Wireless Lab 3

Small Scale Fading of Satellite Systems

1. Introduction

In this lab you will use MATLAB to model fading of a CubeSat satellite system. You will:

a) Determine the Maximum Doppler for the system when relative velocity between the satellite and ground station is 27,400 kilometres per hour,

b) Plot the Doppler spectrum for the system where the relative speed between the satellite and ground station is 27,400 kilometres per hour, and

c) Show what happens to fade duration and fade frequency for the system as distance between the CubeSat and ground station increases.

CubeSats are small, low cost, Low Earth Orbit (LEO) satellites that collect data from multiple transmitters located on the ground as they pass overhead and when over a ground station ("hub") transmit all the collected data in a single long burst back to the ground station which stores the data in a cloud storage service. Users then access the data from the cloud server.

CubeSats move at approximately 27,400 kmph at a height of approximately 200 km. The ground station sensitivity is approximately -95 dBm. The transmit power of the satellite measured 1 metre distance is approximately 30 dBm.

2. Procedure

2.1 Maximum Doppler

Determine the Maximum Doppler for a CubeSat system as the relative velocity between the Base Station and the Mobile Station varies between 0 and 27,400 kilometres per hour. Maximum Doppler is defined as $f_m = \frac{v}{\lambda} = f_c \frac{v}{c}$ where v is the velocity, c is the speed of propagation of e-m radiation (3×10^8 metres per second) and f_c is the carrier frequency. The CubeSat operates at around 145 MHz.

2.2 Doppler Spectrum

Plot the Doppler Spectrum for the CubeSat system. The Doppler Spectrum is

$$S(f) = \frac{1.5/\pi}{f_m\sqrt{1-(\frac{f}{f_m})^2}} \text{ for } |f| < f_m$$

2.2 Rayleigh Fading

In this section you are to plot the fading duration and frequency of fading as the distance between the CubeSat and Ground Station increases from directly overhead at 200 kilometres to a distance of 1000 kilometres. You are to assume the free space model is appropriate and the transmit power of the satellite at one metre is 30 dBm. The sensitivity of the Ground Station receiver is -95 dBm. Assume any signal strength below this is a fade.

Fading rate (sometimes Level Crossing Rate) for a Rayleigh channel is $N_R = \sqrt{2\pi}\, f_m \rho e^{-\rho^2}$.

Average fade duration for a Rayleigh channel is $\bar{\tau} = \frac{e^{\rho^2}-1}{\rho f_m\sqrt{2\pi}}$ The value ρ is a ratio between the mean signal power and the sensitivity of the receiver. That is $\rho = \text{Rx}_{\text{sensitivity}} / \text{Rx}_{\text{RMS}}$.

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3. Discussion topics to be addressed in your report

What information does the Doppler Spectrum provide?

What is the minimum symbol rate needed to avoid Doppler distortion?

If the CubeSat downlink bit rate is 4.3 Mbps how many bits are typically lost during a fade? Assume GMSK with one bit per symbol.

Can you make any recommendations regarding error correction coding for CubeSats?

Is a Rayleigh fading model likely to be accurate for a CubeSat? Are there alternative models that might be better suited to this situation?

4. Report

The report is due two weeks after completion of the lab. The report will be marked out of 11.

The report is to be in IEEE format.

The report for this lab should include the following:

1. Title and author,

2. Abstract (approximately 100 words summarising the experiment and results) ,

3. Introduction (no more than one page giving the theoretical background to the lab as well as a brief discussion of the method used),

4. A results and discussion section (no more than two pages) which is to include MATLAB code, plots and answers to discussion questions,

5. Conclusion (half to one page summary of the experiment results), and

6. References in IEEE format.

5. Assessment

The report will be marked as follows:

Item	Description	Marks allocated
Conforming to IEEE format	You must write the report in IEEE format.	2
Abstract	The abstract is a short summary of the report. It must cover the significant points of the report in as succinct a manner as possible	1
Introduction	No more than one page describing the theoretical background to the lab and a brief discussion of methodology	2
Results and Discussion	No more than one page presenting the results, answering the questions and providing a summary of them	4
Conclusion	A brief summary of the report and results	1

| References | Must include some references and must be in IEEE format | 1 |

A FINAL WARNING:

DO NOT COPY MATERIAL DIRECTLY FROM THE INTERNET.

DO NOT COPY FROM FELLOW STUDENTS.

DO NOT LEND YOUR REPORT TO FELLOW STUDENTS.