Evaluation of Techniques to Better Separate and Utilize Astronomical Radio Telescope Signals from those Due to Disturbances in the Ionosphere

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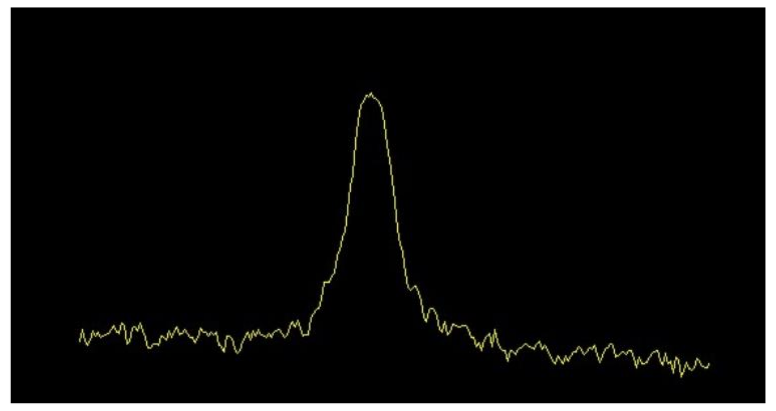
Abstract

Ionospheric disturbances impact radio signals that travel through them. These ionospheric scintillations are observed across the electromagnetic spectrum using a variety of methods. Previous studies have demonstrated that signals from radio telescopes can be used to measure and track these disturbances. Furthermore, a recent study suggests the separation of signals may be enhanced by concurrent measurements of ionospheric disturbances by multiple techniques and at different frequencies. This study discusses how astronomical and ionospheric signals from radio telescopes have been separated, how that separation might be improved by combining radio-telescope data with data from an alternate measurement methods and how ionospheric signals might be used to characterize ionospheric variability over both long- and short-term time scales.

Introduction

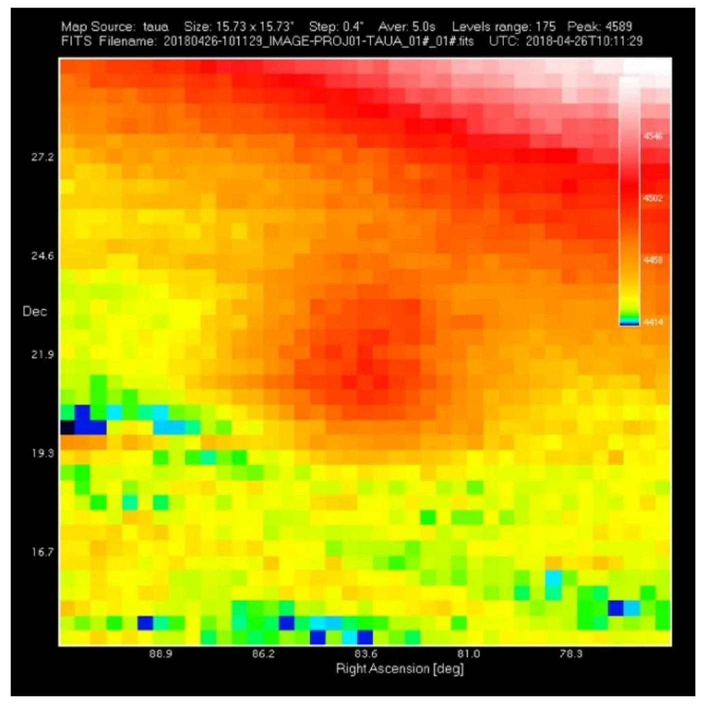
Atmospheric disturbances have long been observed to impact the electromagnetic radiation that traverse them. For example, twinkling of stars has been attributed to these disturbances. Disturbances in the ionosphere that interfere with incoming signals such as GNSS signals or radio telescope signals are referred to as ionospheric scintillations. The effect of scintillations on incoming signals have been modeled to mitigate their effect on incoming signals, and those models have been used to estimate and correct for these effects on distributed receiver systems. These models have also been used to estimate the impact of scintillations on outgoing signals. It has been shown that the effect of scintillations on a signal can be utilized to characterize these disturbances. The theory to understand these scintillations is well developed and has also been extended to investigate the cause of these scintillations using radio telescopes operating between 1 and 2 GHz(1) . The information scintillations can provide on disturbances has been used to investigate the atmosphere on other planets(2). LOFAR radio telescopes have also been used to track these disturbances based on the ability to draw upon a large number of gound based recievers spread out over a wide geographical range (3). With the data obtained from multiple probes operating at multiple frequencies and using multiple techniques is becoming available, the methods suggested by Aol, et.al., to correlate this data to build a much more relatable data set where direct measurements (for example using the Langmuir probes based on the ESA Swarm constellation of satellites to directly measure the ionosphere, and comparing that data to ground based receivers detecting scintillations from the same ionospheric disturbances) provide a much more detailed and complete picture of a layered and complex ionospheric environment. Similar to the LOFAR distributed network of receivers, Frissell, et al, report that similar observations of traveling ionospheric disturbances can be detected using automated amateur radio receiving networks.



A signal taken with the University of Scranton's radio telescope (1420 MHz with a frequency spread shown hereof +/- 600 kHz)

Methodology

In this study we describe a method where a comparison will be made between radio telescope signals from strong astronomical sources will be compared with lower frequency signals from those same astronomical sources. These signals will be analyzed for scintillations using both power spectrum analysis techniques typically used for lower frequencies and calculation of approximated S4 parameters for high frequency signals. Scintillation data obtained from these signals will then be compared to scintillation data obtained from more traditional sources such as ground based GPSS receivers or SuperDARN radar. This study seeks to provide an avenue for the participation of a broader range of participants in the study of ionospheric disturbances through the dissemination of techniques to integrate multiple receivers over large distances to contribute to the overall data available on the ionosphere. Many times, radio telescopes are operated at the limits of their sensitivity. Note this image taken of Taurus A using a SPIDER radio telescope system by RADIO2SPACE. It is possible that these techniques allow for higher resolution measurements to be taken with a broader range of equipment.



Conclusion

Radio telescopes could routinely add to the data currently being collected on atmospheric disturbances. This data can be used to help verify and extend the atmospheric data set being used to confirm the global atmospheric models needed to improve the accuracy of GNSS systems and to increase the value of the data obtained from distributed telescopes. The techniques developed for this study could assist in setting up the automated mining of historical data from radio telescopes so that they might provide additional data to form a long-term picture of these ionospheric atmospheric disturbances. Finally, collecting data on ionospheric scintillations across multiple frequencies and using multiple may provide an empirical mechanism to improve the signal to noise data from radio telescopes to measure better

References

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