ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

Scientific Report

First name / Family name	Melissa Beason
Nationality	USA
Name of the *Host Organisation*	Fraunhofer-Gesellschaft, IOSB
First Name / family name of the *Scientific Coordinator*	Szymon Gladysz
Period of the fellowship	01/02/2019 to 31/01/2020

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

Work during the Fellowship period focused on two areas of activity: (1) non-Kolmogorov turbulence and its effect on a propagating beam, (2) probability density functions to statistically describe intensity fluctuations resulting from propagation through turbulence.

The Fellow collaborated with a host scientist to advance science in non-Kolmogorov turbulence. This collaboration resulted in an Applied Optics publication describing an important aspect of this phenomena. The Fellow also co-taught a tutorial at the non-Kolmogorov and Associated Phenomena workshop describing the effect that deviations in the spectral power law and anisotropy of turbulence have on a propagating beam.

The Fellow performed a detailed statistical analysis looking at probability models to mathematically describe intensity fluctuations of a beam after propagation through atmospheric turbulence. This analysis included varying turbulence regimes, aperture integration, and beam wander. This was a 2-part activity where the first part looked at potential models and the second part calculated the bit error rate and probability of fade resulting from the different models. This was presented at SPIE Remote Sensing conference and published in their proceedings. A peer-reviewed publication of this work is in process with a 3rd publication resulting from this work anticipated.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

M. Beason, L. Andrews, I. Toselli, "Calculating Structure Function Constant from Measured C_n^2 in Non-Kolmogorov and Anisotropic Turbulence Including Inner Scale Effects," Appl Opt **58**(25), 6813-6819 (2019).

Abstract: Optical scintillometers used to characterize turbulence are based on assumptions of isotropic, Kolmogorov turbulence following a $\kappa^{-11/3}$ spectral power law. However, experimental data suggests that the turbulence may at times be anisotropic and non-Kolmogorov. In this work, consideration is given to converting from the structure function constant, C_n^2, based on isotropic, Kolmogorov statistics to its generalized anisotropic, non-Kolmogorov form, $\tilde{C}_n^2$, for point receiver and large-aperture receiver scintillometers. It is found that $\tilde{C}_n^2$ is dependent not only on power law and anisotropy parameters but that it is also a function of inner scale. The large-aperture scintillometer is found to be less sensitive to power law and inner scale than the point-aperture receiver. The optical parameters of two fielded scintillometers are modeled as practical examples of these behaviors.

M. Beason, L. Andrews, S. Gladysz, "Statistical Comparison of Probability Models of Intensity Fluctuation," Proceedings SPIE 11153-12 (2019).

Abstract: Probability Density Functions (PDFs) describing intensity fluctuations of a propagated beam are necessary to reliably predict operation of Free-Space-Optical (FSO) systems. This becomes especially important when considering the tails of the distribution. For example, accuracy in the low-intensity tail is necessary in the design of FSO communication systems as it determines the probability of fade. Accuracy in the high-intensity portion of the tail is necessary for eye-safety calculations and to prevent equipment damage. In this work, we evaluate PDF models considering the statistics of the fit to empirical data for point and distributed apertures for several values of Rytov variance. Based on p-values and level of significance, we compare the quality of the fit of common PDF models to empirical data. As part of this, we evaluate the transition of the best fit PDF as the aperture area is increased. Both simulated and measured data will be included in this analysis.

M. Beason, F. Sanzone, B. Berry, J. Coffaro, J. Spychalski, F. Titus, R. Crabbs, L. Andrews, R. Phillips, "Considering Power Law, Optical Refractivity, and Anisotropy Using Gaussian Beam Statistics," in *Imaging and Applied Optics 2019 (COSI, IS, MATH, pcAOP)*, OSA Technical Digest (Optical Society of America, 2019), paper PTh2D.2.

Abstract: The Rytov approximation is used with different initial beam radius of curvature in orthogonal directions to approximate optical refractivity with an anisotropic non-Kolmogorov spectrum in weak turbulence. Results are compared to experimental data.

M. Beason, S. Gladysz, “Comparison of probability density functions for aperture-averaged-irradiance fluctuations of Gaussian beam with beam wander,” Appl Opt, In Progress (2020).

Abstract: Over the years there has been much interest in the use of optical wavelengths for communication and laser radar because of the potential for high data rates. However, these systems can become significantly degraded due to turbulence induced signal fluctuations. These fluctuations can be minimized by enlarging the receiving aperture thereby averaging the fluctuations. There is extensive interest in developing probability density functions (PDFs) describing these intensity fluctuations so as to accurately predict system performance. This work examines several PDF models that have been suggested to represent fluctuations by comparing them to simulations of realistic propagation scenarios of a collimated Gaussian beam with centroid wander. The empirical PDF shape changes significantly with increased aperture going from a positively skewed to a negatively skewed distribution and therefore the PDF which describes it also changes. In this work, we examine the evolution of the empirical PDF with aperture size and the fit of potential PDF models under various strengths of turbulence.

III – ATTENDED SEMINARS, WORKSHOPS, CONFERENCES

Imaging and Applied Optics Congress, Optical Society of America, 24-28.06.2019, Munich, Germany

Workshop on Non-Kolmogorov Turbulence and Associated Phenomena, 1-3.07.2019, Ettlingen, Germany

SPIE Remote Sensing, 9-12.09.2019, Strasbourg, France

Fiber Optic Sensing in Earth and Atmospheric Sciences, 8-12.10.2019, Castle Thurnau, Germany

Communications and Observations through Atmospheric Turbulence, 2-3.12.2019

IV – RESEARCH EXCHANGE PROGRAMME (REP)

REP Organisation: TNO
Country: Netherlands
Local Scientific Coordinator: Lex van Eijk
Dates: 19.07.2019 to 25.07.2019

During my Research Exchange Program at TNO, Den Haag, Netherlands, I assisted their scientists in setting up and verifying a laser propagation range including a scintillometer, sonic anemometer, laser source, and infrared camera system. This system will measure atmospheric properties and their effect on a laser which can be used to validate mathematical models and simulations. We also collaborated on ideas for joint theoretical and experimental future work.