A newcomer's tour of the Smith Chart

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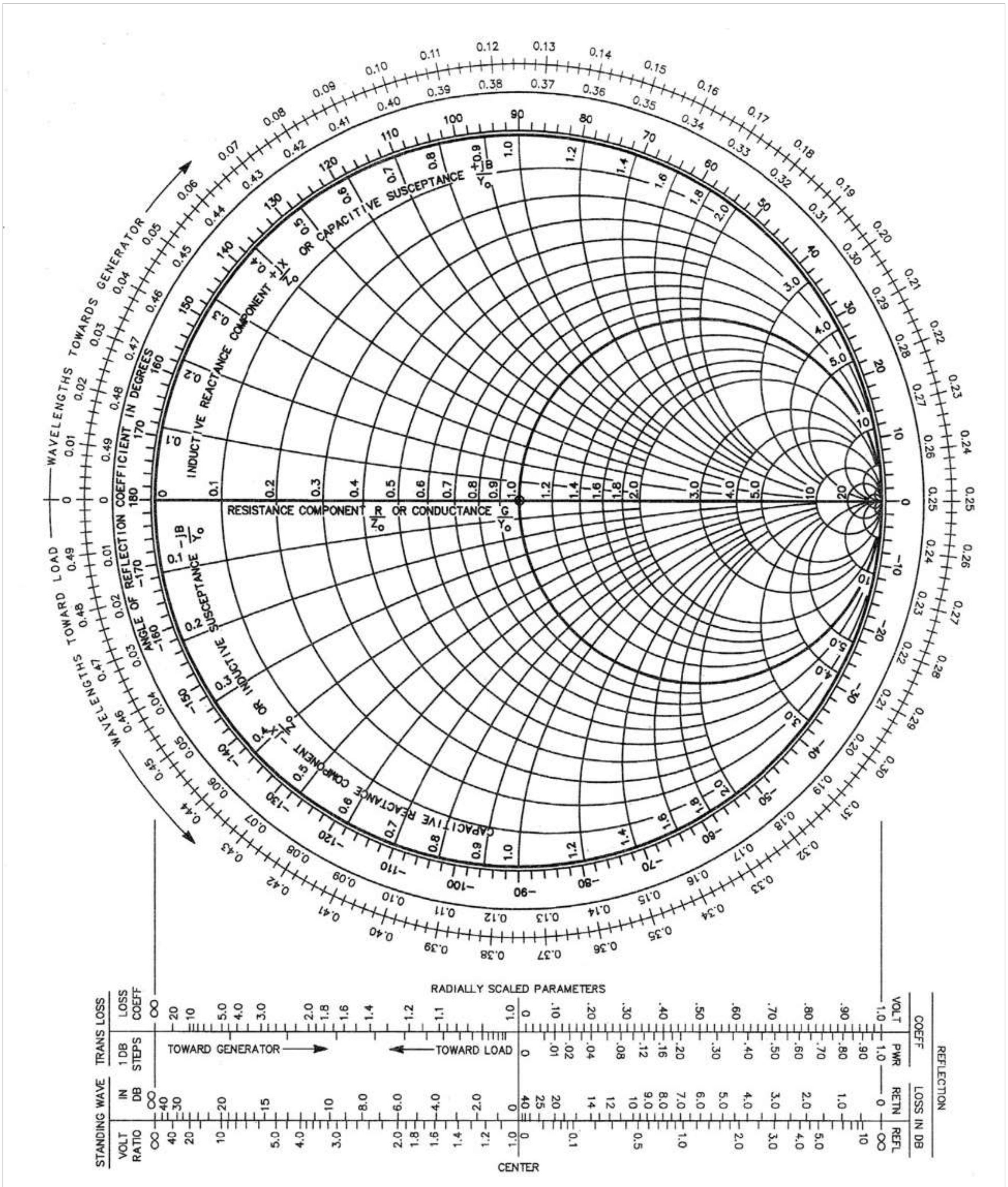
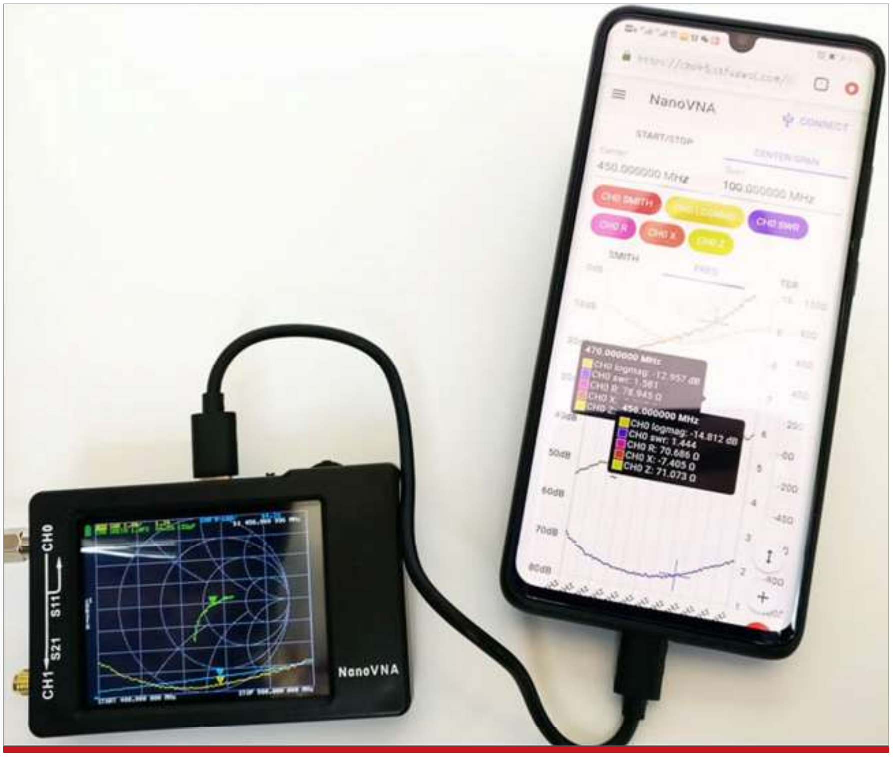


Figure 1. A Smith Chart in all its glory! It is most easily comprehended when broken down into its component parts.



Smith Charts in-hand. The NanoVNA is a popular, modest-cost instrument for measuring antenna characteristics, as well as other impedance measuring applications. Linked to a smartphone, a laptop, or tablet, software enables a host of graphical displays.

A Smith Chart appears complicated, cluttered, and unintelligible when first seen by newcomers. So, let us break it down and help you gain the most from this ingenious chart.

The Smith Chart can display multifaceted computations, but this article will only look at the basics. This is not meant to be a total coverage of what a Smith Chart can do, but an introduction for newcomers and perhaps even the 'not so new.'

In connecting a transmission line to an antenna, we understand that we can get a reflected wave if the impedance of the antenna and transmission line are not matched. You will recall from learning for your amateur radio exam that matching the transmission line to the antenna ensures maximum transfer of a transmitter signal to the antenna (and vice versa for receiving).

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, about which nothing more will be said here.

This reflected wave has a resistive and a reactive component when measured with an instrument designed to derive them. These days, this will generally mean a Vector Network Analyser (VNA) and the impedance 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. Hence, +j indicates it's inductive, while -j indicates it's capacitive. That's as far as we go with complex number mathematics, for now!

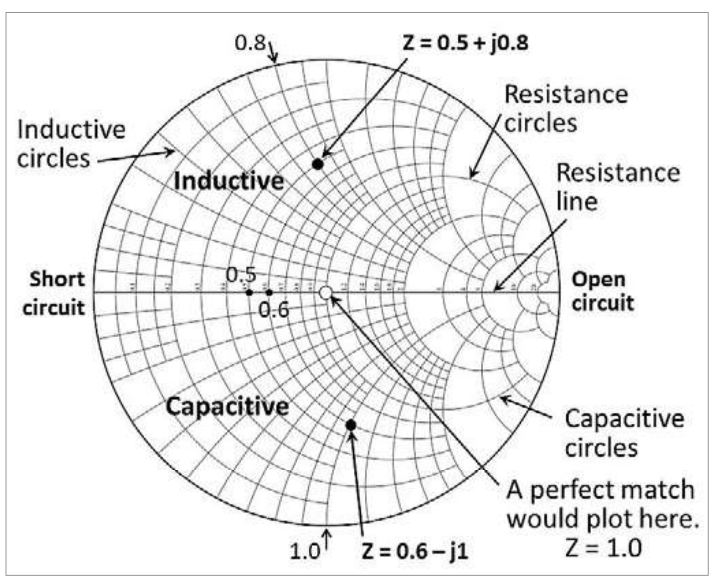


Figure 2. Showing the various components of the Smith Chart and a couple of examples detailed in the text here.

A Smith Chart is shown in **Figure 1** at a reduced size, to fit on the page. The chart has circles and arcs representing units of measurement. The outer rings provide information to assist impedance matching. The ruler below the chart provides additional information on reflection coefficient, SWR and other quantifiable figures derived from what may be plotted on the chart.

For convenience, I will use a stripped-down Smith Chart, as in **Figure 2**, for ease of explanation. The resistance is displayed on the straight line across the middle. The resistance circles cut the resistance line.

The reactance lines curve in from the top and bottom to meet at the open circuit point. The predominant reactance – inductive or capacitive – Is displayed above or below the resistance line. **Table 1** sums it up.

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 would need a matching network for the related antennas to operate efficiently.

Becoming normal

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

- (a) Z = 25 + j40 divided by 50 becomes Z = 0.5 + j0.8
- **(b)** Z = 30 – j50 divided by 50 becomes Z = 0.6 – j1

Position	Indication	Notation	Examples
Above line	Inductive	Positive imaginary number	Z = 25 + j40 // Z = 0.5 + j0.8
Below line	Capacitive	Negative imaginary number	Z = 30 – j60 // Z = 0.6 – j1

Table 1.

Each of these numbers represents the reflection coefficient for the one frequency under test on different antennas. 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 point is '1' on the resistance scale.

Once a normalised impedance 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, which is capacitive.

2/ To move the impedance up, use an inductor (L). To move the impedance down, use a capacitor (C).

3/ The configuration of the matching network is determined by the position of the plotted point. This is not cover here. There are many good lectures on this topic to be found on YouTube on the internet.

The sweep plot

An example sweep plot from 100 MHz to 500 MHz is shown in **Figure 3.** This is hand-drawn and totally hypothetical, but shows the difference in the reflection coefficient versus frequency on a particular antenna. This is a very useful technique.

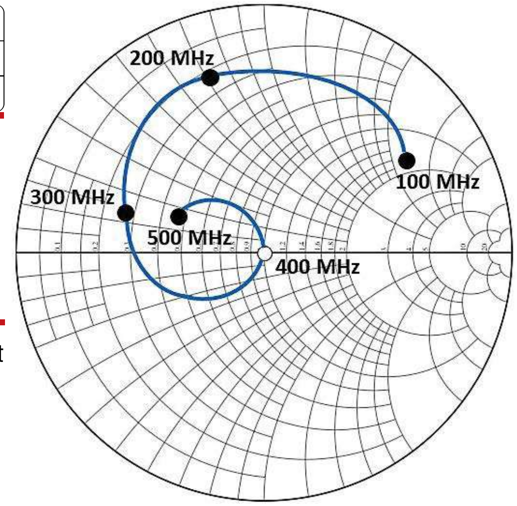


Figure 3. Example of a reflection coefficient plot over a wide range of frequencies. It's inductive from 100 to 300 MHz, then capacitive to 400 MHz, where it's a match, then inductive again through to 500 MHz.

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

An actual VNA plot of my 80 metre antenna is shown in Figure 4. The yellow trace is the SWR, while the green trace is the Smith Chart plot. The VNA sweep was set from 3 MHz to 4 MHz; the results are shown in **Table 2.** These numbers are normalised to 50 Ohms.

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

Table 2.

A basic understanding of the Smith Chart makes tuning and matching antenna circuits much easier, enabling you to know what is actually going on, rather than making assumptions and guesses, and hoping for the best.

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.

Further reading

1/ Going Around in Circles to Get to the Point. tinyurl.com/YO3smith

2/ What is a Smith Chart : Basics, Types & Applications. tinyurl.com/ElProSmith

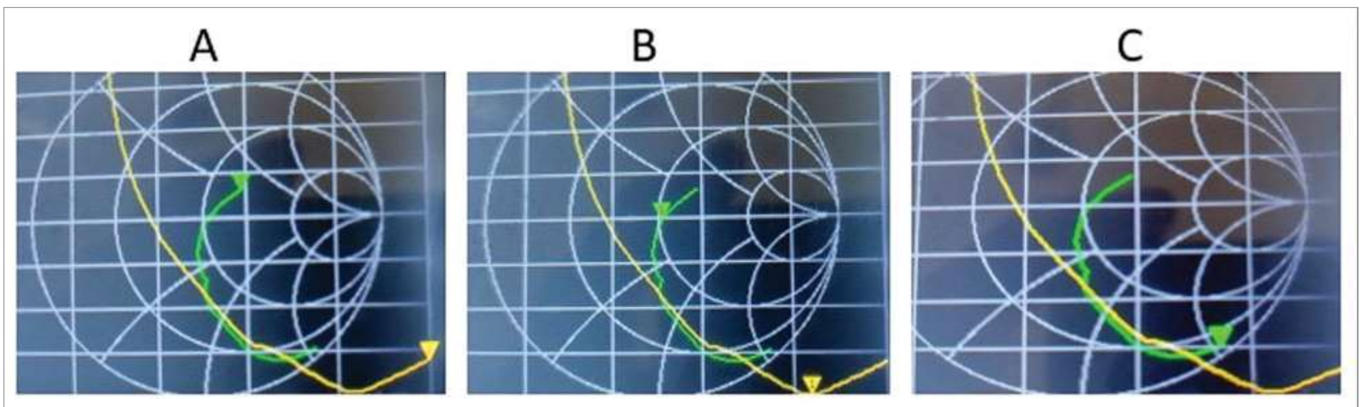


Figure 4. Sample plots of my 80 metre antenna taken with a VNA (a "real" example!).