# VLA Electronics Memo 248

# Total Power Detector Calibrations of the LOIF Converter Modules

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Abstract

The EVLA Converter modules were designed with total power detectors (TPDs) which until recently were inoperable and un-calibrated, which limited their usefulness. The T301 (4P) and T302 (LSC) converter modules have two TPDs in each module, one each for RCP and LCP polarizations. The T303 (UX) has a total of four detectors: RCP, LCP, LO1 and LO2. This document explains the techniques used to characterize each detector, their locations within the system electronics, and the accuracy limitations.

## Introduction

Early EVLA intentions for these modules were a "quick check:go/no-go" to see if RF power was present. If RF power was present, and above a minimum threshold, the software would present a "1" to the monitor point. If the power was below the minimum the monitor would read "0". For a variety of reasons -- including evolving operating conditions, and gain variation between modules and antennas – the thresholds tend to change, and so a binary decision became impractical. For these reasons the detectors should have their power/voltage response characterized, and return a continuous power level to the monitor/control (M&C) system.

The T303 has two detectors (LO1 and LO2), where full characterization was not possible. Therefore the "quick check:go/no-go" approach was utilized. All of the detector characterizations were performed using LabVIEW development programming software. Data was collected using LabVIEW, and a series of LabVIEW virtual interfaces (vi) were written to accomplish these tasks.

Three calibration module test fixtures were built: UX Calibration module; LSC Calibration module; and 4P Noise Source module. Interface control software for these modules was also written in LabVIEW.

The M301 Converter Interface module is responsible for communications to all LOIF converter modules and system switches. Because of this all software programing changes for the converter modules had to be performed to the MIB image in the M301 Converter Interface Module.

All detectors are calibrated to show input total power to the module.

## Methodology

### T301 4P Converter Module and 4P Noise Source module

A test set called the 4P Noise Source module was built specifically to calibrate the T301's TPDs. The 4P test simulates the signal coming from the Low Band receiver, which includes both 4-band and P-band.

Using the 4P Noise Source, the input power to the T301 was varied from -64dbm to -34dbm in 2dB steps. At each step a known power was injected, two detector voltages (xCP_TOTAL_VOLT) were recorded, and all information was written to a file. This was accomplished using a LabVIEW VI to control power levels, take power meter readings, and fetch the RCP and LCP total volt monitor indicators. The same test was run on five modules for a total of 10 different TPDs. The results were averaged and calibrated for cable loss.

The best fit general equation is y=11.63ln(x)-56.10 or (xCP_TOTAL_POWER)=11.63ln(xCP_TOTAL_VOLT)-56.10. Average coefficients are 11.63 and -56.10 respectively. In the M301 these coefficients are labeled as 11.63="slope" and -56.10="intercept."

The M301 MIB image was changed to assert these hard-coded generic coefficients. The same modules were tested again, this time for tracking and linearity. The TPD levels proved accurate to +/-1.5dBm.

In addition to the calibrations, two other monitor points were added. These are called LCP_TOTAL_POWER_AVG and RCP_TOTAL_POWER_AVG. These two new monitors are a running average of the last 20 TPD samples. The intent of these monitor points is to offer better stability in the presence of in-band transient RFI.

T302 Converter module and T302 Calibration module

The T302 Calibration module was built for calibrating the TPDs on the T302. This module contains a single noise source which produces four simultaneous outputs. It can be switched through bandpass filters to one of three different outputs: L-band, S-band, or C-band. The output level can be changed in 1 dB steps using an internal digital variable attenuator. The range of this attenuator is 0-31dB of attenuation. The output total power range for each band is -20 dBm to -50dbm, a range which provides adequate adjustment above and below the nominal operating point

Using the T302 Calibration module, the input power to the T302 was varied from -20dbm to -50dbm in 2dB steps. At each step a known power was injected, two "xCP_TOTAL_VOLT" monitors were noted, and all information was written to a file. This was accomplished using LabVIEW to control power levels, take power meter readings, and fetch the RCP and LCP detector voltages. The same test was run on five modules for a total of 10 different TPDs. The results were averaged and calibrated for cable loss. This procedure was performed for L-Band, S-Band, C-Band and P-Band respectively.

Best fit linear equations were found for each band. The slope has units of dBm/Volt and the intercept has units of dBm.

| | | |
|---|---|---|
| For L-band | (xCP_TOTAL_POWER)=5.41*(xCP_TOTAL_VOLT)-72 | or y=5.41*(x)-72 |
| For S-band | (xCP_TOTAL_POWER)=5.38*(xCP_TOTAL_VOLT)-73.1 | or y=5.38*(x)-73.1 |
| For C-band | (xCP_TOTAL_POWER)=5.41*(xCP_TOTAL_VOLT)-67.4 | or y=5.41*(x)-67.4 |
| For P-band | (xCP_TOTAL_POWER)=5.41*(xCP_TOTAL_VOLT)-71 | or y=5.41*(x)-71 |

The analog-to-digital converter (ADC) scaling factor of 0.00488 V/bit must be included to calculate the coefficients:

L-band 5.41 dBm/V X 0.00488 V/bit = 0.0264dBm/bit
S-band 5.38 dBm/V X 0.00488 V/bit = 0.0263dBm/bit
C-band 5.41 dBm/V X 0.00488 V/bit = 0.0264dBm/bit
P-band 5.41 dBm/V X 0.00488 V/bit = 0.0264dBm/bit

Coefficients for the T302 are:

| Band | Slope (dBm/V) | Intercept (dBm) | Band Select identifier for EEPROM |
|---|---|---|---|
| L-Band | .0264 | -72 | 0 |
| S-Band | .0263 | -73.1 | 1 |
| C-Band | .0264 | -67.4 | 2 |
| P-Band | .0264 | -71 | 3 |

The M301 MIB image was changed to use universal generic coefficients, rather than tracking module-specific calibrations. For the T302 TPDs, a table of these coefficients is written to an EEPROM in the T302. The EEPROM uses an identifier to save to the proper locations. Thus, when an antenna is commanded to L-band, the L-band coefficients are called by the M301 MIB to calculate total power for y=mx+b, where m=slope and b=intercept. The same is true for all bands.

The same T302 modules were tested again, this time for tracking and linearity. The TPD levels proved accurate to +/-1dBm.

In addition to the calibrations, two other monitor points also were added to the T302. These are called LCP_TOTAL_POWER_AVG and RCP_TOTAL_POWER_AVG. These two new monitors are a running average of the last 20 TPD samples. The intent of these monitor points is to offer better stability in the presence of in-band transient RFI.

T303 Converter module and the T303 Calibration module

The T303 Calibration module was built for calibrating the TPDs on the T303. This module contains a single noise source which feeds four simultaneous outputs. It can be switched through bandpass filters to two different outputs: X-band, and U-band. The output level can be changed in 2 dB steps using an internal digital variable attenuator. The range of this attenuator is 0-30dB of attenuation. Output total power range for each band is -20 dBm to -50dbm, which allows adequate adjustment above and below the nominal operating point. This module also has a YIG oscillator tuned to 12.5GHz split into four 7dBm outputs, which serves as the local oscillator for the module under test.

Using the T303 Calibration module, the RF input power to the T303 was varied from -20dbm to -50dbm in 2dB steps. At each step a known power was injected, two “xCP_TOTAL_VOLT” monitors were noted, and all information was written to a file. This was accomplished using LabVIEW to control power levels, take power meter readings, and fetch the RCP and LCP monitor indicators. The same test was run on five modules for a total of 10 different TPDs. The results were averaged and calibrated for cable loss. This procedure was performed for X-band and U-band respectively.

Best fit general equations were found for each band using $y=10*\log_{10}\{(ax^2)+bx+c\}-30$

Total Power=$10*\log_{10}\{(P2)x^2+(P1)x+P0\}-30$, where the coefficients are P2, P1, and P0.

X-band coefficients are called when the T303 S2=1 for RCP and LCP respectively.
U-band coefficients are called when the T303 S2=0 also for RCP and LCP respectively.

Coefficients for the T303 are,

| Switch stage identifier for EEPROM | | P2 (dBm/V) | P1 (dBm/V) | P0 (dBm/V) |
|---|---|---|---|---|
| RCP_S2_ECHO=0 | RCP | 0.0040515 | 0.017237 | 0.0003395 |
| LCP_S2_ECHO=0 | LCP | 0.0038468 | 0.0229485 | -0.003564 |
| RCP_S2_ECHO=1 | RCP | 0.002363 | 0.06405 | -0.02544 |
| LCP_S2_ECHO=1 | LCP | 0.0016275 | 0.077428 | -0.0316 |

For each entry, there are two possible sets of coefficients, and the selection of these sets will be under the control of the monitor points RCP_S2_ECHO and LCP_S2_ECHO. The table will have this form:

| Switch state | | P2 | P1 | P0 |
|---|---|---|---|---|
| RCP_S2_ECHO=1 | RCP | [0,0] | [0,1] | [0,2] |
| LCP_S2_ECHO=1 | LCP | [1,0] | [1,1] | [1,2] |
| RCP_S2_ECHO=0 | RCP | [2,0] | [2,1] | [2,2] |
| LCP_S2_ECHO=0 | LCP | [3,0] | [3,1] | [3,2] |

The M301 MIB image was changed to institute the use of generic coefficients. For the T303 TPDs, a table of these coefficients is written to an EEPROM in the T303. The EEPROM uses an identifier to save to the proper locations. Thus, when an antenna is commanded to X-band, the X-band coefficients are called by the M301 MIB to calculate total power. The same is true for both X-band and U-band.

The same T303 modules were tested again, this time for tracking and linearity. The TPD levels are accurate to about +/-1.5dBm.

However, the logarithm could produce a NaN condition if the argument is zero or negative. So this condition was trapped:

```
if (P2*(RCP_TOTAL_VOLT)^2 + P1* RCP_TOTAL_VOLT + P0 <= 0.01) {
        then RCP_TOTAL_POWER = -55;}
else {
        RCP_TOTAL_POWER=10*log10{P2*(RCP_TOTAL_VOLT)^2 + P1* RCP_TOTAL_VOLT + P0} -30;
}
```

And repeated for LCP_TOTAL_POWER

Another procedure was also performed on the T303 using the LO1 and LO2 inputs of the UX converter using the T303 Calibration module's 12.5GHz LO output. The T303 LOs input were varied from 8 to -18dBm in two dB steps. At each step a known power was injected, two "LOx_TOTAL_VOLT" monitors were noted, and all information was written to a file. This was accomplished using LabVIEW to control power levels, take power meter readings, and fetch the L01 and LO2 monitor indicators. The exact same set-up was run on four modules for a total of 8 different TPDs

These generic LOx results were not applied to the tested modules. It was discovered that the T303 LOx power detectors have a number of different detector responses. Because of this generic coefficients could not accurately indicate the proper power levels on all T303s in the array. After more data analysis it was discovered that all total power detectors shared a range near 0dBm input. With this in mind the "quick check:go/no-go" approach was utilized.

These were changed from numeric-type monitor points to binary-type monitor points.

Their values are

| | |
|---|---|
| 0 | =LOx_TOTAL_VOLT < 3 |
| 1 | =Otherwise |

Conclusion

Calibrated total power detectors aide engineers and technicians in troubleshooting problems. The new set of monitors gives any user instantaneous RF power levels. All RF power levels are archived in the Monitor Data Archive. Because there are several different receivers and converters, all TPDs are not in use all the time. Therefore, alarms are not enabled. Because these calibrated TPDs are now available it is possible to troubleshoot problems within the LOIF module chain. One can use these monitors to verify operations without having to be present in the vertex room. Operational TPDs help to better prepare planned maintenance visits, allows for better time management, and results in more responsible handling of company resources.