Çankaya University – ECE Department – ECE 646 (MT)

Student Name : Date : 29.03.2012

Student Number : Open book exam

Questions

1. (50 Points) Using the MATLAB file named Scin_SinoHyp_L.m (together with dblquade04.m and keeping $r = 0,\ F_s \rightarrow \infty,\ C_n^2 = 10^{-15},\ \lambda = 1.55\ \mu$m settings the same), plot the following (six) curves for a propagation distance range of 100 m to 3500 m with increments of 200 m

   a) Scintillation index variation of a Gaussian beam with $\alpha_{s\ell} = 3$ cm

   b) Scintillation index variation of two cos Gaussian beams with $\alpha_{s\ell} = 3$ cm, and $D_{s\ell} = [30j\ \ -30j]$ and $D_{s\ell} = [60j\ \ -60j]$

   c) Scintillation index variation of two cosh Gaussian beams with $\alpha_{s\ell} = 3$ cm, and $D_{s\ell} = [30\ \ -30]$ and $D_{s\ell} = [60\ \ -60]$

   d) Scintillation index variation of an annular Gaussian beam with $A_{s\ell} = [1\ \ -0.8]$, $\alpha_{s\ell} = [3\ \ 2.5]$ cm

From these curves, explain the dependence of scintillation index of different beams on propagation distance L, source size $\alpha_{s\ell}$ and displacement parameters $D_{s\ell}$ and record on your exam paper at least two readings for each curve.

Repeat the above steps for the same beams by multiplying the source sizes by $1/3$ and displacement parameters by 3. Compare the scintillation index numeric results of the two cases. Also compare the scintillation index dependence on $L,\ \alpha_{s\ell}$ and $D_{s\ell}$ for the two cases.

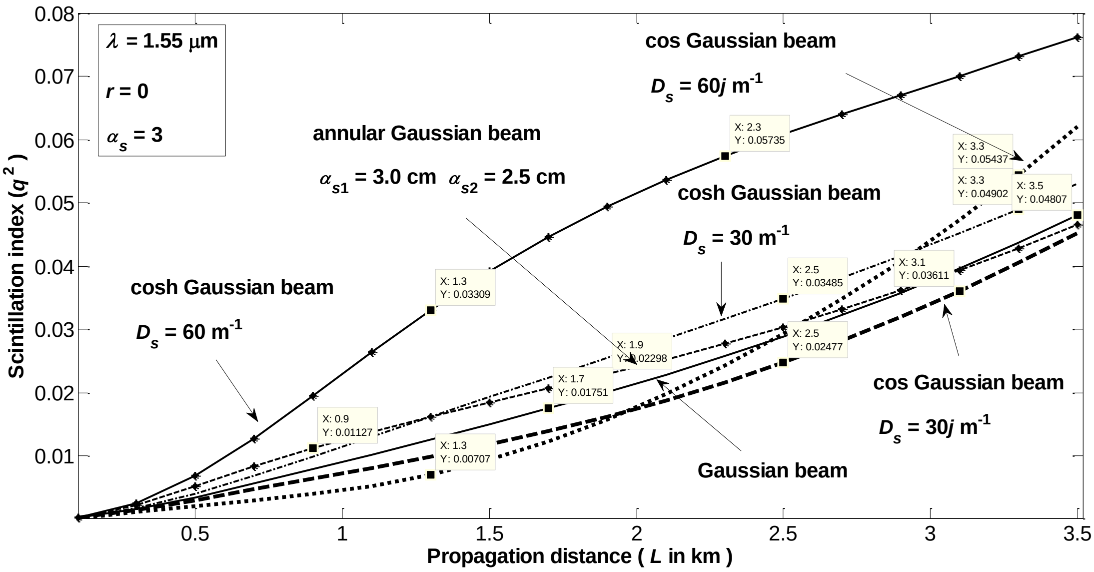
Send your figure files (copied into one single file) to h.eyyuboglu@cankaya.edu.tr address.

Solution : The figure for $\alpha_{s\ell} = 3$ cm (coupled with other specified parameters) is given below. Accordingly (the followings discussions are limited to the range of parameters examined)

a) Scintillation always increase with L,

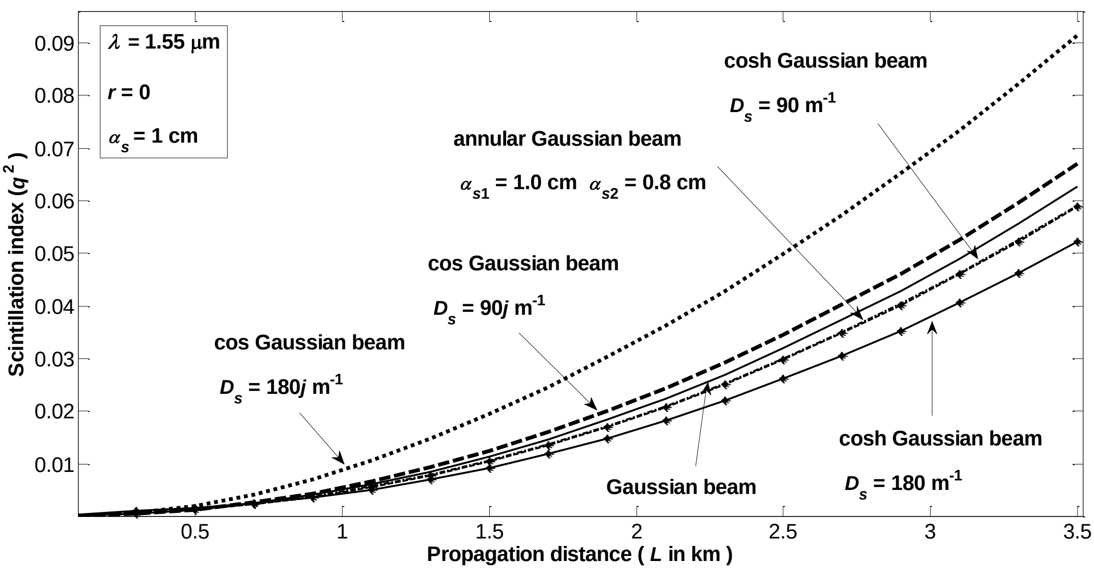
b) With this figure, it is difficult to assess the dependence of scintillation index on source size $\alpha_{s\ell}$, since only one source size is considered.

c) For cos Gaussian beam, bigger values of displacement parameter $D_{s\ell}$ will give lower scintillations at shorter propagation distances, but the reverse will occur at longer propagation distances. For cosh Gaussian beam, bigger displacement values will give higher scintillation values throughout the propagation range considered. Annular beam is independent of displacement parameter settings.



Two readings for each curve are shown on the figure above.

The figure for $\alpha_{s\ell} = 1$ cm (coupled with other specified parameters) is given below



The relevant comments are written below

a) The figure for $\alpha_{s\ell} = 1$ cm, when evaluated within itself, we find again that scintillation increases with propagation distance, cos Gaussian beam with smaller displacement parameter will give lower scintillation all throughout the propagation range considered, cosh Gaussian beam with bigger displacement parameter will give lower scintillations, the scintillation curves of annular Gaussian and cosh Gaussian beam with displacement parameter of $D_{s\ell} = 90$ m^{-1} will coincide.

b) Upon comparing the figures for $\alpha_{s\ell} = 3$ cm and $\alpha_{s\ell} = 1$ cm, we find that there is little change for Gaussian beam, but the respective positions of cos and cosh Gaussian beams have changed, annular beam of $\alpha_{s1} = 3$ cm, $\alpha_{s2} = 2.5$ cm has slightly lower scintillations than that of $\alpha_{s1} = 1$ cm, $\alpha_{s2} = 0.8$ cm.

2. (20 points) By referring to lecture notes or otherwise, explain in full details the steps of arriving at the scintillation index in Rytov method.

Solution : The detailed steps are given in the "Rytov Scintillation Theory" of Notes of ECE 646_HTE_Bahar 2012. Below we give important steps in a descriptive manner

1. First we use the Born approximation as a solution to wave equation containing the randomness of the refractive index of the propagating medium (called turbulent atmosphere). Born approximation basically expresses the field in the form of series, where the first term is the free space (turbulence free) and others are perturbed fields. Perturbed fields are successively found in terms of the preceding one.

2. Then we express the field in Rytov notation, where the perturbations due to turbulence are transferred to the complex phase function. By simple analogy, the first and second perturbations of Rytov are related to first and second perturbations of Born.

3. Scintillation index is expressed as the difference between average of the squared intensity and the square of the average intensity divided by (for normalization) the square of the average intensity. Under weak turbulence conditions, this boils down to the evaluation of Rytov first perturbation function.

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 spreads more than the one propagating in free space : True, since turbulence creates diffraction (like in free space) plus spreading.

b) Partially coherent beams spread less in propagation than the fully coherent beams : False, partially coherent beams spread more that fully coherent beams.

c) Extended Hygens-Fresnel integral helps us to find the average intensity of beam propagating in free space : False, this description is valid for a beam propagating in turbulent atmosphere. And this is done by the inclusion of the turbulence exponential into the classical free space HF integral.

d) Scintillation is the result of source beam being partially coherent : False, scintillation is the result of random fluctuations of the refractive index of the atmosphere both spatially and temporally.

e) Rytov theory is derived from Born approximation : Actually Rytov approximation is developed independently, but to save mathematics, we derive first and second perturbations of Rytov from those of Born approximation.

f) In extended Hygens-Fesnel integral, turbulence is taken into account via a single exponential term : True, by inserting this turbulence exponential term, the classical Huygens-Fresnel integral (of free space) turns into an expression that can handle propagation in turbulent atmosphere. And that expression is called extended Huygens-Fresnel integral.