A CHIRP Pulse Fourier Transform Microwave Spectrometer with Multi-Antenna Detection

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Introduction

In 2019, the Grubbs group showed that it is possible to detect microwave radiation in a CHIRP pulsed Fourier transform microwave spectroscopy (CP-FTMW) experiment that does not co-propagate with the incidence of radiation [1]. This was shown to be achieved by the implementation of a circulator, switch, and low noise amplifier to detect off the broadcasting antenna. For years, the long-standing belief that radiation could only co-propagate made this discovery seem impossible [2]. Thus, it provided the impetus for a new hypothesis to be tested: Could free indication decays (FIDS) be detected at other points not in the direct linear path of the microwave?

Methods

To address this, a newly constructed microwave three-wave mixing (M3WM) instrument based upon the four-antennae design of Pate [3] was utilized in order to employ the orthogonality of the setup for the purposes of CP-FTMW FID collection.

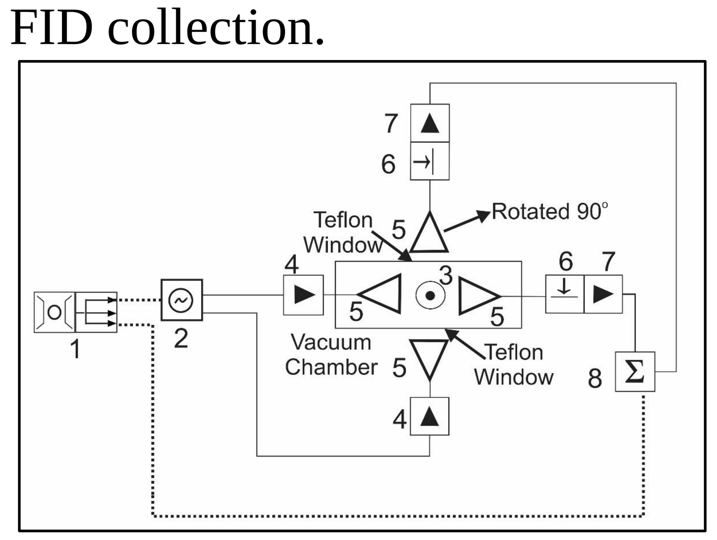

Figure 1: The M3WM is comprised of three systems: a source for sample introduction (3), a vacuum chamber, and a circuit. Inside the vacuum chamber sits four horn antennae (5), which will be used to stimulate and detect molecular signal. The circuit—comprised of a pulse generator (8), amplifier (7), detector (4), and oscilloscope (2)—will be utilized to generate the microwaves and record the resulting spectra.

Results

A total of eight CP-FTMW experiments were run on a sample of 1,3-difluorobenzene. The first four runs consisted of data being collected from all four antennae with microwave foam blocking the traditional receiving antenna. This was done in order to verify that the FIDs being collected on the other antennae were not caused by reflections. The second set of runs then consisted of repeating the first four tests without the foam present.

Foam Testing

The data collected from all four antennae with microwave foam blocking the traditional receiving antenna can be seen below. The data from each antenna was then compared to identify if each detection point could observe the known B-type transition of 1,3-difluorobenzene at 13.6236 GHz and to compare the signal to noise (S/N) ratio observed at each detection point.

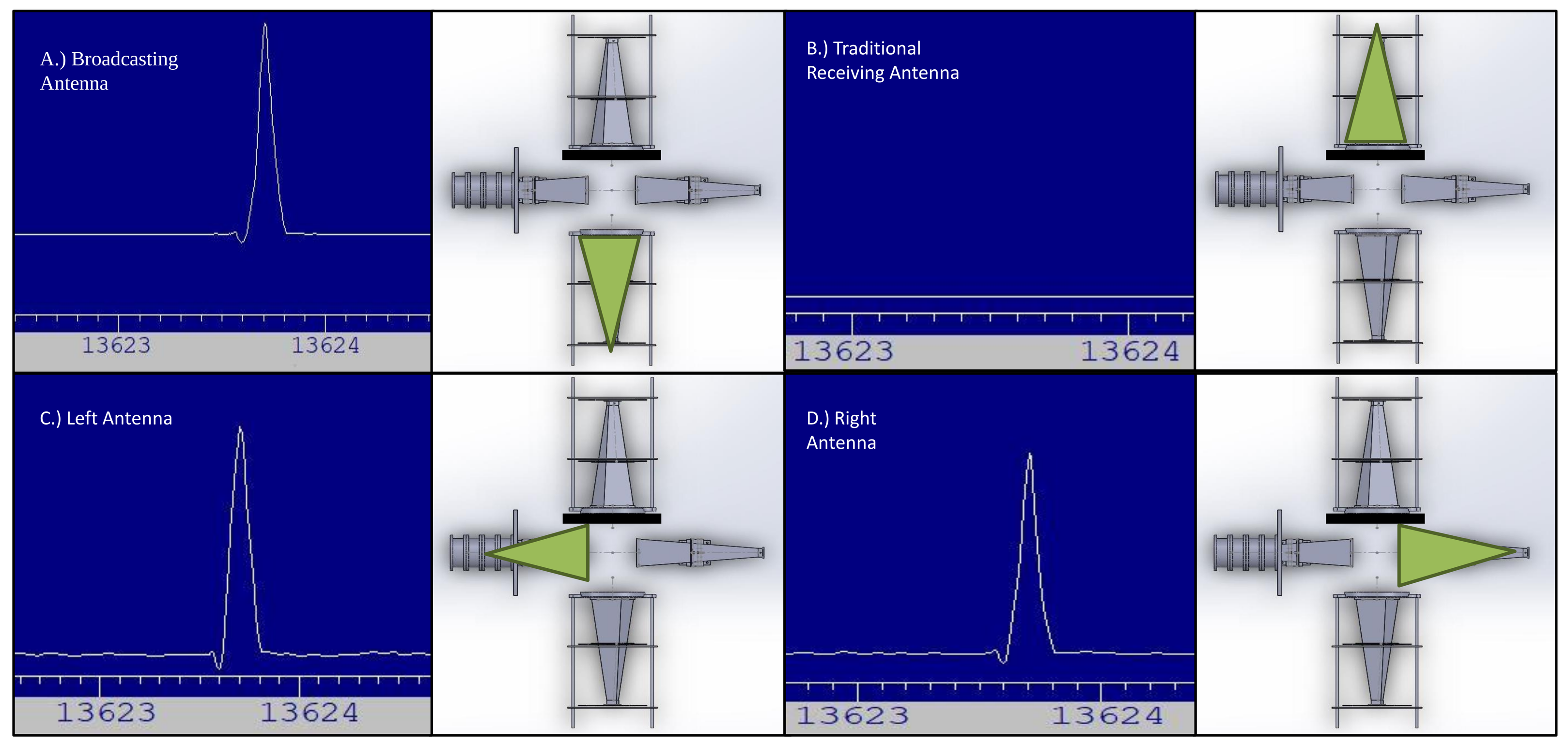

***Figure 2**: Spectra collected from 13.623 to 13.624 GHz at all four detection points accompanied by a schematic of the instrument. The detection points were A.) the broadcasting antenna, B.) traditional receiving antenna, C.) left orthogonal antenna, and D.) right orthogonal antenna. Signal was detected at each point besides the traditional receiving antenna, which was blocked with microwave absorbing foam.*

Detection Point	Signal to Noise Ratio
Broadcasting Antenna	3,500 : 1
Traditional Receiving Antenna	0 : 1
Left Orthogonal Antenna	82 : 1
Right Orthogonal Antenna	190 : 1

***Table 1:** Signal to noise ratios at each detection point with respect to the molecular signal at 13.6236 GHz.*

No Foam Testing

After the foam tests provided the proof of concept that data could be collected at multiple detection points, a new set of tests were run. For the second run, the data was collected from all four antennae with no microwave foam in place.

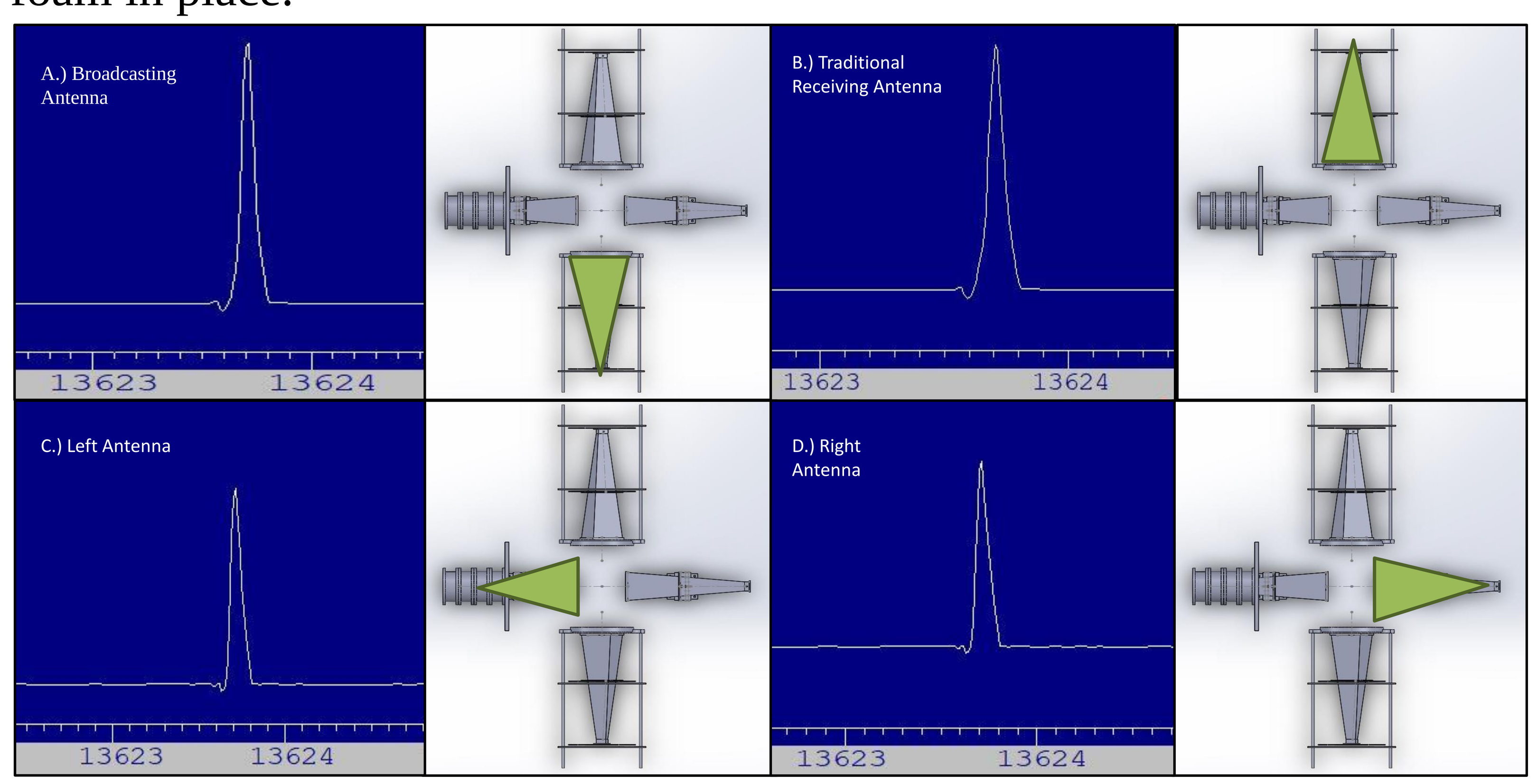

***Figure 3**: Spectra collected from 13.623 to 13.624 GHz at all four detection points accompanied by a schematic of the instrument. Signal was detected at each point including the traditional receiving antenna, which was no longer blocked with microwave absorbing foam.*

Detection Point	Signal to Noise Ratio
Broadcasting Antenna	42,000 : 1
Traditional Receiving Antenna	31,000 : 1
Left Orthogonal Antenna	300 : 1
Right Orthogonal Antenna	500 : 1

***Table 2:** Signal to noise ratios at each detection point with respect to the molecular signal at 13.6236 GHz.*

Conclusions

After analyzing the spectra collected from the eight separate runs, a few things became apparent:

1. The signal at 13.6236 GHz was observed in all the spectra produced besides the one corresponding to the traditional receiving antenna blocked by microwave absorbing foam. This indicates that the signal collected at points outside the direct path of the microwaves were not caused by radiation scattering, but by the molecular signal produced by 1,3-difluorobenzene.

2. While the decrease in S/N between the traditional receiving and the two side antennae was expected—due to the instrument being parameterized with respect to the traditional antenna—the increase in S/N between the traditional and broadcasting antennae was unexpected. This is since the traditional antenna should have received the most amount of molecular signal. More testing is needed to determine if this was caused by a fall out of the specific parameters utilized, or if the broadcasting antenna is truly receiving more signal.

Therefore, while these eight tests provided proof that FIDs can be detected at other points not in the direct path of the microwaves, they also generated many questions. Most important of which is: why can molecular signals be observed at other detection points if theory claims microwave radiation can only co-propagate? As a result, more experiments and careful analysis of the data will have to be done to fully answer the hypothesis proposed.

References

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