

Cs FREQUENCY SYNTHESIS: A NEW APPROACH

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ABSTRACT

This paper describes a new approach to synthesizing the Cs hyperfine frequency of 9.192 GHz that is designed to be sufficiently rugged for use in space, specifically for the primary atomic reference clock in space (PARCS) planned for the international space station, as well as ground applications. This new approach requires no narrow band filters or frequency multiplication and the primary source of cooling is conduction. Instead of frequency multiplication, it uses a custom regenerative divider stage followed by two commercial binary dividers and several mixing stages. A fractional frequency step of 2×10^{-14} is achieved by mixing the output of a 48 bit numerically controlled oscillator with the microwave signal. Preliminary tests on the new synthesizer design indicate an internal fractional frequency stability of 1×10^{-13} at 10 s and 1×10^{-14} at 1 day, dominated by the daily room temperature variations. The phase and amplitude noise are similar to our previous designs that used frequency multiplication and narrow band filters. The temperature coefficient is less than $0.2 \text{ ps/}^\circ\text{C}$.

1. INTRODUCTION

Within the last decade new generations of frequency standards based on laser cooled atoms and ions with stabilities approaching 10^{-16} at 1 day have been developed [1-3]. At these stabilities, the performance of the local oscillator and the microwave synthesis chain appear to be limiting factors. To support NIST's new standards, we have designed a new generation of microwave frequency synthesizers [4-6]. The basic criteria for these designs have been high resolution, low phase modulation (PM) and amplitude modulation (AM) noise, low spurs near the carrier, and very high phase stability with respect to environmental effects.

The aim of the present work was to design a microwave synthesizer for a laser cooled Cs fountain compatible for use in space, specifically for a slow beam Cs primary atomic reference clock in space (PARCS) scheduled for flight the international space

station [7]. This required the use of components that are or can be space-qualified. Other major design goals were that the synthesizer be compact, robust, consume low power, and very importantly, that all dissipated heat be removed by conduction and radiation as there is minimal convection in space. The performance goal was a frequency resolution of at least 10^{-13} and a fractional frequency stability at 1 day of lower than 1×10^{-14} .

In the following section we describe our design. The approach yields a simple synthesis scheme that avoids frequency multiplication, narrow band filters, and phase-locked loops while still producing an output that is suitable with high resolution. We also discuss some initial performance results of the two units that were constructed. All performance goals were met or exceeded.

2. DESIGN DETAILS

Figure 1 shows a schematic block diagram of the synthesizer. The output of a 6.4 GHz voltage-controlled dielectric resonant oscillator (DRO) drives a custom regenerative divide-by-2 circuit [8], comprised of a mixer, a 3.2 GHz low-pass filter, and an amplifier in a closed-loop configuration. This regenerative divider provides low PM noise [9], a very low coefficient of phase shift with temperature, and simultaneous outputs at 0.5 and 1.5 times the input frequency, i.e., at 3.2 GHz and 9.6 GHz. The 3.2 GHz and 9.6 GHz outputs are separated using a diplexer.

The 3.2 GHz output is divided to 100 MHz using a commercial divide-by-8 followed by a commercial divide-by-4 [10]. The 100 MHz output of the dividers is low-pass filtered and buffered in a two-stage amplifier to provide the output reference frequency.

Another key constituent of the synthesizer is a numerically controlled oscillator using a direct digital synthesis (DDS) chip with 48 bit resolution [11]. This unit is clocked by a 50 MHz signal obtained by dividing the 100 MHz by 2. This DDS chip not only provides the high resolution and low spurs, but it is also available in a space-qualified version. The DDS output is a sine wave, which can be set to a resolution of 0.2 μHz and a rate up to 20 MHz using 14 data and control lines. Another feature of this DDS is that its frequency

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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

Orbital Mechanics Tom Logsdon, 1997-10-24 A lively study of orbital mechanics by the writer responsible for the computer simulations and systems analysis for the Saturn V moon rocket Project Skylab and many others Provides thorough coverage of all background theories including unusual concepts and paradoxes that will enhance appreciation of this field Includes discussion of rocket propulsion and optimization of techniques for maximizing payload and minimizing fuel consumption plus complete coverage of the interaction of space vehicles and space bodies

GaAs Technology and Its Impact on Circuits and Systems David Haigh, Jeremy Everard, 1989 This book captures the essence of developments of Gallium Arsenide technology from the research laboratory to the marketplace along with the dramatic increases in complexity from early single devices to ICs of MSI complexity for both analog and digital applications

Proceedings of the Multi-Conference 2011 Himanshu B. Soni, Apurva Shah, 2011-06-06 The International Conference on Signals Systems and Automation ICSSA 2011 aims to spread awareness in the research and academic community regarding cutting edge technological advancements revolutionizing the world The main emphasis of this conference is on dissemination of information experience and research results on the current topics of interest through in depth discussions and participation of researchers from all over the world The objective is to provide a platform to scientists research scholars and industrialists for interacting and exchanging ideas in a number of research areas This will facilitate communication among researchers in different fields of Electronics and Communication Engineering The International Conference on Intelligent System and Data Processing ICISD 2011 is organized to address various issues that will foster the creation of intelligent solutions in the future The primary goal of the conference is to bring together worldwide leading researchers developers practitioners and educators interested in advancing the state of the art in computational intelligence and data processing for exchanging knowledge that encompasses a broad range of disciplines among various distinct communities Another goal is to promote scientific information interchange between researchers developers engineers students and practitioners working in India and abroad

Second International Conference on Environmental Mutagens in Human Populations ,1996

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Machines, and Drives (PEMD 2004) ,2004 *Selected Contributions of 2024 2nd International Conference on Electric Vehicle and Vehicle Engineering* Pak Kin Wong,Jun Xu,2025-06-30 This book presents an extensive exploration of the latest trends in Electric Vehicle and the boundless opportunities they offer It has encompassed various facets including Intelligent Vehicle Electric Vehicle Technology Power Electronics and Motor Drives Energy Systems and Storage Electronic Control Systems Battery Technologies Autonomous and Connected Vehicles The book is tailored for researchers engineers and practitioners deeply involved in the field of Electric Vehicle It delves into the intricate technicalities of EV technology providing profound insights and comprehensive discussions on its fundamental principles **Research & Publications**

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