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Subcarrier Multiplexing in Optical Networks

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Abstract

This paper describes the applicability of subcarrier multiplexing to light wave multiple-access networks. It is shown how currently available microwave and light wave components can be used, by using subcarrier multiplexing, to provide high-capacity networks and also how can increase the number of users who support the network.

Introduction
Multiple-access systems differ from wide-band links in that each user generally requires only a small fraction of the total data throughput. Using TDMA, in which this fraction is time-division-multiplexed into a high bit-rate data stream, does not take advantage of this difference. Each receiver must receive all transmitted data and select the appropriate bits, which requires both wide-band receivers and high-speed demultiplexers. Since receiver sensitivity decreases with increasing bandwidth, these systems are often limited to low total data throughput rates.

Theory
The term subcarrier multiplexing is used to distinguish this technique, which uses microwave subcarriers and optical carriers, from frequency-division multiplexing (FDM). The term FDM, in a light wave system, is reserved for the direct modulation of the optical carrier with data. The photodiode in each receiver detects all subcarrier channels over the total system bandwidth, but only the desired narrow-band channel has to be amplified and demodulated, using conventional microwave techniques. The resulting increase in receiver sensitivity can increase the allowed number of users by increasing the size of star coupler. SCM offers several other attractive features. The spectral characteristics of each source are unimportant so that multimode lasers can be used. Temperature stabilization or wavelength control is not required. These lasers are

capable of output powers of tens of megawatts and are sufficiently linear under direct microwave modulation, for the proposed applications. Finally, one of the main advantages of SCM is that each channel is continuously available and independent of all other channels. There is no need for synchronization between each channel and a high-speed master network clock.

The main purpose of this paper is to discuss how the light wave network is designed which uses SCM multiple-access networks. Before the description of an optimized network or its results lets see SNR v/s frequency response of an FET receiver.

The SNR performance for this type of receiver, neglecting shot noise is shown as the solid curve in Fig.1

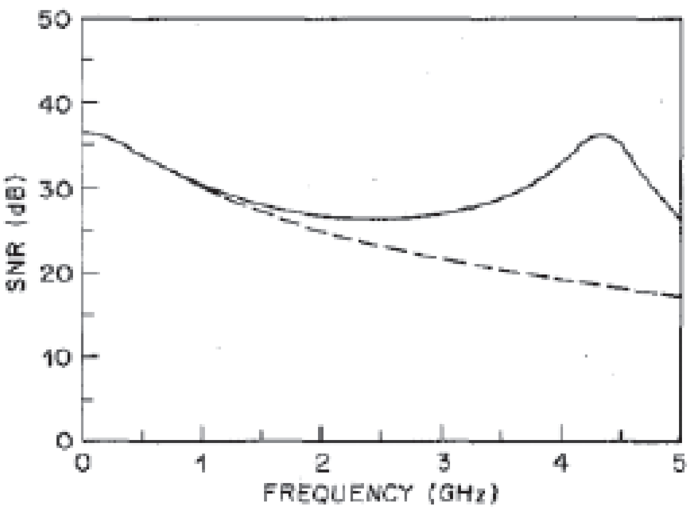

Figure 1 : SNR v/s Frequency curve (Dark line)

Here the component values given by

SNR -1.5 (Is2 /B)

Where Is is the current in microampere and B is the bandwidth is megahertz. If no inductor is used there then dashed line curve is obtained.

Here a simple multiple-access network is presented which is based entirely on SCM. A star coupler is used to interconnect N users such that any user can communicate continuously with any other. The basic configuration is shown in Fig.2 For simplicity, it is assumed that each of the N users can transmit on any subcarrier frequency but receive only on one predetermined frequency.

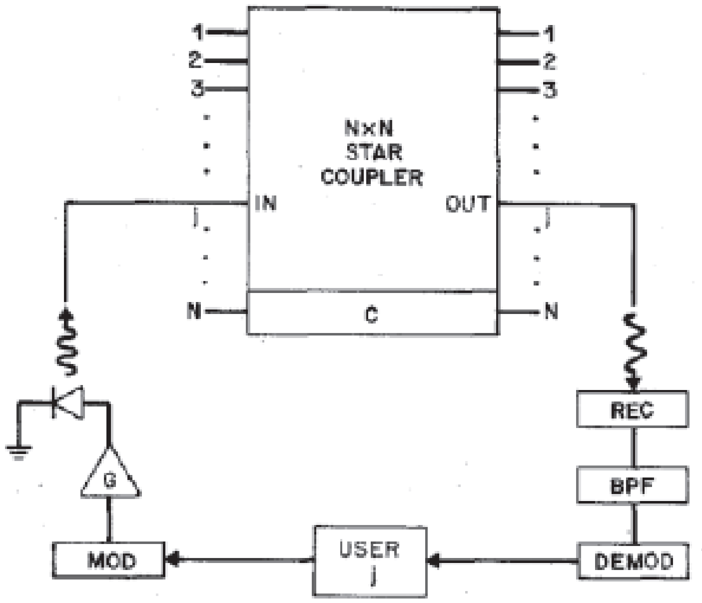

Figure 2 : A simple n*n star coupler

This enables the optimization of the response of each receiver, such that shot noise dominates.

This optimization of the response of each receiver, such that shot noise dominates. This configuration has the advantage of minimizing the dynamic range requirements of the receivers since all channels are received with equal strengths. One or more of the coupler ports may be reserved for network control and to provide a gateway to an external network. Our objective is to determine the limitations of number of users supported (N)

We can simply design a circuit switch network here so that there will be no collision chances. It may be designed such that each user ask the controller before transmission. The controller would maintain a destination list so that if the particular destination is free it can transmit the data otherwise will wait. So in this way the collision minimization and network activity both are maintained.

The shot noise limit is given by

$$NB/ Ldc = \frac{Ro\, m^2\, 10\, (-Mm/10)}{4qSNR_S}$$

Where NB is total usable BW, Ro is the responsively of the photodiode, with units of amperes per watt. Mm is the total loss of a coupler, Actually this equation relates the product NB to the optical power required for error-free demodulation.

If Ro = 0.5 A/ W, SNR, = 16 dB, m = 0.5, and Ldc = 2 mW, then:

NB = 9.8 x 103 x 10 (-Mm/10) (GHz)

On the basis of above calculations system loss for 2^n X 2^n star couplers the corresponding values for NB and B are given by table 1. An additional 2 dB fiber loss is included here.

SCM-STAR LAN

Table 1

N	Coupler loss (dB)	NB(GHz)	B(MHz)
256	28.4	14.2	55
512	31.7	6.63	13
1024	35.0	3.10	3.0
2048	38.3	1.4	0.71

Given that the bandwidth per channel is approximately twice the bit rate, this type of network could support, for example, over 1000 users at data rates of 1.5 Mbps per user. Recall that this channel is continuously available and independent of all other channels. The numbers in Table I also assume that all lasers can transmit simultaneously. If each user were either receiving or transmitting, but never both, then only half of the users would contribute shot noise. The allowed bit rates, or number of users, could then be doubled. Also, if the laser power is doubled then the product NB is also doubled. Continued efforts is develop high-power and high-speed lasers should lead to some very high-capacity networks.

Conclusion

This paper demonstrates the advantages and limitations of a subcarrier multiplexing in optical communications. Along with a relatively simple technique this is also maintain high receiver sensitivity. It can support many architectures and access protocols as this is since each channel is independent and available at regular basis. The total usable bandwidth is limited by large modulation bandwidth of semiconductor laser and high speed response of photodiodes.

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