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Tests of ground-wave communication at 500 kHz during winter 2010 - spring 2011

by

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Abstract

This note presents the results of three daytime tests of ground-wave communication at 500 kHz. The transmitters were located in Iowa, Ohio, and Louisianna, and the path lengths ranged from 150 to 300 mi. The modulation modes were PSK-10, PSK-31, and MSK-31. These tests demonstrate that a useable signal can be radiated from a transportable antenna, and that modern digital signals can be received reliably at regional distances.

Indexing Terms

Radio, amateur
MF
Propagation, ground-wave

1. INTRODUCTION

This note presents the results from three daytime ground-wave tests conducted under the direction of Ralph Wallio W0RPK - WD2XSH/34. These tests occurred in November 2009, April 2011, and May 2011. Transmissions were made from Indianola, IA, Natchitoches, LA, and Kellogsville, OH using PSK-10, PSK-31, and MSK-31. The approximate locations of the transmitters and receivers are shown in Figure 1. Tests were run during the day to minimize the presence of sky-wave signals. These tests demonstrate the ability to use 600 meters for reliable, regional communications from realistic amateur equipment that is capable of being transported and deployed in an emergency.

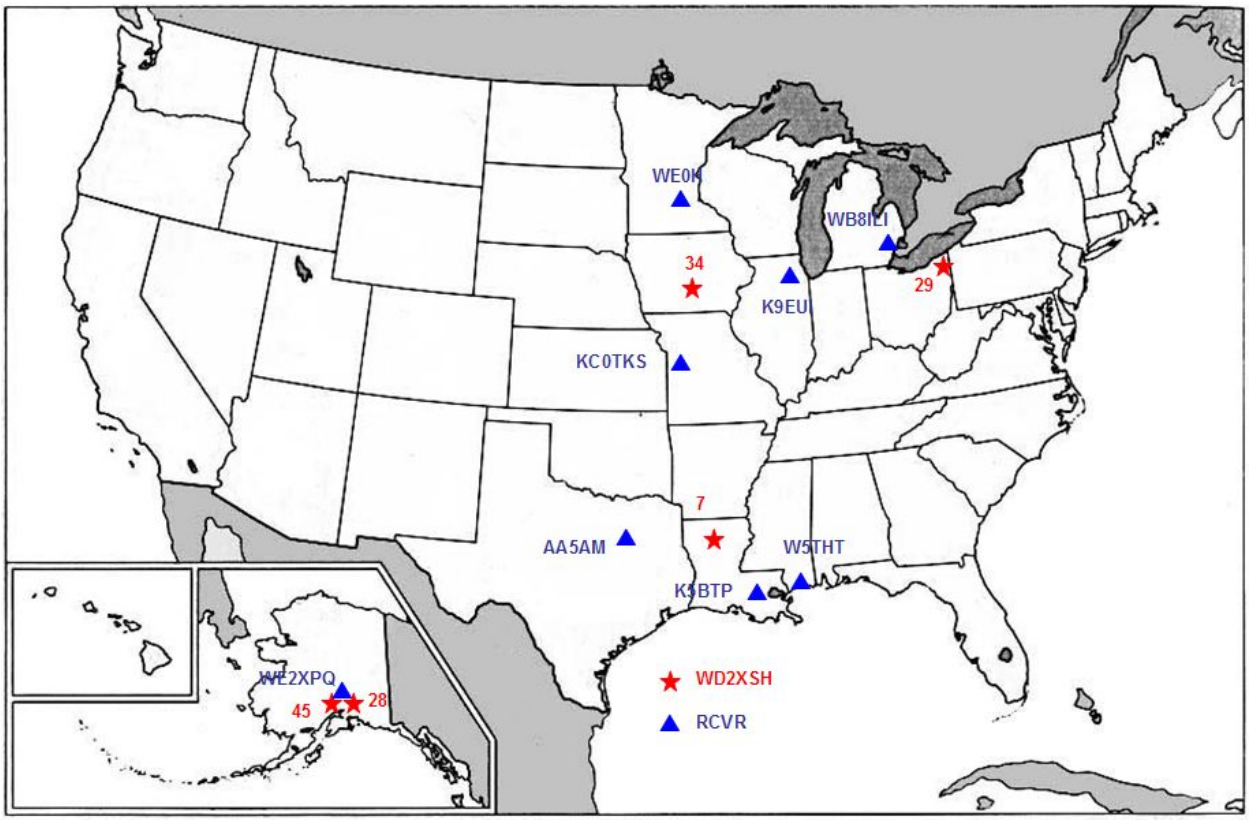

Figure 1. Locations of transmitters and receivers.

2. TEST SERIES #1

Transmissions were from WD2XSH/34 (Ralph Wallio, W0RPK) in Indianola, Iowa (near Des Moines) using PSK-31 and PSK-10. Signals were received by

OPERATOR	CALL SIGN	QTH	DISTANCE, mi	TESTS
Chris Sparks	KC0TKS	Sedalia MO	190	18
Bob Roehrig	K9EUI (WD2XSH/19)	Batavia IL	278	4
Garry Hess	K3SIW	Elgin IL	274	3
Mike Reid	WE0H (WD2XSH/16)	St. Francis MN	273	1

The quality of reception was evaluated in terms of character-error rate (CER).

WD2XSH/34 Transmitter and Antenna

The WD2XSH/34 transmitting station was designed to be transportable and field-deployable for emergency communications. The power amplifier (designed by KN8AZN - WD2XSH/29) is based upon a Small Wonder Labs PSK20/30/40 digital transceiver modified for 600 meters plus a Communications Concepts EB63 power amplifier, also modified for 600 meters. The antenna has a 20-ft vertical radiator with four 40-ft top-loading wires that sag about 10 ft. The loading coil is made from #14 AWG wire wound on 4-in light-weight PVC tubing and is placed at the top of the antenna. The ground system consists of thirty-two 40-ft radials. The antenna efficiency is less than 1 percent, hence the 100-W output from power amplifier produces an ERP of 0.3 to 1 W.

Transmissions

WD2XSH/34 transmitted using both PSK10 (upper-case only) and PSK-31 (both upper and lower case). The messages comprised 122 characters and included date and time stamps:

14/11/09 16:55:56 UTC THE QUICK BROWN FOX JUMPED THE LAZY DOG'S BACK 0123456789 WD2XSH/34 TESTING QSL:W0RPK@ARRL.NET
14/11/09 17:10:31 UTC The quick brown fox jumped the lazy dog's back 0123456789 WD2XSH/34 testing QSL:W0RPK@arrl.net

Reception

The reception results are shown in Figure 2 and Appendix A. While the reports from other stations are encouraging, only KC0TKS filed a sufficient number of reports to warrant statistical analysis. For this 190-mi (311-km) path, the error rates were:

	MEAN	SD
PSK-10	0.002	0.003
PSK-31	0.004	0.004

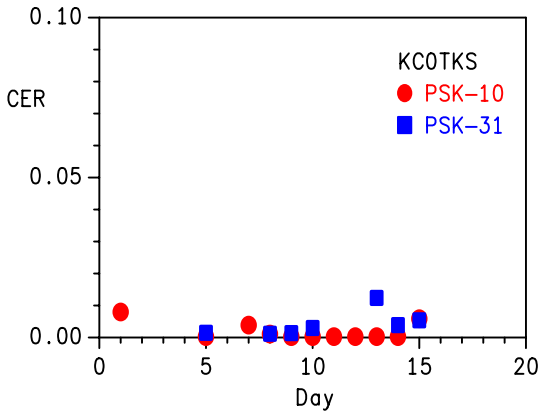

Figure 2. CER for reception of WD2XSH/34 by KC0TKS.

During these tests Chris Sparks, KC0TKS, improved S/N performance of his DIY PA0RDT Mini-whip antenna approximately 5dB by raising its height above surrounding structures and by increasing length of his E-probe. Any resultant improvement in error rate is, however, hard to discern.

Stations K3SIW and K9EIU, both in western Chicago exurbs, are only a few miles apart, but their reception experience was very different. Bob, K9EIU, was using his top-loaded 600-m transmit antenna. Garry, K3SIW, was using a loop antenna. It is not known whether the differences in the antennas, local noise, or some other factor is responsible.

3. TEST SERIES #2

These tests involved transmissions from WD2XSH/29 (Fred Temple, KN8AZN) in Kellogsville, OH to WB8ILI (Bob Harder) in New Baltimore, MI. These tests were conducted in April, 2011.

Transmitting Station

The WD2XSH/29 transmitter is a modified Small Wonder Lab PSK-40 transceiver, which drives a Communications Concepts Inc, EB-63A amplifier that has been modified for use on 600 meters. The antenna was a 160-m half-wave dipole which top-loads the 27-ft twin-lead feeder which acts as a vertical element. The estimated ERP is 3 W.

The WB8ILI receiving antenna is a 160-m full-wave inverted-V dipole running east-to-west. The height is about 50 ft at center and 20 ft at the ends. WB8ILI is 125-mi (205-km) distant from WD2XSH/29 and the path crosses Lake Erie.

Transmissions

All transmissions were made using MSK-31. The message format was similar to that used in test series #1. Character-error rate was evaluated.

Reception

WB8ILI made three receptions using a 160-m inverted V as the receiving antenna. The results are shown in Figure 3 and Appendix B. The CER (mean 0.002, standard deviation 0.001) for this 127-mi (205-km) path is comparable to that for series #1). Unfortunately the small number of receptions does not establish solid statistical confirmation of the reliability of this link.

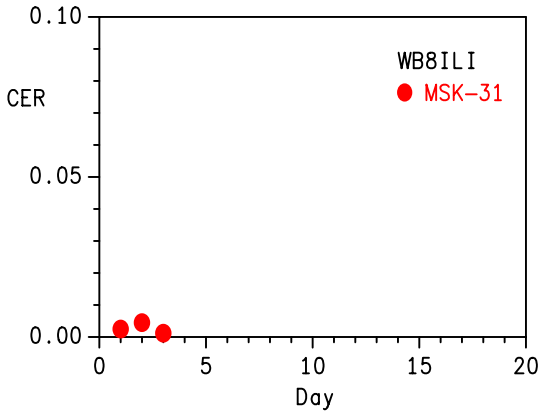

Figure 3. CER for reception of WD2XSH/29 by WB8ILI.

4. TEST SERIES #3

WD2XSH/7 (Ralph Hartwell, W5JGV) was the transmitter for these tests. Four stations attempted to receive the signals; two succeeded.

WD2XSH/7 Transmitter and Antenna

The antenna system consists of a 72-foot high, base-insulated, series-fed vertical antenna of 6-inch diameter. The antenna is constructed from several sections of 6-inch diameter aluminum irrigation pipe. The ground system consists of 480 feet of #6 bare solid copper wire laid out on the surface of the ground and nineteen 8-foot ground rods. The antenna efficiency is about 10 percent, resulting in 20 W ERP when driven by 200 W of RF.

Transmissions

All transmissions were made using MSK-31. The message format was similar to that used in test series #1. Character-error rate was evaluated.

Reception

Ten reception reports were filed by K5BTP (156 mi / 256 km) and nine were filed by AA5AM (216 mi / 354 km). The results are shown below. Of the ten reports from K5BTP, one has an error rate of 0.75 due to local thunderstorms. If this report is excised, both data sets have an error rate of 0.003.

RECEPTION	MEAN	SD	N
K5BTP	0.078	0.224	10
K5BTP-1	0.003	0.003	9
AA5AM	0.003	0.007	7

W5THT (at 261 mi) and KL7UK/5 (377 mi) reported no or very poor reception.

5. CONCLUSIONS

The tests reported here demonstrate that

(1) A useable 1 W ERP can be produced at 500 kHz by an amateur-type transportable station with a modest 20-ft antenna. This antenna can be assembled on the spot, and the 100-W transmitter can easily be powered by any vehicle.

(2) The resultant signal provides nearly error-free digital communication using PSK-10 and PSK-31 at distances up to 190 mi over good-conductivity ground. This is achieved by the ground wave and is therefore independent of the state of the ionosphere.

(3) MSK-31 can also provide close to error-free communication over similar paths (156 and 216 mi) with good ground conductivity.

Neither these tests nor those reported in [RN11-1] are ideal, of course.

Tests depend upon volunteers and participation is limited (especially during the daytime) by jobs, summer travel, and family obligations. There is also in some cases a tendency to regard this as working DX; i.e., having communicated over a path once, there is not as much interest in repeating it over and over again to prove it is reliable.

Restrictions inherent in the WD2XSH license prevent use of some modes such as PSK-31FEC.

The software available for digital communication is "nonorthogonal." For example, one package implements PSK-31 and PSK-10, but another implements MSK-31 but not MSK-10. While both PSK-31 and PSK-31FEC are available, analogous modes (e.g., PSK-16 and PSK-16FEC) that are compatible with the WD2XSH license are not available. The error-correction schemes may differ from one package to another. None of the software gives direct access to bit-error rate, received bit streams, or SNR.

Nonetheless, within these limitations this work and that reported in [RN11-1] clearly demonstrate the likelihood that amateurs can achieve reliable, regional emergency communication on 500 kHz using realistic portable systems. This capability is provided by the ground wave and therefore independent of the state of the ionosphere.

APPENDIX A. RECEPTION REPORTS FOR SERIES #1

BPSK10 ground-wave tests

DATE	TIME INTERVAL	RCVR	PATH	XMIT CHAR	RCV OK	CHAR ERRORS	CHAR OK RATE	
10/11/09	16:15-16:34UT	KC0TKS	190mi	1,662	1,649	13	99.23%	
14/11/09	16:00-17:00UT	KC0TKS	190mi	4,936	4,936	0	100.00%	
14/11/09	16:00-16:40UT	K3SIW	274mi	~2,500	~1,250		<50%	
16/11/09	16:00-17:00UT	KC0TKS	190mi	4,978	4,960	18	99.64%	
17/11/09	16:00-17:00UT	KC0TKS	190mi	4,979	4,975	4	99.92%	
18/11/09	16:21-16:51UT	KC0TKS	190mi	2,487	2,487	0	100.00%	
19/11/09	16:09-16:44UT	KC0TKS	190mi	3,098	3,098	0	100.00%	
20/11/09	16:00-16:40UT	KC0TKS	190mi	3,294	3,294	0	100.00%	
21/11/09	16:00-17:00UT	KC0TKS	190mi	4,514	4,514	0	100.00%	
21/11/09	16:00-17:00UT	K3SIW	274mi	~4,500			<25%	
22/11/09	16:00-16:45UT	KC0TKS	190mi	3,660	3,660	0	100.00%	
22/11/09	16:00-16:45UT	K3SIW	274mi	~3,600			<50%	
22/11/09	16:27-16:44UT	K9EUI	278mi	1,454	1,452	2	99.86%	
23/11/09	16:00-16:29UT	KC0TKS	190mi	2,562	2,562	0	100.00%	[1]
24/11/09	16:00-16:30UT	KC0TKS	190mi	2,505	2,491	14	99.44%	
24/11/09	16:00-16:30UT	K9EUI	278mi	2,460	2,433	27	98.90%	

BPSK31 ground-wave tests

14/11/09	17:02-17:31UT	KC0TKS	190mi	5,612	5,605	7	99.88%	
17/11/09	18:00-18:30UT	KC0TKS	190mi	5,612	5,607	5	99.91%	
18/11/09	16:53-17:22UT	KC0TKS	190mi	5,734	5,728	6	99.89%	[1]
19/11/09	16:47-17:00UT	KC0TKS	190mi	2,562	2,540	7	99.73%	
20/11/09	16:40-17:00UT	KC0TKS	Test aborted extreme local RFI problems					
22/11/09	16:45-17:15UT	KC0TKS	190mi	4,880	4,821	59	98.79%	[1]
22/11/09	16:45-17:15UT	K3SIW	274mi	No copy S/N~-18				
22/11/09	16:45-16:54UT	K9EUI	278mi	1,863	1,799	64	96.56%	
22/11/09	16:45-17:15UT	WE0H	273mi					
23/11/09	16:30-17:00UT	KC0TKS	190mi	5,612	5,592	20	99.64%	[1]
24/11/09	16:30-17:00UT	KC0TKS	190mi	4,540	4,517	23	99.49%	
24/11/09	16:30-17:00UT	K9EUI	278mi	4,267	4,194	73	98.29%	

Note [1]: Chris discovered he had MultiPSK squelch mistakenly set to 1. This was found to be responsible for the loss of the initial few characters in many transmissions. Received data error count has been rescored only if all remaining characters in transmission were error free.

APPENDIX B. TEST SERIES #2

One station attempted to receive CMSK31 test data from Fred Temple KN8AZN WD2XSH/29 during our ground-wave window:

STATION		PATH	DATE	CHAR RCVD	CHAR ERRORS	ERROR RATE	REMARKS
WB8ILI	Bob Harder	125mi	13/04/11	7,665	17	0.22%	
	WSPR SNR +2/-8		14/04/11	9,954	42	0.42%	
			15/04/11	4,374	4	0.09%	

APPENDIX C. TEST SERIES #3

STATION		PATH	DATE	CHAR RCVD	CHAR ERRORS	ERROR RATE	REMARKS
K5BTP	Richard Teague	156mi	21Mar11	19,200	12	0.06%	
	WSPR SNR +3/-2		22Mar11	19,920	169	0.85%	
			23Mar11	19,600	93	0.47%	
			25Mar11	19,689	48	0.24%	
			01Apr11	5,200	0	0.00%	
			03Apr11	19,600	78	0.40%	
			05Apr11	8,800	2	0.02%	
			06Apr11	9,200	0	0.00%	
			07Apr11	1,840	0	0.00%	
AA5AM	Scott Armstrong	216mi	27Mar11	16,800	28	0.17%	
			28Mar11	21,678	0	0.00%	
			05Apr11	18,000	0	0.00%	
			06Apr11	20,400	5	0.02%	
			07Apr11	2,960	0	0.00%	
			08Apr11	18,800	0	0.00%	
			09Apr11	10,640	0	0.00%	
W5THT	Pat Hamel	261mi	22Mar11	No copy			
			24Mar11	No copy			
			25Mar11	Very poor copy			
			29Mar11	No copy			
			03Apr11	No copy			
KL7UK/5	Laurence Howell	377mi	23Mar11	No copy			
	WSPR SNR -17/-32		05Apr11	Very poor copy			