FSL Antenna Design Optimization

All-out Experimentation to Determine Weak-Signal Performance Potential

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Introduction The publication of Graham Maynard's ferrite sleeve antenna article in March of 2011 kicked off a torrent of experimentation in the Ultralight radio enthusiast group, as hobbyists quickly discovered the DXing potential of the new design. Massive orders were placed for Russian surplus ferrite and Chinese Litz wire, while wholesale lots of swimming floatation aides were drafted into service as ferrite padding material. Each individual experimenter had his own ideas about FSL design, and backed them up with serious financial outlays. Multiple design optimization questions went unanswered in the process, but since the new antennas seemed to be working fairly well for everyone, attempts to bridge opinion gaps were few and far between.

One school of thought held that coil diameter was the most important gain factor, while another was that ferrite size and weight was paramount. Ferrite rod versus ferrite bar opinions were also diverse, and even Litz wire variables became part of the controversy. Any newcomer wishing to build an FSL antenna had no shortage of advice—the only problem was which advice to follow.

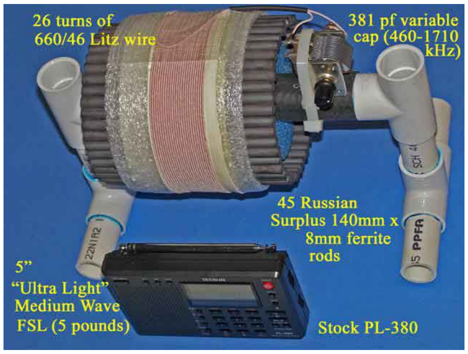
This experimental free-for-all continued for a full year, with various (and diverse) FSL antenna designs published in the process. The performance variables needed to be sorted out in detailed A/B experimentation, conducted by an experimenter with a completely open mind, and with no axe to grind. Although all of my previously-published FSL designs had been based on ferrite rod components, I recalled that a large supply of Russian surplus 100mm x 20mm x 3mm ferrite bars had been received here for some time, and had gone unused. In a serious effort to bridge opinion gaps and provide complete clarity to the design factors influencing any FSL's weak-signal DXing performance, it was time to wipe the slate clean and test out all possible variations of the antenna-- letting the chips fall where they may.

Experimental Objectives The ambitious agenda of the testing included all experimentation necessary to judge the weak-signal performance of ferrite rods compared to ferrite bars, to judge the weak-signal performance of large-diameter FSL models compared to smaller-diameter models with more ferrite weight, and if at all possible, to establish a design formula which could accurately predict the weak-signal DXing performance of any FSL antenna model before it was constructed (as well as rate the effectiveness of any existing model). These were challenging goals, but I was determined to continue the experimentation (and build as many test models as necessary) until complete clarity of all the design optimization factors was reached.

In order to carry out this agenda seven new FSL test models were built, including a diverse variety of ferrite bar models, short ferrite rod models and long ferrite rod models. Deliberate use was made of common material like Russian surplus ferrite (of 400 permeability), single coils composed of 660/46 Litz wire, a common 381 pf variable capacitor and standard PVC-pipe frames. Each test model was constructed with a coil diameter shared by other models using dissimilar ferrite material (bars, short rods or long rods) so that the performance differences between each ferrite type would become obvious. Finally, all test models would be judged in relative weak-signal performance outdoors in an open-air test range, competing with each other in the reception of at least four fringe daytime DX test stations on frequencies throughout the AM band. During this testing relative-reception MP3's would be recorded for each antenna match up, with the antennas switched in the middle of the recording (within 7 seconds, so that the fringe station's signal level would not change). Both FSL test models would be placed on a 5' PVC base for equal elevation, and the antennas would be separated by at least 50 feet so that there would be no possibility of interaction. Additionally, in cases where a relative-strength deadlock was apparent between two FSL test models, a reference antenna (4' sided PVC air core loop) would be used to check if either test model had better performance against the reference antenna. In summary, every possible preparation was made to provide equal testing parameters for accurate relative performance results.

Three Diameter Classes   The test models were divided into 3", 5" and 7" diameter classes. The 3" class included a 200mm long-rod model, a 100mm bar model, and a 65mm short-rod model. The 5" class included a 140mm long-rod model, a 100mm bar model, and a 65mm short-rod model. Finally, the 7" diameter class included a 140mm long-rod model and a 100mm bar model.

Each diameter class would first have relative performance tests against other antennas of the same class, then the top performers in each class would have match ups against each other. With the diverse mix of rods, bars and diameters in the test models, it was presumed that obvious patterns of superior performance would emerge—and they quickly did.



Ferrite Rods or Bars—Which are Better?   In each diameter class a clear pattern emerged immediately, with every model having a longer ferrite material (rod or bar) beating out every model with a shorter ferrite material (rod or bar). The thickness or weight of the ferrite material was irrelevant—even though the 65mm rod models had greater weight and ferrite thickness than the 100mm bar models, they lost out to the bar models every time. But this had nothing to do with any superiority of the bar models—to even the score, the 100mm bar models always lost out to the 140mm and 200mm rod models. So the question of rods or bars had finally been answered—whichever ferrite material was longer had the superior DXing performance. Even a 35mm or 40mm advantage in ferrite length was enough to provide a noticeable edge in weak-signal performance, for a given coil diameter.

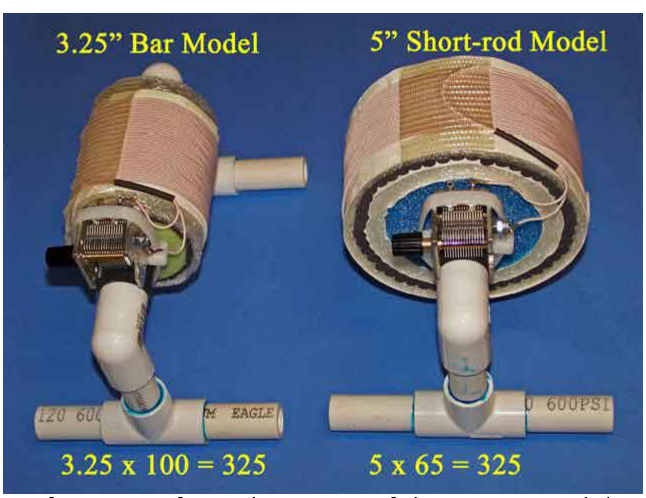
Smaller Diameter FSL Beats Out Two Larger Diameter Models
The 65mm short-rod FSL models proved to be experimental duds, losing out to every other FSL model in their respective diameter classes. But before final elimination from the competition, the 5" short-rod (65mm) model was matched against the 3.5" long rod (200mm) model—and was clearly inferior to it. The 3.5" long-rod (200mm) model not only outpaced the 5" short-rod (65mm) model, but clearly outperformed the 5" bar model (100mm) as well. This was the first experimental proof that a smaller diameter FSL could outperform a larger diameter FSL—and another indication that ferrite length is extremely important to overall DXing performance.

The "Odd Couple" DXing Deadlock   With the overachieving 3.5" long-rod (200mm) model running roughshod over two of the 5" diameter FSL models, it was given a shot at the 7" diameter bar (100mm) model. In what was probably the most important FSL match up in the entire project, the two completely different antennas deadlocked in performance on all 5 of the test signals. This was the first weak-signal deadlock in 10 different FSL match ups, so it was quite a surprise. Both antennas were then tested against the 4' air core reference loop—and both FSL's deadlocked with it, also! There was now no doubt that the DXing performance of these two radically different models was identical, which certainly was a puzzle considering their polar-opposite design.

But when I looked at both models closely, I finally noticed a very peculiar relationship between them… the 3.5" long-rod model's ferrite length (200mm) was twice that of the 7" bar model (100mm), while the 7" bar model's coil diameter was twice that of the 3.5" long-rod model! Could this mean that ferrite length was equally important to coil diameter in determining an FSL's overall performance? It certainly was in these two FSL models—the two models each had their own design advantage, which was resulting in a DXing deadlock!

After stumbling on this concept, I quickly made up a provisional formula to predict an FSL's overall DXing performance: In comparison to other models having equal component parameters (Litz wire type, coil orientation, and ferrite permeability), an FSL's coil diameter times its ferrite length would determine its overall weak-signal capability. Since every current FSL experimenter used inches to measure coil diameter and millimeters to measure the Russian surplus ferrite length, I decided to risk the wrath of purists and simply multiply the two dissimilar measurements together in my formula, which in the case of the 7" bar FSL worked out to an equation of 7 x 100 = 700 points. In the case of the 3.5" long-rod FSL the equation worked out to 3.5 x 200 = 700 points, an identical figure.

But wait—I knew that the 5" Mini FSL model (composed of the 140mm long ferrite rods) had also deadlocked with the 4' air core reference loop, which meant that its performance was also identical to these two deadlocking FSL models. Here was now yet another FSL model which had a design pretty much in the middle of the two radically different models, with equal performance. Theoretically, it should then have the same performance "score" as the other two FSL models in the new equation. It was with some excitement that I quickly did the math… 5 x 140 = 700! All three performance scores agreed with each other, and I was thrilled that the new formula had accurately predicted the 5" Mini-FSL's participation in a 3-way DXing deadlock (as shown in the large group photo of the three FSL's together, at the beginning of this article).



Further Confirmation of the FSL Performance Formula's Accuracy When considering the results of all the FSL test model match ups conducted previously, I finally realized that the new performance formula could have accurately predicted all of the experimental results before any of the test models had even been constructed! But there was one test model match up that had not been tried yet, which was to provide the final confirmation of the formula's accuracy. The 5" short-rod (65mm) model was an under-performer, and had never been matched against the 3" bar (100mm) model. However, the apparent performance formula scores of these two models were extremely close (325 and 300, respectively), and it was time to see how they shook out in an actual weak-signal Shootout. Before running this final confirmation test I carefully measured the actual diameters of the two models, though—and was very lucky to find that the 3” bar model was actually a little bit larger than 3”, having a coil diameter of 3.25”…giving it a dead-even performance score with the 5” short-rod model! I didn’t even need to modify either model, to have another two FSL antennas which (theoretically) should be equal in weak-signal performance, according to the new design formula.

Once again, it was with some excitement that I set up both FSL test models on their 5’ PVC stands in the back yard test range, eager to see if the performance formula had once again clearly predicted the final result. After receiving the very first fringe signal (540-Burien TIS) on both models I knew that I could have saved my trouble… switching between the two antennas in the MP3 recording produced no change in signal quality at all. It was another rare performance deadlock of two diverse FSL test models--- accurately predicted by the new performance formula.

Experimental Wrap Up The objectives of the testing had all been met, and accurate weak-signal design factors for the FSL antenna had finally been determined. To summarize, here were the new discoveries:

1) There is no weak-signal advantage to be gained by using either ferrite bars or ferrite rods. The only performance factor related to ferrite is the ***length*** of the ferrite material, whether it is in bar or rod form. For a given FSL coil diameter, as long as the ferrite permeability is identical, longer ferrite material will always outperform shorter ferrite material, and the weight and thickness of the ferrite material is irrelevant to weak-signal performance (this was proven in seven FSL match ups).

2) The ***length*** of the ferrite material in an FSL antenna is equally important to its coil diameter in providing weak-signal performance. An FSL with twice the ferrite length of another FSL model can still match its weak-signal performance even with a coil diameter half the size of the other model (proven in the case of the 3.5” long-rod model and the 7” bar model).

3) Assuming that all component parameters (Litz wire type, coil orientation and ferrite permeability) are identical between two FSL antenna models, the weak signal performance of any FSL antenna in relation to another can be accurately determined by multiplying the coil diameter times the length of the ferrite material in the sleeve. This product gives a “Performance Score” which can accurately predict the weak-signal reception capability of any FSL antenna in comparison to other FSL models having the same component parameters (proven in three FSL match ups here, with identical signals in switched MP3 recordings).

Summary The ability to accurately determine an FSL antenna’s DXing performance even before construction opens up a fascinating new perspective on design improvements. Aided by the new performance design formula, a hobbyist can concentrate on building highly effective models at a minimum cost and weight. The FSL antenna’s great advantage in relation to other antenna types is its ability to provide low noise, high gain performance from an extremely compact size—and this new design formula emphasizes compact effectiveness, proving that ferrite length is equally important to coil diameter in DXing performance. Future FSL antenna models that combine both ferrite length and coil size are the wave of the future, and now that definite answers have been found for most of the design controversies, we can proceed to design and build our new models with complete assurance of success!

73 and Best Wishes,
Gary DeBock

Relative Strength “Shootout” MP3 Links

For determination of the design factors influencing an FSL antenna’s weak-signal performance, four of the FSL test model match ups were considered very important. These four match ups (with the design factors clarified by the results) were as follows:

1) 3.25” Bar model (100mm ferrite length) outperforms 3.25” Short-rod model (65 mm ferrite length)

Longer ferrite sleeve material is superior in performance to shorter ferrite sleeve material, even if the shorter material is heavier and thicker than the longer material.

2) 3.5” Long-rod model (200mm ferrite length) outperforms 5” Short-rod model (65 mm ferrite)

A smaller diameter FSL model can outperform a larger diameter FSL model if the smaller diameter model has a ferrite sleeve length much greater than that of the larger diameter FSL.

3) 3.5” Long-rod model (200mm ferrite length) deadlocks in weak-signal performance with 7” Bar model (100mm ferrite length)

The ferrite sleeve length of an FSL model is of equal importance to its coil diameter in determining weak-signal performance. An FSL model with twice the ferrite length of another model can match its weak-signal performance even with a coil half the diameter of the other FSL model.

Assuming that component parameters (Litz wire type, coil orientation and ferrite permeability) are identical, any FSL antenna’s weak-signal performance in relation to another FSL antenna can be accurately determined by multiplying its coil diameter times its ferrite sleeve length, and comparing this “Performance Score” with that of the other FSL model.

4) 3.25” Bar model (100mm ferrite length) deadlocks in weak-signal performance with 5” Short-rod model (65mm ferrite length)

The “Performance Score” formula can accurately predict the identical weak-signal performance of two FSL antennas, even when they have different coil diameters and ferrite sleeve lengths.

The detailed MP3 recording links for each of these important FSL test model match ups follow.

1) 3.25” Bar model (100mm ferrite length) outperforms 3.25” Short-rod model (65mm ferrite)
(3.25” Short-rod FSL reception for first 18 seconds, followed by that of the 3.25” Bar FSL)

540-Burien TIS (15 watts at 25 miles)
http://www.mediafire.com/?jqja5qneh3f9chl
790-KGMI (5 kW at 140 miles)
http://www.mediafire.com/?fbobcmhv4d27c47
1230-KWYZ (1 kW at 80 miles)
http://www.mediafire.com/?76nglcufzz1c7pd
1430-KBRC (5 kW at 110 miles)
http://www.mediafire.com/?76nglcufzz1c7pd,lzzz0bamjdt3jgg

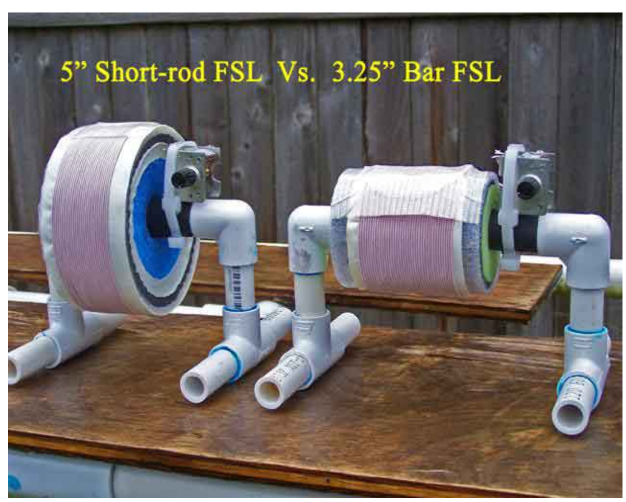
2) 3.5" Long-rod model (200mm ferrite length) outperforms 5" Short-rod model (65mm ferrite)
(5" Short-rod FSL reception for the first 18 seconds, followed by that of the 3.5" Long-rod FSL)

540-Burien TIS (15 watts at 25 miles)
http://www.mediafire.com/?y6j2q0p4e76po6c
1230-KWYZ (1 kW at 80 miles)
http://www.mediafire.com/?i6575pbpkimg4vw
1410-CFUN (50 kW at 160 miles)
http://www.mediafire.com/file/4v7j05y10bg5633/1410-CFUN-5in65mmFSL%252B3inLJFSL.mp3/file
1430-KBRC (5 kw at 110 miles)
http://www.mediafire.com/?zl3ba6dg6pd65ab

3) 3.5" Long-rod model (200mm ferrite length) deadlocks in weak-signal performance with 7" Bar model (100mm ferrite)
(7" Bar model FSL reception for the first 18 seconds, followed by that of the 3.5" Long-rod FSL)

540-Burien TIS (15 watts at 25 miles)
http://www.mediafire.com/?bbuzgs8c819wsrj
750-KXL (50 kW at 150 miles)
http://www.mediafire.com/?87d0ccexi81yhaw
1040-CKST (10 kW at 160 miles)
http://www.mediafire.com/?i8d4jjd4q2vctml
1070-CFAX (10 kW at 90 miles) http://www.mediafire.com/?ghh0omngnn5o9le
1410-CFUN (50 kW at 160 miles) http://www.mediafire.com/?lgfq7r9763g59h8

4) 3.25" Bar model (100mm ferrite length) deadlocks in weak-signal performance with 5" Short-rod model (65mm ferrite)
(5" Short-rod model FSL reception for the first 18 seconds, followed by that of the 3.25" Bar FSL)



540-Burien TIS (15 watts at 25 miles)
http://www.mediafire.com/?5n7vm2upt1zxfn9
750-KXL (50 kW at 150 miles)
http://www.mediafire.com/?ok82g3ey77bxncr
1070-CFAX (10 kW at 90 miles)
http://www.mediafire.com/?1cy43cahub24ylh
1410-CFUN (50 kW at 160 miles)
http://www.mediafire.com/?1v8qa3g3j0dcth3

FSL Test Model Specifications

Model	Ferrite Size	Ferrite Wt.	Total Wt.	Construction Cost*	Performance Score**
3" Short rod	65 x 8mm	1.5 lbs.	2 lbs.	$45	195
3.25" Bar	100 x 20 x 3mm	1.0 lbs.	1.5 lbs.	$40	325
3.5" Long rod	200 x 10mm	4.0 lbs.	4.5 lbs.	$95	700
5" Short rod	65 x 8mm	2.5 lbs.	3.0 lbs.	$65	325
5" Bar	100 x 20 x 3mm	2.0 lbs.	2.5 lbs.	$50	500
5" Long rod	140 x 8mm	4.0 lbs.	5.0 lbs.	$90	700
7" Bar	100 x 20 x 3mm	3.0 lbs.	4.0 lbs.	$65	700
7" Long rod	140 x 8mm	6.0 lbs.	7.0 lbs.	$130	980

* Total cost of components (excluding shipping charges) as of March 2012
** Coil diameter (in inches) times ferrite sleeve length (in millimeters)