THE NAVIC STANDARD

Through Python

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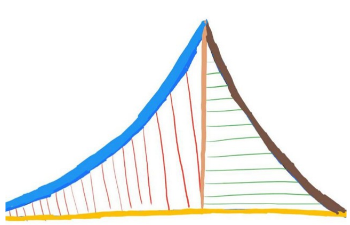

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Introduction

This book introduces the NAVIC communication standard through Python exercises

Chapter 1

Design Parameters

1.1. The Frequency Bands

Chapter 2

Channel Modelling

The phenomena modelled in the satellite communication channel are Doppler shift, delay, power scaling and receiver noise.

2.1. Doppler shift

Due to relative motion between the satellites and the receiver, the transmitted signals undergo a frequency shift before arriving at the receiver. This shiftin frequency is called Doppler shift and can be computed as

$$f_{shift} = f_d - f_c = \left(\frac{V_{rel}}{c - V_{S,dir}}\right) f_c \tag{2.1}$$

where,

f_{Shift} = Frequency shift due to Doppler

f_d = Frequency observed at receiver

f_c = Carrier frequency at transmitter

V_{rel} = Relative velocity of transmitter and receiver

$V_{S,dir}$ = Velocity of satellite along radial direction

c = Speed of light

V_{rel} is given by

$$V_{rel} = V_{S,dir} - V_{R,dir} \tag{2.2}$$

where,

$V_{R,dir}$ = Velocity of receiver along radial direction

$V_{R,dir}$ and $V_{S,dir}$ are given by

$$V_{R,dir} = \mathbf{V}_R \cdot \hat{\mathbf{dir}} \tag{2.3}$$

$$V_{D,dir} = \mathbf{V}_S \cdot \hat{\mathbf{dir}} \tag{2.4}$$

where,

$\hat{\mathbf{dir}}$ = Unit vector from satellite to receiver i.e. radial direction

$\mathbf{V_S}$ = Velocity of satellite

$\mathbf{V_R}$ = Velocity of receiver

$\hat{\mathbf{dir}}$ is given by

$$\hat{\mathbf{dir}} = \frac{\mathbf{P_S} - \mathbf{P_R}}{\|\mathbf{P_S} - \mathbf{P_R}\|} \tag{2.5}$$

where,

$\mathbf{P_S}$ = Position of satellite

$\mathbf{P_R}$ = Position of receiver

The Doppler shift is introduced by muliplying the satellite signal with a complex exponential,

$$x_{Shift}[n] = x[n]\, e^{-2\pi j\left(f_c + f_{Shift}\right)nt_s} \tag{2.6}$$

where,

$x_{Shift}[n]$ = Doppler shifted signal

$x[n]$ = Satellite signal

t_s = Sampling period

2.2. Delay

Since there is a finite distance between the satellite and the receiver, the signal at the reciever is a delayed version of the transmitted signal. This delay is given by

$$D_s = \frac{d}{c} f_s \tag{2.7}$$

where,

D_s = Total delay in samples

d = Distance between satellite and receiver

c = Speed of light

f_s = Sampling rate

The total delay on the satellite signal is modeled in two steps. First, a static delay is modeled which does not change with time and it is always an integer number of samples. Then, a variable delay is modeled which can be a rational number of samples. While modelling the static delay, the entire delay is not introduced so that variable delay modelling handles the remaining delay.

To introduce the static delay, the samples are read from a queue whose size is the desired static delay length. When samples are read from the queue, an equal number of new samples are updated in the queue. To introduce the variable delay, the signal is passed through an all-pass FIR filter with an almost constant phase response. Its coefficients are calculated using the delay value required.

2.3. Power Scaling

When a transmitting antenna transmits radio waves to a receiving antenna, the radio wave power received is given by,

$$P_r = P_t D_t D_r \left(\frac{1}{4\pi \left(f_c + f_{Shift} \right) D} \right)^2 \tag{2.8}$$

where,

P_r = Received power

P_t = Transmitted power

D_t = Directivity of transmitting antenna

D_r = Directivity of receiving antenna

D = Total delay in seconds

To scale the received signal as per the received power calculated,

$$x_{Scaled}\left[n\right] = \frac{\sqrt{P_r}}{\mathrm{rms}\left(x\left[n\right]\right)} x\left[n\right] \tag{2.9}$$

2.4. Receiver noise

Chapter 3

Transmitter

3.1. Frame structure

3.2. Encoding

3.3. Modulation