

Performance evaluation of coherent subcarrier multiplexed optical distribution systems with common local oscillators

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Abstract: Coherent subcarrier multiplexed local distribution systems using a common local oscillator (LO) in which the LO is provided by a distribution centre instead of locally generated at the subscriber premise are described. Both single and multiple optical carrier systems are considered. Because of the low path loss in a local optical network, a common LO system is possible with a LO shared by many subscribers, and indeed provides many advantages. First, a simplified receiver is achievable which eliminates a tunable LO, an automatic frequency control (AFC) circuit, a polarisation controller, and an optical coupler. Secondly, the system cost is decreased due to the reduction of components. Thirdly, laser phase noise and intermediate frequency (IF) drift are expected to be minimised. Fourthly, because no active optical components are placed at the subscriber premises, the system reliability is increased. Fifthly, the common LO system can be expanded with optical amplifiers without increasing the number of LO and simultaneous amplification of the message, and LO signals are achievable. By sharing high power, highly frequency stabilised, and very narrow linewidth LO lasers provided by the centre, it is expected that a simple and reliable coherent optical distributing network can be constructed by using common LO.

1 Introduction

The vast bandwidth provided by a single-mode optical fibre can be fully exploited by coherent schemes [1]. The main driving forces of coherent techniques are the enhancement of frequency selectivity and the increased receiver sensitivity, which make coherent modulation attractive, not only in long-haul fibre systems, but also in local optical networks. In a coherent optical system, broadband information can be either frequency division multiplexed (FDM) on several optical carriers with each carrying a dedicated message [2, 3], or they can first be multiplexed on several microwave subcarriers and then

coherent multiplexed on an optical carrier, called coherent subcarrier multiplexing (SCM). This is an effective way to distribute broadband information [4, 5]. In the latter case, because many subcarriers share an optical carrier, the sensitivity is poorer than the former one. However, the coherent SCM system preserves the advantages of using commercially available microwave electronics to implement multichannel transmission without absolute frequency stabilisation and simultaneously transmitting digital and analogue signals, which is attractive in distributing broadband information such as video signals in local optical networks.

At the receiving end, a straightforward way to select a desired channel from a coherent SCM signal is achieved by tuning a tunable LO [5]. Because the tunable LO is individually placed at the subscriber premises, we call such a system an individual LO (ILO) system. Here the LO plays two roles. First, it acts as a spectrum translator which transposes the signal spectrum from optical ($\sim 10^{14}$ Hz) down to electrical domain ($\sim 10^9$ Hz) such that the signal can be processed by electrical means. Secondly, the carrier to noise ratio (CNR) at the IF stage can be improved by increasing the LO power to increase receiver sensitivity. Usually, the tunable LO requires a narrow linewidth laser to reduce phase noise and should co-operate with an AFC circuit to achieve a stable IF. For a distributing system with N subscribers, N pairs of LO and AFC circuits are therefore necessary. Because the tunable LO is costly, the system cost is significant if N is large. In addition, the message signal and the LO signal polarisations should be matched in a heterodyne coherent receiver, and a polarisation controller is necessary which increases receiver complexity and cost.

As an alternative, we can provide the LO from the distribution centre without placing it at the subscriber premises. In this case, the LO is common to all the subscribers, we call such a system the common LO (CLO) system. A CLO system is possible in a local optical network because of low path loss but is impractical in a long-haul system. The sharing of an optical carrier by several microwave subcarriers is the special feature of SCM systems, here the CLO system further extends the sharing feature by replacing the mass tunable LOs at the subscriber premises by a high power, highly frequency stabilised, and very narrow linewidth laser at the centre. The idea of common LO had been considered in a coherent ring network [6] and the sharing of a common LO at the remote hub station of a coherent SCM system had been discussed [7]. Here, we consider the application of

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using common LO at the distribution centre of a coherent SCM distribution system and compare CLO systems with ILO systems. It is apparent that the use of a common LO can translate the signal from optical domain to electrical as in ILO systems. However, because the LO is provided by the centre, its power is expected to be smaller than that placed at the receiver due to path and branch losses. Hence, poorer sensitivity is expected compared to an ILO system if the same LO is used. To compensate the LO power due to path and branch losses, we can employ high power lasers or optical amplifiers. As few lasers are used, we can implement the system with highly frequency stabilised and very narrow linewidth lasers to minimise IF drift and phase noise. In addition, the receiver structure at the subscriber premises can be greatly simplified.

2 Single carrier system

Many topologies can be used to implement a local optical network [8]. Among them, star topology provides maximum potential bandwidth to each subscriber and maximum flexibility in future upgrading, hence we consider it in our system. The star topology also provides an additional advantage for a CLO system in considering optical nonlinearity. With the star topology, the high power LO signal is split to many subscribers at the distribution centre, so that the optical power launched into the outgoing fibre is believed to be lower than the threshold to cause significant nonlinear conversion [9]. This may not be true for the other topologies.

To further increase the capacity of a coherent SCM system, multiple optical carriers can be employed with each carrying several microwave subcarriers. Compared to a single carrier SCM system, the multicarrier SCM system can increase information capacity by M times if M optical carriers are used. We will describe a coherent SCM system with a single optical carrier in this Section, whereas multicarrier system is discussed in the following Section. We will use the carrier to noise ratio (CNR) at the IF stage to gauge the system performance.

2.1 ILO system

The block diagram of a single carrier individual LO (SC-ILO) coherent star SCM system is shown in Fig. 1 where a centre distributes a coherent SCM signal to N subscribers. q messages with each modulated on a microwave voltage control oscillator (VCO) are summed by a power combiner. The combined microwave signal then phase modulates an optical carrier and results in a coherent SCM signal. The coherent SCM signal feeds to a 1 : N branch coupler to split the signal to N subscribers.

Each receiver at the subscriber premises employs a tunable LO and an AFC circuit to select the desired signal channel. The polarisation controller (PC) is necessary to match the LO polarisation with that of the message signal [10, 11]. A 3 dB coupler is used to mix the message signal and the LO signal, whereas the photodetector (PD) performs the optical/electrical conversion. After passing through the PD, the IF signal reaches a bandpass filter (BPF) with a fixed central frequency f_{BPF} . The selection of a specific channel is achieved by tuning the LO signal and the selected channel is equal to f_{BPF} , therefore only the selected signal can pass through the BPF and baseband information is recovered by a demodulator [5]. With suitable channel spacing, the

channel crosstalk can be neglected. Assuming negligible laser phase noise, the CNR at the IF stage with the consideration of intermodulation distortion (IMD) can be formulated as [5]

$$CNR = 10 \log \frac{2R^2 P_{Li} P_{si} J_1^2(\beta) [J_0(\beta)]^{2q-2}}{\sigma_{sh}^2 + \sigma_{th}^2 + \sigma_{3rd}^2} \quad (1)$$

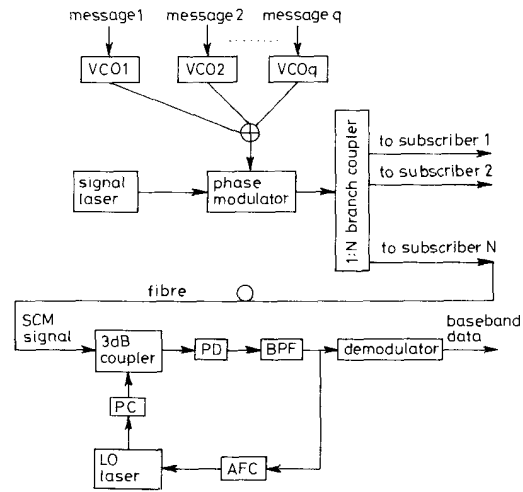


Fig. 1 System block diagram of SC-ILO system

where

$$\sigma_{sh}^2 = 2eR(P_{Li} + P_{si})BW \quad (2)$$

$$\sigma_{th}^2 = N_c BW \quad (3)$$

$$\sigma_{3rd}^2 = 2h_3 K_3 R^2 P_{Li} P_{si} J_3^2(\beta) [J_0(\beta)]^{2q-6} \quad (4)$$

where σ_{sh}^2 , σ_{th}^2 and σ_{3rd}^2 denote the shot noise, thermal noise, and third order IMD noise, respectively. The thermal noise is caused by the amplifiers after the PD (not shown). Here we assume that the q microwave subcarriers are restricted to one octave so that the second order IMD noise is not present. The parameters are given as

- R = PD responsivity (1A/W)
- P_{Li} = the LO signal power incident on the PD
- P_{si} = the message signal power incident on the PD
- $J_i(\cdot)$ = Bessel function of the first kind of order i
- β = phase modulation index (0.17)
- e = electron charge
- BW = BPF bandwidth (200 MHz)
- N_c = thermal noise power spectral density (1.65×10^{-22} A²/Hz)
- q = number of subcarriers (10)
- h_3 = a constant (0.9)
- K_3 = number of third order IMD products (26)

We see that the thermal noise is independent of P_{Li} whereas the shot noise is proportional to $P_{Li} + P_{si}$ and the IMD noise is proportional to the product of P_{Li} and P_{si} . An example of CNR as a function of LO signal power is shown in Fig. 2. It is seen that the increase in LO signal power can significantly improve CNR when P_{Li} is low and the improvement begins to level off when P_{Li} reaches a certain level. When LO signal power is low, the thermal noise dominates so that CNR increases sig-

nificantly with LO signal power. When LO signal power becomes large, shot noise and IMD noise may dominate so that CNR increases less with LO signal power. The incident LO and message signal powers on the PD can be written as

$$P_{Li} = \frac{P_{LO} \gamma_{pc} \gamma_b}{2} \quad (5)$$

$$P_{si} = \frac{P_{s0} e^{-\alpha L} (1 + \log_2 N)}{2N} \quad (6)$$

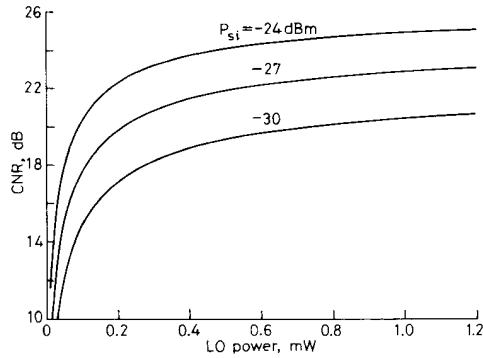


Fig. 2 CNR as function of LO signal power

where P_{LO} and P_{s0} denote the LO output power at the receiver and the coherent SCM signal power at the phase modulator output in the centre, respectively. γ_{pc} , $\gamma_b < 1$ denote the loss of the polarisation controller and the excess loss of the 3 dB branch coupler, respectively. We assume that the 1 : N coupler is formed by $\log_2 N$ stage 3 dB couplers. α is the fibre loss coefficient and L is the fibre length. The factor 2 in both equations accounts for the branch loss of the 3 dB coupler whereas the factor N in eqn. 6 is due to the branch loss of the 1 : N branch coupler. In the following examples, we take $\gamma_b = 0.5$ dB, $\gamma_{pc} = 3$ dB, $\alpha = 0.2$ dB/km, and $L = 10$ km.

Fig. 3 shows the CNR degradation as the number of distributed subscribers increases. With $P_{LO} = 5$ dBm, we

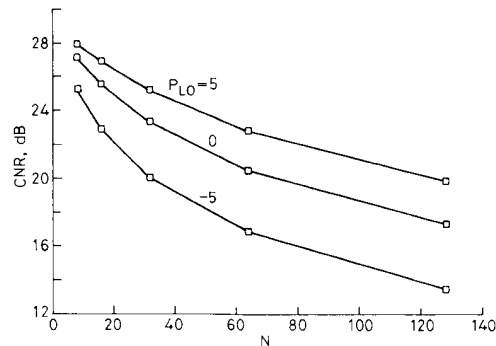


Fig. 3 CNR as function of N for SC-ILO system

can achieve 20 dB CNR for $N = 128$, whereas the number of served subscribers are limited to 32 for the same CNR when $P_{LO} = -5$ dBm.

2.2 CLO system

The transmitter in the centre of a single carrier common LO (SC-CLO) coherent SCM star network is shown in Fig. 4. A coherent SCM signal with many subcarriers is combined with the LO signal by a 3 dB coupler. The frequency of the LO is fixed instead of tunable and is controlled by an AFC circuit to maintain a definite deviation

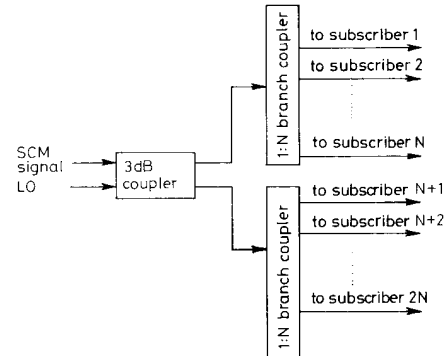


Fig. 4 Schematic illustration of transmitter of SC-CLO system

from the optical carrier frequency. This frequency deviation will become the IF at the receiving end. The outputs of the 3 dB coupler are fed to two 1 : N branch couplers and then transmitted to subscribers through single-mode fibres. With this arrangement, the centre can serve 2N subscribers. We assume that the state of polarisation of the SCM signal and the LO output are linearly polarised and well adjusted to the same direction.

The degradation of polarisation degree along a single-mode optical fibre had been theoretically studied in Reference 12 based on splitting the incident wave into two eigenpolarisation modes with different group velocities. It is found that the polarisation degree can be preserved if only one eigenpolarisation mode is excited at the input end, whereas maximum degradation occurs when the two eigenpolarisation modes are equally excited. Consider a system with a message signal and a LO signal which are linearly polarised along the same direction and the degree of polarisation of the two signals, P , is equal to unity at the input end. Let ω_{sp} denote the angular frequency spacing between the message and LO signals, and $\delta\omega_s$ and $\delta\omega_{LO}$ denote their linewidths, respectively. After propagating a distance L along a single-mode fibre, the polarisation degree becomes [12]

$$P = [1 - (1 - |r|^2)(4R_1 R_2)]^{1/2} \quad (7)$$

where

$$R_1 + R_2 = 1 \quad (8)$$

$$r = \frac{\delta\omega_s \exp[-(\delta\omega_s \Delta\tau L/2)] + K\delta\omega_{LO} \exp[-(\delta\omega_{LO} \Delta\tau L/2)] \exp(j\omega_{sp} \Delta\tau L)}{\delta\omega_s + K\delta\omega_{LO}} \quad (9)$$

Here, R_1 and R_2 are the splitting ratios of the incident wave into the two eigenpolarisation modes, respectively. $\Delta\tau$ is the group delay difference between the two eigenpolarisation modes and K is the power ratio of the LO signal to the message signal. As an illustrating example, consider a system with $\omega_{sp} = 2\pi \times 5$ GHz, $\delta\omega_s = 2\pi \times 200$ MHz, $\delta\omega_{LO} = 2\pi \times 1$ MHz, $\Delta\tau = 1$ ps/km, $K = 1$, and $L = 10$ km. The polarisation degree with

$R_1 = 0.5$, $R_2 = 0.5$ is calculated to be equal to 0.99. We see that even under the worst case condition, when the two eigenpolarisation modes are equally excited, the polarisation degree degrades very little after 10 km transmis-

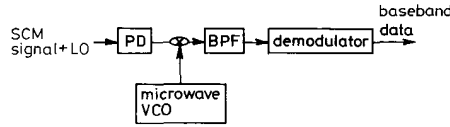


Fig. 5 Receiver structure of SC-CLO system

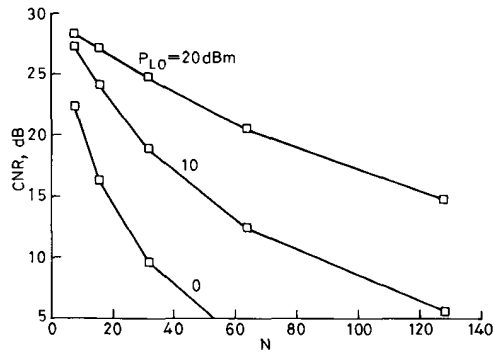


Fig. 6 CNR against N for SC-ILO system
 $P_{s0} = 0$ dBm

sion distance. Thus, we expect that the polarisation degree of the SCM and LO signals is nearly preserved. On the other hand, the states of polarisation of the SCM and LO signals are in general different at the receiving end due to polarisation mode dispersion [13, 14]. However, it is shown that the degradation due to the mismatch in states of polarisation of the LO and SCM signals is negligible in a local network with short transmission distance and narrow frequency deviation [15]. Therefore, the degradation of the CLO system due to polarisation mode dispersion is neglected in the following discussions.

The receiver at the subscriber premises, shown in Fig. 5, is much simpler than that used in an ILO system. Because the signal and LO have been mixed together, they can be directly detected by the PD. Thus, the cost of the system can be greatly reduced and the reliability can be enhanced because the mass number of complicated polarisation controllers, 3 dB couplers, tunable LOs and AFC circuits at the subscribers premises are eliminated. Because the LO frequency is fixed, the selection of a specific channel is accomplished by electrical means instead of optical tuning. Here, a tunable microwave VCO cooperated with a BPF is used to select a specific channel and a demodulator is employed to recover baseband signal.

The message and LO signal powers incident on the PD are easily obtained as

$$P_{Li} = \frac{P_{LO} e^{-\alpha L_b} \gamma_b^{1+\log_2 N}}{2N} \quad (10)$$

$$P_{si} = \frac{P_{s0} e^{-\alpha L_b} \gamma_b^{1+\log_2 N}}{2N} \quad (11)$$

where the losses due to the 3 dB coupler and the 1 : N coupler at the centre are considered. We see that the LO

power is decreased because of the path and branch losses whereas P_{si} is the same as that in the SC-ILO system.

Fig. 6 shows the relationship between CNR and N for various LO signal levels. For $P_{LO} = 0$ dBm, CNR decreases rapidly as N increases. Because the thermal noise dominates at low signal level, CNR decreases as the number of subscribers increases owing to the increased branch loss which weakens the message and LO signal powers. For $P_{LO} = 20$ dBm, we see a slower CNR degradation as N increases. When high power LO is applied, the shot noise and thermal noise dominate and they are proportional to P_{Li} so that CNR is less degraded. Hence, the CNR of a CLO system can be improved and the number of served subscribers can be increased by using a high power LO laser.

3 Multicarrier system

The information carrying capability of a coherent SCM system can be greatly increased by adopting multiple optical carriers with each carrying several microwave subcarriers. If we use M optical carriers, the capacity can increase M times. Thus, the multicarrier SCM system is an effective way to use fibre bandwidth. Again, a coherent multicarrier system can use individual or common LOs. Here, both systems are considered.

3.1 ILO system

The transmitter of a coherent SCM system with multiple carrier and individual LO (MC-ILO) is shown in Fig. 7

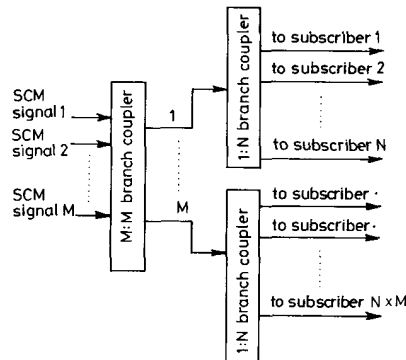


Fig. 7 Schematic illustration of transmitter of MC-ILO system

where M optical carriers are employed. The M SCM signals are formed by M coherent subcarrier multiplexed optical carriers and then are combined with an optical coupler. For an optical coupler with M input ports, if we assume the coupling ratio of the M input ports to output ports is the same, then the maximum coupling ratio for each input to an output port is $1/M$ [16]. Hence, to effectively use the input powers, an $M : M$ optical coupler may be employed to combine the M optical carriers. Each output port of the $M : M$ coupler is fed to a 1 : N coupler and then transmitted to N subscribers. Therefore, each centre can serve $N \times M$ subscribers.

The receiver structure is the same as in Fig. 1 except that we need a tunable LO with wider tuning range to cover the whole signal spectrum. Again, we need a polarisation controller and a 3 dB coupler to effectively mix the message signal with the LO signal. The selection of a specific channel is achieved in a similar way to a SC-ILO system by tuning the LO such that the frequency devi-

ation between the channel and the LO falls within the BPF passband. For the sake of simplicity, we assume the optical carrier frequencies are widely separated so that their mutual interferences are negligible and after heterodyning with the LO, only an optical carrier and the associated subcarriers fall within the IF band and the others are strained out due to limited PD bandwidth. Thus, the CNR is similar to that in a single carrier system except that the message power incident on the PD is given by

$$P_{si} = \frac{P_{s0} e^{-\alpha L \gamma_b^{1 + \log_2 MN}}}{2MN} \quad (12)$$

where we assume the $M:M$ coupler be formed by $\log_2 M$ stage 3 dB couplers. The dependence of CNR on M is depicted in Fig. 8. We see that CNR degrades

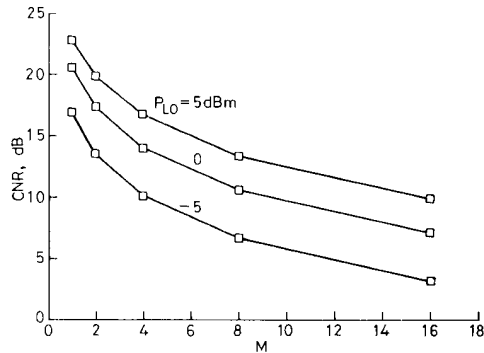


Fig. 8 CNR as function of number of optical carriers for MC-CLO system

$P_{s0} = 0$ dBm, $N = 64$

rapidly with M due to the increased branch loss, and the degradations for different P_{LO} are about the same.

3.2 CLO system

The transmitter of a multicarrier CLO (MC-CLO) system is shown in Fig. 9 where there are M optical carriers and

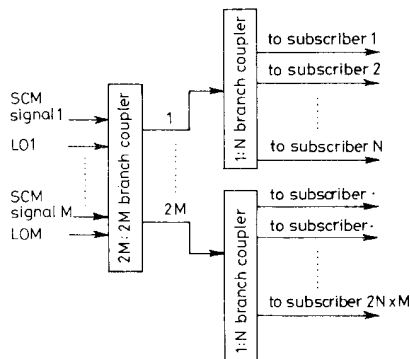


Fig. 9 Schematic illustration of transmitter of MC-CLO system

each carries several microwave subcarriers. A LO is accompanied with every optical carrier. Thus, M LOs are required and they are frequency controlled by AFC circuits to keep definite frequency deviation from their associated optical carriers. To combine the optical carriers and LOs, a $2M:2M$ optical coupler is employed. Because of the presence of M LOs, the ports of the

coupler are two times larger than that in an ILO system. Each output port is fed to a $1:N$ optical coupler to branch to N subscribers, hence, a centre can serve $2M \times N$ subscribers. The branch loss of the $2M:2M$ coupler may become significant if M is large. However, we can employ an optical amplifier to boost the signal at the output port so as to compensate the branch loss. Again we assume the SCM signal and LO signal polarisations are well adjusted to be the same and are maintained throughout the transmission path.

The receiver is shown in Fig. 10 where a tunable optical filter, for example a Fabry-Perot tunable optical

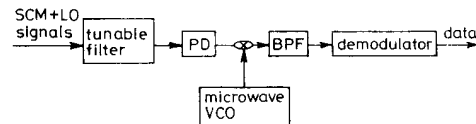


Fig. 10 Receiver structure of MC-CLO system

filter, is placed at the receiver front end to select the desired signal band and the associated LO signal. We assume that the filter passes the selected message and LO signals with negligible distortion and interference from other optical channels. The subcarrier signal is selected by electrical means as in a SC-CLO system. Hence, the CNR for a multicarrier CLO system is similar to a single carrier CLO system except that P_{si} and P_{Li} are different due to the $2M:2M$ optical coupler and the tunable optical filter, given as

$$P_{Li} = \frac{P_{LO} e^{-\alpha L \gamma_b^{1 + \log_2 MN} \gamma_f}}{2MN} \quad (13)$$

$$P_{si} = \frac{P_{s0} e^{-\alpha L \gamma_b^{1 + \log_2 MN} \gamma_f}}{2MN} \quad (14)$$

where γ_f denotes the loss of the tunable optical filter. We see that both the message and the LO signal powers are seriously reduced by the branch losses of the $2M:2M$ and $1:N$ couplers which is expected to result in a low CNR. However, the CNR can be improved by adopting optical amplifiers, such as an erbium doped fibre amplifier [17], to compensate for the branch losses. Because the message and LO signals are mixed together, they can be simultaneously amplified by an optical amplifier. There are two positions where optical amplifiers can be installed. One is at the output ports of the $2M:2M$ coupler at the centre to compensate the branch loss of the coupler. In this case, we just need $2M$ optical amplifiers. The other is at the receiver on the subscriber premises. In this case, we need $2M \times N$ optical amplifiers for the $2M \times N$ subscribers. When an optical amplifier is used at the receiver, we can use a wavelength tunable optical amplifier instead of a tunable optical filter and an optical amplifier, which can simplify the receiver structure. It should be recognised that when optical amplifiers are placed at the centre, since the message and LO signal powers are much larger than those at the receivers, the amplifier gain may be limited by amplifier saturation effect. The experimental result in Reference 17 showed negligible performance degradation due to amplified spontaneous emission noise, indicating that erbium doped fibre amplifiers could be suitable for optical amplification in the MC-CLO systems.

4 Discussion

We have described the single and multiple carrier coherent SCM systems with individual and common LOs. Here we will compare the ILO and CLO systems from several viewpoints.

4.1 Carrier to noise ratio

From previous discussions we see that the major differences between ILO and CLO systems are their received message and LO signal powers.

4.1.1 Single carrier system: The message signal powers for ILO and CLO systems are the same whereas their LO signal powers are different. From eqns. 5 and 10, the LO power of a CLO system differs from that of an ILO system due to the branch loss of the $1:N$ coupler and the fibre loss. As branch loss becomes significant, it can cause serious CNR degradation as shown in Fig. 6. However, because only a LO laser is employed at the centre, we can use a high power laser, for example a high power diode-pumped Nd-YAG laser whose output power may be up to hundreds of milliwatt, to reduce the degradation. On the other hand, we can also adopt an optical amplifier to compensate the branch and the fibre losses.

4.1.2 Multicarrier system: The introduction of a tunable optical filter in a MC-CLO system causes additional loss to the message and LO signals whereas the increased branch loss due to the $2M:2M$ coupler may further reduce the signal powers. Compared to an ILO system, the high branch loss in a CLO system may dramatically degrade the CNR. Again, we can alleviate degradation by using a high power LO laser and employing optical amplifiers.

4.2 Number of components used

The number of components used in the four systems with the transmitters and receivers shown in previous Sections are summarised in Table 1. The use of a common LO can

Table 1: Comparison of components used in four systems

Component	Systems			
	SC-ILO	SC-CLO	MC-ILO	MC-CLO
LO laser	N	1	$M \times N$	$2M$
PC	N	—	$M \times N$	—
3 dB coupler	N	1	$M \times N$	—
$1:N$ coupler	1	2	M	$2M$
$M:M$ coupler	—	—	1	—
$2M:2M$ coupler	—	—	—	1
AFC	N	1	$M \times N$	M
Tunable filter	—	—	—	$2M \times N$
Optical amplifier	—	—	—	required

Note that the number of served subscribers for the four systems are: SC-ILO system: N , SC-CLO system: $2N$, MC-ILO system: $M \times N$, MC-CLO system: $2M \times N$

dramatically eliminate the number of LO lasers, 3 dB couplers, AFC circuits, and polarisation controllers. For single carrier systems, we see that the use of a common LO is most preferable because a very simple receiver is achievable and the number of system components is a minimum. While in the multicarrier system, an additional tunable optical filter should be used at each receiver which causes additional loss. However, the receiver structure of a MC-CLO system is still simpler than that of a MC-ILO system.

4.3 System expansion

In an ILO system, system expansion can be accomplished by using optical amplifiers at appropriate locations to amplify the weakened signals so that they can further distribute to more subscribers with branch couplers. If the LO is placed at the subscriber premises, the number of tunable LO lasers and the associated AFC circuits increase with the number of expanded subscribers. In contrast, we similarly adopt an optical amplifier at an expansion node in a CLO system. Because the message and LO signals are mixed together, they can be simultaneously amplified by an optical amplifier and then further serve more subscribers. Thus the number of LO lasers is not increased while only optical amplifiers are used which can ease system expansion.

4.4 System performance

We have considered the CNR for the four systems. CNR increased with the LO power. The LO power for the CLO system is expected to be smaller than an ILO system because of the branch loss of the branch coupler and fibre loss within the transmission path. For a MC-CLO system, an additional loss due to the tunable optical filter should be considered. On the other hand, loss due to the polarisation controller exists in an ILO system. As described before, the weakened LO power in CLO systems can be compensated for by using high power LO lasers and optical amplifiers.

In the CNR calculation we have neglected the laser phase noise. It can significantly degrade system performance if wide linewidth LO lasers are used. For ILO systems, because the LO laser is placed at the subscriber premises, it is difficult to control the temperature and driving current of the tunable LO lasers. Also, because mass tunable LO lasers are used, it is costly to employ high-quality DFB lasers for the subscribers so that the laser phase noise and the IF drift caused by unstable LO frequency are expected to exist. In comparison, as few LO lasers are used and placed at the distribution centre in a CLO system, the operating conditions of the LO lasers can be circumstantially controlled, and high power, highly frequency stabilised, as well as very narrow linewidth lasers can be adopted so that the phase noise and IF drift can be minimised. Thus, we expect the performance of CLO systems to be superior to ILO systems if the same message and LO signal powers are received.

4.5 System reliability

The tunable laser, for example a multielectrode DFB laser [18], and the polarisation controller are subject to temperature and driving current variations. By placing them at the subscriber premises in an ILO system, it is difficult to control their operating conditions so that the system is easily affected by temperature variation and laser driving current fluctuation. In comparison, if no optical amplification is needed there are no active optical components placed at the subscriber premises in a CLO system. The LO lasers in a CLO system have a fixed frequency and are placed at the distribution centre, the temperature and driving current for the LOs can be deliberately controlled. We can also prepare standby LOs to immediately replace failed LOs. Thus, a CLO system is expected to be more reliable than an ILO system.

5 Conclusion

We have described coherent SCM distribution systems with a common LO. We investigate both singlecarrier

and multicarrier systems. The transmitter at the distribution centre and the receiver at the subscriber premises are considered and the CNR at the IF stage is discussed. The comparisons between the individual and common LO systems are made from several viewpoints. With common LO, the receiver at the subscriber premises can be simplified which eliminates a tunable LO laser with the associated AFC circuit, a 3 dB coupler, and a polarisation controller. This simplified receiver can significantly reduce system cost, particularly in a single carrier system. The use of common LO can also minimise laser phase noise and IF drift. We can use an optical amplifier to compensate the branch and transmission losses of the common LO signal and the SCM signal simultaneously which is the special feature of common LO systems. The expansion of a CLO system is easy without increasing the number of LO lasers and only optical amplifiers are necessary. The CLO system is more reliable because the active optical components are placed at the distribution centre which can be well controlled and standby devices can be prepared to immediately replace failed ones.

The common LO may differ somewhat from the usual understanding of local oscillator because it is remotely provided but not locally generated. However, here we can view the common LO as a spectrum translator which travels through the network and transposes the message signal from optical spectrum down to electrical. Because of the low path loss, the common LO can be present in a local optical network but is impractical in a long-haul system. By using high power lasers and optical amplifiers, the performance of a CLO system can be the same or even better than an ILO system because of the reduced laser phase noise and IF drift. Also, a simpler optical distributing network is possible because of the simplified receiver which is attractive in broadband distribution systems.

6 References

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