UMTS Radio distribution over Transparent Optical Networks

Abstract — In this work the feasibility of UMTS (3G) transmission over Passive Optical Networks (PONs) is evaluated. Based on a simulation model for the system, impairments are identified and characterized.

I. INTRODUCTION

Nowadays, radio access, namely to wireless phone, is a need and a big part of the telecommunications market. Distribution everywhere is therefore needed, even if small number of clients will use it. Especially in closed environments (for example: tunnels, underground parking lots, etc), this becomes more difficult as you grow in data rate, e.g. 3G communications. One solution, which has been pointed out is the hybrid approach radio over fiber (RoF), where radio signals are directly sent through the fiber in a transparent manner. With this, the signals can be transported to less accessible places, and at the same time the antennas become simpler due to the nature of the modulated signals.

One particularity of this last segment of networks is the fact of being typically passive and transparent, usually named as Passive Optical Networks (PON). 3G signals are evolving, giving bases to the following generations. These 3G signals have bands which are accessed and shared through Code Division Multiple Access (CDMA). By transmitting 3G CDMA over fibers some advantages can be obtained. In these conditions a transparent multiple access to the PON passive media without any change in the typical CDMA terminals can be provided. Figure 1 shows a tipycal Passive Optical Network

![Figure 1. Typical Passive Optical Network](image)

In this work the structure of UMTS signals and their coding structure are presented, and some of the parameters performance effects discussed. Following, based on simulation, the characterization of a multiple user uplink is characterized.

II. UMTS

A. Medium access control

For UMTS transmission, there are 2 different bands: one for UPLINK and another for DOWNLINK. Figure 2 shows how the spectral allocation is made. In each band there are 12 different channels, as described in Figure 3.

![Figure 2. UMTS spectral allocation](image)

As shown before, the UMTS system uses FDM (Frequency Division Multiplex) 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 FDM but also CDMA in each frequency slot, making a mixed access system. The medium access is made using orthogonal codes (UMTS uses a code sequence called Walsh-Hadamard) [1]. That is, for each slot, every active connection has a unique orthogonal code, so, when the information from different users overlaps, it is still possible to decode each channel. The code length used can vary from 4 to 256 chips per bit, depending on the number of accesses required. Taking all this into account and since each slot has 3.84 MHz of bandwidth, it can be concluded that the number of connections and bandwidth allocated for each user decreases accordingly. [2]

B. Coding and modulation

As depicted in figure 4 the information to be transmitted is quantified and passes through an orthogonal codification process, the Spreader (usually called “Channelisation”), followed by two more operations.

![Figure 4. UMTS modulator](image)
The spreader block is described in the figure 5. The operation that is done is the product between data signal and a pseudo-random code (the spreading code) that is unique in the system for each user. The length of the spreading code is the spreading factor (SF) and each bit of spreading signal is called a chip.

To get the highest cross-correlation, the encoded signal suffers another operation that is called scramble. This operation gives high synchronization properties to the encoded signal. In figure 8 shows how the scramble process works. The scrambler operation does not change the bandwidth of the encoded signal.

The QPSK modulator sums a sin and a cosin wave in frequency imposed by UMTS specifications [3] for each band (uplink and downlink) and with phase shifts coded by the chips entering modulator. The UMTS specification for uplink and downlink bands is presented in Table 1.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Uplink</th>
<th>Downlink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq. Range</td>
<td>1920MHz - 1980MHz</td>
<td>2110MHz - 2170MHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5 MHz, for any channel within the band</td>
<td></td>
</tr>
<tr>
<td>Max. Out. Power</td>
<td>12dBm</td>
<td>30dBm</td>
</tr>
<tr>
<td>IP3</td>
<td>37dB</td>
<td>49dB</td>
</tr>
</tbody>
</table>

The amplifier in figure 3 will amplify the signal until its maximum and respecting the IP3 minimum value. This amplifier block includes a driver amplifier a power amplifier and an output filter.

III. HEADENDS OF PASSIVE OPTICAL NETWORK

For the whole system, the blocks that support this architecture, in uplink handset side is presented in figure 9.
Figure 10 shows the system in the other end of the fiber optic (the antenna side).

Figure 10. The antenna side system.

In the user side (figure 9) in the uplink section the input filter give the attenuation needed so that the signal produced from power amplifier form the downlink section do not pass to the uplink section. This is needed because the maximum duplexer attenuation in the reject band that it is founded in the market is 50dB so if at downlink section the power amplifier supply the maximum power (30dBm) it pass to the uplink section -20dBm. This signal could reach the uplink LNA input. The amplifier gain controlled (AGC) is a block that prepares the signal to be introduced in the fiber through the Mach-Zehnder modulator (or direct laser modulation). It is an AGC because the gain needed, depends on the laser used and the power the same for each laser used.

In the downlink (figure 9.) the signal received from the photodiode is amplified and prepared to be irradiated. If it is used a direct connection to a UMTS data card the power amplifier is not needed that’s why it is in a gray color.

For other end of the fiber (the antenna side, figure 10) the blocks have the same description.

IV. ARCHITECTURE OF PASSIVE OPTICAL NETWORK

Several limitations were identified in this PON hybrid system. These are normally related to laser characteristics and fiber related issues (coupling, dispersion, etc).

There are two possible architectures that can be used, the STAR and BUS. Figure 11 and 12 show these 2.

In the STAR topology the hosts fiber are all connected to the same coupler. This coupler has the same number is inputs than the number of hosts and after this the fiber is connected to the photodiode in the other end (figure 11)

In the BUS topology each host are connected to one coupler. This coupler has tow inputs one for the user and other for the preceding coupler. The ouput will connect to the next user coupler input (figure 12).

A. Power control

In both BUS and STAR topology, in downlink section there is no problem in controlling the power in each user, since it is done for the whole multiplexed channels in base station. The problem of power control and equality is raised in the uplink section where users have different distance to the base station as stated in figure 13

In this simulation it was used 100 meters from each user to coupler and 10 km from the coupler to the photodiode. Only a maximum of 3 users can share the fiber in the uplink section with acceptable CER. The BUS architecture shows a decisive feature, the optical power control is a crucial feature in the
UMTS system and have to be carefully controlled to ensure the transmission of data.

B. **Instantaneous frequency change due to modulation**

Another of the limitations related to the laser is the instantaneous frequency change due to modulation. In figure 13 are shown simulations of the uplink section using direct and external modulation.

![Figure 13: Simulation of uplink section](image)

**Figure 13. Simulation of uplink section**

For a CER of $10^{-9}$ using direct modulation, figure 14 shows that it can be used up to 3 host and using external modulation it can be used up to 7 hosts.

![Figure 14: Result of CER vs Number of hosts](image)

**C. Instantaneous frequency change due to modulation**

Another limitation of the STAR topology is the fiber length. Figure 15 shows the simulation results with fiber length from star coupler to photodiode of 5km and a variable distance from each user to the coupler. It was simulated a maximum of 6 users with external laser modulation (no chirp effect).

![Figure 15: External laser modulation in star topology](image)

The same scenario but now with direct modulation in each user laser with chirp (100MHz/mA) is shown in figure 16.

With the no frequency change for a CER of $10^{-9}$ a distance of 160km from each host to star coupler can be achieved for any number of host (maximum 6). With instantaneous frequency changing (with chirp) for the same CER the maximum distances achieved depend of the number of users in the system. For 2 users it can reached 10km for the CER considered.

![Figure 16: Direct laser modulation in star topology](image)

**III. CONCLUSIONS**

In this work, the optical and electrical multiplexing and limitations behaviour of 3G signals transmission over PONs was analyzed. The results show that transmission and multiplexing can be achieved with an acceptable CER. The transmission, as long as it stays linear, is not limited by the power and long distances can be achieved (150 km for 10 mW and 200 km for 100 mW). Direct modulation of the laser will degrade the usability of the channel available bandwidth (eg. with 150MHz/mA a two fold decrease was verified in the number of users). For a reference system a tolerable laser chirp was 150 MHz/mA, which can represent a limitation in the choice of the lasers used.

**REFERENCES**

