DIELECTRIC RESONATOR OSCILLATORS AT 4, 6, AND 11 GHz

K. R. Varian

Rockwell International Corporation
Dallas, Texas 75207

ABSTRACT

The microwave circuit used in this paper permits the use of the same power transistor at 4, 6, and 11 GHz. The phase noise of these units at 10 kHz from the carrier in a 1-Hz bandwidth is −116 dBc/Hz at 4 GHz, −113 dBc/Hz at 6 GHz, and −100 dBc/Hz at 11 GHz.

INTRODUCTION

The latest generation digital radios require sources that have low phase noise, moderate power output, moderate stability, mechanical tuning only, and low cost. The frequency range that this family of oscillators covers is the telecommunication bands at 4, 6, and 11 GHz. The units will operate in a ground-benign environment where the temperature range is −20° to +65°C. These requirements are ideal for a dielectric resonator oscillator.

The sources will be used in both up- and down-converter applications where the noise of the source will be added to that of the signal. Consequently, the lower the source noise, the lower the detected signal level. In digital radios, a criterion used to measure this detection of lower signal levels is depicted by Bit Error Rate (BER) curves. Figure 1, shows a typical BER curve for a 4-GHz radio. As the curve moves to the left, lower level signals can be detected; and this difference is expressed in dB.

In the MDR-2xxx family of radios, the demodulator has a phase-locked loop that is used to track low-frequency noise. The loop bandwidth of the phase-locked loop is approximately 20 kHz. Consequently, only source noise greater than 20 kHz is the major contributor to performance degradation in the system.

Another performance criterion is the long-term stability of the source. In the commercial telecommunication business, the FCC requires that the frequency of the transmit sources is verfied at least once a year. The requirement of the FCC is that the transmit frequency is within the licensing tolerance range. In the case of the MDR-2xxxA radio family, this frequency tolerance range is ±25 ppm. The plan for the MDR-2xxxA sources is that of the total 25-ppm range; 20 ppm is allotted to frequency variations over temperature, and 5 ppm for long-term stability. The temperature range over which the units have to meet the required stability is also determined by the FCC and is −20° to +65°C. To ensure that the units meet this stability, the oscillator is kept at an elevated temperature of 85°C with a heater.

The power output requirements of the units are +12 dBm for the down-converter and +17.5 dBm minimum for the up-converter. The 4-GHz units are required to mechanically tune 40 MHz. At 6 GHz and 11 GHz, the required mechanical tuning range is 100 MHz.

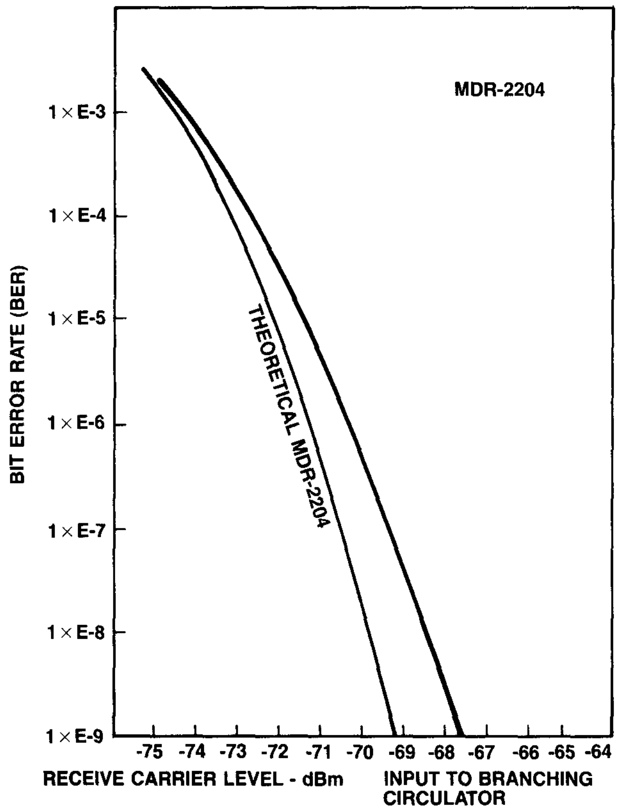

Figure 1. Typical Bit Error Rate Curve.

0149-645X/86/0000-0087$01.00 © 1986 IEEE

CIRCUIT

Since a family of oscillators is being developed, one way of reducing the cost of the individual units is to use similar parts and similar concepts in the design. This action is accomplished by using the same active device and type of circuit at all frequencies. A typical circuit is shown in figure 2. With this type of construction technique, one simply needs to change the dielectric resonator to change the frequency of operation.

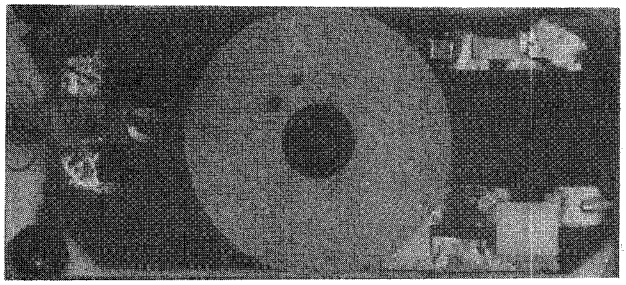

Figure 2. Typical Oscillator Circuit.

For the active device, a 0.5-micron power FET is selected. A power FET is picked for the following three reasons. Camiade, etal (1), reports that a power device should yield lower phase noise. The second reason is the power output requirements, +17.5 dBm minimum at 11.7 GHz. A third reason for using the power FET is the belief that the superior heat sinking and power handling capability of the power FET would yield improved long-term stability.

The dielectric resonator selected is a $(ZrSn)TiO_9$ based ceramic with a dielectric constant of about 38 and a minimum unloaded Q of 6,000 at 6 GHz. Published data on the long-term stability of the resonator is shown in figure 3. The temperature coefficient of the resonator is selected in order to temperature-compensate the mechanical circuit.

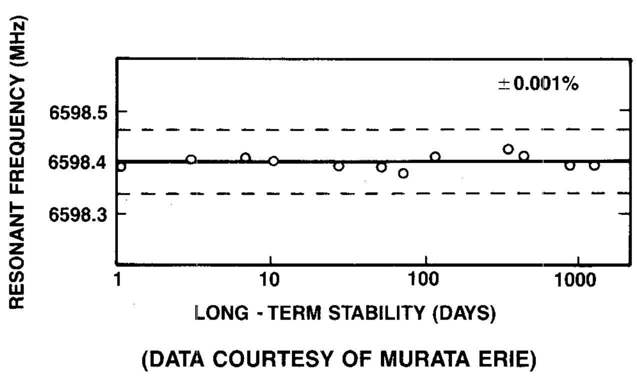

Figure 3. Long-Term Stability.

The electric circuit selected is a conventional circuit with the resonator providing feedback between the drain and the gate. The power is removed at the drain. This circuit, as indicated in the literature (2), has lower phase noise than other circuits and simpler construction. The gate circuit contains a 50-ohm resistor that provides a load for the harmonics. The drain circuit includes a pad to attenuate the signal and to isolate the FET from the load.

RESULTS

The phase noise of the 4-GHz oscillators is shown in figure 4. The phase-noise curve of a phase-locked source is also shown in figure 4 for comparison. It can be seen that the phase noise of the DRO is up to 20 dB better than the phase-locked source above 10 kHz. In the 4-GHz radio, this reduction in phase noise results in 0.4-dB improvement in the BER curve. Based on the compilation of Niehenke (2), this phase noise is better than any reported.

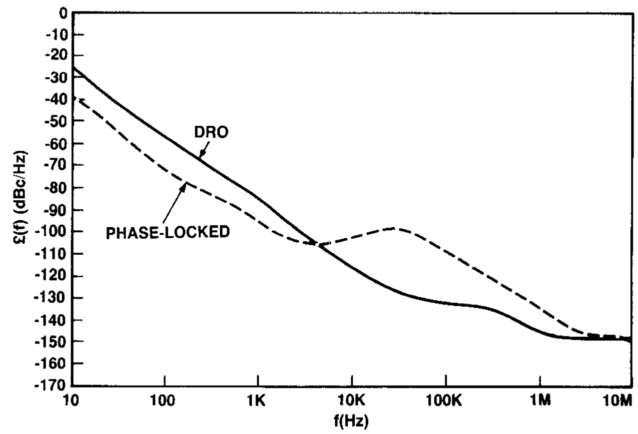

Figure 4. 4-GHz Phase-Locked Source.

The phase noise of the 6-GHz oscillators is shown in figure 5. Based on the compilation of Niehenke (2), this phase noise is better than any reported.

The phase noise of the 11-GHz oscillators is shown in figure 6. Again based on the compilation of Niehenke (2), this phase noise is among the best reported.

Camiade, etal (1), also stated that adjustment of the bias voltage will improve the close in phase noise. The result of changing the bias voltage on the phase noise is shown in figure 7. At 4 GHz, figure 7a, the changes in the phase noise occur at frequencies less than 1 kHz from the carrier. Since the phase noise is only critical at frequencies greater than 20 kHz, the bias voltage does not need to be adjusted for noise for the 4-GHz DROs. In figure 7b, the variation of phase noise with bias voltage is shown for the 6-GHz unit. In this case, bias voltage changes can improve the phase noise at 10 kHz. Figure 7 also indicates the variation in power output with the different bias voltages.

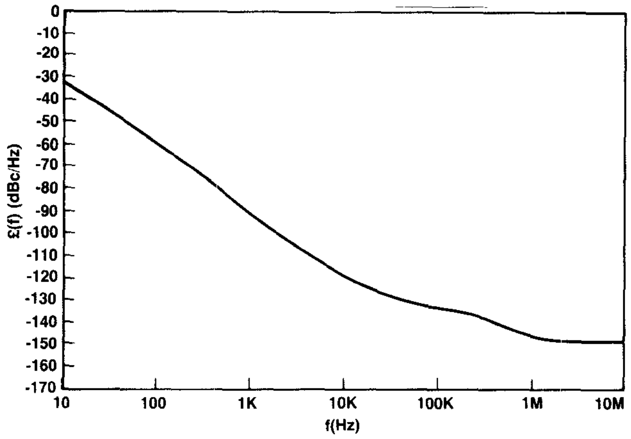

Figure 5. 6.3-GHz Typical Phase-Noise Curve.

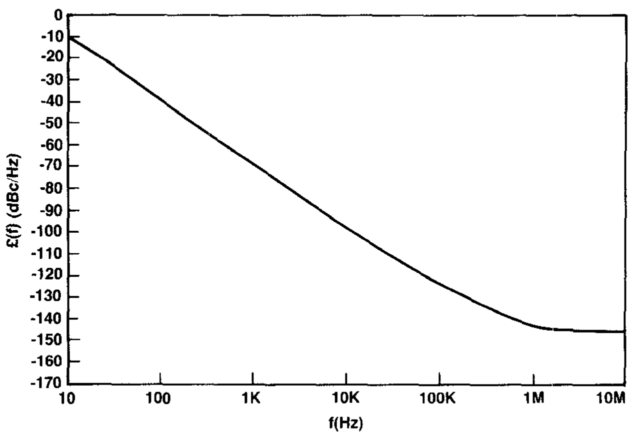

Figure 6. 11-GHz Typical Phase-Noise Curve.

Since the major goal of this project is a low-noise source, the efficiency is not optimized, yet efficiencies as high as 25% have been observed. The external Q is measured to be 450. In figure 8, the frequency drift with temperature is shown for a typical unit.

Several units have been subjected to long-term drift tests. The results of this testing are only preliminary at this time and are shown in figure 9.

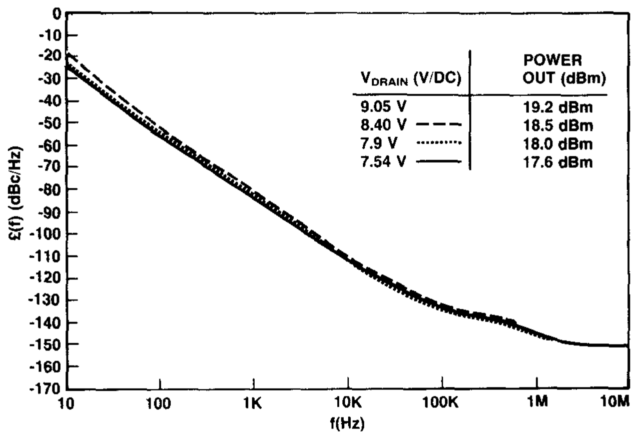

Figure 7a. 4-GHz Variation of Phase Noise with Bias Voltage.

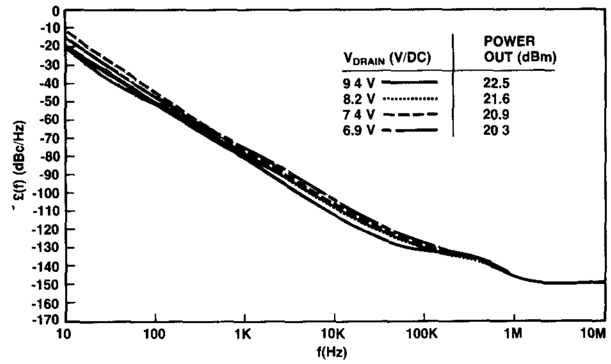

Figure 7b. 6-GHz Variation of Phase Noise with Bias Voltage.

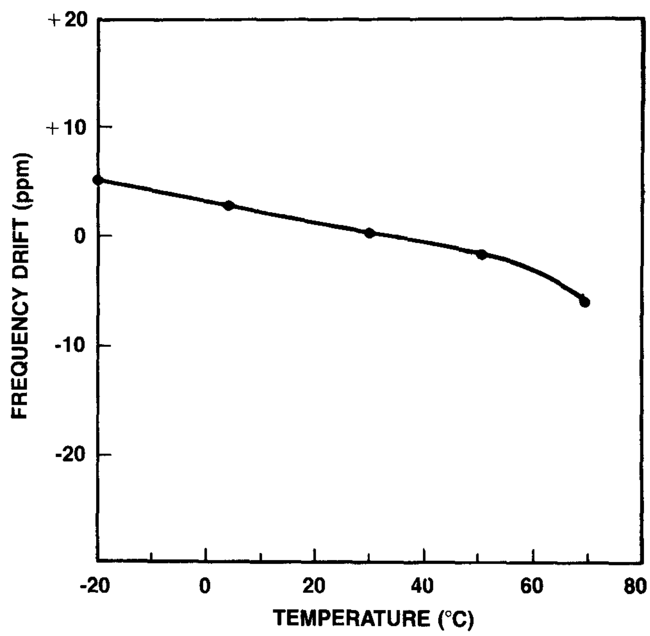

Figure 8. Temperature Variation of Frequency.

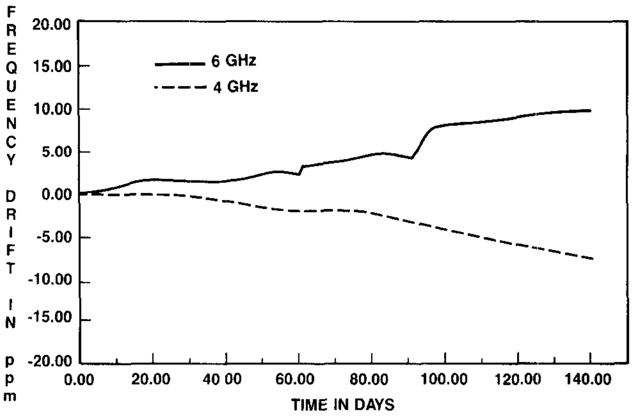

Figure 9. Long-Term Drift, 4- and 6-GHz.

ACKNOWLEDGEMENT

The author would like to thank K. S. Coffee for his support in the assembly and RF measurement of the DROs.

REFERENCES

1. Camiade, M., Bert, A., Graffeuil, J., Pataut, G., "Low Noise Design of Dielectric Resonator FET Oscillators," *13th EMC 1983*, p 297.

2. Niehenke, E. C., "GaAs: Key to Defense Electronics," *Microwave Journal*, Vol 28, No. 9, September 1985 pp 24-44.