Experimental reduction of fiber-induced intensity noise in analog optical links employing chirped fiber Bragg gratings

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Abstract — **The use of chirped fiber Bragg gratings to mitigate dispersion-induced intensity noise in analog optical systems is experimentally demonstrated. the measurements show a 20 dB reduction in a 50 km standard single-mode optical span.**

I. INTRODUCTION

Intensity noise seriously impairs on the performance of analogue optical systems [1]. Lasers with built-in optical isolator provide a relative intensity noise (RIN) as low as −155 dB/Hz. However, an increase in the overall system RIN is expected due to multiple feedback reflections in connectors and splices [2] as well as laser phase noise to intensity noise conversion due to chromatic dispersion in standard single mode fibers, as operating near 1550 nm [3]-[4]. Multiple-reflection-induced RIN can be made negligible by employing optimized APC connectors and optical isolators. On the other hand, linearly chirped fiber Bragg gratings (CFG) have been proposed to compensate for fiber dispersion in analogue optical systems [5], and the use of a CFG to reduce dispersion-induced RIN was previously proposed theoretically [6]. In this Letter, the experimental demonstration of reducing the RIN arising from both chromatic dispersion and fiber nonlinearities is provided. The results show that a RIN level reduction of 20 dB is achieved in a 50 km standard single-mode optical span by employing a 4 nm CFG with a dispersion slope of nearly 850 ps/nm.

II. EXPERIMENTAL IMPLEMENTATION

The experimental arrangement is schematically shown in Fig. 1. The optical source is a DFB laser operating at 1550 nm, with an optical output power of +10 dBm and a linewidth of about 6 MHz. An optical isolator is used at its output for avoiding possible reflections in the optical link The transmission fiber is a standard single-mode fiber (SSMF) spooled on two coils of 25 km-length each one. Therefore, the total fiber-optic link length is 50 km and an erbium doped fiber amplifier (EDFA) is employed between the two fiber coils for setting an optical power of +10 dBm at the input of the second fiber coil. At the output of the fiber-optic link a CFG is employed to compensate for the chromatic dispersion, and thus, the laser phase noise to intensity noise conversion that occurs through the fiber span. Finally, the RIN after the system is measured employing a Lightwave Signal Analyzer (LSA). During the measurements, the resolution bandwidth was 3 MHz. The frequency-dependent thermal noise of the LSA as well as the shot noise can be determined by the LSA and further subtracted from the total system noise for calculating the effective RIN.

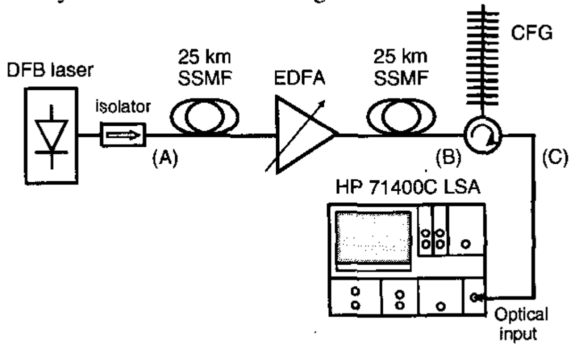

Fig. 1. Experimental set-up.

III. RESULTS AND DISCUSSION

Fig. 2 depicts the measured system RIN levels against frequency at the output of the DFB laser and at the output of the fiber-optic link with and without employing the CFG. These results were obtained using the LSA and correspond to the system RIN, i.e., including also the thermal, shot and ASE noises. The RIN results shown in Fig. 2 can be expressed as the ratio between the optical intensity noise and the square of the average optical power at the output of the system. For the sake of comparison, the optical power at the input of the LSA should be constant during the measurements. The received optical power was adjusted by using the internal optical attenuator of the LSA. As it can be observed in Fig. 2, the measured DFB laser RIN shows a maximum at 13 GHz of about −143 dB/Hz. Furthermore, the DFB laser RIN levels significantly increase as the light passes through the optical fiber span. This effect is due to the

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laser phase noise to intensity noise conversion produced by the chromatic dispersion of the optical fiber and it is proportional to the laser spectral width [3]. A fiber-induced peak RIN value of about −125 dB/Hz at 10 GHz can be seen in Fig. 2. In order to compensate for these higher RIN levels a 4 nm wide CFG with a delay slope of 850 ps/nm was employed. The measured dispersion-compensated RIN trace is also shown in Fig. 2. It can be seen that a RIN level reduction of up to 20 dB is achieved. However, after compensation with the CFG a noise floor remains due to the ASE noise introduced by the EDFA. As mentioned above, Fig. 2 shows the measured system RIN including thermal noise, shot noise and ASE noise. The LSA has an option for calculating the effective RIN noise by subtracting the thermal and shot noises introduced by the optical receiver. Therefore, this measurement is more useful for demonstrating the proposed approach. The calculated RIN levels using the LSA are summarized in Table I for different frequencies. As it is shown in Table I, employing the CFG the RIN level at the output of the fiber-optic link may be reduced up to 17 dB for a frequency of 10 GHz.

TABLE I
Calculated RIN levels in dB/Hz for several frequencies

	2 GHz	5 GHz	10 GHz
Laser RIN	−156.83	−150.82	−142.48
Fiber-induced RIN	−140.63	−132.45	−127.94
CFG-compensated RIN	−143.86	−145.15	−145.05

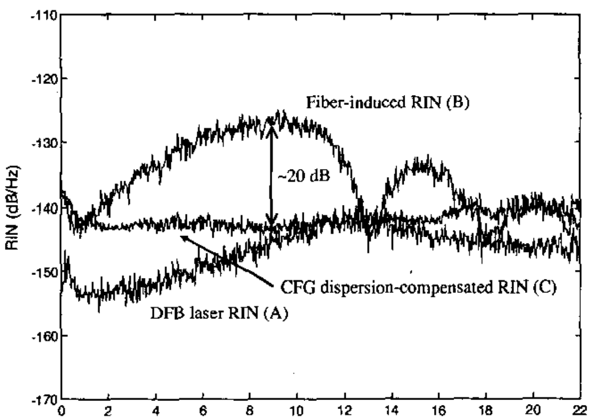

Fig. 2. Measured RIN versus frequency.

At frequencies higher than 14 GHz a small RIN level increase with respect to the DFB laser RIN trace is also shown in Fig. 2. This is due to both the non-exact chromatic dispersion compensation and some residual nonlinear effects. As a +10 dBm optical power signal is launched into both fiber coils nonlinear effects are generated, as were previously observed in [7].

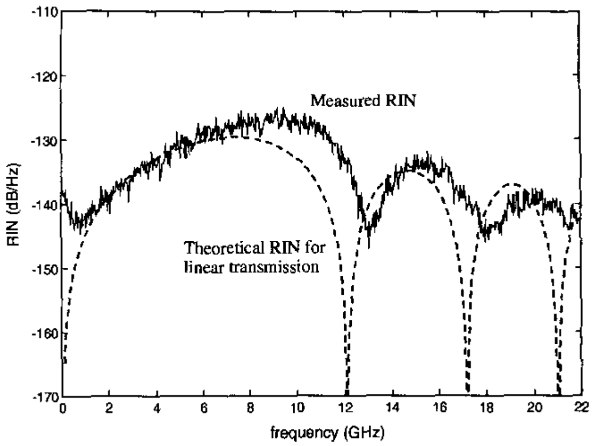

Fig. 3. Comparison of calculated and measured RIN.

Fig. 3 shows the comparison between the measured RIN and the theoretical results obtained from [4], assuming an ideal linear transmission. It can be seen in Fig. 3 that the measured RIN result shifts toward higher frequencies due to the fiber nonlinear effects [7]. The oscillatory behavior with RIN peaks and RIN dips agrees also well with the theory [4]-[7].

IV. Conclusion

The experimental demonstration of the mitigation of fiber-induced RIN arising from the laser phase noise to intensity noise conversion and nonlinear effects in a 50 km standard single-mode optical span by employing a 4 nm CFG with a dispersion slope of nearly 850 ps/nm is provided. A RIN level reduction of 20 dB has been achieved.

Acknowledgement

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REFERENCES

[1] W.I. Way, 'Subcarrier multiplexed lightwave system design considerations for subscriber loop applications," J. Lightwave Technol., vol. 7, no. 11, pp. 1806-1818, November 1989.

[2] W.I. Way, C. Lin, C.E. Zah, L. Curtis, R. Spicer, and W.C: Young, "Multiple-reflection-induced intensity noise studies in a lightwave system for multichannel AM-VSB television signal distribution," IEEE Photon. Technol. Lett., vol. 2, no. 5, pp. 360-362, 1990.

[3] K. Petermann, "FM-AM noise conversion in dispersive single-mode fibre transmission lines," Electron. Lett., vol. 26, no. 25, pp. 2097-2098, 1990.

[4] S. Yamamoto, N. Edagawa, H. Taga, Y. Yoshida, and H. Wakabayashi, "Analysis of laser phase noise to intensity noise conversion by chromatic dispersion in intensity modulation and direct detection optical-fiber transmission," J. Lightwave Technol., vol. 8, no. 11, pp. 1716-1722, 1990.

[5] J. Marti, D. Pastor, M. Tortola, J. Capmany, "Optical equalisation of dispersion-induced nonlinear distortion in subcarrier systems by employing tapered linearly chirped gratings", Electron. Lett., vol. 32, no. 3, pp. 236-237, 1996.

[6] J. Marti, A. Montero, J. Capmany, J.M. Fuster, and D. Pastor, "Reduction of dispersion-induced intensity noise in subcarrier systems by using tapered linearly chirped gratings," Electron. Lett., vol. 32, no. 17, pp. 1605-1606, 1996.

[7] A.V.T. Cartaxo, B. Wedding, and W. Idler, "Influence of fiber nonlinearity on the phase noise to intensity noise conversion in fiber transmission: theoretical and experimental analysis," J. Lightwave Technol., vol. 16, no. 7, pp. 1187-1194, 1998.