Coherent analog FM-SCM video transmission using direct frequency modulation of semiconductor lasers

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ABSTRACT

An analog coherent subcarrier multiplexing system for video transmission using frequency modulation of both the subcarrier and optical carrier is analyzed. Theoretical receiver sensitivity for realistic values of receiver noise and phase noise is approximately -41 dBm for 50 channels and -25 dBm for 100 channels.

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Introduction. The advantages of analog subcarrier-multiplexed (SCM) FM video transmission using frequency modulation of the optical carrier over other analog laser modulation schemes include the reduced impact of laser relative intensity noise and the phase noise suppression achievable in a receiver employing FM demodulation of both the subcarrier and optical carrier. Way *et al.* [1] detected these FM-FM signals using an erbium-doped fiber amplifier and an optical frequency discriminator followed by a direct-detection receiver. We examine the performance of a coherent receiver for the same application.

System Description. Fig. 1 shows a block diagram of the system. FM video signals on microwave subcarriers are power-combined, generating a signal which is used for direct frequency modulation of a laser. The transmitted optical signal travels over single-mode fiber to a coherent receiver, where it is coupled with an optical local oscillator signal. The resulting signal is heterodyne-detected by a PIN photodiode, amplified, and demodulated, as shown in Fig. 2. After the first FM demodulator, the SCM channels are separated using a bandpass filter array, downconverted to a common frequency, and amplified. A second FM demodulator and a lowpass filter recover each baseband video signal.

Analysis. We evaluated the optical receiver sensitivity, defined as the total received optical power needed to achieve a 56 dB output SNR. Photodetector shot noise, thermal noise, amplifier noise, clipping effects, and phase noises of the transmitter and local oscillator lasers were taken into account. FM demodulator performance above and near threshold (approximately 10 dB input CNR) was predicted using the threshold model of Rice [2]. The emphasis improvement factor was assumed to be 13.1 dB as per international (CCIR) standards for FM video transmission systems [3]. Fig. 3 shows a sample of our results for the system parameters given in the figure. The optical receiver sensitivity is plotted versus number of channels; constant optical bandwidth is assumed.

Discussion. Inspection of Fig. 3 reveals that receiver sensitivity depends on the linewidth and on the number of SCM channels. Though increasing linewidth reduces the maximum number of channels, receiver sensitivity is only weakly dependent on linewidth for smaller channel counts. For example, a receiver sensitivity of better than -30 dBm is possible in an 80-channel system, even with 100 MHz linewidth. For linewidths below 100 MHz, a receiver sensitivity of better than -40 dBm can be achieved for up to 50 channels. This sensitivity is within 5 dB of the fundamental limit for the assumed optical bandwidth and is 5 dB better than the fundamental limit for 50-channel coherent FM-SCM video transmission using intensity-modulated lasers [4]. As the channel count decreases below 50, the sensitivity levels off, even though the signal power increases quadratically due to the linearly increasing optical frequency deviation ratio. This sensitivity floor is due to the threshold of the first FM demodulator. For the intensity-modulated case, the fundamental sensitivity limit continues to fall off linearly with decreasing channel counts below 50. As the channel count decreases below 10, the optical frequency deviation ratio increases at a faster than linear rate, causing the curves to turn down.

<u>Conclusions</u>. Excellent sensitivity is generally achievable using analog coherent FM-SCM systems. The essentially constant receiver sensitivity for small channel counts results from the phase noise suppression in a receiver employing double FM demodulation. The wide linewidths of typical semiconductor lasers (100 MHz or more) have no noticeable effect on system performance for up to 50 channels per laser. This important result is similar to that for digital ASK and FSK systems [5]. Thus, coherent FM-SCM systems appear to be well-suited for trunk video transmission.

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Captions

Fig. 1. Block diagram of coherent SCM system using direct laser frequency modulation to transmit FM video channels.

Fig. 2. Expanded block diagram of the demodulator of the system in Fig. 1. The N branches after the downconverters are identical.

Fig. 3. Plot of receiver sensitivity (for output SNR = 56 dB) versus the number of transmitted channels. The linewidths shown ($\Delta\upsilon$) correspond to the sum of the transmitter and LO laser linewidths. Receiver parameters are: photodiode responsivity = 0.7 A/W, optical LO power = 1 mW, amplifier voltage noise = $4*10^{-20}$ A^2/Hz, and amplifier load resistance = 50 Ω. Room temperature is assumed. The leveling off of achievable receiver sensitivity for low channel counts is due to the threshold of the first FM demodulator.

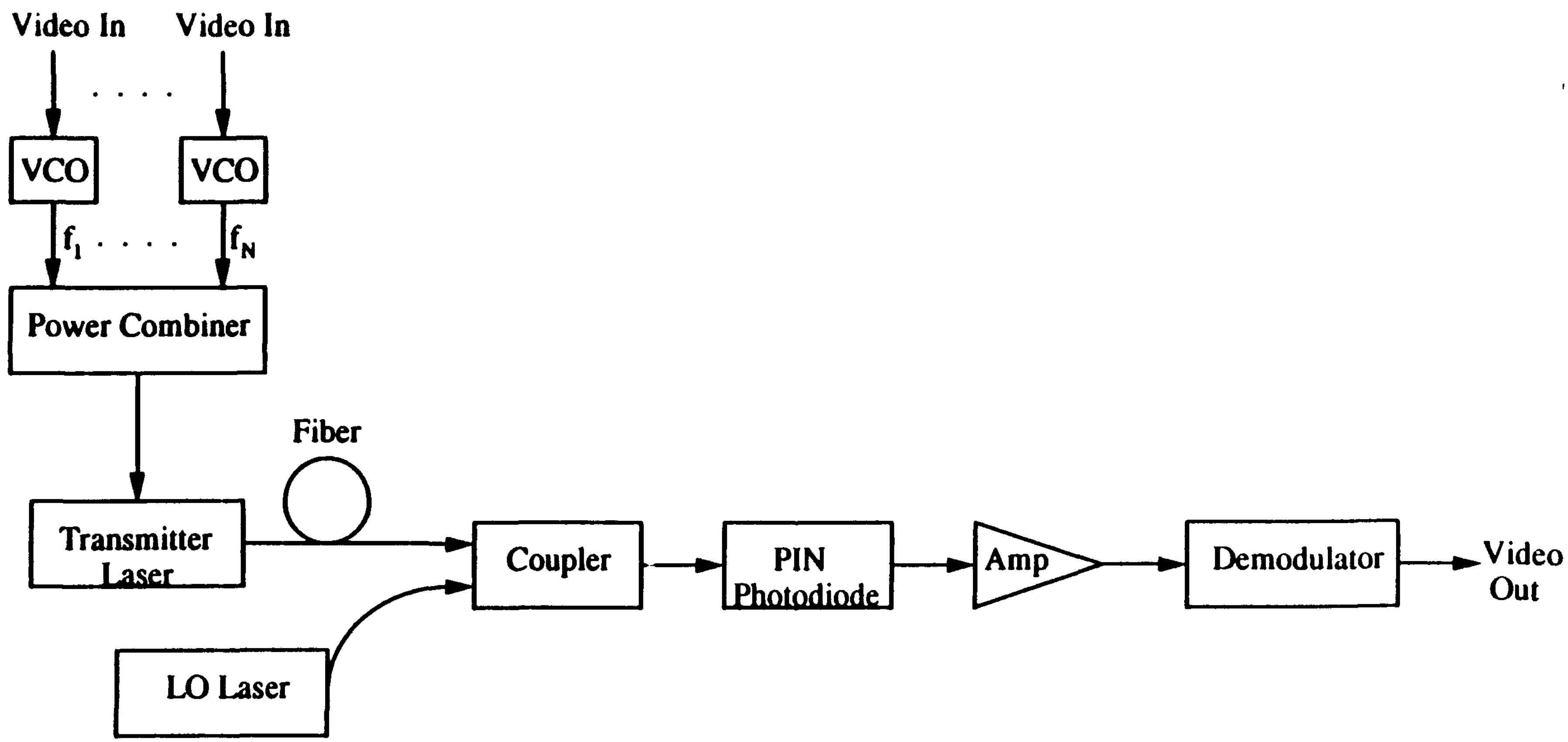

Video In
Video In
VCO
VCO
f1
fN
Power Combiner
Fiber
Transmitter Laser
LO Laser
Coupler
PIN Photodiode
Amp
Demodulator
Video Out

Fig. 1

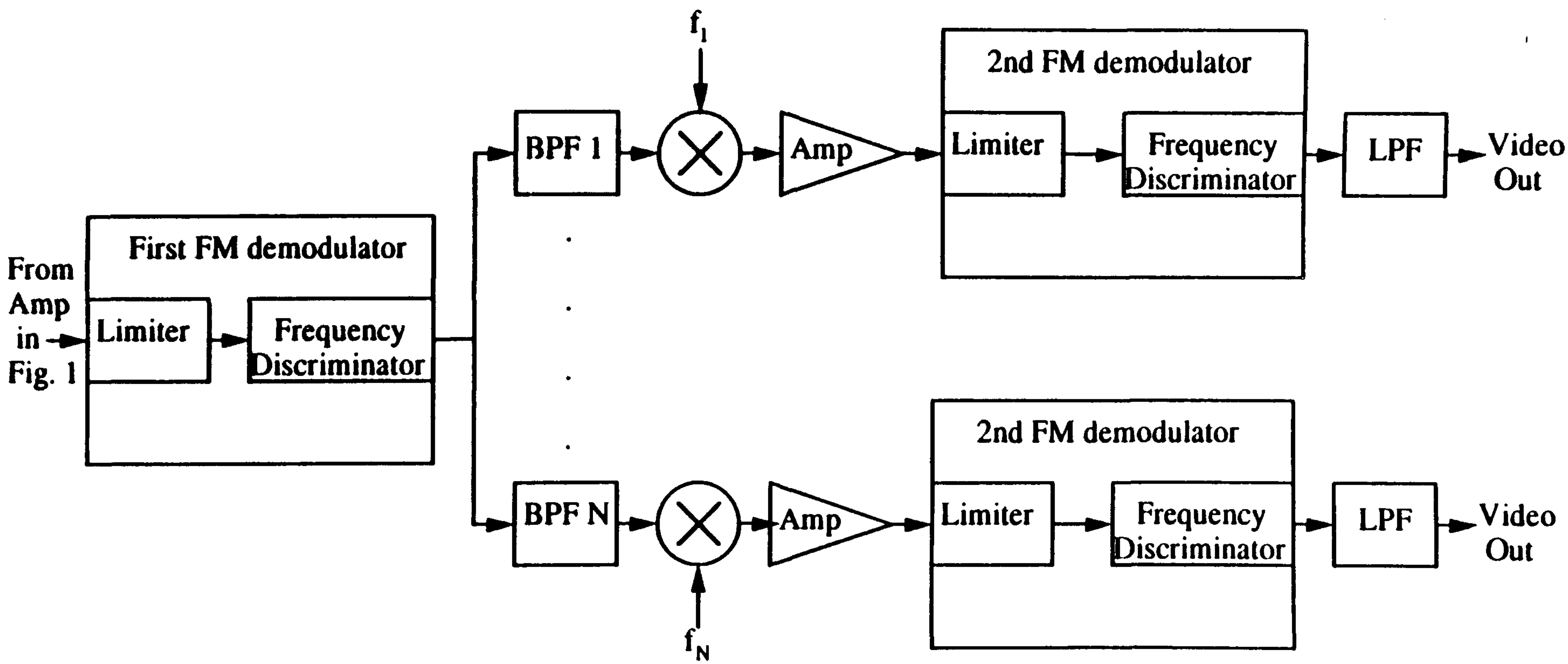
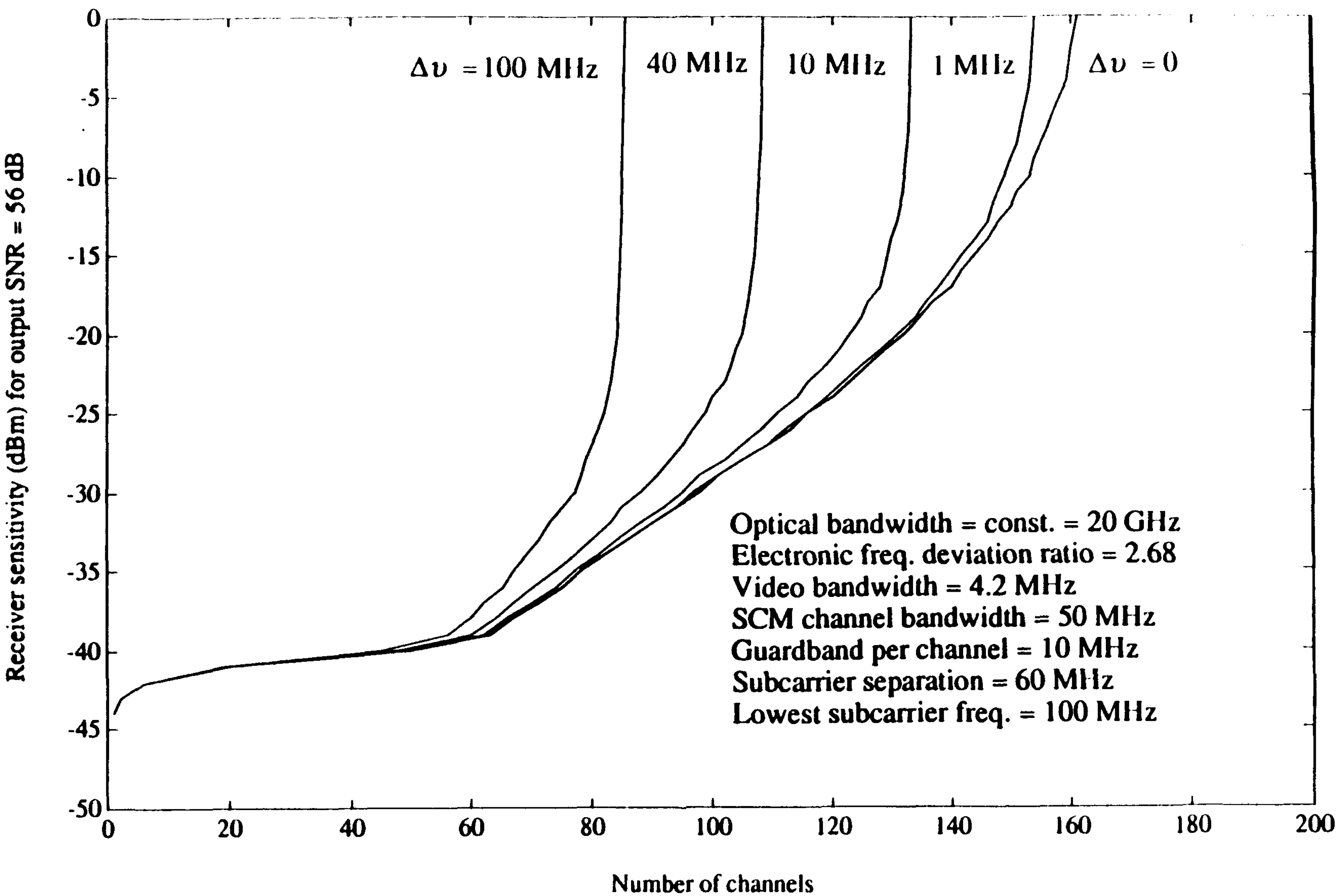

From Amp in Fig. 1
First FM demodulator
Limiter
Frequency Discriminator
BPF 1
BPF N
f1
fN
Amp
Amp
2nd FM demodulator
Limiter
Frequency Discriminator
2nd FM demodulator
Limiter
Frequency Discriminator
LPF
LPF
Video Out
Video Out

Fig. 2



Δυ = 100 MHz
40 MHz
10 MHz
1 MHz
Δυ = 0
Optical bandwidth = const. = 20 GHz
Electronic freq. deviation ratio = 2.68
Video bandwidth = 4.2 MHz
SCM channel bandwidth = 50 MHz
Guardband per channel = 10 MHz
Subcarrier separation = 60 MHz
Lowest subcarrier freq. = 100 MHz
Receiver sensitivity (dBm) for output SNR = 56 dB
Number of channels
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
20
40
60
80
100
120
140
160
180
200

Fig. 3