## White Paper WSPR by Joe Taylor, K1JT for transmit and receive antenna comparison by Larry Plummer, W6LVP January 10, 2017

EZNEC and other analytical tools are great for initial antenna design. Houses, metal objects, and many other variables influence the real-world performance of any antenna. Once the general specifications for an antenna are defined, I like to use on-air tests to measure and optimize antenna performance. Getting objective, quantitative on-air measurement is the challenge and also the key to useful antenna performance feedback.

Switching between two transmit antennas while counting from one to ten and then getting an on-air report from another ham provides rough comparisons. Wouldn't it be great if those A-B comparisons were objective and quantitative? Good news is that there is such a tool and it is widely deployed. It is called WSPR for Weak Signal Propagation Reporter. Although WSPR was developed by Joe Taylor, K1JT, for propagation analysis, it turns out to be a great tool for antenna comparison. It's just a simple matter of repurposing WSPR for another application.

There are thousands of hams, SWLs, and other WSPR reporters worldwide with receivers waiting for your transmitted signal. When these reporters' receivers detect your signal, their computers running WSJT-X software will automatically upload their received signal reports to the WSPRnet.org website for your review and analysis. More than a half million reports are posted every day.

There is also a large number of hams (only hams because transmission requires a license) worldwide transmitting WSPR beacon signals on every band from 2200 meters through VHF/UHF. WSPR signals from a receiver and a computer running WSJT-X software displaying received signal quality is a great way to evaluate receive antennas.

The key to accurate comparison of either transmit or receive antennas is simultaneous reception or transmission. Even though WSPR beacons can be received or transmitted every two minutes, there are too many changes possible from one test cycle to another. For receive testing, most hams transmitting WSPR beacon signals don't transmit every cycle so you may need to wait several minutes to compare the received signal from the same transmitting station. During that delay, propagation conditions will change making for inaccurate comparisons. The solution is two devices, i.e. two transmitters/transceivers for simultaneous transmission from two antenna or two receivers for simultaneous receive antenna comparison. Two devices are critical due rapid QSB and other signal changes that can occur from one two minute WSPR cycle to the next. Alternating one transmitter between two transmit antennas or alternating one receiver between two receive antennas doesn't provide accurate results.

Plus, I don't know any ham that has just one rig. Any transmitter or transceiver can be used for transmit antenna comparison particularly since power levels can be 5 watts or even much lower. You just need to adjust the power output from the two transmitters to the same level.

Receivers are a bit more challenging because not all receivers are the same. However, there is an easy solution to remove any differences in received signal levels due to receiver performance. Simply run the test for a while with each antenna connected to a receiver and after a few WSPR test cycles, reverse the antenna/receiver combinations and repeat the test. Then normalize any variation due to receiver differences.

For either transmit or receive antenna comparison, I like to start with a simple antenna as my reference standard – typically a half-wave dipole. For receive antenna comparison, I connect one receiver to the dipole and a second receiver to the antenna being compared. For transmit antenna comparison, I connect one transmitter/transceiver to the dipole and a second transmitter/transceiver to the antenna under test.

There are a couple of options for transmitting WSPR test signals. One option is to use commercial transceivers operating at very low power – typically less than 5 watts – getting audio modulation signals from computers running WSJT-X software. Alternatively, custom designed WSPR transmitters can be used to compare transmit antennas. The benefit of custom WSPR transmitters is that they are completely self contained and don't require a computer or any other support devices. QRP-labs has a great yet inexpensive QRP WSPR transmitter kit. Using two of these transmitters or any two transmitters will provide simultaneous, side-by-side comparison of the transmission capability of any two antennas. There is another new standalone WSPR transmitter option from SOTABEAMS in the UK called WSPRlite that not only includes a low-power WSPR transmitter but also web-based DXplorer analysis tools for comparing the transmit received reports for two antennas.

## http://www.sotabeams.co.uk/wsprlite

Regardless of the transmitters used, the only requirement is that the power output of the two transmitters be set to the same power level.

Comparing two receive antennas is similar to transmit antenna comparison but in reverse. The audio output from two receivers is connected to the audio input of a computer running two copies of WSJT-X or two computers each running WSJT-X. Although more complex and beyond the scope of this paper, it is possible to run two copies of WSJT-X on the same computer. A much easier approach is simply to run WSJT-X on two computers and connect the received audio output of two receivers/transceivers to the audio input of two computers. Many of the newer transceivers such as the ICOM-7100 and 7300 have built-in digital CAT and audio interfaces. For other transceivers not having these features, there are a number of easy to connect digital interface devices such as the SignaLink USB that provide both audio interface between a computer and rig plus CAT for frequency sync and PTT for transmitter control.

There is a new ARRL book called "Working the World with JT65 and JT9." Although WSPR is a slightly different protocol, WSPR, JT65, and JT9 are all supported by the WSJT-X program. The book goes well beyond the scope of this white paper to provide detailed instructions on the installation, setup, and operation of WSJT-X. With WSJT-X operating, selecting from among these three protocols and even others is as simple as picking from a drop down menu. For anyone wanting to use these protocols for propagation testing, antenna comparison, or just QSOs, this book is a great resource.

A benefit of getting your rig(s) setup to work with WSJT-X is that you now can use the JT-9 and JT-65 digital protocols that are part of the WSJT-X suite. In addition, other digital software programs like FLDIGI use very similar audio and CAT setup.

Very soon after each transmission cycle completes, you can check the received results. Each WSPR transmission cycle starts 2 seconds after each even number minute and lasts one minute and 50 seconds. Typically, within 30 seconds after the end of each cycle, the reports of your signal are posted and available for review. Go to <a href="http://wsprnet.org/drupal/wsprnet/spots">http://wsprnet.org/drupal/wsprnet/spots</a> to check for your reports. You can optionally create a login but one is not required to view or download the signal reports.

I set the transmit frequency in WSJT-X slightly differently for each transmitter so that the two antennas can be differentiated. Even for reporters who don't have precise frequency accuracy, the spread between the two transmitters will always be the same, i.e antenna #1 is the higher frequency reported and antenna #2 is lower.

To view your transmission comparison results, go to WSPRnet.org and enter the band, count of reports you want to review, your call, time frame of interest, and sort. Leaving the Reporter box empty, will show all received reports. I like to sort by Timestamp in Reverse order which shows the most recent reports at the top of the list.



Look for the received reports from the same reporter. Notice that there is a frequency difference between the two reports which you can correlate to a specific antenna. Sometimes reports from a station are not next to each other so you may have to scan the list within a 2 minute time window a bit to match up the stations.

Look at the reports near the middle of the screen for W7KVI. He hears antenna #2 (the one on the higher frequency) better by 5 dB (+2 dB versus -3 dB S/N). You can focus on stations at different distances or different azimuths.

USB dial (MHz): 0.136, 0.4742, 1.8366, 3.5926, 5.2872, 7.0386, Larry 👝 😐

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C ① wsprnet.org/drupal/wsprnet/spots

## Frequencies

Specify query parameters

50 spots:

Database

10.1387, 14.0956, 18.1046,							_				
21.0946, 24.9246, 28.1246,	Timestamp	Call	MHz	SNR	Drift	Grid	Pwr	Reporter	RGrid	km	az
50.293, 70.091, 144.489,	2017-01-06 20:58	W6LVP	14.097179	-10	0	DM04li	0.5	K4COD	EM73sc	3186	83
432.300, 1296.500	2017-01-06 20:58	W6LVP	14.097175	-21	-1	DM04li	0.5	AI4RY	EM72go	3107	84
	2017-01-06 20:58	W6LVP	14.097178	-17	-1	DM04li	0.5	W9HLY	EN70mt	3067	66
Spot Count	2017-01-06 20:58	W6LVP	14.097192	-26	0	DM04li	0.5	K4EH	EM73qk	3163	82
Spor Count	2017-01-06 20:58	W6LVP	14.097198	-15	-1	DM04li	0.5	KC4RSN	EM72hp	3113	84
539,267,831 total spots	2017-01-06 20:58	W6LVP	14.097192	-18	0	DM04li	0.5	W0TBR	CN85qn	1283	347
715,315 in the last 24 hours	2017-01-06 20:58	W6LVP	14.097178	-23	(	DM04li	0.5	VE6SLP	DO33gn	2180	10
39,805 in the last hour	2017-01-06 20:58	W6LVP	14.097190	-9	0	DM04li	0.5	WD5GBS	EM13ne	2049	87
	2017-01-06 20:58	W6LVP	14.097192	-8	(	DM04li	0.5	K4COD	EM73sc	3186	83
Navigation	2017-01-06 20:58	W6LVP	14.097204	-27	(	DM04li	0.5	K4RCG	FM08si	3632	71
	2017-01-06 20:58	W6LVP	14.097177	-12	0	DM04li	0.5	WD5GBS	EM13ne	2049	87
Add content	2017-01-06 20:58	W6LVP	14.097193	-16	(	DM04li	0.5	WD4AHB	EL89rt	3457	88
Forums	2017-01-06 20:58	W6LVP	14.097194	-33	(	DM04li	0.5	W3GXT	FM19ol	3764	69
	2017-01-06 20:58	W6LVP	14.097160	-1	(	DM04li	0.5	KD6RF	EM22lb	2242	90
Who's online	2017-01-06 20:58	W6I VP	14 097192	-25	(	DM04li	0.5	K9AN	EN50wc	2796	68
	2017-01-06 20:58	W6LVP	14 097180	-3	(	DM04li	0.5	W7KVI	CN87ug	1462	350
here are currently 166 users	2017-01-06 20:58	W6LVP	14 097193	+2	(	DM04li	0.5	W7KVI	CN87ug	1462	350
online.	2017-01-06 20:58	WELVP	14 097171	-5	Ċ	DM04li	0.5	N4XWC	EM63nu	2950	82
vk4alf	2017-01-06 20:58	WELVP	14.007158	-0		DM04li	0.5	NAXWC	EM63nu	2050	82
KK4MBI	2017-01-00 20:58	WELVP	14.007100	20			0.5	N2KME	EN33oh	4006	62
N8AUM	2017-01-00 20:58	WELVE	14.007102	-20			0.5	KG5LBS	EM10bf	2038	02
OZ1AAB	2017-01-00 20:58	WELVE	14.097199	-13			0.5	KG5LBS	EM10bf	2030	07
• On/kb	2017-01-00 20:58	WELVE	14.007188	-20			0.5		EN12fr	3688	63
MADDD	2017-01-00 20:58	WELVE	14.097100	-0	1	DM04li	0.5		EM8/uv	33/3	78
	2017-01-00 20:58	WELVE	14.007107	-10	-		0.5	VEGOG	DO33fn	2170	10
ON5VW	2017-01-00 20:58	WELVE	14.097197	-10			0.5	VESHI	EN04cc	2113	60
WB2LMV	2017-01-00 20:50	WELVE	14.097197	-21			0.5	KEYI	EM12kn	2037	80
• 2m0rot	2017-01-00 20:50	WELVD	14.007101	-17	4	DM04Ii	0.5	VEGGLD		2007	10
• VK7BO	2017-01-00 20.30	WELVD	14.097191	-10		DM04II	0.5		EL 15 guy	2100	100
• G0HYT	2017-01-00 20.50	WELVE	14.097101	-21	4	DM04II	0.5		ELTOYW	2210	70
• 2E0FAU	2017-01-00 20.30	WELVE	14.097209	-12	- 1		0.5		EIVIO4UX	2704	74
• G4FDL	2017-01-06 20:58	WOLVP	14.097192	-12			0.5	NOEV		3791	100
• G4ZFQ	2017-01-06 20:58	WOLVP	14.097194	-22	(		0.5	VCOV	EL15gW	2270	109
• LA3JJ	2017-01-06 20:58	WOLVP	14.097197	-17	(		0.5	K/JGM		1480	350
• hb9pkp	2017-01-06 20:58	WELVP	14.09/185	+2	(		0.5	KA/UWO	CN85lh	1265	346
• ACOG	2017-01-06 20 58	W6LVP	14.09/184	-21		DM04li	0.5	K/JGM	CN8/uk	1480	350
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Using WSPR to compare receive antennas is very similar, just in reverse. If supported by your model transceiver, connect it to your computer running WSJT-X. If your transceiver doesn't have direct computer connection integrated, use a digital interface like SignaLink USB to connect your computer to WSJT-X. One of the key features of the WSPR system is the automatic ability for WSJT-X to upload signal reports to the WSPRnet.org website for review by you or anyone. Since during receive, you are not transmitting, you can alter your call sign a bit to differentiate between your two antennas being tested. I normally append a letter or two on the end of my call to identify the specific antenna reports. In this example, I use W6LVP/A1 and W6LVP/A2 to display the received results for two antennas.

I can either immediately see the received signal reports for the two antennas using the WSJT-X display. Like transmit antenna comparison, I can also access the data from WSPRnet.org.

Setup for receive reports is very similar to transmit. Notice that I used my modified call to display the results for each of the two antennas. I need to do this twice using each of the two modified calls.



Database   WSPRnet ×								_		2		
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JSB dial (MHz): 0.136, 0.4742,	Specify query parameters											
1.8366, 3.5926, 5.2872, 7.0386,	50 spots;											
0.1387, 14.0956, 18.1046,	The sector was	0-11			Duitt	0.11		<b>B</b>	Double	I		
1.0946, 24.9246, 28.1246,	Timestamp	Call	MHZ	SNR	Drift	Grid	Pwr	Reporter	RGrid	ĸm	az	
i0.293, 70.091, <b>1</b> 44.489,	2017-01-06 20:26	KG5CER	14.097090	-23	0	EM12mu	0.01	W6LVP/A1	DM04li	2048	281	
32.300, 1296.500	2017-01-06 20:26	N5ALX	14.097116	-19	-1	FM18fm	5	W6LVP/A1	DM04li	3710	276	
	2017-01-06 20:26	AE5HO	14.097130	-6	0	EM13la	0.2	W6LVP/A1	DM04li	2037	280	
Spot Count	2017-01-06 20:24	KG5CER	14.097103	-25	0	EM12mu	0.01	W6LVP/A1	DM04li	2048	281	
spor count	2017-01-06 20:24	KW4TO	14.097124	-29	0	FM17dm	0.5	W6LVP/A1	DM04li	3708	277	
39,267,831 total spots	2017-01-06 20:24	AF7ES	14.097120	-19	0	CN88nq	0.2	W6LVP/A1	DM04li	1625	167	
08,562 in the last 24 hours	2017-01-06 20:24	K4COD	14.097162	0	0	EM73sc	2	W6LVP/A1	DM04li	3186	282	
2,232 in the last hour	2017-01-06 20:24	AA7FV	14.097136	-16	0	DM42pg	2	W6LVP/A1	DM04li	808	289	
	2017-01-06 20:24	N8FWG	14.097069	-20	-1	EN62vm	0.5	W6LVP/A1	DM04li	2979	263	
Navigation	2017-01-06 20:24	W4MO	14.097088	-14	0	EL86	5	W6LVP/A1	DM04li	3541	293	
Add contant	2017-01-06 20:22	K0RCW	14.097091	+7	0	DM79kq	10	W6LVP/A1	DM04li	1368	249	
Add content	2017-01-06 20:22	K7JGM	14.097166	-24	-1	CN87uk	5	W6LVP/A1	DM04li	1480	168	
Forums	2017-01-06 20:22	N4HY	14.097028	-12	0	EM97vf	20	W6LVP/A1	DM04li	3493	277	
	2017-01-06 20:22	N2KMF	14.097105	-21	0	FN33eh	10	W6LVP/A1	DM04li	4006	271	
Vho's online	2017-01-06 20:22	AE2EA	14.097132	-9	0	FN12fr	5	W6LVP/A1	DM04li	3688	269	
	2017-01-06 20:22	VE7UV	14.097184	-23	-1	CO83ow	0.2	W6LVP/A1	DM04li	2197	171	
nere are currently 165 users	2017-01-06 20:20	WK2Y	14.097097	-11	0	EM73uv	10	W6LVP/A1	DM04li	3183	281	
nnine.	2017-01-06 20.20	K5XL	14.097052	-8	0	EM12kp	2	W6LVP/A1	DM04li	2037	281	
	2017 01 00 20:20	W3GXT	14.097102	-24	3	FM19ol	5	W6LVP/A1	DM04li	3764	275	
ON4CDJ	2017-01-06 20:20						Ę		DIAGAN	4400	400	
ON4CDJ N3IZN	2017-01-06 20:20	W7KVI	14.097040	-13	-1	CN87ua	5	VVOLVP/AT	DM041	1462	168	
ON4CDJ N3IZN M0SGL	2017-01-06 20:20 2017-01-06 20:20 2017-01-06 20:20	W7KVI N4TIC	14.097040 14.097182	-13 -23	-1 0	CN87ug FM74	5 01	W6LVP/A1	DM04II DM04Ii	1462 3104	168 280	
ON4CDJ N3IZN M0SGL oz1pif	2017-01-06 20:20 2017-01-06 20:20 2017-01-06 20:20 2017-01-06 20:20	W7KVI N4TIC N8AUM	14.097040 14.097182 14.097142	-13 -23 -20	-1 0 0	CN87ug EM74 EM70em	5 0.1 1	W6LVP/A1	DM04II DM04Ii DM04Ii	1462 3104 3151	168 280 287	

For receive, WSPRnet.org reports are very useful but I normally prefer using the WSJT-X displays to compare received signal reports.

## SJT-X - Analog2 v1.7.0-rc2 by K1JT

File Configurations View Mode Decode Save Help

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UTC	dB	DT	Freq	Drift	Call	Grid	dBm	km			
2022	-9	0.5	14.097132	0	AEZEA	FN12	37	2326			~
2022	-24	0.9	14.097166	-1	K7JGM	CN87	37	931			
2022	-23	0.4	14.097184	-1	VE7UV	C083	23	1337			
									20m		
2024	-20	0.5	14.097069	-1	N8FWG	EN62	27	1817			
2024	-14	0.8	14.097088	0	W4MO	EL86	37	2208			
2024	-25	0.6	14.097103	0	KG5CER	EM12	10	1280			
2024	-19	2.4	14.097120	0	AF7ES	CN88	23	998			
2024	-29	1.2	14.097124	0	KW4TO	FM17	27	2350			
2024	-16	1.4	14.097136	0	AA7FV	DM42	33	484			
2024	-0	0.6	14.097162	0	K4COD	EM73	33	1950			
									20m		
2026	-23	0.5	14.097090	0	KG5CER	EM12	10	1280			
2026	-19	-0.2	14.097116	-1	N5ALX	FM18	37	2342			
2026	-6	0.5	14.097130	0	AE5HO	EM13	23	1267			
									20m		
2028	-25	0.5	14.097035	0	VE7KPB	DN29	37	1067			
2028	-16	0.5	14.097040	-1	W7KVI	CN87	37	931			
2028	-13	0.9	14.097051	0	K5SWA	EM12	27	1280			
2028	-13	0.5	14.097149	0	K3RWR	FM18	37	2342			¥
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Notice the received signal report difference for just two examples at 2028 for VE7KPB and K5SWA. For these two antennas being compared, the antenna in the first report hears VE7KPB stronger by 12 dB (-25 dB versus -13 dB S/N) but K5SWA stronger by 3 dB (-13 dB versus -10 dB S/N). The first antenna is more directional than the second and in better line with K5SWA.

For receive antenna comparison testing, JT65 and JT9 modes can also be used. Again two receivers and two copies of WSJT-X running on one or two computers is also required. For comparing received signals using these modes, the WSJT-X data display works best for me. Although there tend to be fewer stations using JT9, it has S/N dynamic range of -30 to +30 dB similar to WSPR. JT65 reported S/N ranges from about -26 to -1 dB with all stronger signals, regardless of their actual signal strength, reported as -1 dB S/N. Due to this compression of JT65 S/N reports, all stronger signals should not be included.

I hope you have found this paper useful to setup and operate WSPR as a great tool for evaluating both transmit and receive antennas.