Electromagnetic beam propagation through the atmosphere: effects of source coherence and turbulence on the degree of polarization.

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Abstract. The effects of atmospheric turbulence on the degree of polarization (DOP) of a partially coherent electromagnetic Gaussian Schell-model beam are discussed. The analysis is based on unified theory of coherence and polarization and on the extended Huygens-Fresnel principle. Intermediate and far-zone behavior of the DOP are discussed.

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It is generally believed that the changes in the state of polarization of a random electromagnetic beam propagating through the turbulent atmosphere are negligible [1]. However, this opinion is based on the assumption that the beam is monochromatic. Recently it was found that when the beam is partially coherent and hence not strictly monochromatic the degree of polarization (DOP) generally changes as the beam propagates even in free space. For two special types of sources [2] it has been shown that such changes arise from correlation properties of the source. In this presentation we extend the analysis to general electromagnetic Gaussian Schell-model (EGSM) beams and we consider both free-space propagation and propagation through the turbulent atmosphere.

Suppose a polychromatic EGSM beam propagates from the source plane $z = 0$ close to the positive z-axis. Correlation properties of such a beam can be described by a cross-spectral density matrix [3] defined for two points $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$ located in the xy-plane transverse to the direction of propagation:

$$\boldsymbol{W}(\boldsymbol{r_1},\boldsymbol{r_2},z;\omega) \equiv \boldsymbol{W}_{ij}(\boldsymbol{r_1},\boldsymbol{r_2},z;\omega) = \left\langle E_i^*(\boldsymbol{r_1},z;\omega)E_j(\boldsymbol{r_2},z;\omega)\right\rangle, \qquad (i = x, y; \quad j = x, y) \tag{1}$$

where the angular brackets represent the average over an ensemble of realizations of the electric field $\boldsymbol{E} = (E_x, E_y)$ [4]. The DOP of a random electromagnetic beam at point $\boldsymbol{r} = \boldsymbol{r}_1 = \boldsymbol{r}_2$ can be defined as [3]

$$\mathcal{P}(\boldsymbol{r}, z;\omega) = \sqrt{1 - 4Det\ \boldsymbol{W}(\boldsymbol{r},\boldsymbol{r},z;\omega)/\left[Tr\boldsymbol{W}(\boldsymbol{r},\boldsymbol{r},z;\omega)\right]^2}\ . \tag{2}$$

where *Det* and *Tr* are the determinant and the trace of the W-matrix respectively. Assuming that the electromagnetic beam is generated by an Gaussian Schell-model source we derive analytic expressions for the DOP of such a beam propagating both in free space and in atmospheric turbulence [4]. The changes in the DOP are illustrated by a number of numerical examples, covering various cases of interest. The asymptotic expressions (as $kz \to \infty$, $k = \omega / c$) for the DOP of the EGSM beam are also obtained for the far-zone field in free space and in the atmosphere. In particular it is shown that the DOP of the EGSM beam returns to its original value (in the plane $z = 0$) after propagating sufficiently far through the atmosphere.

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