A MINIATURE PRECISION OVEN QUARTZ OSCILLATOR SETS NEW SIZE VS. PERFORMANCE STANDARD

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ABSTRACT

The next generation frequency references for high volume applications, such as base stations and telecom digital switches, require a very stable ovenized crystal oscillator. The 220 Series oscillator has been designed by MTI-Milliren Technologies, Inc. and through extensive testing and evaluation, the oscillator has proven to provide the performance attributes necessary to fulfill most, if not all, future system requirements.

1. INTRODUCTION

The 220 Series oscillator utilizes SC cut quartz resonators in recently developed low profile TO-8 holders, achieving a typical thermal stability of 5e-9 per 100°C at a low cost. Housed in a standard SMT or through-hole 16 pin dual in-line welded hermetic package, the product measures 24.77mm x 20.32mm x 12.70mm. The oscillator consumes 2.5W (typical) during warm-up and approximately 0.8W @ 25°C, steady state. Key parameters, such as thermal stability, phase noise, short term stability, supply voltage sensitivity, and aging are comparable and, in many cases better, than that obtained by traditional and much larger units currently available.

The 220 Series utilizes a new oscillator topology, which reduces the component count and improves reliability by a factor of approximately 2 times over traditional circuit designs. The entire assembly including oven control, heaters, voltage regulation, and oscillator circuit is accomplished with five active components.

The 220 Series has been designed to be a product that can be consistently manufactured in a high volume production environment. Test data characterizing the various key parameters will be shown.

2. PRODUCT DESIGN

The key design goals in developing the 220 Series oscillator have been:

- Thermal Stability < 1e-8 per 100C
- High Reliability, MTBF
- Low Power Consumption
- Very Fast Warm-up
- Standard Package, Reduced Size, Surface Mounting, High Integrity Hermetic Seal, Rugged for High Shock and Vibration Environments
- Manufacturability and Consistency
- Low cost, High Volume Production

A circuit topology was adopted to allow a significant reduction in component count compared to traditional approaches such as Colpitts, Pierce, etc. A MMIC amplifier gain block with the quartz resonator, mode selector, and matching network in the feedback path achieves the targeted goals. Proper choice of the mode selector and matching filter component values allow the quartz to operate around series resonance. Figure 1 shows the oscillator block diagram. The entire oscillator assembly, including buffer amplifiers, is ovenized for best performance.

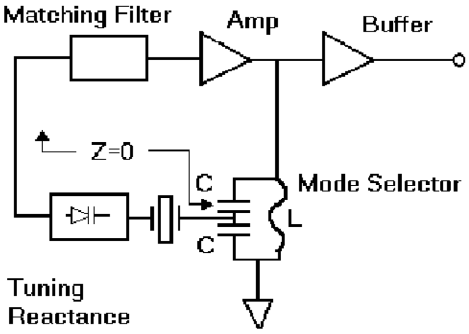

Figure 1

The 220 Series uses a common 16 pin DIL mechanical package which offers good hermetic seal characteristics and the ability to provide a surface mountable package. Figure 2 shows photo of both pin and surface mounting types compared to a US 5 cent coin.

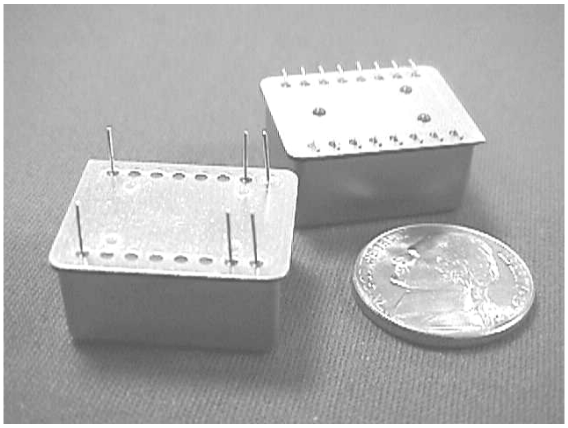

Figure 2

3. PERFORMANCE DATA

Data is shown for a number of important oscillator parameters. Sets of results were chosen to be representative for 2 common products, 5 and 10MHz units using SC cut quartz with 12V supply inputs and +9dBm sine outputs.

3.1 Phase Noise Results

Phase noise data is shown in Figure 3 and Figure 4 for 5 and 10MHz versions respectively. Results were obtained using an HP 3048 system for pairs of like units. Typical specification limits are shown as solid straight lines.

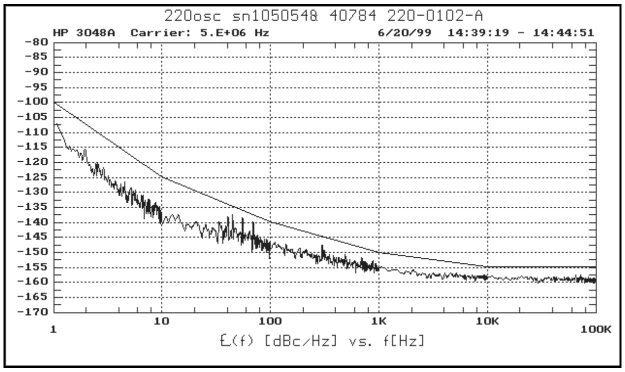

Figure 3

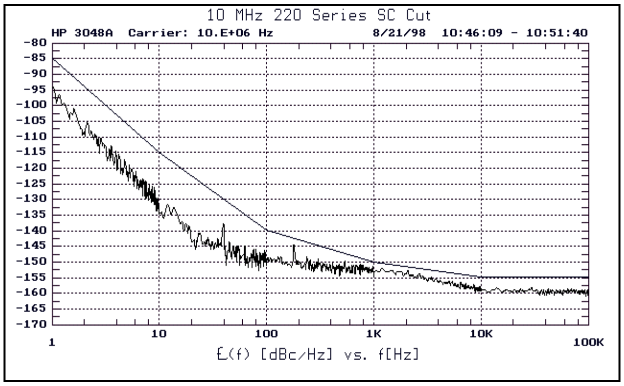

Figure 4

3.2 Output spectrum Results

Output spectrums are shown in Figures 5 and 6 for typical examples of 5 and 10MHz oscillators respectively. The output circuit contains a matching filter, which allows for low harmonic content as seen in the graphs below.

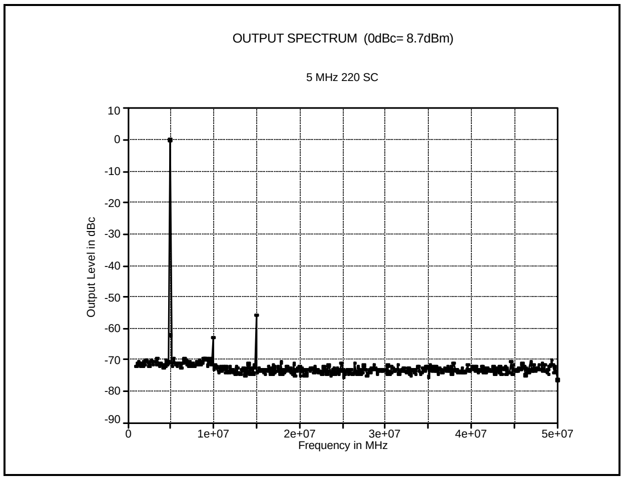

Figure 5

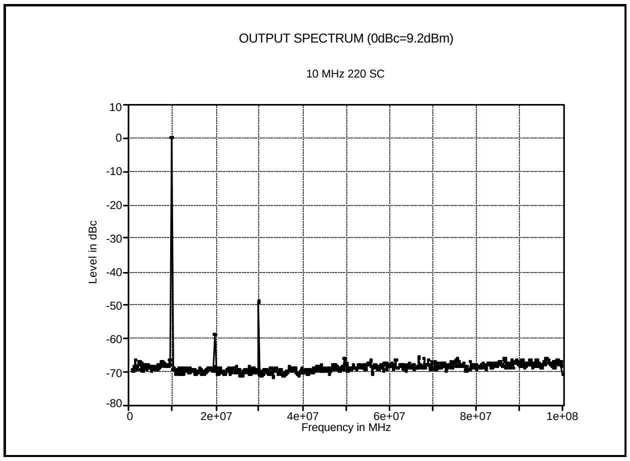

Figure 6

3.3 Thermal stability Results

The thermal stability is shown for both 5 and 10MHz units in Figures 7 and 10. Each stability graph is referenced to its respective “Temperature vs. Time” graph. This method of presentation allows the complete data set to be viewed in context to thermal transients and other phenomena, which might otherwise be missed in a simple Frequency vs. Temperature presentation. The Temperature vs. Time graph is shown for each frequency in Figures 8 and 11 respectively. The data for a 5MHz unit shows an up-down ramp with returns to 25C, while the 10MHz unit is a unidirectional ramp. Up-down ramps are most useful for qualification testing while single direction ramps are most used in production test. Each set of data also includes a Power vs. Time graph, see Figures 9 and 12 for 5 and 10MHz respectively.

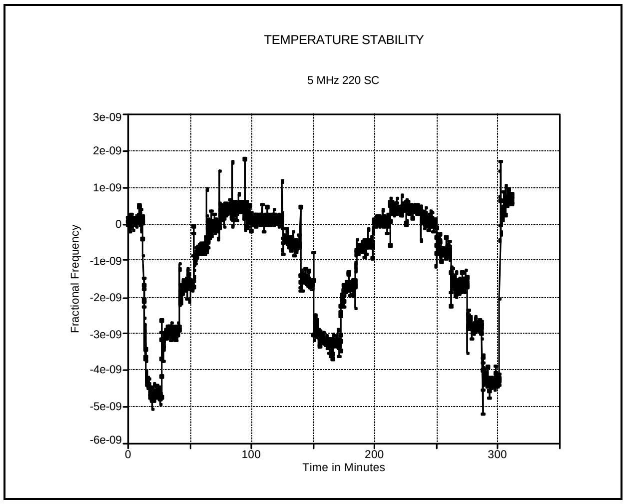

Figure 7

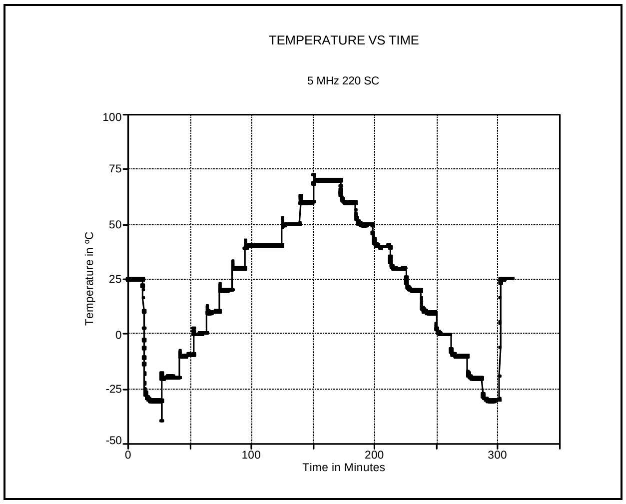

Figure 8

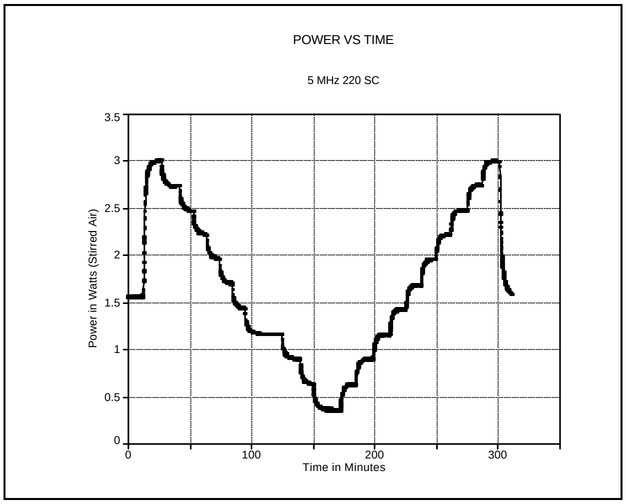

Figure 9

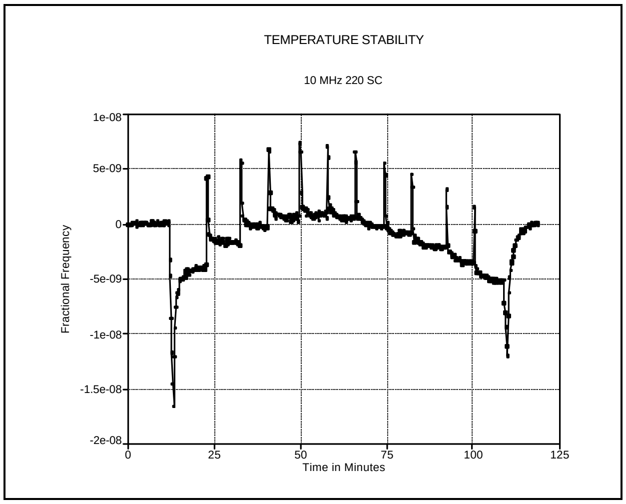

Figure 10

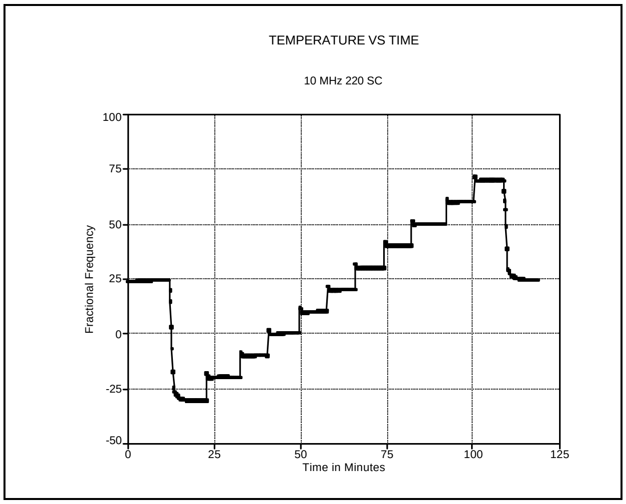

Figure 11

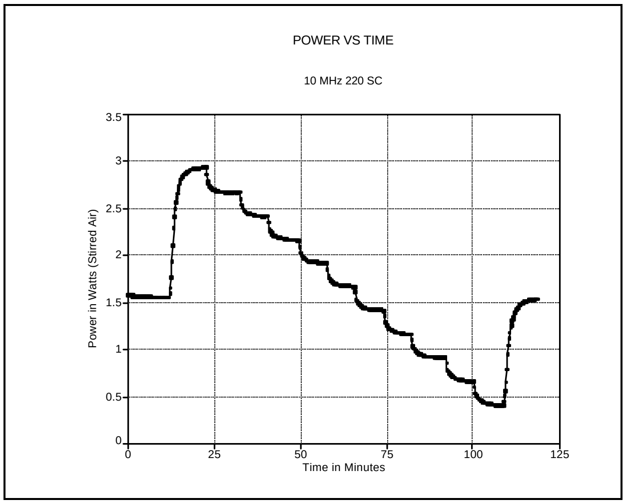

Figure 12

3.4 Warm-up Results

Warm-up data is shown in Figure 13 for a 5MHz SC 220 series oscillator. The measurements were made after an off period of greater than 2 hours. A graph of power vs. time is shown in Figure 14. The power consumption was measured in still air. The frequency is within a 2e-8 window in approximately 2 minutes at 25C. Although not shown, the frequency actually starts out at –20e-6 and quickly rises to the operating frequency. The small positive section of the graph represents an overshoot caused by a less than perfect SC crystal cut. Performance data for 10MHz product is very similar to 5MHz and thus no separate data is presented for this case.

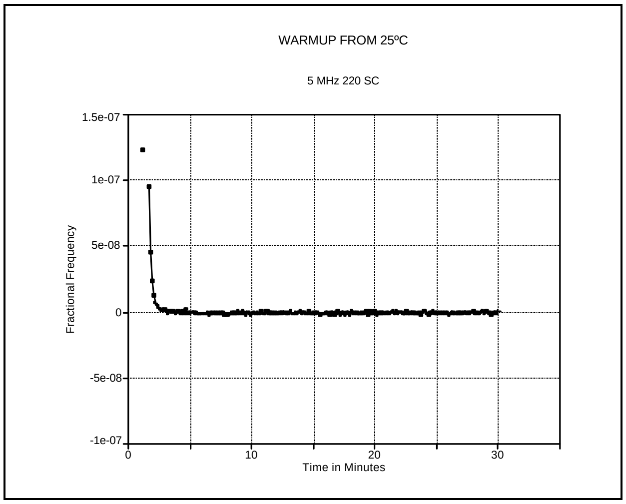

Figure 13

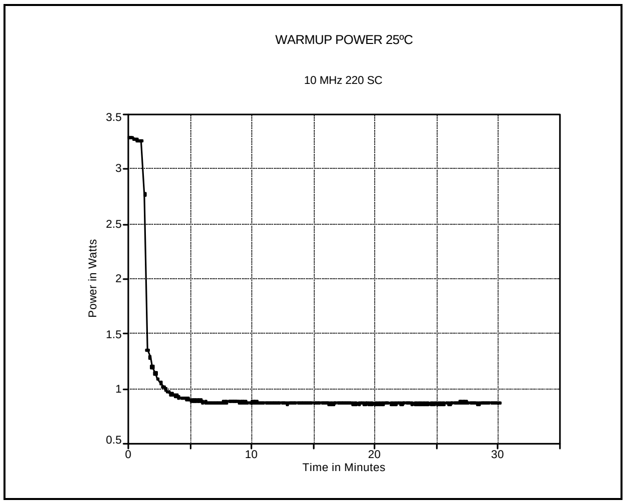

Figure 14

3.5 Tuning Function Results

Tuning curves are shown below for 5 and 10MHz 220 series oscillators in Figures 15 and 16 respectively. Note that the tuning rate of the 10MHz oscillators is approximately 4 times greater than the 5MHz product. The tuning range scales proportionally to the dX/dF of the quartz crystal and the available reactance swing of the tuning varactor diode. Note the non-linearity on the 5MHz plot. Many specifications omit the 0 to 0.5V range to avoid this area. The linearity represented by the graphs below is typically 10% or less.

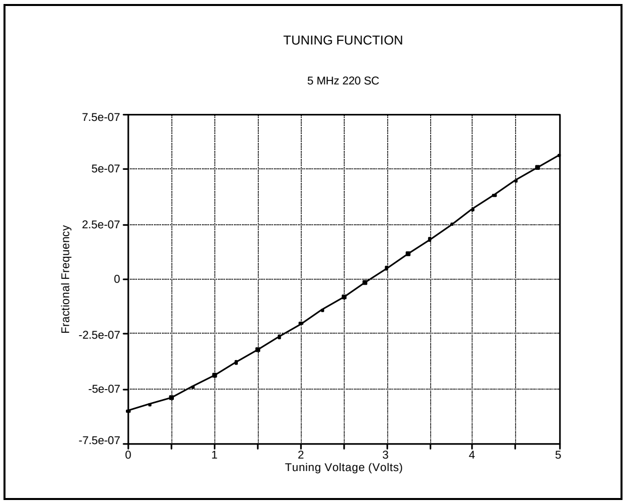

Figure 15

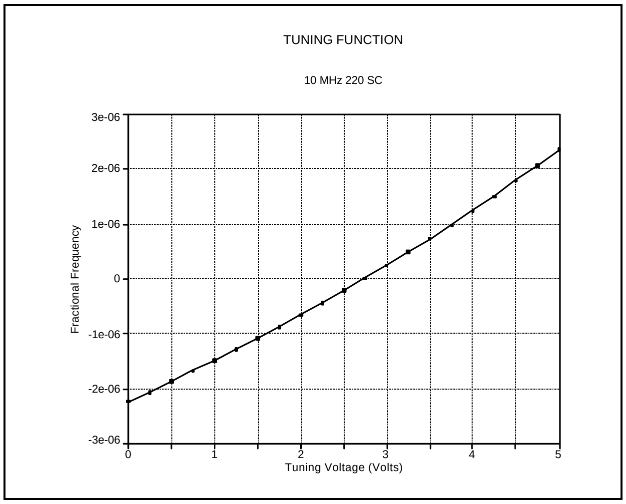

Figure 16

3.6 Supply Sensitivity Results

The supply sensitivity is characterized in a similar fashion to the thermal stability. The supply is varied over the operating extremes while the frequency is being recorded. Like the thermal stability measurements, the frequency and voltage are measured with respect to time, and then correlation is made between the time and voltage axis. As is seen in Figures 17 and 19, this method captures any transient effects, which may occur. Figure 18 shows the Voltage vs. Time function. Note that in each case for 5 and 10MHz the transient behavior is greater in magnitude than the static frequency offsets.

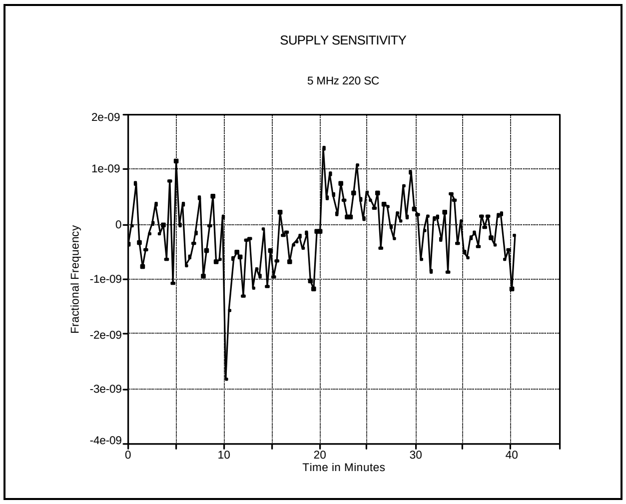

Figure 17

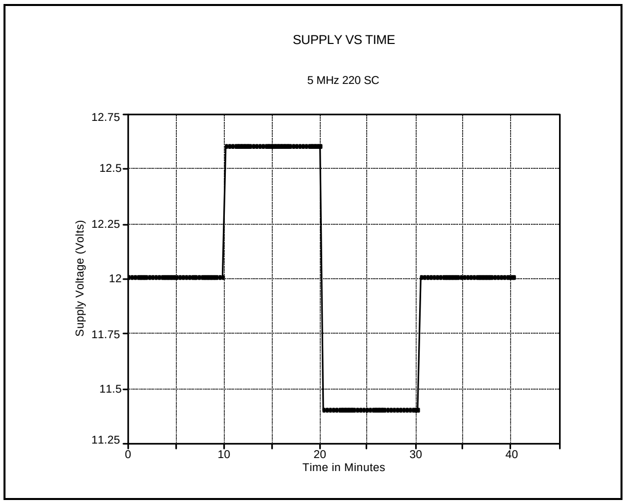

Figure 18

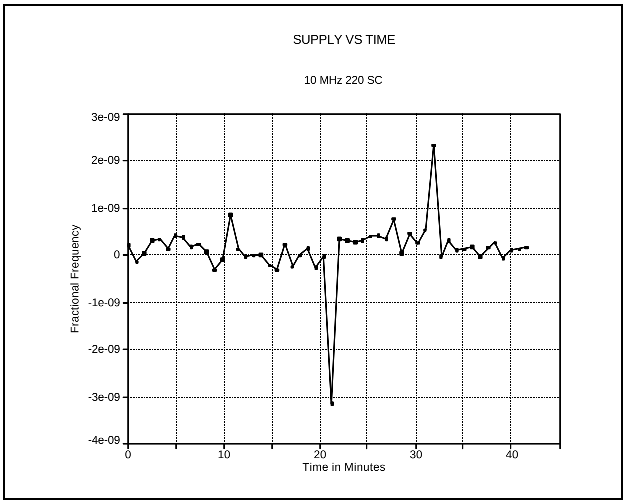

Figure 19

3.7 Aging Test Results

Aging test results for 5 and 10MHz 220 series oscillators are shown below in Figures 20 and 21. The average initial aging rates for 5MHz 220 series units are less than 2e-10/day over the first 30 days. 10MHz types have and average value for the same period of less than 5e-10/day.

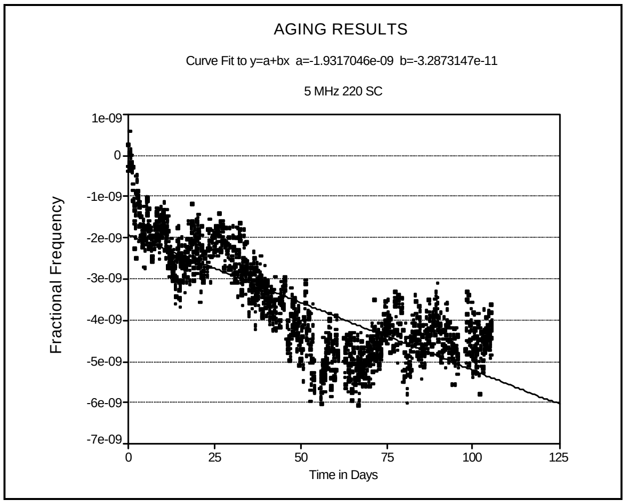

Figure 20

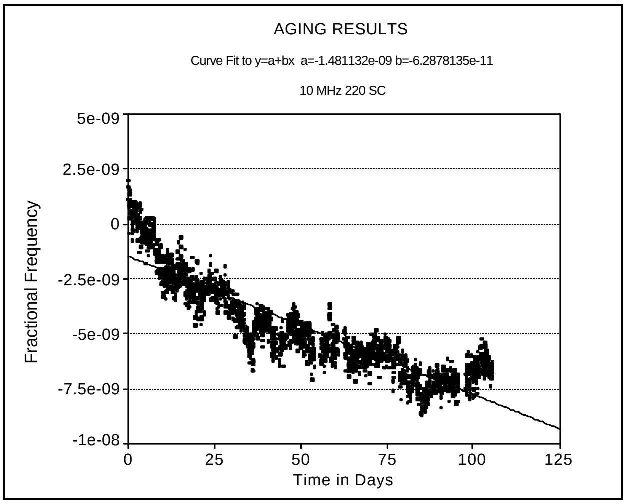

Figure 21

4. CONCLUSION

The data presented gives a brief overview of the 220 series product performance. Results collected over the past 2 years show that oscillators with a small physical size can equal or exceed performance obtained with much larger products of the past. The reduced complexity and lower component stresses help greatly in the goal of improving failure rates as well as reducing overall production costs.

5. REFERENCES

[1] J. Vig, Quartz Crystal Resonators and Oscillators For Frequency Control and Timing Applications A Tutorial, U.S. Army Communications - Electronics Command, January, 2000.

[2] M. M. Driscoll, Low Noise Crystal Oscillators using 50-Ohm, Modular Amplifier Sustaining Stages, Frequency Control Proceeding # 6-40-329.