Guest Editorial
Wireless for Space and Extreme Environments

I. Editorial Overview

SPACEFLIGHT involves critical sensing and communication in extreme environments such as planetary surfaces, space vehicles, and space habitats. The many challenges faced in space sensing and communication are extremely diverse and overlap significantly with those found in many terrestrial examples of extreme environments such as extreme hot or cold locations, extreme high- or low-pressure environments, critical control loops in aircraft and nuclear power plants, high-speed rotating equipment, oil/gas pipelines and platforms, etc. All of these environments pose significant challenges for radio-frequency or optical wireless sensing and communication and will require the application of a broad range of state of the art technologies in order to generate reliable and cost effective solutions. Although the specific challenges vary significantly from the environment to environment, many of the solutions offered by sensing, communication, and statistical signal processing technologies can be applied in multiple environments, and researchers focusing on space applications can benefit greatly from understanding the problems encountered and solutions applied in alternative environments.

This special issue includes invited papers from the 9^{th} IEEE International Conference on Wireless for Space and Extreme Environments (WiSEE),[1] which was organized by NASA GRC in Cleveland, OH, USA and hosted virtually by the University of Maine. Topics ranging from autonomous and connected vehicles in extreme environments to Machine learning, sensing, cognitive networks are covered across 12 accepted articles.

Utilizing drones in extending wireless access coverage or monitoring crowd is becoming increasingly complex. With their limited power, often a drone from a swarm may need to be replaced with another one or some times multiple swarms may need to merge. In all these scenarios, the need for authentication and handover becomes prudent. You can read more about this topic in [A1]. One of the important contributions of this paper is significantly lower required authentication time as compared to 5G standard enabling faster and more reliable next generation secure wireless networking. In addition to drones, any connected vehicle link quality in general can suffer from dust and sand. The wireless link degradation becomes even more notable at higher frequencies such as mm-waves used in 5G and next generation communication systems. Mie scattering model is utilized in [A2] to estimate the free space loss of a region affected by sand and dust. Various link types have been compared in this paper.

Another interesting paper in this special issue presents a bagged tree model to detect phase scintillation in high latitudes, and creates a database for Ionospheric scintillation using machine learning. The proposed method is compared with SVM, k-NN as well as few other decision tree models. For more information see [A3].

In-orbit observers can play a critical role in tracking satellites, space debris, and other objects. While custom mission oriented satellites can be used for this purpose, it is worth looking at the possibility of using existing sensor technologies that can provide range measurements and leverage existing resources. Interesting insight on range measurement for this purpose is presented in [A4].

Extending the wireless sensing in space from narrowband to ultra wideband impulse radios can significantly improve ranging accuracy, and communication bandwidth. Sensors used in body area networks are discussed in [A5]. Both hardware and software concepts are discussed and new applications are outlined for future space missions. NASA's new concept of Lunar communication, LunaNet, with challenges such as scalability, interoperability and reliability are discussed in [A6]. The proposed use of machine learning for routine tasks such as scheduling and network management and automated decision making can reduce human error in such systems. Use of cognitive multi-agent system in this work promised to optimized the future LunaNet. Another challenge on the surface of moon is multipath fading, which is covered in [A7] including an analysis of this problem using map partitioning.

One of the major challenges in low earth orbit missions is the effect of radiation, especially during Geomagnetic storms. The single event upset rates of a LEO mission in the south Atlantic anomaly is studied in [A8].

Backscatter sensors are gaining more popularity in a variety of extreme environment applications due to their battery-free operation. Combining an RFIC, an antenna, and any sensing device such as MEMS can create a usable backscatter sensor. Some results on an over the air sub-carrier allocation scheme are presented in [A9]. This system is implemented on a software defined radio. Energy harvesting tags operate similarly and deal with same challenges. Another angle on this interesting application line of battery-free sensors is discussed next in [A10]. Connectivity of sensor networks is studied using Q-learning in [A11]. This method has been verified for underwater networks using simulation.

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[1]WiSEE conference series is sponsored by IEEE R1, R7, and CRFID as well local IEEE section hosting the event.

This special issue concludes with [A12] that reviews requirements for artificial gravity for long term space missions. The OneMars article follows the systems of systems approach and shows how early detection of weaknesses using this approach can help with the success of the mission.

In conclusion, I would like to thank all the authors of these interesting papers, the reviewers who helped improve the quality of the presentations and the JRFID editorial office for managing this special issue.

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APPENDIX: RELATED ARTICLES

[A1] Y. Aydin, G. K. Kurt, E. Ozdemir, and H. Yanikomeroglu, "Authentication and handover challenges and methods for drone swarms," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 220-228, 2022.

[A2] E. Abuhdima *et al.*, "Impact of dust and sand on 5G communications for connected vehicles applications," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 229-239, 2022.

[A3] M. Bals, C. Thakrar, and K. B. Deshpande, "Creating a database to identify high-latitude scintillation signatures with unsupervised machine learning," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 240-249, 2022.

[A4] M. Driedger, A. Asgari, and P. Ferguson, "Feasibility of gathering resident space object range measurements using in-orbit observers," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 250-257, 2022.

[A5] M. Drobczyk *et al.*, "A wireless communication network with a ballistocardiography experiment on the ISS: Scenario, components and pre-flight demonstration," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 258-268, 2022.

[A6] R. Dudukovich *et al.*, "Towards the development of a multi-agent cognitive networking system for the lunar environment," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 269-283, 2022.

[A7] R. C. Toonen, S. L. Booth, B. W. Welch, and M. J. Zemba, "Optimizing lunar map partitioning for multipath fade loss analyses," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 284-291, 2022.

[A8] K. M. Girgis, T. Hada, S. Matsukiyo, and A. Yoshikawa, "Radiation analysis of LEO mission in the south atlantic anomaly during geomagnetic storm," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 292-298, 2022.

[A9] J, Mitsugi, O. Tokumasu, and Y. Kawakita, "Wireless modal testing with multiple battery-free backscatter sensors," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 299-306, 2022.

[A10] C. Qi *et al.*, "A 5.8 GHz sensor-fusion energy-harvesting tag for sensing applications in space," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 307-317, 2022.

[A11] S. Blouin, M. Babahaji, H. Mahboubi, W. Lucia, M. M. Asadi, and A. G. Aghdam, "Estimation of the connectivity of random graphs through *Q*-learning techniques," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 318-331, 2022.

[A12] R. N. Schmitt, A. B. B. Bertaglia, G. J. Rosa, N. R. Moscati, D. F. M. Moreira, and G. Loureiro, "OneMars: Requirements for a artificial gravity in a spacecraft for transportation of a crew to mars," *IEEE J. Radio Freq. Identificat.*, vol. 6, pp. 332-346, 2022.