8 NOISE FIGURE MEASUREMENTS

1. Introduction

The effect of noise is important to the performance of most RF and microwave communication systems because noise ultimately determines the minimum signal that can be detected by a receiver. In this laboratory session, we will study a RF receiver in terms of noise.

2. Theoretical background

2.1. Noise fundamentals

Noise is a result of random processes such as the thermal vibrations, charge flow vacillation in a solid-state device, propagation through the ionosphere, etc. [1]. Noise can be passed into a system from external sources (through a receiving antenna or generally through any electromagnetic coupling), or generated in the system itself (due to random motions of charges in devices). In either case the noise level of a system sets the lower limit on the strength of a signal that can be detected in the presence of the noise. Thus, it is generally desired to minimise the noise level of a receiver to achieve the best performance.

While there are several mechanisms leading to various types of noise, the noise analysis in RF and microwave systems is the same as long as the noise spectrum is relatively flat over the system bandwidth (which is typically the case). By definition, noise with a flat frequency spectrum is called white noise. The following theoretical considerations assume white noise, hence they are directly applicable to majority of RF and microwave systems.

Consider a resistor $R$ at a physical temperature of $T$ degrees kelvin (K), as shown in Fig. 8.1a). The random motions of electrons in the resistor produce a small, random noise voltage $v_n(t)$. This voltage has a zero average value but a nonzero root-mean-square (rms) value $V_n$ that can be expressed at microwave frequencies as

$$V_n = \sqrt{4kTB} ,$$

where $k = 1.38 \times 10^{-23} \text{ J/K}$ (Boltzmann’s constant), and $B$ is the system bandwidth in Hz (we always assume that noise is passed through a system with a limited bandwidth $B$). The noisy resistor can be replaced with a Thevenin equivalent circuit consisting of a noiseless resistor $R$ and a generator with a voltage $v_n(t)$, as shown in Fig. 8.1b). Connecting a load resistor $R$ to this source results in the maximum power transfer from the noisy resistor. The noise power delivered to the load is in this case

$$N = kTB .$$

From (2) it is clear that systems with smaller bandwidths collect less noise power. Also, cooler devices and components generate less noise power.
In general, white noise sources (regardless if they are thermal or non-thermal) can be characterised with an equivalent noise temperature. This concept can be understood by observing Fig. 8.2. An arbitrary white noise source (that can be an entire electronic device, for instance) loaded by a resistor $R$ delivers a noise power $N$ to the load resistor $R$. This noise source can be replaced by a noisy resistor having the same value $R$ and being at temperature $T_e$. This temperature, called the source equivalent noise temperature (or simply the source noise temperature), is selected so that the noise power delivered to the load remains the same:

$$T_e = \frac{N}{kB}.$$  \hspace{1cm} (3)

The source noise temperature is not necessarily equal to the source physical temperature (in fact, it can be drastically different).

Components can be characterised in terms of noise by their equivalent noise temperature $T_e$. One important example is a noisy amplifier with a bandwidth $B$, gain $G$, and matched to source and load resistors $R$, as shown in Fig. 8.3. Even if the source resistor is at a (hypothetical) temperature of 0 K (zero input noise power), the output noise power $N_{out}$ will not be zero due to extra noise generated in the amplifier itself. We typically model this noise by introducing a noisy resistor $R$ having temperature $T_e$ and driving an idealised (noiseless) version of the amplifier. The resistor temperature is defined simply as $T_e = N_{out}/GkB$ so that the output noise power can be expressed as $N_{out} = GkT_eB$. Temperature $T_e$ is what we call the equivalent noise temperature of the amplifier.
Noise figure $F$ is another convenient measure to characterise devices in terms of noise. It is defined as the ratio of signal-to-noise ratios (SNRs) at the input and the output of a device. An input noise temperature of $T_0 = 290$ K (standard room temperature) and impedance matched device are assumed.

$$ F = \frac{\text{SNR}_{\text{in}}}{\text{SNR}_{\text{out}} |_{T_0}}. \quad (4) $$

Noise figure is a number greater than 1 (or 0 dB) because the output SNR is always lower due to some extra noise generated in any device (which can be directly added to the amplified noise power from the input). It is easy to show [1] that the noise figure $F$ and the equivalent temperature $T_e$ are related as

$$ F = 1 + \frac{T_e}{T_0}, \quad (5) $$

$$ T_e = (F - 1)T_0. \quad (6) $$

In a typical microwave system the input signal travels through a cascade of several different components, each degrading the SNR to some degree. If the noise figure $F_i$ (or equivalent noise temperature $T_{ei}$) and the gain $G_i$ of the individual stages are known, the overall equivalent noise temperature and noise figure can be calculated as

$$ T_e = T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1G_2} + ..., \quad (7) $$

$$ F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + ..., \quad (8) $$

where $F_1$ and $G_1$ are the parameters of the first stage and so forth. It should be noticed from (7) and (8) that the noise characteristics of a cascade are dominated by the noise characteristics of the first stage, especially if the gain of the first stage is high. Therefore, while designing a receiver, expense and effort should be devoted primarily to the first stage, which is typically a preamplifier.

### 2.2. Noise figure measurements

In this laboratory session we will measure the noise figure using a direct method and a comparison method (Y-factor method). The methods are briefly explained in the following.
2.2.1. Direct method

In this method, we start by measuring the output noise power $N_{\text{out}}$ of the DUT being driven with a matched noise source at temperature $T_0$ (for instance a matched load at the room temperature), as shown in Fig. 8.4. Knowing that white noise powers are additive, and assuming that DUT’s equivalent noise temperature is $T_e$, the output noise power is equal to $N_{\text{out}} = G k B (T_0 + T_e)$. By developing the noise figure definition, it is evident from (9) that the noise figure can be calculated if $N_{\text{out}}$, $G$, and $B$ are known, which is exactly what we do here (DUT gain $G$ and bandwidth $B$ can also be obtained relatively easily, which will be detailed later in the experiment instructions). In addition, it is clear that the noise figure can also be formulated as the ratio of the output noise power of the real DUT ($N_{\text{out}}$) and the idealised (noiseless) DUT ($N_{\text{out,ideal}}$):

$$F = \frac{\text{SNR}_{\text{in}}}{\text{SNR}_{\text{out}}} = \frac{\frac{P_{\text{sig}}}{N_{\text{out}}}}{\frac{G P_{\text{sig}}}{G k T_0 B}} = \frac{G k B (T_0 + T_e)}{G k T_0 B} = \frac{N_{\text{out}}}{N_{\text{out,ideal}}}. \quad (9)$$

![Fig. 8.4 Direct noise figure measurement method principle.](image)

2.2.2. Comparison method (Y-factor method)

In the comparison method, illustrated in Fig. 8.5, we drive the DUT by two matched noise sources whose noise temperatures $T_1$ and $T_2$ are significantly different (let $T_2 > T_1$). We obtain the following output noise powers:

$$N_{\text{out,1,2}} = G k B (T_{1,2} + T_e). \quad (10)$$

If we define the output noise ratio as $Y = N_{\text{out,2}} / N_{\text{out,1}}$ (which can be straightforwardly obtained by measurements), the equivalent noise temperature and noise figure of the DUT read

$$T_e = \frac{T_2 - Y T_1}{Y - 1}, \quad (11)$$

$$F = \frac{T_e}{T_0} = \frac{T_2 - Y T_1}{T_0 (Y - 1)} \quad (12)$$

In practice, this measurement is performed by utilising an electronic noise source (often based on an avalanche diode) whose noise temperature can be switched in two states so that $T_{\text{off}} = T_1 = T_0$ and $T_{\text{on}} = T_2$ is known indirectly through an excess noise ratio (ENR) defined as $\text{ENR} = (T_2 - T_0) / T_0$. The ENR is typically given by the manufacturer in a table form (as ENR(dB) vs. frequency). By taking into account that $T_1 = T_0$ and the ENR definition, the noise figure expression from (12) is simplified to

$$F = \frac{\text{ENR}}{Y - 1}. \quad (13)$$
Noise figure analyzer

A noise figure analyzer (or noise figure meter) is an instrument enabling fast and accurate noise figure measurements [2] based on the Y-factor method.

The instrument (see principle scheme in Fig. 8.6) essentially consists of a noise source with two noise temperatures \((T_{\text{off}}\) and \(T_{\text{on}}\)) and a power meter that measures the noise power \(N\). The inherent characteristics of the instrument, such as its own gain, bandwidth, and noise figure can be expressed in the form of a noisy amplifier. When a DUT is connected, a cascade of the DUT and the instrument is actually measured, as illustrated in Fig. 8.6. In order to extract the DUT gain and noise figure, the measurement is preceded by a calibration during which the instrument itself is being measured (the noise source is connected directly to the instrument input). If we assign index ‘2’ to the instrument (as in Fig. 8.6), we can write that

\[
Y_2 = \frac{N_{2 \text{on}}}{N_{2 \text{off}}} = \frac{T_{\text{on}} + T_{e2}}{T_{\text{off}} + T_{e2}} \rightarrow T_{e2} = \frac{T_{\text{on}} - Y_2 T_{\text{off}}}{Y_2 - 1}. \tag{14}
\]

Next, the cascade is being measured. By assigning index ‘12’ to the cascade we obtain

\[
Y_{12} = \frac{N_{12 \text{on}}}{N_{12 \text{off}}} = \frac{T_{\text{on}} + T_{e12}}{T_{\text{off}} + T_{e12}} \rightarrow T_{e12} = \frac{T_{\text{on}} - Y_{12} T_{\text{off}}}{Y_{12} - 1}. \tag{15}
\]

Further post-processing of the measured noise power values \(N_{2 \text{on}}\), \(N_{2 \text{off}}\), \(N_{12 \text{on}}\), and \(N_{12 \text{off}}\) enables the straightforward DUT gain calculation. We can write:

\[
N_{2 \text{on/off}} = (T_{\text{on/off}} + T_{e2}) G_2 kB, \tag{16}
\]

\[
N_{12 \text{on/off}} = (T_{\text{on/off}} + T_{e12}) G_1 G_2 kB + T_{e2} G_2 kB. \tag{17}
\]

DUT gain \(G_1\) can be obtained from (16) and (17) as

\[
G_1 = \frac{N_{12 \text{on/off}} - N_{12 \text{off}}}{N_{2 \text{on/off}} - N_{2 \text{off}}}. \tag{18}
\]

Finally, since the equivalent noise temperature of the cascade \(T_{e12}\) and of the instrument \(T_{e2}\) are already known, the DUT equivalent noise temperature \(T_{e1}\) and noise figure \(F_1\) can be calculated from (7) and (5) as

\[
T_{e1} = T_{e12} - T_{e2} / G_1 \rightarrow F_1 = 1 + \frac{T_{e1}}{T_{0}}. \tag{19}
\]
By default, the instrument display shows the results interesting to the operator, therefore the DUT gain $G_1$ and noise figure (temperature) $F_1 (T_{e_1})$ vs. frequency.

![Noise figure analyzer principle](Fig. 8.6 Noise figure analyzer principle.)

### 3. Experiments

#### 3.1. Utilised equipment

- ‘870 MHz receiver for noise measurement’
- DC-power supply HP E3630A x2
- DC-power supply HP E3612A
- Oscillator 870 MHz
- Step attenuator 0 – 110 dB HP 8496B
- Fixed attenuator 3 dB Narda 757C
- Matched load Narda 370NM
- Signal generator HP 8648C
- Noise source Ailtech 7615
- Power meter HP 438A with the power sensors HP 8458A and HP 8481D
- Spectrum analyzer HP 8561E
- Noise figure analyzer Agilent N8975A with the noise source Agilent N4002A
- Some adapters (SMAm-SMAf /push-on/ x3, SMAm-SMAm, SMAf-SMAf, NF-SMAf, Nm-SMAm…)

#### 3.2. Experiment setup

The ‘870 MHz receiver for noise measurement’ (see the block diagram in Fig. 8.7) is an assembly forming a UHF heterodyne receiver (without detector) at 870 MHz. It comprises:

- A low noise preamplifier in the 870 MHz band ($G = 23$ dB, $F = 2$ dB)
- A three-stage coupled line band-pass filter ($B = 59$ MHz)
- A mixer
- An intermediate frequency (IF) stage ($f_{IF} = 250$ MHz) consisting of a four-stage band-pass filter ($B = 7$ MHz), amplifier ($G = 60$ dB, $F = 1.5$ dB), and a single stage filter ($B = 15$ MHz)

The receiver must be biased by 15 V from the HP E3630A DC power supply.
The 870 MHz oscillator (biased with 12 V from the second HP E3630A DC power supply) connected to the receiver RF input (via the step attenuator) will play the role of the RF signal and it will be utilised to measure the receiver gain. The signal generator serves as the local oscillator (LO). The matched load will be used as a matched noise source at the room temperature $T_0$ in the direct noise figure measurement method. The electronic noise source Ailtech 7615 will be utilised in the noise figure measurement based on the Y-factor. Power measurements (signal and noise) will be performed by the power meter, and a few verifications and measurements will be done using the spectrum analyzer. Finally, the capabilities of the noise figure analyzer will be demonstrated on the same receiver.

3.3. Measurements

Convention used in this document: HARD KEY, Soft Key.

3.3.1. Direct noise figure measurement

This measurement method is described in Section 2.2.1. Therefore, what we have to do is to measure the output noise power $N_{out}$, gain $G$, and bandwidth $B$ of the receiver, and apply (9). The ambient temperature is assumed to be $T_0 = 290$ K ($17^\circ$ C).

Experiment setup preparation

Adjust the step attenuator to 70 dB and connect it together with the 870 MHz oscillator to the RF input. Turn on all the equipment and let it warm up for at least 20 min. Set the power level of the signal generator to +8 dBm (so that +7 dBm is delivered to the mixer after passing through the cable), and frequency to 620 MHz. Zero the power meter for both power sensors (note that no signal must be present on the power sensor while zeroing). Adjust the spectrum analyzer. Start by pressing PRESET to bring it in a well-defined default state. Then, set FREQUENCY/Center Freq/250 MHZ, SPAN/50 MHZ. Fine tune the signal generator (LO) frequency to get the IF spectral line in the middle of the ‘noise bump’ on the spectrum analyzer display. This can be done precisely by observing the signal power level on the spectrum analyzer and bringing it to the maximum value by adjusting the LO frequency.

Note: Handle the 870 MHz oscillator gently. Its operating frequency can considerably change even if it is slightly taped (for instance by putting it on the table in a reckless manner).
**Output noise power** \( N_{\text{out}} \)

Connect the matched load (i.e. the matched noise source at \( T_0 \)) to the RF input of the receiver, turn off the 870 MHz oscillator (the receiver is very sensitive and picks the oscillator signal even when there is no direct connection), and connect the spectrum analyzer to the IF output. Observe the ‘noise bump’. Try to explain its width and shape. Disconnect the spectrum analyzer from the IF output and connect the power sensor \( HP \ 8481D \) (range 100 pW – 10 \( \mu \)W) instead. Write down the measured value in Table 8.1, repeat the measurement twice, and calculate the mean value.

**Gain** \( G \)

**IMPORTANT:** The attenuation of the step attenuator must always be greater than 20 dB when it is connected to the receiver. Otherwise, the preamplifier may be destroyed.

Connect the assembly of the 870 MHz oscillator and the step attenuator (set to 100 dB) to the RF input of the receiver. Connect the spectrum analyzer to the IF output. The IF spectral line should reappear nearly in the middle of the ‘noise bump’ (if needed, re-tune the LO frequency to get it back in the middle). Now, reduce the attenuator in steps of 10 dB (do not go under 20 dB) and observe the spectrum analyzer display. To what corresponds the observed effect?

Reset the attenuation to 70 dB. Apparently, this value is a good compromise as the receiver operates in the linear region (no distortion) and the output SNR is high (so the measured signal power will not be affected by noise).

Connect the power sensor \( HP \ 8485A \) (range 1 \( \mu \)W – 100 mW) to the IF output. Set the power mode on dBm mode and press REL. The displayed value will turn to 0 dBm. Now connect the probe directly to the step attenuator output, and reduce its attenuation until reading a value between 0 dBm and –10 dBm (now the attenuation can be reduced even below 20 dB since the step attenuator is not connected to the receiver). We can then calculate the gain of the receiver directly from the attenuation difference and the value displayed on the power meter: \( G = 70 \text{ dB} - \text{(final attenuation)} + \text{abs(final reading)} \). This is a substitution measurement that we need to resort to since the dynamic range of the power meter is not large enough for direct measurement.

Write down the measured value in Table 8.1. **Reset the step attenuator to 70 dB.** Repeat the measurement twice and calculate the mean value of \( G \) (calculate the mean value using the numerical values, not the values in dB). Before each measurement check that the IF spectral line is still in the middle of the receiver bandwidth (adjust the LO frequency if necessary).

**Bandwidth** \( B \)

Connect the spectrum analyzer to the IF output of the receiver and the matched load to the RF input. Adjust the center frequency of the spectral analyzer to have the ‘noise bump’ in the middle of the display. Furthermore, set the following: SPAN/10 MHz, AMPLITUDE/Log dB/div/1 dB, AMPLITUDE/Ref Lvl/-47 dB, BW/Video BW/Man/30 Hz, TRACE/More/Video Avg/On. Measure the 3 dB-bandwidth \( B_{3\text{dB}} \) using the automatic procedure available: USER MEAS/3 dB Points. Since the IF filter is not ideal (and in the noise calculations we assume ideal filters with infinitely steep slope), the bandwidth \( B \) that is required for calculations is nearly equal to the 3 dB-bandwidth multiplied by a factor which depends on the IF filter frequency response. Here
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this factor is estimated to be around 1.2, \( B = 1.2 \times B_{3dB} \). Write down the measured value (corrected by the factor 1.2) in Table 8.1, repeat the measurement twice, and calculate the mean value.

Noise figure \( F \)

Calculate the noise figure from the obtained measurement results as:

\[
F = \frac{N_{\text{out}}}{kT_B G}.
\]

The noise figure can be transformed in decibels as \( F, \text{dB} = 10\log_{10}(F) \).

\[
F = \text{_______ ; _______ dB (direct measurement method).}
\]

Table 8.1 Direct measurement method results.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>( N_{\text{out}}, \mu W )</th>
<th>( G, \text{dB} )</th>
<th>( B, \text{MHz} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2\textsuperscript{nd}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3\textsuperscript{rd}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean value</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.2. Comparison method (Y-factor method)

This measurement method is described in Section 2.2.2. We will use the noise source Ailtech 7615 to generate two levels of noise at the RF input, namely \( T_1 = T_0 \) and \( T_2 \). The ENR of this noise source is given as a table on its casing; the value at 870 MHz is 15.2 dB (33.11). The noise at the IF output \( N_{\text{out1,2}} \) will be measured by the power meter. Finally, the noise figure will be calculated from (13).

Experiment setup preparation

Before this measurement, connect the assembly of the 870 MHz oscillator and step attenuator (set to 70 dB) to the RF input. Connect the spectrum analyzer to the IF output and, if necessary, fine tune the LO frequency in order to get the IF spectral line in the middle of the ‘noise bump’. Then remove this assembly and the spectrum analyzer and connect the noise source Ailtech 7615 to the RF input of the receiver. Repeat the zero procedure for the power meter (both power sensors).

Measurement

The noise source Ailtech 7615 is biased by the HP E3612A DC power supply. When the DC power is off, the noise source acts as the matched source at the temperature \( T_0 \). When the DC voltage is set to 28 V, the noise source acts as the matched source at the temperature \( T_2 \).

Measure three times the output noise power \( N_{\text{out1}} \) (DC power off; source at \( T_0 \)) using the power sensor HP 8481D and \( N_{\text{out2}} \) (DC voltage at 28 V; source at \( T_2 \)) using the power sensor HP 8485A. Calculate each time the ratio \( Y = N_{\text{out2}}/N_{\text{out1}} \) and find the mean value for \( Y \). Write the results in Table 8.2.
Calculate the noise figure from the obtained results as $F = \frac{ENR}{Y - 1}$. Transform this value in decibels as well.

$F = \________ ; \________$ dB (comparison (Y-factor) measurement method).

Compare and comment the results obtained by the two noise measurement methods.

Table 8.2 Comparison (Y-factor) measurement method results.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>$N_{out1}$, $\mu W$</th>
<th>$N_{out2}$, $\mu W$</th>
<th>$Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3rd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean value</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**3.3.3. Measurements with $f_{LO} > f_{RF}$**

Until this point, the measurements have been performed with $f_{LO} = 620$ MHz. As the RF signal is at $f_{RF} = 870$ MHz, the mixing product $f_{RF} - f_{LO} = 250$ MHz (that could carry the same information as the input RF signal) was exactly at the IF frequency $f_{IF}$. Therefore, this signal was passed by the IF section and appeared at the IF output. However, we must always be aware that the mixer is a non-linear device meaning that any combination of the input signal frequencies theoretically exists at its output. Consequently, the same RF signal $f_{RF} = 870$ MHz could be processed by the same receiver even if the local oscillator frequency was $f_{LO} = 1120$ MHz because in this case we would have the mixing product $f_{LO} - f_{RF} = 250$ MHz that would again be exactly at the IF frequency.

We will first verify that the above discussion holds in practice. Therefore, connect the spectrum analyzer to the IF output, preset it, and set **FREQUENCY/Center Freq/250 MHz, SPAN/50 MHz**. Now connect again the same assembly of the 870 MHz oscillator and step attenuator (set to 70 dB) to the RF input, but this time set the local oscillator frequency to $f_{LO} = 1120$ MHz. The IF spectral line should appear on the spectrum analyzer display, which means that the receiver still works and that the above discussion is correct. If necessary, fine-tune the LO frequency to get the spectral line in the middle of the ‘noise bump’.

Repeat the noise figure measurement (using the Y-method only).

$F = \________ ; \________$ dB (comparison (Y-factor) measurement method; $f_{LO} > f_{RF}$).

What causes the difference between this result and the result obtained by the same method but with $f_{LO} < f_{RF}$ (previous section)?
Table 8.3 Comparison (Y-factor) method results; \( f_{LO} > f_{RF} \).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>( N_{out1}, \mu W )</th>
<th>( N_{out2}, \mu W )</th>
<th>( Y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(^{st} )</td>
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<td></td>
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<td>2(^{nd} )</td>
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</tr>
<tr>
<td>3(^{rd} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean value</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Another consequence of the inherent non-linear mixer behaviour is that for a given local oscillator frequency \( f_{LO} \), two different RF signals \( f_{RF1} \) and \( f_{RF2} \), (where \( \frac{f_{RF1} + f_{RF2}}{2} = f_{LO} \) and \( f_{RF2} - f_{RF1} = 2f_{IF} \)) are down-converted to the same IF frequency as \( f_{LO} - f_{RF1} = f_{IF} \) and \( f_{RF2} - f_{LO} = f_{IF} \). Since the frequency is the same, separation by the bandpass filters in the IF section is impossible. Because these two components in general carry different information (as they stem from different RF signals) they will interfere one with each other. As a result, the reception of any of the two signals will be blocked. This is why a heterodyne receiver contains a lowpass or bandpass (preselector) filter at its input. The role of this filter is to suppress one of the RF signals (the image frequency) entering the receiver and consequently the interference in the IF section. The preselector filter of our receiver is located after the preamplifier. As its bandwidth is 59 MHz, it significantly supresses signal at the image frequency (which would be 370 MHz for \( f_{LO} = 620 \) MHz or 1370 MHz for \( f_{LO} = 1120 \) MHz).

3.3.4. Noise figure analyzer demonstration

As a final point of this laboratory session, some basic capabilities of the noise figure analyzer Agilent N8975A will be demonstrated.

Calibration

As explained in the theoretical part (Section 2.2.2.), the NF analyzer must be calibrated prior to the measurements. Here we will calibrate it in the frequency band 820 MHz to 920 MHz because we will use it to measure some components of our receiver. During the calibration, the instrument measures ‘itself’, so the noise source is connected directly to the instrument input. Any cables that may be required during the measurements should be included in the calibration process (as if they were a part of the instrument).

Measurement

We will start by measuring the noise figure of the preamplifier (with the preselector). Therefore, we will remove the cable connecting the preselector filter with the mixer, connect the noise source to the RF input, and connect the preselector to the instrument input (the preselector has virtually no influence on the noise figure and gain around the operating frequency of 870 MHz). Write down the measured gain and noise factor at 870 MHz. Also, take a photo of the instrument display.

\[ G = \text{_______ dB; } F = \text{_______ dB (preamplifier).} \]
Of course, the noise factor measured here cannot be directly compared to the results obtained previously because here the IF section is omitted. However, since the gain of the preamplifier is rather high, the noise figure of the whole receiver is determined mainly by the preamplifier.

Now, we will measure the 3 dB attenuator. Theoretically [1], the noise figure of an attenuator is equal to its attenuation. Write down the measured gain and noise factor at 870 MHz. Also, take a photo of the instrument display.

\[ G = \ldots \text{dB}; \quad F = \ldots \text{dB} \text{ (attenuator).} \]

Finally, we will measure the cascade of the attenuator and the preamplifier. First, let us connect the attenuator as the first device in the cascade (therefore at the input). Write down the measured gain and noise factor at 870 MHz. Also, take a photo of the instrument display. Then, let us interchange the component order (attenuator to be the last component of the cascade). Write down the measured gain and noise factor at 870 MHz. Also, take a photo of the instrument display.

\[ G = \ldots \text{dB}; \quad F = \ldots \text{dB} \text{ (attenuator + preamplifier);} \]
\[ G = \ldots \text{dB}; \quad F = \ldots \text{dB} \text{ (preamplifier + attenuator).} \]

What is the difference between these two results above? Can you think of any impact this result may have in practice?

4. References

[2] Agilent Application Note AN57-2: Noise Figure Measurement Accuracy – The Y-Factor Method
http://www.home.agilent.com/agilent/redirector.jspx?action=ref&cname=AGILENT_EDITORIAL&ckey=100000179%3Aepsg%3Aapn&lc=ger&cc=CH&nfr=-536902445.0.00