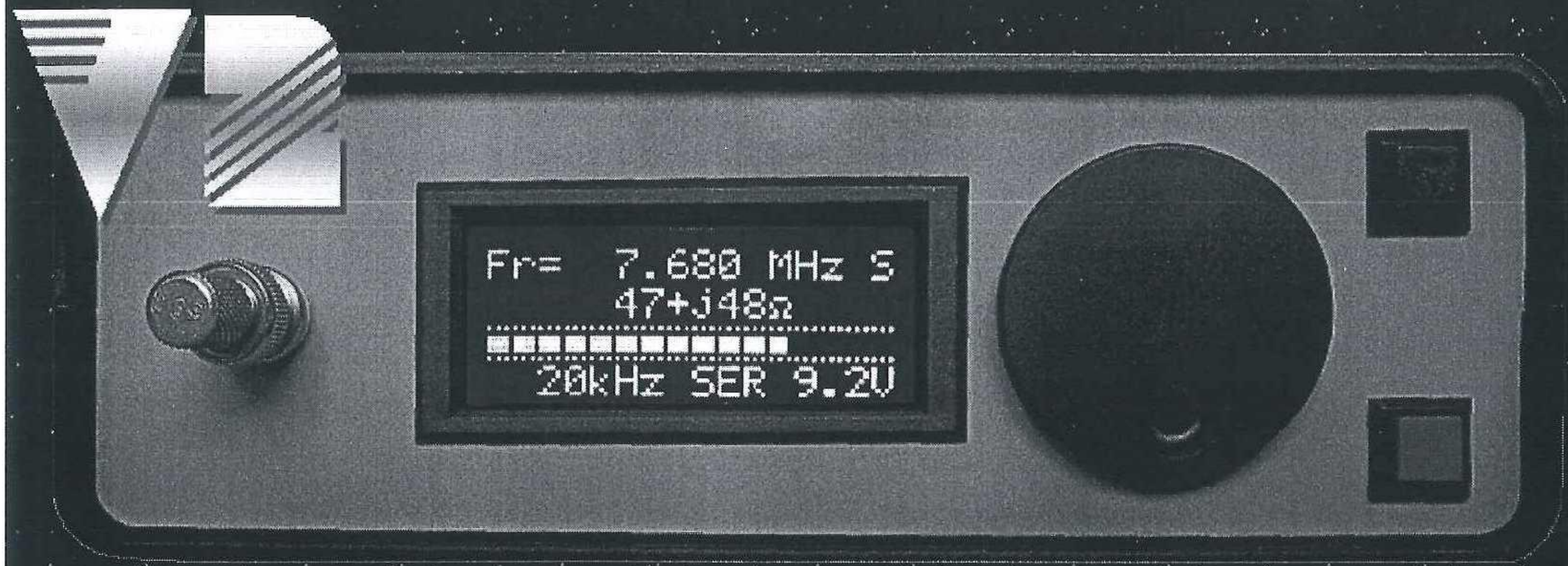
Another Antenna Analyzer



History

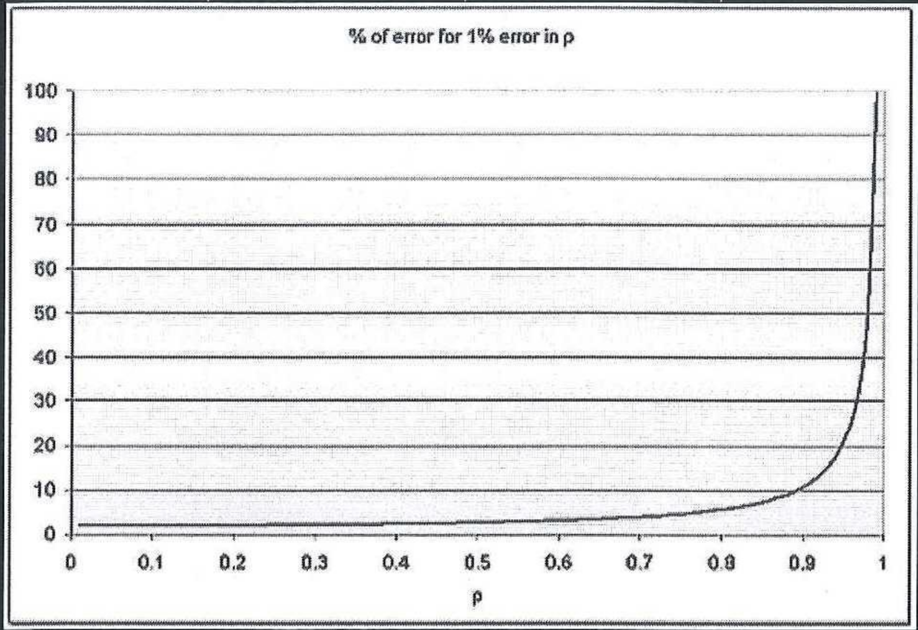
This is yet another antenna analyzer, but with a twist. The analyzer was originally designed to replace my good old MFJ-259. (not the B version) Although the MFJ has proven to be a useful tool, it is not a serious measurement instrument. That's fine for most applications, but if you want evaluate system loss or verify antenna models you really need something more accurate. There are a lot of these analyzers available both from well known manufacturers like MFJ, AEA, Timewave, Palstar etc. as well as individual amateurs and radio clubs.

The majority of these instruments are based on a reflection bridge in some shape or form. As I will explain this limits the impedance range of an instrument for a given accuracy. Since I mainly work with open line fed antennas I needed an instrument that could cope with the broad impedance range these antennas exhibit. So I decided to design and build my own analyzer based on a different measurement method.

Although the concept for this analyzer was conceived early 2005, the first prototype, which I will refer to as **version 1** was built in 2007. This version had the basic functionality and was designed around an Atmega8 controller. During the second part of 2007 the software was rewritten and a number of additional features were added. To accommodate the extra code I needed to switch to a different controller with a little more memory space.

Version 2 is based on an ATMega168, which is pin compatible with the original Mega8. Therefor only minor changes in the hardware were needed to make it work. Although some routines were made "more elegant" and additional routines were added, most of the code remained unchanged. After a period of debugging and testing I now feel that Version 2 is ready to be released.

Measurement method

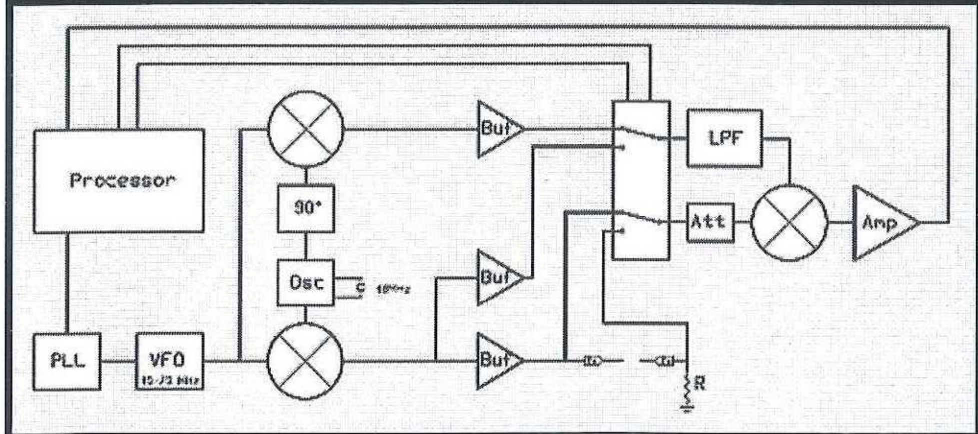


The problem with the reflection based method is its accuracy over a wide range of impedances. Let me illustrate this with an example:
A 1kΩ load would result in a reflection coefficient **ρ** of 0.904 in a 50Ω system. 2kΩ gives a value for **ρ** of 0.975. So a 100% increase in impedance only results in a 8% increase in the value of **ρ**. Given the fact that **ρ** can only be measured with a finite accuracy the overall error for the impedance will increase rapidly as **ρ** approaches unity. This is illustrated in the diagram on the left. For a 1% error in **ρ** the resulting error in the calculated impedance is already 10 times larger for a value of **ρ** just under 0.9. The problem gets even worse if the unknown impedance is highly reactive. For pure reactive loads **ρ** is always 1 irrespective of the reactance. The actual value is now solely determined by the phase of **ρ**. Accurate phase measurements on HF, however, are difficult. So I decided to adopt a more classical approach and **simply measure the voltage across the load and the current through it as well as the phase difference between the two**. Strangely enough most professional units are also based on a reflection measurement and I know of only one instrument that uses the voltage current method : The Tomco TE1000

Design objectives

- Frequency range of 1 - 30 MHz
- Good accuracy over a broad range of impedances
- Low cost.
- Low power.
- Stand alone solution.
- Battery operated.
- PC interface for frequency scans and impedance plots
- In-circuit programmable

Circuit description



Crucial to this design is the choice of the type of detector. In an application like an antenna analyzer the detector should have a good linearity over a wide dynamic range. In most other designs either diode detectors or logarithmic amplifiers are used. These often lack linearity and accuracy. In this case a synchronous detector was chosen. In addition to a good linearity over a wide enough range a synchronous detector has some other distinct advantages; It is a narrow band detector, which helps rejecting signals received by the antenna itself, and it combines the function of both amplitude and phase detector.
The DC voltage at the output is proportional to Vin*COS(Φ), where Φ is the phase difference between the input signal and the reference signal. So, to determine the magnitude and phase of either Voltage or Current two measurements are necessary. One at 0° and one at 90°. This is known as **I**n-phase and **Q**uadrature detection, in short **I/Q.** From these four values (Vi,Vq,Ii

and Iq) the real and imaginary parts of the impedance can be directly calculated:

$$R_S = \frac{V_I I_I + V_Q I_Q}{I_I^2 + I_Q^2} \text{ and } X_S = \frac{V_Q I_I - V_I I_Q}{I_I^2 + I_Q^2}$$

The subscript S denotes the series equivalent of the impedance as in Z = Rs + jXs. Note that the calculation does not involve trigonometric functions like SIN(Φ) and COS(Φ), which are difficult to evaluate with a simple controller. Some designs using a separate phase detector, notably the ones based on a AD8302 have the problem of phase ambiguity. So whilst these analyzers are able to measure the magnitude of a reactance, they cannot tell whether it is inductive or capacitive. The MFJ269 is an example of such an instrument. In the TAPR VNA this is solved by using the I/Q technique with two AD8302 circuits. The synchronous detector does not have this problem. The output of the detector can go negative as well as positive. So the phase angle is defined in all four quadrants. (0° - 360°)

The measurement signal is generated by a classical PLL synthesizer. No single VCO will be able to run from 1 MHz to 30 MHz without switching inductances or capacitors. Therefore the VCO runs at 49 MHz to 78 MHz and is than down converted to 1-30 MHz by mixing it with a 48 MHz X-tal oscillator. This arrangement also makes it possible to generate the necessary I/Q reference signals. The fixed 48MHz signal is split into a +45° and a -45° component which are fed to two separate down converting mixers. The output of the mixers are therefore always 90° out of phase.

To prevent systematic errors due to gain differences a single detector –amplifier chain is used for all voltage and current measurements. Reference, voltage and current signals are fed to the detector through diode switches. The current measurement is done by measuring the voltage across a sense resistor in series with the unknown load.

Look here for a more details