vation plane has to be payed for the compensation. The investigations were carried out for two linear polarisations in the frequency band 9–11 GHz. Except for the typical beamwidth/frequency dependence of an aperture radiator the performance of the corrugated feed horn did not change remarkably. Fig. 3 shows the influence of the dielectric inserts on cross over level and peak cross-polarisation within the 1 dB beamwidth of the shell antenna for horizontal and vertical polarisation.

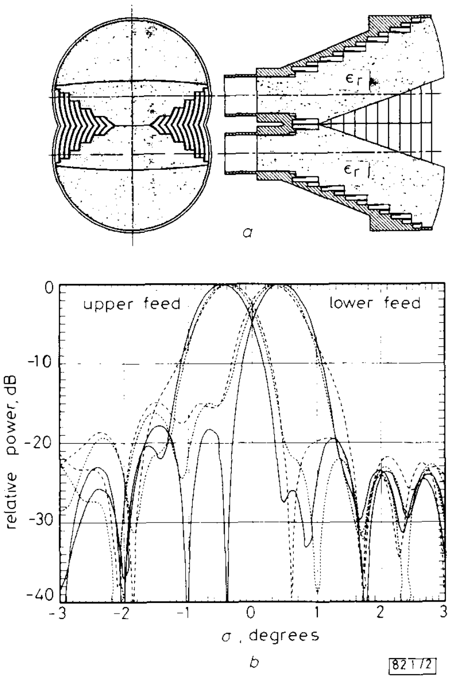

Fig. 2 *Corrugated dual feed horn with dielectric insert*

a Front view and cross-sectional view

b Radiation pattern of 3 m shell antenna in elevation plane 10 GHz; horizontal polarisation

——— $\varepsilon_r = 1\cdot 0$

------ $\varepsilon_r = 1\cdot 1$

–––– $\varepsilon_r = 1\cdot 2$

Conclusion: It is possible to produce a very simple dual feed horn by cutting off a part of one side of a corrugated horn and fitting two of them together. A common ridge between both horns and, at least, one complete slot in each horn part is necessary to decouple them sufficiently. The horn can be used for orthogonal polarisations with good cross-polar performance over a frequency band of about 20%. A conventional dual-offset reflector antenna can be equipped by this dual feed horn with only minor constructional changes in order to enable the use of angle diversity on digital radio-relay links with its clear improvement in case of multipath fading.

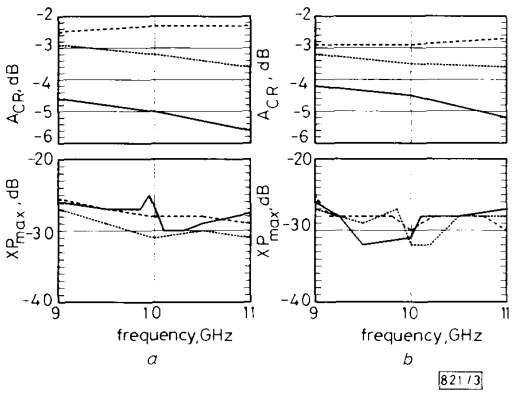

Fig. 3 *Cross-over level and peak cross-polar level of shell antenna with corrugated dual feed*

——— $\varepsilon_r = 1\cdot 0$

······· $\varepsilon_r = 1\cdot 1$

------ $\varepsilon_r = 1\cdot 2$

a Horizontal polarisation

b Vertical polarisation

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COHERENT SUBCARRIER MULTIPLEXED STAR DISTRIBUTION SYSTEM USING SINGLE LOCAL OSCILLATOR

Indexing terms: Optical communications, Networks and network topologies

Taking advantage of the low path loss in a local optical network, a coherent subcarrier multiplexed star distribution system with a local oscillator (LO) generated at the centre and shared by all the subscribers is introduced. The potential advantages of this single LO system include: simple receiver structure, system cost effectiveness, enhanced system reliability, minimised laser phase noise and IF drift, as well as easy system expansion.

Introduction: Coherent subcarrier multiplexed (SCM) schemes are an effective way to exploit the vast bandwidth provided by single mode optical fibres.[1,2] They are particularly useful in distributing broadband information such as video signals by firstly modulating the broadband signals on several microwave subcarriers and then modulating the subcarriers on a coherent optical carrier. In this way we can use commercially available microwave electronics to implement multichannel transmission systems.

In a coherent SCM distribution system, the number of receivers at the subscriber premises are usually costly because each subscriber needs a tunable LO to select a specific channel and an automatic frequency control (AFC) circuit to obtain a stable intermediate frequency (IF).[2] An optical coupler operating with an polarisation-state controller is also required to effectively mix the SCM signal with the LO signal in the subscribers premises,[3] Thus the system is significant if the number of subscribers is large.

Taking advantage of the low path loss in a local optical network, we consider a rather different approach to the implementation of a coherent SCM distribution system by using a single LO laser. The single LO distribution system is formed by employing a high power, highly frequency stabilised, very narrow linewidth, and fixed frequency LO laser at the distribution centre instead of using a tunable LO laser at each subscriber premises. The LO signal is mixed together with the SCM signal at the centre and distributed to the subscribers through singlemode fibres. In this case since the LO is common to all the subscribers, we call such a system the common LO system. An apparent advantage of using the common LO system is the replacement of mass number of LO lasers at the receivers of subscriber premises with a high power LO at the centre. There are many other advantages of this system and it is expected that a simple and reliable distribution system can be constructed with a common LO. This letter intends to describe the common LO system and show its potential advantages.

Analysis: Fig. 1 shows the coherent SCM common LO distribution system with a star configuration. q digital messages are frequency modulated on microwave voltage control oscillators (VCOs) to form FSK modulated microwave subcarriers. After the power combiner, the microwave subcarrier phase modulates the signal laser which results in a coherent SCM signal. Then the SCM signal and a LO signal are coupled into the 3 dB coupler and the 1 : N couplers as shown in Fig. 1. An appropriate AFC circuit is employed to maintain a definite frequency deviation between the signal and the LO lasers.

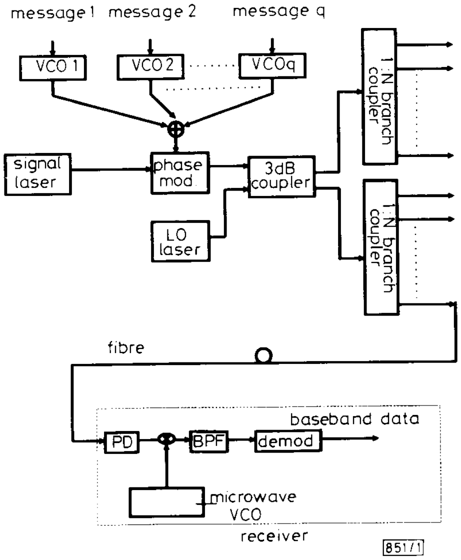

Fig. 1 *Coherent SCM star system with single LO*

This frequency deviation will become the IF at the receiving end. We assume the state of polarisations of the SCM signal and the LO output are linearly polarised and they are well adjusted to the same direction at the centre. In a local distribution network with short transmission distance, the degree of polarisations of the two signals are almost preserved[4] and we expect that the two waves nearly polarise along the same direction at the receiving end. We can also use polarisation-maintaining fibres if the distribution length is long enough to result in noticeable polarisation mismatch between the two signals.

At the receiver of the subscriber premises, the combined SCM and LO signals are directly detected by a photodetector (PD) without complicated mixing process resulting in a very simple receiver. The PD performs optical/electrical conversion and transposes the signals from optical spectrum down to the IF band. Since the LO frequency is fixed, the selection of a specific channel is accomplished by electrical means instead of optical tuning. We use a tunable microwave VCO and a bandpass filter (BPF) to select a specific channel and employ an FSK demodulator to recover the baseband data. With a common LO we can eliminate a tunable laser, a polarisation-state controller, an AFC circuit, and an optical coupler at each receiver thus significantly reducing the system cost. The complicated optical mixing has been accomplished at the distribution centre and the channel selection is reached by electrical tuning instead of optical tuning so that the receiver structure is greatly simplified. The sharing of an optical carrier by many microwave subcarriers is the special feature of a SCM system. The common LO system further extends this feature with a LO shared by all the subscribers thus significantly reducing the system complexity and cost.

From Fig. 1 the SCM and LO signal powers incident on the PD are easily obtained as

$$P_{si} = \frac{P_{s0}\, e^{-\alpha L} \gamma^{1 + \log_2 N}}{2N} \tag{1}$$

$$P_{Li} = \frac{P_{L0}\, e^{-\alpha L} \gamma^{1 + \log_2 N}}{2N} \tag{2}$$

where P_{s0} and P_{L0} denote the SCM signal power at the phase modulator output and the LO output power in the centre. L and α are the fibre length and loss coefficient, respectively. $\gamma < 1$ accounts for the excess loss of the 3 dB coupler and we assume the 1 : N branch coupler is formed by $\log_2 N$ stage 3 dB couplers. The factor $2N$ in both equations is caused by the branch losses of the 3 dB coupler and the 1 : N branch coupler.

With negligible laser phase noise, the carrier to noise ratio (CNR) at the IF stage with the consideration of intermodulation distortion (IMD) can be formulated as[2]

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

where

$$\sigma_{sh}^2 = 2eR(P_{Li} + P_{si})BW \tag{4}$$

$$\sigma_{th}^2 = \frac{NFkTBW}{R_L} \tag{5}$$

$$\sigma_{3rd}^2 = 2h_3 K_3 R^2 P_{Li} P_{si} J_1^6(\beta)[J_0(\beta)]^{2q-6} \tag{6}$$

where σ_{sh}^2, σ_{th}^2 and σ_{3rd}^2 denote the shot noise, thermal noise, and third-order IMD noise, respectively. We assume the q microwave subcarriers are restricted to one octave so that the second-order IMD noise is not present. R is the PD resposivity, β is the phase modulation index, e is the electron charge, BW is the BPF bandwidth, NF is the circuit noise figure, k is the Boltzmann constant, T is the absolute temperature, R_L is the load resistance, h_3 is a constant, and K_3 is the number of third order IMD products.

Discussion and conclusion: Fig. 2 shows the relationship between CNR and N for various LO signal levels. For $P_{LO} =$ 0 dBm, CNR decreases rapidly as N increases. The thermal noise dominates at low signal level so CNR decreases as the number of subscribers increases because of the increased branch loss which weakens the SCM and LO signal powers.

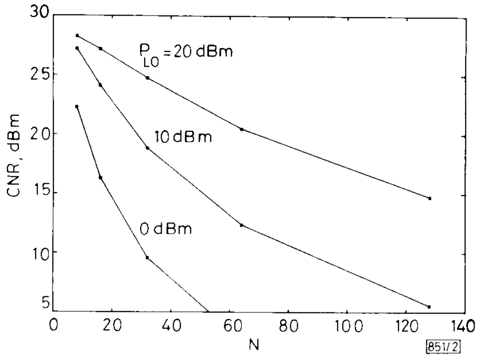

Fig. 2 *CNR against N*

$P_{s0} = 0$ dBm; $\gamma = 0{\cdot}5$ dB; $\alpha = 0{\cdot}2$ dB/km; $L = 10$ km
$\beta = 0{\cdot}17$; $BW = 200$ MHz; $NF = 3$ dB; $T = 300$ K
$R_L = 50\,\Omega$; $q = 10$; $h_3 = 0{\cdot}9$; $K_3 = 26$

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 which are proportional to P_{Li} dominate, so that CNR is less degraded. Fig. 3 illustrates the relationship between CNR and the LO signal power. The required CNR to achieve 10^{-9} bit error rate is estimated to be about 18 dB.[2] For $N = 32$, we see that the required LO output power to achieve 18 dB CNR is about 10 dBm. For $N = 128$, a high power LO laser is needed to achieve the acceptable CNR because of the serious branch loss. From both Figures we conclude that a common LO system is indeed applicable to local distribution system which can serve a number of subscribers with only a high power LO laser. It is partly because of the short transmission distance in a local optical network so that the path loss is not significant, and partly because we just need a medium LO power level to reach the acceptable CNR, that if the LO power at the centre is high enough it indeed can be shared by many receivers.

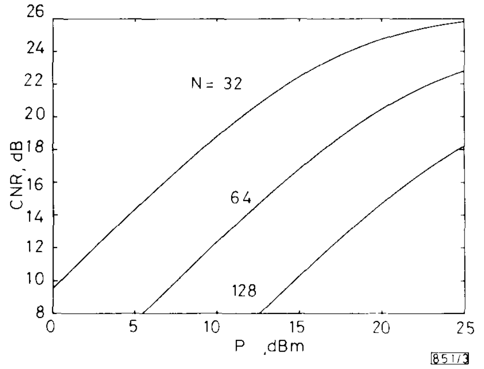

Fig. 3 *CNR against P_{LO}*

$P_{s0} = 0\,\text{dBm}; \gamma = 0{\cdot}5\,\text{dB}; \alpha = 0{\cdot}2\,\text{dB/km}; L = 10\,\text{km}$
$\beta = 0{\cdot}17; BW = 200\,\text{MHz}; NF = 3\,\text{dB}; T = 300\,\text{K}$
$R_L = 50\,\Omega; q = 10; h_3 = 0{\cdot}9; K_3 = 26$

In addition to the use of simple and low cost receivers, there are other advantages provided by the common LO system. Since only an LO laser is employed and located at the distribution centre, its operating environment can be circumstantially controlled and we can adopt a very narrow linewidth and highly frequency stabilised laser to implement the LO, thus minimising the laser phase noise and the IF drift to improve the system performance. There are no active optical components placed at the receivers of the subscriber premises and we can also prepare a standby LO at the centre to enhance the system reliability. We can expand the system to more subscribers by employing optical amplifiers at appropriate locations. Since the SCM and LO signals are mixed together in the transmission fibre, they can be simultaneously amplified by an optical amplifier. In addition, we do not need additional LO lasers. The common LO system can thus be easily expanded.

In conclusion we have considered a coherent SCM star distribution system using a single LO laser at the distribution centre. The system is significantly different from long haul coherent systems where the LOs are generally located at the receiving end. Taking advantage of the short transmission path and the low loss nature of singlemode optical fibres, the common LO system is found to be possible and indeed provides many advantages. We expect a simple, low cost, reliable and easily expanded coherent distribution system can be implemented by using a common LO.

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FORMULA FOR THE STEADY-STATE GAIN OF A RECURSIVE ESTIMATOR

Indexing terms: Markov fields, Recursive estimation, Image processing

A formula for the direct computation of the steady-state gain of a recursive estimator is derived. The estimator is presented as a general 3-D recursive filter for noise smoothing of 3-D wide-sense Markov fields. The 1-D and 2-D estimators are special cases of the general filter presented. The filter with its steady-state gain computed from the derived formula is very useful because of its computational efficiency.

Noise is almost always present in recorded images or image sequences, therefore noise filtering will improve the visual quality of the images and the performance of subsequent image processing tasks (e.g., coding). In general, let $y(\boldsymbol{n})$, where $\boldsymbol{n} = (n_1, n_2, n_3)$, be the observed noisy image sequence

$$y(\boldsymbol{n}) = x(\boldsymbol{n}) + v(\boldsymbol{n}) \tag{1}$$

where $x(\boldsymbol{n})$ (with variance σ_x^2) and $v(\boldsymbol{n})$ (with variance σ_v^2) are the original image sequence and white Gaussian observation noise independent of $x(\boldsymbol{n})$, respectively. The original image sequence is modelled by a wide-sense stationary process which has the following 3-D autocorrelation function:

$$R_x(l_1, l_2, l_3) = \sigma_x^2 \rho_1^{|l_1|} \rho_2^{|l_2|} \rho_3^{|l_3|} \tag{2}$$

This separable model represents a 3-D wide-sense Markov field and results in mathematically tractable expressions. The parameters ρ_1 and ρ_2 are the vertical and horizontal spatial correlation coefficients, respectively, and ρ_3 is the temporal correlation coefficient. When dealing with image sequences the motion-compensated frames should be used in place of the original frames in eqn. 1. Otherwise, unacceptable smoothing of edges result because of the significant motion of large objects. Thus, ρ_3 represents the temporal correlation coefficient in the motion trajectory.[3] The 2D case has been extensively used for image processing with success.[2,4] Using the general model of eqn. 2, other noise smoothing filters can be derived, such as purely spatial filters ($\rho_3 = \delta(l_3)$) and purely temporal filters ($\rho_1 = \delta(l_2)$) and ($\rho_2 = \delta(l_3)$), where $\delta(\,.\,)$ is the delta function.[3] The values of the correlation coefficients may also be adapted to both the image content (edges, textures, etc.), and to specific motion features (e.g., occlusion).

Discrete random fields with the above autocorrelation function are stationary autoregressive sources of the type

$$x(\boldsymbol{n}) = \sum_{s \in S} a(s) x(\boldsymbol{n} - s) + u(\boldsymbol{n}) \tag{3}$$

where $s = (s_1, s_2, s_3)$, S is the 3D causal support of the AR model which contains seven points and extends one point in each direction, and $a(s)$ are the prediction coefficients. By fitting the model of eqn. 2 into the data, we get

$$a(s) = -(-\rho_1)^{s_1}(-\rho_2)^{s_2}(-\rho_3)^{s_3} \quad s \in S \tag{4}$$

where $u(\boldsymbol{n})$ is a zero-mean white noise input process with variance equal to the mean-squared prediction error, ε^2, which is given by

$$\begin{aligned} \varepsilon^2 = E\{u(n)^2\} &= (1 - \rho_1^2)(1 - \rho_2^2)(1 - \rho_3^2)\sigma_x^2 \\ &= \phi \sigma_x^2 \end{aligned} \tag{5}$$

Based on the model of eqn. 3, a recursive spatio-temporal noise smoothing filter is derived, which represents an exten-