FREQUENCY MODULATION RESPONSE OF SEMICONDUCTOR LASERS AND OPTICAL FSK COMMUNICATION SYSTEMS

by

SANDEEP DILWALI

Department of Electrical Engineering

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Dedicated to

my wife, *Sunita*

and

our children,

Sahil,

Sagar,

Sonam

CERTIFICATE

This is to certify that the thesis entitled "**FREQUENCY MODULATION RESPONSE OF SEMICONDUCTOR LASERS AND OPTICAL FSK COMMUNICATION SYSTEMS**", *which is being submitted by* **SANDEEP DILWALI** *to the Department of Electrical Engineering, Indian Institute of Technology, Delhi, in fulfillment for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work carried out by him under my supervision and guidance. He has fulfilled all the requirements for the submission of the thesis, which has reached the requisite standard.*

The results contained in this thesis have not been submitted in any form to any other University or Institute for award of any Degree or Diploma.

G Soundra Pandian

Dr. G. SOUNDRA PANDIAN

Asst. Professor

Department of Electrical Engineering

Indian Institute of Technology, Delhi

India

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Sandeep Dilwali

Department of Electrical Engineering

IIT, New Delhi

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ABSTRACT

A theoretical expression for the transfer function of the thermal FM response of laser diodes is given, that is in excellent agreement with the experimentally measured FM response and agrees in general with an empirical expression reported earlier in the literature. The characteristic dip in the FM response and the time-domain step-response of the laser frequency are analyzed theoretically as a function of a thermal cutoff frequency and the ratio of thermal FM at dc to the carrier FM at dc. From the step response analysis, the lower bound on the bitrate for penalty-free AMI-FSK transmission is derived which tallies well with the experimental observations.

A theory given in the literature for the equalization of FM response using passive RC ladder networks is questioned. It is shown that if an additional low-pass filter is used along with the suggested RC ladder network, an acceptable equalization is possible at low bit rates less than the frequency at which the FM phase angle becomes 90°.

A novel method of equalizing the FM response of a laser diode is proposed for optical FSK transmission. It is shown that a complete equalization is possible when the ratio of thermal FM to carrier FM at dc, β, is less than 1. When $\beta \geq 1$, it is theoretically not possible to achieve a 100% equalization, since an ideal equalizing filter required in this case represents an unstable system. However, an approximate equalization is proposed for $\beta \geq 1$. A closed

loop system with an RC transmission line is proposed as an equalizing filter for $\beta < 1$ and a low-pass filter cum adder circuit for $\beta \geq 1$. The low-pass filter cum adder circuit is useful at higher bit rates greater than the frequency at which the laser FM phase response is 90°. For lower bit rates, the low-pass filter cum ladder network is desirable.

A bit-error-rate (BER) analysis for two types of optical FSK transmission systems using a Mach-Zehnder interferometer as a discriminator is done. In one case the discriminator is assumed to be kept on the transmitter side and in the second case, on the receiver side. The analysis takes into account the linewidth of the source and other noises in the system. The discriminator disperses the input pulse, and an optimum filter required to produce a raised cosine output pulse spectrum is proposed. Such an optimum filter gives the minimum noise bandwidth without causing any ISI at the decision instant. The values of the equivalent noise-bandwidth factors I_2 and I_3 of the filter vary between 0.563 to 0.822 and 0.086 to 0.193, respectively, when the interferometer delay time τ is varied from zero to bit time. BER curves are given for various conditions of the FSK systems. To avoid an error floor the linewidth of the source should be less than $0.01/\tau$.

When stabilising a fiber optic Mach-Zehnder interferometer using a PZT, the maximum possible closed loop bandwidth is limited by the resonance frequency of the PZT. A PZT control circuit using a current source drive is proposed

that gives an improved control bandwidth when compared to a voltage source drive. Equations are given to select the parameters of the system to get an optimum second order response, along with experimental results.

Results of a theoretical simulation on the dynamic response of a dispersion equalizing scheme employing a ring resonator are given, when transmitting chirped Gaussian optical pulses over a long distance fiber. It is shown that two pulses which merge into each other due to dispersion are recovered by the resonator. The selection of the optimum resonator parameters in relation to the overall response is described.

CONTENTS

Chapter 6

OPTICAL PHASE STABILIZATION OF A MACH-ZEHNDER INTERFEROMETER USING A PZT WITH A PROVISION TO LOCK TO THE CENTER FRINGE

Chapter 7

OPTICAL EQUALIZATION OF FIBER DISPERSION

BASED ON AN OPTICAL RESONATOR

Chapter 8

CONCLUSION