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Hufnagel R E & Stanley N R. Modulation transfer function associated with image transmission through turbulent media.
J. Opt. Soc. Amer. 54:52-61, 1964.
[Perkin-Elmer Corporation, Norwalk, CT]

Image blur is shown to be related to the loss of optical coherence. An expression for the coherence is derived. A model of the distribution of turbulence *vs.* altitude is developed. These combined results yield a quantitative expression for the blur. [The *SCI*® indicates that this paper has been cited in over 210 publications since 1964.]

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"Soon after the invention of the telescope, astronomers discovered that their ability to see fine detail was limited by the Earth's atmosphere. Sir Isaac Newton correctly associated the problem with random inhomogeneities in the air. By the year 1961 several hundred papers had been written on this subject,[1] but none had yet correctly and quantitatively described the image degradation process. A translation of a Russian book authored by V.I. Tatarski[2] then appeared in the US which combined Kolmogoroff's theory of turbulence with Rytov's approximate solution of the optical wave equation. The result was a statistical description of optical wave fronts and amplitudes which set the stage for modern development in this field.

"From the modern theory of image formation, we knew that we should study not optical wave fronts and amplitudes, but a single related quantity called the coherence function. This change in viewpoint led us to the discovery of a statistical solution of the optical wave equation which appeared to be more general than that which could be obtained from Rytov's approximations. We quickly determined that our results encompassed and agreed with every prior solution of the wave equation. Our solution was so simple and elegant that intuition alone suggested that it had to be right. It formed the basis for this paper.

"A year after publication, however, we received letters from Tatarski, M. Beran, and D.M. Chase pointing out that we had not correctly proved our solution to be the only one possible. Chase's discussion was the most complete and the one published.[3]

"The problem was caused by an extra term in the solution arising from a possible statistical correlation between the coherence function and the local variation in the air's index of refraction. Some time later it was shown that this extra term was equal to zero, and that our solution was indeed correct.[4]

"One reason for this paper being cited many times may be that the three parts of the paper are separably useful in other problems in optics. For example, when the paper was written there did not exist a quantitative model for the altitude distribution of the strength of the atmosphere's turbulence. Of necessity, we developed such a model and included it in the paper. More importantly, perhaps, this publication has been cited often because it used modern concepts and answered a 300-year-old problem."

1. **Wimbush M H.** *Optical astronomical seeing: a review.* Honolulu, HI: University of Hawaii, Hawaii Institute of Geophysics, May 1961. Scientific Report No. 1. AF 19(604)-2292. ASTIA No. 265402.
2. **Tatarski V I.** *Wave propagation in a turbulent medium.* New York: McGraw-Hill, 1961. 285 p.
3. **Chase D M.** Coherence function for waves in random media. *J. Opt. Soc. Amer.* 55:1559-60, 1965.
4. **Strohbehn J W.** Modern theories in the propagation of optical waves in a turbulent medium. (Strohbehn J W, ed.) *Laser beam propagation in the atmosphere.* Berlin: Springer-Verlag, 1978.