RECEIVING WWVB WITH HACKRF PRO

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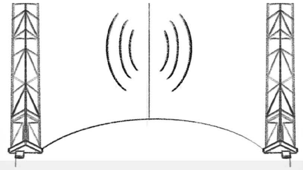
100 kHz is the lower edge of HackRF Pro's official operating frequency range, but that isn't a hard limit. While working on the design, we realized that it should work fairly well to pick up longwave time signals such as WWVB, broadcast at 60 kHz from Colorado, USA.

WWVB provides a stable frequency reference and time code. If you have a radio-controlled clock in North America, it probably uses the signal from WWVB to maintain the correct time. WWVB can also be used to discipline a laboratory frequency standard, eliminating the need for a local atomic clock in many cases.

WHY USE WWVB?

Nearly every electronic device contains some sort of oscillator or clock. HackRF Pro, for example, contains a temperature-compensated crystal oscillator (TCXO) which is better than the crystal oscillator (XO) used in HackRF One. Having a better internal clock means that radio frequencies received or transmitted by the device are more accurate.

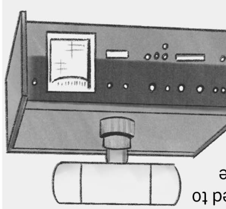
A good alternative to an expensive atomic clock would be an oven-controlled crystal oscillator (OCXO) that has been recently calibrated or that is disciplined by a remote atomic clock. One such remote frequency reference is WWVB, which has several orders of magnitude less frequency uncertainty than the TCXO in HackRF Pro. WWVB also provides a digital time code indicating the time of day.



WHY NOT A GPSDO?

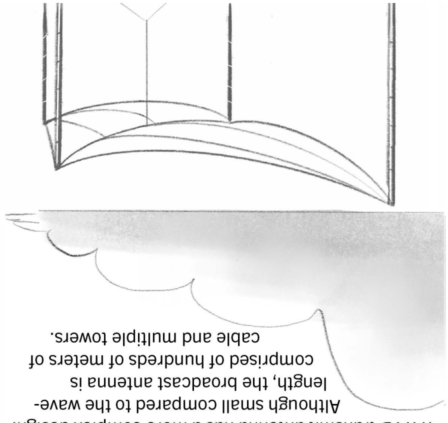
Before GPS Disciplined Oscillators became available, some test equipment manufacturers sold WWVB disciplined oscillators, but these products are no longer made. They had already become unpopular before the broadcast format of WWVB was changed in 2012 with the introduction of phase modulation that broke compatibility with commercial oscillators.

We like the idea of making our own WWVB disciplined oscillator, partly because a GPS receiver needs an active antenna placed somewhere with a view of the sky whereas a WWVB receiver can be located indoors. A WWVB receiver can have a relatively simple design and does not need to constantly track multiple moving satellites, is stable, and will not be adversely affected by Kessler syndrome. Plus, it turned into a fun project!



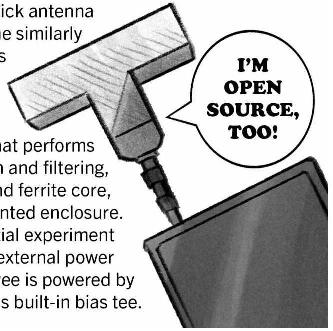
AN ACTIVE ANTENNA FOR 60 kHz

Radio antennas are generally sized in proportion to wavelength, and the wavelength at 60 kHz is very long (about 5000 m). A vertically polarized quarter-wave monopole antenna for 60 kHz would be the tallest structure in the world! To avoid such an impractical construction, the WWVB transmit antenna has a more complex design. Although small compared to the wavelength, the broadcast antenna is comprised of hundreds of meters of cable and multiple towers.



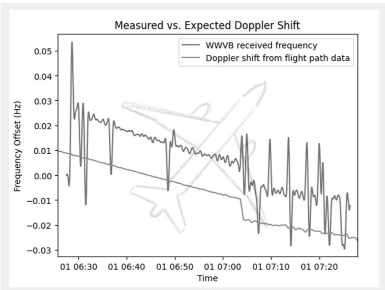
WWVB receivers use small loop antennas which detect changes in the magnetic field. Several amateur radio operators have constructed air core loop antennas for WWVB with diameters of one to two meters while radio-controlled clocks use much smaller ferrite core ("loopstick") antennas. Michael thought it would be fun to build a small active loopstick antenna that is compatible with HackRF Pro. He experimented by piecing together a few RF amplifier and filter test PCBs and connected them to a loopstick antenna pulled from an AM radio kit. He used a VNA to tune the antenna for 60 kHz and with two amplifier ICs and a low-pass filter, was able to detect WWVB all the way from Ontario!

Based on this success, he designed Teewee, an active loopstick antenna named for the similarly shaped Tetris block. Teewee consists of a small PCB that performs amplification and filtering, a hand-wound ferrite core, and a 3D-printed enclosure. While his initial experiment required an external power supply, Teewee is powered by HackRF Pro's built-in bias tee.



MEASURING DOPPLER SHIFT WITH WWVB

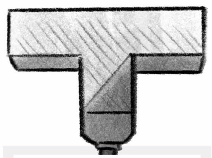
After getting Teewee working, Michael traveled to British Columbia and decided to try picking up WWVB on a cross-country flight. By placing Teewee in a window, connected to a HackRF Pro by an SMA cable, he captured the signal from WWVB for a full hour while the plane headed west, starting at a point roughly north of the transmitter. He analyzed the capture and found that the Doppler shift was evident when plotting the received WWVB frequency over time. Michael later downloaded ADSB flight data and used it to plot the expected Doppler shift. This correlated quite well with the WWVB observations.



TRY IT YOURSELF!

Teewee's design has been published for anyone who would like to build their own and use with HackRF Pro!

github.com/mossmann/teewee



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To find specs of, open source documentation for, and resellers currently carrying HackRF Pro, head to

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