Determination of Image Rejection with an Uncalibrated RF Source

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The image rejection of a sideband-separating receiver can be measured by injecting CW signals into the upper and lower sidebands and measuring the IF response to each. If the relative RF power levels of the two sideband signals are known, the calculation is straight forward. At millimeter wavelengths, however, it is extremely difficult to determine accurately the relative power levels of two extremely low level signals separated in frequency by twice the IF (8–24 GHz in the case of ALMA receivers). The image rejection can be determined without a knowledge of the RF signal levels if the IF response to calibrated broadband RF noise sources at two temperatures is also measured.

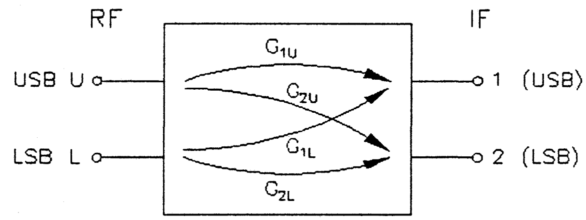

Fig. 1. Definition of terms for the sideband-separating receiver. The RF upper and lower sideband ports would normally be the same waveguide or transmission line, but are shown separately here for clarity.

The sideband separating receiver is depicted in Fig. 1, with the conversion gains from each RF input port to each IF output port denoted by the quantities $G_{i,j}$. The desired image rejection ratios are:

$$R_1 = \frac{G_{1U}}{G_{1L}} \text{ at IF port 1, and } R_2 = \frac{G_{2L}}{G_{2U}} \text{ at IF port 2.}$$

The following measurements are made:

(i) With an RF test signal (of unknown amplitude) in the upper sideband, the corresponding IF signals at IF ports 1 and 2 are measured. The ratio of these powers is

$$M_U = \frac{G_{1U}}{G_{2U}} . \tag{1}$$

(ii) With an RF test signal (of unknown amplitude) in the lower sideband, the corresponding IF signals at IF ports 1 and 2 are measured. The ratio of these powers is

$$M_L = \frac{G_{2L}}{G_{1L}} . \tag{2}$$

(iii) With hot and cold loads at the receiver input, measure the change of output power at IF ports 1 and 2. If the difference in noise temperature between the hot and cold loads is ΔT, then

$$\Delta P_1 = kB\Delta T\left(G_{1U} + G_{1L}\right) , \tag{3a}$$

$$\Delta P_2 = kB\Delta T\left(G_{2U} + G_{2L}\right) . \tag{3b}$$

Define

$$M_{DSB} \triangleq \frac{\Delta P_1}{\Delta P_2} = \frac{G_{1U} + G_{1L}}{G_{2U} + G_{2L}} . \tag{4}$$

The measured quantities M_U, M_L, and M_{DSB} can now be used to deduce the sideband separation ratios R_1 and R_2.

First, it is convenient to normalize all the G_{ij} to G_{2L}, so $g_{1U} = \frac{G_{1U}}{G_{2L}}$, $g_{2U} = \frac{G_{2U}}{G_{2L}}$, $g_{1L} = \frac{G_{1L}}{G_{2L}}$,

and $g_{2L} = 1$. The desired image rejection ratios become:

$$R_1 = \frac{g_{1U}}{g_{1L}} \text{ and } R_2 = \frac{g_{2L}}{g_{2U}} = \frac{1}{g_{2U}}. \tag{5}$$

From (1):
$$0 = g_{1U} - M_U g_{2U} \quad \Rightarrow \quad g_{2U} = \frac{g_{1U}}{M_U} \ . \tag{6}$$

From (2):
$$0 = 1 - M_L g_{1L} \quad \Rightarrow \quad g_{1L} = \frac{1}{M_L} \ . \tag{7}$$

From (4):
$$0 = g_{1U} + g_{1L} - M_{DSB} - M_{DSB} g_{2U} \ . \tag{8}$$

From (6), (7) and (8):
$$0 = g_{1U} + \frac{1}{M_L} - M_{DSB} - M_{DSB} \cdot \frac{g_{1U}}{M_U} \ ,$$

Therefore,
$$g_{1U} = \frac{M_{DSB} - \frac{1}{M_L}}{1 - \frac{M_{DSB}}{M_U}} . \tag{9}$$

From (9) and (6):
$$g_{2U} = \frac{M_{DSB} - \frac{1}{M_L}}{M_U - M_{DSB}} \ . \tag{10}$$

So, in (5):
$$R_1 = \frac{g_{1U}}{g_{1L}} = M_U \cdot \frac{M_L M_{DSB} - 1}{M_U - M_{DSB}} \ , \tag{11}$$

and
$$R_2 = \frac{g_{2L}}{g_{2U}} = M_L \cdot \frac{M_U - M_{DSB}}{M_L M_{DSB} - 1} \ . \tag{12}$$

Note that
$$R_1 R_2 = M_U M_L \ . \tag{13}$$

<u>Discussion</u>

The frequencies of the upper- and lower-sideband CW test signals used in determining M_U and M_L must be chosen to give the same intermediate frequency f_0. During the measurements with the RF noise sources, a narrow-band IF filter centered at the same f_0 should be used. The bandwidth B of the filter should be smaller than the width of any features on the receiver gain, noise, or image rejection characteristics.

The levels of the CW test signals need not be known, but they must be low enough to avoid saturation in the IF measuring system, and large enough to give a measurable response above the noise floor at the isolated ports.

It is not necessary to know the noise temperatures of the hot and cold RF loads, nor the difference ΔT. However, ΔT should be sufficiently large not to compromise the measurement accuracy.

Depending on the details of the sideband separating receiver in Fig. 1, it may be necessary to ensure that the terminations on IF ports 1 and 2 do not change during the measurements. If the receiver contains IF amplifiers or isolators in such a way that ports 1 and 2 are isolated from one another, then the measurement of M_U, M_L, and M_{DSB} can be done by connecting the IF measuring system to ports 1 and 2 without concern for the termination on the unused port (*e.g.*, using a simple coaxial SP2T switch). If, on the other hand, IF ports 1 and 2 are not isolated, as would be the case when ports 1 and 2 are the output ports of the IF quadrature hybrid of a sideband separating mixer, then care must be taken to ensure that both ports remain properly terminated throughout the measurement. This can be achieved using a coaxial changeover switch.

If an IF switch is used in these measurements and is connected to the junctions of an SIS mixer, it must be chosen to have low static. We have found that most mechanical microwave switches generate a static pulse during switching sufficient to damage an SIS mixer.