

Description

The present invention relates to optical networks, and particularly but not exclusively to broadband passive optical networks (BPON) for carrying high definition television (HDTV) signals.

It is well known to use a BPON having a branched configuration to convey suitably encoded signals from a head-end station to a number of customer stations. The use of such a system has been proposed for carrying standard definition PAL television. The proposed technical standards for BPONs require a maximum head-end to customer power loss of 26 dB. With a zero dBm launch power, this power budget is adequate to enable up to 32 channels of standard definition PAL to be carried using standard technology. HDTV however requires a far higher bandwidth than conventional television channels and so it is possible to fit only a few channels within the power budget of a conventional BPON. Along with the developments in technical standards associated with the switch from PAL to HDTV there is expected to be a proliferation in the number of channels available to the viewer. According to an optical system capable of carrying fewer than, say, 16 channels is likely to be commercially unacceptable to cable network operators.

There is disclosed in ECOC 87, Technical Digest, vol II, pages 122-125; R. Olshansky: "RF multiplexing techniques applied to video distribution in local networks" a system employing sub-carrier multiplexing in a head station for the distribution of video signals over an optical network.

In the Olshansky system a number of voltage controlled oscillators operating at microwave frequencies are directly frequency modulated. The outputs from the oscillators are combined in a combiner whose output is used to intensity modulate the transmitter laser, and Olshansky refers to wide bandwidth (15 GHz) devices as detectors in the remote terminals. With the Olshansky head-end arrangement, it would not be possible to employ a coherent heterodyne detection system in the customer stations because of a characteristic of the transmission spectrum of such a head-end known by engineers as "chirp".

This problem is avoided in the system of the present invention by the use of the external modulator which receives the light from the head-end laser and modulates it with the transmission signal.

There is known from ECOC 87; Technical Digest, Vol III, pages 79-87; C. Baack et al.: "Coherent multi-carrier techniques in future broadband communication networks" a system for providing ISDN services, broadband communication service, video telephone and broadband distribution services such as HDTV to customers via respective single fibres. The head station employs a separate laser for each wavelength to be transmitted onto the fibre network and the custom-

er's station employs heterodyne detection. Upstream transmission from a customer's station is obtained by feeding the output of a separate opto-electronic converter into a fibre coupler in the customer's station and, for each customer, feeding an output from a respective coupler at the head station to a respective opto-electronic converter.

According to the present invention a system for distributing a plurality of channels from a head station to a number of customer stations comprises;

a head station arranged to provide a plurality of output channels at respective frequencies, a plurality of customer stations, and a broadband passive branched optical network coupled to the output of the head station and arranged to distribute the output channels from the head station to the customer stations, each customer station including a coherent receiver having a local oscillator laser and arranged to demodulate a selected one of the channels: characterised in that the head station comprises a head-end optical source having a frequency f_0 ; and an associated modulator arranged to receive light from the optical source and to modulate the light with a sub-carrier multiplex of n channels, where n is a integer greater than 2, the n channels having frequencies $f_1, f_2, \dots, f_n$ separated in frequency-space from each other and from f_0 , the output of the modulator forming the output of the head station.

The present invention provides a system with a combination of features which together give it a number of significant advantages, particularly for HDTV. The use in a preferred embodiment of a single source and wavelength multiplexing at the head-end in combination with coherent detection at the customer end makes it possible to increase significantly the number of channels which can be encompassed within the limits of the power budget. With the system of the present invention it is not necessary unduly to increase the number of sources used at the head-end, which would add undesirably to the cost and complexity of the head-end, and it may be possible to use only one source. Equally it is not necessary to increase the power of the optical source used: the use of high-power lasers is undesirable since in general they have a higher cost and shorter mean lifetime. Since the system of the present invention uses coherent detection it is possible to use a low-frequency heterodyne receiver at the customer end. The use of such a receiver rather than the broadband envelope detectors commonly used with BPONs leads to improved performance at the customer station. The use of a low-frequency receiver is particularly advantageous in that a much higher sensitivity can be achieved than can be realised using a wideband receiver. With a receiver bandwidth of 80 MHz, the theoretical sensitivity for an amplitude-shift-keyed heterodyne system with sufficient correctly polarised local oscillator power, is approximately -60 dBm. This is approximately

35 dB better than could be achieved by a wideband receiver having the 4 GHz bandwidth necessary to encompass a typical sixteen channel sub-carrier multiplex of analogue HDTV signals. In practice some of this power advantage is lost by the effective splitting of the transmitter power between the channels, but even so using the system of the present invention a power advantage of the order of 13 dB has been realised. Although in practice this power advantage is found to be most effectively used to enable a reduction in the power of the source and an increase in the number of channels it may in some applications be used alternatively to allow an increase in the number of customers served by one head-end transmitter or to allow the use of other services at different wavelengths on the same network. A further advantage of the system of the present invention is that because each customer station includes its own local oscillator laser the system can readily be adapted to provide a two-way service with upstream data transmission from the customer stations to the head-end in addition to the transmission downstream from the head-end to the receivers.

Preferably each customer station includes frequency control means arranged to control the frequency of the local oscillator laser, a modulator arranged to receive at least a portion of the light output by the local oscillator laser and to modulate the light received from the local oscillator laser with data for transmission upstream to the head-end station, the frequency control means being arranged to select a frequency f_0 , where f_0 is a frequency different from the frequencies $f_1, f_2, \dots, f_n$ of the downstream channels, when data is to be transmitted upstream from the customer stations.

Preferably n is greater than or equal to 16.

Preferably the system includes at least 16 customer stations and the single optical source of the head-end station has an optical power output of substantially 1mW.

A system in accordance with the present invention will now be described in detail with respect to the accompanying drawings in which:

Figure 1 is a block diagram;

Figure 2 is a schematic showing the head-end station in greater detail;

Figure 3 is a graph showing the spectral positions of frequency components of an HDTV signal; and
Figure 4 is a schematic showing a customer station.

A system for distributing HDTV signals comprises a head-end station 1 connected via a passive branched optical fibre network 2 to a number of customer stations 3. In Figure 1, for clarity, only a single customer station is shown but in practice 16 or more stations will be connected to a single head-end station. The head-end station 1 includes a single optical source, which in the present example is provided by

a distributed feedback laser 4 having an operating wavelength of 1.52nm and an output power of 1mW. The output from the laser 4 is fed to an external LiNbO₃ modulator 5 where it is intensity-modulated by a sub-carrier multiplex signal as described below. Alternatively a modulator formed from potassium titanyl phosphate (KTP) may be used.

The amplitude of the optical output from the modulator 5 varies in accordance with the applied modulating signal. Phase or frequency modulation may alternatively be used. In the present example the modulating signal is a sub-carrier multiplex of 16 HDTV channels occupying a total bandwidth of approximately 10GHz. Although the channels may be analogue encoded in the preferred example they are digitally encoded with a data rate of the order of 500Mb/s, in which case the signals are encoded on the carrier from the laser using frequency shift keying. Figure 3 shows part of the spectrum of the output from the modulator.

The signal from the modulator 5 is coupled to the optical fibre network 2 via a birefringent coupler 10. The network 2 comprises a broadband passive branched optical network using a configuration with a single fibre extending to each customer station and passive splitters or couplers at each node of the network.

In Figure 2 the coupler 10 is shown as having two output ports connected to two fibres, and may be considered as the first stage of splitting in the branched network. Depending on the coupler construction it may have any convenient number of output ports.

Each customer station 3 includes a receiver employing a coherent heterodyne detection system. The respective arm of the fibre network 2 is fed to a coupler 6 at the input of each receiver. The coupler 6 also receives an optical input from a local oscillator laser 7 which is mixed with the input signal from the network. The frequency of the local oscillator laser 7 is controlled by an AFC control loop 8 which is in turn controlled by an input from a channel select circuit 9. The AFC control 8 locks the local oscillator laser 7 at a frequency offset from the 1.52nm carrier frequency by an appropriate amount to select a desired channel. Then when the signal from the local oscillator laser 7 is mixed with the input to the coupler 6 a low-frequency heterodyne output is produced. This output is fed to a low-frequency optical receiver 16 having a bandwidth of approximately 80 MHz for an analogue system or 350 MHz for a digital system. Such an ASK heterodyne system has a theoretical maximum sensitivity of -60 dBm and in practice a sensitivity as high as -50 dBm can be achieved.

The data output from the receiver may be used to provide feedback to the channel select mechanism, the initial tuning being achieved by looking for an encoded channel identification on the received signals and the lock subsequently being maintained by the

AFC loop. The tuning is controlled by varying the drive current to the local oscillator and only a small shift is required to select a given channel.

In the preferred embodiment digital modulation is used and then it is straightforward to provide polarisation independence in the demodulation at the receiver. If however it is required to carry analogue modulated signals on the network then polarisation scrambling is used at the receiver to provide the required polarisation independence. The techniques of polarisation scrambling in coherent detection are described in detail in the paper by T.G. Hodgkinson et al. published at pages 513-514 of Electronics Letters, Vol. 23, No.10, 7th May 1987.

Since each receiver includes its own local laser the system can be adapted to provide upstream data transmission from the customer station to the head-end station. As shown in Figure 4, each customer includes a modulator 11 and polarization scrambler 12 placed in a signal path between its respective laser 7 and the coupler 6 joining the receiver to the network. The head-end station includes a conventional wide-band optical receiver 17 and microwave system. The system for upstream data transmission is described and claimed in our application WO-A-90 14733, published on 29 November 1990. Although, as shown in Figure 4, the upstream transmissions are conveyed on the same fibre as the downstream transmission, an alternative arrangement would be separate go and return fibres to each customer.

Claims

1. A system for distributing a plurality of channels from a head station (1) to a number of customer stations (3), comprises; a head station (1) arranged to provide a plurality of output channels at respective frequencies, a plurality of customer stations (3), and a broadband passive branched optical network (2) coupled to the output of the head station (1) and arranged to distribute the output channels from the head station (1) to the customer stations (3), each customer station (3) including a coherent receiver (6, 7, 8 16) having a local oscillator laser (7) and arranged to demodulate a selected one of the channels: characterised in that the head station (1) comprises a head-end optical source (4) having a frequency f_0 ; and an associated modulator (5) arranged to receive light from the optical source (4) and to modulate the light with a sub-carrier multiplex of n channels, where n is a integer greater than 2, the n channels having frequencies $f_1, f_2, \dots, f_n$ separated in frequency-space from each other and from f_0 , the output of the modulator forming the output of the head-end station (1).
2. A system according to claim 1, in which each customer station includes frequency control means (8, 9) arranged to control the frequency of the local laser oscillator (7), and a modulator (13) arranged to receive at least a portion of the light output by the local oscillator laser and to modulate the light received from the local oscillator laser with data for transmission upstream to the head station (1), the frequency control means being arranged to select a frequency f_0 , where f_0 is a frequency different from the frequencies $f_1, f_2, \dots, f_n$ of the downstream channels, when data is to be transmitted upstream from the customer stations.
3. A system according to claim 2, in which n is greater than or equal to 16.
4. A system according to any one of the preceding claims, in which the system includes at least 16 customer stations (3) and the optical source (4) of the head station has an optical power output of substantially 1mW.
5. A system according to any one of the preceding claims, in which the head station (1) includes a bi-refrigrant coupler (10) arranged to couple the output of the modulator (5) to the network (2).
6. A system according to any one of the preceding claims, in which the head station includes a further head-end optical source (4) having a frequency f_0 and an associated modulator (5), the n channels of the corresponding sub-carrier multiplex having frequencies $f_1, f_2, \dots, f_n$ separated in frequency - space from each other and f_0 and from $f_0, f_1, f_2, \dots, f_n$.

Patentansprüche

1. System für die Verteilung einer Vielzahl von Kanälen von einer Hauptstelle (1) auf eine Zahl von Nebenstellen (3), das umfaßt: eine Hauptstelle (1), die eine Vielzahl von Ausgangskanälen entsprechend häufig bedienen kann, eine Vielzahl von Nebenstellen (3) und ein passives verzweigtes optisches Breitbandnetzwerk (2), das an den Ausgang der Hauptstelle (1) gekoppelt ist und die Ausgangskanäle von der Hauptstelle (1) auf die Nebenstellen (3) verteilen kann, wobei jede Nebenstelle (3) einen kohärenten Empfänger (6, 7, 8, 16) mit einem lokalen Laseroszillator (7) umfaßt, und so angeordnet ist, einen selektierten unter den Kanälen zu demodulieren: dadurch gekennzeichnet, daß die Hauptstelle (1) kopfseitig eine optische



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In the preferred embodiment digital modulation is used and then it is straightforward to provide polarisation independence in the demodulation at the receiver. If however it is required to carry analogue modulated signals on the network then polarisation scrambling is used at the receiver to provide the required polarisation independence. The techniques of polarisation scrambling in coherent detection are described in detail in the paper by T.G. Hodgkinson et al. published at pages 513-514 of Electronics Letters, Vol. 23, No.10, 7th May 1987.

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2. A system according to claim 1, in which each customer station includes frequency control means (8, 9) arranged to control the frequency of the local laser oscillator (7), and a modulator (13) arranged to receive at least a portion of the light output by the local oscillator laser and to modulate the light received from the local oscillator laser with data for transmission upstream to the head station (1), the frequency control means being arranged to select a frequency f_0 , where f_0 is a frequency different from the frequencies $f_1, f_2, \dots, f_n$ of the downstream channels, when data is to be transmitted upstream from the customer stations.
3. A system according to claim 2, in which n is greater than or equal to 16.
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5. A system according to any one of the preceding claims, in which the head station (1) includes a bi-refrigent coupler (10) arranged to couple the output of the modulator (5) to the network (2).
6. A system according to any one of the preceding claims, in which the head station includes a further head-end optical source (4) having a frequency f_0 and an associated modulator (5), the n channels of the corresponding sub-carrier multiplex having frequencies $f_1, f_2, \dots, f_n$ separated in frequency - space from each other and f_0 and from $f_0, f_1, f_2, \dots, f_n$.

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Quelle (4) mit einer Frequenz f_0 und einen dazugehörigen Modulator (5) hat, der Licht von der optischen Quelle (4) empfangen kann und das Licht mit einer Subträgervielfalt von n Kanälen modulieren kann, wobei n eine ganze Zahl größer als 2 ist, und die n Kanäle die Frequenzen $f_1, f_2, \dots, f_n$ haben, die im Frequenzraum voneinander und von f_0 getrennt sind, wobei der Ausgang des Modulators den Ausgang der kopfseitigen Station (1) bildet.

2. System nach Anspruch 1, in welchem jede Nebenstelle eine Frequenzsteuervorrichtung (8, 9) umfaßt, die die Frequenz des lokalen Laseroszillators (7) steuern kann, und einen Modulator (13), der wenigstens einen Teil des Lichtes, das von dem lokalen Laseroszillator emittiert wird, empfängt und das von dem lokalen Laseroszillator empfangene Licht mit Daten für die Stromaufwärtsübertragung an die Hauptstelle (1) modulieren kann, wobei die Frequenzsteuervorrichtung eine Frequenz f_0 selektieren kann, wobei f_0 eine Frequenz ist, die sich von den Frequenzen $f_1, f_2, \dots, f_n$ der stromabwärtigen Kanäle unterscheidet, wenn Daten stromaufwärts von den Nebenstellen übertragen werden sollen.
3. System nach Anspruch 2, bei welchem n größer oder gleich 16 ist.
4. System nach einem der vorangehenden Ansprüche, bei welchem das System wenigstens 16 Nebenstellen (3) umfaßt und die optische Quelle (4) der Hauptstelle die optische Ausgangsleistung von etwa 1 mW hat.
5. System nach einem der vorangehenden Ansprüche, bei welchem die Hauptstelle (1) einen doppelbrechenden Koppler (10) umfaßt, der den Ausgang des Modulators (5) ins Netzwerk (2) koppeln kann.
6. System nach einem der vorangehenden Ansprüche, bei welchem die Hauptstelle eine weitere kopfseitige optische Quelle (4) mit einer Frequenz f_0' sowie einen dazugehörigen Modulator (5) umfaßt, wobei die n Kanäle der entsprechenden Subträgervielfalt die Frequenzen $f_1', f_2', \dots, f_n'$ haben, die im Frequenzraum voneinander und von f_0' sowie von $f_0, f_1, f_2, \dots, f_n$ getrennt sind.

Revendications

1. Système pour distribuer une pluralité de canaux depuis un poste de tête de réseau (1) à un nombre de postes d'abonnés (3), comportant un poste de tête de réseau (1) agencé de manière à dé-

livrer une pluralité de canaux de sortie à des fréquences respectives, une pluralité de postes d'abonnés (3), et un réseau optique dérivé passif à large bande (2) couplé à la sortie du poste de tête de réseau (1) et agencés de manière à distribuer les canaux de sortie depuis le poste de tête de réseau (1) aux postes d'abonnés (3), chaque poste d'abonné (3) possédant un récepteur cohérent (6,7,8,16) possédant un laser oscillateur local (7) et agencé de manière à démoduler l'un sélectionné des canaux; caractérisé en ce que le poste de tête de réseau (1) comprend une source optique de tête de réseau (4) possédant une fréquence f_0 ; et un modulateur associé (5) agencé de manière à recevoir une lumière de la source optique (4) et à moduler la lumière avec un multiplex de sous-porteuses de n canaux, n étant un entier supérieur à 2, les n canaux possédant les fréquences $f_1, f_2, \dots, f_n$ séparées les unes des autres et de f_0 dans une gamme de fréquences, la sortie du modulateur constituant la sortie du poste de tête de réseau (1).

2. Système selon la revendication 1, dans lequel chaque poste d'abonné comprend des moyens de commande de fréquence (8, 9) agencés de manière à commander la fréquence de l'oscillateur local (7), et un modulateur (13) agencé de manière à recevoir au moins une partie du signal de sortie lumineux délivré par le laser de l'oscillateur local, et à moduler la lumière reçue de la part du laser de l'oscillateur local, au moyen de données pour une retransmission amont au poste de tête de réseau (1), les moyens de commande de fréquence étant agencés de manière à sélectionner une fréquence f_0 , f_0 étant une fréquence différente des fréquences $f_1, f_2, \dots, f_n$ des canaux aval, lorsque des données doivent être transmises en amont à partir des postes d'abonnés.
3. Système selon la revendication 2, dans lequel n est supérieur ou égal à 16.
4. Système selon l'une quelconque des revendications précédentes, dans lequel le système comprend au moins 16 postes d'abonnés (3) et la source optique (4) du poste de tête de réseau possède une puissance de sortie optique égale sensiblement à 1 mW.
5. Système selon l'une quelconque des revendications précédentes, dans lequel le poste de tête de réseau (1) comprend un coupleur biréfringent (10) agencé de manière à accoupler la sortie du modulateur (5) au réseau (2).
6. Système selon l'une quelconque des revendica-



tions précédentes, dans lequel le poste de tête de réseau comprend une autre source optique de tête de réseau (4) possédant une fréquence f_0 , et un modulateur associé (5), les n canaux du multiplex de sous-porteuses correspondant possédant des fréquences $f_1, f_2, \dots, f_n$, séparées les unes des autres et de f_0 ainsi que de $f_0, f_1, f_2, \dots, f_n$, dans la gamme des fréquences.

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