Abstract.- Increase on the demand of the telecommunications services is related with systems based on different technological alternatives. One of them, that is being developed in the last years is the use of aircrafts or airships technologies. The High Altitude Platforms Stations (HAPS) represent one attractive option today. In this paper, a statistical switched broadband channel model is postulated and analyzed by simulation and several conditions related with the coverage and environmental conditions are analyzed. A system model is postulated and evaluated considering different coded signals transmitted on the channel model proposed.

Index terms. HAPS, broadband switched channel.

I.- INTRODUCTION.

This paper presents a statistical switched broadband channel model for digital transmission in HAPS link. Performance results were obtained by simulation. In section II are presented some ideas related with HAPS and signal fluctuations. A switched channel model based on semi-Markovian process is presented in section III. A broadband channel model is proposed in section IV. Finally, results and conclusions obtained are shown in sections V and VI respectively.

II.- HAPS (High Altitude Platforms Stations).

A.- Systems based on HAPS.

Figure No.1 Coverage areas in systems based on HAPS.
and is defined as the ratio between the average power of the direct component (LOS) and average power associated to the multipaths.

In the suburban area, the obstacles near to the receiver cause a signal shadowing and an attenuation of the direct signal. The attenuation of the direct signal varies due that some obstacles are moving (vehicles). The attenuation of the direct signal undergoes log-normal distribution [6]

\[ p(s) = \frac{10}{\sqrt{2\pi \ln(10)}} \frac{1}{s} \exp\left(-\frac{(10\log s - \mu)^2}{2\sigma^2}\right) \] (3)

where \( \mu \) and \( \sigma \) are the mean value and the standard deviation expressed in dB.

### III.- SWITCHED CHANNEL MODEL.

**A.- Three state semi-Markov chain model.**

As the environmental properties change, the received signal cannot be represented by a model with constant parameters, and then the channel must be modeled using a finite states Markov chain model. The transitions among states are determined by a matrix \( \mathbf{P} \), where each element \( P_{ij} \) represents the probability that the channel changes from the \( i \) to the \( j \) state. For the channel model with three states A, B and C, is defined a transition matrix

\[
\begin{pmatrix}
P_{AA} & P_{AB} & P_{AC} \\
P_{BA} & P_{BB} & P_{BC} \\
P_{CA} & P_{CB} & P_{CC}
\end{pmatrix}
\] (4)

A stationary state vector \( \pi \) is calculated, using the properties of the Markov processes as

\[ \pi(\mathbf{I} - \mathbf{P}) = 0 \] (5)

\[ \pi \mathbf{e} = 1 \] (6)

where \( \mathbf{I} \) is the identity matrix, \( \mathbf{P} \) is the transition matrix and \( \mathbf{e} = [1 \ 1 \ \ldots \ 1]^T \) [7]. Each element \( \pi_i \) represents the percentage of the total time that the process remains in the \( i \) state.

\[ \pi = (\pi_A \ \pi_B \ \pi_C) \] (7)

A semi-Markov process is a Markov chain where the time between changes of states are random and defined for some kind of distribution [8]. From a Markov process, a new semi-Markovian process may be defined and this process will be described by a new transition matrix \( \mathbf{r} \) [8], where

\[ r_{ij} = \frac{P_{ij}}{1 - P_{ii}} \quad \text{for} \quad r \neq j \quad \text{and} \quad r_{ii} = 0 \] (8)

The scheme of the figure No. 2 indicates a graphical representation of a semi-Markovian process.

### B.- Fades Distributions.

Some distributions are described for fade duration in the ITU-R Recommendation P.681-6 [8]. In this Recommendation are defined three types of channel:

- A state. LOS condition.
- B state. Slight shadowing.
- C state. Total obstruction.

For the A state, the duration follows an exponential distribution given by

\[ P_A(D \leq d) = 1 - \beta d^{-\gamma} \] (9)

where the parameters \( \beta \) and \( \gamma \) are function of the level of the shadowing and for \( d > \beta^{1/\gamma} \). The duration for the others states follows a lognormal distribution valid for \( d > 0.1 \text{ m} \), with

\[ P_{B,C}(D \leq d) = (1 + \text{erf}[(\ln(d) - \ln(\alpha))/\sqrt{2}\sigma])/2 \] (10)

where \( \sigma \) is the standard deviation of \( \ln(d) \), the mean value of \( \ln(d) \) is \( \ln(\alpha) \) and the error function is defined in the ITU-R Recommendation P.1057. The ITU-R Recommendation P.681 establishes the parameters for the duration of these states and the distribution of the duration and these durations can be established in agreement with the characteristics of each state. Besides the transitions probabilities are defined for a semi-Markovian process with three states for different kinds of environments. Parameters above are shown in the Table No. 1.

### III.- MULTIPATH RADIO CHANNELS.

**A.- Time Delay Spread.**

In a mobile radio environment a single impulse originates many echoes of this impulse at the receiver. The received signal may be formulated as

\[ h(t,x) = \sum_{i=1}^{N(x)} a_i(t,x) \delta(t - \tau_i(t,x)) \] (11)

where \( a_i \) are the amplitude of the \( i \)th signal with a delay \( \tau_i \). The variable \( N \) represents the number of echos considered. An important parameter is the time delay spread interval which is measured from the first symbol to the last detectable echo, and is different for each kind of environment. The time delay
spread would cause intersymbol interference (ISI) for digital transmission.

<table>
<thead>
<tr>
<th>Environments</th>
<th>Suburban I</th>
<th>Suburban II</th>
<th>Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>β</td>
<td>γ</td>
<td>α</td>
</tr>
<tr>
<td></td>
<td>0.88</td>
<td>0.83</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>0.61</td>
<td>0.66</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>1.73</td>
<td>1.89</td>
<td>2.05</td>
</tr>
</tbody>
</table>

Hereby is possible to establish that a channel is less selective in frequency if $T_m$ is smaller than the time symbol $T_s$. If the power delay profile is known then is possible to modulate it by means of a tapped delay line [10] (Figure No.3).

![Figure No.3 Tapped delay line model.](image)

where $a(t)$ is a complex Gaussian process; $A_i$ are the attenuations signal component and $\tau_i$ are the paths delays. Then the output signal is given by

$$y(t) = \sum_{k=1}^{N(x)} a_k(t) e^{-j2\pi f \tau_k(t)} u(t - \tau_k(t))$$

(17)

For our analysis is considered the power delay profile reported in [12], which was computed using parameters in the L band and with an elevation angle of 45°. At same time, the model was evaluated using the power delay profile calculated for a HAPS link proposed in [11].

### IV. BROADBAND CHANNEL MODEL

In [11] are reported results related with HAPS performance and considering a not switched channel model. In this paper are considered switched channel models with two and three states. Some values of average time delay spread for different environmental conditions are reported in the literature; typical values of 0.5 µs for suburban and 3 µs for urban areas were founds [9]. In the model proposed by Dovis [11] are reported theoretical values for systems based on HAPS: 21 ns (rms delay spread) and 952.38 Khz (coherence bandwidth).

In the approach of this paper are modified some hypothesis of the reference [11] and [12] related with the tapped delay line model. Besides it was postulated and evaluated a system with a digital transmission rate of 200 Kbits/seg (under these circumstances there is not ISI effect due to the channel).

#### A.- Two states channel model.

In agreement with tapped delay line model, a broadband switched channel model may be implemented by switching from a propagation condition characterized by a Rice fading (good channel) to a total obstruction condition of the signal using a Lognormal fading (bad channel); the paths are characterized by a Rayleigh-Lognormal and Lognormal fading respectively. Figure No 4.
In this situation the transition matrix of the Markov process is
\[
P = \begin{pmatrix} P_{gg} & P_{gb} \\ P_{bg} & P_{bb} \end{pmatrix} = \begin{pmatrix} 0.99735 & 2.65 \times 10^{-3} \\ 3.45 \times 10^{-3} & 0.99654 \end{pmatrix}
\]  
and the stationary probability \( \pi \) can be computed from the matrix equations indicated in (5) and (6) as
\[
\pi = (0.565, 0.434)
\]  
These values were obtained from the information given on the reference [6].

The time shared of shadowing \( A \) is related to the durations of each of the states, \( D_g \) and \( D_b \), and following to Lutz [6], may be defined as
\[
A = \frac{D_b}{D_b + D_g}
\]  
and the switched broadband channel model may be represented by the blocks diagram of the Figure No.4.

**A.- Three states channel model.**

We add transitions among three states, therefore the scheme of the model is similar to the two states channel model. The transition matrix is defined in the Table No.1 as
\[
P = \begin{pmatrix} 0 & 1 & 0 \\ 0.65 & 0 & 0.35 \\ 0 & 1 & 0 \end{pmatrix}
\]  
and the parameters for the fading durations were established for the Suburban I environment indicated in the same Table, and we can see that the model just has transitions between adjacent states too (Figure No. 5). The transition matrix for a suburban environment I and II are the same, but the values of the parameters for the fading distribution change.
V.- RESULTS

In the figure No. 6 and 7 are shown the performance of the two and the three states channel models and are compared with the results obtained in a not switched channel model. When are considered coded signals the performance is better, as shown in the same Figure.

VI.- CONCLUSIONS

Using the two and three state channel models is possible to evaluate the system performance under different channel conditions.

VII.- REFERENCES


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