Time Frequency Analysis of RF data of the Vela Pulsar recieved at the Ooty Radio Telescope

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Abstract

In this article, the procedure to conduct the time-frequency analysis of data recieved from distant pulsars, such as the Vela pulsar is explored. Problems that are encountered and solutions to these problems are are also mentioned.

1 The Vela Pulsar

The Vela Pulsar (PSR J0835-4510 or PSR B0833-45) is a radio, optical, X-ray- and gamma-emitting pulsar associated with the Vela Supernova Remnant in the constellation of Vela. For most studies on pulsars, the Vela pulsar is chosen as a standard mainly because of its typical characteristics and its almost unmatched brightness across the electromagnetic spectrum. For the analysis described in this article, the data was recorded at the Ooty Radio Telescope situated in the southern Indian state of Tamil Nadu.

2 Time Frequency Analysis

To understand the characteristics of the Vela pulsar, a visual representation is considered to be the most intuitive. Therefore, the author seeks to pictorally represent the variation of frequencies with respect to time. The calculation of the frequencies with respect to time is done as follows.

Result: Time-Frequency data
Start with first 512 data points
while $time<m$ **do**
  1) Find DFT of the data points
  2) Take absolute values of the DFT to get the magnitude spectrum
  3) Choose only the positive frequencies and ignore the negative frequencies
  4) Add this data as a new column of the time-frequency matrix
  5) Consider next 512 points
end

Algorithm 1: Algorithm to obtain the time-frequency data from time only values

Figure 1: The Vela Pulsar- image from Wikipedia

Now that this data has been obtained, an issue arises. The time resolution isn't good enough to physically see the pulses in the image. To avoid this problem, a grouping of data has to be performed.

3 Time resolution correction

In the matrix obtained in the previous section, the data collected has to be grouped together to obtain satisfactory results. This is done by considering every N columns of data and calculating its mean or average value and displaying only the average column instead of the original data. This data is more easy to visualise. For the experiment done, the ideal value of N was found to be around 60.

4 The Program

This is the program used to perform all the calculations and obtain the time-frequency data

```
data = dlmread('1',' ',0,0); #Read the data
i = 1;
j = i+511;
#Only first column, which is the data from the northern
#array of the Ooty Radio Telescope
sdata = data(:,1);
fdata = [];
while j < length(sdata)
i
fflush(stdout)
temp_data = sdata(i:j);
trdata = abs(fft(temp_data));
trdata = trdata(1:256);
fdata = [fdata trdata];
i = i+512;
j = j+512;
end
%Magnitude spectrum found for every 512 samples
%However, the time resolution isn't good enough to notice
%anything in the beginning.
%So, combine every time_res samples
%and average it to get a better resolution spectrum to be viewed visually
time_res = 60;
adata = [];
i = 1;
while i < 58000
```

```
    tempdata = zeros(256,1);
    for j = i:i+time_res
      tempdata = tempdata + fdata(:,j);
    end
    tempdata = tempdata/time_res;
    adata = [adata tempdata];
    i = i+time_res;
end
%To visually view this time-frequency data, use imagesc
imagesc(adata);

%Note: This code has been tested on GNU Octave only.
%Due to some syntax issues, it's possible that this may not run
%on MATLAB. The logic is not flawed.
 So, in case of errors, make sure the code matches the latest syntax on
%the platform of your choice
```

This program yields the following result-

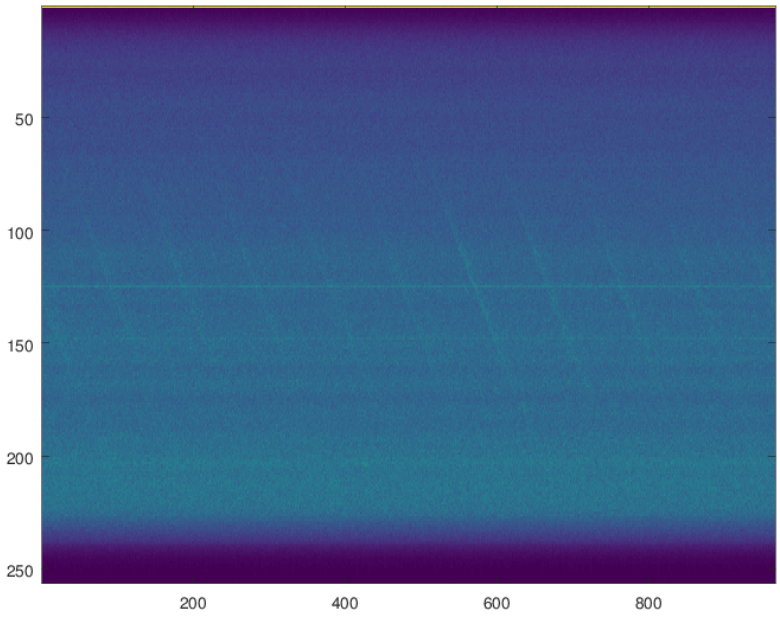

Figure 2: Vela pulsar's time frequency plot

5 Results

From the above image, it is clearly seen that there are over 10 streaks that represent pulses emitted by the Vela pulsar. As the original data used here was recorded over a time duration of 1 second, it can be concluded that the Vela pulsar emits pulses at a rate of over $10 pulses/s$.

6 Conclusion

I thank the Raman Research Institute, Bangalore, India for providing me with the data obtained from the Ooty Radio Telescope. But more importantly, I thank the universe for providing such astounding phenomena that allows us to look up at the sky and enjoy its beauty and features. I hope that this article is useful to those entering both the world of astronomy and the world of signal processing.