



**TECHNIQUES FOR SIGNAL TO NOISE RATIO ADAPTATION IN
INFARED OPTICAL WIRELESS FOR OPTIMISATION OF
RECEIVER PERFORMANCE**

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**A thesis submitted in partial fulfilment of the requirements for the degree
of Doctor of Philosophy**

**The University Of Warwick
Division of Electrical & Electronic Engineering,
School Of Engineering,
December 2006**

CONTENTS		Pages
TITLE PAGE		i
TABLE OF CONTENTS		ii
LIST OF TABLES		vi
LIST OF FIGURES		vii
GLOSSARY		xiv
ACKNOWLEDGEMENTS		xv
DECLARATION		xvi
ABSTRACT		xvii
1	Introduction	1
1.1	Overview	1
1.2	The wireless infrared medium – advantages and drawbacks.....	6
1.3	Recent wireless infrared communication systems	9
1.3.1	Indoor application	9
1.3.2	Outdoor application	10
1.4	Optical wireless link design	12
1.5	Motivation	13
1.6	Organisation of the thesis	16
	References	20
2	Background and Related Work	24
2.1	Photodetectors	25

2.2	Optical preamplifier structures	31
2.2.1	High impedance amplifier	32
2.2.2	Transimpedance amplifier	35
2.3	Transimpedance amplifier design requirements	38
2.3.1	Wide dynamic range	38
2.3.2	Bandwidth enhancement	43
2.3.3	Noise reduction	55
2.4	Voltage feedback amplifier versus Current feedback amplifier ...	58
2.5	Definition of dynamic service quality	60
2.6	Summary	61
	References	63
3	New transimpedance amplifier structures	69
3.1	Transimpedance Amplifier with FET voltage control filter	72
3.2	Transimpedance Amplifier with external voltage control	80
3.3	Bootstrap Transimpedance Amplifier with adjustable capacitor ...	85
3.4	Summary	92
	References	94
4	Composite transimpedance amplifier bandwidth adjustment structures	95
4.1	Combination of voltage feedback and current feedback amplifier	96
4.2	Combination of bootstrap transimpedance amplifier and voltage feedback amplifier	104

4.3	Combination of dual feedback loop and voltage feedback amplifier	109
4.4	Summary	115
	References	117
5	Integration of bandwidth control and automatic gain control	119
5.1	Automatic gain control (AGC) theory	120
5.2	Automatic gain control circuit configuration	123
5.3	Integration of AGC with bandwidth control circuits frequency response analysis	130
5.4	Bandwidth control and AGC or AGC and bandwidth control?	138
5.5	Summary	141
	References	143
6	Signal to noise ratio (SNR) – optical wireless systems	144
6.1	Definition of noise in infrared communication	145
6.2	Noise model of a receiver	149
6.2.1	Noise current of shot noise and thermal noise	156
6.2.2	Relationship between SNR and bandwidth	158
6.3	Output noise density of the designed circuits	161
6.4	Signal to Noise Ratio module design configuration	181
6.5	Summary	187
	References	190

7	Receiver fabrication and practical implementation setup	192
7.1	Hardware design documentation and setup	193
7.2	Experimental results	199
7.3	Summary	207
	References	209
8	Conclusions and Further Work	210
8.1	Summary of the work	210
8.2	Application of this research	212
8.3	Future improvements and suggestion for further work	214
	References	218
	Appendix	219



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List of Tables	Pages
1.1 Properties of Infrared and Radio Channels.....	8
1.2 Receivers designed.....	17
2.1 Noise in Front Ends	31
3.1 C_p versus voltage control and bandwidth	75
3.2 R_f versus voltage control and bandwidth	84
3.3 R_f versus capacitor, C_p bandwidth and gain	88
3.4 Comparison of technique	92
4.1 LMH6732 parameters related to supply current	98
4.2 R_f selection for various gain settings and I_{cc}	99
4.3 R_f versus Frequency response	105
4.4 Feedback resistor, R_f and R_{f1} versus gain	108
4.5 Comparison of composite amplifier technique	116
5.1 R_f versus gain and bandwidth	130
5.2 Composite amplifier circuit with AGC	141
5.3 Comparison between VBA-VGA or VGA-VBA	142
6.1 Summary of the output noise density for the six designed techniques	187
6.2 Summary of the output noise density for composite amplifier with AGC	187
6.3 Comparison of output noise density between VBA-VGA or VGA-VBA	188
7.1 Comparison between simulated and practical results	207

List of Figures	Pages
1.1	Wired backbone and wireless access network 2
1.2	The main features of IrDA 5
1.3	Infrared transmission speed, time and coverage area 5
1.4	An example of an IrDA link and the IrDA protocol stack 6
1.5	Ambient Light Noises and Silicon Photodiode Responsivity 8
1.6	Example of an IEEE 802.11 network with infrared transmission 10
1.7	System image of a traffic information offering system using Infrared traffic light 11
1.8	Block diagram of a typical optical wireless link 12
1.9	Modeling a link as a baseband filter and time-invariant system having an impulse response $h(t)$, with signal-independent, additive noise $N(t)$. The photodetector has responsivity R 15
2.1	Photodetector 26
2.2	Small-signal equivalent circuit model of photodiode 27
2.3	Relative spectral sensitivity of (SFH 206K) silicon photodiode 28
2.4	Photodiode capacitance versus Reverse bias voltage 30
2.5	Receiver preamplifier based on a termination resistor 33
2.6	High impedance amplifier with equalisation 33
2.7	Small-signal noise model of the optical preamplifier based on a termination resistor 35

2.8	Receiver preamplifier based on a transimpedance amplifier	37
2.9	Various methods of increasing dynamic range :	
	1) output signal limiting, 2) input current steering,	
	3) variable transimpedance gain 4) multiple feedback impedance	
	transimpedance amplifier control	39
2.10	Two existing variable gain transimpedance amplifier designs	42
2.11	Basic receiver front-end using positive feedback	44
2.12	Response as a function of frequency. The basic system, the feedback system and the trade-off cases are shown	45
2.13	Two bootstrap transimpedance method :	
	1) Shunt bootstrap 2) Buffer bootstrap	47
2.14	Bootstrap transimpedance amplifier	48
2.15	Schematic of TIA with parasitic capacitances and inductors	49
2.16	TIA with peaking buffer	50
2.17	a) Circuit of C-peaking transimpedance amplifier b) Equivalent open-loop circuit of transimpedance amplifier with and without a peaking capacitor	51
2.18	Common base transimpedance preamplifier with regulated cascade	53
2.19	Inverting amplifier with T network	54
2.20	Topology of transimpedance amplifier	55
2.21	High feedback resistance and the capacitance of the input circuit causing the amplifier noise gain A_{noise} rise at the higher frequency until level by the stray capacitance and finally rolled off by the amplifier open-loop response	56
2.22	Voltage feedback amplifier and current feedback amplifier	59

3.1	Circuit stimulation of a photodiode	70
3.2	Frequency response plot when the photodiode junction capacitance is 13pF	71
3.3	Frequency response plot when the photodiode junction capacitance is 1.5pF	71
3.4	Characteristics JFET	72
3.5	Photodiode with FET as a voltage controlled filter	74
3.6	Frequency response of changing FET V_{GS} from -0.1V to -3V	74
3.7	Transimpedance amplifier with voltage control filter	76
3.8	Transimpedance as a function of frequency	78
3.9	Gain control circuit	79
3.10	Transimpedance with gain control as a function of frequency	79
3.11	Transimpedance amplifier with external voltage control	81
3.12	V_{BQ3} versus $V_{control}$	82
3.13	Simulated transfer function of the transimpedance amplifier	85
3.14	BTA Circuit	86
3.15	Simplified model of Figure 3.14	86
3.16	Modified BTA circuit	89
3.17	BTA Bandwidth	89
3.18	Modified BTA Bandwidth	90
3.19	Simplified model of Figure 3.16	90
4.1	LMH6624 current noise density versus R_f	97
4.2	LMH6732 supply current control's simplified schematic	98
4.3	Graph $I_p(\mu A)$ versus $B_w(MHz)$	100
4.4	Composite Voltage and Current feedback amplifier	101

4.5	Frequency responses versus gain	101
4.6	Practical measurements for LMH6624 and LMH6732	102
4.7	Frequency versus V_{control}	103
4.8	Composite bootstrap transimpedance amplifier with VFA	105
4.9	Frequency response composite transimpedance amplifier	106
4.10	Simplified model of Figure 4.8	107
4.11	Composite dual feedback loop with VFA	110
4.12	Array of RC filter with comparator	111
4.13	Frequency response composite transimpedance amplifier	112
4.14	Simplified model of Figure 4.11	113
5.1(a)	AGC block diagram	121
5.1(b)	A typical AGC's transfer function	121
5.2	Proposed AGC circuit	124
5.3	Simplified model of Figure 5.2	125
5.4	Variation of input signal, V_{in} amplitude with time	128
5.5	AGC circuit frequency responses	129
5.6	Integration of AGC with voltage feedback and current feedback amplifier	132
5.7	Frequency response of Figure 5.6	133
5.8	Integration of AGC with bootstrap transimpedance amplifier and voltage feedback amplifier	134
5.9	Frequency response of Figure 5.8	135
5.10	Integration of AGC with dual feedback loop and voltage feedback amplifier ...	136
5.11	Frequency response of Figure 5.10	137

5.12	Simplified model of VBA before VGA configuration	138
5.13	AGC before bandwidth control configuration	139
5.14	Frequency response of Figure 5.13	140
6.1	Simple receiver model and noise sources in the receiver	146
6.2	Noise model of amplifier	150
6.3	An equivalent noise model of input stage of preamplifier, where I_p is the photocurrent, I_{nd} is the detector noise, I_{nb} is the background noise, C_d , R_d are capacitance and resistance of a detector, I_n , V_n are current noise and voltage noise of a preamplifier, R_i , C_i are input resistance and input capacitance of a preamplifier, G is the voltage gain of a preamplifier	152
6.4	Plot of Noise current for shot noise	157
6.5	Plot of Noise current for thermal noise	158
6.6	I_p and Quantum shot noise versus P_t	159
6.7	Relationship between SNR and bandwidth	160
6.8	FET small-signal model	162
6.9	BJT small-signal hybrid- π model	162
6.10	Circuit Noise Model for case (a)	163
6.11	Input and Output noise density for FET Voltage control filter and transimpedance amplifier	164
6.12	Input and Output noise density for transimpedance amplifier with external voltage control	167
6.13	Input and Output noise density for bootstrap transimpedance amplifier with adjusting capacitor	168

6.14	Circuit noise model for case (d)	170
6.15	Input and Output noise density for voltage feedback amplifier and current feedback amplifier	171
6.16	Input and Output noise density for bootstrap transimpedance amplifier with voltage feedback amplifier	173
6.17	BJT small-signal hybrid- π model with series inductor	175
6.18	Input and Output noise density for dual feedback loop amplifier with voltage feedback amplifier	176
6.19	Input and Output Noise density for AGC circuit	178
6.20	Output noise density for composite VFA and CFA amplifier with AGC	179
6.21	Output noise density for BTA and VFA amplifier with AGC	179
6.22	Output noise density for dual loop feedback and VFA amplifier with AGC	180
6.23	Output noise density for AGC before bandwidth control	180
6.24	Block diagram of a multiplier	181
6.25(a)	First part of SNR measurement circuit	182
6.25(b)	Second part of SNR measurement circuit	183
6.26	AC-DC converters with inverting amplifier.....	185
6.27	Simulated transient responses for the SNR circuit	186
6.28	Simulated transient responses for the input SNR versus output SNR	186
6.29	Noise Figure, F_A and F_B versus Gain	189
7.1	Simplified block diagram of the transmitter-receiver frond-end	193
7.2	Laser diode bias-T PCB	194
7.3	Laser diode capacitance versus forward voltage	195

7.4	Laser diode : Forward voltage versus Forward current	196
7.5	Remodel of Figure 7.2	196
7.6	Frequency response of the transmitter	197
7.7	Micrographs of the bandwidth adjustment amplifier	198
7.8	Frequency response when $V_{\text{control}}=0\text{V}$	200
7.9	Frequency response when $V_{\text{control}} = -2.55\text{V}$	200
7.10	Output waveform from oscilloscope when $F = 50\text{MHz}$	201
7.11	Output waveform from oscilloscope when $F = 60\text{MHz}$	202
7.12	Output spectrum when $V_{\text{control}} = -2.55\text{V}$	203
7.13	Output spectrum when $V_{\text{control}} = 0\text{V}$	204
7.14	Comparison between simulated and practical for $V_{\text{control}}=0\text{V}$	205
7.15	Comparison between simulated and practical for $V_{\text{control}}=-2.55\text{V}$	206
8.1	Suggested intelligent indoor all optical home networks	213
8.2	Principles of wireless optical in seat entertainment	214
8.3	A low voltage transimpedance amplifier	216
8.4	An alternative low voltage transimpedance amplifier	217

GLOSSARY

AGC	Automatic gain control
BJT	Bipolar junction transistor
BTA	Bootstrapped transimpedance amplifier
CFA	Current feedback amplifier
EMI	Electro-magnetic interference
FET	Field effect transistor
FTTH	Fibre-to-the-home
IrDA	Infrared data association
LAN	Local Area Network
NF	Noise figure
QoS	Quality-of-service
SNR	Signal-to-noise ratio
VCR	Variable resistor
VFA	Voltage feedback amplifier
VFIR	Very Fast IR
VGA	Variable gain amplifier
USB	Universal serial bus

Acknowledgements

First of all I would like to thank God and the many people that had helped me to make this study and thesis possible. I am indebted to my supervisor, Prof Roger Green, for being my mentor for the last four years, for his keen guidance, encouragement and valuable comments throughout my research. I wish to thank my second supervisor, Dr. Mark Leeson for his valuable comments and suggestions throughout the research and thesis. I endeavour to pass on to future students that which I have experienced from them. I wish to express my gratitude to the Ministry of Science and Technology Malaysia and College University Technology Tun Hussein Onn for their financial support of this study.

I would also like to express my thanks to all the technical staff of the University of Warwick, Jonathan and Ian for their technical support.

I wish to thank my friends in the Communications and Signal Processing Research Group, my friends back in Malaysia and my friends who are venturing the same journey in other universities in United Kingdom for providing valuable support over the years.

Special gratitude to my loving wife, Anika Zafiah: for being a wonderful wife and for your tireless support of our family, even though you are striving for your PhD research studies at the same time. To you I wish you the very best of luck in your viva and I owe everything to you with compound interest. I wish to thank my parents, Gwi Peng for her support. A special thanks goes to my brother-in law, Akmal for his invaluable support. To our three loving children, Zu Arasy (6), Sadrina (5) and Syakib (3), who was born 4 months after we began our PhD studies, for constantly bringing joy, excitement and always testing our parenting skill. Finally this thesis is also dedicated to our “baby” who is going to be born at the end of March 2007.

DECLARATION

The work described in this thesis is entirely original and my own, except where otherwise indicated.

Parts of this work were presented at conferences, namely

“Optical Wireless Front-Ends”, 2nd Malaysian Research Group Annual Conference, Manchester, Sept 2003.
(www.mrg-online.org/conference/02/mohdabdullah.htm)

“Optical Wireless Communication Front-Ends” High Frequency Postgraduate Student Colloquium, pp. 3-8, Manchester, 6-7 Sept 2004.



Signed

11/6/2007

Date

ABSTRACT

The challenge of creating a new environment of links for wireless infrared and optical local area networks (LANs) is driving new innovations in the design of optical transceivers. This thesis is concerned with a systematic approach to the design of receivers for indoor optical wireless communication. In particular, it is concerned with how to offer bandwidth adjustment capability in a receiver according to the dynamic service quality of the incoming signals. Another part of the discussion of the thesis is how one can properly choose the front-end preamplifier and biasing circuitry for the photodetector. Also, comparison is made between different types of amplifier, and the methods of bandwidth enhancement.

The designs of six different techniques of integrating transimpedance amplifiers, with photodetectors to adapt an adjustable bandwidth control receiver are discussed. The proposed topologies provide an adjustable range of bandwidths for different frequency ranges, typically between 52Hz to 115MHz. The composite technique designs were used to incorporate into a system with an automatic gain control to study its effect, on an optical wireless receiver which had bandwidth adjustment and automatic gain adjustment. Theoretical analysis of noise performance for all the designed circuits is also presented. The theory and design of obstacles of indoor optical wireless receiver delivery, in addition to techniques for mitigating these effects, are discussed. This shows that infrared is a viable alternative to radio for certain applications.

Introduction

- 1.1 Overview
 - 1.2 Wireless Infrared Medium – Advantages and Drawbacks
 - 1.3 Recent Wireless Infrared Communication Systems
 - 1.3.1 Indoor Application
 - 1.3.2 Outdoor Application
 - 1.4 Optical wireless link design
 - 1.5 Motivation
 - 1.6 Organisation of the Thesis
- References
-

1.1 Overview

Trends in the telecommunications and computer industries suggest that the network of the future will consist of a high capacity backbone network with short range communication links providing network access to portable communicators and portable computers. In this vision of the future, mobile users will have access to similar grade high-speed network services available to wired terminals. For this purpose, some parts of communication links

need to be constructed wirelessly. This situation is illustrated in Fig. 1.1. During the last decade, therefore, wireless communication technology, such as optical local area networks (LANs) and wireless infrared (IR) communication systems has grown rapidly [1.1 – 1.5]. Optical LANs use fibre as the physical transmission medium for networks serving resources within a small geographic area, while wireless IR uses free space as a communication channel for short-range, localised networks. Optical wireless communications is becoming one of the cornerstones of today's revolution in information technology because of its benefits of high speed transmission and isolation from electromagnetic interference. With the drive towards portable and multimedia communications, we are faced with the challenge of bringing the capacity of our communications infrastructure directly to the user, providing seamless access to large quantities of information anywhere and at any time. To accomplish this however, will require mid-range or short-range wireless communication links with extremely high capacity. In an extreme case, for example, uncompressed high-definition video can require a data rate of in excess of 100 Mbit/s.

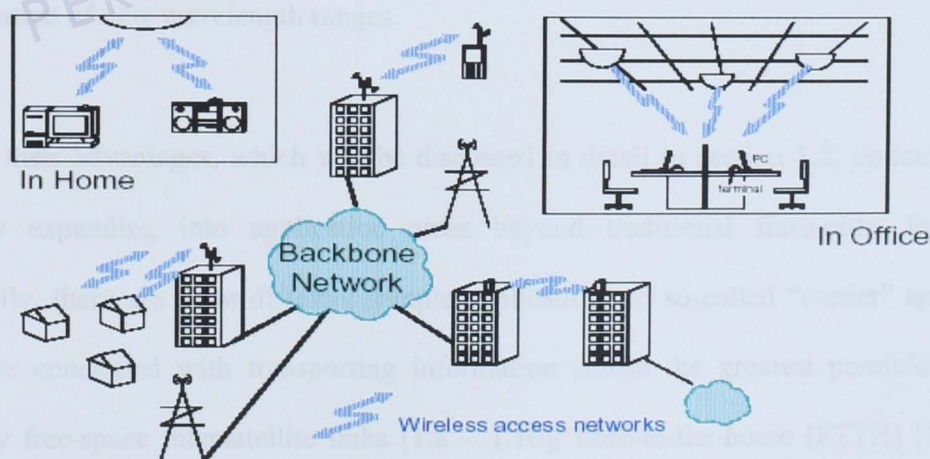


Figure 1.1 Wired backbone and wireless access network [1.1]

Light offers great advantages as a medium of communication. It enjoys unequalled channel bandwidth and is capable of data rates in the terabits per second range, whether traveling through free space or through optical fibre. This tremendous capacity is due to the nature of the photons that constitute an optical signal. Unlike electrons, photons react weakly to their environment and to one another as such optical signals neither generate nor are sensitive to electromagnetic interference (EMI), parasitic coupling and other problems faced by electrical signals [1.6]. In comparison, from IR to radio frequencies, the technology suffers from electro-magnetic interference (EMI) problems as the radio spectrum gets increasingly crowded. Now that personal communications and wireless computer networks are evolving rapidly, the available spectrum is considered to be a scarce resource. Simultaneously, there is an increase in the interference level caused by switched node power supplies and other high-frequency equipment. Particularly in hospitals and industrial environments, the applicability of radio systems is already seriously limited by these problems. Extensive frequency allocation regulations can only partly solve them. Eventually although EMI aspects will become an integral part of every system design, future applications require the exploration of new wavelength ranges.

Given their advantages, which will be discussed in detail in section 1.2, optical links are rapidly expanding into application areas beyond traditional fibre-optic links [1.7]. Basically, there are three different sample applications of so-called “carrier” applications that are concerned with transporting information across the greatest possible distance, namely free-space intersatellite links [1.8 – 1.10], fibre-to-the-home (FTTH) [1.11-1.12]

and terrestrial free-space links for inter-building communications [1.13]. Current optical LANs, represented by the Gigabit Ethernet and ATM-PON network specifications, can be used to realise high data rate systems that find their application in parallel processing environments, newspaper and magazine production, and medical imaging networks [1.14]. The immunity of fibre optic LANs to electromagnetic radiation makes this technology an attractive choice for implementation in sensitive environments, such as in aircraft and vehicles [1.15-1.16]. Furthermore, broadband requirements to connect central office locations to customer premises benefit from the high bandwidths made feasible through the use of FTTH technology. Today, the limiting factor in the deployment of advanced optical LANs is the prohibitive cost of the transmitter and receiver [1.17]. However, novel integrated circuit design techniques are helping drive down the cost of implementation, in order for these LAN solutions to become more common. Finally, so called “optical wireless links” provide a communications solution for portable applications [1.18]. In particular, short range “point-and-shoot” systems in accordance with the infrared Data Association (IrDA) standard provide a simple solution for transferring information to and from portable devices, offering high data rates at low cost and with a small form factor that is not prone to mechanical wear [1.19].

The success of such short range systems is particularly showing how optical communication systems are likely to proliferate in the future, where IrDA wireless links have overshadowed both the Universal Serial Bus (USB) and IEEE 1394 FireWire to become the leading serial port alternative for connectivity [1.20]. A new technology has been proposed for indoor, short range wireless communication, called IrGate. IrGate core

technology is based on a method of diffused-infrared (DIR) communication links, performing at high bit rates reaching up to 10Mbps [1.21]. IrDA is also extending its IR-PHY standard to 16Mbps, a new high speed extension called Very Fast IR (VFIR). VFIR is designed as an extension to the current 4Mbps FIR, where the much higher throughput enables wider applications beyond the current perception of a “wire replacement” [1.22]. Figure 1.2 and Figure 1.3 show the main features of the IrDA standards and the IR transmission speed, time and coverage area of the current implementations.

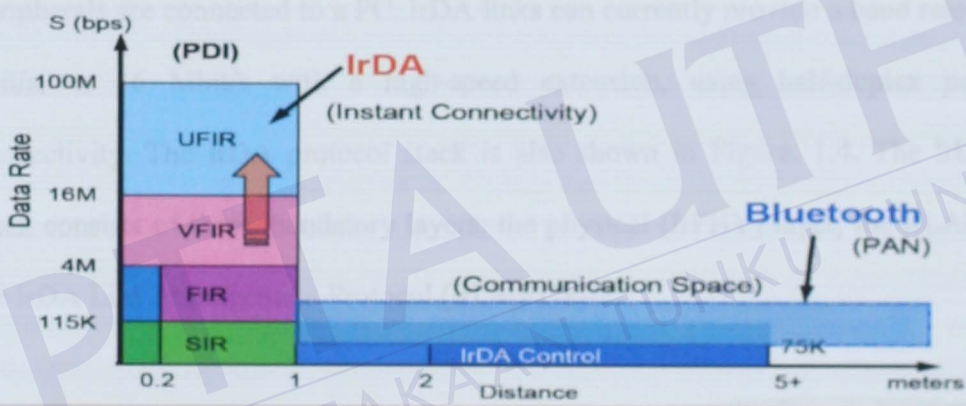


Figure 1.2 The main features of IrDA [1.23]

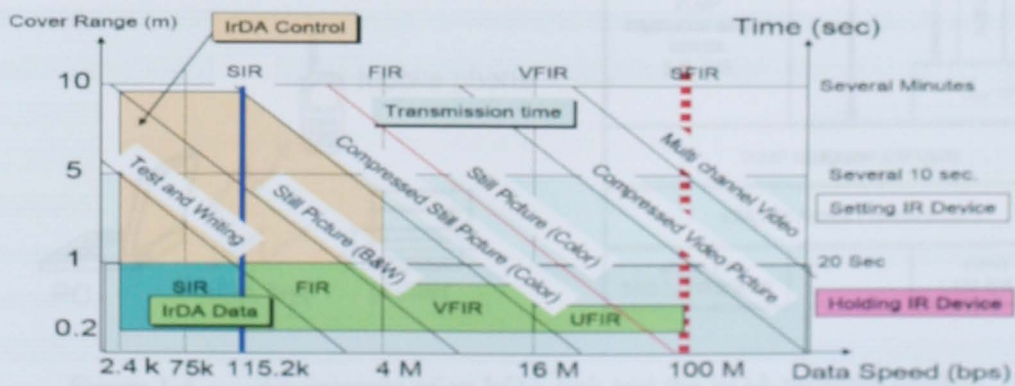


Figure 1.3 Infrared transmission speed, time and coverage area [1.23]

1.2 Wireless Infrared Medium – Advantages and Drawbacks

The infrared data association (IrDA) was established in 1993 as a collaboration between major industrial organisations in order to establish an open standard for infrared (IR) data communication [1.20] [1.24-1.28]. The resulting IrDA protocol aimed to provide a simple, low-cost, reliable means of IR communication between devices such as portable computers, desktop computers, printers, other peripherals and LANs using directed point-to-point connectivity. Figure 1.4 illustrates an example image of an IrDA link with which PC peripherals are connected to a PC. IrDA links can currently provide a baud rate up to 115.2 kbit/s, or 16 Mbit/s with a high-speed extension, using half-duplex point-to-point connectivity. The IrDA protocol stack is also shown in Figure. 1.4. The IrDA protocol stack consists of three mandatory layers: the physical (IrPHY) layer, the IrLAP layer, and the IrDA Link Management Protocol (IrLMP) layer.

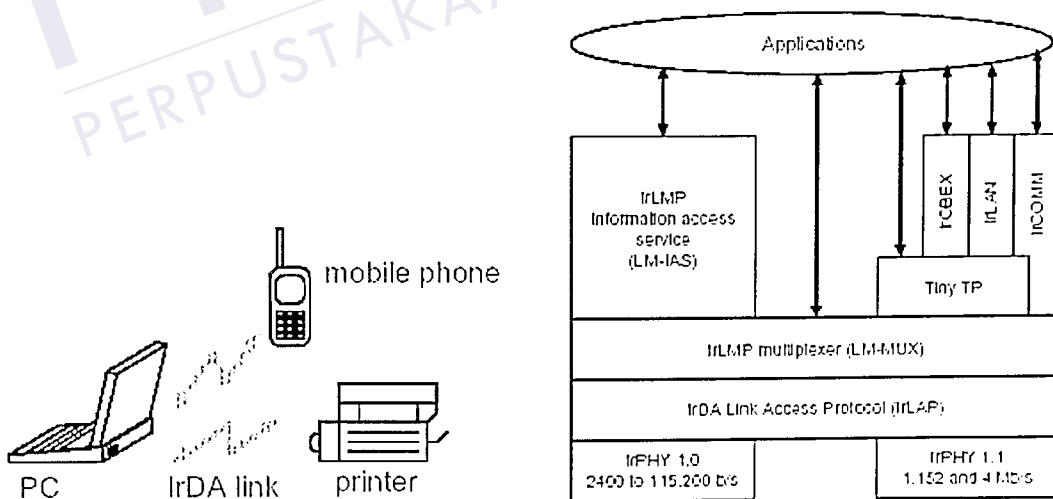


Figure 1.4 An example of an IrDA link and the IrDA protocol stack [1.20]

Therefore, one of the prime motivators for considering the use of an optical carrier in the wireless context is the demand for greater transmission bandwidths. As previously discussed, the radio frequency spectrum has already exceedingly become congested and frequency allocations of sufficient bandwidths are extremely hard to obtain [1.29]. As a medium for short-range wireless communication, IR radiation has several advantages over radio. The primary advantage is an abundance of unregulated bandwidth, with a range of more than 130THz. In addition, being similar in wavelength, part of the infrared spectrum shares many of the features of visible light; in particular, infrared radiation does not pass through walls or other opaque barriers, so that an infrared signal is confined to the room in which it originates. More importantly, it allows neighbouring rooms to use independent infrared links without interference. Furthermore, infrared links using intensity modulation and direct detection receivers do not suffer from multipath fading [1.30].

Nevertheless, IR does have some drawbacks as well, offering a limited range because the noise from ambient light is high, as shown in Figure 1.5 [1.30]. Also, the square-law nature of a direct-detection receiver doubles the effective path loss in dB when compared to a linear detector. Moreover, strict power limitations, due to eye and skin safety considerations, restrict the transmitter output power. IR is also susceptible to blocking, either from objects or personnel, resulting in loss of the communication link. The differences between radio and IR are summarised in Table 1.

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