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OPTICAL COHERENT TRANSMISSION IN MULTIPOINT APPLICATIONS: SYSTEMS AND DEVICES

ALCATEL
FACE

A 565 Mbit/s Optical Coherent System Using DFB Lasers with Large Phase Noise.

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Abstract

A 565 Mbit/s FSK optical coherent system was developed using commercially available DFB lasers with IF beat linewidth of 120 MHz. BER of 10^{-9} was achieved for a 2^{15} -1 PRBS and input power of -43.1 dBm (including coupler excess losses). No evidence of BER floor has been observed.

Introduction

Large deviation FSK or ASK coherent system with asynchronous demodulation can in principle relax the requirement on laser linewidth providing that enough bandwidth is available at the IF stage [1]. This feature may prove important in application such local area distribution networks where it would be desirable to use a compact and inexpensive set of sources providing many laser beams for each channel and where a key issues will also be the low cost for the receivers.

For relatively high bit rates, however it may be difficult to meet in practice the opposite constraints arising from the IF central frequency, which has to be kept sufficiently low for allowing the construction of a simple and low-noise balanced front-end receiver, and the large fractional bandwidth therefore required for the asynchronous square-law demodulator. We have however already reported that the latter problem can be effectively overcome by using a novel type of intrinsically broadband square-law demodulator, which can be realised simply and at very low cost [2].
Here we report a 565 Mbit/s system entirely realised with commercial components and making use of DFB lasers with a relatively large linewidth of about 50-60 MHz.

Description

Fig. 1 shows the block diagram of the system, which operates at 565 Mbit/s and utilises FSK large deviation modulation with single branch asynchronous detection. The lasers used were DFB commercial devices operating at λ = 1535 nm. The lasers are butterfly packaged with integral optical isolator providing 30 dB isolation. A second polarisation insensitive pigtailed optical isolator was used for both transmitter and local oscillator lasers for a total isolation greater than 60 dB.
The linewidth of the two lasers were measured to be 50 and 60 MHz respectively using a commercially available linewidth analyser based on the delayed self-heterodyne method [3]. The measured locked IF beat linewidth was approximately 120 MHz, the further increase being probably due to residual 1/f components of the total frequency noise [4]. The optical frequency of the transmitter laser was directly modulated by varing its injection current. The non compensated FM frequency response of the

transmitter laser showed a pronounced dip at approximately 10 KHz and a 180^0 phase shift spread over several decades centred at this frequency. The FM response was electrically equalised to give an FM coefficient of 162 MHz/mA +/- 6% between 50 KHz and 500 MHz. Fig. 2 shows the amplitude and phase responses of the uncompensated and compensated laser. The separation between mark and zero utilised for the system was 2.6 GHz.

The output signal was optically attenuated and fed to the optical coupler via low reflection optical connector. The receiver consisted of a balanced front-end configuration followed by an IF strip providing 30 dB gain with 20 dB variable attenuation for AGC operation. The IF centre frequency was 2.26 GHz. The IF bandwidth was between 1.0 to 3.4 GHz being limited by the front-end roll-off and by a 3rd order Butterworth high pass filter. The balanced front-end made use of a matched pair of commercially available photodiodes with 25 GHz bandwidth and quantum efficiency greater than 80%. Total coupling and quantum efficiency losses were estimated to be 1.4 dB. Total input capacitance was approximately 0.3 pF. The transimpedance amplifier consisted of a first transimpedance stage and a second equalising stage which counteracts the roll-off caused by the first stage at high frequencies. Series inductive tuning was used to further extend the bandwidth and reduce the noise. The total input noise was below 8 pA/(Hz)$^{1/2}$ and the transimpedance was approximately 46 +/- 1.5 dBohm. RIN cancellation was better than 15 dB. Fig. 3 shows the measured input current noise for the front-end.

The AFC signal was given by the differential reading between two power detectors. A low pass filter converted frequency to power fluctuations which were then compared to the constant power level from the other detector which also provided the error signal for the AGC. Once both AGC and AFC were in operation the locked frequency showed an RMS error of +/- 3.5 MHz for periods as long as one day. Input power to the demodulator was approximately -20 dBm. Fig. 4 shows the locked and unlocked unmodulated IF linewidth obtained by monitoring the corresponding IF signals using the spectrum analyser in peak-hold mode for approximately 30 minutes.

Demodulation was accomplished by means of a novel type of square-law demodulator [2], followed by a limiting amplifier. The available local oscillator power was approximately 0.5 dBm. The optical isolator has 1 dB insertion loss and the optical coupler shows excess losses of 1.9 dB and 1.4 dB for the L.O. and signal arm respectively. Polarisation was manually adjusted to match that of the incoming signal. The demodulated signal was fed to an error detector for BER measurement with clock provided directly from the pattern generator.

Results and Discussion

Fig. 5 shows the eye diagram at the input of the error detector for optical input power of approximately -43 dBm. Fig. 6 shows the measured BER of the system with power measured at the input connector and plotted against the theoretical limit for this system (having penalties of 0.9 dB, 1.4 dB and 0.4 dB due to phase noise, photodiodes coupling plus quantum efficiency and connector loss respectively) taking into account the excess losses of the optical coupler. A BER of 10^{-9} was achieved for an input power of -43.1 dBm at the input connector of the coupler for a 2^{15}-1 PRBS. No error floor has been measured.

This performance is 6.4 dB away from the theoretical limit for this system and approximately 1 dB from the best performing systems of this kind at similar bit rates [5], [6]. Our system however was characterised by considerably higher phase noise which greatly increases the practical problems involved in acheiving the required large and flat IF bandwidth especially so when using conventional square-law devices based on microwave passive double balanced mixers.

Still a major impairment for the present system is the non flatness of the IF strip, although in our case this is mainly due to mismatch between the front-end output and the IF strip input resulting from the direct connection of a commercially available IF amplifier to the front-end. The inclusion of an impedance matching stage should greatly reduce the observed 4.5 dip at approximately 2.1 GHz. The estimated penalty from this was 2.5 dB.

Other problems were related to optical reflections, residual thermal noise and non optimum RIN cancellation causing estimated penalty of 2 dB. Comparison between the 1010 pattern and the PRBS sequence suggests that a 1.3 dB penalty still exists due to non optimum FM compensation. This was partly due to non optimum temperature operation for the FM compensated transmitter laser, whose optical frequency could not be tuned by adjusting the temperature of the L.O. laser alone, whilst operating at the maximum L.O. power. For reduced L.O. injection currents and under optimised temperature for the FM compensated transmitter laser the penalty was confined to 0.5 dB.

The remaining penalty is due to residual ISI caused by insufficient baseband bandwidth at the output of the demodulator.

Conclusion

A 565 MBit/s FSK single filter optical coherent system has been constructed using commercially available devices. In particular DFB lasers have been employed with relatively large phase noise. A 10^{-9} BER has been measured for input power of -43.1 dBm (including coupler losses) for a 2^{15}-1 PRBS signal. Analysis of the impairment suggests that at least 3 dB improvement can be achieved by reducing the mismatch between front-end and IF strip, reducing optical reflections and increasing RIN cancellation.

References

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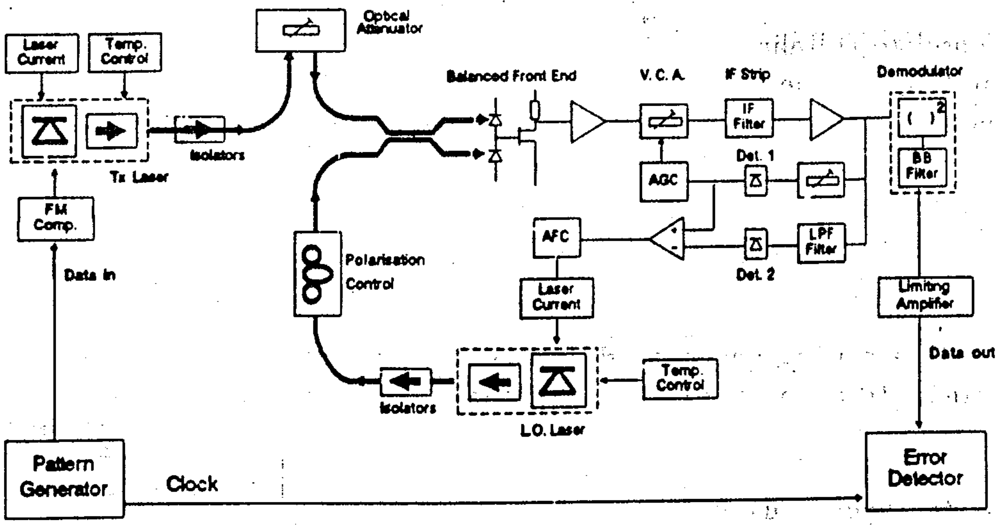

Fig. 1 System Experimental Set-Up

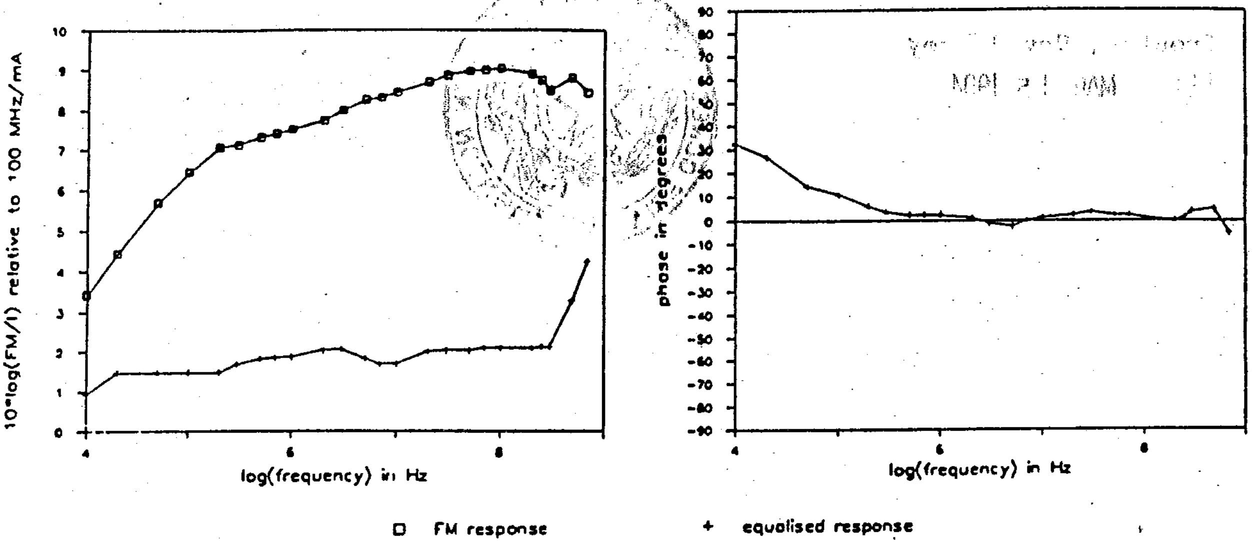

Fig. 2 Measured and compensated FM frequency response of the transmitter laser

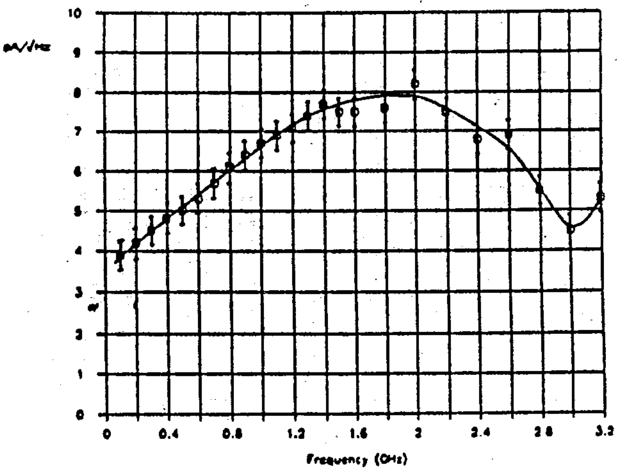

Fig. 3 Input current noise of the front-end

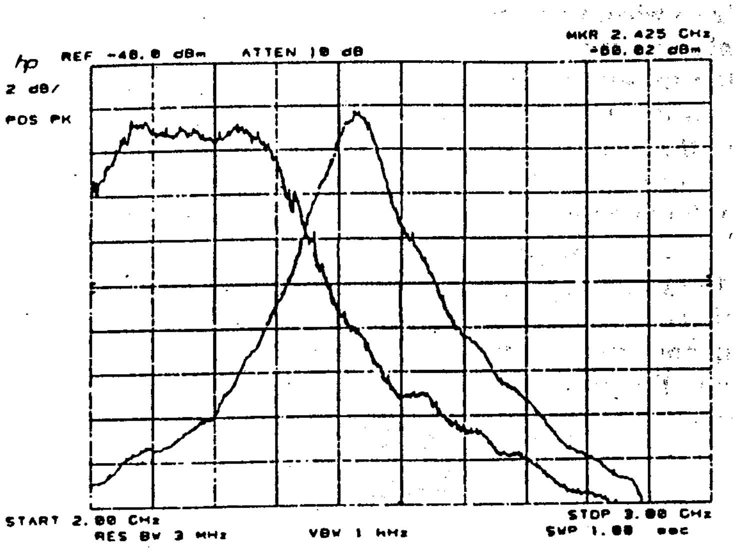

Fig. 4 Drift in heterodyne frequency with AFC locked and unlocked over 30 minutes

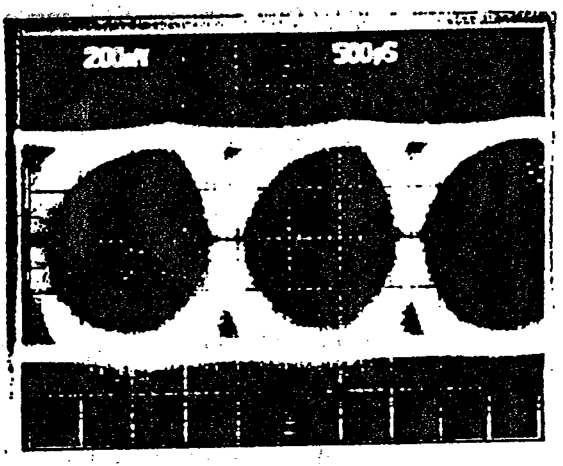

Fig.5 Eye diagram at the input of the Error Detector

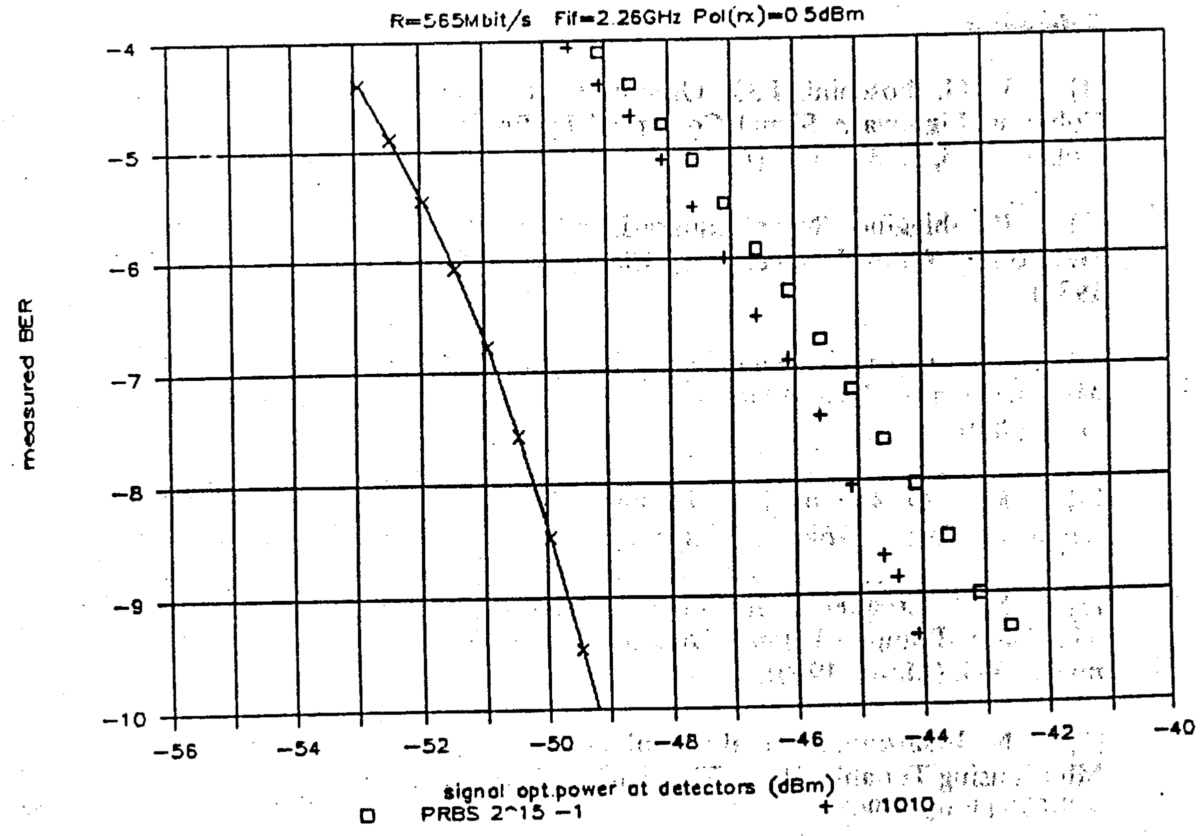

Fig. 6 Measured BER Curves