**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | **Simulation of Flat Fading Channel relevant for IEEE 802.15.4q**  |
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| Re: | Task Group 15.4q Channel Models Recommended to evaluate Proposals  |
| Abstract | TG4q – Simulation of Flat Ricean Fading Channel |
| Purpose | Flat fading Ricean channel models suitable for applications mentioned in IEEE 802.15.4q to serve as reference for fair comparison of proposals and system evaluation |
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Simulation of Flat Ricean Fading Channel Model

# Introduction

The document describes the simulation of a flat fading channel with a LOS component. This is a typical channel model encountered in many applications of interest to TG4q as explained in [1]. The simulator has been created in response to the demand from the TG4q group. The coefficients generated from the simulation may be multiplied with the incoming signals at the appropriate rate prior to noise addition.

***1.1*** ***Purpose***

The purpose of the document is to create a reference flat fading channel simulator for TG4q for system evaluation and fair comparison of PHY proposals

1. **Description of the Simulation**

The recommendation from the group is to specify a simulator for a flat fading channel with a Ricean factor of K= 0dB and a mobility of around 2 miles/hr. The code accepts the K factor in dB, the mobility in miles/hr, the center frequency and the channel sampling rate in Hz as inputs and outputs the channel coefficients at the specified channel sampling rate. The result of the code is to produce channel coefficients at an arbitrary (channel) sampling rate.

***2.1 Generation of Ricean Fading Co-efficient***

We use the method of filtered noise to generate channel coefficients with the specified distribution and spectral

power density. For each tap a set of complex zero-mean Gaussian distributed numbers is generated with a variance of 0.5 for the real and imaginary part, so that the total average power of this distribution is 1. This yields a normalized Rayleigh distribution (equivalent to Rice with K=0) for the magnitude of the complex coefficients. If a Ricean distribution (K>0 implied) is needed, a constant path component m has to be added to the Rayleigh set of coefficients. The ratio of powers between this constant part and the Rayleigh (variable) part is specified by the K-factor. For this general case, we show how to distribute the power correctly. The total power is assumed to be normalized to 1.

$$1= \left|m\right|^{2}+σ^{2} (1)$$

Where m is the constant and $σ^{2}$ the variance of the complex Gaussian set. The ratio of powers is

$$K= \frac{\left|m\right|^{2}}{σ^{2}} (2)$$

From these equations, we can find the power of the complex Gaussian and the power of the constant part as

$$\left|m\right|^{2}=\frac{K}{K+1}, σ^{2}=\frac{1}{K+1} (3)$$

***2.2 Doppler Spectrum***

The complex Gaussian distributed numbers are filtered using Doppler filters with the power spectrum given by

$$S(f)=\frac{1}{πf\_{d}\sqrt{1-\left(\frac{f}{f\_{d}}\right)^{2}}}, \left|f\right|<f\_{d}, f\_{d}=\frac{vf\_{c}}{c} (4) $$

Here $f\_{d}, f\_{c}, c,v $are the Doppler frequency, center frequency, the velocity of light and the pedestrian mobility considered here. Two sets of zero mean complex Gaussian numbers are arranged symmetrically and multiplied with the Doppler filter in the frequency domain. The symmetry ensures that real outputs are obtained, one each for the in-phase and quadrature arms respectively. The normalization of the power to adjust for the power in the spectral components and the NLOS components is then carried out.

1. **Matlab Simulation Code**

function f = ChannSim4q()

clc;close all;clear all;

v = 3.6; % Km/hr equivalent to 2.23miles/hr;

fc = 2.4e9; % Center Frequency Hz

Kf = 0; % Ricean K factor in dB

fs = 1e6; % Channel Sampling Rate in Hz

h = FlatFad2(Kf, v, fc, fs);

figure;

semilogy([0:floor(length(h)/10)-1].\*1./fs,abs(h(1:floor(length(h)/10))));

xlabel('Time (seconds)');

ylabel('Amplitude');

title('Ricean Flat Fading Channel')

end

function Str = FlatFad2(Kf, m, fc, BWsamp)

%--------------------Derived Parameters -----------------------------------

v = m\*1e3/(3600); % Velocity in m/s

c = 3e8; % Velocity of light in m/s

fd = floor(v\*fc/c); % Maximum Doppler Frequency in Hz

fsamp = 256; % Number of frequency smaples within Doppler Bandwidth

fdmax = 100; % Hz (BW = 2\*fdmax)

K = 10^(0.1\*Kf); % dB to linear scale conversion

s2 = 1./(K+1); % Calculate variance scaling for complex Gaussian process

m2 = K./(K+1); % Calculate constant power for specular component

%--------------------Doppler Filter----------------------------------------

ft = [-fd:2\*fd/(fsamp):fd]; % Frequency axis of Doppler Filter

Sf = 1.5./(pi\*fd\*sqrt(1-(ft/fd).^2)); % Doppler Filter

Sf(1) = 1000; % limiting the infinite values

Sf(end) = Sf(1);

Sf = sqrt(Sf);

%-------------------Frequency axis for fdmax sampling ---------------------

fre = round((fdmax-fd)\*fsamp/(2\*fd));

lft = [ -fd-fre\*2\*fd/(fsamp):2\*fd/(fsamp):-fd-2\*fd/(fsamp)];

rft = [ fd + 2\*fd/(fsamp):2\*fd/(fsamp): fd + fre\*2\*fd/(fsamp)];

faxis = [lft ft rft];

%-------------------Generation of in-phase component-----------------------

I = randn(1,fsamp/2)+randn(1,fsamp/2)\*1i; % Complex Gaussian Process

Im = [I 0 fliplr(conj(I))]; % Symmetrical Output

ISfiltBB = [Sf(1+fsamp/2:end).\*Im(1+fsamp/2:end) zeros(1,2\*fre)...

 Sf(1:fsamp/2).\*Im(1:fsamp/2)]; % Frequency Domain Filtering and

 % Interpolation

In = ifft([ISfiltBB]); % Generation of In-phase component

In = 1./sqrt(2)\*In./(sqrt(mean(In.^2))); % Normalization

%-------------------Generation of Quadrature component---------------------

Q = randn(1,fsamp/2)+i\*randn(1,fsamp/2)\*1i; % Complex Gaussian Process

Qm = [Q 0 fliplr(conj(Q))]; % Symmetrical Output

QSfiltBB = [Sf(1+fsamp/2:end).\*Qm(1+fsamp/2:end) zeros(1,2\*fre)...

 Sf(1:fsamp/2).\*Qm(1:fsamp/2)]; % Frequency Domain Filtering and

 % Interpolation

Qn = ifft([QSfiltBB]); % Generation of Quadrature component

Qn = 1./sqrt(2)\*Qn./(sqrt(mean(Qn.^2))); % Normalization

Sr = (In+Qn\*1i); % Generation of the Rayleigh Fading Component

St = sqrt(m2) + sqrt(s2).\*Sr; % Generation of the Ricean Fading i.e. LOS and NLOS

Str = resample(St(1:2000),BWsamp/1,(2\*fdmax)); % Matching to Channel Sampling Rate

 % 10 seconds simulation at 1MHz sampling

end

#

Fig: Exemplary Ricean fading channel amplitudes as a function of time

If simulation related errors are displayed due to the usage of a different version of Matlab, store the two functions in different files say “ChannSim4q.m” for the function ChannSim4q and “FlatFad2.m” for the function FlatFad2 in one folder and make this the working folder in Matlab. Comment “function f = ChannSim4q()” and “end” in ChannSim4q.m. To generate the co-efficient, run ChannSim4q.m.

# References

1. Jinesh Nair, Kiran Bynam and Youngsoo Kim, “Channel Models for IEEE 802.15.4q” IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs), DCN: 15-12-0329-00, May. 2013.