A Beam Summation Scheme for Ultra-wideband RCS Calculations in the High frequency Regime

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The work is concerned with the radar cross section (RCS) calculations for the complex targets in the high-frequency regime. Such targets combine, in general large smooth surfaces, regions with intricate details. Exact numerical solutions cannot be used in the high-frequency regime due to their complexity, hence the calculations are usually done by physical optics (PO) integration or ray-based methods or a hybrid combination of these approaches. Two major concerns are the scaling of the complexity of these algorithms with frequency and the additional cost of calculating the RCS over a wide frequency band. Therefore, the goal of the present research is to formulate a beam summation (BS) scheme for calculating the RCS of large complex targets. Beam summation methods have long been utilized for modeling wave propagation in the complex environments. Several schemes for expanding time-harmonic source-excited fields in the terms of spectral beam waves have been introduced in the past [1].

For calculating the RCS where the incident field is a plane wave, the appropriate strategy is the called ultra-wideband phase-space Gaussian beam summation (UWB-PS-GBSM) scheme originally introduced in [2-4]. The formulation is based on the windowed Fourier transform (WFT) frame theory. The incident impinging plane wave field is expanded into frequency independent iso-diffracting Gaussian beam (ID-GB) lattice, emerging from the phase-space (PS) lattice. The choice of iso-diffracting Gaussian window provides the optimal frame representation for all the frequencies, thus generating stable and localized expansion coefficients. Furthermore, the beams are fully characterized by frequency independent parameters hence need to be traced and computed once for all the frequencies in the band. The field of each GB is then tracked through multiple surfaces within the scatters domain until the beam emerges out and propagates in the scattering zone, where the beam contributions are summed up to obtain the scattered field, hence eventually the radar cross section. In the current research, we have thoroughly investigated the UWB-PS-GSBM algorithm's expansion parameters and UWB bistatic RCS over a one-octave frequency band. Currently, we are exploring the multiband formulation, following [3], we divide the frequency band of the problem into one-octave-sub-bands. The sub-bands are arranged in a special self-consistent hierarchy so that they share the same beam lattice and beam propagators. To explore the complexity of the algorithm, we have computed the monostatic and the bistatic RCS of the sphere of radius $a = 1$ m over an ultrawide-band $k = [1000,16000]$, while also exploring the number of beams required in the computation obtained via thresholding the beam contribution in the far-zone at some frequencies as described in the table below

k	$k_1 = 1000$	$k_2 = 2000$	$k_3 = 4000$	$k_4 = 8000$	$k_4 = 16000$
Interlaced $x - \xi$ up sampling scheme	3029	1049	2493	1117	1589

Table 1. Number of beams required to compute the Monostatic RCS of the sphere $a = 1m$ at the frequencies k_1, k_2, k_3 and k_4 via Interlaced $x - \xi$ up sampling.

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