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Remediation of Radiation Belt Energetic Particle Populations with Ionospheric Amplification of EMIC and Whistler Mode Waves

Paul A Bernhardt[(1)], Man Hua[(2)], Jacob Bortnik[(2)], Qianli Ma[(3)], Vijay Harid[(4)], Mark Golkowski(4), Andrew D. Howarth[(5)], Carl L. Seifring[(6)]

(1) University of Alaska, Fairbanks, Alaska, USA
(2) University of California Los Angeles, Atmospheric and Oceanic Sciences, Los Angeles, CA, USA
(3) Boston University, Boston, MA, USA, (4) University of Colorado Denver, Denver, CO, USA
(5) Andrew David Howarth, University of Calgary, Calgary, AB, Canada
(6) Plasma Physics Division, Naval Research Laboratory, Washington, DC USA

Large amplitude (300 to 1000 pT) whistlers generated by controlled amplification of existing ELF and VLF sources are sufficient for localized reductions of the energetic particle population in the radiation belts after a few minutes rather than the multi-day periods it would take naturally. Lightning and dedicated submarine transmitters can launch ELF waves that excite the EMIC mode below the ion cyclotron frequency in the magnetosphere. Ground-based VLF transmitters located around the world generate signals that leak through the bottom side of the ionosphere in the form of whistler mode waves. Both the EMIC and Whistler waves can scatter trapped energetic electrons and ions into low pitch angle orbits resulting in enhanced particle precipitation and absorption in the lower atmosphere. This energetic electron loss process is greatly enhanced by intentional amplification of whistler waves in the ionosphere with a Parametric Amplifier pumped by artificial lower hybrid waves.

Such parametric amplification is driven by a Lower Hybrid (LH) wave pump that may be generated (1) by pickup ions from orbiting rocket motor burns or (2) with high power HF facilities such as HAARP in Alaska. Satellite measurements of WTWPA, using intense LH-pump oscillations found in spacecraft exhaust plumes, have shown between 30- and 50-dB intensification of whistler waves in space. The scattering of radiation-belt, energetic particles by amplified whistlers employs either the UCLA quasi-linear Fokker Planck model (QLFP) or the UCD Vlasov-Maxwell (V-M) model to compute the fluxes of precipitating electrons [Bernhardt et al., 2022]. The quasi-linear and non-linear wave-particle interaction approaches are examined for suitability to represent the impacts the intensified low-frequency EM waves on the space weather environment.

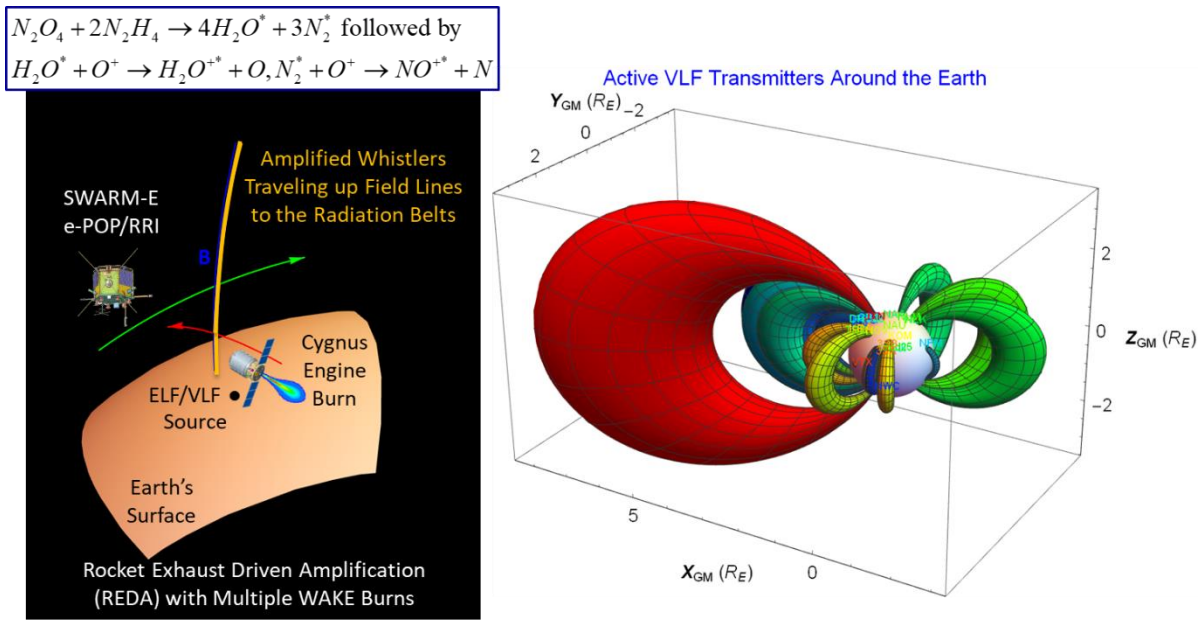

Figure 1. Rocket Exhaust Driven Amplification (REDA) yields 30 dB enhancements of EMIC and Whistler waves from ground sources (left) to interact with magnetic flux tubes (right) with trapped particle radiation.

Experimental demonstrations of ionospheric amplification by artificial lower hybrid waves are being planned with dedicated ion beams generated by rocket engine burns over ground transmitters and by HF stimulated emissions with ground transmissions of high-power HF waves. Participation in these experiments is solicited from the international community for providing exhaust injections from spacecraft servicing the International Space Station and for providing diagnostics of both EMIC/whistler wave amplification and enhanced particle fluxes by wave-particle interactions in the radiation belts. In addition, observations of enhanced D-regions and Bremsstrahlung x-rays from the precipitation are needed from ground based and near-earth sensors.

References

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