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Ph.D. DISSERTATION DEFENSE

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Title: An Analysis of Spatial Adaptive Processing for Geo-location of Non-Uniform Distributed Sensors

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ABSTRACT

Radio frequency (RF) sensors must be able to geolocate themselves when collecting data, often in RF contested environments. One of the most common methods of geolocation is the Global Positioning System (GPS). Because GPS remains one of the most omnipresent, accurate, and affordable options for positioning, navigation, and timing (PNT), many users, sensors, or systems rely on a GPS receiver for PNT. However, the GPS signal from space is easily denied to unprotected users with relatively low jamming from malicious attackers. The most common type of protection used for GPS receivers is an anti-jam (AJ) antenna. AJ antennas can provide considerable protection to ensure users maintain access to the GPS signal from space, but will significantly increase the cost, size, and power consumption of the GPS receiver. To preserve the affordability, size, and power consumption of the GPS receiver, a different method of protection must be used. In many civilian and military applications, systems are becoming more networked providing possible means for alternate protection from this problem. In traditional spatial adaptive processing (SAP) applications for AJ antennas, there are both positive and negative impacts on downstream code phase signal processing estimation techniques used for geolocation and navigation. This also proves true for use of SAP in collaborative sensor positioning applications; however, the impacts are vastly different.

This research explores the use of SAP techniques to protect networked sensors or systems from adversarial denial of service attacks. The objective is to provide a comprehensive analysis of the potential benefits SAP can provide in some scenarios. The analysis includes the ability of SAP to suppress intended interference, the effect of applying SAP to the preservation of the signal of interest (SoI), and impacts of SAP on traditional navigation signal processing techniques. Using SAP on distributed sensors for collaborative positioning presents new and unique challenges. By investigating the benefits of SAP for a collaborative sensor group, new space and time distortions to signals must be characterized from combining observations from distributed locations. Random spacing and orientation of the sensor group relative to the SoI and threat

sources, asynchronous timing errors amongst the sensor group, and environmentally driven signal propagation fading are the primary causes for these distortions. The proposed solution will not apply to all applications and use cases, but has the potential to change the way protection of GPS (and other GNSS) type signals is done. If the challenges with using this type of a solution can be overcome, then it will advance collaborative positioning (and navigation) significantly for some applications including randomly distributed sensors or systems.

This first part of this dissertation provides a brief overview of SAP and code phase estimation signal processing techniques used for navigation, both of which are needed to analyze the proposed collaborative positioning solution. A brief description of the modeling and simulation environment used to perform the analysis is provided. Then lastly, the potential benefits of SAP for the proposed solution are characterized from a geospatial perspective only without timing or signal propagation fading errors. A positive result is one in which intentional interference is attenuated comparable to traditional AJ antennas, while the SoI is preserved.

The second part of this dissertation expands the analysis to include asynchronous clock error accumulation and environmental signal propagation fading effects across networked sensors. A brief discussion on measuring and characterizing clock errors, and signal propagation fading is provided. A unique clock model is developed that fits our analysis and applied to our existing model along with signal propagation fading effects. Lastly, we consider the impacts of these additional error sources to provide a comprehensive analysis of applying SAP to randomly distributed sensors.