Realtime Geospatial Spectrum Sharing between Earth Exploration Satellite Services and Communication Networks via Geofencing of co-operative 5G/6G transmitters

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Abstract—**Real-time Geo-fencing for Spectrum Sharing (RGSS) is a dynamic, software driven spatiotemporal sharing mechanism which utilises the orbital motion of the EESS satellites relative to the ground, and the rotational motion of the instrument scan-head; in order to automatically schedule cessation of interfering transmissions by co-operative terrestrial 5G/6G networks, during "dark times". Statistics of the "dark time" periods, for a chosen location within the contiguous US, incorporating – inter alia – duration, and period of recurrence – across all currently operational satellite radiometers; and a demonstration of the RGSS via a web-based API front-end are presented.**

Keywords—Geofencing; Microwave radiometry; satellite orbit prediction; styling;

I. BACKGROUND

Global weather forecasting utilises complex Numerical Weather Prediction (NWP) models, instantiated and periodically corrected by empirical observations of the state (and dynamics) of the atmosphere obtained from various remote, and in-situ sensing platforms. Among these, microwave remote sensing observations of water vapour [1], and the atmospheric vertical temperature profile, contribute to the largest decreases in forecast error[2]. These are obtained by satellite-borne passive microwave sounders, which perform total power measurements in various frequency channels, and deliver radiometric brightness temperatures as their raw data product. One of the channels used for ascertaining water vapour burden[3] is the 23.6 GHz – 24 GHz Earth Exploration Satellite Service (EESS) passive band (shared with Radio Astronomy, and Space Research)[4], which is situated close to the NR FR2 n258 band (24.25 – 27.50 GHz) used by terrestrial 5G networks[5]. The NEΔT (Noise Equivalent Delta Temperature) – a measure of the sensitivity – of the ATMS (Advanced Technology Microwave Sounder) is *only* 0.25 K, at 23.8 GHz[3] and thus EESS measurements are prone to the adjacent channel interference caused by upwelling terrestrial 5G/6G transmissions. Furthermore, disentangling individual contributions to brightness temperatures by the different components of the atmosphere – requires simultaneous observations in multiple frequency bands. Therefore, data corruption due to radio-frequency interference (RFI) in one frequency band imperils data collected at other bands, amplifying the problem. The financial impact of degraded forecasts alone, have been estimated at ~$200M annually[6]. Coupled to the fact that current regulations on transmission power limits, impose an opportunity cost on telecommunication service providers (since they are derived from obsolete Monte Carlo approximations of network deployment, and compliance with a *static*, 'worst case scenario'[7]), the loss to the economy is significantly higher.

II. SYSTEM DESCRIPTION

Real-time Geo-fencing for Spectrum Sharing (RGSS) is a *dynamic* spatiotemporal sharing mechanism which utilises the orbital motion of the EESS satellites relative to the ground, and the rotational motion of the instrument scan-head; in order to automatically schedule cessation of interfering transmissions by co-operative terrestrial 5G/6G networks. This software solution utilises – *(i)* Two Line Element (TLE) data for the ~20 orbital radiometers[8] with orbital propagation[9] to predict satellite position, and *(ii)* geo-referenced and time-stamped satellite operator data to predict instrument attitude – as functions of time. In concert with the published radiometer antenna specifications, a subroutine computes the region of sensitivity of a radiometer, and its intersection with the Earth's surface – termed a pixel. A database of these geo-referenced and time-stamped pixels is constructed, and queried by a 5G/6G network operator's Network Management System (NMS), to derive a list of "dark times"[10] advised for a particular fixed base station – when the network performs implements one or more of the following schemes to mitigate interference: (a) turning off temporarily (b) moving traffic to a different band, or (c) lowering transmit power (d) beamforming, etc. It is to be noted that (a) would result in a *complete*[11] avoidance of interference to the radiometers, while still achieving >99% network availability[7]. Conversely, the incentive for the network providers is the ability to operate with more power (and therefore more data bandwidth, more users and hence more revenue) for a majority of the time. RGSS is also built to easily incorporate antenna sidelobes; terrain, and elevation data – e.g. Digital Elevation Maps (DEMs), in the computation of pixels – facilitating the integration of ray tracing based mm-wave propagation models, which can increase the accuracy of link budgets for aggregate interference at the satellite, due to non-line-of-sight (NLOS) propagation via diffraction, and multipath reflections[12]. Present work on experimental verification of RGSS via the use of an "RF-Flashlight Test-bed" – at the Hat Creek Radio Observatory (HCRO), a prototype **National Radio Dynamic Zone (NRDZ)** is ongoing. This will use RGSS, and a controlled 5G/6G transmitter to deliberately cause "do-no-harm" interference (to spare orbital assets, for instance), and verify compliance, for overlapping pixels. Experimental validation of the mm-wave propagation models by this test-bed, will, in turn enable more precise physical channel characterisation via remote sensing: both of which could facilitate more effective RFI excision from Radio Astronomy signal processing pipelines. Statistics of the "dark time" periods – duration, and frequency – across all currently operational satellite radiometers; and a demonstration of the RGSS via a web-based API front-end are presented.

A. *Figures*

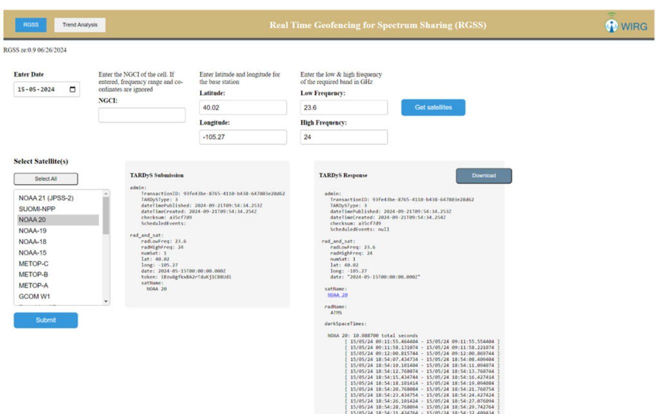

Figure 1. A Screenshot of the RGSS Web-based User Interface

Figure 2. Radiometer pixels and satellite ground track plotted against a geographical map (Mercator projection)

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[10] Nomenclature is an analogue of terrestrial spectrum sharing with "TV whitespace"

[11] There would still be the radiation from the UEs (User Equipments), but it is conceivable to have an extension of this RGSS framework that uses the network itself to instruct registered UEs to also cease transmissions during dark times

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