PERFORMANCE EVALUATION OF RECEIVERS IN DIGITAL COHERENT OPTICAL FIBER COMMUNICATION SYSTEMS

A Dissertation Submitted to the
Indian Institute of Technology, Delhi
for the Fulfilment ot the Degree of

Doctor of Philosophy

By

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CERTIFICATE

This is to certify that the thesis entitled "Performance evaluation of receivers in digital coherent optical fiber communication systems" being submitted by Nar Singh for the award of the degree of Doctor of Philosophy to the Indian Institute of Technology, Delhi is a record of the bonafide research work carried out by him. He has worked under our supervision and guidance during the period December 1985 to July 1989. He has fulfilled all the requirements for the submission of the thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted either in part or in full to any other University or Institute for the award of any degree or diploma.

(Prof. H.M. Gupta and Dr. V.K. JAIN)

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ABSTRACT

This thesis is concerned with the performance evaluation of coherent optical fiber communication (COFC) systems and receiver design. Expressions for probability of error are derived considering shot noise alone, shot noise with local oscillator (LO) excess noise, shot noise with laser phase noise, shot noise with time jitter. Binary and M-ary PSK, FSK and ASK signalling schemes with synchronous demodulation are considered. Power penalties due to LO excess noise, laser phase noise and time jitter are obtained. Error rate floors due to laser phase noise have been computed.

In presence of shot noise, the performance of M-PSK and M-FSK systems degrades as M increases and in M-FSK systems it improves. However, in M-FSK systems bandwidth requirement increases as M increases. The effect of LO excess noise is to increase the probability of error for the same signal power. The power penalty due to LO excess noise is smaller for higher LO power source. Further, this penalty is invariant of the choice of signalling scheme and the order of system.

Presence of laser phase noise also leads to power penalty. This penalty depends on the phase noise variance or equivalently source linewidth, choice of signalling scheme, order of the system, data rate and required error rate. Variation of this

penalty with laser phase noise variance exhibits a threshold effect. The penalty is same for BPSK and BFSK and is relatively larger for BASK (OOK). As M increases, the penalty remains almost same in M-FSK systems, while it increases in M-PSK and M-ASK systems. The power penalty, for a given source linewidth, decreases as data rate and required error rate increases.

Time jitter also leads to some power penalty. As in the case of laser phase noise, power penalty due to time jitter depends upon the time jitter variance, choice of signalling scheme, order of the system, data rate and required error rate. Its variation with time jitter variance also exhibits a threshold effect. For binary signalling schemes, penalty is same for BPSK and BFSK and is little larger for BASK. As M increases, it decreases slightly in M-PSK systems, remains almost same in M-FSK systems and increases in M-ASK systems. It also decreases with the increase in data rate and required error rate.

Performance of dual-detector receiver has been analysed and compared with the performance of single detector receiver. For optimum performance, the power splitting coefficient of the beam splitter should be equal to 0.5, both detectors should be identical and path lengths in both the branches should be same. Degradation in the performance due to non-ideal beam splitter, non-identical detectors and path length difference has been worked out. Dual-detector receiver is found to be superior to conventional single detector receiver mainly due to its ability

to cancel LO excess noise and utilisation of all available LO and received signal powers.

Phase and polarisation diversity receivers are studied in this thesis. Two new receiver structures which are insensitive to LO excess noise in addition to phase and polarisation fluctuations of the received signal have been proposed. These structures have been analysed both in ideal and non-ideal conditions for ASK and DPSK signalling schemes. Degradations due to non-ideal 180° and 90° optical hybrids and unequal quantum efficiencies of photodetectors are obtained. It is found that the choice of 90° hybrids is more critical as compared to 180° hybrid. In DPSK scheme, the choice of intermediate frequency plays an important role. It is found that at lower bit rates (< 1 Gbit/s), it can be chosen as 50 % of the bit rate. At higher bit rates, it should be chosen between 1-5 % of the bit rate.

The thesis also includes some suggestions for future work.

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