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Master Degree Course Electronics Engineering, MSc EE

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Master 2006

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Noise Analysis of Components in a Transmission System for Space Application

ABSTRACT - Masterthesis

In the context of this work, noise analysis, noise measurements and noise propagation in an electro-optical design for long haul intersatellite communication systems using binary phase shift keying and homodyne detection were performed. First, a detailed discussion of the different kinds of noise in electronic circuits is presented. This discussion is followed by an introduction to the 4-level-rate equations and a derivation of the amplitude and frequency transfer function and to the small signal response of solid state laser systems. The last major part of the introduction to noise represents the widely used Relative Intensity Noise (RIN) spectrum, for describing noise in optical systems and its derivation from Fourier Theory.

In the second chapter the electro-optical system used for intersatellite communication as designed by Tesat- Spacecom GmbH & Co.KG, is introduced with a detailed discussion of the parameters that influence the noise properties of the single elements.

In the last chapter the noise measurements with the subsequent noise analysis are presented for a commercially available current source, for a Pump Module Head (PMH), for interconnecting multimode fibers having two different fiber core geometries and for the Neodymium Ytterbium Aluminium Garnet (Nd:YAG) Non-Planar Ring Oscillator (NPRO) solid state laser.

It was found that the RIN spectrum of the current source contains spurious noise amplitudes from the mains and from electromagnetic waves originating from devices in the vicinity of the current source which induce transients in the electrical wiring of the measurement setup. Those spurious noise amplitudes are not only a disadvantage when driving the pump module head, but also present easily recognisable features in the PMH RIN spectrum, which can directly be related to the noise of the current source. Thus the propagation of noise from the electrical into the optical domain was proved by the reappearance of the noise amplitudes from the current source in the RIN spectrum of the PMH. As the current source and PMH were analysed and described by their RIN spectrums the noise measurement of the two different types of interconnecting multimode fibers having a radial symmetric and D- shaped core geometry, were performed. The results of these measurements showed that the RIN of the fibers strongly depend an the coupling conditions of the PMH laser radiation

into the fiber. The level of the RIN spectrum of the standard Step- Index Multimode Fiber (SI-MMF) tightly fixed, i. e. spot welded to the chassis of the PMH is exceedingly lower than the RIN levels of the two different fibers with free space light coupling. A difference in the RIN between the two different fiber calculated for 4 different measurement setups was only very small, with lower noise contribution of the radial core symmetric SI-MMF. A graphical analysis for the far field radiation angle of the spot welded SI-MMF was presented that presents a powerful tool for describing the speckle pattern due to modal noise. Concerning the two different fibers too, it was shown that a measurement of the far field radiation angles with PMH laser radiation coupled into the fibers with a focussing unit could not be done properly, because of the beam properties of the PMH.

The noise measurements performed with the LH showed an increase of the noise amplitudes in RIN spectrum at the relaxation oscillation frequency that is inherent to the photon emission process. Additionally to this it was found that at very low LH crystal temperatures around -10°C the otherwise continuous light emission switched to a pulsed optical output. Several measurements concerning this problem identified the gyromagnetic constant, responsible for the Faraday Effect, as most probable cause for the pulsed operation.