1.4 Experimental loop testing

To evaluate the usefulness of software modeling I needed a set of experimental values to compare with modeling predictions. Figure 6 is photo of a frame on which I wound experimental loops. The diameter was 126". The wire support combs allowed N to be varied from 1 to 16 with a wire spacing of 0.5". #18 solid wire was used. In addition to the octagonal shape, I removed four arms from the frame to wind square loops of the same diameter.

Figure 6 - Octagonal test loop.

The first step was to measure the self resonant frequency (SRF). One way was to connect a VNA directly across the feedpoint terminals, with a common mode choke for decoupling, and measure the impedance. Figure 7 is a graph for Rin for an 8T octagonal loop.

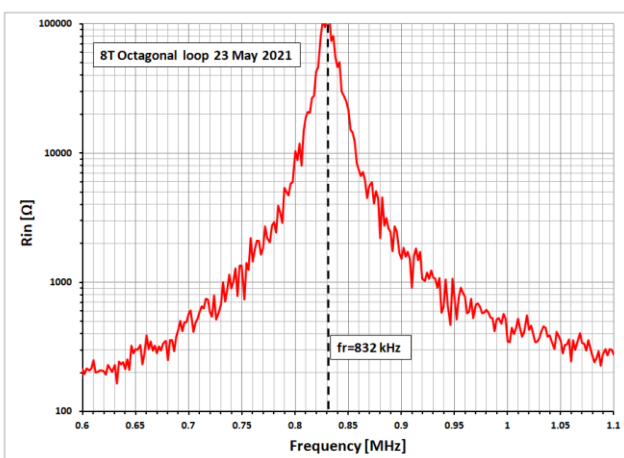

Figure 7 - Input resistance (Rin) for an 8T octagonal loop.

In this example the peak is at 832 kHz, which would appear to represent the SRF. However, the measurement is very sensitive to stray capacitance so getting good measurements is a tricky business at best. With a direct VNA measurement the interaction was too great, significantly lowering the "apparent" SRF much lower than the coupling loop method and the modeling derived values.

Figure 8 - Test loop SRF measurement.

In the end I used a separate single turn loop spaced 10' away from the loop under test as shown in figure 8. This provided minimal disturbance. Figure 9 shows an example of Rs on the coupling loop for the 8T octagon. The peak is quite sharp and easy to see.

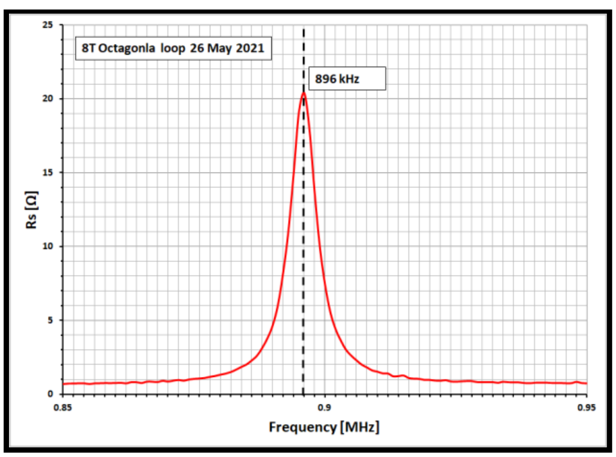

Figure 9 - Rs of the sampling loop.

As a check I increased the spacing between the loop under test and the sample loop to decrease the effect of the coupling loop on the measurement. This reduced the peak value for

Rs but it was still easy to see. This increased fr to 903 kHz. However, further increasing spacing had little effect on measured fr.

1.5 SRF measurement results

Five antennas were built, all with D=126", #18 wire, 0.5" turn-to-turn wire spacing: 8, 12 and 16 turns square, 8 and 16 turns octagonal. The SRF measurements are summarized in table 1.

Table 1 - Measured SRF

loop configuration	Measured SRF
8T square	995 kHz
12T square	684 kHz
16T square	517 kHz
8T octagonal	903 kHz
16T octagonal	472 kHz

1.5 Modeling

The experimental results were very useful for the tested examples but I want to solve the general problem of any loop at any frequency. It's not practical to do that experimentally, you have to use some form of software simulation. I have access to NEC4 and NEC5 based software which I used for modeling. Figure 10 is a typical example of one of the models. The loops were placed in the X-Z plane.

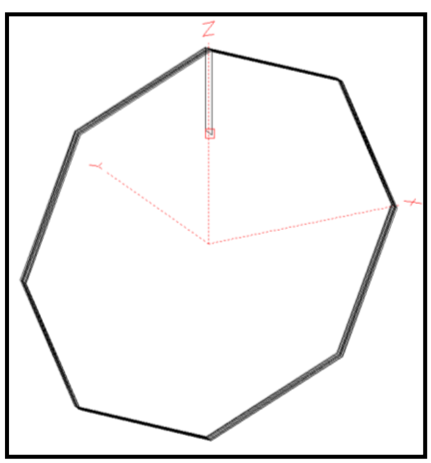

Figure 10 - 8T octagonal NEC model.

Because NEC5 is relatively new not very many people have purchased the required license and NEC4 software is widely used I felt I needed a comparison between them. When modeling the degree of segmentation is varied from sparse to dense to check the stability of the solutions. A point of interest was the effect of segmentation on predicted SRF.

Table 2 gives a summary of measured and modeled values of SRF for the test loops. The segment lengths were varied from 1' to 0.5' and then to 0.25'. Each step doubles the total segment number.

NEC5 is consistently closer to the measured values and very insensitive to segmentation. At low segmentation NEC4 is much further away from the measured values but improves substantially as segmentation is increased. For the 16T octagon there are 2313 segments when 0.25' segment length is used. That makes for slow computation. 1' segment lengths result in 774 segments which run much faster. The lower segmentation is fine with NEC5 but not so good for NEC4. My conclusion is that one can model loops using NEC4 with useful accuracy is one uses a large number of segments and accepts long computation times.

Table 2 - Measured and predicted SRF values in kHz.

loop	measured SRF	Segment size =>	1'	0.5'	0.25'
8T square	995	NEC5	1049	1053	1054
-	-	NEC4	1272	1125	1074
-	-	-	-	-	-
12T square	684	NEC5	711	714	714
-	-	NEC4	813	745	723
-	-	-	-	-	-
16T square	517	NEC5	545	547	548
-	-	NEC4	602	565	553
-	-	-	-	-	-
8T octagon	903	NEC5	932	933	934
-	-	NEC4	1114	1019	938
-	-	-	-	-	-
16T octagon	472	NEC5	480	480	480
-	-	NEC4	527	501	487

The SRF values using NEC5 may actually be even closer than the table shows. To determine SRF in the model a load consisting of a 1 MΩ resistor in parallel with a 1 pF capacitor was placed in series with the feedpoint. The loop was then excited with a plane wave (PW) and the current in the resistor calculated. From the current the voltage across the feedpoint (vs) was found. The frequency of the PW was then varied to determine the lowest frequency at which vs peaked. This was assumed to be the SRF. This part of the modeling assumed ideal loop construction, i.e. no stray capacitances, etc. That's not realistic. To estimate the effect of stray capacitance, using the 16T octagonal loop model, I added a small amount of shunt C across the feedpoint resistor which shifted the SRF lower as shown in table 3.

Table 3 - Effect of shunt capacitance across the loop feedpoint.

shunt capacitance pF	SRF kHz
0	484
0.1	483
1	480
2	476
3	472
10	448

I think table 3 makes clear how sensitive SRF is to stray capacitance and shows why a direct VNA measurement did not work well. It also shows why the actual SRF of a real loop would almost certainly be lower than the modeling predicts which is consistent with the modeling results.