MICROWAVE TRANSISTOR OSCILLATORS STABILIZED WITH DIELECTRIC RESONATOR

Hiroyuki Abe
Central Research Laboratories
Nippon Electric Company, Ltd
Kawasaki-shi, Japan

Opening Statement for Panel Discussion

Owing to their high thermal stability and high Q value, BaO-TiO_2 system ceramic resonators have been investigated as frequency controlling devices and are now in practical use. Relatively high dielectric constant makes it possible to obtain a small size resonator which is compatible with stabilized oscillator design. Dielectric resonators are readily incorporated into MIC transistor oscillators and result in a highly-stabilized, low-noise microwave power source.

Low-Loss Ceramic Material

$(BaO)_x(TiO_2)_{1-x}$ system ceramic ($x \sim 0.2$) with additional oxides of a few mol-percent has excellent dielectric properties. In such a material, for example NED-39 developed at NEC Central Research Laboratories, dielectric constant temperature coefficient $1/\varepsilon_r \cdot d\varepsilon_r/dT$ and expansion coefficient $1/\ell \cdot d\ell/dT$ offset each other and result in a small resonat frequency temperature coefficient k.

$$k = \frac{1}{f_r}\frac{df_r}{dT} \simeq -\frac{1}{2}\frac{1}{\varepsilon_r}\frac{d\varepsilon_r}{dT} - \frac{1}{\ell}\frac{d\ell}{dT} \sim 0$$

By changing additional oxides content, resonant frequency temperature coefficient can be changed from 0 ppm/°C to 50ppm/°C. In NED-39, relative dielectric constant ε_r is 39. Unloaded Q value is 7000 at 6 GHz and shows a slight degradation at higher frequencies.

Resonant Circuit

Coupling between dielectric resonator and microstripline is realized by placing resonator near microstripline. In this configuration, the resonant circuit has a triple-layered structure of substrate material, dielectric resonator and air gap between the resonator and the top cover. Resonant frequency f_{rc} and unloaded Q value Q_u depend not only on resonator dimension but also on substrate thickness and on air gap thickness.

Resonant frequency can be mechanically tuned by changing air gap thickness. Tuning range around 1% is possible without degrading unloaded Q value seriously. Another tuning technique utilizes sub-resonator consisitng of microstripline and varactor diode. Electrical tuning is realized by changing varactor bias voltage in sub-resonator coupled to dielectric resonator.

Microwave Transistor Oscillator

Three terminal active devices, such as GaAs field effect transistors (C and X band) and Si stepped electrode bipolar transistors (C band), are suitable for fundamental-frequency MIC oscillator design. They are more efficient than Gunn diodes and have better noise characteristics than IMPATT diodes.

Negative resistance is obtained by adding external feedback network or grounding appropriate terminal. Large signal impedance of these negative resistance devices is measured to obtain the Rieke diagram and is used to realize optimal coupling condition between transistor oscillator and stabilizing resonant circuit.

When transistor oscillators are coupled to an electrically tunable resonant circuit, voltage controlled oscillators are obtained. They have a wide range of application as FM modulators or phase locked oscillators.

GaAs FET Stabilized Oscillator

Table I shows the performance of GaAs FET stabilized oscillators at 7 GHz and 11 GHz. Dielectric material NED-39 and FETs NE464 and NE869 are used in these oscillators. The positive temperature coefficient of resonator resonant frequency compensated for the negative temperature coefficient of unstabilized oscillator frequency and brought about a high thermal stability better than 2ppm/°C. FM noise level was reduced more than 30dB by stabilization.

Conclusion

Microwave transistor oscillators stabilized with low-loss, thermally stable dielectric resonator provide highly frequency-stabilized, low noise, compact microwave power source. The stabilized oscillator performance is sufficient for microwave communications systems.

References

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Frequency	7.00 GHz	11.00 GHz
Power(Efficiency)	100 mW(14%)	60 mW(6%)
Frequency Stability	110 ppm/60°C	45 ppm/30°C
Pushing Fig. for V_{GS}	0.8 MHz/V	2 MHz/V
Resonator Dimen. (mm)	7.5$^\phi$ x 3h	5$^\phi$ x 2^h
GaAs FET (W_g)	NE464A(1.5mm)	NE869C(1.5mm)
Configuration	common-drain packaged Tr	common-source chip Tr

Table I Stabilized GaAs FET Oscillator Performance