Loop-Over-Earth

[updated 8 August 2024]

The Loop-Over-Earth (previously referred to as “Loop-on-Ground” or “LoG”) has recently been recognized as a potentially quiet antenna that when deployed well can rival the Beverage, another near-earth antenna as well as many other types of amateur receiving antennas. Like a Beverage, it is an inefficient antenna. There is quite a lot of loss, modeling shows 9 dB of attenuation over typical earth which is why a preamp is present and one reason it isn't normally used for transmitting. Mesurement over well-watered lawn shows a great deal more attenuation and absorption. Also like the Beverage, the antenna rejects very low-angle signals but has relatively large response above a few degrees.

While a rhombus is modeled here, the antenna can also be arranged in other shapes such as a loop or a rectangle. Also, modeling seems to suggest the potential for azimuthal directivity with some configurations but this has not been explored yet.

The LoE has been in use as part of a hybrid antenna system in combination with of a 2m tip-tip active dipole for lower frequencies, LF-mid-HF, and an LoE for 9-30 MHz at a couple of remote receive sites. These sites have used KiwiSDRs and have used appropriate preamplifiers and diplexers. One of these hybrid systems is located at about 7500’ above sea level in the Front Range of the Colorado Rocky Mountains and another has been used at VY0ERC on Ellesmere Island at the Polar Environment Atmospheric Research Laboratory very near the earth’s magnetic north pole. These receive systems have been used particularly to spot world-wide WSPR and FST4W with the Colorado station IDed as “N6GN/K” and the Canadian one as “VY0ERC”.

Results from these two sites have been excellent and the LoEs they’ve used have worked very well. Configured properly it appears that receive system noise floor can be lower than the ITU Rec. ITU-R P.372-16 propagated noise predictions much of the time up through mid-HF, though not yet optimized for operation to 30 MHz.

It should be recognized that the ITU noise measurements referenced only serve as a useful target rather than a prediction of the noise level in any actual antenna at any location and in any season. The many measurements made that went into those results used a particular [5 meter?] vertical monopole working against particular types of soil and wide area image planes. This makes the values only a guideline rather than a perfect target that will guarantee particular performance in all other situations.

As part of creating quiet and effective receive systems, here are results from a simple NEC model of the LoE. The model shown here is of a square loop 10cm above a “Real Ground’ having 4 equal 5m sides for a total perimeter of 20m and constructed with AWG#25 copper magnet wire while being fed at a corner.

Using SWTL theory as a means of understanding and analyzing the LoE, wire diameter and spacing above earth are influential in unbalancing the TM_{00} *mode so can signicantly affect performance. As with the noise target, all of this should be taken as guideline and not an* *exhaustive description. This theory corresponds to an SWTL traveling wave understanding for these antennas where the presence of nearby earth unbalances the TM_{00} mode leaving a vertically polarized traveling wave that produces radiation in the far-field.*

4NEC2 Modeled Results

4NEC2 analysis predicts that a small LoE that can work well to 30 MHz. This is very similar to what is in use at the remote sites mentioned.

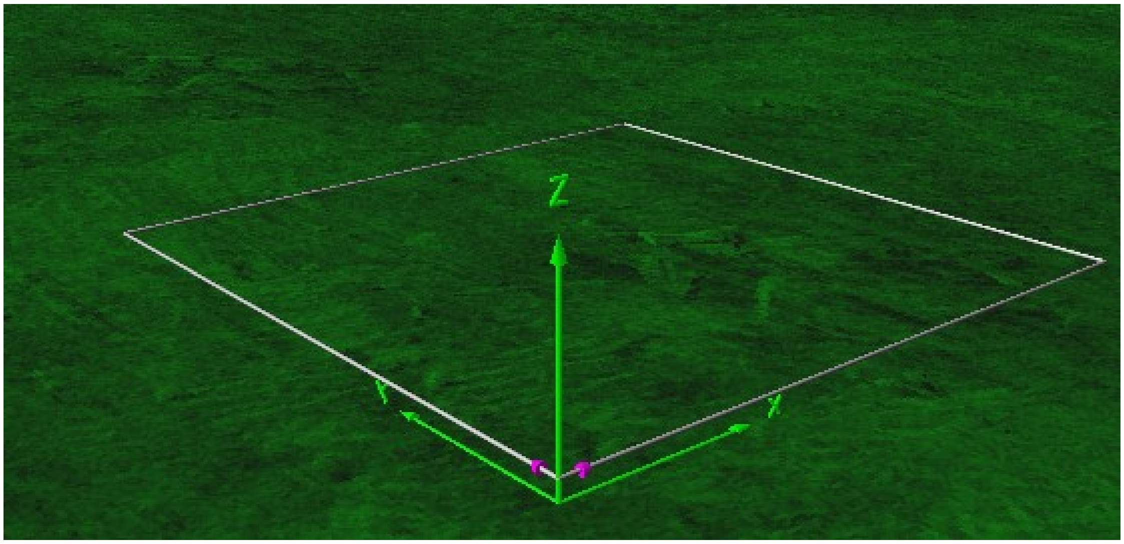

Figure 1: 5m/side LoE, 10cm above 'Real ground'

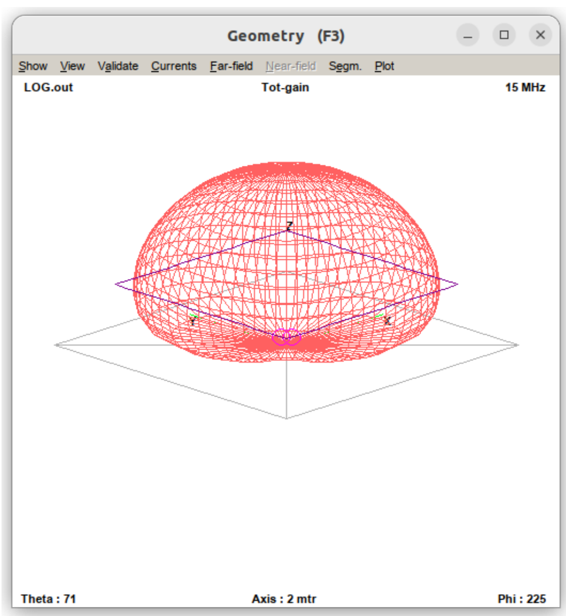

Figure 2: 4NEC2 model of LoE radiation pattern over ''Real ground''

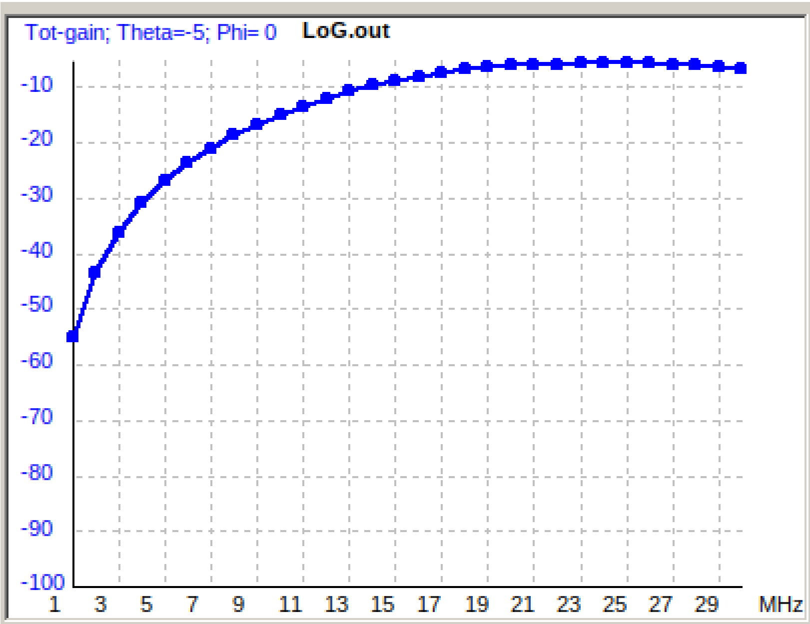

Figure 3: 4NEC2 modeled LoE efficiency over "Real ground"

Figure 3 may be a little misleading since it is 'total gain' and as the loop gets further from earth the H component isn't absorbed the same way and the pattern changes. There is higher sensitivity to spacing at the high frequency end which is where efficiency is especially desired for the hybrid antenna system mentioned. The LoE is a high-pass device so there is also low frequency roll-off with a corner that is mainly driven by loop size.

To make the antenna system work well over a range of, say, 10-30 MHz, it needs to be arranged to produce a noise floor that is dominated by propagated noise. This noise target is becoming lower and more difficult to achieve as frequency increases and is only about 20 dB above thermal noise at 30 MHz according to ITU measurements. These describe the noise in a matched antenna, in the hypotherical radiation resistance and not necessarily a resistance actually measured somewhere.

Good deployment requires that unwanted noise ingress be low in comparison to the ITU targets and that mismatch loss and preamplifier noise be low enough to achieve that limit.With the configuration modeled here this requires perhaps a -160 dBm/Hz floor at the antenna connection point or no more than a 16 dB noise figure plus mismatch loss along with sufficient amplifier gain to overcome the noise floor of the following receiver stages.

The LoE is being operated as a matched rather than as aprobe antenna so total mismatch loss and preamp noise should stay below this 14 dB margin.

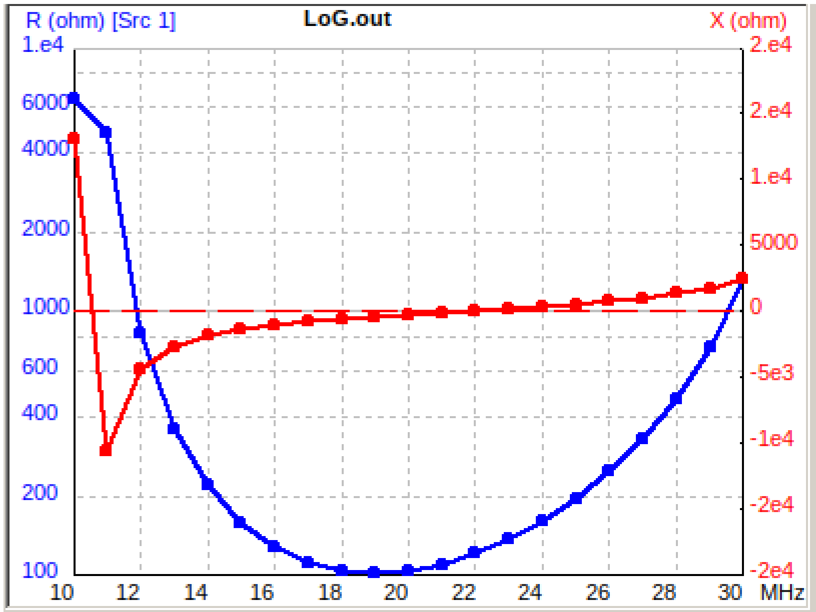

Figure 4: NEC2 prediction of real and imaginary components of 5m/side LoE impedance

The impedance and resistance that need to be matched and presented by this LoE is generally high, very high in places but not dropping below about 100 ohms over the range of interest, as shown in Figure 4 (blue).

This suggests a significant degree of transformation between the connection point and a [50 ohm] preamplifier input.

For broadband use, a 3:1 or 4:1 turns ratio on a suitable core, wound so as to have low common mode coupling from inter-winding capacitance, can move the center of match to a 50 ohm preamplifier up to around 600 ohms and help keep the total mismatch loss from degrading the system performance over the mid-upper HF range too much. When used with a 100 ohm differential input preamplifer, a repurposed 75:300 ohm FM/TV balun core can be wound with a 5:2 turns ratio to accomplish this.

Measured Results

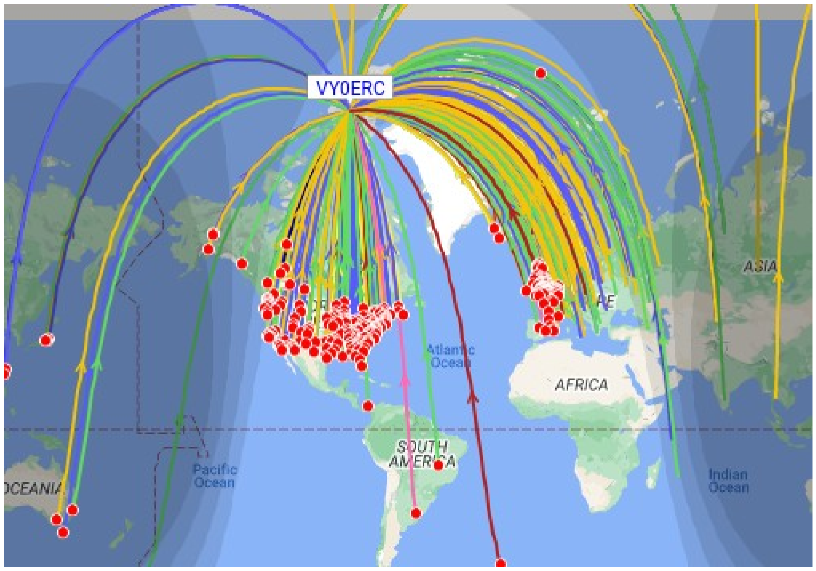

Figure 5: WSPR & FST4W spots reported by VY0ERC using LoE

The spot reports for the two remote systems shown did not have optimum gain to perfectly meet the ITU target when used with the KiwiSDR. Since the time that these reports were made, shaped-gain differential preamplifiers were developed to improve the system high frequency performance. But even without this improvement the performance, as indicated by these comparative WSPR spots, have been excellent. Figure 5 shows a representative plot of a few days of reported results from near the Northern magnetic pole.

It’s worth mentioning that even when covered with snow and ice the antenna has performed similarly well at the N6GN/K site. Recent implementations that enclose the LoE conductor through ½” landscaping tubing have also performed well. These keep a fragile conductor from being broken by humans and animals and also serve to disguise it from HOAs.

Figure 6: 5m/side square LoE #25AWG conductor enclosed in .5” drip water line 10-20cm above the earth

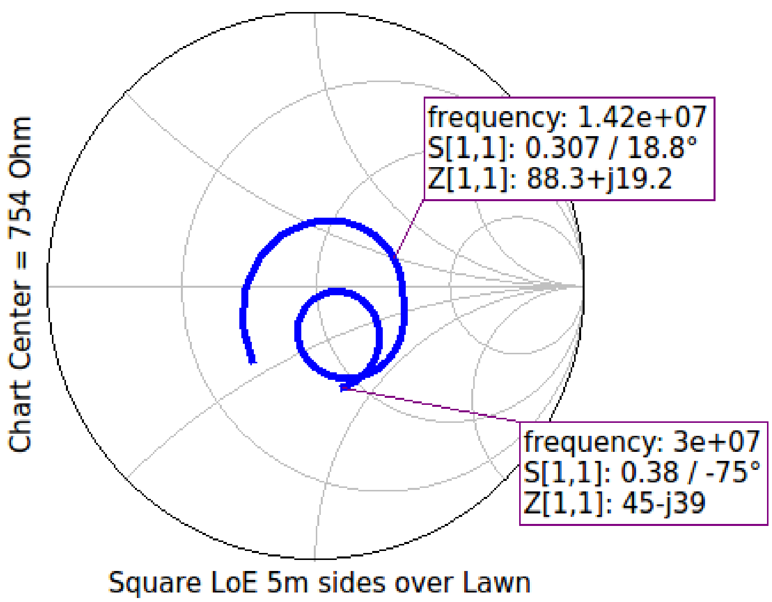

Figure 7: Measured S_{11} in a calibrated 754 ohm reference differential test fixture

A 5m/side LoE, pictured in Figure 6, was built and measured with a tinyVNA using a simple fixture having a T6-1 transformer connected to provide 1:9 impedance transformation. The tinyVNA was then calibrated with OSL standards using a 754 ohm resistor, wire short and disconnect for the open standard. It was deployed over lawn with very wet earth underneath.

As revealed by the measurements shown in Figure 7 and Figure 8, matching ths LoE to a 600 ohm load incurs less than 2 dB mismatch loss from 15-30 MHz and less than 5 dB from 10-30 MHz even with no special attention other than a 12:1 transformer.

From the Smith chart plot in Figure 7, above 10 MHz, where the perimeter is about a half-wavelength, the plot is approaching a circle around a chart centered on 754 ohms. At lower frequency the conductor is not long enough to fully support launch of a TM_{00} wave so the impedance tends toward a short.

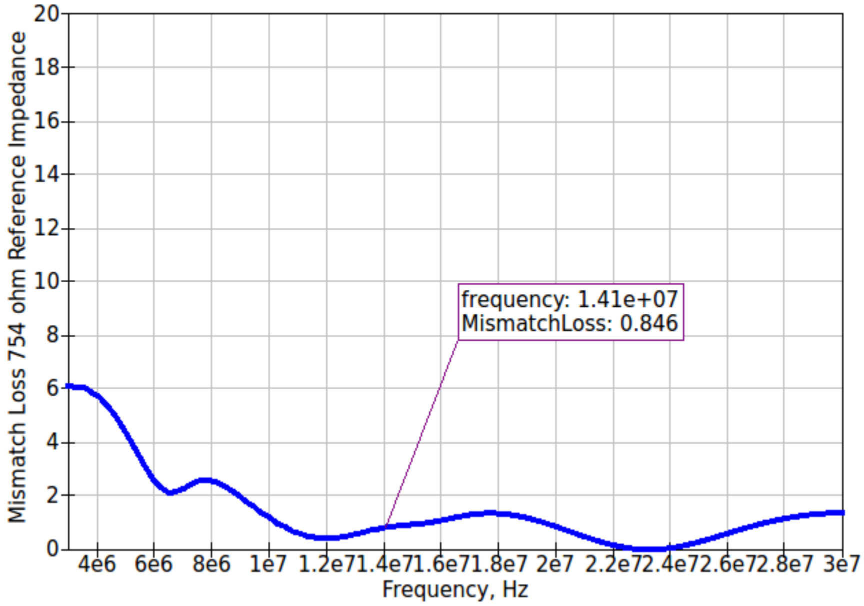

Figure 8: Mismatch loss at 754 ohms for a 5m/side LoE

Determining Antenna Efficiency

Alone these models and measurements do not indicate antenna efficiency since an unknown part of the total resistance is associated with absorbtion. To determine that, comparitive ERP and SNR measurements with a known antenna were made with a slightly smaller, 3.7m/side LoE at the same location.

ERP measurements have the advantage that they don't include noise floor difference between a reference antenna and an antenna under test. Varying noise would affect SNR measurements.

Simple matching at 14.1 MHz to a 50 ohm environment of a previously constructed and measured 3.7m/side LoE had already been performed. Using a sell matched nearby half wave vertical dipole having the bottom element tip about 2m above earth as a reference antenna, delivered signal power comparisons were made. across a very low-angle but nearly LOS 20 km path to the two antennas.

With both antennas well matched to the transmitter the result of this comarison showed the LoE **almost 25 dB** below the vertical dipole. A comparison by using SNR of received signals showed the dipole at least 20 dB better.

Comparing the entire receive spectrum which no doubt includes higher elevation angle arrival signals, this lead to the conclusion that there was likely at least 99% absorption by the earth under the loop. It demonstrates that the 4NEC2 model did not match measurement. It also raises the question of why a nearby LoE, postioned not over lawn but over stone operates so differently and better.

The 5m/side Loe was constructed to reconcile these differences and perhaps improve the poor measured efficiency

To understand the approach taken it is useful to return to SWTL theory.

To Be Continued...