Solar Eclipse 2017

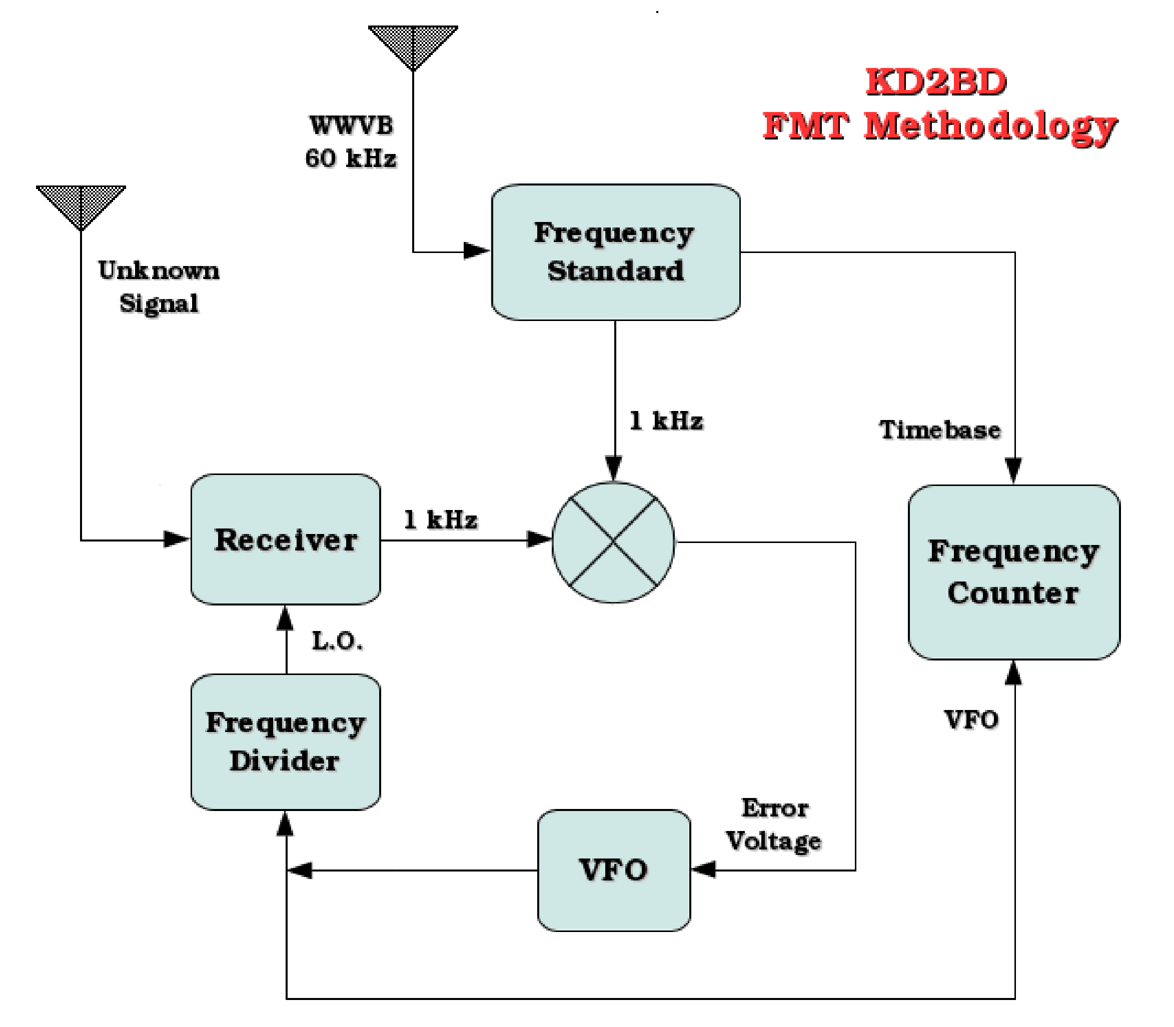
LF Radio Propagation Experiment

Measurement of Amplitude and Phase
Perturbations to 60 kHz WWVB Reception
During the 2017 Great American Solar Eclipse

By: John Magliacane, KD2BD

How It All Began…

- ✓ Built an Elecraft K2/100 HF transceiver in the Spring of 2003.
- ✓ The K2 led to the development of a WWVB-based frequency standard that led to a successful participation in the November 2003 ARRL Frequency Measuring Test.
- ✓ FMT experience led to the design of specialized hardware that made even better FMT results possible.
- ✓ FMT error analysis led to making HF Ionospheric studies in between FMTs.


KD2BD
FMT Methodology
WWVB
60 kHz
Unknown
Signal
Frequency
Standard
1 kHz
Timebase
Receiver
1 kHz
Frequency
Counter
L.O.
Frequency
Divider
VFO
Error
Voltage
VFO

KD2BD's FMT Hardware

Normally, the frequency of the on-air signal = (VFO / 4) + 1000 Hz
Here, the VFO is operating 4x the frequency needed by the receiver.
Therefore, the on-air signal = (VFO / 16) + 1000 Hz
= (10,544,000.00 Hz / 16) + 1000 Hz

On-air signal = 660,000.00 Hz +/- 0.000625 Hz

— Certificate of Participation —

ARRL Centennial – W1ØØAW/5

April 2014 Frequency Measuring Test

April 10, 2014

This certifies that

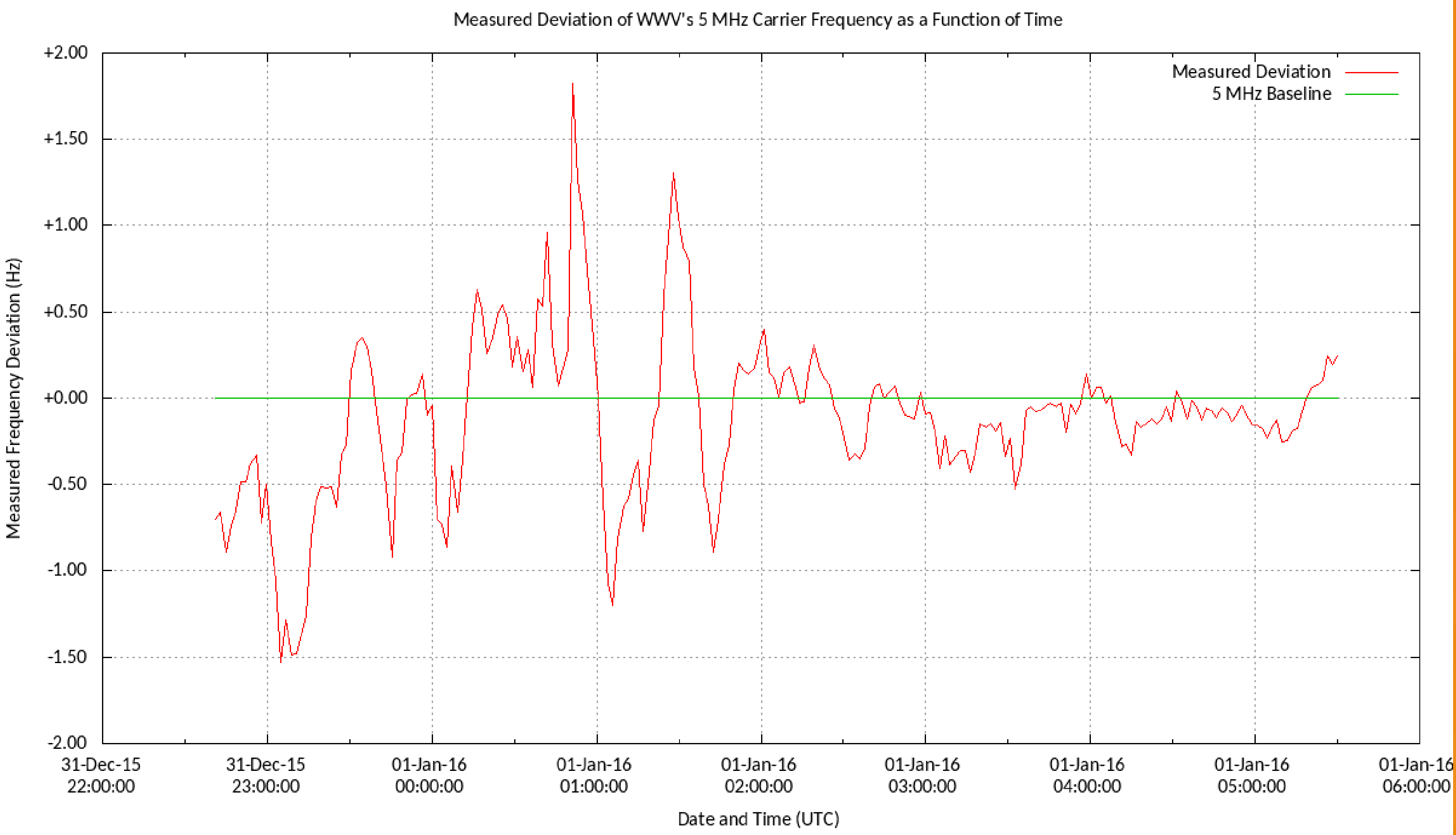
John A. Magliacane, KD2BD

submitted frequency measurements
taken during the April 2014 Frequency Measuring Test.
The results are as follows:

Band	Measured Frequency (Hz)	Frequency Error (Hz)	Error (± Parts Per Million)
80m	3,598,137.75	0.01	<0.01
40m	7,058,632.38	0.01	<0.01

W1ØØAW/5 Transmit Frequencies
80 meters – 3,598,137.74 Hz
40 meters – 7,058,632.37 Hz
20 meters – 14,121,135.32 Hz

K1ZZ
W1AW Station Trustee


Measured Deviation of WWV's 5 MHz Carrier Frequency as a Function of Time
Measured Deviation
5 MHz Baseline
Measured Frequency Deviation (Hz)
+2.00
+1.50
+1.00
+0.50
+0.00
-0.50
-1.00
-1.50
-2.00
31-Dec-15 22:00:00
31-Dec-15 23:00:00
01-Jan-16 00:00:00
01-Jan-16 01:00:00
01-Jan-16 02:00:00
01-Jan-16 03:00:00
01-Jan-16 04:00:00
01-Jan-16 05:00:00
01-Jan-16 06:00:00
Date and Time (UTC)

“A Frequency Standard For Today’s WWVB”

Design Published in November/December 2015 QEX

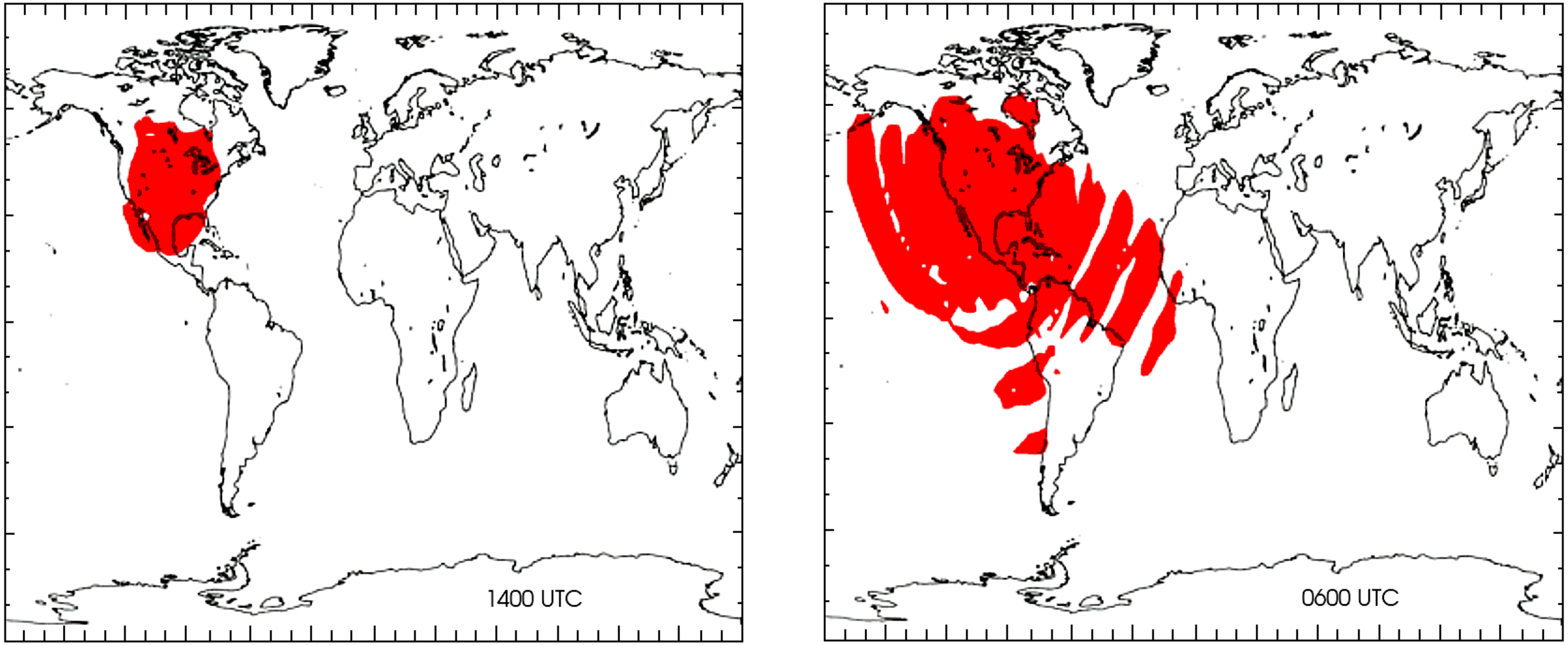
An Antenna for WWVB Reception

- A single turn of 40 conductor ribbon cable, 5 meters in length
- Forms a 40 turn coil containing 200 meters of wire
- Balanced H-Field probe with dipole-like directivity
- Parallel capacitance establishes resonance at 60 kHz

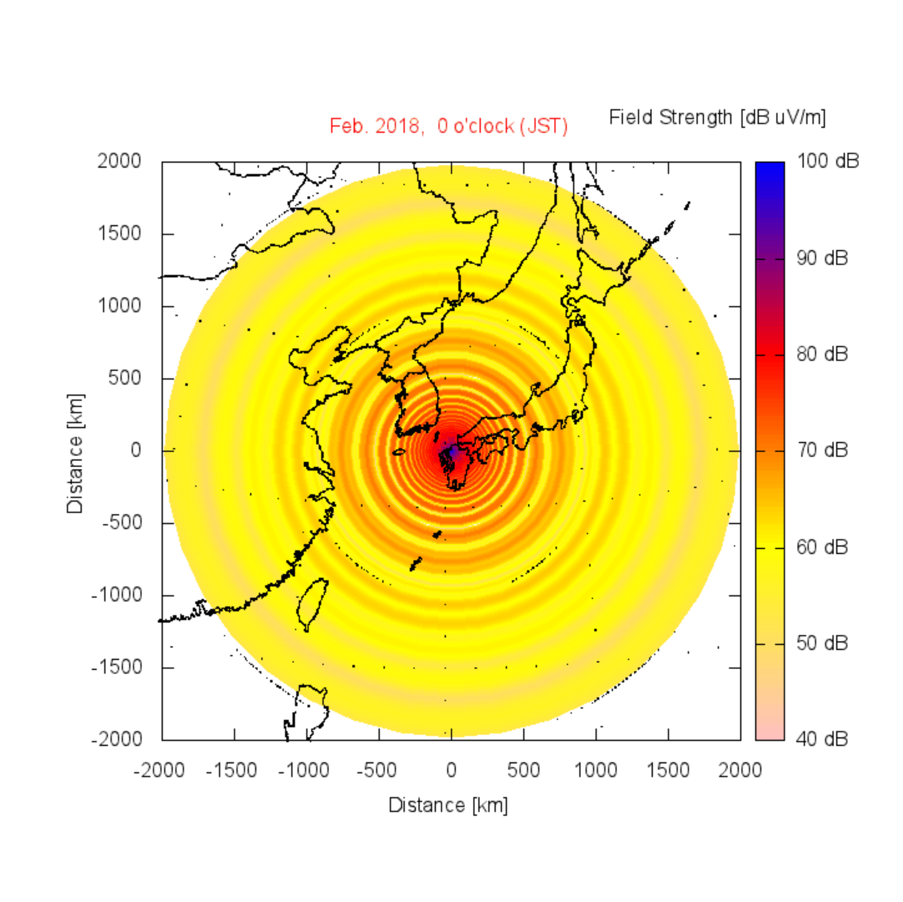
Some Interesting LF Propagation Effects

- Reception is generally due to some combination of skywave and groundwave propagation.
- Skywave propagation is the result of D-Layer refraction.
- The D-Layer ***does NOT*** completely dissipate after sunset!
- Propagation favors West → East paths over East → West paths.
- Signals are v-*e-r-y* stable. Fading is v-*e-r-y s-l-o-w!*

Predicted Contours:
WWVB 70 kW ERP at 60 kHz



JJY in Japan: 50 kW ERP at 60 kHz



Challenge... Accepted!

Re: [FMT-nuts] Total solar eclipse and the ionosphere

Wednesday, May 31, 2017 9:13 AM

From: "Ethan Miller K8GU ethan@k8gu.com [FMT-nuts]" <FMT-nuts@yahoogroups.com>

To: FMT-nuts@yahoogroups.com "Nathaniel Frissell" <nafrissell@gmail.com>

Steve,

Great summary. Sub-minute cadences are probably not necessary to capture the dynamics that are going to be of interest here, except perhaps the recombination of the D and E regions when they go into darkness, and even then, I'm not sure how much you will see that is of interest. I'm expecting Doppler shifts on the order of 1-2 Hz (negative) around 5 MHz, so the key will be Doppler resolution; 0.01 Hz would not be a luxury and I know many of you report to that or better. I use a broadband SDR (gnuradio and Ettus USRP N210 mostly) for this kind of thing so I'm not familiar with the techniques and setup of SpectrumLab with a ham rig.

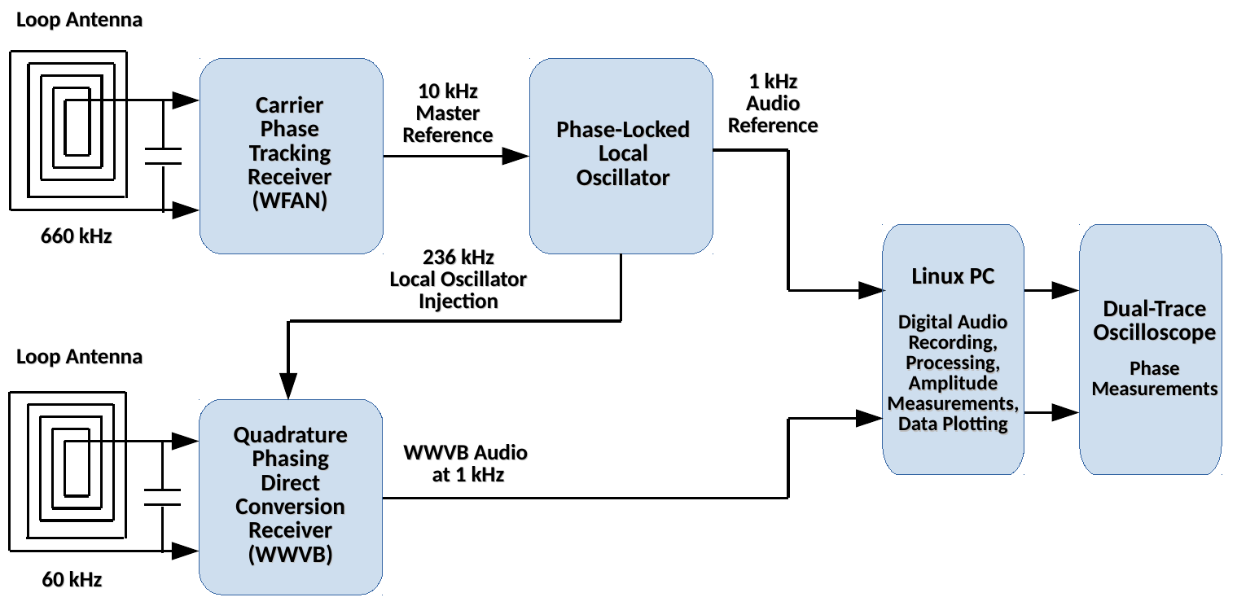
Another thing that may be of interest...does anyone here routinely play with WWVB? I know there was some traffic a couple of weeks ago. Especially if you can make phase observations, that would be helpful, but also amplitude. I can put you all in contact with someone who is interested in that aspect.

73,

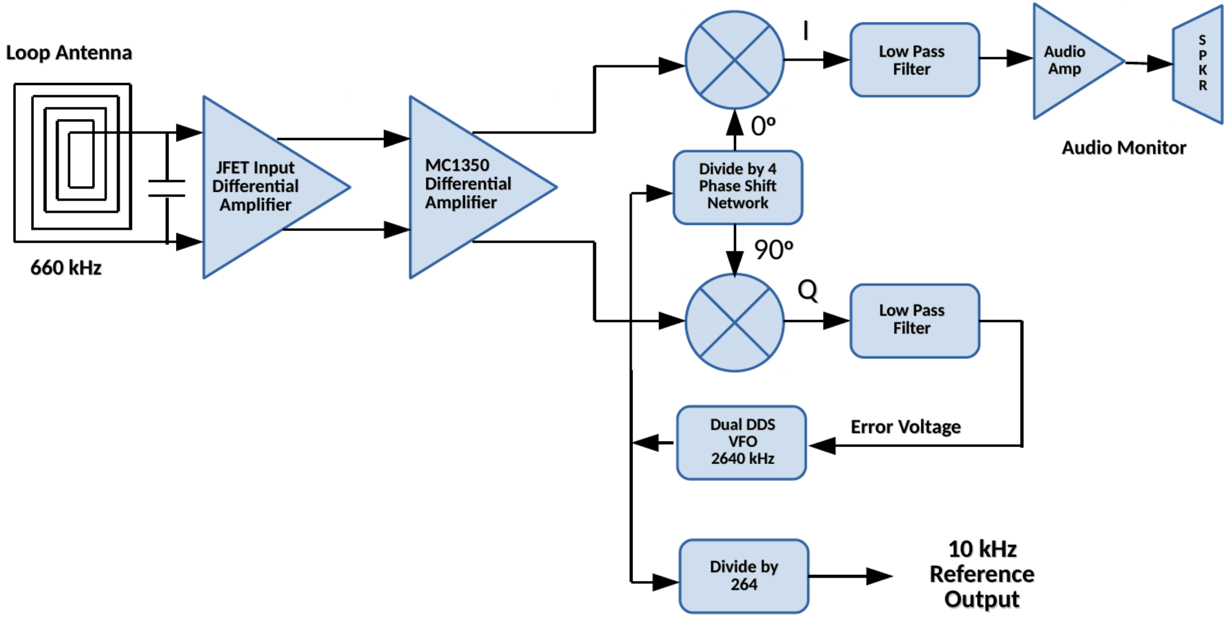
--Ethan, K8GU.

How to "FMT" WWVB
Without a GPS Disciplined Oscillator?

- Use WFAN on 660 kHz as a frequency reference.
- Use existing FMT receiver for WWVB reception.
- Discipline a local oscillator against WFAN to serve as both a WWVB receiver LO and as a precise 1 kHz phase reference signal.
- Keep it interesting… Homebrew everything!

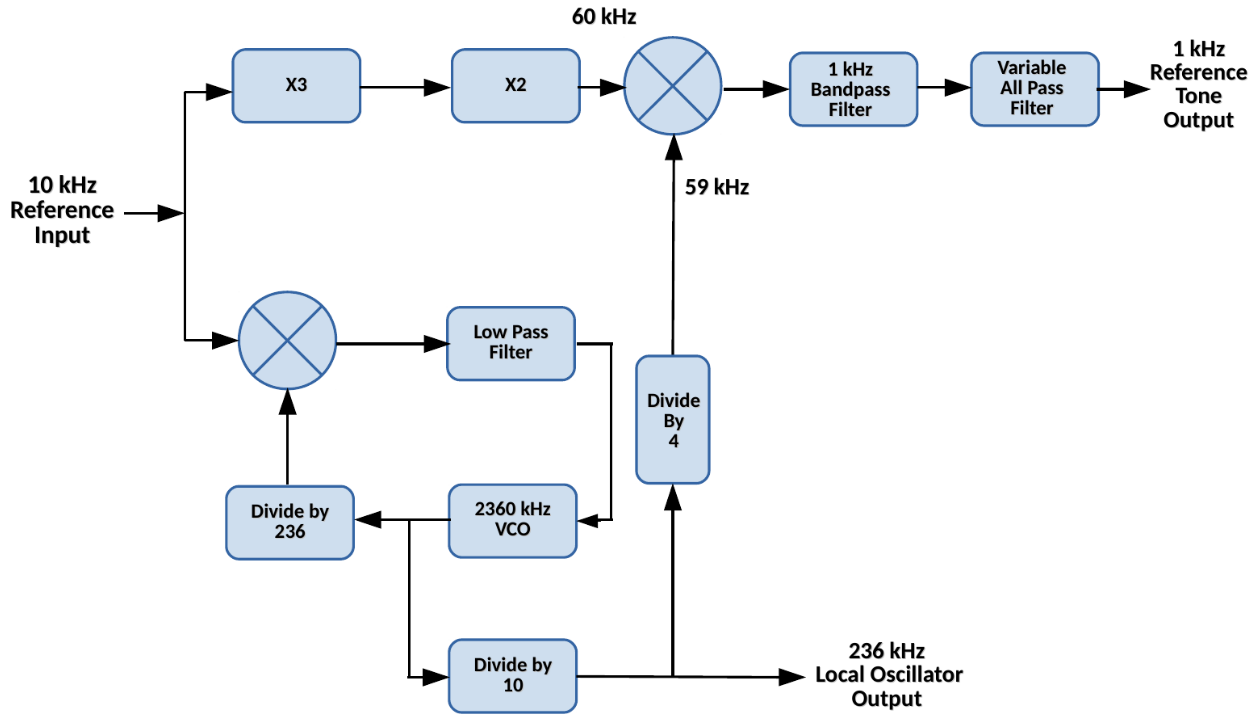


System Block Diagram
KD2BD 2017 Solar Eclipse Propagation Experiment
For Measuring WWVB Amplitude and Phase Perturbations



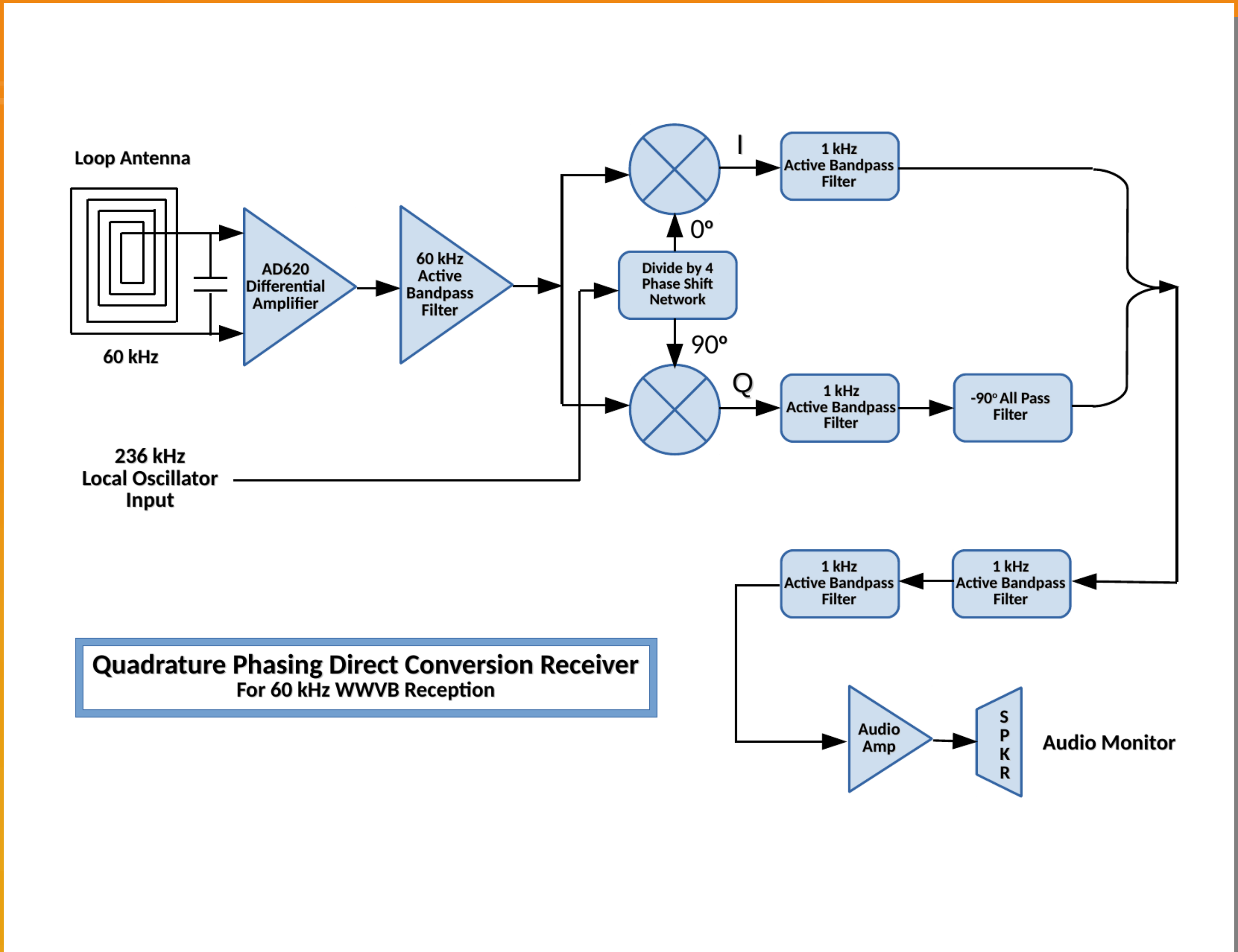
Carrier Phase Tracking Receiver

Using an AM Radio Station as a Frequency Reference



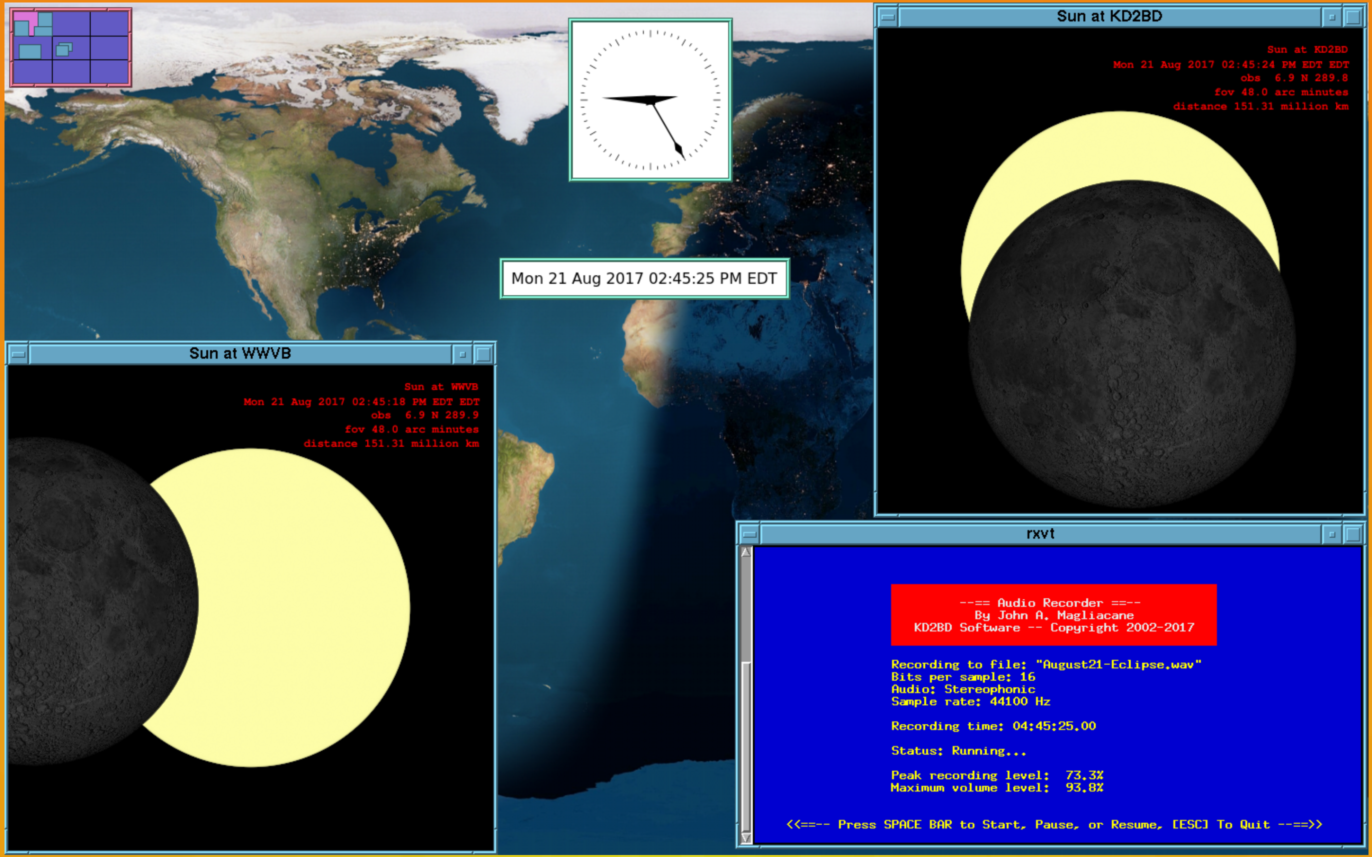
Phase Locked Local Oscillator

For WWVB Reception and Phase Measurement Referencing



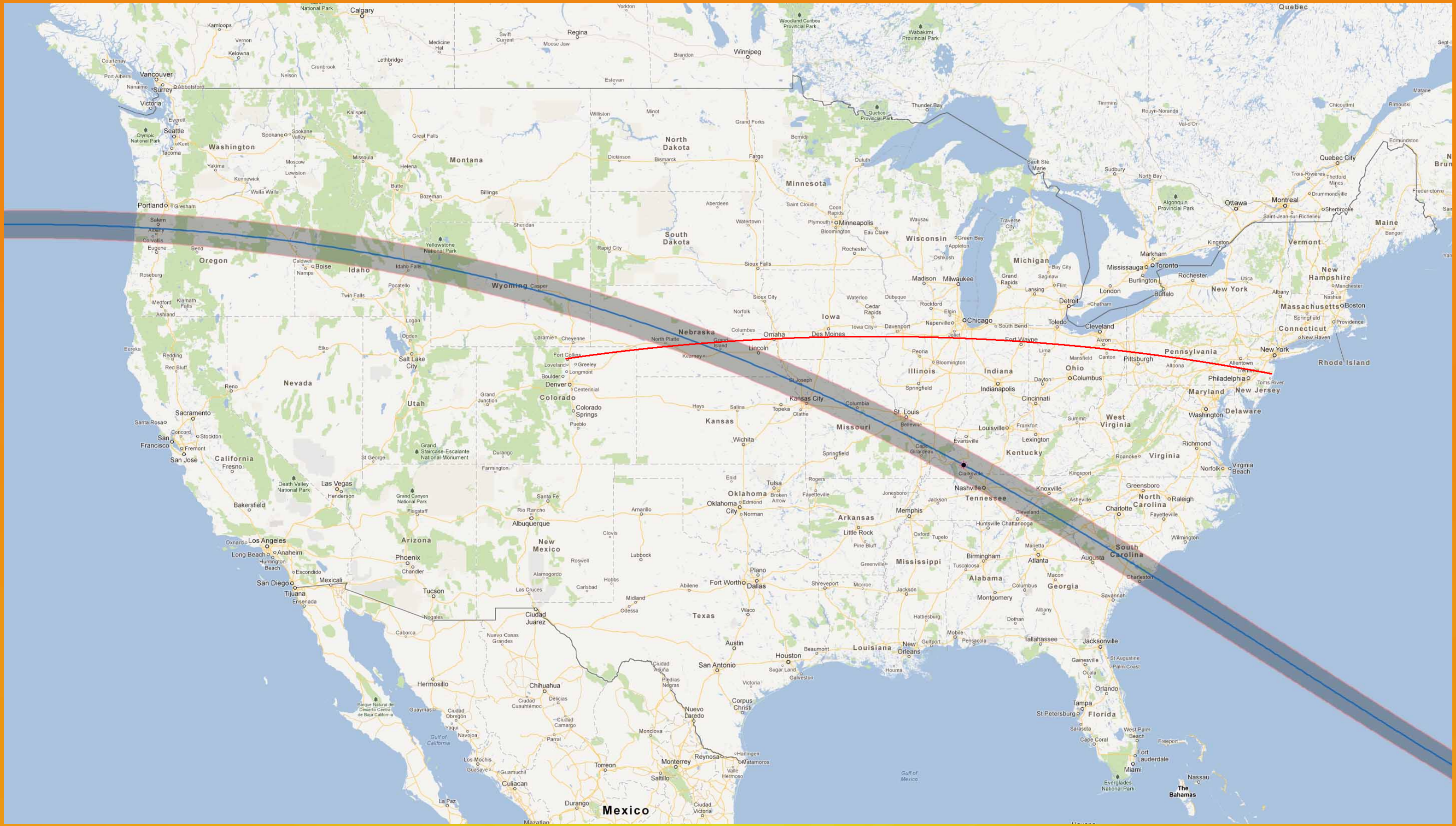
Loop Antenna
60 kHz
AD620 Differential Amplifier
60 kHz Active Bandpass Filter
236 kHz Local Oscillator Input
Divide by 4 Phase Shift Network
0°
90°
I
Q
1 kHz Active Bandpass Filter
1 kHz Active Bandpass Filter
-90° All Pass Filter
1 kHz Active Bandpass Filter
1 kHz Active Bandpass Filter
Audio Amp
SPKR
Audio Monitor
Quadrature Phasing Direct Conversion Receiver
For 60 kHz WWVB Reception

Tracking the Eclipse

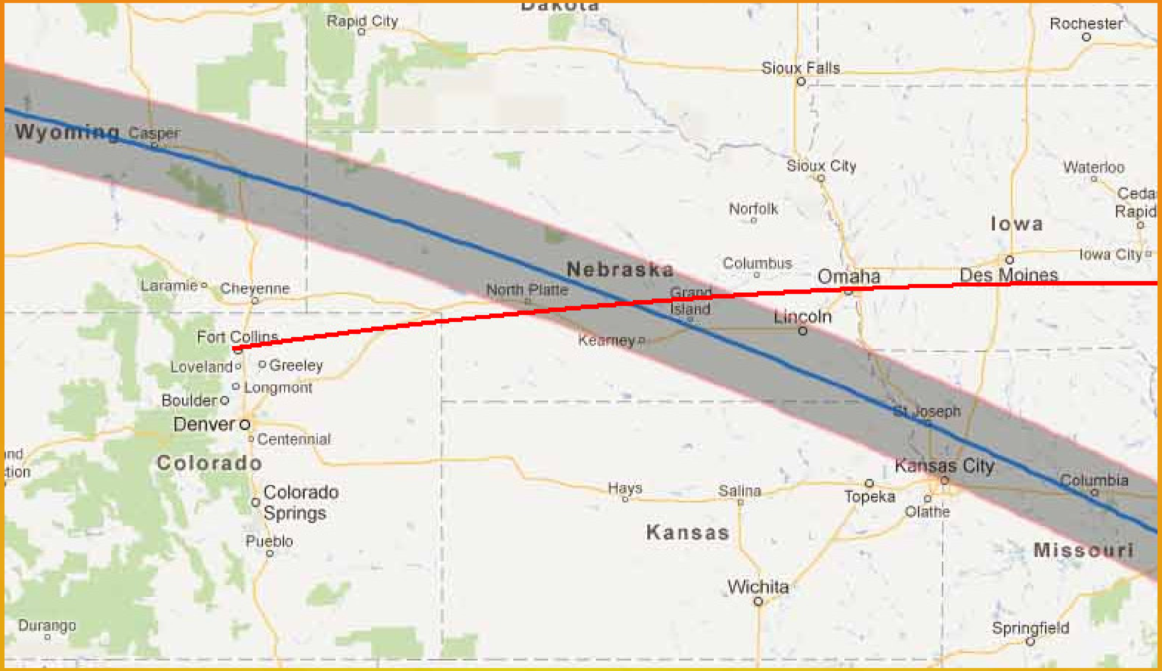


Viewing the Eclipse

Great Circle RF Path from WWVB to KD2BD

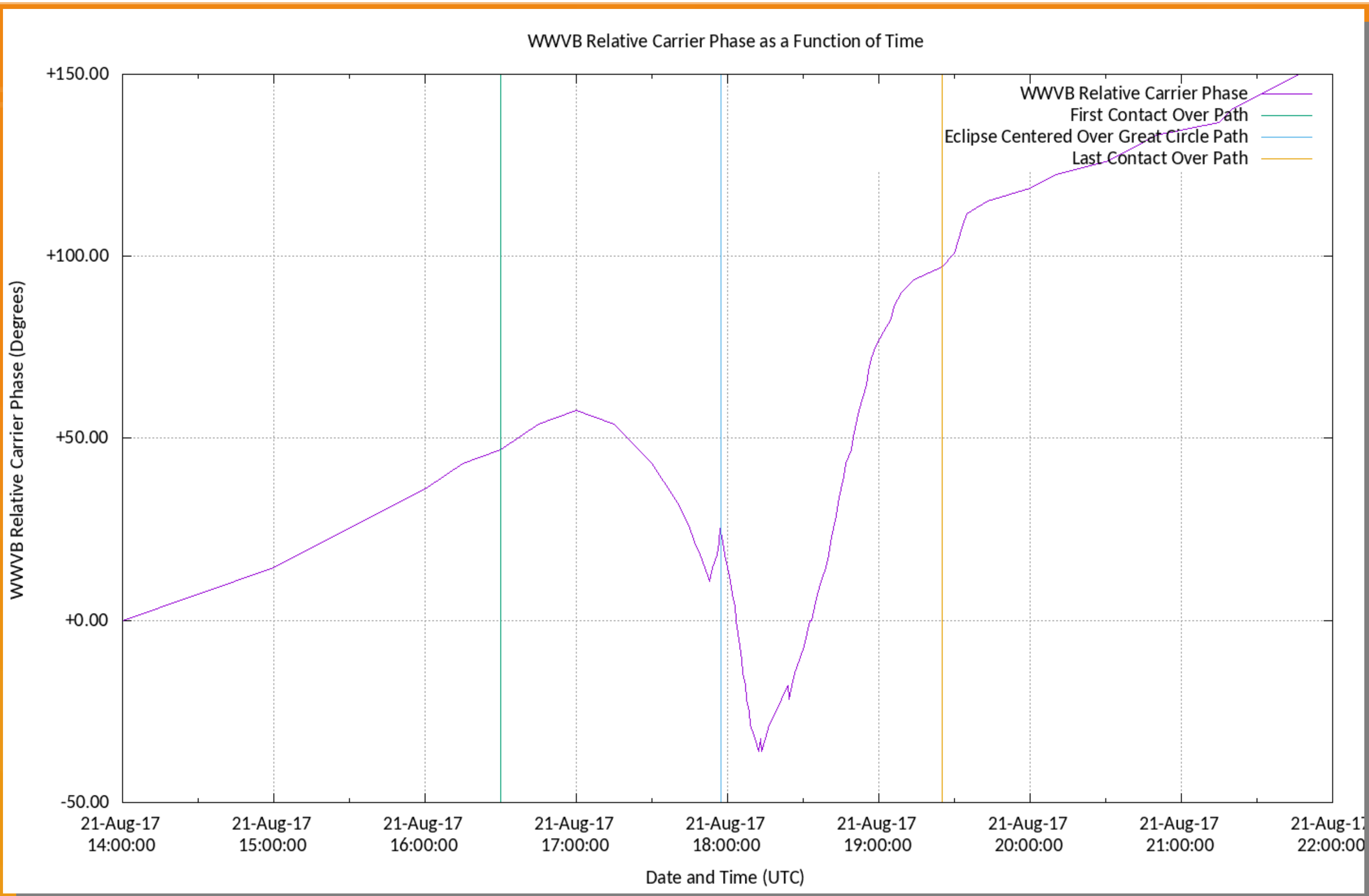


Path Intersection Over Nebraska
at 17:57:20 UTC

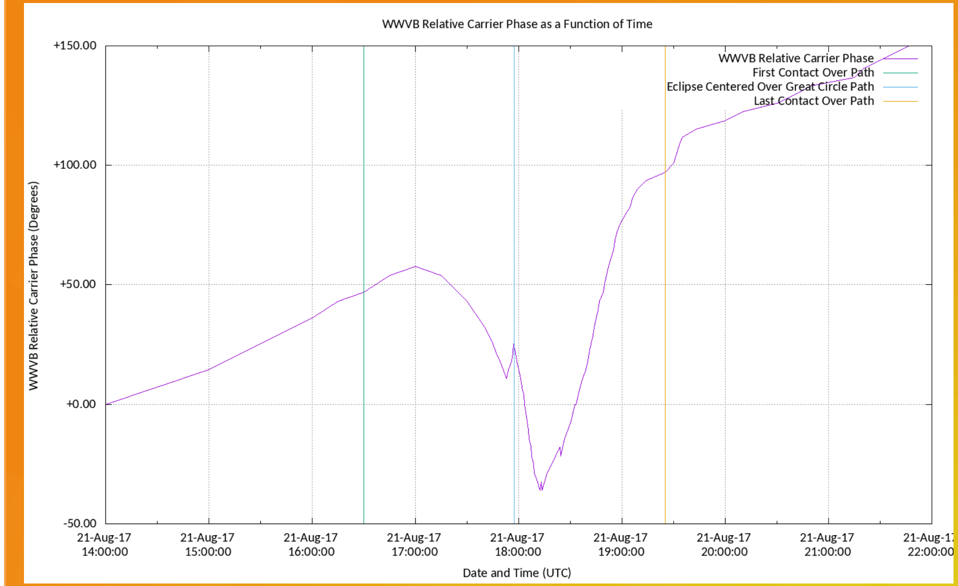


41.2 N Latitude / 99.55 W Longitude

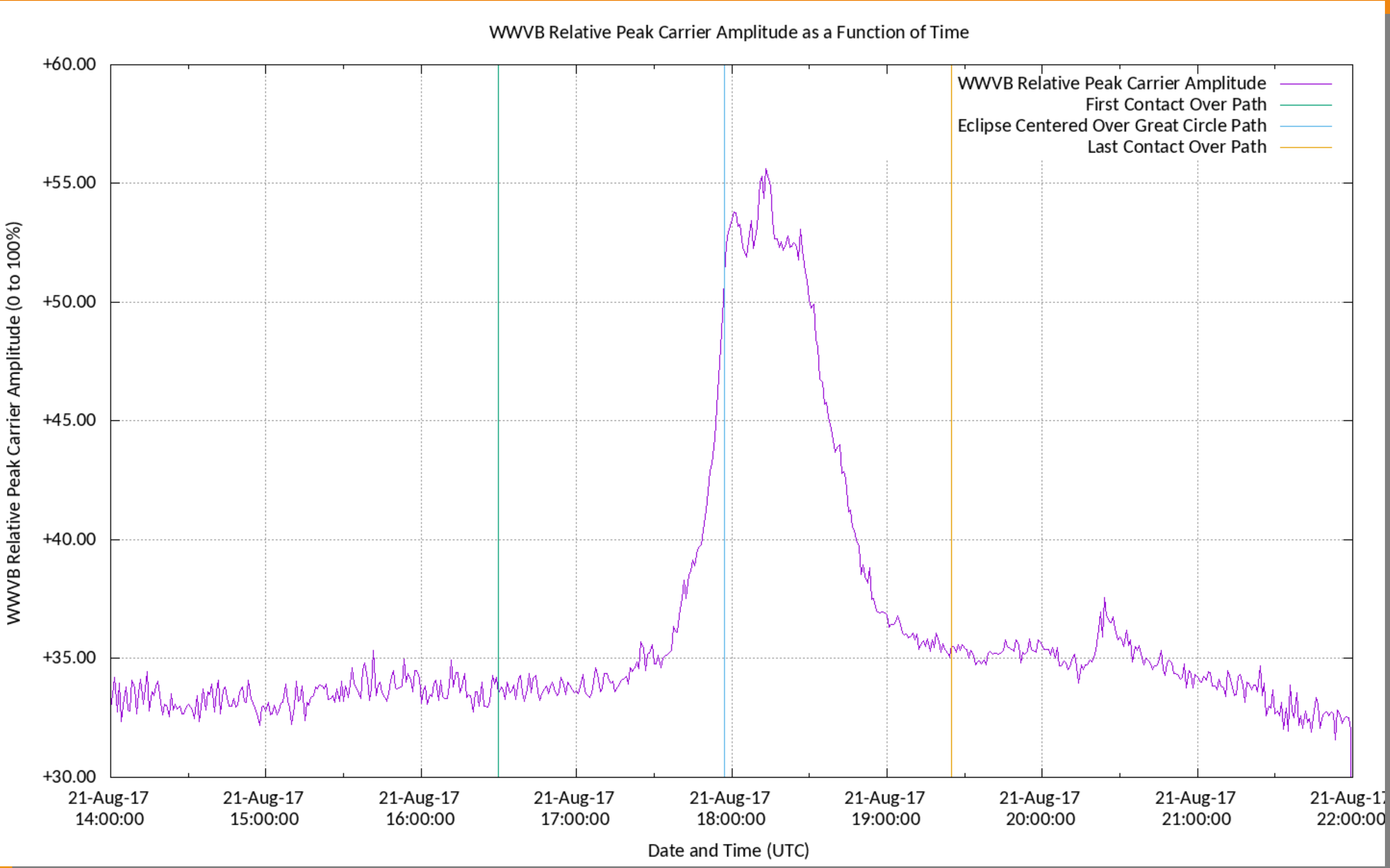
289 surface miles (93 wavelengths) from WWVB


WWVB Relative Carrier Phase as a Function of Time
WWVB Relative Carrier Phase (Degrees)
+150.00
+100.00
+50.00
+0.00
-50.00
WWVB Relative Carrier Phase
First Contact Over Path
Eclipse Centered Over Great Circle Path
Last Contact Over Path
21-Aug-17 14:00:00
21-Aug-17 15:00:00
21-Aug-17 16:00:00
21-Aug-17 17:00:00
21-Aug-17 18:00:00
21-Aug-17 19:00:00
21-Aug-17 20:00:00
21-Aug-17 21:00:00
21-Aug-17 22:00:00
Date and Time (UTC)

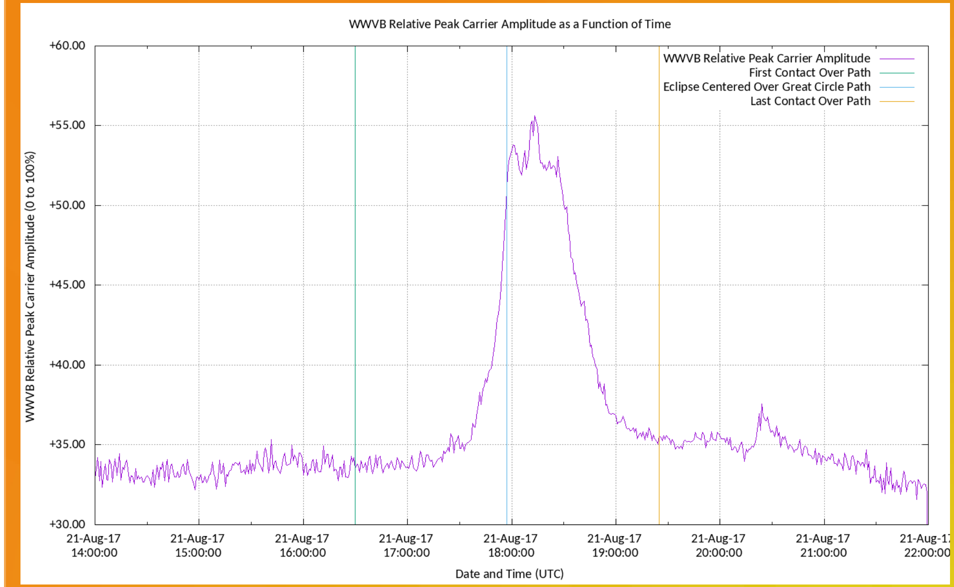
Phase Plot Observations



- 17.75 degree/hour average phase advancement over 8 hours.
- Solar flare occurred just as RF path entered totality.
- Maximum phase shift occurred 13 minutes ***after*** totality crossed the RF path.
- D-Layer rise of about one half mile.

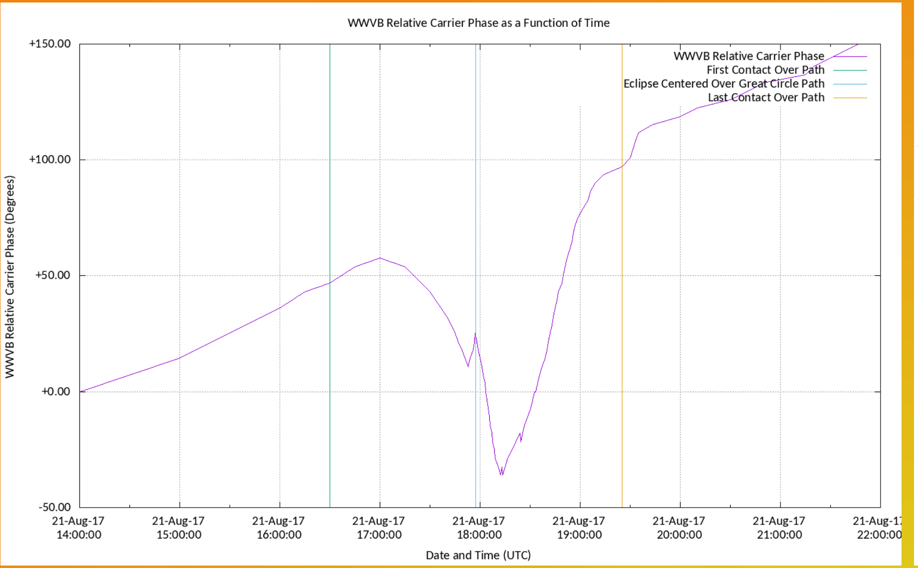

WWVB Relative Peak Carrier Amplitude as a Function of Time
WWVB Relative Peak Carrier Amplitude (0 to 100%)
+60.00
+55.00
+50.00
+45.00
+40.00
+35.00
+30.00
WWVB Relative Peak Carrier Amplitude
First Contact Over Path
Eclipse Centered Over Great Circle Path
Last Contact Over Path
21-Aug-17 14:00:00
21-Aug-17 15:00:00
21-Aug-17 16:00:00
21-Aug-17 17:00:00
21-Aug-17 18:00:00
21-Aug-17 19:00:00
21-Aug-17 20:00:00
21-Aug-17 21:00:00
22:00:00
Date and Time (UTC)

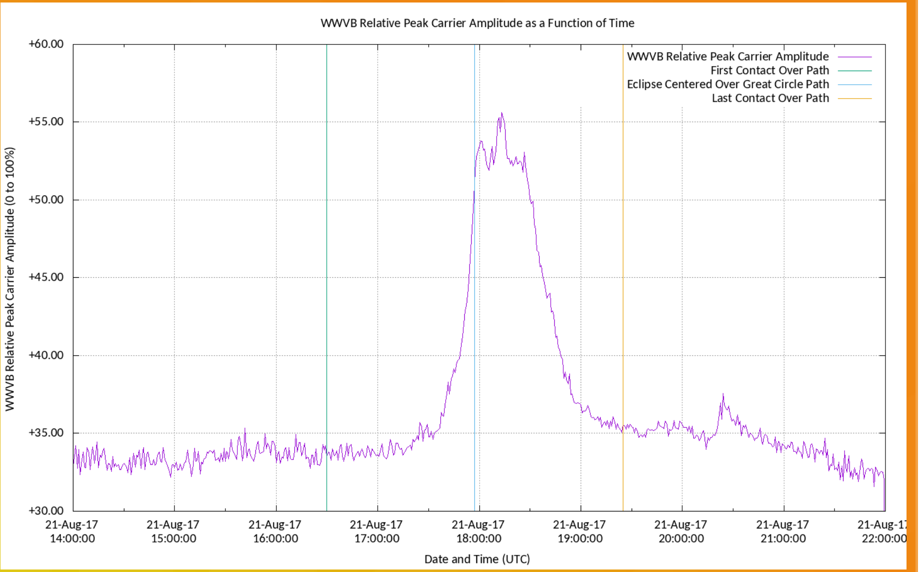
Amplitude Plot Observations



- Signal strength increased 4 dB above “normal”.
- Maximum signal strength and maximum phase shift occurred simultaneously.
- Each occurred 13 minutes ***after*** totality crossed the RF path.
- Skywave dominant path since the amplitude was ***not*** affected by the gradual D-layer height reduction during the day.

Further Information





http://www.qsl.net/kd2bd/eclipse_experiment.html