PHASE NOISE ORIGINS & MEASUREMENT

Presented by:

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MISSION

Provide the industry with highly innovative, high performing, accurate and reliable phase noise analysis products at the absolute best performance-to-price ratios available.

ULTRA LOW PHASE NOISE IS OUR BUSINESS

WHAT IS PHASE NOISE?

HISTORICAL SUMMARY

WWII - With the advent of military radar and mobile communications systems the need to quantify the frequency stability of crystal oscillators being used as LOs and system clocks had emerged.

1970s - IEEE established the basis for the initial 1139 standard, defining the basic characteristics of phase noise. Phase noise measurements were slow and complex, primarily used by defense systems providers (radar systems) and high end oscillator manufactures.

1980s - IEEE released STD 1139-1988 *standard definitions of physical quantities for fundamental, frequency and time metrology-random instabilities,* which has been revised over the years to help define "stability" for the wide variety of components and systems that were being innovated.

Today - With modern defense and commercial communications systems, phase noise and jitter are being universally adopted as the prime verification standard for signal stability.

- Modern cross correlation measurement systems enable measurement floors that were impossible up until the early 2000s.

POWER SPECTRAL DENSITY

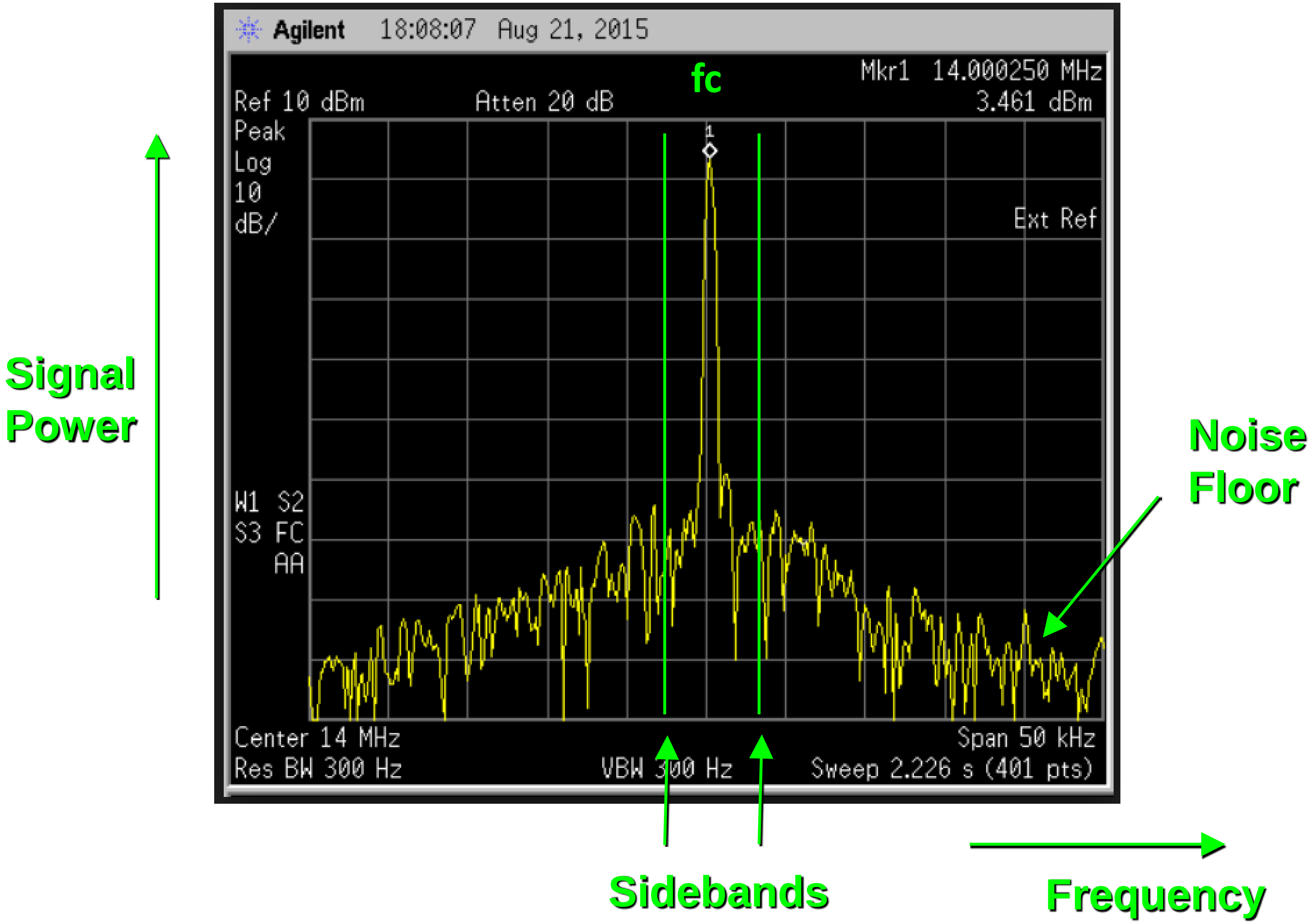
- NIST defines SSB (Single Side Band) Phase Noise as the RATIO between the power density of a signal at a specific frequency offset from the carrier to the total power of the carrier signal = **POWER SPECTRAL DENSITY** (dBc/Hz)

- This is the most common way to describe phase noise. SSB phase noise is expressed as $\mathcal{L}(f)=1/2 \cdot \mathcal{S}_{\phi}$

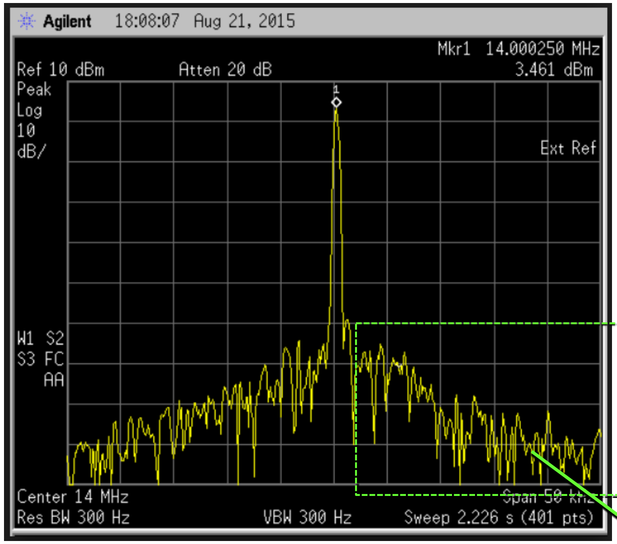
- SSB phase noise is a precise method of quantifying Frequency Stability over a specified time period

- Frequency Stability can be broken down into:
  - Long Term Stability: hours, days, months, years
  - Short Term Stability: seconds to femtoseconds

SPECTRUM ANALYZERS

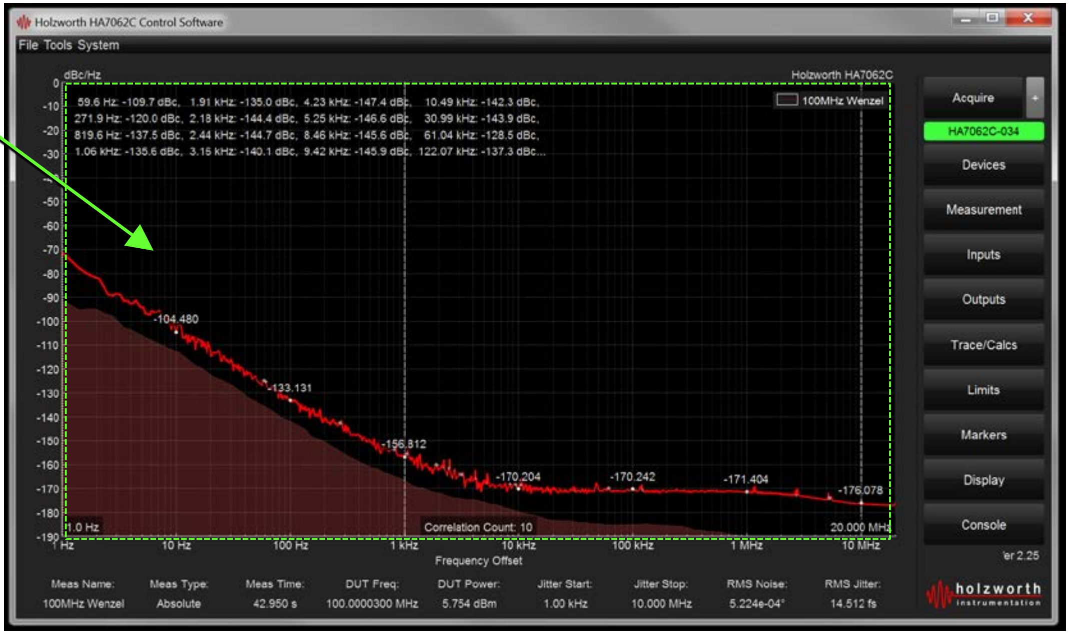


SSB = SINGLE SIDE BAND

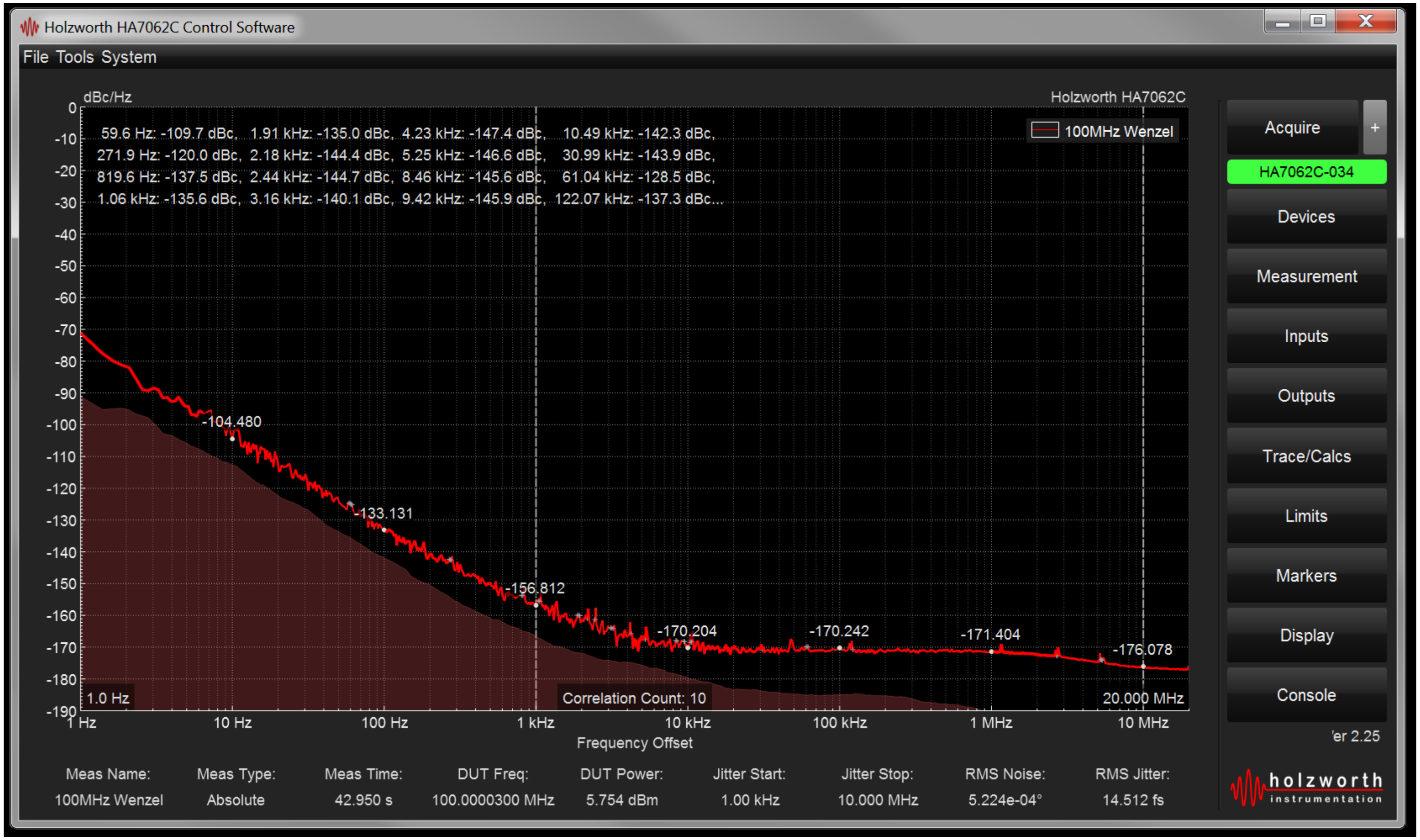


- High end Spectrum Analyzers have a *limited* noise floor of approximately -150dBc far from the carrier.

- High end Phase Noise Analyzers have noise floors to well below -190dBc/Hz



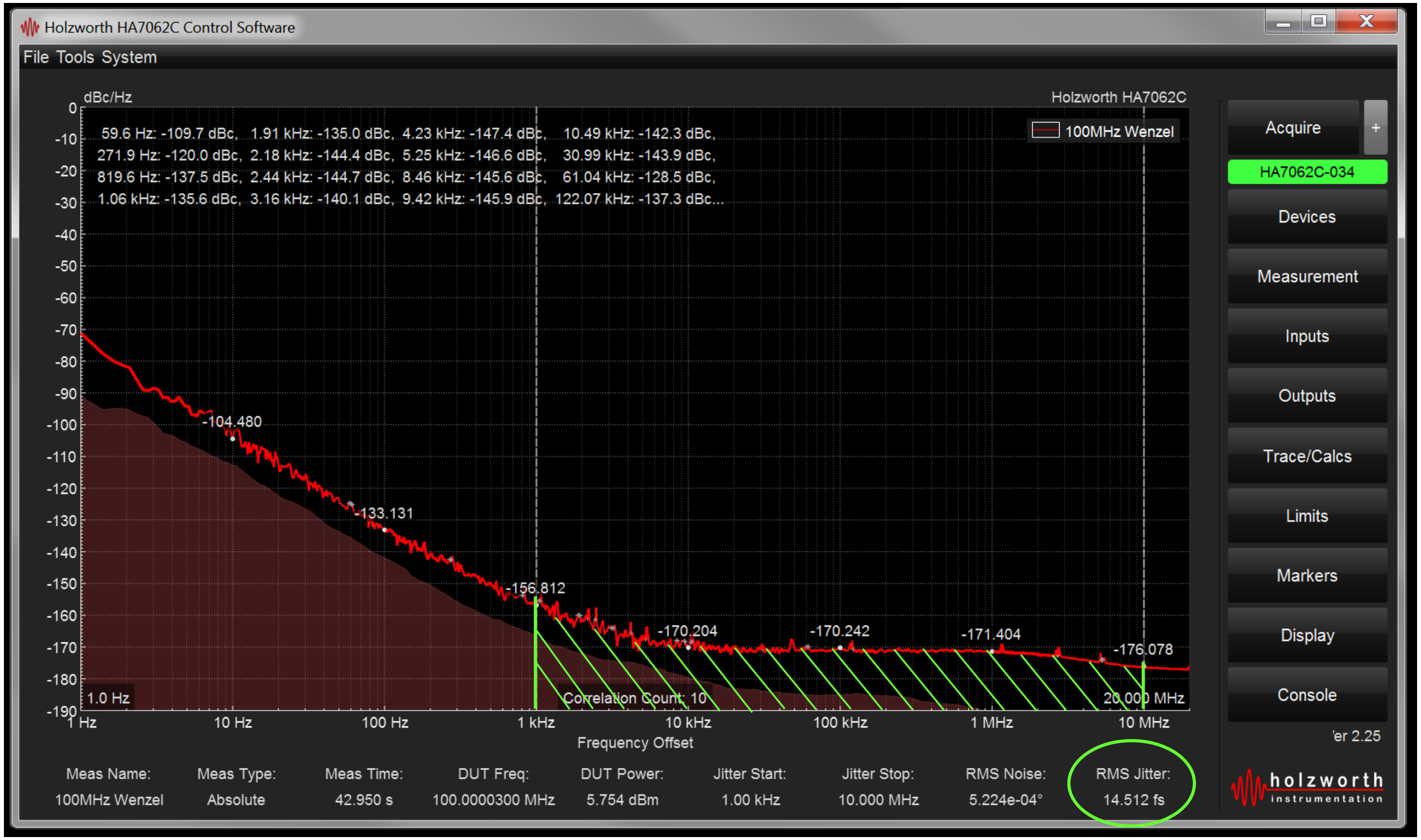
PHASE NOISE & STABILITY



"Close to the Carrier"
= Long Term Stability

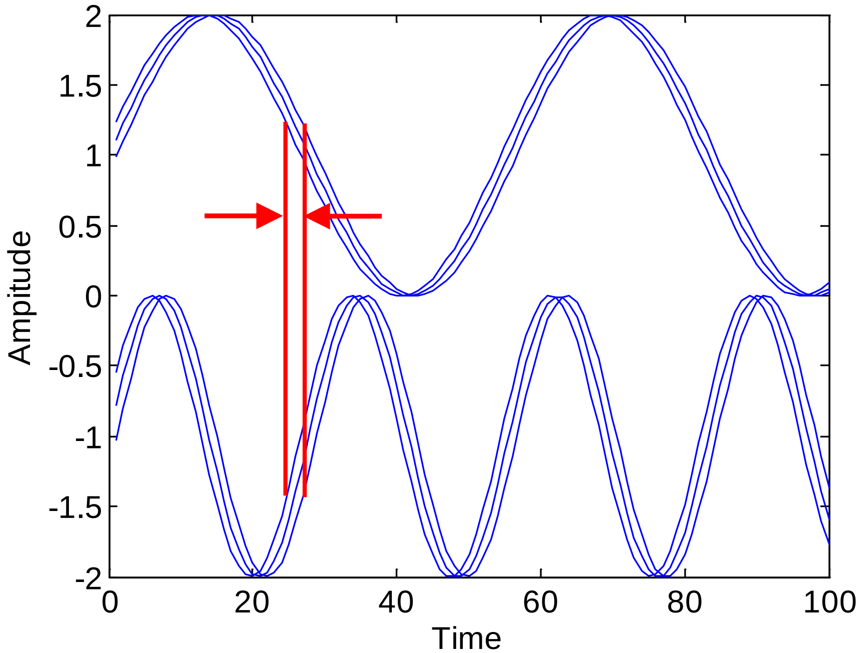
"Far from the Carrier"
= Short Term Stability

PHASE NOISE & JITTER



<u>Integration</u> of the SSB phase noise curve will provide the user with <u>RMS Jitter</u> information

PHASE NOISE & JITTER **(the math)**



$$v(t) = \left(V_0 + n(t)\right)\cos\left(2\pi f_0 + \Delta\varphi(t)\right)$$

$$v(t) = \left(V_0 + n(t)\right)\cos\left(4\pi f_0 + 2\Delta\varphi(t)\right)$$

Additional Phase Noise
$20\log_{10}N$
(N = Frequency Multiplier)

JITTER REMAINS CONSTANT WITH FREQUENCY MULTIPLICATION

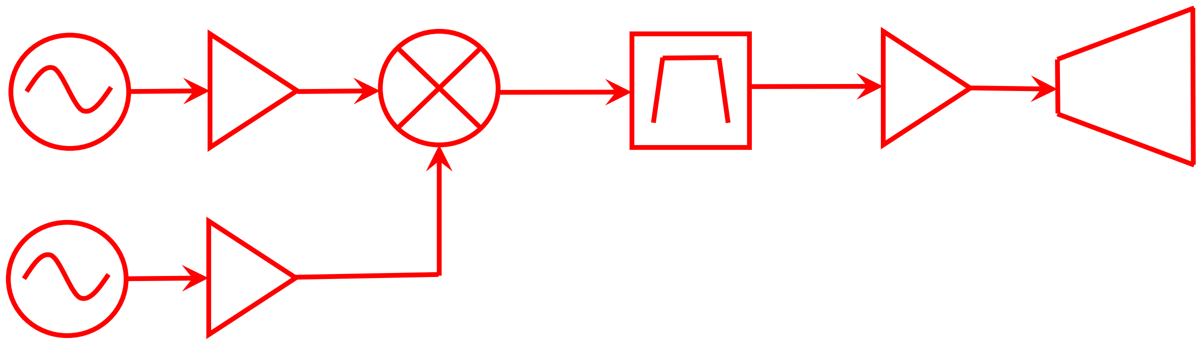
TWO PHASE NOISE MEASURMENTS

ABSOLUTE PHASE NOISE

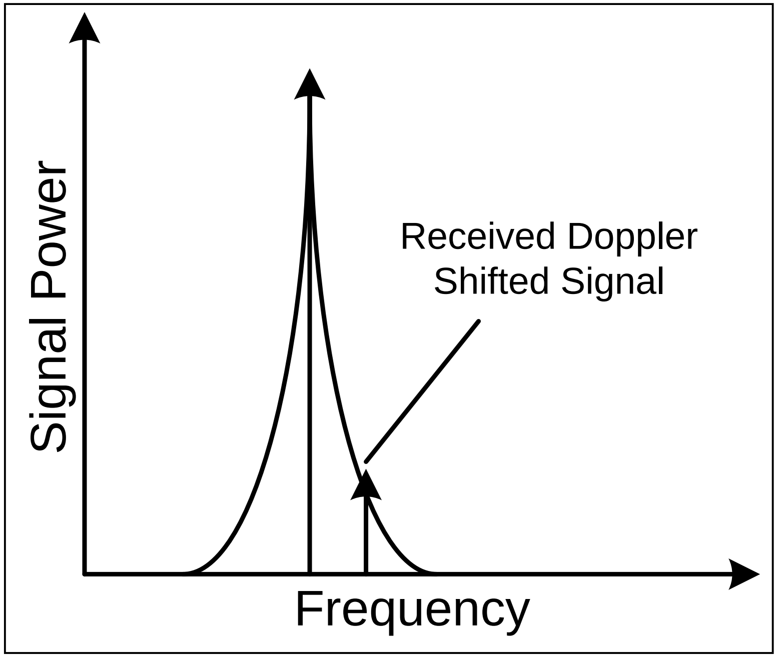
- SIGNAL SOURCE MEASUREMENTS
- Oscillators… OXCO, TCXO, VCO, DRO, CRO, etc.
- RF Synthesizers, Signal Generators, Clocks, DDS, *etc.*

ADDITIVE (RESIDUAL) PHASE NOISE

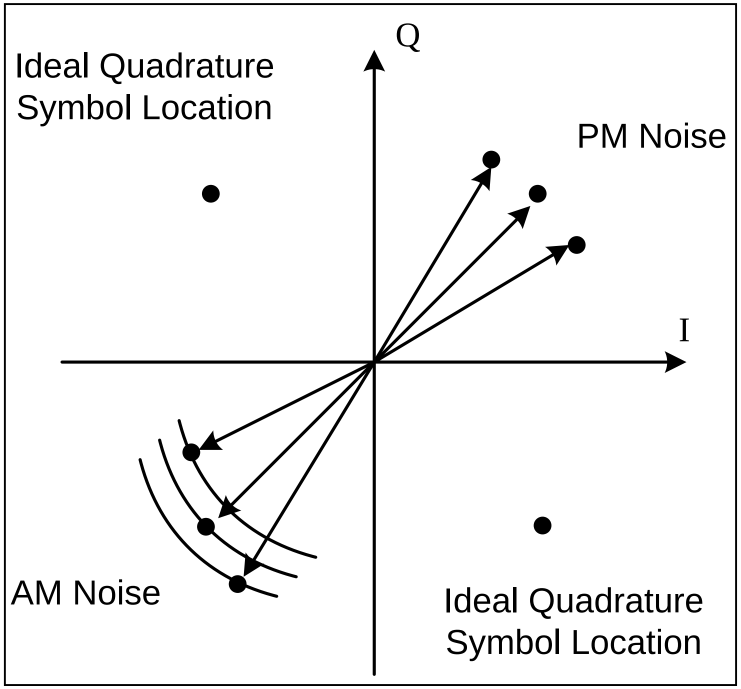
- 2+ PORT DEVICE MEASUREMENTS
- Amplifiers, mixers, multipliers, switches, diplexers, *etc*.



PHASE NOISE IN SYSTEMS



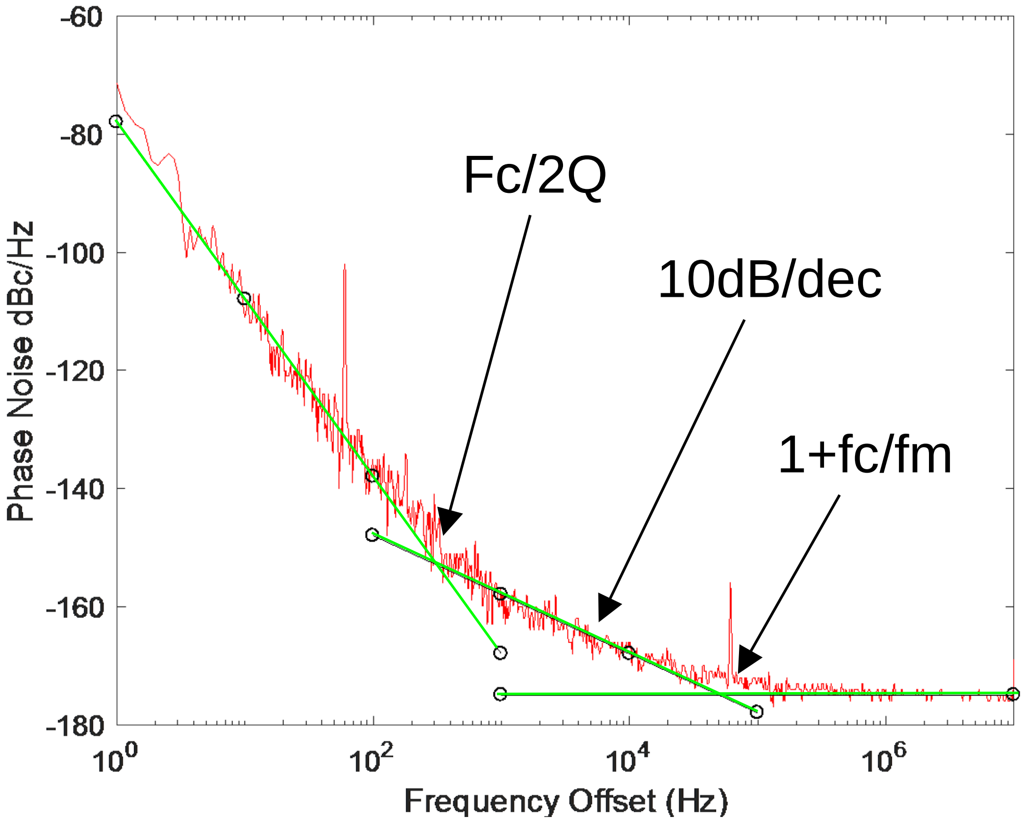
RADAR SYSTEMS



COMMUNICATIONS SYSTEMS

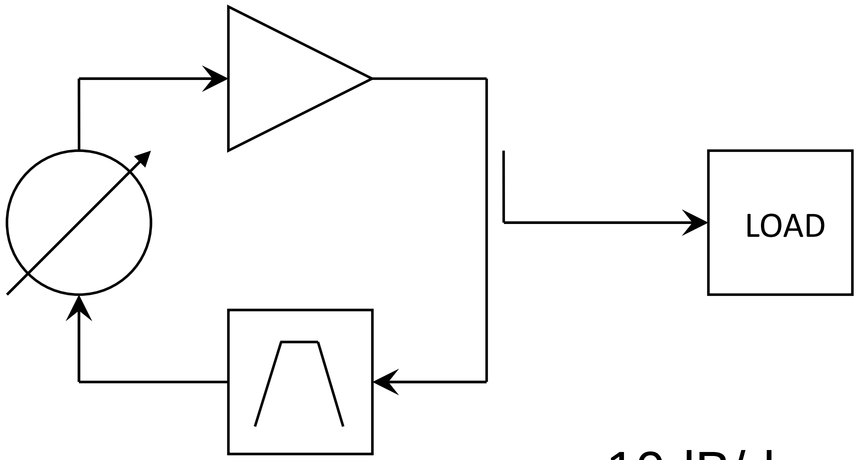
100MHz Crystal Oscillator (OCXO)

30dB/dec (20dB resonator + 10dB flicker)



-177 – Pin + NF →

OSCILLATOR AND LEESON'S EQ.



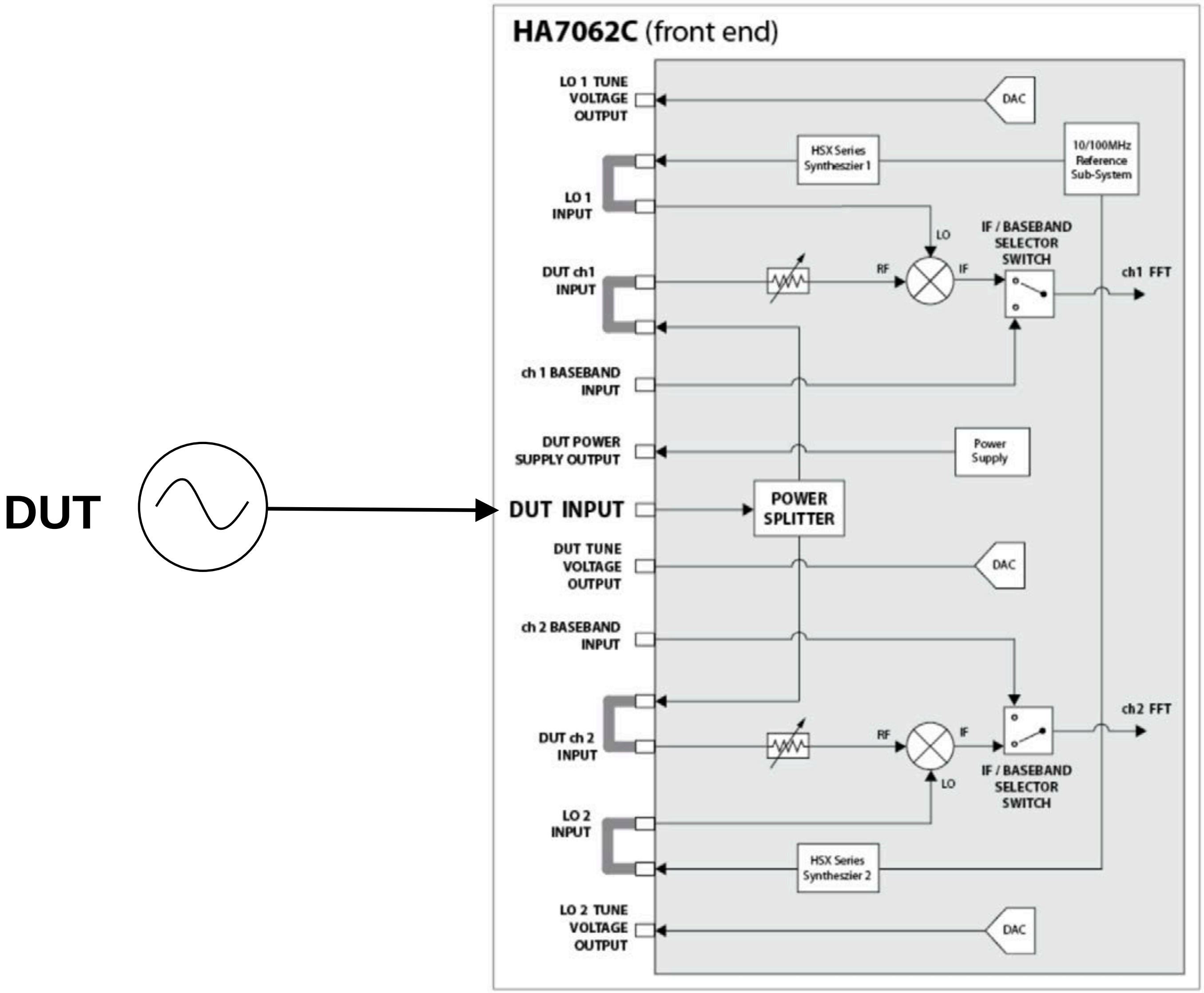
10dB/dec
Amplifier Flicker Noise

$$L(f_m) = 10\log\left[\frac{1}{2}\left(\left(\frac{f_0}{2Q_l f_m}\right)^2 + 1\right)\left(\frac{f_c}{f_m} + 1\right)\left(\frac{FkT}{P_s}\right)\right]$$

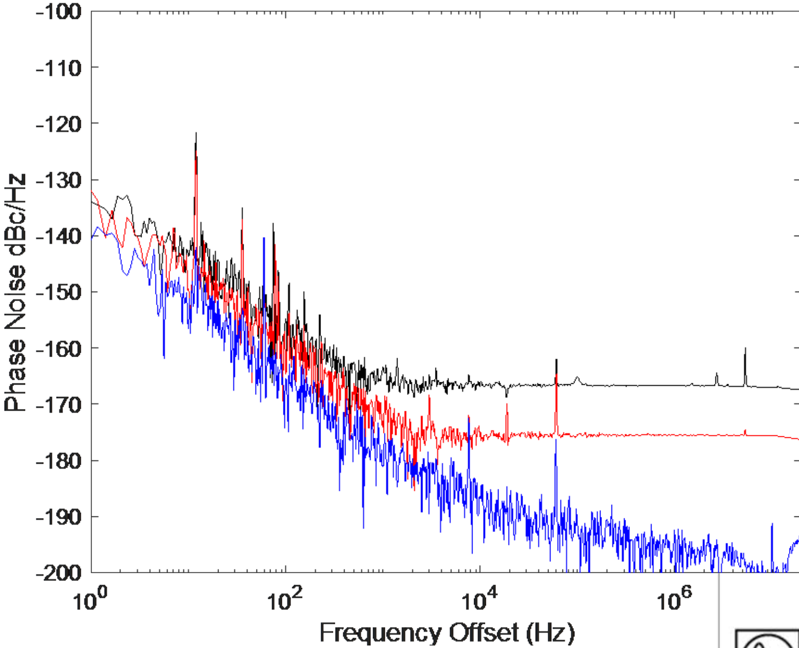
20dB/dec
Resonator
Starts at BW of Resonator

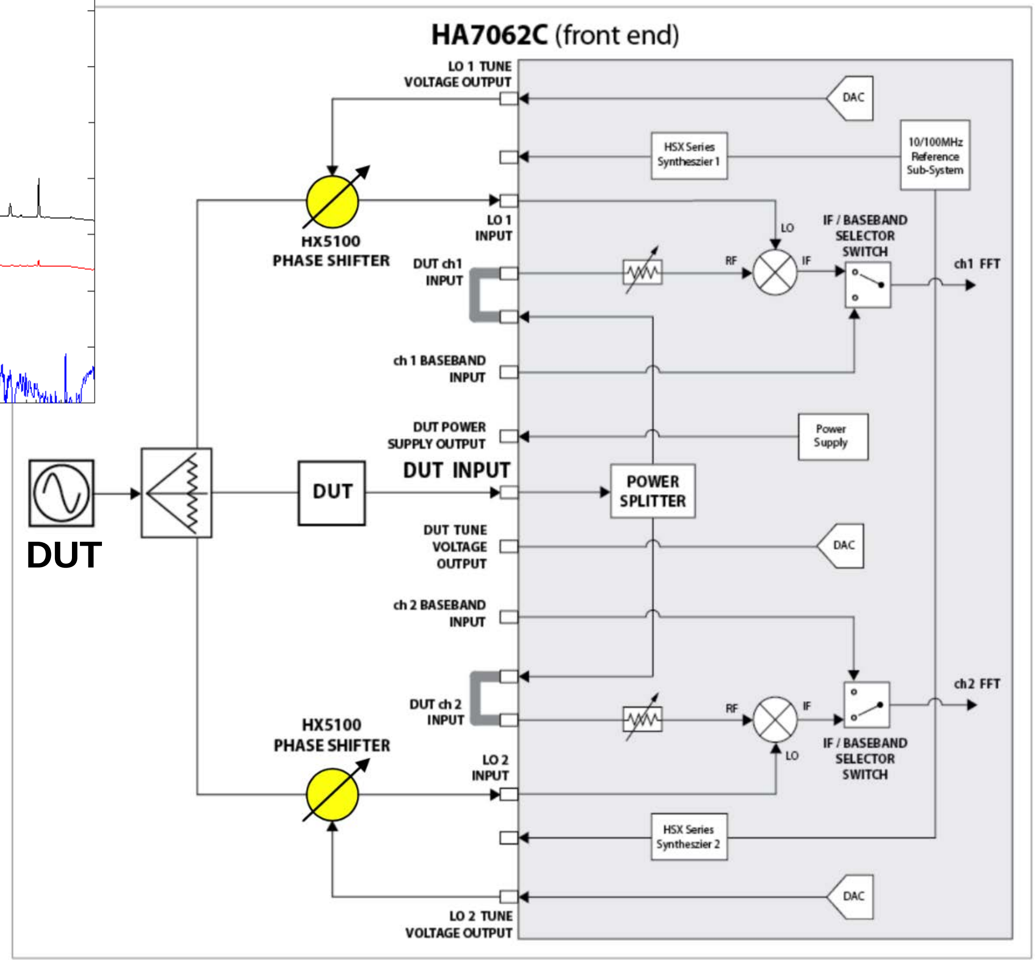
-177dBm - Ps + NF
White Noise of Amp

HA7062C ABSOLUTE MEASUREMENT



HA7062C ADDITIVE MEASUREMENT

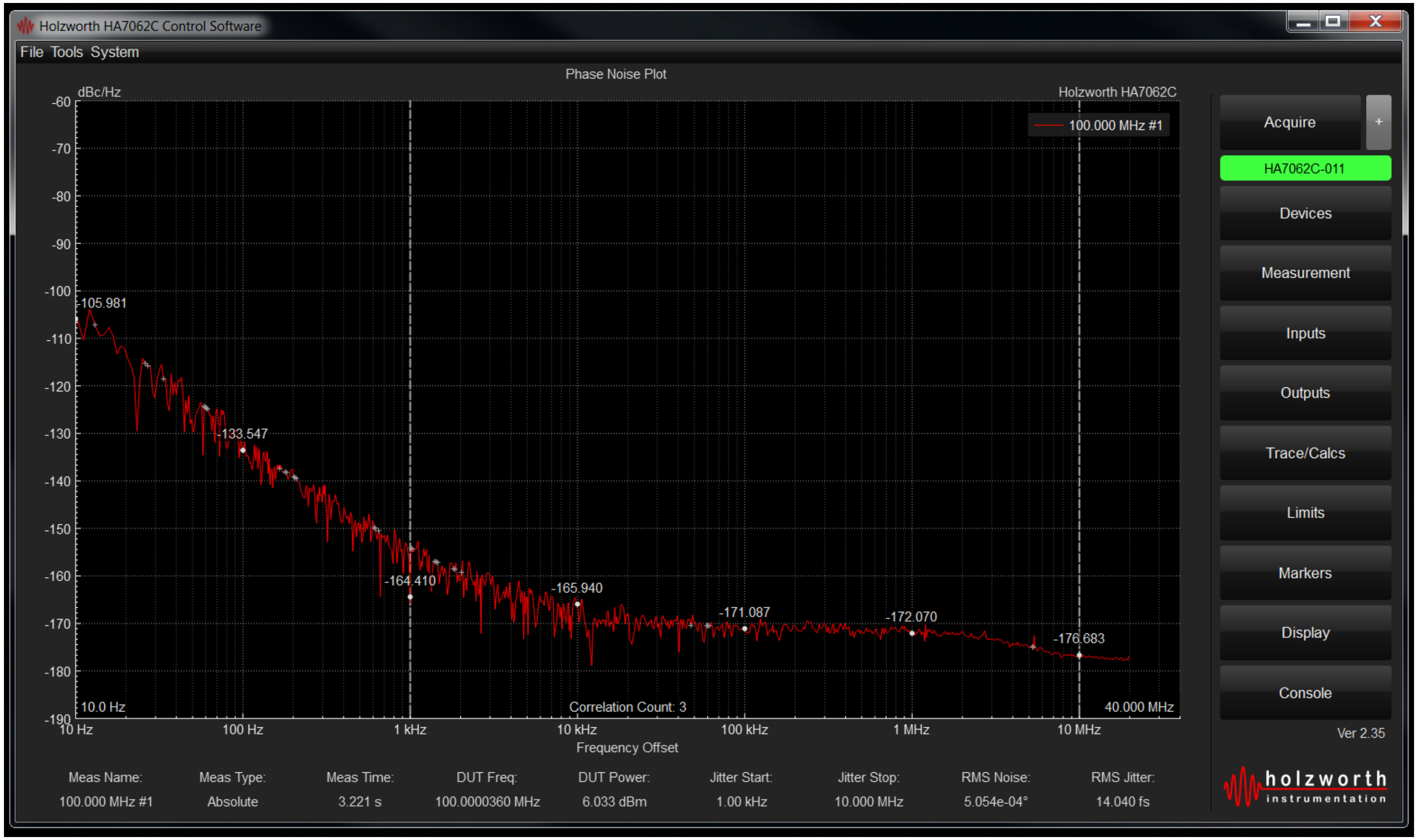




ENVORINMENTAL CONSIDERATIONS

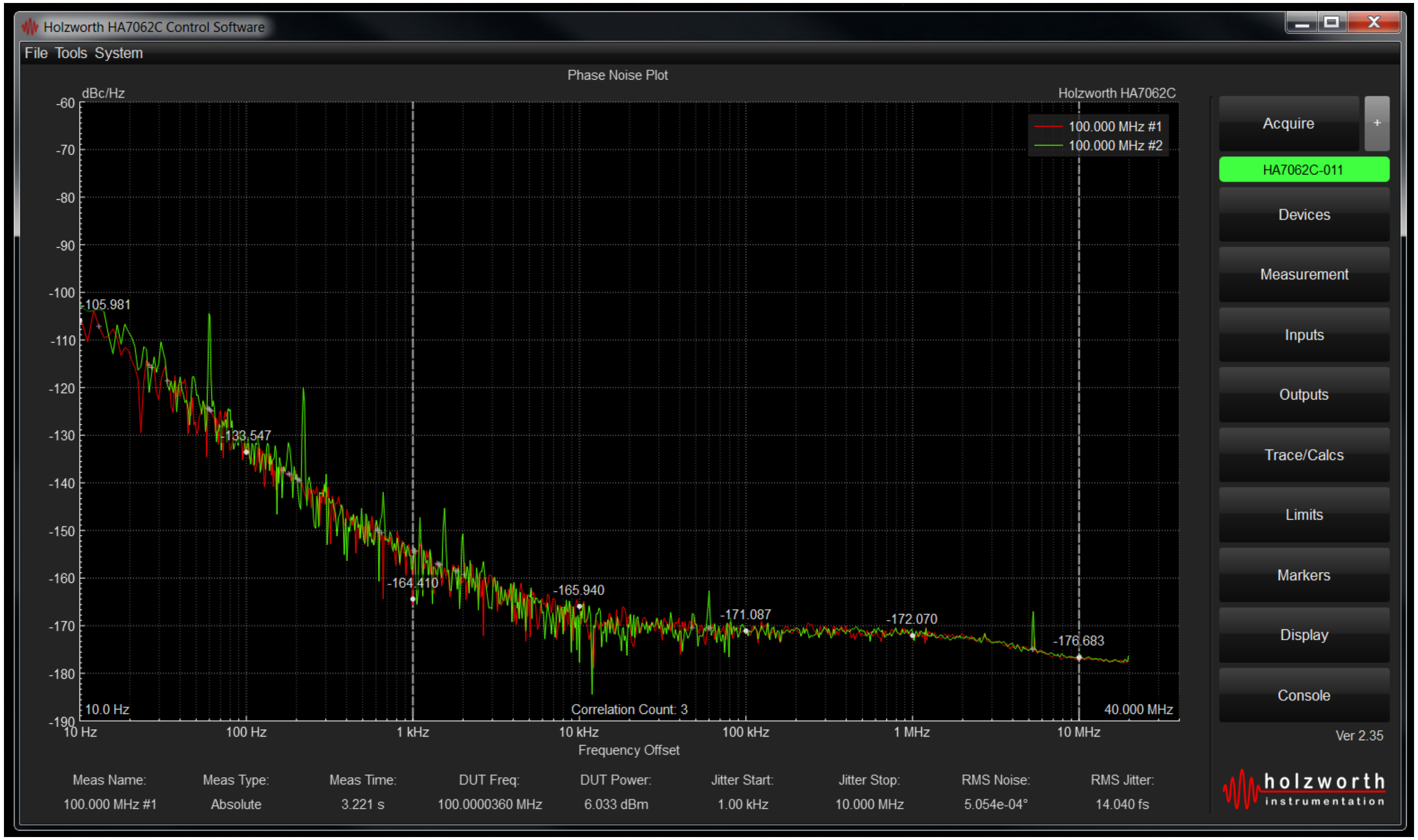
- Phase noise measurements quantify **spectral purity** to the absolute **lowest levels possible.**
- The cleanest of test system setups may be susceptible to nearly every form of **environmental noise**
- **Electrical Noise** can be caused by poorly filtered power supplies, ground loops, smart power grids, lights, *etc*.
- **Mechanical Noise** is caused by **microphonics** coming from nearby road traffic, music, and even system fans if not properly isolated.
- Many precision tests are ran in electrical isolation chambers, on mechanical isolation tables, and at “off-hours”.
- **Fast measurement speeds** can help to reduce some environmental effects.

ABSOLUTE MEASUREMENT DATA



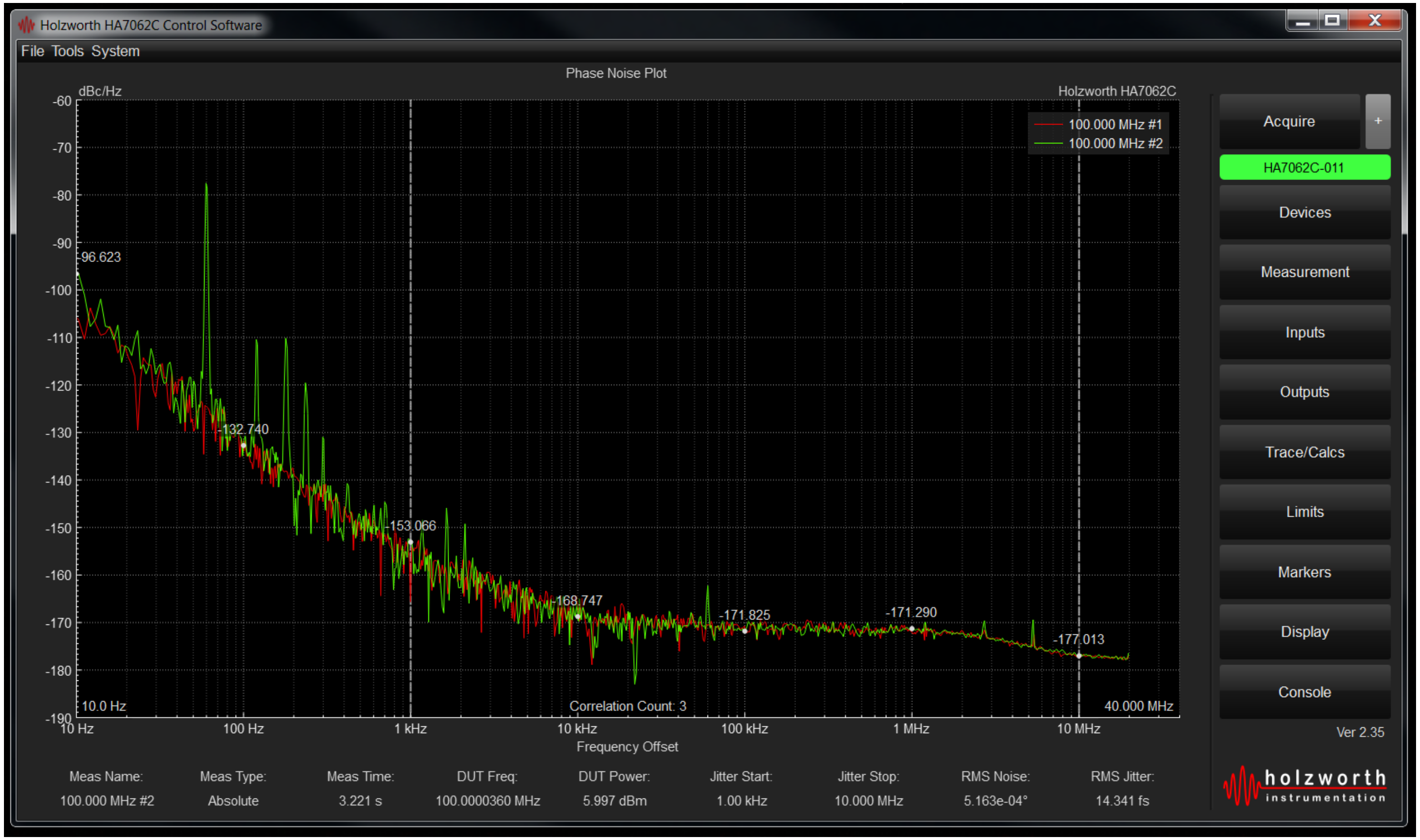
Oscillator phase noise measurement in a clean, isolated environment

ABSOLUTE MEASUREMENT DATA



Oscillator phase noise in un-controlled office environment

ABSOLUTE MEASUREMENT DATA



Oscillator phase noise with microphonics introduced

THANK YOU

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instrumentation

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