BHW Technologies (博泓微科技有限公司)

Advanced RF IC, Antenna, Filter, RF Front-End and Wireless System Solutions

BHW Application Note #016

Improving GNSS NF Measurement Accuracy Using Broadband LNA BHWL161 as Pre-Amp

Rev. 1.5

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Background: Ultra-Low LNA for Next-Gen GNSS

Technical Challenges:

- LNA with Ultra-Low Noise Figure (NF) is Critical to Achieve High C/N0 for GNSS Receivers, Especially for Emerging Multi-Band Multi-Constellation GNSS Systems
- Many LNA Vendors Have Published NF Specs in Second-Digit Accuracy such as 0.55dB, 0.53dB and 0.37dB
- A Survey of State-of-the-Art RF Test Equipment Vendors Indicates that Current NF Measurement Systems Are Difficult to Guarantee Second-Digit Accuracy in NF Test Results

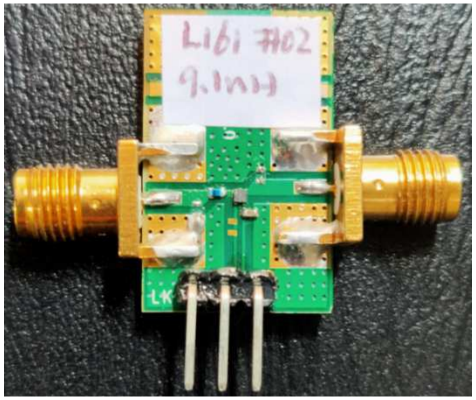
Proposed Solutions:

- A Detailed Investigation and Analysis of Measurement Uncertainties in GNSS LNA Noise Figure Has Been Conducted
- A Broadband LNA Based on Advanced GaAs ED-PHEMT Technology, BHWL161, Has Been Used to Show Significant Improvement in Calibration Accuracy and Stability
- Case Study of Third-Party LNA Product Indicates Potential for ~0.05dB Accuracy in NF Measurement
- The Proposed Test Approach Enables Accurate, High-Confidence Measurement of NF without Having to Use the Most-Expensive Test Equipment

In this AppNote we compared 3 different methods of measuring the NF of a GNSS LNA, showing their limitations and advantages, and finally suggested a cost-effect approach to measure sub-0.5dB ultra low NF products with high accuracy.

Method A: Basic Y-Factor Test with Manual Correction

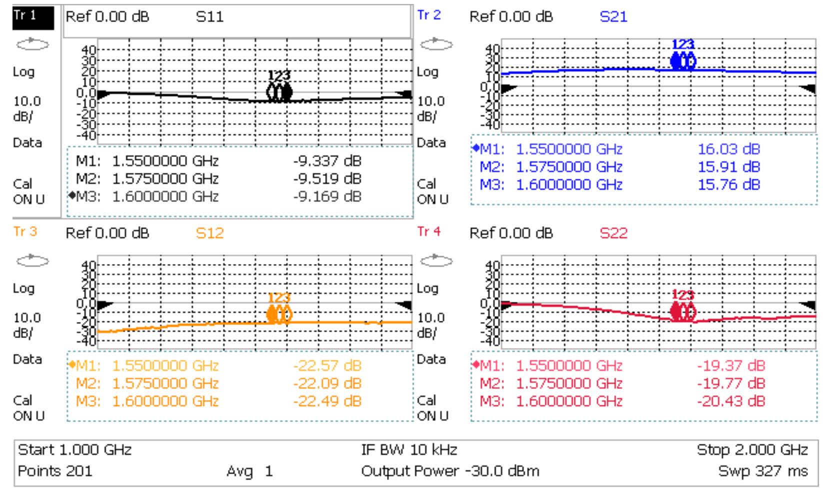
DUT: BHWL161 EVB #02, 3.3V/6.7mA



HP 8970A Uncorrected NF=8.90dB at 1575MHz

DUT Uncorrected NF=1.13dB at 1575MHz

Measured S-Parameters with VNA



De-Embedded NF of DUT:
F_DUT = F_Total – (F_NFA – 1) / G_DUT
NF_DUT = 10*Log10(F_DUT)

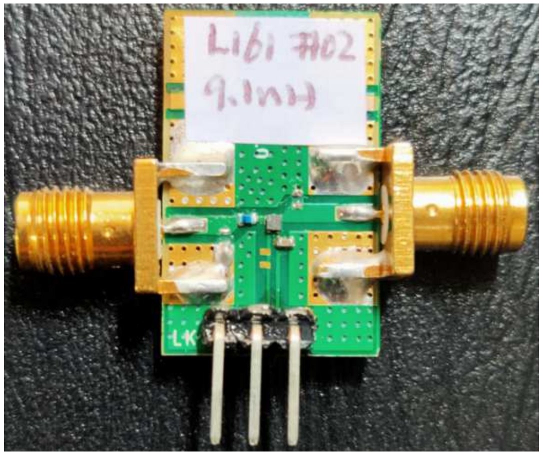
Frequency (MHz)	1550	1575	1600
NF_NFA (dB)	8.70	8.90	9.25
F_NFA	7.413	7.762	8.414
Gain_DUT (dB)	16.03	15.91	15.76
G_DUT	40.087	38.994	37.670
NF_Total (dB)	1.08	1.13	1.19
F_total	1.282	1.297	1.315
F_DUT	1.122	1.124	1.118
NF_DUT (dB)	**0.50**	**0.51**	**0.49**

Comments:

- **This method goes back to the most fundamental NF measurement based on the Y-Factor method, without using any calibration.**
- **Advantage: LNA gain can be measured very accurately with a network analyzer.**
- **Limitation: Relatively high noise contribution of the test equipment, especially for those without built-in Pre-Amp.**
- **Key sources of uncertainty: ENR Table and Power Measurement.**
- **Will compare these test results with calibrated tests later.**

Method B: Calibrated Test without Pre-Amplifier

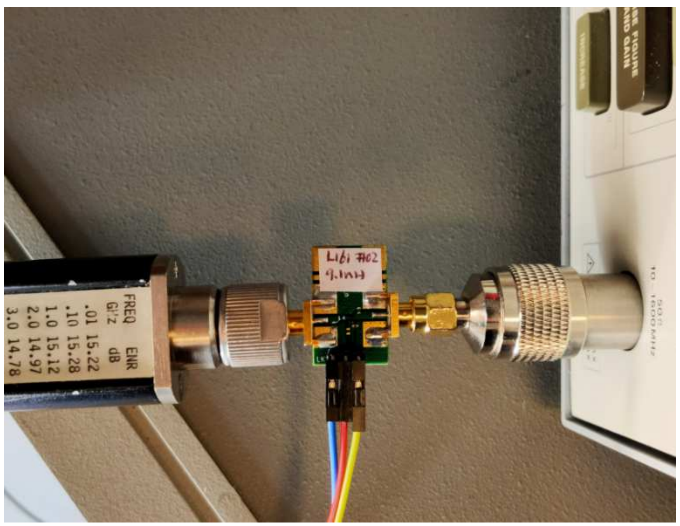
DUT: BHWL161 EVB #02, 3.3V/6.7mA



Gain & NF of Calibration at 1575MHz

DUT Gain & NF Measured at 1575MHz

DUT Test after Calibration without Pre-Amp



Comparison of Method A & B

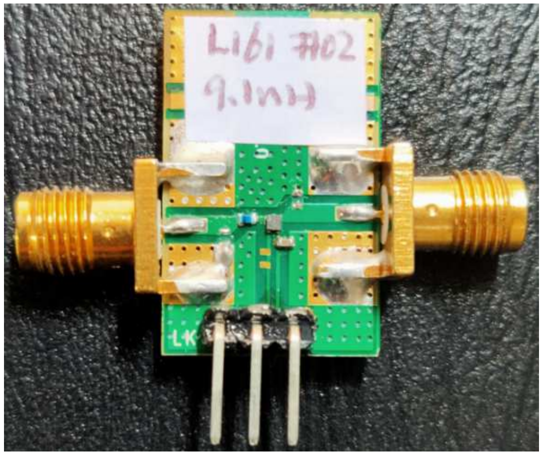
Frequency (MHz)	1550	1575	1600
Method A, Manual Correction, No Calibration	0.50	0.51	0.49
Method B, Calibrated Test, No Pre-Amp	0.53	0.56	0.54

Comments:

- Although the calibration process can eliminate the noise contribution of the test equipment in principle, there is still a relatively high level of uncertainty(up to ~0.1dB), causing potential errors in NF of the DUT.
- As shown on page 4, even some of the more sophisticated NF equipment have calibration uncertainties of this level, or even higher.

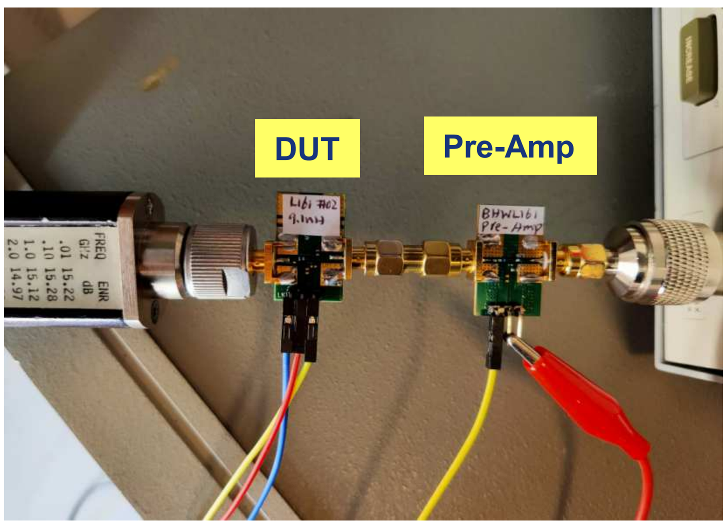
Method C: Calibrated Test with BHWL161 as Pre-Amp

DUT: BHWL161 EVB #02, 3.3V/6.7mA



Gain & NF of Calibration at 1575MHz

DUT Test after Calibration with Pre-Amp



DUT Gain & NF at 1575MHz

Comparison of All Three Methods

Frequency (MHz)	1550	1575	1600
Method A, Manual Correction, No Calibration	0.50	0.51	0.49
Method B, Calibrated Test, No Pre-Amp	0.53	0.56	0.54
Method C, Callibrated Test, With Pre-Amp	0.52	0.52	0.49

Comments:

- **A much stable and low-level uncertainty in Gain/NF is achieved using BHWL161 as Pre-Amp for calibration, typically below 0.03dB.**
- **This calibration accuracy is even better than some of the more expensive NF equipment as shown on page 4.**

Case Study: NXP BGU8109 NF Test with Method C

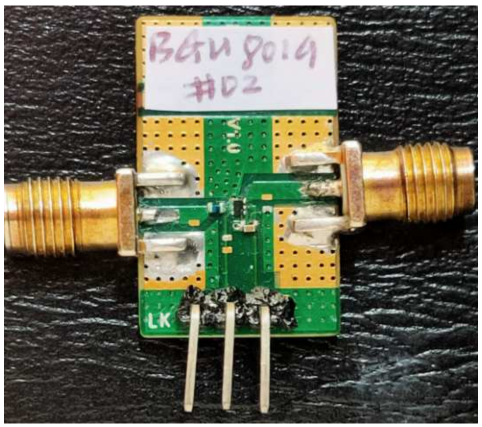
NXP Semiconductors **BGU8019**

SiGe:C Low Noise Amplifier MMIC for GPS, GLONASS, Galileo, and Compass

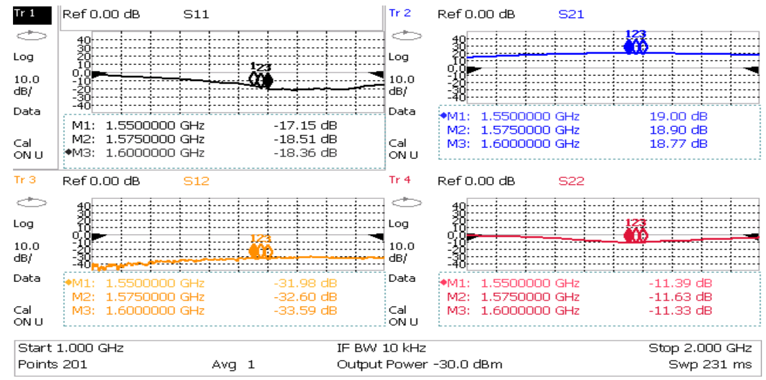
Table 9. Characteristics at V_{CC} = 2.85 V

f = 1575 MHz; V_{CC} = 2.85 V; $V_{I(ENABLE)} \geq 0.8$ V; $P_i < -40$ dBm; T_{amb} = 25 °C; input matched to 50 Ω using a 6.8 nH inductor, see Figure 1; unless otherwise specified.

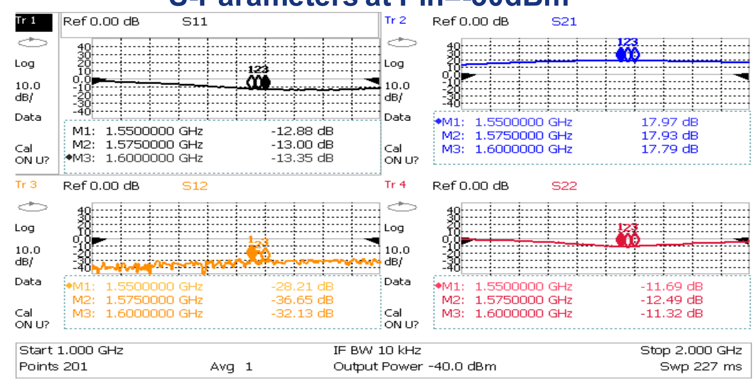
Symbol	Parameter	Conditions		Min	Typ	Max	Unit
I_{CC}	supply current	$V_{I(ENABLE)} \geq 0.8$ V					
		$P_i < -40$ dBm		-	4.6	-	mA
		$P_i = -20$ dBm		-	10	-	mA
		$V_{I(ENABLE)} \leq 0.3$ V		-	-	1	μA
G_p	power gain	no jammer		-	18.5	-	dB
		$P_{jam} = -20$ dBm; f_{jam} = 850 MHz		-	20.0	-	dB
		$P_{jam} = -20$ dBm; f_{jam} = 1850 MHz		-	20.5	-	dB
RL_{in}	input return loss	$P_i < -40$ dBm		-	13	-	dB
		$P_i = -20$ dBm		-	22	-	dB
RL_{out}	output return loss	$P_i < -40$ dBm		-	13	-	dB
		$P_i = -20$ dBm		-	12	-	dB
ISL	isolation			-	30	-	dB
NF	noise figure	$P_i = -40$ dBm, no jammer	[1]	-	0.55	-	dB
		$P_i = -40$ dBm, no jammer	[2]	-	0.60	-	dB
		$P_{jam} = -20$ dBm; f_{jam} = 850 MHz	[2]	-	0.9	-	dB
		$P_{jam} = -20$ dBm; f_{jam} = 1850 MHz	[2]	-	1.3	-	dB
$P_{i(1dB)}$	input power at 1 dB gain compression			-	-7	-	dBm



S-Parameters at Pin=-40dBm



S-Parameters at Pin=-30dBm



- DC Bias: Vdd=Ven=2.85V, Idq~5.3mA, Ta~25 Deg C.
- Assuming 0.05dB EVB loss, the measured NF is consistent with BGU8019 datasheet spec.
- The test result indicates ~0.05dB measurement uncertainty by using a BHWL161 broadband LNA as Pre-Amp.

Concluding Remarks

- Due to the random nature of noise, accurate measurement of noise figure, especially for ultra-low NF LNAs for GNSS has been a challenge to the RF community.
- Even built-in pre-amplifiers inside some high-end NF test equipment are often insufficient to provide the tight accuracy requirement for Best-Class GNSS LNAs with around half-dB NF, or even lower.
- This investigation indicates that by using a low-NF, broadband and stable LNA as external Pre-Amp, such as BHWL161, it is possible to reduce test uncertainty to ~0.05dB or lower, enabling NF measurement with better accuracy and high confidence.

BHW RF Front-End AppNote Library

This is an abridged version of BHW AppNote #016. Please contact BHW Support or your local sales rep/distributor for a complete copy of the document and other related information.

BHW RF Front-End Solutions AppNote Library

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- BHW AppNote #001 - Cross-Over Cascade of BHWM253 to Boost Tx Power and Rx Sensitivity of 2.4GHz Systems
- BHW AppNote #002 - Accurate Benchmark of GNSS CN0 Using the Power-Splitter Method
- BHW AppNote #003 - Boosting Wi-Fi Tx Power and Rx Sensitivity with BHWA251 and BHWM252
- BHW AppNote #004 - UHF 900MHz RF Front-End Solution Using BHWA251 Half-Watt PA and BHWL160 Sub-1dB-NF LNA
- BHW AppNote #005 - Sub-1GHz Applications of BHWA350 2-in-1 Wideband Fully Matched Amplifier
- BHW AppNote #006 - Low-Noise High-IIP3 LNB Architecture for Dual-Band High-Precision GNSS Using Cascade of BHWL160
- BHW AppNote #007 - UWB RF Front-End Solution Using BHWA350 and BHWM552
- BHW AppNote #008 - High-Power 5.8GHz RF Front-End Solution Using BHWA555 and BHWM552 for ETC, V2X and Wireless Video
- BHW AppNote #009 - 5.8GHz RF Front-End Using BHWA350 and BHWM552 for Wireless Audio
- BHW AppNote #010 - Multi-Constellation GNSS Active Antenna Using BHWL161 Cascade and Single-Fed Dual-Band Antenna
- BHW AppNote #011 - BHWL161 Super-Compact Low-Power Low Noise Amplifier for Range Extension of 2.4GHz RC and IoT
- BHW AppNote #012 - Enabling Cost-Effective High-Precision GNSS Using BHWL161 and Linear-Polarization PCB Antenna
- BHW AppNote #013 - GNSS Noise Floor vs Receiver Architecture
- BHW AppNote #014 - Designing Ultra Low-Power High-Performance GNSS Products Using BHWL160 GaAs PHEMT LNA
- BHW AppNote #015 - BHWL161 GNSS Full-Band High-Performance LNA in Super-Compact 1x1mm DFN with Relaxed Pin Pitch
- BHW AppNote #016 - Improving GNSS NF Measurement Accuracy Using Broadband LNA BHWL161 as Pre-Amp
- BHW AppNote #017 - High-Efficiency, Low-NF 2.4GHz Front-End Solution for IoT Using BHWA251 and BHWM252
- BHW AppNote #018 - Optimizing BHWA555 Wideband One-Watt PA for Long-Range 5.8GHz Transmitter Applications
- BHW AppNote #019 - Miniature 2.4GHz RF Front-End with Integrated Chip Antenna and BHWM253 for TWS and IoT
- BHW AppNote #020 - Multiplying the Range for 2.4GHz Music Streaming with BHWR250L Active Integrated Antenna (AiA)
- BHW AppNote #021 - Range Extension for 2.4GHz Wireless Systems with BHWR250M Active Integrated Antenna (AiA)
- BHW AppNote #022 - Enabling Long-Range Angle-of-Arrival for High-Precision Indoor Positioning with BHWR250N RF AiA
- BHW AppNote #023 - Extend the Range for 5.8GHz Audio/Video Streaming with BHWR580M Active Integrated Antenna (AiA)
- BHW AppNote #024 - Improving 5.8GHz Radio Link Budget with BHWR580L Active Integrated Antenna (AiA)
- BHW AppNote #025 - Improving Range and Throughput of 2.4GHz Wi-Fi with BHWR250 Array Antenna
- BHW AppNote #026 - Improving Range and Throughput of 5GHz Wi-Fi with BHWR550 Array Antenna
- BHW AppNote #027 - Multi-Band High-Accuracy GNSS Solutions Using BHWP150 DFN1x1 Ultra-Compact Power Divider & Combiner
- BHW AppNote #028 - Use BHWM252 Cascade to Extend Range of 2.4GHz Wireless Systems with Single-Port SoCs
- BHW AppNote #029 - Improving Range of 2.4GHz Wireless Microphones and Audio Systems with BHWR250A Active Integrated Antenna (AiA)
- BHW AppNote #030 - Simultaneous Improvement in Range and Battery Life of 2.4GHz Wireless Systems with BHWR250M AiA

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