

RADIO OVER MULTIMODE FIBER USING VCSELS

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Summary

The aim of this research project is to address the transmission of radio signals like UWB or Wireless LAN signals over cheaper multimode fiber (MMF) links which are evolving along with the Gigabit / 10G Ethernet standards. These MMF links are based on 850nm VCSEL laser diodes and laser optimized graded index fibers and is meant for short distances up to 300 - 550 meters for 10Gbps data rate.

Large signal circuit models were created and implemented in ADS simulator to characterize the MMF link. The VCSEL model is a semiconductor rate equation model adopted for circuit simulation. The MMF model is a transfer function model based on modal delays and a simplified modal power distribution. The PIN diode model is a simple small signal equivalent circuit. The entire link was characterized and validated using the S-parameters and group delay simulations for small signal performance.

A pulsed UWB transmission over fiber is simulated and validated against the experimental results where the temporal signal qualities were analyzed. Also WLAN IEEE 802.11a/11g system's EVM performances for ROF transmission predicted by the simulation were consistent with experiments. This was further used to predict the EVM performance of the 802.11a system in the presence of UWB signal over ROF.

From the results it was concluded that the low cost MMF link could serve as a potential range extension structure for wireless networks.

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List of Symbols

Multimode Fiber

$\alpha(\lambda)$ - Attenuation Coefficient in dB/Km

n_1 - refractive index at $r = 0$

N_{eff} - Effective Group Index of Refraction

Δ - Normalized Refractive Index Difference

λ_0 - Zero dispersion wavelength in nm

S_0 - Zero dispersion slope in ps/(nm².km)

$D(\lambda)$ - chromatic dispersion coefficient in ps/(nm.km)

a - Core radius in μm

α - Profile Exponent

β_m - propagation constant of each mode group m

m - Mode group

$H_{\text{ch}}(\omega)$ - Chromatic dispersion transfer function

$H_{\text{mod}}(\omega)$ - Modal transfer function

$H_{\text{mmf}}(\omega)$ - Multimode fiber transfer function

σ_λ - Source spectral line width in nm

W_m - Modal power distribution in each mode group m

z - Length of the fiber

τ_m - Modal delays per unit length of each mode group m

VCSEL

$N(t)$ - Active region carrier density in cm^{-3}

$S(t)$ - Photon density in cm^{-3}

$P_o(t)$ - VCSEL output power in mW

$I(t)$ - Injection current in A

η_i - Current injection efficiency

V_a - Active volume of VCSEL Cavity in cm^3

τ_n - Carrier lifetime in s

τ_s - Photon lifetime in s

v_g - Group velocity ms^{-1}

g_0 - Differential gain cm^{-2}

N_{tr} - Transparency carrier density cm^{-3}

ε - Gain compression coefficient cm^3

Γ - Optical confinement factor

β - Spontaneous emission coefficient

η_{opt} - Optical efficiency

λ - Operating Wavelength in nm

h - Planck's constant

C_0 - Speed of light in vacuum in ms^{-1}

z_n, k - arbitrary constants

δ - a small constant

VCSEL Parasitics

R_q - Driver output resistance in Ω

C_q - Driver output capacitance in pF

R_w - Bond-wire resistance in Ω

L_w - Bond-wire inductance in nH

R_p - Pad resistance in Ω

C_p - Pad capacitance in pF

R_s - Series Resistance in Ω

R_a - Active layer resistance in Ω

C_a - Active layer capacitance in pF

Photo diode

I_{photo} - Photo current in A

P_{pd} - Input optical power in W

q - Electronic charge

ν - Optical frequency in Hz

η_{pd} - Quantum efficiency

I_{sat} - Reverse saturation current (dark) in A

Photo diode parasitics

R_d - “Dark” or “Shunt” resistance

C_d - Junction capacitance

R_{ser} - Series diode resistance

L_{ser} - Parasitic Inductance

List of Abbreviations

ROF - Radio Over Fiber
VCSEL - Vertical Cavity Surface Emitting Laser
LW - Long Wavelength
FP - Fabry Perot
DFB - Distributed Feed Back
DBR - Distributed Bragg-Reflector
SMF - Single Mode Fiber
MMF - Multi Mode Fiber
WAN - Wide Area Network
LAN - Local Area Network
PAN - Personal Area Network
SAN - Storage Area Network
WLAN - Wireless Local Area Network
WPAN - Wireless Personal Area Network
UWB - Ultra Wide Band
SGS - Single mode-Graded-Single mode
PDA - Personal Digital Assistant
GSM - Global System for Mobile Communications
DCS - Digital Cellular System
PCS - Personal Communications Service
GPRS - General Packet Radio Service
EDGE - Enhanced Data Rates for GSM Evolution
CDMA - Code Division Multiple Access
WCDMA - Wideband Code Division Multiple Access
UMTS - Universal Mobile Telecommunications System
HTSG - High throughput study group
MBWA - Mobile Broadband Wireless Access
MBS - Mobile Broadband Services
SCM - Sun Carrier Multiplexing

IMDD - Intensity-Modulated Direct-Detection
FDDI - Fiber Distributed Data Interface
OFL - Over Filled Launch
MPD - Modal Power Distribution
RML - Restricted Mode Launch
EF - Encircled Flux
DMD - Differential Modal Delay
SFDR - Spurious free Dynamic Range
TIA - Trans Impedance Amplifier
SDD - Symbolic Defined Devices
WKB - Wentzel Kramers Brillouin
EMB - Effective Modal Bandwidth
EIRP - Effective Radiated Power
FHSS - Frequency Hopping Spread Spectrum
DSSS - Direct Sequence Spread Spectrum
CCK - Complementary Code Keying
PBCC - Packet Binary Convolutional Coding
OFDM - Orthogonal Frequency Division Multiplexing
BPSK - Binary Phase Shift Keying
QPSK - Quadrature Phase Shift Keying
DBPSK - Differential Binary Phase Shift Keying
DQPSK - Differential Quadrature Phase Shift Keying
QAM - Quadrature Amplitude Modulation
BER - Bit Error Rate
PER - Packet Error Rate
EVM - Error Vector Magnitude