Fiber dispersion effect on envelope detection of intensity modulated signals in Suppressed Carrier (SC) Subcarrier Modulated (SCM) systems

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1. Introduction

In optical transmission systems fiber dispersion can have a significant effect over medium or long distance transmission lines. This is also true for Carrier Suppressed (SC) Subcarrier Modulated (SCM) systems, where several frequency components are involved in transmission. Since the transfer medium - the fiber - is dispersive, signal detection can be degraded, if the transmitted frequency components have a phase difference at the detector. This phase difference arises from the frequency dependent delay time, caused by dispersion.

The effect of fiber dispersion on baseband modulation content was analysed and reported in several articles [1,2] also taking into account the distortion of harmonic frequencies [3]. However, dispersion effect on subcarrier modulated signals have not been investigated deeply yet.

In this paper fiber dispersion effect considering a subcarrier modulated system with suppressed carrier is analysed. Calculations are given for the case, when the modulation content on the subcarrier is a sinus. A phase delay between the sideband subcarriers is also taken into account. This will give the theoretical background of the simulations, where a whole transmission system is taken into account. Fiber dispersion is simulated through an all-pass filter with special phase characteristic, modulation contents are PRBS signals both in the baseband of the optical carrier and of the subcarriers, and effect of imperfect carrier suppression is also taken into account.

2. Fiber dispersion

Although we think of an optical light "pulse" as consisting of a single wavelength of light, there is actually some width of its spectrum. In silica, slightly different wavelengths of light travel at slightly different velocities and lead to pulse compression or pulse expansion. For continuous modulation content this time delay between wavelength components means that at the detector the side-band components meet with a phase difference and constructive or destructive detection could arise.

Wavelength components for an intensity modulated are shown in Fig. 1.a.

Problem can arise due to fiber dispersion, if the two side-band signals, ω_c-ω_m and ω_c+ω_m, arrives to the detector with a phase difference. The baseband modulation component is the beat result of these two signals and the carrier. In case these signals meet incoherently at the detector, than attenuation could occur. At worst case, when the phase difference is exactly π, there will be a signal with zero magnitude at ω_m frequency after the demodulation.

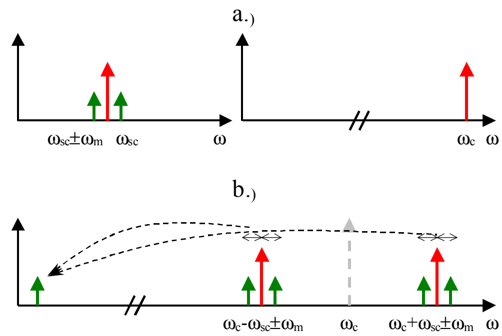

Fig 1. a. *the AM modulated signal and the optical carrier*
b. *SCM signal with suppressed carrier*

There have been several studies, investigating this signal extinction due to fiber dispersion for different frequencies and fiber lengths [1,2,3].

3. Carrier suppressed subcarrier modulated signals

Carrier suppressed subcarrier modulated optical signals can be produced by two stage modulation. At first step an electrical μ-wave carrier (ω_{sc}) is modulated by a baseband information signal (ω_m), and in the second step the optical carrier (ω_c). The wavelength components for this signal after carrier suppression can be seen in Fig. 1. b.

In this case the sum of the optical side-band signals give a signal, with an envelope of the baseband modulation content, which can be detected by a photodetector. The question is, how fiber dispersion can corrupt the detected signal.

In practice we can have subcarrier modulated signals with suppressed carrier in label routed packet switched networks. These networks are the most promising types of future photonic networks, where the label switching of packet flows can be combined with wavelength division multiplexing in the optical domain. In this way optical networks can be easily integrated with the Internet Protocol.

4. Numeric results

The time domain signal of the components of Fig. 1. b. after a square low detection is plotted in Fig 2.

We can calculate the resulting components after photodetection by making the square of the original expression, which components are shown in Fig. 1. As it is indicated there, the baseband modulation content is generated from the modulation content of the subcarriers, so we can expect, that only the phase difference between the modulated signal components and not the phase difference between the side-bands will affect the detected signal quality.

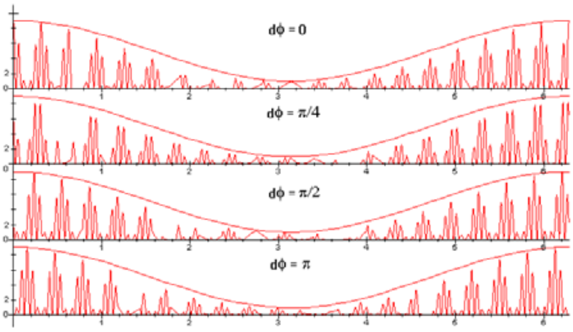

Fig 2. AM-DSB-CS signal with various φ phase difference between the side-bands

The effect of a φ phase difference between the side-bands is shown in Fig. 2. We can see – also have the same results from numeric calculations - that there is only a slight dispersion penalty due to this phase difference. However, this does not mean that SCM-SC systems are insensitive for dispersion. Fiber dispersion should be taken into account for the modulation content on each subcarrier independently, as it was shown earlier.

5. Simulations

In the simulations a typical SCM-SC transmission system was investigated, focusing on the effect of fiber dispersion, the imperfect carrier suppression and undesired signal mixing due to non-linear elements. The basic block scheme of the simulation system is shown in Fig. 3. Optical elements are modelled by electronic components.

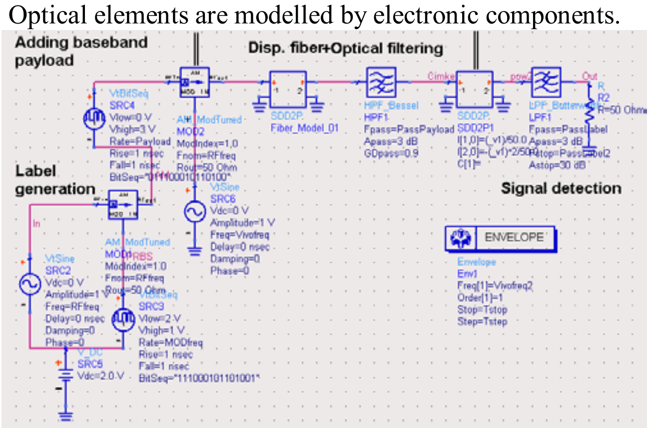

Fig 3. AM-DSB-CS signal with various φ phase difference between the side-bands

Label is generated by AM modulating an RF carrier. Than the baseband information content is added. For the first approach, an ideal laser transmitter represented by an AM modulator was supposed. The signal from the laser is transmitted than through a dispersive fiber, which was modelled by an all-pass filter, with special group delay characteristic. Through the filter parameters group delay could be adjusted according to different fiber dispersion characteristics.

As we are interested only in the label detection, the baseband information together with the optical carrier is filtered out by an optical filter. Finally the labels are detected by a photodetector.

The main goal of this work is to investigate the effect of fiber dispersion. For this the results correlates quite good with what we expect according to the previous calculations. However much more can be shown with this simulations. In Fig. 4. simulation result is shown where the dispersion effect could have been neglected, but the filter was not ideal. In the upper figure the transmitted signal is shown, in the lower figure can be seen the detected.

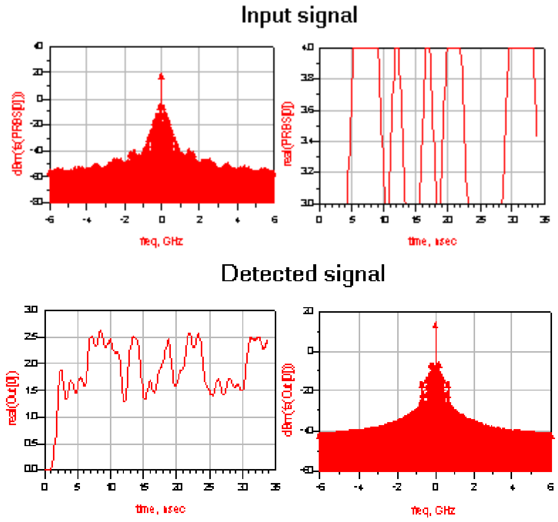

Fig 4. Time domain signals and spectra of input and detected signals

Other results can also be presented from this simulations, like the effect of highly dispersive or long length fibers, where the dispersion effect must be taken into account for the so called baseband content of the subcarriers.

6. Conclusions

In this paper fiber dispersion effect on SCM-SC signals was investigated. It was shown by calculations, that phase delay caused by dispersion corrupts the detected signal only in the context of detecting the components around each subcarrier. Simulations gave the same results, and showed several more interesting things, like the effect of the imperfect carrier suppression and undesired signal mixing due to non-linear elements. However, by improving the applied models do measurements can point out these possible problems more detailed and can be the topic of further work.

7. References

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