

A 1 GHz OPTICAL-DELAY-LINE OSCILLATOR DRIVEN BY A DIODE LASER

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Abstract: Experimental results are presented on a hybrid optical/electronic oscillator which uses an optical delay line to generate high spectral purity microwave signals. At Fourier frequencies above 10 kHz, the single sideband (SSB) phase noise spectrum decreases as roughly $1/f^2$ attaining a value of -138 dB below the carrier in a 1 Hz bandwidth (dBc/Hz) at 20 kHz offset. The origin of this noise is in part the fundamental shot noise on the light itself, although other optical noise sources such as double Rayleigh scattering and stimulated Brillouin scattering also appear to be important under certain operating conditions. The frequency stability over several hours is dominated by changes in the fiber ambient temperature with a coefficient of about $10^{-8}/\text{K}$ originating mostly from changes in the fiber refractive index with temperature.

Introduction

Stable S-band and X-band oscillators play a role in numerous applications ranging from precision metrology to optical communication systems. There are several traditional methods of generating low phase noise oscillation at these frequencies. Bulk acoustic wave (BAW) oscillators, oscillating at 5 or 10 MHz can be multiplied up to GHz frequencies. Although the initial BAW oscillator may be extremely stable, the multiplication process usually adds substantial additional noise, particularly at frequencies far from the carrier, which seriously degrades the original performance of the oscillator. Surface acoustic wave (SAW) oscillators have been used to directly generate oscillation in the frequency range of 100 MHz to a few GHz with somewhat inferior close-in phase noise performance than low frequency BAW oscillators. For even higher frequencies, up to tens of GHz, dielectric resonator

oscillators (DRO's) are most often used; sapphire is the dielectric material of choice for obtaining the lowest phase noise. While these methods have been, on the whole, successful, particularly in producing signals with extremely low phase noise, their lack of tunability and difficulty of fabrication limit their usefulness in many critical applications.

Recently, a novel hybrid optical/electronic approach to this problem was proposed [1, 2]. This uses an optical fiber delay line to achieve phase noise performance competitive with the best commercially available synthesizers. These optical-delay-line oscillators (ODLO's) or light-induced microwave oscillators also have a number of highly desirable features not available in other oscillators: they are highly tunable; have oscillation frequencies which can potentially range from hundreds of kHz to tens of GHz; can have moderately low phase noise; have both optical and electronic inputs and outputs facilitating their integration with other optical systems; and can be constructed with no precision components other than commercially available optical fiber. Another important aspect of these oscillators is that their phase noise performance is independent of oscillation frequency making them excellent candidates for generating microwave signals above 10 GHz. Recent experimental results for an 800 MHz oscillator [3, 4] have demonstrated a SSB phase noise of less than -140 dBc/Hz at 30 kHz frequency offset and many future improvements seem likely.

The Optical Delay Line Oscillator

The ODLO takes advantage of the extremely low loss and long delay times which can be achieved in optical fibers in order to provide the frequency discrimination necessary for low phase noise oscillation. A diagram of one of the oscillators built at NIST is shown in Figure 1. An electronic signal is first translated into amplitude modulation on an optical carrier generated by

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Frequency Control and Synthesis, 1989. Second International Conference on, 1989 Second International Conference on Frequency Control and Synthesis, 1989 Second International Conference on Frequency Control and Synthesis, 2002 *Intelligent Materials, Second International Conference Proceedings* Craig A. Rogers, 1994-01-01 The key science and technology challenges which will facilitate the transition from a make do and mend philosophy inevitably restricting the degree of intelligence which can be engineered and the designer materials systems philosophy which is the ultimate goal are considered The longer term vision will need to accord much more closely with nature's design paradigms with control at the molecular nano micro and macro level of synthesis and assembly of active self repair materials systems in function shapes *Understanding the Navstar* Tom Logsdon, 2013-03-14 The Navstar Global Positioning System GPS is being financed by military dollars but the precise navigation signals it broadcasts are available free of charge to anyone anywhere Over the next ten years sponsors of Navstar navigation will be investing an estimated *Noise Analysis of Radio Frequency Circuits* Amit Mehrotra, Alberto L. Sangiovanni-Vincentelli, 2013-04-17 In this book we concentrate on developing noise simulation techniques for RF circuits The difference between our approach of performing noise analysis for RF circuits and the traditional techniques is that we first concentrate on the noise analysis for oscillators instead of non oscillatory circuits As a first step we develop a new quantitative description of the dynamics of stable nonlinear oscillators in presence of deterministic perturbations Unlike previous such attempts this description is not limited to two dimensional system of equations and does not make any assumptions about the type of nonlinearity By considering stochastic perturbations in a stochastic differential calculus setting we obtain a correct mathematical characterization of the noisy oscillator output We present efficient numerical techniques both in time domain and in frequency domain for computing the phase noise of oscillators This approach also determines the relative contribution of the device noise sources to phase noise which is very useful for oscillator design *Detecting and Classifying Low Probability of Intercept Radar* Phillip E. Pace, 2009 This comprehensive book presents LPI radar design essentials including ambiguity analysis of LPI waveforms FMCW radar and phase shift and frequency shift keying techniques Moreover you find details on new OTHR modulation schemes noise radar and spatial multiple input multiple output MIMO systems The book explores autonomous non linear classification signal processing algorithms for identifying LPI modulations It also demonstrates four intercept receiver signal processing techniques for LPI radar detection that helps you determine which time frequency bi frequency technique best suits any LPI modulation of interest Publisher **The Navstar Global Positioning System** Tom Logsdon, 2012-12-06 **Direct Digital Frequency Synthesizers** Venceslav F. Kroupa, 1998-11-18 With the advent of integrated circuits IC digital systems have become widely used in modern electronic devices including communications and measurement equipment Direct Digital Frequency Synthesizers DDS are used in communications as transmitter exciters and local oscillators in receivers The

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