Sensitivity Corrections of CHIME for FRB repeating source R3

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I. INTRODUCTION

Working with supervisor Dr. Paul Scholz on Fast Radio Bursts (FRB), the given project was to account for the sensitivity of the CHIME radio telescope and correct the spectra of multiple events from FRB repeater R3. Fast Radio Burst are phenomena that have only recently been documented, characterized as bright millisecond radio bursts with large excess dispersion measures suggesting extragalatic origins. R3 is one of the only known FRB sources with a periodic event timing and has been very well localized so its position is known to great precision. Spectra are corrected for sensitivity of FRB events 71784510, 20425523, 23491552, 23588210, 40363754, and 83984528.

II. METHOD

In order to correct for the sensitivity of CHIME, a model known as the Beam Model [1] was applied. The Beam model takes in the beam ids, positional arguments and an array of frequencies and gives back a multidimensional array for which the elements of single rows are the various sensitivity of the given frequency which has been calculated for each beam and position. The sensitivity of the beam is dependent on the beam id which is one of the 1024 antenna, position x and y, measured in degrees from the origin and frequency of the spectra to be measured which are on the order of hundreds of Megahertz. The output spectra of the FRB from the input intensity data may be mathematically represented by equation (1).

$$I_{corrected} = \frac{I_{original}(t,\lambda)}{sens(beam,x,y,\lambda)} \tag{1}$$

For each event one beam with the highest signal to noise ratio (SNR) was used for the beam id, the position was held constant at the right ascension (RA) and declination (DEC) of R3 which is 29.503125, 65.716756 respectively. This means that the sensitivity was a single array consisting of elements which corresponded to the sensitivity of the beam at a frequency in the original array with the same index number. As the observed response must be divided out, the sensitivity array was then converted so each element was $\frac{1}{sensitivity}$. The intensity matrix was then multiplied by the manipulated sensitivity matrix to output the intensities of the FRB. These output values give the intensity of the spectra for the FRB event independent of the sensitivity of the beam.

The following are contour plots of the uncorrected and corrected spectra of FRB events.

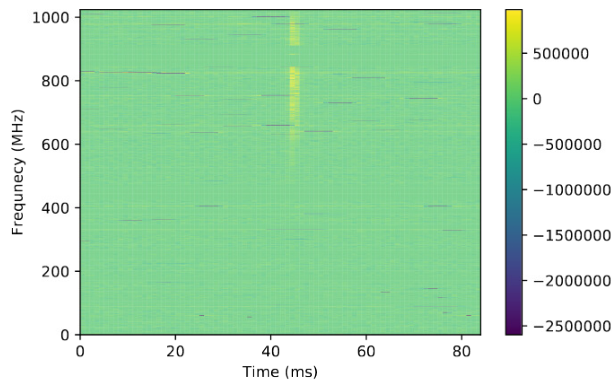

Fig. 1: Intensity of FRB event 71784510

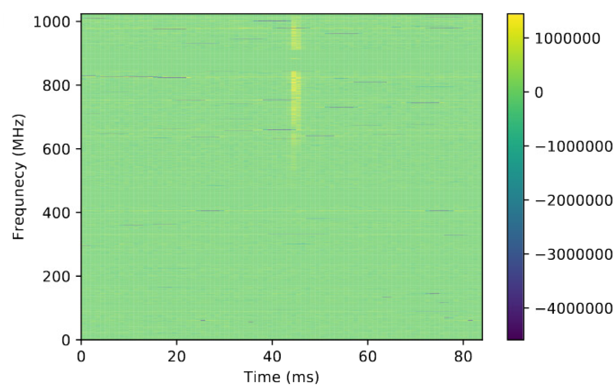

Fig. 2: Corrected Intensity of FRB event 71784510

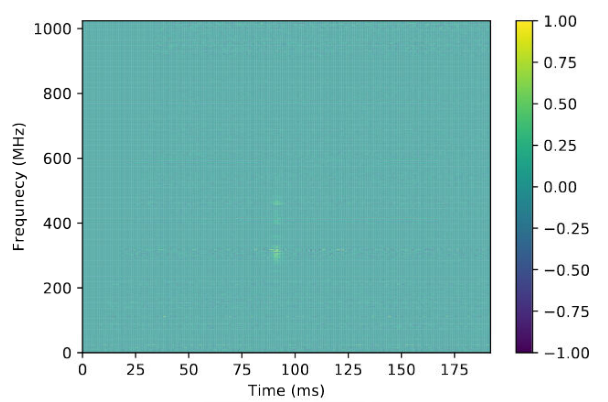

Fig. 3: Intensity of FRB event 20425523

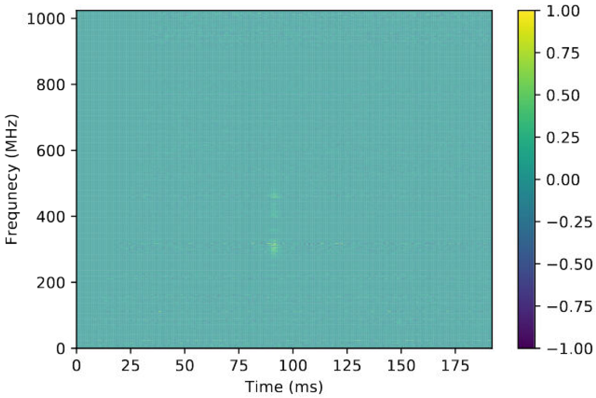

Fig. 4: Corrected Intensity of FRB event 20425523

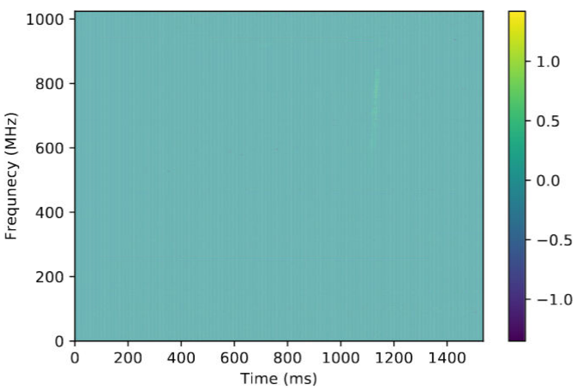

Fig. 5: Intensity of FRB event 23491522

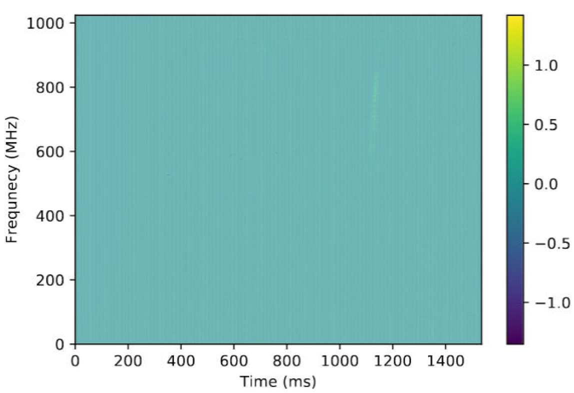

Fig. 6: Corrected Intensity of FRB event 23491522

III. Analysis

The FRB event from R3 with the highest SNR was 71784510 and so is used an example for the code. Figure 1 is the intensity of the spectra of the event before taking into account sensitivity and figure 2 is the corrected spectra using the Beam Model. The contour plots have axes of time and frequency where the milisecond FRB can be seen to have a spectra ranging from approximately 600-1000 MHZ.

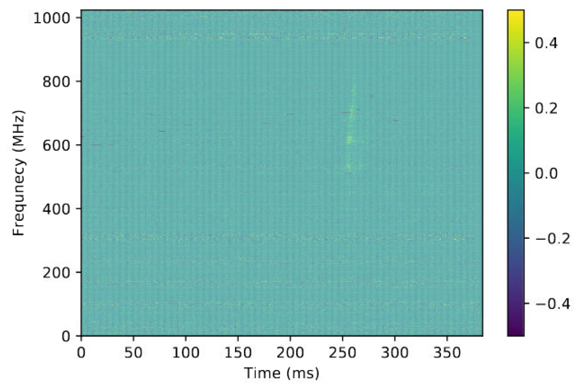

Fig. 7: Intensity of FRB event 23588210

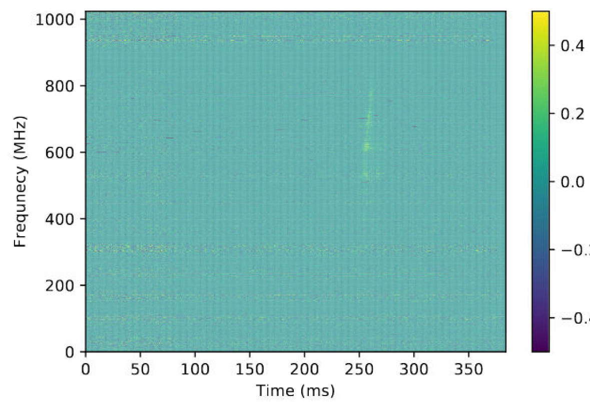

Fig. 8: Corrected Intensity of FRB event 23588210

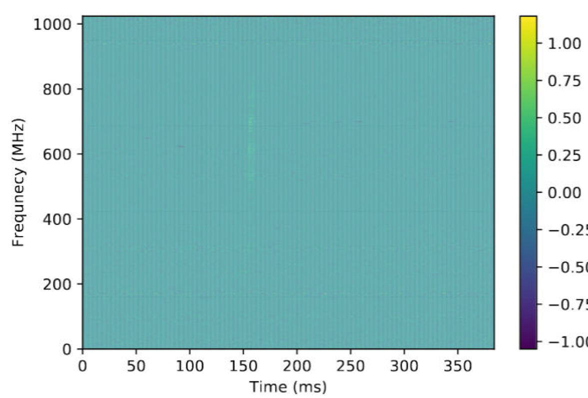

Fig. 9: Intensity of FRB event 40363754

IV. Source Code

Source code for example FRB event 71784510 corrected for sensitivity of CHIME is available in at `https://dineend@github.com/dineend/CTA200.git`

References

1] CHIME. Beam model. CHIME FRB Collaboration.

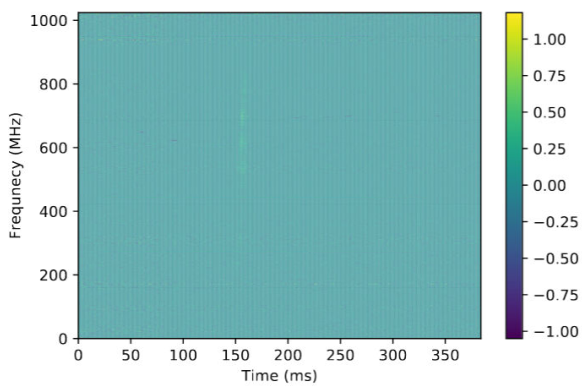

Fig. 10: Corrected Intensity of FRB event 40363754

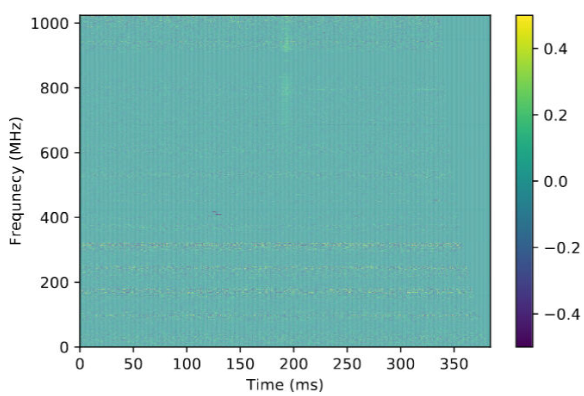

Fig. 11: Intensity of FRB event 83984528

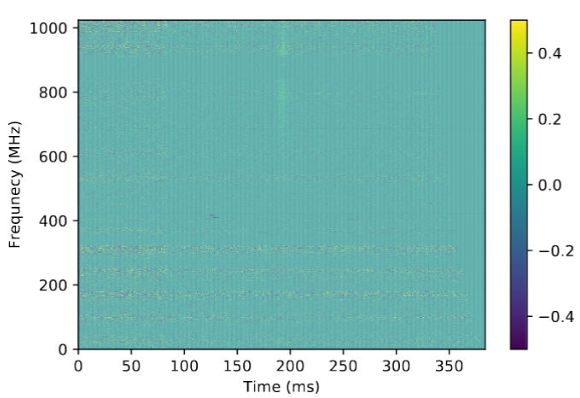

Fig. 12: Corrected Intensity of FRB event 83984528