Distribution of 3G signals over fiber

Daniel L. Beato, António J. V. Amador, N. Martins, R. Nogueira, A. Teixeira, P. André, M. Lima

***Resumo* – Neste trabalho é estudada a viabilidade da transmissão de sinais UMTS, vulgarmente conhecidos como 3G, em redes do tipo P.O.N. (Passive optical networks). Para tal foi desenvolvido um simulador que permitiu modelar o sistema e auferir das condicionantes dessa mesma transmissão. Os resultados obtidos validam este tipo de transmissão e permitem evidenciar as limitações associadas.**

***Abstract* – In this work we study the feasibility of UMTS (3G) transmission over Passive Optical Networks (P.O.N.). In order to achieve such objective, it was developed a simulator, so that we could correctly model the system and conclude about its impairments. The simulation results obtained validate this kind of transmission and highlight the associated limitations.**

I. Introduction

This study is part of a wider project called RaTON (Radio Techniques over Optical Acess Network), which objective is the development of a structure that supports 3G communications (UMTS) in closed environments (for example: tunnels, underground parking lots, etc) in a transparent manner, and evidencing the possibility of having a unique standard interface for local area networks. For such objective it is proposed to test the same concept of Radio access, namely the 3G, in P.O.N. (Passive Optical Networks). In these networks, the infrastrucures are passive and transparent.

One of the major advantages that optical communications bring to this particular application is based on the exploitation of the guided wide bandwidth of low loss available in optical fibres. With these conditions, it is possible to overcome distances that for radio waves are not possible and at the same time define new environements or networks.

To achieve the objective proposed, we started by developing a simulator that allowed us to evaluate the influence of each noise and distortion source. Taking this into account, it is possible to weight the commitments to make viable options available, etc. Aiming that, we have used OSIP software developed in the University of Aveiro.

II. UMTS Signal Characterization

A. *Medium access control*

First of all, we must characterize the UMTS transmission. For UMTS transmission, there are 2 diferent bands: one for UPLINK and another for DOWNLINK. The figure below shows how the spectral allocation is made.

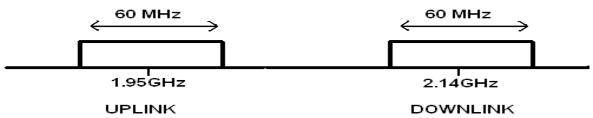

Figure 1-UMTS spectrum allocation

In each band there are 12 different channels, as described below.

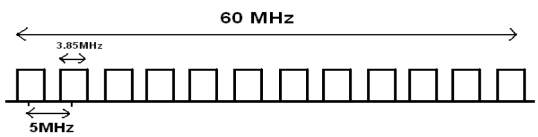

Figure 2-UMTS uplink band

As shown before, the UMTS system uses FDD (frequency multiplexing) to control the medium access (MAC). If each connection used an entire channel, the number of connections would be limited to 12. Thus, the UMTS system uses, not only FDD, but also CDMA (code division multiple access) in each frequency slot, making a mixed access system. The media access is made using orthogonal codes (UMTS uses a code sequence called Walsh-Hadamard) 0. That is, for each slot, every active connection has a unique orthogonal code, so when the information overlaps from different users, it is still possible to decode each channel. The code length varies from 4 to 256 chips per bit (i.e.1 bit is expanded to 4 up to 256 chips), depending on the number of accesses requeried 0. Taking all this into account and since each slot has 3.84 MHz of bandwith, it can be seen that the number of connections and bandwith allocated for each one are inversly proportional, as depicted in the table below (Figure 3).

DPDCH spreading factor	DPDCH channel bit rate (kbps)	Maximum user data rate with $\frac{1}{2}$-rate coding (approx.)
256	15	7.5 kbps
128	30	15 kbps
64	60	30 kbps
32	120	60 kbps
16	240	120 kbps
8	480	240 kbps
4	960	480 kbps
4, with 6 parallel codes	5740	2.8 Mbps

Figure 3-Bit rate vs number of users 0

B. Coding and modulation

As explained before, the transmitted information passes through a codification process called "Channelisation", which consists of making the information orthogonal as described above. Afterwards, two more operations are made:

- Scrambling (using "Gold Codes"): as we know, Walsh-Hadamard codes efficiency is highly dependent on its synchronization. In fact, code words are orthogonal to each other only, and if only, they are perfectly synchronized. In real applications, this synchronization is illusory. A scrambling operation is applied to information, so that cross orthogonal properties are passed to data 0.
- QPSK modulation: after codifying the information with the necessary requeriments, comes the modulation operation. UMTS uses QPSK modulation with carrier frequency around 2 GHz (depending on uplink/downlink and frequency slot used) 0.

Operador	Canal	Frequência Central UL	Frequência Central DL	Frequência do Oscilador Local $f_{OL} = f_{RF} - f_{IF}$
Operador A	Canal 1	1922,5 *MHz*	2112,5 *MHz*	1542,5 *MHz*
	Canal 2	1927,5 *MHz*	2117,5 *MHz*	1547,5 *MHz*
	Canal 3	1932,5 *MHz*	2122,5 *MHz*	1552,5 *MHz*
Operador B	Canal 1	1937,5 *MHz*	2127,5 *MHz*	1557,5 *MHz*
	Canal 2	1942,5 *MHz*	2132,5 *MHz*	1562,5 *MHz*
	Canal 3	1947,5 *MHz*	2137,5 *MHz*	1567,5 *MHz*
Operador C	Canal 1	1952,5 *MHz*	2142,5 *MHz*	1572,5 *MHz*
	Canal 2	1957,5 *MHz*	2147,5 *MHz*	1577,5 *MHz*
	Canal 3	1962,5 *MHz*	2152,5 *MHz*	1582,5 *MHz*
Operador D	Canal 1	1967,5 *MHz*	2157,5 *MHz*	1587,5 *MHz*
	Canal 2	1972,5 *MHz*	2162,5 *MHz*	1592,5 *MHz*
	Canal 3	1977,5 *MHz*	2167,5 *MHz*	1597,5 *MHz*

Figure 4-QPSK carrier frequencies for UMTS 0

C. Multilevel CER/BER

The overlap of information from different connections leads to a multilevel signal. From this point, it is clear that a typical quality factor (Q) analysis cannot be done to the chip error rate (CER). To analyse this new signal, the new approach must take into account the different transitions between the n+1 levels of the signal (from n signals present and added). Considering the states that had been referred before, each transition will have an eye diagram associated (for example, if 3 signals were added, there would be 4 possible levels, corresponding to 6 transitions and 6 diferent eye diagrams).

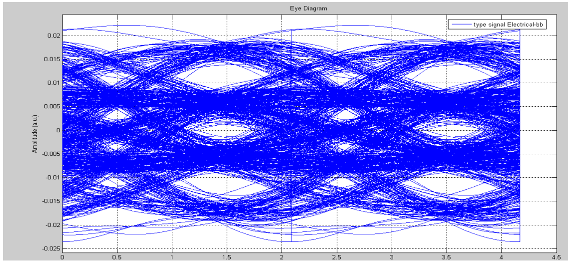

Figure 5-Eye diagram (multilevel)

So, each transition (eye diagram) will correspond to an error probability and to a transition probability. This transition probability will depend on the number of chips present in the generic levels: m and m+1. Therefore, this transition probability can be calculated by:

$$P_{TRANSITION}(Q_n) = \frac{2 \times N_m \times N_{m+1}}{N_{TOTAL}}$$

Where Q_n represents the quality factor 0 associated to transition n.

Also notice here the factor 2, as it must be taken into acount transitions from m to m+1 and m+1 to m (that are numerically equal).

Then, the final CER will be given by:

$$CER_{TOTAL} = \sum_{n=1}^{N} P_{ERROR}(Q_n) \times P_{TRANSITION}(Q_n)$$

This, results from the product of the different contributions (present in $P(Q_i)$) and weights (represented by $P_{transitions}$) of the several eyes by the error probability associated to each eye ($P_{ERROR}(Q_n) = \frac{1}{2} erfc\left(Q/\sqrt{2}\right)$) .

Similarly to CER, also BER can be estimated. It is a simpler process; all that has to be done is to decode information. To calculate its Error probability, it must be taken into account that the final signal will be a 2 level signal, so a typical and simple Q analysis is possible 0.

It should be noticed that all this analysis is only valid if the coded UMTS signal plus the noise follows a Gaussian distribution, wich is going to be analysed later in section III.

III. SIMULATION

A. Schematic

After a brief discussion on UMTS characterization, it is now time to describe the simulation and present the results. As refered previously, the optical simulator used was OSIP. This simulator is a software (built over Matlab) in continuous developement at Universidade de Aveiro since 2 years ago. The latest version provides a large number of different optical blocks with a graphic interface. In order to simulate the 3G signal transmission, some UMTS blocks were developed in addition to those available in OSIP. The simulation schematic is shown in the figure below.

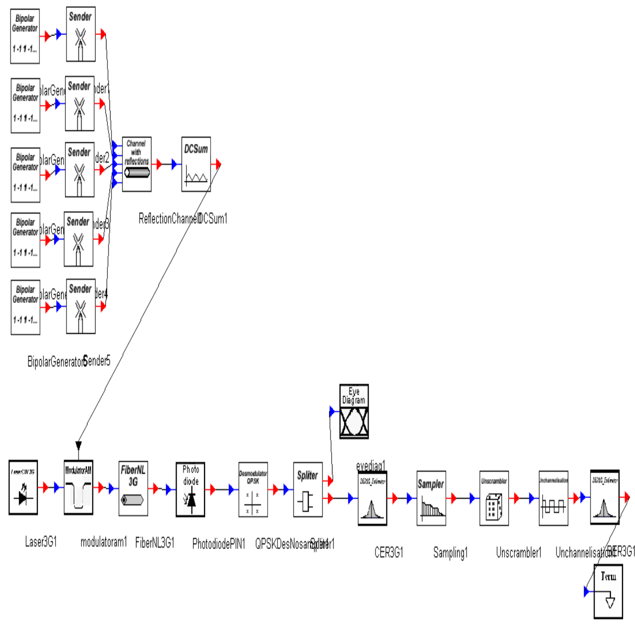

Figure 6-Simulation schematic

Looking to the schematic, some considerations must be made. First of all, all the blocks that are connected to block DCSUM represent the UMTS signal generation. The laser will be modulated by the generated signal, using an AM modulator. Afterwards, the modulated optical carrier is sent over the fiber and received in the photodiode. The next step consists on demodulating the QPSK signal, so CER estimation can be computed. At the end, in order to estimate BER, the signal is decoded (first unscrambled, and then unchannalised).

B. Simulation parameters

First of all, there are several variables to be assigned in the simulation. The most important is the allocation in the frequency slots of the different connections (senders). Since the target implementations require a limited number of connections; a number of 5 connections has been considered adequate for this purpose (3 of them in the same frequency slot, using different channelisation codes). Taking this in account, 2 different simulation procedures were followed:

- The first used consecutive frequency slots, so the interfering of different slots could be measured;
- The second, with slots apart from each other, to measure the interference of the different connections in the same frequency slot, using different channelisation codes.

For the remaining simulation parameters, namely those related to optical elements, we considered typical values.

C. Simulation results

First of all, all the theorical analysis made before to CER and BER is only valid if the resulting signal presents a Gaussian distribution. In order to prove this, 10 connections were overlapped (the number of connections represents here the amount of information flowing from different sources). The resultant histogram, as shown in the figure, proved the assumptions made earlier.

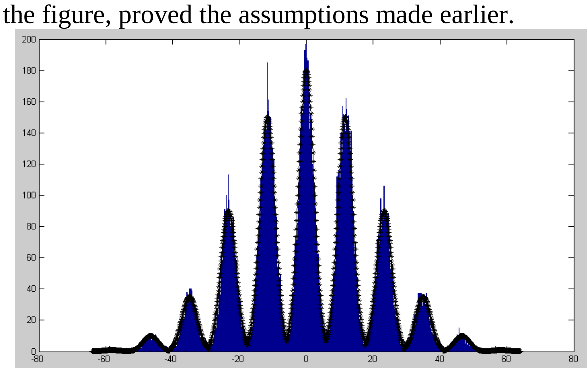

Figure 7- UMTS signal distribution

Simulating now the system described before, considering a Laser Power of 10 mW, we have obtained the following results for CER and BER as a function of the fiber length (figures 8 and 9). For a Laser Power of 100mW, the CER and BER values obtained were the depicted in figures 10 and 11.

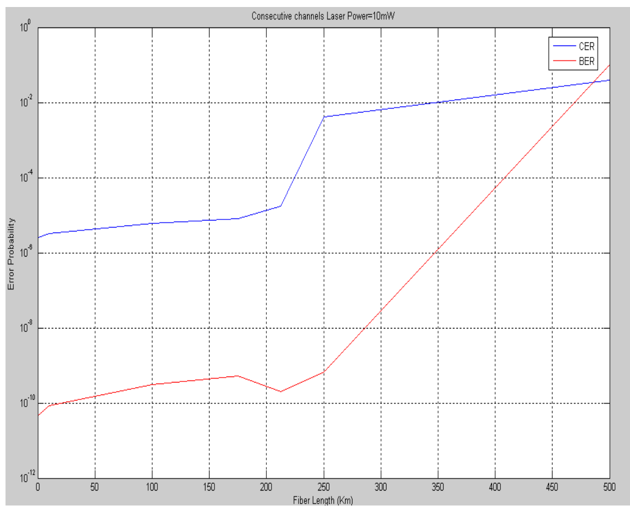

Figure 8- Consecutive channels with Laser Power =10 mW

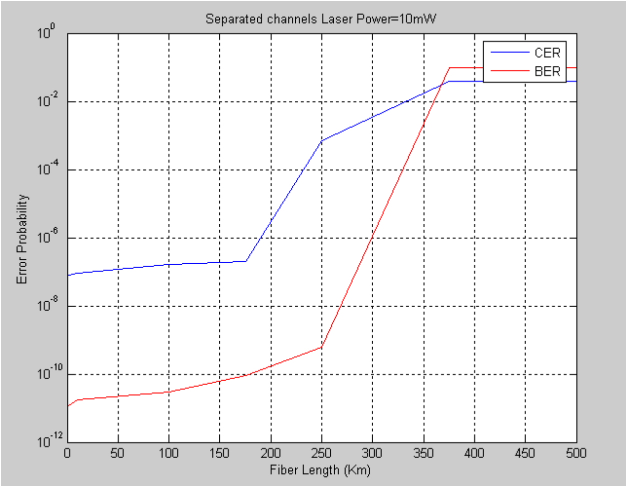

Figure 9- Separated channels with Laser Power =10 mW

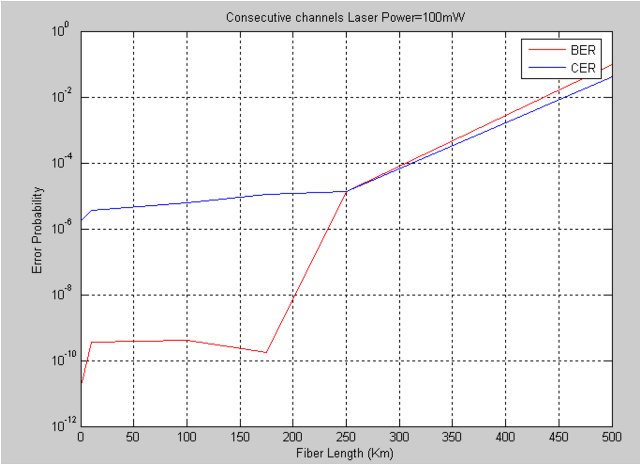

Figure 10- Consecutive channels, Laser Power =100 mW

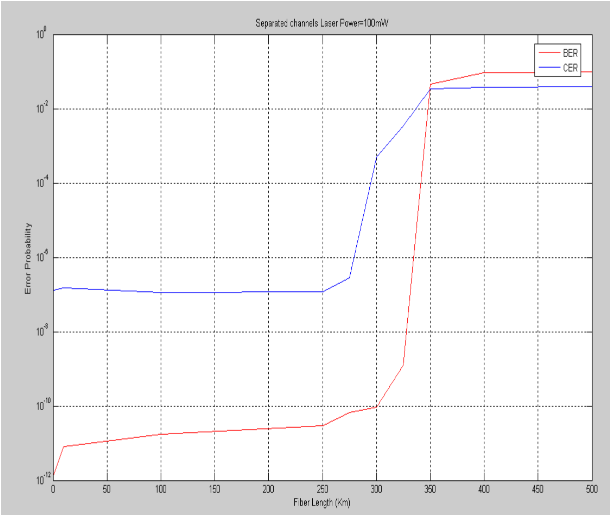

Figure 11- Separated channels with Laser Power =100 mW

Analysing the obtained results, it can be concluded that the system has an acceptable error probability until 200 km. After that, the quality of the response in terms of Error Probability decreases, and by 300 km it is overwhelming. The difference between 10 and 100 mW in the laser power results in aproximately one order of magnitude in terms of error probability and therefore its value will be a compromise, depending on the system characteristics demanded.

IV. CONCLUSIONS

In this paper, we tried to prove the feasibility of 3G signals transmission over PONs. The simulation results proved that the transmission can be done with a relative low and acceptable BER, and the information can be sent on a transparent basis. Taking into account the application purposes of the study, the optical fiber distance obtained is quite satisfactory, with distances as far as 100 km. The study is presently being completed with laboratory tests, so that simulation results can be confirmed.

ACKNOWLEDGEMENTS

This work was supported by the POSC program, financed by the European Union FEDER fund and by the Portuguese scientific program. The support of IT Laboratório Associado through the RaTON (P311) project is also gratefully acknowledged.

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