Newcomers' Notebook

Running circles around the Smith Chart

Simple explanation without complex mathematics

by Jules Perrin VK3JFP

A Smith Chart appears complicated, cluttered, and unintelligible to the newcomer. So let us break it down and help you to gain the most from them. The Smith Chart can display multifaceted computations, but this article will only look at the basics. This article is not meant to be a total coverage of what a Smith Chart can do, but as an introduction for Newcomers.

Connecting a transmission line to antenna, we understand that we can get a reflecting wave if the impedance of the antenna and transmission line are not matched. Matching the transmission line to the antenna ensures maximum transfer of the signal to the antenna.

The ratio of the reflected wave amplitude to the transmitted wave amplitude is called the reflection coefficient. This reflection coefficient is represented by the Greek letter gamma (Γ). This reflected wave has a resistance and a reactance component when measured with a Vector Network Analyser (VNA) and is displayed as a complex number such as Z = 25 + j40.

A complex number is the sum of a real number (In this case 25) and an imaginary number. (In this case j40) The real number is the resistance, and the imaginary part is the reactance. That's as far as we go with complex number mathematics.

Smith Chart

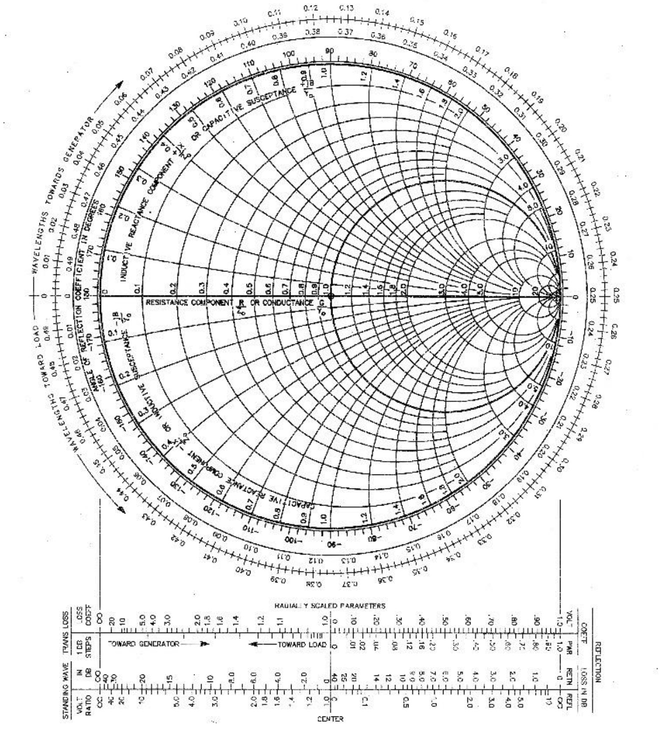

Figure 1: Smith Chart.

A Smith Chart is shown in Figure 1 at a reduced size. The chart has circles / arcs representing units of measurement. The outer rings provide information to assist impedance matching.

The ruler below the chart provides additional information on SWR and other quantifiable figures derived from the plot.

This article will use a stripped-down Smith Chart is shown at Figure 2 for ease of explanation. The resistance is displayed on the straight line across the middle. The resistance circles cut the resistance line.

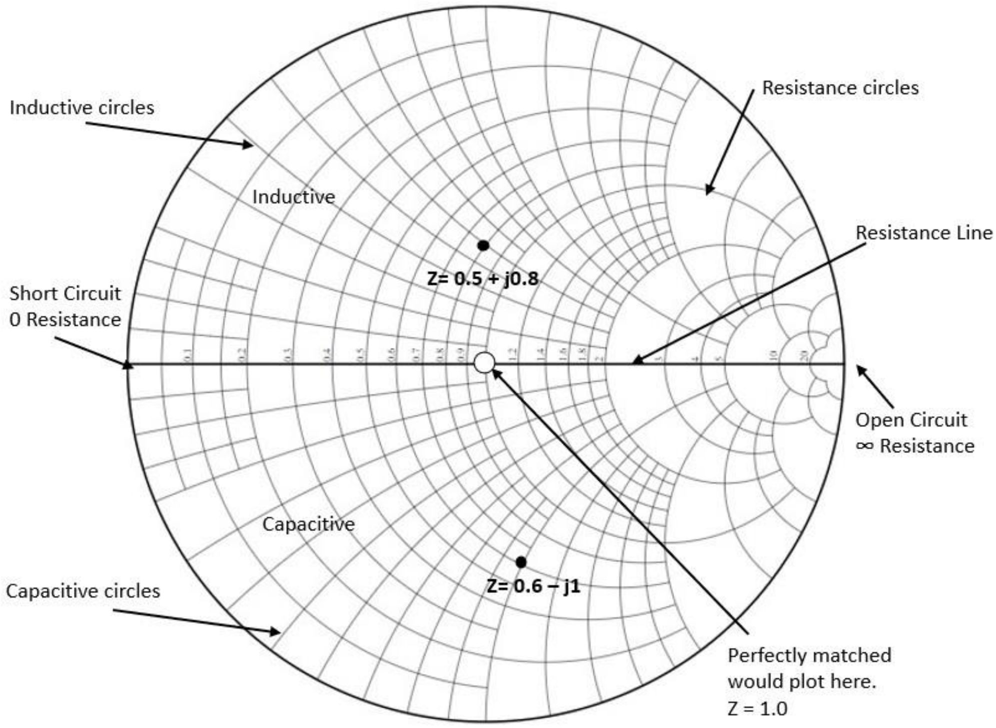

Figure 2: Smith Chart parts.

The reactance lines curve in from the top and bottom to meet at the open circuit point.

The predominant reactance is displayed above or below the resistance line.

Position	Indication	Notation	Example
Above line	Inductive	Positive imaginary number	Z = 25 + j40
Below Line	Capacitive	Negative imaginary number	Z = 30 – j50

The examples shown, are two different plots of two antennas at the selected frequency. Neither of these antennas are a perfect match to the transmission line. Both plots would need a matching network for their antennas to operate efficiently.

Normalisation

Before plotting the number on the Smith Chart, the number is normalised to the transmission line impedance. In our case this is 50Ω. To do this, divide each number by 50.

- Z = 25 + j40 divided by 50 becomes Z = 0.5 + j0.8
- Z = 30 – j50 divided by 50 becomes Z = 0.6 – j1

Each of these numbers represents the reflection coefficient for the one frequency under test on different antenna. To plot the numbers, follow to resistance line to 0.5 and as the number is positive, follow the reactance circle above the line for 0.8. Where these two lines cross is the plotting point. As shown in Figure 2. The ideal matching pint is one (1) on the resistance scale.

Once this point is plotted a matching network can be designed using a few rules.

1. A Smith chart is divided into the upper half which is inductive, and the lower half is capacitive.
2. Moving the impedance up, use an inductor (L). Moving the impedance down, use a capacitor (C).
3. The configuration of the matching network is determined by the position of the plotted point. This not included in this article. There are many good lectures on this topic on the internet.

Sweep Plot

A sweep plot from 100MHz to 500MHz is shown in Figure 2. This is hand drawn and totally hypothetic but shows the difference in the reflective coefficient over frequency on one antenna.

Between 100MHz and 300MHz, the coefficient is inductive. Dipping below 300MHz, the reactance goes capacitive then gets a perfect match of 1 at 400MHz. The plot then continues inductive to 500MHz.

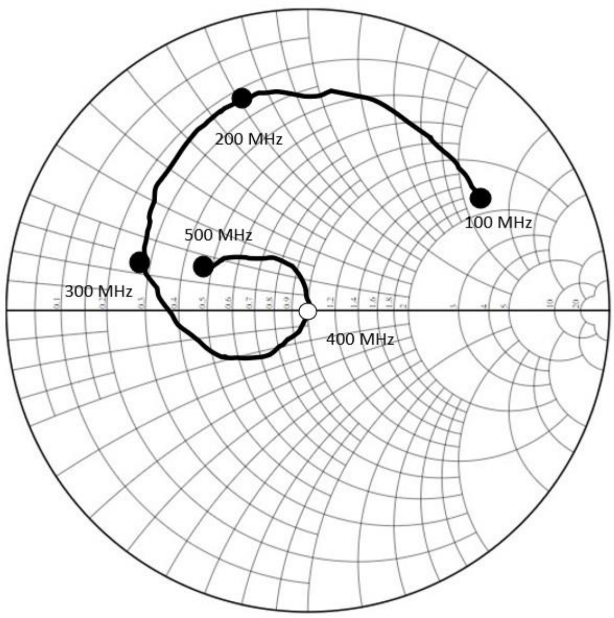

Figure 3: Smith Chart sample plots.

Figure 4 is an actual VNA plot of my 80M antenna. The yellow trace is the SWR and the green trace is the Smith Chart plot. The VNA sweep was set from 3MHz to 4MHz and the results are shown below. These numbers are normalised at 50Ω.

Figure 4 Photo	Frequency	Smith Chart Plot	SWR
A	4MHz	Z = 0.22 + j0.15	1.77
B	3.6MHz	Z = 0.03 + j0.01	1.07
C	3Mhz	Z = 0.61 – j0.74	50

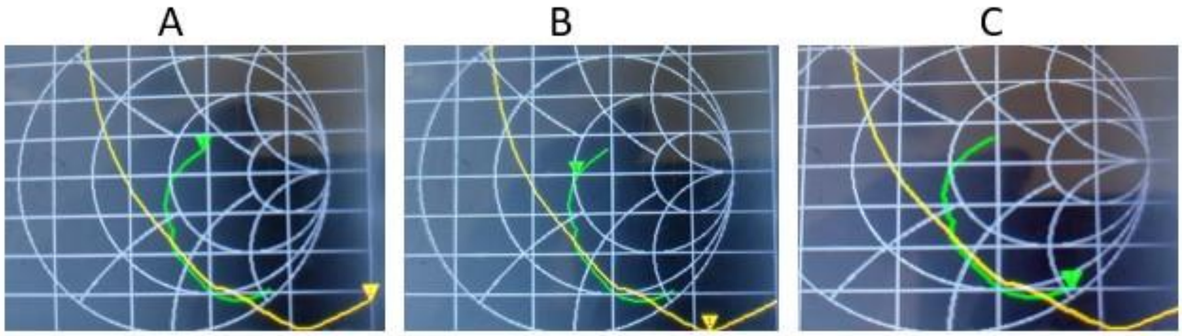

Figure 4: 80M VNA sample plots.

If you have a topic you would like to nominate to be covered in a future instalment of Newcomers' Notebook, email Jules at jp.bqt@bigpond.net.au

Have fun and stay safe.