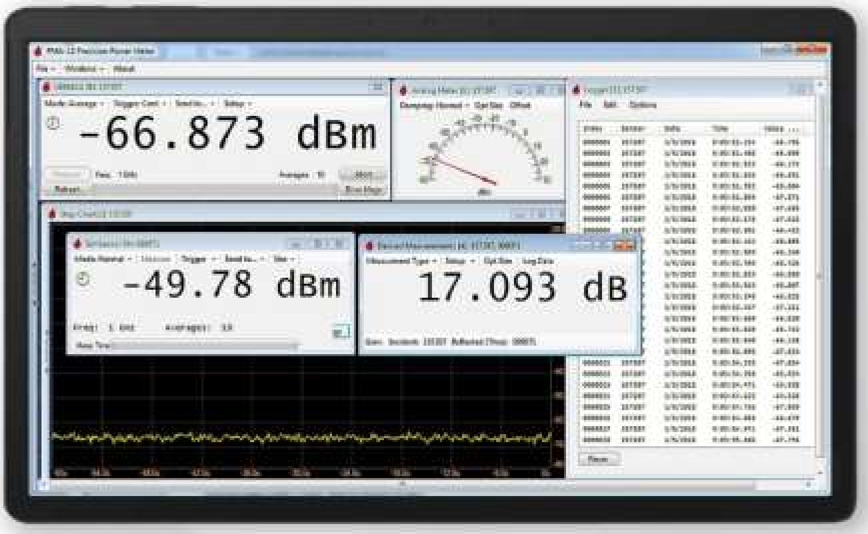
LadyBug Technologies

Small Form Factor Power Sensors
LBSFXXX True-RMS Series
Technical Data Sheet
LBSF09A
LBSF09L



Contents

PowerSensor+^{TM} Highlights

- Frequency Range:
  - LBSF09A: 1 MHz to 9 GHz
  - LBSF09L: 4 kHz to 9 GHz
- Dynamic Range: -60 dBm to +23 dBm
- < 1.1:1 Typical VSWR
- RMS Responding & modulation independent
- Interfaces: USBTMC, USBHID - Optional LAN, TTL (SPI or I2C)
- Industry compatible IEEE 488.2 SCPI Command Set
- Thermally Stable - no drift
- No User Zero required before use
- Compatible with Windows, LINUX & More

Specification Terms & Conditions

LBSF09A & LBSF09L Specifications

Frequency Range	LBSF09A	1MHz to 9GHz
	LBSF09L	4kHz[1] to 9GHz
Power measurement range	Calibrated measurement range	-60 dBm to +23 dBm 1nW to 200mW
Maximum power (Damage level)	Average power	+26dBm / 400mW
	Pulsed power for 5-us	+30dBm / 1 W
	DC voltage	10 VDC
Impedance		50 Ohms
RF Connector	LBSF09X-ONM	Type-N Male
	LBSF09X (Standard connector)	SMA Male
	LBSF09X-OSF	SMA Female
	LBSF09X-ONF	Type-N Female
Match (VSWR) (SMA Male)	4 kHz to < 9 kHz	< 1.5
	9 kHz to < 15 kHz	< 1.45
	15 kHz to < 40 kHz	< 1.25
	40 kHz to < 2 GHz	< 1.13
	2 GHz to 9 GHz	< 1.18
Measurement types	Continuous	Average
	Externally Triggered[2]	Average
		Burst Average
Dynamic response	Video rise time (10% to 90%)	< 7ms
Zero offset[3]	[(0.5nW @ 25ºC) + |ΔT| x(0.0375nW/ºC)] ± 0.005nW /month	
Noise[4]	-40 dBm to +23 dBm	0.35%
	-60 dBm to -40 dBm	0.5nW
Maximum Power Level[5]	CW average power [damage level]	+23dBm (400 mW)[+26 dBm]

[1] LBSF09X lower measurement frequency 4kHz. LBSFxxA models have a min frequency of 1MHz, LBBSFxxL models have a min frequency of 9KHz, When Option 4KZ added to a LBSFxxL the minimum frequency is lowered to 4Khz.

[2] A module is available providing access to Trigger in, Trigger out, Analog Recorder Out, and the SPI / I2Cc connections.

[3] Use the following formula to determine Zero Offset uncertainty (%): Z = ((Zero Offset Power / Measured Power)*100).

[4] Noise is based on 2 times the standard deviation of 100 measurement points. When Measurement rate (MRAT) is set to Normal, there are 16 samples per average. Noise is determined by multiplying the value by 4/sqrt(Normal measurement rate averages) Example (Specification): For 1024 Averages noise is less than 0.5nW*(4/sqrt(1024)) = 0.063nW. When MRAT is set to Normal, the number of averages is greater than 16, and the power level is above -40dBm, noise error is insignificant.

[5] Pulse repetition must respect average power over anyone pulse duty cycle, regardless of varying duty cycle.

	Peak and Pulse power [damage level]	+30dBm (1 W) [+30 dBm]
	Max energy per pulse [damage level]	10 W-us [+27 W-us]
Max DC input voltage	20 VDC (rf input)	
Interface	Connector	USB-C, USB-C secure connection
	USB Device Class	USB HID
		USBTMC
	USB Operating Mode	USB 2.0
	Option: SPI[2] (SPI or I2C)	Uses USB-C connector pins
	Triggering[2]	Uses USB-C connector pins
	Option: 01[1] Recorder Out	Uses USB-C connector pins
	Option: LAN	Factory added connectivity module
Supply power Input	USB, SPI, I2C	4.65 VDC to 5.35 VDC
		Current: TBA
Programmatic control	Standard SCPI commands	Specification: IEEE 488.2
Trigger Input	Trigger in high (1) voltage	2.0 V (nom)
	Trigger in low (0) voltage	0.8 V (nom)
	Allowable input voltage	-0.5 VDC to +5.5 VDC
	SPI / I2C	
Recommended Calibration Cycle	1 Year	

Calibration Specification

This data sheet utilizes industry standard RF power measurement terminology.
Calibration is done in accordance with ISO17025

Valid Data

Data is valid data under the following conditions.

- The device is within the valid calibration period
- The device is operating within Environmental operating Parameters
- The device required initial stabilization time has been satisfied

Absolute Power Measurement Uncertainty[6,7,8]

4kHz to 9kHz				
	-60dBm to -20dBm	-20dBm to -10dBm	-10dBm to +10dBm	+10dBm to +20dBm
0°C to 10°C	0.158 dB	0.151 dB	0.153 dB	0.153 dB
10°C to 20°C	0.114 dB	0.107 dB	0.109 dB	0.109 dB
20°C to 30°C	0.114 dB	0.107 dB	0.109 dB	0.109 dB
30°C to 40°C	0.114 dB	0.107 dB	0.109 dB	0.109 dB
40°C to 50°C	0.158 dB	0.151 dB	0.153 dB	0.153 dB

9kHz to 60kHz				
	-60dBm to -20dBm	-20dBm to -10dBm	-10dBm to +10dBm	+10dBm to +20dBm
0°C to 10°C	0.153 dB	0.147 dB	0.149 dB	0.149 dB
10°C to 20°C	0.109 dB	0.103 dB	0.105 dB	0.105 dB
20°C to 30°C	0.109 dB	0.103 dB	0.105 dB	0.105 dB
30°C to 40°C	0.109 dB	0.103 dB	0.105 dB	0.105 dB
40°C to 50°C	0.153 dB	0.147 dB	0.149 dB	0.149 dB

60kHz to 2GHz				
	-60dBm to -20dBm	-20dBm to -10dBm	-10dBm to +10dBm	+10dBm to +20dBm
0°C to 10°C	0.185 dB	0.179 dB	0.181 dB	0.181 dB
10°C to 20°C	0.141 dB	0.135 dB	0.137 dB	0.137 dB
20°C to 30°C	0.141 dB	0.135 dB	0.137 dB	0.137 dB
30°C to 40°C	0.141 dB	0.135 dB	0.137 dB	0.137 dB
40°C to 50°C	0.185 dB	0.179 dB	0.181 dB	0.181 dB

2GHz to 9GHz				
	-60dBm to -20dBm	-20dBm to -10dBm	-10dBm to +10dBm	+10dBm to +20dBm
0°C to 10°C	0.239 dB	0.233 dB	0.235 dB	0.235 dB
10°C to 20°C	0.195 dB	0.189 dB	0.191 dB	0.191 dB
20°C to 30°C	0.195 dB	0.189 dB	0.191 dB	0.191 dB
30°C to 40°C	0.195 dB	0.189 dB	0.191 dB	0.191 dB
40°C to 50°C	0.239 dB	0.233 dB	0.235 dB	0.235 dB

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[6] The expanded (K=2) absolute power measurement uncertainty for includes calibration uncertainty, linearity, and temperature. For signals below -40dBm, the effects of noise and zero offset uncertainty should also be considered in the uncertainty, as shown below.
Example: An applied CW signal of -52dBm at 6.1 GHz, with the sensor at 21°C room temperature is applied. From the uncertainty table, the absolute uncertainty is 0.166dB. Referring to the noise specification if 0.5nW and using averaging of 1,024 with MRAT set to Normal.
[7] Uncertainties presented in dB using positive side errors
[8] Uncertainties listed are for standard connector

PMA-12 Precision Power Meter Software

PMA-12 Power Meter features

- For use with LBSF (Small Form Factor) and LB5900 Series Sensors.
- All sensor features are included with no software registration requirement or fees.
- The software can be used on as many computers as required without additional charge.
- Two sensor calculation window with calculations for Gain, Loss VSWR, Reflection Coefficient, Mismatch Loss, Return Loss.
- The multithreaded USB interface increases performance when using multiple sensors.
- Triggering controls - per sensor capabilities.
- Tabular logging with file storage and retrieval
- Strip Chart including scaling, pause, store, recall etc.
- Attractive Analog Meter with damping control and sizing
- Controls for the sensors Option 001 (Analog Recorder Out)
- Controls the sensors simple offset and frequency dependent offset tables
- Default and User Presets
- For detailed application overview please see PMA-12 application manual

Measurement Uncertainty

Accuracy, Level and Linearity

Accuracy (Total RSS Unc = $\sqrt{(Mm^2+CF^2+L^2+N^2+T^2+Z^2)}$
Mm (Mismatch); CF (Cal Factor); N (Noise); L (Linearity); T (Temperature); Z (Zero Offset). All uncertainty terms are converted to percentages for RSS calculation. 2 Use the following formula to determine Zero Offset uncertainty (%): Z = (Zero Offset Power / Measured Power)*100. 3 Linearity and Zero Offset are measured as a combined specification as LadyBug sensors require no meter zeroing or reference calibration before use. Please refer to *Initial Stabilization Time* section for additional details.

Parameter	**Specification**	**Typical**
Calibration Factor Unc (SMA male)	K=2 (K is coverage factor)	K=1
9 kHz to 40 kHz	2.88%	1.44%
40 kHz to 2 GHz	2.23%	1.12%
2 GHz to 9 GHz	2.45%	1.23%
Absolute Linearity Unc		
+10 dBm to +20 dBm	2.5%	1.25%
-10 dBm to +10 dBm	2.5%	1.25%
-20 dBm to -10 dBm	2.5%	1.5%
-60 dBm to -20 dBm	3.5%	1.75%
Noise @ Power Range[1,2]		
-40 dBm to +26 dBm[3]	0.35%	0.025% to 0.15%[4]
-60 dBm to -40 dBm	0.5nW[5]	0.2nW[6]

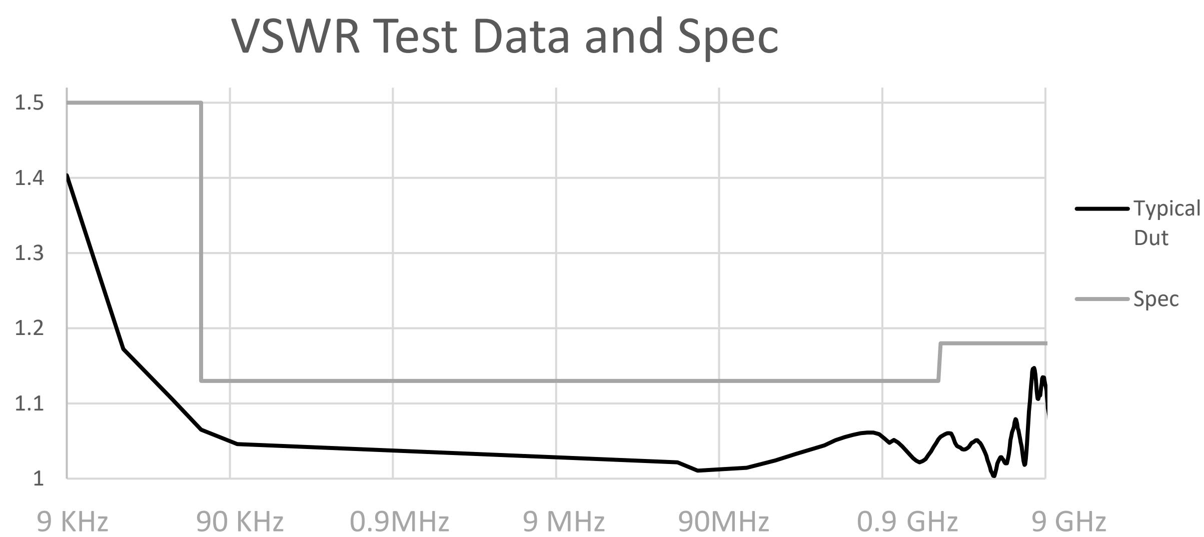
Noise notes:
1. Noise is two times the standard deviation of 100 measurement points
2. Number of Averages for each measurement rate
   Normal 16; Double 32; Super 384
3. For Normal measurement rate, when averages above 16 and power is above -40 dBm noise error is insignificant
4. Varies with power level
5. Noise is determined by multiplying the value by 4/sqrt(Normal measurement rate averages)
   Example 1(Specification): For 1024 Averages noise is less than 0.5nW*(4/sqrt(1024)) = 0.063nW
   Example 2(Specification): For 128 Averages noise is less than 0.5nW*(4/sqrt(128)) = 0.18nW
6. Noise is determined by multiplying the value by 4/sqrt(Normal measurement rate averages)
   Example 1(Typical): For 1024 Averages noise is less than 0.2nW*(4/sqrt(1024)) = 0.025nW
   Example 2(Typical): For 128 Averages noise is less than 0.2nW*(4/sqrt(128)) = 0.071nW

Parameter	**Specification**	**Typical**
Zero Offset[1,2]	{[(1.0nW @ 25ºC) + |ΔT| x(0.075nW/ºC)] ± 0.01nW /month}	{[(0.5nW @ 25ºC) + |ΔT| x(0.0375nW/ºC)] ± 0.005nW /month}

Zero Offset Notes
1. Use the following formula to determine Zero Offset uncertainty (%): Z = (Zero Offset Power / Measured Power)*100.
2. Linearity and Zero Offset are measured as a combined specification as LadyBug sensors require no meter zeroing or reference calibration before use.

VSWR

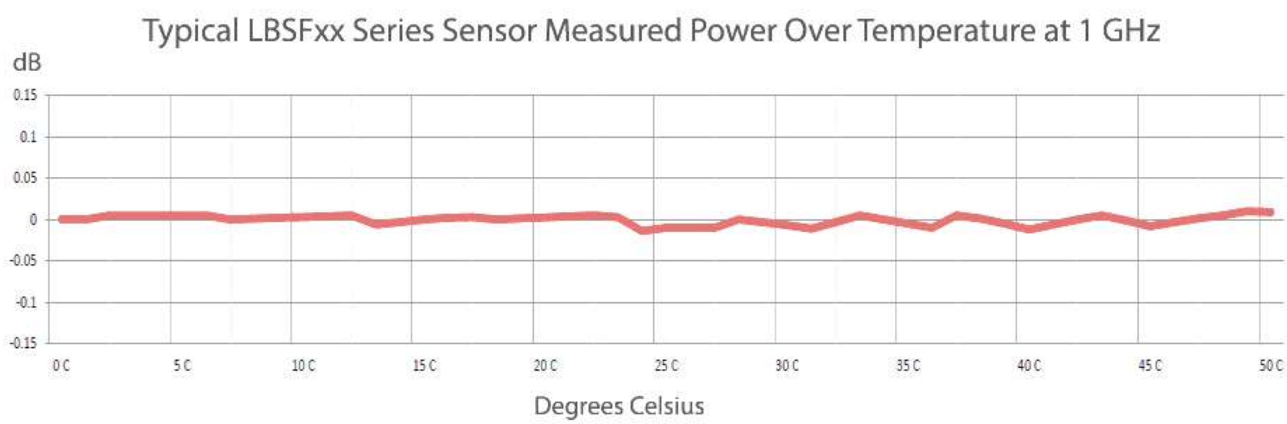
Parameter	Specification	Typical
Match (SMA male)		
4 kHz to 9 kHz	1.8 VSWR	1.5 VSWR
9 kHz to 15 kHz	1.5 VSWR	1.25 VSWR
15 kHz to 60 kHz	1.5 VSWR	1.12 VSWR
60 kHz to 2 GHz	1.13 VSWR	1.05 VSWR
2 GHz to 9 GHz	1.18 VSWR	1.07 VSWR



Thermal Stability

LadyBug's patented thermal stability technology is utilized in the LBSF09X sensor. Measurements remain stable over the entire operating temperature range. No user intervention, zeroing or calibration is required. This patented process also defines the zero-power conditions and eliminates zeroing requirements. Measurements are not interrupted for zeroing or calibration. Note: Consider Option LTX, the Option adds an internal analog controlled heater that extends the low temperature range to -55C

Parameter	Specification	Typical
Temperature Unc		
40°C - 55°C	2.5%	0.5%
30°C - 40°C	0.5%	0%
20°C - 30°C	0%	0%
10°C - 20°C	0.5%	0%
0°C - 10°C	2.5%	0.5%



Initial Stabilization Time

For general use, LBSF series sensors are stable 5 minutes after electrical power is applied. For the greatest accuracy and adherence to the specifications detailed in this datasheet, allow a 30-minute warm up period. When Option LTX is installed,

Valid Data

Data is valid data under the following conditions.

- The device is within the valid calibration period
- The device is operating within Environmental operating Parameters
- The device required initial stabilization time has been satisfied

Environmental operating parameters

Specifications apply over the listed temperature and relative humidity range unless otherwise stated.

Environmental	Operating	Storage
Temperature	0°C to 55°C	-40°C to +55°C
Temperature (With Option LTX)	-55C to +55C	-40C to +55C
Humidity	15% - 95% non-condensing	15% - 95% non-condensing
Altitude	10,000 feet (3,000 meters)	50,000 feet (15,000 meters)

Triggering

True-RMS LBSF Series Sensors' trigger functions including slope, level, trigger delay, hold off and rearm delay can be set. External trigger Input and output are available for synchronizing multiple sensors, or other purposes. Trigger Input and output use spare USB lines and require a breakout cable. Trigger Out is shared with Recorder Out and can not be used while Recorder Out is active.

General	
Trigger source	External.
Trigger Delay range	+ 10 Seconds
Auto trigger delay	Varies based on resolution setting.
Resolution	1us
Trigger Out pulse width	500 ns
Trigger Out level	High level 3.3V with 600-ohm load. Max low level 0.8 V. Minimum load resistance 200 ohms.
Trigger input	Min high level 2.0 Volts, Max low level 0.8 Volts.
Input load	Selectable 100 kΩ or 50 Ω
Timing requirements	Minimum pulse: Width 25 ns (on), 25 ns (off); Repetition: 50 ns (min)
Absolute input limits	+5.5 Volts maximum; -0.5 Volts minimum

Store and Recall Memory

The LBSF09X sensor series contains volatile and non-volatile memory.

Store & recall functions for the sensor's state and register functions such as Frequency, Averages and Analog Recorder Out settings have a lifetime of 1 million write and erase cycles.

Note: If option MIL (security) is ordered, non-volatile memory is not accessible. This includes all state and register functions such as Frequency, Averages, Analog Recorder Out etc.

Interface Connectivity

LBSF series power sensors USB interface utilizes either USBTMC or USB HID. Option LAN features HiSLIP (High Speed LAN Instrument Protocol) connectivity. Direct control of the sensor is also possible using optional SPI and I2C interface ports. The sensors can be set up, controlled and data taken using any of the connectivity options. LadyBug sensors are provided with a full featured application that utilizes the sensors USB interface. Please refer to the Option LAN and SPI documentation for details regarding LAN, I2C and SPI interfaces.

USBTMC	USB488 compliant
USB HID	USB Human Interface Device Class compliant
LAN	HiSLIP High Speed LAN Interface Protocol
SPI / I2C (Option SPI)	Cable and connector are included with option SPI. Cable may also be used to power the sensor for unattended applications.

Remote Programming

The sensor is designed for full programmatic control in ATE systems and other applications requiring remote programming. LBSF series sensors use SCPI (Standard Commands for Programmable Instruments) commands. All four of the sensor's connectivity options use the standard SCPI command set. LadyBug's SICL test harness, and/or the LAN browser based Interactive IO/Power Meter can be utilized for testing and developing automated test systems. Refer to the LBSF programming guide for additional information on remote programming.

Supporting Ports	USBTMC, USB HID, Ethernet, SPI/I2C
Command Set	SCPI (Standard Commands for Programmable Instruments)
Compatibility	Compatible with systems using USBTMC programmatic control, NI™ & Keysight™ Visa IO libraries & others using SCPI command set.*

* Agilent is a trademark of Agilent Technologies Inc; NI is a trademark of National Instruments, Inc.

Option Information

Sensor Family Frequency Range Options

- LBSFxxA sensors have a low frequency of 1MHz
- LBSFxxL sensors have a low frequency of 4KHz

Analog Recorder Output

Option 001, Analog Recorder Out. Recorder Output is a filtered analog output that can be used for various purposes. The output provides an accurate scaled voltage representing the signal's power level. The output is linear (not log dB) and can be scaled as required. Recorder Out uses one of the unused USB leads and requires a breakout cable. This same connection is shared by Trigger Out, therefore only one can be used at any given time. However both Recorder Out and Trigger Out can coexist and be activated by user selection.

Output filter bandwidth	0.001 Hz to 32 Hz (settable)
Output range	0 to 1 Volt into 1,000 Ohms. Note: Transient Potential of 3.3 Volts
Output impedance	1 k Ohms
Resolution	+/- 25 µV
DC Offset	0 to 5 mV
Scale	Linear
Connector	USB

Option MIL

Option MIL is designed to address security and data sanitization issues. When purchased with this option, the user cannot write to any non-volatile memory. Consult the factory for additional information regarding option MIL.

Option SEC Sanitization

The sanitization option adds secure erase capability. When the SEC command is executed, all non-volatile memory is erased including User Presets, Persona information, Store & Recall data, User Cal, Simple offsets and FDO tables. The process is an *erase - random overwrite - erase* process. For additional security users can execute the command repeatedly. The option is not available if Option MIL is purchased because non-volatile memory writes are disallowed with the option.

Option LTX Low Temperature Extension

Option LXT is an internal feature available for LadyBug's SF series of compact power sensors. This option extends the operating temperature range of the sensors by linearly adding controlled heat. It employs an integrated proportional heater for temperature regulation, eliminating the need for external control. The heater can be enabled using SCPI commands. The regulated heating system draws power from the 5-volt USB supply, allowing for up to 10 watts of additional heat.

LBSF series sensor with Option LTX combined specifications:

After warmup time unless otherwise stated. Device mounted[2] in still air environment.

	MIN	TYP	MAX	UNIT
Operating temperature range	-55		55	°C
Temperature Uncertainty (Average Mode)				
0°C to 55°C		base device specifications		%
-55°C to 0°C and heater active		0.5	2.5	%
Heater active temperature:				
Device		25 and lower		°C
Environment		15 and lower		°C
Temperature ramp to maintain full accuracy	-0.05		0.05	°C/min
Minimum enumeration temperature[1]		-55	-40	°C
Minimum warmup time when temperature:				
Greater than 15°C		base device specifications		min
Is 0°C to 15°C and heater active		90		min
Less than 0°C and heater active		120		min
Additional warmup time after temperature ramp:				
Exceeds ±0.05 °C/min		15		min
Exceeds ±0.1 °C/min		30		min
Exceeds ±0.5 °C/min		60		min
Exceeds ±1 °C/min		90		min
USB Specification		Type-C 1.2		
USB Power requirements[2]				
Voltage, USB powered host side	4.75		5.5	V
Heater current, heater off or inactive, 25°C			600	µA
Device current, heater active, -55°C				
Settled		1.6		A
Cold turn on peak		2.3	3	A

1 When temperature is below -40°C, device enumeration may be delayed until device temperature exceeds -40°C. After 15 min of heater active warm up, device power may need to be cycled off to guarantee enumeration.

2 Device USB connection, RF connection and mounting
USB cable, 5-amp, 2-meter maximum length between powered host and device.
RF cable, minimum 4” 0.141 or equivalent, connected to RF input.
Four-point mounting hole hardware kit included with the option

Consult the Option LTX specifications document for further details, mounting & application informatuion.

Uncertainty Calculation Work Sheet

Use this sheet to calculate uncertainty for a specific set of conditions using the root sum of squares method.

Conditions

Operating Frequency (GHz)	
Power Level (dBm)	
DUT Match (VSWR)	
Temperature (°C)	

Sensor characteristics at conditions

Cal Factor (% & Actual)		
Linearity (% & Actual)		
Noise (% & Actual)		
Uncertainty Due To Temperature (% & Actual)		
Match (VSWR)		
Zero Offset		

1. Calculate Sensor reflection coefficient, ρ from Sensor VSWR

   ρ_{sens} = (VSWR-1)/(VSWR+1)

   ρ_{sens} =

2. Calculate DUT reflection coefficient, ρ from DUT VSWR

   ρ_{DUT} = (VSWR-1)/(VSWR+1)

   ρ_{DUT} =

Note: Reflection coefficient can be calculated from return loss using the formula $\rho=10^{(-RL/20)}$

3. Calculate total match uncertainty

   Mm = $(1+(\rho_{sens} * \rho_{DUT}))^2-1$

   Mm =

4. Calculate Zero Offset uncertainty (See Specification and notations)
   a. Convert power from dBm to Linear

      Linear Power = $10^{(PowdBm/10)}$

      Linear Power =

   b. Calculate Zero Offset

      Zero Offset = (Zero Offset Specification/Linear Power)

      Zero Offset =

5. Calculate Total RSS uncertainty

   Uncertainty (%) = $\sqrt{(Mm^{2+}CF^2+L^2+N^2+T^2+Z^2)}*100$

   Uncertainty (%) =

Uncertainty Calculation Work Sheet Example

Provided Soon

LBSFxxx Mechanical Specifications

Dimension tolerance +/- 0.063”