URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

The Impact of GPS satellites in Radio Astronomy

Isaac Sihlangu*(1)(2)
(1) South African Radio Astronomy Observatory, Cape Town, South Africa
(2) Department of Physics and Electronics, Rhodes University, P.O. Box 94, Makhanda 6140, South Africa

Radio Astronomy is a branch of astronomy that focuses on celestial objects that emit electromagnetic radiation in the radio part of the spectrum. Historical radio astronomy has been haunted by Radio Frequency Interference (RFI). These RFI signals are defined as any signal that the telescope will receive that is not from astronomical sources. The RFI signals are generated from man-made electronics such as a television, microwave, cellphone, car engines as well as any device that emits radio signals.

The current generation of telescopes such as MeerKAT and the upcoming Square Kilometre Array (SKA) will observe the sky with unprecedented details due to their magnificent sensitivity to pick faint signals. The increased sensitivity of radio telescopes is also a curse because that means picking up more faint man-made signals. Thus, astronomers, governments, communities and industries must work together to protect the radio astronomy sites such that valuable and integrity research can be conducted. Over, the years' astronomers have developed sophisticated techniques and methods to mitigate the impact of RFI in astronomical data. However, little has been done to understand the nature and evolution of RFI over astronomy sites.

In this work, we looked at the impact of the Global Positioning System (GPS) on radio astronomy data. The Global Positioning System is currently a system of 31 satellites that uses triangulation techniques to accurately pinpoint the geographical location of the users anywhere on Earth. The GPS satellites transmit radio signals to the GPS receiver (e.g cellphones, car GPS devices). At least five to eight satellites should be detected by the receiver at any position on earth at any one time to accurately determine the position of the receiver. We carried out the analysis on the MeerKAT L-band (856 - 1712 MHz) data using the Karoo Array Historical Probability of RFI (KATHPRFI) framework. The KATHPRFI is designed to aid to understand the nature and evolution of RFI over radio astronomy sites [1].

The radio signals from GPS satellites are subdivided into multiple ranges of frequencies from L1 to L5. All the GPS satellites broadcast at the two frequencies L1 and L2 has a bandwidth of 15.3 MHz and 11 MHz, with a central frequency of 1575.4 MHz and 1227.6 MHZ respectively. The L3 band has a central frequency of 1381.05 MHz and is used by the United States to detect Nuclear Detonation (NUDET) and has a bandwidth of 10 MHz. The L4 band is utilised for ionospheric studies and has a central frequency of 1379.9 MHz and spans 10 MHz of bandwidth. The L5 band has a central frequency of 1176.5 MHz with a bandwidth of 12.5 MHz.

One will expect that everywhere you are on Earth, you should be able to receive signals from at least four GPS satellites. As a result, we expect all the MeerKAT antennas to pick up the GPS signals at all times. We noticed that the distribution of the RFI probability for the L1, L2 and the L5 band is fairly smeared overall directions as compared to the L3 and L3 which are quite moderated over the site, we see a hot spot at lower Elevation (10◦ - 20◦) and Azimuth of 270◦. We also note that the RFI detected from the L5 band is almost constant in all directions with an average of approximately 80%.

One can expect to see a fairly constant RFI occupancy as a function of the time of the day. This is because, at all times, all antennas will at least pick GPS satellites in the main or sidelobes. We found that the L1, L2 and L5 bands have similar RFI occupancy distribution. Furthermore, the L3 and L4 have almost identical RFI occupancy distribution, this may be due to the overlapping of frequencies of the two bands. Collectively, when looking at the 68% confidence level the variation that we are observing of the RFI occupancy as a function of time is negligible. Hence, on this basis, we conclude that indeed the GPS emissions are constant over time.

References

[1] Isaac Sihlangu, Nadeem Oozeer, and Bruce A. Bassett, "Multi-dimensional radio frequency interference framework for characterizing radio astronomy observatories," Journal of Astronomical Telescopes, Instruments, and Systems, October 2021, doi: 10.1117/1.JATIS.8.1.011003.