Using Ham Band WSPR Transmissions for Ionospheric Research

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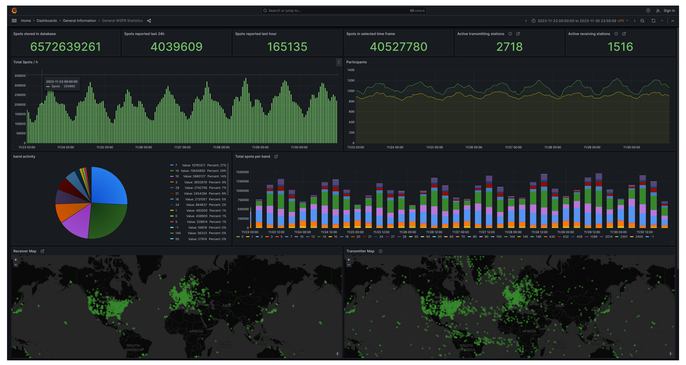
Abstract

There are currently over 4000 ham radio stations worldwide continuously transmitting and receiving beacon signals using the WSPR RF modulation format. It is implemented in the open source WSJT-x application program authored by Nobel Laureate Joe Taylor and a large group of contributors. Recent software enhancements to WSJT-x and newly available low cost transmit and receive hardware using GPS disciplined oscillators permit records of these transmissions (known as 'spots') to be used to study ionospheric events like Travelling Ionospheric Disturbances. Records of those 3 million+ receptions per day are publicly available to all researchers and citizen scientists in a SQL database which ensures access for all. In this presentation we give an introduction to WSPR, the publicly available databases where the 'spots' are stored. Also included are websites with text, map and graphical outputs which allow easy queries about 'spots' and examples of low cost research quality transmitters and receivers which are in operation.

The WSPR Network

- WSPR (Weak Signal Propagation Reporter) is a digital communication protocol used by hams (amateur radio operators) for low power radio communication
- There are over 2700 transmit (beacon) sites and over 1500 receive sites in operation around the world
- Most beacons transmit at least several times per hour on one or more bands with output power in the range of 0.2 to 5 watts
- Receive sites listen on one or more bands and decode beacon transmissions
- Spots are logged to the online database wsprnet.org
- All 6.6 Billion spots from 2008-2023 are available at the public SQL database wspr.live
- Increasing numbers of beacons and receivers are disciplined by GPS phase locked clocks. The frequency accuracy and stability recorded for those transmissions rival those for measurements from WWV reception



Grafana page courtesy of http://wspr.live

Table View of WSPR spots

- Each recorded reception (called a "spot" in that system) contains:
  1) The ham call sign of the transmitter
  2) The transmitter's approximate Maidenhead geographic location
  3) The transmit power level
  4) The receiver's measurement of the transmit frequency to 0.1 Hz resolution
  5) The receiver's measurement of the signal to noise ratio
- This is a small portion of the 2042 spots reported in one hour by the station KFS located 30 miles south of San Francisco

[2042 spots] 2041 to 0
wspr.live search time was 0.052079692 secs

Table options | find duplicates | Saved searches

help | SQL | charts | map | table | search

▲ status -> locator RR84bc, 1ST 03:17

** Click table cells for more info. ** Right-click rows for Search options.

local y-m-d	txCall	txGrid	rxCall	rxGrid	MHz	W	SNR	drift		k	txAz°	mode	k/W	spotQ	version
2023-12-09 07:34	KN4JTB	EM66tx	KFS	CM87lj	28.126097	5	-19	0		3170	282	WSPR2	634	290	WD_3.1.3
2023-12-09 07:34	WB6CXC	CM88lj	KFS	CM87lj	28.126102	1	-18	0		126	152	WSPR2	126	61	WD_3.1.3
2023-12-09 07:34	AL7DS	EN61bn	KFS	CM87lj	28.126119	10	-13	0		2977	273	WSPR2	298	187	WD_3.1.3
2023-12-09 07:34	WB2TKP	FN20	KFS	CM87lj	24.926081	0.2	-26	0		4059	281	WSPR2	20295	5219	WD_3.1.3
2023-12-09 07:34	AE5HO	EM13	KFS	CM87lj	24.926123	0.005	-18	0		2329	288	WSPR2	465800	226246	WD_3.1.3
2023-12-09 07:34	K3WRG	FM28	KFS	CM87lj	21.095999	0.2	-27	0		4106	284	WSPR2	20530	4693	WD_3.1.3
2023-12-09 07:34	KK1D	FN31vi	KFS	CM87lj	21.096014	1	-10	0		4274	281	WSPR2	4274	3053	WD_3.1.3
2023-12-09 07:34	KG5TW	EM00	KFS	CM87lj	21.096023	0.2	1	0		2278	296	WSPR2	11390	11715	WD_3.1.3
2023-12-09 07:34	W2WNN	FM29	KFS	CM87lj	21.096034	0.2	-14	0		4081	282	WSPR2	20405	12243	WD_3.1.3
2023-12-09 07:34	W8AC	EN91jm	KFS	CM87lj	21.096041	1	-4	0		3530	276	WSPR2	3530	3127	WD_3.1.3
2023-12-09 07:34	NE3Z	FM18fg	KFS	CM87lj	21.096044	0.2	-7	0		3899	283	WSPR2	19495	15596	WD_3.1.3
2023-12-09 07:34	HP1GDP	EJ09	KFS	CM87lj	21.096065	0.2	-14	0		5330	313	WSPR2	26650	15990	WD_3.1.3
2023-12-09 07:34	WA9WTK	FN42fk	KFS	CM87lj	21.096062	10	-13	0		4306	280	WSPR2	431	271	WD_3.1.3
2023-12-09 07:34	VE2SIL	FN35cm	KFS	CM87lj	21.096079	0.2	-25	0		4083	275	WSPR2	20415	5833	WD_3.1.3
2023-12-09 07:34	KR6RG	DM13em	KFS	CM87lj	21.096083	0.2	-22	0		609	316	WSPR2	3045	1131	WD_3.1.3
2023-12-09 07:34	KF4HCW	FM19fc	KFS	CM87lj	21.096087	2	-5	0		3880	282	WSPR2	1940	1663	WD_3.1.3
2023-12-09 07:34	W3ENR	FM28jh	KFS	CM87lj	21.0961	0.2	-18	0		4096	284	WSPR2	20480	9947	WD_3.1.3
2023-12-09 07:34	WB6CXC	CM88lj	KFS	CM87lj	21.096103	1	-22	0		126	152	WSPR2	126	47	WD_3.1.3
2023-12-09 07:34	LU4AA	GF05	KFS	CM87lj	21.096103	0.2	-16	0		10329	315	WSPR2	51645	28036	WD_3.1.3

Graphical view of WSPR spots

- The http://wspr.rocks/ web site offers many easily customizable graphical reports
- This is a map view of all the spots in the above table

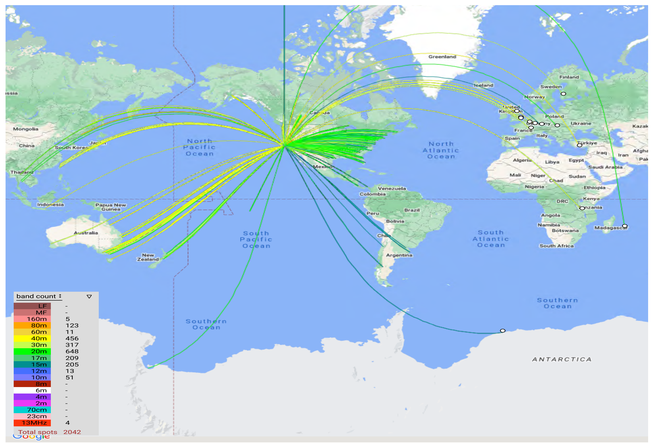
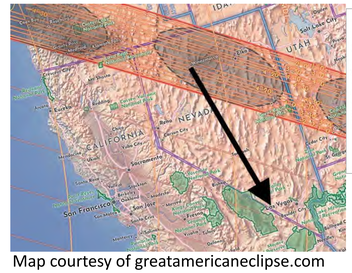
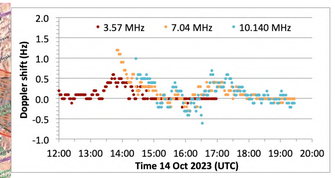


Table and map courtesy of http://wspr.rocks

Ionospheric Motion Case Study

- Determine F-layer motion during the 14 October 2023 Annular Eclipse
- Using Multi-frequency ionospheric Doppler measurements
- Transmissions were for a 545 km path from WO7I in Winnemucca, NV to ND7M in Pahrump, NV





Map courtesy of greatamericaneclipse.com

The WsprSonde 8 Transmitter

- GPS disciplined to better than 0.001 Hz accuracy and stability is several orders of magnitude better than the 10s of mHz or more of doppler shift introduced by ionospheric motion
- Continuous 1W transmissions on 8 bands
- Using the optional 4 and 6 band combiners, one multiband antenna can radiate many of the output channels
- Available from Turn Island Systems: https://turnislandsystems.com

The Wsprdaemon Receive System

- By using the KA9Q-radio library (https://github.com/ka9q/ka9q-radio) Wsprdaemon (WD) Linux software (https://github.com/rrobinett/wsprdaemon) simultaneously decodes and records signals on 14 ham bands from multiple low cost, GPS disciplined RX-888 Mk II SDRs
- Spots recorded by WD include a rich set of metadata including doppler-induced spreading, background noise level and receiver overload event count

Acknowledgement

The WSPR protocol and its implementation in the open source WSJT-x project is the work of Joe Taylor, Steve Franke and a large number of contributors whose work can found at https://wsjt.sourceforge.io/wsjtx.html