

**To:** Dr. Al Wootten  
John Effland

**From:** Tim Thacker

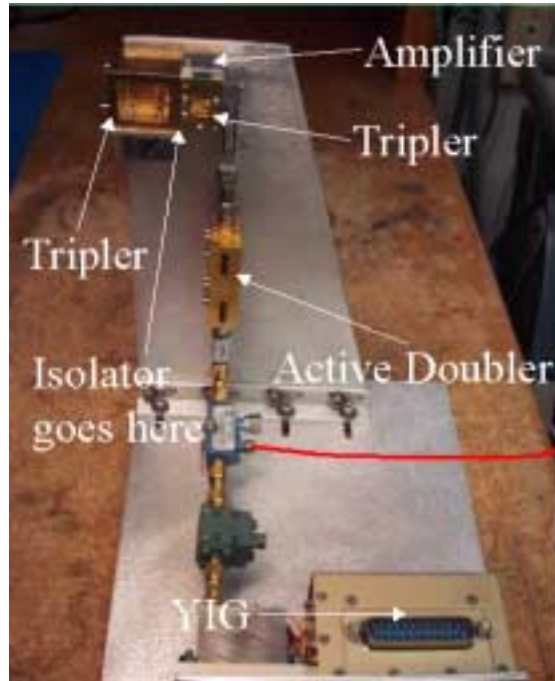
**Date:** 2003-10-20

<b>Revisions:</b>	<b>Date</b>	<b>Who</b>	<b>Reason</b>
00	2002-08-06	Tim Thacker	Initial
01	2003-10-20	Tim Thacker	Deleted unsubstantiated vendor comparison in paragraph following Figure 7.

**Subject:** End of Summer Report

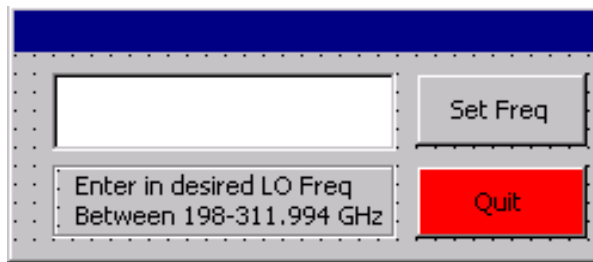
This summer's internship was spent with the NRAO Central Development Lab's (CDL) SIS Mixer Group. The job involved design, development, and testing of SIS Dewar system equipment. Specifically, software was designed, coded, tested and finally used to check out a new automated local oscillator system, called the LO Plate. Additional student tasks included creating object-oriented software classes for various pieces of testing equipment such as the Tektronics 2784 spectrum analyzer and the HP 8720C network analyzer. The spectrum analyzer software provides an automated technique to detect and measure the level of spurious signals generated by the automated LO system. Measurement data were collected and analyzed by the student for two different Triplers that comprise the final stage of the automated local oscillator.

The LO Plate (pictured in **Figure 1**) generates a local oscillator signal that is used by the Superconducting-Insulating-Superconducting (SIS) mixers in the cryogenic Dewar system. The LO signal originates in a YIG oscillator which produces a signal of a frequency between 11GHz and 17.4 GHz (refer to **Figure 1** to follow the signal path). The signal is then passed to an Active Doubler, which multiplies times two the frequency of the signal; from there it moves on to the first Tripler. The Tripler further multiplies by three the frequency of the signal which continues into an amplifier that boosts the signal levels and also provides output level control. The signal is now at times six of its original frequency.



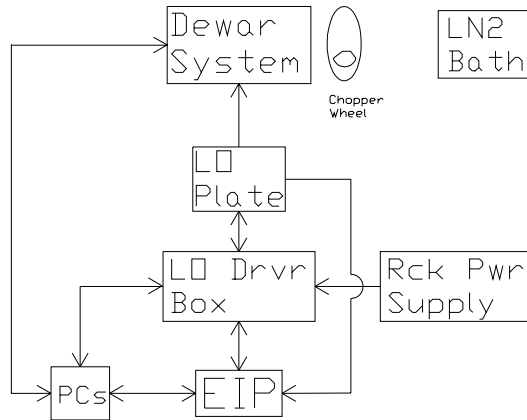
**Figure 1:** LO Plate showing major components

The signal then passes through an isolator. The isolator helps control output level changes that result from mismatches between windows. The isolator reduces these variations and attenuates the signal's power by a few dB, which has the added benefit of protecting the final tripler from damage). The final tripler multiplies the signal to the desired LO range of frequencies, 198-311.994 GHz, which is 18 times the frequency the YIG had produced. The user controls the YIG frequency via a dialog box that appears after running an Excel-based Visual Basic program (see **Figure 2**).



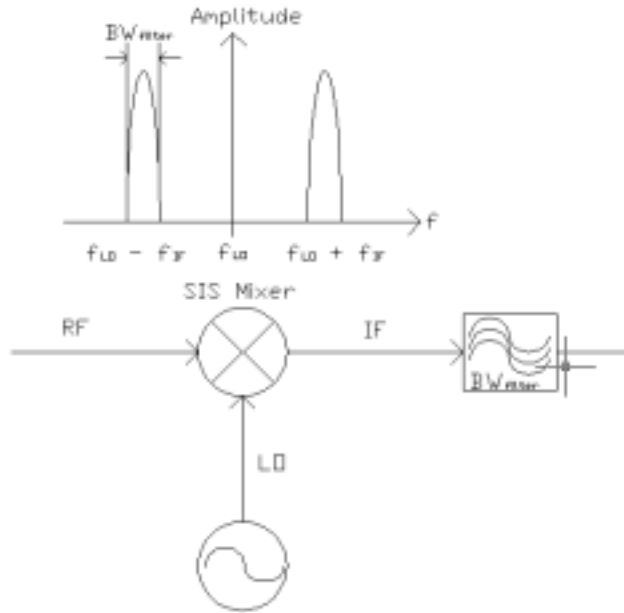
**Figure 2:** Dialog Box from program that sets LO frequency

The user enters a desired LO frequency, and the program sets the YIG accordingly by dividing the desired frequency by 18 to determine the YIG frequency (refer to **Figure 3** for setup of LO to Dewar system). The SIS mixer then uses this LO frequency to downconvert a RF signal to the IF frequency for further analysis (see **Figure 4**).

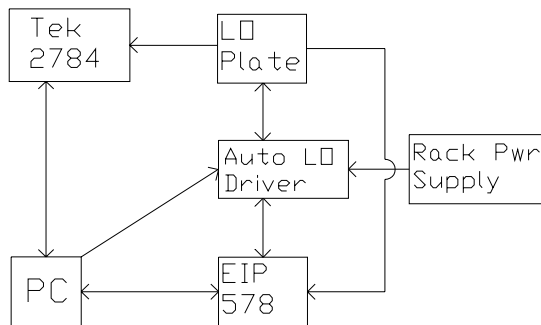


**Figure 3:** Block diagram of system setup with Dewar

To test the LO Plate, a spectrum analyzer is connected (refer to **Figure 5** for connection set up) to the output of the second tripler. By reading the signal at this point on the spectrum analyzer one can determine the frequencies and levels of both desired and undesired (spurious) signals generated by the plate. Software developed by the student is then run (see **Figure 6**) that automatically steps through multiple LO frequencies while sweeping a wide range of frequencies on a spectrum analyzer to locate and identify all the signals output by the local oscillator plate. The program prompts the user to set desired start/stop/step frequency parameters for the LO, and similarly start/stop frequencies as



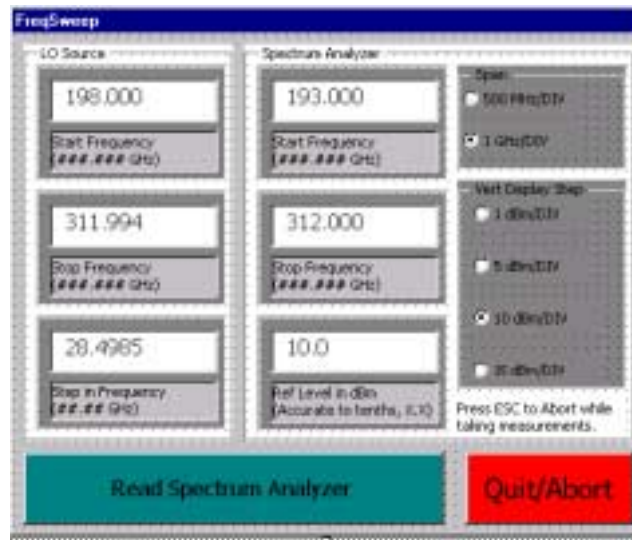
**Figure 4:** Diagram of how SIS Mixer uses LO frequency with IF frequency to downconvert RF frequencies.



**Figure 5:** Block Diagram showing setup for use with spectrum analyzer.

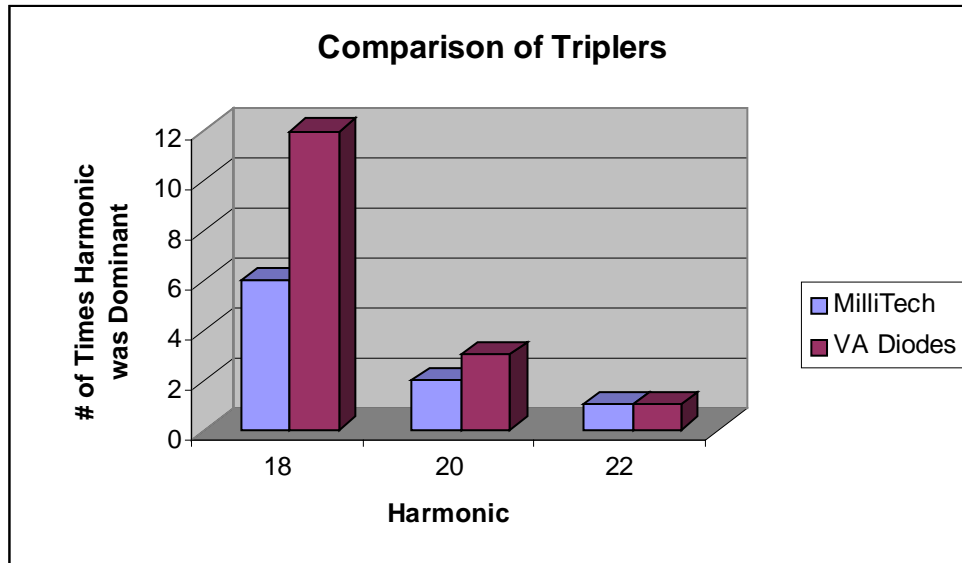
well as other parameters for the spectrum analyzer. The program begins at a user defined start LO frequency and continues until the stop frequency has been surpassed. During each LO frequency step, the program sweeps through the user-defined start/stop spectrum analyzer frequencies searching for real signals. A significant complication in the process is that the spectrum analyzer also displays its own, internally generated spurious signals. The analyzer determines whether the signal is real or imaginary by using an identifier

trace capability. When the signal and identifier traces both have responses nearly the same frequencies, the signal is real. The program records these frequencies and focuses in on each response individually to determine if the signal is real or imaginary. Once the signal has been confirmed as real, the program records the signal's frequency, amplitude, and the time of the recording. The program then plots all real responses found. After the spikes are recorded and graphed, the program moves on to the next LO frequency, and repeats the process above until all LO frequencies requested by the user are completed.



**Figure 6:** Dialog Box from the program that steps through multiple LO frequencies and sweeps a spectrum analyzer for real spurious signals

A comparison between the two triplers manufactured by Virginia Diodes and by MilliTech, was conducted using the LO Sweep program described in the previous paragraphs. The program was used to measure the frequencies and power levels (in dBm) of the spurious response at different LO frequencies. The data showed that the VA Diodes tripler produced stronger signals, and though the majority were at the desired 18<sup>th</sup> harmonic (see **Figure 7**), at the lower end of the frequency band other harmonics were stronger. The MilliTech tripler produced signals not as strong as the VA Diodes, and did not even produce measurable signal levels at the higher frequencies (which can be explained because a harmonic mixer was used with the analyzer that was only rated from 140-220 GHz and hence had low sensitivity over the band of interest).



**Figure 7:** Chart comparing the two Triplers on which harmonic was dominant more often.

During the comparison, the VA Diodes ceased working due to overdriving, and in later tests another VA Diodes was damaged under what appeared to be normal operating conditions.

One observation about both triplers was that they both had significant losses, and both let through too many harmonics of the signal at the lower LO frequencies. When the power was measured from the output of the amplifier after the first tripler on the LO plate, the desired harmonic (the 6<sup>th</sup> harmonic) was by far, over 25 dB greater, the most dominant signal. By stepping the YIG oscillator from 11 GHz to 17.333 GHz in 0.5 GHz intervals, it was shown that the 6<sup>th</sup> harmonic was the strongest signal found every time. This result gives the impression that the second tripler is somehow dissipating power and in the lower LO frequencies causing other harmonics to become the dominant signal.

Visual Basic code was also developed by the student to control the TEK 2784 spectrum analyzer and the HP 8720C network analyzer. The code was developed to take data and waveforms from the two pieces of equipment, and to be able to operate them through the computer.

This summer has been very beneficial. Many tasks (tests, coding, equipment comparison, etc...) concerning the LO Plate were accomplished and improved upon. A greater understanding of microwave engineering was obtained, which is very useful for upcoming classes, as well as for future careers.