# Impedance, admittance, Nyquist, Bode, Black, etc.

### *Available instruments for impedance measurements*

| *Instrument* | *MPG* | *VMP* | *VMP2* | *BiStat* |
|---|---|---|---|---|
| Used | | | × | |
| Alternative | | | | × |

## IMPEDANCE OR ADMITTANCE NYQUIST'S DIAGRAMS

Impedance **Z** and admittance **Y** are two inverse transfer functions linked by the following very simple relation:

$$Z = \frac{1}{Y} \qquad (1)$$

Let us consider the electrical circuit shown in Fig. 1 corresponding to test circuit #1 of the VMP2 and BiStat testing box.

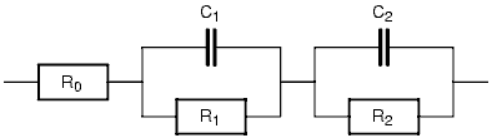


**Figure 1 – Voigt circuit made of three Rs and two Cs.**

The experimental Nyquist diagram of the impedance **Z** is show in Fig. 2 (cf. Linear vs. non linear systems application note). Frequency values are lost in the Nyquist diagram therefore it is useful to indicate the frequency of some characteristic points (top of the semi-circles).

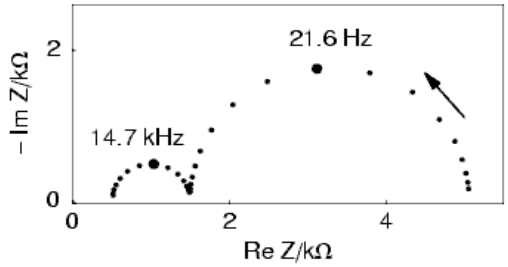


**Figure 2 – Nyquist impedance diagram of the electrical circuit shown in Fig. 1. Arrow always indicates increasing frequencies.**

Obviously the high frequency semi-circle is smaller than the low frequency semi-circle. To highlight the high frequency part of the diagram it is better to plot admittance diagram instead of impedance diagram as it is shown in Fig. 3.

Admittance diagram in Fig. 3 better shows the high frequency semi-circle. Does the graph of the admittance contain more information than the graph of the impedance? In fact admittance diagram only presents information differently.

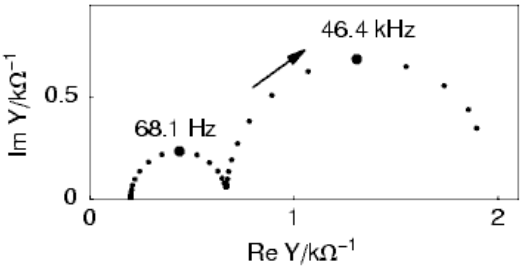


**Figure 3 – Nyquist admittance diagram of the electrical circuit shown in Fig. 1.**

## IMPEDANCE OR ADMITTANCE BODE DIAGRAMS

To be convinced of that we can plot the impedance and admittance Bode diagrams as shown in Figure 4. Let us recall that plotting the Bode diagram of a transfer function **H** consists in plotting the decimal logarithm of the magnitude of **H** given by:

$$|H| = \sqrt{(\mathrm{Re}\,H)^2 + (\mathrm{Im}\,H)^2}$$

and the phase of **H** given by:

$$\varphi_H = \arctan\frac{\mathrm{Im}\,H}{\mathrm{Re}\,H}$$

versus the decimal logarithm of frequency or radial frequency.

According to Eq. (1) it is obvious that

$$\log|Y| = -\log|Z|$$

and

$$\varphi_Y = -\varphi_Z$$

The graphs showing magnitude and phases on figure 4 are symmetrical with respect to the horizontal axis. There is no more information in an admittance diagram than in an impedance diagram.

## IMPEDANCE OR ADMITTANCE BLACK DIAGRAM

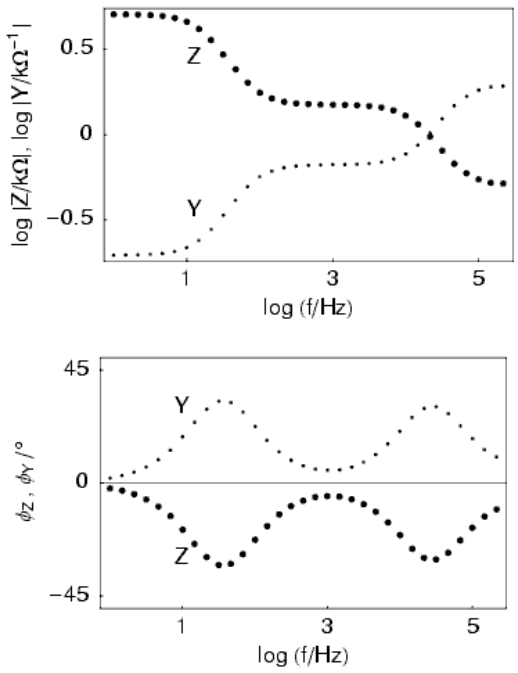


**Figure 4 – Bode impedance and admittance diagrams of the electrical circuit shown in Fig. 1. Thick curves : Z, thin curves : Y.**

Electricians use other representations, such as Black diagrams for example where the decimal logarithm of the magnitude is plotted versus the phase (Fig. 5).

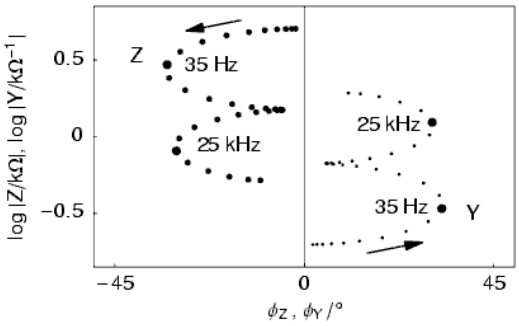


**Figure 5 – Black impedance and admittance diagrams of the electrical circuit shown in Fig. 1. Thick curves : Z, thin curves : Y.**

As for Nyquist diagram frequency values are lost in Black diagram, therefore it is useful to indicate the frequency of some characteristic points.

Note: the diagrams of this document have been plotted with Mathematica ™ software from experimental data obtained with EC-Lab software.