Metal or Plastic? (Boom that is…)

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I had the opportunity in a previous *Journal* to share with you a Signal Fading Study Technique [1] that I developed to take a closer look at signal fading between the satellites and a ground station. I also had a secondary purpose for that study, to see if I could quantifiably evaluate my station performance to make better judgments on improvements to my antenna system. The technique was based on some homegrown software [2] that reads the rig's (IC-910) S-meter during a pass and dumps the time-stamped data to Excel for exploitation and analysis. The technique worked pretty well and provided some good insights that allowed me to at least convince myself how to prioritize my antenna projects.

I was using M² antennas for up and down links mounted on a metal cross boom made from scrap fencing material. In the antenna documentation, M² states, "The [antenna] is a circular polarized antenna and creates a field in all planes or polarities. Performance DETERIORATES SIGNIFICANTLY if it is mounted on a metal (conductive) mast or crossboom." [3] I suspected that I had seen the effects of that predicted "deteriorated polarity pattern" because of my metal-cross boom during my signal fading study, but I wanted to know just how much of a problem it was. Seizing the opportunity during a visit to M² and their annual BBQ (and a severe moment of weakness on the part of my XYL), I picked up an 11-foot fiberglass cross boom for my antenna system. Having a price tag of $186 (list), I needed to convince myself that the price was worth the added performance, if any, and I wanted to validate the intuitively obvious disclaimer in the M² documentation. The Signal Fading Study Technique was again used in this effort.

Procedure

I had collected data on a number of AO-51 and AO-27 passes during the previous study. I had also done a pretty comprehensive SWR evaluation of the antennas. My metal boom was 11-feet, the same length as the replacement fiberglass boom, therefore it was easy to make a quick swap and have the only change in the antenna installation be the fiberglass boom. So my previous data was usable.

During this study I did:

1. A subjective anecdotal (gut) evaluation of changes in signal strength and de-sensing.
2. The same SWR evaluation of the antennas on the fiberglass boom.
3. Collected pass data as was done during the previous study.
4. Some additional statistical analysis to quantify any differences between the two booms.

I wanted to see if there were any noticeable changes in signal strength, in de-sensing during cross-band duplex operation, in the antenna SWR and in signal fading. Intuitively, there was no doubt that the fiberglass boom should improve the circularity of the antennas, but what was unknown was how much the improvement in circularity would improve the satellite reception.

Anecdotal Observations

I immediately noticed during the first satellite pass that the signal strength appeared to be about two S-units better than before. This again was observed during the next and subsequent passes. I also noticed a dramatic reduction in de-sensing while transmitting. In fact it was only detectable at the higher power levels. So things were looking pretty good, but I was also cautiously optimistic. Remember I had just spent $186 on an 11-foot section of plastic pipe (and admittedly, the XYL wasn't all that impressed).

Empirical Observations, SWR

The next test was to evaluate the SWR. I used a Bird 43 Watt Meter with the appropriate slugs. The two SWR curves are shown in Figures 1 and 2. The metal boom related graphs are depicted with dashed lines. The fiberglass boom related graphs are depicted with the solid lines. The results of my SWR evaluation were a bit unexpected. The overall SWR of both antennas is very good so I am not complaining, but there appeared to be no significant change in the SWR of the 2-meter antenna, and a slight degradation in the SWR of the 70-CM antenna.

Signal Strength

To evaluate the change in received signal strength, I compared the measured signal strength at the maximum elevation of the satellite for a number of passes for each satellite, AO51 and AO27. The results are depicted in Figures 3 and 4 and again the metal boom data is shown by the dashed line and the fiberglass boom data is shown by the solid line. I used the scatter plot graphing function and trend-line analysis function of Excel to do a curve fit of the data. There appears to be about a 12-dB increase in signal strength using the fiberglass boom over the metal boom. This is consistent with my anecdotal observations.

Signal Fading

I came to the conclusion during the Signal Fading Study that the apparent fading experienced during a pass could be mitigated somewhat by using circularly polarized antennas. Circularly polarized antennas can provide the better opportunity to capture the most signal from a changing polarized signal coming down from the satellite. If I assume that the metal-cross boom distorts the circularity of the antenna polarization, then I would expect deeper fading because the elliptical polarization pattern would not be as effective in capturing as much signal from the meandering polarized signal. On the other hand, the fiberglass-cross boom would have minimal effect on the antenna circularity and therefore the fading should not be as deep.

To test this theory, I collected pass data with the fiberglass boom as I had done previously

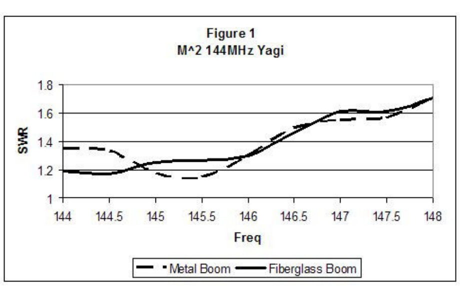

Figure 1
M^2 144MHz Yagi

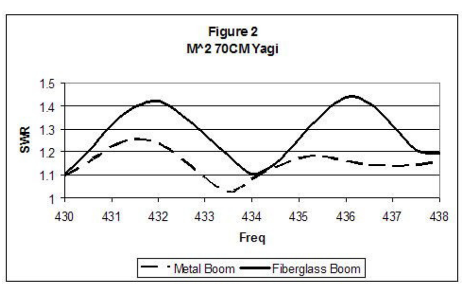

Figure 2
M^2 70CM Yagi

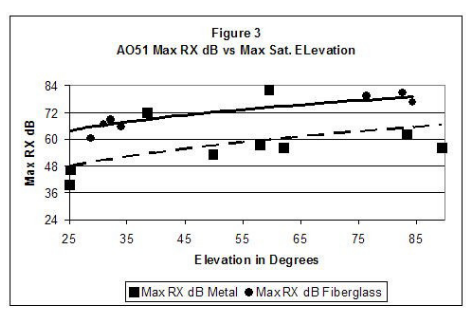

Figure 3
AO51 Max RX dB vs Max Sat. ELevation

with the metal boom. The data consisted of signal strength as indicated by the receiver S-meter and the calculated path loss due to the distance traveled from the satellite to the ground station. The path loss is the theoretical "best case" signal strength that can be expected. Any deviation from the "best case" is the result of things that we can attempt to mitigate through station and antenna design.

To then compare the two sets of data (measured signal strength and expected signal strength, i.e., path loss), I used the correlation statistical analysis function of Excel. The correlation coefficient is a measure of the extent to which two measurements (data sets) "vary together." The two data sets do not need to be of the same scale, or even measure the same thing. For instance, there can be a correlation between height and weight of a group of individuals. In this case, I am using the correlation analysis tool to examine each pair of data points (signal strength vs. path loss) to determine if the two data sets move together. If there is perfect correlation (they go up or go down together at the same scaled relative rates), then the correlation is equal to 1. If there is perfect negative correlation (one goes up while the other goes down, but at the same relative rates, just different directions) then the correlation is equal to -1. If there is absolutely no connection between the measurements, then the correlation is 0 (zero). So the bottom line is, the closer the correlation is to 1, the more closely connected the data sets are. (That is your statistics lesson for today.)

Let's take a look at AO-51 first. The graphic of a typical AO-51 pass is shown in Figure 5. The smooth curve is the calculated path loss (from a NOVA generated list for the pass). The erratic curve is the measured signal strength. The magnitude of the deviations from a smooth curve for the measured signal strength indicates the level or amount of fading that occurred. Using the correlation function to compare the path loss curve to the measured signal strength over a number of passes while using the metal boom resulted in an average correlation coefficient of 0.8643. This is pretty good (remember a perfect correlation would be 1). This level of correlation should be expected because the polarization of AO-51 is RHCP (in this mode), which matches the polarization of the antenna. In comparison, the same evaluation was made of AO-51 passes using the fiberglass boom. The average correlation coefficient was 0.8637 - virtually no difference! (This was confirmed using the statistical T-Test that indicated there was no significant statistical difference.) At first I was disappointed that there wasn't a difference, but then I considered that since the correlation was pretty good to begin with, any improvement with the fiberglass boom would be minimal at best.

Now let's turn to AO-27. The graphic of a typical AO-27 pass is shown in Figure 6. The measured signal strength plot is definitely different than that generated by AO-51. The depth of the fades is greater and there is some periodicity in the fades, probably due to the satellite's rotation. Remember AO-27 uses a vertically polarized antenna, so deeper fades should be anticipated - but how bad? Analyzing the AO-27 pass data with the correlation function revealed that the average correlation coefficient for the metal boom was 0.3849, showing less than optimal correlation (this is confirmed just by looking at the graph and the depth of the fades). In comparison, the average correlation coefficient when using the fiberglass boom was 0.5300! Now this was an improvement. This improvement was verified by using the T-Test, which showed that the difference between the data sets was a statistically significant improvement. In applying a little common sense here, there was more room for improvement to begin with, and the improved circularity of the antenna pattern allows the antenna to more efficiently capture the signal as it changes and shifts its polarity. If I had to put a number to the amount of improvement, I'd be comfortable in stating a 25% improvement in signal quality.

Education Slant

For the educators among the readers, you might consider an adaptation of this activity for your classroom. This activity would be good for instruction in problem solving, using the scientific method, hypothesis development and testing, data collection, data manipulation and analysis and statistical analysis. For readers with youngsters, your student might consider an adaptation of this activity for a science fair project. If well done and well presented, a project similar to this would blow the competition away.

Conclusion

So what did I find when I compared the metal boom to the fiberglass boom? I summarize my observations in Table 1. There was marginal effect on the antenna SWR; however, it was good to begin with. There was (subjectively) improvement in de-sensing. There was about 12 dB increase in signal strength. There was no real improvement in signal fading with AO-51, but again, it was pretty good to begin with. There was significant improvement in signal fading with AO-27. So what's the bottom line? Is it worth using a non-conductive boom? I guess it all depends on what your definition of "is" - is…oops, I mean "significant." I'd say the improvement in received signal strength justifies the fiberglass boom, but the improvement in signal stability, particularly for the linearly polarized satellites, is a good side benefit.

So have I been able to convince my XYL of the benefits of a fiberglass boom?…yah, right, I suspect you know the answer to that.

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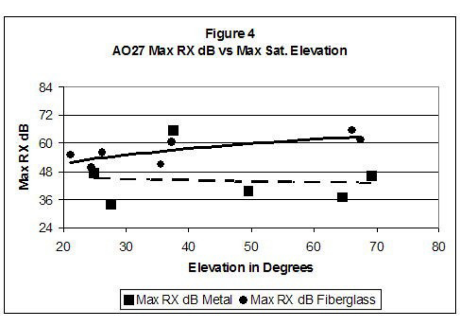

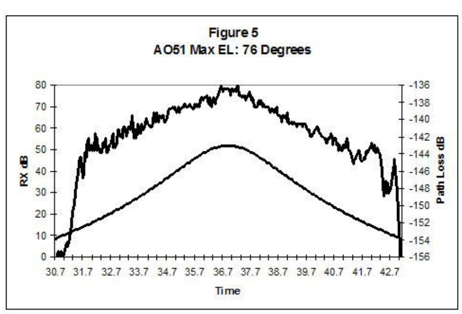

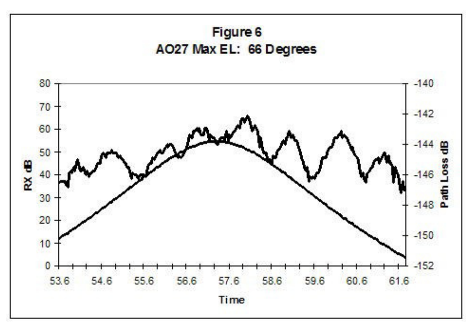

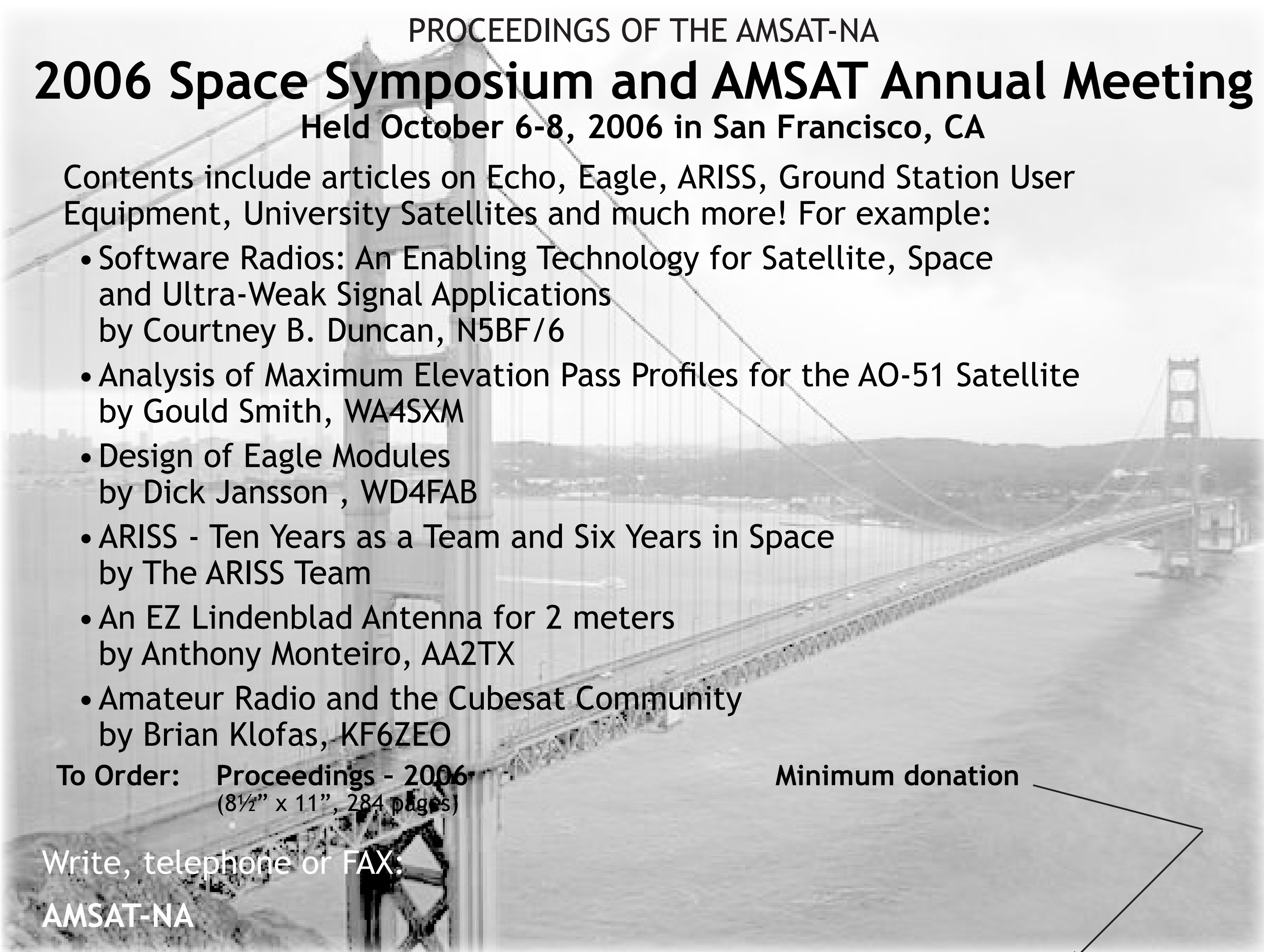

Metal or Plastic

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References

[1] *The AMSAT Journal*, March/April 2007, page 4.

[2] The software is written in Visual Basic 6.0 specifically for the IC-910 with CI-V interface. The software has only been tested with Windows XP. The source code and executable file are available for the price of an e-mail request to the author.

[3] M^2 Circular Polarization Yagi documentation.

Table 1

SWR	2 Meters	↔
	70 CM	↓
De-sensing		↑
Signal Strength	AO-51	↑
	AO-27	↑
Signal Fade	AO-51	↔
	AO-27	↑