

## Application Note

### UNDERSTANDING SPECIFICATIONS

The following discussion will help to specify your microwave source. Understanding specifications will prevent less than optimal system performance and unnecessary cost.

#### **FREQUENCY RANGE (Start/Stop frequency end points)**

When the required frequency range exceeds approximately 25% bandwidth, oscillator design approaches must be used which will cause increased phase noise. If your system is phase noise sensitive, keep the required RF tuning range to a minimum.

#### **TUNING VOLTAGE LIMITS (Start/Stop frequency end points)**

When specifying an oscillator, there is a direct correlation between cost and tuning voltage limit specifications. When specifying tuning range limits, consider:

- Octave bandwidth oscillators using hyperabrupt varactors can be produced with tuning range limits of 0 to 13 volts. Allowing up to 17 volts makes the VCO easier to produce.
- When very low phase noise is required, a different design approach is used. This design places practical tuning bandwidth limits at 50%, although to reach optimum low phase noise levels, the oscillator bandwidth should be limited to 5 to 10%. This limitation is due to a finite amount of  $1/f$  noise in the varactor diode and in the RF oscillator transistor. As modulation sensitivity (defined as MHz/Volt) is reduced, the impact of this noise is reduced.

If possible, do not require specific tune voltages at the frequency endpoints. Just specify the voltage limits over which the VCO must tune under all conditions (temperature range, load pulling, etc.). If your system must have an oscillator tuned between specific endpoints, Spinnaker Microwave will perform the following sequences:

- Make a prototype run of 5 units.
- The data, assembly, and tuning patterns will be analyzed and documented. As long as the same lot of varactor tuning diodes are available, tuning endpoints can usually be held to +/- 10% of the tuning voltage range.

#### **RF POWER OUTPUT**

RF power output levels from 10 to 17 dBm can be achieved with little cost impact. Flatness into a 50 ohm load, for octave bandwidth units, can usually be held to +/- 1.5 dB. Power variation of unheated units can be held to +/- 1.5 dB over the -20 to + 85 degree C. temperature range.

In heated units, the complete power variation over temperature and frequency can be held to +/- 1.5 dB. In suboctave heated oscillators, RF power variations on the order of +/- 0.5 dB can be achieved.

#### **MODULATION SENSITIVITY RATIO (Ratio of max to min tuning sensitivity)**

Modulation sensitivity (MHz/Volt) defines how far an oscillator will tune for a given voltage change. This sensitivity ratio effectively equates to loop gain changes in a closed loop system. Below is a description of the two diode types used in microwave oscillators:

Hyperabrupt varactor diodes are used in broadband designs of any oscillator where the following characteristics are needed:

- Widest tuning range with the minimum tuning voltage.
- Best possible tuning linearity (linear change in frequency for linear change in tuning voltage).

Abrupt varactor diodes are used in relatively narrowband oscillators or in any oscillator where the following characteristics are needed:

- Lowest possible phase noise regardless of oscillator design chosen.
- Mathematically predictable modulation sensitivity curve.

### **LOAD PULLING (Frequency change due to an RF output load mismatch)**

Always specify the load pulling as "MHz of frequency shift of a given load mismatch" (defined as either VSWR or RETURN LOSS rotated through 360 degrees of phase shift). It is important to note that tight load pulling requirements need not necessarily be placed on the oscillator because most VCOs look into a fixed mismatch, such as a mixer or amplifier. This fixed mismatch will show up as a non-time dependent fine grain linearity error. This periodic error or "frequency ripple" will be equal to the distance between the oscillator and load converted to its equivalent 1/4 wavelength frequency. In open loop systems, this error is small when compared to the natural linearity error of the oscillator. In a closed loop system, this error is removed.

Load pulling specifications are critical when the oscillator is looking into a switched load. In this type of system, the switched load will cause two sets of undesired signals.

- The actual original signal shifts in frequency by an amount up to the load pull specification.
- A second "set" of side band signals will appear around this set of signals. They will be lower in magnitude and separated in frequency by the amount equal to the switching rate. Even if the rate of switching is slow, these errors can cause a locked system to momentarily lose lock.

When the load pulling specification is critical, a second load isolation device must be used. This device usually will consume power and add cost to the oscillator.

### **PUSHING (Change in frequency for a change in supply voltage)**

Most commercial oscillators come with no internal voltage regulation, thus having "pushing specifications" of 10 to 15 MHz/Volt. Depending upon the need, Spinnaker Microwave can add internal voltage regulation to reduce this pushing to less than 1 MHz/Volt. In some systems where high digital noise is present, it may be advisable to specify a tighter than normal pushing requirement to keep spurious sidebands to a minimum.

### **POST TUNING DRIFT (Frequency drift after tuning)**

In open loop systems, an oscillator will drift after being tuned to a new frequency. This drift, called Post Tuning Drift (PTD), is usually caused by thermal effect within the oscillator. These effects settle out within the first 100 ms to 1 sec following the tuning command. The amount of this drift can be as much as 20 MHz. If this error is of concern, please specify the allowed post tuning drift for the oscillator. Special techniques can reduce this drift to 2 MHz.

### **NOISE SPECIFICATIONS (dBc/Hz @ kHz from carrier)**

Narrow band noise oscillators, in the 9 - 10 GHz frequency range will meet the following performance levels:

80 dBc 10 kHz from carrier  
105 dBc 100 kHz from carrier  
120 dbc 1 MHz from carrier

As the frequency goes down, phase noise gets better. Broadband oscillators will classically have 15 to 20 dBc higher noise levels when compared to narrowband VCOs.

### **TEMPERATURE DRIFT (Frequency Change/degree C)**

Most uncompensated oscillators will drift approximately 0.1% of the tuning bandwidth per degree C. This equates to a 70 MHz drift over a 70 degree C temperature range in a 1 to 2 GHz oscillator. Drift can be reduced to 0.05% (35 MHz in the above case) with compensation techniques.



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With a special heater installed, this drift can be reduced to less than .002% (2 MHz in the above case). This technique makes use of a micropower heater consuming less than 5 watts over a - 55 to +75 degrees C temperature range. Warm up time for this heated oscillator is less than three minutes.