Frequency Measurements and Mixer

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1 Introduction

In this laboratory the student will use and measure a frequency translating device (mixer).
A mixer is used to provide frequency translation from the input signal to the output signal. When a mixer is used for down-conversion, the input is the RF signal and the output is the IF; for up-conversion the opposite is true. In this document, the down-converter notation will be used. The specification of the mixer used for this laboratory is attached at the end of this notes. A mixer is characterized by a set of parameters here discussed:

1.1 Conversion Loss

Conversion loss is a measure of the efficiency of the mixer in providing frequency translation from the RF input signal to the IF output signal. For given RF and LO frequencies, two nominally equal-amplitude output signals are produced at the sum and the difference of the RF and LO frequencies. Since only one of these products (or sidebands) is utilized in most applications, the specifications given in data sheets are typically for a single-sideband output. If both sidebands are utilized, the conversion loss is 3 dB lower than in the single-sideband case.

Conversion loss of a mixer is equal to the ratio of the RF input power to the IF single sideband output power, expressed as a positive number in dB. All measurements are based on a 50-ohm system, with local oscillator level as specified for the pertinent mixer type. For example: for a Level 7 mixer it is +7 dBm; for Level 17, +17 dBm; and for Level 23, +23 dBm. When the local oscillator power level deviates from the recommended level, the conversion loss will change slightly.

1.2 Conversion Gain

Some mixers have an internal amplifier in one or more of the three signal paths. When the amplifier is in the RF or IF path, it generally provides IF output power that is greater than the RF input power. Therefore, conversion gain is specified instead of conversion loss; it is equal to the ratio of the IF single-sideband output power to the RF input power, expressed as a positive number in dB.

1.3 Conversion Compression

Conversion compression is a measure of the maximum RF input signal for which the mixer will provide linear operation in terms of constant conversion loss. At low RF signal power, the IF output power and RF input power have a constant ratio, observed as a constant difference in dB. However, when the RF signal power is within about 10 dB of the LO drive level, the IF output power no longer follows the increase in RF input exactly and the ratio between IF and RF power exhibits a change of about 0.1 dB. As the RF power increases further there will be a greater change in the ratio, with conversion loss increasing as the RF input power increases.

The criterion used to describe the deviation from linearity between the RF input power and the IF output is a fixed amount of compression. Most mixer data sheet specify the typical RF input power at the 1-dB compression point, where conversion loss is 1 dB greater than it is at low RF power.

Since the compression point changes with LO drive level, it is important to select a mixer having LO drive level that affords the required compression point for the application. The importance of this performance measure is its utility in comparing dynamic range in terms of maximum input for various mixers.

1.4 Isolation

Isolation is a measure of the circuit balance within the mixer. When the isolation is high, the amount of ”leakage” or ”feed through” between the mixer ports will be very small. Typically, mixer isolation falls off with frequency due to the unbalance in the transformer, lead inductance, and capacitive unbalance between diodes.

The LO-to-RF isolation is the amount the LO drive power is attenuated when it is measured at the RF port, the IF port being terminated with 50 ohms. The LO-to-IF isolation is the amount the LO drive power is attenuated when it is measured at the IF port, the RF port being terminated with 50 ohms. Normally, only the LO isolations are specified, not RF isolation. This is because the RF signal power is much lower than the LO drive level; therefore, RF leakage is usually not a limiting performance factor.

1.5 Dynamic Range

The dynamic range (dB) of a mixer is the range of input RF power levels (dBm) for which the mixer produces useful IF output power. Dynamic range is limited at the low end by the noise performance of the mixer devices. When the input power is such as to produce a discernable IF output signal a constant power ratio (equal to the conversion loss) is established between input RF power and output IF power. As input power is increased, a point is reached where this constant power ratio is no longer maintained and conversion loss begins to increase. When conversion loss has increased by 1 dB, the upper limit of the mixers dynamic range is deemed to have been reached and this “1 dB compression point” generally delineates the upper level of input power for which the mixer should be used.

1.6 DC Polarity

This characteristic applies to mixers having IF response down to DC. DC polarity defines the polarity of the IF output voltage when the mixer is used as a phase detector, with RF and LO signals that are equal in frequency and are in-phase (0° difference).

1.7 DC Offset

DC offset is a measure of the unbalance of the mixer. For an ideal (perfectly balanced) mixer, the DC offset is zero. DC offset defines the IF output voltage when the mixer is used as a phase detector and a signal is applied only to the LO port, with the RF-port terminated in 50 ohms.

2 Instrumentation

For this practical session you will use the following instrumentation:

- waveform generator (Hameg 8130, Hameg 8131)
- LED quartz oscillator
- an oscilloscope
- a frequency counter (Hameg HM 8122)

- a mixer

For manuals and documentation, please refer to the following link:
http://led.polito.it/main_it/instrumentation.asp
(it is recommended you download the information for the Hameg HM 8122 frequency counter in advance).

2.1 Quartz generator

The quartz generators are the LED quartz oscillator (quartz n. 1) and the waveform generator (quartz n. 2).

2.2 Mixer

The internal scheme and the pins of the *mixer* are shown in figures 1 and 2.

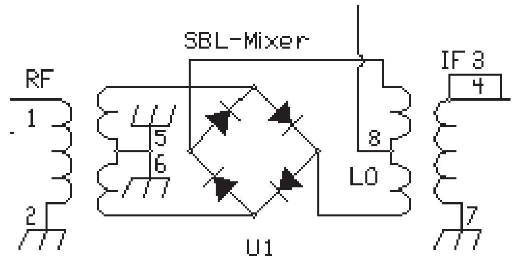


Figure 1: Simplified scheme of the SBL-3 *mixer*.

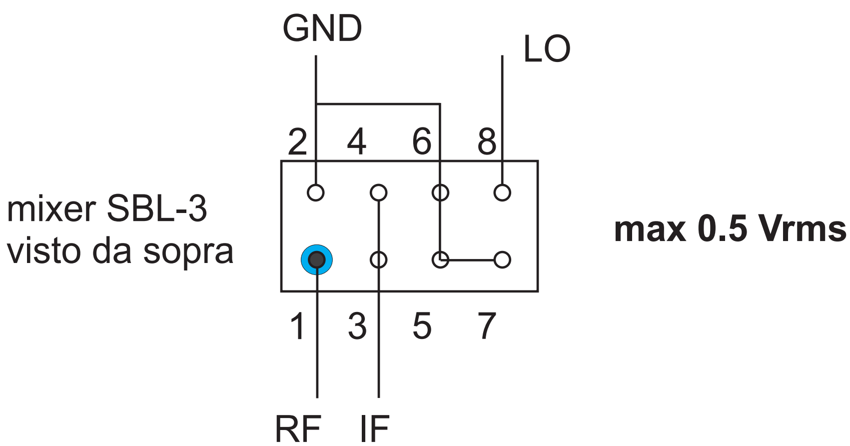


Figure 2: Pin scheme for the SBL-3 *mixer* (seen from top).

3 Frequency measurements

Measure the frequency of the signals indicated in Table I, with the frequency counter Hameg HM 8122 (compute the uncertainty following the manual instructions). Set the waveform generator (Hameg 8130 or Hameg 8131) to generate sinusoidal signals.

Table 1: Frequency measurements

Signal	f	$\delta f)$
15 Hz (from waveform generator)	...	...
1 kHz (from waveform generator)	...	...
5 MHz (from waveform generator)	...	...
5 MHz (from LED quartz)	...	...
5 MHz (from waveform generator)	...	...

4 Frequency difference measurement

4.1 Using the counter

Compute the frequency difference of quartz n. 1 and n. 2, starting from the measurements you just performed. Compute the uncertainty.

4.2 Using the oscilloscope

Compute the frequency difference of quartz n. 1 and n. 2, using just the two channels of the oscilloscope. Give an estimation of the uncertainty.

4.3 Using the mixer

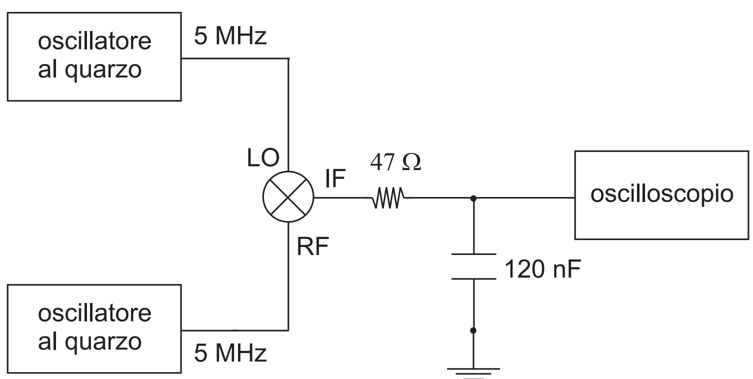


Figure 3: Frequency difference measurement, using the mixer.

Mount the circuit of figure 3 on your breadboard. What is the use of the resistor and capacitor in the configuration of figure 3? Measure the frequency difference and compute the uncertainty.

4.4 Comparison

With the measurements you just performed, fill the table below.

5 Homodyne operation

Observe the behavior of the mixer in homodyne operation, by measuring the DC voltage at the IF output. Use only one RF generator (HP), frequency 20 MHz and power -5 dBm. Draw the scheme of the measurement

Table 2: Frequency difference measurements

Method	f_{Q1}-f_{Q2}	$\delta(f_{Q1} - f_{Q2})$
counter	...	...
oscilloscope	...	...
mixer	...	...

set-up, using the tester to measure the DC voltage. Measure the voltage changes when introducing an additional cable on the RF (or LO) path. Observe and measure the voltage variation when changing the RF frequency from 5 MHz to 15 MHz, with 2 MHz steps, with and without the additional cable.

Table 3: Homodyne operation

f_{RF}	V_{DC} at IF port
5 MHz	...
7 MHz	...
9 MHz	...
11 MHz	...
13 MHz	...
15 MHz	...

6 Etherodyne Operation: Compression Point

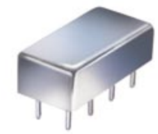
Plot the graph of the mixer IF power vs the RF one assuming 50Ω load. Find the 1dB compression point by setting the LO=5MHz usign the quartz, RF=5.1 MHz using the generator and by sweepting the input power.

Plug-In

Frequency Mixer

SBL-1+

Level 7 (LO Power +7 dBm) 1 to 500 MHz



CASE STYLE: A06
PRICE: $8.00 ea. QTY (1-9)

+ RoHS compliant in accordance with EU Directive (2002/95/EC)

The +Suffix has been added in order to identify RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications.

Maximum Ratings

Operating Temperature	-55°C to 100°C
Storage Temperature	-55°C to 100°C
RF Power	50mW
IF Current	40mA

Features

- excellent conversion loss, 5.6 dB typ.
- high L-R isolation, 45 dB typ. L-I isolation, 40 dB typ.
- rugged welded construction

Applications

- VHF
- defense & federal communications

Pin Connections

LO	8
RF	1
IF	3,4^
GROUND	2,5,6,7

^ pins must be connected together externally

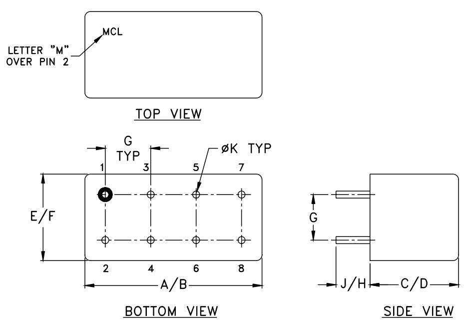
Electrical Specifications

FREQUENCY (MHz)		CONVERSION LOSS (dB)				LO-RF ISOLATION (dB)						LO-IF ISOLATION (dB)					
LO/RF	IF	Mid-Band m			Total Range	L		M		U		L		M		U	
f_L-f_U		$\overline{X}$	σ	Max.	Max.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.
1-500	DC-500	5.60	.09	7.0	8.0	60	45	45	35	40	25	45	35	40	25	30	20

1 dB COMP.: +1 dBm typ.

L = low range [f_L to 10 f_L] M = mid range [10 f_L to f_U/2] U = upper range [f_U/2 to f_U]
m= mid band [2f_L to f_U/2]

Outline Drawing



Outline Dimensions (inch / mm)

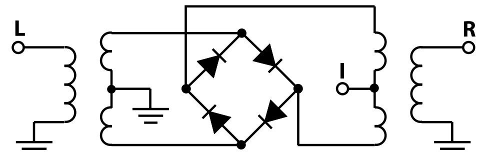
A	B	C	D	E	F
.770	.800	.285	.310	.370	.400
19.56	20.32	7.24	7.87	9.40	10.16

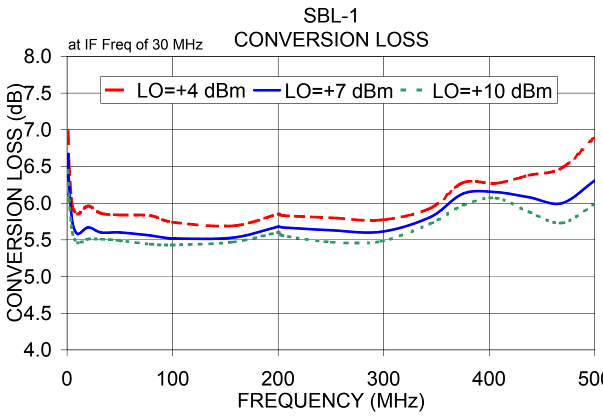
G	H	J	K	wt
.200	.20	.14	.031	grams
5.08	5.08	3.56	0.79	5.2

Typical Performance Data

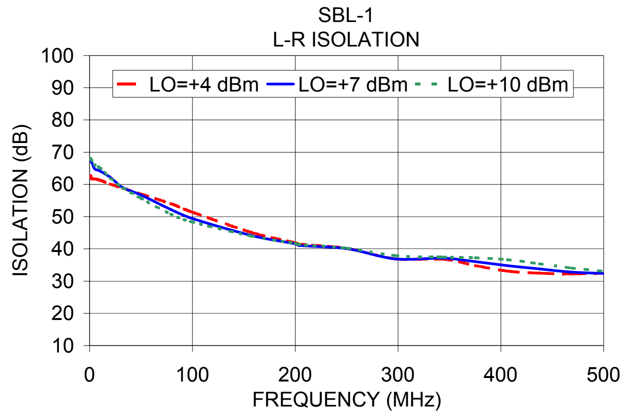
Frequency (MHz)		Conversion Loss (dB)	Isolation L-R (dB)	Isolation L-I (dB)	VSWR RF Port (:1)	VSWR LO Port (:1)
RF	LO	LO +7dBm	LO +7dBm	LO +7dBm	LO +7dBm	LO +7dBm
1.00	31.00	6.67	67.00	65.61	1.80	3.75
2.00	32.00	6.24	67.00	67.00	1.14	2.81
5.00	35.00	5.74	64.84	67.00	1.14	2.89
10.00	40.00	5.58	64.19	64.81	1.14	2.83
20.00	50.00	5.67	62.22	61.69	1.15	2.69
32.19	62.19	5.60	59.04	57.74	1.16	2.72
50.00	80.00	5.60	56.71	54.39	1.17	2.62
78.97	48.97	5.56	52.21	49.67	1.18	2.62
100.00	70.00	5.52	49.41	46.90	1.20	2.66
156.94	126.94	5.53	44.20	41.66	1.22	2.62
200.00	170.00	5.68	41.56	38.98	1.26	2.58
203.72	173.72	5.67	41.05	38.52	1.26	2.56
250.50	220.50	5.63	40.04	37.29	1.28	2.59
297.29	267.29	5.61	36.90	33.97	1.30	2.64
344.07	314.07	5.81	37.11	33.88	1.31	2.59
375.26	345.26	6.13	36.02	32.79	1.30	2.60
406.44	376.44	6.15	34.80	31.05	1.28	2.72
437.63	407.63	6.08	33.79	30.39	1.27	2.77
468.82	438.82	6.00	32.80	30.12	1.24	2.82
500.00	470.00	6.31	32.36	30.37	1.21	3.01

Electrical Schematic

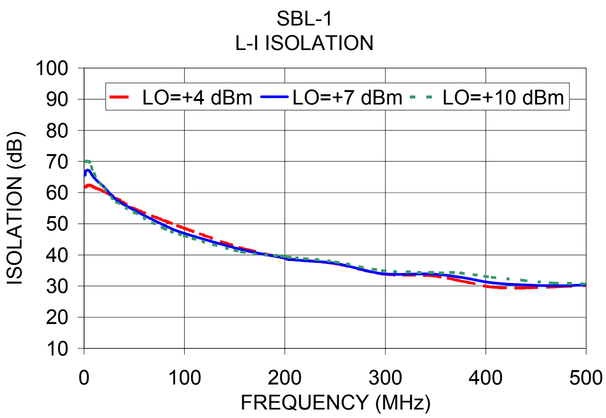




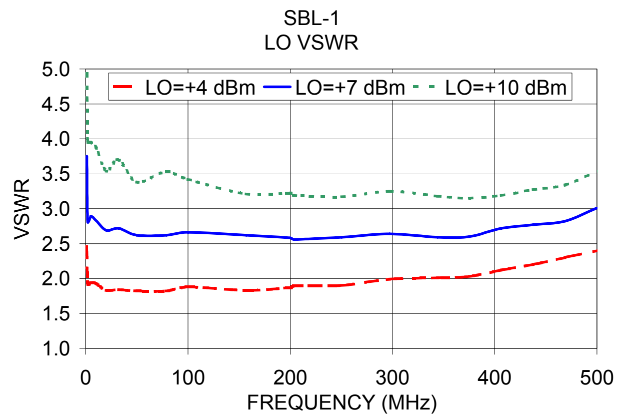
SBL-1
CONVERSION LOSS
at IF Freq of 30 MHz
LO=+4 dBm
LO=+7 dBm
LO=+10 dBm
CONVERSION LOSS (dB)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
0
100
200
300
400
500
FREQUENCY (MHz)



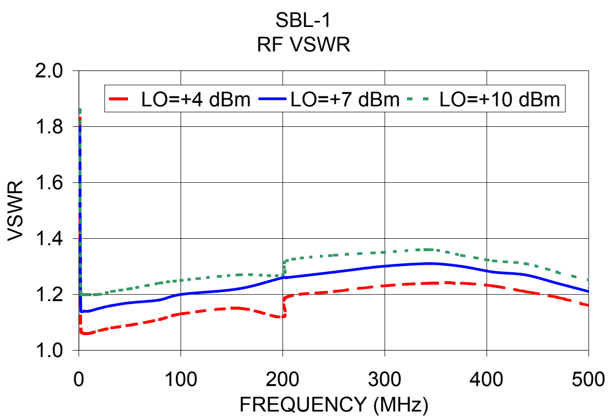
SBL-1
L-R ISOLATION
LO=+4 dBm
LO=+7 dBm
LO=+10 dBm
ISOLATION (dB)
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
FREQUENCY (MHz)



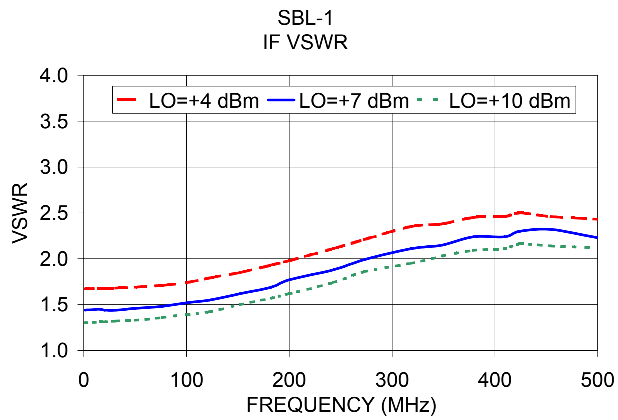
SBL-1
L-I ISOLATION
LO=+4 dBm
LO=+7 dBm
LO=+10 dBm
ISOLATION (dB)
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
FREQUENCY (MHz)



SBL-1
LO VSWR
LO=+4 dBm
LO=+7 dBm
LO=+10 dBm
VSWR
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
100
200
300
400
500
FREQUENCY (MHz)



SBL-1
RF VSWR
LO=+4 dBm
LO=+7 dBm
LO=+10 dBm
VSWR
2.0
1.8
1.6
1.4
1.2
1.0
0
100
200
300
400
500
FREQUENCY (MHz)



SBL-1
IF VSWR
LO=+4 dBm
LO=+7 dBm
LO=+10 dBm
VSWR
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
100
200
300
400
500
FREQUENCY (MHz)