Radio Measurements for the Amateur

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Etherkit

https://github.com/NT7S/RadioMeasurements

Contents

Chapter 1

Introduction

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Chapter 2

Glossary

AF	Audio Frequency
CW	Continuous Wave, i.e. a single tone
DUT	Device Under Test
RMS	Root-mean-square
DMM	Digital Multimeter
AGC	Automatic Gain control
THD	Total Harmonic Distortion

Chapter 3

Test Equipment

Some instruments are necessary in order to perform the measurements outlined in this document. While some can be homebrewed, and some projects are provided, the experimenter may need to get some new or surplus instruments. In the following sections we will discuss some of the basic needed instruments, and give some hints in selection.

3.1 DC measurements

For the basic DC measurements, a good quality Digital Multimeter (DMM) would satisfy most of the measurements. For measuring current on a high power transmitter, a shunt resistor of known value may be obtained, and the current measured as voltage drop over this. Several 0.003Ω shunts are available new for reasonable prices.

3.2 Audio measurements

The most important measurements can be done using a true RMS audio voltmeter or a thermal converting meter. In addition a suitable computer soundcard with proper audio spectrum analyzer software can do all of the measurements outlined. Programs are available for soundcard distortion meters, power meter and spectrum analyser. Spectrum Lab by DL4YHF is a large suite of programs suited to doing audio measurements. Two-tone audio generators can be built with low distortion, and used to test other audio instruments.

3.3 Receiver measurements

Measuring receivers are mostly related to signal sources and attenuators. A high impedance, high dynamic range audio amplifier with variable terminations and connections to other instruments should be a suitable project in order to test receivers. Small and large signal sources can be built using crystal oscillators. Directional couplers, Wilkinson splitters and AGC test

3.4 Transmitter measurements

Oscilloscopes and spectrum analyzers are best bought ready made. Accessories like directional couplers, attenuators and dummy loads can all be built with good performance. For transmitter measurements, its important to use good quality coax cables. Most amateur cables have a fairly high amount of leakage, and can distort measurements.

Chapter 4

Receiver Measurements

4.1 Minimum Discernible Signal (MDS)

Overview

The purpose of this test is to measure the lowest-level CW signal which can be detected by a receiver. This is defined as a signal input at the receiver antenna port which produces the same amount of AF power output as the intrinsic background noise of the receiver. In other words, when a signal at the MDS level is applied to the antenna port, a 3 dB increase in output power is measured over the receiver's internal noise level measurement.

Equipment List

- RF Signal Generator
- 100 dB Step Attenuator (at least 1 dB steps required)
- AC RMS Voltmeter (preferably with dB scale)
- AF Monitor Amplifier or 8 Ω Resistive Load

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually coaxial cables (such as RG-58) with BNC Male-to-BNC Male connectors
- 1 — audio jumper cable
  Varies depending on the connectors on your receiver and AF amplifier or load

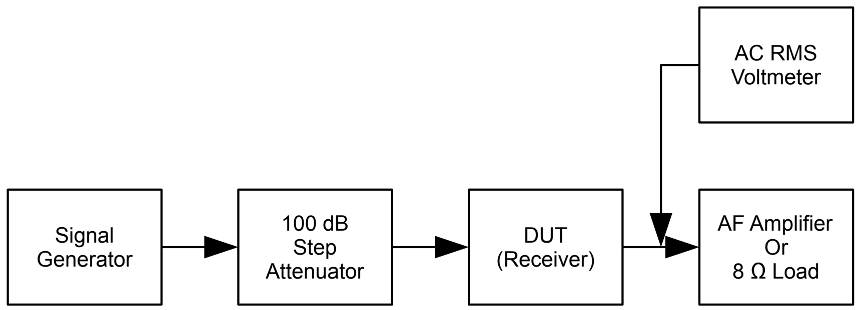

Figure 4.1: MDS Measurement Setup

- 1 — set of voltage probe test leads Your choice of connector for measuring

  AC RMS voltage output

Connections

Make sure all equipment is powered off before making any connections.

- Connect the signal generator output to one port of the step attenuator using a 50 Ω jumper cable.
- Connect the other port of the step attenuator to the DUT (receiver) using a 50 Ω jumper cable.
- Connect the audio output of the DUT (receiver) to the AF amplifier or 8 Ω load using an audio jumper cable.
- Connect the AC RMS voltmeter probes to the properly loaded audio output of the DUT (receiver).

Presets

- Turn ON the signal generator but make sure that the output is OFF. Set the output level to -50 dBm (if you are able to). Set the output frequency to the desired test frequency.
- Set the step attenuator for -40 dB. This will give an initial test signal level of -90 dBm. If you are not able to set your signal generator to -50 dBm, set the step attenuator to give you -90 dBm of test signal output.
- Turn ON the AF amplifier.
- Turn ON the DUT (receiver) and set for the desired measurement band and frequency. Set the AF gain (volume) control fully-counterclockwise

(no AF output), then set to an appropriate level for normal listening. If your receiver has AGC, disable it.

- Turn ON the AC RMS voltmeter. Set the meter scale as necessary.

Test Procedure

1. Turn ON the signal generator output. You should hear a CW tone from the AF amplifier.

2. Fine-tune the tune control of the DUT (receiver) until the CW tone is centered in the passband and is at maximum level.

3. Turn OFF the signal generator output.

4. Note the reading of the AC RMS voltmeter in dB. If the meter reading is fluctuating quite a bit, you may need to increase the AF gain control of the DUT (receiver) in order to get a more stable reading.

   AF Noise Power ____________________

5. The MDS level will be the AF power level 3 dB higher than the measurement made in the previous step. Calculate it below.

   AF Noise + MDS Signal Power ____________________

6. Turn ON the signal generator output. The reading from the AC RMS voltmeter should be significantly higher than the calculated level in step 5 (if you are using an external AF amplifier, you may need to turn down its gain control). Use the controls on the step attenuator to step down the test signal level until you have a reading on the AC RMS voltmeter that is closest to the figure derived in previous step. Note the amount of attenuation set on the step attenuator, then subtract that from the output level of the signal generator. This is your MDS figure.

   MDS ____________________

For example, if your signal generator is set to -50 dBm and the step attenuator is set to 81 dB, then your MDS is -131 dBm.

Hints and Tips

- Many QRP receivers and transceivers have a relatively low-level audio output, designed for either headphones-only or for a small speaker. In order to make the most accurate measurement, you may need to turn the AF gain control to maximum.

4.2 IF Rejection

Overview

The purpose of this test is to measure the level a CW signal on the IF frequency can bleed into an receiver and get detected as a valid signal. This is defined as a signal on the IF frequency at the receiver antenna port which produces the same amount of AF power output as the intrinsic background noise of the receiver. For this procedure to work its important to have preformed the MDS measurement as outlined earlier in this document or the noise figure measurement.

Equipment List

- RF Signal Generator
- 100 dB Step Attenuator (at least 1 dB steps required)
- AC RMS Voltmeter
- AF Monitor Amplifier or 8 Ω Resistive Load

Test Setup

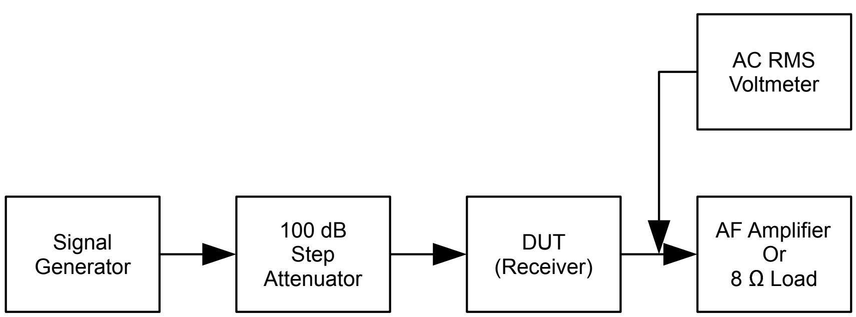

Figure 4.2: IF Rejection Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male
- 1 — audio jumper cable
  Varies depending on the connectors on your receiver and AF amplifier or load
- 1 — set of voltage probe test leads
  Your choice of connector for measuring AC RMS voltage output

Connections

Make sure all equipment is powered off before making any connections.

- Connect the signal generator output to one port of the step attenuator using a 50 Ω jumper cable.
- Connect the other port of the step attenuator to the DUT (receiver) using a 50 Ω jumper cable.
- Connect the audio output of the DUT (receiver) to the AF amplifier or 8 Ω load using an audio jumper cable.
- Connect the AC RMS voltmeter probes to the properly loaded audio output of the DUT (receiver).

Presets

- Turn ON the signal generator but make sure that the output is OFF. Set the output level to -30 dBm (if you are able to). Set the output frequency to the desired test frequency.
- Set the step attenuator for -40 dB. This will give an initial test signal level of -70 dBm. If you are not able to set your signal generator to -50 dBm, set the step attenuator to give you -70 dBm of test signal output.
- Turn ON the AF amplifier.
- Turn ON the DUT (receiver) and set for the desired measurement band and frequency. Set the AF gain (volume) control fully-counterclockwise (no AF output), then set to an appropriate level for normal listening. If your receiver has AGC, disable it.
- Turn ON the AC RMS voltmeter. Set the meter scale as necessary.

Test Procedure

1. Turn ON the signal generator output and reduce the attenuation. You should hear a CW tone from the AF amplifier. Adjust the frequency so the tone is sentered in the receiver's passband.

   IF center frequency ____________________ MHz.

2. Turn OFF the signal generator output.
3. Note the reading of the AC RMS voltmeter in dB. If the meter reading is fluctuating quite a bit, you may need to increase the AF gain control of the DUT (receiver) in order to get a more stable reading.

AF noise power ____________

4. The IF rejection power level will be the AF power level 3 dB higher than the measurement made in step 4. Calculate it below.

   AF Noise + IF rejection power level ____________

5. Turn ON the signal generator output. The reading from the AC RMS voltmeter should be significantly higher than the calculated level in step 4 . Use the controls on the step attenuator to step down the test signal level until you have a reading on the AC RMS voltmeter that is closest to the figure derived in step 4. Note the amount of attenuation set on the step attenuator, then subtract that from the output level of the signal generator. This is your IF rejection power level in dBm.

   IF rejection power: ____________ dBm.

6. The total IF rejection is now calculated by subtracting the IF rejection power level from the MDS of the receiver.

   IF rejection: ____________ dB.

   For example, if your signal generator is set to 0 dBm and the step attenuator is set to 43 dB, then your IF rejection power level is -43dBm. With an receiver MDS of -131dBm the IF rejection will then be: -43dbm -(-131dBm)=88dB.

Hints and Tips

- Many QRP receivers and transceivers have a relatively low-level audio output, designed for either headphones-only or for a small speaker. In order to make the most accurate measurement, you may need to turn the AF gain control to maximum.
- If the noise vary to much for your readings to be stable, a low pass integrating filter will smooth out the noise and give a stable reading. A suitable filter is a resistor of 10 k in series with the signal lead and a 1 μF capacitor, if the noise vary to much increase the capacitor to 10 μF.
- The IF rejection is the product of the mixer balance and the filter attenuation. Improving the mixer balance will improve the IF rejection.

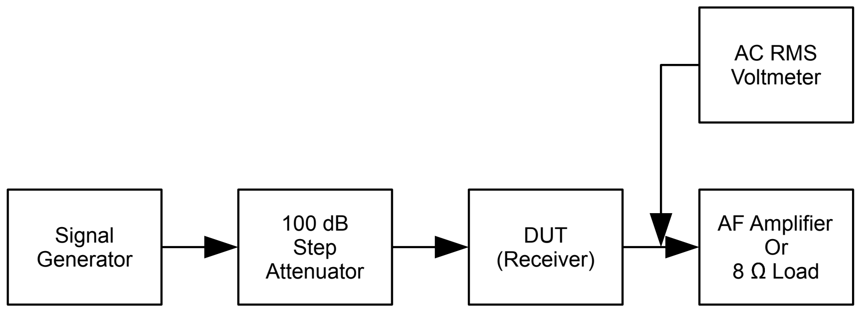

Figure 4.3: Image Rejection Measurement Setup

4.3 Image Rejection

The purpose of this test is to measure the level a CW signal on the frequency that are the same distance from the IF as the wanted signal, but in the oposite direction. This is defined as a signal on the Image frequency at the receiver antenna port which produces the same amount of AF power output as the intrinsic background noise of the receiver. For this procedure to work its important to have preformed the MDS measurement as outlined earlier in this document or the noise figure measurement.

Overview method 1

Equipment List

- RF Signal Generator
- 100 dB Step Attenuator (at least 1 dB steps required)
- AC RMS Voltmeter (preferably with dB scale)
- AF Monitor Amplifier or 8 Ω Resistive Load

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male
- 1 — audio jumper cable
  Varies depending on the connectors on your receiver and AF amplifier or load
- 1 — set of voltage probe test leads
  Your choice of connector for measuring AC RMS voltage output

Connections

Make sure all equipment is powered off before making any connections.

- Connect the signal generator output to one port of the step attenuator using a 50 Ω jumper cable.
- Connect the other port of the step attenuator to the DUT (receiver) using a 50 Ω jumper cable.
- Connect the audio output of the DUT (receiver) to the AF amplifier or 8 Ω load using an audio jumper cable.
- Connect the AC RMS voltmeter probes to the properly loaded audio output of the DUT (receiver).

Presets

- Turn ON the signal generator but make sure that the output is OFF. Set the output level to -30 dBm (if you are able to). Set the output frequency to the desired test frequency.
- Set the step attenuator for -40 dB. This will give an initial test signal level of -70 dBm. If you are not able to set your signal generator to -50 dBm, set the step attenuator to give you -70 dBm of test signal output.
- Turn ON the AF amplifier.
- Turn ON the DUT (receiver) and set for the desired measurement band and frequency. Set the AF gain (volume) control fully-counterclockwise (no AF output), then set to an appropriate level for normal listening. If your receiver has AGC, disable it.
- Turn ON the AC RMS voltmeter. Set the meter scale as necessary.

Test Procedure

1. Calculate the image frequency. If the local oscilator is higher than the reciver frequency F: $F_{IM} = F + 2 \cdot F_{IF}$ or if the local oscilator is lower than the reciver frequency F: $F_{IM} = F - 2 \cdot F_{IF}$

   Image Frequency ______________ MHz.

2. Note the reading of the AC RMS voltmeter in dB. If the meter reading is fluctuating quite a bit, you may need to increase the AF gain control of the DUT (receiver) in order to get a more stable reading.

   AF noise power ______________

3. The Image rejection power level will be the AF power level 3 dB higher than the measurement made in step 2. Calculate it below.

   AF Noise + Image rejection power level ________________

4. Turn ON the signal generator output. The reading from the AC RMS voltmeter should be significantly higher than the calculated level in step 4 . Use the controls on the step attenuator to step down the test signal level until you have a reading on the AC RMS voltmeter that is closest to the figure derived in step 4. Note the amount of attenuation set on the step attenuator, then subtract that from the output level of the signal generator. This is your Image rejection power level in dBm.

   Image rejection power: ________________ dBm.

5. The total IF rejection is now calculated by subtracting the IF rejection power level from the MDS of the receiver.

   Iimage rejection: ________________ dB.

   For example, if your signal generator is set to -30 dBm and the step attenuator is set to 6 dB, then your IF rejection power level is -36dBm. With an receiver MDS of -131dBm the IF rejection will then be: -36dbm -(-131dBm)=95dB.

Hints and Tips

- Many QRP receivers and transceivers have a relatively low-level audio output, designed for either headphones-only or for a small speaker. In order to make the most accurate measurement, you may need to turn the AF gain control to maximum.
- If the noise vary to much for your readings to be stable, a low pass integrating filter will smooth out the noise and give a stable reading. A suitable filter is a resistor of 10 k in series with the signal lead and a 1 μF capacitor, if the noise vary to much increase the capacitor to 10 μF.

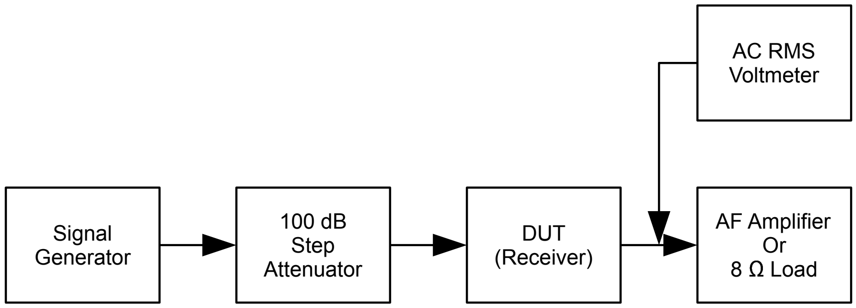

Figure 4.4: Oposite Sideband Rejection Measurement Setup

4.4 Opposite Sideband Rejection

The purpose of this test is to measure the level a CW signal on the frequency that makes the oposite sideband in the receiver. This is defined as a signal on the Image frequency at the receiver antenna port which produces the same amount of AF power output as the intrinsic background noise of the receiver. For this procedure to work its important to have preformed the MDS measurement as outlined earlier in this document or the noise figure measurement.

Overview method 1

Equipment List

- RF Signal Generator
- 100 dB Step Attenuator (at least 1 dB steps required)
- AC RMS Voltmeter (preferably with dB scale)
- AF Monitor Amplifier or 8 Ω Resistive Load

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male
- 1 — audio jumper cable
  Varies depending on the connectors on your receiver and AF amplifier or load
- 1 — set of voltage probe test leads
  Your choice of connector for measuring AC RMS voltage output

Connections

Make sure all equipment is powered off before making any connections.

- Connect the signal generator output to one port of the step attenuator using a 50 Ω jumper cable.
- Connect the other port of the step attenuator to the DUT (receiver) using a 50 Ω jumper cable.
- Connect the audio output of the DUT (receiver) to the AF amplifier or 8 Ω load using an audio jumper cable.
- Connect the AC RMS voltmeter probes to the properly loaded audio output of the DUT (receiver).

Presets

- Turn ON the signal generator but make sure that the output is OFF. Set the output level to -30 dBm (if you are able to). Set the output frequency to the desired test frequency.
- Set the step attenuator for -40 dB. This will give an initial test signal level of -70 dBm. If you are not able to set your signal generator to -50 dBm, set the step attenuator to give you -70 dBm of test signal output.
- Turn ON the AF amplifier.
- Turn ON the DUT (receiver) and set for the desired measurement band and frequency. Set the AF gain (volume) control fully-counterclockwise (no AF output), then set to an appropriate level for normal listening. If your receiver has AGC, disable it.
- Turn ON the AC RMS voltmeter. Set the meter scale as necessary.

Test Procedure

1. Calculate the center frequency of the Oposite Sideband. This should be the frequency that the receiver is tuned to subtracted from the CW tone picth if the receiver is for LSB and subtracted for USB.

   Oposite Sideband Frequency ________________ MHz.

2. Note the reading of the AC RMS voltmeter in dB. If the meter reading is fluctuating quite a bit, you may need to increase the AF gain control of the DUT (receiver) in order to get a more stable reading.

   AF noise power ________________

3. The oposite sideband power level will be the AF power level 3 dB higher than the measurement made in step 2. Calculate it below.

   AF Noise + Image rejection power level ________________

4. Turn ON the signal generator output. The reading from the AC RMS voltmeter should be significantly higher than the calculated level in step 4 . Use the controls on the step attenuator to step down the test signal level until you have a reading on the AC RMS voltmeter that is closest to the figure derived in step 4. Note the amount of attenuation set on the step attenuator, then subtract that from the output level of the signal generator. This is your Oposite sideband rejection power level in dBm.

   Oposite Sideband rejection power: ________________ dBm.

5. The total oposite sideband rejection is now calculated by subtracting the Oposite Sideband rejection power level from the MDS of the receiver.

   Oposite sideband rejection: ________________ dB.

   For example, if your signal generator is set to 0 dBm and the step attenuator is set to 16 dB, then your IF rejection power level is -16dBm. With an receiver MDS of -131dBm the IF rejection will then be: -16dbm -(-131dBm)=115dB.

Hints and Tips

- This test requires that both the receiver and signal generator are frequency stable and that the phase noise are low.
- Many QRP receivers and transceivers have a relatively low-level audio output, designed for either headphones-only or for a small speaker. In order to make the most accurate measurement, you may need to turn the AF gain control to maximum.
- If the noise vary to much for your readings to be stable, a low pass integrating filter will smooth out the noise and give a stable reading. A suitable filter is a resistor of 10 k in series with the signal lead and a 1 μF capacitor, if the noise vary to much increase the capacitor to 10 μF.

4.5 Two-Tone Third Order Dynamic Range

Equipment List

- low distortion signal source (2 pcs spaced 20KHz).
- Hybrid combiner or wilkinson divider for the frequency band of choise
- AC RMS Voltmeter (preferably with dB scale)
- AF Monitor Amplifier or 8 Ω Resistive Load (depends on speaker output impedance)

4.6 Blocking Gain Compression

4.7 Noise Figure

Noise figure measurement has the advantage of being independent from the bandwidth of the receiver. The MDS can then be calculated from the bandwidth of the receiver.

Equipment List

- Noise source with known output noise (ENR).
- AC RMS Voltmeter (preferably with dB scale)
- AF Monitor Amplifier or 8 Ω Resistive Load

Test Setup

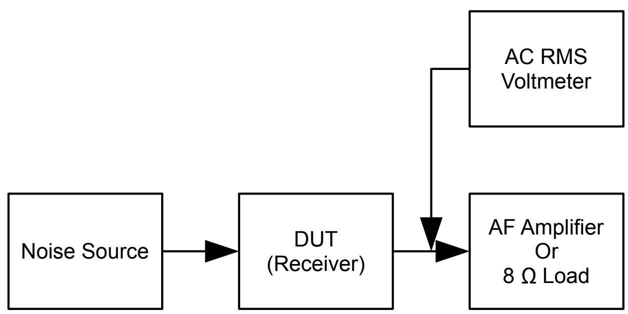

Figure 4.5: Noise Figure Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male
- 1 — audio jumper cable
  Varies depending on the connectors on your receiver and AF amplifier or load
- 1 — set of voltage probe test leads
  Your choice of connector for measuring AC RMS voltage output

Connections

Make sure all equipment is powered off before making any connections.

- Connect the noise source to the receiver input, avoid using excessive coax cables and adapters if possible.

- Connect the audio output of the DUT (receiver) to the AF amplifier or 8 Ω load using an audio jumper cable.
- Connect the AC RMS voltmeter probes to the properly loaded audio output of the DUT (receiver).

Presets

- Turn OFF the noise source.
- Turn ON the AF amplifier.
- Turn ON the DUT (receiver) and set for the desired measurement band and frequency. Set the AF gain (volume) control fully-counterclockwise (no AF output), then set to an appropriate level for normal listening. If your receiver has AGC, disable it.
- Turn ON the AC RMS voltmeter. Set the meter scale as necessary

Test Procedure

1. Record the amplitude in dB of the noise from the receiver with the noise source off.

   AF noise power __________________ dB/mV.

2. Turn on the noise source and let the output stabilize.
3. Record the amplitude in dB of the noise from the receiver with the noise source on.

   AF noise power __________________ dB/mV.

4. The ratio of the noise with the noise source on to off is the Y factor. If the measurements of the noise are in dB, the Y factor is: $Y(dB) = dB(on) - dB(off)$ If the measurement of the noise are in mV then the Y factor is: $Y = \frac{on(mV)}{off(mV)}$

   Y: __________________

5. For the noise figure calculations, the calculation is different if the measurements are done in dB or in Volt. This is due to how multiplications are done with logarithms.

6. for mV: $f = \dfrac{ENR}{Y-1}$ usually we give noise figure in dB: $NF = 20 \cdot \log(f)$
7. For the noise figure calculation in dB the noise figure is: $NF(dB) = ENR(dB) - Y(dB)$

   NF: ________________ dB

8. from the noise figure, the MDS can be calculated, knowing the receiver bandwith (BW): $MDS(dBm) = -174dBm + 10\log(BW) + NF$

   MDS: ________________ dBm

4.8 Audio Frequency Response

Overview

Audio frequency response of a receiver is how the receiver shapes the output audio. This is a important measurement to determine if the baseband and BFO is adjusted correctly. The audio frequency response is measured using white noise instead of a audio signal.

Equipment List

- RF white noise source
- step attenuator
- AF monitor amplifier or 8Ω resistive load, depending on receiver.
- Audio spectrum analyser or sound-card with spectrum analyser program.

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male
- 2 — audio jumper cables
  Varies depending on the connectors on your receiver and AF amplifier or load.

Connections

Make sure all equipment is powered off before making any connections.

- Connect the noise source to the input of the attenuator using a 50Ω jumper cable.
- Connect the output of the attenuator to the input of the receiver using a 50Ω jumper cable.
- Connect the receiver output, to the input of the monitor amplifier or load using a audio jumper cable.
- Connect the output from the monitor amplifier or load to audio spectrum analyser or computer sound-card.

Presets

- Turn on the AF amplifier.
- Turn on the Audio spectrum analyser, or start computer program and select a bandwidth of 100Hz to 5KHz, Select a proper sample rate and linear frequency. Select dB scale (logarithmic) display.
- Turn on the DUT (receiver) and set for desired measurement band and frequency. set the AF gain (volume) control to a appropriate level for normal listening. If your receiver has AGC, disable it. Put markers at the knee frequencies of your filter. For SSB this is usually 300Hz and 3000Hz.
- Set the variable attenuator at 0dB.
-

Test Procedure

1. Turn on the RF white noise source. The noise level in the receiver should increase.
2. In the spectrum analyser window, the bandwith of the filter should be visible. Adjust the RF attenuator so that the input noise level does not damage the receiver, and keep the IF amplifier in their linear range. There should be only random noise visible on the spectrum analyser.
3. Adjust the audio volume so that the spectrum analyzer shows a 20dB-40dB range between the noise output and the base noise (the RF noise generator turned off)
4. The filter frequencies should be centred on your wanted frequency and ideally mirrored around the center. If not, then this may be a proper place to adjust the BFO frequency and re-visit.

   Upper Frequency ____________________ Hz.

   Lower Frequency ____________________ Hz.

   Filter Bandwith ____________________ Hz.
5. Enable averaging and set the averaging count on the spectrum analyser to a suitable level(50 measurements). Let it run for a while to get data. Store the filter screen plot for further analysis.
6. Repeat point 3-5 for each filter in the receiver.

Hints and Tips

- Due to the power distribution of regular audio, the receiver should ideally have a slight upward slope with frequency, while transmitters should have a slight downward slope. This can usually be realized with a RC filter in the audio section.
- Most crystal filters have in-band ripple, making the measurement difficult to interpret.
- using this setup to adjust the BFO to proper frequency should make the BFO adjustment easy to do.
-

4.9 Audio Distortion

Overview

Audio distortion in a receiver is a function of both distortion in IF and audio amplifiers and in mixers. As such this measurement may be difficult to preform.

Equipment List

- RF signal generator
- Step attenuator
- AF monitor or 8Ω resistive load, depending on receiver.
- Distortion meter or computer soundcard with proper software.

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male, some adapters may be necessary
- 2 — Audio jumper cables
  Varies depending on the connectors on your receiver and AF amplifier.

Connections

Make sure all equipment is powered off before making any connections.

- Connect the output from the signal generator to the attenuator input using a 50 Ω jumper cable.
- Connect the output from the attenuator to the input of the receiver using a 50 Ω jumper cable.
- Connect the receiver output to the input of the monitor amplifier or load using a Audio jumper cable.
- Connect the output of the monitor amplifier or receiver load to the input of the distortion meter or computer sound-card.

Presets

- Turn on the AF amplifier and distortion meter or start computer program.
- Turn on signal generator. Disable the output or increase the attenuator to max and let it heat up for 1 hr. Set the signal generator to the wanted test frequency.

- Turn on the receiver, enable AGC and select a narrow filter. Tune to the frequency of the test. Set the AF control to a appropriate level for normal listening. Observe that some distortion meters require the test tone to be at a given, fixed frequency usually near 1KHz.
- Tune the receiver so that the tone is at a normal pitch (600Hz).
- Set the signal generator output level after the attenuator to a S5 level (-97dBm).

Test Procedure

1. Measure the output total amplitude without enabling the distortion meter notch, and note the amplitude:

   Output amplitude ________________ V.

2. Enable the notch and adjust to minimum deflection either by adjusting the notch frequency or by tuning the receiver to minimum output. note the amplitude:

   notched amplitude ________________ V.

3. Calculate the total distortion in

$$THD\% = \frac{Notchedamplitude}{outputamplitude} \cdot 100\%$$

   Total audio distortion ________________ %.

Hints and Tips

- This measurement can give different results with different signal levels and audio levels. The receiver noise will give high readings due to its random nature.

- This measurements should be preformed with all the different filter alternatives in the receiver.
- Most distortion analysers preform the calculations outlined automatic and the total distortion can be read off a meter. Consult your distortion meter manual.
- If this measurement are to be done with the AGC off, make sure to reduce the IF gain or reducing the input signal to avoid overloading the receiver.

4.10 Audio Power Output

Overview

Equipment List

- items

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male

Connections

Make sure all equipment is powered off before making any connections.

-

Presets

-

Test Procedure

1.

Hints and Tips

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Chapter 5

Transmitter Measurements

5.1 Transmitter Power Output

5.2 Transmitter CW Keying Waveform

5.3 Transmitter Spectral Purity

5.4 Transmitter Carrier and Unwanted Sideband Suppression

5.5 Transmitter Two-Tone Intermodulation Distortion (IMD)

Chapter 6

Components and Circuits

6.1 Crystal Parameters

Overview method 1

This method of measuring crystal parameters utilize the fact that a crystal have both a series resonance and a parallel resonance. The frequency of these are measured and the crystal parameters are then calculated. This (should) gives an improved accuracy compared to simpler methods.

Equipment List

- RF Signal Generator, DDS or synthesized with 1Hz tuning step.
- Crystal measurement jig as described under DIY equipment.
- RF RMS Voltmeter or power meter(preferably with dB scale, HP3400 or HP432 recommended.)
- 100Ω non inductive trim potentiometer

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually N Male-to-N Male
- 1 — Adapter
  Varies depending on the connectors on your generator and meter.

Connections

Make sure all equipment is powered off before making any connections.

- connect the signal generator to the series jig.
- connect the RF RMS voltmeter or power meter to the series jig.

Presets

- Set signal generator to 0dBm (1mW). Most crystals will get damaged at higher power levels.
- connect a wire, as short as possible over the crystal connections, and note the meter reading. This is your 0dB level. For the short, one can also use the shunt jig without any wire connected.

Calibration level: ________________

Test Procedure

1. Measure the parasitic package capacitance of the crystal. This should be done on a frequency far away from the crystal frequency, most meters measure this in the 100 kHz range.

2. Measure series resonance frequency in series jig by inserting the crystal and finding the frequency where the amplitude read on the meter is max. This frequency is your series frequency F_s.

   F_s: ________________ Hz.

3. Note the amplitude of the meter. This amplitude is proportional to the internal resistance in your crystal. Calculate the dB loss, this should be a negative value.
   $dB = crystalloss(dB) - referencelevel(dB)$

4. Calculate the internal resistance of the crystal: $R_s = 100 \cdot ((10^{\frac{dB}{20}})^{-1} - 1)$

   R_s: ________________ Ω.

5. measure parallel resonance freq. in shunt jig by inserting the crystal and finding the frequency where the amplitude read on the meter is max. This frequency is your parallel frequency F_p.

   F_p: ________________ Hz.

6. do some math on the data, flush and repeat..

7. The crystal motional series capacitor C_m is found by calculation:
   $C_m = C_p \cdot \frac{(F_p^2 - F_s^2)}{F_s^2}$

8. then the inductance can be found: $L_m = \dfrac{1}{c_p \cdot 4 \cdot \pi^2 \cdot (F_p^2 - F_s^2)}$

9. The Q factor of the crystal can then be found: $Q = \frac{L_m \cdot 2 \cdot \pi \cdot F_s}{R_s}$

10. With these calculations done, the crystal parameters are characterized. The accuracy of the frequency measurement is what defines the accuracy of this method.

Hints and Tips

- An automated test for this can be done with computer controlled equipment, and the crystal parameters can then be calculated automatic. This is the method most network analyzers use for characterizing crystals.

6.2 Third-Order Intercept

Overview method 1

Equipment List

- items

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male

Connections

Make sure all equipment is powered off before making any connections.

-

Presets

-

Test Procedure

1.

Hints and Tips

-

6.3 Noise Figure

Overview method 1

Equipment List

- items

Test Setup

Required Cabling

- 2 — 50 Ω jumper cables
  Usually BNC Male-to-BNC Male

Connections

Make sure all equipment is powered off before making any connections.

-

Presets

-

Test Procedure

1.

Hints and Tips

-

6.4 Resonator Q

Chapter 7

DIY Test Equipment

The projects described here are all suggestions. There are no step-by-step instructions on how to build these projects. Some projects may have kits available from Etherkit. All of the designs are open source.

7.1 Crystal Measurement Jig

- Cut 2 traces in a PCB (or order it from OSHpark: `https://oshpark.com/shared_projects/Ert6eRmg`)

- Fit 2 pieces of an IC socket to it so you keep the 50 ohm environment but it allows for measurement of crystals.

- Use good sockets, gold-plated preferred.

- Adding some attenuators helps in providing a 50 ohm environment. A matched set of attenuators can be built on the PCB's by cutting traces, and adding SMD resistors. 6dB in each leg should help the impedance match if the generator or meter impedance is not close to 50 ohms

7.2 Noise sources

The noise sources outlined here should be built using proper RF technique, and well screened. Output signal should be lead through the box using a good coax connector and feed-through capacitor for DC. Running off a 9V battery is recommended to avoid ground loop problems.

RF Noise source

Audio noise source

7.3 Distortion analyser notch filter

http://kennethkuhn.com/electronics/distortion_analyzer.pdf

7.4 AF RMS power meter

7.5 2-tone generator

7.6 Keying generator

7.7 RF -40dB power sampler

7.8 Crystal test sources

7.9 Noise sources