

High Spectral Purity Microwave Oscillator Design using Conventional Air-dielectric Cavity

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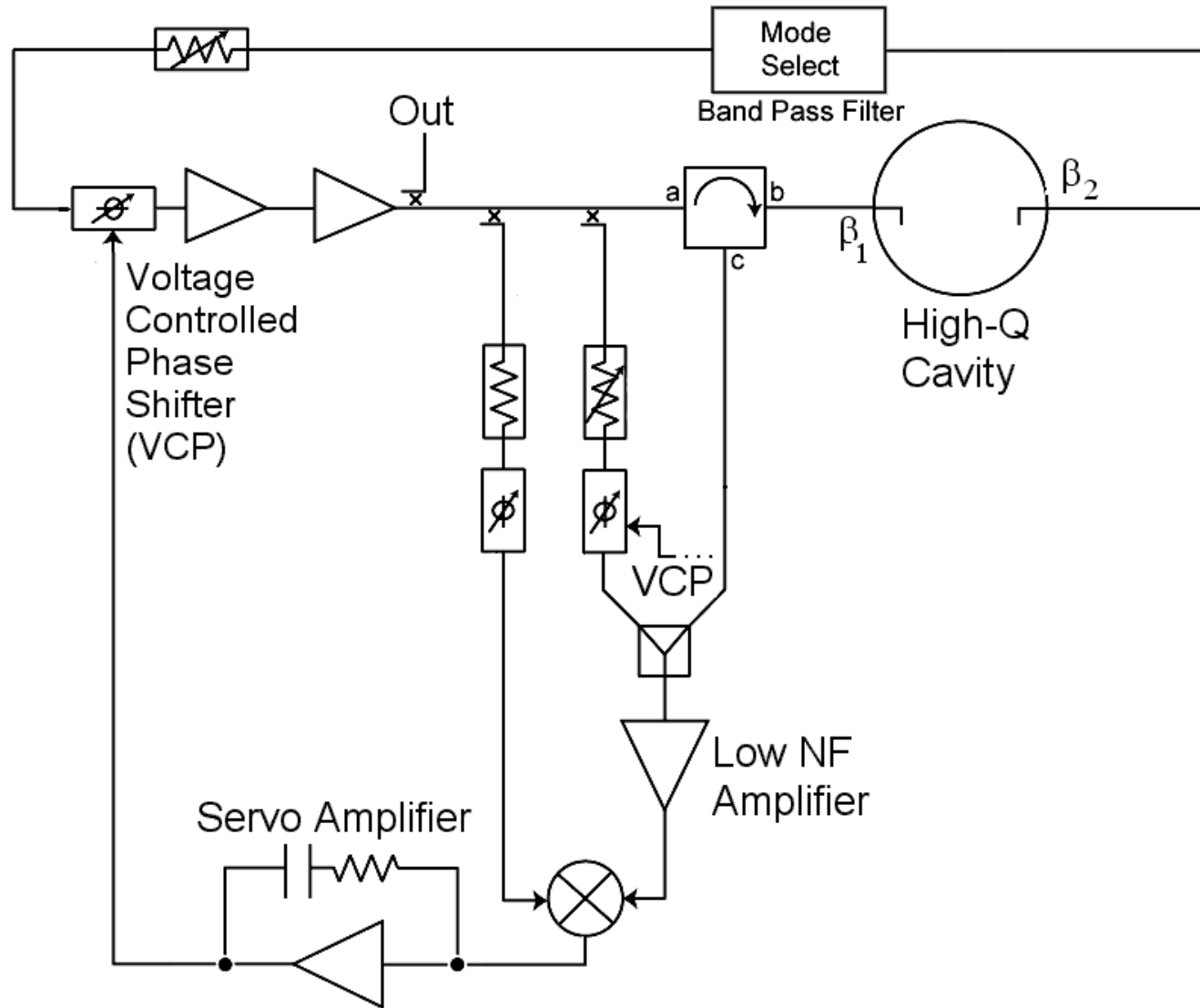
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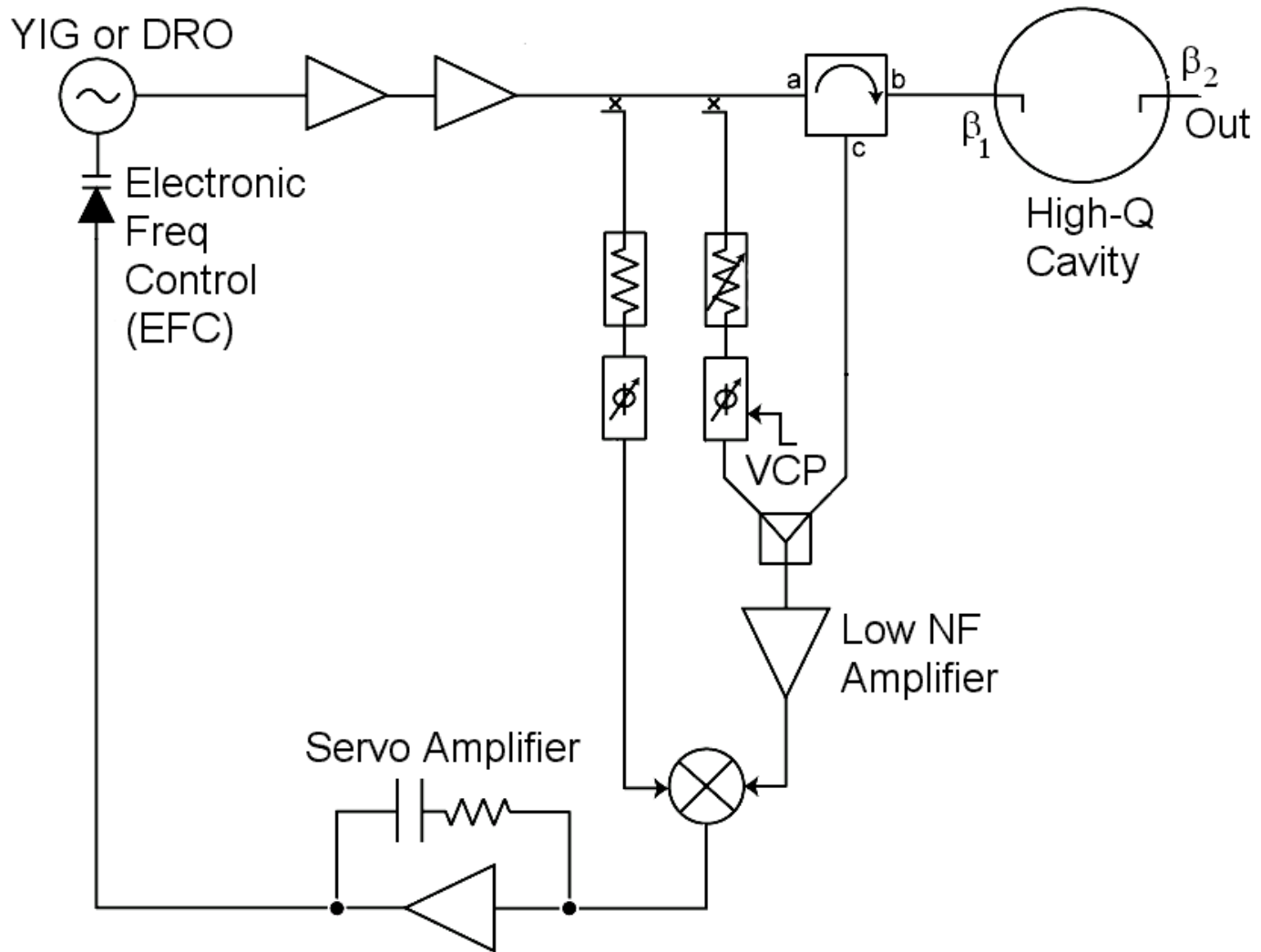
Total Frequency, Boulder CO, USA

Motivation

- As Low Noise 10 GHz Reference Source for a W-Band Synthesizer (94-96 GHz) Goal: -130 dBc/Hz @ 10kHz
- Extension of earlier work at NIST on lowering PM noise of a noisy X-Band DRO using an overmoded cavity as a discriminator (Walls & Martin, 1980)
- We expect to improve noise performance by using
 - a) Carrier suppression
 - b) Very near critical coupling
 - c) Higher microwave power into cavity



Active oscillator in which the high-Q cavity serves both as the resonator and the discriminator



Microwave oscillator (YIG or DRO) cleaned up using a high-Q cavity as a discriminator

Noise Floor of the Cavity Discriminator

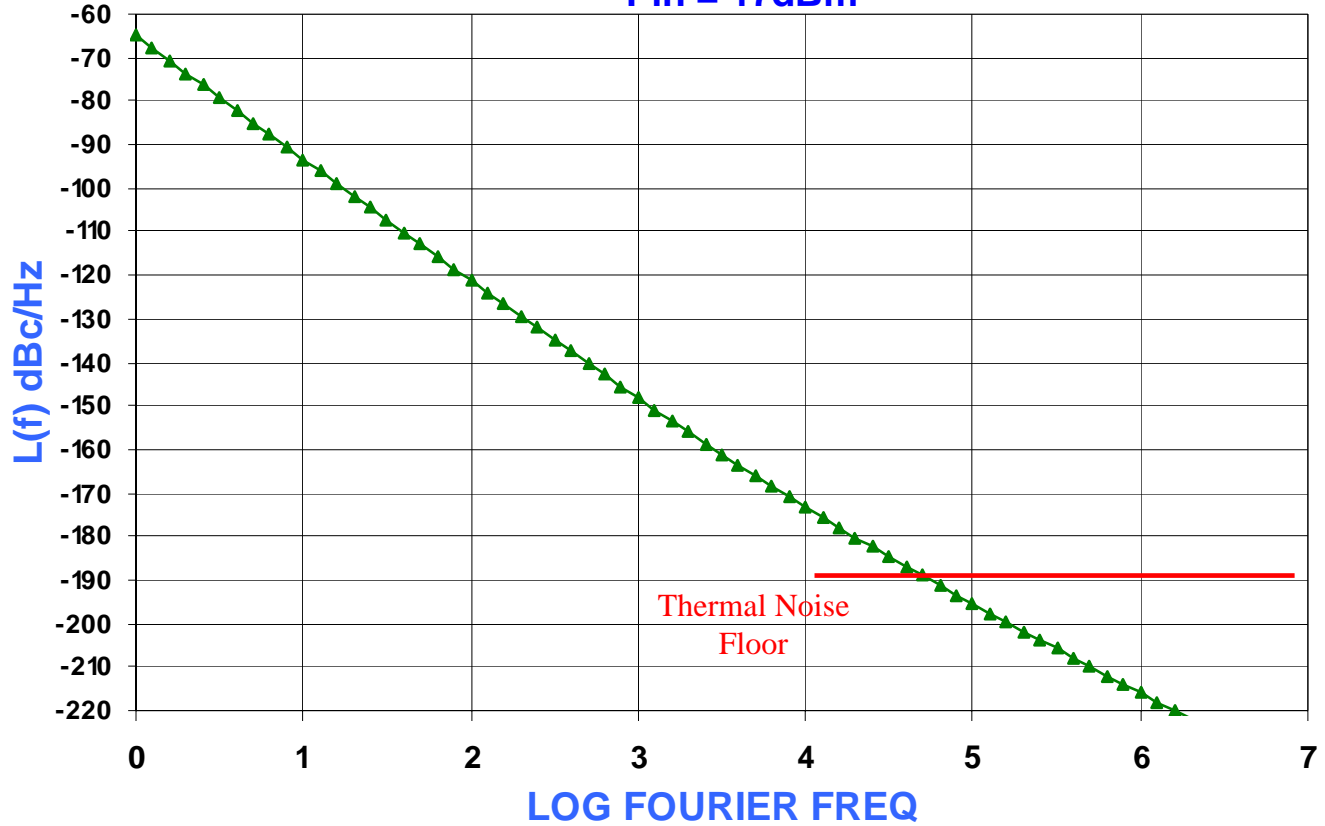
$$S_{\varphi}^{nf} = \frac{k_B(T_{amp} + T_0)}{P_i} \cdot \frac{(1 + \beta_e)^2}{4\beta_e} \cdot \left(\frac{HLB}{f}\right)^2 +$$
$$+ S_{\varphi}^{circ}(f) + \left\{ \frac{(1 - \beta_e)^2}{4\beta_e^2} \cdot \left(\frac{HLB}{f}\right)^2 \right\} \cdot [S_{\varphi}^{circ}(f) + S_{\varphi}^{vcp}(f)]$$

Noise Models for Circulator and VCP (Ivanov et al 1998)

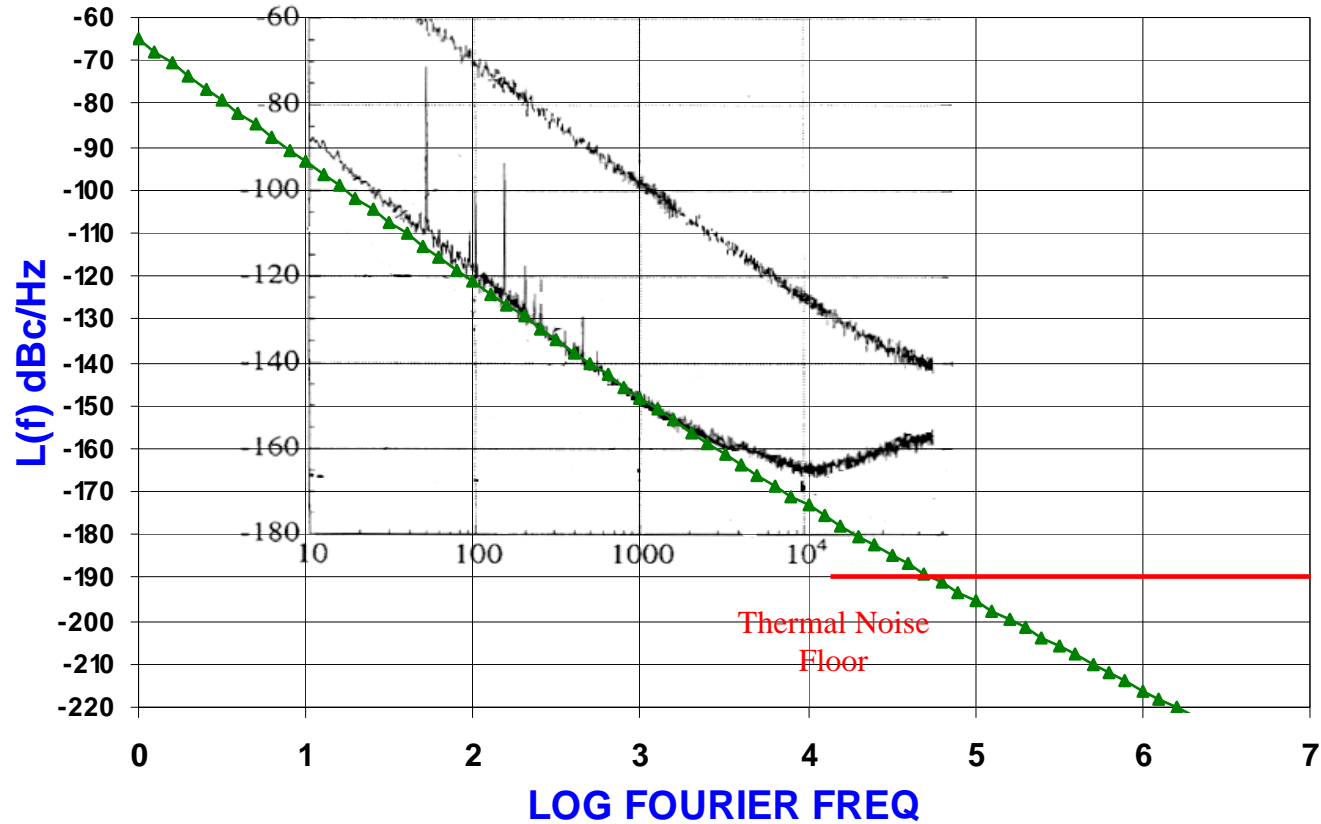
Circulator : $S_{\varphi}^{circ}(f) = -150 - 12 \log_{10}(f)$

VCP : $S_{\varphi}^{vcp}(f) = -147 - 7.5 \log_{10}(f)$

**Noise Floor of the Cavity Discriminator
(SLCO) - $Q_u=190,000$; $\text{Beta}_1=0.75$; $\text{Beta}_2=0.15$
 $P_{in} = 17\text{dBm}$**



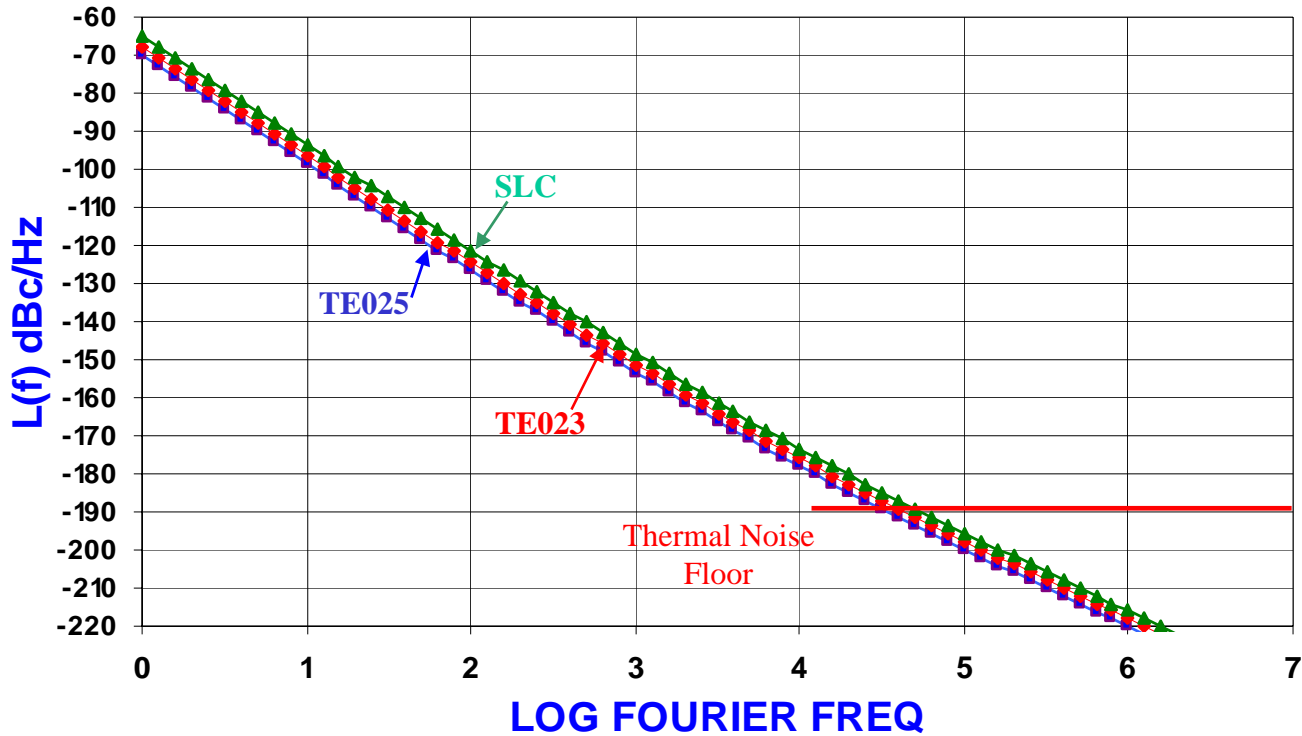
Noise Floor of the Sapphire Loaded Cavity Discriminator Comparison with Observations (Ivanov et al, 1998)



Noise Floor of Air Dielectric Cavity Discriminator

Beta1=0.95; Beta2=0.02; Pin = 1.5W

TE023 : Qu=59,000 TE025 : Qu = 73,000





Cylindrical Cavity Resonator Operating in TE₀₂₃ or TE₀₂₅

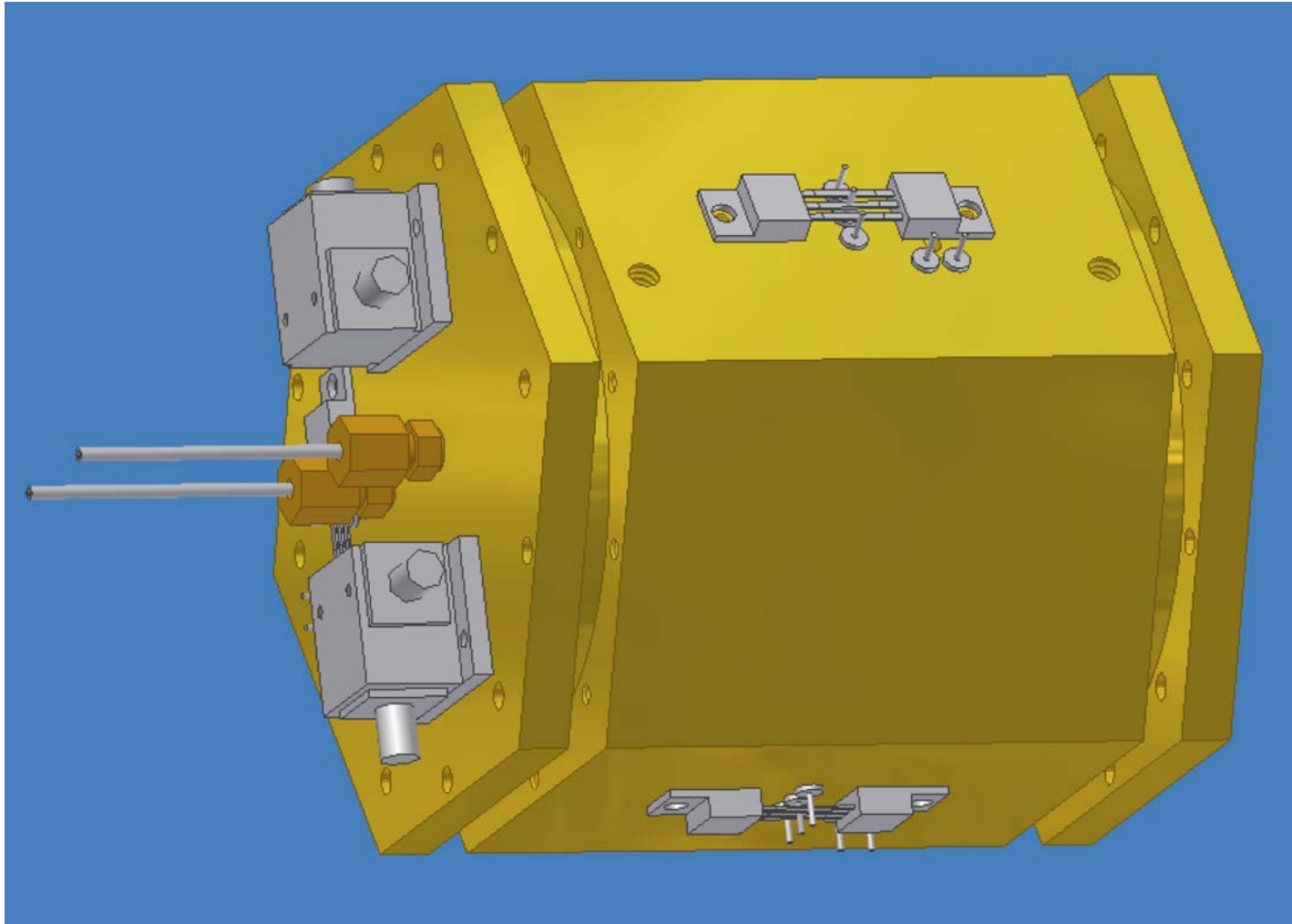
For TE₀₂₃ mode

$$f_{res} = \frac{c}{2\pi} \sqrt{\left(\frac{7.016}{a}\right)^2 + \left(\frac{3\pi}{d}\right)^2}$$

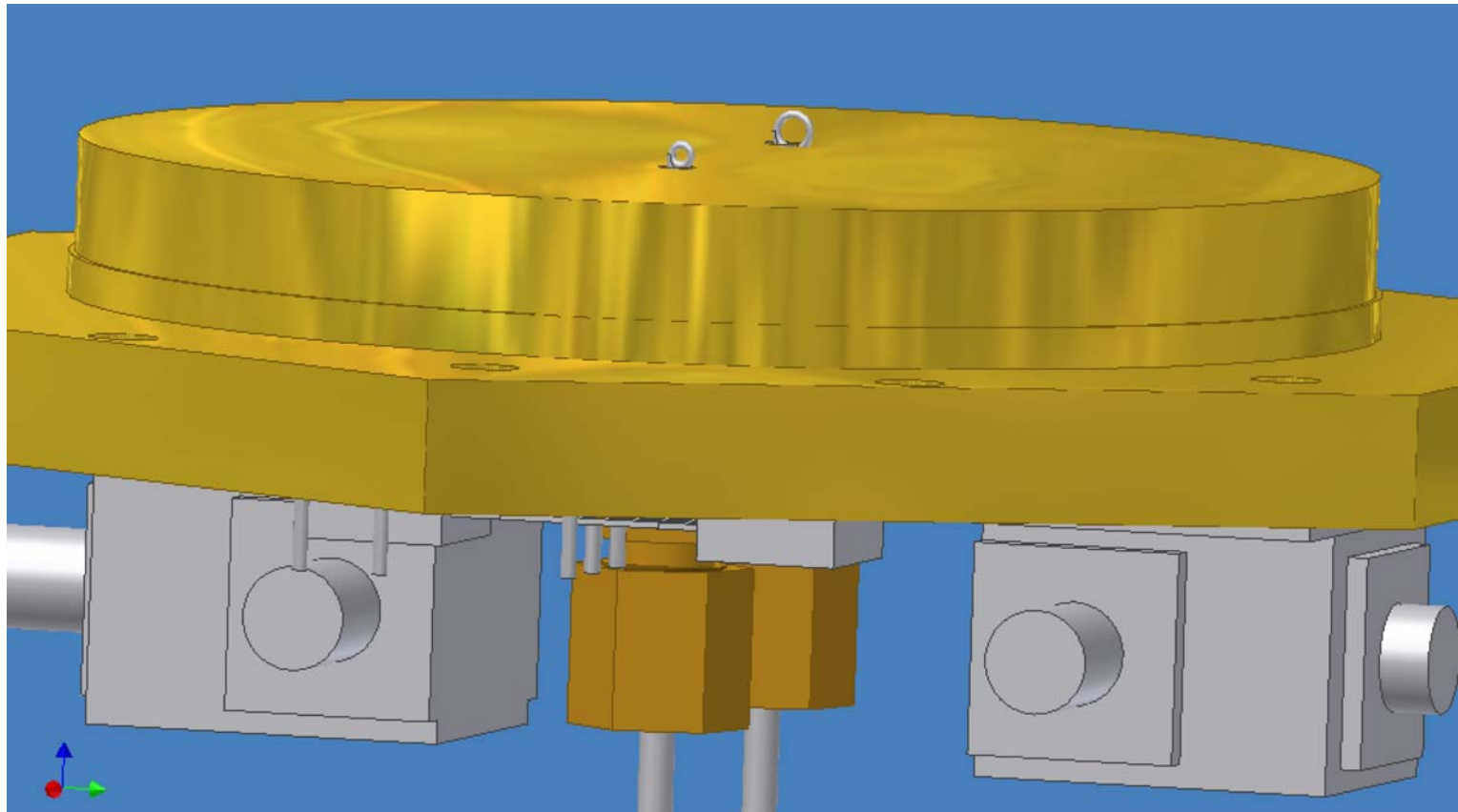
$f_{res} = 10\text{GHz}$ for $a, d \sim 8\text{cm}$

$Q_u = 63,000$

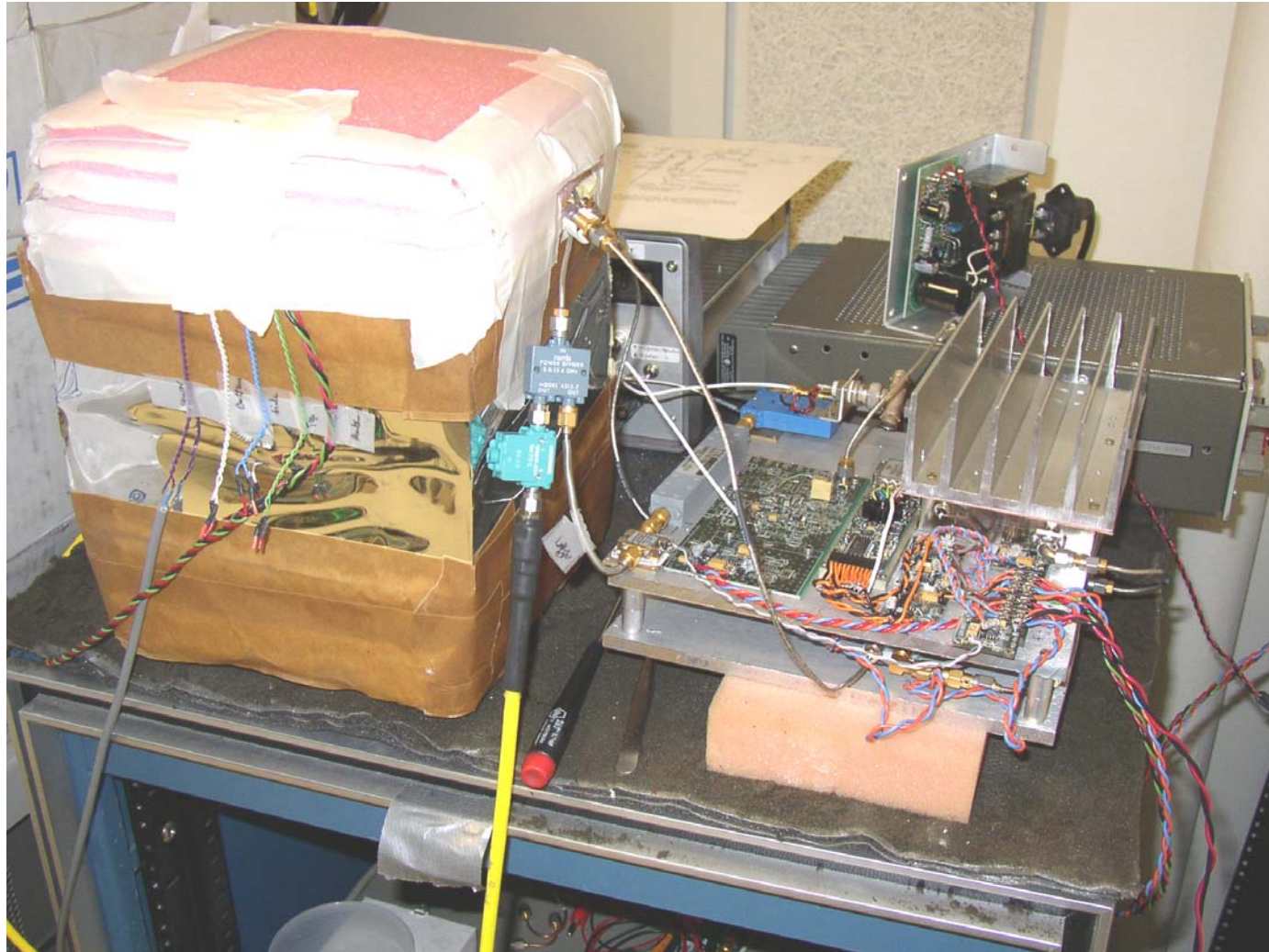
Cylindrical TE023 Cavity showing Layout of some Parts on the Outside



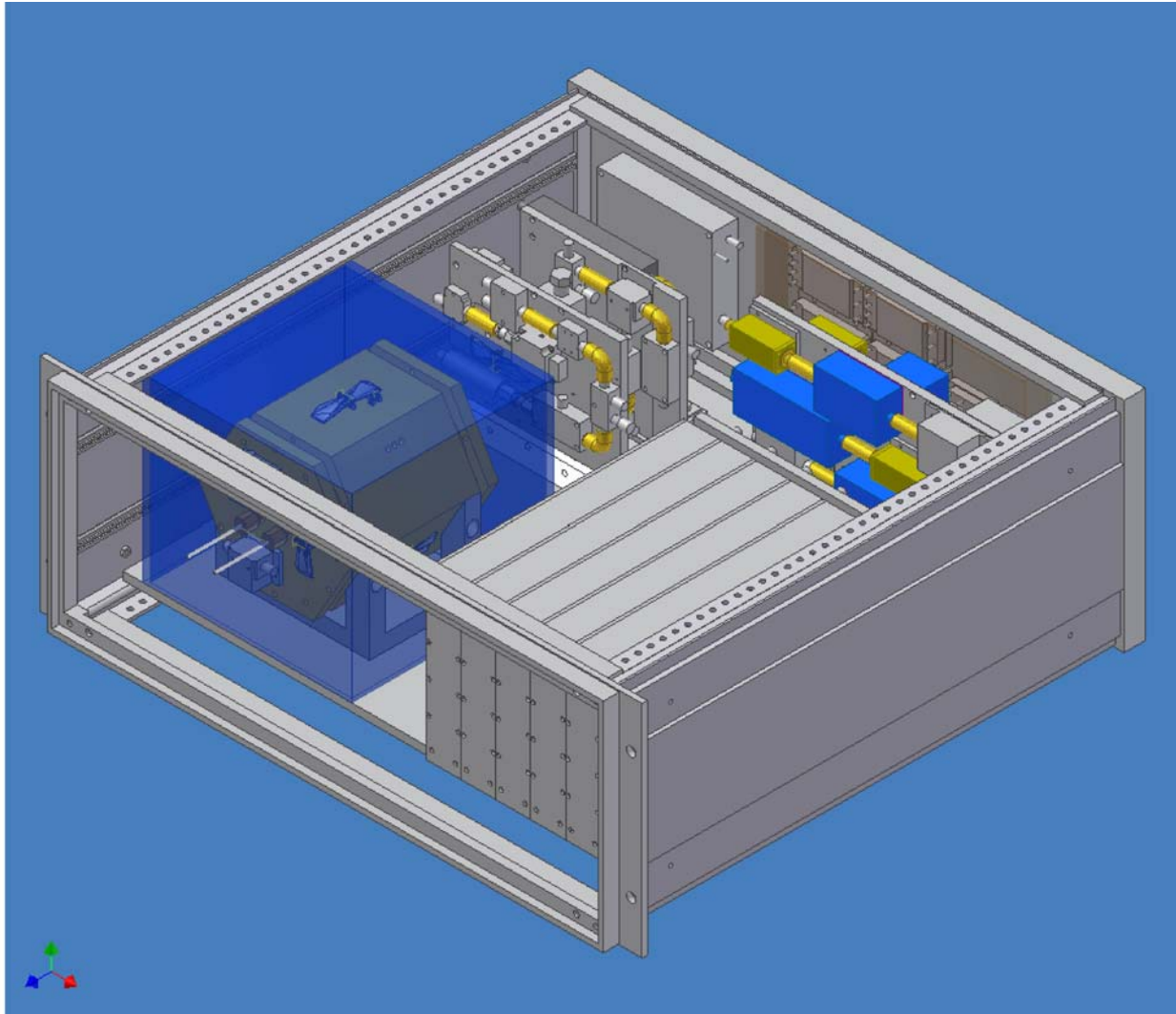
Cavity Lid, Showing the Choke Ring and the Coupling Loops



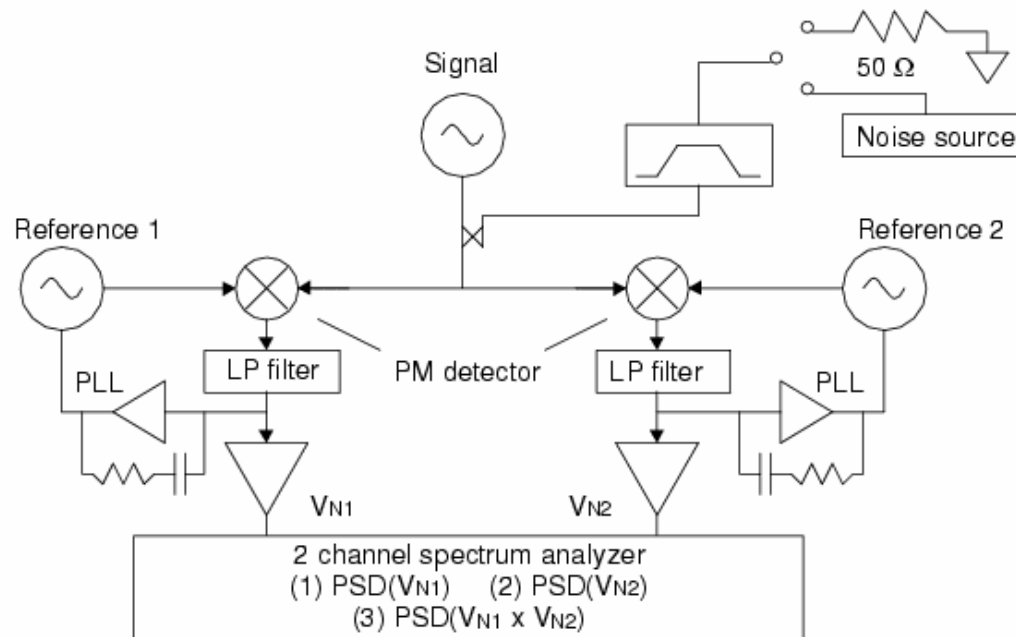
Prototype Air Dielectric Power Cavity Oscillator



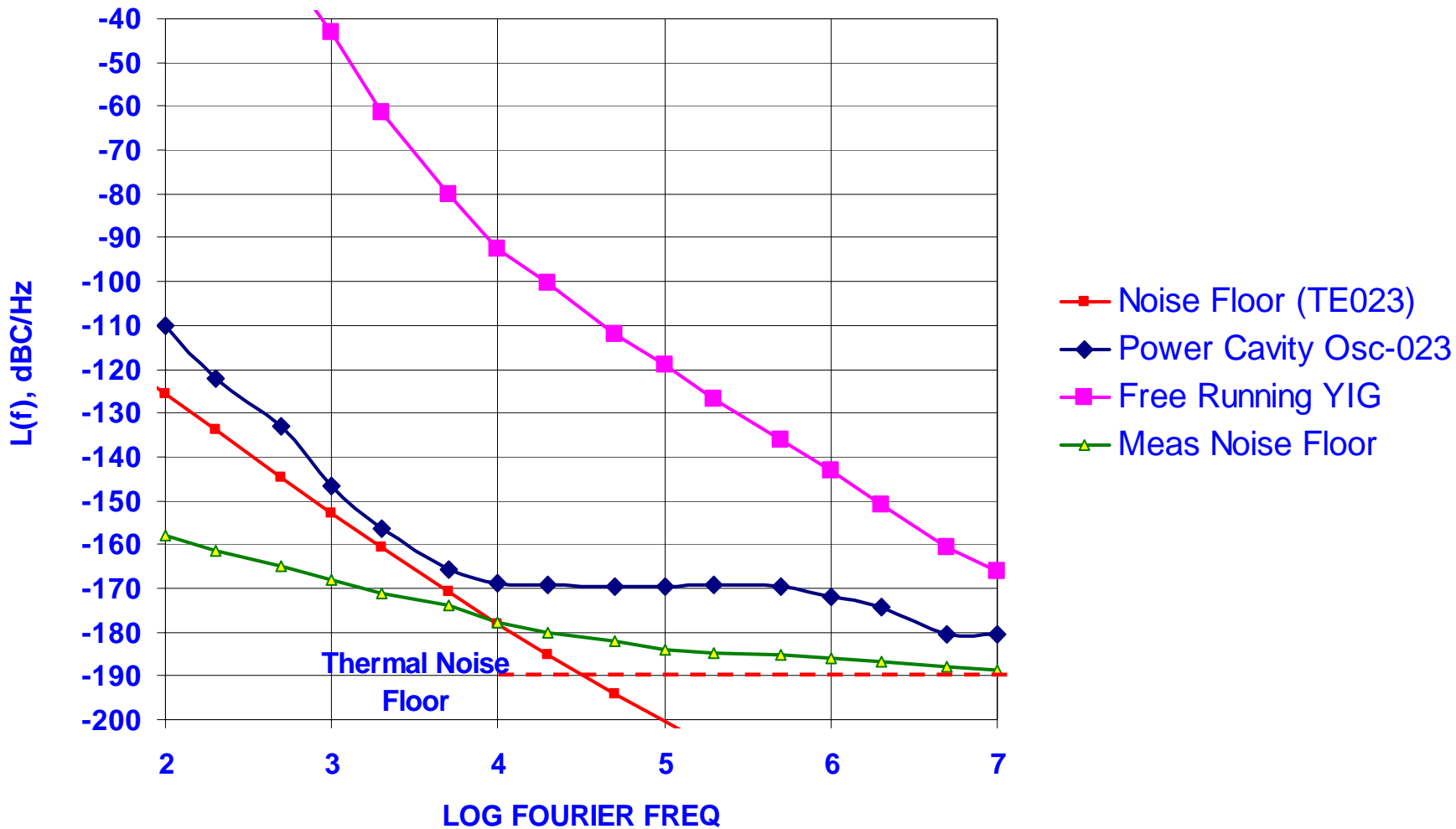
Proposed Layout of the W-Band Synthesizer based on Power Cavity Oscillator



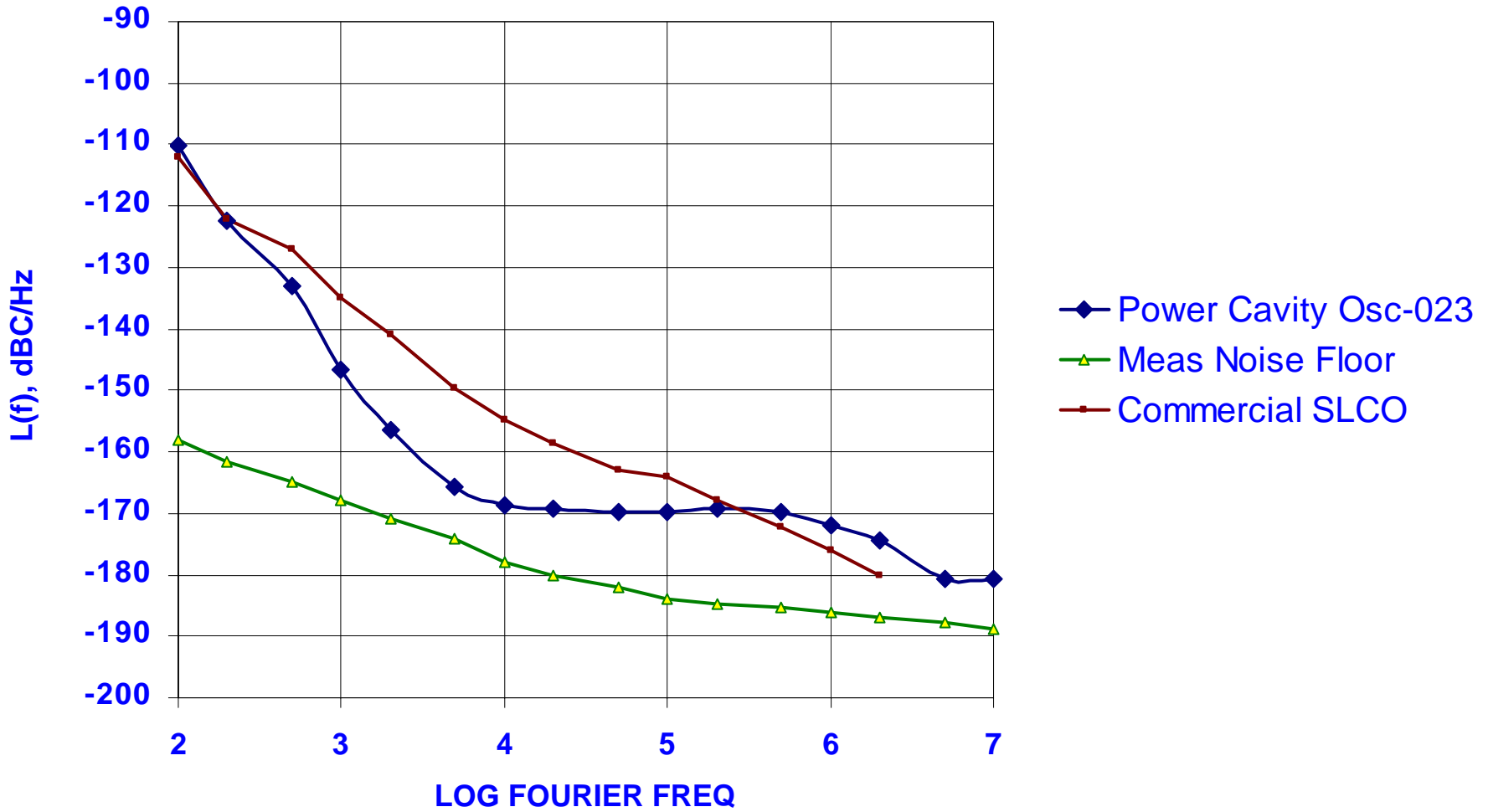
Cross-correlation PM Noise Measurement System for Oscillators



EXPERIMENTAL RESULTS



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SUMMARY

- X-Band Cavity Stabilized YIG Oscillator (CSO) using an Air-Dielectric Overmoded (TE023) Cavity Resonator as Frequency Discriminator.
- Cavity in TE023 Mode, unloaded $Q = 59,000$, input coupling coefficient = 0.95, power input to cavity = 33dBm
- CSO phase noise : -110dBc/Hz @ 100Hz
-147dBc/Hz @ 1kHz
-174dBc/Hz @ 1MHz
- At lower Fourier frequencies PM noise is degraded because of
a) inadequate environmental isolation, b) inadequate servo gain
- In Future we plan to
a) Improve cavity temp. control
(Temperature compensated cavity?)
b) Have more rigid mounting
c) Possibly use higher Carrier Frequency
- With some refinements, we expect the CSO to rival the SLCO

We acknowledge very helpful discussions with Eugene Ivanov