# Radar Overload Regulation Using Intelligent Agents

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*Abstract*—**In a multifunction phased array radar, scheduler is designed to schedule worst case scenario and provide guaranteed performance in case of overload. Conventional radar having basic functions of either searching or tracking, can be optimized using standard optimization techniques. But for multi-function phased array radars, optimizing the radar's performance belongs to class of NP-complete problems [1]. This assumption demands that radar multiple functions needs to collaborate to conserve resources during under-load/normal load and collaborate during over-load to utilize conserved resources to enhance time before reaching overload condition. Simulation results have shown that at best 25% time can be conserved therefore reducing overload duration. There are specific scenarios with short load time where load is completely handled. Conservation overhead is in terms of intelligent agent's implementation and management.**

## I. Introduction

A multifunction phased array radar scheduler is designed to perform scheduling of search dwells for volumetric search along with other radar functions. Burst Plot (detection) return from these dwells is eligible candidate for confirmation & tracking if measured parameters are more than detection thresholds. Confirmations and tracking of confirmed targets can be managed using search dwells as in TWS (Track While Scan) radar. In such a case, scheduler will not be overloaded in terms of radar time irrespective of number of targets getting detected. But tracking of targets outside search volume can still demand radar time. In multifunction radar, confirmations and tracking need to be dedicated to guarantee initiation of track and continuous tracking. Cue from external C3I system can also demand radar time considerably. Objects emanating from target under track can also demand radar time. All these demands of radar time distributed temporally, can overload radar scheduler in different ways.

A radar scheduler, schedules dwells to provide fair radar resources of time and antenna space to all dwells. This fairness increases delay in scheduling of dwells during radar overload, in turn making more radar dwells (generated to ensure radar guaranteed performance of measurements) to compete radar resources. Based on the lifetime characteristics of load, radar load can be of short or long durations. In proposed technique of overload regulation, intelligent agents conserve radar resources in anticipated overload areas. Even when load increases, same agents reduce total load lifetime by making use of conserved resources and regulating under loaded and overloaded areas.

## II. Overload Characterization

Scheduler overloading can happen due to computation demand more than computational capability of scheduler. Computational demand in radar increases when multiple targets get detected in vicinity, target detection and tracking rate is higher as compared to target drop/loss rate and tracking of high resource demanding targets.

Radar load is cumulative relative delays of radar dwells from scan to scan. Relative delay of dwell is ratio of time taken to schedule dwell versus allocated time for schedule. Time taken to schedule is dependent on scheduling policy & dwell arrival pattern and is indicative of current load, scheduler is handling.

Radar load is dependent on rate of dwell arrival and dwell durations with constraints. Based on arrival rate, radar dwells can be temporally characterized into periodic (synchronous), asynchronous (soft deadline) and urgent (asynchronous firm deadline). Periodic dwell arrival rate is decided based on user selected frame time for search and predefined update rate selected for target. Asynchronous dwells arrive from external systems and do not follow predefined rate. Urgent dwells need radar time within bounded time. Load can be characterized into instantaneous (single and multiple instances) or gradual based on inter-arrival time.

Radar load can also be characterized based on spatial distribution into local or distributed. In case of local load, radar time demand will be from detections in vicinity of targets. Example of local load can be chaff, clutter and decoys. In case of distributed load, radar time demand will be from detections distributed spatially. Example of distributed load can be targets distributed spatially, false detections from different directions.

There exists dependency between spatial and temporal loads. Instantaneous load is generally localized and gradual load is generally distributed. Based on arrival pattern and inter-arrival time, radar load can be characterized into following;

**Single Instance Short Duration Overload (SSDO):** Due to search dwell resulting in detections (both false and real targets), instantaneous overload may happen. This overload will be due to confirmations, track initialization (firm time bound) and tentative track dwells. This load will become normal as track gets established. But can be problematic if target is false. As confirmation/track initialization will fail for false targets and search will provide detections from scan to scan. Identification of false target can be confirmed using intelligent search agents and can be memorized for prolonged period. This load will be localized to area where false targets are available.

Sometimes cue received from external system can be cause for SSDO. But this will become normal after cue execution is completed by radar. This load will be localized to area where it is generated. Load characteristic is shown in fig 1.

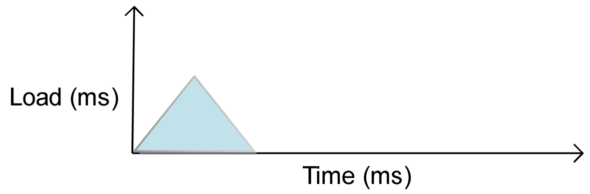


Fig1. SSDO Load

As shown in Fig1., SSDO type of load increases for the time bounded by the dwell duration of dwell causing it. Load (ms) is dependent on the relative delays of dwells. Amplitude of load is bounded by the search frame time, its amplitude is indicator of severity of overload.

**Multiple Instance Long Duration Overload (MLDO)**: This problem will happen during chaff, flair, formation detection by radar. This condition will keep scheduler overloaded for long duration localized to initiation or along target path.

Also during sudden unintentional objects emanating from A tracked target. This load will be localized but elongated along the target path

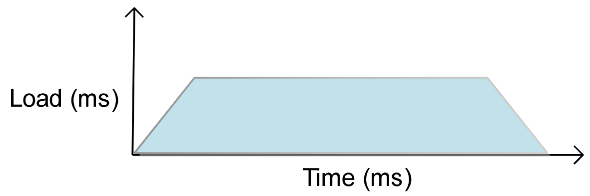


Fig2. MLDO Load

As shown in Fig.2, MLDO is similar to SSDO except that it stays for longer duration. Longer duration is bounded by the time for which load remains in spatial domain. For targets, based on the kinematics, load moves from one spatial zone to other. In this case amplitude of load is not relevant as the duration of load will be higher.

**Gradual Increasing Short Duration Overload (GSDO)**: This overload condition will be encountered during separation, cross over, target decoy & intentional objects emanating from existing target. This load will be localized to area of initiation and will be gradually moving with kinemics of the target. This load will subside once the event of separation, cross over etc. is completed.

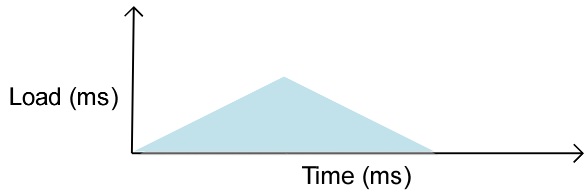


Fig3. GSDO Load

As shown in Fig3, GSDO increases gradually as the event of separation or cross over progress. Overload time is bounded by the duration of event taking place.

**Gradual Increasing Long Duration Overload (GLDO)**: This overload condition will happen due to uniformly distributed targets more than what radar can handle.

This problem can also arise due to tracking of high resource demanding target(s) at higher update rate.

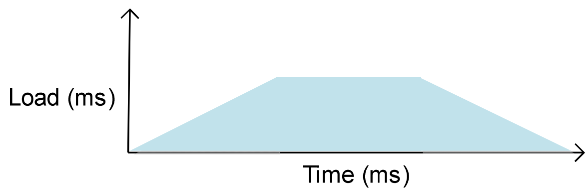


Fig4. GLDO Load

As shown in Fig4, GLDO increases gradually same as GSDO but stays in load condition for extended time. This load is time bounded by lifetime of high resource demanding targets. These targets lifetime is of the order seconds.

## III. Regulation Technique using Intelligent Agents

Generic definition for agents from literature is "Agents are problem solving objects and communicate and coordinate with other agents to modify their behavior as a function of a changing environment. These agents become intelligent if they are to learn from environment during operation and use learned information to take decision or help other agents to make decision. In radar scheduler, agents are objects, capable of communication and coordinating with other objects and take decision in standalone or collective mode during situations of radar overload. According to radar load characteristics, overloading of radar scheduler can recur in both spatial and temporal domain. So, to regulate load in spatial domain, agents are required all throughout volumetric search or at least have capability to move to required area. In this paper, we are proposing spread of agents throughout volumetric search area. These agents are multi-function agents. As these agents can take multiple role of search and track load regulation. Also agents are required where volumetric search is not there but tracking of targets is possible. In this area also agents are spread. These agents are track only agents. Multi-function agents will conserve time resource by regulating frame time of search dwells.

For regulation of load in temporal domain, based on load characteristics agents will be generated dynamically. These agents will have fixed lifetime. If the target is remaining in radar coverage for more than life time of agent then characteristics of agent will be inherited by existing agent or new agent. Track agents will regulate update rate of track dwells based on track life-time and track quality. This will reduce overload duration during gradual long duration overload.

Agents will be there with life time more than radar operation sessions. These agents will memorize spatial characteristics of multifunction agents and track agents. Agents temporal characteristics are also memorized for limited time and will be updated from radar session to session. Radar session is continuous radar operation in specific mode to achieve set goal.

In this paper we have simulated three types of agents in hierarchy. Timer agent is having highest priority and responsible for controlling other agents in scheduler. Local agents such as search agent's periodicity (frame time) and duration is predefined. External agents such as track agent's periodicity is fixed in simulation (can be varied for further improvement). In simulation all agents are predefined with fixed parameters.

**Regulation in SSDO:** Timer agent responsible for allocating time resource to radar dwell distinguishes local agents such as search from external agents such as track. In absence of any external agents, local agents perform conservation of resources bounded by radar scan rate. Conservation is performed by timer agent based on feedback provided by search agents for probable load. If any search agent is expected to be overloaded, timer agent conserves time resource for that search agent and first level agents related spatially to expected search agent.

External agent such as track is time bounded by dwell time for tracking target at maximum range with maximum update rate. So, this time bound is the maximum expected load that can be incurred by track dwell. Timer agent conserves expected load of track dwell by increasing frame time of expected search dwell and related search dwells. This regulation guarantees, in presence of track dwells, search dwells will not be overloaded. To avoid idle time, conserved time resource will be given to search or track dwell not related to expected search dwell randomly.

**Regulation in MLDO**; Timer agent senses MLDO condition by counting number of external agents in a specific area. But regulates each expected search dwell load using SSDO regulation. This regulation is limited in the sense that once regulated search dwell cannot be regulated once again. Related search dwells also get regulated for duration till external agents are available in their zone.

MLDO regulation reduces the start of the load time. But once regulation is performed, remaining load will be distributed by timer agent to local agents.

**Regulation in GSDO**; Timer agent start regulation of GSDO load same as SSDO. But by sensing load interval, distinguishes GSDO load from SSDO load and adjusts increase in frame time based on interval of external agents initiation. Related search agents communicate to ensure that conservation takes place for search agent where GSDO load gradually passes.

This regulation is effective to reduce the amplitude of load and reduce load start time.

**Regulation of GLDO**: This load is regulated in two different ways. If the load is initiated from high resource demanding target then regulation shall be same as GSDO, except rate of frame time variation. Frame rate is increased to handle complete load instantly. This regulation in certain instances increases frame time to the extent that local agents become ineffective. Operational point of view, external agents priority is more as compared to local agents.

## IV. SIMULATION

We have simulated scenario for multifunction radar having 200 search beam positions in one elevation and 2 elevation layers. So total of 400 local search agents to regulate search load. Search dwell duration is 10ms average. Maximum targets that can be tracked by radar data processor is 400, so external track agents required are 400. Track dwell duration varies from 2ms to 100ms based on target position and kinematics. Antenna scan rate is 8 sec. Scheduling interval is 10ms. Search frame time is 8 sec. Target update rate of 4sec

Scenario consists of one timer agent, 400 local search agents and 400 external track agents.

Simulation performed without any track resulted in reduction in frame time to handle idle time.

Simulation for SSDO load and regulation of load showed that SSDO load of 50ms is handled completely.

MLDO load time of 360s is reduced to 288s after using regulation technique.

GSDO load time of 8s is reduced to 6.4s. Load amplitude of 100ms is reduced to 50ms after using regulation technique.

GLDO load time of 1200s is reduced to 900s.

## V. CONCLUSIONS

Simulation of agent based radar load regulation has shown effective handling of short duration overloads. Overload of less than 50ms is completely handled in 8s search frame time with fixed track update rate.

During long duration overload, agent based regulation is effective in GLDO. This regulation technique has reduced overload duration by maximum of 25%.

Extension to this work, simulation will be performed by allowing external agents to modify update rate of track for handing load.

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