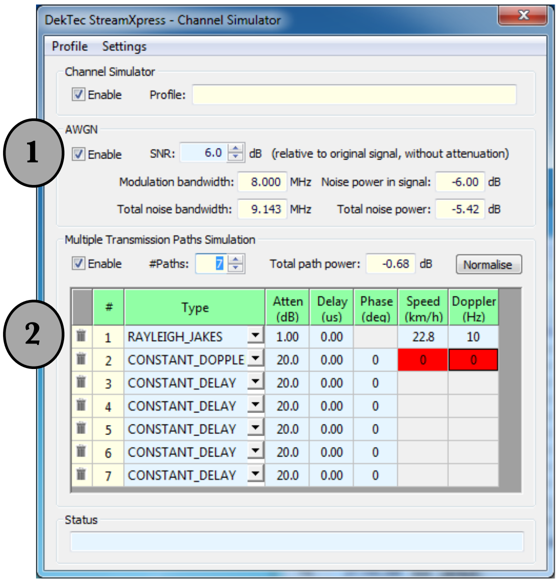
APPLICATION NOTE

HOW TO USE THE CHANNEL SIMULATOR

1. GENERAL OVERVIEW

The channel simulator gives you the possibility to test receivers in conditions of reception that are closer from reality by adding noise to the modulated signal.



The output of the channel modulator will be subject to two types of noise:
1. AWGN (White Gaussian Noise)
2. Additional Channel (Rayleigh, Doppler, Delay). The maximum number of channels to be simulated at the same time is 32.

Once you have defined all parameters required for your simulation, you can save it as a "profile".

2. WHITE GAUSSIAN NOISE

White Gaussian noise is added throughout the RF channel bandwidth, and is defined by the Signal to Noise Ratio (SNR). A standard receiver should be able to decode properly a noised signal with SNR above 20.0 dB.

3. CONSTANT DELAY CHANNEL

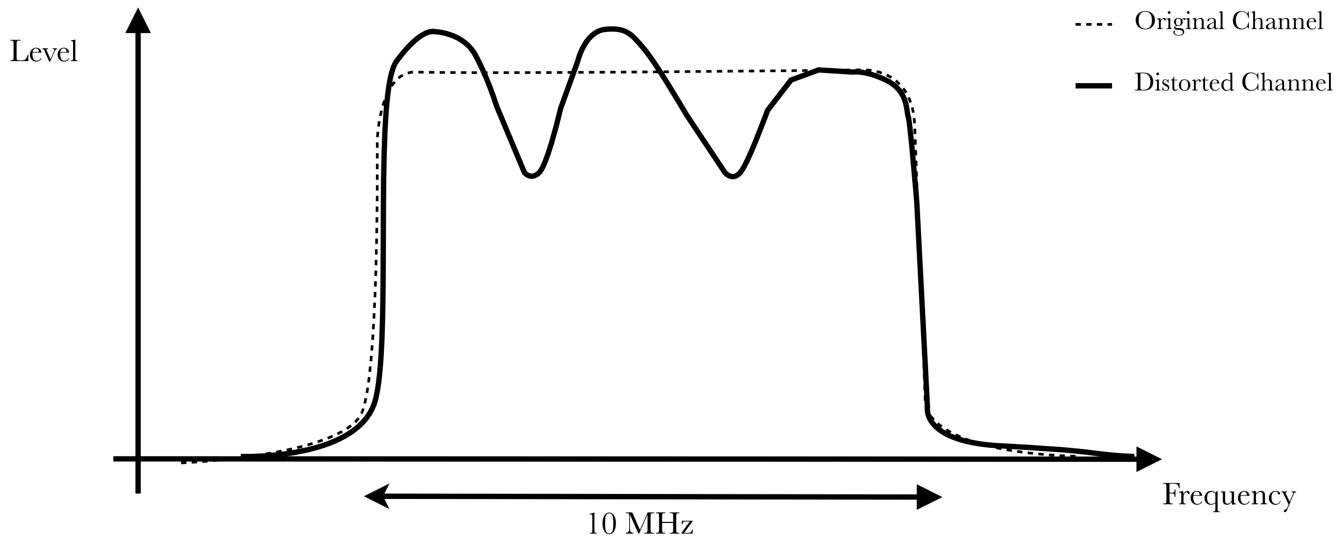
Fading generally occurs during a **reflection** (on a building, on a mountain slope, etc...). Each reflection will affect the signal strength (level loss) and its phase (phase shift).
Example:
- Reflection of a signal on a metallic surface will not lead to a level loss but a **phase shift of 180°**.
- Reflection on a building, will lead to a **large level loss** and an undefined phase shift.

So, to define a constant delay channel you will need three main parameters:
- **level loss** on this path (dB)
- **delay** compared to main channel (ns)
- **phase angle** (deg)

If, as an example, we have two channels (one main and one reflected) as follows:

	Channel 1	**Channel 2**
Attenuation	1.5 dB	7.0 dB
Delay	0 ns	250 ns
Phase	0 °	83 °

The resulting signal will be distorted, a dip will occur throughout the channel as shown in figure below.



- The dip is due to the reflected channel 2, and will occur every 1/250ns = 4 MHz
- The **phase** of the reflected channel **will affect its constellation**. In our example, the constellation of channel 2 will be rotated 83° from the original channel 1.

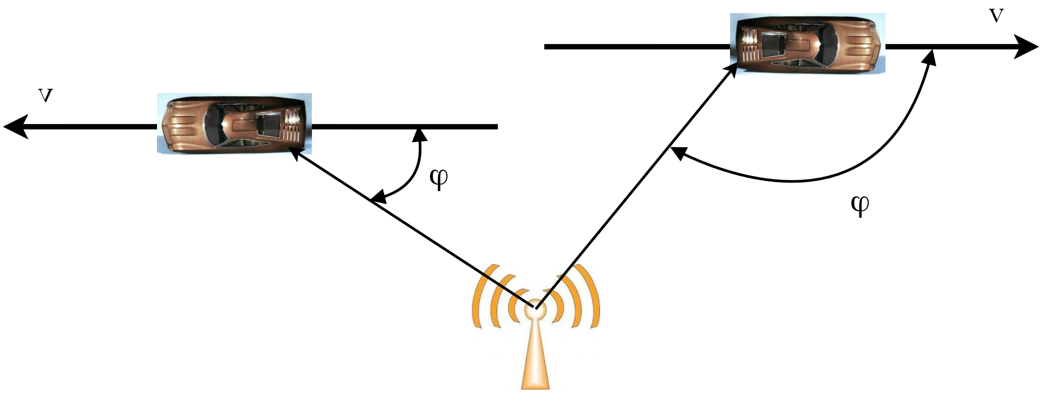
To counter the two issues cited above (dip in frequency spectrum, and constellation rotation) the receiver will have to use the compensation of an **adaptative equalizer** (or “channel estimator”).

4. CONSTANT DOPPLER CHANNEL

Fading also occurs when the receiver is in movement compared to the transmitter. This will generally lead to a **frequency shift** due to Doppler effect.
The frequency shift can be calculated as follows:

$$f_s = v \cdot \frac{f}{c} \cdot \cos(\varphi)$$

Where:
- fs is the frequency shift resulting from Doppler
- v is the speed of the receiver
- f is the base frequency of the carrier
- c is the speed of light
- φ is the angle between the direction of the transmitter and the receiver



Attention: In the channel simulator, you will have to enter only the relative speed of the vehicle towards the transmitter, that is to say:

$$v_r = v_{vehicle} \cdot \cos(\varphi)$$

As the Doppler effect will be maximal for cos(φ) = 1 or -1, the limit cases are the most interesting ones to test the receivers:
- The vehicle is moving towards the receiver, hence φ=0 and cos(φ) = 1.
- The vehicle is moving away from the receiver, hence φ=180 and cos(φ) = -1.
- When the vehicle is moving around the receiver in circles, φ=90 and cos(φ) = 0, in this case the Doppler effect is null.

5. JAKES RAYLEIGH CHANNEL

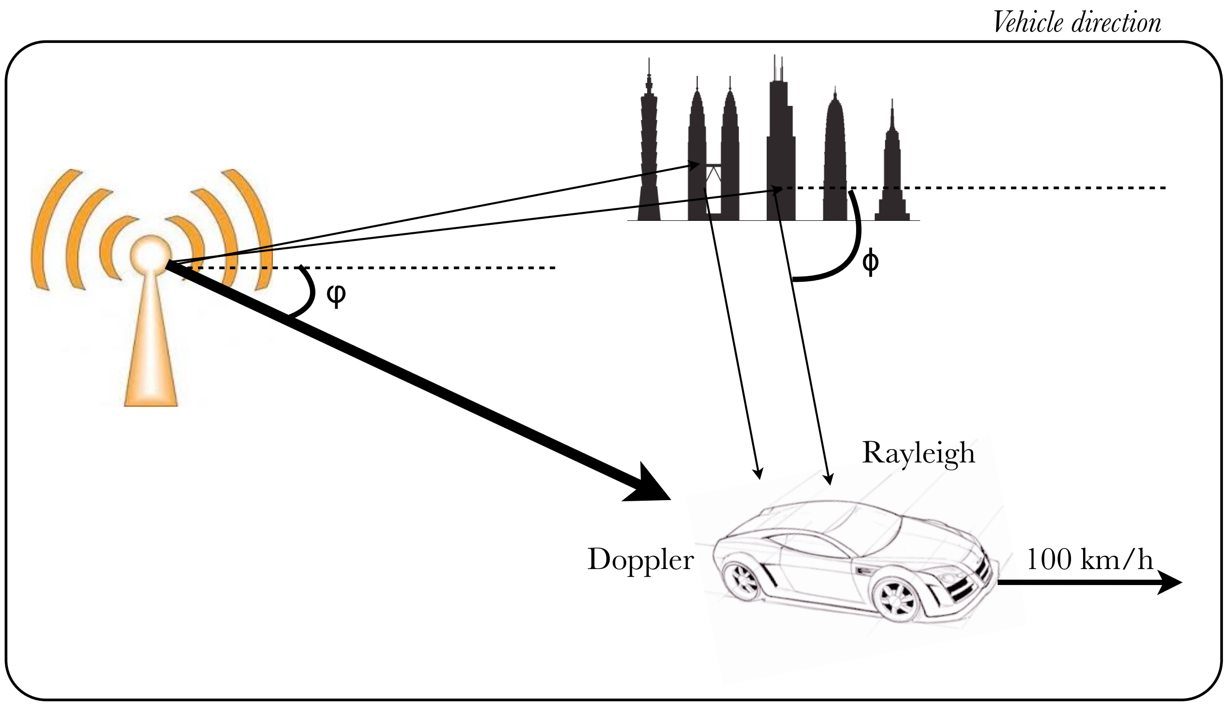
The Jakes Rayleigh channel ("Jakes" is often omitted) is a good model to simulate mobile systems when there is no direct path between the Tx antenna and the mobile Rx antenna.
A Rayleigh path is characterized with gain 'G', delay 'd', and normalized frequency shift f_s.
For the Jakes Rayleigh channel, more information about the frequency response can be found at: http://en.wikipedia.org/wiki/Rayleigh_fading#Doppler_power_spectral_density (there are two spikes at "f_d" and "-f_d").

6. GAUSSIAN RAYLEIGH CHANNEL

For the Gaussian Rayleigh channel, the frequency response is a normalized Gaussian curve centered on $f = 0$ with $\sigma = \frac{f_d}{2}$.
The exact model is the same as the one used to simulate the Digital Radio Mondiale channels found in ETSI ES 201 980, annex B. The Gaussian Rayleigh channel is interesting to simulate Ionospheric propagation. Not really useful outside the Digital Radio Mondiale standard.

7. RICE CHANNEL

The Ricean channel is a Rayleigh channel with a direct path from the Tx antenna to the mobile Rx antenna. It simulates a Rayleigh radio hop along with a strong direct signal.
It can be simulated by using a **constant Doppler** channel (main path) **and** normal (Jakes) **Rayleigh** channels (reflections).



After adding two channels in the multi path windows, you can use below convenient parameters to characterize it:

- Doppler path:
  - gain 'G', stronger than other paths as it is the main one, e.g. 1dB attenuation
  - vehicle speed relatively to the antenna, so

$$v_r = v_{vehicle} \cdot \cos(\varphi)$$

- Jakes Rayleigh path:
  - gain 'G', more attenuated than the Doppler main path, e.g. 20.00dB
  - delay 'd', depending on the distance of the reflecting buildings, e.g. 1µs
  - vehicle speed relatively to the reflecting building, so

$$v_r = v_{vehicle} \cdot \cos(\phi)$$

Sources:
Rhode & Schwarz: http://www2.rohde-schwarz.com/file_1072/7BM05_1E.pdf
Wikipedia: http://en.wikipedia.org/wiki/Rayleigh_fading#Doppler_power_spectral_density