

Contents

1	Introduction	1
2	Historical Perspective	5
3	The Optical Data Transmission System	7
3.1	The Optical Fiber as Communication Channel	8
3.1.1	Optical Amplifiers	9
3.2	Transmitter	9
3.2.1	Laser	10
3.2.2	Modulator	10
3.2.3	Modulator Driver	12
3.3	Receiver	12
3.3.1	Photodetector	12
3.3.2	Preamplifier	13
3.3.3	Main Amplifier and Limiting Amplifier	13
3.3.4	Clock and Data Recovery Circuit	14
3.4	Modulation Formats	14
3.4.1	Non-Return-to-Zero Modulation	14
3.4.2	Return-to-Zero Modulation	15
3.4.3	Duobinary Modulation	15
4	Requirements for Analog Wideband Circuits	16
4.1	Eye Diagram	16
4.2	Bandwidth Requirements	16
4.2.1	Rise and Fall Times	17
4.3	Group-Delay Dispersion	19
4.4	Noise Figure	19
4.5	Output Voltage Swing	19

5	Preamplifier	20
5.1	High-Impedance Amplifier	21
5.2	Transimpedance Amplifier	22
5.2.1	Standard Concept	26
5.2.2	Transimpedance Amplifier with a Transistor in Common-Gate Configuration at the Input	33
5.3	Distributed Amplifier	43
5.3.1	Fundamentals of Distributed Amplifiers	44
5.3.2	Distributed Amplifier Concepts	53
5.3.3	Amplifier Design	57
5.3.4	Measurement Results	68
5.4	Demonstrator	74
5.4.1	Substrate Material	74
5.4.2	Connectors	76
5.4.3	Assembly of the Amplifier	76
5.4.4	Measurement Results	79
6	Modulator Driver	83
6.1	Eight Unit-Cells Distributed Amplifier	85
6.1.1	Circuit Design	85
6.1.2	Measurement Results	88
6.2	Six Unit-Cells Distributed Amplifier with Capacitive Division	92
6.2.1	Circuit Design	92
6.2.2	Measurement Results	96
6.3	Six Unit-Cells Distributed Amplifier with Positive Gain Slope	99
6.3.1	Circuit Design	99
6.3.2	Measurement Results	100
6.3.3	Cascade with the Preamplifier	105
7	Discussion	110
8	Conclusion	113

<i>CONTENTS</i>	ix
A UMS Processes	ii
A.1 UMS PH15	iii
A.2 UMS PPH15	iii
A.3 Layout of the Complete Reticle for the PPH15 Wafer-Run	iv
B Detailed Calculations of the Output Impedance of a Cascode	v
C Duobinary Modulation	vi
D Measurement Setups	x

Chapter 1

Introduction

The need for communication is a human necessity. With the invention of telephony by A. G. Bell in 1876 [1], communication over long distances became possible for many people in the western world. Besides telephony the use of other services increased during the last couple of years. With the birth of the Internet and the possibility for sending text messages by electronic mail (email), people were able to communicate between continents and different time zones in a cheap and fast way. Also, sharing pictures, electronic documents, and files became easy and extremely fast compared to conventional mail. With the introduction of analog dial-in modems, Internet access became affordable for private households and the Internet experienced an apparently irresistible triumphal procession.

Our modern service society asks for always more complex communication systems. The transported amount of data grows exponentially. Globalization of markets requires quick and easy share of information. Handling and transportation of this digitally coded information becomes increasingly important. While in earlier days data was transported via a copper wire, since some decades optical glass fiber is used, at least for information transportation over long distances. The advantages of communication via glass fiber compared to copper wire can be easily seen in Table 1.1.

	Diameter [mm]	Weight [g/m]	Loss [dB/km]
Fiber	0.2	0.073	0.2-0.8 ^a
Coaxial cable	5	30-100	100-1500 ^b

^adepending on the wavelength

^bdepending on the frequency

Table 1.1: Comparison of fiber with coaxial cable. Other advantages of optical fiber are flexibility and inertness against electromagnetic interference.