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RN11-1

# Tests of ground-wave communication at 500 kHz during summer 2010

by

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## Abstract

WD2XSH stations conducted tests of ground-wave communication during the summer of 2008. Transmissions were made from several stations to one or more receiving stations. Transmission modes included CW, QRSS3, WSPR, PSK-10, and PSK-31. Reliable ground-wave communication was achieved in most cases at distances up to 150 km. Communication was not reliable during local thunderstorms or over irregular, mountainous terrain. Significant sky-wave signal appears to be present even at mid day except perhaps at the summer solstice.

## Indexing Terms

Radio, amateur
MF
Propagation, ground-wave

## 1. INTRODUCTION

Tests were conducted during the summer of 2010 to ascertain the reliability of ground-wave communication at 500 kHz using ordinary amateur-type equipment. These tests expand upon those conducted in the summer of 2008 [RN09-17]. The participants were grouped in seven "clusters" as shown in Figure 1.

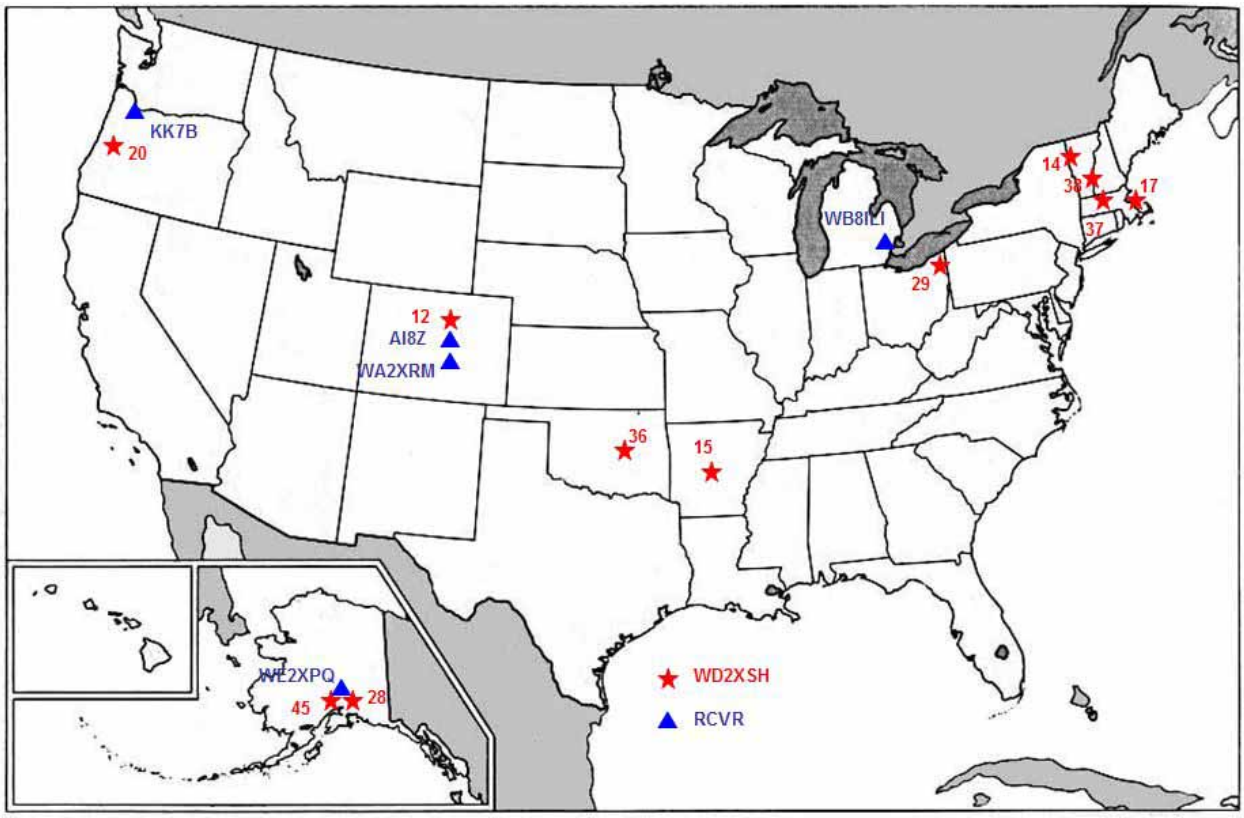


Figure 1. Locations of ground-wave links.

Tests were conducted from May 1 through September 30. All tests were conducted between 10:00 and 15:00 local daylight time to ensure a strong D layer and therefore minimal sky-wave interference.

The signals used included CW, QRSS3, PSK-10, PSK-31, and WSPR. The durations and observed parameters are given in Table 1. Different stations had different capabilities, hence each cluster used a different subset of these five signals. Detailed instructions for transmission and logging are given in [M10-4].

| SIGNAL | DURATION | | OBSERVED |
|---|---|---|---|
| | min | Description | |
| WSPR | 10 | 5 cycles | Signal-to-Noise Ratio (SNR) |
| PSK-31 | 5 | 8 repeated data frames | Character error rate (CER) |
| PSK-10 | 5 | 3 repeated data frames | Character error rate (CER) |
| QRSS3 | 10 | | Percent copy |
| CW | 5 | | Percent copy |

Table 1. Signals and characteristics.

The PSK transmissions have 115 characters per frame, hence PSK-31 transmissions have a total of 920 characters while PSK-10 has a total of 345 characters. Character error rate is not an ideal parameter for comparison since the variable-rate coding results in a variable number of character errors for a given number of bit errors. However, no available software appears to provide the basic bit-error rate or bit pattern as an output.

The observations of CW and QRSS are qualitative and observer-dependent.

WSPR provides a measure of the signal-to-noise ratio (SNR). The SNR is scaled to a 2500-Hz and 0-dBm of transmitter power. The approximate corrections required to convert a WSPR SNR into the detection SNR for other modulations are given in Table 2.

| | WSPR | CW | PSK-10 | PSK-31 |
|---|---|---|---|---|
| BW, Hz | 2500 | 100 | 20 | 62 |
| SNR, dB | 0 | +14.0 | +21.0 | +16.1 |

Table 2. SNR conversions.

## 2. CLUSTER 1 - OREGON

WD2XSH/20 (N6LF) in Cottage Grove, OR made 11 CW transmissions to KK7B in Beaverton, OR. The path length is 127 mi. WD2XSH/20 has a large top-loaded vertical and an ERP of nearly 20 W. In some cases, two or three transmissions are made on the same day, separated by one to three hours.

The results are shown in Figure 2. CW copy is mostly 100 percent, with an average of 86.4 percent and standard deviation of 19.5 percent.

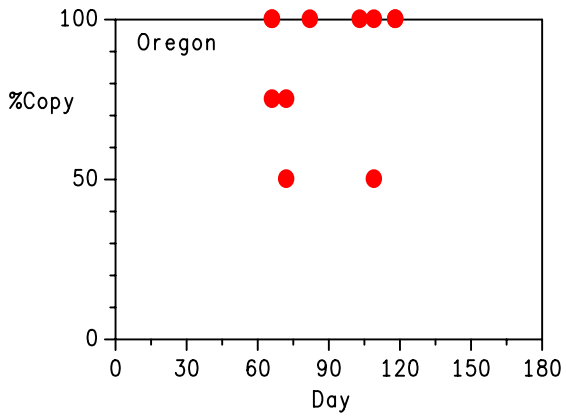


Figure 2. Oregon.

## 3. CLUSTER 3 - COLORADO

Transmissions were made by WD2XSH/12 (AI8Z home) in Nederland, CO. Reception sites included both W0RW in Colorado Springs (140 km = 87 mi) and AI8Z (office) in Westminster, CO (25 mi / 40 km). The AI8Z receiver consisted of an indoor ferrite-rod antenna located at the same position and orientation for all reports, a homebrew RF preamp, and an IC706 receiver. The IF Bandwidth was set to 2.1 kHz for a reception tests. QRM from office computer equipment was prevalent. QRN and QSB were never factors during any of the reception periods. The results are shown in Figure 3.

The nine reports from W0RW were highly varied. The average CW copy is 41 percent, but the standard deviation is 38.9 percent. Ground-wave propagation may be poor because of the irregular nature of the terrain in this path.

CQ, PSK-10, and PSK-31 reception at AI8Z is nearly perfect. The one bad point (PSK-10 on the last day of testing) was caused by QRM from office machinery. The CER was 0.0002 for PSK-10 and 0.001 for PSK-31.

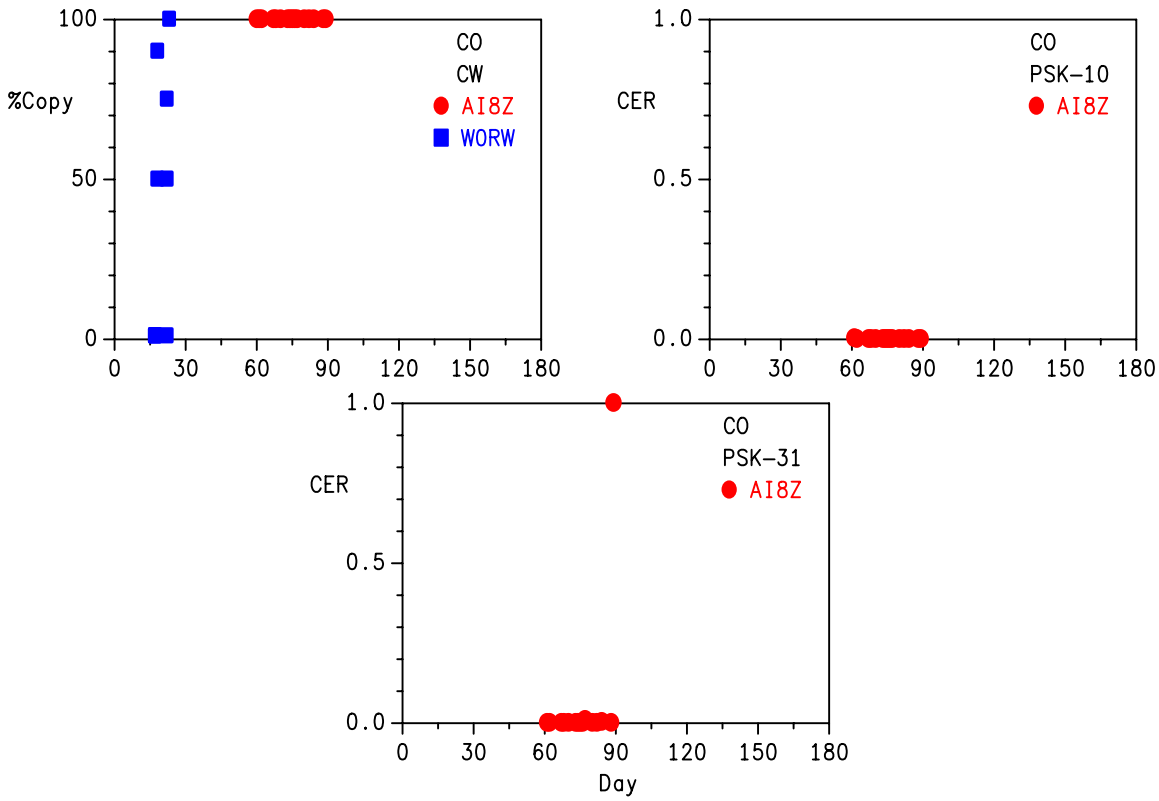


Figure 3. Colorado.

## 4. CLUSTER 6 - ARKANSAS TO OKLAHOMA

WD2XSH/15 (W5OR) in Little Rock, Arkansas made two CW transmissions to WD2XSH/36 (W5GHZ) in Bethany, OK, which is a 474-km (294 mi) path. Both resulted in 100-percent copy.

## 5. CLUSTER 9 - OHIO TO MICHIGAN

Transmissions were made from WD2XSH/29 (KN8AZN) in Kellogsville, OH to WB8ILI in New Baltimore, MI. This 205-km (127-mi) path crosses Lake Erie and about half of the path is over water. Transmission modes included WSPR, CW, PSK-31, and PSK-10.

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. Tests were run with both 25- and 100-W outputs. 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 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.

The results are shown in Figure 4. The SNR for WSPR ranges from 0 to +5 dB for 25 W and from +4 to +8 dB for 100 W. The low SNR on days 54 and 96 was due to local thunderstorm activity, which caused poor performance for all modes. CW copy was usually 100 percent except for the days with local thunderstorms. The character-error rate for PSK-31 was 0 to 2 percent, and the error rate for PSK-10 was 0 to 1 percent except when local thunderstorms were present.

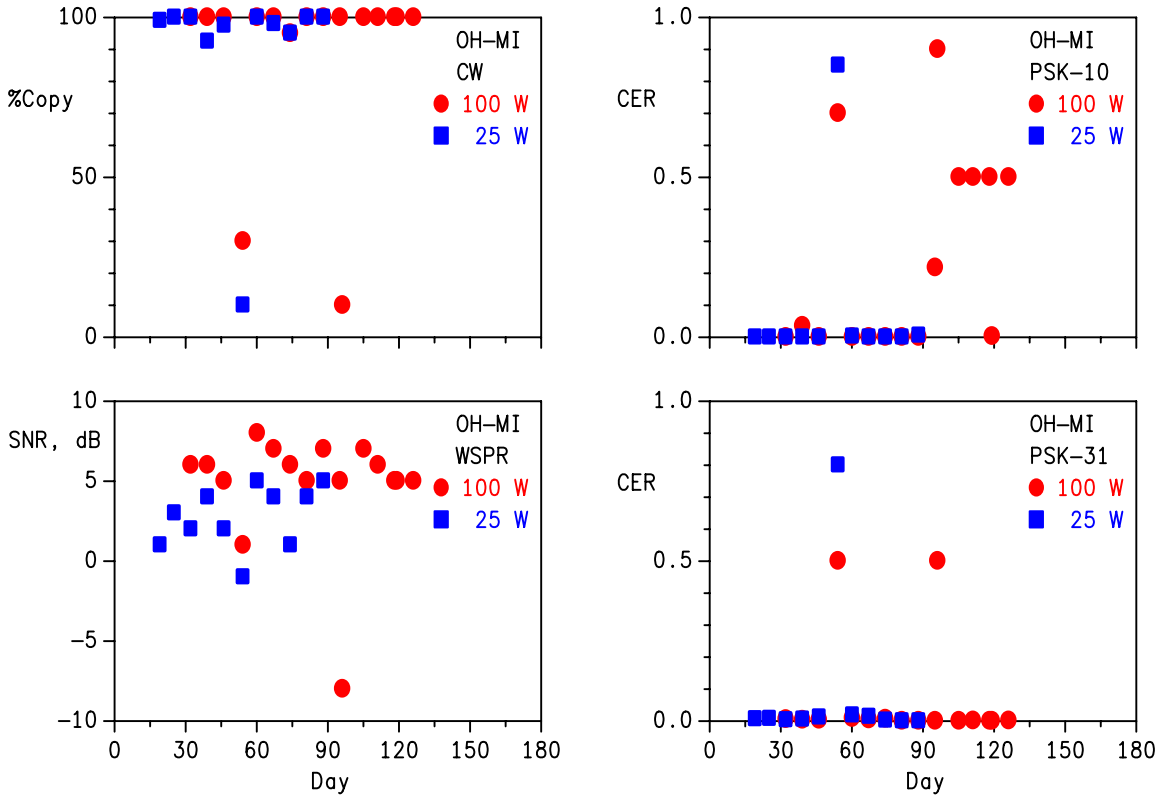


Figure 4. Ohio - Michigan path.

## 6. CLUSTER 10 - NEW HAMPSHIRE - VERMONT

Transmissions were made by station /38 (KN1H) in Charleston, NH. This home-brew transmitter has a 10-W output and the antenna is an end-fed U-shaped wire with a maximum height of 110 ft. The estimated ERP is 1.4 W.

Signals were received by station /14 (W1FR) in Colchester, VT. The path is 153.2 km (93.5 mi) long. It is mountainous terrain with low conductivity (0.3 to 1 mS/m). The receiver is a Ten-Tec Paragon with an LF Engineering L100B active antenna.

All tests in this group used QRSS3 modulation. The percent copy estimated from the Argo display is shown in Figure 5 as a function of date, with May 1 as day 1. The average copy factor ranged from 11 to 70. The ability to copy definitely increased during the period of the

tests (June 22 to September 3), which suggests a steadily weakening D layer and increased sky-wave signal.

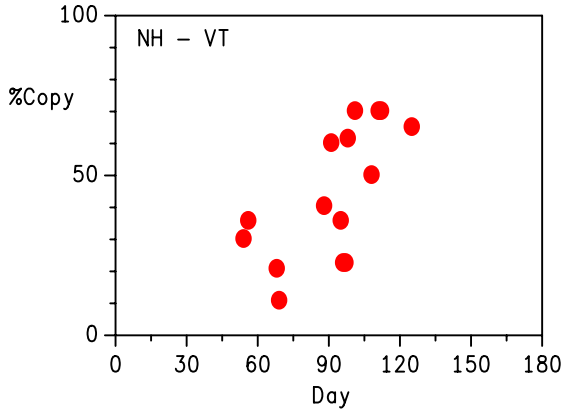


Figure 5. New Hampshire - Vermont Path.

These tests show that 10 W (1.4 W ERP) is insufficient for ground-wave communication over poor soil and mountainous terrain. Increasing the power to 100 W should make QRSS3 detection reliable and perhaps allow detection of CW.

## 7. CLUSTER 11 - ALASKA

CW transmissions were made by WD2XSH/45 (KL7UW) in Nikiski, Alaska and received by WD2XSH/28 (KL7Q) in Wasilla, Alaska and KL7UK in Palmer, Alaska. The transmitter was an Elecraft K3 driving an NDB transmitter (78 W). The transmitting antenna was a 43-ft by 130-ft inverted L, resulting in an ERP of 3.24 W. KL7UK's remotely controlled site used an ICOM-R75 receiver with RF pre-amps off, AGC off, noise blanker off, and bandwidth set to 3 kHz. The antenna is a large K9AY array. WD2XSH/28 used a 45-ft by 400-ft inverted L and a Navy RBL-2 receiver. KL7UK is 153 km (95.1 mi) distant, while KL7Q is 147 km (91.5 mi) distant.

The results are shown in Figure 6. All ten receptions by KL7Q and all nine receptions at KL7UK resulted in 100-percent copy. There were some WSPR transmissions, one two-way QSO between /45 and /28, and receptions by two other stations, but these did not produce enough data for analysis.

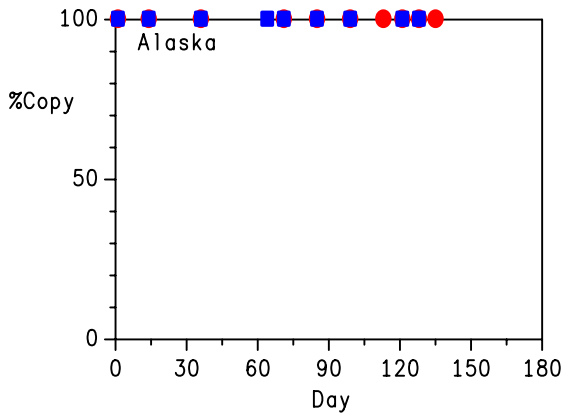


Figure 6. Alaska.

## 8. NEW ENGLAND WSPR TESTS

Stations WD2XSH/17 (AA1A) and WD2XSH/38 (W1XP) made WSPR transmissions over a 91-km (56-mi) path. The WSPR data-collection system logged 3241 SNRs for transmission from /17 to /37, all of which were done with an ERP of 30 dBm (1 W). It logged 2192 SNRs for transmission from /37 to /17. The ERP from /37 varied from 17 to 33 dBm, hence the reported SNR was corrected to an ERP of 1 W.

The results are shown in Figure 7. The SNR is significantly lower than that reported on the Ohio-Michigan path. It is also lower for /37-to-/17 (=13.1 dB average with standard deviation of 4.8) than for /17-to-/37 (18.7 dB with SD of 4.2). These differences could be due to local noise and receivers.

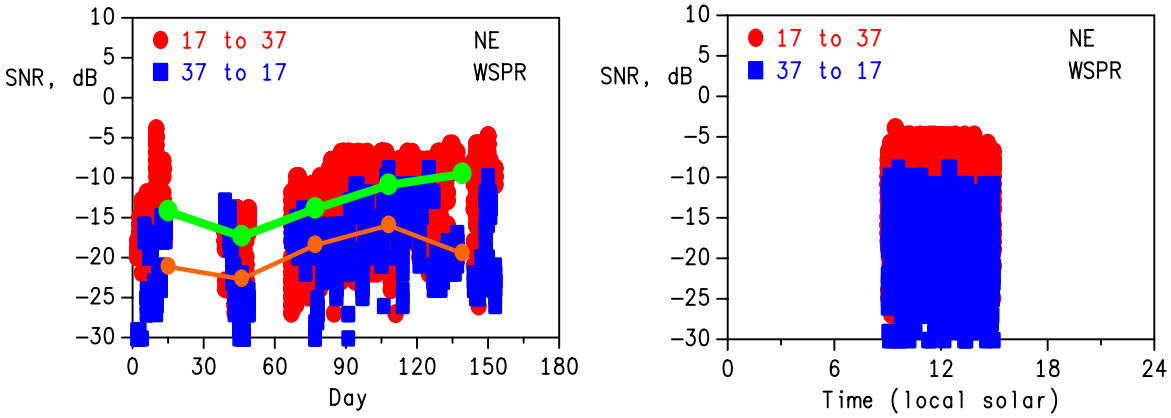


Figure 7. New-England WSPR SNRs.

Of particular interest is variation of the SNR with the day. The SNR is definitely lower in June near the summer solstice when the D layer is strongest. The SNR increases toward September as the D layer weakens. The difference is 7 to 8 dB, which is two standard

deviations and therefore significant. This strongly suggests that the D layer is weakening and that the later measurements contain a significant amount of sky-wave signal.

There is considerable variation of SNR during the day. However, no trend is obvious.

## 9. CONCLUSIONS

These tests demonstrate the following:

1. For most paths, ground-wave communication is quite reliable over distances up to 100 mi.
2. Problems occur when there are local thunderstorms.
3. Ground-wave communication over irregular, mountainous terrain is limited to slower data rates or shorter distances.
4. Sky-wave can be significant, even at mid day. The exception may be near the summer solstice.

## 10. ACKNOWLEDGEMENT

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