10 Gbit/s Optical Single Sideband Prototype

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Abstract — This paper reports the construction and optimization of an Optical Single Sideband (OSSB) prototype for a transmission rate of 10 Gbit/s. The system robustness to chromatic dispersion as well as the efficiency of the electric chromatic dispersion compensation were evaluated and reported.

I. INTRODUCTION

In the last years, the volume of telecommunications has increased globally. With the constant integration of new services, the telecommunication operators start to require more available bandwidth for their networks. From their point of view there are two ways to increase the transmission bandwidth: rearrange or even replace the installed network, or increase the efficiency of their terminal equipments. The first solution is highly undesirable because it is very costly. Therefore, the preferable intervention will be made at the terminal equipment level. In fact, there is a strong and increasing investigation in this field. One of the topics of the research is the modulation formats used in the information transmission. The main aim of these studies is to develop modulation formats that are simple to be implemented, spectrally efficient, and robust to the transmission channel degradation effects. As a result, several modulation schemes were proposed including the Optical Single Side Band (OSSB). This format needs only half of the bandwidth required for an equivalent Optical Double Side Band (ODSB) signal, is more tolerant to the chromatic dispersion than the latter and is suitable for electric chromatic dispersion compensation. For these reasons, OSSB is a very promising modulation format, not only for long haul transmission, but also for metropolitan networks as referred by D. Fonseca et al. in [1].

II. PROTOTYPE IMPLEMENTATION

A method to create OSSB, based on the modulation of a dual arm Mach Zehnder, was proposed and demonstrated by Sieben et al. in [2]. Accordingly with these authors, an OSSB signal is generated when a dual arm Mach-Zehnder is driven with the following electrical signals:

\begin{align}
    d_1(t) &= x \cdot V_s \cdot (m(t) + \hat{m}(t)) - \frac{V_s}{4} \\
    d_2(t) &= x \cdot V_s \cdot (\bar{m}(t) + \hat{m}(t)) + \frac{V_s}{4}
\end{align}

Where:
- \(x\) is the modulation depth,
- \(m(t)\) is an AC coupled of the original NRZ binary data,
- \(\bar{m}(t)\) is the complementary signal of \(m(t)\),
- \(\hat{m}(t)\) is the Hilbert transform of the binary data and
- \(V_s\) is the modulator switching voltage.

Tiago Maia et al. have proposed in [3] the following implementation for this modulation scheme:

Figure 1: Implementation proposed by Tiago Maia et al. in [3]

In order to attain the maximum possible bandwidth, signals \(m(t)\), \(\bar{m}(t)\) and \(\hat{m}(t)\) are added in resistive power combining/splitting devices. However, the isolation between input ports and output ports, for these devices, is very poor. As an example, for this configuration, the Hilbert transform signal has the same power level at the Mach-Zehnder arms and at the output ports of amplifiers G1 and G4. Depending on the signal level, which is normally high, this can compromise the amplifiers performance.

To improve the system performance, a new transmitter version was investigated and implemented based on the following modifications:

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• Replacement of the electrical signal combination/splitting block for a totally passive version.

• Inclusion of a third phase adjuster in an arm of the Mach-Zehnder modulator;

The new circuit configuration is illustrated in figure 2.

In the new configuration the amplifiers were removed from the different signals paths. Amplifiers G2 and G3 (figure 1) whose function is to amplify and isolate the hybrid coupler output from the complementary data signals are indeed not require. It can be seen that the input signals are complementary and the circuit has symmetry relatively to input ports, if we terminate de hybrid coupler input port by a matched load. In this case, the signals present at the hybrid coupler output port as a result of $m(t), \overline{m}(t)$ cancel each other. Regarding the Hilbert signal being fed back to the input ports data signal the attenuation they suffer is sufficiently high to prevent any significant penalty to the transmitter performance. For this configuration the signal is attenuated a minimum of 15 dB between the power combiner (6 dB) and the input port. The additional 9 dB are from an attenuator which accounts for losses in the hybrid coupler signal path. It was concluded by simulation and also experimentally that the total isolation obtained is enough for this type of application. Hence, this unit could be redesigned to be simple, reducing the number of active components and a lower power consumption; that could be relevant in future system integration.

From the previous considerations, the new configuration only requires two amplifiers, G1 and G2 (figure 2), in order to guarantee the proper amplitude for the modulator driving signals as illustrated in figure 2.

The inclusion of the third phase adjuster was required to ensure a precise synchronization between the Mach-Zehnder driving signals. This is important in order to optimize the sideband suppression. A time delay of 4 ps between the MZ input signal already has impact on the transmitter performance.

Adding the necessary attenuators to balance the signal amplitude in each circuit parts as well as a power supply unit, it was constructed the prototype depicted in figure 3:

![Figure 3: Prototype internal view](image)

### III. EXPERIMENTAL RESULTS

For the experimental characterization of the transmitter prototype, the extinction ratio was adjusted to 6 dB, in conformity with recommendation made by Sieben et al. in [2]. The experimental results were the following:

A. Back to Back

Figure 4 illustrates the eye diagram, acquired by a 65GHz optical sampling oscilloscope, of the modulated OSSB signal at the transmitter side. The picture shows a near ideal eye diagram with very low jitter and the intersymbolic interference. The inclusion of the third phase adjustor allowed a fine phase adjustment between the two modulator signals increasing the signal integrity of the optical modulated signal.

![Figure 4: Back to back eye diagram](image)

A significant improvement of sideband suppression were also obtained as illustrate in Figure 5. The measured suppression at 5 GHz apart from carrier was close to 20 dB.
B. Transmission without chromatic dispersion compensation

The OSSB signals are known to be more robust to chromatic dispersion than the conventional ODSB. In order to verify this assumption, the test setup of Figure 6 is employed.

The detected eye diagrams were the following:

As can be observed, even after 160 km of optical fibre without resorting to any chromatic dispersion compensation, the detected signal still presents an open eye diagram. If the same transmission was made in ODSB, the eye diagram will be practically closed after the first 100 km of optical fibre [4]. With these results, the robustness of OSSB to chromatic dispersion was one more time demonstrated.

C. Transmission with chromatic dispersion compensation

Further than the robustness of OSSB to chromatic dispersion, this modulation format has an additional feature; it is compatible with the electrical chromatic dispersion compensation. This compensation scheme could be implemented by several ways; one of them is the use of dispersive microstrip lines as referred by T. Silveira et al. in [5]. In order to test the effectiveness of this method, the following test setup was used:

The obtained results were the following:
The efficiency of this method could be verified by figures 8 and 10. Even starting with a much degraded signal, it was possible to totally recover it. Therefore, an open eye diagrams can be achieved even after 240 km of optical fibre as can be seen at figure 11.

D. Sensivity measurements

Experimental sensitivity measurements for different transmission distances were also realized to better assess the transmitter performance. The results were illustrated at Figure 12.

As can be observed in the latter graphic, the robustness of OSSB to chromatic dispersion is remarkable. The 80 km curve almost overlaps the back to back curve. On other hand, the efficiency of chromatic dispersion compensation is also very noticeable. The behaviour of the 0 and 80 km curves is similar to the curves for 160 km + EDC 140 km and 240 km + EDC 140 km. Hence, could be proved that this compensation scheme is not only very efficient but is also not dependent of the accumulated chromatic dispersion level.

IV. CONCLUSIONS

The developed prototype has demonstrated one more time the potentialities of OSSB as an efficient modulation format as well as their implementation viability. In the transmission aspects, the 240 km results are outstanding. A closer look to the eye diagram after this transmission distance leads us to conclude that the signal quality is sufficient to transmit at higher distances.

The electric chromatic dispersion compensation have also revealed very efficient with the advantage of being totally independent of the wavelength used on the transmission. On the topic of the system implementation, the simplification made in the combination/splitting unit have reduced the number of amplifiers and also have increased the robustness of the implementation. With this block totally passive, their integration on technologies such as Low temperature cofired ceramics (LTCC) will be very simplified which could be very important if there was a commercial interest on this type of solution.

REFERENCES


