# TEMPERATURE STABLE, LOW-PHASE NOISE 2 GHz DIELECTRIC RESONATOR OSCILLATOR

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## ABSTRACT

The results of a rigorous analysis of a state-of-the-art 2 GHz dielectric resonator oscillator (DRO) are presented in this paper. The performance of the DRO was determined by measuring the phase noise, loaded quality factor and frequency versus temperature response of the oscillator. These test results represent the lowest reported phase noise for a 2 GHz DRO, with the oscillator exhibiting single sideband phase noise levels of -100 dBc/Hz and -126 dBc/Hz at carrier offset frequencies of 100 Hz and 1 kHz respectively. A superb frequency vs. temperature response is also shown. The DRO exhibits a frequency stability of 1.31 ppm /K over the temperature range +55$^{o}$C to -45$^{o}$C.

## INTRODUCTION

The stringent performance requirements of future radar systems, satellite communications systems, atmospheric profilers and ECM receivers call for high frequency signals with extremely good spectral purity. Dielectric resonator oscillators (DROs) have been shown to be extremely low phase noise and highly temperature stable frequency sources (1). The dielectric resonator is used as the frequency determining circuit element in a parallel feedback oscillator. The feedback oscillator offers FM noise performance and frequency stability that is much better than that of a reflection oscillator. It also offers a high efficiency circuit and much simpler construction. The DRO cited in this paper is fabricated using low cost commercially available components. The 2 GHz DRO phase noise performance demonstrates a further improvement in the current state-of-the-art (2).

## OSCILLATOR DESIGN AND PERFORMANCE

Figure 1 shows an overall block diagram for the DRO. The amplifier needed to build the feedback DRO was first designed by using S-parameters and selecting appropriate input and output matching networks (3). The amplifier was designed such that its residual phase noise was below the residual noise of the resonator (4). It should be noted that oscillator noise can be degraded by the residual noise of the amplifier if the electronic components are not chosen carefully. The loaded quality factor, Q, of the oscillator was determined by opening the loop with the amplifier turned on. The result of this two-port Q measurement is illustrated in Figure 2. A loaded Q of 20,000 was obtained from this measurement. For an oscillator application, it is desirable to achieve as high a circuit quality factor as possible.

To minimize the radiation losses of the unbound $TE_{01}$ mode, the resonator is shielded in a critically dimensioned metal cavity. The cavity dimensions are very critical in obtaining the optimal loaded Q and temperature stability.

## MEASURED DATA AND RESULTS

The measured 2 GHz DRO output phase noise spectra is shown in Figure 3. The measurement was made by locking the 155 MHz difference frequency signal, derived by mixing the test DRO with a low-noise High-overtone Bulk Acoustic Resonator (HBAR) oscillator, to a Hewlett Packard (HP) 8662A frequency synthesizer driven by an external 10 MHz VCXO. The phase noise measurement test setup as shown in Figure 4 is limited by the HP 8662A noise spectra at 155 MHz. At 10 kHz carrier offset frequency, the system can only detect -143 dBc/Hz. The DRO noise performance of -155 dBc/Hz at 10 kHz carrier offset frequency, as predicted by the measured loaded Q, is masked by the HP 8662A Synthesizer. The phase noise result, as shown in Figure 3, is valid up to 1 kHz carrier offset frequency. The bright lines in the phase noise data are due to noise injected by peripheral circuitry, i.e., power supplies, AC lines, etc., and are not due to the source.

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The frequency and power versus temperature data, Figures 5 and 6 respectively, were obtained using a computer controlled environmental chamber. The DRO was subjected to a temperature profile that began with a 15 minute soak at +55°C and then proceeded to drop at a rate of 1 K per minute from +55°C to -50°C during which an automated frequency counter and power meter were used to record the frequency and power output of the oscillator. From the data in Figure 5, the frequency stability from +55°C to -45°C is 131 ppm. The power vs. temperature data seen in Figure 6 shows that over the same 100 K temperature differential the total change in output power was 0.86 dBm.

CONCLUSIONS

The measured data clearly illustrate the low phase noise and excellent frequency stability of this 2 GHz DRO. For comparison purposes, it can be shown that the 2 GHz DRO operating at direct frequency displays a phase noise performance which is approximately 3 dBc/Hz better than the state-of-the-art 500 MHz SAW resonator oscillator reported in Reference 5 when multiplied up to 2 GHz (5).

Besides these primary oscillator characteristics, there are several other desirable attributes displayed by this oscillator. First, the frequency stability of the DRO is superb, even after a 1 hour operation period, the center frequency exhibits a standard deviation that is less than +/- 1400 Hz from its mean value during this interval. Besides demonstrating good frequency stability, the oscillator shows a mechanical tuning bandwidth capability of 1 +/- 0.0001 MHz, via a tuning screw located in the resonator cavity, without degradation of the loaded Q. Another beneficial characteristic of this oscillator is that its simple design and construction combined with the use of commercially available electronic components will allow low cost, mass production of high performance oscillator at L-band.

ACKNOWLEDGMENTS

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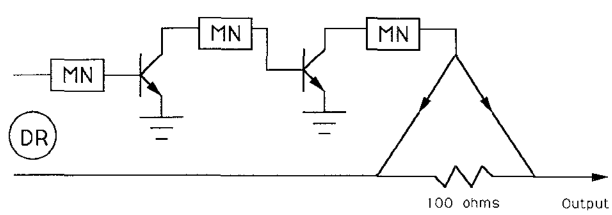


Figure 1 2 GHz Dielectric Resonator Oscillator Block Diagram

MN Matching Network

DR Dielectric Resonator

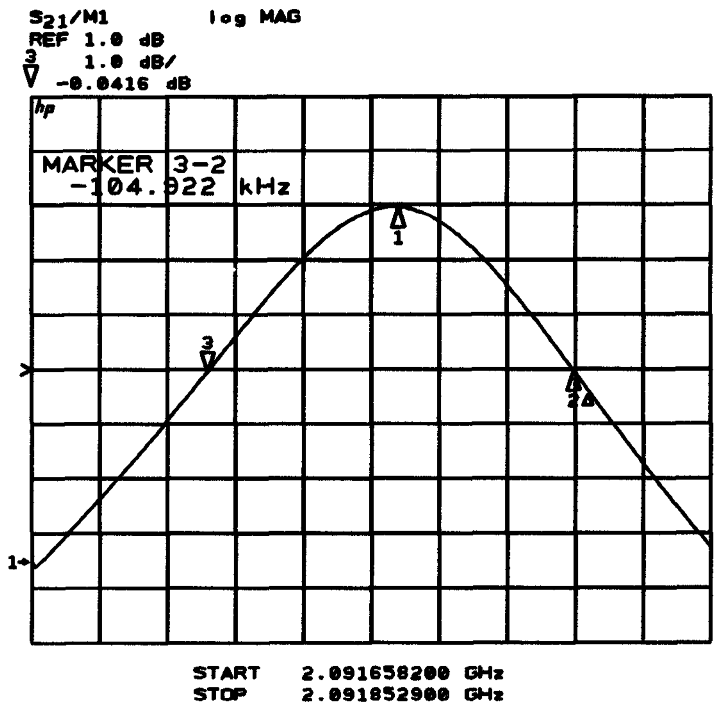


Figure 2 Loaded Q Data

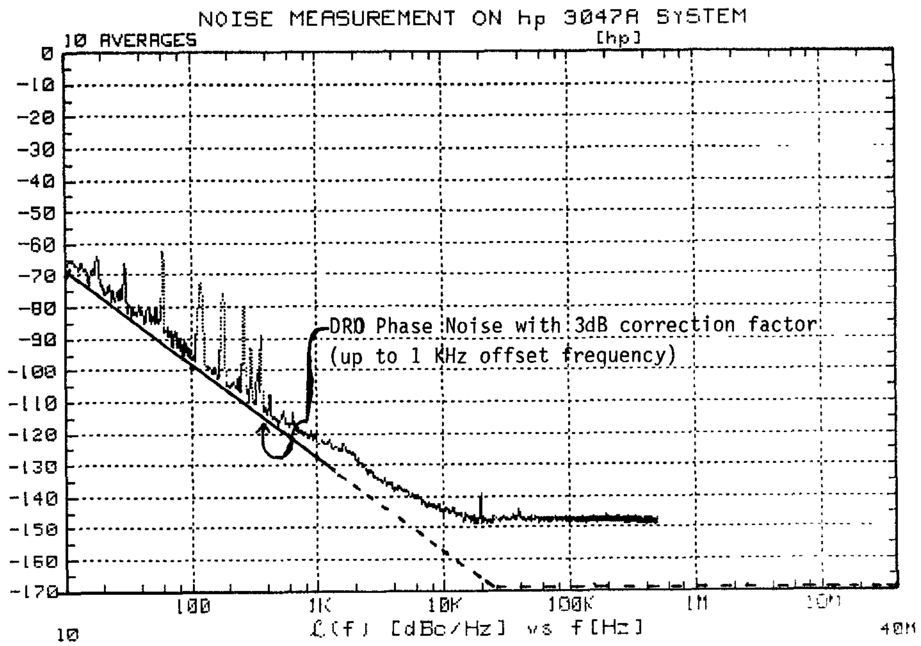


Figure 3 Phase Noise Plot

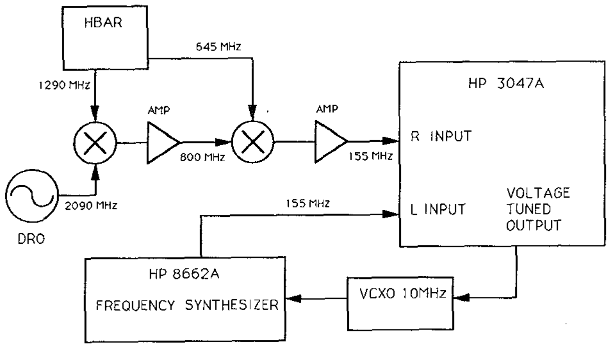


Figure 4 2GHz DRO Phase Noise Measurement Test Setup

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

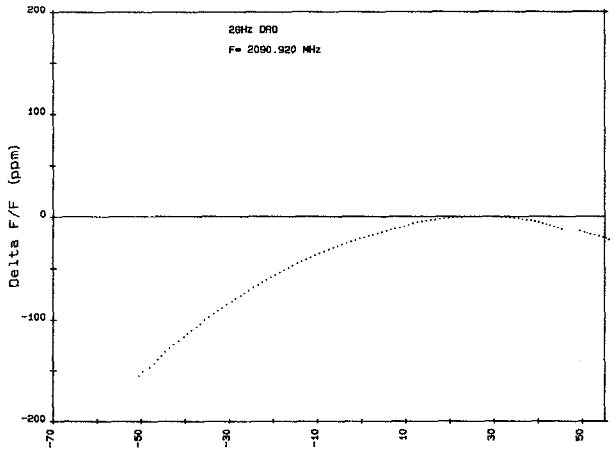


Figure 5 Frequency vs. Temperature Plot

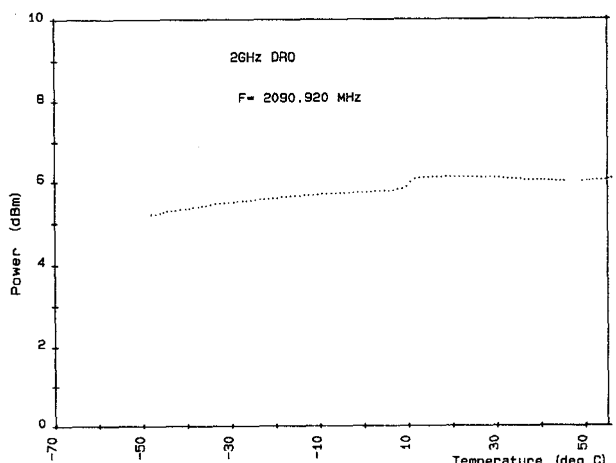


Figure 6 Power vs. Temperature Plot