W-band dual channel AM/PM noise measurement system- an update

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What are we doing?

- Providing a PM/AM noise measurement system and calibration service within W-band (center frequency at 94 GHz).
- Developing new low-noise methodologies at W-band to support development of next-generation digital logic, radar, communications, etc.

What is goal of research?

- Measure noise of W-band amplifiers, mixers, oscillators, and other components.
- Obtain low-cost noise measurement capability for emerging applications at W-band.
- Develop low-noise W-band frequency synthesizers.
- Measure jitter at below the 100 femtosecond level.

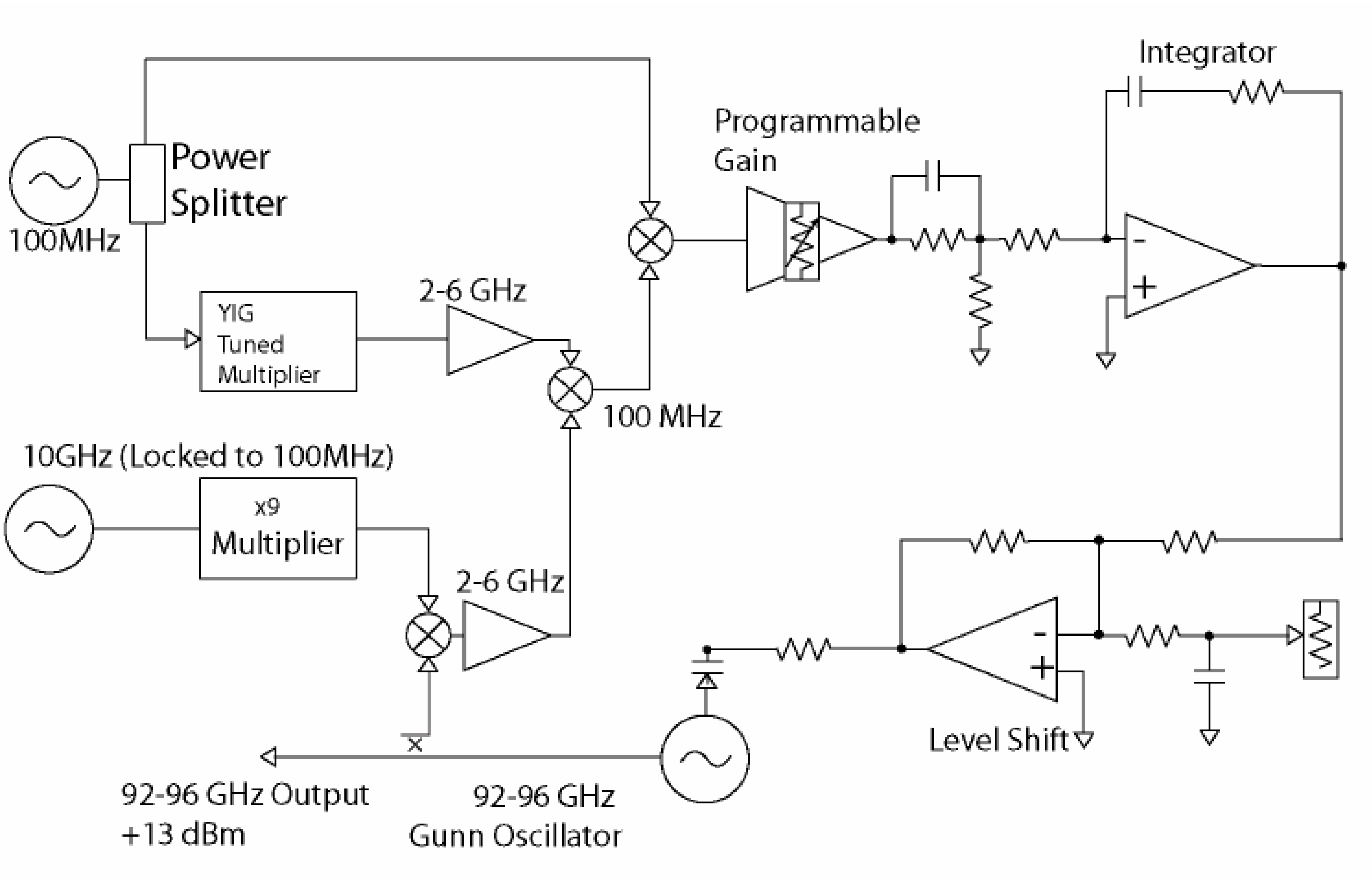
Why is this important?

- There is exponential growth of migration of existing applications to higher speeds, in particular, W-band.
- The success of new high-speed digital systems depends critically on the ability to reduce the phase-noise of the reference clock signal and other electronics operating at W-band.
- Currently, there are limited regular (NIST) noise calibration services and supporting standards at W-band.

What is primary application?

- Secure protocols and signals, broadband telecommunications, imaging, digital logic, signal processing, on-chip clock development, spectrum usage, weather, programmed beams.

Synthesis of 92-96 GHz Low Phase Noise Reference from NIST 10 GHz Cavity Stabilized Oscillator



NIST 10 GHz Cavity Stabilized Oscillator with Synthesis of 92-96 GHz Low Phase Noise Reference

Goals of PM noise of W-band reference source and measurement system

Principally designed to measure amplifiers in pulsed mode with a duty cycle of 5 % to 100 % (CW).
Synthesis of 92-96 GHz Low Phase Noise Reference from NIST Cavity Stabilized Oscillator.
Lowest possible noise within the cost guidelines.

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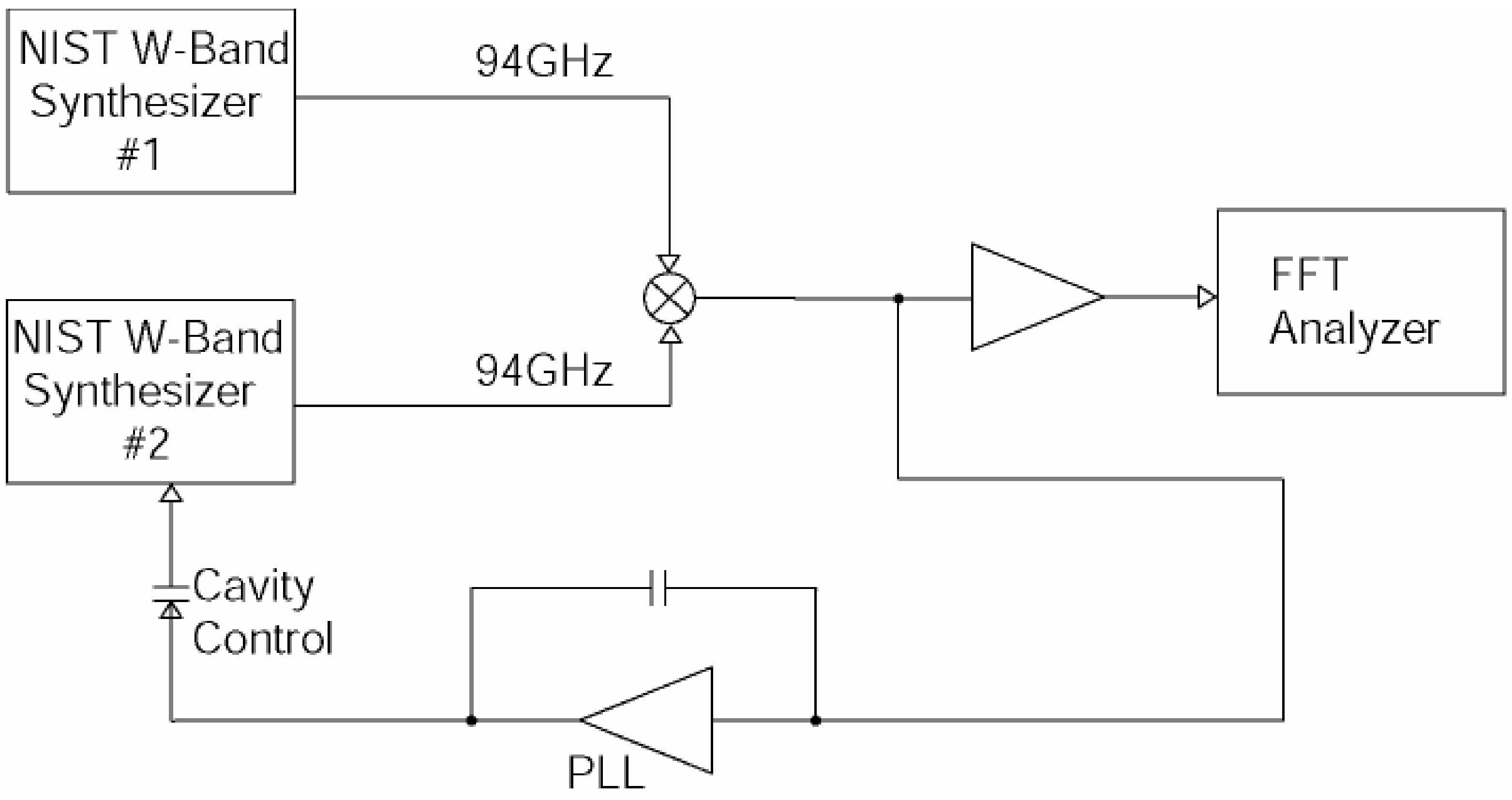
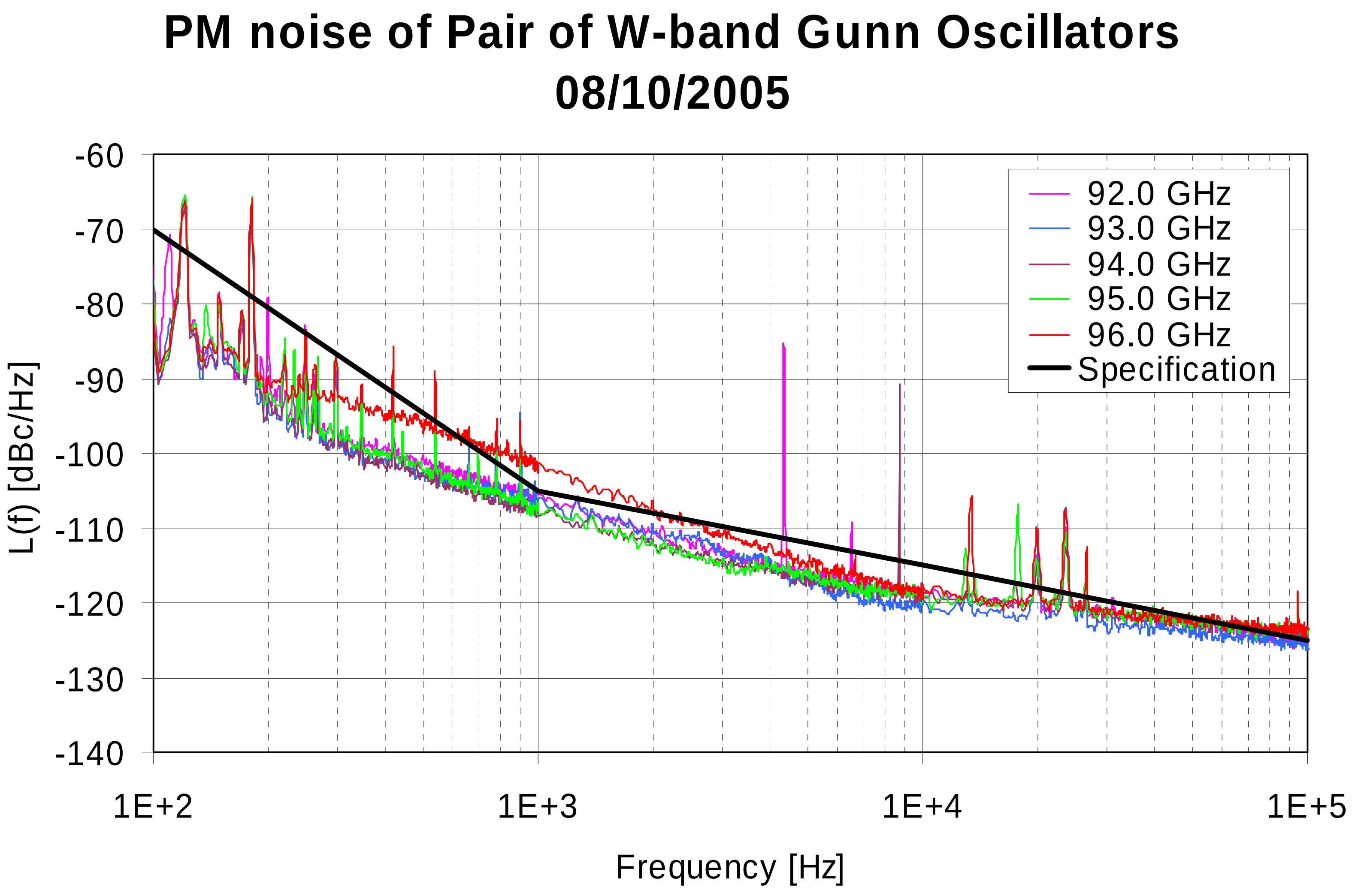
PM noise of W-band source		PM noise floor 10% / 100% duty cycle	
L(100) =	-70 dBc/Hz	L(100) =	-80 / -90 dBc/Hz
L(1 kHz) =	-105 dBc/Hz	L(1 kHz) =	-100 / -110 dBc/Hz
L(10 kHz) =	-115 dBc/Hz	L(10 kHz) =	-120 / -130 dBc/Hz
L(100 kHz) =	-125 dBc/Hz	L(100 kHz) =	-130 / -140 dBc/Hz

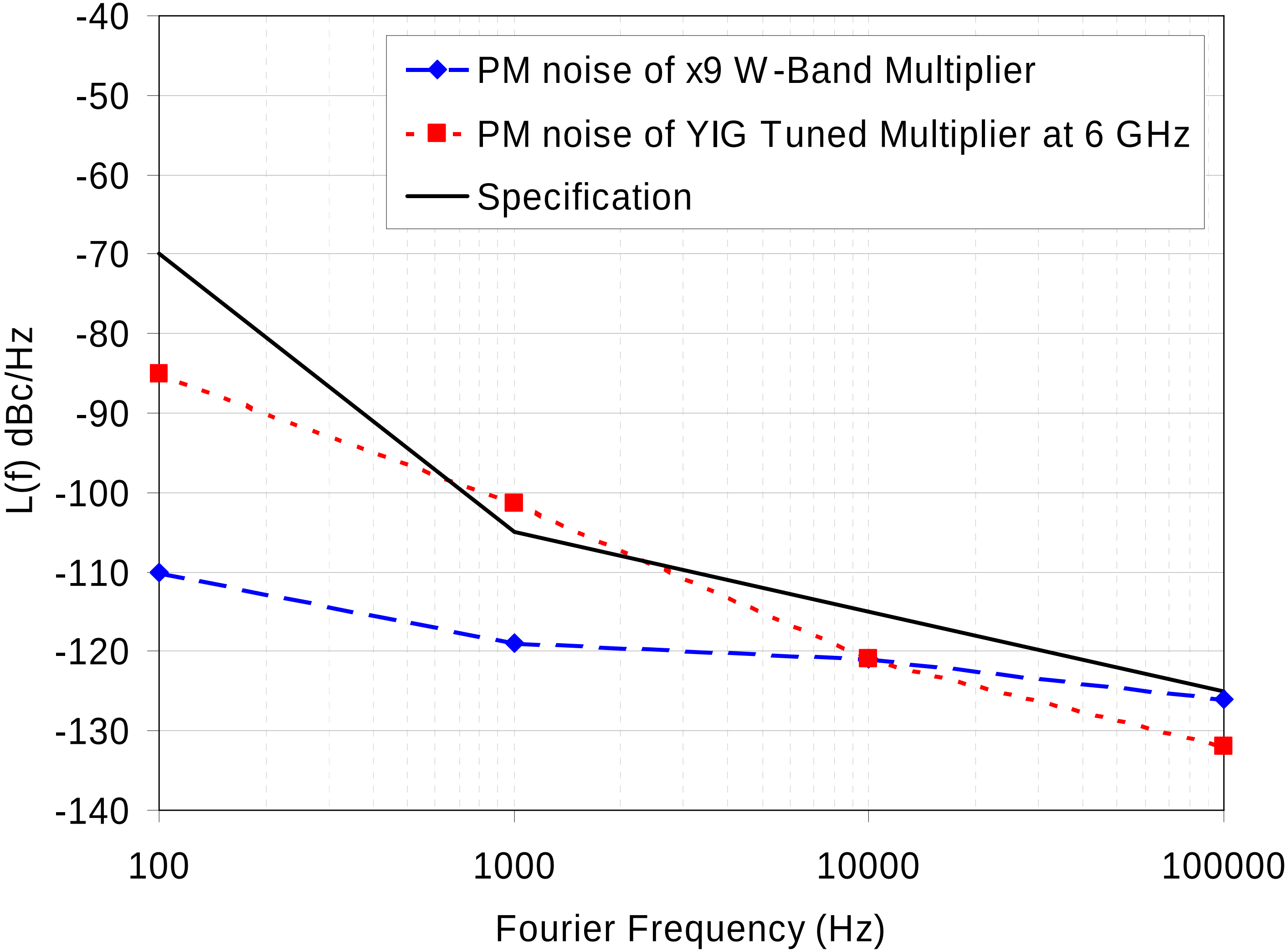
- Synthesis of 92-96 GHz Low Phase Noise Reference from NIST Cavity Stabilized Oscillator

Single Channel PM Noise Measurement Set-up for W-band Source

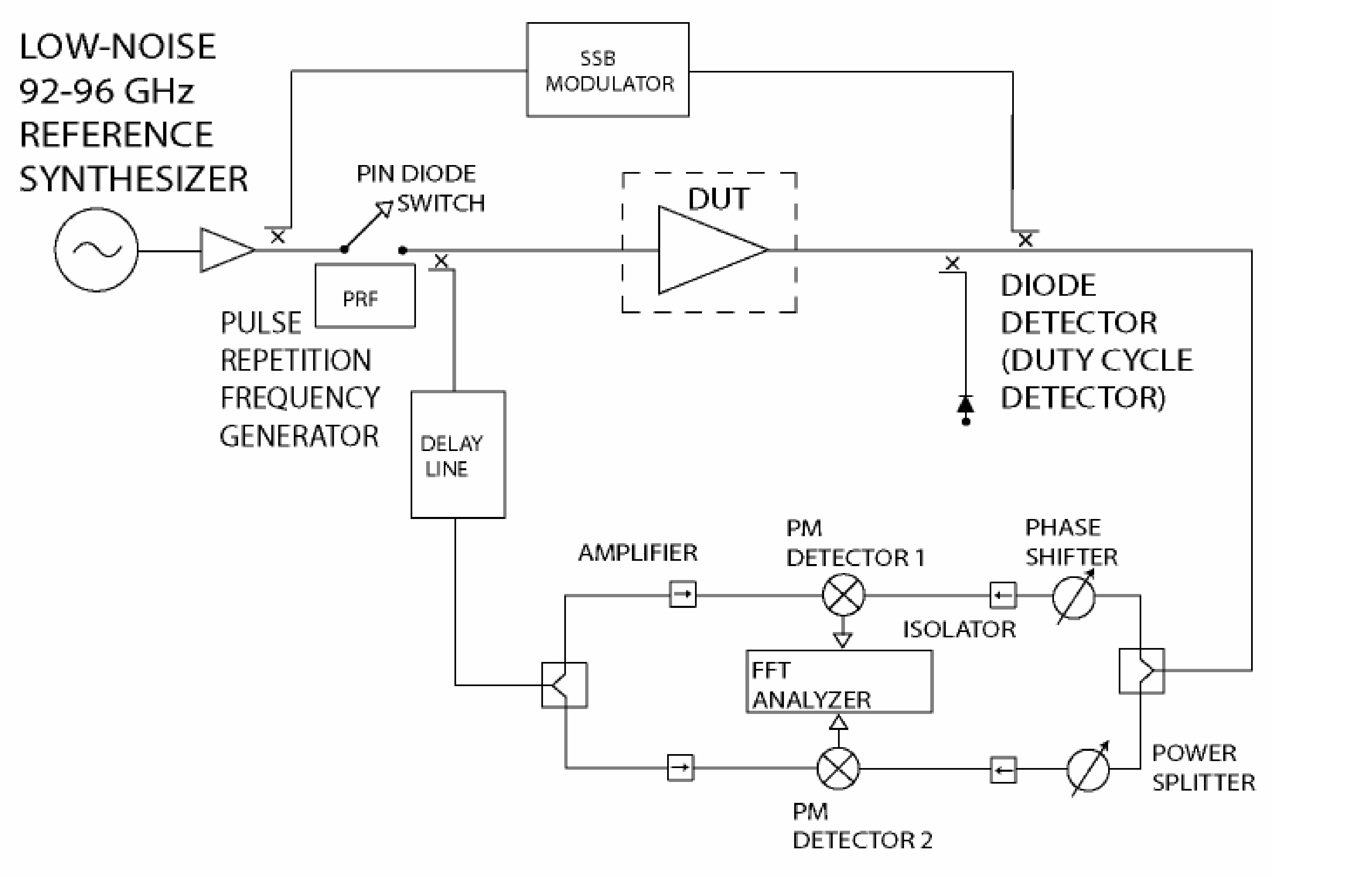



PM noise of Pair of W-band Gunn Oscillators
08/10/2005
-60
-70
-80
-90
-100
-110
-120
-130
-140
L(f) [dBc/Hz]
1E+2
1E+3
1E+4
1E+5
Frequency [Hz]
92.0 GHz
93.0 GHz
94.0 GHz
95.0 GHz
96.0 GHz
Specification

Limiting Factor for PM noise of W-band Source



NIST W-Band Phase Noise Measurement System



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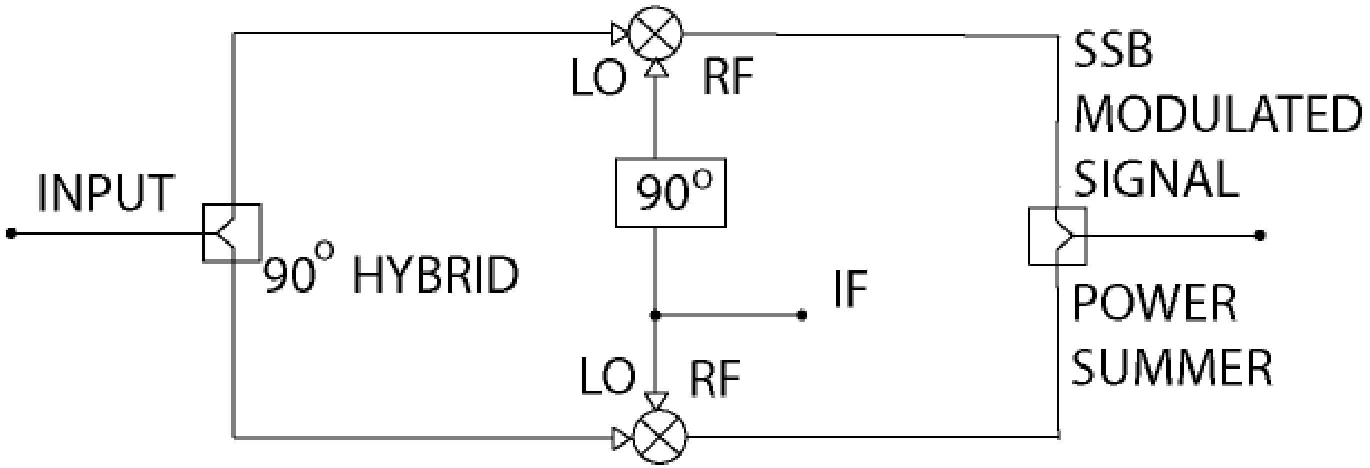
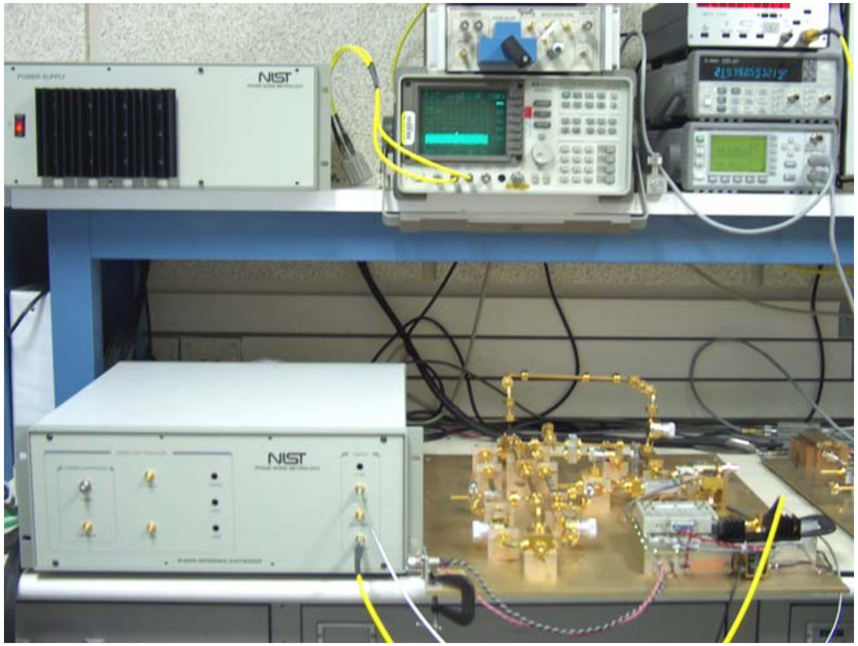
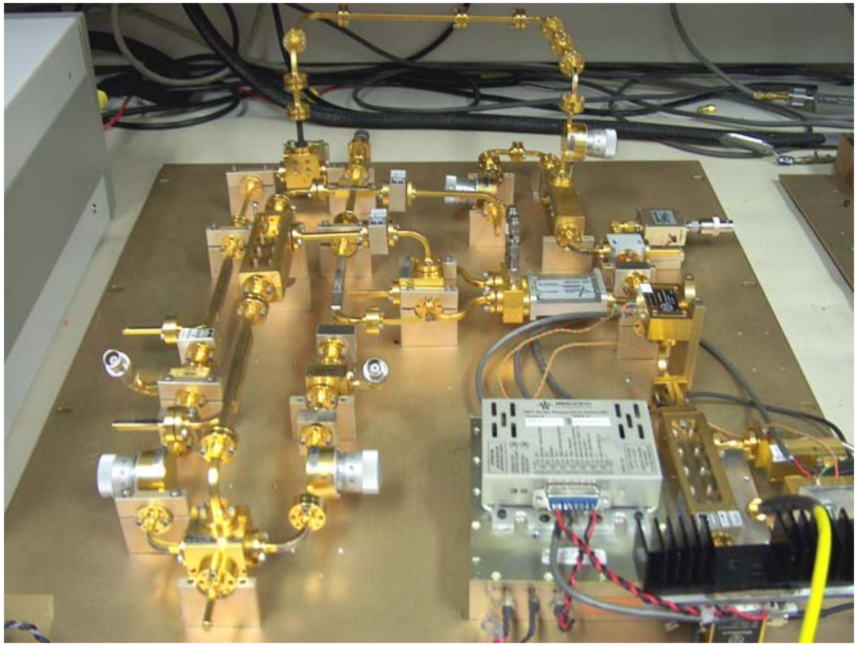
SSB Modulation Scheme to Calibrate PM/AM Measurement System

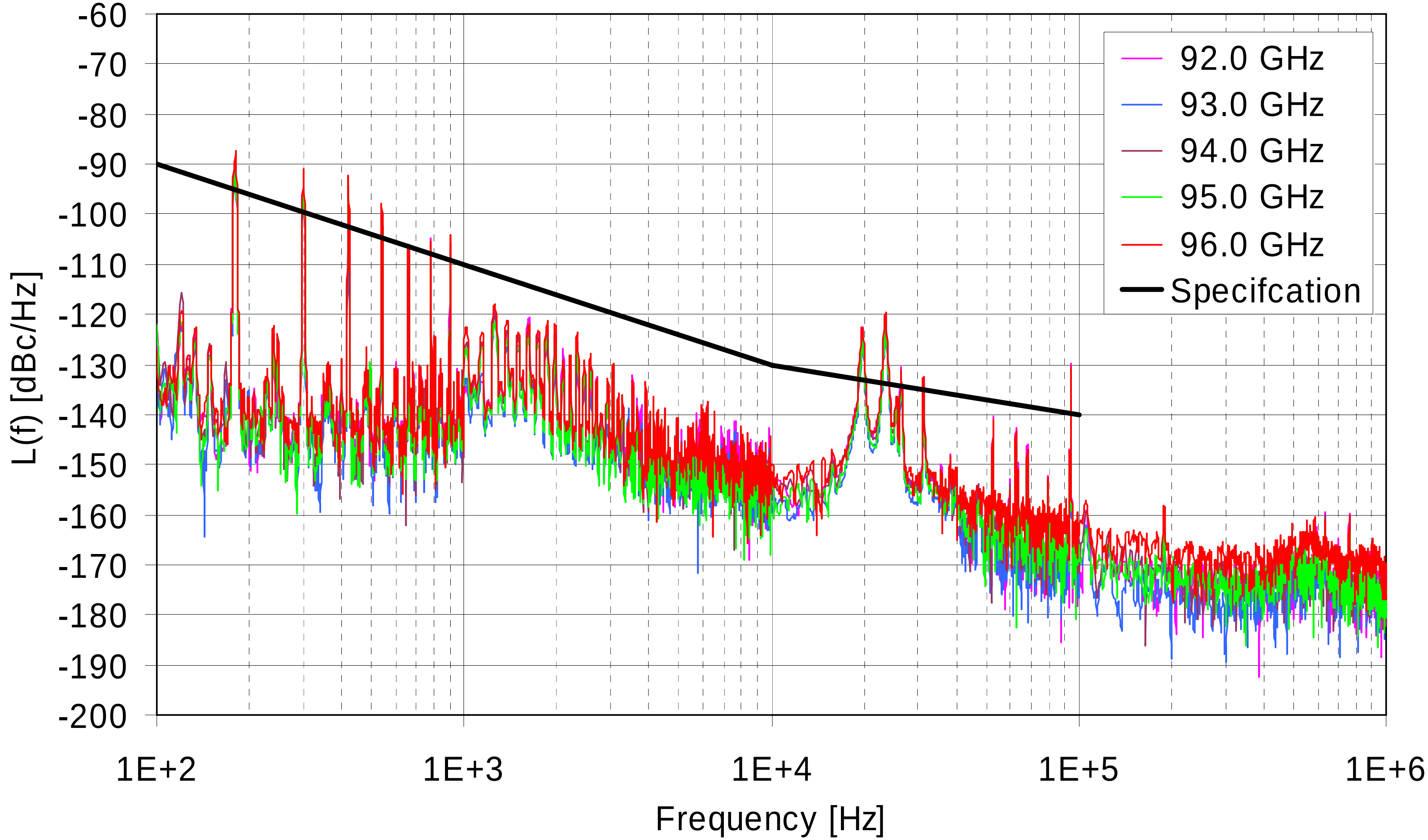


W-Band Synthesizer and Dual Channel Measurement System

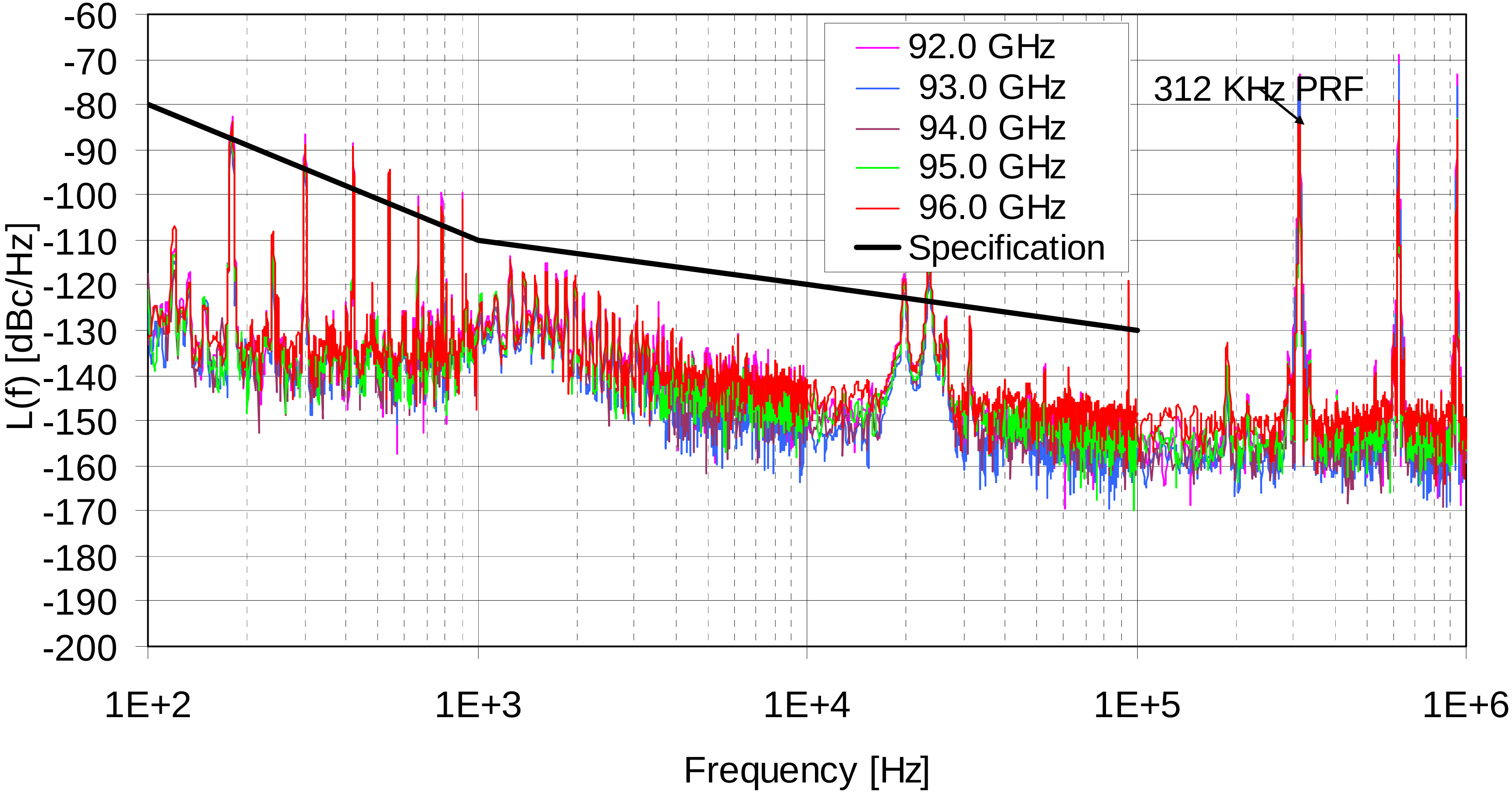




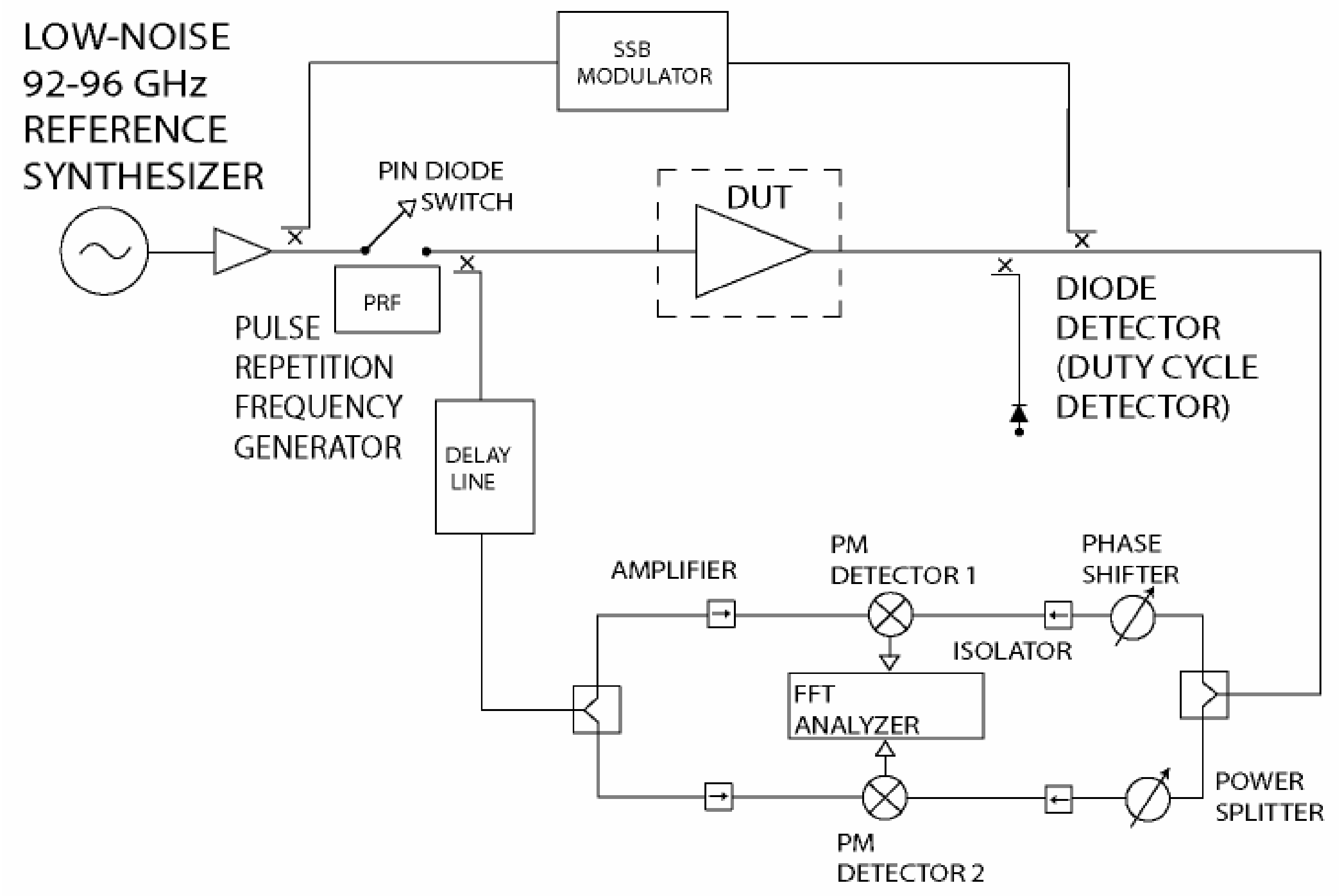
PM Noise Floor of W-band Measurement System - CW Mode (08/10/2005)



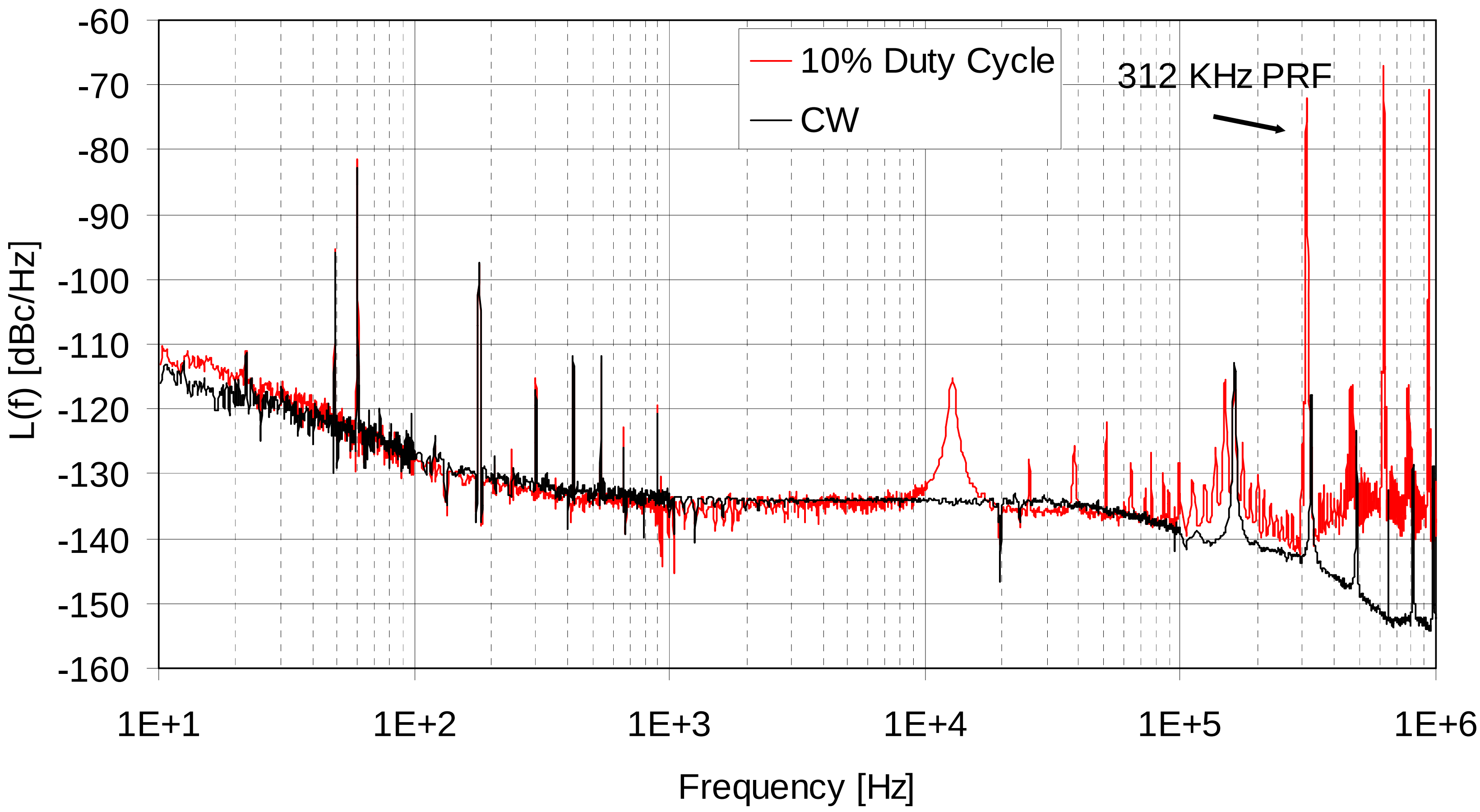
PM Noise Floor of W-band Measurement System- 10% Duty Cycle (08/10/2005)



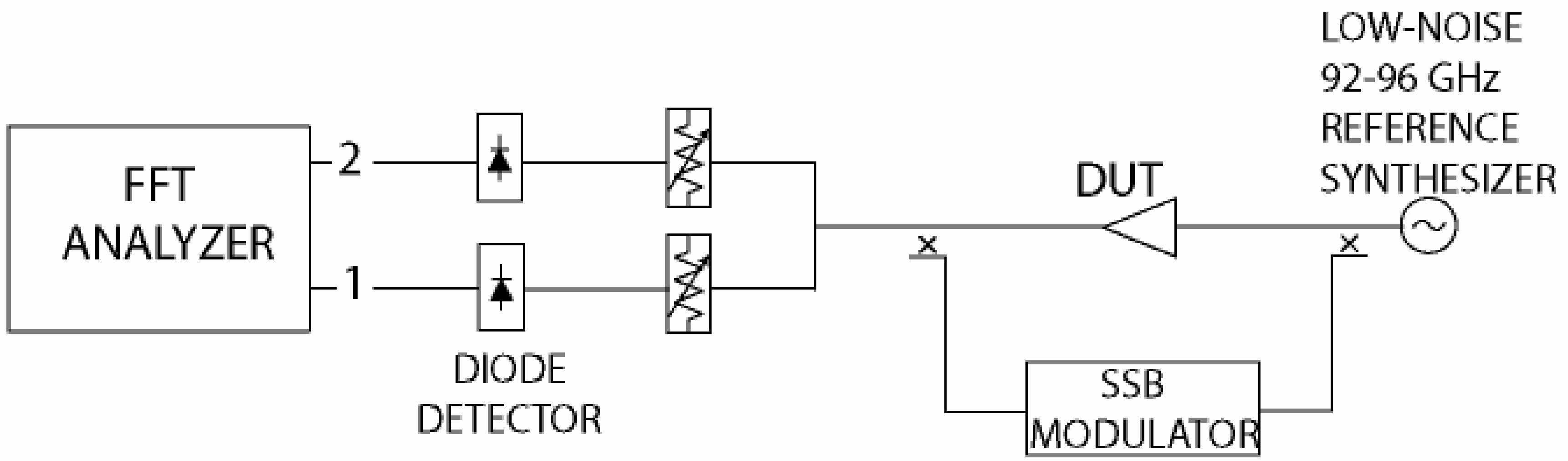
NIST W-Band Phase Noise Measurement System



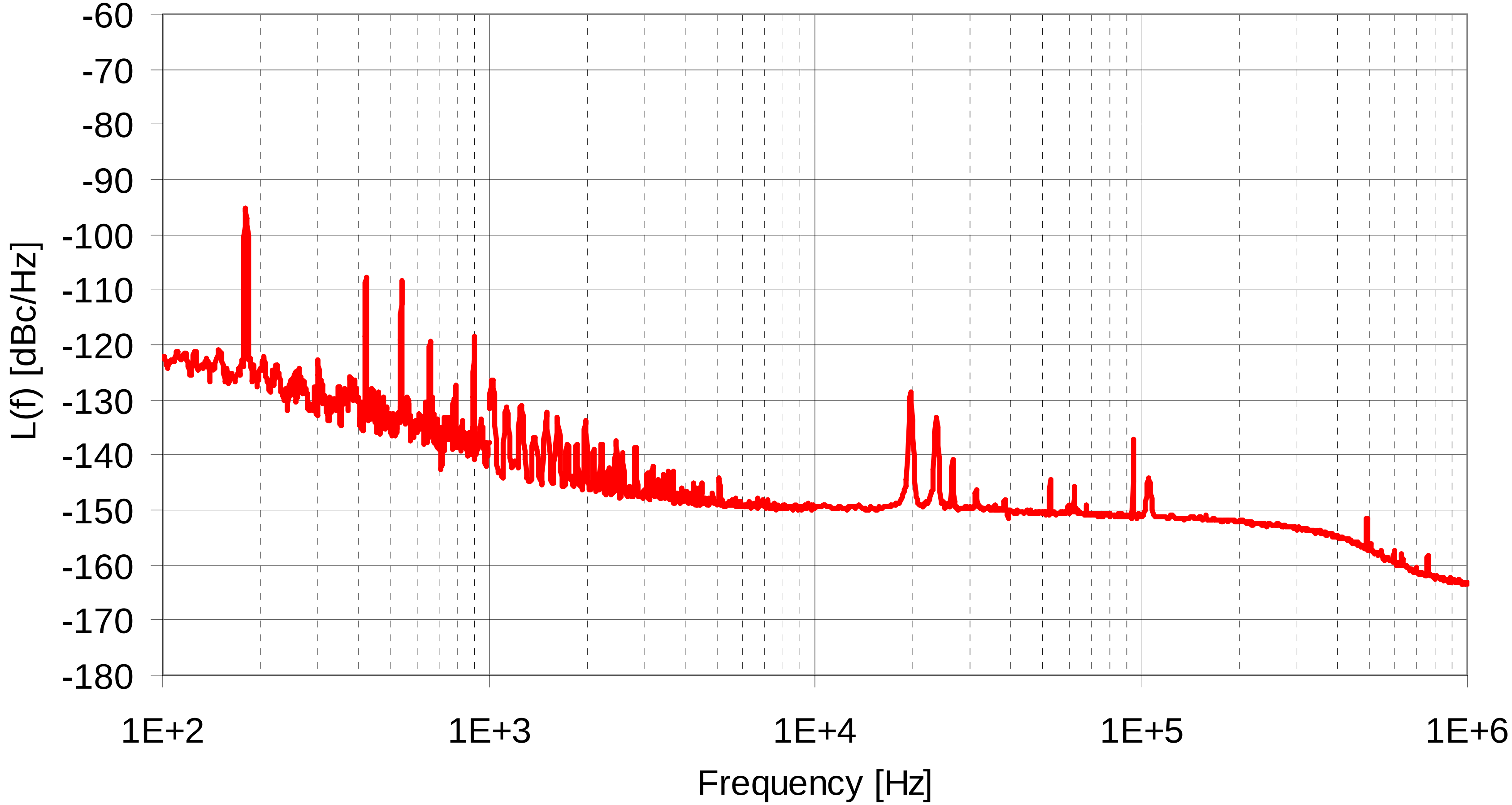
PM noise of InP Amplifier at 94 GHz, Pin=-2.5 dBm (08/17/2005)



Cross-correlation AM Noise Measurement



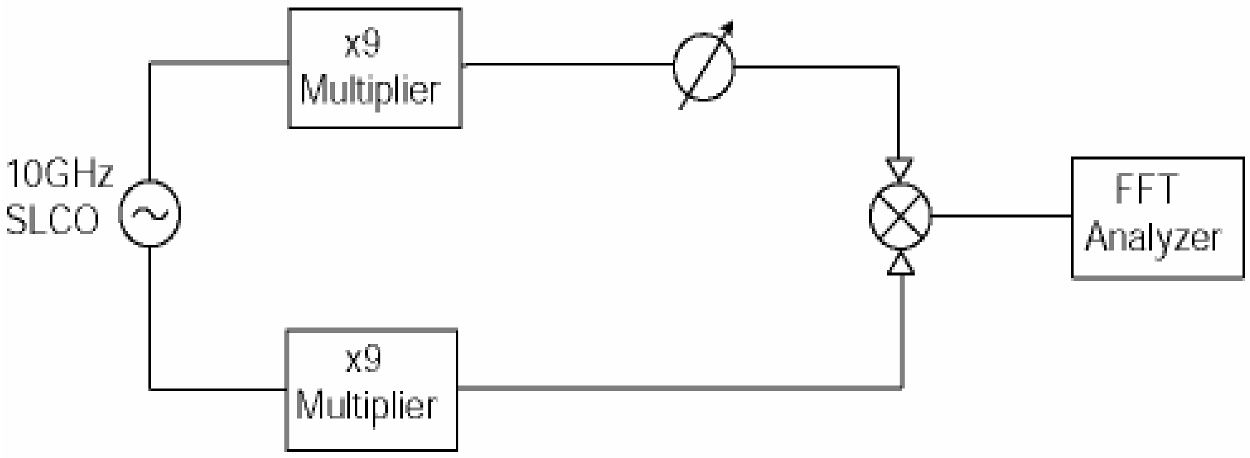
AM noise of Gunn Oscillator at 94 GHz - CW Mode 08/23/2005

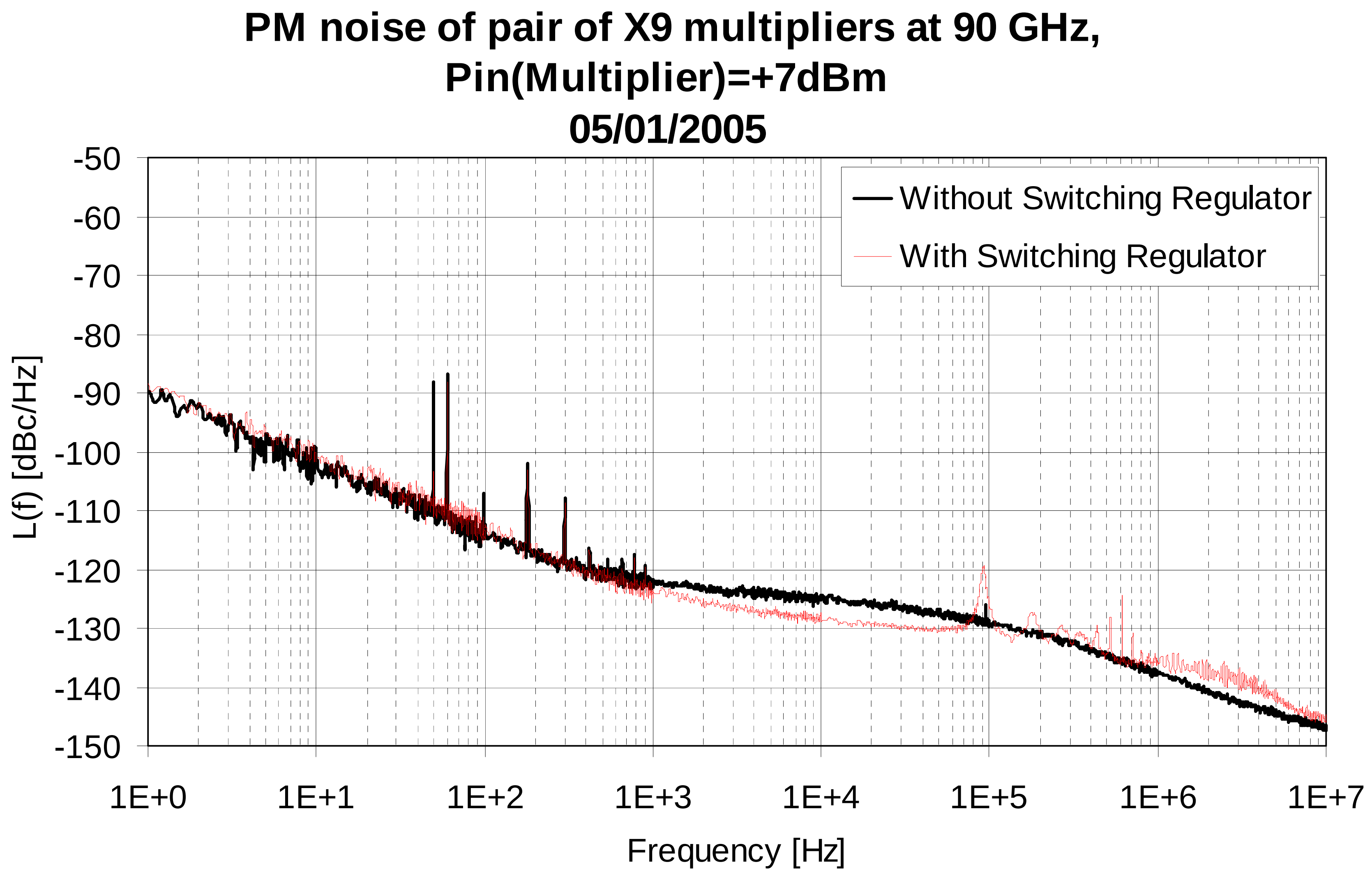


Conclusion

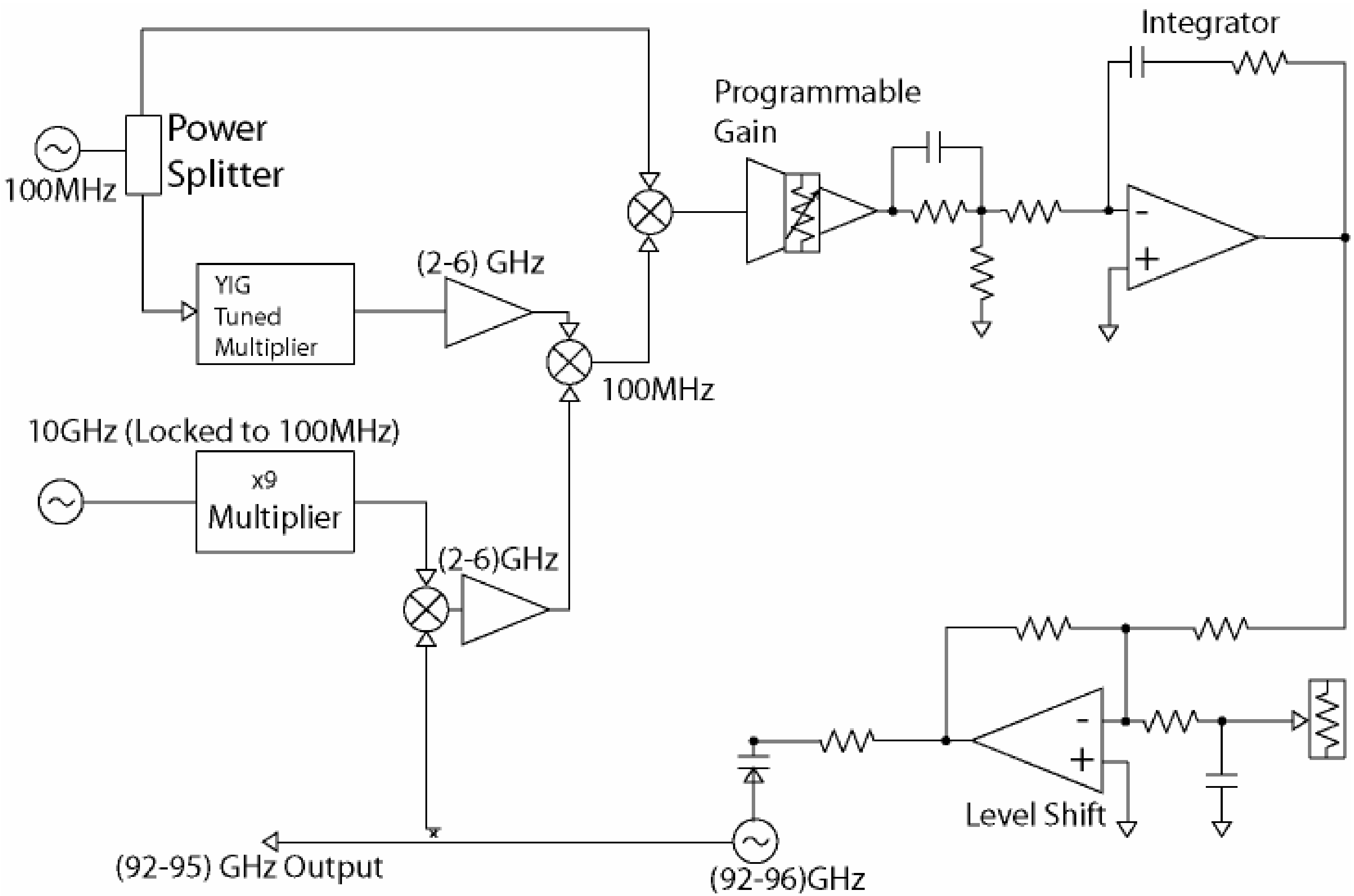
- NIST plays a key role in the development, testing, and certification of security and surveillance electronic systems extending to 100 GHz.
- NIST has significantly improved its CW and pulsed W-band oscillator, synthesizer, and amplifier phase-noise metrology.

Single Channel PM noise Measurement of Pair of W-band x9 Multiplier




PM noise of pair of X9 multipliers at 90 GHz,
Pin(Multiplier)=+7dBm
05/01/2005
L(f) [dBc/Hz]
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
1E+0
1E+1
1E+2
1E+3
1E+4
1E+5
1E+6
1E+7
Frequency [Hz]
Without Switching Regulator
With Switching Regulator

Synthesis of 92-96 GHz Low Phase Noise Reference from NIST 10 GHz Cavity Stabilized Oscillator



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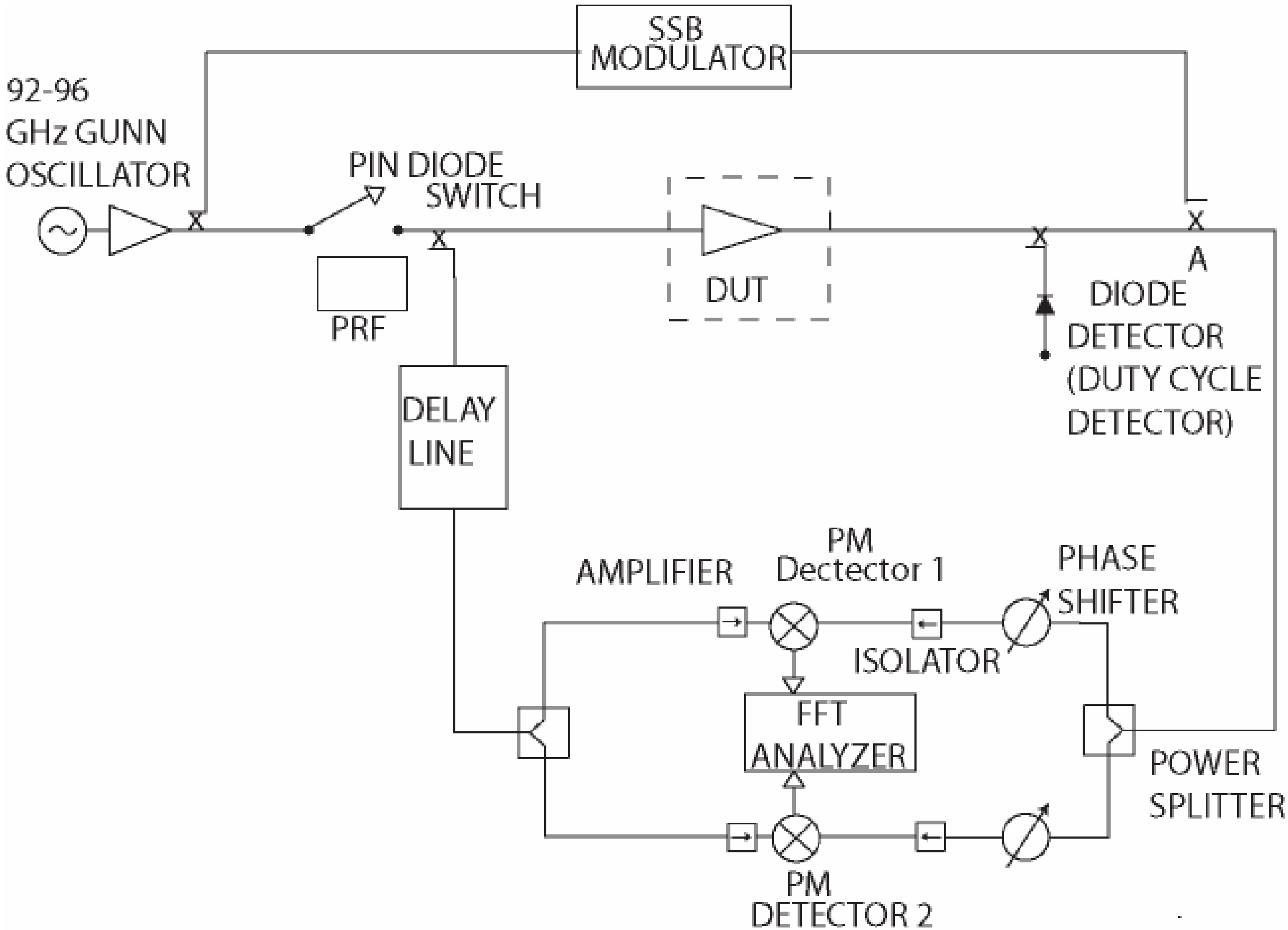
NIST W-Band Phase Noise Measurement System



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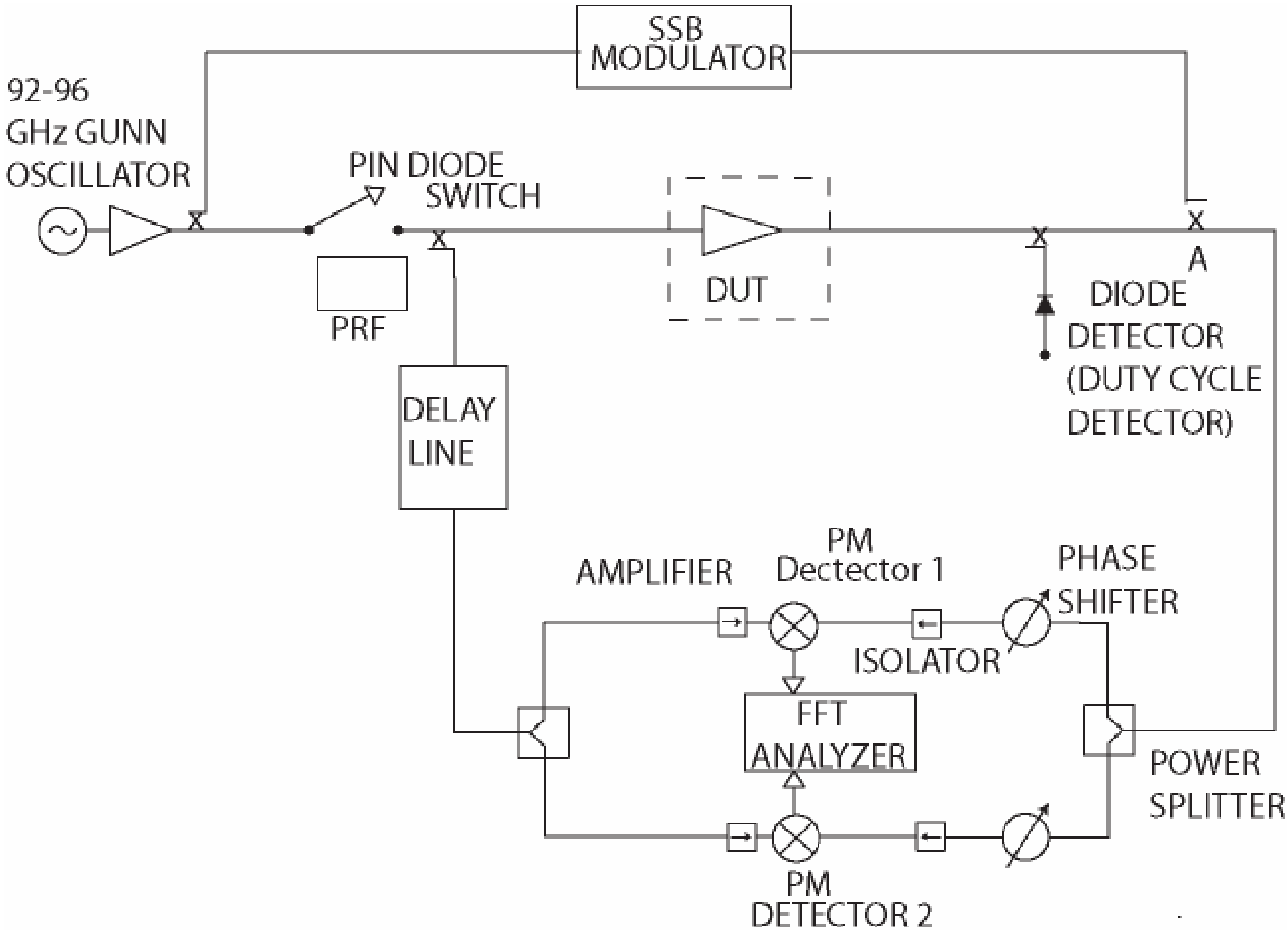
NIST W-Band Phase Noise Measurement System



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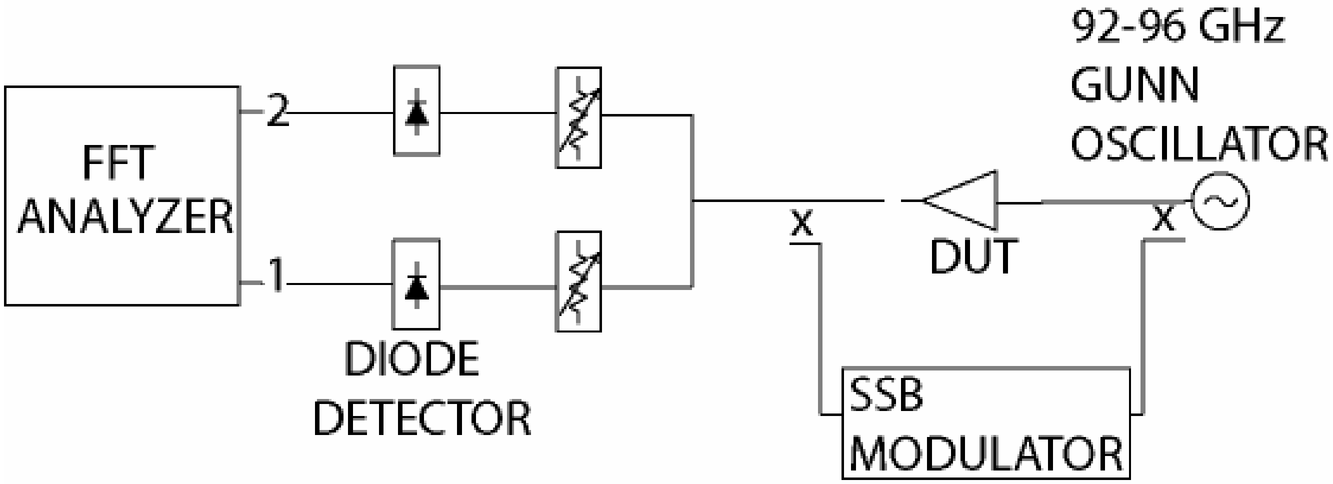
Cross-correlation AM Noise Measurement



W-band Noise Issues for High-speed Clocking

- **Measurement - Construct test sets which assure state-of-the-art phase noise measurements.**
- **Characterization - Devise suitable standard statistical tests of clock time "jitter" in the presence of other expected noises. Provide conversion algorithms from phase noise test set data.**

Physical Causes of Noise

- **Random walk FM follows a $1/f^4$ power-law behavior. The noise indicates an environmental sensitivity. In the oscillator, this noise typifies random "bumps" in the resonance frequency. There is no mechanism for the frequency to return to a mean, or previous, frequency after a random bump.**

- **Flicker FM follows a $1/f^3$ power-law behavior. This noise is common in the frequency-determining resonator or sustaining amplifier in the oscillating loop.**

- **White FM follows a $1/f^2$ power-law behavior. White FM is always characteristic of atomic frequency standards, in which a local oscillator is locked to an FM discriminator such as that provided by a Cs or Rb atomic resonance.**

- **White PM (no f-dependence) and Flicker PM (1/f) originate from late stages of amplification, frequency synthesis, frequency multiplication and division. These PM noises do not relate to an oscillator's basic resonance mechanism, such as a Qz crystal or atomic resonance.**

What is basic approach?

- Apply proven noise measurement techniques and strategies to W-band.
- Build new test sets, purchase capital equipment, engage in emerging W-band applications, research metrology needs, suggest standards.
- Extend 94 GHz gunn oscillator electronic frequency control bandwidth to several megahertz. Use high slew-rate, low-noise servo amplifiers (video) to permit noise reduction of reference synthesis to optimum theoretical noise limit.
- Purchase and install two W-band InP amplifiers to increase input sensitivity of cross-correlation measurement system.