# Shack-Hartmann wavefront sensor design for strong scintillation conditions

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**Abstract**

In the case of an optical link with a LEO satellite, it is crucial to maximize the duration of the downlink, even at low elevations, in order to transfer the largest amount of data possible at each pass. However, in this context, amplitude fluctuations (or scintillation) are challenging the operation of Adaptive Optics (AO) systems, starting with its wavefront sensing function.
Indeed, low elevations implies being in the strong perturbation regime as the propagation distance through turbulent atmosphere layers increases with zenithal angle, causing log-amplitude variance to reach saturation, i.e. with propagation conditions beyond the Rytov's approximation (1).

In the case of a Shack-Hartmann Wavefront Sensor (SHWFS), scintillation induces a wide intensity range across the pupil resulting in some subapertures being saturated and other being extinguished (cf. Figure). Besides, when the intensity distribution is non-uniform in a given subaperture, the slope measurement is shown to be biased (2). Moreover, some subapertures point-spread functions suffer from diffraction-induced deformations making it difficult to compute the centroids and hence to obtain accurate slope measurements.

We have performed propagation simulations through strong perturbations considering $Cn^2$ profiles with ranging from 4cm to 1cm, and ranging from 0,08 to 0,9. Such diversity enabled us to progressively leave Rytov's regime, and observe the effect of increasing scintillation.

We then study the effect on wavefront sensing accuracy of the complex amplitude sampling by the subapertures grid. We compare three SHWFS configurations featuring increasing number of subapertures, in presence of scintillation, considering noise sources and detector dynamic range. We highlight the improvement brought by oversampling the SHWFS in comparison to usual designs. Finally, we present a noise propagation model on the phase reconstructed from SHWFS data.

References

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