Background Study on MeerKAT SETI Search

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1 Introduction

In the universe, numerous signals are in the form of electromagnetic(EM) waves, such as communication signals, These signals are strongly coherent, which means the power spectrum of such signals would be a narrow band. However, these signals will show a drift rate with respect to time, when detecting, due to Doppler effect. Therefore, Search for Extraterrestrial Intelligence(SETI) is a research based on analyzing the drift rate to seek possible transmitter signals from exoplanets. Currently, The research is being conducted on MeerKAT. It is a large radio telescope array focusing, which mainly detects two bands of signals - one is 856-1712MHz and another is 544-1088MHz. In this report, it is primarily centered on the basic understanding of SETI.

2 Theory

In order to conclude all the possible signals, maximum drift rate is the foremost variables studied. To calculate the maximum drift rate, there are four dominant factors: 1.Rotational acceleration of Earth 2.Orbital acceleration of Earth 3.Rotational acceleration of the observed object 4.Orbital acceleration of the observed object Based on the above, the maximum drift rate is given by,

$$\dot{f} = \frac{f_{rest}}{c}(\frac{4\pi^2 R_\oplus}{P^2_{rot,\oplus}} + \frac{4\pi^2 R}{P^2_{rot}} + \frac{GM_\odot}{r^2_\oplus} + \frac{GM}{r^2}) \tag{1}$$

where f_{rest} is the minimal detectable frequency, r and $r_\oplus$ are the orbital radius of the observed object and Earth, R and $R_\oplus$ are the radii of the observed object and Earth, P_{rot} and $P_{rot,\oplus}$ are the rotation period of the observed object and Earth.[1]

3 Known Objects

By applying equation 1 to a few know objects,

Name	r_obs(km)	P_obs(day)	R_obs(km)	M_center(Kg)	drift_rate_1	drift_rate_2
Earth	6371.0	1.000	1.496e+08	1.989e+30	0.226125	0.143706
Moon	1737.1	27.322	3.844e+05	5.972e+24	0.120794	0.076767
Mercury	4880.0	58.646	5.791e+07	1.989e+30	0.226034	0.143648
Jupiter	69911.0	0.414	7.786e+11	1.989e+30	6.268084	3.983455
Io	1821.6	1.769	4.217e+05	1.898e+27	2.154424	1.369167
51 Pegasi b	135830.0	21.900	7.880e+06	2.208e+30	6.889148	4.378150
Tau Boötis b	11945.6	3.310	9.343e+11	2.765e+30	0.129515	0.082309
Beta Pic b	102070.1	0.338	1.376e+09	3.481e+30	13.595275	8.639988

Table 1: A few known objects and their drift rate under two different bands.

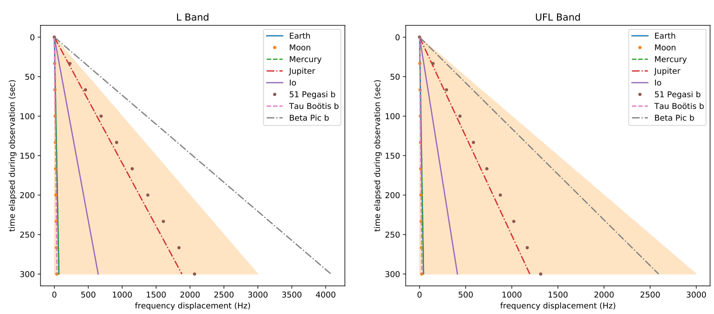

Figure 1: A simulation of 5 mins observation of narrow bandwidths for various drift rate, starting at $f_{rest} = 856MHz$(left) and $f_{rest} = 544MHz$(right). The shaded area is where the drift rate is 10Hz/s.

From fig.1, it is clearly that 10Hz/s of drift rate is not enough, even for known objects. The maximum drift rate during 5 mins for L band is 2.853 MHz/s, and for UFL band is 1.813 MHz/s.

4 Voyager

Voyager has collected a significantly large amount of signals. Here are two plots of time and power with respect to a range of frequency from 8418.457034043968 MHz to 8421.38671875 MHz

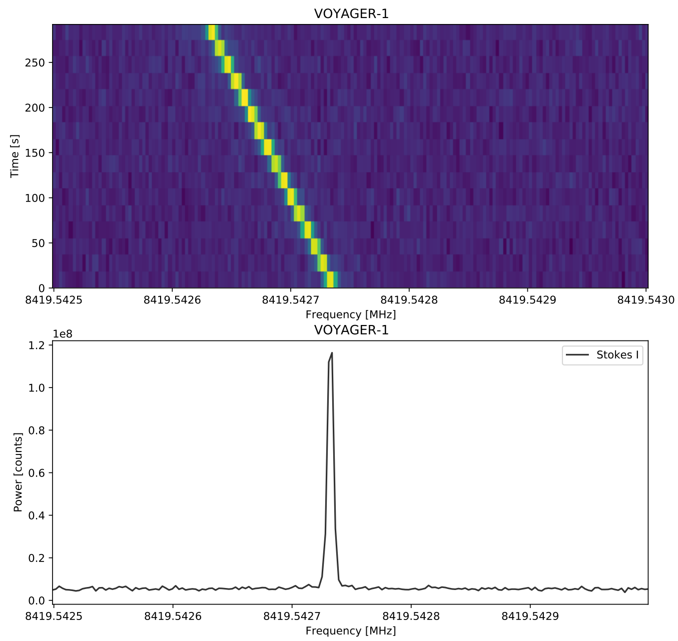

Figure 2: The collected data from voyager from 8418.457034043968 MHz to 8421.38671875 MHz. The figure above is the time elapsed vs frequency, and the figure below is the power vs frequency.

In Sheikh et al., it was suggested that above 200nHz of normalized drift rate is worth further study. From this range of frequency. The drift rate 0.363527 Hz/s. If MeerKAT is used, the normalized drift rate is 0.425 nHz for L band and 0.668 nHz. MeerKAT won't detect such signal because it exceeds the bandwidth. It is not compatible with what Sheikh et al. range.

5 Extension

Due to the lack of access to off-satellite MeerKAT observation data, there is only the power spectrum plot of the on-satellite data.

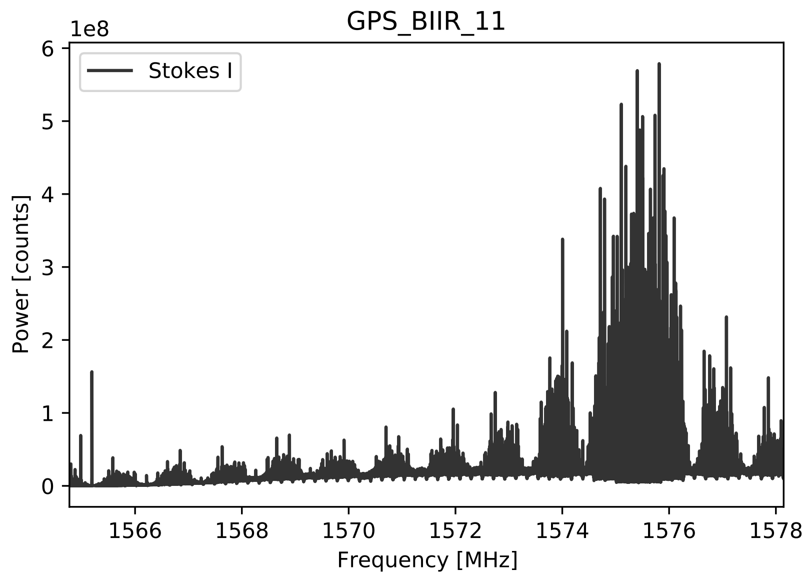

Figure 3: On-satellite signal power spectrum from MeerKAT.

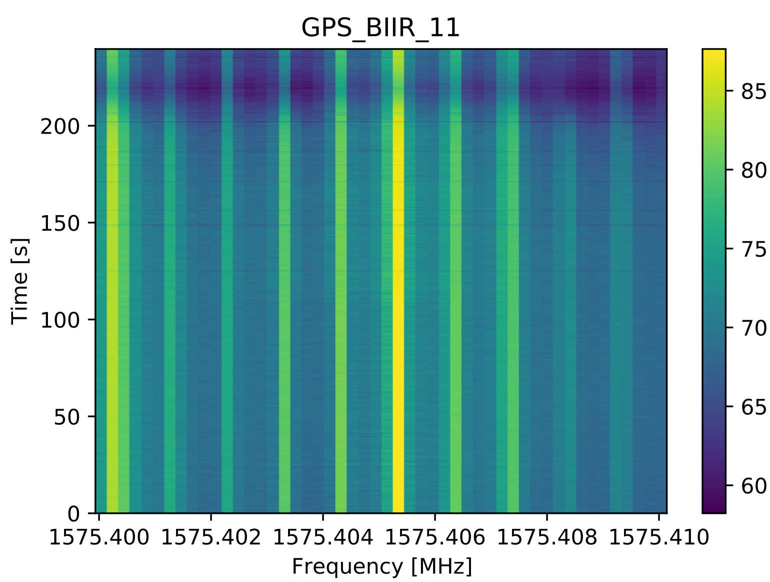

Figure 4: On-satellite signal waterfall from MeerKAT.

The drift rate for this satellite signal is significantly small to be recognized. The frequency at 1575.4055MHz is most likely to be compromised by Radio Frequency Interference

References

[1] Sofia Z. Sheikh, Jason T. Wright, Andrew Siemion, and J. Emilio Enriquez. Choosing a Maximum Drift Rate in a SETI Search: Astrophysical Considerations. , 884(1):14, October 2019.