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Husimi function for time-frequency analysis in optical, microwave and plasmonics aplications

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Many real-world signals, occurring in everyday engineering practice are non-stationary, and as a result, their frequency components may change gradually or abruptly over time. Such signals are typically analyzed using Fourier transform, however, this type of analysis is often not sufficient to reveal the true nature of localized (in time) frequency content. This is where time-frequency analysis (TFA) can be of great help. Several approaches of TFA exist, and in this paper we use Husimi function (Gaussian smoothed Wigner function) for this purpose [1,2,3].

Both the Wigner and Husimi functions are the phase space quasidistributions in quantum mechanics [4,5]. In quantum mechanics, Husimi function of a quantum mechanical state arises when simultaneous measurement of quantum conjugated observables - coordinate and momentum, is performed. Similarly, in signal analysis, conjugated variables are time and frequency. If the measurement has the highest physically possible accuracy (as dictated by the Heisenberg uncertainty relations), then the product of standard deviations of conjugated observables equals $\hbar/2$ and Gaussian smoothed Wigner function for in such a way chosen parameters is known as a Husimi function (HF) [2,5].

In this paper, characteristic signals which describe behavior of several devices used in optics, microwave engineering and plasmonics were obtained via 3D electromagnetic numerical simulations. These signals, and their time and frequency evolution, were then analyzed using specifically tailored HF.

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