 5x less critical in Az, El and kHz, so 125x easier 😊
 - Lower path loss, stronger signals easier to find
 - With a common ref osc, can scale any freq error by 122500/24192
 - Use **sliding feed stage** or **flip mirror** to change bands without losing aim

Possible Improvements

1. Radio is OK as is (60 km QSOs already); no need to tear into it
 - A lot to be said for just getting it working as is
2. Replace 280 ppB TCXO with external 5 ppB OCXO for better temp stability?
 - GPS only has 1PPS updates, provides long term accuracy, not short term stability
 - Either way, thermally insulate your reference for better temp stability
 - TCXO OK for FM, maybe CW, QSOs; more stability helps WS CW & digital QSOs
 - Can use GPS to find freq, then turn off 1 PPS for slow drift/no jumps during QSO
 - Latest ext ref mod in July Construction Notes (remove r200, not c200)
 - Will need some work to restore FM
 - Restore FM audio using “V” link *or* by routing FM audio to similar Vtune pin on ext ref
 - Will lose FM tone CW
3. FM deviation / limiter / mic preamp?
 - Designed for electret mic modulating the TCXO
 - G4EML suggests dev adj + preamp for fuller voice modulation
4. Image Reject Hybrid?
 - VK3CV built IQ phase shifter to reject the image freq and get 3 dB better Rx NF
5. Reduce Noise & Spurs?
 - Under investigation (shared 3.3v power, RS232, sidetone, other PIC main loop activities)
 - 12V to 5V Murata switcher vs linear 7805 (efficiency vs possible noise)

Quick & Dirty WSJT using FM tones

- WSJT & other MFSK digital mode transmitters are meant to frequency shift the carrier just a few Hz (ppt), which is difficult at this high freq (but I'm working on it)
- **Meanwhile, here is an easy 'cheat'... use FM audio tone modulation to produce a carrier + multiple sidebands**
 - The cost: wasted Tx power & spectrum
- Connect 1st PC sound output to FM audio input of 1st (Tx) radio and use **FM voice mode** to FM tone modulate carrier
 - Or, if using ext ref, connect directly thru a blocking cap (2-4 kHz HPF) to Vtune pin of OXCO
- Connect 2nd PC sound input to audio output from IF Rx of 2nd (Rx) radio, running in **USB mode**. Tune to carrier freq & use WSJT spectrum display.
- Choose a mode with tone spacing wider than your typical reference carrier drift rate (as seen on Rx spectrum), perhaps JT4D (38 Hz / 1min) or maybe FT4 (21 Hz / 15 sec).
 - If your ref is stable you may be able to work down to progressively narrower spacings (JT4C, JT65C, QRA64C, FT8 .. QRA64A); if not, you may have to go to wider spacings (JT4E, JT4F, JT4G)
- Choose a low Tx base audio frequency (400-500 Hz), but higher than the bandwidth of the selected mode (so 1st & 2nd sidebands don't overlap)
- Enable Tx message sending. **Adjust the Tx PC sound output level to maximize the first upper sideband of message**
 - At zero sound level, only the carrier will be visible and full power
 - As the sound level is increased, the first upper and lower sidebands (spaced above and below the a carrier by the Tx audio base freq) will start to grow as the carrier starts to fall



- **Maximum 1st USB/LSB signal will occur when the carrier and 2nd USB/LSB are approximately equal, but weaker than the 1st USB/LSB.**
- The Rx PC should decode the first upper sideband signal; it will not decode any other signals

coming soon ...

Mt Allison Beacon

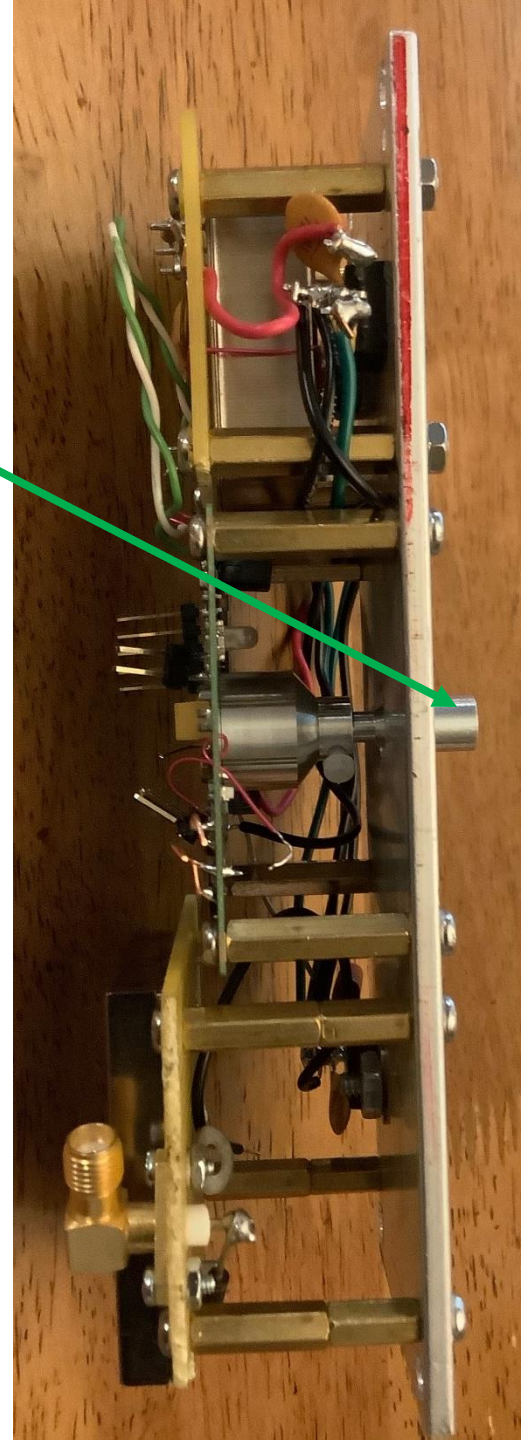
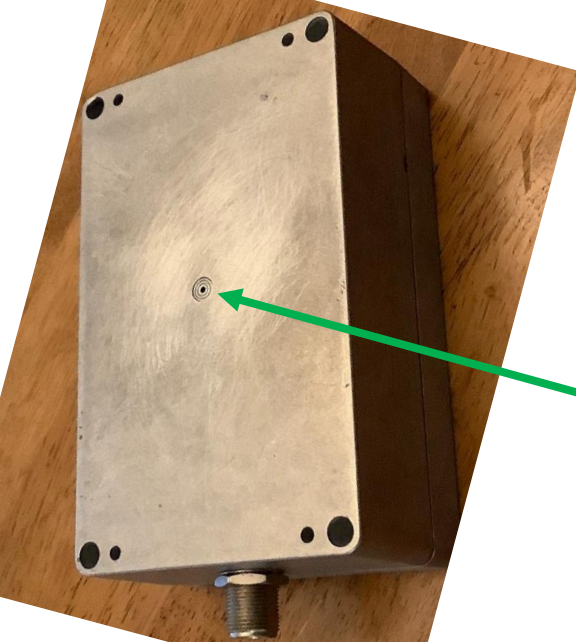
CM97bl59

OCXO external ref, linear regulators
VK3CV board

Tedlar tape over Chaparral feed
-48V to +12V DC-DC inverter

122400.000 GHz (Ch "6A"), CW ID
70 degree beam width aimed ~SW
Approximately 1 milliwatt EIRP

Expect about 10-15 km range to a rough
focused 12" dish (Alviso Marina)
Maybe 25-40 km to a well tuned 2' dish
(Cupertino hills, Stanford, Skyline Dr)



VK3CV Builder's Roundtable

- Please introduce yourself
- Show & Tell Us what you've done/are doing
- Questions, answers and comments

Roundtable

- Introduce yourself
- What's new?
 - Projects
 - Contacts (DX, Contests, EME, other activity)
 - 10 Ghz and Up contest in the COVID era?
 - Activity Days for microwaves, mmwaves?
 - Feedback on meetings/nets