AMiBA Project
Academia Sinica, Institute of Astronomy & Astrophysics

Subject: Test Results, Marki Microwave 4-Lag Correlator Module	**Date:** 6 May 2003		**From:** Derek Kubo
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References: 1. Specifications for the AMiBA 4-Lag Correlator, version 080102A, D. Kubo

I. Summary

The Marki Microwave 4-lag correlator module has been characterized to have the following performance parameters:

- Responsivity (10 GHz) = 95 V_{rms}/W, average of 4 lags (spec is >/= 80 V_{rms}/W)
- Responsivity flatness verses frequency (2 - 18 GHz): I1 = 3.9 dB, I2 = 3.7 dB, I3 = 4.4 dB, I4 = 3.5 dB (spec is </= 3 dB)
- Phase flatness verses frequency (2 – 18 GHz): 40°, 35°, 38°, and 30° for lags 1-4 respectively[1] (spec is 30 degrees peak-to-peak)
- Delay accuracy: lag 1-2 = 26.1 psec, lag 2-3 = 23.6 psec, lag 3–4 = 27.8 psec (spec is 25 +/- 2.5 psec).
- Input 1 dB compression point = approximately -5.2 dBm for I1, I2, and I3, and -5.9 dBm for I4 (spec is >/= -5.0 dBm)
- Output impedance at -10 dBm input = approximately 75 kOhms for the four channels (spec is </= 100 kOhms)

II. Item Description

Marki Microwave has delivered two prototype correlator modules to the AMiBA project. These modules were constructed in accordance[2] to the correlator specifications of Reference 1. The first correlator module was received on 27-March-2003 (see *Figure 1*). This module was tested to have an excessively high output impedance of 2.7 MOhms and was returned to Marki Microwave on 17-April-2003.

A second correlator module was constructed by Marki Microwave using lower barrier mixer diodes. This module was received on 21-April-2003 and its test results are the subject of this memo.

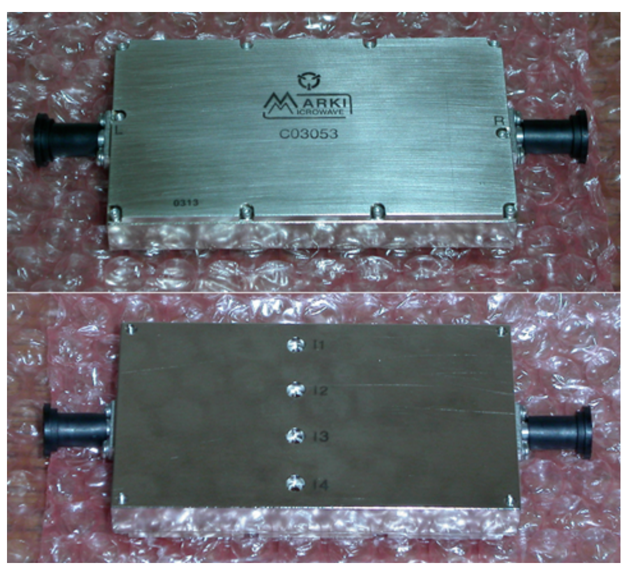

Figure 1 – Photos of the Marki Correlator Module

[1] Numbers do not include phase spike at ~3.6 GHz.
[2] Exceptions: 1) 6 dB pads were deleted; 2) used SMA(f) connectors instead of BMA(f).

III. Test Setup and Results

1. **Responsivity vs. Frequency**: *Figure 2* describes the setup used the characterize responsivity. Two separate synthesizers were used to generate frequencies F1 and F2, where F2 – F1 = 1.0 kHz. The two synthesizers were phase locked using the 10 MHz reference located on the rear panel of the instruments.

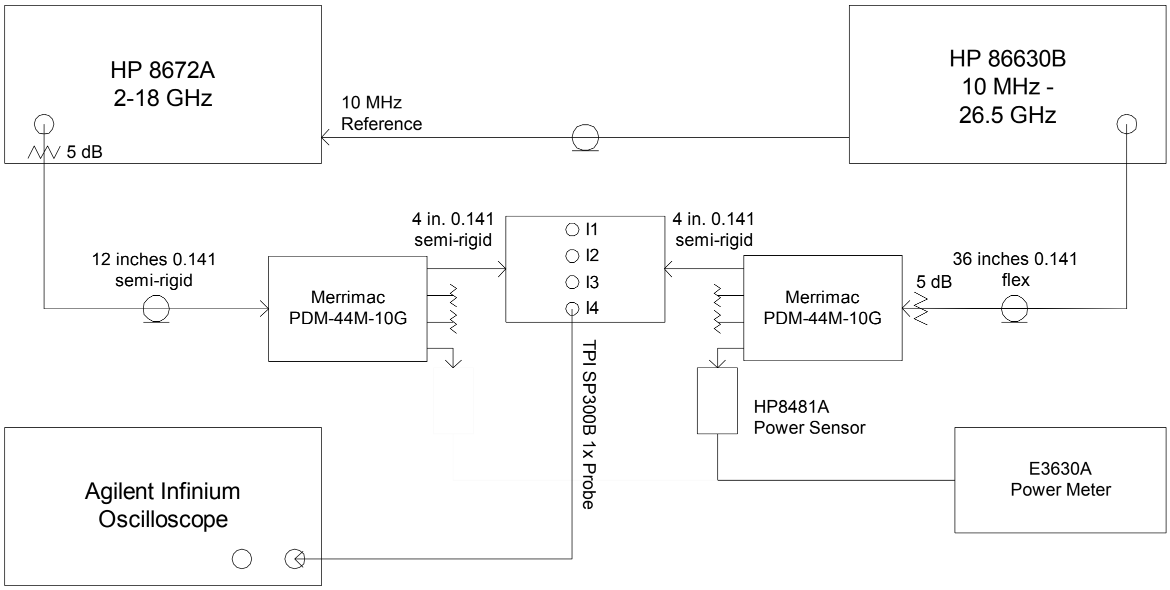

Figure 2 – Block Diagram of Responsivity Test Setup

Responsivity was characterized from 2.0 to 18.0 GHz, in 200 MHz increments (5 frequency points per GHz). A single power sensor[3] and meter was used to measure and set the input power to -7.0 dBm +/-0.1 dB for each of the 80 frequency points of both synthesizers. A photo of the test configuration is shown in *Figure 3*.

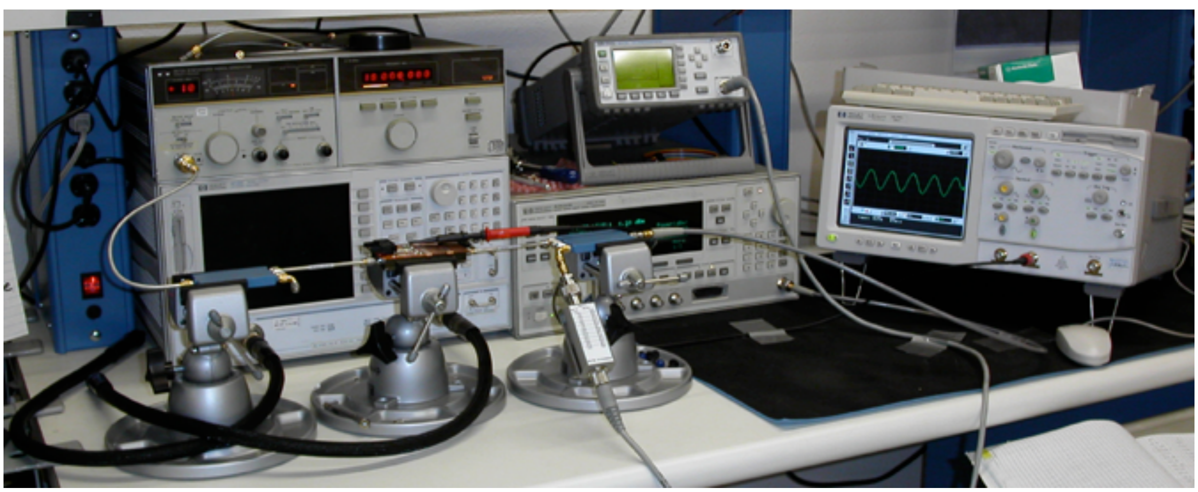

Figure 3 – Photo of Responsivity Test Setup

[3] The calibration factors for the power sensor were set at 3.0, 5.0, 7.0, 9.0, 11.0, 13.0, 15.0, and 17.0 GHz to insure accurate power measurement at different frequencies.

The four IF outputs from the correlator module were monitored using an Agilent oscilloscope and TPI[4] 1x probe. The input impedance of the oscilloscope was set to 1 MOhm. Measurement of the I1, I2, I3, and I4 outputs were performed by manually moving the probe and recording the peak-to-peak amplitude of the 1 kHz sinusoid waveform. Responsivity was calculated as follows:

$$\text{Responsivity} = V_{rms}/P_{in} = \{V_{pp}/(2*\text{sqrt}(2))\}/P_{in}, \text{ where } P_{in} = 2.0 \times 10^{-4} \text{ W}$$

Figure 4 shows a plot of the data. Note that the specification of 80 V_{rms}/W at 10 GHz has been met for all four channels. The amplitude variation verses frequency, however, exceeds the specification of 3 dB. The cause for the large and fast moving variations between 2.5 and 3.8 GHz is not known as of this writing.

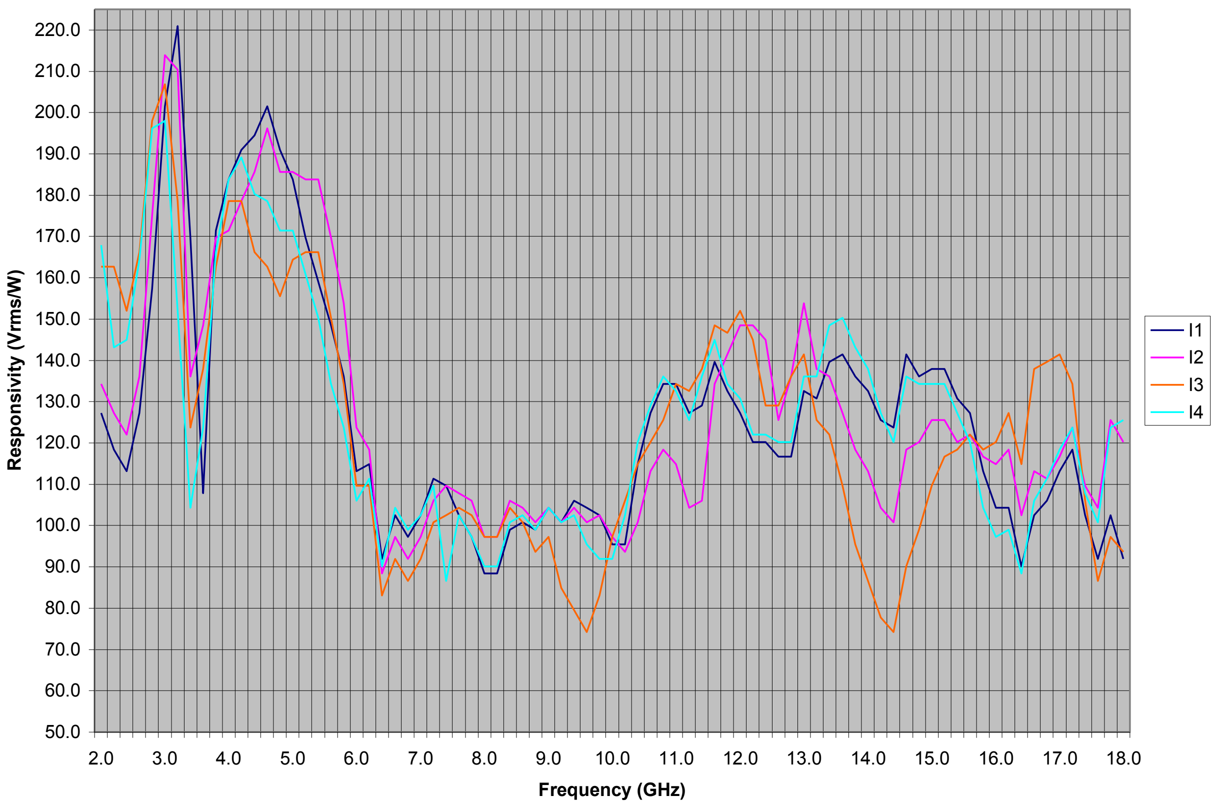

Figure 4 – Responsivity verses Frequency

2. **Input 1 dB Compression Point**: The compression point was characterized using the setup shown in *Figure 2*. The frequency was fixed to 10 GHz with a 1 kHz offset and the input power to the correlator was increased from -10 to -2 dBm (0.10 mW to 0.63 mW) in 1 dB increments. The output waveform amplitude is plotted against input power in *Figure 5*. 1 dB compression of the output occurs at an input power of approximately -5.1 dBm for channels I1, I2, and I3, and –5.9 dBm for I4.

[4] Test Products International, Inc.

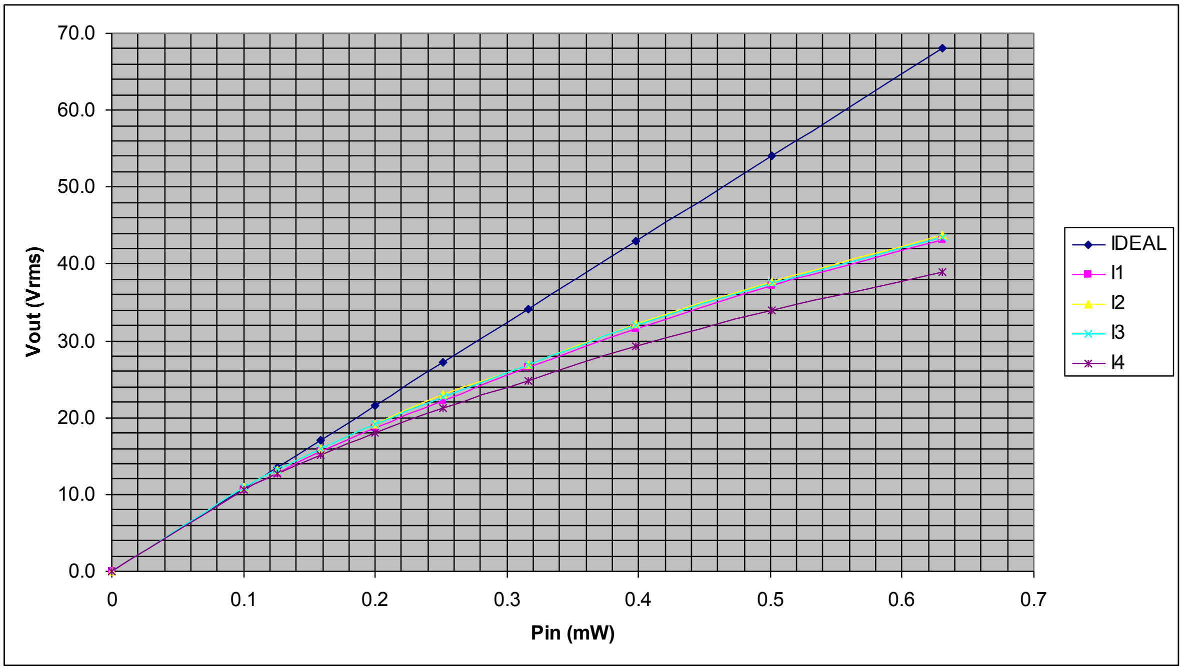

Figure 5 – V_{rms} Output verses Input Power (10 GHz)

3. **Output Impedance**: The output impedance was characterized at 10 GHz using the setup shown in *Figure 2*. A 100 kOhm potentiometer was inserted between a single IF output and ground. The resistance was adjusted to reduce the 1 kHz waveform amplitude to ½ of the non-loaded value. This represents a condition where the source resistance equals the potentiometer resistance. Measured potentiometer values are as follows:

   -10 dBm input – approximately 75 kOhms (all 4 channels)
   -7 dBm input – approximately 65 kOhms (all 4 channels)
   -4 dBm input – approximately 33 kOhms (all 4 channels)

4. **Phase vs. Frequency**: *Figure 6* describes the setup for this test. An external reference mixer[5] was used for relative phase comparison of the lag outputs. Particular care was taken to use equal length cables, adapters, and pads on the left and right sides between the power dividers to the correlator module inputs (see photo in *Figure 7*). Similar care was taken to use equal length devices between the power dividers and the reference mixer. The lengths between the correlator module and the reference mixer were not made equal in length.

   The 1 kHz waveform from the reference mixer was used to trigger the oscilloscope and served as the reference. The oscilloscope was set to AC coupling to remove any DC offset output from the mixers. The oscilloscope was then configured to automatically measure the zero crossing time difference between the reference waveform and the measured waveform from each of the four correlator outputs. A negative value indicates that the measured zero crossing time leads (appears to the left of) the reference waveform. Measurements were conducted in 200 MHz increments from 2 GHz to 18 GHz. A power meter was used to monitor and maintain -7.0 dBm +/- 0.1 dB into the correlator module.

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[5] Marki Microwave biasable mixer, bias of 2.6V provided by two AA batteries.

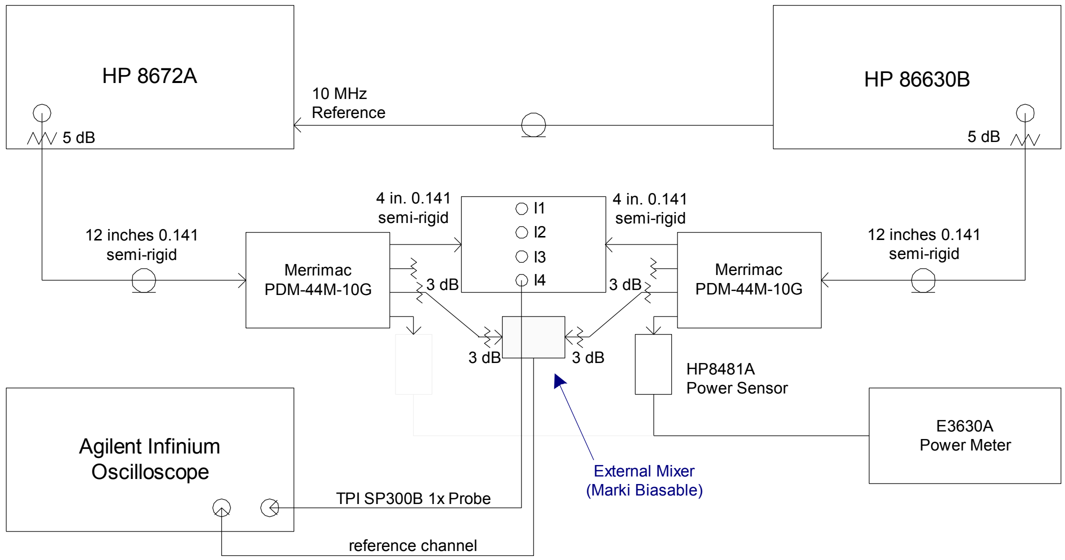

Figure 6 – Block Diagram of Phase Test Setup

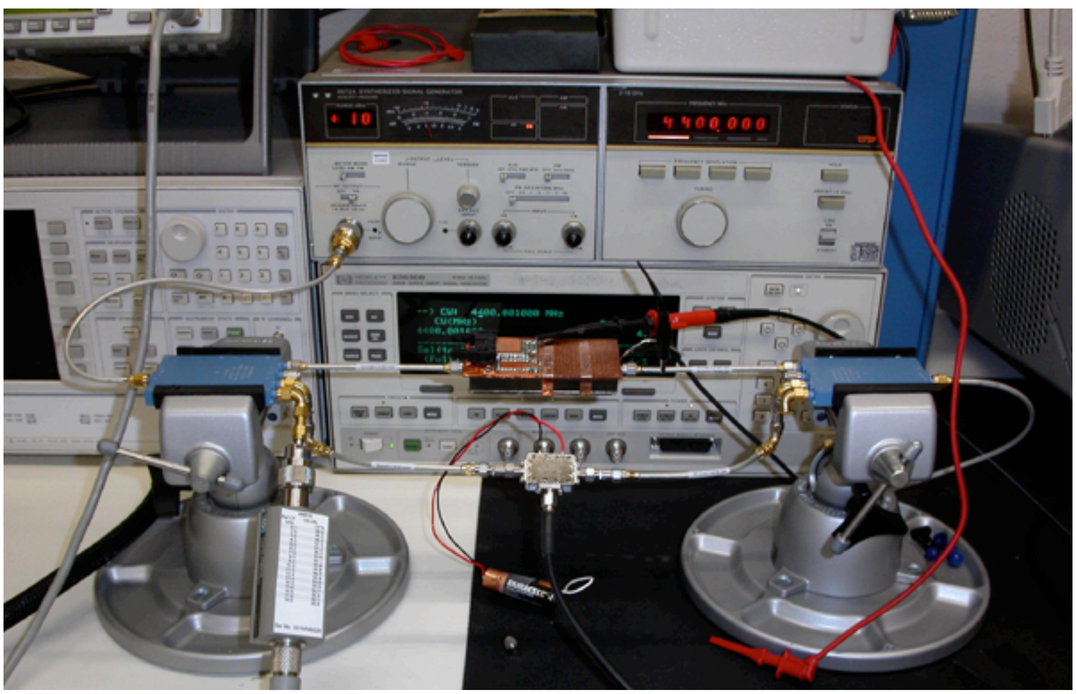

Figure 7 – Photo of Phase Test Setup

The delta time difference was converted to phase according to:

Phase = {(Δt)/1000μsec}*360, where 1000μsec is the period of the 1 kHz waveform

These phase values were plotted directly into *Figure 8*.

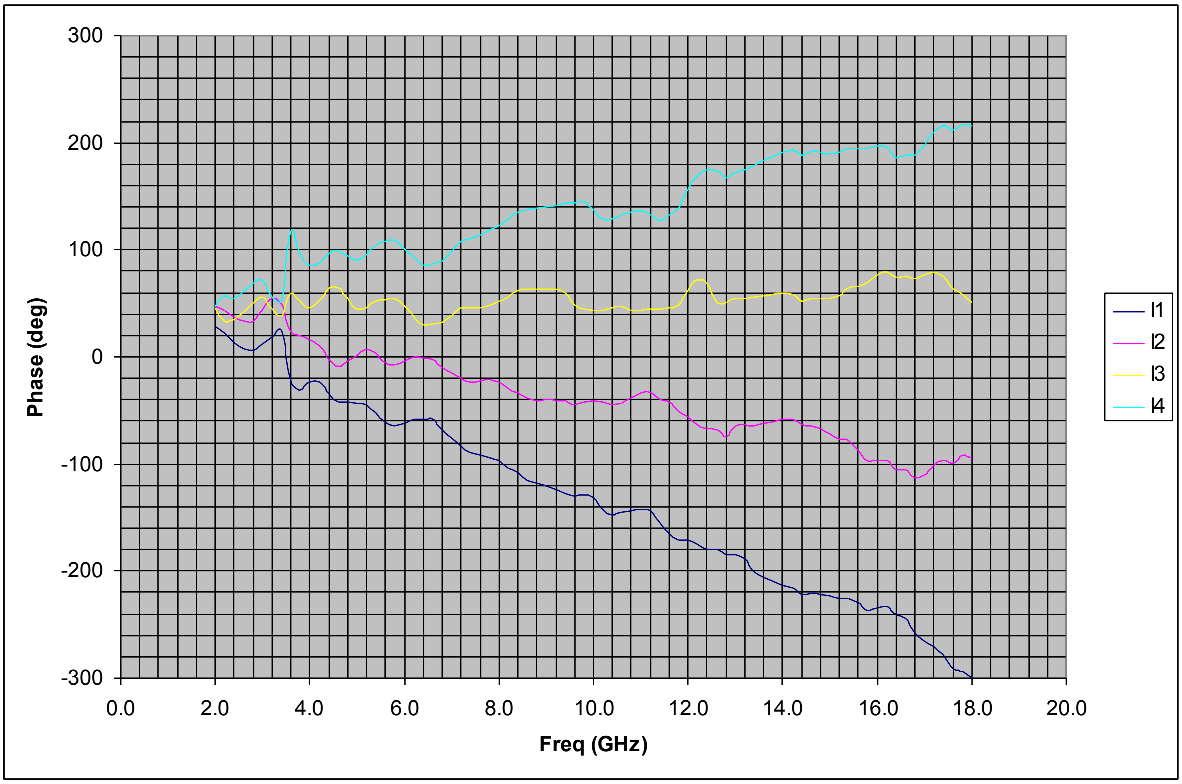

Figure 8 – Raw Phase verses Frequency

One aspect to note about the plot is that the phase does not converge to 0 degrees at 0 Hz. Extrapolating down to 0 Hz (ignoring the 2 to 5 GHz portion) indicates an approximate 0 Hz intercept point of +40 degrees. I can't explain this as of this writing but will attempt to resolve this in the future.

The specification is 30 degrees peak-to-peak, from 2 to 18 GHz. Ignoring the spikes at approximately 3.6 GHz, the peak-to-peak phase variation (from linear phase) is as follows:

Lag 1 = 40 degrees
Lag 2 = 35 degrees
Lag 3 = 38 degrees
Lag 4 = 30 degree

Relative lag delay is calculated[6] based on the phase slope of *Figure 8*.

Lag 1: slope = 9.9°/GHz, delay = 27.5 psec
Lag 2: slope = 0.5°/GHz, delay = 1.4 psec
Lag 3: slope = -8.0°/GHz, delay = -22.2 psec
Lag 4: slope = -18°/GHz, delay = -50.0 psec

It appears that lag 2 is at nearly the same physical position the reference mixer.

[6] Delay = (ϕ/Hz)/360°

IV. Conclusions and Recommendations

The Marki Microwave correlator module has good responsivity, decent amplitude response, maybe acceptable phase response, and acceptable output impedance. It is important to note that this design does not have the 6 dB isolation pads between the delay lines and the mixer as called out in the referenced specification.

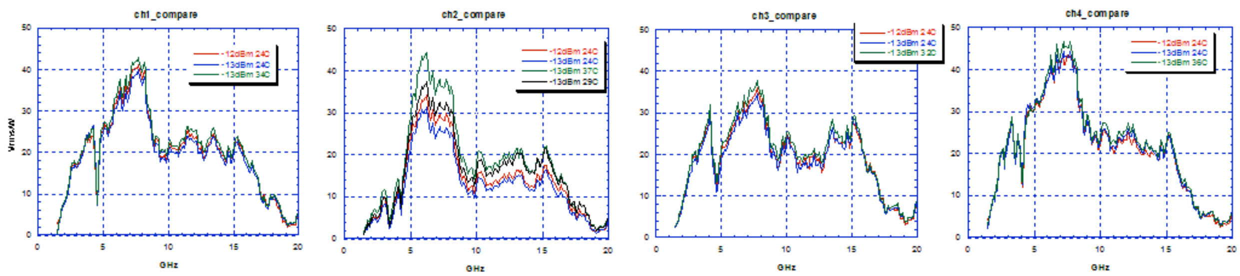

Figure 9 – Meridian 4-Lag Correlator Responsivity

Figure 9 shows responsivity data taken by C.T. Li for the Meridian 4-lag correlator module. If one assumes an average responsivity of 20 V_{rms}/W then removing the 6 dB pads should conceivably increase this to 80 V_{rms}/W. Doing this, however, will not improve the lack of performance at the lower and upper frequency band ends.

The phase plot for the Meridian correlator is shown in *Figure 10* (courtesy of C.T. Li). Note that the performance is quite nice with the exception of the glitches below 5 GHz. This near linear phase response may likely be due to the 6 dB pads surrounding the mixers.

The Meridian module has been installed in the AMiBA prototype telescope on Mauna Loa for approximately 2 months. The Marki module has just been installed into the prototype. This will allow for side by side comparison of overall SNR and effective bandwidth. Thereafter, a selection can be made to proceed with our initial order of 55 modules.

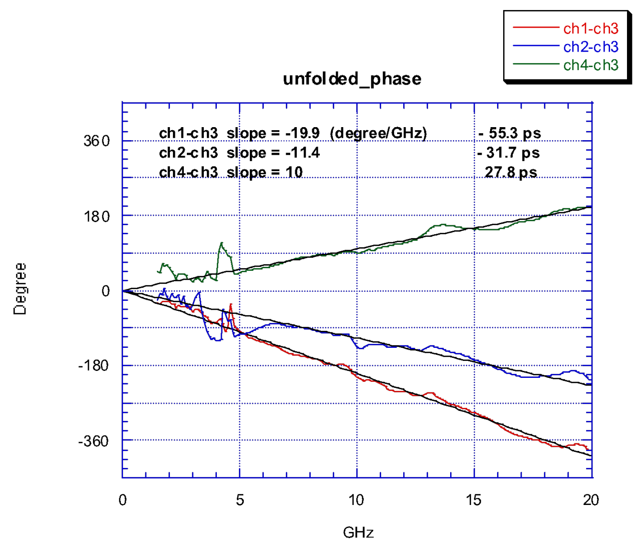

Figure 10 – Meridian 4-Lag Phase Response