Multiband OFDM Transmission in RoF Systems

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Abstract — **In this paper, a study on the transmission of multiband-OFDM (MB-OFDM) UWB-based signals in a Radio-over-Fibre (RoF) system is presented. Some simulations are made and EVM parameter is analyzed to evaluate the performance of the system for different bit rates, fibre lengths and laser power. Also, it is studied the influence of the noise introduced by the FBG in the system.**

I. INTRODUCTION

In the last decade, wireless communications have experienced an explosive growth with the demand for higher data rates to accommodate new services growing rapidly ever since. A number of wireless systems have been gradually introduced including novel mobile and fixed wireless systems. These events have been associated with important repercussions at the society, economic and political levels.

The realization of truly broadband wireless systems calls for the migration from the currently relatively congested microwave frequency band to the less occupied millimetre-wave frequency region. In this context, hybrid fibre-radio technology is a very attractive system concept to support the deployment of broadband millimetre-wave wireless communications systems. Fibre-radio systems exploit optical signal generation and transport techniques of the millimetre-wave RF signals to interconnect the central office to the micro- or pico-cellular base stations.

Fibre-radio systems can also exploit wavelength division multiplexing (WDM) techniques to interconnect the central office to the base stations leading to additional advantages in terms of capacity upgrade and reconfiguration, routing flexibility and network protection. WDM millimetre-wave fibre-radio systems are a key technology to accelerate the deployment of broadband millimetre-wave wireless communications systems.

As for the broadband wireless access, orthogonal frequency division multiplexing (OFDM) technique has been pointed as one of the best because it provides increased robustness against frequency selective fading, narrow band interference, high channel efficiency and greater capability that rivals single carrier systems [1].

Among the radio technologies using OFDM, Ultra Wideband (UWB) appears as a promising solution for high rate networks. UWB radios typically have short range in outdoor and indoor environments since the power level is regulated to -41 dBm/MHz across most part of the 3.1 to 10.6 GHz spectrum in compliance to Federal Communication Commission (FCC) Part 15 [2]. In addition, emerging standards for wireless personal area network (WPAN) in IEEE 802.15.3a [3] and ECMA-368 [4] demands very high data rate ranging from 100Mbps to 500Mbps [5]. Hence, the range is expected to be further reduced with higher data rate. One way to extend the wireless range is to use RoF technology.

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In this paper, a study on the transmission of multiband-OFDM UWB-based signals in a RoF system is presented. First, a brief explanation of the MB-OFDM UWB technology is given to introduce the reader to some characteristics of the simulated signals. Then, we present the system used in the simulations and, concentrating on the error vector magnitude (EVM) parameter, the results obtained are analysed for different parameter combinations. Also, it is analyzed the influence of the noise introduced by the fibre Bragg grating (FBG) in the system performance.

II. MB-OFDM APPROACH

In the multiband OFDM approach [3], UWB signal occupies 528 MHz of bandwidth, so 14 of these signals cover the entire 7.5-GHz band, as shown in Fig. 1.

The OFDM has 128 subcarriers, and quadrature phase shift keying (QPSK) is used to modulate the transmitter signal at the subcarriers.

The multiband OFDM system can support 10 different data rates, including 53.3, 55, 80, 106.7, 110, 160, 200, 320, 400, and 480 Mbps. Different data rates are achieved by using a different channel coding rate, frequency spreading gain or time spreading gain.

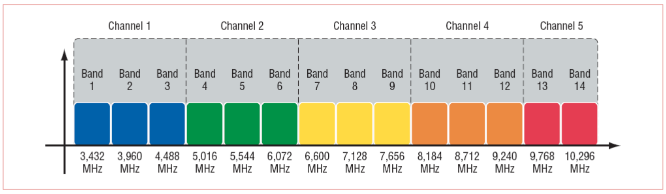

Fig. 1: Band division in multiband OFDM ECMA-368 UWB standard.

III. SYSTEM DESCRIPTION

The system is composed by three channels with three sub-bands each. A uniform FBG is used to do the drop of the desired channel.

The signals consist of random sequences of bits generated at a given bit rate. These signals are coded using QPSK and then, modulated using OFDM technique.

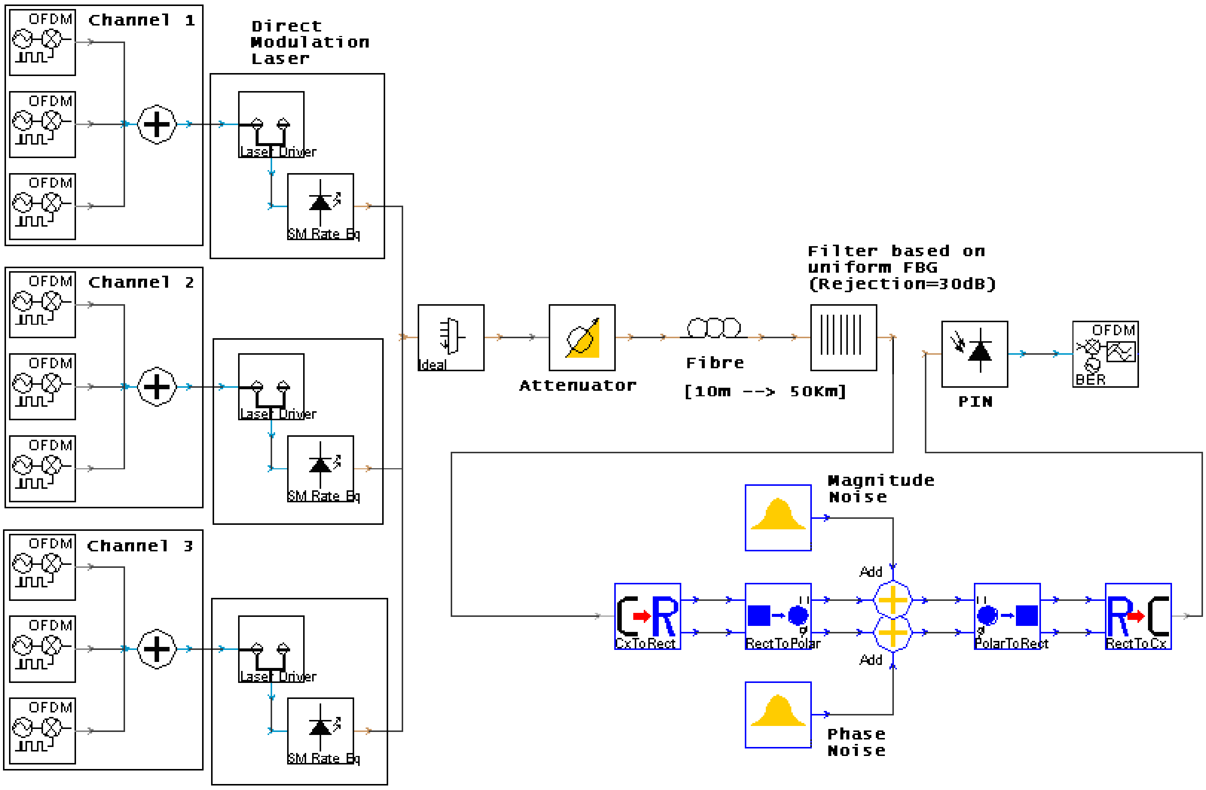

Fig. 2: Simulation setup schematic.

An external laser for each channel modulates the three sub-bands OFDM electrical signal; afterwards, the channels are multiplexed and transmitted over the fibre. In the receiver end, after selecting the desired channel using a uniform FBG, a PIN detects the electrical signal and passes it through the QPSK-OFDM receiver, which selects only one of the sub-bands. In this block, the EVM is measured to verify the system performance.

The sub-circuit after the FBG is used only in the simulations of section IV.C. This sub-circuit separates the x and y polarization. In the x-polarization, the signal is converted to real and then to polar coordinates, where a Gaussian noise is introduced in the phase and in the magnitude. After that, the inverse process is applied, composing an optical signal again. Fig. 2 shows the simulation setup.

IV. SIMULATION RESULTS AND ANALYSIS

A. Preliminary Simulations

In this section, the simulations only contemplated 1 sub-band; consequently, the simulation setup of Fig. 2 was simplified, since there was no need for the FBG and for the WDM multiplexer. The main objective of these preliminary simulations was to observe how the system performance is affected by variations in the bit rate, fibre length and laser power.

Observing Fig. 3, we can verify that, as intuitively expected, the EVM penalty increases with the increasing length of the fibre. For longer fibres, the accumulation of impairing effects like attenuation and dispersion increases the degradation of the signal transmitted.

Another important aspect is the laser power. As the power in the laser is increased, the system performance is improved. Keeping the EVM in the lower value possible for each fibre length implies a power value of at least -10dBm.

As can be noted in Fig. 4, in a general way, as the bit rate is raised, the EVM penalty increases too. Nevertheless, the difference between the higher and lower bit rates, in terms of EVM, is no more than 2%. From the power point of view, there is a tendency to poor the performance as the power decreases.

B. Increasing Data Simulations

In this section, we simulated the system for 3, 6 and 9 sub-bands, and consequently one, two and the three channels) to see the effect of increasing data in the fibre, which was 1 km long. Fig. 5 shows that there are no significant differences in the system performance for increasing number of channels in the fibre. However, the higher bit rate leads the EVM value close to 8%. Still, it meets the MB-OFDM specifications for EVM parameter, which is equal or better than -19.5dB (around 10%) [6].

C. FBG Noise Simulations

In this section, the aim was to quantify the maximum amount of noise that can be introduced by the FBG in the system. Since the uniform FBG used in the simulation has an almost ideal behaviour, the sub-system, illustrated in the lower right part of Fig. 2, introduces noise in the magnitude and in the phase of the filtered signal.

The performance was evaluated in terms of EVM for 6 sub-bands (2 channels), 320 Mbps of bit rate and 1 km of fibre. The optical power entering the fibre was -1dBm. These parameters were chosen based on the previous simulations, since they guaranteed good performance.

As shown in Fig. 6, the system only tolerates magnitude induced noise variance lower than -25 dBm, which is 0.8% of the mean value. In this case, the EVM parameter is kept below 10%. For variances lower than -40 dBm, which is 0.025% of the mean value, the noise does not have influence in the system. By introducing noise in the phase, no significant change was noticed.

III. CONCLUSION

A study about the transmission of multiband OFDM signals was presented. Simulations were carried out to understand how the system responds to different combinations of bit rate, fibre length and lasers power. Also, it was verified that the FBG fluctuations must be kept below 0.8% of the mean value. In very preliminary results using apodized FBGs, we obtained some improvements in the EVM parameter, which indicates that this is the way to follow.

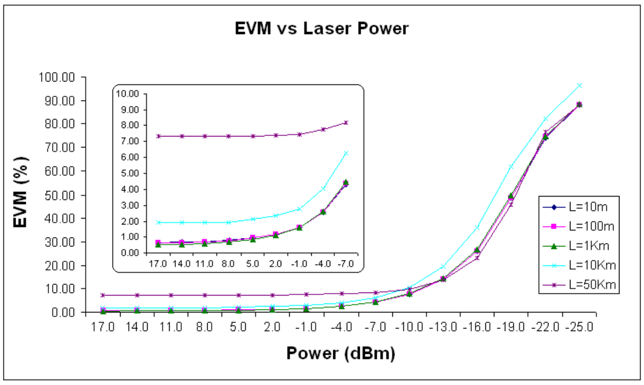

Fig. 3: EVM vs. Laser power at 480Mbps. Inset: a more detailed view of the curves in the range [-7.0; 17.0] dBm.

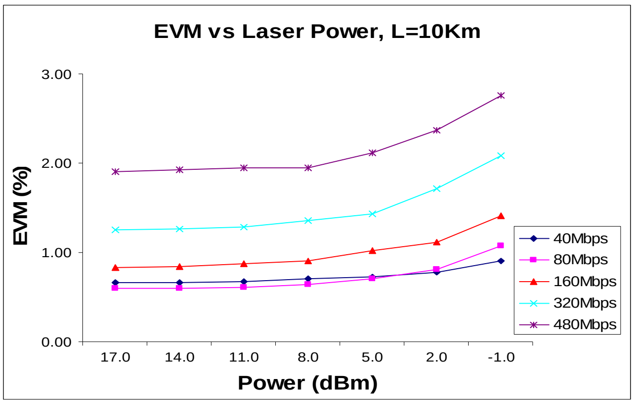

Fig. 4: EVM vs Laser power for different bit rates and fibre length of 10Km.

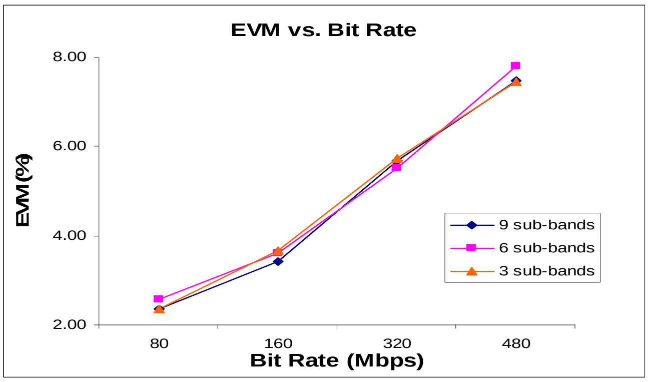

Fig. 5: EVM vs. Bit rate for increasing number of sub-bands.

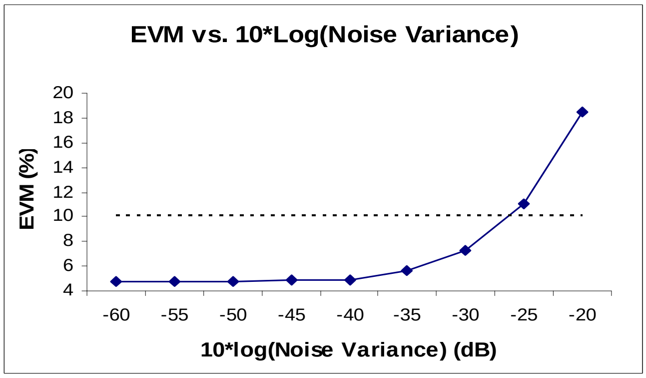

Fig. 6 EVM vs. 10*log(Noise variance). The signal magnitude is -4 dBm.

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