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Full Length Research Paper

Behavior of a radio channel in the WLL (Wireless Local Loop)

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The local loop can be of two kinds, the local loop with copper wires and the local loop that use radio technology. Under certain conditions, the wireless Local Loop (WLL) can be an alternative more interesting than the copper local loop. We study in this paper the behavior of a radio channel and the multipath effect in a WLL transmission.

Key words: Wireless Local Loop (WLL), radio channel propagation, multipath, channel modeling, time excess delay, coherence bandwidth, frequency selective, frequency non selective fading channels.

INTRODUCTION

Wireless local loop, is defined by the last/first mile link connecting the subscriber terminals to the operator network, using wireless access. In place of physical supports such as copper wire, coaxial cable or optical fiber, radio technology is deployed in the access network to provide basic telecommunication services (Pandya, 2004).

In a WLL system, components of the emitted signal are reflected by obstacles. We have a multipath effect. Each component, reaches the receiver with relative amplitude and a delay. A modeling followed by a simulation of the radio channel proves to be necessary in order to have better performances during a design of the WLL network. Using tapped-delay-line structure for randomly time-varying radio channels gives a deep insight into the channel distortions caused by scattering components with different propagation delays.

ADVANTAGES OF WLL SYSTEMS

Some advantages of WLL systems compared to wireline access systems are (Gagnaire, 1997):

i. Fast and easy deployment of the network infrastructure and costumer units.
ii. Low construction cost of WLL system.
iii. Potential for reduces operation and maintenance costs.
iv. Brief repair time.
v. Lower network extension costs.
vi. Secure communication.
vii. Allow limited mobility.
viii. Deliver variety of services like data, multimedia and voice.

The services offered by the WLL system in Algeria are:

i. Basic telephony services (voice, fax, etc).
ii. Data sevice in voice band (14.4kbps).
iii. Internet and multimedia services (up to 153.6 kbps)

The frequency bands of interest are:

i. 400MHz band,
ii. 1900MHz band

PROBLEM: THE MULTIPATH

The WLL system operates in VHF/UHF frequency band where the communication takes place via the direct and

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ground-reflected components of the space wave (Parsons, 2000).

However, in any wireless communication system using that range of frequencies, there will be different ways in which the emitted signal can travel to reach the receiver, due to various (natural and man-made) obstacles in the environment.

According to the nature of the interaction between the wave and the obstacle, the signal can be reflected, diffracted or diffused. This phenomenon, referred to as multipath propagation.

Because of the multipath nature of propagation, the received signal consists of attenuated and delayed copies of the same transmission, resulting in spreading of the signal in time.

MODELING OF MULTIPATH PROPAGATION CHANNEL

We cosider a discret multipath propagation channel, thus the number of paths is finite.

If we assume that the number of multipath componants and delays will vary slowly compared to the variations in attenuations (constant delays during the period of simulation), the channel impulse response takes the form (Tranter et al., 2003):

$$\tilde{h}(t,\tau) = \sum_{k=1}^{N} \tilde{a}_k(t)\, \tilde{\delta}(t-\tau_k)$$

This equation represents a time-varying discrete multipath channel model where:

$\tilde{a}_k(t)$: is the complex path attenuation for path *k*,

τ_k : is the delay of path *k*.

In the case of stationary channel, the impulse response will be:

$$\tilde{h}(t) = \sum_{k=1}^{N} \tilde{a}_k\, \tilde{\delta}(t-\tau_k)$$

If '$\tilde{x}(t)$' is the emitted signal and '$\tilde{y}(t)$' is the received one, then the input-output relationship of a discrete multipath channel is:

$$\tilde{y}(t) = \sum_{k=1}^{N} \tilde{a}_k\, \tilde{x}(t-\tau_k)$$

This equation is implemented using a 'Tapped Delay Line (TDL)' filter as shown in Figure 1.

The simulation of this model may pose problem when the differential delays $(\tau_N - \tau_{N-1})$ are small compared to the simulation sampling time or are not integer multiples of this sampling period of the filter. To avoid this, it is important to bandlimit the channel by an ideal filter with bandwidth equal to that of the input signal (Jeruchim et al., 2002).

We consider B this bandwidth and applying sampling theorem on the input signal we obtain:

$$\tilde{x}(t-\tau_k) = \sum_{n=-m}^{n=+m} \tilde{x}_k(t-nT)\ sinc[B(\tau_k - nT)]$$

Substituting '$\tilde{x}(t-\tau_k)$' in the previous relation:

$$\tilde{y}(t) = \sum_{k=1}^{N} \tilde{a}_k \sum_{n=-m}^{n=+m} \tilde{x}_k(t-nT)\ sinc[B(\tau_k - nT)]$$

$$\tilde{y}(t) = \sum_{k=1}^{N} \tilde{x}_k(t-nT) \sum_{n=-m}^{n=+m} \tilde{a}_k\ sinc[B(\tau_k - nT)]$$

We define $\tilde{g}_n$ such as:

$$\tilde{g}_n = \sum_{k=1}^{N} \tilde{a}_k\ sinc[B(\tau_k - nT)]$$

Since the input period to the channel T=1/B, so:

$$\tilde{g}_n = \sum_{k=1}^{N} \tilde{a}_k\ sinc\left(\frac{\tau_k}{T} - n\right)$$

The input-output relationship becomes:

$$\tilde{y}(t) = \sum_{n=-m}^{n=+m} \tilde{x}(t-nT)\, \tilde{g}_n$$

It is the *'uniformly spaced TDL'* Model for discrete multipath fading channels with '$\tilde{g}_n$' the bandlimited impulse response. The 'TDL' structure is shown in Figure 2.

SIMULATION OF THE MULTIPATH FADING CHANNEL

Multipath fading channel is modeled as a linear finite impulse-response 'FIR' filter.

The *maximum excess delay time* "T_m" is the diffrence between the largest and smallest path delays ariving at the receiver.

The *coherence bandwidth* "f_0" is defined as the frequency range where all frequency components are correlated. That is, the spectral components in that range fade together.

"f_0" is inversely proportional to "T_m" (Godara , 2002):

$$f_0 \approx \frac{1}{T_m}$$

The simulation of the discrete model describing above, is

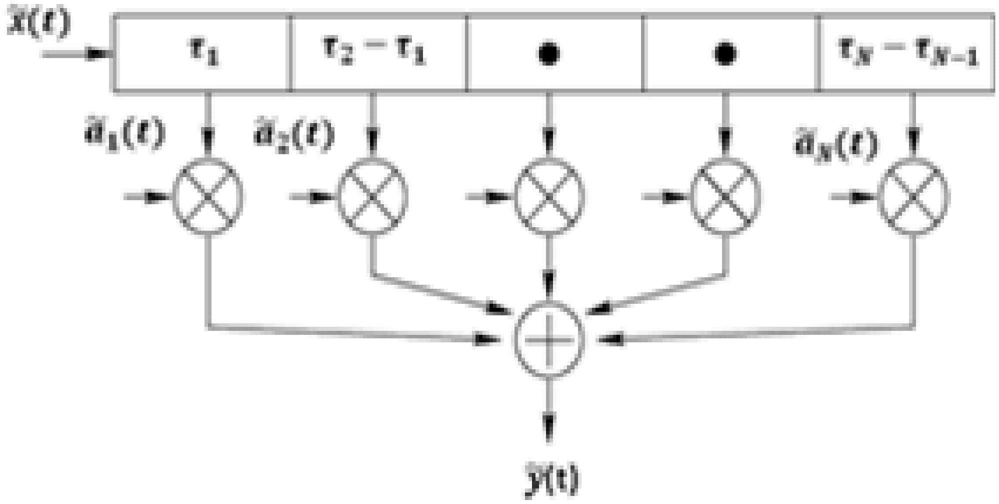

Figure 1. A variable delay TDL model for discrete multipath channels.

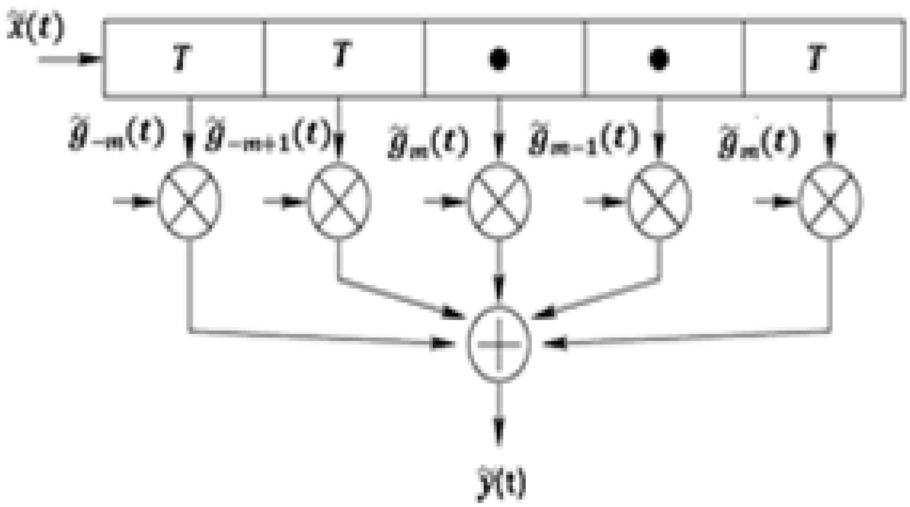

Figure 2. Uniformly spaced TDL model for a discrete multipath channel.

achieved using MATLAB command language and applying the following properties:

i. Fading multipath is Rayleigh distributed.
ii. Each path is modeled with an independent Rayleigh process (Cavers, 2002).
iii. The impulse response of Rayleigh channel is modeled by FIR filter.

Case 1 - Frequency selective channel

The channel is composed of N = 5 fading paths, each one with its own time delay $\tau_{1,5} = (0, 2, 3.2, 5, 10)exp - 6\ s$,

The emitted signal is wideband signal with symbol duration $T_s = 1exp - 6\ s$.

Time domain

This plot (Figure 3.) illustrates the evolution of the magnitudes of two impulse responses. The multipath response "$\tilde{h}(t)$" (infinite bandwidth) and the band limited channel impulse response"$\tilde{g}_n$".

The multipath response is represented by stems, each stem corresponding to one multipath component. The first stem (starting by the left) represents the component

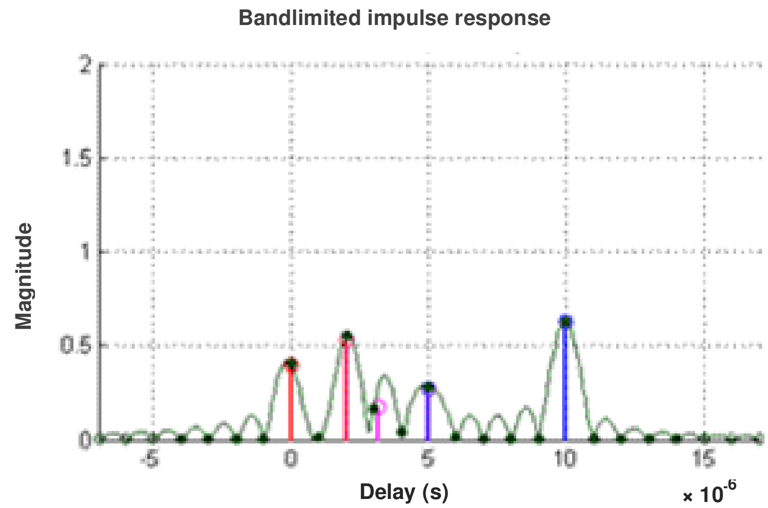

Figure 3. Impulse response.

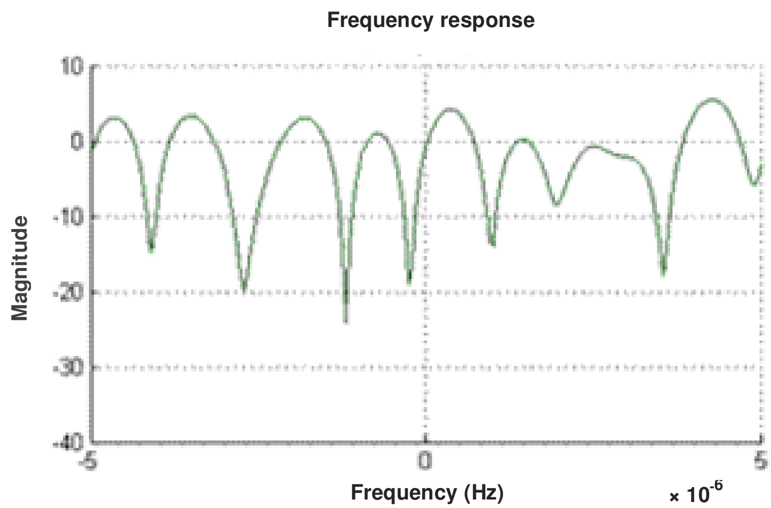

Figure 4. Frequency response.

with the smallest delay value; the last stem is the one with the largest delay value. The bandlimited channel response is designated by the curve. This response is the result of convolving the multipath impulse response, described above, with a cardinal sine "sinc" pulse of period "T", equal to the channel input signal's sample period.

The output of the channel filter is the convolution of the input signal sampled at period "T" with this discrete-time FIR channel filter response.

Interpretation

The plot shows that the bandlimited impulse response is not well-approximated by a sinc pulse. In addition, $T_m >$ T_s so the channel is said to exhibit 'frequency selective fading' and introduces intersymbol interference 'ISI'. In fact, another name for this category of fading degradation is 'channel-induced ISI'.

Frequency domain

The magnitude in dB of the frequency response of the multipath channel over the signal bandwidth is given by Figure 4.

Interpretation

The frequency transfer function shows that various

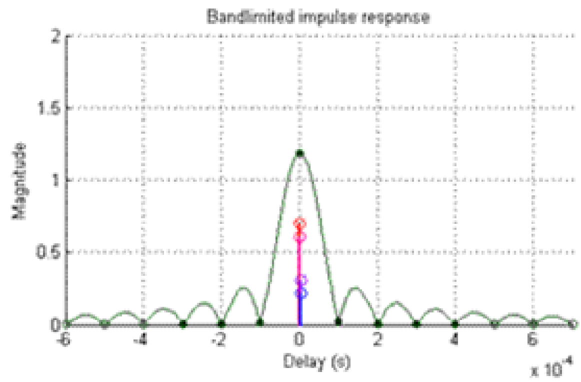

Figure 5. Impulse response.

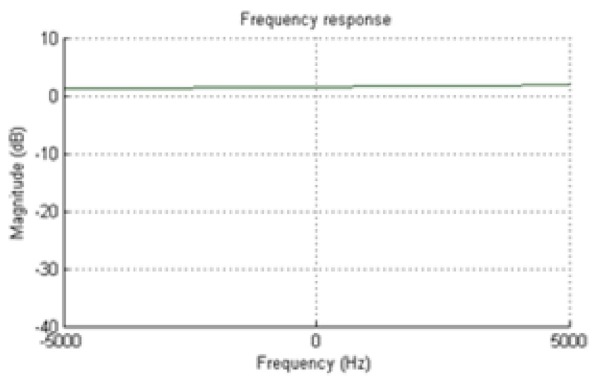

Figure 6. Frequency response.

spectral components of the transmitted signal are affected differently. This occurs whenever $f_0 < 1/T_s$, the channel is referred to as frequency selective fading.

Case 2 - Frequency non-selective channel

The channel is composed of N = 4 paths, each with its own delay:

$$\tau_{1,5} = (0, 1, 2.5, 4)exp - 6\ s,$$

The input channel signal is narrowband signal with symbol time:

$$T_s = 1exp - 4\ s.$$

Time domain

The channel impulse response is presented by the diagram of Figure 5.

Interpretation

The bandlimited impulse response closely approximates a sinc pulse.

Since $T_m < T_s$, the channel is referred to as flat or frequency non-selective and does not introduce 'ISI'.

Frequency domain

On the plot of Figure 6 is the frequency response of frequency non-selective channel.

Interpretation

The frequency response is flat, that is all the signal spectral components are affected by the channel in approximately the same way.

This is because $f_0 > 1/T_s$, in this condition the channel is said to exhibit frequency non-selective or flat fading.

CONCLUSION

Modeling multipath propagation channels was necessary in order to predict the behavior of the signal propagating in such environment. The simulation of the model permitted us to analyze the effect of multipath channel on the received signal. If the emitted signal is narrowband, all spectral components undergo similar variations. The received power is then approximately flat over all the signal bandwidth. We are faced non selective frequency or flat fading channel. For wideband signals the multipath components extend beyond the symbol duration. There will be strongest fluctuations in the received power, since various spectral components are affected differently by the channel. These fluctuations are known by frequency selective fading.

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