Ceramic Dielectric Resonator Oscillator Aging

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ABSTRACT

Two Ceramic Dielectric Resonator Oscillators (CDROs), one operating at center frequency of 1.5 GHz and the other one operating at 8.3 GHz is being investigated for its frequency aging characteristic. The oscillators were ovenized in a Sigma temperature chamber with aging temperature set at +65°C. Datas are taken with an automated test system. The frequency aging for the 1.5 GHz CDRO is found to be ± 0.5 ppm/3 months and 40 ppb/hour. Aging is better than ± 3 ppm/two month for the X-band CDRO. The oscillators were also evaluated for its single side band phase noise characteristic. The measured phase noise levels for the L-band oscillator were -100 dBc/Hz and -130 dBc/Hz at 100 Hz and 1 kHz carrier offset frequencies, respectively. The X-band CDRO's phase noise levels were -66 dBc/Hz and -93 dBc/Hz, at 100 Hz and 1 kHz carrier offset frequencies, respectively.

BACKGROUND

Although the L- and X-band ceramic dielectric resonator oscillators were investigated for its long term stability, in reality the oscillators were designed for low phase noise, for application in high dynamic range radar, and digital communication systems. In the process of evaluating the short term stability it was observed that frequency fluctuations exhibited by the CDROs were exceptionally good. So it was decided to investigate the aging characteristic for these CDROs even though it wasn't designed for such application.

The oscillators were designed and fabricated using a Murata Erie's dielectric resonator in a patented dielectric resonator oscillator structure which provided a loaded Q of about 25,000 at L-

band and 14,000 at X-band for TE_{018} mode of operation. The L-band oscillator uses a Bipolar Junction Transistor (BJT) amplifier and the X-band oscillator utilizes medium power Field Effect Transistor (FET) amplifier. The amplifiers were tested for its residual phase noise to ensure acceptable 1/f noise levels. Positive feedback loop oscillator configuration is used in which the dielectric resonator is employed as the frequency determining element. The design is very simple and costs effective. The design consists of a loop amplifier, power divider, and a resonator enclosed in a metal cavity. Amplitude limiting is achieved by the non-linearities in the loop amplifier. Detailed information on how to design ultra stable frequency sources can be found in reference [1-4].

The oscillators were evaluated for phase noise, frequency vs temperature behavior, and frequency aging characteristics. For the aging measurement, the frequency sampling interval was set to 10 minute, initially, subsequently changed to 30 minute interval few days after the experiment started.

MEASURED RESULTS

The CDROs were first evaluated for its phase noise performance. The measurement was performed on a HP3047A noise measurement system. A high overtone bulk acoustic resonator based oscillator that was capable of generating frequencies from 635 MHz to 10.320 GHz was used for downconverting both L and X-band CDROs to an intermediate frequency below 160 MHz which was then measured against HP8662A frequency synthesizer. The use of this measurement technique limited the absolute phase noise measurement to less than 1 kHz carrier offset frequencies for 1.5 GHz CDRO and to about 10 kHz carrier offset frequencies for the 8.3 GHz CDRO due to

synthesizer phase noise. The measured phase noise for both the oscillators are shown in Figure 1 and 2. The L-band CDRO exhibited phase noise levels of -100 dBc/Hz at 100 Hz from the carrier. At 1 kHz carrier offset frequency the phase noise level should have been -130 dBc/Hz, but unfortunately it was masked by the synthesizer noise. The 8.3 GHz CDRO's phase noise levels were -66 dBc/Hz and -93 dBc/Hz at 100 Hz and 1 kHz from the carrier, respectively.

The oscillators were also evaluated for its center frequency variation as a function of temperature. A programmable Tenny Jr. temperature chamber was used to perform this operation. The output frequencies were recorded while the temperature in the chamber was varied from -60°C to +80°C for L-band oscillator and from -50°C to +60°C for X-band oscillators. The L-band oscillator exhibited parabolic temperature behavior with zero temperature coefficient occurring at +20°C. This is illustrated in Figure 3. The maximum frequency drift was about 40 parts per million over the stated wide temperature range. The frequency vs temperature plot for X-band CDRO is shown in Figure 4. The worst frequency variation is about 65 parts per million (ppm). The frequency-temperature behavior of the L-band CDRO, shown in Figure 3, is significantly different from X-band CDRO, shown in Figure 4. This is mainly because the resonator is constructed of different materials.

Finally, the oscillators are being tested for the frequency aging characteristic. Test setup is shown in Figure 5. The oscillators were ovenized in a Sigma temperature chamber and stabilized for about 4 hour at the aging temperature of 65°C before taking data. At this temperature the frequency vs temperature curve for the 8.3 GHz CDRO is reasonably flat, but not so for the L-band CDRO, it has a slop of about 0.4 ppm/°C (60°C-80°C). Frequency aging for 1.5 GHz CDRO is shown in Figure 6. Since we did not monitored the oven temperature we can not say for sure that the frequency drift is due to the variation in oven temperature or the oscillator itself. We are currently investigating the actual cause of the reported frequency variation. In any case the total frequency variation over a period of three months is less than ± 0.5 ppm. The aging performance for the 8.3 GHz oscillator is shown in Figure 7. Frequency varied from 8.323925 GHz to 8.323950 GHz. The frequency deviation is about 25 kHz. These results indicate that ceramic dielectric

resonator oscillators are highly stable frequency sources and are suitable for commercial and military systems use.

CONCLUSION

Aging characteristic of Ceramic dielectric resonator based oscillators are reported in this paper. The CDROs operating at 1.5 GHz and 8.3 GHz exhibited excellent long term as well as short term stability. The long term stability could be improved by using proper resonator and innovative circuit design technique.

REFERENCES

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Figure 1. Phase Noise of 1.5 GHz CDRO

Figure 2. Phase Noise of 8.3 GHz CDRO

Figure 3. Frequency vs Temperature Behavior of L-band CDRO

Figure 4. Frequency vs Temperature Characteristic, X-band CDRO

Figure 5. CDRO Aging Test Setup

Figure 6. Long term stability of 1.5 GHz CDRO

Figure 7. X-band CDRO Aging Performance