Phase Noise
Signal Source Analyzer E5052B (+E5053A)
Single side band noise spectrum: \( L(f) \)

SSB is extracted from the frequency domain signal:

\[
L(f) = \frac{1}{2P_c} \frac{\Delta P(f)}{\Delta f} = \frac{\text{Power density of one phase modulation sideband}}{\text{Carrier Power}} \quad \text{dBc/Hz}
\]

\[
\log(L(f)) = \log(P) - \log(f - f_c)
\]

\( f_c \) is the carrier frequency, and \( f \) is the frequency of the signal.
The SSB spectrum and the phase spectral density

\[ L(f) = \frac{1}{2P_c} \frac{\Delta P(f_{\phi})}{\Delta f_{\phi}} \]

\[ = \frac{1}{\Delta f_{\phi}} \frac{1}{2} \frac{\Delta v_{\text{Noise rms}}}{v_{\text{Carrier}}} / R \]

\[ = \frac{1}{2\Delta f_{\phi}} \frac{\Delta v_{\text{Noise rms}}}{v_{\text{Carrier}}} \]

\[ = \frac{\Delta v_{\text{rms}}^2}{2\Delta f} = \frac{1}{2} S_v(f) \approx \frac{\Delta \phi_{\text{rms}}^2}{2\Delta f_{\phi}} = \frac{1}{2} S_{\phi}(f_{\phi}) \]

(if \(|\Delta \phi|\) is small enough.)

Voltage Spectral Density
\[ S_v(f) = \frac{\Delta v_{\text{rms}}^2(f)}{\Delta f} \left[ \frac{v^2}{\text{Hz}} \right] \]

Phase Spectral Density
\[ S_{\phi}(f_{\phi}) = \frac{\Delta \phi_{\text{rms}}^2(f_{\phi})}{\Delta f_{\phi}} \left[ \frac{\text{rad}^2}{\text{Hz}} \right] \]
Signal Source Analyzer E5052B (+E5053A)

ALL-IN-ONE instrument: 6 basic functions in one box.

- **PM Noise**
- **RF input**
- **VCO Test**
- **RF input**
- **V control**
- **V supply**
- **AM Noise**
- **RF input**
- **Baseband Noise**
- **BB input**

- **Spectrum Monitoring (~Δ15MHz)**
- **RF input**
- **Transient Meas.**
- **RF input**

$\sim 26.5$GHz
“Normal” PN / PLL method (Direct Homodyne)

Basic theory of operation (for a single channel of E5052B)

\[ f_{LO} = f_{RF} \]

and the phase difference between two signals is kept at 90 deg \((\pi/2\) rad) by PLL operation.
VCO Phase Noise - 800 MHz Band GSM VCO -

-166 to -167 dBC/Hz @ 20 MHz offset
Phase Noise - 1GHz Carrier
Phase Noise - 2.5Ghz Carrier
Phase Noise - 1.75Ghz Carrier

Integrated Noise and Jitter Conversion

Band marker function is available for setting trace integration range (start/stop offset frequencies)

- Integ Noise: dBC/Hz
- RMS Noise: Rad, Deg
- RMS Jitter: sec
SSA Block Diagrams and Signal Paths

The Signal Source Analyzer’s advanced architecture brings phase noise measurement to a new level.
Correlation technique for noise floor reduction

Two-channel Cross-Correlation Technique

\[ N_{\text{meas}} = N_{S.U.T.} + \left( N_1 + N_2 \right) / \sqrt{M} \]

Assuming \( N_1 \) and \( N_2 \) are uncorrelated.

<table>
<thead>
<tr>
<th>( M ) (number of correlation)</th>
<th>10</th>
<th>100</th>
<th>1,000</th>
<th>10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise reduction on ( (N_1+N_2) )</td>
<td>-5dB</td>
<td>-10dB</td>
<td>-15dB</td>
<td>-20dB</td>
</tr>
</tbody>
</table>
E5052B SSB-PN Sensitivity Improvement by Correlation @1 GHz

SSB phase noise [dBc/Hz]


1 10 100 1k 10k 100k 1M 10M 100M

corr. = 1
corr. = 10
corr. = 100
- 184 dBc/Hz @ 10 MHz, 70 MHz Carrier

Effect of cross-correlation example
Signal Generators @ 640MHz
Crystal Oscillator @10MHz

Without Cross-Correlation

With Cross-Correlation
Signal Generators @ 232MHz
“Wide” PN / Heterodyne (digital) discriminator method

Basic theory of operation (for a single channel of the E5052B)
AM noise measurement

Basic theory of operation (for a single channel of the E5052B)

![Diagram of AM noise measurement process]

Note that a main signal still exists at this point!
“Normal” PN / PLL method (E5053A + E5052B)

Basic theory of operation (for a single channel of E5053A + E5052B)

A very stable L.O.

(frequency down converter)

(E5053A)

(E5052B)

The phase difference between two signals is kept at 90 deg (π/2 rad) due to PLL operation.
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E5053A Microwave down-converter

LO out
IF in
IF out
LO in
RF
IF amp.

(3 to 10 GHz)

Fundamental or 3rd harmonic mixing

3 GHz to 26.5 GHz Input

E5052B Signal Source Analyzer

(10 MHz to 7 GHz)

D-PLL
ADC
FFT
DSP (Correlation)
Display

RF in
RF out

10 MHz to 3 GHz Input

CH 1

RF in
RF out

CH 2

ADC
D-PLL
FFT

October 20, 2011
Radar Seminar
E5052B + E5053A System SSB-PN Sensitivity (SPD)

SSB phase noise [dBc/Hz]

Offset frequency [Hz]


1   10   100  1k  10k  100k  1M  10M  100M

-  3 GHz
-  10 GHz
-  18 GHz
-  26.5 GHz
mmWave Unstable Source Measurement Setup

- **11970 Harmonic Mixer**
- **mmWave Source**
- **E5053A Microwave Downconverter**
  - LO: 3 to 10 GHz, 50 MHz step +16 dBm
- **Bias1**
- **Bias2**
- **IF Gain 0 to 36 dB**

**Agilent Technologies**

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*33A Microwave Expansion*

*September 2009*

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*E5063A IF Freq: 250 M to 1250 MHz*

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*8447D IF AMP*

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*Freq. Divider*

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*To E5062A*

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*To E5062A*
Baseband noise measurement

Basic theory of operation

Min. frequency: 1Hz / 1kHz
Max. frequency: 100MHz

DC cut off filter (Low/High) capacitors (1410uF/10uF)
50 Ohm Input Impedance

Baseband input port (BNC)

Caution!

“Discharge DC Block Capacitor”
when reconnecting to low-voltage devices.

LPF → ADC

250MHz sampling

IF Gain

DSP (FFT)
VCO Freq, Power, DC Current Tester Mode Measurement Results - 800 MHz Band GSM VCO -
PLL Synthesizer Measurement Result
- 1.75 GHz Synthesizer -