WIRELESS AND CELLULAR COMMUNICATION

COMPUTER ASSIGNMENT 1

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PROBLEM 1 :

Simulation of Jakes' model :

This is a deterministic, time domain model for effective fading channel simulation. The fading waveform is modeled using M + 1 oscillators. The oscillator frequencies are given by $f_n = f_d \cos(2\pi n/N)$ for n = 1, 2, 3, ...M, where N = 4M + 2 and f_d is the maximum doppler frequency. The expression for the fading model is given by the following expression:

where $\beta_n = \pi n/(M+1)$ and φ_n are uniformly distributed between $[-\pi, \pi)$.

NOTE :
The simulation was performed using Matlab.
The number of samples per second was taken as 1000 samples/s.

Solutions:

a)
The simulation code to generate Rayleigh fading by Jakes' method is written in ee17b072_ca1.m and the plots obtained are shown below.

The plot of received envelope v (in dB) versus time for f_d = 1 Hz, 10 Hz and 100 Hz, for a duration of 1 second are shown in Figures 1,2 and 3 respectively. Note that these envelopes have been normalised.

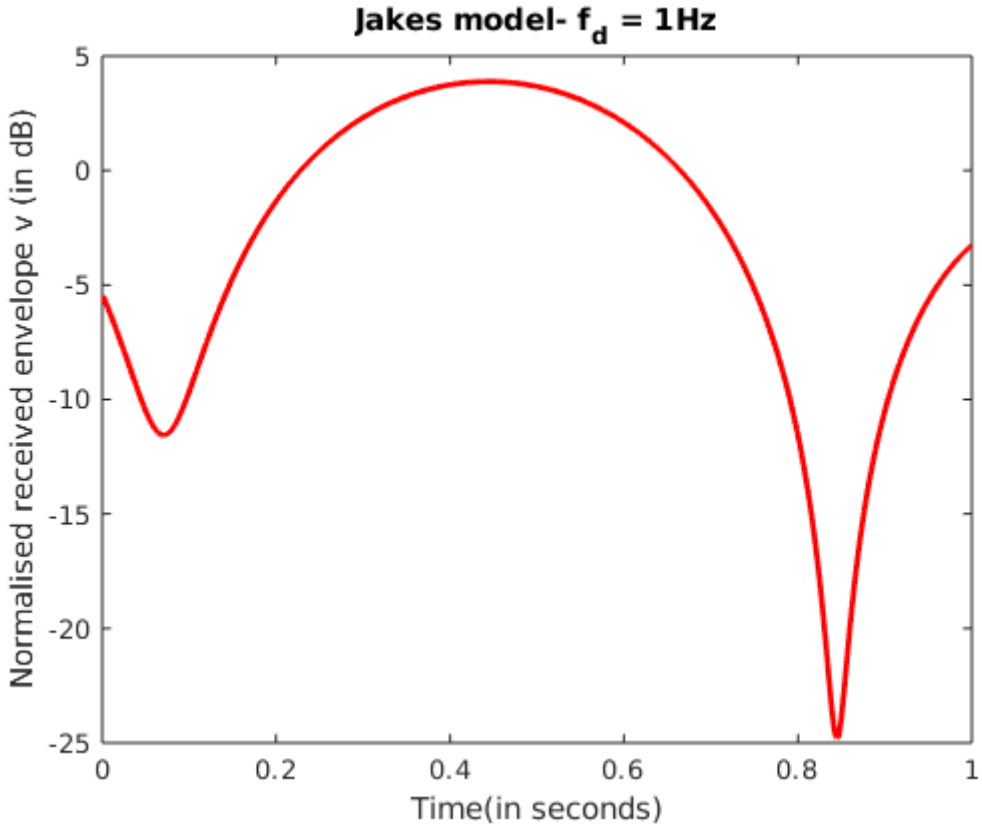

FIGURE 1

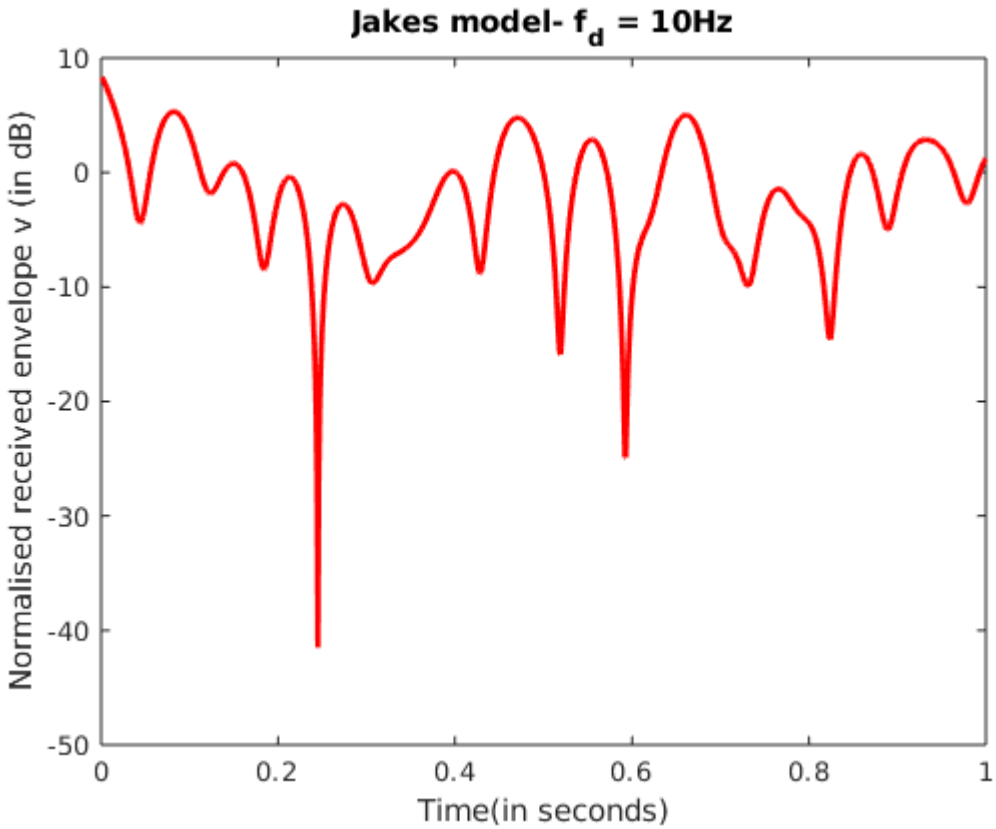

FIGURE 2

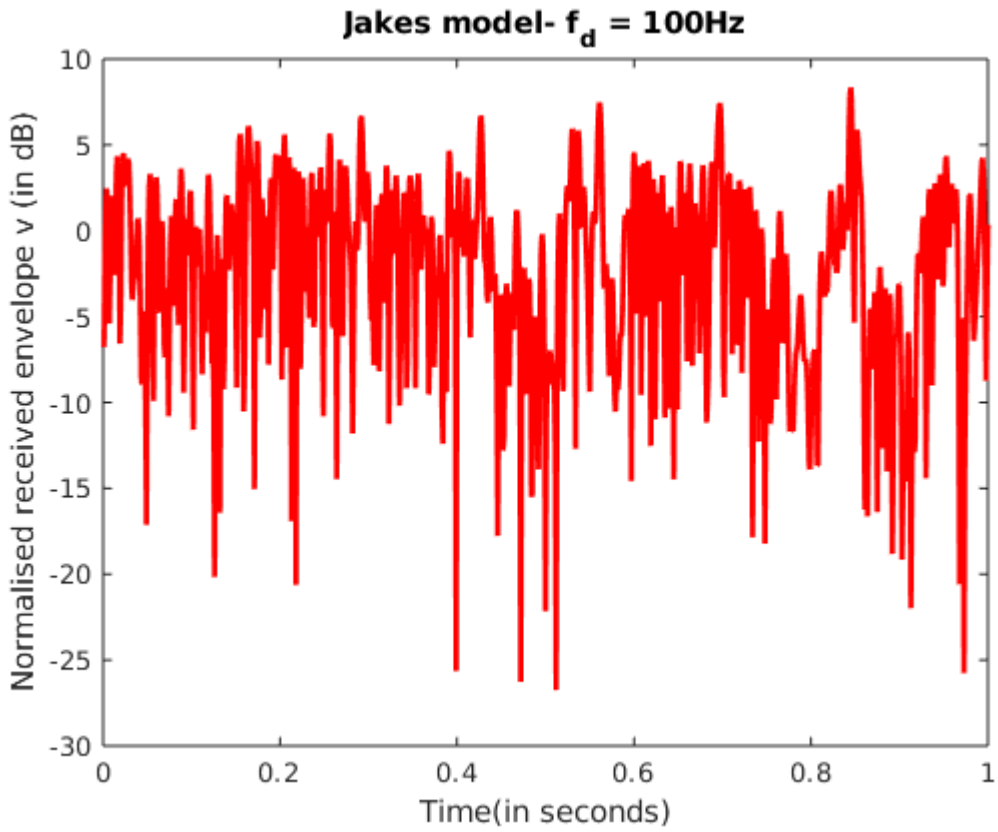

FIGURE 3

b)

Comparison of measured and theoretical level crossing rate:

Definition of level crossing rate:
The number of times a normalised Rayleigh fading signal crossing a pre-defined threshold in the positive going direction.
This is given by the formula : √2pi *(Doppler frequency) *exp(-ρ^2)* ρ, where ρ is the threshold in dB.
For fd=100Hz and for a time duration of 5 seconds, we generated a Rayleigh fading signal and calculated the number of times it crosses the given threshold and normalised this value.
The plot comparing measured and theoretical LCR is shown in Figure 4.

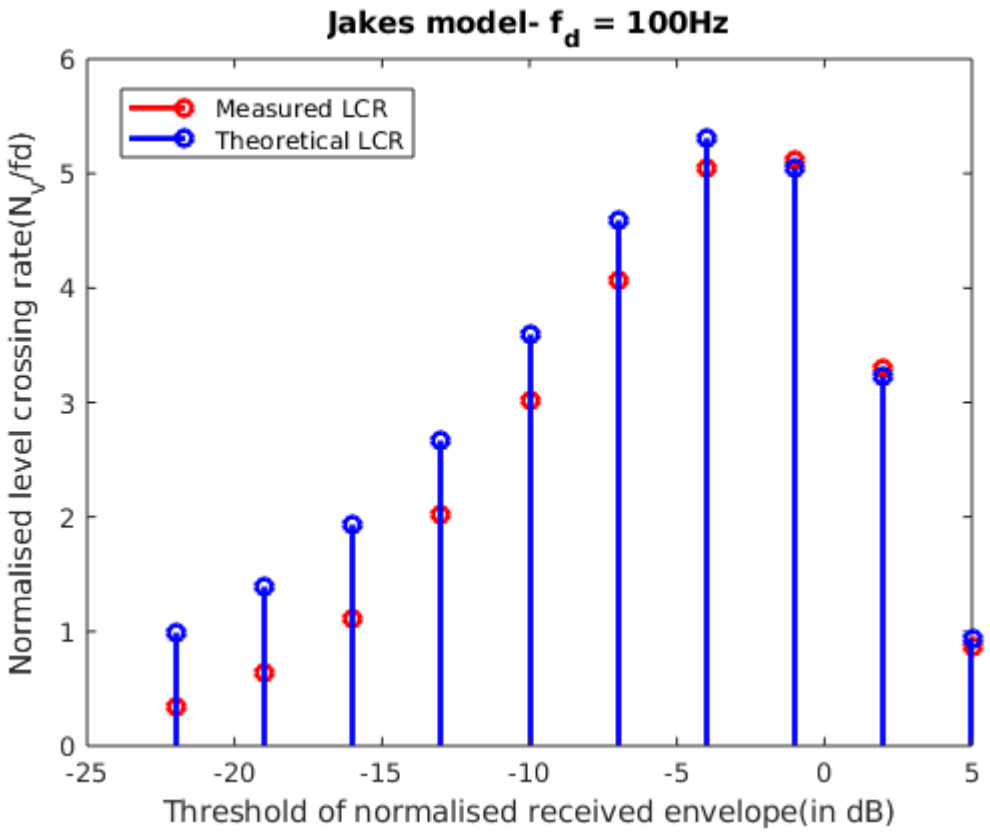

FIGURE 4

Here the theoretical LCR is slightly greater than the measured LCR because, for a given time period there may be many crossings, which we ignore due to the fact that we are taking only 1000 samples per second. In the theoretical LCR, an integration is performed such that all these crossings are taken into account, however this is not possible to do computationally.

NOTE : Due to the fact that we are taking only 1000 samples per second, we cannot capture the entire duration of time in which the fading signal is below the threshold. During the time between two samples, there may be many more crossings, which implies that the theoretical LCR is greater than the measured LCR, and the theoretical duration of fading is lesser than the measured time of fading, as shown by Figure 4 and Figure 5.

c)
Comparison of measured and theoretical normalized duration of fades :

Definition of duration of fade:
The time for which the Rayleigh fading is below a particular threshold is known as duration of fade.
Since we are required to compute the normalized duration of fade, we multiply the obtained time by fd and divide it by the total duration to obtain the average.

The comparison of the theoretical and measured duration of fade is shown in Figure 5 for Doppler frequency of 10 Hz.

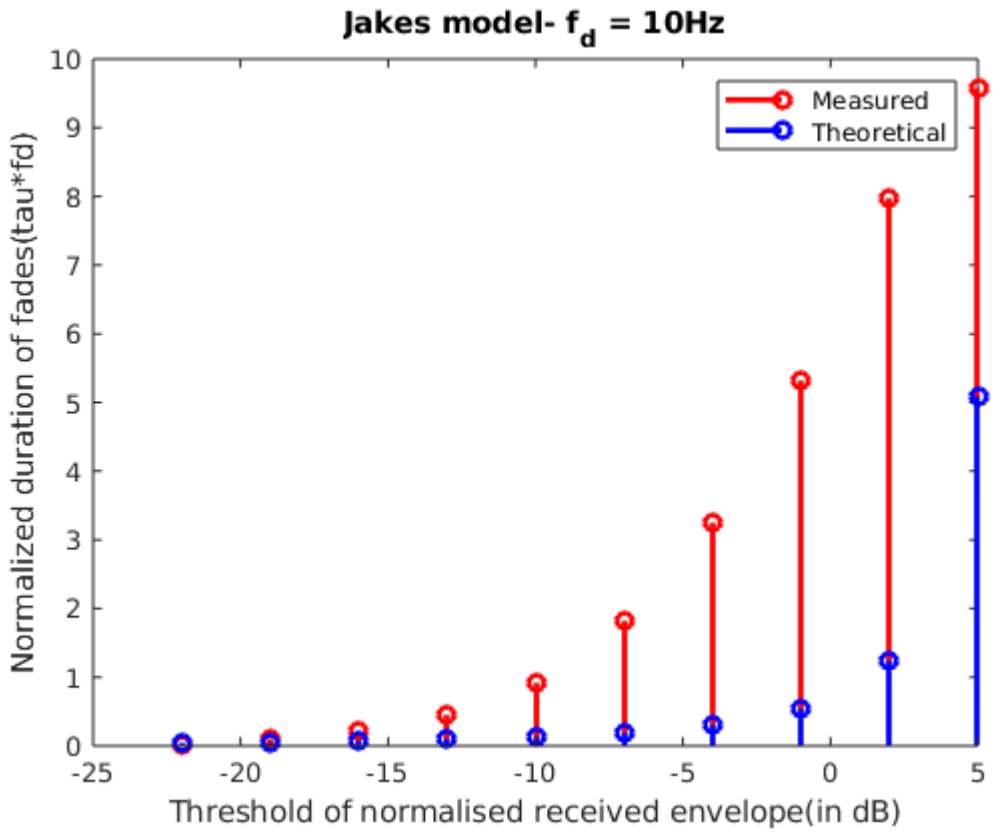

FIGURE 5

The inference made in the note above is therefore valid (the theoretical duration of fading is lesser than the measured time of fading).

d)
Modify the Jakes' model to generate Ricean fading:

We first compute the variance of the Jakes' model observations. The using the following relation, we can compute the distribution of the Ricean model for different values of k. Using this distribution, we can compute the Ricean and its component Rayleigh fading for a time duration of 1 second. The following figures shown both Ricean and Rayleigh fading obtained from the modified Jakes' model.

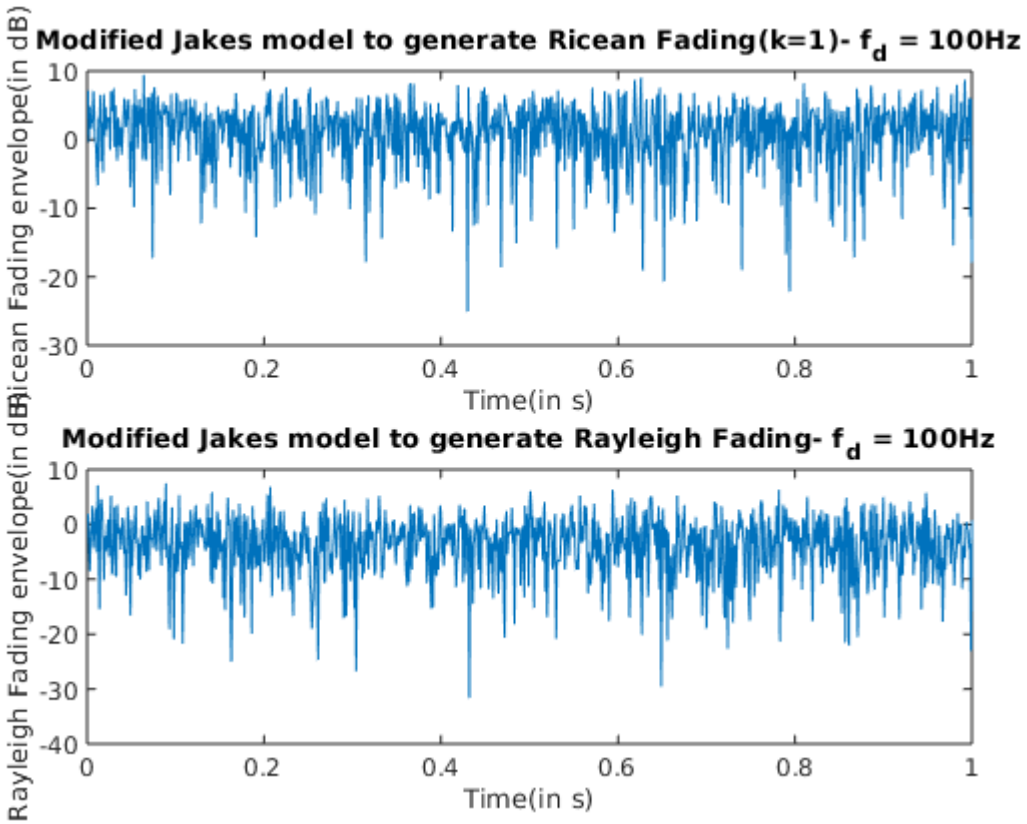

FIGURE 6

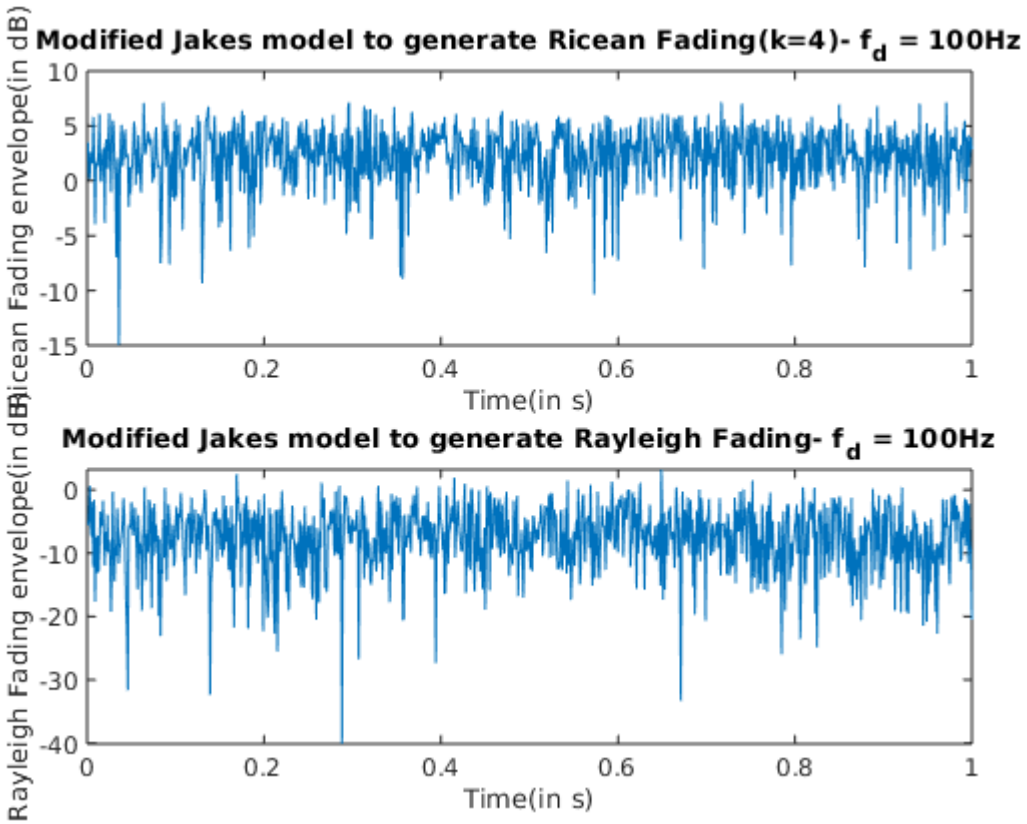

FIGURE 7

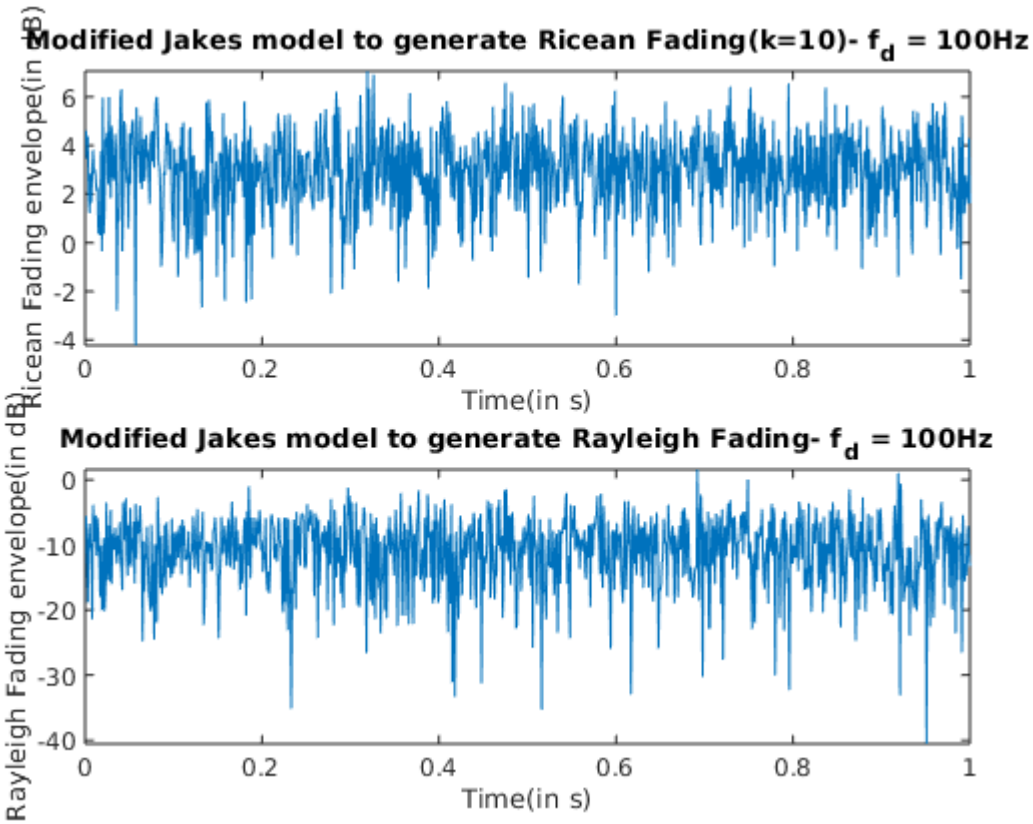

FIGURE 8

PROBLEM 2 :

Simulation of Clarke's Model (Frequency Domain) :

Following the steps of simulation of Clarke's model given in Rapport, the system was set up, and the fading time signal was generated for N=1024 samples.
The parameters, LCR and average duration of fade were computed and compared with the theoretical values for two different Doppler frequencies.

The Rayleigh fading waveform for Doppler frequency of 10 Hz is shown below.

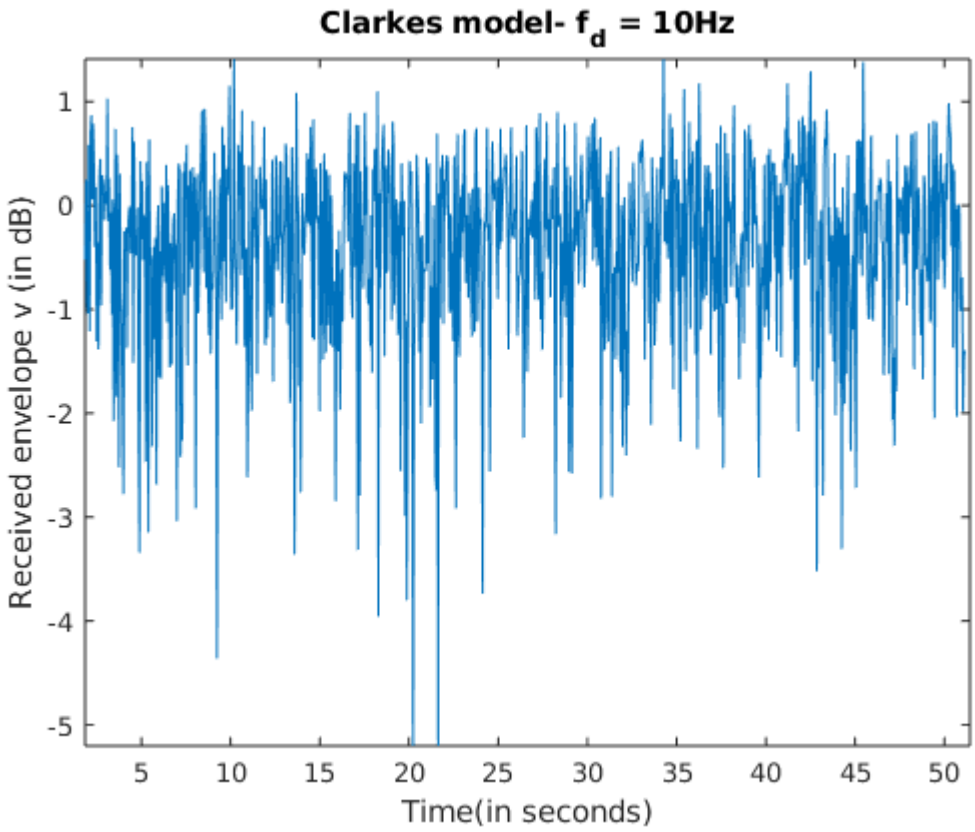

FIGURE 9

1. For Doppler frequency of 10 Hz

Comparison of theoretical and measured level crossing rates :

50 sample functions of fading data set were generated and the level crossing rate was computed for each of the sample functions. An average over 50 sample functions was taken and plotted alongside the theoretical LCR as shown in Figure 10 below.

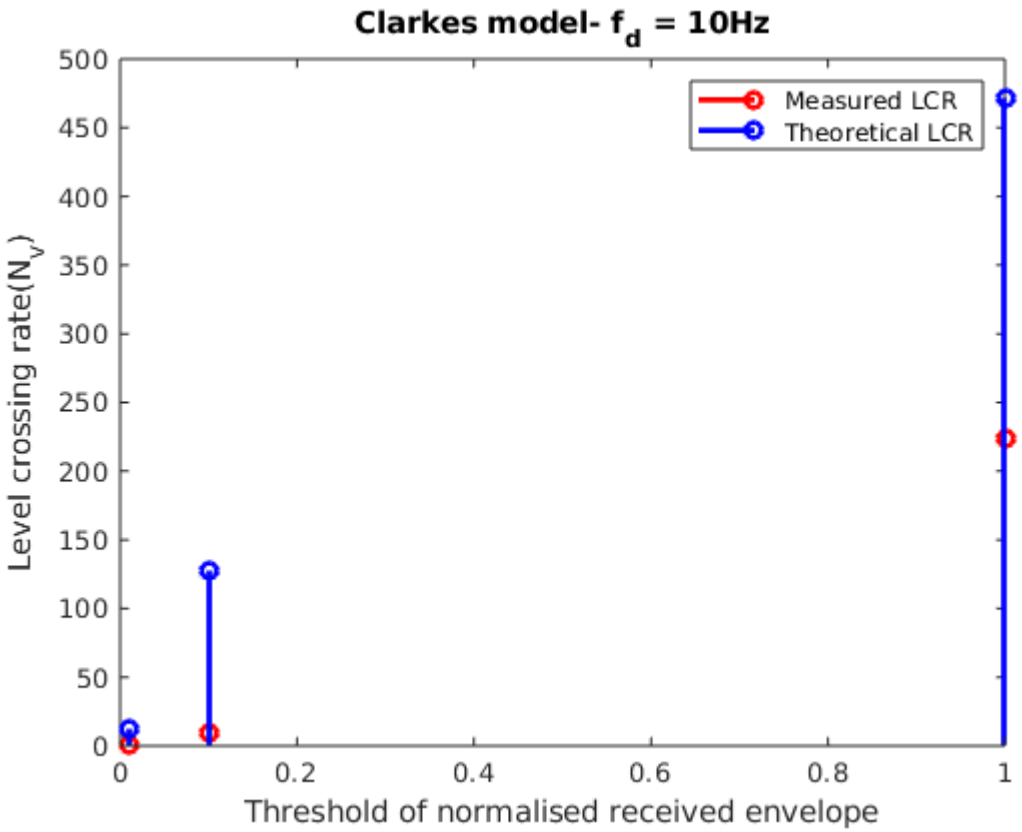

FIGURE 10

Comparison of theoretical and measured average duration of fading :

50 sample functions of fading data set were generated and the average duration of fading was computed for each of the sample functions. The total number of instants for which the fading signal was above a particular threshold was computed and divided by N, to find the average value of fading duration. An average over 50 sample functions was taken and plotted alongside the theoretical duration of fade as shown in Figure 11 below.

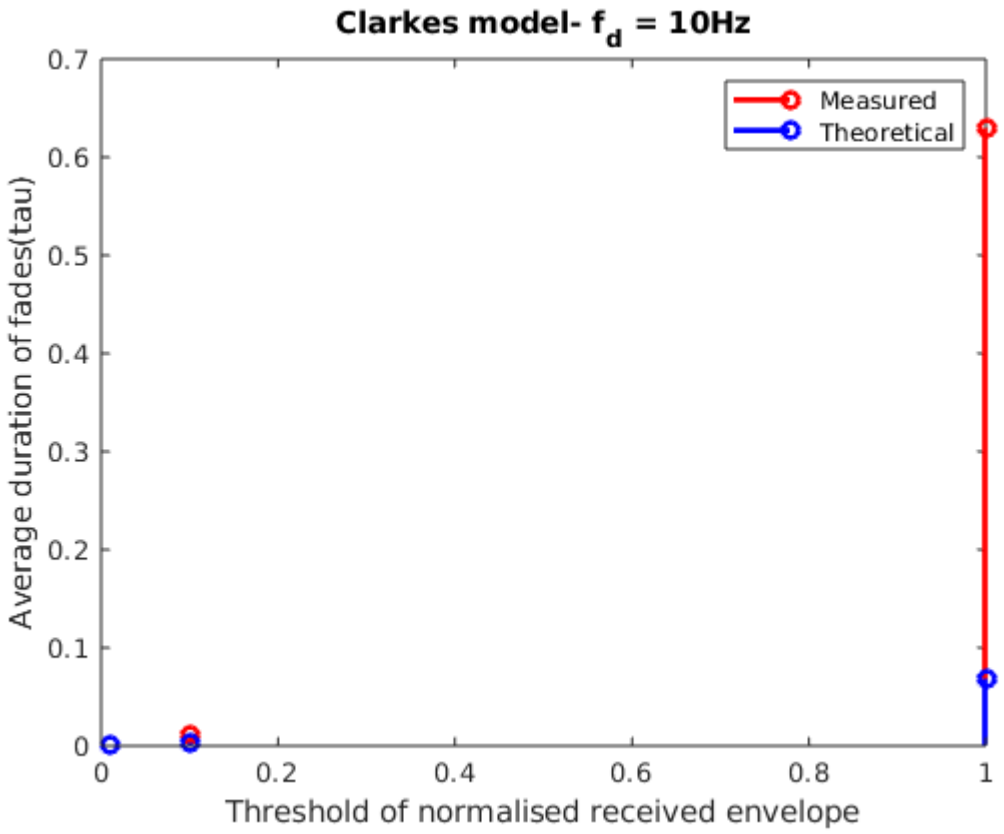

FIGURE 11

2. For Doppler frequency of 100 Hz :

For a frequency of 100Hz, the same procedure was followed and the plots below were generated similarly.

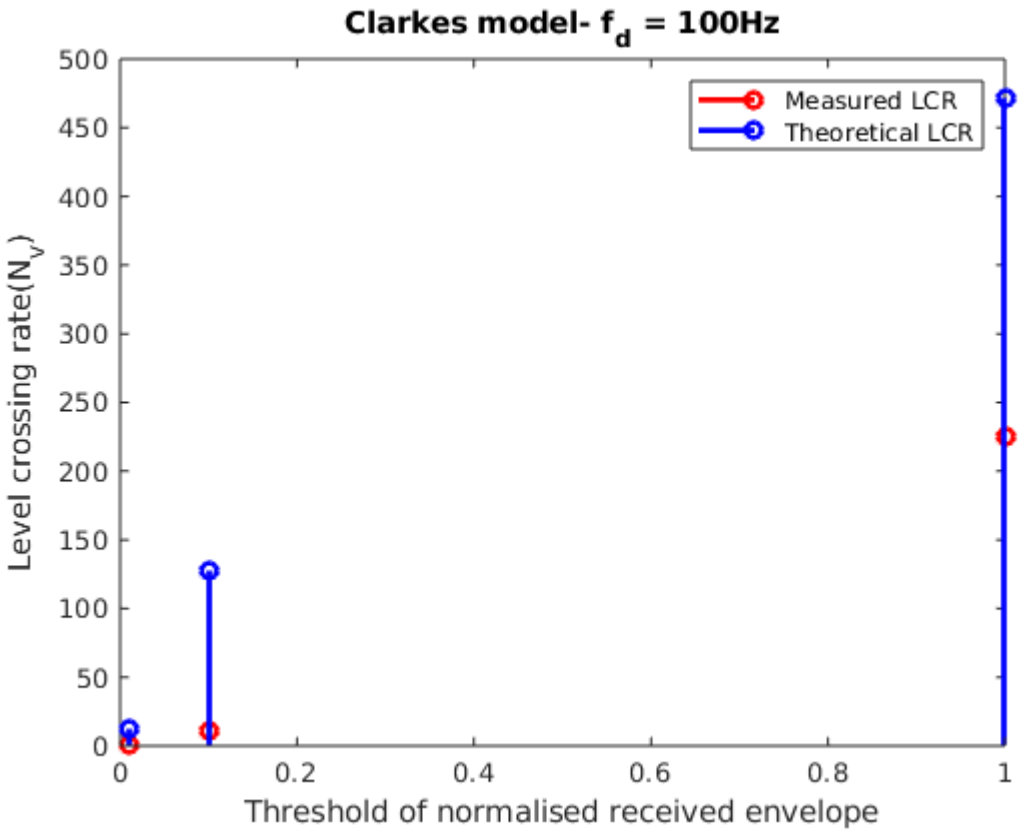

FIGURE 12

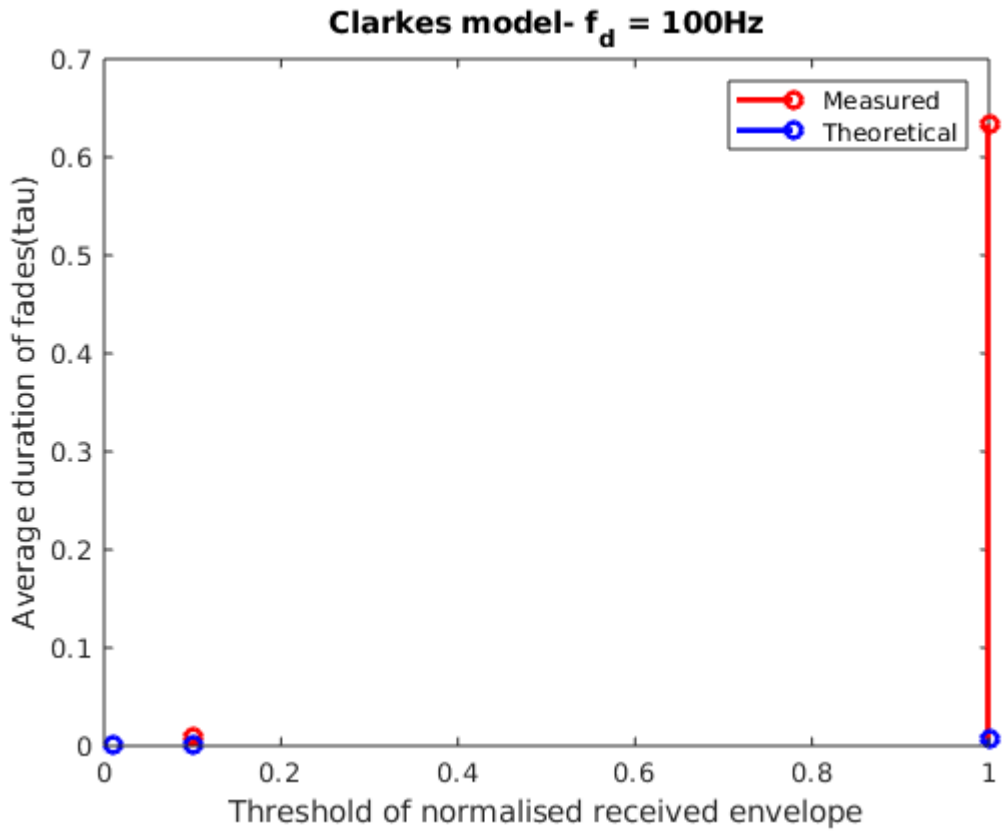

FIGURE 13

Conclusions:

1. The Jakes' and Clarkes model simulation of Rayleigh fading was performed.

2. Level crossing rates and average durations of fade were measured from the simulation for both these models.

3. It was observed that the theoretical value of LCR is greater than the measured value because, since we are limited by the digital domain (by taking only 1000 samples/second- infinite samples is not computationally possible) – there will be more number of crossings theoretically which we will not be able to capture.

4. Due to the same reason, the average duration of fading was more when computed in the simulation than the theoretical value. This is because when between two samples that we take, the fading signal might have crossed the threshold again multiple times, thereby reducing the actual time it spends below it (and also increasing the theoretical LCR).

5. The above two points are clearly seen in the figures comparing the theoretical and simulated parameters of LCR and duration of fade.