article is dedicated to the late Steve Carr, who taught the author many practicalities of LNA design.

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THE EFFECT OF LASER CHIRPING ON OPTICAL SUBCARRIER MULTIPLEXED SYSTEM WITH HIGH-BIT-RATE BASEBAND SIGNAL

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KEY TERMS

Optical communications, subcarriers multiplexed system, laser chirping

ABSTRACT

The mixed transmission of digital and analog signals via single-mode fiber has potential in future fiber-optic systems. We have studied the effect of chirping of the baseband digital signal on the analog subcarrier channels using computer simulation. If the location of the subcarriers or the bias of the laser is selected properly, the SNR penalty due to chirping and cross talk will be less than 0.5 dB.

INTRODUCTION

For short-haul application, it may be more convenient and cost effective to integrate a high-bit-rate digital data/voice system with an analog video system using existing fiber-optic system facilities [1, 2]. The simultaneous transmission of an optical subcarrier with a baseband digital signal is also reported in [3, 4]. For high-bit-rate application, the direct current modulation of laser diode causes a dynamic shift of the peak emission wavelength [5], and thus the subcarrier channels are much affected by the digital data. Since the baseband digital service is little affected by the optical subcarriers [1–4], in this article we study only the effect of the digital data on the optical subcarriers with FM-TV signals.

The schematic diagram is shown in Figure 1 with a baseband digital data stream and subcarrier FM-TV signal [1, 2]. In low-bit-rate applications [3, 4], the effect of chirping will not be serious. In high-bit-rate application, the subcarriers have been proposed to be located at the node point $2R_b$ (R_b is the baseband bit rate) [1, 2], but the effect of chirping may affect the subcarriers seriously.

SIMULATION

To investigate the effect of chirping on the subcarrier channel, we used a simulation technique [6, 7] which numerically integrates the well-known single-mode laser rate equations:

$$\frac{dn_e}{dt} = \frac{I}{eV_{\mathrm{act}}} - g_0\frac{(n_e - N_0)S}{1 + \varepsilon S} - \frac{n_e}{\tau_n}, \tag{1}$$

$$\frac{dS}{dt} = \Gamma g_0\frac{(n_e - N_0)S}{1 + \varepsilon S} + \beta\frac{n_e}{\tau_n} - \frac{S}{\tau_p}, \tag{2}$$

where the spontaneous recombination and photon absorption are represented by phenomenological carrier and photon lifetimes (τ_n, τ_p), respectively, and where the saturation of the differential optical gain (g_0) is represented by a linear term, $(1 + \varepsilon S)$; n_e is the electron excess density and S is the photon density, respectively; N_0 is the electron density at transpar-

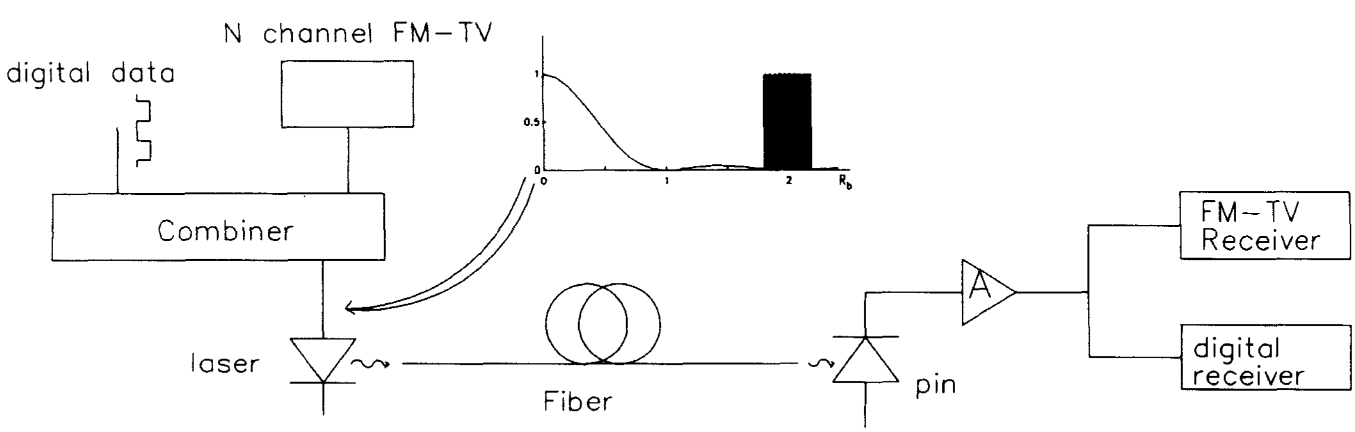

Figure 1 Schematic diagram of the lightwave communication system with baseband digital data stream and optical subcarriers. The insert graph is the spectrum at the input

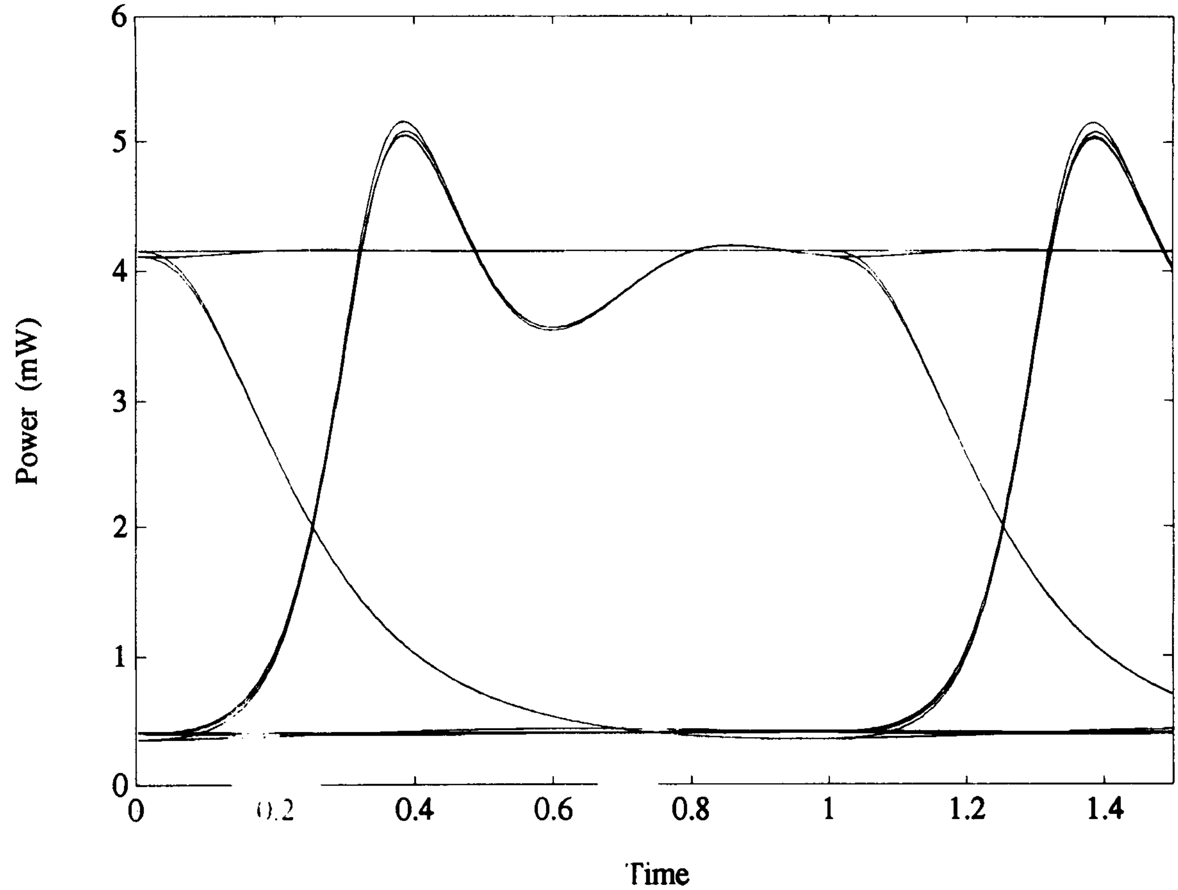

Figure 2 Eye diagram of the laser output intensity with R_b = 2 Gbit/sec, $I_{\text{bias}} = 1.5I_{\text{th}}$ and $I_m = I_{\text{th}}$

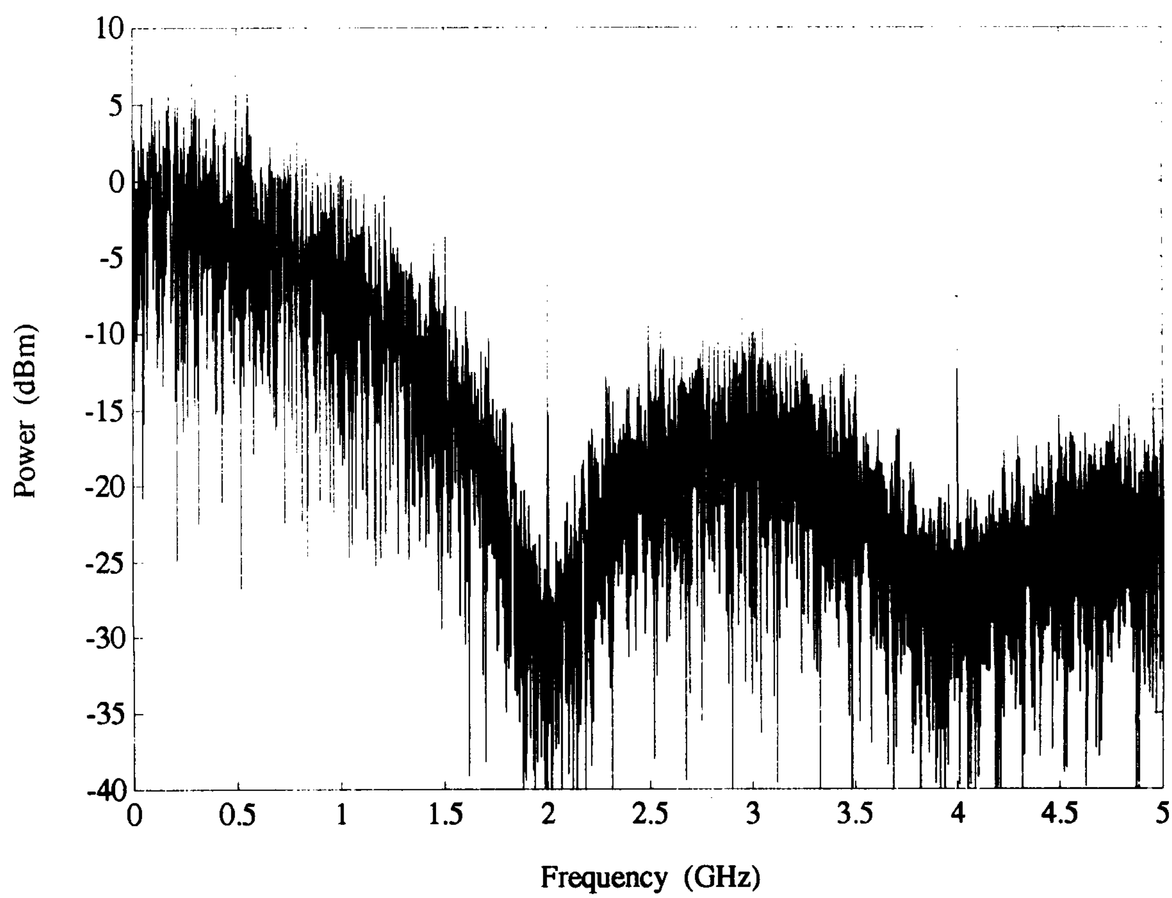

Figure 3 The spectrum of the laser output intensity with parameter the same as Figure 2

ency, V_{act} is the volume of the active layer, β is the spontaneous emission coupling constant, I is the injection current, e is the electron charge, and Γ is the photon confinement factor. Laser parasitics and intentional transmitter filtering are accounted for by a single-pole RC prefiltering of the injection current.

Our simulation uses the laser parameters given in [7], with the injection current of the laser as

$$I(t) = I_{bias} + \sum_j a_j I_m p(t - jT), \tag{3}$$

where I_{bias} is the dc bias current, I_m is the height of the current pulse, a_j is the binary data (0, +1), and $p(t)$ is the current pulse [6, 7]. The rise time of the injection current is 100 ps. With R_b = 2 Gbit/sec, $I_{bias} = 1.5 I_{th}$ with $I_{th} = eV_{act}N_0/\tau_n$ [8], we find the eye pattern of the output of the laser as Figure 2 and the spectrum of the baseband signal as Figure 3. We can see that at the node point ($2R_b$), there is a tone induced by chirping. This side tone will affect seriously the system such as [1, 2] because the subcarriers are just located near this tone.

The subcarriers are FM-TV signal with a bandwidth of 30 MHz. We can find the power contained in the 30-MHz band by using fast Fourier transform. We define the chirping-to-carrier ratio (CCR) as P_c/P_{dig}, with P_c the total chirping and cross-talk power resulting from the digital channel that falls to the FM-TV band, and P_{dig} the ac power of the digital channel. Figure 4 is the simulated CCR at three different bias currents. Three curves are the CCR of the channel centered at (a) the node point $2R_b$; (b) the peak of the sideband 1.5 R_b; (c) $2R_b$ − 240 MHz, which is corresponding to the first channel of a 10-channel FM-TV signal centered at $2R_b$. As the bit rate increases, the CCR in the node point is even worse than the CCR at the secondary peak.

Also shown in Figure 4 are the CCR curves below which the degradation of signal-to-noise ratio (SNR) are less than 3 and 0.5 dB, respectively. If there is only white Gaussian noise, the SNR of digital channel or carrier-to-noise ratio

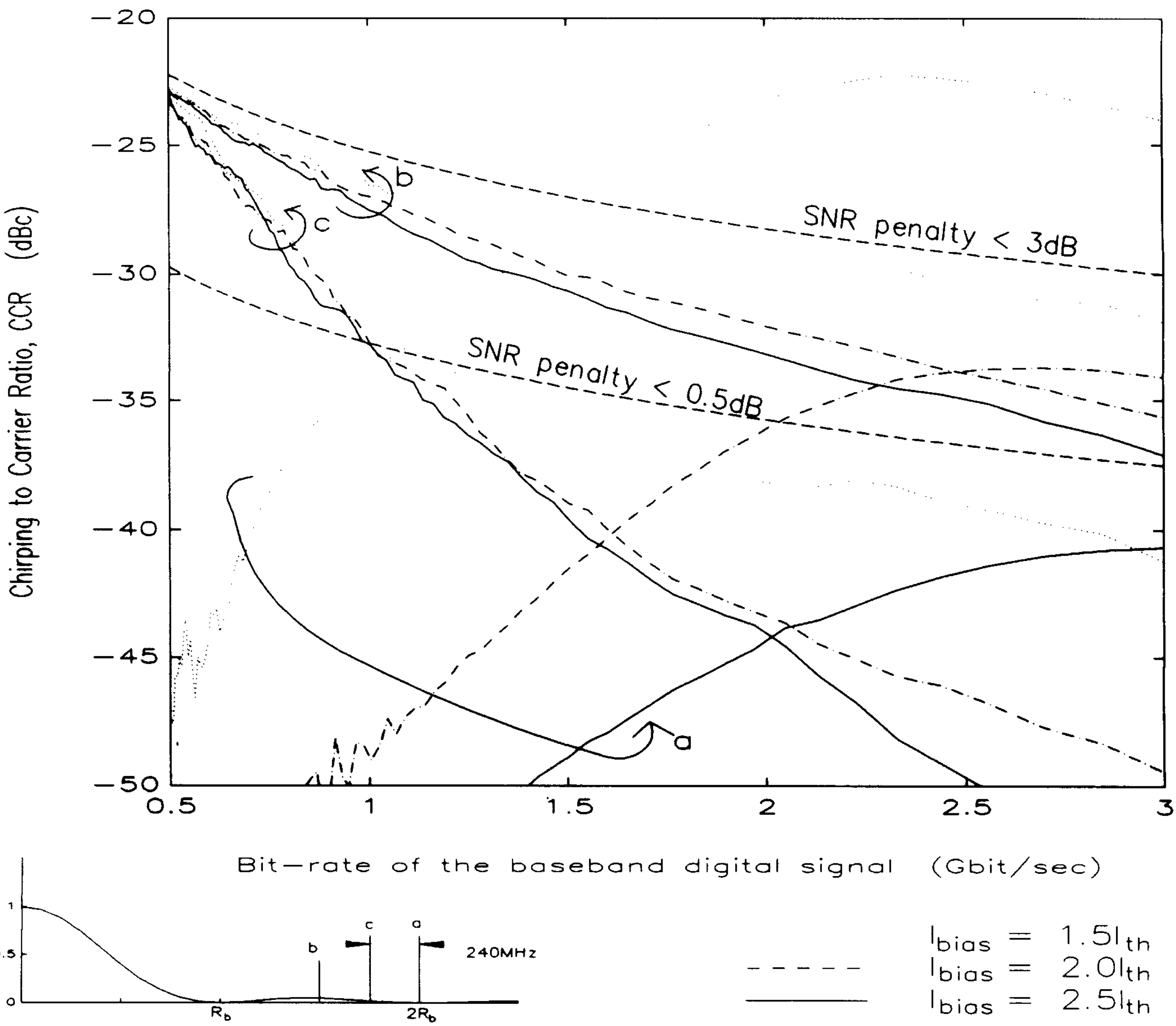

Figure 4 The CCR versus modulation bit rate with difference bias current. Below the dashed lines are the required CCR to achieve simultaneously a γ = 16.5 dB for analog channels and a γ = 6 for digital signals with a SNR penalty of less than 3 or 0.5 dB, respectively

(CNR) of analog channel is $\gamma = P/N_0B$, with P the signal (carrier) power, N_0 the noise spectrum density, and B the bandwidth. For FM-TV signal, $\gamma = 16.5$ dB is necessary to achieve an SNR of 56 dB [9]. For a digital channel, $\gamma = 6$ is necessary to achieve a bit error rate (BER) of less than 10^{-9} [10]. To achieve a $\gamma = 16.5$ dB for an analog channel and $\gamma = 6$ for a digital signal simultaneously, the power of analog and digital signal must satisfy the expression (if we consider white noise only)

$$P_a/P_d = 9.21\ (\mathrm{dB}) - 10\log_{10}(R_b/B_a), \qquad (4)$$

where P_a, P_d are the ac power of the analog and digital signals, respectively. B_a is the signal bandwidth of subcarriers. For example, if $B_a = 30$ MHz, $R_b = 2$ Gbit/sec, $P_a/P_d \approx -9.5$ dB. If we restrict the SNR penalty of the FM-TV signal to be less than 3 dB and the modulation index is estimated by (4), the CCR of the FM-TV signal must less than -10 (dB) $- 10\log_{10}(R_b/B_a)$. If the restriction is 0.5 dB, CCR must be less than -17.5 (dB) $- 10\log_{10}(R_b/B_a)$.

When the bit rate of baseband is less than 1 Gbit/sec, the subcarrier may be located at $2R_b$ and SNR penalty will be less than 0.5 dB. With a bit rate larger than 1.5 Gbit/sec, the subcarriers should be located within $2R_b \pm 240$ MHz but excluding the region very near $2R_b$ to avoid the side tone. The SNR penalty can also less than 0.5 dB.

CONCLUSION

For a system with both baseband digital service and analog subcarrier channels, simulation results on the effect of laser chirping due to the baseband digital service on the analog channel using the well-known monomode rate equations have been presented. It is found that simultaneous transmission of both digital and analog channels is possible using a laser diode provided that the location of the subcarriers and bias current is chosen properly. The SNR penalty may be made less than 0.5 dB.

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RADIATED FIELDS OF MICROSTRIP PATCHES AT ARBITRARY ANGULAR POSITIONS

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KEY TERMS
Microstrip patch, array, radiation pattern

ABSTRACT
This article investigates the radiation characteristics of microstrip patch antennas located at arbitrary angular positions. The aperture method was employed to determine the radiated far field of the patch. A circular arrangement of the patch antennas was studied. The effect of the array configuration on the radiation characteristics are presented and analyzed.

INTRODUCTION

Microstrip antennas have been analyzed by many investigators [1–5] using techniques such as the Sommerfeld integral method, cavity model method, method of moments, image theory, vector potential method, etc. and the effect of the feed mechanisms, substrate, etc., on the gain and radiation characteristics have been reported. Analysis of planar arrays of printed dipoles and rectangular and circular patches have also been reported in the literature [6–8]. The radiation properties of an infinite phased array of circular patches have been reported in [9]. In this article the radiated fields due to patches arranged in arbitrary angular positions are investigated. The aperture method is employed to determine the fields of the patch, and for this initial study the effects of mutual coupling are not included. The practical applications of this array configuration are of interest for radar systems, and air and space navigation systems.

FORMULATION

The total radiated field of a circular arrangement of microstrip antennas is obtained by summing the contributions of each patch contained in the array. The aperture method is employed to express the radiated fields of each individual patch as a function of its angular and radial position. The angular position of an element is denoted as ϕ_{si} with the first element at $\phi = 0$.