Radio Engineering: Third Lab Session

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1 Problem 1: Simulation of a Rayleigh fading channel using the sum-of-sinusoids method

Implement the sum-of-sinusoids method for the generation of a narrowband Rayleigh fading channel with a Jakes Doppler spectrum given by

$$h_m = \sum_{p=0}^{P-1} \beta_p e^{2\pi j(\phi_p + m\nu_p)},$$

where $\nu_p = \omega_p T_S$ is the normalized Doppler shift of path p with

- $\beta_p = 1/\sqrt{P}$,
- $\nu_p = \nu_{\max} \cos\psi_p$ where $\nu_{\max} = \omega_{\max} T_S$ is the maximum normalized Doppler shift and ψ_p is the AoA of path p
- ϕ_p and ψ_p are mutually independent and uniformly distributed in $[-\pi, \pi)$

The function should have as input parameters the sample time T_S, the maximum Doppler shift $\omega_{\max}$, the number of paths P and the number of samples to generate.

With the help of the new function, generate a channel of length 10ms with a sample rate of 7.68 MHz and a maximum Doppler shift of 300 Hz. For comparison, generate a channel with the same statistics using the Matlab-internal function, which uses a filter based method for the generation of the correlated sequence:

```
rayChanObj = rayleighchan(T_S, omega_max, 0, 0) ;
rayChanObj.StoreHistory = 1;
x = ones(nb_samples,1);
y = filter(rayChanObj,x);
g = rayChanObj.PathGains;
```

Compute the autocorrelation function of both sequences and plot them. Compare your results with the theoretical autocorrleation function.

2 Problem 2: Capacity of MIMO channels

To solve this problem you will need to download and extract the archive (Linux/Windows)[1]

`/datas/teaching/courses/RADIO/lab2015/capacity.zip`
`\\datas\teaching\courses\RADIO\lab2015\capacity.zip`

Assume a simple Kronecker MIMO channel model

$$\mathbf{R} = \mathbf{R}_{Tx} \otimes \mathbf{R}_{Rx}$$

with

$$\mathbf{R}_{Tx} = \begin{pmatrix} 1 & \alpha \\ \alpha^* & 1 \end{pmatrix} \quad \text{and} \quad \mathbf{R}_{Rx} = \begin{pmatrix} 1 & \beta \\ \beta^* & 1 \end{pmatrix}$$

There are 3 different scenarios

- low correlation: $\alpha = \beta = 0$
- medium correlation: $\alpha = 0.3, \beta = 0.9$
- high correlation: $\alpha = \beta = 0.9$

For each of those 3 scenarios, generate a narrowband Rayleigh fading channel with the given correlation matrix. To achieve this, first generate 4 independet fading channels using the function and the parameters from the previous problem and arrange them in a matrix $\mathbf{G}$ of size $2 \times 2 \times N_{\text{samples}}$. Then, for each sample $\mathbf{G}_n = \mathbf{G}(:, :, n)$, correlate the entries of the matrix using the stochastic method for Kronecker models:

$$\mathbf{H}_n = \mathbf{R}_{Rx}^{\frac{1}{2}} \mathbf{G}_n (\mathbf{R}_{Tx}^{\frac{1}{2}})^T.$$

Use the Maltab function `sqrtm` to calculate the matrix square root.

Then use the capacity function `capacity_SU_CL_ML` provided in the archive to calculate the capacity for these three channels. Use an SNR range of -20 to 30 dB in steps of 10 dB. Use the build-in help function to learn the syntax. Plot the mean capacity over the SNR range and compare the results for all three scenarios.

[1]The file can also be downloaded from the course webpage