K2 Phase Noise

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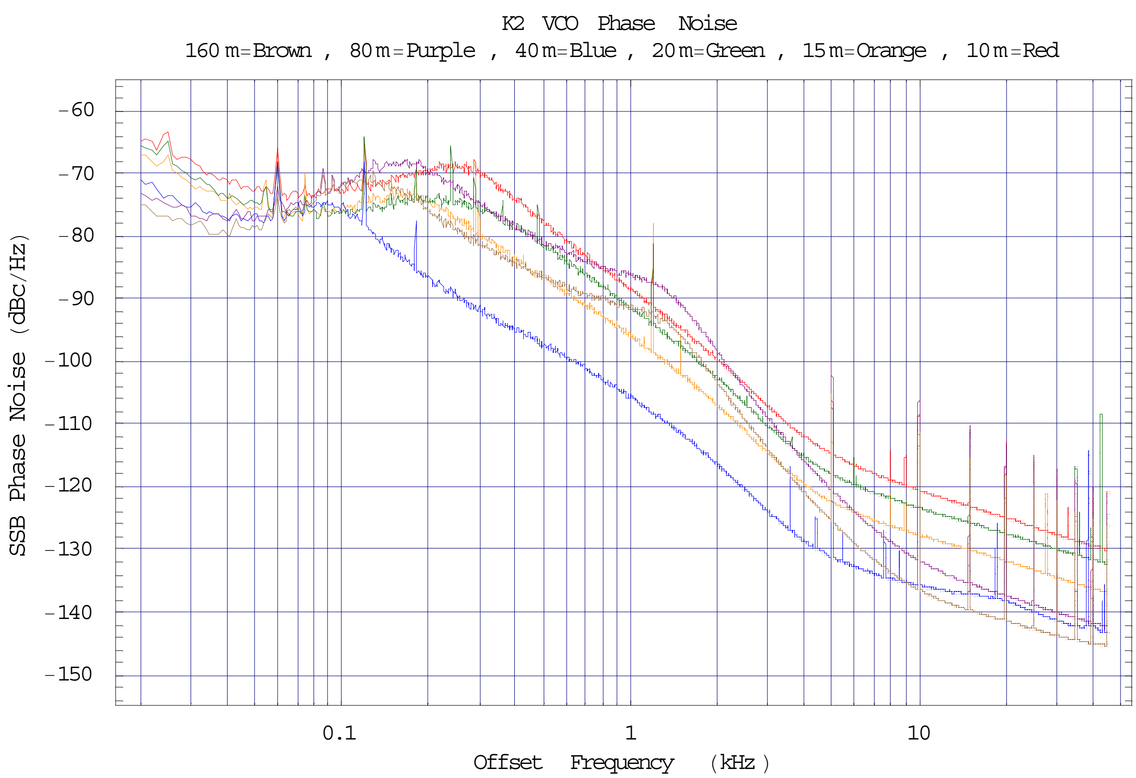
This is an update to the K2 phase noise measurements I originally posted over a year ago. The new phase noise measurements are done over a much wider frequency range of 20 Hz to 45 kHz. However, these new measurements give the same results as the older ones where the two sets of measurements overlap.

This set of measurements shows the phase noise of the K2 VCO and the K2 transmit phase noise. Finally, a phase noise plot of an HP8640B low phase noise signal generator is shown.

K2 VCO Phase Noise

The chart below shows the K2 VCO phase noise on all major bands from 160 to 10 meters. The measurements were done at the mixer LO input. The spurs are shown with their true level in dBc. These spurs would be nearly invisible if measured with a spectrum analyzer with a 100 Hz resolution bandwidth. In a typical receiver bandwidth, the power in the phase noise will be substantially larger than the power in the spur, so they have no effect on the receiver performance.



At offset frequencies larger than 10 kHz, the phase noise is proportional to the VCO control voltage sensitivity. At a 20 kHz offset frequency, the phase noise is due entirely to voltage noise FM modulating the varactor diodes. The source of this noise is primarily U6B with a smaller contribution from R31 and R32. The noise from U6B is 22 nV/sqrt-Hz and from R31 and R32 is 13 nV/sqrt-Hz. If either noise source is reduced, the phase noise drops.

One other item of interest is that the phase noise on 160 and 80 meters starts to increase more rapidly below a 10 kHz offset than on the other bands. This effect is caused by the 1SV149 varactor diodes used on these two bands. These diodes lower the Q of the tuned circuit, which leads to this higher level of phase noise at smaller offset frequencies.

The following table will illustrate this FM noise modulation much better. It shows the predicted and measured phase noise for each band. The measurements were taken above the lower band edge (same location at the ARRL uses for transmit phase noise measurements). The phase noise does get a few dB better as you tune up in the band.

Band (meters)	**Ko (kHz/V)**	**FM Modulation (Hz rms)**	**Predicted Phase Noise @ 20 kHz (dBc/Hz)**	**Measured Phase Noise @ 20 kHz (dBc/Hz)**
160	102	0.0026	-143.7	-142
80	189	0.0048	-138.4	-137
40	122	0.0031	-142.2	-138
30	238	0.0061	-136.4	
20	625	0.0159	-128.0	-128
17	769	0.0196	-126.2	
15	385	0.0098	-132.2	-132
12	455	0.0116	-130.7	
10	800	0.0204	-126.2	-126

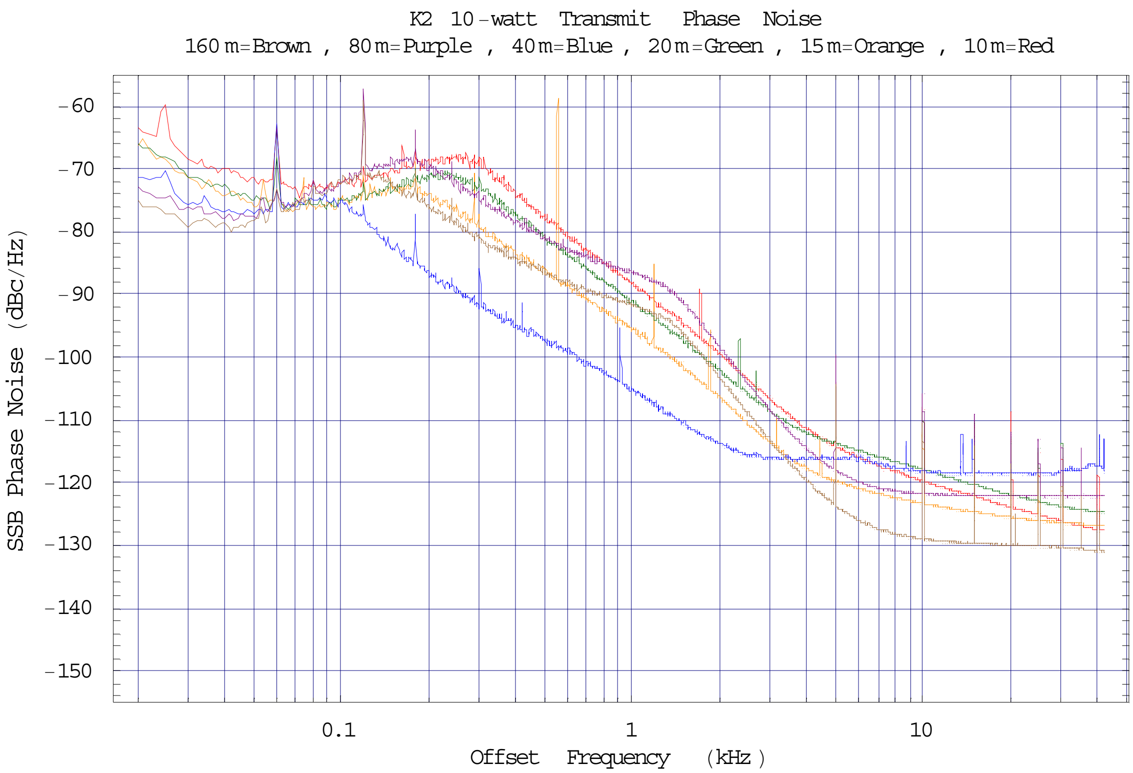
The K2 phase noise is limited by thermal and device noise in the existing design. It doesn't appear possible to make a substantial (>10 dB) reduction in the phase noise with any reasonable modification.

The phase noise in a receiver primarily limits the dynamic range of the receiver. In particular, the phase noise may limit the measured two-tone dynamic range. In a 500-Hz bandwidth, the phase noise limiting dynamic range can be computed by taking the measured phase noise in dBc/Hz at an offset frequency equal to the two tone separation and adding 27 dB to that value.

In the table above, the phase noise on 20 meters at a 20 kHz offset is -128 dBc/Hz. Adding 27 dB to that value gives 101 dB as the phase noise limited two-tone dynamic range. The ARRL measured 97 dB, which indicates that the RF or IF circuitry is limiting the dynamic range. At a 5 kHz offset, the phase noise on 20 meters is -118 dBc/Hz, which implies that the phase noise limiting dynamic range is 91 dB. The ARRL measured the two-tone dynamic range for 5 kHz tones as 91 dB, and noted that the measurement was phase noise limited.

K2 Transmit Phase Noise

I also measured the transmit phase noise with a power output of 10 watts. The transmit phase noise is effected by noise in the various transmit amplifiers. These will inevitably increase the phase noise, especially at the larger offset frequencies. The graph below shows the K2 transmit phase noise.



The phase noise at less than a 2 kHz offset is identical to the VCO phase noise measurements. Above this offset frequency, some of the bands begin to show a higher level of phase noise. This is due to the degradation of the phase noise by the transmit amplifier chain.

HP8640B Phase Noise

Finally, to check the validity of the phase noise measurements, I measured the phase noise of an HP-8640B signal generator. This signal generator has very low phase noise and will push the capability of any phase noise test setup.