Creating a 40 – 60 GHz Broadband Microwave Spectrometer

Motivation
There are no operating 40 – 60 GHz broadband spectrometers despite their usefulness to astrochemical detection.

Introduction
The purpose of this project is to develop a spectrometer to function well in the 40 – 60 GHz range. There are no previous broadband spectrometers in this range because of the limited components and lack of literature produced so far. This project intends to create benchmark measurements to set a precedent.

One reason to get readings in this range is because the Green Bank Telescope (GBT) has shown that there are dense spectra in the Q-band (33 – 50 GHz), as is shown in Sgr B2(N) and Orion KL. By producing lab data, scientists will be able to identify molecules in space by comparing different spectra. This will require numerous precise measurements of emission lines from each molecule, both in the lab and in space.

Experimental Design
There were two methods possible for this experiment. The first method would be to use a Cavity and mirrors, the Cavity Fourier Transform Microwave (CFTMW). Pros:
- Simple design
- No parts requiring tuning
- Allows for broadband spectroscopy (wider range)
Cons:
- Microwave-Microwave double resonance capabilities
- Components are very limited

CFTMW was chosen, mainly because the large bandwidth which makes searching for signals easier.

Challenges
- Would a direct signal from a local oscillator work better than a signal mixed
- Reducing power loss throughout the system
- Improving signal/noise ratios when producing spectra
- Examining the spectra of various other gases
- Using 100mW at 40 GHz

Opportunities in this Lab
- Instrument design and development
- Astrochemistry (collaboration with NRAO, multiple universities, and national institutes)

Progress
The previous spectrometer schematic is shown to the left.

The new spectrometer schematic is shown to the right. The components that are new to the setup are the synthesizer and switches. This is where the bulk of the time in this project was spent.

- The issue of power was resolved by using a segmented technique. By breaking the total bandwidth down into small portions, more power could be distributed to each individual segment.
- Noise reduction was solved by using a second switch that was not in the previous set up, which removed noise contamination by the quadrupler on the excitation side.
- Although the power drop is close the data shows that there is less drop when mixing a 2.7 GHz signal with the PDRO than the direct 11.3 GHz signal. As well, there is better phase stability when mixing with the FDRO. Greater signal purity and better signal to noise ratio resulted.

The data below is a comparison of noise from the Agilent 83620B synthesizer and the AWG7102. The noise level for the synthesizer signal is ~30 dB lower than that of the AWG.

The graph to the left shows how the emission spectrum of methyl formate at a 4 MHz bandwidth. The graph to the right shows how a larger bandwidth decreases the signal significantly.

Conclusions
The Broadband Spectrometer has the potential to obtain high resolution, high sensitivity spectra between 40 and 60 GHz. The spectra generated by the current spectrometer were compared to spectra generated by the previous setup of the Spectrometer to find matching transitions.

The graph to the left shows the emission spectrum of methanol at a 4 MHz bandwidth. The graph to the right is the same data with 100x magnification to show the noise levels.

While the previous arrangement produced a signal to noise ratio of 150:1, the current set up produces a ratio of 2360:1.

Future Work
Future work needs to be done in the following areas:
- Improving signal/noise ratios when producing spectra
- Examining the spectra of various other gases
- Investigating alternatives to current components to reduce costs
- Comparing the spectra produced in the lab with the spectra from space molecules

Ideally, lab data will be used to get lab spectra of molecules in space, such as MeHCOO, BPL, and EtHOOC

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References
www.spytallouge.net

The molecules that have been used to test the performance of our scope have been Methyl formate and Methanol.

Methyl formate (CH3COOH)
Methanol (CH3OH)

These molecules were chosen because they have been heavily studied, making them ideal test molecules. Also, these molecules had been used in previous setups so the results could be compared to the new system.

The previous arrangement produced a signal to noise ratio of 150:1, the current set up produces a ratio of 2360:1.