The MIT Incoherent Scatter Performance Simulator (MIPS)

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Next generation Geospace Radar systems can be constructed using digital radio arrays in combination with appropriate transmitter systems. This leads to a radar architecture capable of a wide range of active and passive measurements of the Geospace environment. Such systems go beyond traditional incoherent scatter radars by incorporating aspects of modern low frequency astronomical radio arrays. If costs can be kept low enough, these designs make feasible the construction of a global network of systems capable of autonomous operation. This would provide wide scale, ground based measurements of fundamental physical parameters in the Geospace environment. Such measurements enable diverse scientific investigations from the lower atmosphere to the surface of the Sun. Investigations can also extend to the larger universe beyond for specific astronomical goals (e.g. fast transient searches).

Efficient application of the instrument to these diverse areas can be realized by a software based approach, with the benefit of tractability for support of a large scientific user base. In particular, an all-digital software radio technology can be combined with a cloud computing architecture and application specific software signal processing to implement specific instrument observation modes. In many cases, simultaneous measurements of multiple types are possible. We expect this approach will provide major advances in resolution, measurement speed, coverage, occupancy, consistency, and responsiveness over existing ground based radar instruments. A global network would enable significant advances in our physical understanding of the atmosphere, the space environment, the Sun, and the coupling between them by allowing targeted physical measurements of the critical regions in a manner ideal for system science studies.

For incoherent scatter radar (ISR) applications studying the near-Earth space environment, the instrument design parameter space for a modern Geospace Radar is very large. Particular areas of design freedom include transmitted waveforms (e.g. required bandwidth, center frequency, duty cycle), array configuration (e.g. element number and configuration), spatial diversity (monostatic vs. locally bistatic), receiver sensitivity tradeoffs, and power-aperture product choices (e.g. high power with few elements versus low power with many elements). The MIT Incoherent Scatter Performance Simulator (MIPS) has been recently developed in order to explore these design spaces. MIPS is a physics based radar performance model that incorporates first and second order effects and measurement statistics. The model is parameterized and allows straightforward optimization and design tradeoffs to be evaluated for IS radar performance metrics. We will describe the content of the MIPS model, how it can be applied, and give some evaluation examples that illuminate key criteria needed for cost effective Geospace Radar system designs.