An Antenna Remote Control Tuning System

Hamcation 2025

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Slides at www.KA2C.com/antennas

See QST Nov, 2024

Remote Integrated Antenna Tuning Low Bands

- An Antenna Remote Control Tuning System
  - Bias Tee and shared coax
    - 1.5 kW TX HF power
    - 12 VDC at 2.5 Amps
    - 2.4 GHz IOT/WIFI port for control & monitoring
  - Arduino ESP32 based **automatic pre-tuning**
- High Performance Integrated Antenna Tuner – 160-80-40 meters Dipoles, Inverted Vees and Verticals
- Basic Integrated Antenna Tuner Alternatives
- Manual Remote Control Alternatives

Why Remote Tuning or Integrated Antenna Tuning for Low Bands?

- Place impedance matching directly at the antenna elements
  - Variable inductive loading
  - Multimatch BALUN's or UNUN's
- Bandwidth of 160, 80 & 40 meter antennas
- Coax losses
- High voltages
- BALUN or UNUN losses

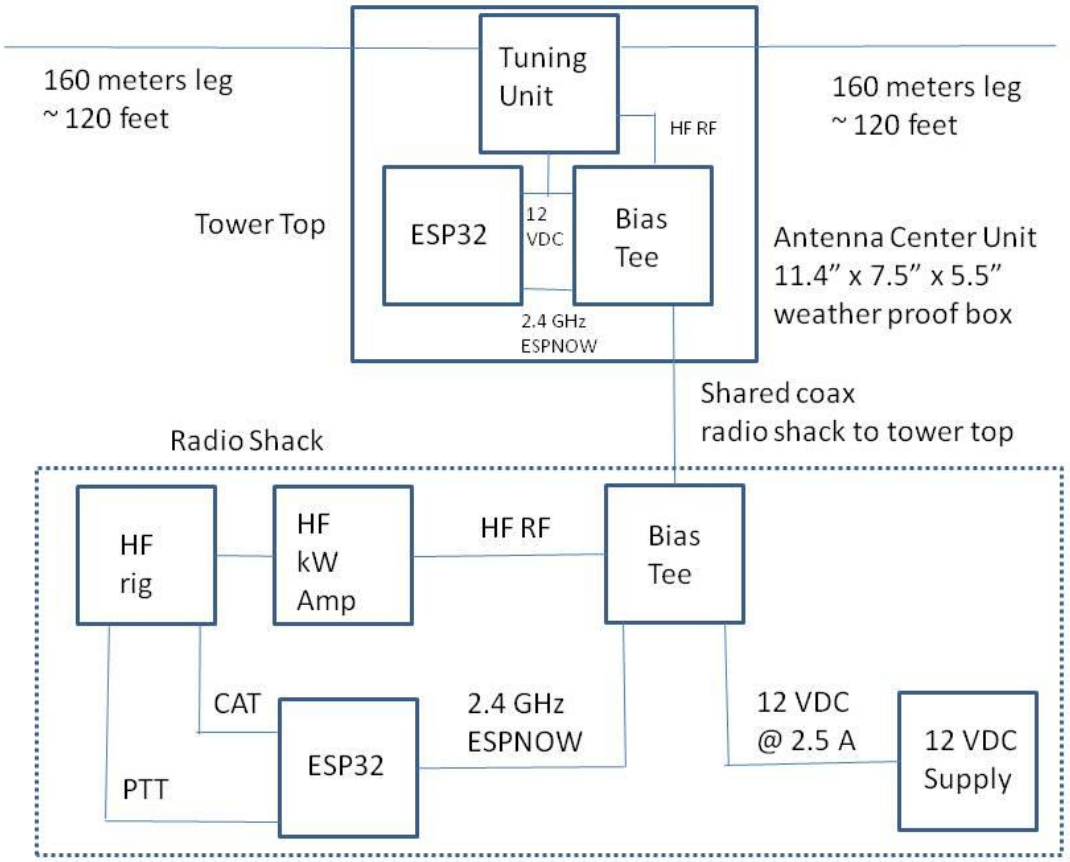
Remote Integrated Antenna Tuning Challenges for Low Bands

- Few commercial remote tuners available – especially with MFJ's shutdown
- Commercial remote tuners
  - Limited control features – usually automatic only
  - Single-sided L network tuners are not ideal for dipoles
  - May work with only the manufacturer's rigs/amps
  - General purpose design raises cost but may limit power and performance
- Power and control issues for a remote tuner
  - 12 VDC with a bias tee
  - 2-way, high-speed and general purpose control
- Weather & external units
  - rain, snow & ice,..
  - wind

Commercial Band Segment Remote Integrated Antenna Tuners

- Antennas-Amplifiers – 2-segment SSB/CW 80 meters dipole or verticals
- Vertical-Array – 2-segment selection on 160 and 80 meters
- Opti-beam, JK Antennas, Array-Solutions,…. provide remote switching for 4 band segments on 80 meter Yagi's

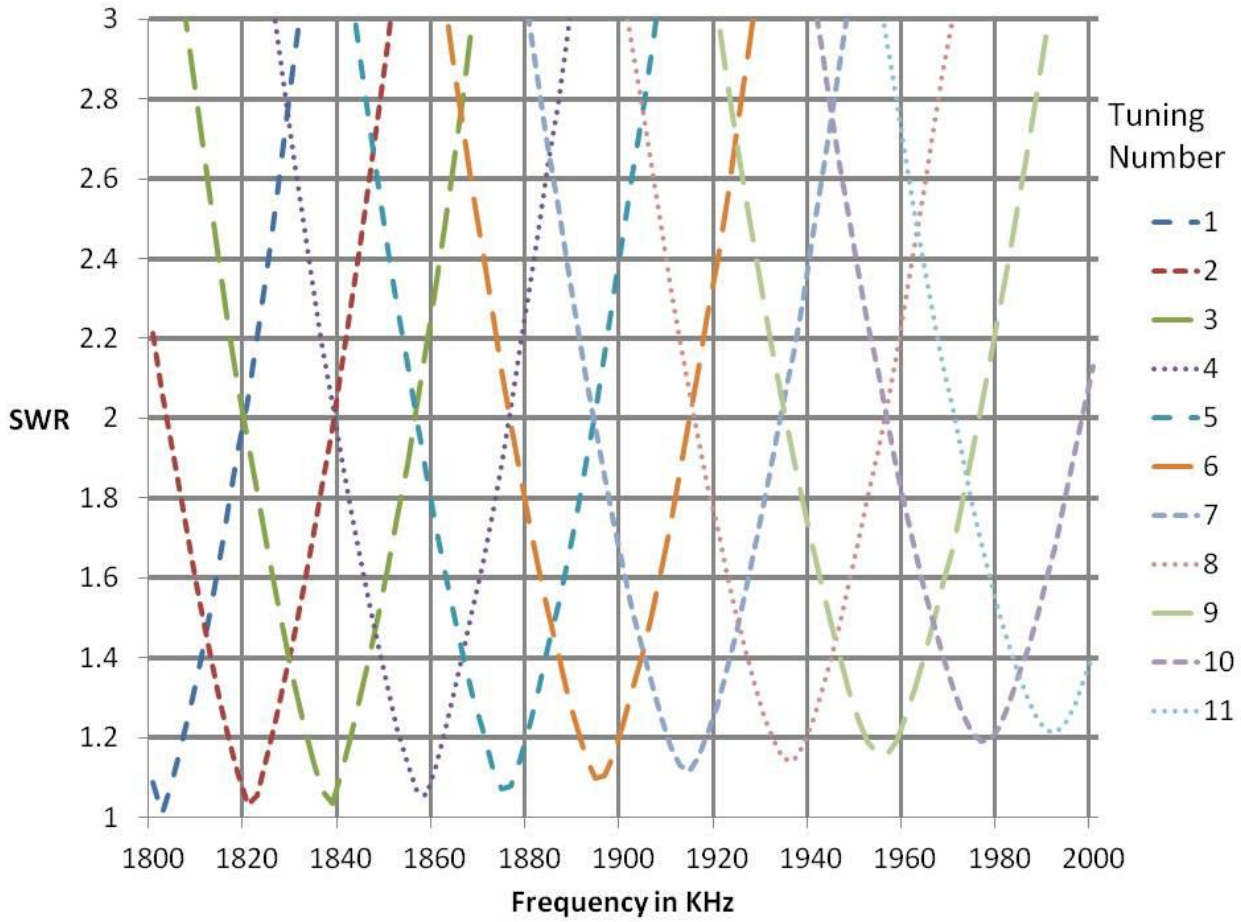
Automatic Antenna Pre-Tuning with a Shared Coax



System Features

- Shared Coax for 1.5 kW RF, 12 VDC up to 2.5 Amp and 2.4 GHz IOT remote control at 1 Mbps
- Flat response (SWR < 1.5 from 1.8 to 2.0 MHz on 160 meters or 80 and 40 meters)
- Full-band low SWR over the entire system including the coax to the antenna
- Automatic instant pre-tuning based on the rig's frequency – using pre-determined SW tables
- Low sensitivity to antenna placement and characteristics – assuming the raw antenna is resonant near the top of the band

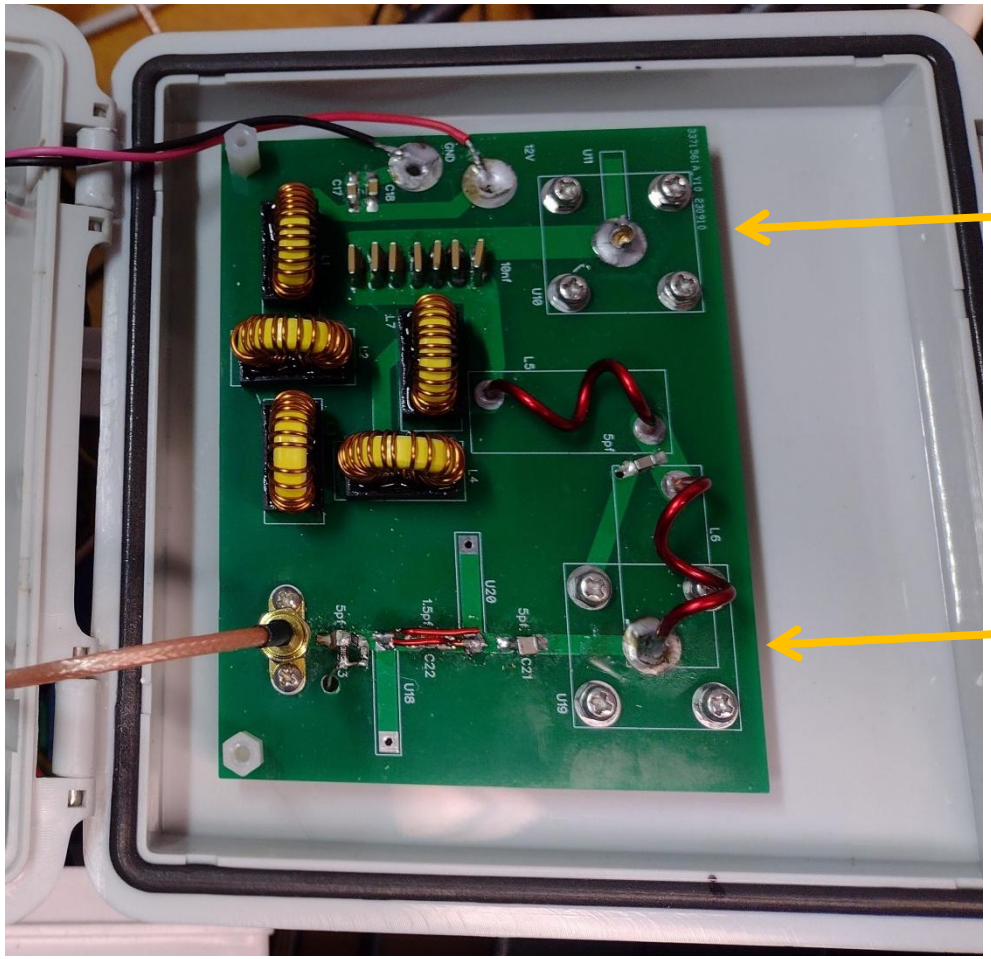
Pre-Tuning Antenna Matching Measurements



Bias Tee with a 2.4 GHz Port PCB used in the Shack and at the Antenna

12 VDC

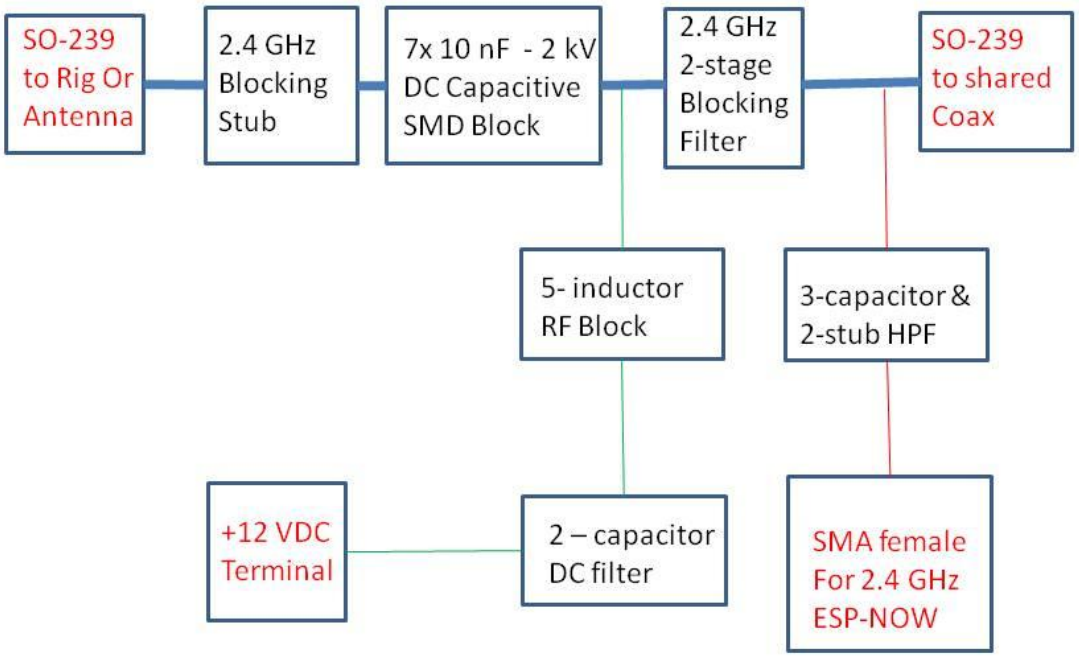
2.4 GHz



Rig/Amp or Antenna

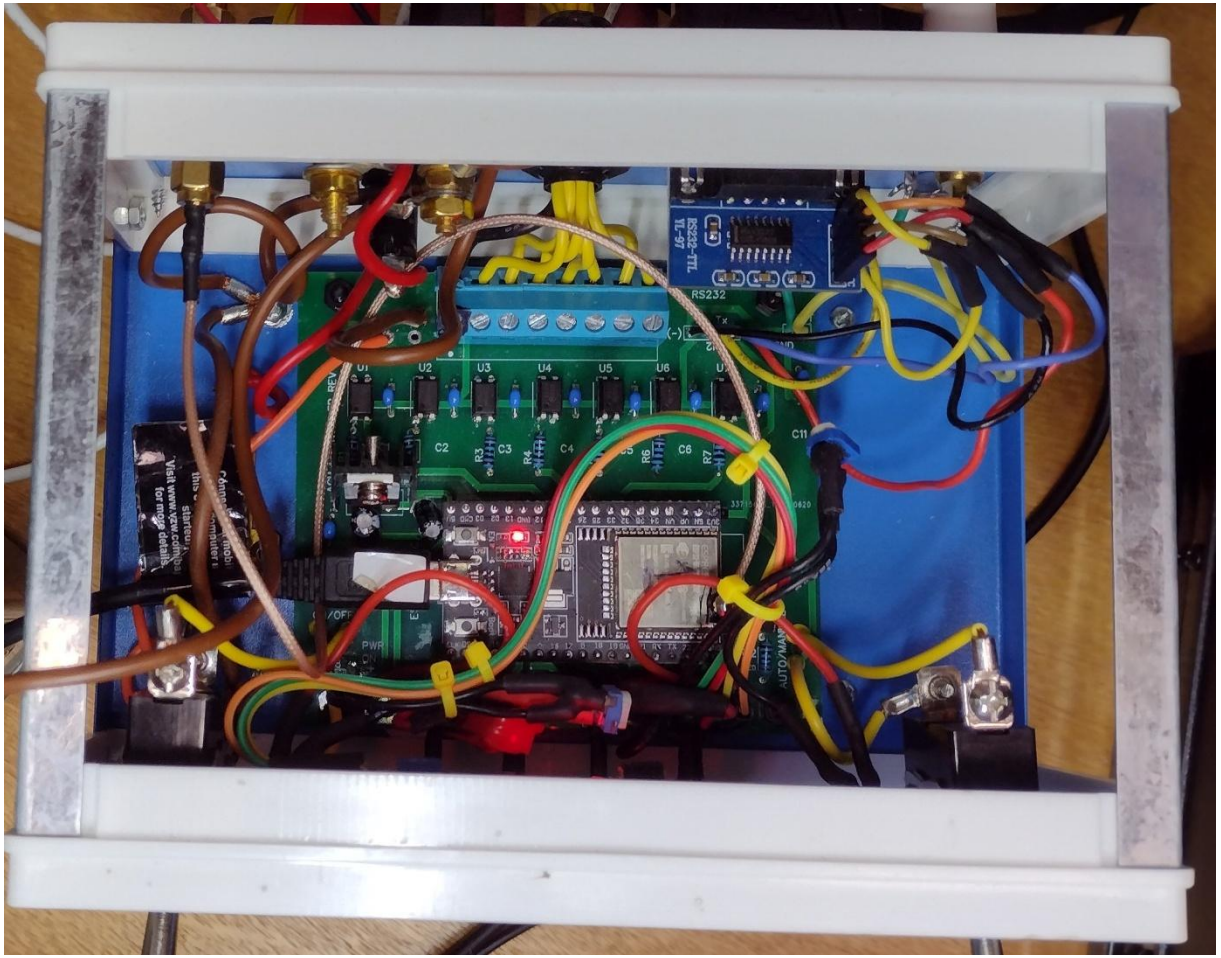
Shared Coax

Bias Tee Diagram

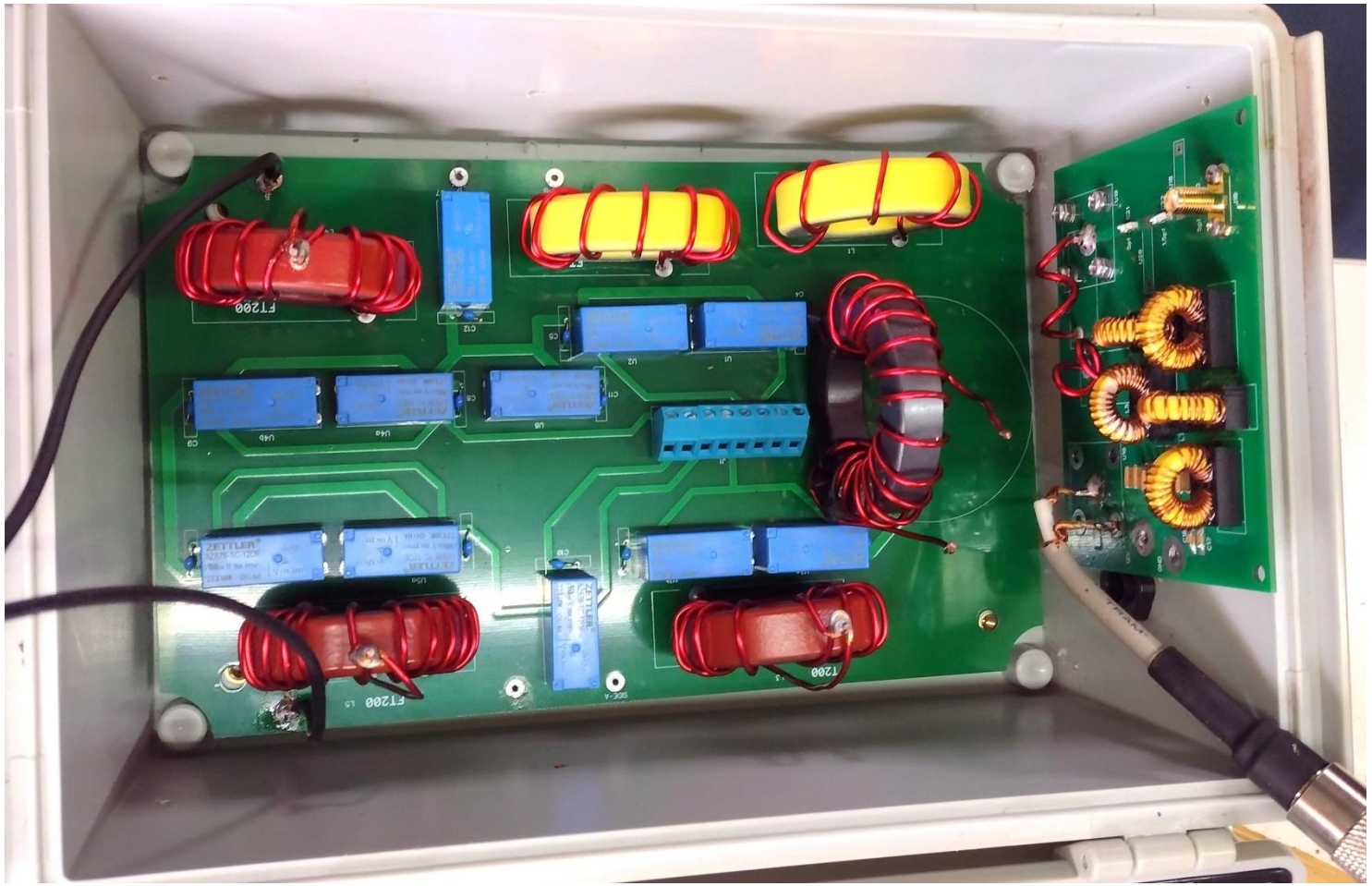


Control Unit in the Radio Shack

Control Unit Interior

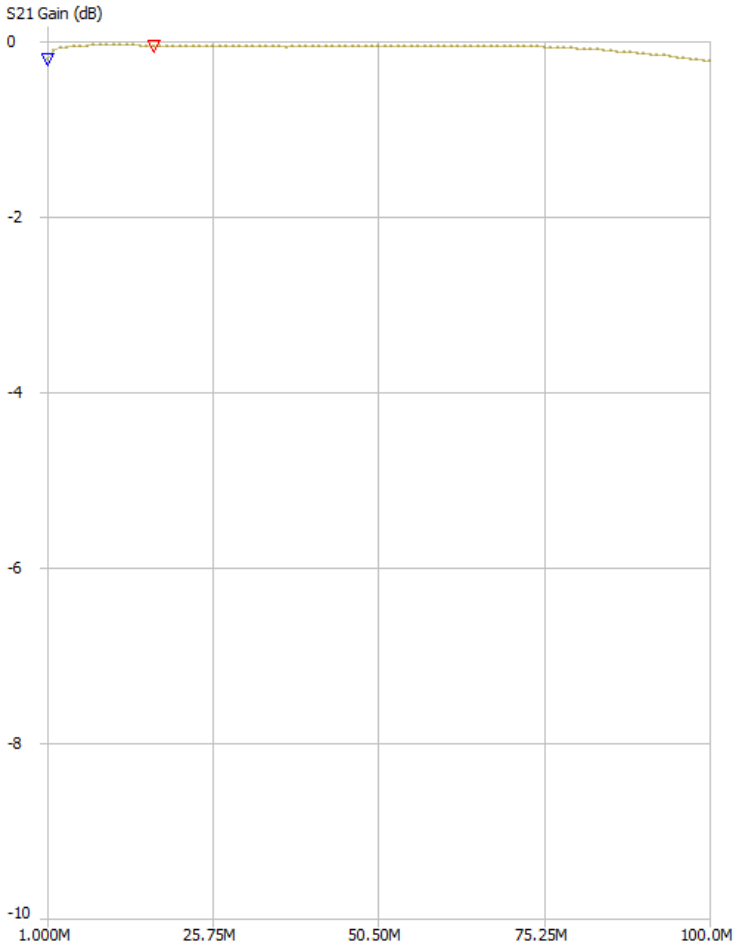


Integrated Antenna Tuner

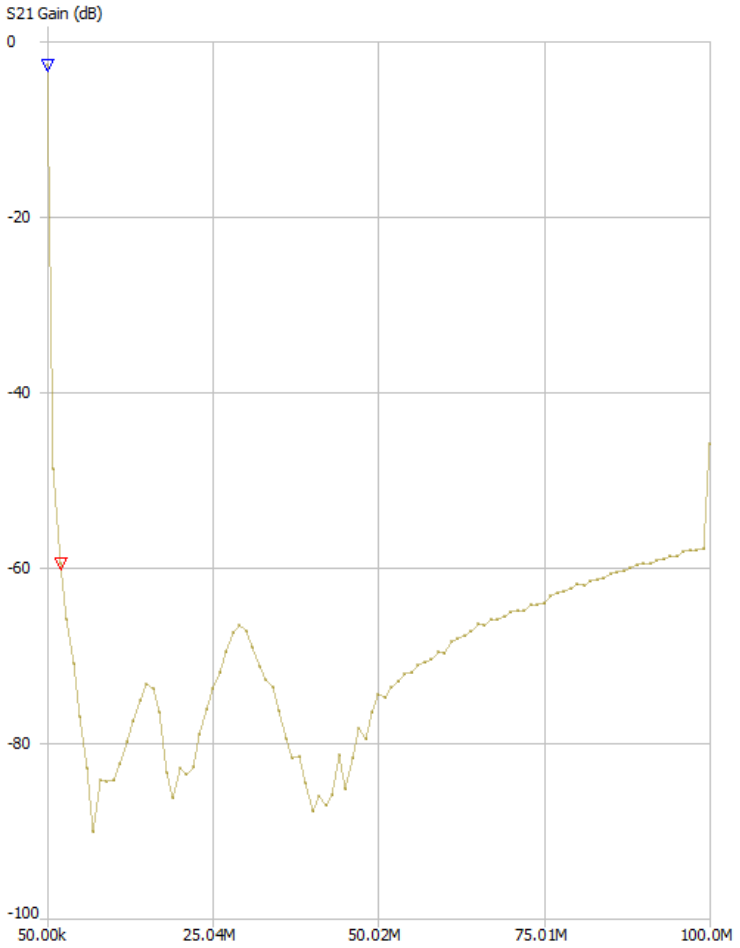


Integrated Antenna Tuner with the Remote ESP32

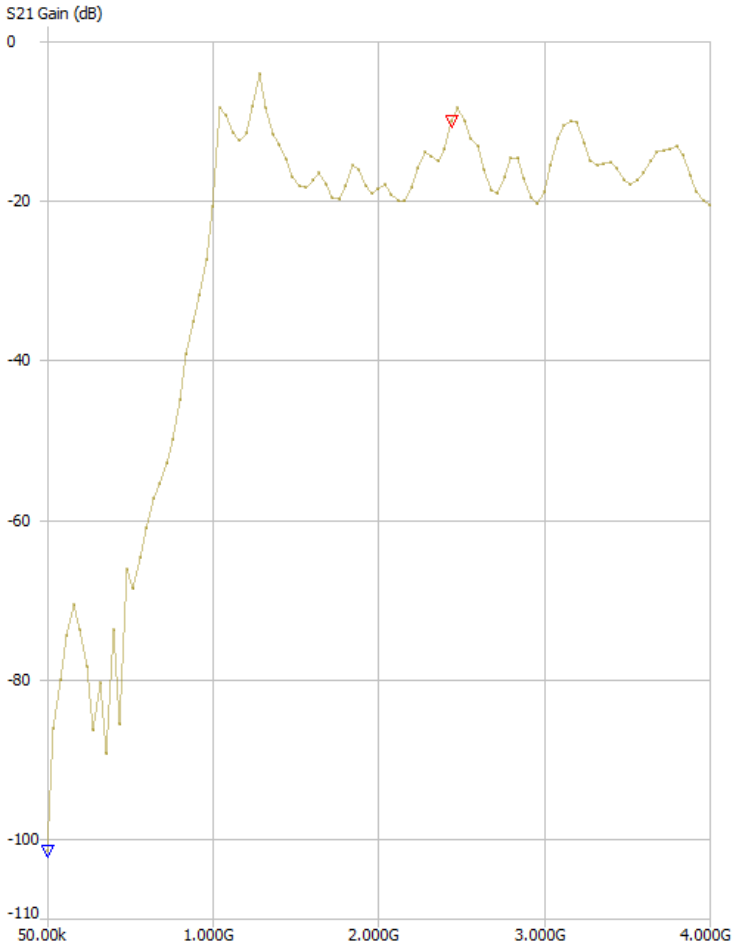
Measured Loss on High Power RF Path



Measured Loss of DC Path



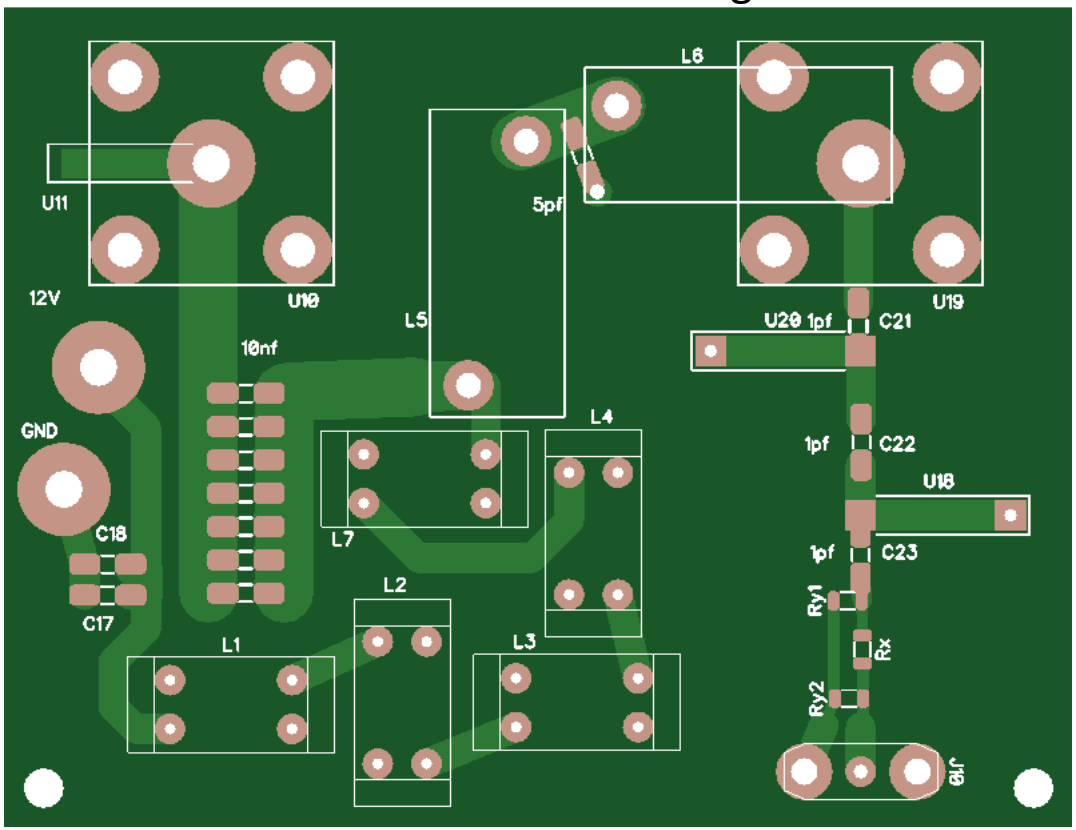
Measured Loss of 2.4 GHz Path



Bias Tee PCB Rev 3.1
Use in Radio Shack and at Antenna Tuner

2.4 GHz blocking filter

SO-239
Rig/amp
Or Antenna



Shared COAX
SO-239

+12 VDC
And GND
Power

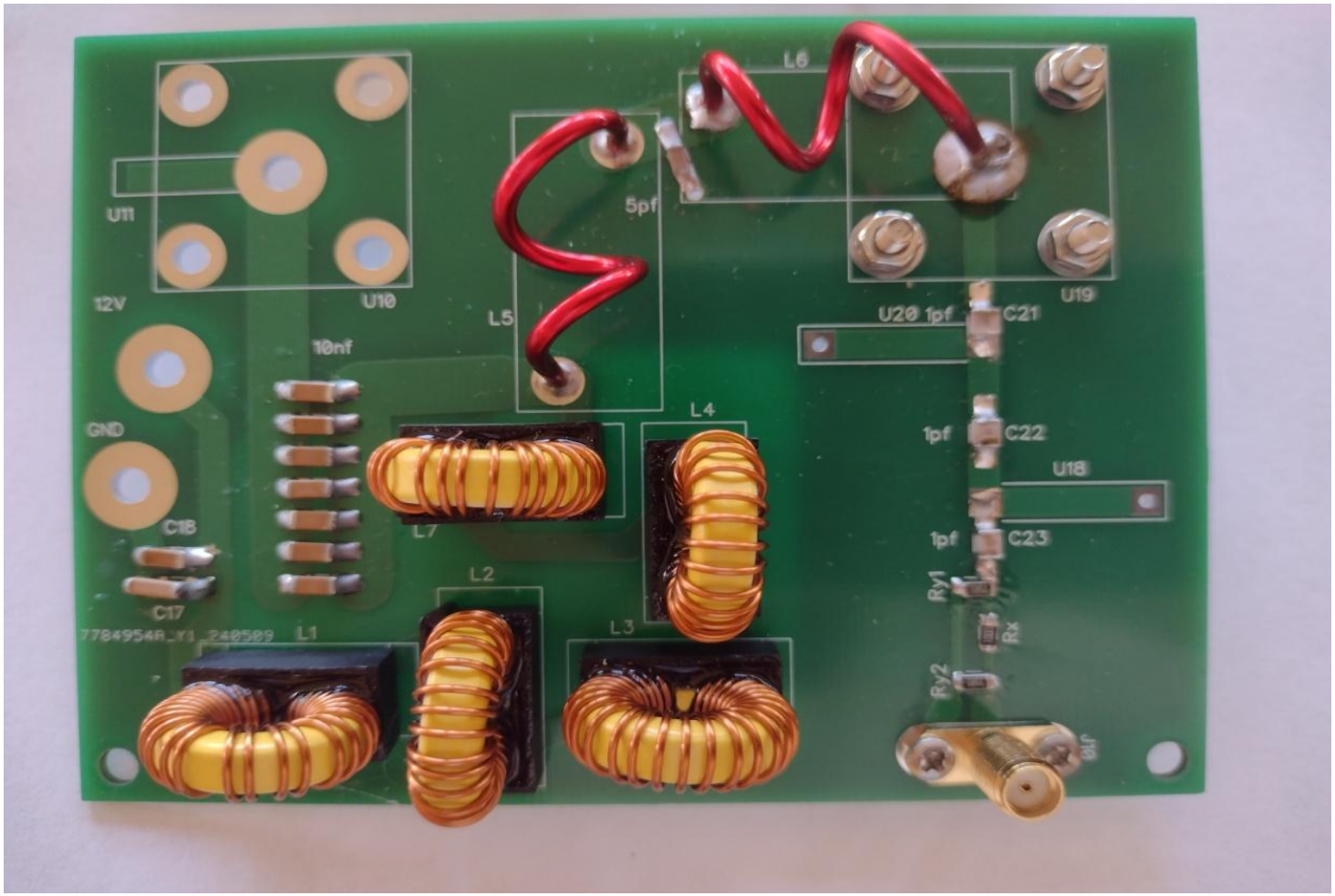
2 GHz
HPF

2.4 GHz Fixed
attenuator

Five Murata 32330C
33 µH 2.5 A toroid
inductors

2.4 GHz
SMA Connector

Completed Bias Tee PCB Rev 3.1

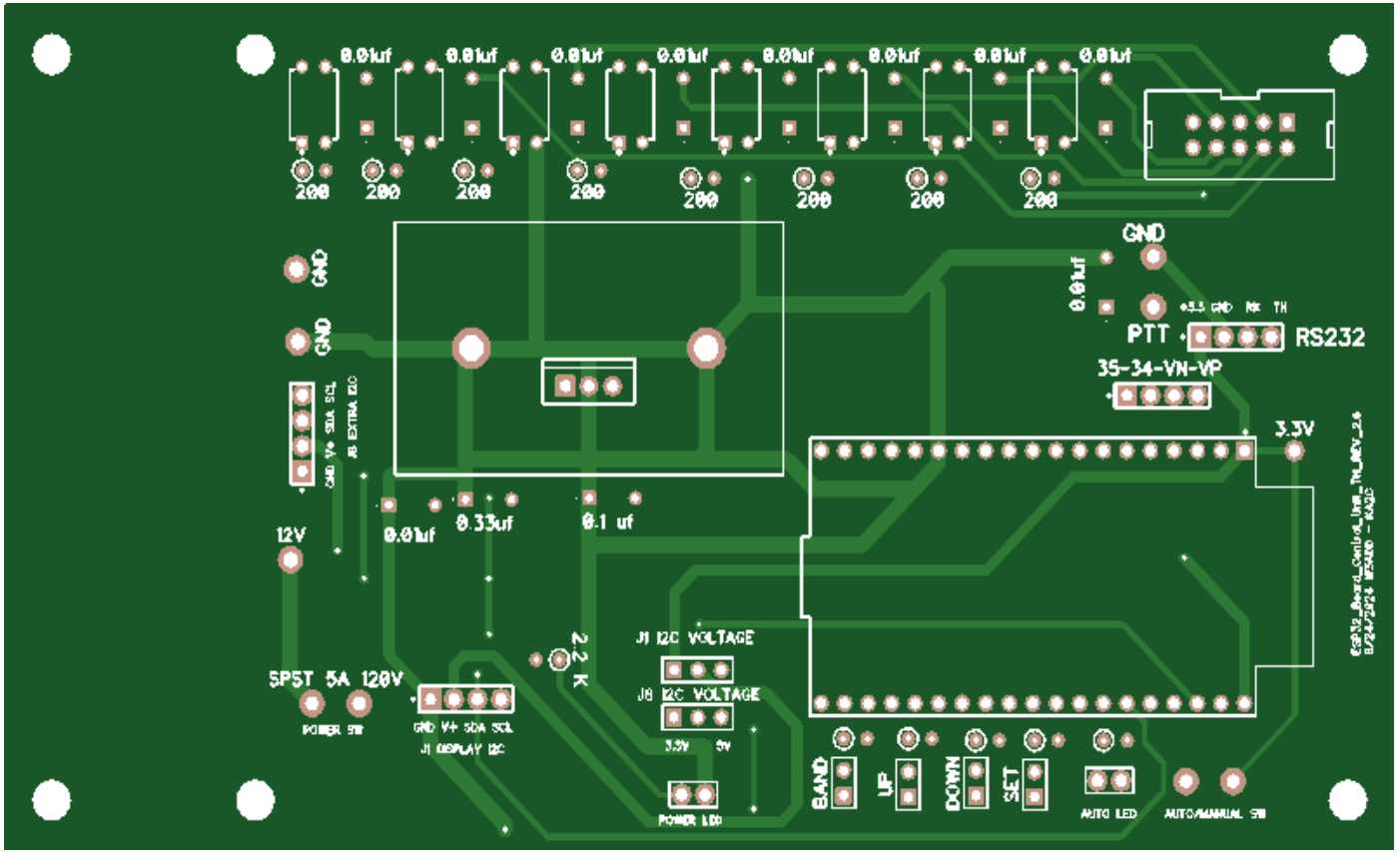


Arduino ESP32 PCB Rev 2.6
Use in Radio Shack and at Antenna Tuner

8x Opto-isolator relay drivers

Ribbon control
Cable connector

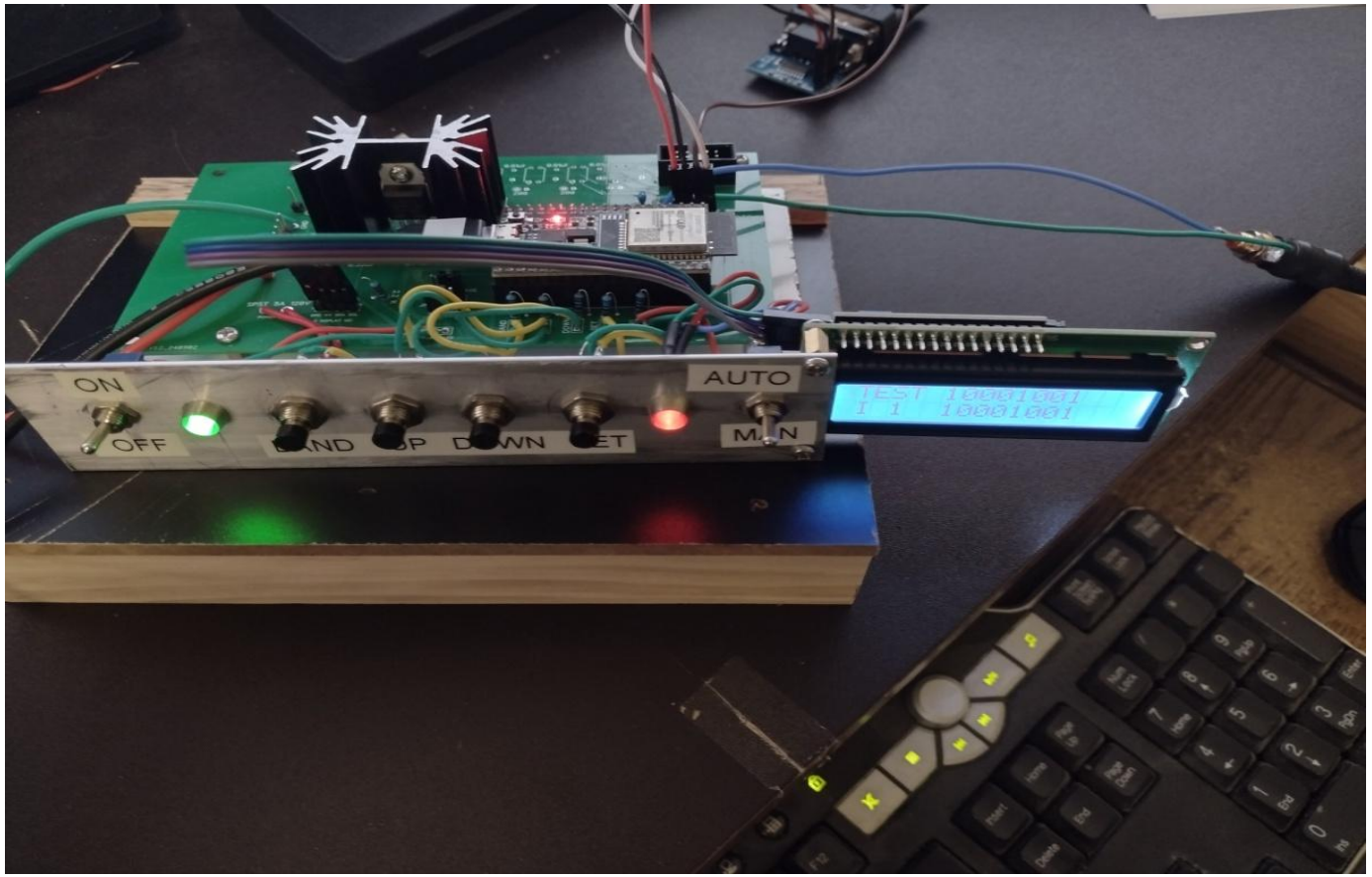
5 Volt
Regulator
And heat
sink



Through-hole PCB design

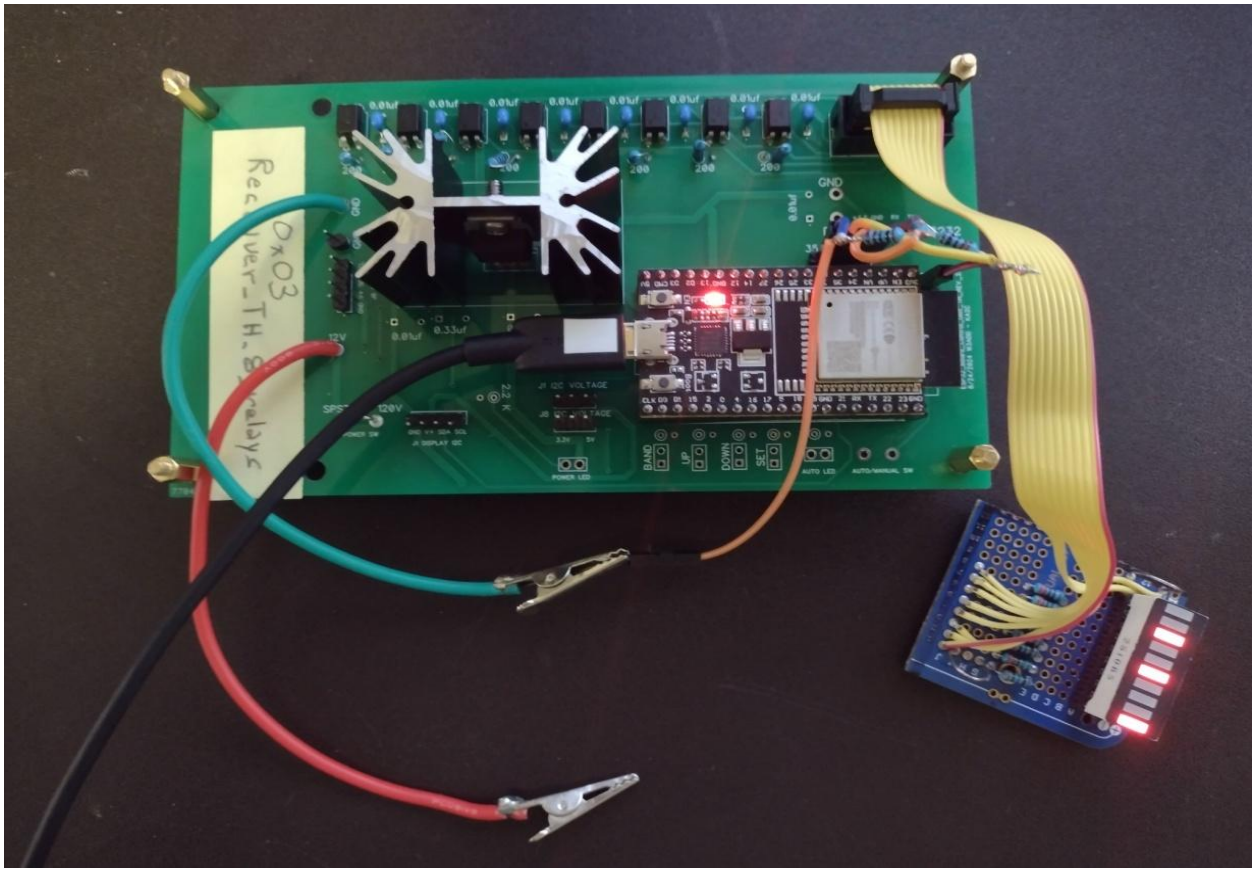
ESP32-DEVKITC-VIE

ESP32 Radio Shack
Control Unit Bench Testing



8 opto-isolators and associated components are not used

ESP32 Remote Unit
Bench Testing



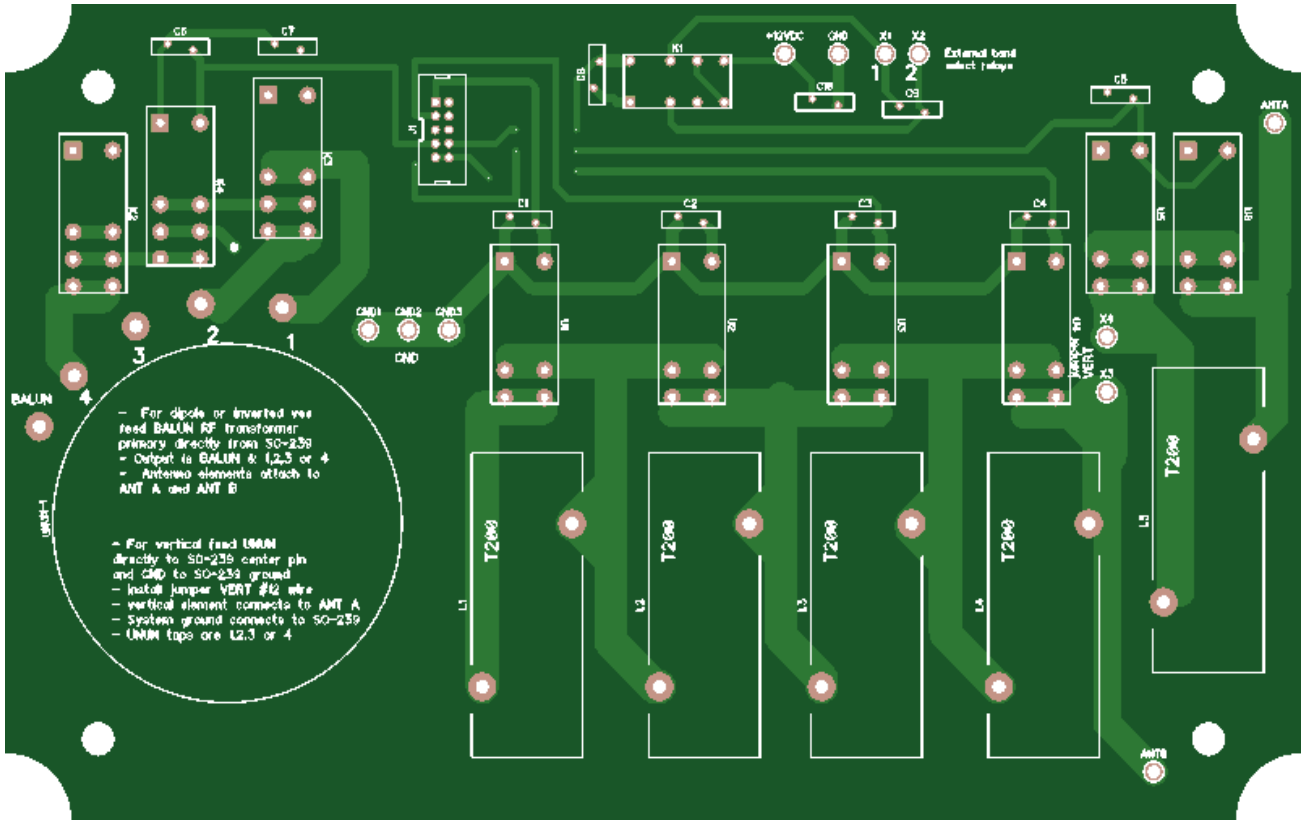
LCD display, rig CAT, PTT, and front panel LED indicators & switches are not used

A High Performance 1.5 kW Integrated Antenna Remote Tuner PCB

Ribbon cable connector

External band selection relay

Multimatch Selection Relays



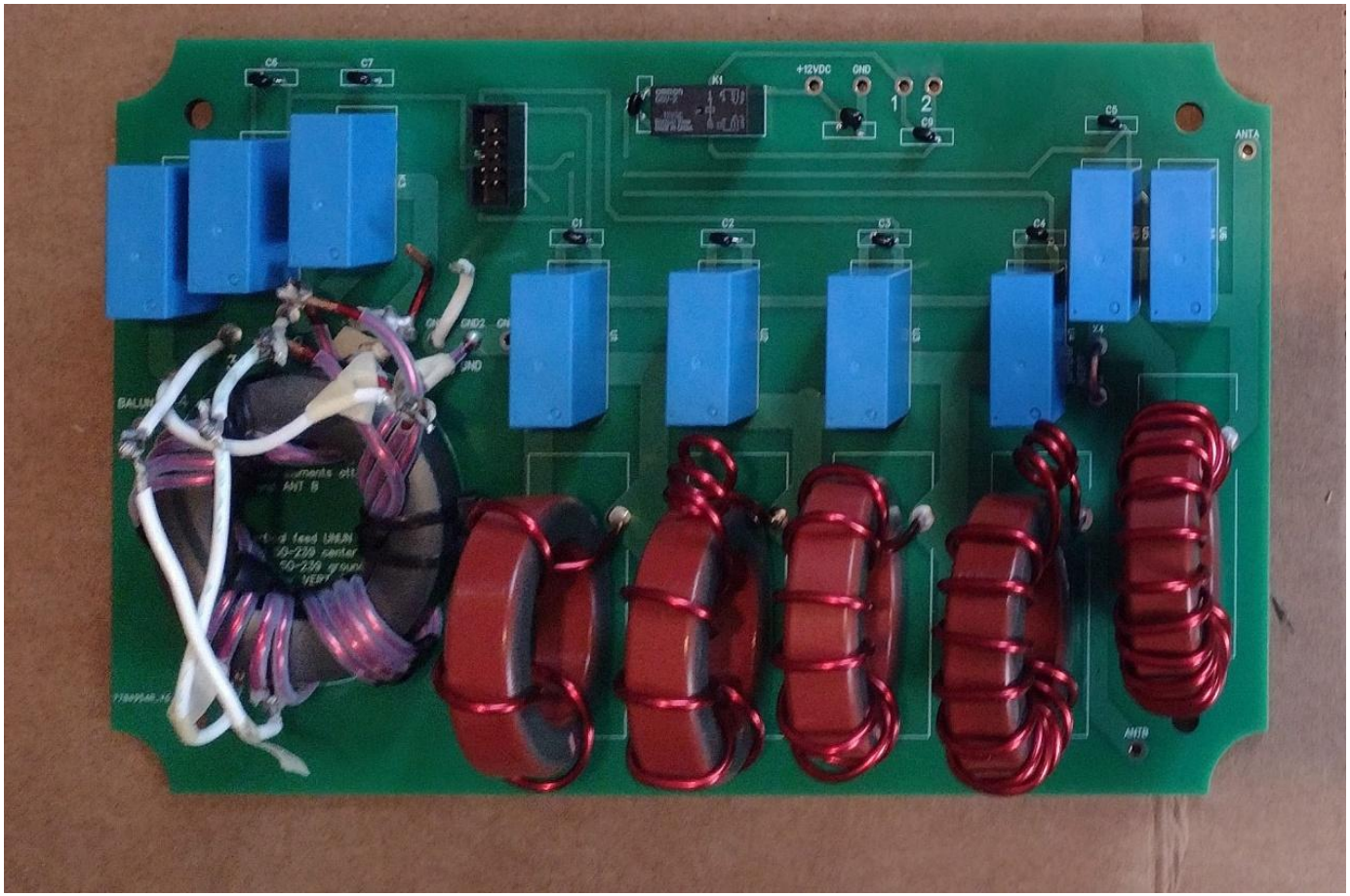
Multimatch BALUN or UNUN FT-240-43

Antenna Element Connection

Inductor Shorting relays

5 toroid Inductors T200-2

Completed Tuner PCB



Input multimatch UNUN
- quadrifilar with 4 output taps

Binary configured toroid inductors

PCB's

- Design files and Gerber files are available which can be used online for fabrication requests – see QST-in-Depth – Nov, 2024
  - Bias Tee with a 2.4 GHz port PCB
  - ESP32 processor PCB
  - Tuner with 5 inductors and BALUN/UNUN PCB
  - Optional 8-bit I/O PCB
- All PCB's are basic 2-layer 1.6 mm FR4 material
- JLCPCB provided tools and fabrication
- Free Diptrace tools used – www.diptrace.com

ESPNOW

- Expressif proprietary protocol for ESP32 Arduino devices with integrated WiFi modems
- Drivers provided by Expressif
- Designed for low-latency and low-power operation
- Multiple modes supported – master/slave, star & broadcast
- 2.4 GHz ISM band
- 1 Mbps default raw data rate
- Uses WiFi physical layer
- Reliable Auto-Repeat-Request built into drivers
- Sensitivity of -97 dBm
- TX power of +20 dBm
- Max path loss of 117 dB allows for long lossy coaxial connections

Arduino ESP32 Software

- Control Unit sketch – about 1000 lines total
  - ESPNOW master or initiator mode
  - CAT RS-232 interface to the rig for frequency
  - PTT interface to the rig to block updates during TX
  - User button interface for manual controls
  - 2x16 LCD interface – frequency, relay settings,….
- Remote Unit sketch – about 100 lines total
  - ESPNOW slave or responder mode
  - Parallel I/O to relay optoisolator drivers

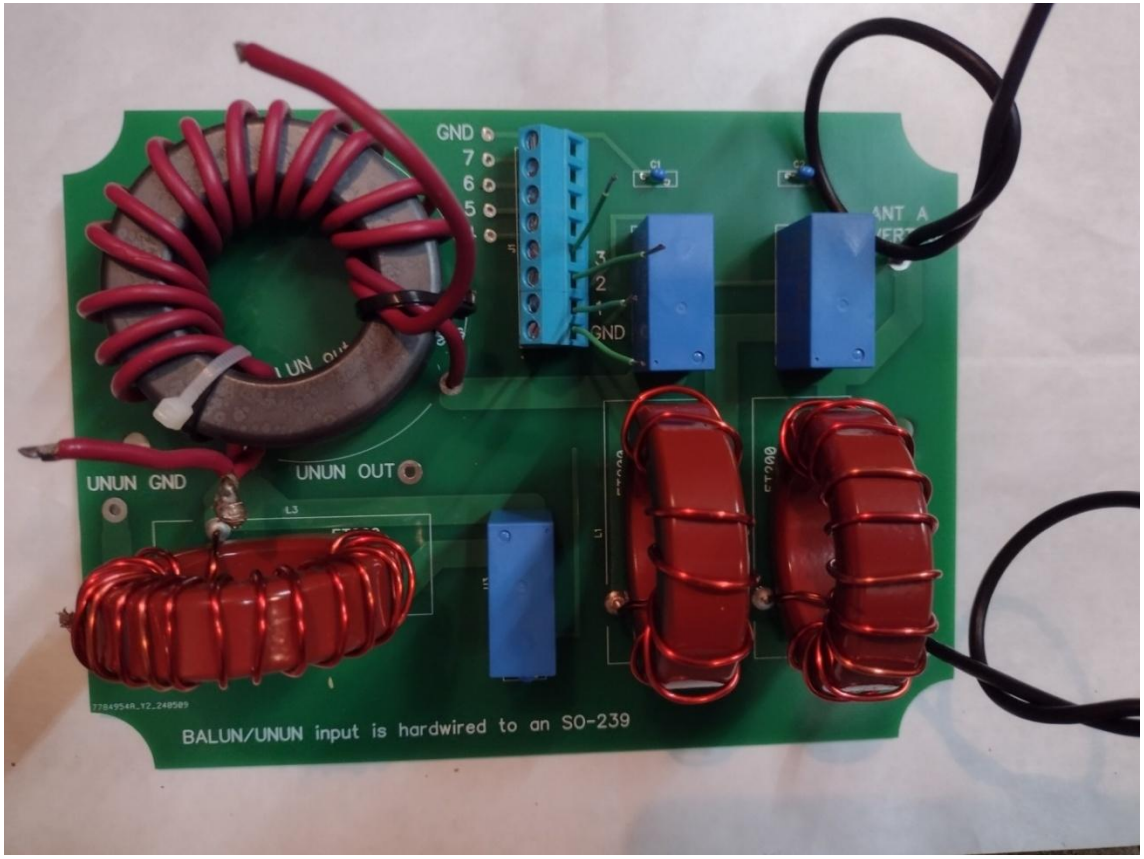
Control Unit Modes

- Test mode is used initially
  - Allows choosing any setting of tuning relays using pushbuttons on the front panel
  - Used to set tuning table for auto/manual mode
- Auto mode - normal operation
  - Rig's frequency is translated using the tuning table to tuning settings and commands sent to the remote unit as needed
  - Updates blocked when PTT is active
- Manual mode
  - Rig's frequency is ignored
  - Updates blocked when PTT is active
  - User selects a table entry for tuning control using pushbuttons on the front panel

Antenna Remote Tuning System
Possible Extensions

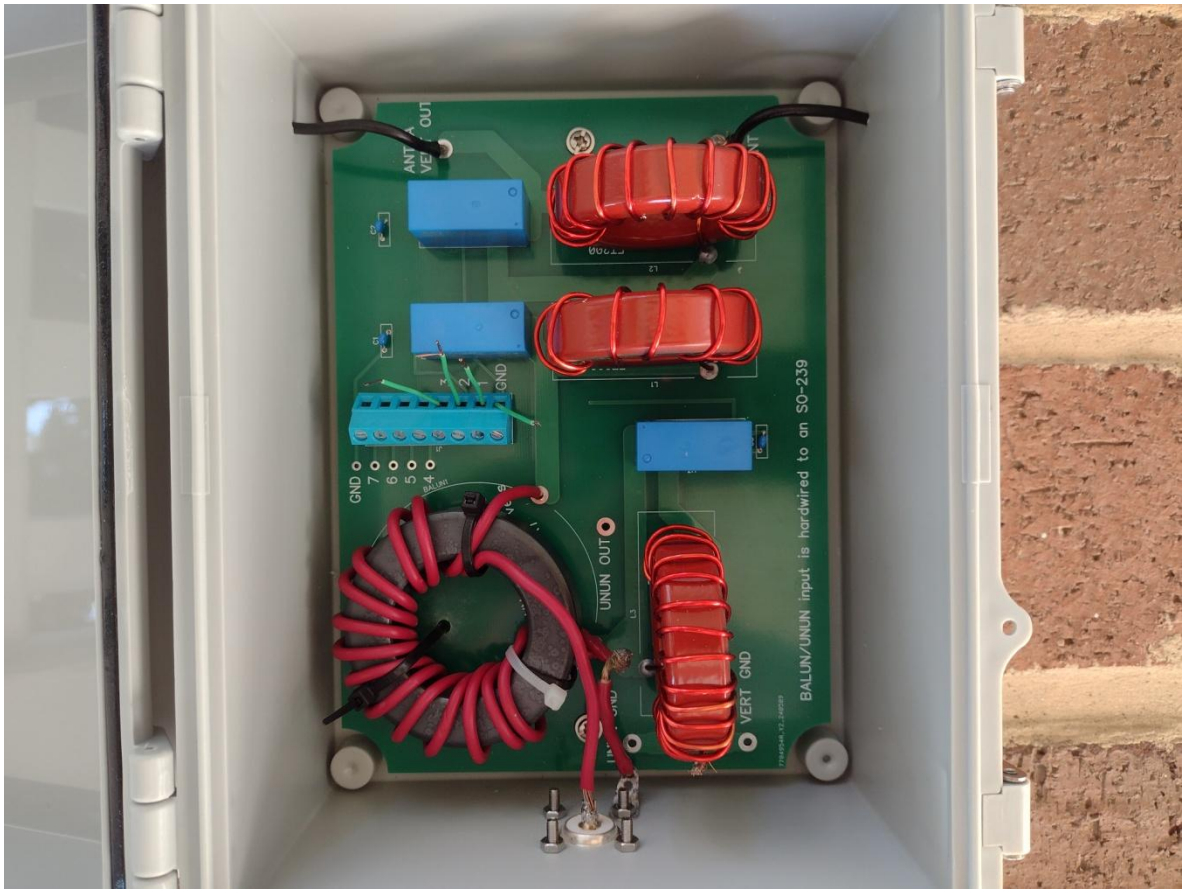
- 8 bit I/O extension PCB with 8 optoisolator outputs for relays (add 1, 2 or more on I2C bus)
- Star network for multiple antennas with 1 controller and 2 or more remote units on different coaxial cables
- Remote antenna switches
- Remote SWR or antenna impedance measurements, temperature,….
- Remote general purpose tuner control
- Adaptation for rotor control using 2-way ESPNOW transmissions

Basic Tuner Alternatives



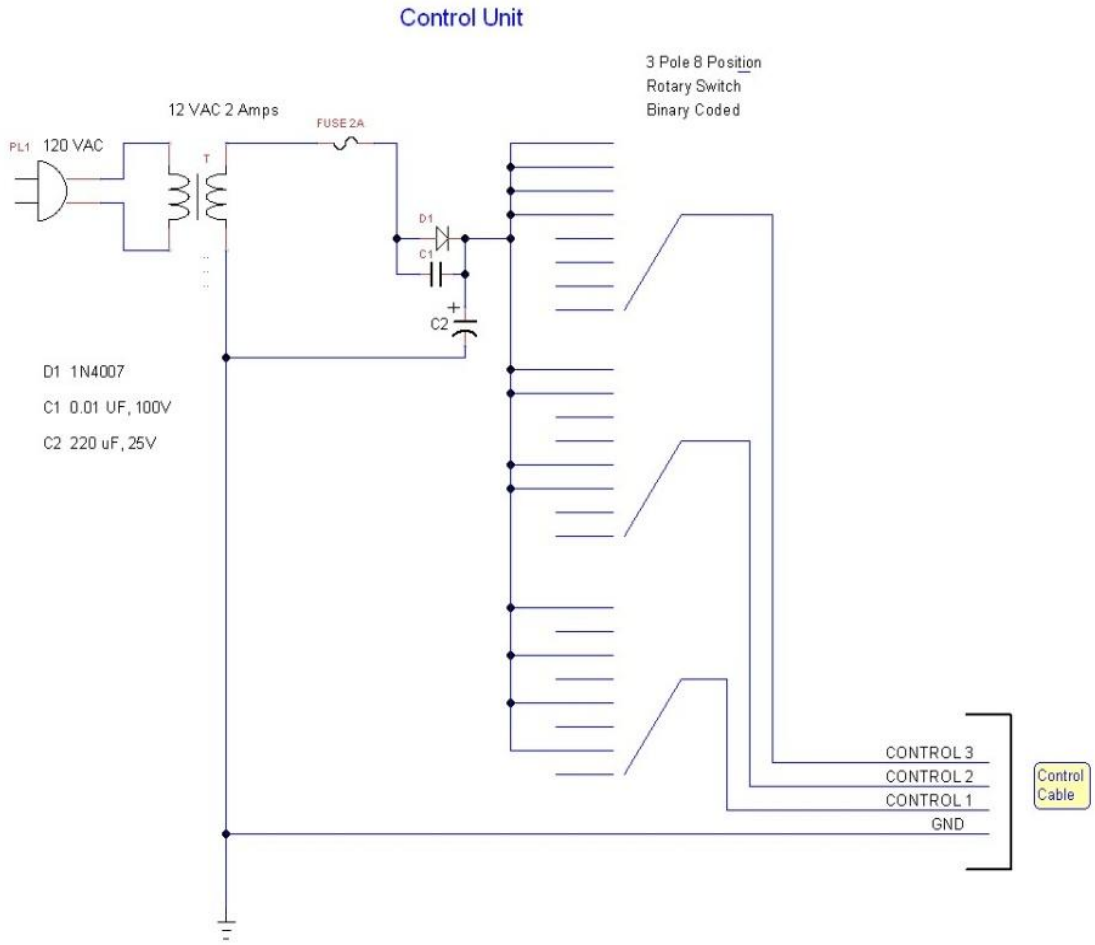
- PCB 7.3” x 5.3” - 1.5 kw – verticals or dipoles/inverted-vees
- 3 toroid inductors/relays provide 8 frequency steps across the band
- input BALUN or UNUN with fixed matching – 8T to 7T (38 Ohm) in the example
- http://www.ka2c.com/wp-content/uploads/2024/08/Remote-Tuner-System-for-160-to-40-Meters.pdf

Center Unit for 160 or 80 meters Dipole or Inverted Vee



- Zulkit weatherproof electrical box measuring 8.7” x 6.7” x 4.3”
-Flexweave wire connecting to antenna elements
- 4-wire control cable - 3 control wires + ground

Manual Control Unit



EZNEC Modeled Antennas for a Basic Manual Tuner

- 160 m Inverted Vee at 40 feet center and 15 feet ends
- 160 m Inverted Vee at 80 feet center and 40 feet ends
- 80 meters Inverted Vee at 40 feet center
- 80 meters Inverted Vee at 80 feet center
- 80 meters dipole at 30 feet with bent legs
- 160 meters dipole at 30 feet with bent legs
- 80 meters inverted vee at 30 feet with legs bent under
- 160 meters inverted vee at 30 feet with legs bent under
- 160 m full size vertical 32 buried radials
- 80 m full size vertical 32 buried radials
- 160 m compact vertical dipole at 65 feet
- 80 m compact vertical dipole at 36 feet
- 160 m 43 feet vertical 4 tophat wires 32 buried radials
- 80 m 33 feet vertical 4 tophat wires 32 buried radials
- 160 m 43 feet inverted L 32 buried radials
- 160 m 33 feet inverted L 32 buried radials
- 160 m inverted L at 43 feet with K2AV FCP
- 160 m inverted L at 33 feet with K2AV FCP
- 80 m 33 feet inverted L 32 buried radials
- 80 m inverted L at 33 feet with FCP
- 160-80-40 m fan dipole at 30 feet with bent legs

High Performance Tuner - Tuning

- Configurable for verticals or dipoles
- 5 inductors to provide 32 frequency steps across the band – T200-2 or T-200-6
- Improved flexibility for multiband antennas
- 2 relays in series on the largest inductor to tolerate about 2 kV

High Performance Tuner - Matching

- BALUN or UNUN at the input – FT240-43
- Multimatch support
- 4 taps on the BALUN or UNUN selected by relays
- UNUN ex. - 4 turns quadrifilar – taps for 50, 38, 19.5 and 12.5 Ohms – 160 to 40 meters
- UNUN ex. – 3 turns trifilar – taps for 50, 39, 30 and 22 Ohms – 160 to 10 meters
- BALUN ex. 8 turn primary interleaved with 8 turn secondary – taps for 50, 38, 28 and 19.5 Ohms – 160 to 10 meters

Automatic Pre-Tuning

- Instant antenna tuning based on rig frequency
- Table based tuning – determined during setup
- CAT interface with rig
- Remote tuner
- Use antennas with fair to good SWR bandwidth – not antennas with poor/very narrow bandwidth – no high inductive loading
- Automatic table generation may be possible

PCB's, SW, EZNEC Models & More Information

- www.KA2C.com/antennas
- Automatic and manual remote pre-tuning systems for low-band antennas
- Bias Tee with a 2.4 GHz port
- Basic and High Performance tuner boards
- ESP32 PCB & SW for control and remote units