ABSTRACT

There is a critical need for the development of new navigation technologies that can provide accurate and uninterrupted position, navigation, and timing (PNT) information of the global positioning system (GPS) receiver, in civilian and military applications. Since the GPS signal is very weak, it is susceptible to multi-path interference, intentional and unintentional jamming, thus affecting the accuracy, availability and continuity of GPS. A 50W hostile source at 100 Kms can easily jam a GPS receiver.

Despite the antenna’s privileged position as the first line of defense against interferers and jammers, the current mitigation techniques are mostly realized in the receiver’s backend signal processing blocks. Anti-jamming measures, anchored at antenna stage itself, will reduce the design complexity of the subsequent stages. Hence this research focuses on implementation of the anti-jamming techniques pertaining to the antenna system, to enhance the robustness and overall performance of the receiver. After a literature review the research is explored and comprehensive & computationally less intensive anti–jamming systems have been proposed to suit the requirements of different application platforms and jamming environment.

To start with for GPS airborne platforms, an ‘Autonomous GPS single antenna anti-jamming system’ based on ‘Phase only controlled - polarization filtering’ technique has been proposed. Mathematical & vector diagram validations, simulated performance evaluation under various interference conditions have been carried out. The “Interference Rejection Ratios (IRR)” obtained are more than -50 dB for L1 and -30 dB for L2 for all in-band interferences with different polarizations and power levels. An improvement of 25 dB in IRR has been achieved compared to other similar systems along with “Aeronautical Radio incorporated (ARINC) 743” form factor compliance. Also due to its autonomous operation capability, the intervention of the pilot/flight engineer is not required.
Then for ground based static and mobile GPS platforms a novel ‘High Mask Angle Antenna (HMAA) anti-jamming system’ has been proposed designed and fabricated. With the obtained mask angle of 20.3°, the proposed system suppresses most of the multipath and interferences irrespective of their polarization, bandwidths and power levels up to 20.3° since almost all multipath and ground based interferences emanate only up to 20° to 25° from the horizon. The Dilution Of Precision (DOP) caused by the high mask angle of the antenna is overcome by using a multi constellation receiver along with the HMAA. This proposition may enjoy high traction with the availability of ultra-compact multi constellation receivers, incorporating the emerging technologies in this field.

Then for all GPS anti-jamming antenna platforms, where space is a constraint, size reduction of the antenna based on ‘Fractal miniaturization technique’ has been proposed. Fractal design up to second iteration, modification with air gap & shorting wall and fabrication of the antennas have been carried out. With size reduction of 59.18% achieved by this technique, the overall electronic real estate of the GPS anti-jamming system can be reduced by more than 50%.

Then for all GPS anti-jamming systems operating in severe interference environment, where IRR of more than 60 dB is required to suppress the interferences irrespective of their Direction Of Arrival (DOA), band widths, polarization including spoofing and multipath, ‘Array antenna anti-jamming system’ based on ‘Adaptive phase only controlled-spatial filtering’ technique optimized by evolutionary algorithms has been proposed.

To realize this as a first step, adaptive phase only nulling anti-jamming linear array antenna systems optimized by Artificial Bee Colony (ABC) algorithm (3 element array), Cuckoo Search (CS) algorithm (8 & 16 element) have been implemented and their performance evaluated & compared with similar systems. The proposed ‘array antenna anti-jamming systems’ yielded deep nulls of more than -65 dB in a multi interference
environment, converging in 111 and 37 iterations respectively performing better than other similar systems.

Finally for dynamic mobile platforms, where roll rate is very high like guided missiles, the GPS anti-jamming system should have compact size, an IRR of more than 50 dB, faster angular navigation ability and fastest convergence. To meet these requirements ‘Phase only nulling, modified 5 element circular array anti-jamming antenna system with an additional element at the center (based on ‘Adaptive phase only controlled-spatial filtering’ technique), optimized by hybrid algorithm (ABC+CS)’ has been proposed and implemented. The proposed modified circular array has an optimum geometric efficiency occupying a minimum electronic real estate and the presence of a center element increases the angular navigation ability of the beam.

The 5 element modified circular array has been designed and fabricated. Simulated performance evaluation of this proposed system has produced deeper nulls (greater than -65 dB) and faster convergence (within 21 iterations) compared to similar systems in multiple interference environment.

This hybrid (ABC+CS) algorithm in this research work may emerge as a powerful tool not only for electromagnetic community but also for other researchers in dealing with optimization problem due to its simplicity, faster convergence and ability to provide high quality global solutions even in noisy environment.

A seamless vertical integration of antennas, anti-jamming techniques, optimization algorithms and development of robust pre correlation anti-jamming systems, which works without a priori information about the satellites or jamming sources have been presented in this research work. Thus it advances the state-of-the-art anti-jamming systems.