INTERNATIONAL HELLENIC UNIVERSITY
School of Science and Technology

Virtual Labs #2: "Fading Processes-Channel Characterization": Documentation

Referring to Courses:
Mobile Communication Networks,
MSc in Information and Communication Technology Systems

prepared by

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1.0 Preface

This report constitutes the documentation of the 2^{nd} virtual laboratory environment that was developed for the "Mobile Communication Networks" and "Sensor Networks" courses of the MSc in Information and Communication Technology Systems, International Hellenic University.

Purpose of the present work is to familiarize the user with the concepts of E/M fading processes with regard to user mobility and modulation-encoding configurations, and enable the user to characterize a channel as narrowband or wideband depending on its characteristics.

The report consists of four main sections.

The fist section outlines the basics of E/M propagation theory that are examined in the context of this lab. This is not intended to be a thorough study or teaching material in any case, but rather a starter for more in-depth research and study.

The following three sections provide usage information for the simple user (student of an MSc program in Telecommunications), the supervisor (academic assistant with some knowledge of programming in MATLAB) and the programmer (expert in generic object oriented programming and particularly in MATLAB). The provided information in this leaflet intends to familiarize the simple user with the graphical interface and its potential, endow the supervisor with enough knowledge to create custom exercise scenarios and program expansions, and provide a blueprint for the programmer that has been bestowed with the task of heavily modifying/expanding the original program.

Finally a list of the main MATLAB files/functions that comprise the program is supplied.

September 8, 2010

Liaskos Christos, Electrical Engineer, Dpt. of Informatics, A.U.Th.

2.0 Introduction: Theoretical concepts

2.1 Fading processes

In wireless communications, fading is deviation of the attenuation that a carrier-modulated telecommunication signal experiences over certain propagation media. The fading may vary with time, geographical position and/or radio frequency, and is often modelled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading.

The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and phase shift while travelling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal-to-noise ratio.

A common example of multipath fading is the experience of stopping at a traffic light and hearing an FM broadcast degenerate into static, while the signal is re-acquired if the vehicle moves only a fraction of a meter. The loss of the broadcast is caused by the vehicle stopping at a point where the signal experienced severe destructive interference. Cellular phones can also exhibit similar momentary fades.

Fading channel models are often used to model the effects of electromagnetic transmission of information over the air in cellular networks and broadcast communication. Fading channel models are also used in underwater acoustic communications to model the distortion caused by the water. Mathematically, fading is usually modeled as a time-varying random change in the amplitude and phase of the transmitted signal.

Slow versus fast fading

The terms slow and fast fading refer to the rate at which the magnitude and phase change imposed by the channel on the signal changes. The coherence time is a measure of the minimum time required for the magnitude change of the channel to become uncorrelated from its previous value.

- Slow fading arises when the coherence time of the channel is large relative to the delay constraint of the channel. In this regime, the amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver. The amplitude change caused by shadowing is often modeled using a log-normal distribution with a standard deviation according to the log-distance path loss model.
- Fast fading occurs when the coherence time of the channel is small relative to the delay constraint of the channel. In this regime, the amplitude and phase change imposed by the channel varies considerably over the period of use.

In a fast-fading channel, the transmitter may take advantage of the variations in the channel conditions using time diversity to help increase robustness of the communication to a temporary deep fade. Although a deep fade may temporarily erase some of the information transmitted, use of an error-correcting code coupled with successfully transmitted bits during other time instances (interleaving) can allow for the erased bits to be recovered. In a slow-fading channel, it is not possible to use time diversity because the transmitter sees only a single realization of the channel within its delay constraint. A deep fade therefore lasts the entire duration of transmission and cannot be mitigated using coding.

The coherence time of the channel is related to a quantity known as the Doppler spread of the channel. When a user (or reflectors in its environment) is moving, the user's velocity causes a shift in the frequency of the signal transmitted along each signal path. This phenomenon is known as the Doppler shift. Signals traveling along different paths can have different Doppler shifts, corresponding to different rates of change in phase. The difference in Doppler shifts between different signal components contributing to a single fading channel tap is known as the Doppler spread. Channels with a large Doppler spread have signal components that are each changing independently in phase over time. Since fading depends on whether signal components add constructively or destructively, such channels have a very short coherence time. In general, coherence time is inversely related to Doppler spread, typically expressed as

$$T_c = \frac{k}{D_s}$$

where T_c is the coherence time, D_s is the Doppler spread, and k is a constant taking on values in the range of 0.25 to 0.5.

Flat versus frequency-selective fading

As the carrier frequency of a signal is varied, the magnitude of the change in amplitude will vary. The coherence bandwidth measures the separation in frequency after which two signals will experience uncorrelated fading. In flat fading, the coherence bandwidth of the channel is larger than the bandwidth of the signal. Therefore, all frequency components of the signal will experience the same magnitude of fading. In frequency-selective fading, the coherence bandwidth of the channel is smaller than the bandwidth of the signal. Different frequency components of the signal therefore experience decorrelated fading. Since different frequency components of the signal are affected independently, it is highly unlikely that all parts of the signal will be simultaneously affected by a deep fade. Certain modulation schemes such as OFDM and CDMA are well-suited to employing frequency diversity to provide robustness to fading. OFDM divides the wideband signal into many slowly modulated narrowband subcarriers, each exposed to flat fading rather than frequency selective fading. This can be combated by means of error coding, simple equalization or adaptive bit loading. Intersymbol interference is avoided by introducing a guard interval between the symbols. CDMA uses the Rake receiver to deal with each echo separately. Frequency-selective fading channels are also dispersive, in that the signal energy associated with each symbol is spread out in time. This causes transmitted symbols that are adjacent in time to interfere with each other. Equalizers are often deployed in such channels to compensate for the effects of the intersymbol interference. The echoes may also be exposed to Doppler shift, resulting in a time varying channel model.

Fading models

Examples of popular fading models for the distribution of the attenuation are:

- Rayleigh fading
- Rician fading

Less popular models not examined in this context are:

- Nakagami fading
- Weibull fading
- Dispersive fading models, with several echoes, each exposed to different delay, gain and phase shift, often constant. This results in frequency selective fading and inter-symbol

interference. The gains may be Rayleigh or Rician distributed. The echoes may also be exposed to Doppler shift, resulting in a time varying channel model.

- Log-normal shadow fading

Mitigation

Fading can cause poor performance in a communication system because it can result in a loss of signal power without reducing the power of the noise. This signal loss can be over some or all of the signal bandwidth. Fading can also be a problem as it changes over time: communication systems are often designed to adapt to such impairments, but the fading can change faster than the adaptations can be made. In such cases, the probability of experiencing a fade (and associated bit errors as the signal-to-noise ratio drops) on the channel becomes the limiting factor in the link's performance. The effects of fading can be combated by using diversity to transmit the signal over multiple channels that experience independent fading and coherently combining them at the receiver. The probability of experiencing a fade in this composite channel is then proportional to the probability that all the component channels simultaneously experience a fade, a much more unlikely event.

Diversity can be achieved in time, frequency, or space. Common techniques used to overcome signal fading include:

- Diversity reception and transmission
- OFDM
- Rake receivers
- Spacetime codes
- MIMO

2.2 Rayleigh Fading

As described, Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices.

Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables.

Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable.

The model

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and $2 \cdot \pi$ radians. The envelope of the channel response will therefore be Rayleigh distributed.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes.

Applicability

The requirement that there be many scatterers present means that Rayleigh fading can be a useful model in heavily built-up city centres where there is no line of sight between the transmitter and receiver and many buildings and other objects attenuate, reflect, refract and diffract the signal. Experimental work in Manhattan has found near-Rayleigh fading there. In tropospheric and ionospheric signal propagation the many particles in the atmospheric layers act as scatterers and this kind of environment may also approximate Rayleigh fading. If the environment is such that, in addition to the scattering, there is a strongly dominant signal seen at the receiver, usually caused by a line of sight, then the mean of the random process will no longer be zero, varying instead around the power-level of the dominant path. Such a situation may be better modelled as Rician fading.

Figure 1: Densely-built Manhattan has been shown to approach a Rayleigh fading environment.

Note that Rayleigh fading is a small-scale effect. There will be bulk properties of the environment such as path loss and shadowing upon which the fading is superimposed. How rapidly the channel fades will be affected by how fast the receiver and/or transmitter are moving. Motion causes Doppler shift in the received signal components. The figures show the power variation over 1 second of a constant signal after passing through a single-path

Rayleigh fading channel with a maximum Doppler shift of 10 Hz and 100 Hz. These Doppler shifts correspond to velocities of about 6 km/h (4 mph) and 60 km/h (40 mph) respectively at 1800 MHz, one of the operating frequencies for GSM mobile phones. This is the classic shape of Rayleigh fading. Note in particular the 'deep fades' where signal strength can drop by a factor of several thousand, or $30 - 40$ dB.

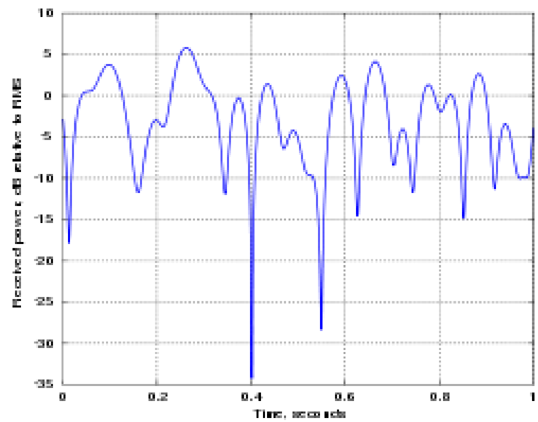

Figure 2: One second of Rayleigh fading with a maximum Doppler shift of $10Hz$.

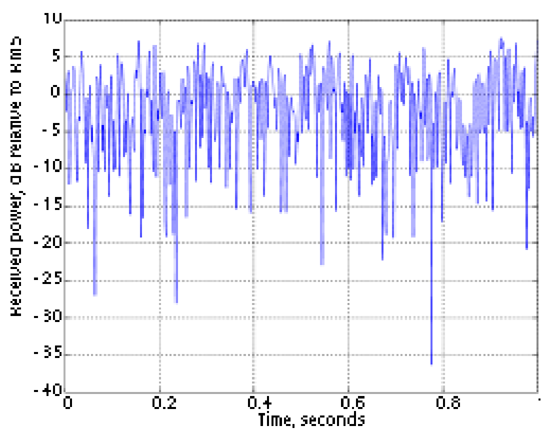

Figure 3: One second of Rayleigh fading with a maximum Doppler shift of $100Hz$.

Properties

Since it is based on a well-studied distribution with special properties, the Rayleigh distribution lends itself to analysis, and the key features that affect the performance of a wireless network have analytic expressions. Note that the parameters discussed here are for a non-static channel. If a channel is not changing with time, clearly it does not fade and instead remains at some particular level. Separate instances of the channel in this case will be uncorrelated with one another owing to the assumption that each of the scattered components fades independently. Once relative motion is introduced between any of the transmitter, receiver and scatterers, the fading becomes correlated and varying in time.

Correlation

The normalized autocorrelation function of a Rayleigh faded channel with motion at a constant velocity is a zeroth-order Bessel function of the first kind:

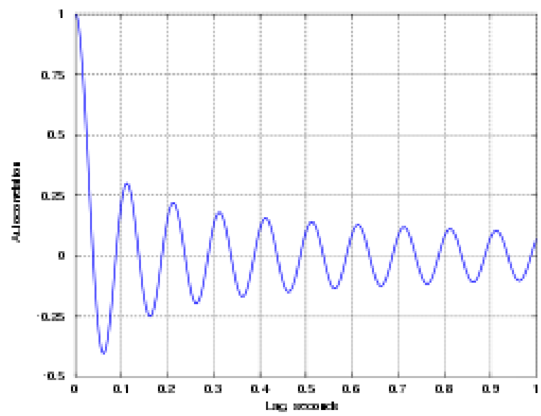

Figure 4: The autocorrelation function of the 10Hz Doppler Rayleigh fading channel.

Level crossing rate The level crossing rate is a measure of the rapidity of the fading. It quantifies how often the fading crosses some threshold, usually in the positive-going direction. For Rayleigh fading, the level crossing rate is:

$$LCR = \sqrt{2\pi} f_d \rho e^{-\rho^2}$$

where f_d is the maximum Doppler shift and ρ is the threshold level normalized to the root mean square (RMS) signal level

Average fade duration

The average fade duration quantifies how long the signal spends below the threshold . For Rayleigh fading, the average fade duration is:

$$AFD = \frac{1 - e^{-\rho^2}}{LCR}$$

The level crossing rate and average fade duration taken together give a useful means of characterizing the severity of the fading over time.

Doppler power spectral density

The Doppler power spectral density of a fading channel describes how much spectral broadening it causes. This shows how a pure frequency e.g. a pure sinusoid, which is an impulse in the frequency domain is spread out across frequency when it passes through the channel. It is the Fourier transform of the time-autocorrelation function. For Rayleigh fading with a vertical receive antenna with equal sensitivity in all directions, this has been shown to be:

$$S(\nu) = \frac{1}{\pi f_d \sqrt{1 - \left(\frac{\nu}{f_d}\right)^2}}$$

where ν is the frequency shift relative to the carrier frequency. This equation is only valid for values of ν between $\pm f_d$ the spectrum is zero outside this range. This spectrum is shown in the figure for a maximum Doppler shift of 10 Hz. The 'bowl shape' or 'bathtub shape' is the classic form of this Doppler spectrum.

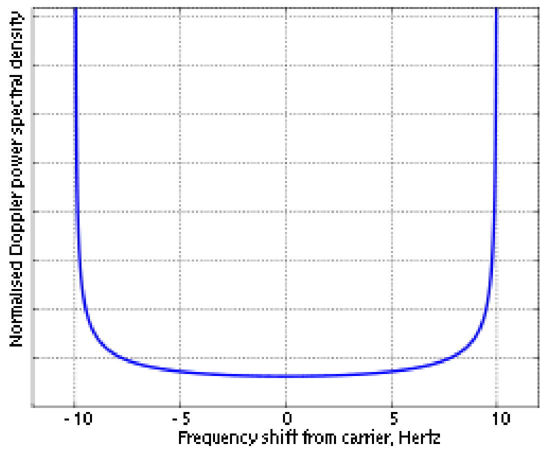

Figure 5: The normalized Doppler power spectrum of Rayleigh fading with a maximum Doppler shift of 10Hz.

2.3 Rician Fading

Rician fading is a stochastic model for radio propagation anomaly caused by partial cancellation of a radio signal by itself the signal arrives at the receiver by two different paths (hence exhibiting multipath interference), and at least one of the paths is changing (lengthening or shortening). Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution. Rayleigh fading is the specialized model for stochastic fading when there is no line of sight signal, and is sometimes considered as a special case of the more generalized concept of Rician fading. In Rayleigh fading, the amplitude gain is characterized by a Rayleigh distribution.

2.4 Further reading

See references [1, 2]. The above content was based on corresponding entries of "*wikipedia, the online encyclopedia*".

3.0 User's Manual

3.1 Requirements

- MATLAB version 2009b or 100% compatible. Consult the manual of your version of MATLAB for backwards compatibility, if you intend to use a more recent version of MATLAB.
- The Simulink package with the virtual reality toolbox installed.
- A version of Microsoft Windows capable of running the used MATLAB version.
- Dual core CPU with 2GB RAM. Quad core CPU with 4GB RAM ensures optimal performance.

3.2 Installation Notes

The installation procedure follows that of the 1^{st} virtual lab "Antennas and Propagation":

- Place the provided application files in a folder that you specify, denoted as $USER\_DIR$. This folder will contain the files (.m, .fig) and folders (BaseClasses, customClasses, demo, functions, java, originals, rician, slprj, texture) that comprise the application.
- Add the $USER\_DIR$ and all contained subfolders EXCEPT FOR THE "ORIGINALS" FOLDER to the MATLAB path. Consult the manual of your version of MATLAB for more details.
- Make sure that none of the application files are shadowed by same-named but irrelevant files already in the MATLAB path. It is advised to revert the MATLAB path to its factory default value before step 2, to avoid any shadowing problem. For more information on shadowing consult the manual of your version of MATLAB.

- Create a REG_SZ entry at windows registry location 'HKLM/SOFTWARE/IHUvlab2' with the name 'installPath' and content the absolute installation path of the application.

3.3 Application execution and usage

To start the application, change the current working path of MATLAB to $USER\_DIR$ and issue "vlabs2" at the MATLAB command prompt.

The simulation setup form and the 3D visualization form will appear:

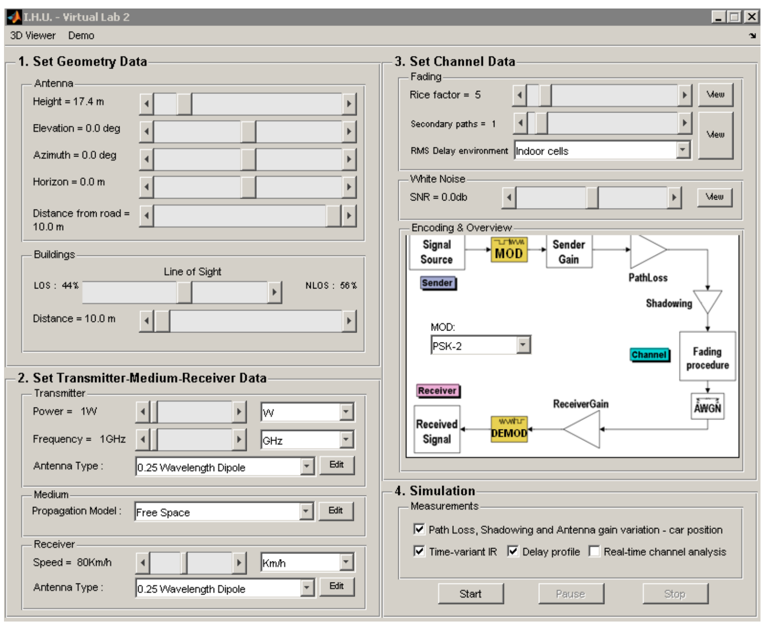

Figure 6: The simulation setup form.

Understanding the 3D visualization and related control.

The 3D visualization form displays a vehicle moving on a road between two rows of buildings. An transmitting antenna is placed at an arbitrary point on the plane. The car carries a receiving antenna. Due to the obstruction of buildings and the movement of the client/vehicle, electromagnetic shadowing, fading and doppler frequency shift phenomena occur. The user

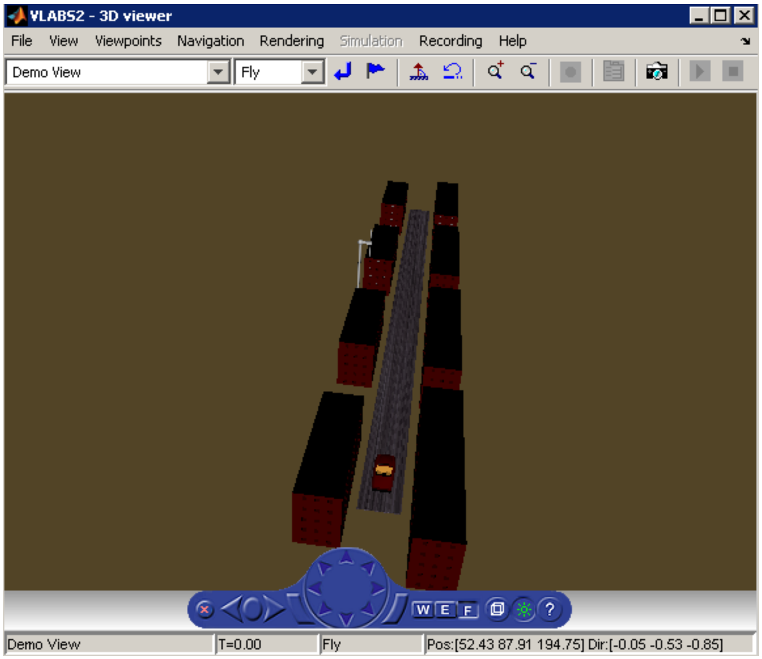

Figure 7: The 3D visualization form.

can study the effects of this phenomena on the signal reception quality, while varying the system's geometry and signal modulation parameters in pre-specified ways.

Using the menu bar, toolbar, and navigation panel on the 3D visualization form, you can

- Customize the Orbisnap window
- Manage virtual world viewpoints
- Manage scene rendering
- Navigate in the scene

Menu Bar The menu bar has the following menus:

- File – General file operation options, including:
- ++Open – Invokes a browser that you can use to browse to the virtual world you want to visualize.

- ++Connect to server – Allows you to connect to a Simulink 3D Animation server. Enter the IP address or host name of the host computer running the Simulink 3D Animation server (127.0.0.1 by default) and the port number at which the Simulink 3D Animation server is listening (8124 by default).
- ++Reload – Reloads the saved virtual world. Note that if you have created any viewpoints in this session, they are not retained unless you have saved those viewpoints with the Save As option.
- ++Save As – Allows you to save the virtual world.
- ++Close – Closes the form.
- View – Enables you to customize the form, including:
- ++Toolbar – Toggles the toolbar display.
- ++Status Bar – Toggles the status bar display at the bottom of the form. This display includes the current viewpoint, simulation time, navigation method, and the camera position and direction.
- ++Navigation Zones – Toggles the navigation zones on/off (see Navigation for a description of how to use navigation zones).
- ++Navigation Panel – Controls the display of the navigation panel, including toggling it.
- ++Zoom In/Out – Zooms in or out of the world view.
- ++Normal (100%) – Returns the zoom to normal (initial viewpoint setting).
- Viewpoints – Manages the virtual world viewpoints.
- Navigation – Manages scene navigation.

- Rendering – Manages scene rendering.
- Help – Displays the Help browser.

Toolbar The toolbar has buttons for some of the more commonly used operations available from the menu bar. These buttons include:

- Drop-down list that displays all the viewpoints in the virtual world
- Return to viewpoint button
- Create viewpoint button
- Straighten up button
- Drop-down list that displays the navigation options Walk, Examine, and Fly.
- Undo move button
- Zoom in/out buttons ,

Navigation Panel The navigation panel has navigation controls for some of the more commonly used navigation operations available from the menu bar. These controls include:

Hide panel – Toggles the navigation panel. Next/previous viewpoint – Toggles through the list of viewpoints. Return to default viewpoint – Returns focus to original default viewpoint. Slide left/right – Slides the view left or right. Navigation wheel – Moves view in one of eight directions. Navigation method – Manages scene navigation. Wireframe toggle – Toggles scene wireframe rendering. Headlight toggle – Toggles camera headlight. Help – Invokes the online help.

Navigation

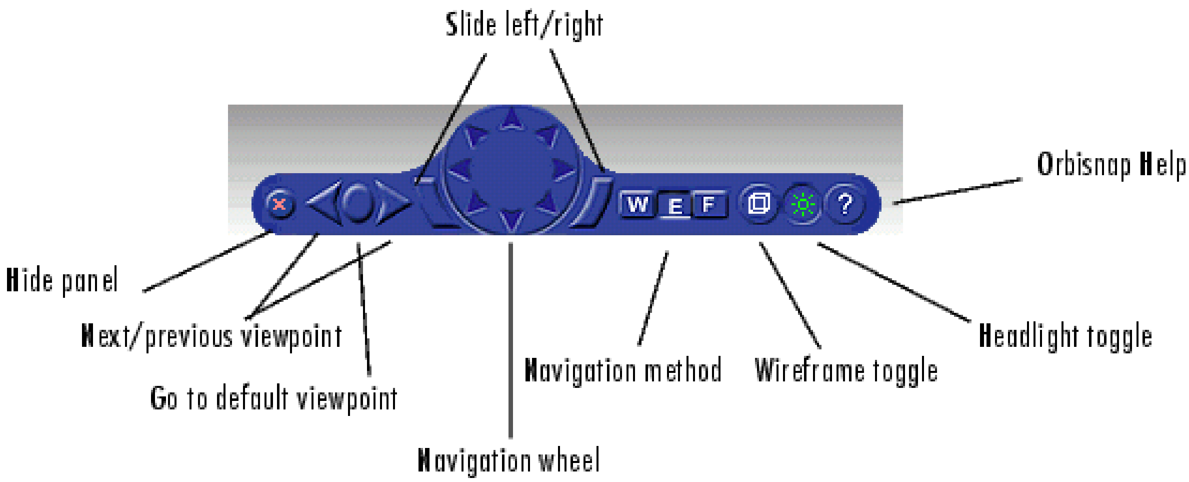

Figure 8: Navigation Panel.

You can navigate around a virtual world using the menu bar, toolbar, navigation panel, mouse, and keyboard.

Navigation view – You can change the camera position. From the menu bar, select the Navigation menu Straighten Up option. Alternatively, you can click the Straighten Up control from the toolbar or press F9 on the keyboard. This option resets the camera so that it points straight ahead.

Navigation methods – Navigation with the mouse depends on the navigation method you select and the navigation zone you are in when you first click and hold down the mouse button. You can set the navigation method using one of the following:

From the menu bar, select the Navigation menu Method option. This option provides three choices, Walk, Examine, or Fly. See the table Mouse Navigation. From the toolbar, select the drop-down menu that displays the navigation options Walk, Examine, and Fly. From the navigation panel, click the W, E, or F buttons. From the keyboard, press Shift+W, Shift+E, or Shift+F. Navigation zones – You can view the navigation zones for a virtual world through the menu bar or keyboard.

From the menu bar, select the View menu Navigation Zones option. The virtual world changes as the navigation zones are toggled on and appear in the virtual world. Alternatively, from the keyboard, press the F7 key.

The following table summarizes the behavior associated with the movement modes and navigation zones when you use your mouse to navigate through a virtual world. Turn the navigation zones on and experiment by clicking and dragging your mouse in the different zones of a virtual world.

Movement Mode	Zone and Description
Walk	**Outer** -- Click and drag the mouse up, down, left, or right to slide the camera in any of these directions in a single plane. **Inner** -- Click and drag the mouse up and down to move forward and backward. Drag the mouse left and right to turn left or right.
Examine	**Outer** -- Click and drag the mouse up and down to move forward and backward. Drag the mouse left and right to slide left or right. **Inner** -- Click and drag the mouse to rotate the viewpoint around the origin of the scene.
Fly	**Outer** -- Click and drag the mouse to tilt the view either left or right. **Inner** -- Click and drag the mouse to pan the camera up, down, left, or right within the scene. **Center** -- Click and drag the mouse up and down to move forward and backward. Move the mouse left or right to turn in either of these directions.

Figure 9: Navigation through mouse.

Understanding the simulation setup form controls. This form contains all the controls than enable you to create customized scenarios and study the fading processes with regard to client mobility.

Menu Bar

- 3D viewer: Enables you to reopen the 3D viewer form if it has been closed.
- Demo : A non-interactive demo of the application will be played.

To setup a simulation follow through the panels described below in the mentioned order:

1. "Set Geometry Data" panel:

Use the contained controls at the "Antenna" sub-panel to place the antenna at the desired location on the field. Labels are trivial and self-descriptive. Any change will be reflected instantly at the 3D visualization form.

Use the contained controls at the "Buildings" sub-panel to define the street's width ("Distance") and building size ("LOS"). The former will affect the distribution model used to generate the secondary propagation paths and will alter the value of the "RMS Delay environment" listbox in Panel No. 3 ("set channel data" / "Fading"). The latter will define the time percentage during the vehicle's movement that there is visual contact (Line Of Sight-LOS) between the antenna and the vehicle.

2. "Set Transmitter-Medium-Receiver Data" panel:

Use the contained controls to change the carrier frequency, power and antenna types of the transmitter and receiver. Propagation models of the medium can also be altered through the corresponding control. A more detail description of these controls have been given at "Virtual Lab 1: Antennas and propagation".

3. "Set Channel Data" panel:

Use the contained controls to set the rice factor for the line-of-sight part of the vehicle's trip. The corresponding non-line-of-sight value of this parameter is hardwired to 0 and may not be changed.

Use the "secondary paths" slider to set the number of secondary propagation paths.

Use the "AWGN" slider to set the $\frac{E_b}{N_0}$ ratio.

In any case, the corresponding "View" buttons will show an **indicative** altered form of the original signal. The parameters that will be used during the simulation are set randomly at the beginning of its execution.

The "Encoding and Overview" panel includes a block diagram representation of the system and a modulation selection that will be used during the simulation.

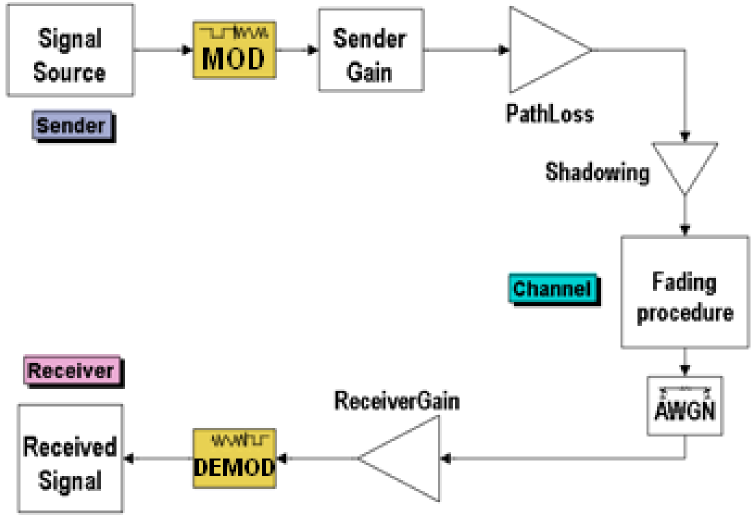

Figure 10: A signal source is modulated, altered (in terms of gain) by the transmitting antenna, endures losses according to the selected medium model, suffers the effect of shadowing (only when obstructed by one of the four buildings) and fading (according to selected LOS rice factor, number of paths, and RMS environment). White noise is then added at the entry point of the receiving antenna (selected $\frac{E_b}{N_0}$ is used). The gain of the receiving antenna is taken into account (geometry and vehicle relative position counts). The signal is then demodulated and the number of erroneous bits and symbols ir measured.

4. "Simulation" panel:

In this panel the user may set the metrics that he wishes to be recorded during the simulation. Labels are self-describing, with he exception of the "real-time analysis" option. Check this box to open the MATLAB channel visualization tool when the simulation starts. Notice that this will have a great negative impact on the simulation speed. You may close the tool at any moment for the simulation to return to normal execution speed. However, you may not re-open it during simulation. For more information on this tool consult the MATLAB documentation on "Using the Channel Visualization Tool".

Finally, the controls "Start", "Stop" and "Pause" have the corresponding effect on the simulation.

3.4 Simulating and obtaining results

Once all the described parameters are set, click on the "start" button. The vehicle on the 3D visualization form will start to move towards the end of the road. If the "real-time analysis" option has been checked, the MATLAB channdel visualization tool will open as well. Once the car has reached the end, the simulation stops and the following result forms are shown:

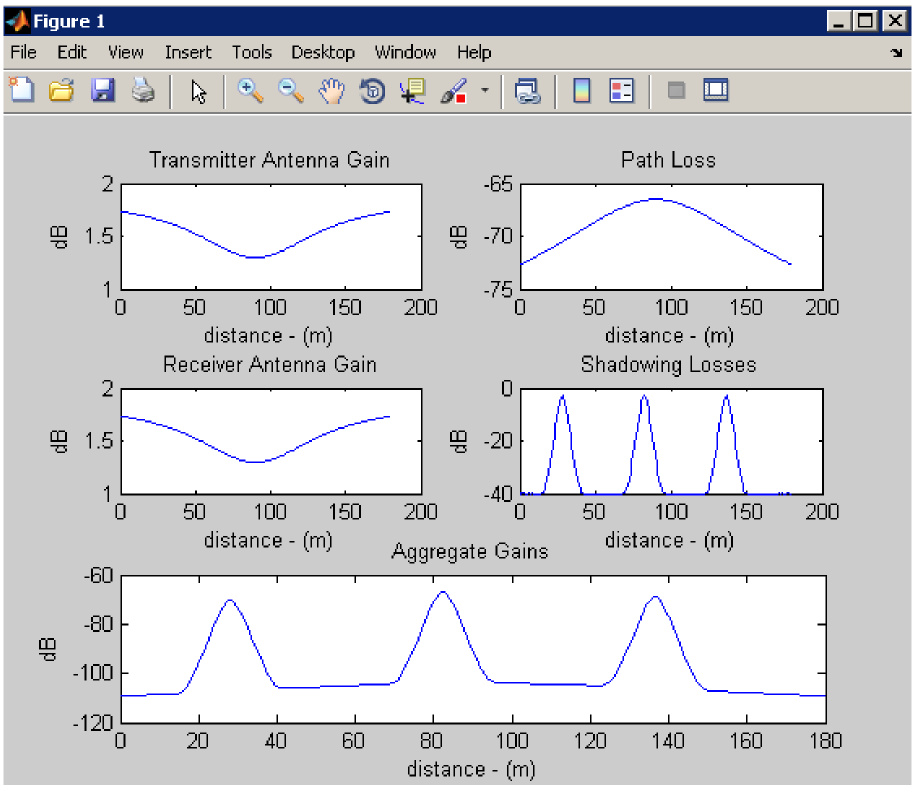

Figure 11: Gain forms. This forms shows the antenna gains, the shadowing losses and their aggregation as a function of the vehicle's position.

3.5 Characterizing the wireless channel

The second results' form contains as described a panel showing the Power Delay Profile (PDP) of the channel. This is sufficient for characterizing the bandwidth of the channel. [2] describes the complete procedure for this purpose. No additional data is required for this task, both in theory and in practice.

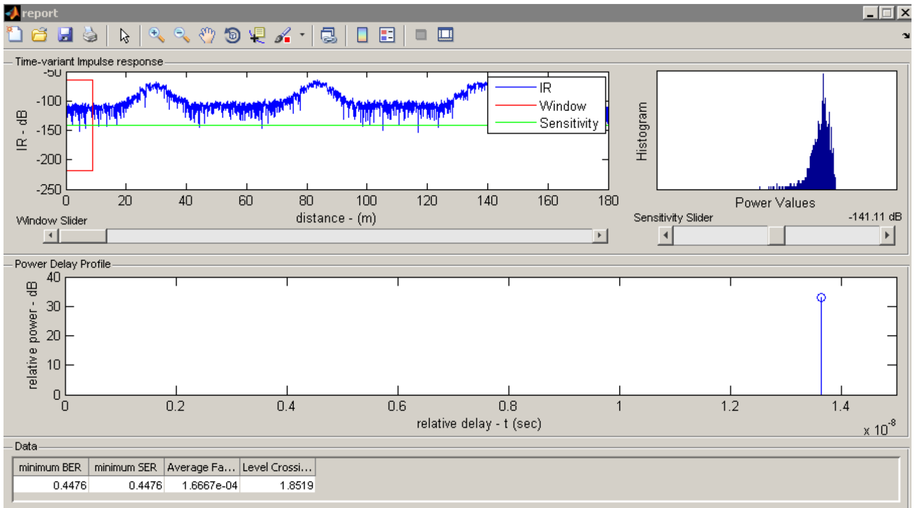

Figure 12: Results forms. Three distinct panels are visible or not, depending on the choices of the user in the "Simulation" panel described above. In this figure, all panels are visible and active. The topmost panel shows the time-variant impulse response. The user may move the "window" slider to obtain a histogram of values inside the red window. This can be used for checking that the values follow the rice distribution. By altering the sensitivity slider, the green line denoting the receiver's sensitivity is shifted proportionately. This affects the Average Fade Duration and Level Crossing Frequency values at the lower most panel. Notice that the SER/BER values correspond to a receiver of unlimited sensitivity, and the extraction of their practical values is left as an exercise to the user. The power delay profile is shown in the middle panel. NOTICE: this form may not show if the simulation is stopped prematurely, due to lack of sufficient number of results.

3.6 Uninstalling the application

The un-installation process is simple; no special utility is needed. Simply restore the MATLAB paths and remove all application files by deletion.

4.0 Supervisor's Manual

4.1 Extending the application

Features and limitations

It is possible to add new antenna and space loss models, in the fashion described in "Virtual Laboratory #1: Antennas and propagation". Please refer to the corresponding entry of the application's manual for obtaining the detailed procedure.

Notice that custom measurements, nodes and signals (inheriting the TMeasurement, TNode and TSignal classes respectively) do not apply in the context of the present application, and adding such expansions will have no effect.

There is no user-friendly, non-programmatical way of altering the environment and its $3D$ representation. Apart from the custom antenna and space loss additions, any other modification must be handled by an experienced programmer and in accordance with the programmer's manual.

5.0 Programmer's Manual

5.1 Portability

While the application is written for the Microsoft Windows OS family, any OS that supports MATLAB 2009b and 100% compatibles can act as the application's host.

The application uses registry information to locate its files. This information is read at file "APP_DIR/FUNCTIONS/GUIRelated/initGUI2.m", line 7:

handles.installPath=winqueryreg('HKEY_LOCAL_MACHINE', 'SOFTWARE IHUvlab2', 'installPath');

Replace this line with any OS-specific information on the application's install path and store it in the "handles" structure as "handles.installPath".

This concludes the portability procedure.

5.2 Explaining the directory structure

The application folder contains the following directories:

- BASECLASSES: As in "virtual laboratory 1: Antennas and Propagation".
- CUSTOMCLASSES: As in "virtual laboratory 1: Antennas and Propagation".
  Additional files for VLAB2:
  +++"Measurements/TVLABS2CustomMeasurement.m": A custom measurement for measuring space loss and antenna gains for every position of the car.
- JAVA: As in "virtual laboratory 1: Antennas and Propagation".

- FUNCTION: As in ”virtual laboratory 1: Antennas and Propagation”.

  Additional files for VLAB2:

  +++”Generic/rician/*”: Utilities for producing rician p.d.f.s.

  +++”Generic/jakes.m”: implementation of the Jakes [3] fading simulation model.

  +++”Generic/lcr.m”: Calculate the Level Crossing Frequency and Average Fade duration for a given signal and a threshold.

  +++”Generic/pulses.m”: creates a signal of N smoothed pulses, emulating the shadowing imposed by the buildings.

  +++”Generic/translate.m”: Translates all slider values to real world units for use in measurements.

  +++”Generic/timevary.m”: CORE FUNCTION! synchronizes the 3D visualization form with the simulation states.

  +++”GUIRelated/drawlines.m”: Draws the LOS and NLOS 3D lines in the demo.

  +++”GUIRelated/InitGUI2.m”: Initializes the application and GUI.

  +++”GUIRelated/setcarpos.m”: Moves the 3D car to a defined point.

  +++”GUIRelated/linesvisible.m”: Sets the visibility (or not) of the rays in demo.

  +++”GUIRelated/UpdateVRadnStaticTexts.m”: reads the slider values and updates the corresponding VR and slider static text.

  +++”GUIRelated/vrCustomLine.m”: Manipulates a cylinder to become a 3D-line connecting two given points.

- MODELS: Contains the CORE simulink model ”rayleighAWGN”. File ”TSimModelHandler.m” is a custom class for handling Simulink models.

- ORIGINALS: Backups are kept here (application-external).

- TEXTURE: Textures used in the 3D world.

- ./report.m(fig): the form used to display simulation results.

- ./vlabs2.m(fig): the main application form.
- ./myworld.wrl: A VRML model of the 3D world.
- ./blocks.png: The block diagram image displayed on the main form.
- ./demotext.png: A static text displayed on the demo form. DO NOT ALTER DIMENSIONS.

5.3 Conventions

- OOP is avoided throughout the application as it hampered performance when it was initially used. Procedural programming is used throughout the application with the exception of the common files with VLAB1.
- All handling events of a .fig are stored inside the corresponding .m file that MATLAB auto-creates.
- A form passes data to another (e.g. the main form to report.fig) via standard function arguments.
- The standard MATLAB in-function documentation is used. No naming convention are used except for files that are common with VLAB1. However, files should be categorized by their use via the described directory structure.

5.4 Architecture

Knowledge of the virtual reality toolbox and simulink concepts is necessary. Before altering the application code make sure that you are able to:

- Write, edit and debug VRML.

- Draw a 3D environment in VRML.
- Alter the contained objects programmatically through MATLAB.
- Connect the Orbisnap viewer (provided with matlab) with an arbitrary simulink model via TCP communication.
- Construct lightweight embedded functions for the Embedded Toolbox of simulink.

The "rayleighAWGN" model is the cornerstone of the application:

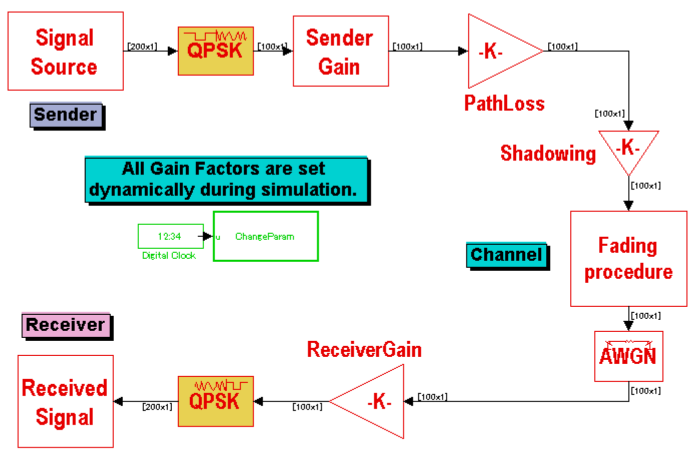

Figure 13: The rayleighAWGN Simulink Model.

The application essentially starts with the "VLABS2.FIG" form in order to gather all required parameters and store them as global variables in the MATLAB namespace. When the user presses the "start" button in the simulation panel, the model is executed via matlab scripting. A digital clock component triggers the execution of an embedded function, passing the current time as an argument. The "timevary.m" function is then called, which can now-given the current time and the environment parameters as global variables-alter the 3D model and record results. Simulation events (START, STOP, PAUSE) are handled internally in the event of the model.

5.5 List of MATLAB function files

TVLABS2CustomMeasurement.m: Custom TMeasurement for internal use in the VLABs2. Functions are modified to return the Gains of the receiving antenna Gr, the transmitting antenna Gs and the space loss L.

lcr.m: Calculates level cross frequency and average fade duration

ricedemo.m: Demonstrate ricernd, ricepdf, and ricestat, in the context of simulating Rician distributed noise for Magnetic Resonance Imaging magnitude data.

ricefit: Estimate parameters for Rice/Rician distribution from data.

ricepdf: Rice/Rician probability density function (pdf).

ricernd.m: Random samples from the Rice/Rician probability distribution.

ricestat.m: Mean and variance of Rice/Rician probability distribution.

jakes.m: The jakes fading signal creation method.

lcr.m: Calculate the Level Crossing Frequency and Average Fade duration for a given signal and a threshold.

pulses.m: creates a signal of N smoothed pulses, emulating the shadowing imposed by the buildings.

”timevary.m”: CORE FUNCTION! synchronizes the 3D visualization form with the simulation states.

”translate.m”: Translates all slider values to real world units for use in measurements.

”drawlines.m”: Draws the LOS and NLOS 3D lines in the demo.

”InitGUI2.m”: Initializes the application and GUI.

”setcarpos.m”: Moves the 3D car to a defined point.

”UpdateVRadnStaticTexts.m”: reads the slider values and updates the corresponding VR and slider static text.

”vrCustomLine.m”: Manipulates a cylinder to become a 3D-line connecting two given points.

”TSimModelHandler.m” is a custom class for handling Simulink models.

”linesvisible.m”: Sets the visibility (or not) of the rays in demo.

References

[1] John G. Proakis (1995). Digital Communications (3rd ed.). Singapore: McGraw-Hill Book Co. ISBN 0-07-113814-5.

[2] Simon R. Saunders (1999). Antennas and Propagation for Wireless Communication Systems. Wiley, ISBN 0471986097.

[3] Patzold, M.; Killat, U.; Li, Y.; Laue, F.; (1997), Modeling, analysis, and simulation of nonfrequency-selective mobile radio channels with asymmetrical Doppler power spectral density shapes, Vehicular Technology, IEEE Transactions on, Volume: 46 , Issue: 2.