EXTREMELY LOW-PHASE NOISE X-BAND FIELD EFFECT TRANSISTOR DIELECTRIC RESONATOR OSCILLATOR

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ABSTRACT

The 9 GHz Field Effect Transistor (FET) Dielectric Resonator Oscillator (DRO) presented in this paper represents the best X-band DRO reported to date. The merit of the oscillator was determined by measuring the loaded quality factor, single sideband phase noise and frequency stability of the device. Additionally, the residual phase noise of the dielectric resonator and the FET amplifier were measured to determine the limiting element in the oscillator. The 9 GHz FET DRO displays a single sideband phase noise which is 3 dBc/Hz better than the previous state-of-the-art, while it exhibits a frequency stability of 0.65 ppm/K.

INTRODUCTION

Future radar and communication systems will have a need for very low phase noise, compact, high efficiency, and high frequency sources (1). Low phase noise signals are absolutely critical for CW Doppler type radars, both very close-in to the carrier and also at large offset frequencies from the carrier. At present, X-band frequencies are generated by multiplying a low frequency reference source. Multiplication is a very inefficient process; for example, 20 watts of input power may only generate 100 milliwatts of X-band power. A fundamentally operated DRO like the one reported in this paper has the potential to satisfy the phase noise requirements for a multitude of systems and requires less than 2 watts of input power to generate 100 milliwatts of X-band power.

OSCILLATOR DESIGN AND CONSTRUCTION

A Dielectric Resonator (DR) is used as the parallel feedback element in the oscillator circuit shown in Figure 1. The dielectric resonator consists of a high dielectric constant, high quality factor (Q) material supported inside a metal cavity by a low loss, low dielectric constant material (2). Coupling is achieved via microstrip 50 ohm transmission lines constructed on a Duroid 5880 substrate located at the bottom of the cavity. After measuring the loss and phase of the DR, the appropriate loop amplifier was designed using two GaAs FETs as shown in Figure 1. The loop circuit is then constructed such that the gain and the phase requirements for the oscillator are satisfied once the loop is closed. The loaded Q of this circuit with an insertion loss of 12dB was measured to be 13,000 at an operating frequency of 9.043 GHz. The results of the loaded Q measurement are shown in Figure 2.

MEASURED DATA AND RESULTS

The residual phase noise of oscillator components such as the dielectric resonator and FET amplifier were measured and are shown in Figures 3 and 4 respectively. The residual noise measurement is necessary for designing low phase noise oscillators (3). The results of the residual noise measurements clearly indicate that the amplifier noise is better than the dielectric resonator noise which is required for low noise design applications. The increasing noise level in Figure 3 at the offset frequency of 1 kHz and up is due to signal generator noise not canceled in the unbalanced bridge measurement configuration. The system noise floor at the operating frequency is shown in Figure 5.

The single side-band phase noise results of the 9 GHz FET DRO are shown in Figure 6. The data was measured on the Hewlett Packard (HP) 3047A phase noise measurement system. The block diagram of this test set-up is shown in Figure 7. The phase noise measurement was made by locking the 153 MHz difference frequency signal, derived by mixing the test DRO with a low noise High-overtone Bulk Acoustic Resonator (HBAR) oscillator, to an HP8662A frequency synthesizer driven by an external 10 MHz VCXO. The single

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sideband phase noise data reported here is at least 3 dBc/Hz better than the most recently published 8.73 GHz BJT DRO data of Jones and Estrick (4). Frequency stability of this 9 GHz FET DRO is less than 600 kHz over the temperature range of +50°C to -50°C with an output power greater than +16 dBm. The frequency and power versus temperature data are shown in Figures 8 and 9, respectively. The frequency stability and output power of the BJT DRO reported by Jones are on the order of 10 MHz and -2 dBm respectively. It should also be noted that the best commercially available DRO has a frequency stability of 3-4 MHz over the stated temperature range.

CONCLUSIONS

The 9 GHz FET DRO reported here exhibits state-of-the-art oscillator performance in several ways. Besides demonstrating low phase noise and frequency stability of 0.65 ppm/K, the oscillator also shows high efficiency in comparison to existing X-band sources. The basic design of the oscillator also lends itself to simple construction and the use of low cost commercially avail able electronic components.

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REFERENCE

(1) R.A. Jelen and M.M. Driscoll, "Multiple Frequency Source for Air Defense Radar", R&D Technical Report SLCET-TR-87-0718-F, September 1990.

(2) K. Wakino, T. Nishikawa, H. Tamura and T. Sudo, "Dielectric Resonator Materials and their Applications", Microwave Journal, June 1987, pp. 133-150.

(3) T.R. Faulkner, "Residual Phase Noise Measurement", Microwave Journal, 1989 State Of The Art Reference, pp. 135-143.

(4) R. Jones and V. Estrick, "Low Phase Noise Dielectric Resonator Oscillator", Proceedings of the 44th Annual Syposium on Frequency Control 1990, pp. 549-554.

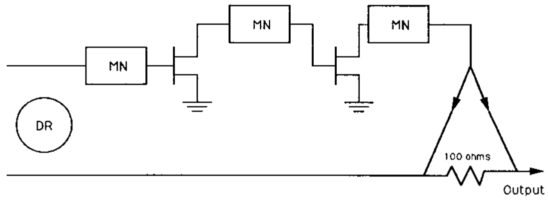

Figure 1 9 GHz Dielectric Resonator Oscillator Block Diagram

MN Matching Network

DR Dielectric Resonator

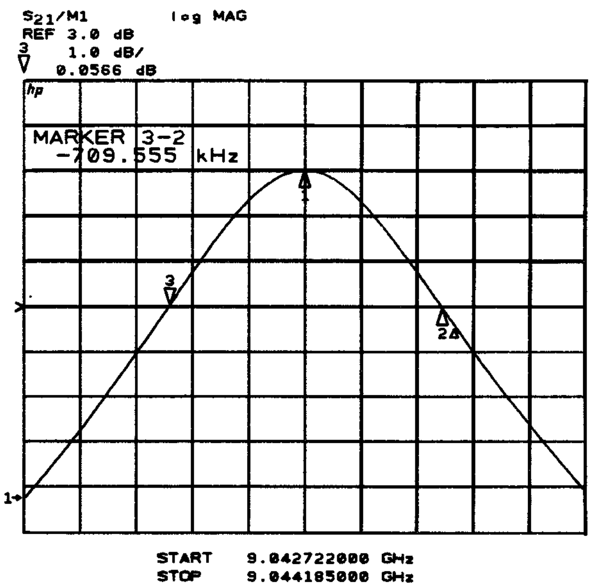

Figure 2 Loaded Q Data

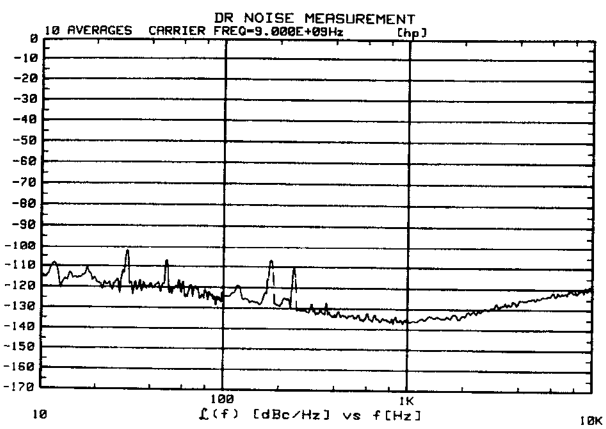

Figure 3 Residual Phase Noise Plot of 9 GHz Dielectric Resonator

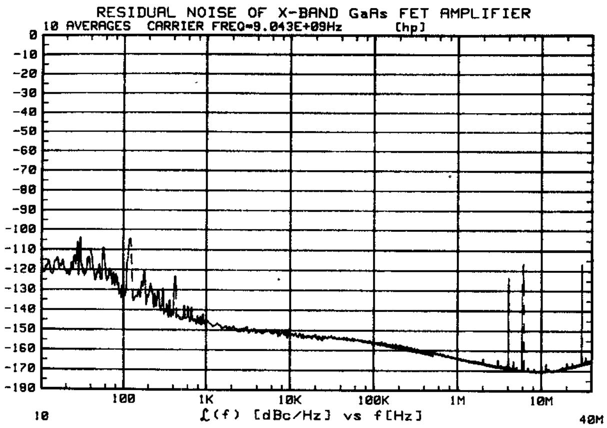

Figure 4 Residual Phase Noise Plot of X-Band Amplifier

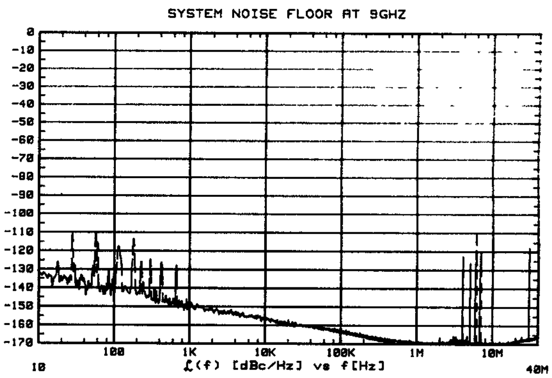

Figure 5 9 GHz System Noise Floor

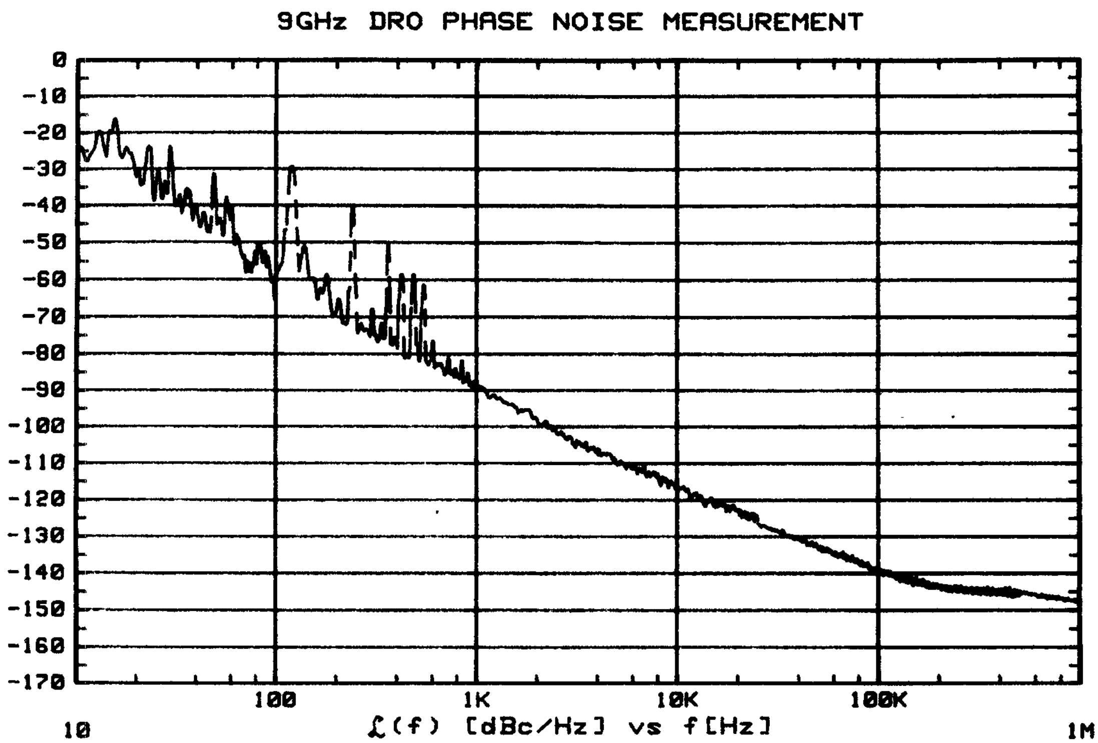

Figure 6 Absolute Phase Noise Plot of 9GHz DRO

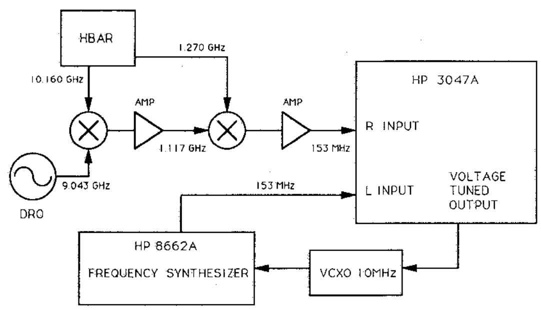

Figure 7 9GHz DRO Phase Noise Measurement Test Setup

HBAR: High Overtone Bulk Acoustic Resonator developed by Westinghouse for US Army, LABCOM ETDL.

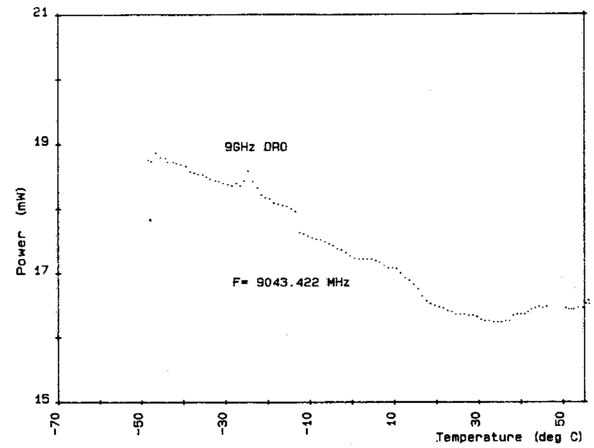

Figure 9 Power vs. Temperature Plot

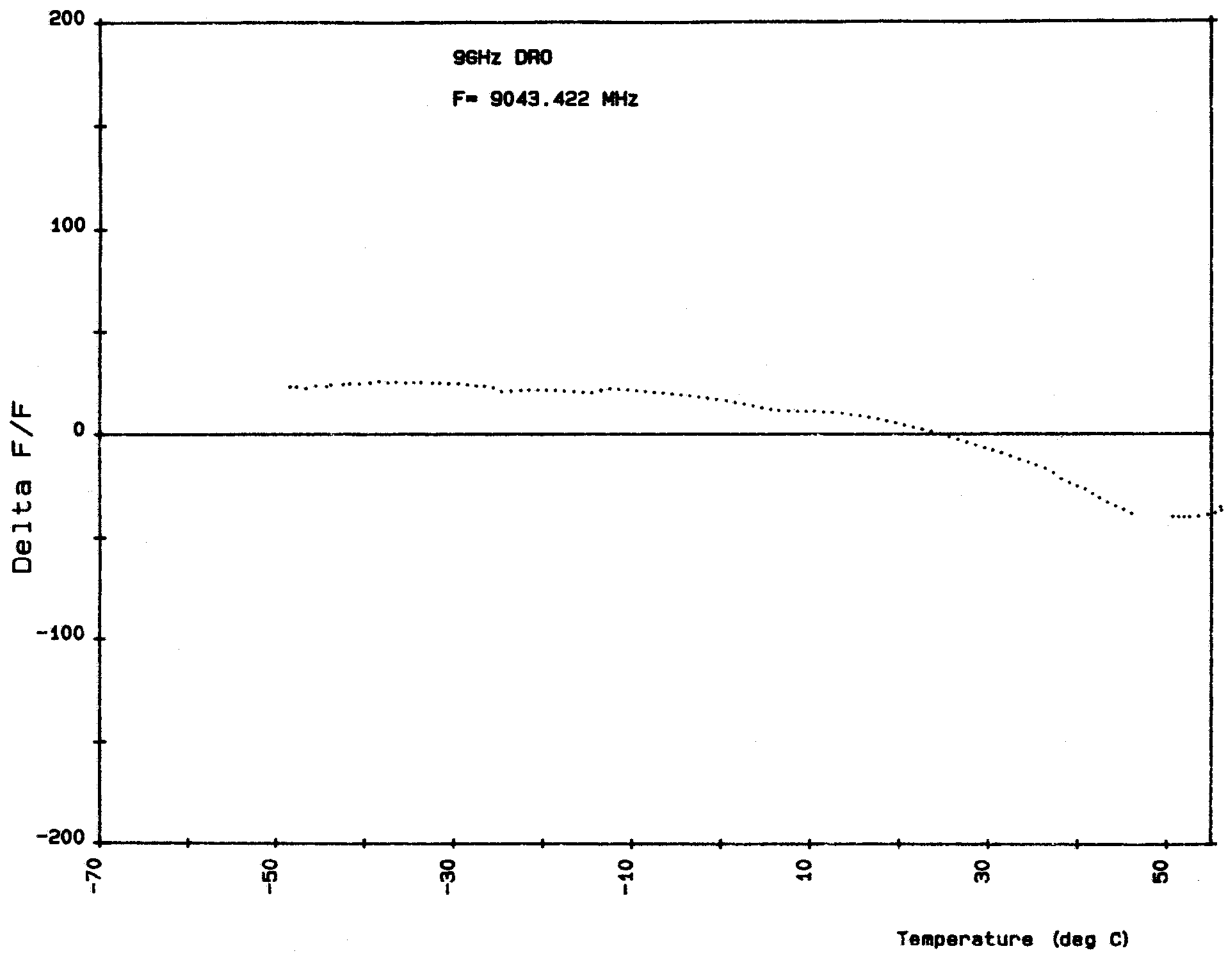

Figure 8 Frequency vs. Temperature Plot