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Introduction And Conclusions top

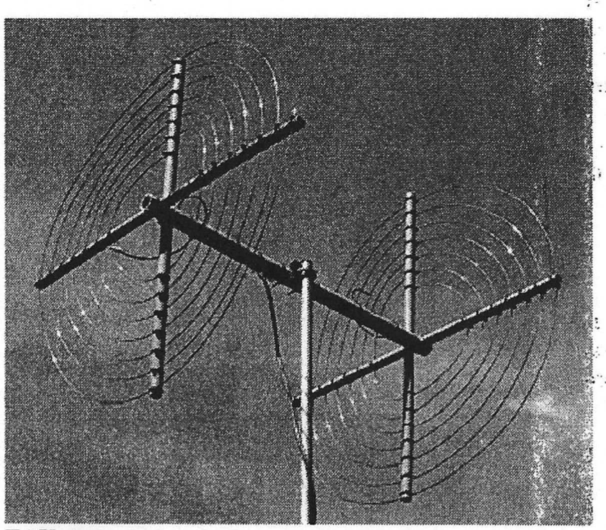
An experimental antenna similar to the TAK spiral antenna was evaluated for SWR response over the frequency range of 7.0 to 7.3 MHz, or the 40-meter band.

Summary of results

1. Beam length has a significant effect on SWR response. Increasing the distance between spirals increases the antenna's resonant frequency. Beam length can be used to fine-tune a spiral antenna to the desired resonant frequency.
2. The combined length of antenna and hookup wire has a significant effect on the antenna's resonant frequency. The longer the combination, the lower the resonant frequency.
3. The diameter of a spiral antenna affects its bandwidth, as measured by the frequency range where the SWR is equal to or less than a value of 2. Increasing spiral diameter increases bandwidth.

Background top

TAK markets and sells a 40-meter antenna that is a unique arrangement of a simple dipole where the quarter wave sections are wound into flat spirals instead of being arranged in a straight line. The advantage of this configuration lies mainly in its compact size. The finished antenna easily fits into a 3-foot cube.



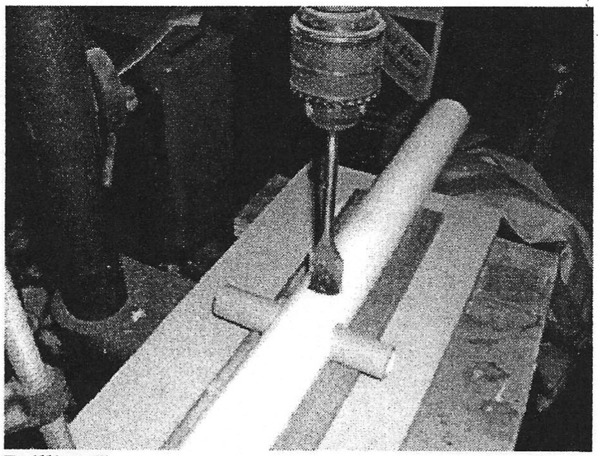
TAK Antenna

George Mann, the president of the Lakeland Radio Amateurs Club was kind enough to let me study his TAK antenna. For this experiment the TAK's major drawback was its fixed length beam. An easy to construct design that overcame this shortcoming was needed.

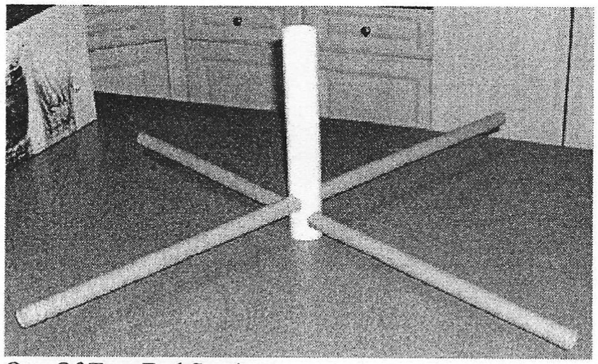
Materials used to construct an adjustable length beam antenna are available at any home center and consist mainly of PVC electrical conduit, and two sizes of PVC water pipe. Fourteen-gauge aluminum wire was chosen for the antenna because of its low cost.

Design and Construction Of An Adjustable Beam Spiral Antenna top

Construction consisted mainly in cutting PVC to length and drilling holes. A modified spade bit, ground to the diameter of the gray PVC conduit used for the cross arms, was used to drill holes in the movable sections of the beam. To insure that the holes were at right angles to each other, a simple jig was used to hold the beam member during the drilling operation.

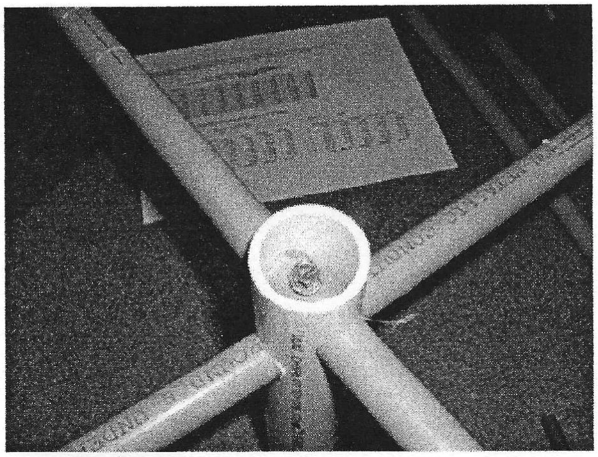

Drilling Jig

The image above shows the jig in use during the drilling operation. After the first pair of through-holes are drilled, a piece of scrap PVC is inserted through these holes, and the piece is then returned to the jig with the scrap PVC now resting on the locating rails. This insures that the next pair of holes in the PVC will be at right angles to the first pair.

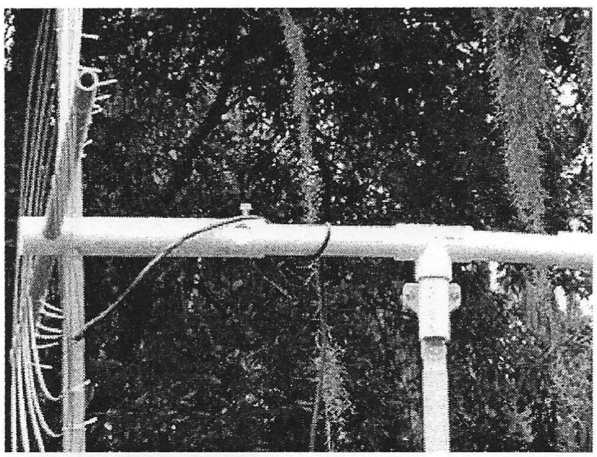

One Of Two End Sections

In the above photo, the larger diameter PVC has been drilled and the spiral arms inserted.

The two cross members are secured with a single self-tapping screw.



Arm Attachment



Adjustable Beam Length

In contrast with the TAK, the beam in this design is not one but three pieces. Two hold the spiral supporting arms, while the third, smaller in diameter section, fits into the other two. This arrangement produces an adjustable beam. The above image shows how one section slides over the other, in trombone fashion, allowing for the beam length to be varied.

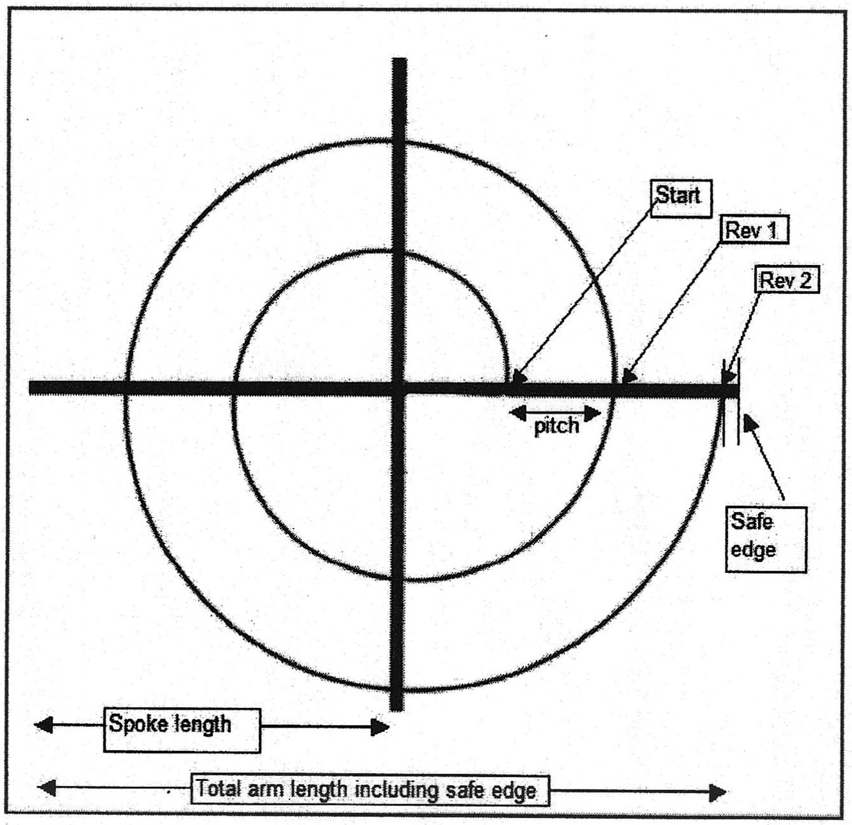
Spiral Antenna Design top

The primary spiral antenna design parameters are: the desired resonant frequency, the length of the hook up wire that connect the antenna to the coax, and the minimum distance the antenna wire is allowed to come to the end of any one PVC support arms. Once these parameters have been determined, many spiral designs are possible by varying the spiral pitch, or distance between turns, and the starting distance from the hub of the spiral.

From a mechanical perspective the most important design consideration is how close the outermost end of the antenna wire comes to its supporting spoke. An antenna wire that is an inch too short will leave a large section of antenna wire unsupported, whereas one that is an inch or two longer than needed to reach the last support is easily tolerated, and may even be an advantage in subsequent tuning. Therefore, it is important to choose pitch and start values with this in mind.

Calculating the effects of starting distance and pitch on a known length of wire can be tedious, and finding the combination that satisfies the condition that the wire reach the last spoke with little or no overhang can be daunting. To address these concerns a spiral antenna spreadsheet model was created to do the calculations for the designer.

For clarity the spreadsheet begins with a graphic showing the spiral antenna's most important parameters which are: start point, pitch, safe edge, spoke length, and arm length.



A table of inputs and outputs follows the diagram. Inputs are in peach, outputs are in yellow colored cells. The designer enters the desired frequency, the length of hookup wire, assumed velocity factor, and safe edge. In response, the spreadsheet calculates the required length of antenna wire in both inches as well as feet and inches. The spreadsheet does its calculations in inches, but the user will find the conversion to feet and inches more practical when cutting wire to length.

Of the remaining two boxes, one is labeled pitch, or the distance between turns, and the other is labeled start, or the distance from the hub to the point on spoke R1 where the antenna will start. Adjacent to these two inputs are two outputs labeled turns and min spoke. The significance of turns is that values ending in 0, .25, .5, or .75 signify that the end of the outermost lap of wire just reaches a spoke. A value not ending in one of the above fractions means that the antenna wire will end between spokes. As mentioned above, a little over is much more desirable than a little under.

Minimum spoke determines the overall size of the antenna. In fact the diameter of the antenna will be twice this value. The length of the cross arms will be twice the sum of the min spoke plus the safe edge.

Step 1. Enter parameters.

desired frequency	7.2	Mhz		
hookup wire one side	15	inches		
velocity factor 1 if none	1.00		feet	inches
safe edge for each arm	0.50	inches		
			feet	inches
calculated length of antenna wire needed	395.104	inches or	32.00	11.10
each spiral or quarter wave				

Step 2. Adjust pitch and starting distance from the center to result in the desired length ending as nearly as possible on an arm. In other words, the coil should have made x.0, x.25, x.5, or x.75 turns exactly.

Spiral Antenna Model

pitch	2.10	**turns**	5.72	
start	5.00	**min spoke**	17.02	inches

Arm length including safe edge 35.03 Cut cross arms to this length in inches

Kerf marking table Mark from the center of each cross member out

	R1	R2	R3	R4		"1/16"
0	5.00	5.53	6.05	6.58	**0.10**	**1.60**
1	7.10	7.63	8.15	8.68	**0.20**	**3.20**
2	9.20	9.73	10.25	10.78	**0.30**	**4.80**
3	11.30	11.83	12.35	12.88	**0.40**	**6.40**
4	13.40	13.93	14.45	14.98	**0.50**	**8.00**
5	15.50	16.03	16.55		**0.60**	**9.60**
6					**0.70**	**11.20**
7					**0.80**	**12.80**
8					**0.90**	**14.40**
9					**1.00**	**16.00**
10						

Trimming Calculator

Actual Res	Change antenna by	
7.08	-7.21	subtract this number of inches

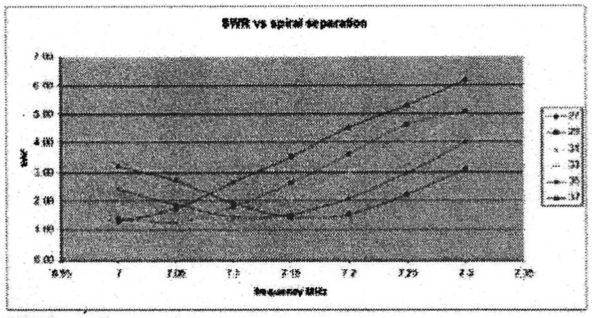
The overall antenna diameter is calculated as values for pitch and start are entered. The same is true for the overall arm length, the measurement needed to cut the support arms to proper length.

Kerfs, or saw cuts made in the PVC support arms, in combination with plastic wire-ties, are used retain the antenna wire. The spreadsheet creates a kerf cutting table based on the pitch and start values entered. In practice two cross arms are placed at right angles to each other forming a plus sign. Then in either clockwise or counter clockwise fashion, spokes are labeled R1 through R4. The center is marked on each arm, and the table values are then transfered to each spoke, starting at the center of each arm and working out to the end.

The Effect Of Beam Length On SWR top

(Note: all SWR measurements were made using the MFJ Model xxx antenna analyzer. In each case the test antenna was raised thirteen feet above the ground and connected to the analyzer through approximately 60 feet of RG8 mini coax.)

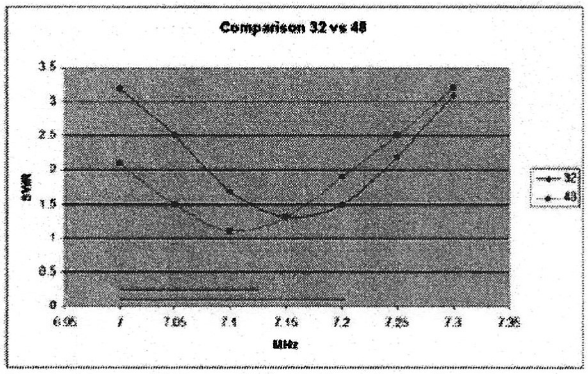
The following graph shows the result of beam length on SWR. It is clear from these data that as the beam is lengthened, or the spirals are moved farther apart, the resonant frequency is increased. In this experiment the separation was varied from 27 to 37 inches in two-inch increments. Over this distance the resonant frequency shifted approximately .18 MHz or just over half the 40-meter bandwidth.



SWR vs Separation

The Effect of Spiral Diameter On Bandwidth top

Spiral diameter has an effect on bandwidth. Two antennas were compared, one with a 32-inch diameter spiral, and another with a 48-inch diameter spiral. Tracing along the line equal to an SWR of 2 the bandwidths of each variation can be compared. In this experiment the frequency range at or below an SWR of 2 was much greater for the 48-inch model than for the 32-inch model. The two horizontal lines at the bottom of the chart represent this difference and are equal in length to the bandwidths of the 32 and 48-inch antennas respectively. See figure below.



Comparison of 32 vs. 48-Inch Arm Length

Model Verification - Does the model work? top

A model is only as good as the results it produces. To test the validity of the spiral antenna model an antenna was constructed according to the following parameters. See table below. After selecting the resonant frequency, hookup wire length, and velocity factor, pitch and start values were varied to produce an antenna with a slight overhang past its last supporting point. This is one of many configurations that could have been selected.

Step 1. Enter parameters.

desired frequency	7.15	Mhz			
hookup wire one side	15	inches			
velocity factor 1 if none	1.00			feet	inches
safe edge for each arm	0.50	inches			
				feet	inches
calculated length of antenna wire needed	397.972	inches	or	33.00	1.97
each spiral or quarter wave					

Step 2. Adjust pitch and starting distance from the center to result in the desired length ending as nearly as possible on an arm. In other words, the coil should have made x.0, x.25, x.5, or x.75 turns exactly

Spiral Antenna Model

pitch	1.80	turns	6.06	
start	5.00	min spoke	15.90	inches

Arm length including safe edge 32.80 Cut cross arms to this length in inches

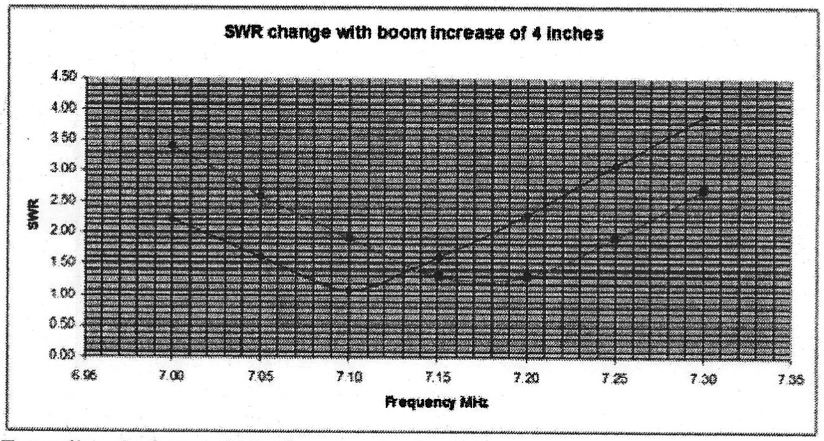
Kerf marking table — Mark from the center of each cross member out

	R1	R2	R3	R4		"1/16"
0	5.00	5.45	5.90	6.35	0.10	1.60
1	6.80	7.25	7.70	8.15	0.20	3.20
2	8.60	9.05	9.50	9.95	0.30	4.80
3	10.40	10.85	11.30	11.75	0.40	6.40
4	12.20	12.65	13.10	13.55	0.50	8.00
5	14.00	14.45	14.90	15.35	0.60	9.60
6	15.80				0.70	11.20
7					0.80	12.80
8					0.90	14.40
9					1.00	16.00
10						

The exact length predicted by the model was marked on a length of 14-gauge aluminum wire. The wire was then cut a few inches longer than required. Next, two spirals were wound according to the table above. The model predicts that there will be 6.06 revolutions. The additional .06 revolutions amounts to 21.6 degrees and equates to an approximate distance along the outermost lap of this spiral design of 5.8 inches. The average overhang for both test spirals was just over an inch less than the theoretical value. This discrepancy can easily be accounted for by construction technique.

After attaching the spirals to a beam, a series of SWR tests were made. In each case the antenna was connected to 60 foot of RG8 mini and elevated 13 feet above the ground. The antenna wire length was intentionally set long to insure that it would not be necessary to add extra wire in the tuning process. Consequently, initial SWR measurements suggested that the resonance point was low. Material was removed from the outer lap of each spiral until the exact length of antenna wire determined by the model was reached. At that condition the resonant frequency was 7.075 MHz. The aim was 7.15MHz. After two additional inches of antenna wire were removed from the outermost lap of each spiral, the resonant frequency increased to 7.096 MHz. Beam length was then increased by 4 inches to arrive at a final spiral separation of 28.75 inches. This brought the resonant frequency to 7.17 MHz, slightly above aim and favoring the voice portion of the 40-meter band.

The following graphic shows the SWR response as a function of frequency before and after the final length adjustment. After adjustment, the SWR vs. Frequency curve can be seen to shift to the right.



Extending the beam shifts the curve to the right.

Summary top

The spiral antenna spreadsheet model accurately predicts the number of revolutions expected for a given antenna length, pitch, and starting distance from the center of the spiral.

The spiral spreadsheet model has proved to be a useful tool for designing and building spiral antennas for the 40-meter band.

Future Work top

There are many possibilities for future investigation. Some suggestions are:

- The effect of wire gauge on SWR and bandwidth.
- Directional properties of the spiral antenna.
- The inclusion of a calculator within this web page