The Active Bridge
11/20/09

The Active Bridge is an op-amp based reflection bridge that produces an output proportional to the signal reflected by an attached device under test (DUT). It can therefore be used with the MSA in Reflection mode to measure reflection coefficients, also known as S_{11}.

The schematic of the active bridge is shown in Appendix A. A photo of an assembled bridge is shown in Appendix B. The bridge contains two op amps. The input is buffered by the first op amp and sent to an output connector for the DUT. The reflection from the DUT returns to that connector where it is amplified by the second op amp. The DUT port presents a nice 50-ohm impedance to the DUT, which as we will see is an important feature

The mechanism by which the second op amp ends up amplifying the reflection from the DUT, rather than the signal sent to the DUT, is a little tricky. It is explained here by Charles Wenzel, who devised the original op amp circulator circuit from which the Active Bridge was derived. Suffice it to say that any signal received at the DUT port is amplified by the second op amp, but any signal transmitted out the DUT port is not.

The Active Bridge can also be used simply as a buffer amplifier, as described below.

Test Setup for Reflection Mode
Consider the test setup of Figure 1.

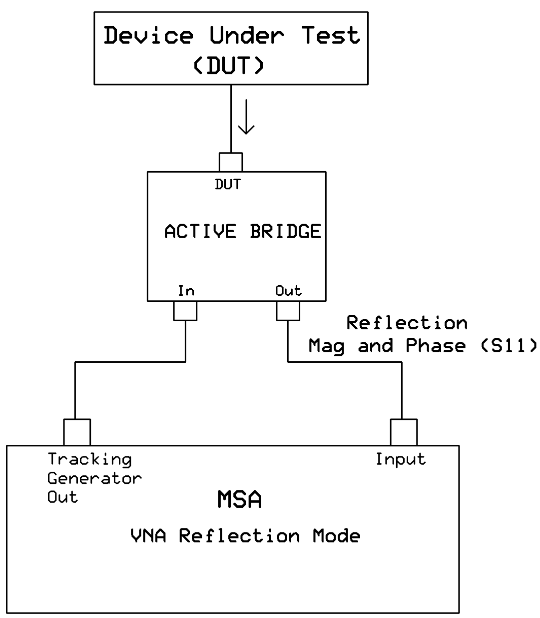
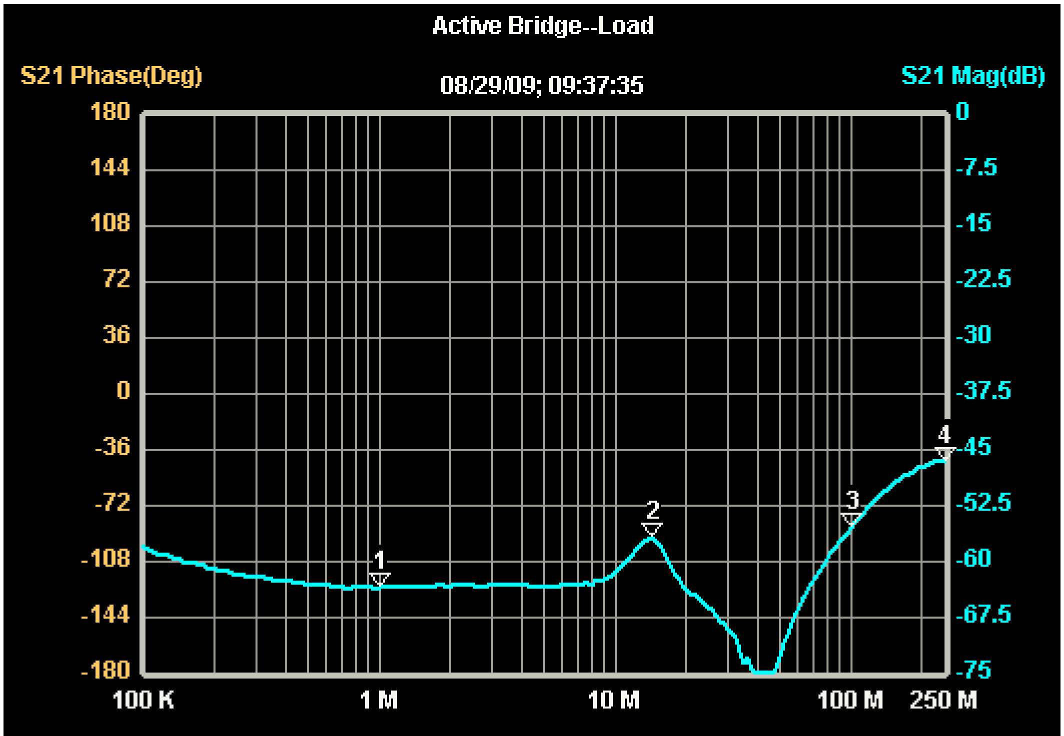


Figure 1—Active Bridge used to Measure Reflection

Figure 1 shows the Active Bridge being used for its original purpose, measurement of reflection. The TG signal arrives at the bridge input where it is buffered and sent to the DUT port with approx. 0 dB gain. The reflection is returned to the DUT port, where it is buffered with about 4 dB gain and sent to the MSA. In many cases, the only calibration required is measurement of an Open DUT to be used as reference for subsequent measurements. It is also possible to perform full OSL calibration, which involves measurement of an Open, Short and 50-ohm Load.

Technically, the signal sent to the MSA input by the Active Bridge is the inverse of the reflection, but this inversion is effectively removed by calibration.

The performance of the Active Bridge, as discussed below, is good enough that full OSL calibration is often not required, greatly simplifying many measurements. If full OSL calibration is used, a bridge does not have to be of especially high quality. However, to use the simpler Reference calibration, the bridge must perform well in two respects: (1) It must have minimal output when a 50-ohm DUT is attached (since there is no actual reflection); the absolute value of the S_{11} (in dB) actually measured is called the Directivity of the bridge. (2) the output with and open and shorted DUT attached must be very close in magnitude, and opposite in phase. Figure 2 shows the Directivity of the Active Bridge.



Mark	Freq (MHz)	S21 dB	S21 Deg
1	1.005524	-63.64	14.69
2	14.377782	-56.90	-9.20
3	101.666274	-55.59	114.50
4	250.000000	-46.60	109.99

Figure 2—Directivity of Active Bridge

The Directivity is better than 60 dB for most of the range up to 80 MHz, and respectable beyond that. As a practical matter, this means Directivity is not much of an issue unless we are trying to measure return losses better than 40 dB.

Figure 3 shows the output of a Short DUT, measured relative to the open; we hope for a value of 0 dB at 180 degrees.

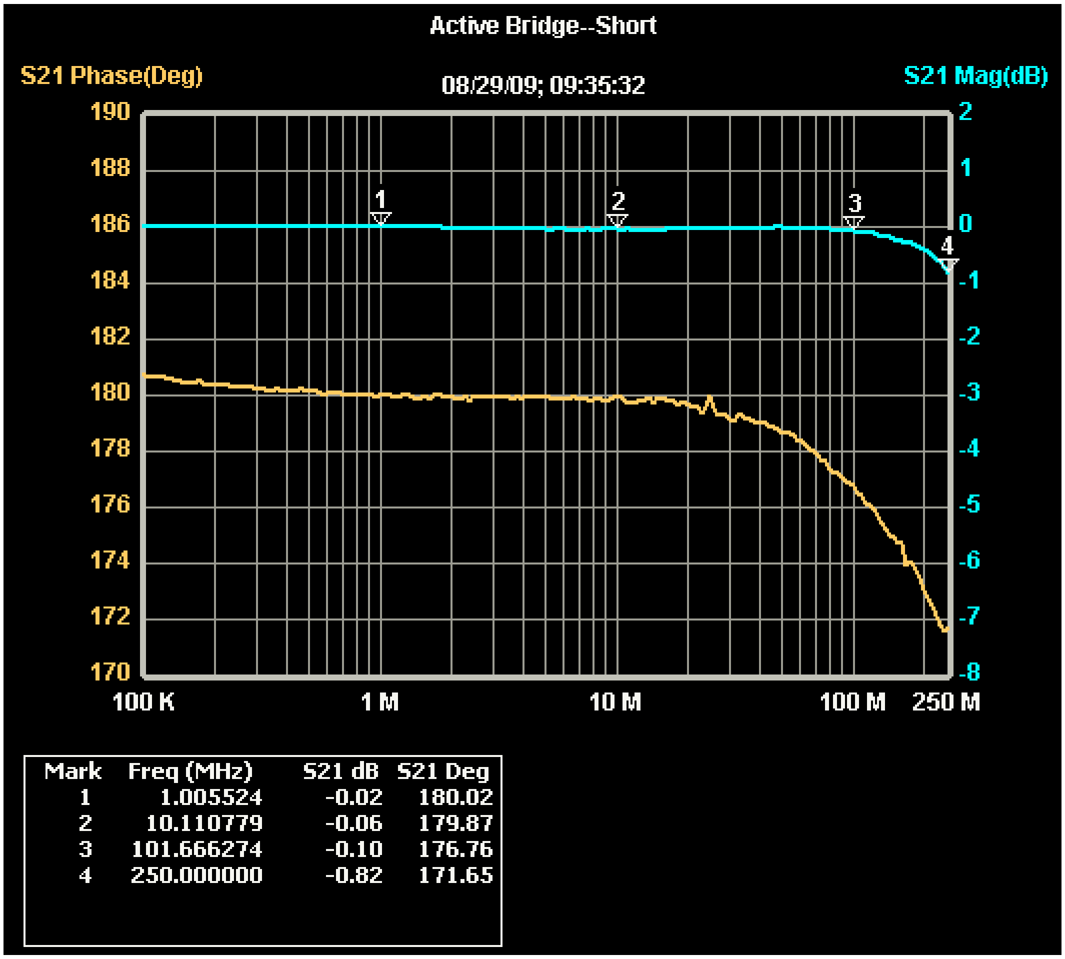


Figure 3—Active Bridge Short, Relative to the Open

The Open and Short magnitudes match very well to 100 MHz. The phase deteriorates a little sooner than that, but is within a degree of the target until 40 MHz.

The bottom line is that the Active Bridge can be used with Reference calibration to at least 30 MHz, and often as high as 100 MHz, depending on accuracy requirements. With full OSL calibration, it is useable beyond 250 MHz. However, at frequencies above 150 MHz, self-heating of the op amps can cause minor phase drift of a few tenths of a degree, soto get maximum accuracy the scan must be allowed to run a few minutes before calibrating.

One advantage of the Active Bridge is that the maximum signal output is somewhat higher than the signal input, so it does not have the signal losses associated with attenuators. In fact, to put the output within the range of best accuracy of the MSA may require 6 dB of attenuation on the input.

The amplification ability of the Active Bridge can be put to use even in Transmission mode, using the Active Bridge as a buffer amplifier to present a solid 50-ohm interface to the DUT without the need for attenuators.

Figure 4 shows the Active Bridge used as a buffer amplifier for measurement of transmission.

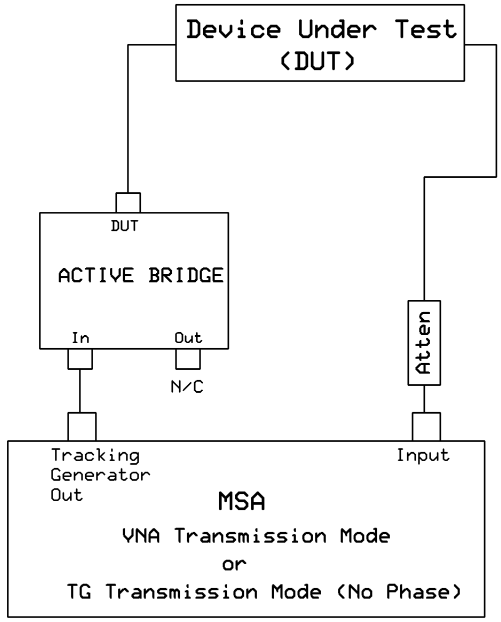


Figure 4—Use of the Active Bridge as Buffer Amp for Transmission Measurement
This setup is a Series Fixture

The Active Bridge actually contains two amplifiers, so there are several ways to configure it as a buffer amplifier, as shown in Figure 5.

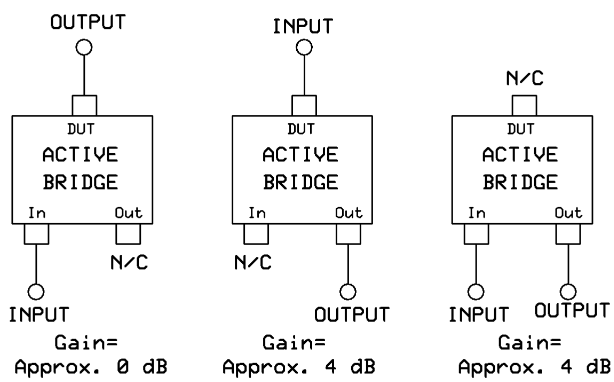


Figure 5—Configurations of the Active Bridge as a Buffer Amp

When the Active Bridge is used as a buffer amplifier in place of an attenuator, the primary goal is to present the DUT with a 50-ohm interface—that is, the output return loss of the amplifier should be high (S_{11} dB should be very negative). Figure 6 shows the S_{11} of the DUT port (we could call this S_{22}, since we are looking at the port as an output, but we will consistently use S_{11}).

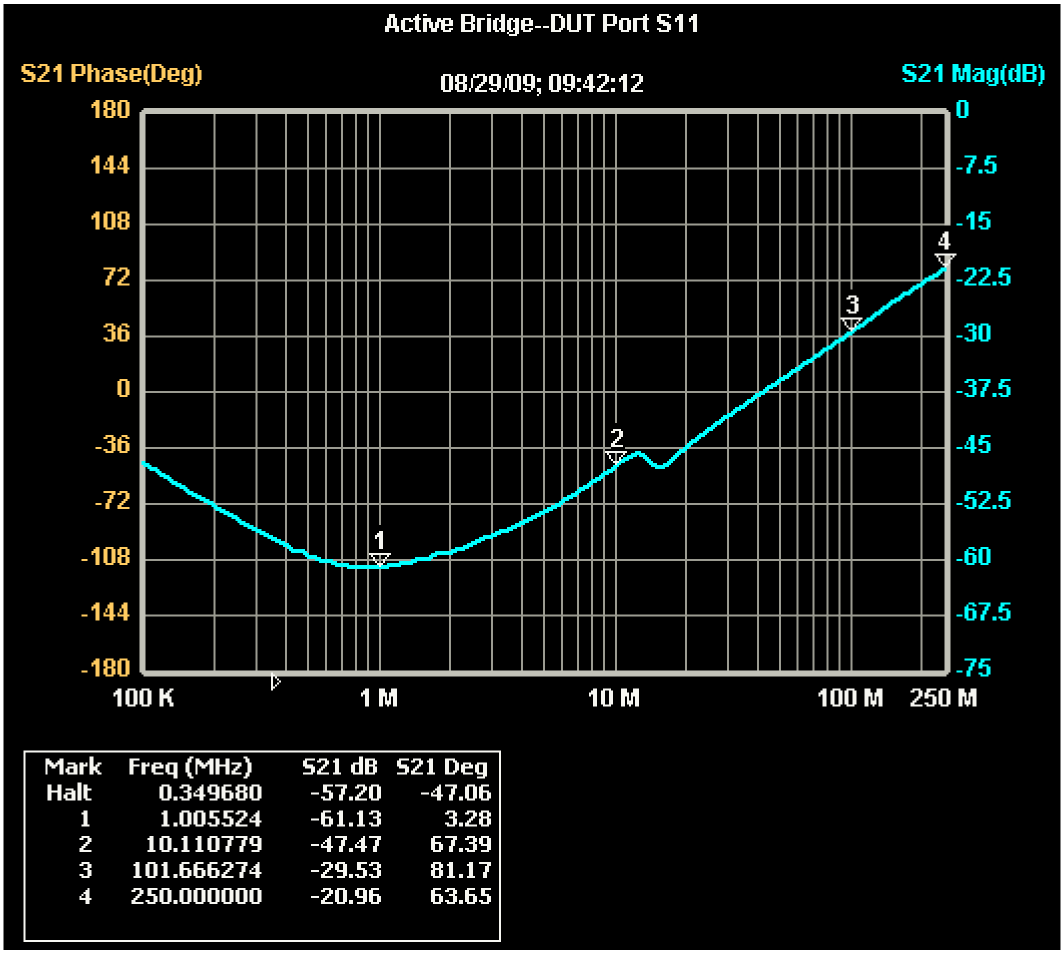


Figure 6—S_{11} of DUT Port of Active Bridge

Right axis is labeled S_{21}, but due to the technique used, this is actually S_{11}

The return loss of the DUT port is very good up to 20 MHz. Beyond that, it is good but not spectacular. Better return loss can be obtained by using either of the other two configurations shown in Figure 5.

If the bridge “Output” is used as the amplifier output, we get the S_{11} shown in Figure 7.

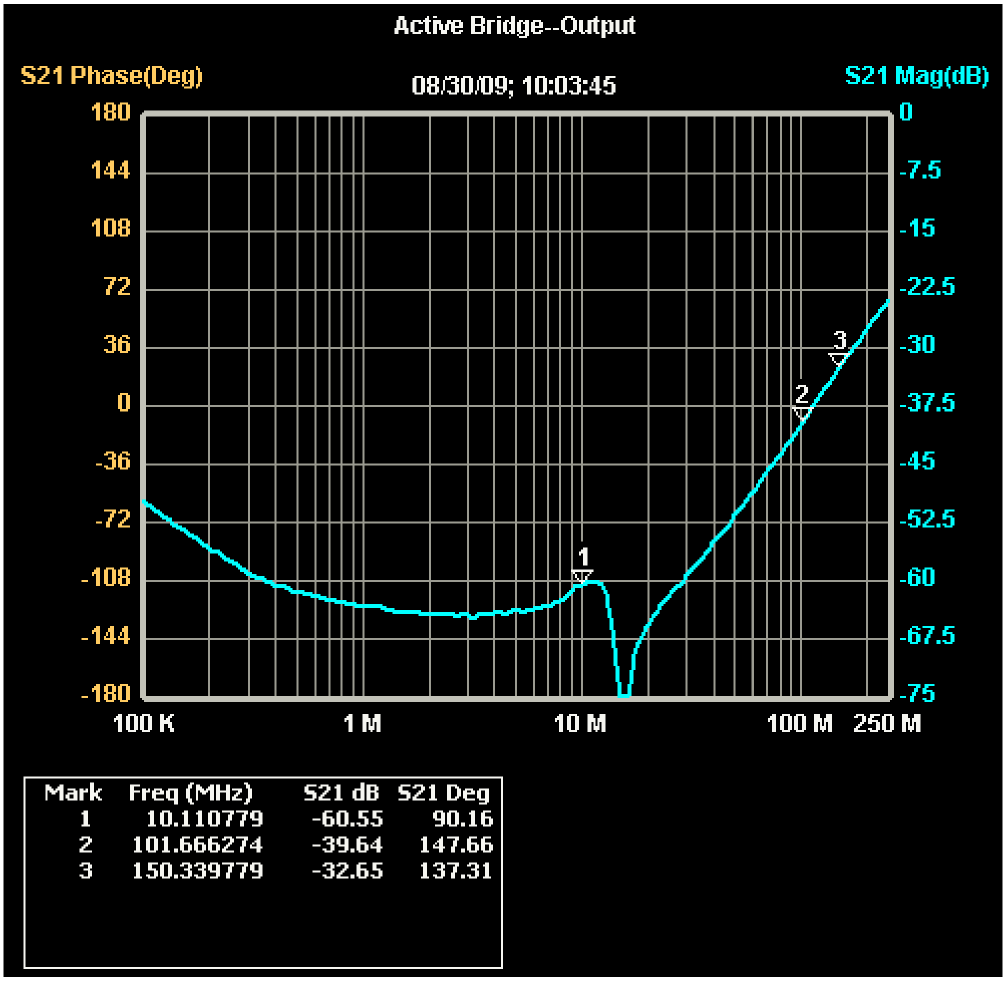


Figure 7—Reflection of Output Port of Active Bridge

Right axis is labeled S_{21}, but due to the technique used this is actually S_{11}

Figure 7 shows that we obtain spectacular return loss to at least 30 MHz, and extremely good return loss to 150 MHz.

We could also move the buffer amplifier in Figure 4 to the output of the DUT, swapping the amplifier and the attenuator, connecting the DUT output to the bridge input, and taking the amplifier output from either the DUT port or the bridge Output port. In that case we would like the return loss at the bridge Input port to be high. Figure 8 shows the reflection of the Input port.

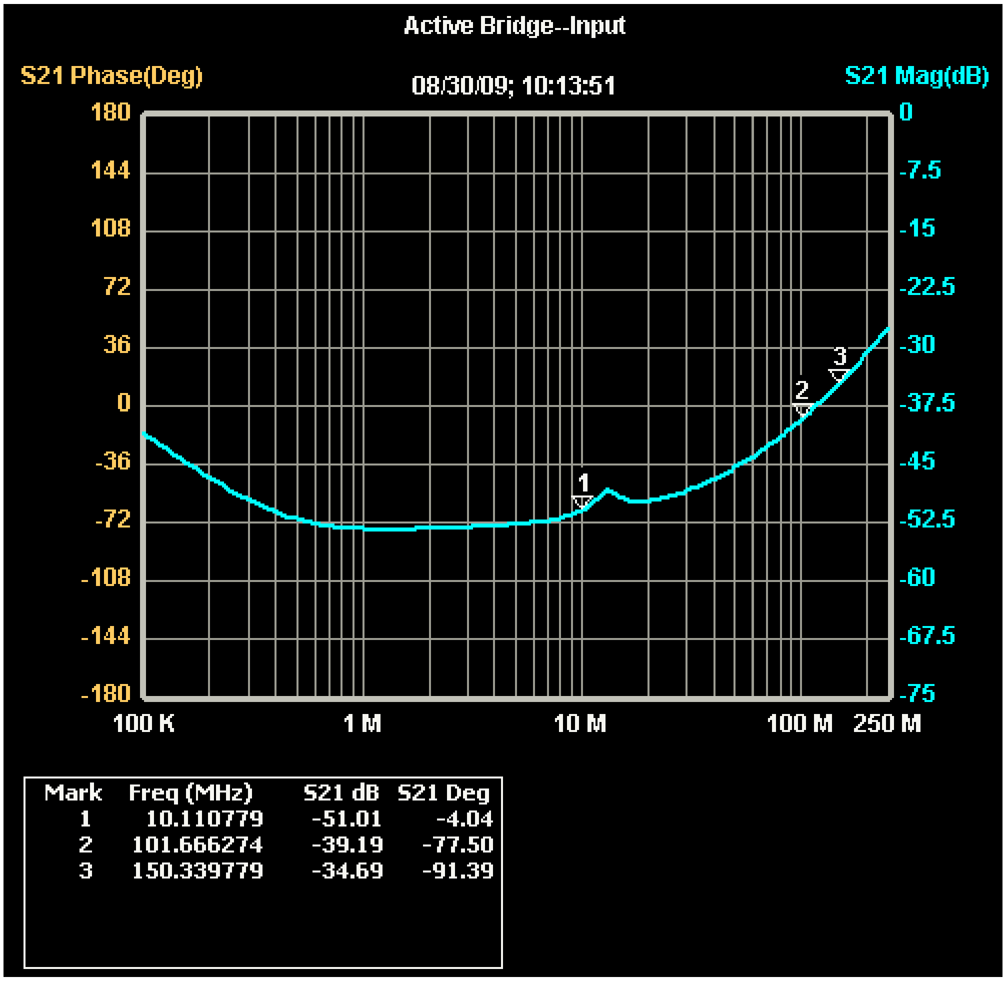


Figure 8—Reflection of Input Port of Active Bridge
Right axis is labeled S_{21}, but due to the technique used this is actually S_{11}

Figure 8 shows that the bridge Input port does not achieve the extremely high return losses of the Output port, but nevertheless has very good return loss to 150 MHz.

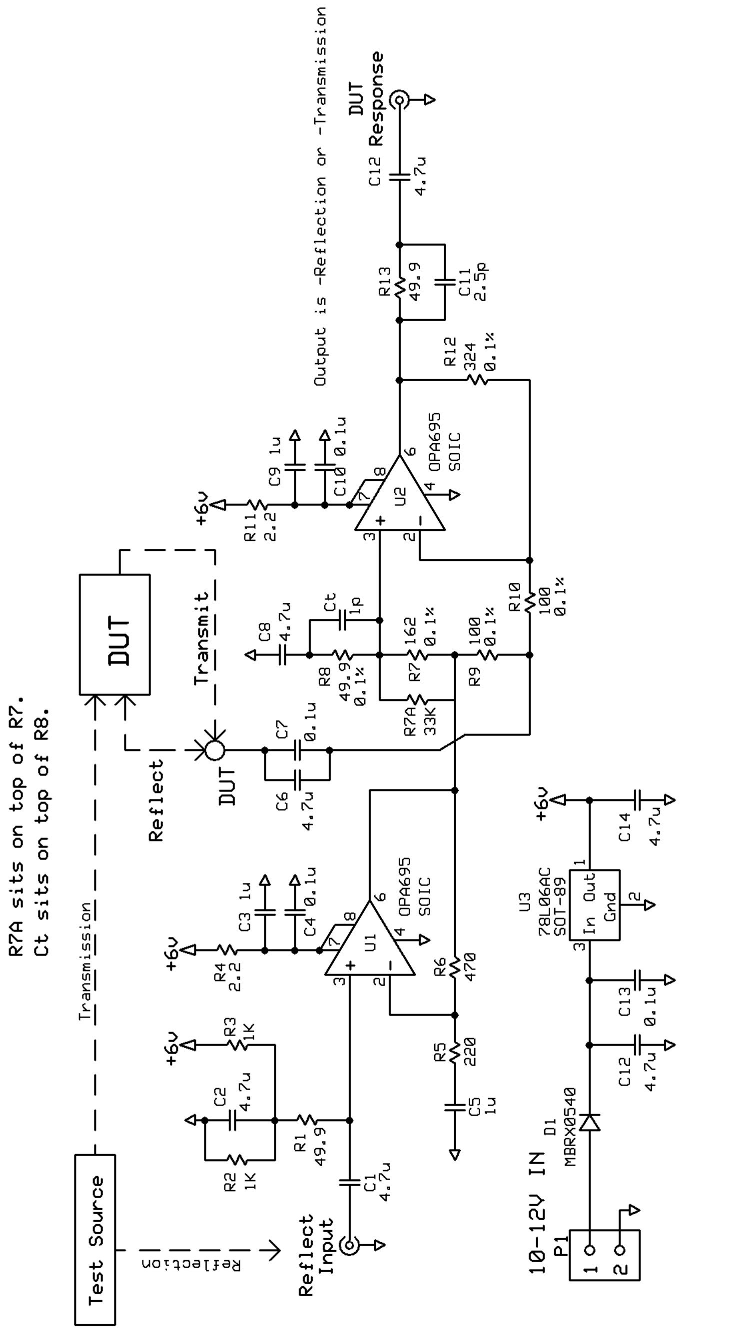
Conclusion

The Active Bridge used as a reflection bridge performs well enough below 30 MHz that full OSL calibration would rarely have any benefit, and the bridge can be used with just Reference calibration. Above that frequency, depending on accuracy requirements, the Active Bridge may be useable with Reference calibration as high as 80 or 100 MHz. With full OSL calibration, it is useable beyond 250 MHz.

As a buffer amplifier in Transmission Mode, the Active Bridge will present an excellent 50-ohm interface to the DUT up to 150 MHz.

While we are concerned here with frequencies above 100 kHz, the Active Bridge could perform at arbitrarily low frequencies by increasing capacitor sizes, or by utilizing + and – power supplies with no coupling capacitors.

APPENDIX A
Schematic of Active Bridge



6 V regulator is shown, but 5 V is preferable.
C11 sits on top of R13 but is not present in photo in Appendix B

APPENDIX B
Photo of Active Bridge