PERFORMANCE SIMULATION IN HIGH ALTITUDE PLATFORMS (HAPs) COMMUNICATIONS SYSTEMS

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Abstract: *This paper considers the analysis by simulation of a digital narrowband communication system for an scenario which consists of a High-Altitude aeronautical Platform (HAP) and fixed/ mobile terrestrial transceivers. The aeronautical channel is modelled considering geometrical (angle of elevation vs. horizontal distance of the terrestrial reflectors) and statistical arguments and under these circumstances a serial concatenated coded digital transmission is analysed for several hypothesis related to radio-electric coverage areas. The results indicate a good feasibility for the communication system proposed and analysed*

I.- INTRODUCTION

Point-to-multipoint radio communications are possible when are considered high-altitude aeronautical platforms (HAP´s) and terrestrial transceivers. Research about the use of HAP´s for narrow and broad band communication systems is in progress abroad [1,2]. One open problem is the performance of these systems for different telecommunications services-mobile and/or fixed terrestrial ambient. From the point of view of the digital transmission theory, the aeronautical channel modelling is an important aspect to consider[3,4,5]. This paper deals with the theoretical derivation of a channel model for the communication link between the platform and terrestrial mobile/fixed users and stations. The channel model may be analysed considering geometrical and statistical arguments and the paper follows this reasoning.

HAP´s can be considered as being a hybrid architecture, they have some zones in common with terrestrial communications, particularly Fixed Wireless Access, but are similar to satellites in terms of power constraints and general network architecture. In a mobile communication context is the fact it could replace or support the terrestrial network, avoiding problems with environmental impact and electromagnetic pollution. Platform design has several constraints related to the applications to achieve: power available for the payload, stability, maximum transmit power of the transmitters, link availability and so on.

In the following paragraph is presented an scenario about the radio communication system to analyse and their variables/parameters more important under these circumstances. The third paragraph considers a relationship between geometrical and statistical aspects related to angle of elevation vs. Rice coefficient vs. horizontal distance of the terrestrial reflectors. The fourth paragraph considers the concatenated coded digital transmission and simulation models. Results and conclusions are presented in the last paragraphs.

II. –RADIO ELECTRIC SCENARIO

The propagation of radio signals from/to HAP to/from ground antennae is affected by the aeronautical channel in several ways, but the most important effect is related to the multipath phenomena and therefore with the availability of the radio link. The scenario to consider for this aeronautical channel may define three areas: an urban zone, a suburban or opened zone and a rural zone.[6]

Hear, the Fig.1 may represent the following scene: an airborne (e.g. globe, airplane, helicopter) and a transceiver on the ground. For this down link three aspects are of particular interest:

- The direct ray (Line-of-sight).This signal may be adjusted from the platform.

- The elevation angle “α”. This angle is determined by the horizontal distance, "r", and the flight height, "h". Changes in the elevation angle generate variations in the delays of the received signals and an increase of the multipath.

- The shadows. The displacement of the receiver in areas where the elevation angle is smaller than that of the half height (45°), it will cause shadows of the order of 50% in time of connection.

The adjustment of the level of the power from the platform and the effects of the shadows will not be taken care of in this paper.

In the Fig. 1, the transmitter is labelled Tx (on HAP) and the receiver is on the ground (Rx). The figure represents a direct ray(LOS) and a reflected ray(Refl.) in the receiver. Therefore, the reception will consist of two signals in this first approach. From geometrical considerations, the parameters or variables to consider are:

$$d_{LOS} = h/\sin(\alpha) \qquad (1)$$

$$d_{eco} = \sqrt{(\Delta r + r)^2} + h^2 + |\Delta r| \qquad (2)$$

$$r = h/tg(\alpha) \qquad (3)$$

r = horizontal distance receiver
Δr = delta r (horizontal distance reflector)

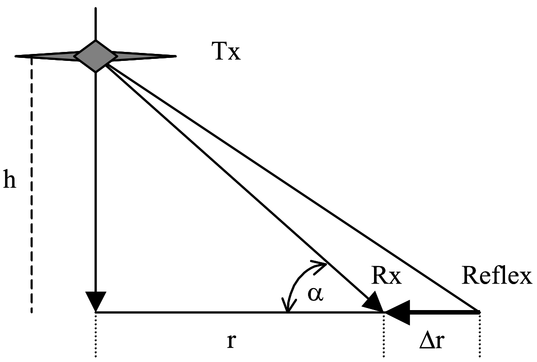

Fig. 1. Platform air terminal. (direct ray + reflected ray or echo).

A.- Echo delay

The propagation times are proportional to the corresponding slant ranges plus detours, then the echo delay may be formulated as:

$$\Delta\tau = \tau_{echo} - \tau_{los}$$

$$\Delta\tau = \frac{1}{c}\left(\sqrt{\left(\Delta r + \frac{h}{tg\alpha}\right)^2 + h^2} + |\Delta r| - \frac{h}{\sin\alpha}\right) \qquad (4)$$

where c is the speed of light. When $h \to \infty \Rightarrow \Delta\tau min = (1+\cos\alpha)|\Delta r|/c$ (HAP case) and when $h \to 0 \Rightarrow \Delta\tau \max = 2|\Delta r|/c$ (worse case) .The Fig.2 indicates this relationship.

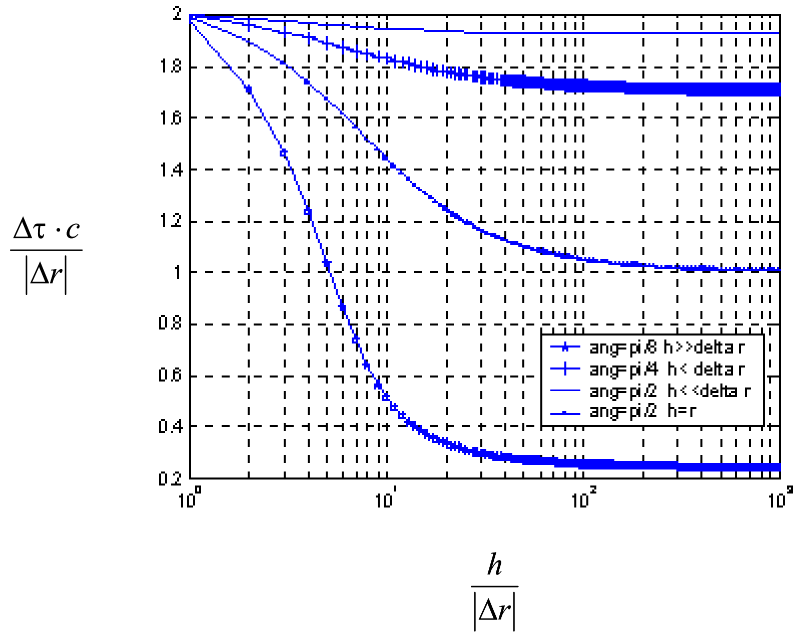

Fig. 2. Graph $\Delta\tau \cdot c/|\Delta r|$ *v/s* $h/|\Delta r|$*, distortion of the delays of the reflected ray.*

B.- Amplitude of the echo.

Following the considerations of [4], the echo signal can be related with the Free Space Loss (FSL) by the formula:

$$\Delta \text{FSL} = 20\text{Log} \quad (d_{eco} / d_{LOS}) \text{ dB}$$

and considering (1) and (2), the result for FSL is:

$$\Delta FSL = 20 Log \frac{\left(\sqrt{(\Delta r + r)^2 + h^2} + |\Delta r|\right)\sin\alpha}{h} dB, \qquad (5)$$

The Fig.3 indicates this relationship.

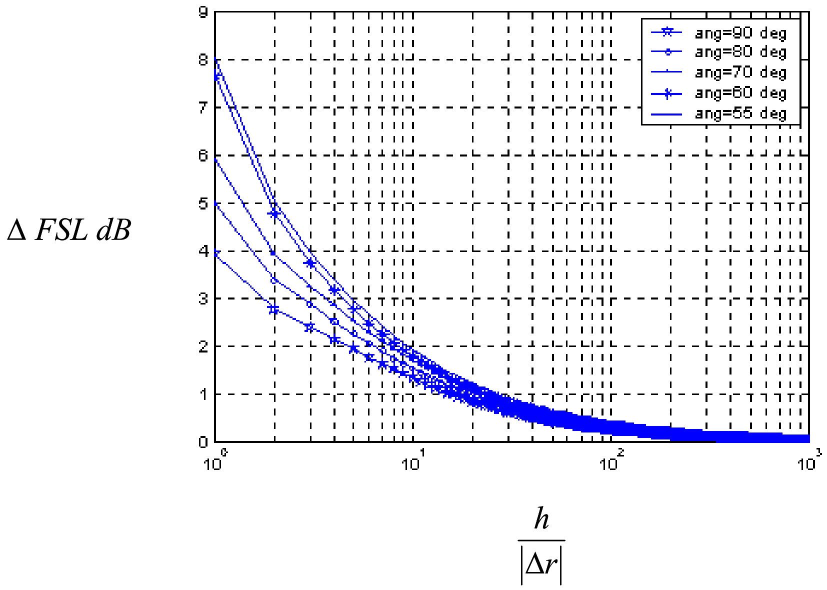

Figure 3. Distortion of the echo amplitudes affecting the delay power spectrum,ΔFSL dB.

When $h \to \infty \Rightarrow \ \Delta\,\mathrm{FSL} \to 0$ (special case for the stratospheric platforms) and when

$h \to 0 \Rightarrow \Delta\,\mathrm{FSL} \to \infty$. Besides, if $h \to \infty \Rightarrow$ angle $\alpha \to 90°$, and if $h \to 0 \Rightarrow$ angle $\alpha \to 0°$

Then $\alpha \to 90° \Rightarrow \Delta\,\mathrm{FSL} \to 0$ (absence reflected ray) and $\alpha \to 0° \Rightarrow \Delta\,\mathrm{FSL} \to \infty$ (absence direct ray).

III.-GEOMETRICAL-STATISTICAL RELATIONSHIP CHANNEL

From the statistical point of view, the amplitude probability density function in Rx is:

$$pdf_{Rice} = \frac{r}{\sigma^2} I_0\left(\frac{r \cdot r_s^2}{\sigma^2}\right) \exp\left(\frac{-r^2 + r_s^2}{2\sigma^2}\right) \qquad (6)$$

where $r^2{}_s$ amplitude direct ray, I_o function of Bessel of first type and order zero.

The so called Rice factor, K, is defined as

$$K = 10 \cdot \log \cdot \left(\frac{r_s^2}{2\sigma^2}\right) dB \qquad (7)$$

However, K can be formulate from a geometrical point of view as: K = 10 Log$\left(\frac{a}{c}\right)^2 dB$,

where " a " is related with the direct ray: $d_{LOS} = h / \sin\alpha$ and " c " is related with the reflected ray as: $d_{eco} = \sqrt{(\Delta r + r)^2 + h^2} + |\Delta r|$

$$K(\alpha) = 20Log\left[\frac{(h/\sin\alpha)}{\sqrt{(\Delta r + r)^2 + h^2 + |\Delta r|}}\right]dB; \qquad (8)$$

On the figure is assumed that the attenuation product of the reflectors located to a distance delta r (Δr) is near to 15 dB.

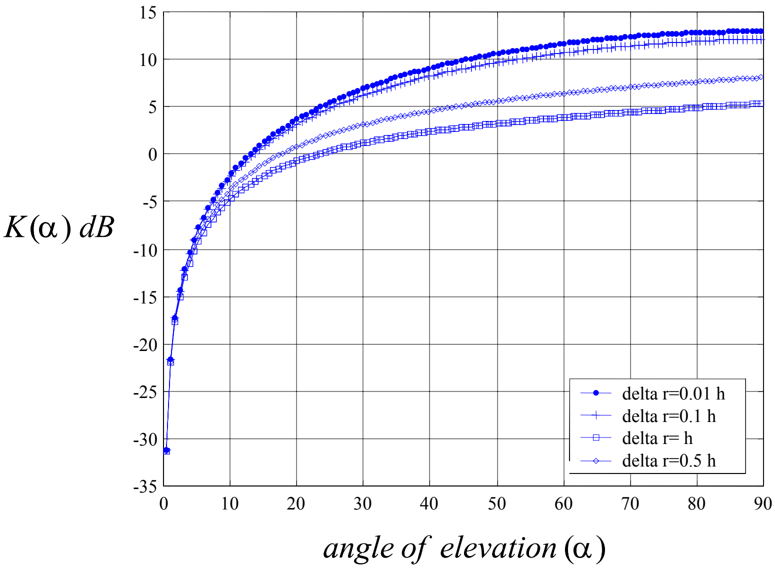

Fig. 4.Rice Coefficient K in function of the angle of elevation (α) and horizontal distance of the reflectors (Δr ,delta r).

Then :

$\alpha \to 90° \Rightarrow K \to \infty$ Gaussian Channel.

$\alpha \to [12° < \alpha < 90°] \Rightarrow$ Rice Channel.

$\alpha < 12° \Rightarrow K \leq 0$ Rayleigh Channel.

With the considerations above may be write the probality density function p(r) conditionated to the new parameter K(α) as:

$$p_{K(\alpha)}(r) = \frac{2r10^{K(\alpha)/10}}{r_s^2}\exp\left[-\frac{10^{K(\alpha)/10}}{r_s^2}\left(r^2 + r_s^2\right)\right]I_o\left[\frac{2r10^{K(\alpha)10}}{r_s}\right] \qquad (9)$$

IV.- COMMUNICATION SYSTEM SIMULATION MODEL

On the basis of the previous analysis, a simulation model is considered with the aim of studying the effects of the aeronautical channel on the communications between the platform and a fixed / mobile terrestrial receiver.

The aeronautical channel (narrow band channel) is modelled following some considerations referenced on [3,4,5] and the previous analysis. The simulation model of the channel is shown in the Fig.5

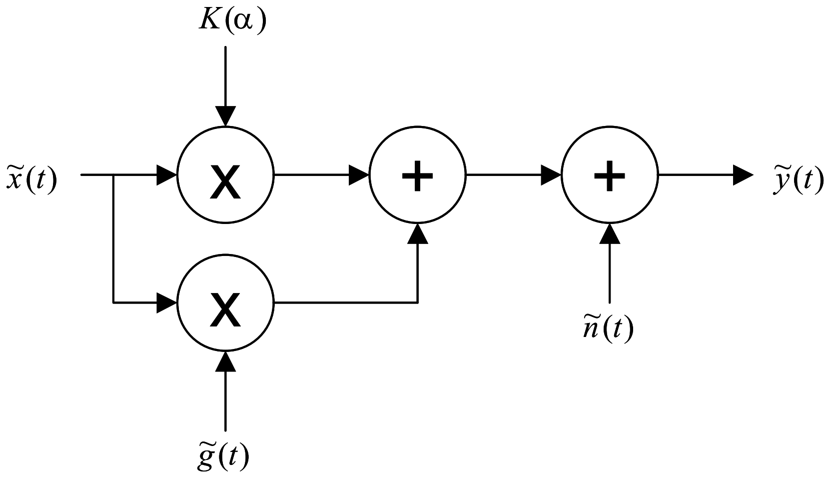

Fig. 5 Simulation model of the channel.

Where $\tilde{x}(t)$ is the complex envelope of the serial concatenated coded signal, $\tilde{g}(t)$ is the unitary power fading process, $K(\alpha)$ is de multiplicative function which allows to vary the ratio between the average powers of the line of sight and diffuse signals, $\tilde{n}(t)$ represents the white noise process.

As an application example, it is considered the transmission of a concatenated coded DQPSK modulated signal at a carrier frequency of fo =2.0 Ghz. The Forward Error Control is achieved by a concatenation of a RS coder with a block interleaver and together with a convolutional coder.

Other parameters to consider are:

- Platform at h=25 Km.
- Users are positioned in α= 45º (elevation angle)
- Δr = delta r (horizontal distance reflector) = 0.001· h = 25 m. , and so $K(\alpha)$=10 dB.
- $\Delta\tau \text{ min} = (1+\cos\alpha)|\Delta r|/c$ = 0.142 μs (typical case)
- $\Delta\tau \text{ max} = 2|\Delta r|/c$ = 0.166 μs ,therefore (worse case)
- The coherence bandwidth, $B_c = \dfrac{1}{2\pi\Delta\tau}$ = 958.64 KHz.
- Speed of the platform v_p= 110 km/h.
- Speed of the users v_m= 50 km/h.
- Maximum Doppler spread is $f_d = f_p + f_m = (v_p + v_m)\dfrac{f_o}{c}$ = 296.29 Hz.
- Coherence time, $T_c = \dfrac{9}{16\pi f_d}$ = 0.604 ms.

These values are interesting to consider a situation of conventional Rician flat-fading model.
This model is usually employed whenever transmitter and receiver are in line of sight, as typically assumed in a HAP scenario. In the Fig.6 is shown the block diagram of the simulated system.

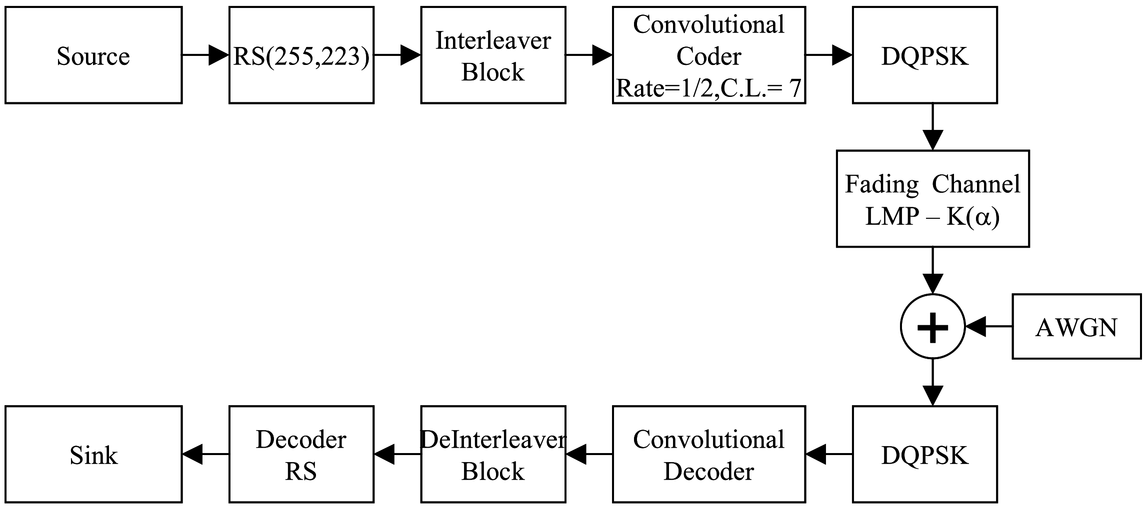

Fig.6 Block diagram of concatenated coding system.

V.-RESULTS

The performance simulation was achieved considering a source of 32 Kb/s. with a concatenated coding (R-S, interleaving and convolutional codes).This information protected with this FEC modulates a DQPSK and is transmitted over an aeronautical channel. Several values of K are considered and the performance of the received digits is evaluated by BER vs. Eb/No measures. On the Figures 7 and 8 are presented results for several circumstances.

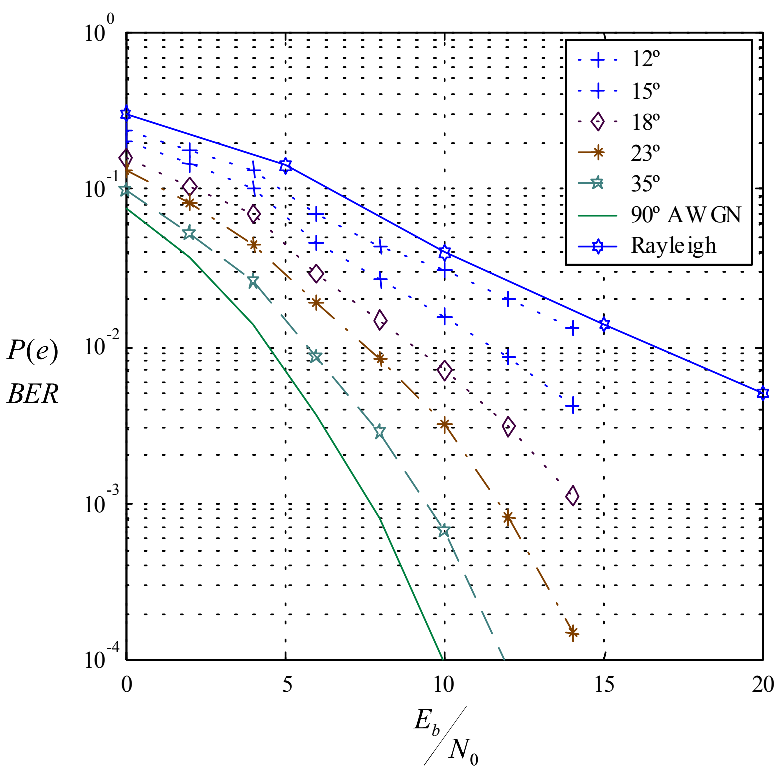

Fig.7 Platform channel v/s angle of elevation modulations DQPSK. Gain Rice K(α).

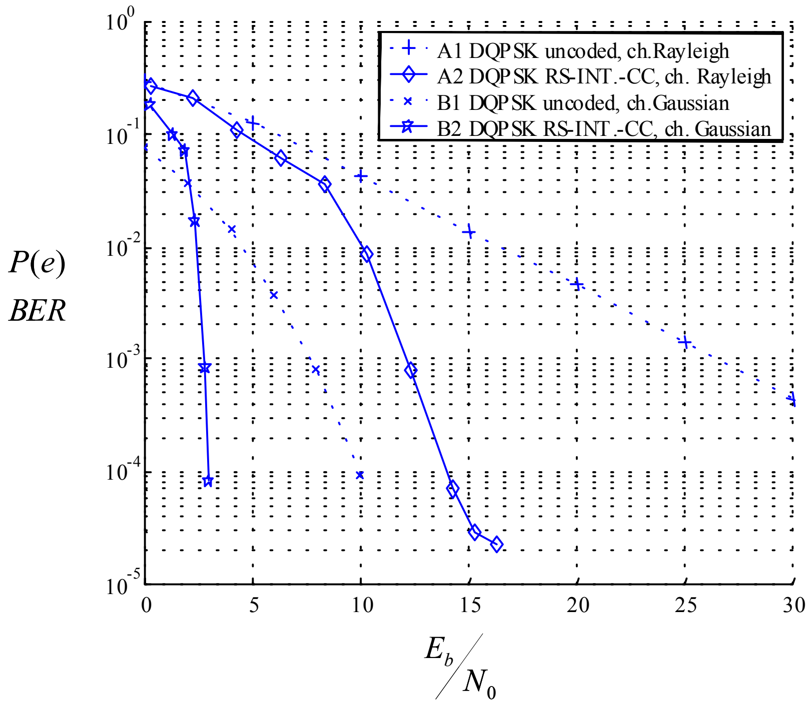

Fig.8 Channel codifications : A1, worse case Rayleigh. Channel; A2 concatenated coding ; B1, better case, Gaussian channel; B2, concatenated coding.

The dash curve, A1, corresponds to the analytical bound for worse case (channel with angle elevations in the 0^o-12^o degrees range, with height, h=25 km). While solid curve A2, is obtained by Monte Carlo simulations with concatenated coding. The dash curve, B1, corresponds to the analytical bound for better case (channel with angle elevations in the 50^o-90^o degrees range). While solid curve B2 is the same better channel with concatenated coding.

VI.- CONCLUSIONS

In this paper, a geometrical-statistical channel model is considered. An application using serial concatenated coding digital transmission for contending the flat-fading effects is analysed in several circumstances following authors referenced, and the results indicate a good feasibility for the communication system proposed and analysed.

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