A Low-Power HF Amateur Radio Beacon

Jack K. Horner

W0JKH

Email: jhorner@cybermesa.com

Personal web site: http://jkhorner.com

Overview

- What is a radio beacon?
- WSPRnet
- My beacon
- Some reporter distribution results

What is a radio beacon?

- A radio transmitter/antenna system that periodically broadcasts (but does not receive) messages that can contain information such as
  - beacon power
  - beacon location
  - beacon identifier

WSPRnet

- Worldwide network of low-power (typically < 250 mW) amateur radio beacons and reporter stations
- The primary objective of WSPRnet is to help characterize low-power radio propagation for radio amateurs. Indirectly, low-power radio propagation studies help to characterize the state of the ionosphere
- Typical WSPR *beacons* operate automatically, transmitting beacon power, beacon location, and beacon identifier
- In typical operation, WSPRnet *reporters* (receivers) automatically send reports (via the Internet) of reception of beacons to a WSPRnet reporter logging database. The database can be queried by registered users
- http://www.wsprnet.org/drupal/

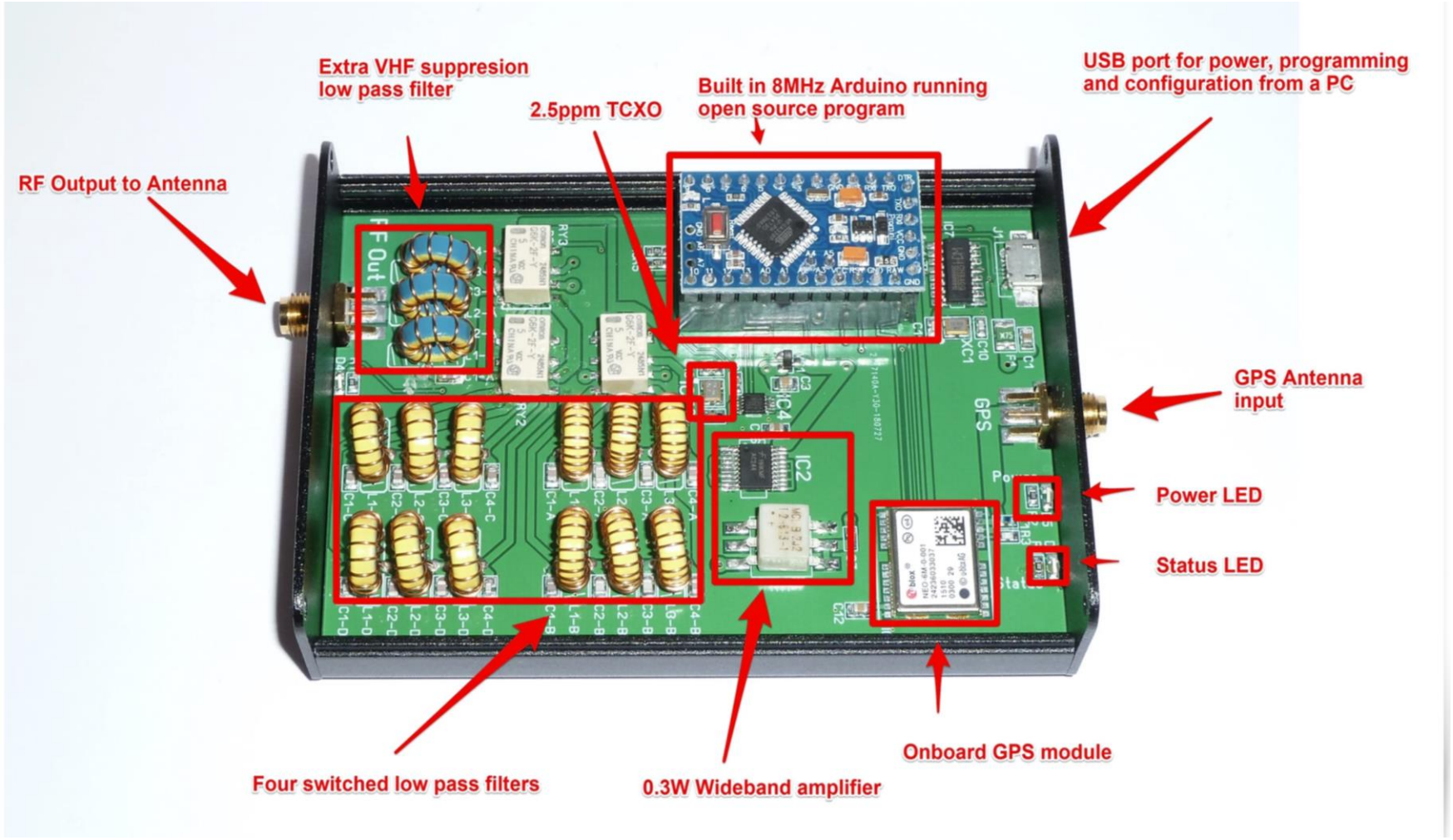
My beacon (transmitter operation)

- Transmitter is ZachTek WSPR Desktop transmitter (https://www.zachtek.com/wspr-tx)
  - Physical dimensions (approximate): 4” x 3” x 1”
  - 200 mW RF output
  - Any user-selected subset of amateur bands, 80-10 m
  - Can be operated under computer control or run standalone
- Located in Lawrence KS (grid EM28)
- I typically program the beacon to operate standalone with 2-minute transmissions on each of 40, 20, 15, and 10 m in succession, followed by an 8-minute wait. This pattern repeats until stopped by user.

My beacon (antenna system)

- MFJ-1984MP end-fed multiband (40, 20, 15, 10 m) wire
  - toroidal transformer impedance matching at antenna feedpoint
  - located about 10 m above ground
- Transmission line, viewed from transmitter to antenna
  - ~1 m SMA-to-SO-239 jumper (50 ohm)
  - ~3 m of 50-ohm coax
  - MFJ-270 fast-gas-discharge lightning arrestor (50 ohm)
  - ~13 m of 50-ohm coax (terminates at antenna feed)
- Installed antenna system SWR (measured by a Rig Expert AA-600 antenna analyzer) is < 1.3:1 at manufacturer's resonant frequency) on all bands; presents 52 ohms to transmitter output

The ZachTek WSPR desktop transmitter



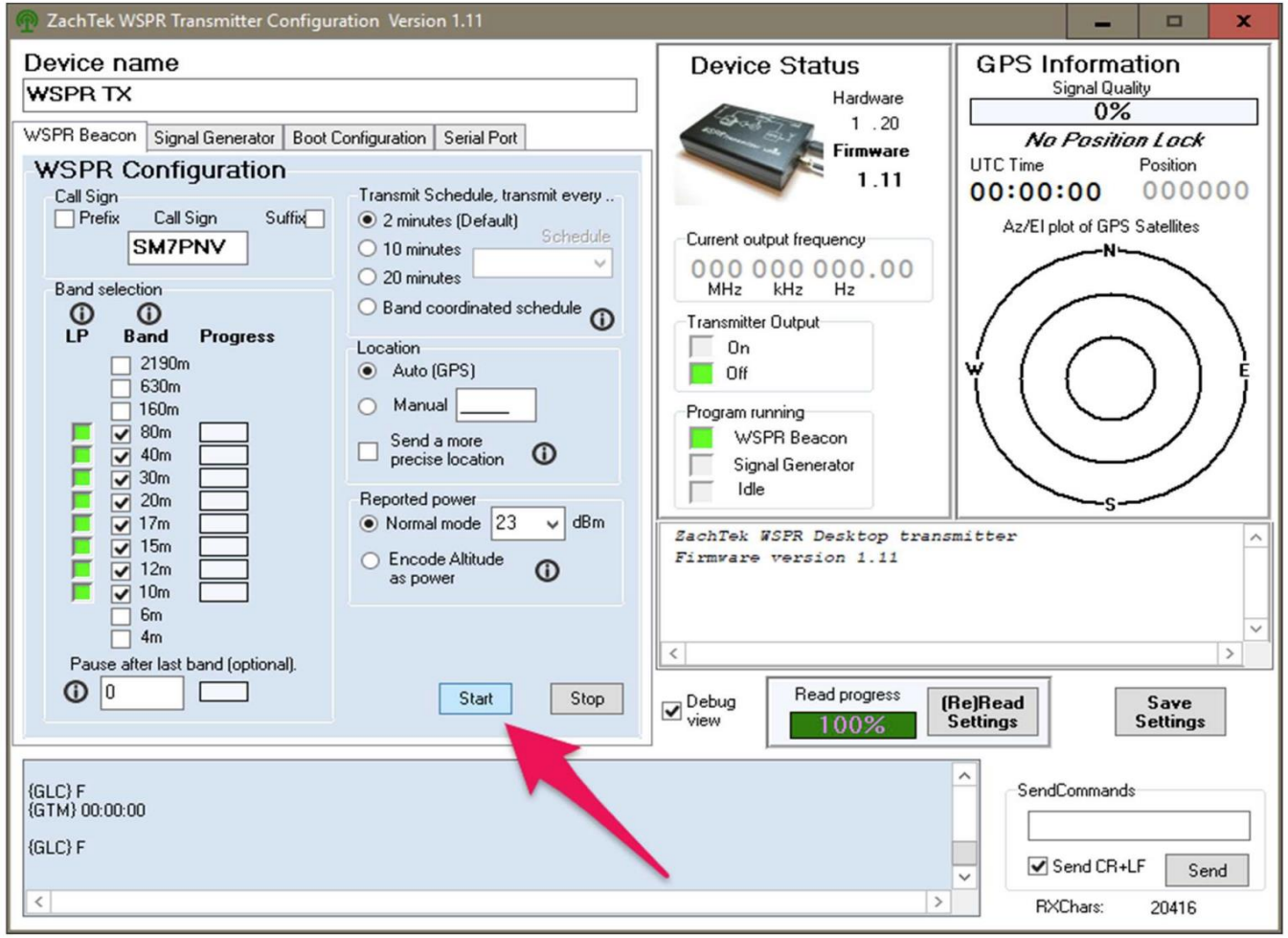
Theory of operation(1)

- Arduino firmware encodes WSPR packets (beacon_id + beacon_location + beacon_power; https://www.physics.princeton.edu/pulsar/K1JT/doc/wspr/wspr-main.html#PROTOCOL, Appendix B) and sends them to a Silicon Labs Si5351 phase-locked loop (PLL; acts as an RF oscillator).
- The reference clock for the PLL is a 25 MHz Abracon ASTX-H11 TCXO oscillator. The clock has 2.5 ppm stability.
- The output from the PLL is a square wave that is amplified by a 74AC244 line driver IC

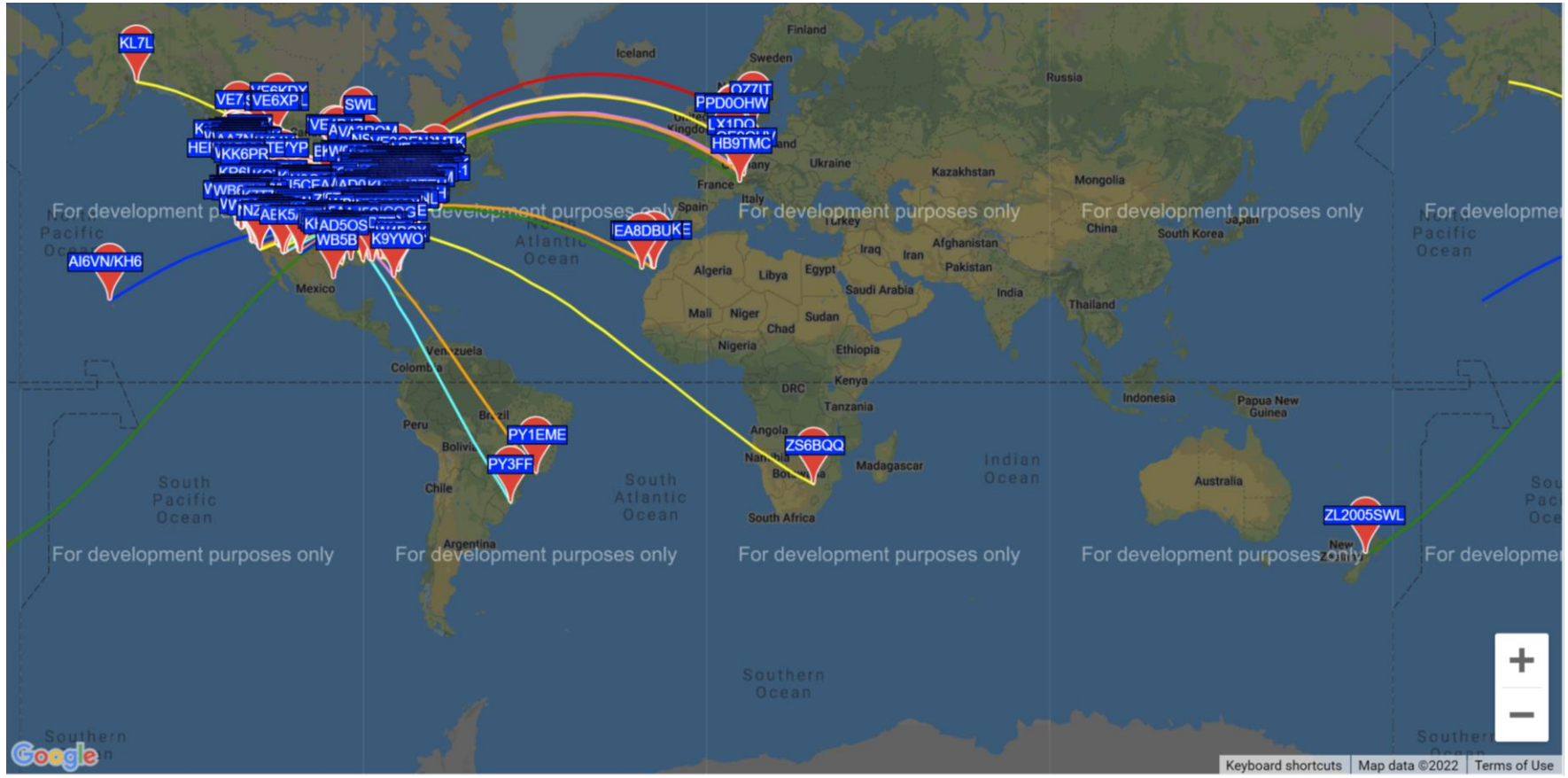
Theory of operation (2)

- The signal exits the power amplifier (the line driver IC) as a square wave and is filtered by four switched low pass filters and an extra VHF suppression low pass filter. The latter suppresses harmonics 50 dB or more compared to the carrier.
- An on-board GPS module acquires satellites and automatically determines the transmitter's location

Configuring the transmitter



Typical 24-hour reporter distribution map for my system (mid-February 2022)



An interesting report

Timestamp	Call	MHz	SNR	Drift	Grid
2022-02-16 00:08	W0JKH	14.097128	-15	0	EM28

Pwr	Reporter	RGrid	km	az	Mode
0.2	DP0GVN/3	IB59ui	13890	156	2

The reporting station is a German WSPR reporter operating at a science station in Antarctica (see https://dxnews.com/dp0gvn_neumayer-station_antarctica/).

A reporter-distribution analysis

- I wrote some experimental software to help assess whether the reporting stations were more or less uniformly distributed by azimuth
- Software tries to normalize
  - Population density in the “region” of the reporter, and
  - Distance from beacon
- I initially thought my antenna might impose some significant directional bias in the distribution
- The software analyzed ~30 days of WSPRnet logging records for my beacon and reported no significant directional feature in the data

Candidate experiments

- WSPRnet logging data directly supports analyses of low-power propagation as a function of any subset of
  - Time
  - Distance
  - Direction
  - Beacon power
- When conjoined with other data, WSPRnet logging data can also support analyses of
  - Reporter sensitivity
  - Beacon and reporter antenna system properties
  - The state of the ionosphere
  - Effects of solar cycle phases
  - Effects of transient solar events (e.g., mass ejections)