Highlights of Stanford University MURI Work During 2010

MURI Grant Sponsored by the Office of Naval Research

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Below we report progress on three of the major MURI topics addressed by Stanford University during the year 2010.

1. Precipitation of Energetic RB Electrons by VLF Waves.

- Starks et al. [2009] found that the input VLF transmitter signal intensity at low altitude is approximately 20 dB below that predicted by present models of VLF wave transionospheric propagation.
- This loss of intensity may be due to linear mode coupling as the transmitter signals scatter from small scale magnetic-field-aligned plasma density irregularities in the topside ionosphere [Bell et al., 2008; Faust et al., 2010].
- Given that VLF transmitter signals play a lesser role in precipitating radiation belt electrons than previously believed, there is a need to determine which other VLF wave type is responsible for the observed rates of energetic electron precipitation from the belts.
- One likely candidate is the VLF wave energy radiated by lightning discharges in the Earth's atmosphere.
- Erin Gemelos will report on this topic this afternoon.

2. VLF wave power loss due to linear mode coupling.

- During the past year we have completed an extensive study of the loss of electromagnetic VLF wave power due to linear mode coupling as the waves propagate through regions containing small scale (2-50 m) magnetic-field-aligned plasma density irregularities.

- A portion of this work is reported in a paper published in the Journal of Geophysical Research [Faust et al., 2010]. It was found that power losses up to 20 dB were possible during trans-ionospheric propagation, but smaller losses were more likely.

- One major difficulty in simulating the linear mode coupling mechanism is the fact that the spectral distribution of the small scale irregularities is very poorly known.

- For example, DEMETER measurements of the local plasma density provide a spatial resolution of $\simeq$ 7.5 km, whereas the required resolution is $\simeq$ 10 meters.

- Forrest Faust will report on this topic this afternoon.

3. Further Development of the Antenna in Plasma Code

- We have installed a super computer cluster whose main purpose will be to support simulations using the Stanford Antenna in Plasma (AIP) code.
- Funds to purchase the cluster were not supplied by ONR, but by another government agency. Thus the MURI program has been significantly leveraged through this acquistion.
- We need the super computer aspect, because with our previous computer resources a single simulation at relatively low driving voltages and reduced ion mass ratio would take approximately one month to complete.
- With the new cluster, a single simulation at intermediate voltage levels can be completed in a few days.
- We have now begun new simulations by increasing the applied voltage on the plasma immersed dipole antenna up to 5000 V, the maximum value envisioned for the DSX mission.
- We now use the true proton mass in the simulations, rather than the reduced mass introduced to speed the early simulations.
- Linhai Qiu will report this afternoon on our recent simulations using the new computer cluster.

Stanford Graduate Students Supported By MURI Grant

1. Tim Chevalier
2. Erin Gemelos
3. Forrest Faust
4. Kevin Graf
5. Linhai Qiu

Publications and Presentations Resulting from Stanford MURI Work

The Stanford MURI work has been very productive. So far, 6 peer reviewed publications have been generated, and at least 3 more will appear in 2011.

Publications

1. Bell, T. F., U.S.Inan, D. Piddyachyi, and P. Kulkarni, The Effects of Plasma Density Irregularities on the Pitch Angle Scattering of Radiation Belt Electrons by Signals from Ground Based VLF Transmitters, Geophysical Research Letters, 113, A09203, doi: 10.1029/2008JA013120, 2008.

2. Chevalier, T, W., U. S. Inan, and T. F. Bell, Terminal Impedance and Current Distribution of a VLF Electric Dipole in

the Inner Magnetosphere, IEEE Trans. Ant. Prop., 56, 2454, 2008.

3. Chevalier, T. W., U. S. Inan, and T. F. Bell, Fluid Simulation of the Collisionless Plasma Sheath Surrounding an Electric Dipole Antenna in the Inner Magnetosphere, Radio Science, 45, RS1010, doi: 10.1029/2008RS003843 2010.

4. Starks, M. J., T. F. Bell, R. A. Quinn, U. S. Inan, D. Piddyachyi, and M. Parrot, Modeling of Doppler - Shifted Terrestrial VLF Transmitter Signals Observed by DEMETER, Geophysical Research Letters, April, 2009.

5. Gemelos, E. S., U. S. Inan, M. Walt, M. Parrot, and J. A. Sauvaud, Seasonal dependence of energetic electron precipitation: Evidence for a global role of lightning, Geophysical Research Letters, doi: 10.1029/2009GL040396, 2009.

6. Foust, F. R., U. S. Inan, T. F. Bell, and N.G. Lehtinen, Quasi-electrostatic whistler mode wave excitation by linear scattering of EM whistler mode waves from magnetic field-aligned density irregularities, accepted for publication, Journal of Geophysical Research, August, 2010.

7. Bell, T. F., K. Graf, U. S. Inan, and D. Piddyachiy, The Propagation of Quasi-electrostatic Whistler Mode Waves Generated above the NWC VLF Transmitter, in preparation for Geophysical Research Letters, August, 2010.

Presentations

1. Bell, T. F., U. S. Inan, N. Lehtinen, K. Graf, and M. Parrot, Precipitation of Inner Belt Energetic Protons by Quasi-Electrostatic VLF Transmitter Signals Scattered by Plasma Density Irregularities, poster paper presented in Session SA03, San Francisco Fall AGU Meeting, December, 2008.

2. Piddyachyi, D., U. S. Inan, T. F. Bell, and M. Parrot, Characterization of the Ionosphere above the HAARP HF Heater using DEMETER Satellite Data, poster paper presented in Session SA03, San Francisco Fall AGU Meeting, December, 2008.

3. Piddyachiy, D., U. S. Inan, T. F. Bell, M. Cohen, and M. Parrot, Recent results of DEMETER satellite observations of HAARP generated HF and ELF waves, paper SA13A-1476, AGU Fall Meeting, San Francisco, 14-18 December, 2009.

4. Gemelos, E. S., U. S. Inan, M. Walt, M. Parrot, and J. A. Sauvaud, Seasonal dependence of energetic electron precipitation: Evidence for a global role of lightning, paper SM23A-1575, AGU Fall Meeting, San Francisco, 14-18 December, 2009.

5. K. Graf, Bell, T. F., D. Piddyachiy, U. S. Inan, and M. Parrot, DEMETER observations of Ionospheric Heating by Powerful VLF transmitters, paper SA33A-1758, AGU Fall Meeting, San Francisco, 13-17 December, 2010.

6. F. Faust, T. F. Bell, U. S. Inan, and N. G. Lehtinen, VLF Transmitter Signal Power Loss to Quasi-Electrostatic Whistler Mode Waves in Regions Containing Plasma Density Irregularities,

paper SA33A-1757, AGU Fall Meeting, San Francisco, 13-17 December, 2010.