

**POWER BUDGET ANALYSIS FOR BROADCAST
PASSIVE OPTICAL NETWORK**

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the Degree Master of Engineering (Electrical)**

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DEDICATION

This research work is dedicated to my beloved father, Mr. LIEW SIN WAH for all his loving and caring throughout my life, my loving mother, Mdm Lim Gwi Peng and brother, Liew Foo Keong for their encouragement and love, my loving wife, Anika Zafiah binti Mohd Rus for her support and love.



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ABSTRACT

Optical fibre technology is vital for broadband communication and multimedia applications because single-mode optical fibres have a very low attenuation and a vast bandwidth at 1.3 μm and 1.55 μm wavelengths regions. The ever increasing demand for high speed data transmission and multimedia applications will inevitably results in optical fibre communication being used to replace copper cables all the way to the subscriber's home. A long term saving in maintenance cost can also be expected. This thesis presents an idealised mathematical model of the power requirement of a simple broadcast Fibre To The Home (FTTH) network based on the bus, star and bus-star topologies. Power requirement at central office (CO) is one of the main parameters that must be taken into consideration by system designers in their planning for the implementation of FTTH. A mathematical model was developed for each of the topology, which relates the power needed at the CO to the parameters of the network such as fibre loss, coupling loss, splitters loss, detection method and signal quality. This software package requires input specifications from the designer, and the output is a complete power budget analysis in a graphical form which can be used to understand the behaviour of each topology related to its power requirement. The numerical results show close agreement with manual power budget calculation using the same set of input parameters. The results can serve as useful guidance for system designers to evaluate the capability at the central office. However, apart from the limited topologies, the software concentrates mainly on one way transmission and limited modulation techniques. Future improvement can be implemented based on the software developed in this thesis.

ABSTRAK

Teknologi gentian optik merupakan satu teknologi yang penting dalam sistem perhubungan jalur luas dan penggunaan multimedia kerana gentian optik mod tunggal mempunyai kehilangan yang rendah dengan lebar jalur yang luas pada jarak gelombang $1.3\mu\text{m}$ dan $1.55\mu\text{m}$. Permintaan yang tinggi untuk penghantaran data lebih cepat dan penggunaan multimedia akan mendorong gentian optik digunakan untuk menggantikan semua sambungan kabel kuprum hingga ke rumah pengguna. Dalam jangka masa panjang ia akan menjimatkan kos penyelenggaraannya. Tesis ini membentangkan satu model matematik keperluan kuasa penghantaran sehala sambungan gentian optik ke rumah mengenai rangkaian bus, rangkaian bintang dan rangkaian bintang-bus. Keperluan kuasa pada rangkaian pusat merupakan satu parameter utama yang perlu diambil kira oleh perekabentuk sistem dalam rancangan untuk mewujudkan sambungan gentian optik ke rumah. Satu model matematik telah dibangunkan untuk setiap rangkaian yang mengaitkan keperluan kuasa pada rangkaian pusat dengan parameter-parameter rangkaian seperti kehilangan gentian, kehilangan pembahagian, teknik-teknik pemodulatan dan kualiti isyarat. Perisian yang dibangunkan memerlukan spesifikasi data kemasukan daripada perekabentuk dan paparan keluarannya dapat digunakan untuk memahami ciri-ciri setiap topologi yang berhubungkait dengan keperluan kuasa. Keputusan pengiraan menggunakan perisian yang dibangunkan menunjukkan nilai yang hampir sama dengan pengiraan yang dibuat secara manual dengan menggunakan input parameter yang sama. Keputusan ini juga boleh membantu perekabentuk sistem dalam menilai keupayaan ibusawat pusat. Walaubagaimanapun, di samping daripada jenis rangkaian yang terhad, perisian yang dibangunkan hanya boleh membuat perkiraan keperluan kuasa untuk penghantaran sehala untuk beberapa jenis teknik pemodulatan. Namun demikian, perisian ini boleh dipertingkatkan lagi di masa akan datang berdasarkan perisian yang dibangunkan dalam kajian ini.

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LIST OF SYMBOL

A_c	-	Peak Amplitude of subcarrier
B	-	Bandwidth
B_a	-	Bandwidth of intensity modulated optical signal
B_M	-	Bandwidth of intensity modulated optical signal
B_T	-	Bitrate
c	-	Speed of light (3×10^8)
C_L	-	Total channel loss
D_f	-	Frequency Deviation Ratio
e	-	Charge of an electron
erfc	-	Complementary error function
F_n	-	Noise Figure
$F(M)$	-	Excess Avalanche Noise Factor
h	-	Planck's Constant (6.634×10^{-34})
I_d	-	Dark current
I_p	-	Photocurrent
K	-	Coupling Factor or Boltzmann's constant
L	-	Distance in km
L_{cr}	-	Connector loss
L_e	-	Loss due to splitter in dB
L_j	-	Splicing loss
m	-	Number of connector
M	-	Avalanche Multiplication Factor
m_a	-	Modulation index
M_a	-	Safety Margin

n	-	Number of splicing
N	-	Number of subscribers
N_c	-	Number of couplers needed
P_a	-	Total power in baseband message signal
P_i	-	Power Required to transmit from central office
P_m	-	Total power in an intensity modulated optical signal
P_R	-	Power Received at tap node
P_S	-	Power Received at end user
R_L	-	Load Resistance
T	-	Absolute Temperature
Z_m	-	Average number of photons
α	-	Combination of fibre attenuation, Connector loss, Splicing loss
α_{fc}	-	Fibre attenuation
λ	-	Wavelength
η	-	Quantum Efficiency
β	-	Splitter loss



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LIST OF ABBREVIATIONS

ANSI	-	American National Standards Institute
BAP	-	Broadband Access Point
BER	-	Bit Error Rate
BIDS	-	Broadband Integrated Distributed Star
BISDN	-	Broadband Integrated Service Digital Network
BNR	-	Bell - Northern Research
BPON	-	Broadband Passive Optical Network
BT	-	British Telecom
CAC	-	Customer Accesses Connections
CAD	-	Computer Aided Design
CATV	-	Community Antenna Television
CCITT	-	Consultative Committee in International Telegraphy and Telephony
CO	-	Central Office (Exchange)
DTV	-	Digital TV
EDFA	-	Erbium Doped Fibre Amplifiers
EIA	-	Electronic Industries Association
EURESCOM	-	European Institute of Research and Strategic Studies in Telecommunication
FITL	-	Fibre in the Loop
FTP	-	File Transfer Protocol
FTTB	-	Fibre to the Basement
FTTC	-	Fibre to the Curb
FTTD	-	Fibre to the Desk

FTTF	-	Fibre to the Floor
FTTH	-	Fibre to the Home
FTTO	-	Fibre to the Office
FTTS	-	Fibre to the Street
FTTZ	-	Fibre to the Zone
HDTV	-	High- Definition Television
IEEE	-	Institute of Electrical and Electronics Engineers
IMTV	-	Interactive Multimedia TV
ISDN	-	Integrated Service Digital Network
ITU	-	International Telecommunication Union
LAN	-	Local Area Network
LED	-	Light Emitted Detector
NBS	-	National Bureau of Standards
OAN	-	Optical Access Network
ODN	-	Optical Distribution Network
OLT	-	Optical Line Terminal
ONU	-	Optical Network Unit
PABX	-	Private Automatic Branch Exchange
PCM	-	Pulse Code Modulation
PON	-	Passive Optical Network
POTS	-	Plain Old Telephone Service
SCM	-	Subcarrier Multiplexing
SNR	-	Signal to Noise Ratio
SWAN	-	Socio - cultural Welfare Advanced Network
TDM	-	Time Division Multiplexing
TPON	-	Telephony Passive Optical Network
WDM	-	Wavelength Division Multiplexing

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CHAPTER I

INTRODUCTION

1.1 General

The research of optical fibre as a transmission line started in the 1960s, where at the same time T.H. Maiman developed a ruby laser [1]. Initially, glass fibres having an attenuation of greater than 1000 dB/km were considered, but the systems were impractical. In 1966, K.C. Kao and B.A. Hockham at Standard Telecommunications Laboratories in England studied the loss mechanisms in fibres and anticipated a low-loss optical fibre along with the investigation of laser diode [2]. In 1970, when Kapron and his colleagues at Corning glass produced a fibre with a loss of 20 dB/km [3], optical transmission systems have become a reality, not a dream. The work towards reducing the fibre loss continued at several laboratories, and losses under 1 dB/km were obtained in pure silica fibres. Following the successful demonstration of a low-loss optical fibre, the first lightwave communication systems were developed using multimode fibres in combination with Light Emitting Diode (LED) or laser source. The big leap in performance of systems came with the development of a singlemode fibre, which has both lower dispersion and lower loss [4]. During the mid 1980s, coherent detection techniques were explored in optical fibre receiving systems [5]. Since then, fibre optic cable has been accepted as a viable communication medium. Today, communication transmission systems for trunk lines using optical fibres have been used worldwide.

In the past few decades, digital and optical communication technologies were evolving in such a rapid phase that a new integrated service in communication is needed. Based on Integrated Services Digital Network (ISDN), multimedia application and the introduction of fibre optic, Broadband Integrated Service Digital Network (BISDN) was

proposed [6]. Initially, the system must be able to provide existing services for subscribers that is distributive TV (CATV), distribute Audio/ hi-fi, Telephony (POTS and ISDN) [7]. Broadcasting service will be one of the major services to be provided by BISDN where the digital video technology such as digital TV (DTV) and high definition TV (HDTV) have been widely accepted by major telecommunication companies for future deployment to subscribers [15]. Therefore, it is inevitable that fibre optic should be expanded to cover various user premises. This concept is known as Fibre in The Loop (FITL).

1.2 Background and Rational

In planning the FITL network, areas are to be divided into urban (corporate, high rise, shop houses, government office), suburban (industrial estate, shop houses, housing estate), rural (industrial estate, FELDA scheme, traditional village) and holiday resort. The various technologies and services to deploy a subscriber network that have been used are FTTO (Fibre To The Office), FTTC (Fibre To the Curb), FTTS (Fibre To The Street), FTTZ (Fibre To The Zone) and FTTH (Fibre To The Home). The future deployment however is dependent on geographical conditions, trends in policies and technological developments and existing networks. The layout for FTTO, FTTC, FTTS and FTTZ is to install optical cables to building entrances or unit areas of hundreds of subscribers where Plain Old Telephone Service (POTS) and CATV services are provided using copper lines and coax from the exchange (COT) to subscriber premises. The evolution of fibre in the local loop goes through the following stages, broadly categorised as :

i) Fibre to the office (FTTO)

This is equivalent to the direct feed cable in the present copper network. In this application fibre is terminated direct in the customer's premises, catering primarily to the demand of the corporate sector. FTTO comprises of :-

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