Çankaya University – ECE Department – ECE 646 (MT)

Student Name : Date : 01.04.2014

Student Number : Open book exam

Questions

1. (50 Points) Using the MATLAB file named Scin_SinoHyp_L.m, together with dblquade04.m and adjust the initial settings as $r = 1$ cm, $\phi = \pi / 4$, $F_s \rightarrow \infty$, $C_n^2 = 10^{-15}$, $\lambda = 1.55\ \mu\text{m}$, plot the following (four) curves on the same graph, for a propagation distance range of 100 m to 3400 m with increments of 100 m

   a) Scintillation index variation of a Gaussian beam with $\alpha_{s\ell} = 2$ cm

   b) Scintillation index variation of a cos Gaussian beams with $\alpha_{s\ell} = 2$ cm, and $D_{s\ell} = [50j\ \ -50j]$

   c) Scintillation index variation of a cosh Gaussian beams with $\alpha_{s\ell} = 2$ cm, and $D_{s\ell} = [50\ \ -50]$

   d) Scintillation index variation of an annular Gaussian beam with $A_{s\ell} = [1\ \ -0.9]$, $\alpha_{s\ell} = [2\ \ 1.8]$ cm

From these curves, explain the dependence of scintillation index on propagation distance (L), beam type and record on your exam paper at least two readings for each curve.

Repeat the above steps for the same beams by changing to $r = 0$, $\lambda = 1.55\ \mu\text{m}$ and $r = 0$, $\lambda = 1.31\ \mu\text{m}$, thus obtaining eight more curves, four on each graph. From this total of twelve curves on three graphs, discuss the scintillation index dependence on receiver plane radial distance, r and source wavelength, λ.

Send your figure files (copied into one single file, not as individual files) to the mail address h.eyyuboglu@cankaya.edu.tr .

Solution : The relevant graphs are given in Figs. 1.1, 1.2 and 1.3

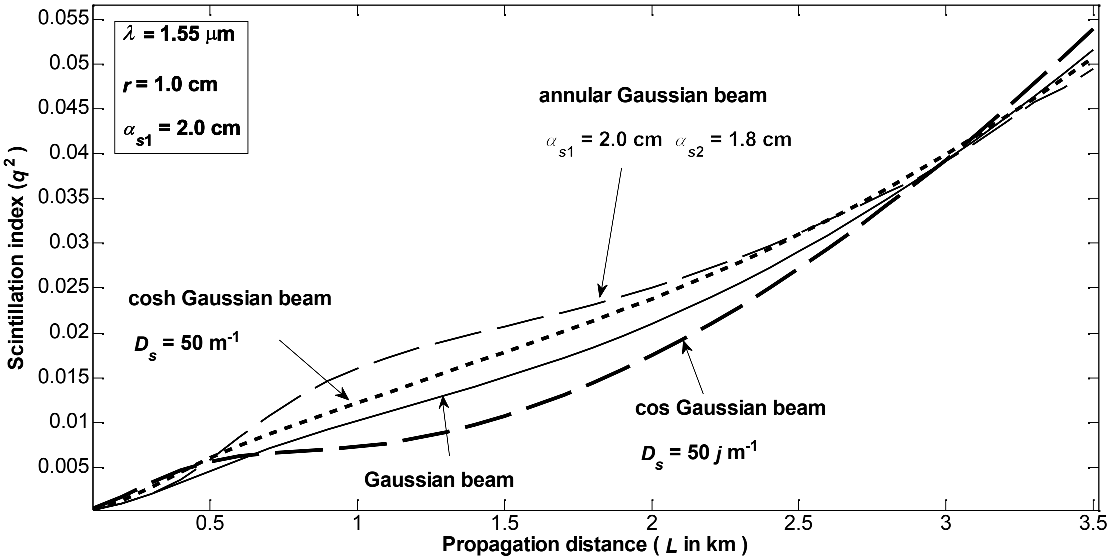

Fig1.1 Scintillation index curves of Gaussian, cos Gaussian, cosh Gaussian and annular Gaussian beams with the given settings at $r = 1$ cm, $\lambda = 1.55\ \mu$m .

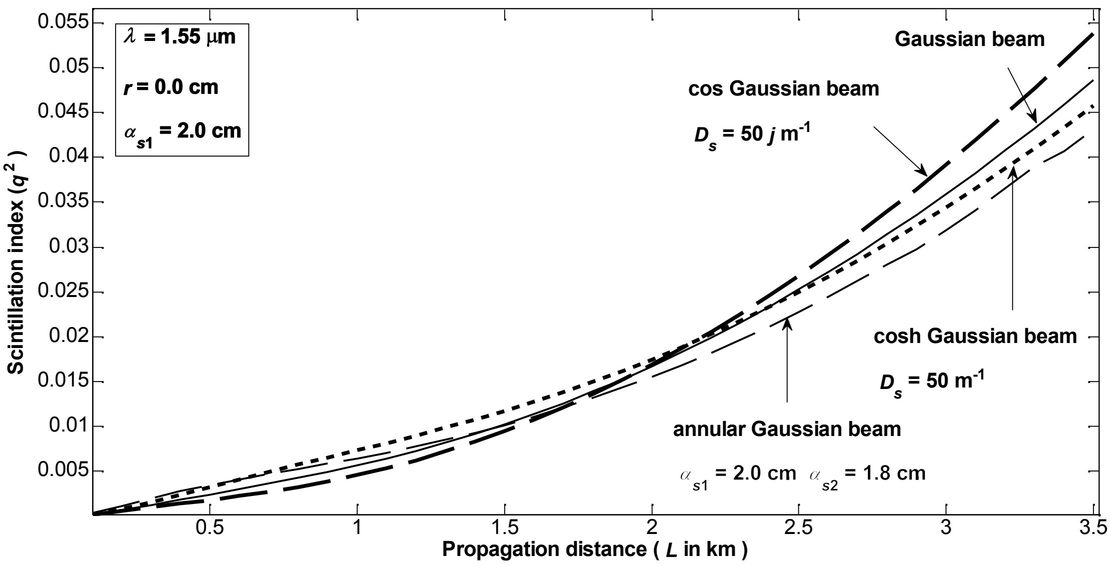

Fig1.2 Scintillation index curves of Gaussian, cos Gaussian, cosh Gaussian and annular Gaussian beams with the given settings at $r = 0$, $\lambda = 1.55\ \mu$m.

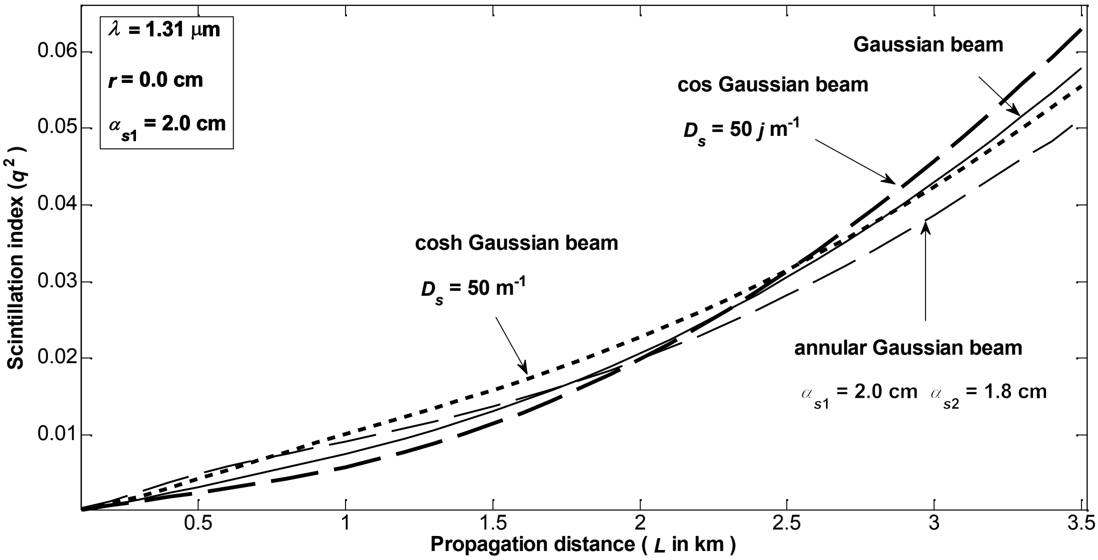

Fig1.3 Scintillation index curves of Gaussian, cos Gaussian, cosh Gaussian and annular Gaussian beams with the given settings at $r = 0,\ \lambda = 1.31\ \mu\text{m}$.

Looking at Figs. 1.1 to 1.3, we can make the following comments ;

a) Organize the terms of $r = 1$ cm, up to $L = 3$ km, scintillation index ordering from highest to lowest is annular Gaussian beam, cosh Gaussian beam, Gaussian beam and cos Gaussian beam. This ordering seems to reverse after $L = 3$ km.

b) At on-axis position of $r = 0$, roughly up to $L = 2.5$ km, scintillation index ordering from highest to lowest is cosh Gaussian beam, annular Gaussian beam, Gaussian beam and cos Gaussian beam. Beyond $L = 2.5$ km, the situation is almost reversed with the order becoming cos Gaussian beam, Gaussian beam, cosh Gaussian beam, annular Gaussian beam.

c) Comparing Fig. 1.1 to 1.2 and 1.3, we see that the off-axis scintillation is generally higher than on-axis scintillation

d) Comparing Fig. 1.2 and 1.3, we see that there is more scintillation at shorter wavelengths.

2. (20 points) By referring to lecture notes or otherwise, explain in full details the steps of solving the Huygens Fresnel integral in a semi-analytic manner. State how we can organize the matrix elements for sinusoidal hyperbolic Gaussian beam.

Solution : These are explained on pp. 27 – 37 of Notes of ECE 646_HTE_Bahar 2012 in section 4. Scintillation Formulation via Extended Huygens-Fresnel Integral. The main steps are summarized below

a) Organize the terms of $\langle I(\mathbf{r},L)\rangle$ and particularly $\langle I^2(\mathbf{r},L)\rangle$ so that they are in the forms of the terms in the quadruple integral of (4.3) of ECE 646_HTE_Bahar 2012.

b) Prepare the corresponding $\mathbf{Q}$, $\mathbf{R}$, $\mathbf{N}$ and $\mathbf{M}$ matrices. Particularly pay attention to the differences between $\mathbf{Q}_{Ax}$, $\mathbf{Q}_{Bx}$, $\mathbf{Q}_{Cx}$ for $\langle I^2(\mathbf{r},L)\rangle$

c) Use Sino_Hyp_Her4HFScin.m to get results for different source and propagation settings.

3. (30 Points) Answer the following questions as **True** or **False.** For the **False** ones give the correct answer or the reason. For the **True** ones, justify your answer

a) When a beam propagates in turbulence, it starts to scintillate : True, scintillation is the result of refractive index fluctuations in the atmospheric turbulence.

b) When a beam propagates in free space, it does not scintillate : True, free space refers to a propagation medium where the refractive index does not change in time and space (along temporal and spatial axes)

c) In Rytov method, we evaluate scintillation index under weak turbulence conditions : True, according to (3.36) of Notes of ECE 646_HTE_Bahar 2012.

d) Scintillation changes with source size of the beam : True, since source size is a parameter embedded in the scintillation index formulation.

e) Scintillation is independent of the structure constant, C_n^2 : False, in Rytov weak scintillation theory, scintillation is directly proportional to C_n^2, whereas in extended Huygens-Fresnel integral method, the proportionally is somewhat complicated manner.

f) Scintillation parameter measures the fluctuations in intensity level : True, scintillation index is the normalized intensity variance.