Fun On The Smith Chart
Designing a QRP Antenna Matching Circuit For The 80 Meter Data Sub-band

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Introduction

Joining the MI QRP Club renewed my interest in the 80 meter band. I wanted to extend my JT9, JT65, and PSK31 digital work to the 80 meter band, but I don't have an 80 meter antenna. My only HF antenna is a multi-band OCF dipole, specifically designed for 40, 20, 10, and 6 meters. Knowing that digital modes excel at weak signal QSOs, I thought a suitable antenna matching circuit might enable me to use my existing antenna for QRP digital work on 80 meters. The results have been encouraging.

This article documents the use of the Smith Chart to design a simple QRP antenna matching circuit for the 80 meter data sub-band, 3.500 - 3.600 MHz. The Smith Chart dates from the 1930s, but I still find it useful (and fun) for RF projects like this. The chart can appear formidable on first approach, but it's easier to use than you might think. If you're not already a user, I hope this article will encourage you to explore the Smith Chart.

The Smith Chart Design Process

All work on the Smith Chart is done with *normalized* impedance (Z = R + jX) and *normalized* admittance (Y = G + jB), where Y = 1/Z. For a 50-ohm system like this matching circuit

Normalized Z = Physical Z / 50 Physical Z = Normalized Z × 50
Normalized Y = Physical Y / 0.02 Physical Y = Normalized Y × 0.02

The Smith Chart of Fig. 3 documents the design of the matching circuit, centered on 3.535 MHz. The design is developed graphically by constructing an impedance/admittance path on the Smith Chart from Point A, representing the output port with the load connected, to Point E at the center of the chart, where normalized Z = 1 + j0 represents our objective: a 50 ohm input port. The path is built incrementally by alternately adding circular arcs and straight line segments. We do not use the Smith Chart wavelength markings for this project.

Every circular arc segment, shown as a solid line in Fig. 3, connects either two impedance points or two admittance points (we plot both on the same Smith Chart) and adds an inductor or capacitor to the circuit. An arc between two impedance points adds a series-connected component to the circuit. An arc between two admittance points adds a component connected to ground.

Every reflection of a point through the center of the chart, shown as a dashed line in Fig. 3, transforms an impedance point into an equivalent admittance point, or vise versa. Reflections do not add components. Instead, they establish the starting point for the next circular arc segment. Every circular arc segment is followed by a reflection; every reflection is followed by a circular arc.

The Circuit Design In Five Steps

Here are the matching circuit design steps. Points A through E refer to the Smith Chart of Fig 3.

1. At 3.535 MHz., the load impedance at my radio measures 143 + j129 ohms (SWR = 5.35). The normalized value, Za = (143 + j 129)/50 = 2.86 + j 2.58, is Point A on the Smith Chart.
2. Transform impedance Point A to equivalent admittance Point B by reflecting it through the Smith Chart center point. At Point B, the normalized admittance is Yb = 1/Za = 0.193 - j 0.174.

3. Extend the path in a circular arc from Point B to Point C, which is on or very near the gray circle,. At Point C, Yc = 0.193 + j0.395. The change in normalized susceptance along this arc is ΔB = 0.569. At 3.535 MHz, this ΔB is implemented as a 512 pF capacitor to ground, shown in Fig. 1.

   Note: All normalized admittance points on the gray circle share a special property: reflection through the Smith Chart center point puts the equivalent normalized impedance point somewhere on the R = 1 circle. From there , adding series reactance of appropriate value will extend the path to our objective: the center point where normalized Z = 1 + j0, corresponding to a perfect 50 ohm input.

4. Transform admittance Point C to equivalent impedance Point D by reflecting it through the Smith Chart center point. At Point D, Zd = 1/Yc = 0.997 - j2.044.

5. Finally, extend the path along a circular arc from Point D to Point E, which represents the input port. At Point E, Ze = 1.00 + j0, which represents an input impedance of 50.0 + j0 ohms. The change in normalized reactance along this arc is ΔX = 2.044. At 3.535 MHz, this ΔX is implemented as a 4.60 uH series-connected inductor, shown in Fig. 1. This completes the design.

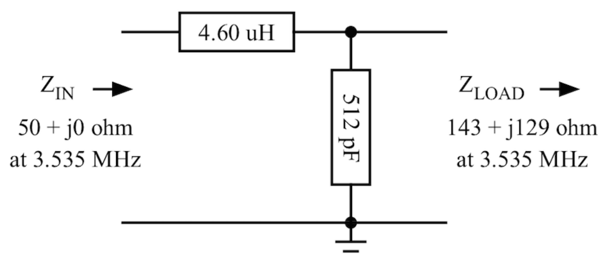

Fig. 1
The QRP 80 Meter Data Sub-band Matching Circuit

<u>Build and Test</u>

Fig. 2 shows the matching circuit, as built. As with most circuits, some tweaking was required. The final coil inductance is 4.57 uH, very close to the design value, but the capacitance had to be increased by 15% to 590 pF. The inductor is 16 turns of #24 AWG hook-up wire, wound on a short piece of 3/4" diameter PVC pipe and held in place with clear sealant. The capacitors are 470 pF and 120 pF silvered mica, connected in parallel.

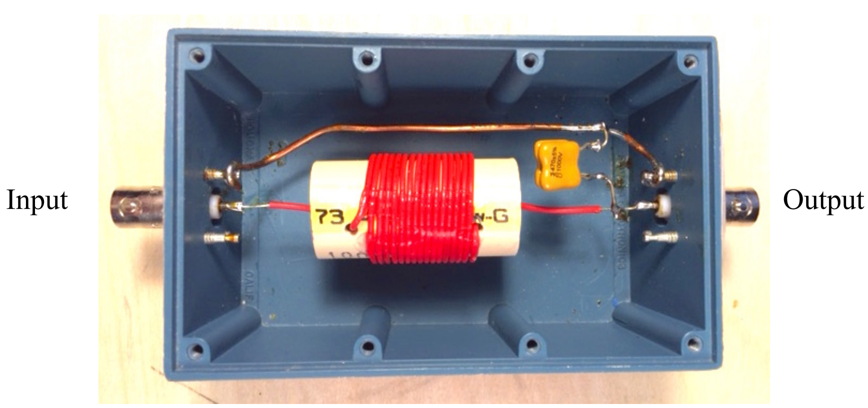

Fig. 2
The QRP 80 Meter Data Sub-band Matching Circuit, As Built

With the matching circuit connected to my feedline, the antenna analyzer measured an input minimum SWR of 1.4 at 3.54 MHz., increasing to a maximum of 2 at both 3.50 MHz and 3.59 MHz. The SWR values are higher than expected, but the circuit still provides a useable match over the entire 80 meter data sub-band.

Of course a decent match does not guarantee effective radiation, but in this case all went well. (Other antennas may react differently). While testing on 80 meters at 10 watts, I logged a JT5 QSO at 660 miles (KC1BAA, Centerville, MA) and a JT9 QSO at 1096 miles (W5KDJ, Montgomery, TX).

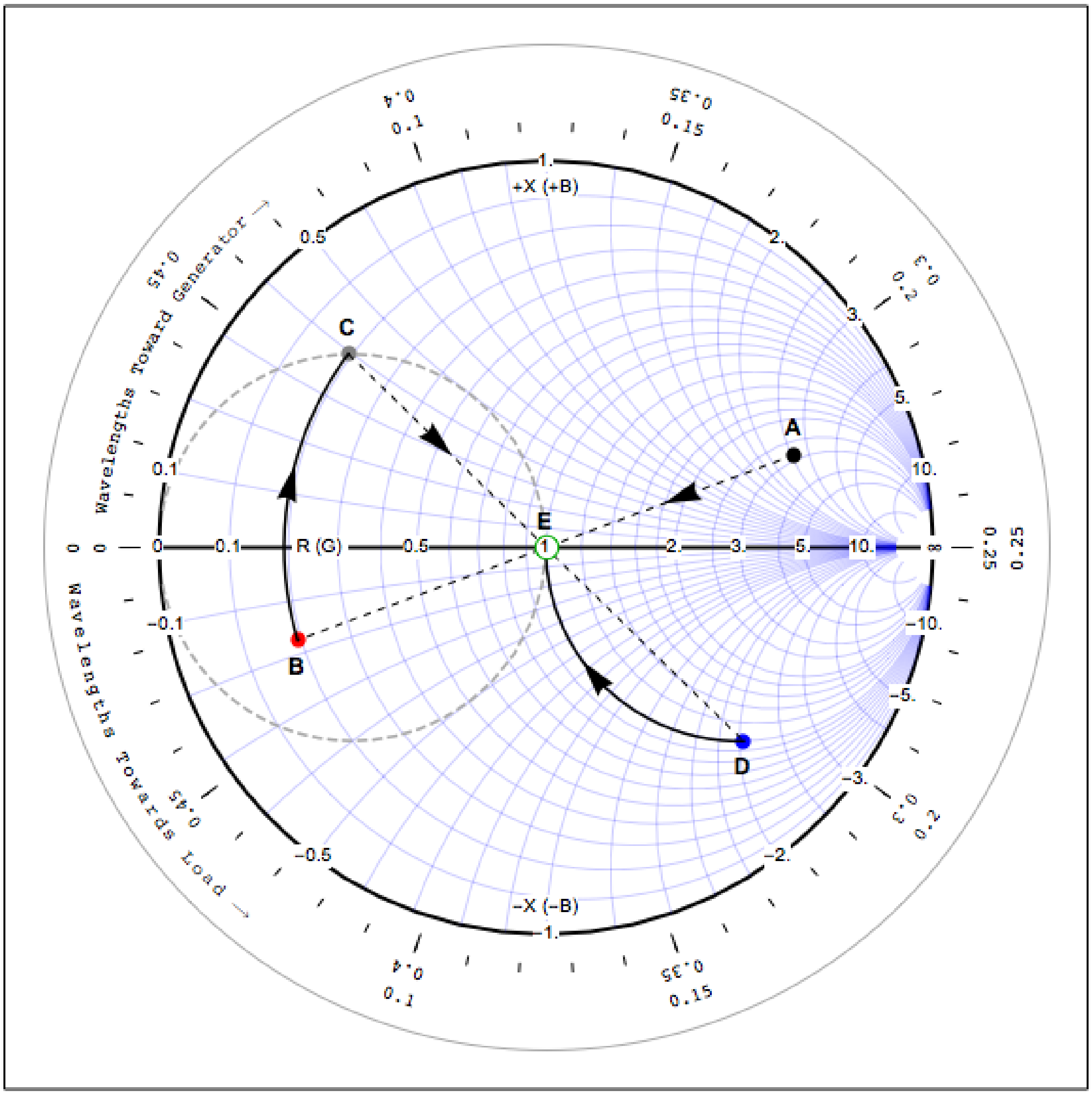

Fig. 3
Smith Chart
Showing The Impedance/Admittance Path Development From Point A to Point E
For The QRP 80 Meter Data Sub-band Antenna Matching Circuit

Designing this matching circuit on the Smith Chart was an interesting exercise. The 80 meter digital QSOs have been fun. I hope this will encourage you to try the Smith Chart for a future RF project.

73
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