RF Measurements tutorial | RF device test and measurement basics

This rf measurements tutorial covers RF device testing basics using RF equipments. It covers RF test and RF measurements parameters viz. power, gain, spurious, harmonics, P1dB, noise figure, image rejection, return loss, phase noise, group delay, frequency stability, TOI, AM-PM conversion and more RF measurements.

It covers RF transmitter and RF receiver

RF WIRELESS TUTORIALS

5G NR | Zigbee | z-wave | Bluetooth | GSM | UMTS | LTE | WLAN | 802.11ac | IoT

measurements. This tutorial will help RF engineers in how to test and measure various RF specifications of RF power amplifier, RF LNA and RF transceiver using RF test and measurement equipments such as spectrum analyzer, signal generator, sweep oscillator, power meter etc.

Gain measurement

It is the ratio of output power to the input power and is expressed in dB. For example if gain of the amplifier is mentioned as 20dB it means if the input to the amplifier/DUT (device under test) is -15dBm, output power will be +5dBm.

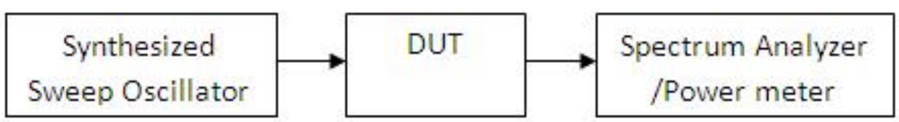


Fig.1

Gain Flatness measurement

The gain flatness or gain response is the measurement of the gain variation at different frequency of operation of the RF systems such as RF Transceiver, RF Power amplifier etc.

Gain Flatness Measurement➤➤

Spurious measurement

| RADAR |
satellite |
Waveguide |

POPULAR TUTORIALS

DECT | ISDN | ATM | WBAN | TransferJet | BLE | Femtocell | HSPA | BACnet | Ethernet | TETRA | Underwater wireless | 5G | LiFi | LoRa | NFC | Infrared | RF measurements | VSAT | Diode | SS7 |

Unwanted frequencies at the output of the DUT usually devices having mixer devices e.g. RF frequency converters is called spurious frequencies. These spurious frequencies will be usually at non-integer multiples of the input frequency fed to the DUT.

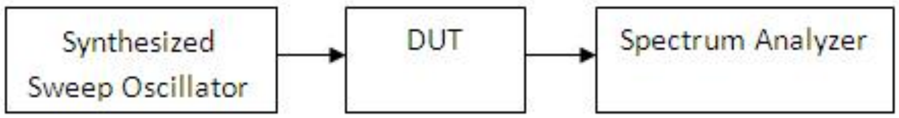


Fig.2

Harmonics measurement

This is also unwanted frequencies at the output of DUT as mentioned above but will be at integer multiples of the input frequency.same Fig.2 is used for measurement of harmonics.

RF Harmonic Measurement and test setup➤➤

Spurious vs Harmonics

Refer our page on Spurious vs Harmonics to know more.

1dB compression point measurement

It is also called as gain compression point; it is the output power till DUT works well and does not go into saturation condition. Keep varying the input power and

Networking | Network Security | FTTH | KNX | WAP | Mobile IP

measure the output power. From the measurement find out place where, 2 dB variation of input there is 1 dB variation in the output. These are input and output 1dB compression points.

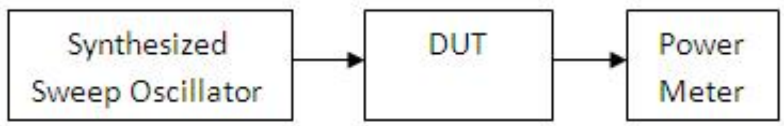


Fig.3

Noise figure measurement

It is the measure of the amount of noise generated by amplifier/DUT. It is related to noise temperature as mentioned below.

NF= 10 log(1+T/290),

Where T is the noise temperature in Kelvins and NF is in dB

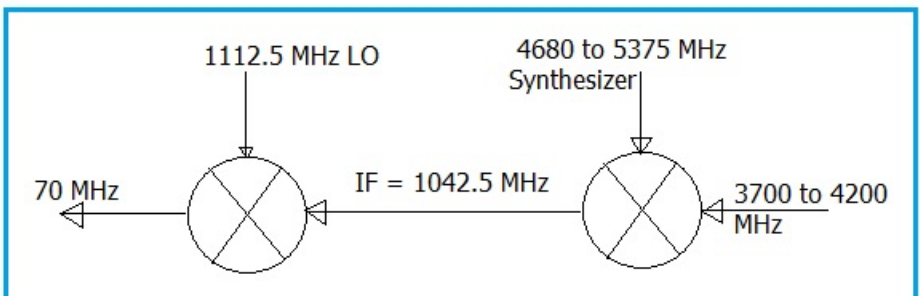
Refer Noise Figure Measurement of RF LNA➤➤

Noise figure Relation with Noise temperature and Noise Factor

Noise Factor versus Noise Figure   Noise figure vs Noise Temperature

Image frequency rejection measurement

It is the specification of receiver part in RF transceiver. For example we need to measure image frequency rejection of C band down converter operating at input frequency of 3700-4200 MHz and having 52-88 MHz output frequency. We need to find two input frequencies f1 and f2 at the receiver or down converter which will produce same frequency as output (say 70 MHz). in this case these two frequencies are said to be images of each other. Frequency 5785 MHz is the image frequency of 3700 MHz. This has been derived from, Fimage = 3700 + 2*(1042.5) = 5785 MHz. Here IF of 1042.5 MHz is used as per heterodyne down converter diagram shown below.



Part of C Band Down Converter

Fimage=Fs+2*IF

In order to measure the rejection, we need to feed f1(equal to 3700 MHz) and note down the output frequency power level (say P1). Then we need to feed f2(equal to 5785 MHz image frequency) and note down the power level (say P2). The difference between these two power levels are said to be image frequency rejection. It is usually specified in dBc.

Return loss measurement

It is measured at all the ports of the DUT. It is the measure of accuracy of impedance matching at the ports.

Refer Reflection coefficient vs Return loss vs VSWR for more.

RL=20*Log (VSWR+1/VSWR-1)

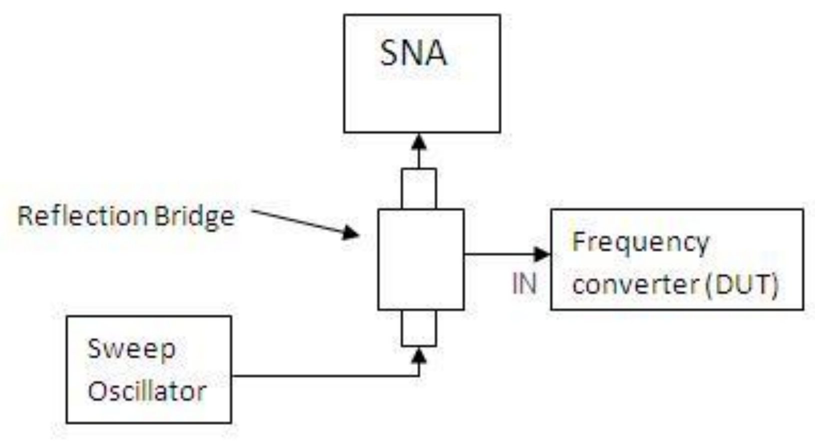


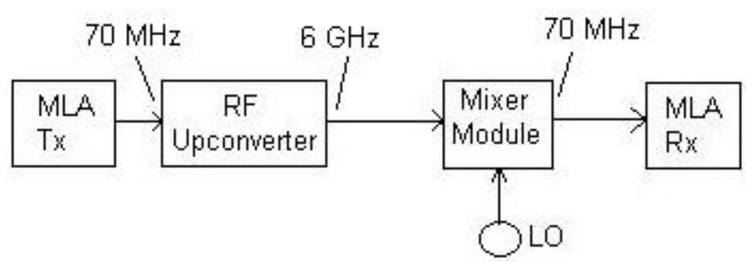
Fig.4

Phase Noise measurement

It is the ratio of signal to noise power measured in 1 Hz bandwidth, usually expressed at some frequency offset from RF carrier and unit of measurement is dBc/Hz. For example phase noise is 1 KHz offset from RF carrier is -60dBc/Hz. Same Fig.2 is used for measurements. Refer phase noise and jitter measurement basics and RF Phase Noise Measurement setup➤➤

Group Delay measurement

Delay for the signal to transit from input to output for Device under Test (DUT).



Set-up for Group delay measurement

Here as shown in the figure MLA(Microwave Link Analyzer) is used for group delay measurement of RF Upconverter.

Group delay of upconverter = measure of group delay of above setup - group delay of mixer module.

Similarly group delay for SSPA or down converter can be measured by replacing upconverter mentioned in the setup with DUT.

Frequency stability measurement

It is the change in frequency of the DUT due to aging and temperature. They are two types short term and long term and measured in PPM/day or PPM/year respectively. ppm means parts per million. READ MORE .

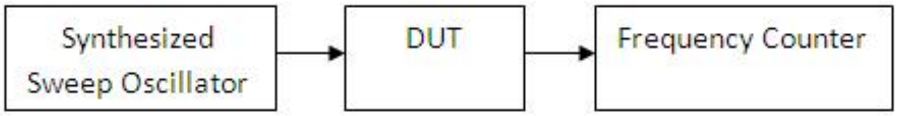
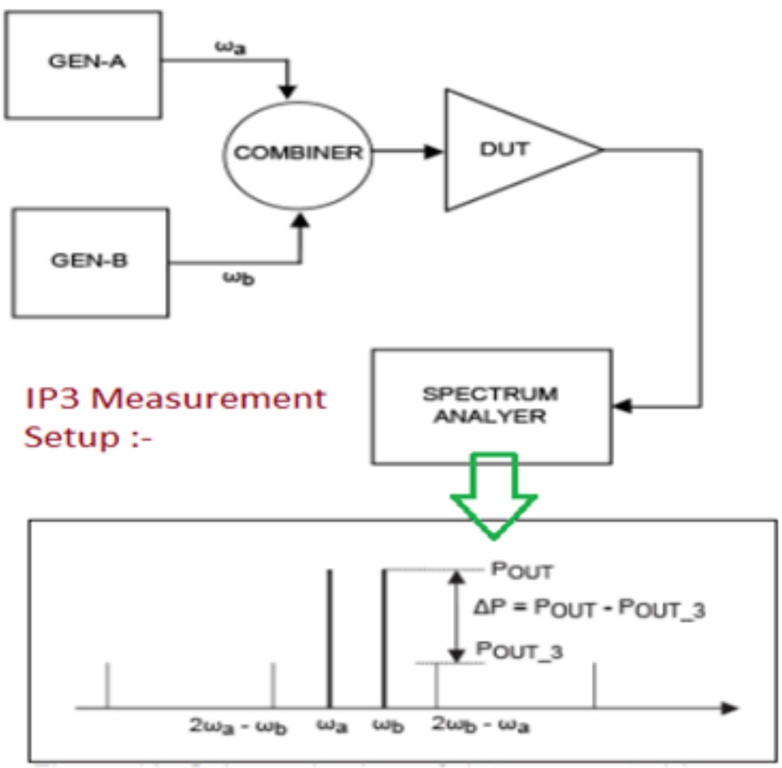


Fig.5

3rd order intercept point RF measurement



It is a measure of linearity which describes the amount of third order harmonic that can be expressed in a device. It is referred to the input and output of a module.

TOI in dBm = (Input signal levels in dBm) + (distortion products (dBc)/2)

Refer IP3 measurement >> which describes IIP3 and OIP3 measurement block diagram using spectrum analyzer.

P1dB versus TOI

Refer following links to know more on P1dB versus TOI, 2nd order Intercept point vs 3rd order Intercept point.

P1dB vs TOI second order intercept point vs third order intercept point

AM-PM conversion measurement

AM-PM conversion measures the amount of undesired phase deviation (PM) that is caused by amplitude variations (AM) of the system.

Measurement setup for AM-PM and TOI point is mentioned below.

AM-PM conversion, $Kp=13.2 \times 10^{-(Pint-Pi-G)/10}$

where, Pint is the Third Order Intercept Point or TOI

Pi is input level in dBm

and G is the Gain of Up converter

For Example, if Pi=-33dBm, Gain=30dB ,

TOI=+17.41dBm

By putting values in the above equation, we will get

Kp=0.1203 degree/dB

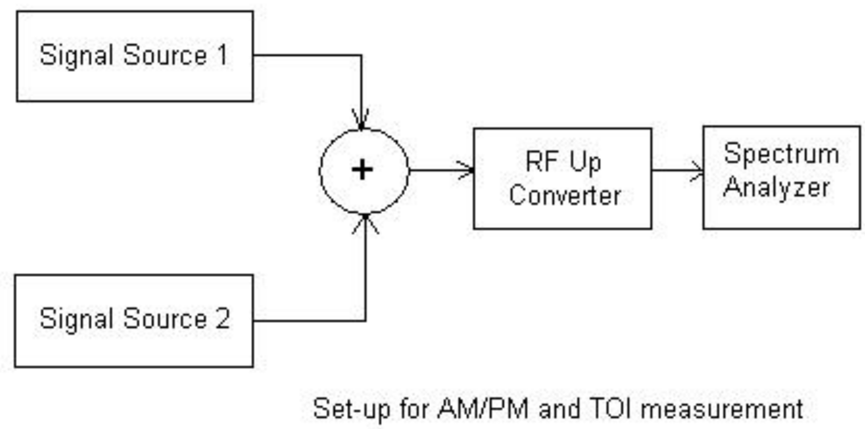
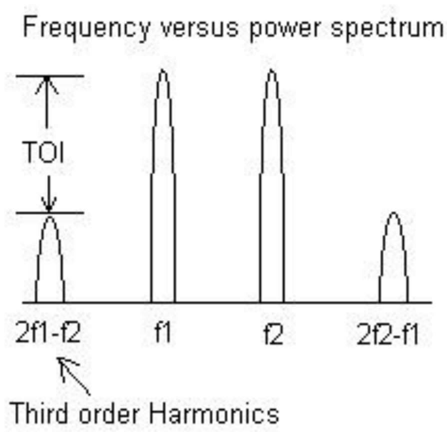


Fig. AM-PM conversion and TOI measurement

As shown in the figure set Signal Source 1 to say f1(70 MHz) and feed this signal and adjust power level such that it gives output power of (P1dB-3) dB.

Switch off Signal Source 1 and set Signal source 2 to 71.001 MHz and adjust power level in Signal source 2 such that spectrum analyzer shows (P1dB-3) dBm as output.



Now simultaneously feed both the signals with the power levels just derived from above and note down the TOI as shown in the figure above.

Refer following links to read more on RF measurements :

AM to AM Conversion and AM to PM Conversion

Test and Measurement Section

Refer Test and Measurement Section which mentions link to many such RF measurements which include following:

• ACPR measurement• RF harmonic distortion measurement• RF intermodulation distortion measurement • RF Wafer testing• Impedance measurement• BER testing• Synthesizer settling time• RF receiver max. tolerable test• receiver sensitivity test• antenna test and measurements etc.

Go to Test and Measurement Main Page➤➤

RF Measurements RELATED LINKS

Following are the useful links on wireless and rf measurements.

Error Vector Magnitude
RF Link Budget
Physical layer measurements
Design of RF frequency converter
C band RF Transceiver Design and Development
Production tests on RF and SoC devices
RF Terminology
what is RF
RF Power Amplifier
RF Mixer basics
rf synthesizer design
Noise figure vs Noise Temperature

RF Wireless Tutorials

GSM TD-SCDMA wimax LTE UMTS
GPRS CDMA SCADA WLAN 802.11ac
802.11ad GPS Zigbee z-wave Bluetooth
UWB IoT T&M satellite Antenna RADAR
RFID

Share this page

Translate this page