Signal Fading Study Technique

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Satellite signal fading is an operating reality that each satellite user deals with. Through observation and listening to others on the birds, some interesting and conflicting effects of fading become evident. Some operators would comment on deep fades while I did not experience any fading at all. At other times, I experienced a deep fade while other operators carried on as if nothing had happened. Additionally, some satellites seemed to be more prone to fading than others.

I thought it would be interesting to try to quantify signal fading to see if I could get my arms around what is happening and perhaps come to some conclusion as how to mitigate the effects of signal fading by improving my station. In particular, I wanted to see if polarity switching of my RHCP antenna would be worth the cost, effort, and complexity.

And, as always, I also wanted to explore a technique that teachers might be able use with their students to advance the student's work with satellites and perhaps do a little research of their own. The three sidebars are specific "Benchmarks" [1], or learning objectives, that should be taught to high school students as part of the curriculum that leads them to gain "Science Literacy." The activity described here is one way that teachers can combine the use of ham radio satellites with the learning objectives required in the student's mathematics and science curriculum.

Background

One of the most understandable discussions I have come across on the efficiency of signal reception related to antenna design and performance and RF propagation issues are contained in a paper published by Cushcraft Corporation [2]. I highly recommend this reading as a good starting point for those interested in signal fading.

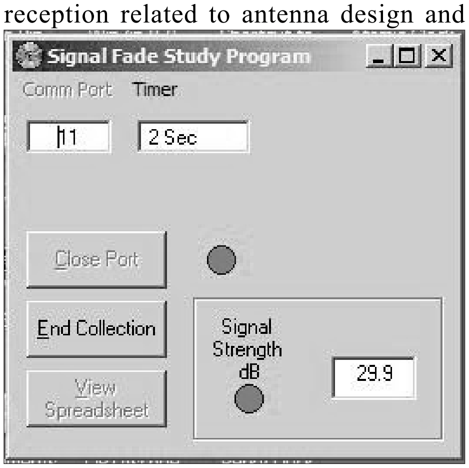

Figure 1: Calculation software.

In this signal fading study technique, you need to have a constant carrier from the satellite. The prime candidates of course are AO51 and AO27. I would have loved to be able to look into SO50, because this bird seems to experience the deepest fades, but the bird is carrier activated and I have yet to figure out a way to work with an intermittent carrier. Also, to study signal fading, you need a way to sample and measure the signal strength from the bird during the pass.

Station Setup

The station setup that I used for this activity consisted of an Icom IC-910, antenna mounted pre-amp, an M^2 436CP30 30-element RHCP Yagi antenna, a 7-element Arrow Yagi antenna mounted for horizontal polarization and a full AZ/EL rotor system. I also use a homebrew USB/CI-V interface to control the IC-910 with a computer [3]. By sending a command to the IC-910 through the CI-V port, the radio will report back to the computer the S-meter level with a number between 0 and 255 (the ADC value of the signal level).

I developed a simple computer program (Signal Fade Study Program) that sends the query to read the S-meter of the IC-910, converts the returned S-meter reading to decibels and dumps the data with a time stamp to an Excel spreadsheet. Figure 1 is a screen shot of the operating software. The program is written in Visual Basic 6.0. (The source code and program are available for the cost of an e-mail request to the author at mspencer@arrl.org. This program is specifically for the IC-910 and has only been run and tested on a Windows XP machine.)

Methodology

I collected data from a number of AO51 and AO27 passes using both the RHCP and horizontal Yagi antennas. As the satellite approached AOS, I launched the Study Program and tuned the IC-910 to the downlink frequency. When the satellite downlink was heard, I started collecting data and manually tracked the downlink frequency. At LOS, I stopped data collection and saved the Excel spreadsheet for further analysis. To provide a reference for signal strength, I imported into the Excel spreadsheet the distance between the satellite and the station using the NOVA list utility. Then using an Excel math formula, the path loss was calculated and the result was added to the graph of collected signal strength for comparison. The formula for converting distance between the satellite and the station to path loss is:

$$dB_{PathLoss} = -20\log\left(\frac{4\pi D_{meters}}{\lambda_{meters}}\right)$$

Figures 2 through 7 are representative graphs for data collected from AO51 and AO27 using the indicated antenna, either RHCP (with and without pre-amp) or horizontal Yagis.

Observations

Many of the antenna system performance challenges detailed in the Cushcraft paper are indicated in the graphs. The reader is encouraged to interpret the data and come to his/her own conclusions. A few of the observations that came from my interpretation of the data include:

1. The signal from AO51 appears more stable (reduced fading) than AO27. (Probably due to the RHCP antenna on AO51 on this downlink frequency and the linear antenna on AO27.)
2. The relative amount of fading was less for both AO51 and AO27 when using the RHCP antenna when compared to the fixed horizontal Yagi (taking into account the difference in gain).
3. The pre-amp helped to bring most of the deep fades up above the minimum signal level required for usable signals.
4. There are other interesting patterns, for instance, the periodicity of the AO27 signal fades (which are probably related to the rotation of the satellite).

For students, the real power of this activity is interpreting the graphs and speculating on what is going on. This speculation could lead to further investigation (the real reason behind the learning objectives).

Receive-Diversity Techniques

There are numerous techniques that can be employed to reduce the effect that signal fading has on a successful satellite QSO. A short list of these techniques includes improving antenna gain, adding pre-

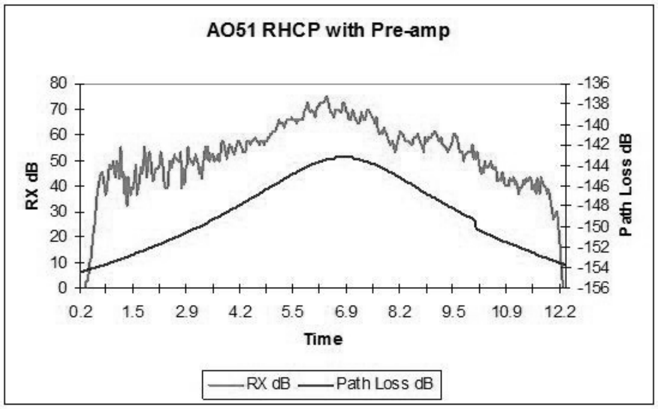

Figure 2

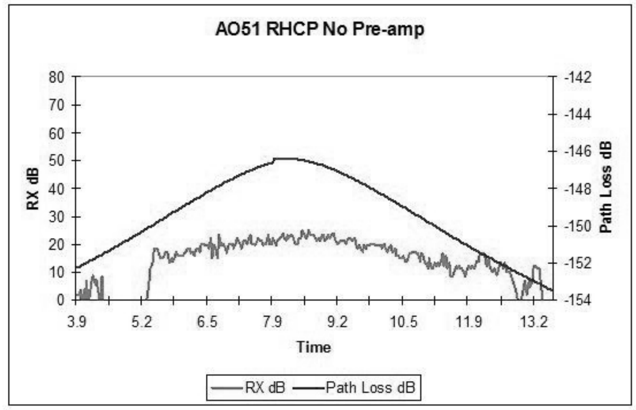

Figure 3

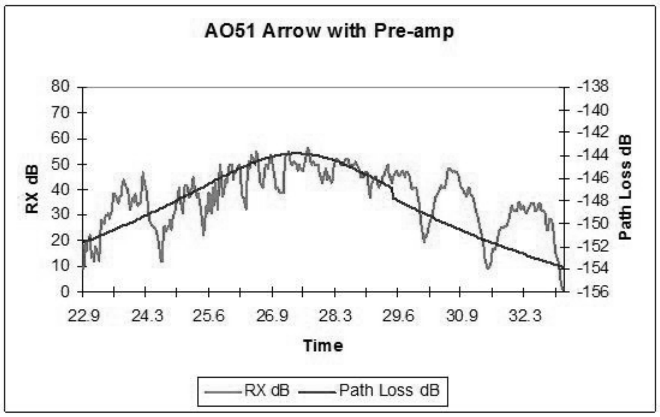

Figure 4

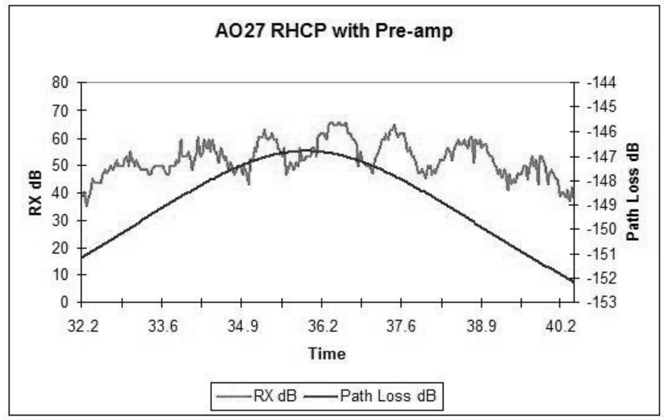

Figure 5

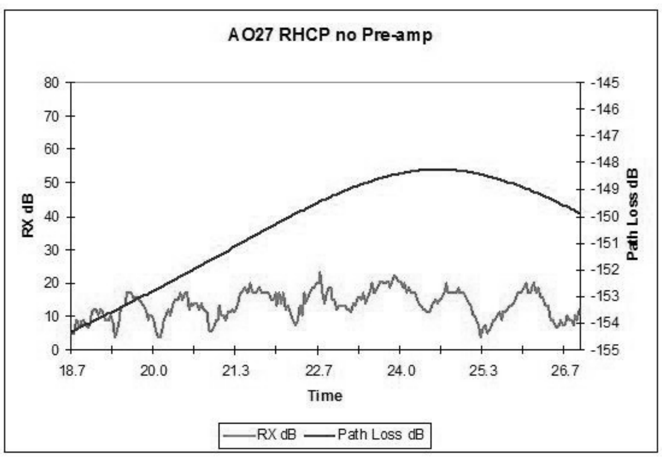

Figure 6

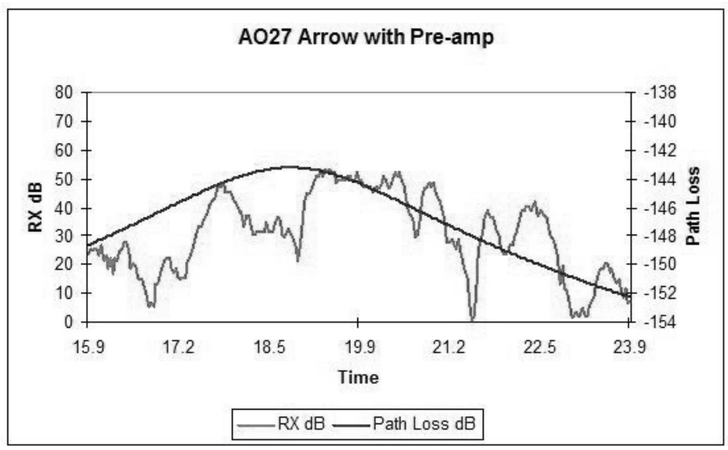

Figure 7

amplifiers, upgrading coax and connectors, adding circular polarization and adding polarization agility (switching). It really comes down to how much each technique costs and/or how much effort is required to implement the technique, i.e., getting the most bang for the buck.

The prioritized list of antenna system improvements (getting the most bang for the buck) that became clear to me as a result of this activity is:

1. Upgrading coax and connectors. Reducing signal loss in the antenna feed line system will improve overall antenna system performance no matter what antenna changes are made.
2. Increase antenna gain and/or adding antenna-mounted pre-amps. Increasing antenna gain will bring the fade "minimums" up to a level that will perhaps be above the minimum usable signal level of the receiver.
3. Upgrade the antenna to appropriate circular polarization sense for the satellites of interest (either RHCP or LHCP). Circular polarization will provide some improvement in performance regardless of the shifting polarity of the signal. (I tend now to think more along the lines of elliptical polarization versus circular polarization.)
4. Add polarization agility (RH/LH CP switching). This capability would provide the flexibility to work different satellites with different antenna polarization architectures and also provides some flexibility to react to real-time signal fading. To answer my own question, RH/LH CP switching would be nice to have but not worth the expense for my current interests.

The basic idea of mathematical modeling is to find a mathematical relationship that behaves in the same ways as the objects or processes under investigation. A mathematical model may give insight about how something really works or may fit observations very well without any intuitive meaning.

More on Computer Modeling

The Signal Fading Study Program can also be used with other antenna modeling programs to address other education benchmarks. I used the ARRL EZNEC 3.0 program that comes with the *ARRL Antenna Handbook* [4] to model the Arrow antenna. This provides the computer-generated prediction of the antenna radiation pattern addressed in the benchmark. Then I used an HT (with some attenuation) as a signal source, the Study Program and IC-910 connected to the Arrow antenna and collected signal strength data as a function of azimuth angle to the signal source to create the actual antenna pattern (the second part of the benchmark). The results are displayed in the graphics of Figures 8 and 9. The measured antenna pattern compares remarkably well to the predicted radiation pattern modeled by the computer and attests to the utility of computer modeling of real world systems (the desired outcome of the benchmark).

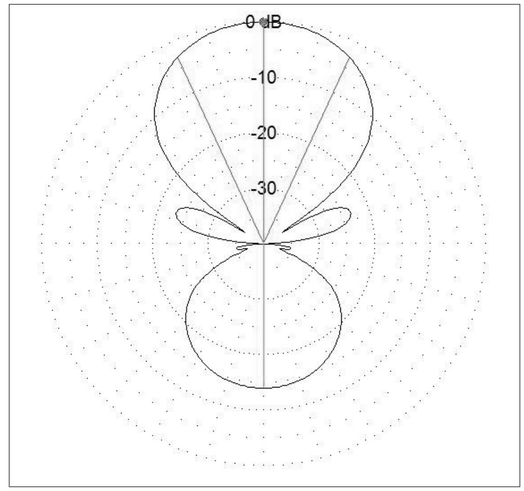

Figure 8

The usefulness of a model can be tested by comparing its predictions to actual observations in the real world. But a close match does not necessarily mean that the model is the only "true" model or the only one that would work.

Conclusion

You can explore many facets of ham radio satellites without sophisticated and expensive test equipment. By adapting your current radio equipment and exploiting all of the features, you can take a closer look at the science of radio under practical conditions. In this case, a simple computer program that uses off-the-shelf software (Excel) can provide some interesting insights as to what is happening between the satellite and your station, and can provide inexpensive learning opportunities for students that address learning objectives in a non-traditional, fun, and meaningful way.

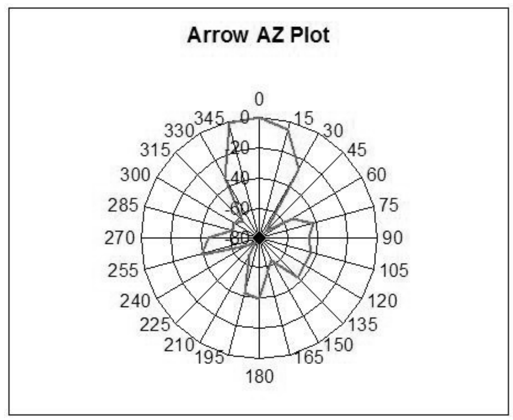

Figure 9

References

[1] *Benchmarks for Science Literacy*, American Association for the Advancement of Science, 1993, ISBN-0-19-508986-3.

[2] *Antenna Polarization Considerations in Wireless Communications Systems,* Cushcraft Corporation, http://www.cushcraft.com/comm/support/pdf/Antenna-Polarization-14B32.pdf

[3] May 2007 *QST Magazine*.

[4] *The ARRL Antenna Handbook*, 20th Edition, 2003, ISBN-0-87259-904-3

Computers have greatly improved the power and use of mathematical models by performing computations that are very long, very complicated, or repetitive. Therefore computers can show the consequences of applying complex rules or of changing the rules. The graphic capabilities of computers make them useful in the design and testing of devices and structures and in the simulation of complicated processes.