A High Performance Class of DSTBC for HAPs

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Abstract: High Altitude Platforms (HAPs) has been an interesting topic for years, but today it has a renewed interest for several companies, organizations and governments. In this paper a high performance class of Differential Space Time Block Codes (DSTBCs) is analysed for HAPs. The results show that this particular class of DSTBCs is a good alternative to consider for HAPs communications.

1 INTRODUCTION

HAPs is not a new topic, but it has renewed attention from the moment that Google [1] and some governments, like the Brazilian one [2] pay attention to it. In Google's web page for "Project Loon" a description of Google project can be read. The idea is to provide Internet access without using traditional infrastructure, in this way places where Internet is still not available can be served. For this purpose, stratospheric balloons powered by solar energy at an altitude of 20 km approximately are considered.

If it is true that there are several organizational tasks to solve in this particular project, probably global and giant companies like Google are the ones who have the best conditions to cope with them.

On the other hand, as it was said, it is not a new idea [3] [4] [5], there is an accumulated amount of know how over this technology, just by reference Skynet, Skystation projects are two Japanese projects in these area. HeliNet and CAPANINA (Eurpean projects) and ETRI and KARI (Korean projects) are other examples of research in this area.

Provided that Orthogonal Frequency Division Multiplexing (OFDM) is a robust and well proved system in several different applications is natural to consider it as an alternative and evaluate it. Some differences between HAPs and other wireless systems is the particular channel and high frequencies used for them (40 GHz) [6].

The robust Space Time Block Coding (STBC) technique has already been considered for HAPs applications [7]. In this work a particular Differential Space Time Block Code (DSTBC) technique, proposed for OFDM systems will be evaluated for HAPs applications.

For more information about the use of MIMO-OFDM in HAPs communications, the reader can check Chapter 20 in (Jiang et al., 2010). Just to show the potential of this technology, a recent trial in Sweden can be mentioned, there, operating in the range of millimeter waves, at 24 km of altitude, a coverage area of 60 km in diameter was achieved. Three important advantages of HAPs compared with satellite systems are that the first ones are much more cheaper, faster to deploy and are placed at less altitude (less distance for the radio link) than the second ones. Among the applications tested over HAPs are: Internet access via WiFi, High Definition Television (HDTV), mobile communications, etc.

2 CHANNEL MODEL AND SCENARIOS

The stratospheric channels may cause strong attenuation, Doppler shifts and multipath fading, apart form atmospheric attenuation due to rain when millimeter waves band is used. To model this kind of wireless

[1] http://www.google.com/intl/es419/loon/?utm_source=google&utm_medium=cpc&utm_campaign=Global_semBK_es.

[2] http://www.telesemana.com/blog/2013/10/15/al-igual-que-google-brasil-llevara-internet-a-zonas-remotas-a-traves-de-globos/

[3] http://www.haps.cl/tour_arte5.htm.

[4] http://www.wtec.org/loyola/wireless/0d_14.htm.

[5] http://www.stanford.edu/class/msande237/viewgraphs/Ohmori3.pdf

[6] http://www.haps.cl/documentos/12.pdf.

[7] http://www.haps.cl/documentos/14.pdf.

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communications three scenarios can be considered, “Parking on land”, “Takeoff and landing” and “Flying platform” (as in footnote 6). The evaluation of the HAPs in these three scenarios is representative of its general performance during operation.

The system is considered to work around a central frequency (f_0) of 40 GHz. For “Parking on land” scenario a velocity of 3 m/s was considered, for “Takeoff and landing” scenario the velocity was of 15 m/s and for the “Flying platform” scenarios a velocity of 30 m/s was used (as in footnote 6).

As channel model, a Wide Sense Stationary with Uncorrelated Scattered (WSSUS) channel was considered. In order to estimate the maximum time delay for multipath fading (τ_{max}) the decision to consider reflections inside a radius of 200 meters was made.

At 40 GHz the electromagnetic waves are attenuated by rain falls, but in this work this natural phenomena is not considered. To have a raw idea of how millimeter wave are attenuated with rain falls (ITU-R, 2005), (Barabino and Rodríguez, 2013) and (El-Disi, 2010) can be consulted.

On Table 1 the simulation parameters used for these three scenarios are shown.

Table 1: Simulation parameters.

Parameter	Value
Carrier Frequency	$f_c = 40\ GHz$
Bandwidth	$B = 16\ MHz$
Number of subcarriers	$N_{FFT} = 128$
Subcarrier spacing	$\Delta f = \frac{B}{N_{FFT}} = 125\ KHz$
Symbol Duration	$T_s = 8\ \mu s$
Guard interval	$T_G = \frac{T_s}{8} = 1\ \mu s$
Symbol interval	$T_{S+G} = T_s + T_G = 9\ \mu s$
Number of paths	$P = 30$
Number of clusters (groups of paths)	$N_c = 1$
Maximum time delay	$\tau_{max} = 0,8895//0,6313//0,6067\ \mu s$
HAP velocity	$v = 3//15//30\ m/s$
Maximum Doppler shift	$f_{Dmax} = f_0 \cdot \frac{v}{c} \approx 400//2000//4000\ Hz$ using $f_0 = f_c$
Time Delay distribution	$b = \frac{\tau_{max}}{\ln(1000)} = 0,1288//0,0914//0,0878\ \mu s$

3 TRANSMISSION SYSTEM

As a transmission system, a DSTBC OFDM system with 2 transmit antennas and 1 receive antenna (2x1) is considered. It has been extensively proved as an efficient and very robust system. Particularly in this work the DSTBC class defined in (Rodríguez and Rohling, 2006) (“4A16PSK PCM2”) and extensively analysed in (Rodríguez and Rohling, 2007), (Rodríguez, 2007), (Rodríguez, 2012) is evaluated for HAPs applications. The description of 4A16PSK PCM2 can also be read from Chapter 10 in (Jiang et al., 2010).

4 RESULTS

To estimate the performance of 4A16PSK PCM2 technique for HAPs applications, three representative scenarios were considered as it was previously explained. In this section the results obtained for each scenario are discussed.

• PARKING ON LAND

The simulation parameters considered for this scenario were: $f_0 = 40\ GHz$, $v = 3\ m/s$ and $\tau_{max} = 0,8895\ \mu s$.

In Fig. 1, the performance of 4A16PSK PCM2 technique is compared with conventional 64-PSK modulation used in DSTBC. By comparing the average performance obtained for 4A16PSK PCM2 and for 64-PSK a good advantage for the first one can be observed. In particular for $BER = 1\text{x}10^{-1}$ an improvement of 4,6 dB can be obtained by using 4A16PSK PCM2 instead of 64-PSK. These results were compared without using any channel coding technique in order to compare directly the performance difference between these two techniques (the proposed in (Rodríguez and Rohling, 2006) and the reference technique -conventional 64-PSK-). How things change when channel coding is used is analysed in (Rodríguez, 2007). There the reader can see that the advantage for 4A16PSK PCM2 is maintained but a little bit diminished; how much can depend on the channel coding technique considered, in (Rodríguez, 2007) convolutional coding and Viterbi decoding was considered.

• TAKEOFF AND LANDING

At this scenario the simulation parameters were: $f_0 = 40\ GHz$, $v = 15\ m/s$ and $\tau_{max} = 0,6313\ \mu s$.

In Fig. 2 an improvement of 10 dB can be obtained for $BER = 1\text{x}10^{-1}$. For this scenario the improvement is much higher than for the previous one. The convenience of considering 4A16PSK PCM2 is very clear. Further more, considering the simplicity of this technique, this should be had in account for these kind of applications.

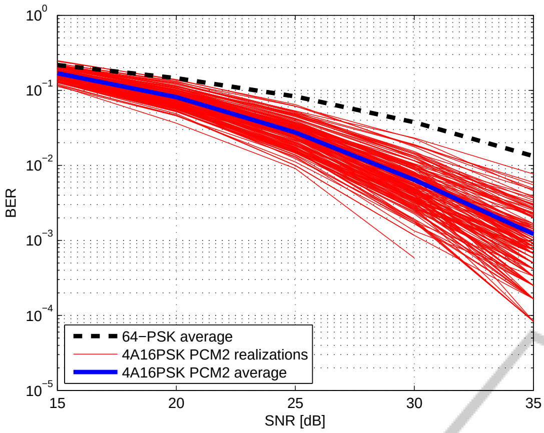

Figure 1: BER versus SNR results for "Parking on Land" scenario.

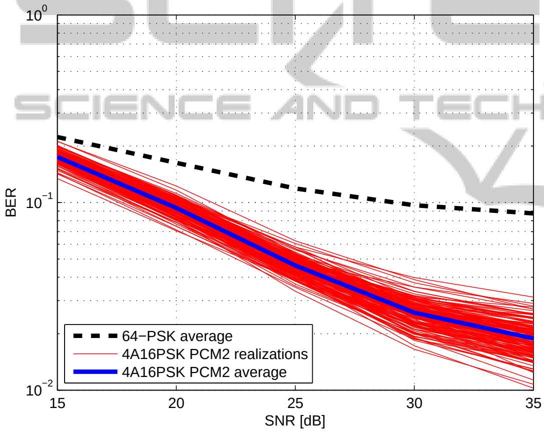

Figure 2: BER versus SNR results for "Takeoff and Landing" scenario.

• FLYING PLATFORM

The parameters considered for this scenario were: $f_0 = 40\ GHz$, $v = 30\ m/s$ and $\tau_{max} = 0,6067\ \mu s$.

In Fig. 3 is also very evident the advantage of using 4A16PSK PCM2 instead of 64-PSK in DSTBCs. In this figure, something that can take the reader's attention is that BER do not improves enough when the SNR is increased. To explain it, the results in Fig. 4 are shown, there the same scenario is analyzed but this time with a central frequency of 4 GHz instead of 40 GHz, then a more natural behaviour for BER versus SNR is observed. What happens is that for central frequency of 40 GHz, a velocity of 30 m/s is very high one, and it deteriorates the performance definitively, then the improvement in SNR do not play a perceptively role in the general performance. When the central frequency is diminished to 4 GHz, then for this frequency 30 m/s is not a so high velocity and does not deteriorate the performance in a so severe way than previously; then for this case when SNR is increased BER is improved in a much more natural way.

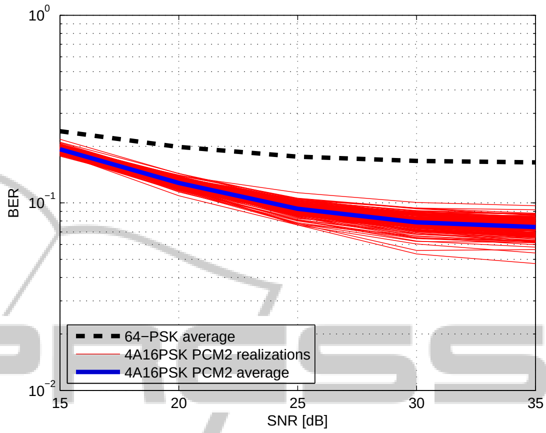

Figure 3: BER versus SNR results for "Flying Platform" scenario.

The parameters considered in Fig. 4 simulation were: $f_0 = 4\ GHz$, $v = 30\ m/s$ and $\tau_{max} = 0,6067\ \mu s$.

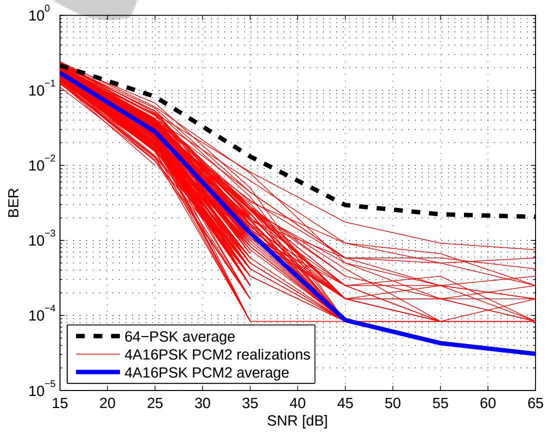

Figure 4: BER versus SNR results for "Flying Platform" scenario ($f_0 = 4\ GHz$).

5 CONCLUSIONS

For the three considered scenarios, 4A16PSK PCM2 demonstrated to be a much better option to conventional 64-PSK modulation technique, when DSTBC OFDM systems are considered for HAPs applications. In (Rodríguez, 2007) the reader can check that the difference in complexity between these two techniques are not high.

At 40 GHz, even a speed of 30 m/s is high speed distorting very much the performance of the transmission. Apart from that 40 GHz is a frequency that can be significantly affected by rain falls. These are two challenging aspects of working in this range of frequencies. By considering lower frequencies these two aspects could be improved.

It is also interesting to remark that by using receive diversity in the downlink, the performance can be significantly improved (see Section 7 in (Rodríguez, 2007)). Which is still more interesting considering that at 40 GHz is not a problem to have several antennas in the receiver. Also is possible to have receive diversity in the uplink by using several receive antennas in the HAP.

Considering the present interest in HAPs, and what the state of the art of the OFDM techniques can offer nowadays, HAPs seems to be a very promising alternative in near future.

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