THEORETICAL ANALYSIS OF PHOTOPARAMETRIC AMPLIFIER

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ABSTRACT

A fundamental requirement in the design of an optical receiver is the achievement of high sensitivity and broad bandwidth. These two features are very important in getting reliable system.

In this project a receiver circuit based on Photo parametric Amplifier (PPA), which is one of the alternative for receiver detection and amplification techniques is fully described. The PPA mode of operation involves optical detection and amplification within a single device. It is able to provide selectivity and sensitivity at the same time, as required for wireless optical communications.

The most common problem that any communication system might face is the noise which must be eliminated or at least reduce it. In order to reduce the noise, filters have been implemented before the signal is passing into an amplifier. In this project Up converter has been placed at the transmitter circuit in order to obtain high frequency, while at the receiver side, filters has been placed with Down converter to obtain the desired frequency.

The first method is to use Matlab software in implement is the Up and Down converters circuits at the receiver. The second method is to use Optiwave software in implement is the photo parametric amplifier circuit. Photo diode PIN type has been used to detect any coming signal at the receiver circuit. Results showed that the output signal has been improved; with more strength power and noise reduction which showe that photo parametric amplifier is more reliable and suitable to be used in wireless optical communication system.

ABSTRAK

Syarat-syarat asas dalam rekabentuk penerima optik adalah pencapaian dalam sensitiviti yang tinggi dan lebar jalur yang luas. Kedua-dua ciri ini sangat penting dalam mendapatkan sistem yang lebih cekap.

Dalam projek ini, rangkaian penerima berdasarkan Photo Parametric Amplifier (PPA), yang merupakan salah satu alternatif untuk teknik pengesanan dan amplifikasi penerima sepenuhnya dijelaskan. Mod operasi PPA melibatkan pengesanan optik dan amplifikasi dalam satu peranti. Pada masa yang sama, ia dapat memberikan pilihan dan sensitiviti yang diperlukan untuk komunikasi optik tanpa wayar.

Masalah yang paling umum mungkin dihadapi oleh setiap sistem komunikasi adalah hingar di mana ianya harus disingkirkan ataupun dikurangkan, bagi mengurangkan hingar penapis telah digunakan sebelum isyarat masuk ke dalam amplifier. Up converter telah digunakan dalam rangkaian pemancar untuk mendapatkan frekuensi tinggi, di sudut yang lain, di sisi penerima, penapis telah digunakan dengan Down converter untuk mendapatkan frekuensi yang diingini yang sesuai untuk rangkaian dan aplikasi yang telah dirancang.

Perisian Matlab telah digunakan untuk melaksanakan litar Up dan Down converter kepada penerima. Perisian Optiwave telah digunakan bagi melaksanakan litar Photo Parametric Amplifier (PPA). Gambar diod jenis PIN telah digunakan untuk mengesan isyarat yang datang dalam rangkaian penerima. Isyarat keluaran telah dipertingkatkan; peningkatan kuasa dan mengurangkan hingar yang membuatkan litar lebih mantap dan sesuai untuk digunakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

Hz	-	Hertz
B,BW	-	bandwidth
TIA	-	Trans-impedance Amplifier
PD	-	photo detector.
FSO	-	free space optic
OW	-	optical wireless
JB	-	Johor Bahru
KL	-	Kuala Lumpur

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Wireless optical communication systems were the subject of a great deal of research and development activity between 1960 and 1970. Recently, with the development of applications in space technology and the increasing importance of wireless systems for mobile and interior communications, interest has increased again. Wireless optical communication may also have a role in short links (between buildings, for example), because of local circumstances such as difficulty to run cable across the intervening space. In all these situations, optical links are in competition with radio and microwave systems. Wireless or free space light wave propagation is a growing field in today's world due to its many advantages as compared to microwave propagation and its application. The requirements for free space optical links are different than for optical fiber links. The laser wavelength must be chosen for optimum atmospheric transmission, and very importantly, the photo detection scheme chosen to give high sensitivity and selectivity. The EFDA (erbium doped fiber amplifier) cannot be used in wireless systems, but another solution has been found; photo parametric Amplifier (PPA) (S.M.Idrus, AMIEE', et al, 2004).

A generalized optical communication link is well illustrated in Figure 1.1. The information to be transmitted to the receiver is assumed to exist initially in an electrical form. The information source modulates the field generated by the optical source. The modulated optical field then propagates through a transmission channel such as an optical fiber or a free-space path before arriving at the receiver. The receiver may perform optical processing on the incoming signal. The optical processing may correspond to a simple optical filter or it may involve interferometers, the introduction of additional optical fields, or the use of an optical amplifier. Once the received field is optically processed it is detected. The photo detection process generates an electrical signal that varies in response to the modulations present in the received optical field. Electrical signal processing is then used to finish recovering the information that is being transmitted (Alexander, S.B, 1997).

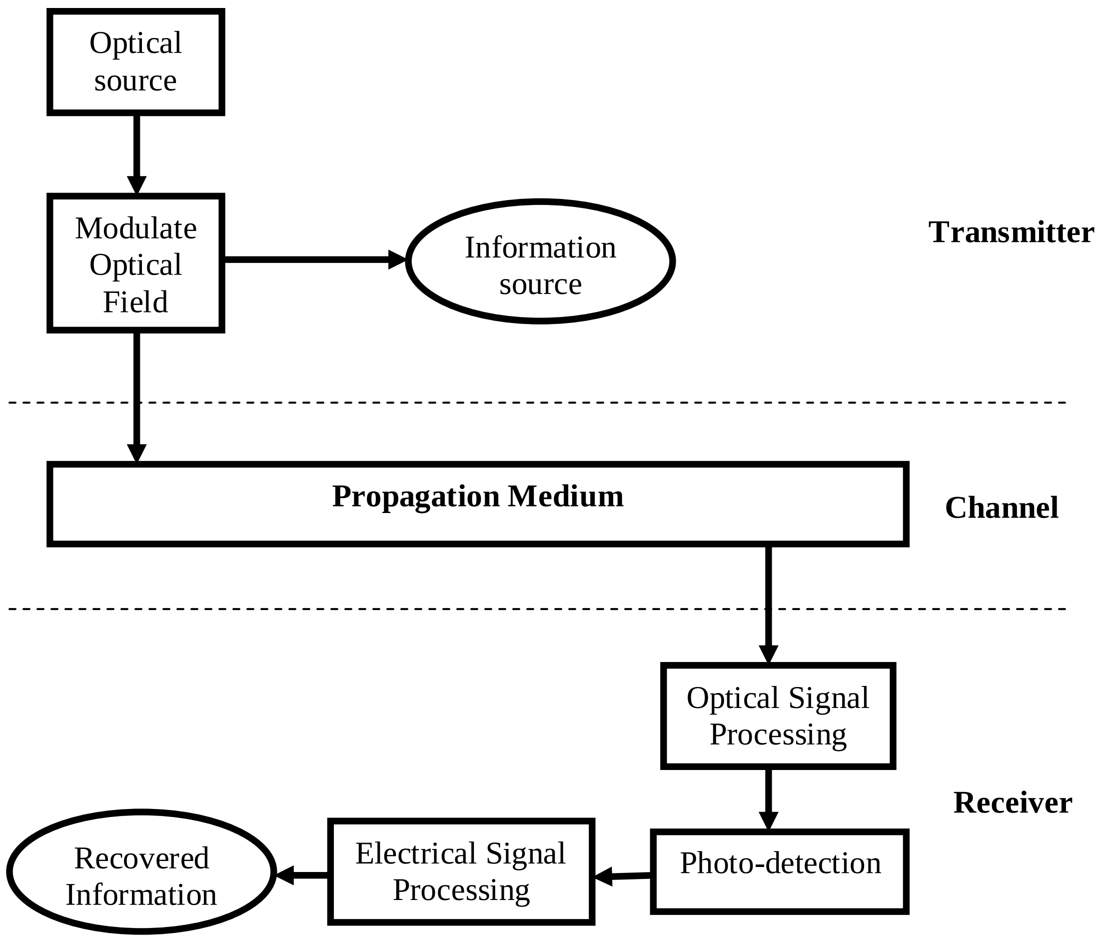


Figure 1.1 Generalized optical communication link

Transmitting signals as pulses of light through a thinner than human hair strand of glass or plastic at data carrying capacity (bandwidth) far greater than possible with any other physical medium. Under the AT&T's SONET standard data speeds of over 2.5 Gbps are common, whereas the maximum limit for a copper cable (without compression) is 16 Mbps. The attainable limit of fiber optic transmission is 2 trillion bits per second, enough to handle the amount of data handled by all US telecommunication companies put together. Fiber-optic uses less energy, is immune to static (electromagnetic interference), and is almost entirely secure from tempering or wire tapping. The problem of handling a low-level received signal with minimum degradation of signal-to-noise ratio was attacked by two approaches: low –noise parametric amplification and tunnel-diode down-conversion with gain. A study of the various types of par amps was conducted with some experimental verification of theory using the S-band breadboard par amp constructed during Contract NAS 8-1 643. Most of the tunnel-diode down-converter work was experimental and was conducted at both L- and S-band frequencies (Michel E. Marhic, 1973).

1.2 Project Objectives

Objectives of this project are as follows:-

- To improve receiver performance with improved noise performance and bandwidth enhancement.
- To model and simulate the design using MATLAB and OPTIWAVE.

1.3 Scopes

A free-space optical system block diagram is shown in Figure 1.2.The main scope concentrates on the front-end receiver which contains only a detector and of the work preamplifier.

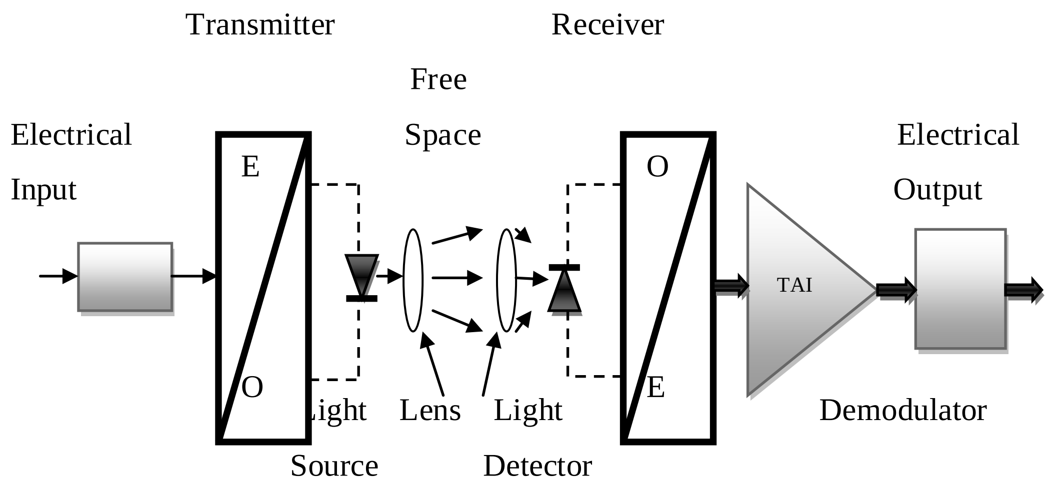


Figure 1.2 Free-Spaces Optical Systems

This study will focus on:-

1. Theoretical study for circuit (PPA) at receiver.
2. Photodiode
3. Source pumps (Frequency)
4. Parametric Down-conversion or Parametric Up-conversion
5. Types of band pass filters
6. The trans-impedance amplifier.

There are two methods used in this project which are:

- First method is to use Matlab to design and simulate the circuit and study the Up and Down converters circuit.
- The second method is to use the optiwave software to design and simulate the circuit using Up converter at the transmitter side and Down converter at the receiver side.

The main focus of this project is to improve front-end receiver performance with and bandwidth enhancement noise performance using Photo parametric Amplification (PPA).

The PPA would improved receiver performance especially in terms of bandwidth using Non degenerate mode, Up-converter with output frequency higher than input frequency or Down-converter with output frequency lower than input frequency.
The improvement of noise and bandwidth using PPA will be modeled and simulated using Matlab and Optiwave. The frequency response of Photo parametric Amplification will be plotted and analyze in order to determine the performance characterization of PPA (Professor Roger J. Green, et al, 2007).

1.4 Problem Statement

A fundamental requirement in the design of an optical receiver is the achievement of high sensitivity and broad bandwidth. These two features are very important in getting reliable system. Generally, the main issue is to consider in how one can design the frontend of an optical detector (photo diode) and amplifier with parametric Down-converter or parametric Up-converter known as photo parametric amplifier (PPA). The noise problem at the receiver side will be solved in order to obtain better output.

1.5 Summary of chapter 1

Chapter one has come up with some points which can be summarized in:

- Firstly a background on the parametric amplifier was explained in this chapter to give a brief idea about it and the improvements that have been done by some researchers in this major.
- The objectives have cleared up the main work to be done throughout this project.

- Lastly the scope of this research has showed the ways that going to be used and the steps of this project. Now to get more understanding in this regard, some previous works will be studied which can be basic information that can help to achieve the mentioned objectives of this research.

CHAPTER 2

LITERATURE REVIEW

This project examines some of the issues involved in the design of optical receivers for free space optics. Trans-impedance preamplifiers were investigated as a technique for mitigating the effects of the large capacitances associated with the photo detector.

2.1 Free-Space Optics (FSO)

The concept of transmitting information through the air by means of a modulated light signal is quite old; and although significant advances have been made over the past 10 years, the concept remains relatively simple: a narrow beam of light is launched at a transmission station, transmitted through the atmosphere, and subsequently received at the receive station. The advances, which have led to what now in this work referred to as free-space optical communications, or FSO, have come about in response to a need for greater bandwidth and improved communications systems.

2.2 The Technology at the Heart of Optical Wireless

Imagine a technology that offers full-duplex Gigabit Ethernet throughput. A technology that can be installed license-free worldwide, can be installed in less than a day. A technology that offers a fast is free-space optics (FSO). This line-of-sight technology approach uses invisible beams of light to provide optical bandwidth connections. It's capable of sending up to 1.25 Gbps of data, voice, and video communications simultaneously through the air; enabling fiber-optic connectivity without requiring physical fiber-optic cable. It enables optical communications at the speed of light. And it forms the basis of a new category of products that is optical wireless products such as from Light Pointe, the recognized leader in outdoor wireless bridging communications.

FSO is a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive voice, video, and data information. Today, FSO technology is the foundation of Light Pointe's optical wireless offerings which has enabled the development of a new category of outdoor wireless products that can transmit voice, data, and video at bandwidths up to 1.25 Gbps. This optical connectivity doesn't require expensive fiber-optic cable or securing spectrum licenses for radio frequency (RF) solutions. FSO technology requires light. The use of light is a simple concept similar to optical transmissions using fiber-optic cables; the only difference is the medium. Light travels through air faster than it does through glass, so it is fair to classify FSO technology as optical communications at the speed of light. For providing high-speed connections, across Enterprises and between cell-site towers, it is the best technology available (Siti Sara Binti Rais, 2006 / 2007).

2.3 What is FSO?

FSO technology is based on connectivity between FSO-based optical wireless units, each consisting of an optical transceiver with a transmitter and a receiver to provide full-duplex (bidirectional) capability. Each optical wireless unit uses an optical source, plus a lens or telescope that transmits light through the atmosphere to another lens receiving the information. At this point, the receiving lens or telescope connects to a high-sensitivity receiver via optical fiber.

This FSO technology approach has a number of advantages:

i. Requires no RF spectrum licensing.

ii. Is easily upgradeable, and its open interfaces support equipment from a variety of vendors, which helps enterprises and service providers protect their investment in embedded telecommunications infrastructures.

iii. Requires no security software upgrades.

iv. Is immune to radio frequency interference or saturation.

v. Can be deployed behind windows, eliminating the need for costly rooftop rights.

2.4 FSO: Optical or Wireless?

Optical wireless, based on FSO-technology, is an outdoor wireless product category that provides the speed of fiber, with the flexibility of wireless. It enables optical transmission at speeds of up to 1.25 Gbps and, in the future, is capable of speeds of 10 Gbps using WDM. This is not possible with any fixed wireless or RF technology. Optical wireless also eliminates the need to buy expensive spectrum (it requires no municipal license approvals worldwide), which further distinguishes it from fixed wireless technologies. Moreover, FSO technology's narrow beam transmission is typically two meters versus 20 meters and more for traditional, even newer radio-based technologies such as millimeter-wave radio. Optical wireless products similarities with conventional wired optical solutions enable the seamless integration of access networks with optical core networks and help to realize the vision of an all-optical network.

Mobility embraces wide area 'roaming' at one end of the spectrum, and users within a room demanding extremely high bandwidths and mobility at the other. In this regime there is an increasing mismatch between fixed and mobile networks: Fiber optic LANs will be carrying traffic at data rates of Gbits/s in the near future whereas data rates of 10s of Mbits/s are difficult to provide to mobile users. We believe that optical channels, offering Terahertz of bandwidth may offer a means to break this bottleneck, allowing in-building wireless connections at upwards of 100Mb/s per channel.

2.5 Photo detector

A detector's function is to convert the received optical signal into an electrical signal, which is then amplified before further processing. Therefore when considering signal attenuation along the link, the system performance is determined at the detector. Improvement of detector characteristics and performance thus allows the installation of fewer repeater stations and lowers both the capital investment and maintenance costs.

The role the detector plays demand that it must satisfy very stringent requirements for performance and compatibility. The following criteria define the important performance and compatibility requirements for detectors which are generally similar to the requirements for sources (Senior J.M, 1992).

2.6 Requirements for choosing the detectors (Senior J.M, 1992).

i. High sensitivity at the operating wavelength.

ii. High fidelity - to reproduce the received signal waveform with fidelity (example: for analog transmission the response of the photo detector must be linear with regard to the optical signal over a wide range.

iii. Large electrical response to the received optical signal - the photo detector should produce a maximum electrical signal for a given amount of optical power

iv. Short response time. (pn-msec, PIN/APD - nsec)

v. Minimum noise.

vi. Stability.

vii. Small size

viii. Low bias voltage.

ix. High reliability.

x. Low cost.

The most important characteristics of light detectors are responsively, dark current, transit time, spectral response and light sensitivity. Responsively is a measure of the conversion efficiency of a photo detector. It is the ration of the output current of a photodiode to the input optical power and has the unit of ampere/watt. Responsively is generally given for a particular wavelength or frequency. Dark current is the leakage current that flows through a photodiode with no light input. Dark current is caused by thermally generated carriers in the photodiode. Transit time is the time it takes a light-induced carrier to travel across the depletion region. This parameter determines the maximum bit rate possible with a particular photodiode. Spectral response is the range of wavelength values that can be used for a given photodiode. Generally, relative spectral response is graphed as a function of wavelength or frequency. In essence, light sensitivity is the minimum optical power a light detector can receive and still produce a usable electrical output signal. Light sensitivity is generally given for a particular wavelength in either dBm or dBμ (Tomasi, W, 2000).

A variety of theoretical techniques have been developed to describe the generation, propagation and detection of light. Geometrical-optics, also known as ray-optics, is primarily concerned with image formation from lenses and mirrors. Wave-optics describes light as a scalar sinusoidal light wave and is adequate to explain many interference and diffraction effects. Electromagnetic-optics introduces a vector form for the light wave, which allows the explanation of polarization effects and propagation in dielectric media. Quantum-optics is the most complete and fundamental technique and allows the prediction of virtually all observed phenomena, including the details of interactions between light waves and atoms.

The ability to respond to light is a fundamental requirement of all optical receivers. Several methods to detect the presence of an optical signal have been developed, with photographic film probably being the most widely manufactured ‘detector’. In communication applications, the photo detection method employed must convert the received optical signal into an electrical signal that is then processed by conventional electronics to recover the information being transmitted. Table 2.1 lists the techniques that are those most often associated with the detection of optical signals (Alexander, S.B, 1997).

Table 2.1:-Photo detection techniques (Alexander, S.B. 1997).

Thermal Effects Wave	**Interaction Effects Photon**	**Effects**
Thermoelectric Effect	Parametric Down-conversion	Photoconductors
Pyromagnetic Effect	Parametric Up-conversion	Photo missives
Pyroelectric Effect	Parametric Amplifiers	Photovoltaic’s
Liquid Crystal		
Bolometer		

Thermal effects involve energy being absorbed from the received optical signal so that the photo detector’s temperature is altered. The change in detector temperature in turn alters some other device parameter that can then be externally sensed. Examples of thermal effect detectors are bolometer, which change their electrical resistance when illuminated, and pyroelectric detectors, which change their capacitive charge. Thermal effect detectors typically have slow response times when used in high-sensitivity applications and are generally not used in communication systems.

A second, somewhat unconventional technique uses the interaction between light waves and a nonlinear material to form sum or difference frequency light waves. These wave interactions are the basis for the construction of optical parametric amplifiers and frequency doublers. Unfortunately, efficient optical parametric amplifiers are relatively complex to implement and have not been widely used in communication applications.

In the third and most popular technique, the photo detector absorbs photons from the incident light wave through atomic interactions in the photo detector material. These interactions produce photo-excited electrical carriers or ‘photo carriers’. The generation of a photo carrier corresponds to the formation of an electron-hole pair in the photo detector material. When these photo carriers transport charge they form an electrical photocurrent that can be processed using conventional electronics. Excellent results have been obtained using this technique and virtually all practical communication systems use it (Alexander, S.B, 1997).

The heart of an optical communication receiver is the optoelectronic device that is used as the photo detector .Ideally, a photo detector would detect all incident photons, respond to the fastest changes in the incoming signal that were interest, and not introduce additional noise beyond the inherent quantum shot-noise from the received signal. In most practical applications, additional desirable characteristics can be defined. The photo detector should be small, lightweight, rugged, reliable and cost-effective, and its characteristics should remain unaffected by age and environment. Unfortunately, realistic photo detectors have limited bandwidths with finite response times. They introduce unwanted noise into the detection process, and the probability of detecting an individual photon is less than 100%. Some detector technologies are fragile and environmentally sensitive; others may have finite lifetimes or may degrade unacceptably as they age (Alexander, S.B.1997).

The photon-effect based photo detectors that are used in optical communication systems are those that directly generate photocurrents from interactions between photons and atoms in the detector material. When light penetrates into a photodetector material, the volume of material illuminated contains a tremendous number of atoms. The probability that a specific atom will be absorbs a photon and generates free carriers that form a photocurrent is quite small. However, since the number of atoms is huge, the probability that some atom will interact with an incident photon to form photo-excited free carriers can be quite high in a well designed detector. Photon-effect photo detectors can be constructed to simultaneously exhibit the high sensitivities and fast response times needed for high data-rate communications and are frequently grouped into one four general categories; photomultipliers, photoconductors, photodiodes and avalanche Photodiodes (Alexander, S.B, 1997).

2 .7 Optical Communication Systems

A further strand concerns optical receiver analysis, in particular with respect to the use of optical preamplifiers. To operate a system including an optical preamplifier it is necessary to reduce the amplified spontaneous emission (ASE) noise by use of a filter. It is common to utilize a Fabry-Perot (FP) filter in either bulk or fiber versions and thus an extra component are required at the receiver. Work in the group has focused on bit error rate analyses including realistic filter characteristics and pulse shapes. Furthermore, approximation techniques for rapid receiver analysis have also been developed.

One option is to use an optical filter to provide narrow slice of a broadband noise source producing an approach commonly known as spectral or spectrum slicing (SS). This provides a cost-effective alternative to laser diode sources for WDM systems but introduces excess intensity noise due to the source incoherence. Modeling work in this area produced has led to several significant insights, including demonstrating that SS systems are limited by the interference between pulses (intersymbol interference) before the excess noise becomes the greatest problem. Figure 2.1 shows Block diagram of an optical transmission system employing spectral slicing (Professor Roger J. Green, et al, 2007).

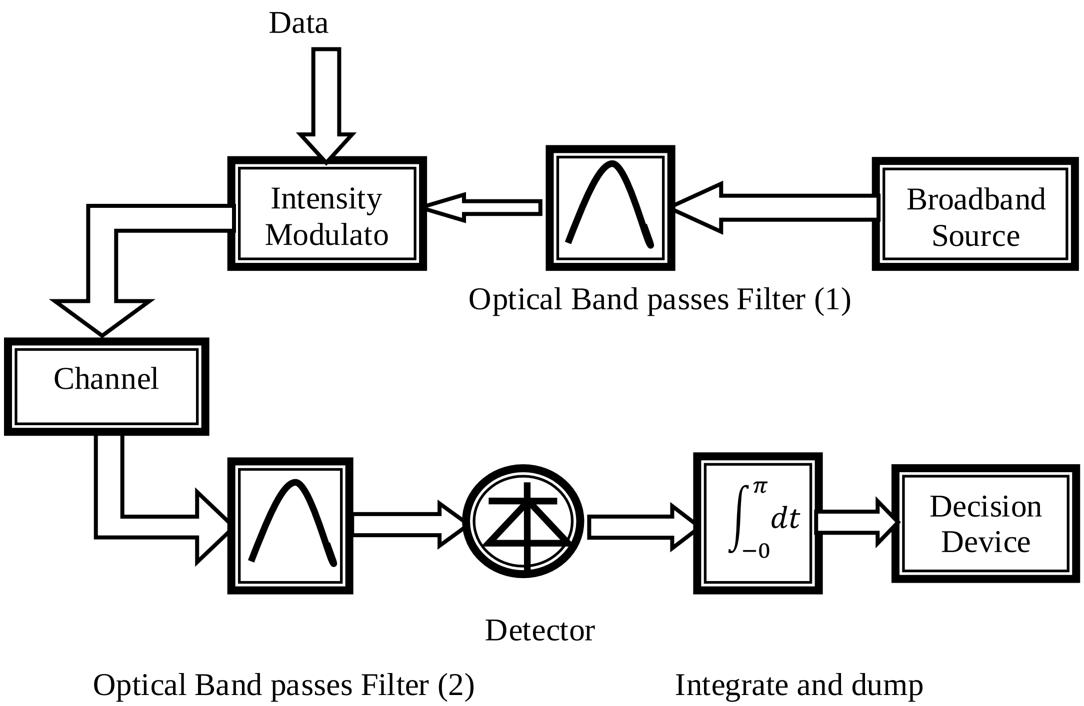


Figure 2.1 Block diagram of an optical transmission system employing spectral slicing

2.8 Optical Receivers

In order to advance the technology, new receiver-detector devices are being investigated, especially the photo parametric amplifier, which combines advantageously optical detection with parametric amplification? In addition, diffuse optical distribution systems are being developed, in order that users can operate anywhere within a building environment, and be offered a consistent quality of service. Figure 2.2 shows the block diagram of an Optical Receiver. (Alexander, S.B. 1997)

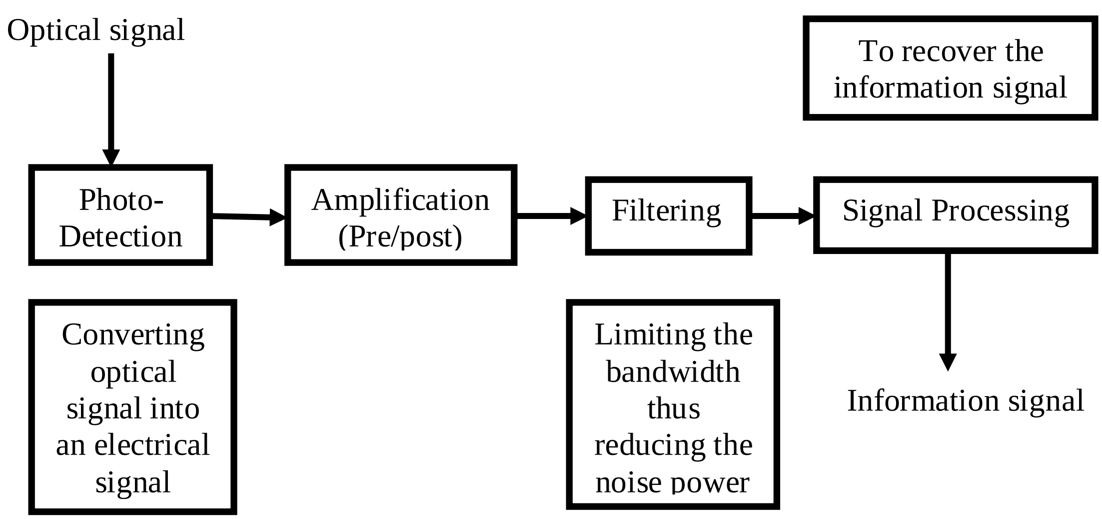


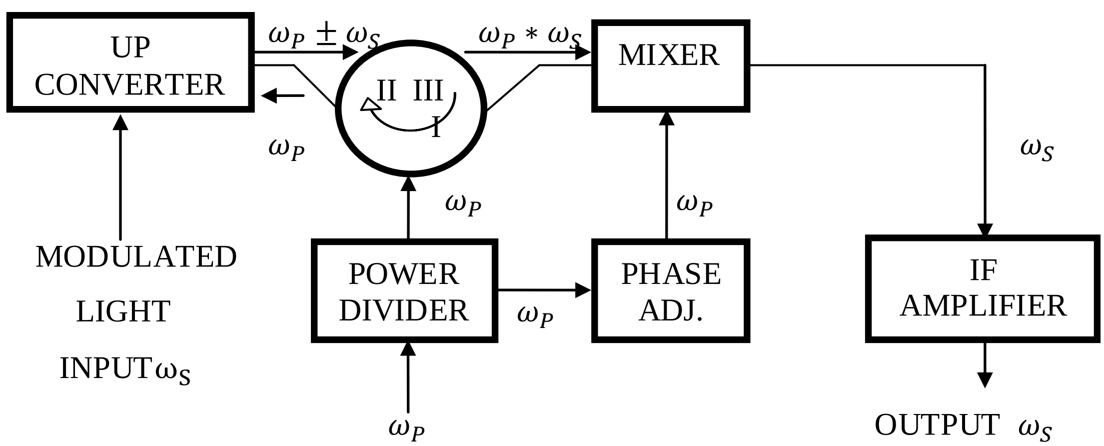
Figure 2.2 Block diagram of an Optical Receiver

2.9 Work Done Elsewhere

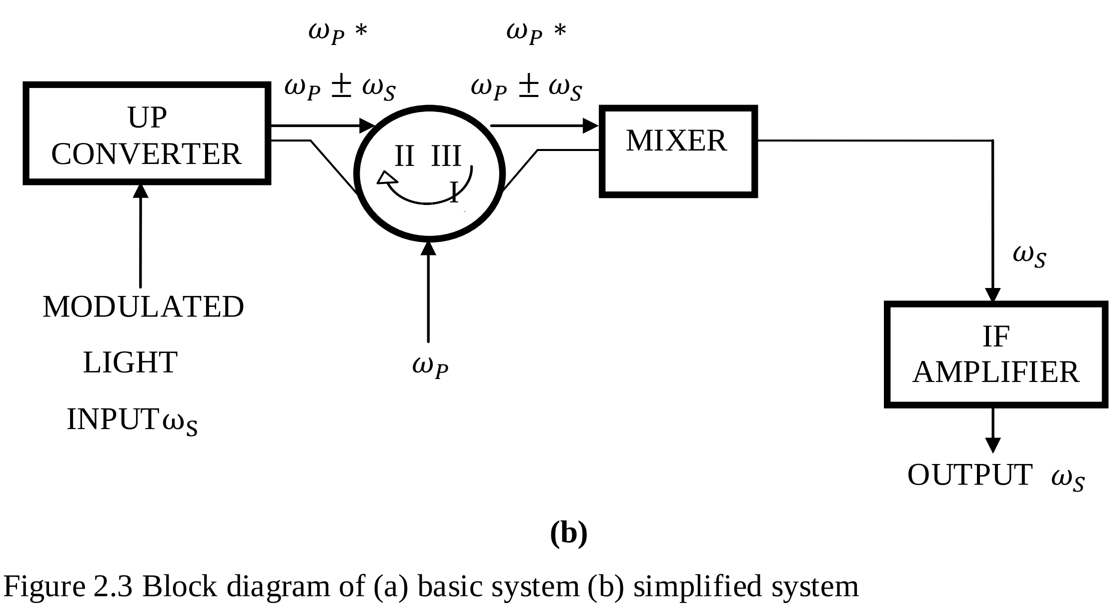
- **D. J.ROULSTON, 1968.**

In this paper the up-converter consists of a single trip late line with one coaxial output connected to a circulator, through which the pump is applied and the signal extracted. The other end of the line is connected to the photo diode via a small coupling capacitor. The light is modulated at frequencies from a few hertz to some upper limit (in the experiment described, about 10 MHz) determined by the bandwidth of the trip late circuit, This arrangement is shown to give excellent results and the limit performance, as determined only by the diode parameters may be attained by following the up-converter with a degenerate parametric amplifier using the same pump plus a varactor doubler. Emphasis is placed throughout on the ultimate limitation of such a system and the results are expressed in a form enabling easy comparison with other optical detectors

The results found which are in good agreement with theory. The basic system of Figure 2.3 (a) Or (b) is extremely simple and stable in operation.



(a)



(b)

Figure 2.3 Block diagram of (a) basic system (b) simplified system

The addition of a degenerate parametric amplifier enables the theoretical limits of the up-converter diode to be attained. It is interesting to compare the results with those obtainable using the same diode followed by a classical km-noise amplifier. Two cases may be considered:

1- An unturned, wide-band system
2- A tuned system centered on some high frequency with the same signal bandwidth as in 1.

Referring to the circuit shown in Figure.2.4 (a) and assigning an equivalent noise temperature TL to the load Rf_i it may easily be shown that the signal-to-noise ratio is given by

$$\frac{S}{N} \cong \frac{I_S^2}{[32\pi^2 KT_0 B^3 R_d C^2 3]} \times \frac{1}{[1 + 3Q_d T_l/4T_0]^2}$$

Where the light is modulated from 0 to B Hz

$$Q_d = (2\pi BCR_d)^{-1}$$

And

$$2\pi BCR_l = 1 \quad \ldots\ldots(2.1)$$

In Figure 2.4 (b) where we show a tuned amplifier with the same bandwidth it is easily shown that

$$\frac{S}{N} \cong \frac{I_S^2}{[32\pi^2 KT_0 B^3 R_d C^2 3]} \times \frac{B/f_C}{[1 + T_1/T_0} \quad \ldots\ldots(2.2)$$

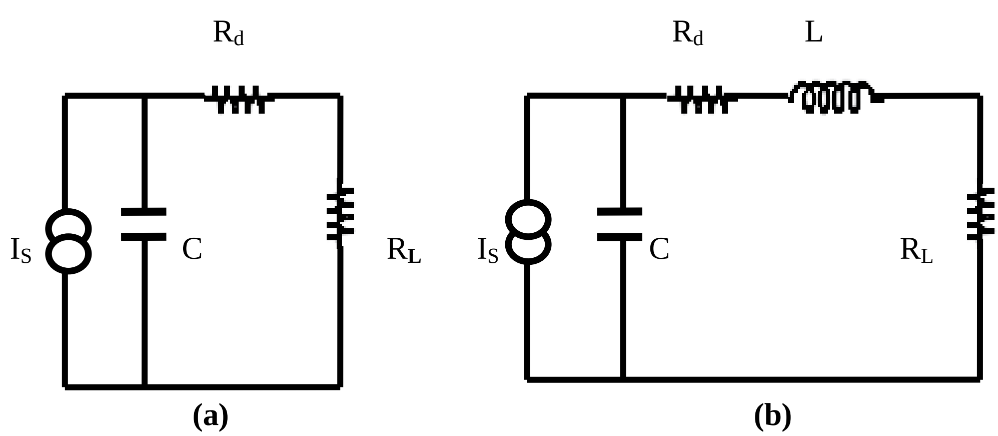


Figure 2.4 (a) Photo diode followed by unturned amplifier; (b) tuned amplifier

- **1992 A. Khanifar and R. J. Green, 1992.**

The receiver is based on the photo-parametric mode of operation, where a photo detector is pumped at microwave frequencies and photo detection and parametric amplification are achieved simultaneously in a single device. Frequency conversion/ amplification are also possible to suit particular system applications.

The layout of the required hardware is shown in Figure 2.5. The photo diode is pumped and the photo detected signal is up-converted and amplified. The upper and lower side-bands generated (idlers) are short circuited and phase adjusted to be reflected back.

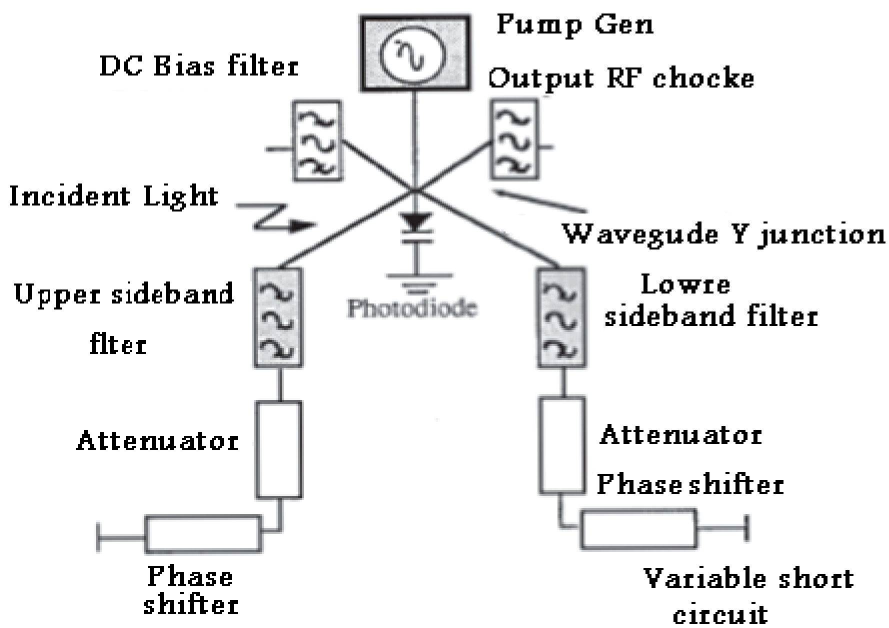
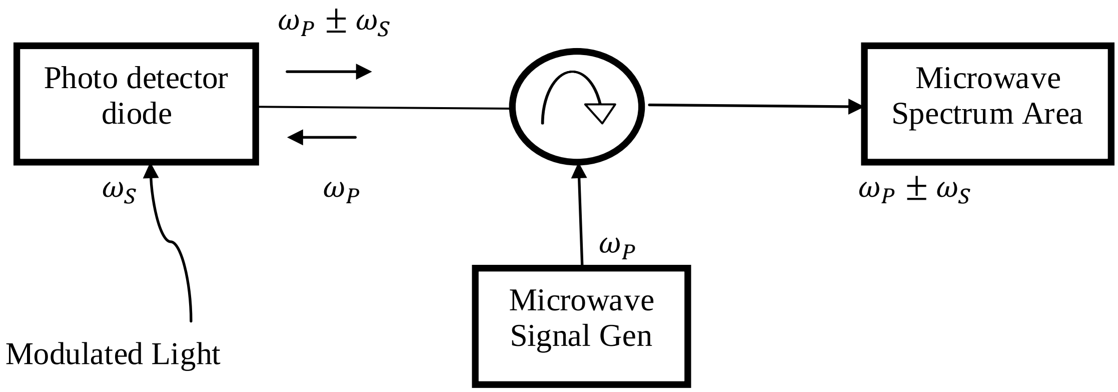
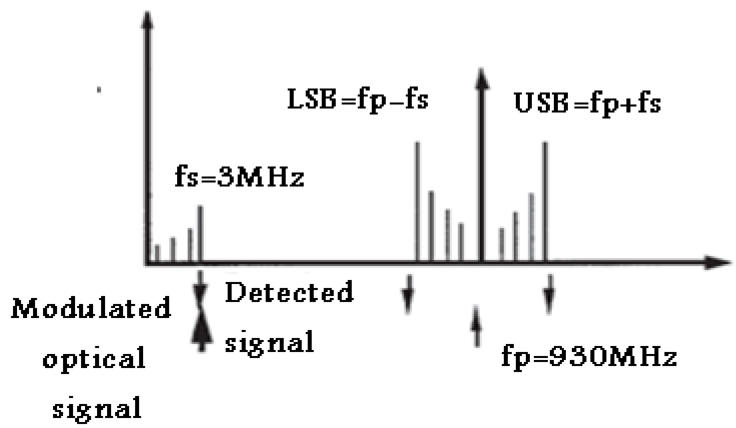


Figure 2.5 The experimental set up of direct baseband receiver

The block diagram of the basic circuit is shown in Figure 2.6 The circulator provides a convenient method of applying the pump to the diode and extracting the signal while at the same time isolating the load from the up convertor. The unconverted output can be down converted to recover the signal by using a mixer, whose local oscillator originates from the same source as the pump via a suitable attenuator and phase adjuster.



(a)



(b)

Figure 2.6 (a) The experimental set up and (b) The spectrum of signals across the diode

Clearly the starting point for the design of a tailor-made diode for the photo parametric mode of operation requires a theoretical study at device level. An attempt was made to address some of the issues involved both at circuit and device levels. The practical measurement carried out indicates that the performance of the photo-parametric up-converter described in a good agreement with the theory presented.

- **A.Khanifar and R.J.Green, 1999.**

The paper investigates the performance, of various modes of operation. Circuit simulations and practical results are compared and discussed, with particular attention to the sub-carrier multiplexed system application. The required device characteristics that influence the diode structure are determined using nonlinear simulation techniques

Various photo parametric amplifier modes of operation were studied in detail. By making use of modern nonlinear simulation tools (harmonic balanced technique), it was possible to estimate the required device performance (C-V characteristics) for satisfactory operation, and also to optimize the RF circuitry. Prototypes were designed, ‘built and experimented with, to validate the simulated performance for each mode of operation. The investigation suggests that PPAs offer potential advantages over conventional receivers with respect to frequency tenability. Based on the simulated results, the noise performance is, also potentially superior to, or at least comparable with, a top quality receiver chain. There are implications on the gain bandwidth products, which should be balanced against the simplicity of the detection and de-multiplexing hardware. The PPA unique frequency selectivity feature seems particularly attractive for SCM and wireless optical system applications and can reduce the receiver complexity and cost. The concept shows much promise and applicability in the set-top box receiver, when fiber-to-the-home becomes widespread. The PPA is equally suitable for the detection of analogue-, digital-, and mixed optical modulation types, and is easy to configure.

The block diagram of the basic circuit is shown in Fig. 2.7. A quadrature hybrid circuit or a circulator provides a convenient method of applying the pump to the diode and extracting the output signal, while at the same time isolating the load from the pump. The up-converted output is fed to a mixer, whose local oscillator originates from the same source as the pump, via a suitable attenuator and phase adjuster.

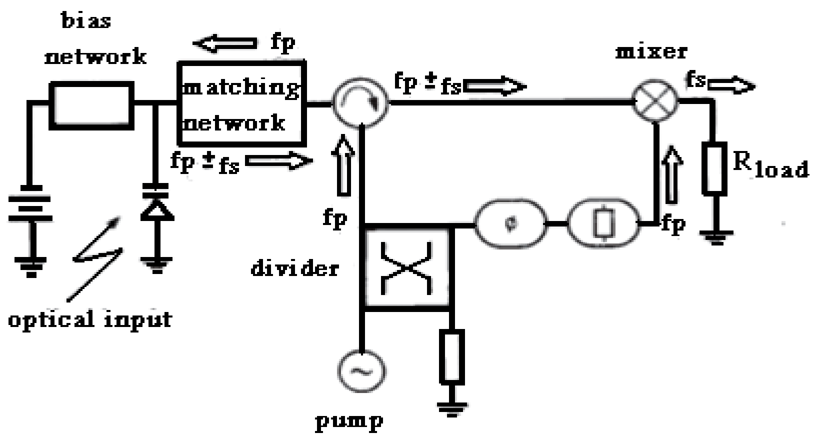


Figure 2.7 Photo parametric up-converter circuit

Two-stub tuners for matching purposes help to form the down-converter setup shown in Figure 2.8. The signal and the pump frequencies in this setup were at 900 and 990MHz, respectively

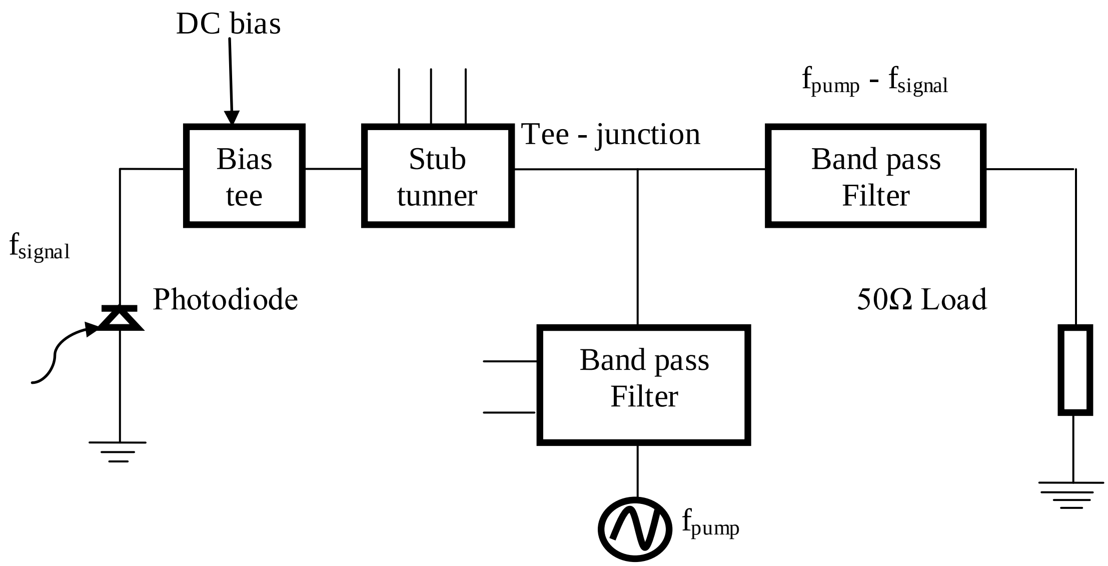


Figure 2.8 Block diagram of down-converter set-up

- **S. M. ldrus, R. J. Green et al, 2005.**

An optical receiver's front-end design can be usually grouped into one of four basic configurations: (1) a resistor termination with a low-impedance voltage amplifier, (2) a high impedance amplifier, (3) a trans-impedance amplifier, and (4) a noise-matched or resonant amplifier. It will be presented by device of structure of the PPA . The amplifier operation is based on the non-linear characteristics of the photodiode and therefore, the mechanism constituting gain is highly non-linear and different to that in a conventional amplifier/mixer chain. The PPA has been successfully simulated using a nonlinear microwave simulator to perform harmonics balance analysis, which represented actual photodiode model and nonlinear dynamic capacitance behavior. The simulation predicted a PPA up-conversion gain as high as 43dB and this agreed with conventional theoretical analysis. The up-converter gain has been shown to be directly related to the level of pump input and signal input. If there is a limit to pump power, then the gain may be recovered by appropriate adjustment of the ratio of pump to signal frequencies. It was found that .The analysis shows that the gain is directly related to pump input parameters. Therefore, if there is a limit to pump power, then the gain may be recovered by appropriate adjustment of the ratio of the pump to signal frequencies. The photo parametric amplification approach has been shown to work in:-

1- subcarrier multiplexed systems
2- millimeter-wave fiber radio system

The PPA has detection, gain and frequency transition all together, and the noise sources have lower overall significance.

- **Mark S. Lesson**, **Roger J. Green**, **Matthew D. Higgins, 2008.**

The term parametric is used to describe a system that achieves amplification, oscillation, frequency changing or harmonic generation through the variation of a parameter in the system. Inductive parametric amplifiers can be realized through the variation of nonlinear properties of certain ferrites but suffer from a high noise figure. Referring to Figure 2.9 (a), capacitive parametric amplifiers typically employ the nonlinear characteristics within the depletion region of p-n junction varactor diode. Signal energy, at frequency ω_s is coupled via a tuned circuit to the varactor, which is pumped by a second signal with energy at ω_p. This pump modulates the capacitance of the varactor in such a way that the signal power is amplified by the energy transfer from the pump. A filter network is then employed to collect the energy from a chosen sideband. It is possible to extract energy at the same frequency as the signal, known as degenerate mode, or at the frequency of one of the sidebands, known as idlers,

$$\omega_i = n\omega_s \pm m\omega_s \quad \text{Where } \{n, m\} \in Z^+ \ldots\ldots\ldots\ldots (2.3)$$

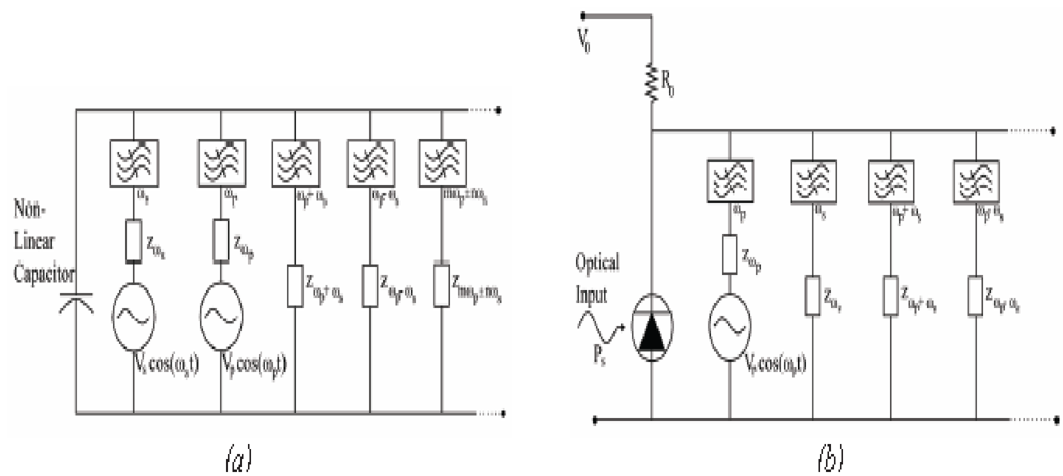


Figure 2.9 Idealized parametric amplifier configurations: (a) Conventional,
(b) Photo parametric

The presence of optical power flow the source in the PPA means that the classic Manley-Rowe equations may not be directly applied. Here, the results of appropriate analysis for the PPA have been outlined for both the degenerate mode, when the output is baseband, and for the non-degenerate mode. The utilization of the DHPPA configuration, where an IF is employed, has also been discussed. A proof of principle experiment of this approach has demonstrated a measured gain of in excess of 7 dB, with the potential for higher figures by appropriate adjustment of the pump. The PPA is a versatile receiver component that offers the prospect of significant benefits to OW and FSO aiding their widespread implementation as well as offering improved performance in fiber access networks. To date, the PPA devices have been discrete in nature and so one strand of current work is to investigate the design of microwave monolithic integrated circuits (MMICs). By moving to a MMIC based implementation, increased compactness and the reduction of parasitic effects will be achieved. The provision of an integrated PPA receiver will lead to economies of scale facilitating the mass production of, say, the DHPPA for just a few dollars, offering substantial yet affordable benefits in the access network.

2.10 Summary of chapter 2

This chapter has discussed the optical communication system and explained in details. The free space optic (FSO) has been studied as well as the mechanism of how it works. More ever, this chapter explained and discussed whether FSO is optical or wireless and the similarities between both of those techniques. The photo detector has been studied in details and how it can be used to detect any incoming signal. There are some considerations must be taken into account when choosing the photo detector so that, the requirements of choosing the suitable photo detector is included in this chapter as well. Some previous works and studies which had been done before have been studied to understand and use them as basic work and background guideline in Chapter 3 methodology design of the work.