Optimization of Enhanced Observing Payload System through characterization of calibration and historical data sampling

T. Tabuchi, S.S Choi, J. Castillo

Northrop Grumman Electronic Systems ISR Division, Azusa CA 91702

Abstract

Northrop Grumman Electronic Systems (NGES) in Azusa is a leading systems integrator for Microwave payloads that supports—many government programs DMSP, JPSS, METOP, and others. NGES has developed imager and sounder payloads like AMSU, ATMS, and SSMIS which have been flying operationally for decades, providing successful data for weather forecasting over different frequency channels and data fusion for improved weather characterization.

We would like to share, our conceptual instrument's capability (based on the SSMIS) for improved detection and forecasting through a highly evolved noise injection calibration method. We will show how low-cost improvements may be made to the design to significantly improve the weather forecasting capabilities of the sensor.

Figures 1 through 3 [5] show typical data products taken from the SSMIS sensor. As useful as these data products are, the next generation sensor will certainly increase the fidelity and resolution of its data products.

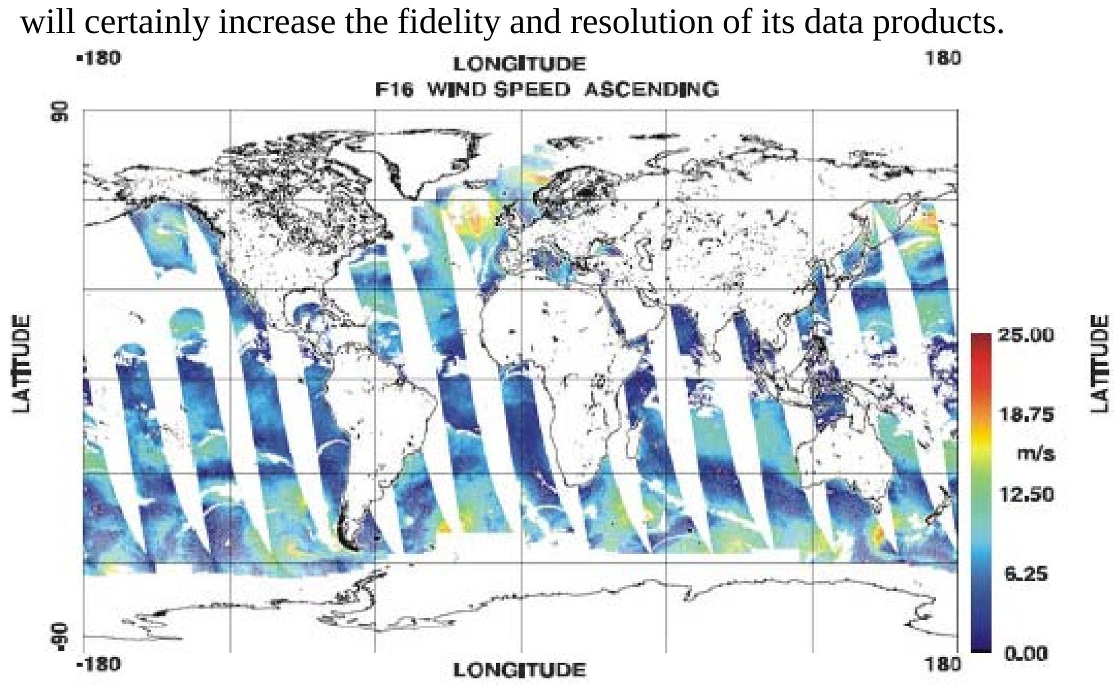

Figure 1. Wind Speed Image provided by SSMIS to NOAA for data extraction in 2003.

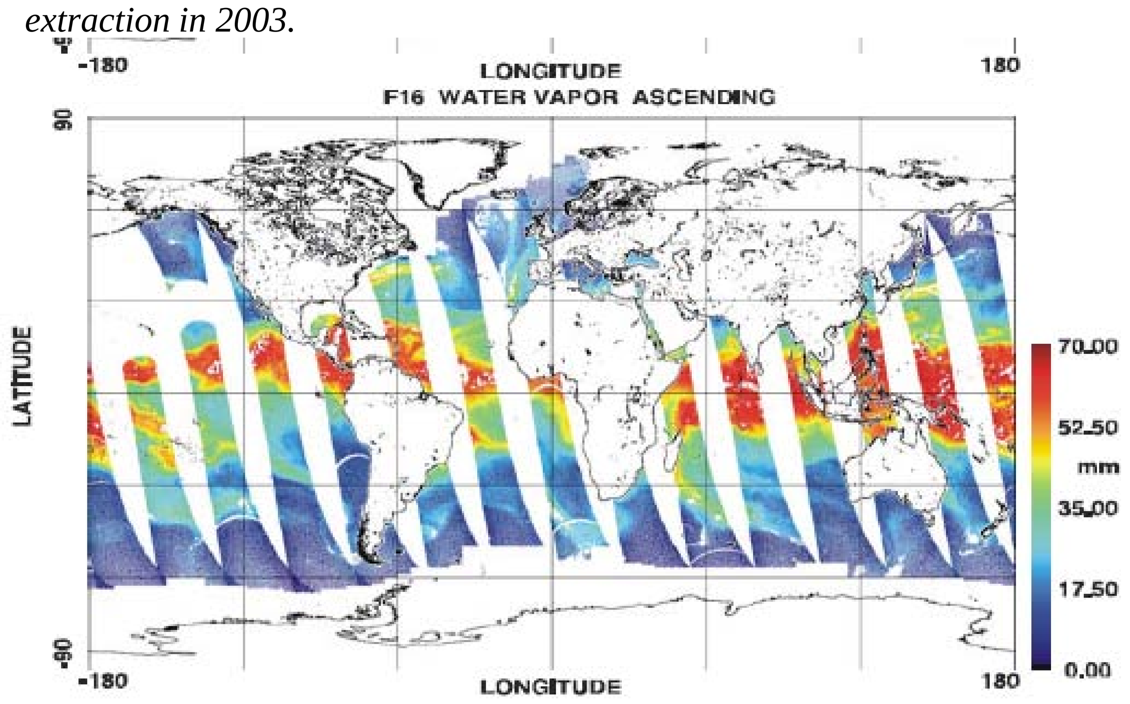

Figure 2. Water Vapor Image provided by SSMIS to NOAA for data extraction in 2003.

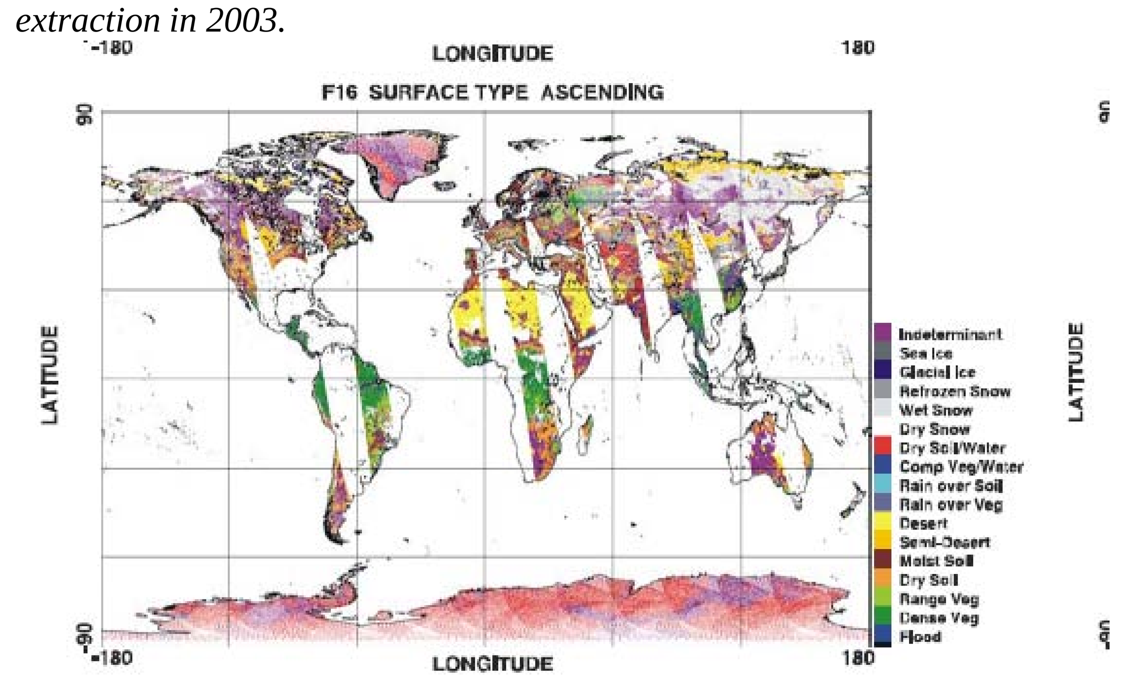

Figure 3. Land Surface Type Image provided by SSMIS to NOAA for data extraction in 2003.

Motivation

Most weather payloads utilize two points (warm and cold targets) to calibrate an instrument. The 2-point method forces a linear regression approximation for the calibration curve, but introduces errors from calibration uncertainty. A more accurate calibration curve would not be a linear system. There are many ways to compensate for the linear approximation of the calibration curve, but each method is still limited by the errors introduced by the 2-point calibration method.

Most current instruments use the linear approximation of the calibration curve to calculate NEΔT. Data, generally collected from a specified number of scans, is used in a Linear Least Squares (LLS) mathematical model to perform the calculation.

With the power controlled noise injection calibration method, each instrument can provide multiple points for a more accurate calibration curve approximation which is 4 to 8 times greater than current methods. The better accuracy in the calibration results in higher pixel quality.

Modeling & Methods

Factory testing uses a mathematical linear fit model for the slope equation to generate accurate calibration. This slope is then used for NEΔT and absolute accuracy (AC) calculations.

This linear fit model will contain typical errors that add to the calibration uncertainty. As shown in ***Figure 4,*** the error margin can be significant depending on how the two target points are measured. However, with the noise injection model, one can eliminate this by adding additional points to the curve.

The additional points are derived from both warm and cold target points through noise injection. The number of calibration points is dependent upon the ability to control the noise injection.

The additional points obtained from the noise injection must apply to the atmospheric weather collection frequencies which are in the 20-183 GHz range. This requires a reliable and repeatable noise source. The proprietary circuit geometry developed by Northrop Grumman Electronic Systems allows for better control of the noise source which then provides the ability to use the noise to create the additional points for calibration. Better control than has previously been obtained allows the system to utilize a low frequency noise source to output a high frequency set point.

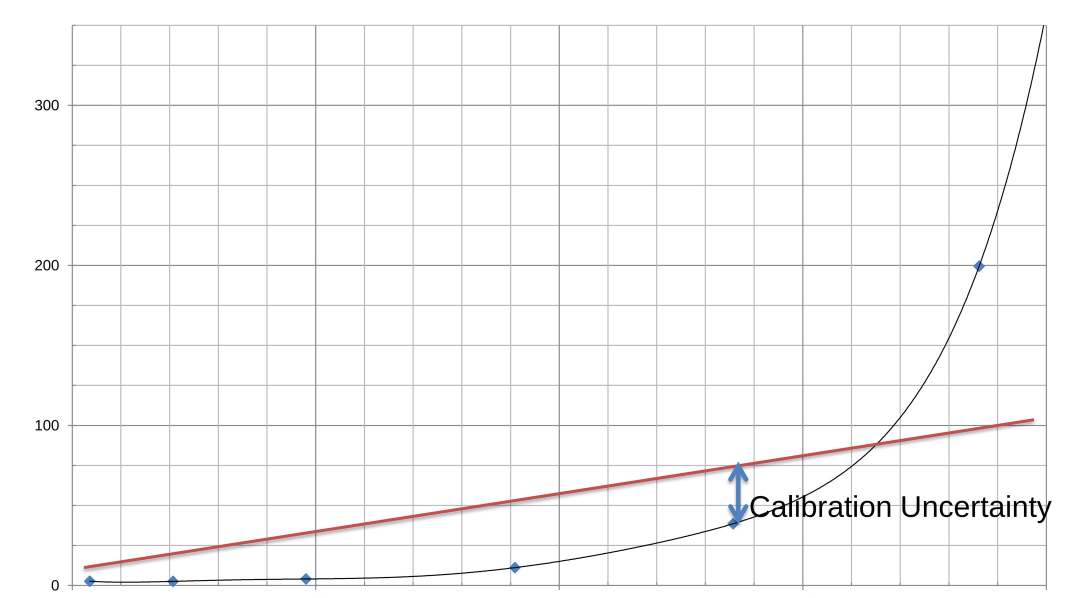

Figure 4. The difference between the Noise Injection (Black) vs. No Injection which is the traditional calibration method (Red) is shown.

Results

For this study, we demonstrated that the noise injection method can be controlled. ***Figure 5*** illustrates the power spectrum obtained with and without using the noise injection method. One can see the same characteristics yet a slight shift in the overall spectrum. This shift was carefully calibrated by measuring each injection and its respective output.

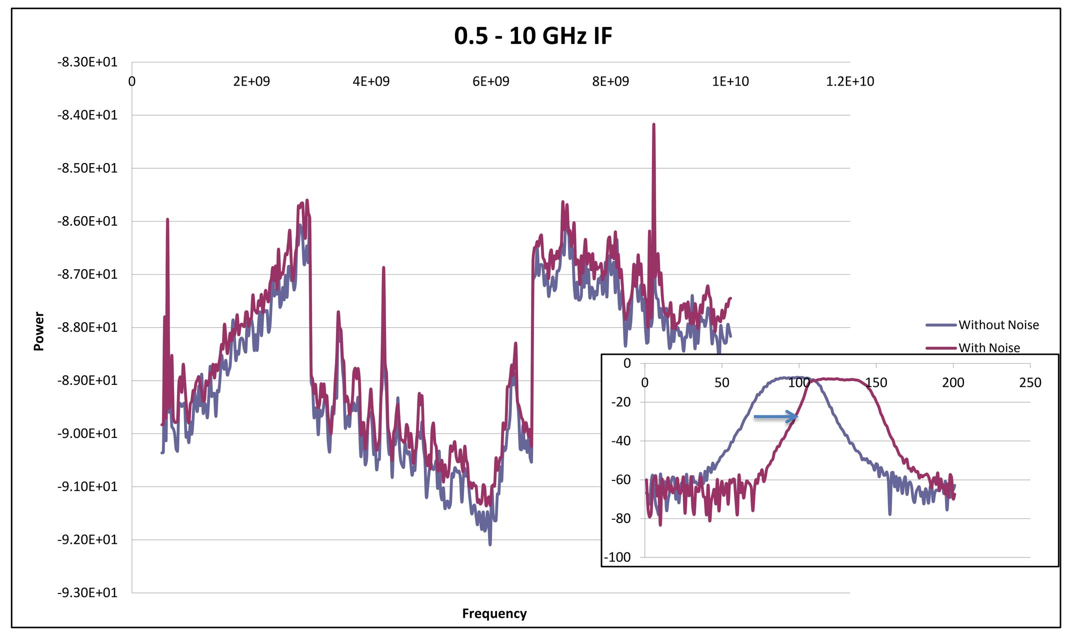

Figure 5*. With Noise Injection vs Without Noise Injection for 0.5 GHz to 10 GHz Range (Main). Noise Injection Shift is shown (Below)*

By increasing power to the noise source we were able to obtain the plot in ***Figure 6.*** Each linear fit represents a different coupling multiplier for the noise for 91-183 GHz, and even higher frequencies, which are quite valuable for weather modeling and detection.

Also at low power noise injection the calibration points were observed to be clustered together. This shows that the noise injection methodology encompasses the linear modeling if the user desires to compare the data between the linear model versus the noise injection model.

The typical repeatable correlation factor in this experiment was R^2=0.996, and the power required for the source to generate the injection noise was no more than 100 mW. The differential point was about 0.02 dBm.

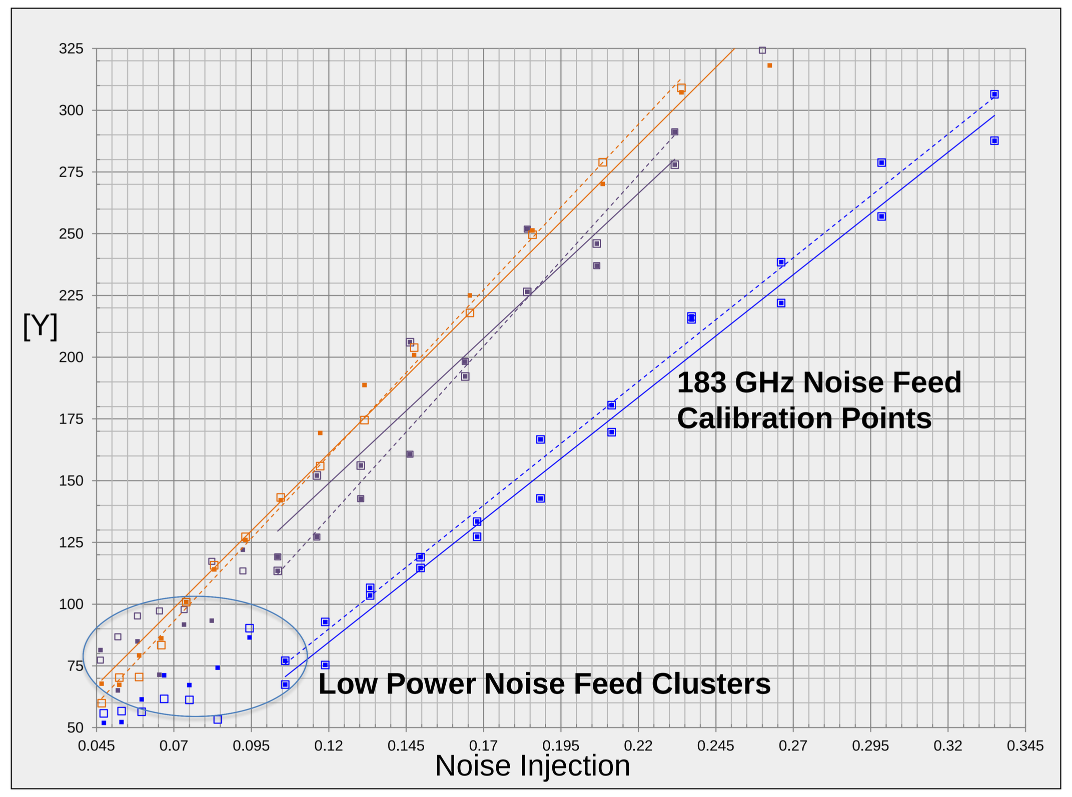

Figure 6*. Different Noise Injection Power per Attenuation Shifts. The Power increase in Noise Injection shows an increase in Calibration point shift (Main).*

Generally throughout the experiment, when the noise feed was within the calibration range, we were able to obtain 2 to 3 clear H(t)+ and H(t) – points as well as C(t)+ and C(t)- points as shown on ***Figure 7***.

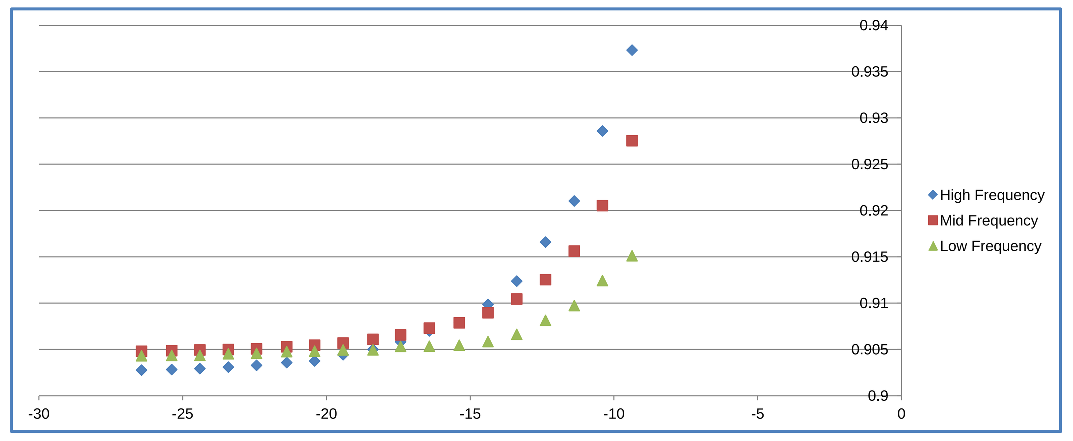

Figure 7*. Broad spectrum Differential Points*

Summary & Conclusion

In our experiments we were able to demonstrate that the noise injection model can improve an instrument's capability to collect real-time data by at least a factor of 2 based on the increased calibration accuracy. This improvement results in higher resolution pixel information and more accurate measurements for weather sensors. This not only gives a potential enhancement to imager and sounder weather instruments such as AMSU, ATMS, and SSMIS (see ***Figure 8***), but also provides the capability to eliminate known calibration uncertainties. This allows users to have better weather forecasting as a consequence of the improved data quality.

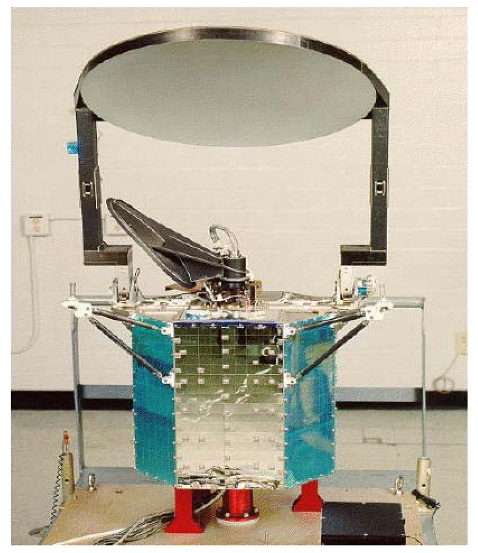

Figure 8. *The SSMIS mass model*

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