Tunnel-Diode Detector Nonlinearity Characterization and Minimization

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Outline

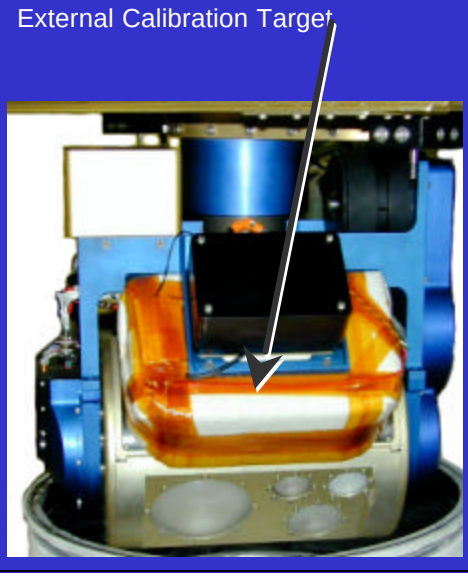
- Motivation: CoSMIR Performance
- Detector Characterization
  - Two-Tone Test
  - Voltage Response Test
- Practical Examples
- Discussion and Recommendations

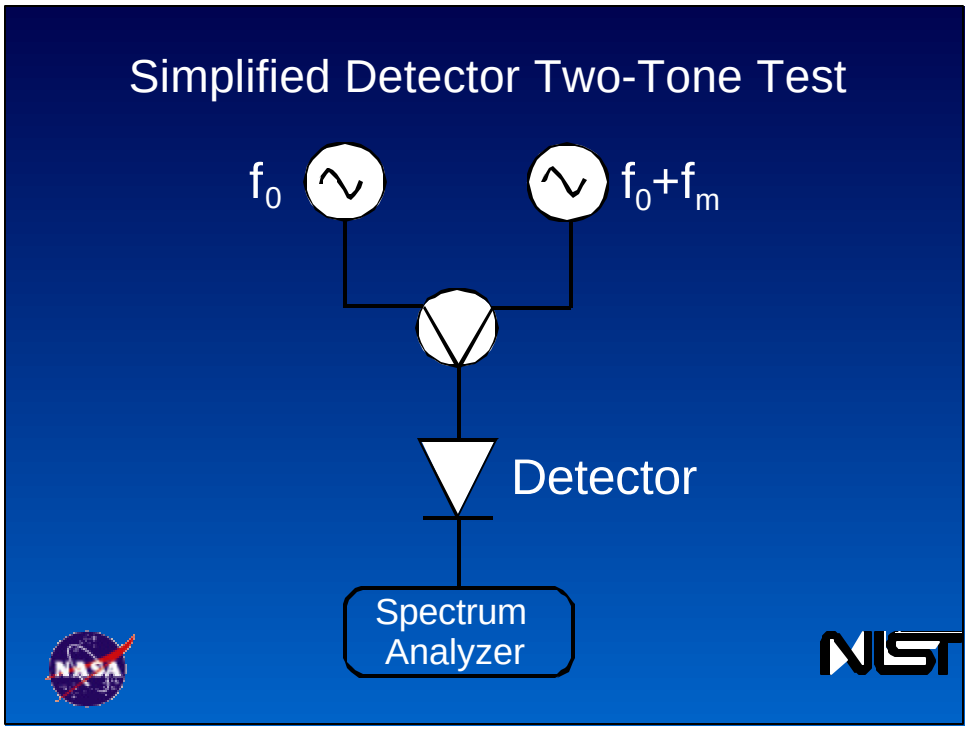
CoSMIR Background

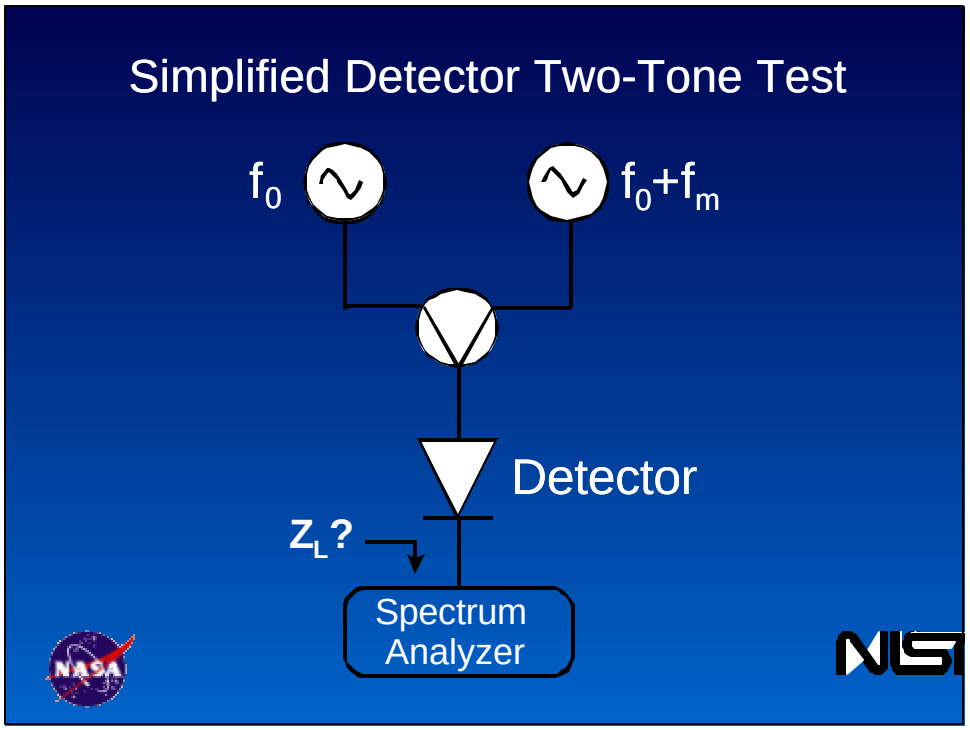
- SSMIS Calibration/Validation
  - Conduct underflights of SSMIS with CoSMIR for calibration/validation of SSMIS measurements.
  - Validate atmospheric absorption and ocean surface emission models for usage with SSMIS data.
  - T_B from 100 K – 300 K

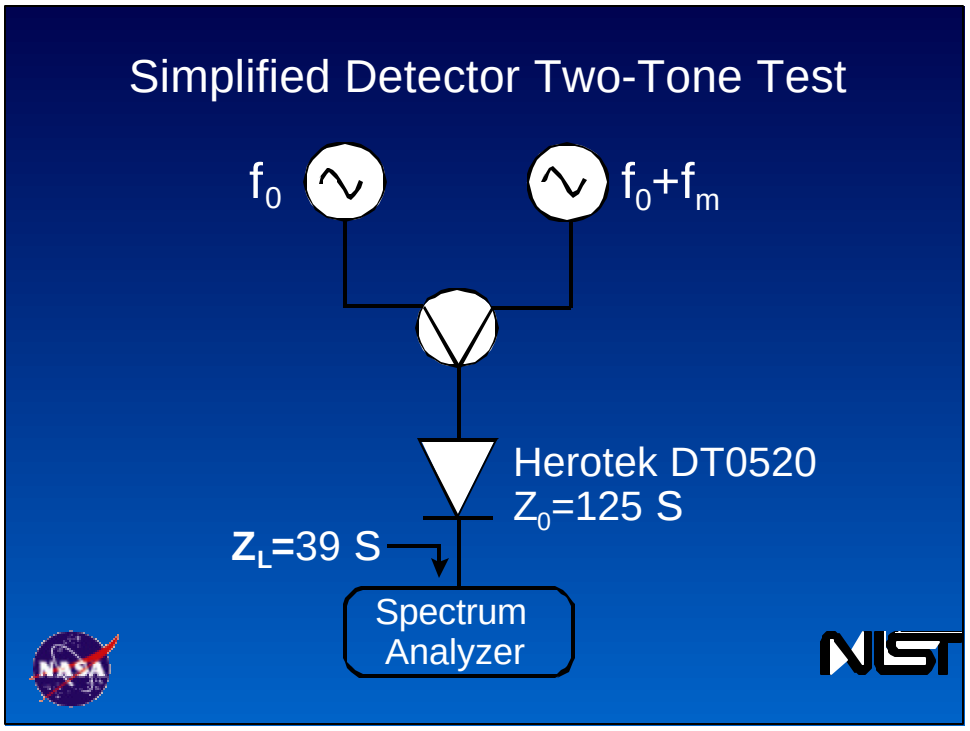
Calibration System

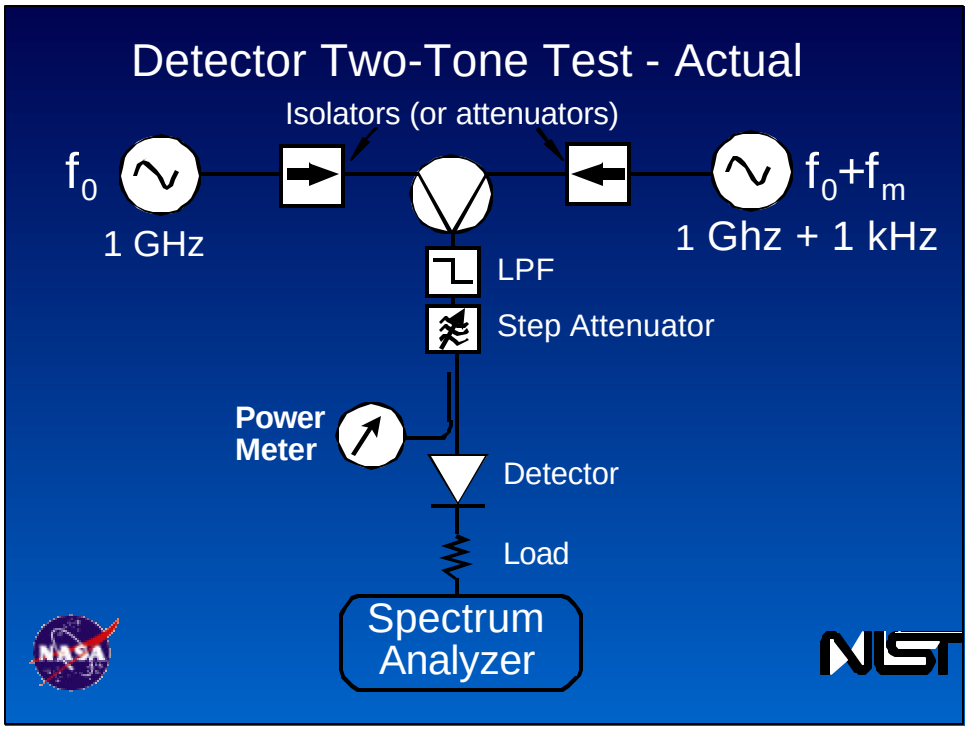
- ~1/2 K absolute error
- Periodic cal: ~5 sec
- External calibration targets
  - Iron/epoxy absorber on aluminum substrate
  - Hot load: heated to ~328K
  - Ambient load – 240-250K
- Close coupling of targets
- Thermometry
  - 8 RTDs on each calibration target – <0.05 K accuracy
- Post flight averaging using optimal filter
- Post processing correction of a/c pitch and roll variations



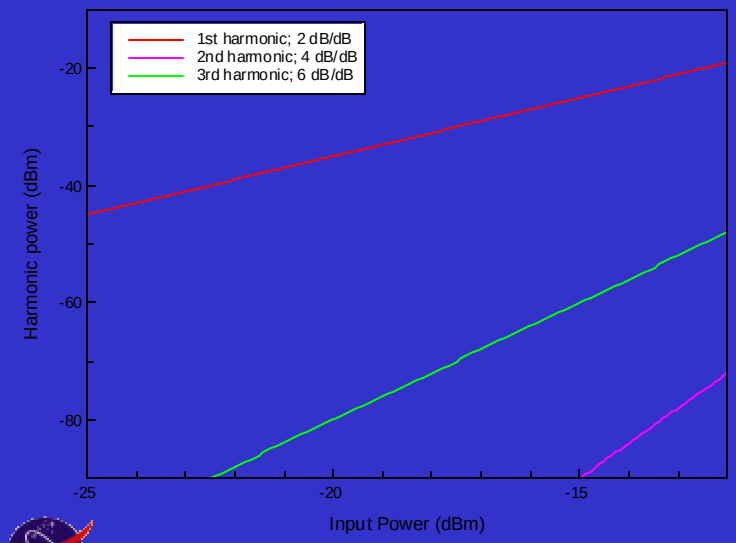

Simplified Detector Two-Tone Test
f_0
f_0+f_m
Detector
Spectrum Analyzer


Simplified Detector Two-Tone Test
f_0
f_0+f_m
Detector
Z_L?
Spectrum Analyzer

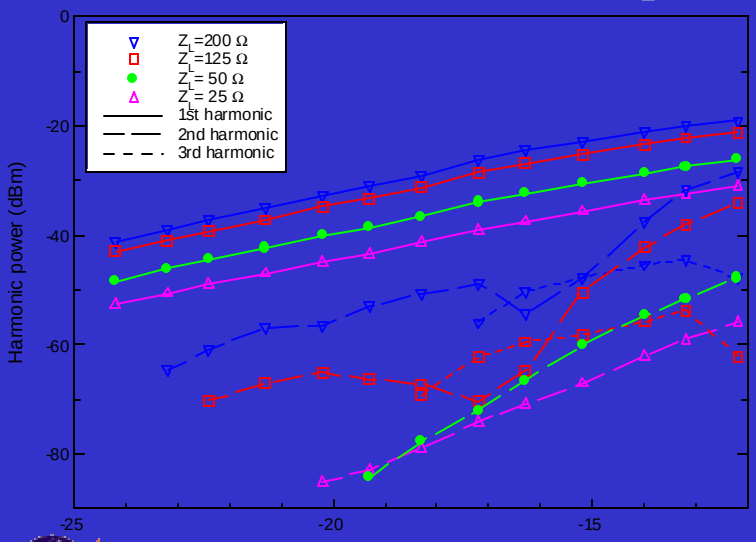

Simplified Detector Two-Tone Test
f_0
f_0+f_m
Herotek DT0520
Z_0=125 S
Z_L=39 S
Spectrum Analyzer


Detector Two-Tone Test - Actual
Isolators (or attenuators)
f_0
1 GHz
f_0+f_m
1 Ghz + 1 kHz
LPF
Step Attenuator
Power Meter
Detector
Load
Spectrum Analyzer

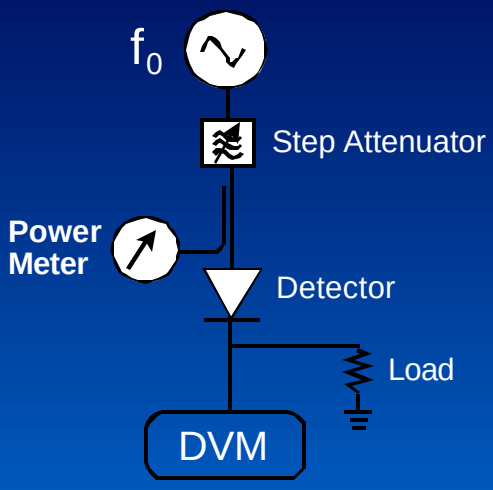
Classical Harmonic Output



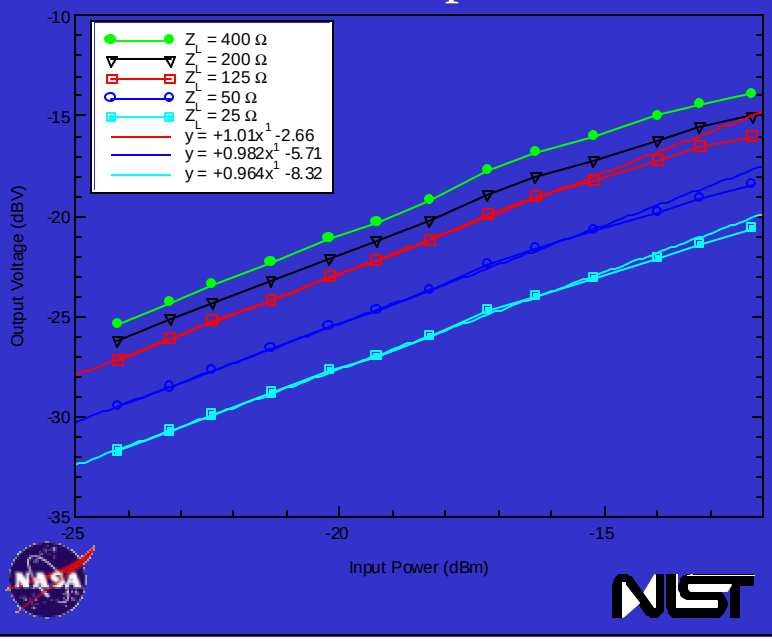
Detector Harmonic Output



Detector P-V Response



P-V Response



Predicting *T Due to Nonlinearity

- $\hat{T}=T_c+[(T_h-T_c)/(V_h-V_c)](V-V_c)$
- Quadratic approximation:

  $V\%P-CP^2$
- Worst-Case Interpolation Error:

  $*T=(C/4)\,(T_h-T_c)/(P_h-P_c)]$
- Worst-Case Extrapolation Error:
  - Use Point-Slope eq'n; include C_h and C_c
- Ref: Reinhardt *et al.*, IEEE Trans. MTT, April 1995.

CoSMIR Radiometer Overview

Center Frequency (GHz)	IF Bandwidth (MHz)	Noise Figure (dB)	Sensitivity 100 ms int. (K)
50.3	400	4.8 (SSB)	0.13
52.8	400	4.8 (SSB)	0.13
53.6	400	4.8 (SSB)	0.13
91.655	1000	6.5	0.10
150.0	1000	10.5	0.30
183.31±1	500	7.8	0.30
183.31±3	1000	7.8	0.21
183.31±6.6	1500	7.8	0.17

Examples of Predicted *T

	T_h	T_c	T range
CoSMIR T_N=500 K	325 K	245 K	245-325 K
CoSMIR T_N=500 K	325 K	245 K	100-325 K
Sat. Rad. T_N=500 K	300 K	0 K	0-300 K
Sat. Rad. T_N=100 K	300 K	0 K	0-300 K

Temperature Error for P_h= -21.3 dBm

	Z_L=200Ω	Z_L=125Ω	Z_L=50Ω
CoSMIR Interpolated	0.06 K	0.01 K	<0.01 K
CoSMIR Extrapolated	16.2 K	1.6 K	0.02 K
Sat. T_N=500 K, Interpolated	0.83 K	0.13 K	<0.01 K
Sat. T_N=100 K, Interpolated	1.57 K	0.25 K	<0.01 K

Discussion

- Commercial tunnel-diode detector char.
  - Two-tone method with S.A. preferred
  - Single-tone with DVM as “sanity check”
  - Vary load impedance
- Bias point and Z_L optimization
  - Receiver dynamic range—T and T_N; interp/extrap.
  - Z_L . 50 S (but not lower); consider $G_{op.\ amp}$
    - Potential improvement in *T of 10X or more
    - 7 dB higher P_{in} for same *T
    - Same Z_L on both op amp inputs to \common-mode noise
    - Caution: might not apply to other detectors, and what happens at lower power levels?

Detector Harmonic Output