Measuring Phase

- Inputs:

$$V_1 = A(t)\sin(\omega t + \phi(t))$$

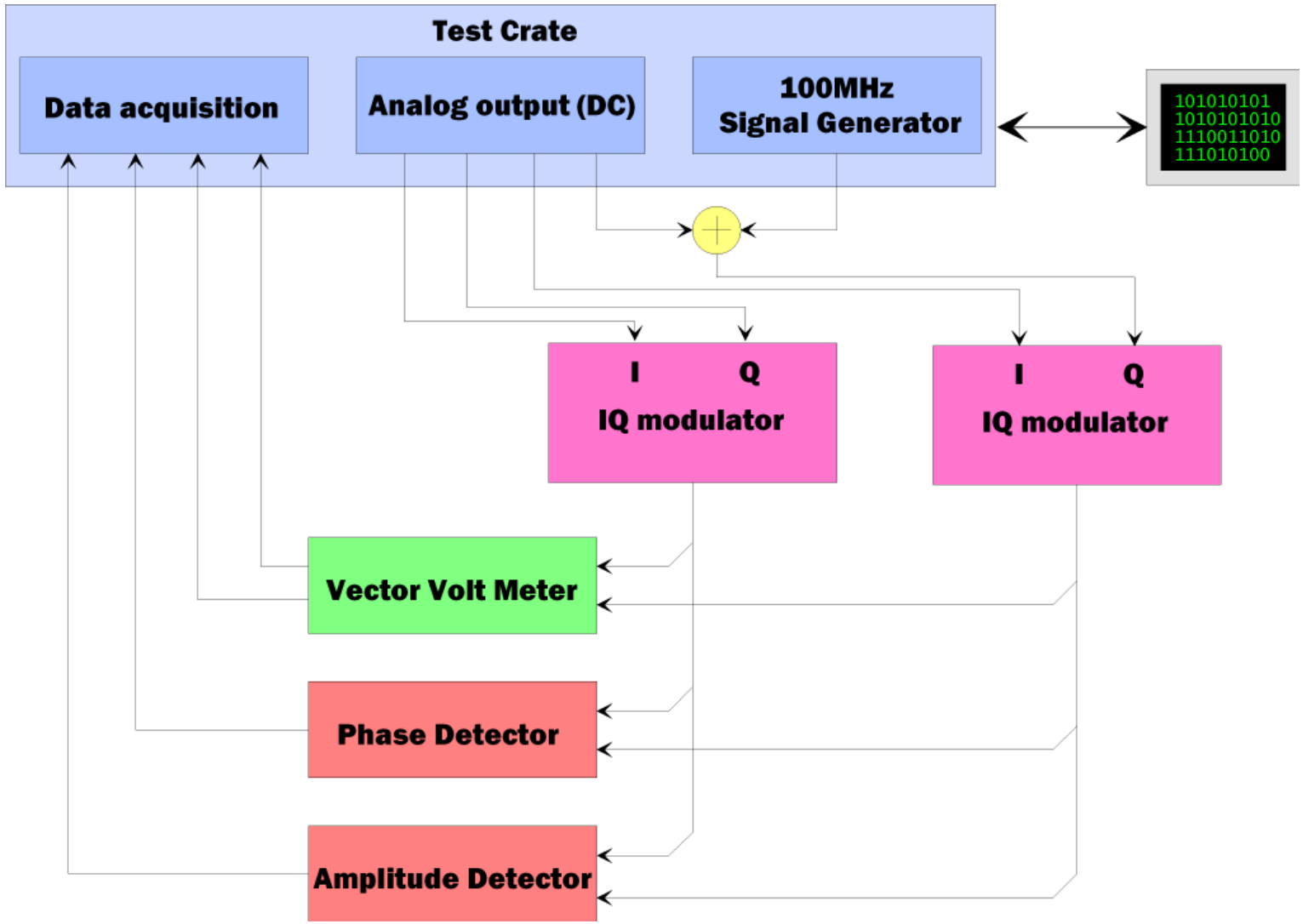
$$V_2 = \cos \omega t$$

- Output, ideal mixer/multiplier

$$V_\phi = \frac{A(t)}{2}\sin(2\omega t + \phi(t)) - \frac{A(t)}{2}\sin \phi(t)$$

- Real devices have more complicated amplitude dependence.

Test Setup


Test Crate
Data acquisition
Analog output (DC)
100MHz
Signal Generator
101010101
1010101010
1110011010
111010100
I
Q
IQ modulator
I
Q
IQ modulator
Vector Volt Meter
Phase Detector
Amplitude Detector

Test Setup Limitations

- IQ modulators: Amplitude modulation introduces phase modulation as well.
- Fix: Introduce DC amplitude shift, measure phase shift with narrow-band vector volt meter.
- Limitation: vector volt meter has only 0.1º phase resolution

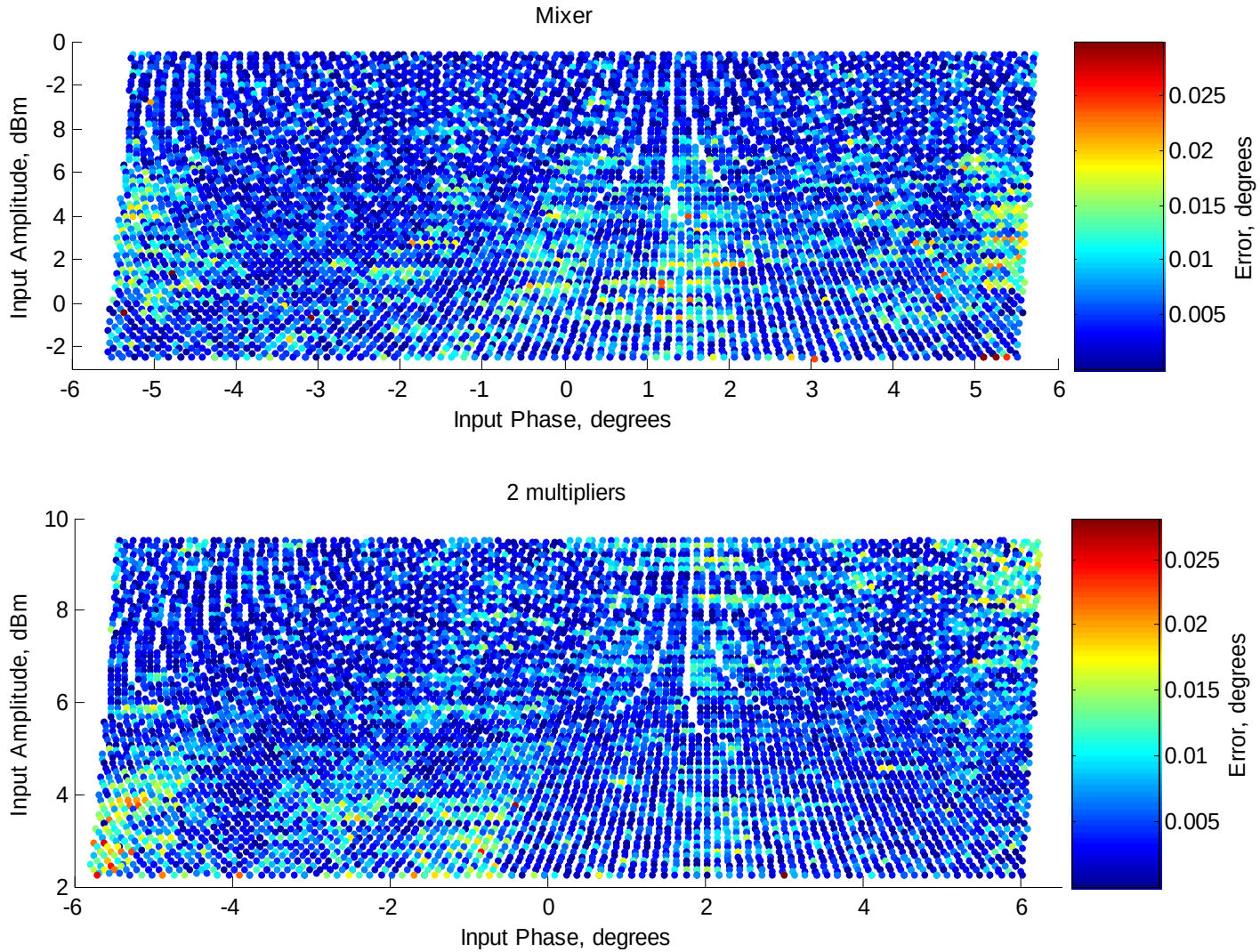
Tests

- Two phase detectors:
  - Analog multiplier Analog Devices AD835
  - Double balanced mixer Mini-Circuits ZFM-2000
- Amplitude detector:
  - Analog devices AD8318
- Measure phase detector output V_ϕ and amplitude detector output V_A
- Fit to input phase using polynomial of 3rd order in V_ϕ and first order in V_A

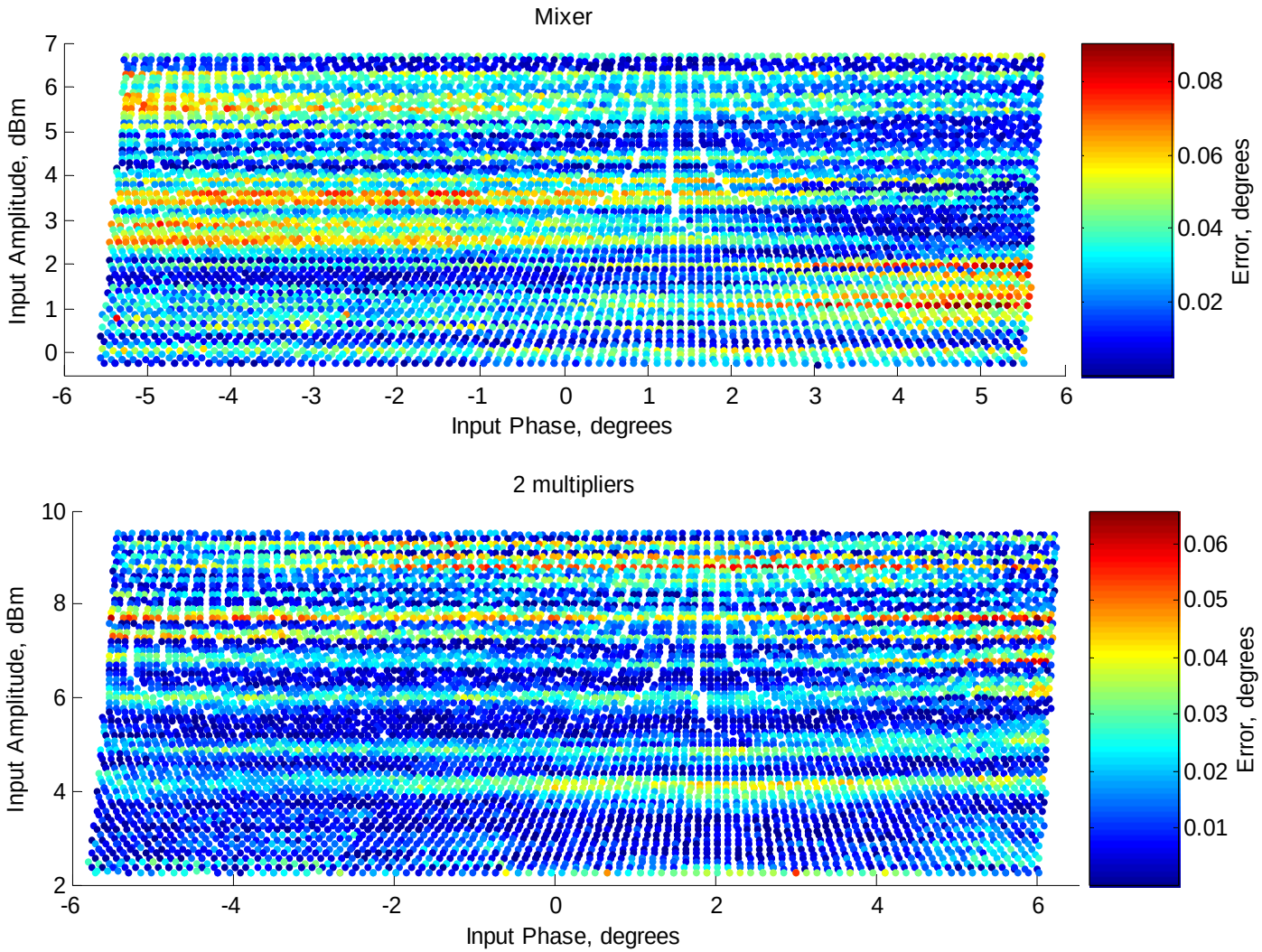
Goals of Initial Tests

- Find at least one phase detector device which is likely to work.
  - Characterize non-linearities
  - Characterize noise, test device averaging scheme
  - Determine bandwidth of devices
- Select Intermediary Frequency
  - Devices tested at 250MHz and 750MHz since these frequencies are readily available in CTF3

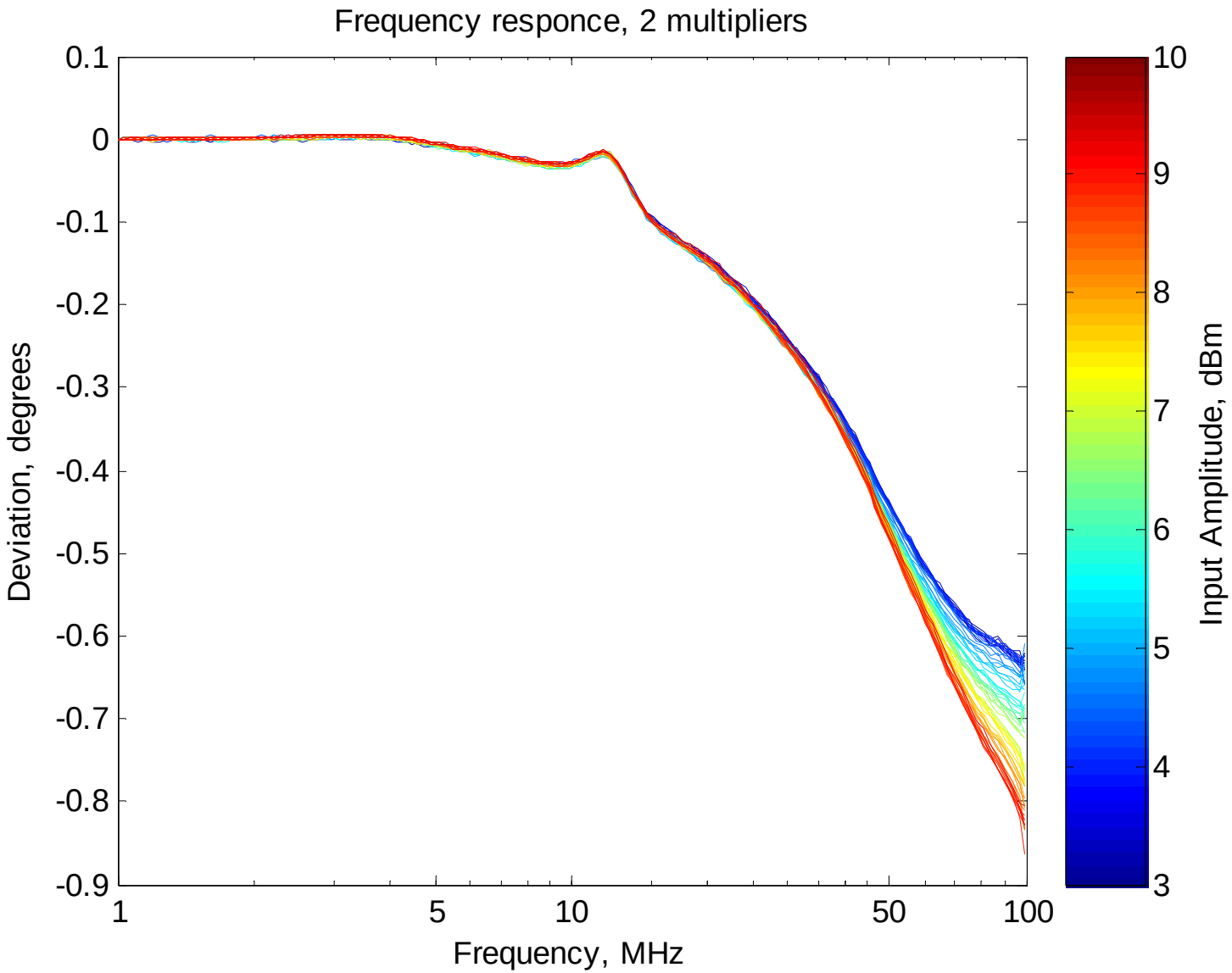
Errors, phase fit, 750MHz



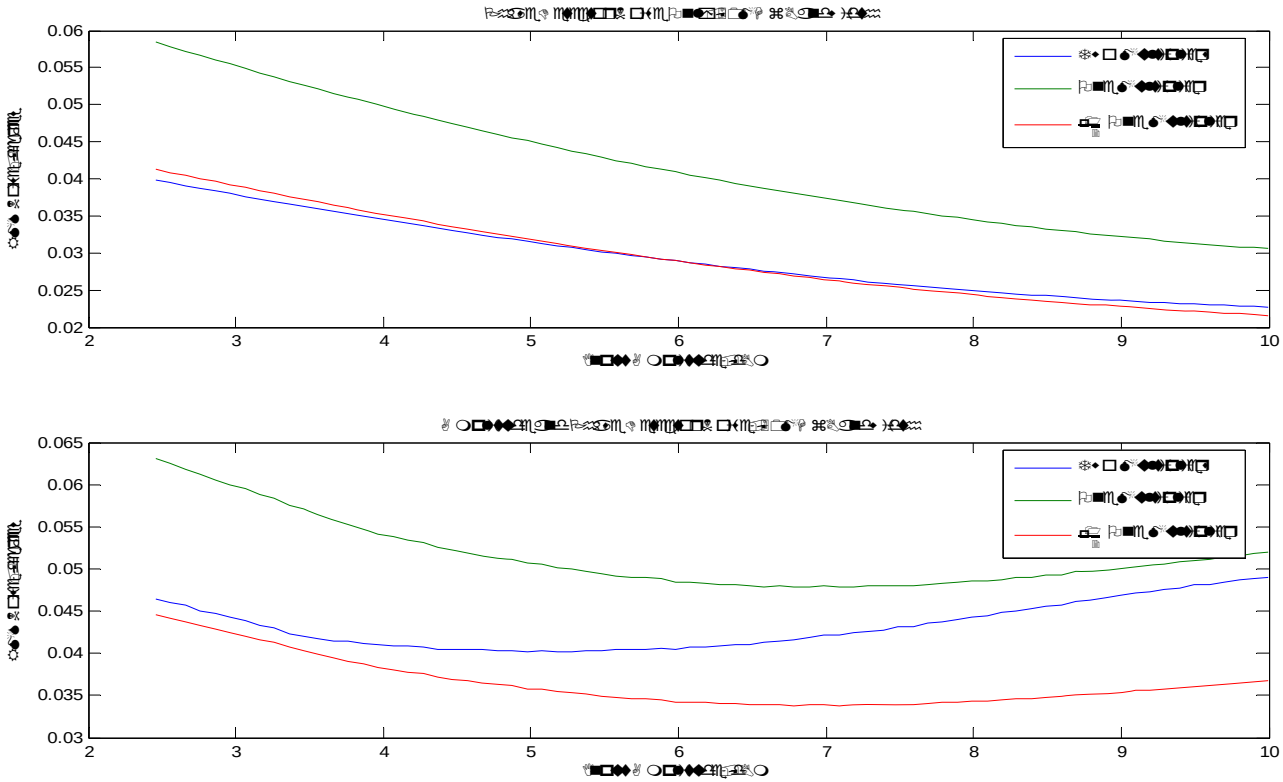
Errors, phase and amplitude fit, 750MHz



- Considering the limitations on measurement of narrow band input phase, errors look okay.
- Similar results at 250MHz and 750MHz for all tests
- Multipliers look better than mixer
- 30GHz components more easily realizable with an IF of 750MHz than 250MHz


Frequency responce, 2 multipliers
Deviation, degrees
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
1
5
10
50
100
Frequency, MHz
Input Amplitude, dBm
10
9
8
7
6
5
4
3

Noise


0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
2
3
4
5
6
7
8
9
10
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03

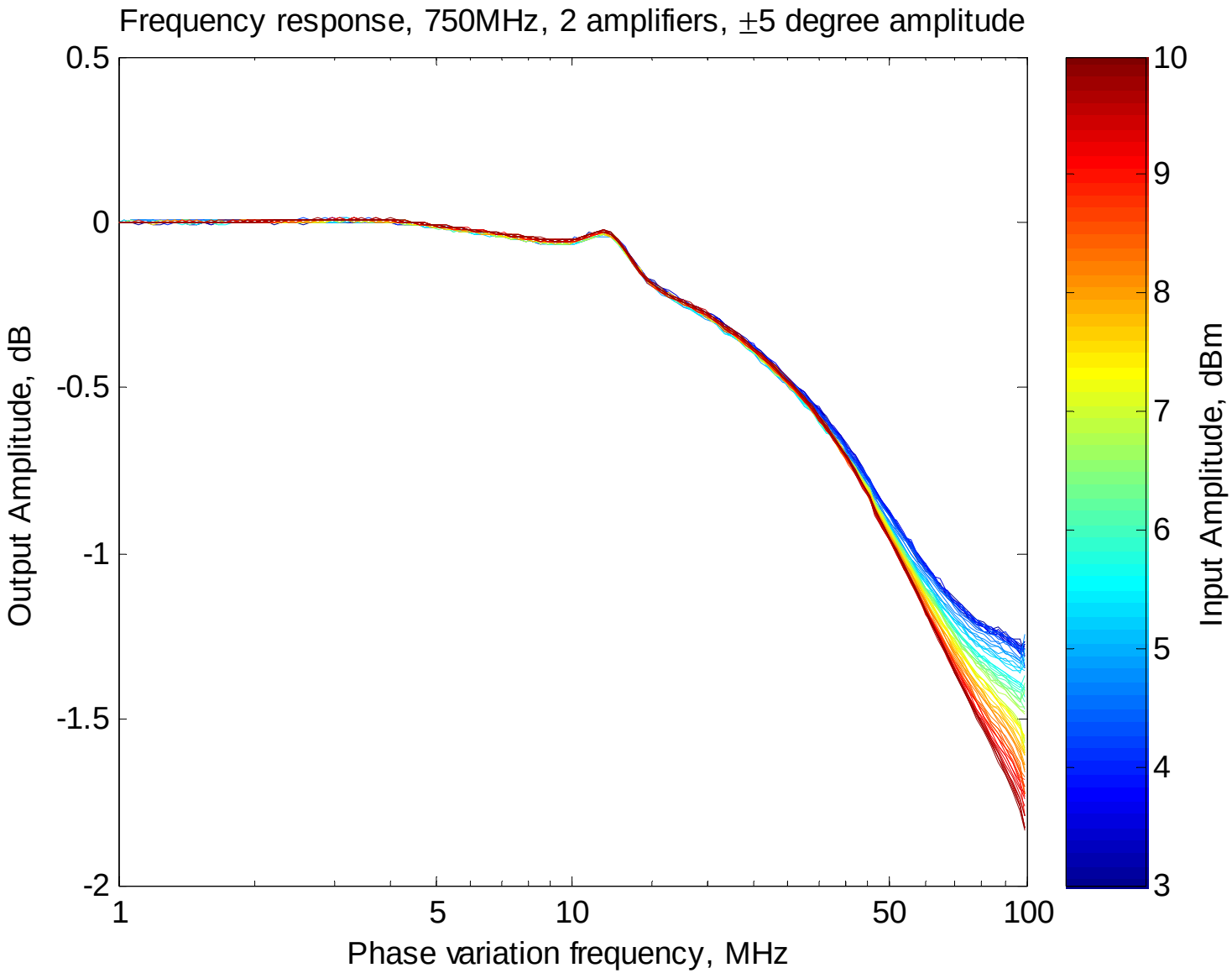
Noise

- Two sources of noise, amplitude and phase detectors
- 3rd degree amplitude correction yields more severe impact of amplitude noise at extremes of range.
- Averaging both amplitude and phase detectors necessary.
- Averaging 2 phase detectors yields the expected improvement

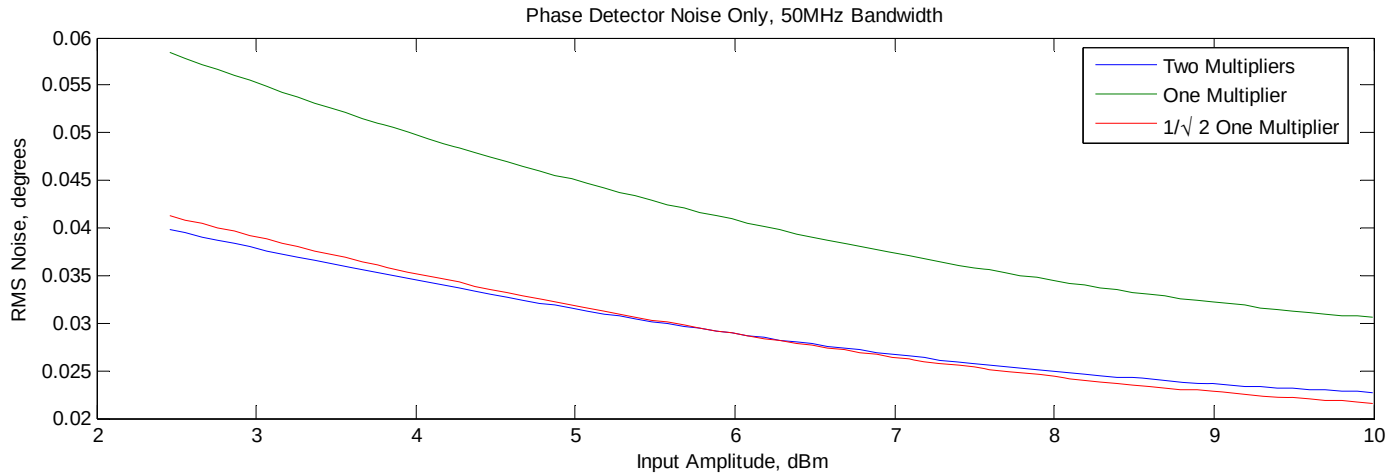
PCB

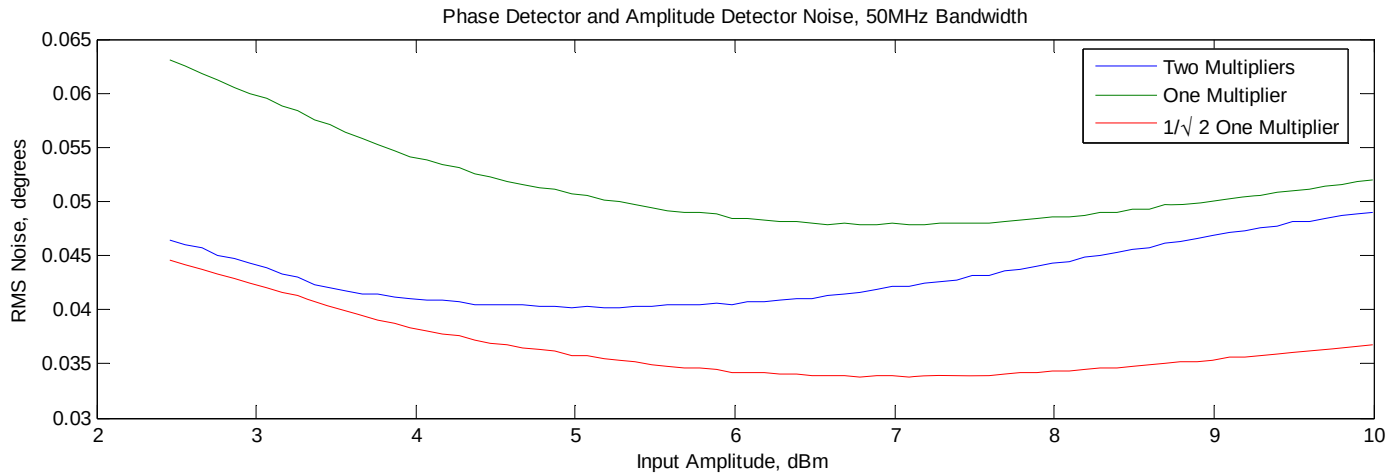
- More than two of each detectors must be averaged for adequate noise reduction
- PCB has been designed and is presently being manufactured for this purpose
- 8 amplitude detectors, 8 phase detectors in parallel.
- Also, hope to confirm that averaging amplitude detectors yields required improvement

NO MORE!


Frequency response, 750MHz, 2 amplifiers, ±5 degree amplitude
Output Amplitude, dB
0.5
0
-0.5
-1
-1.5
-2
1
5
10
50
100
Phase variation frequency, MHz
Input Amplitude, dBm
10
9
8
7
6
5
4
3

Noise


Phase Detector Noise Only, 50MHz Bandwidth
RMS Noise, degrees
Input Amplitude, dBm
Two Multipliers
One Multiplier
1/√ 2 One Multiplier
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
2
3
4
5
6
7
8
9
10


Phase Detector and Amplitude Detector Noise, 50MHz Bandwidth
RMS Noise, degrees
Input Amplitude, dBm
Two Multipliers
One Multiplier
1/√ 2 One Multiplier
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
2
3
4
5
6
7
8
9
10