The secrets of the Smith chart

by
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If you look through the normal run of electronics text books, such as those produced by the RSGB, you will see some weird and wonderful formulae to calculate the component values for interstage couplings and the input and output networks of HF and VHF power transistors. If you are a lover of mathematics, they have a strange beauty, and they can be translated into forms which whizz round the innards of computers and are regurgitated into long lists of numbers for idiot use. Such a list is the Motorola Application Note, AN-267, Matching Network Designs with Computer Solutions, by Frank Davis. It is a crib to give component values for four commonly-used networks.

Dreamed of designing your own power amplifiers, aerial systems? Then read on. . .

But the normal design laboratory doesn't do things that way. They prefer to use a graphical method, which is of sufficient accuracy. This is a **Smith Chart**. It is a system invented in the 1930s by a man called Smith (surprise!). It is so new that 20 years ago, when I was in college, they didn't even mention it — like some other things now common. It is a circular graph derived from the lines of force as seen in waveguides. It works as easily as finding your way on the London Tube network.

The making of a Smith chart

The Smith chart is, in fact, just a formalisation of the phasor diagrams that are used to represent resistive and reactive impedances. This is possible to do provided that you consider only series or parallel impedances at the same time.

How is the chart constructed? Take a circle, and draw across it a horizontal diameter. On the right hand side, draw a tangent normal (90°) to this diameter. This line is for constructional purposes only. The chart is normalised (that is, a design value which could be, but need not be 50 ohms is taken as unity, and all values drawn on the chart are divided by the design value). The point on the horizontal diameter at the centre of the big circle is taken as the unity value. Thus one chart can be used for all ranges of impedance without cramping of scale. The diameter line is the normalised resistance axis (R/Z_0). Circles are then constructed along the diameter with radius $1/(1+R/Z_0)$, as in **Fig. 1**. All these circles form lines of constant resistance.

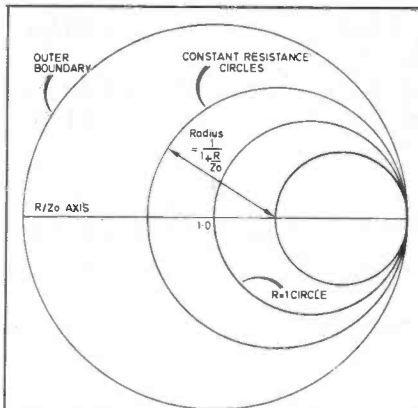

Fig. 1. Resistance circles (real part of the Smith chart)

Now construct arcs of circles with their centres lying on the tangent to the diameter. The radius of these arcs are $1/(+jX/Z_0)$ and $1/(-jX/Z_0)$. These form a family of lines of constant reactance, **Fig. 2**.

Put the two together, and the Smith Chart is formed. I include a complete Smith Chart as part of this article (**Fig. 3**). Blank charts are available from Chartwell, reference numbers 7510 and 7513. As you will see, there are peripheral scales on the complete chart. There are various forms of peripheral scales available. The ones we will consider later in this article are marked as electrical length in wavelengths, and phase angle of the voltage reflection coefficient scale. For the moment, we will ignore them. Others before me have had a go at explaining the Smith Chart elsewhere. I am trying to keep things as simple as possible, so if you want to know more, look up the info. You could do worse than look up Phillip H. Smith's "Electronic Applications of the Smith Chart", published by McGraw-Hill, price £29+, which is my source book.

As an engineer, for me, mathematics are a tool, just as much as a soldering iron. The Smith Chart is another tool, and the purpose of this article is to help you to find ways of using this tool, in the first case to help you to roll your own power amplifiers, and secondly, using the outer scales, to design an aerial. With this as a basis, you can follow by teaching yourself the other uses.

Three types of ohms

There are three types of ohms. There are ohms resistive, which come from a pure resistor. There

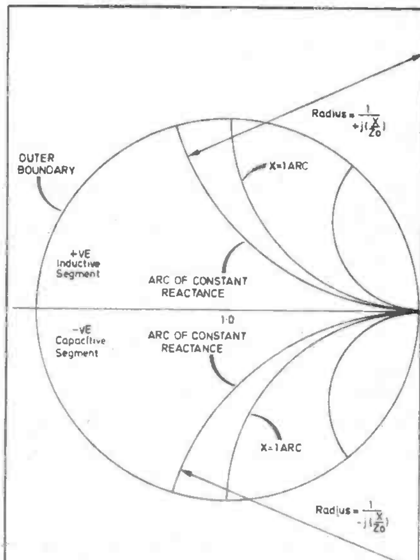

Fig. 2. Reactance arcs (imaginary part of the Smith chart).