# EDTN Memo 233

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## Test Dewar Design

To extend the measurement range and provide more accurate calibration, both the small and large test Dewar's are equipped with short stainless-steel coax cables followed by two K connector beads, which provide thermal isolation, on both input and output lines.[1] Figure 1 shows the ACAD drawing and CST model. The improved impedance match and reduced insertion ripple over frequency improves the measurement accuracy. The CST EM model S-parameter results of the K connectors and bead combination are imported into the AWR/Microwave Office model of the coaxial cables, Figure 2. Since this model includes a temperature coefficient of loss, the noise temperature contributions can be accurately predicted. The S parameters are compared with VNA measurements to verify the predictions. The physical temperatures of all the components are needed for accurate calculation of noise contributions These are derived by temperature sensor readings that are input to the ANSYS thermal model of all the components, Figure 3.

The thermal model is defined and verified using temperature sensor readings from four sensors inside the test Dewar. Two sensors are positioned on the 50K and 15K plates, at the ends of the thermal straps attached to those plates. Two other sensors are placed at key points along the stainless-steel coax lines, one at the second K-connector bead and one at the block tying the coax lines to the 50K plate. The temperatures obtained from the sensors at the 50 and 15K plates are set in the Ansys model to drive the simulation. The temperatures of every other component in the model are calculated based on the temperatures at those locations, and the outside of the Dewar being 300K. The accuracy of the simulation is verified by comparing the predicted temperature at the other two locations to the measurements from the sensors.

Figures 4 and 5 show the AWR predictions for insertion loss and calculated noise temperature contributions using an approximation of the temperature profile for the coax lines derived from the Ansys simulation.

## Calibration

Without the ability to execute the SOLT calibration method at cryogenic temperatures, VNA measurements are relative to the warm reference plane, the SMA inputs of the Dewar. The characterization of the losses is accomplished by series of measurements. First the S parameters of one flexible line connecting the two airlines is measured. This assumes that both the airlines behave identically upon cooling and the loss and mismatch of the semi flex is negligible compared to the airlines. The matched insertion loss assumption may deviate at cryogenic temperatures. With the airlines calibrated the attenuator is inserted into the path for measure. The predicted and measured quantities allow accurate predictions of the $T_{hot}$ and $T_{cold}$ values over the frequency of interest in equation 5 and equation 6. These values allow calculation of noise temperature derived in equations 1 through 4.

$$P_{hot} = {g_{rx}}^2 k_b (T_{hot} + T_{Rx})\Delta\nu \quad (1)$$

$$P_{cold} = {g_{rx}}^2 k_b (T_{cold} + T_{Rx})\Delta\nu \quad (2)$$

where $\Delta\nu$ is bandwidth, $g_{rx}$ is gain, and $k_b$ *is the Boltzmann constant*.

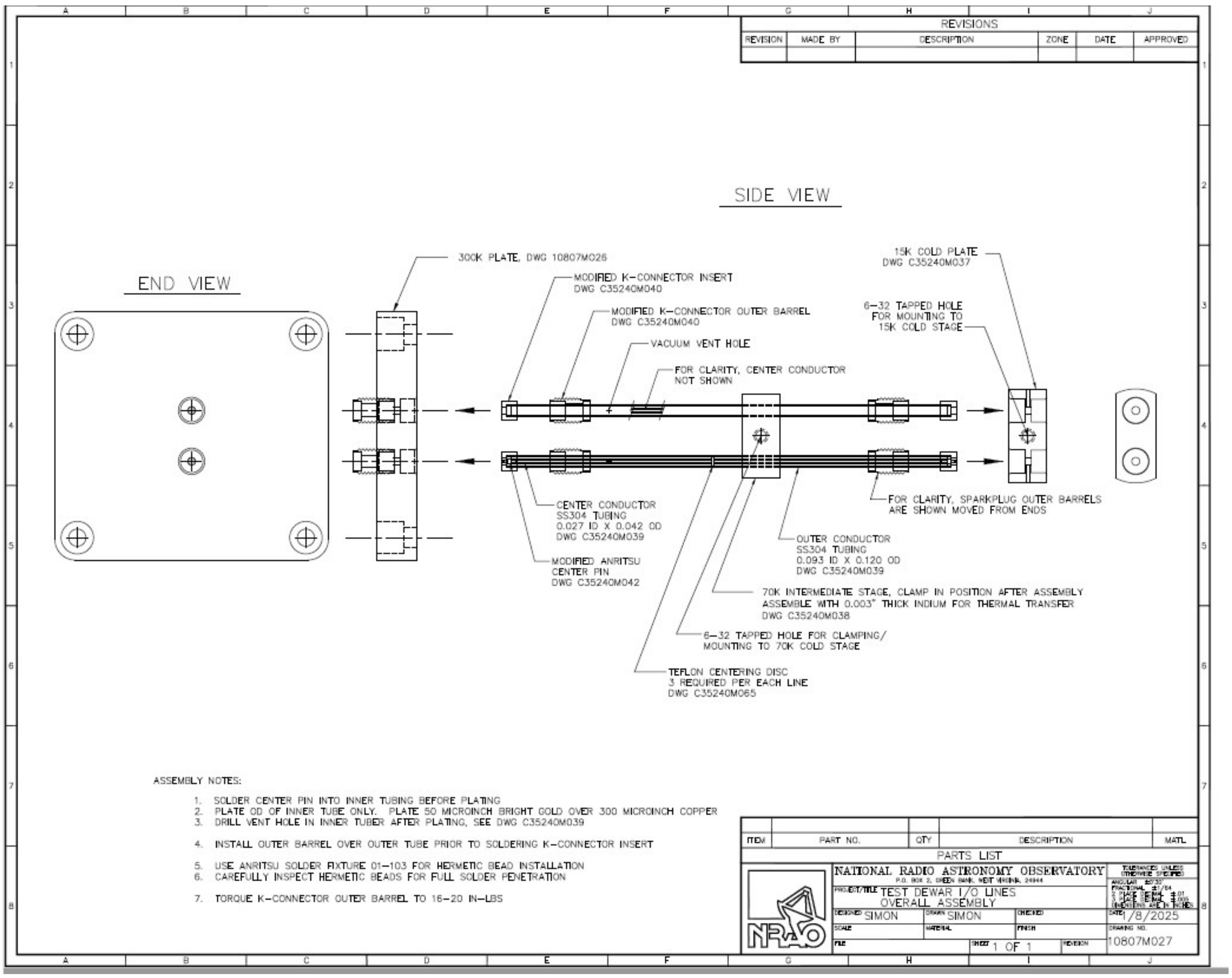
$$Y = \frac{P_{hot}}{P_{cold}} \quad (3)$$

$$T_{Rx} = \frac{T_{hot} - Y(T_{cold})}{Y-1} \quad (4)$$

$$T_{hot} = \frac{(F+1)*290}{L_{ss}\ L_{kbead}\, L_{attn}} + \frac{(L_{ss}-1)*T_{ss}}{L_{kbead}\, L_{attn}} + \frac{(L_{kbead}-1)*T_{kbead}}{L_{attn}} + T_{attn} \quad (5)$$

$$T_{cold} = \frac{T_{amb}}{L_{ss}\ L_{kbead}\, L_{attn}} + \frac{(L_{ss}-1)*T_{ss}}{L_{kbead}\, L_{attn}} + \frac{(L_{kbead}-1)*T_{kbead}}{L_{attn}} + T_{attn} \quad (6)$$

*where the* L′s and T′s are loss and temperature of each component, respecitvely, and *F is the noise factor for the diode*. All quantities have an implicit frequency dependence.



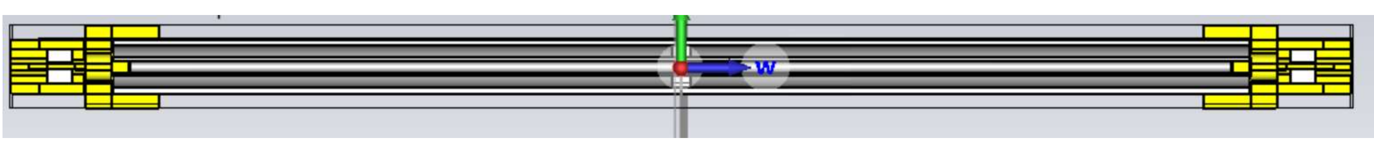




*Figure 1 CST model below (K100 Bead x2 Airline.cst) of Air Line with ACAD mechanical drawing above.*

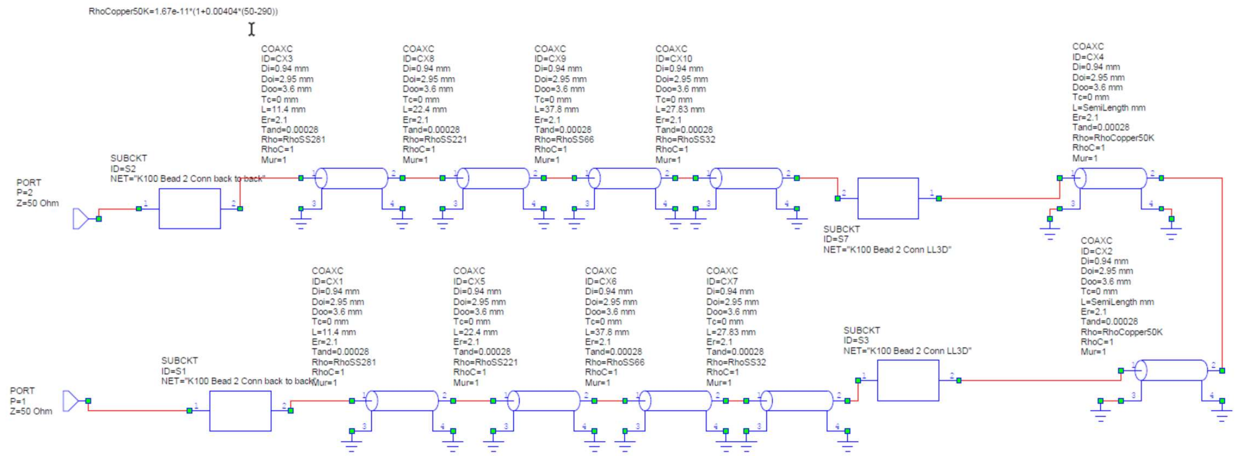


*Figure 2. AWR Microwave Office circuit model for loss dependence upon temperature of the coaxial cables. These incorporate the ANSYS temperature model results. The K100 beads S-parameters are generated from a CST model.*

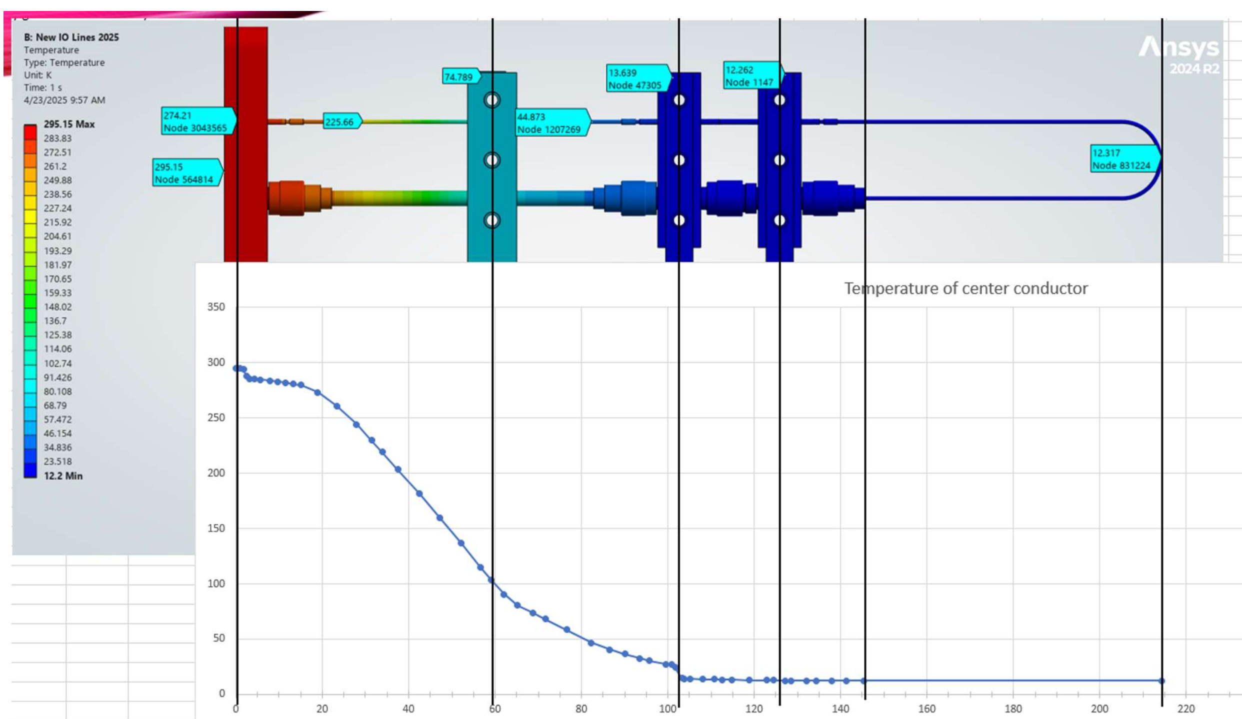



*Figure 3. ANSYS thermal model of the Test Dewar components.*

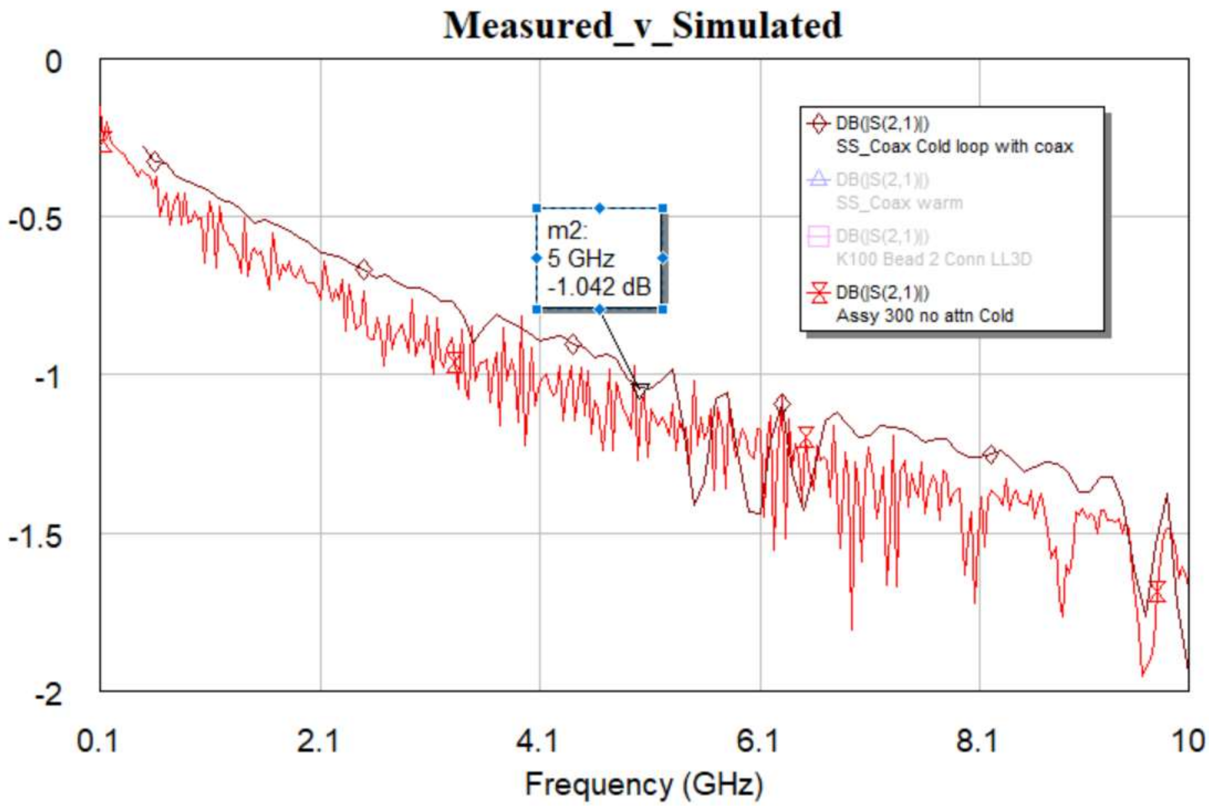



*Figure 4 Predicted insertion loss comparing AWR combined with CST models to VNA measurements with input and output looped together.*

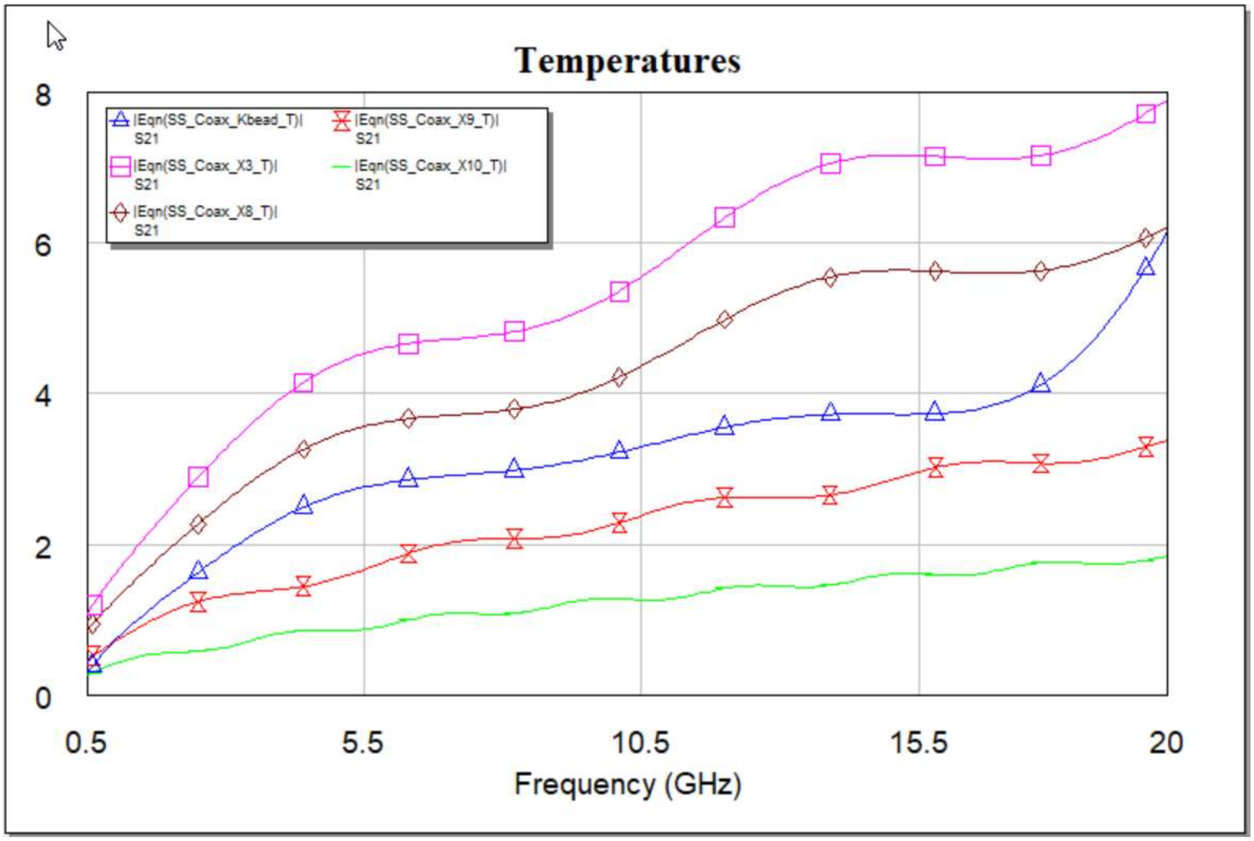



*Figure 5. Predicted noise temperature contributions from the individual components. The model for the stainless-steel line divides it into four segments and characterizes the noise temperature at physical temperatures of 281, 221, 66, and 32 degrees Kelvin.*

# L-band Measurement

With each component in the Test Dewar characterized for noise temperature the low noise amplifiers are cooled and tested. The spreadsheet, Table 1:4, generates the calibration file required for noise temperature measurement at the frequencies of interest. All L band amplifiers in possession where measured. The amplifiers are labeled L109, L108, L129, L22, and L59. The provenance of these amplifiers is unknown; however, L129 was originally the YR channel amplifier, with L108 in the XL LNA. The test is conducted with the short rack, drawing C35240K003, followed by a 500/50 bandpass filter and then detected by the low power head and Agilent power meter. A Labview program ran on computer Buri, Table 1:5, controls the synthesizer and reads the power meter data for the cold and hot load then calculates and graphs the noise temperature. The files are available as *.csv exports. These agree well with the CDL published data. Since L22 has lower return loss and better noise characteristics, it will be replacing the YR channel amplifier.

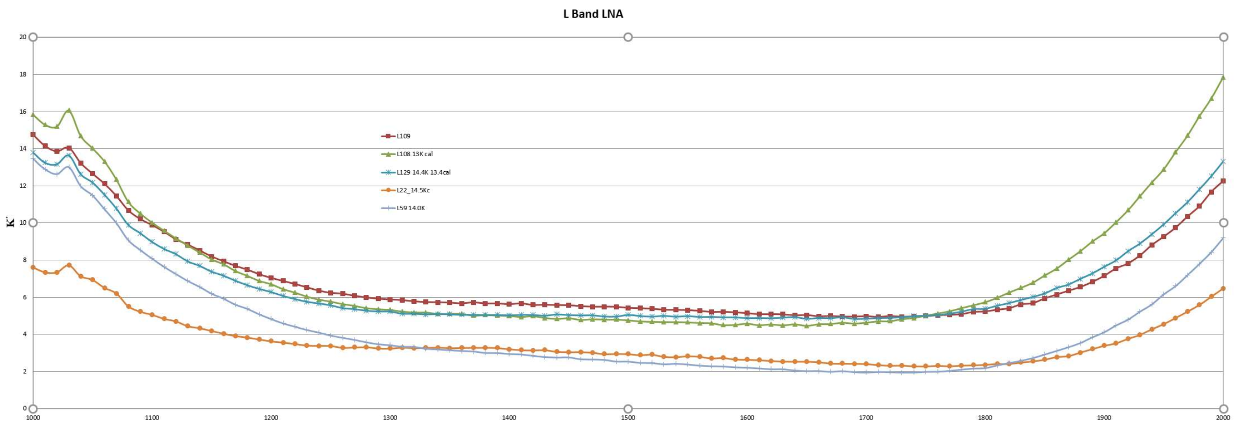



*Figure 6. Noise temperature measurement of amplifiers, L109, L108, L129, L22, and L59. This can be compared with the CDL data in files of the same designation at cvfiller\cv-cdl-pub\AmplifierTestData$\1.2_1.8_GHz\.*

Equations 5 and 6 can be modified depending upon the test configuration. In the example below, a transition from coax to waveguide is required for noise testing of an LNA with waveguide input. The quantified parameters temperature and insertion loss, $T_{trans}$ and $L_{trans}$, are inserted to fully characterize $T_{ho}$ and $T_{cold}$.

$$T_{hot} = \frac{(F+1)*290}{L_{ss}\ L_{kbead}\ L_{attn}L_{trans}} + \frac{(L_{ss}-1)*T_{ss}}{L_{kbead}\ L_{attn}L_{trans}} + \frac{(L_{kbead}-1)*T_{kbead}}{L_{attn}\ L_{trans}} + \frac{(L_{attn}-1)*T_{attn}}{L_{trans}} + (L_{trans}-1)*T_{trans}$$

$$T_{cold} = \frac{T_{amb}}{L_{ss}\ L_{kbead}\ L_{attn}L_{trans}} + \frac{(L_{ss}-1)*T_{ss}}{L_{kbead}\ L_{attn}L_{trans}} + \frac{(L_{kbead}-1)*T_{kbead}}{L_{attn}\ L_{trans}} + \frac{(L_{attn}-1)*T_{attn}}{L_{trans}} + (L_{trans}-1)*T_{trans}$$

| Files | | | |
|---|---|---|---|
| # | | File | Description |
| 1 | \Excel\VNA | VNA analysis | Comparison of VNA vs CST results |
| 2 | GBAWR:users\swhite\Documents\AWR Projects | Test_Dewar.emp | AWR Airline simulation |
| 3 | GBAWR:users\swhite\Documents\AWR Projects | Test_Dewar_Kbead_Kbead_fix_Temp.emp | AWR Test Dewar with temperature dependent coax loss simulation |
| 4 | GBCST:E:\swhite CST Files\Kconn wMS\ | K100 Bead x2 Airline.cst | CST Airline simulation |
| 5 | Gbfiler\swhite\Excel\Noise Calibration\EXCEL | NW346163601_7p0_13p0_1_pad_June18_2025.xlsm | Calibration File |
| 6 | gbfiler\swhite\LabView Files\Noise Temperature\Short Rack | ColdAttenuatorNTwE4418space__June2025_LOcorrect.vi | Labview VI |

*Table 1 Data Files.*

# References


1. Gallego J.D., Lopez-Fernandez I. Diez, C. , A Measurement Test Set for ALMA Band 9 Amplifiers. Centor Astronomico de Yebe, Observatorio Astronomico Nacional (Spain). RadioNet 1st Engineering Forum Workshop 2009.06.24.

2. Cano JL, Gallego J.D., Estimation of Uncertainty in Noise Measurements Using Monte Carlo Analysis: A Practical View. Centor Astronomico de Yebe, Observatorio Astronomico Nacional (Spain). RadioNet 1st Engineering Forum Workshop 2009.06.24.