Agilent Technologies
S800 Training, Fall 2013
Lab guide

Santa Rosa, CA: MODIN_S13_Lab3.1
Lab Title: Phase Measurements using MATLAB
Duration: 25min

Agilent Technologies

Table of contents

Objectives of lab

Introduce user to MATLAB application demonstrating M9703A as a multi-channel phase coherent measurement receiver.

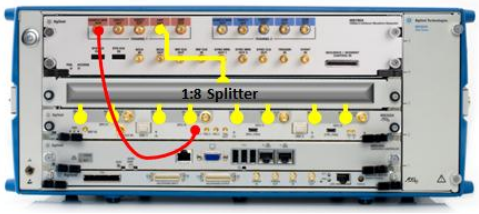
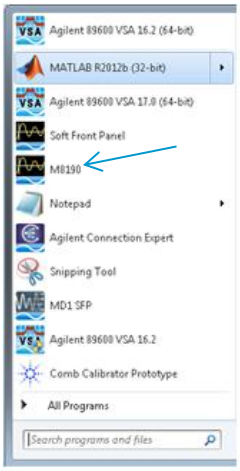
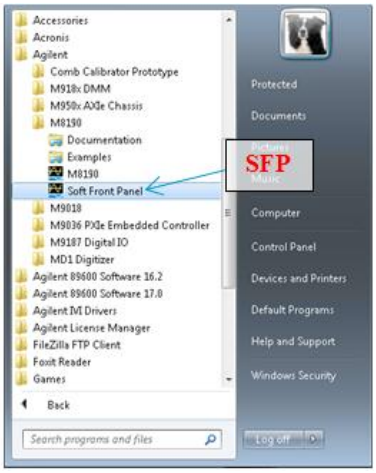
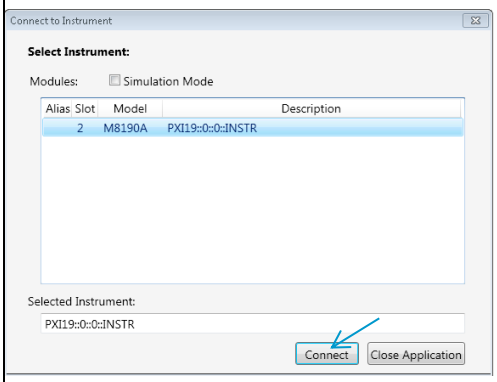
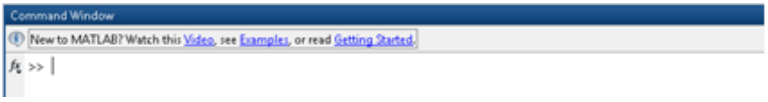
The lab procedure is presented in an extended table as shown below.

- Left side is the **Procedure -** Follow these steps to execute the lab.
- Right side is **Results/Explanation -** Explanation of the results of each procedure step.

Procedure	Results / Explanation
This side contains the lab process to follow	This side contains graphics and explainations to help understand the process step

Lab part 1 – Narrow-band techniques to measure cross-channel phase on analytic signals

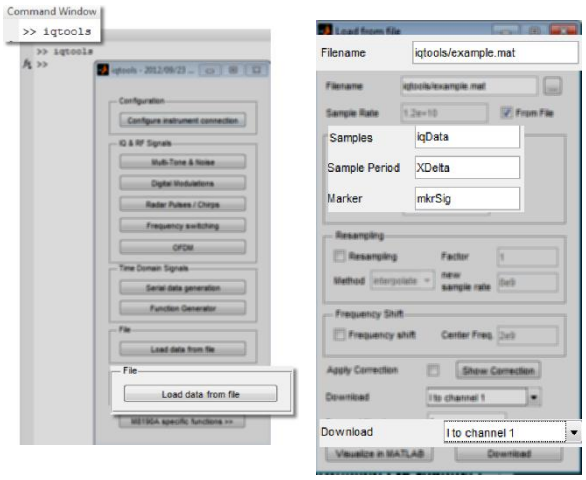
Introducing co-developed MATLAB App implementing narrow-band and wide-band cross-channel phase and magnitude measurement algorithms… Yes you get the source code!! ☺ Go to http://sms-apps.engineering.agilent.com/Software.htm.

Procedure	Results / Explanation
Confirm equipment setup as shown… **Open MATLAB** • Launch MATLAB R2012b (32-bit). **Open M8190A SFP** • While MATLAB is coming up, also start M8190A software front panel (SFP). **In MATLAB** • **Once >> prompt appears** in MATLAB command window, please proceed….	 First launch:  Then launch:    Confirm you see below prompt in MATLAB: 

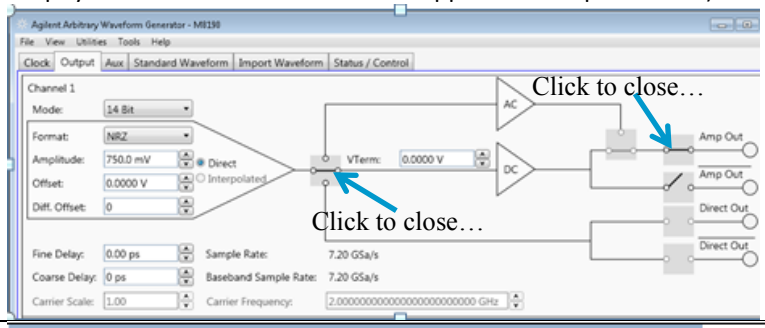
Configure M8190A with IQTools

- Launch **iqtools** from MATLAB prompt - type **iqtools** and press **enter**.
- Select **Load data from file**.
- Configure the Load from file to read in the file named **<Desktop>/S800 2013/MATLAB_IQToolsNarrowBand_PM.mat**.
- Configure parameters as follows (others leave at default value):
  Samples: **iqData**
  Sample Period: **XDelta**
  Marker: **mkrSig**
  Download: **I to channel 1**
- **Press Download**
- Switch to the **M8190A SFP**. Confirm/change M8190A channel 1 output to **Amp output**. Amplitude should be ≥ 750 mV.

Note: IQTools is MATLAB-based utility for configuring basic waveforms to be loaded into a variety of supported Agilent arbitrary waveform generators. It is included in the Examples folder with the M8190A driver installation.

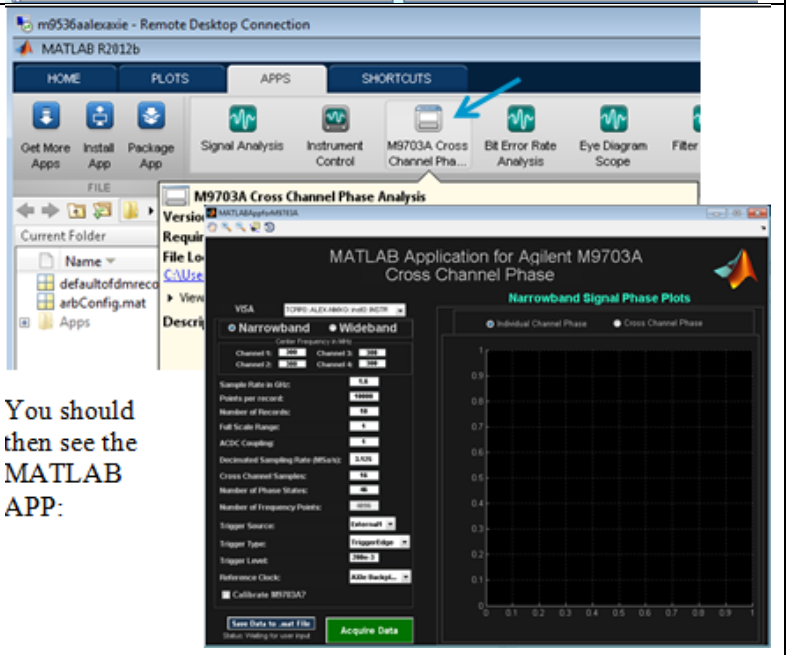


Here we configure the M8190A to output a **pulse phase modulated signal with various phase shifts that persist for 16 sample periods** so that we can take advantage of oversampling. The modulation is on a carrier frequency of 300MHz (signal was generated using MATLAB script you can read more about in the appendix – script included).



Open the MATLAB App

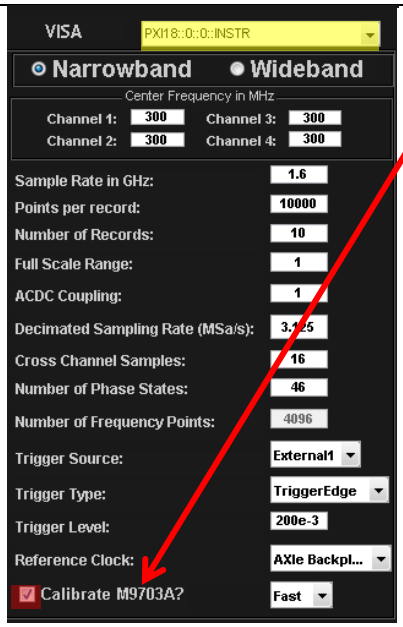
- Within MATLAB, navigate to the "APPS" tab. This is a new addition to the ribbon interface in MATLAB 2012b.
- Launch M9703A Cross Channel Phase Analysis APP.



You should then see the MATLAB APP:

Configure the MATLAB App

- Enter the VISA address for the M9703A (get from Agilent Connection Expert).
- Set up the app (**Narrowband mode**) to make phase measurements across ch 1-4. All center frequency and channel/trigger parameters can be left at the default for this Narrowband example.
- Make sure to do a self-calibration (**check mark in Calibrate M9703A?** option) before the first run.



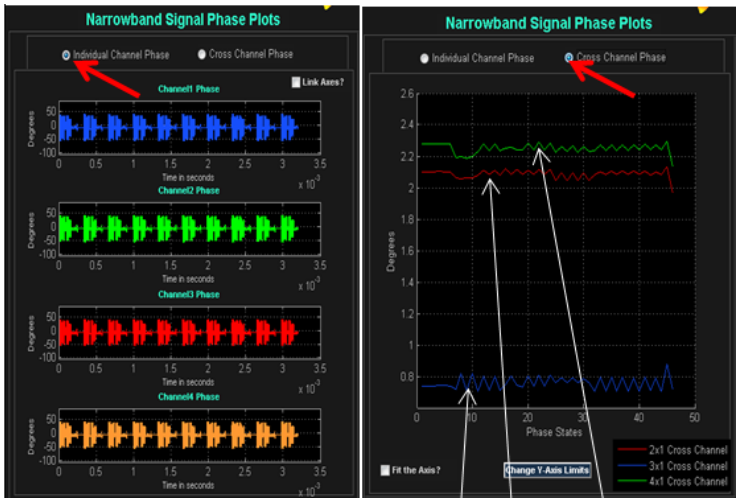
The self-calibration is always recommended for Agilent modular digitizers to obtain the best performance. There are two options, the fast calibration or the full calibration. The fast calibration will complete in just a few seconds whereas the full calibration takes about 2 minutes. Fast calibration is fine for this experiment.

Hint: If no calibration is performed, cross-channel phase measurement plots show large fixed skew offsets because the relative phase the multiple samplers in the digitizer start up at is not compensated.

Run the MATLAB App

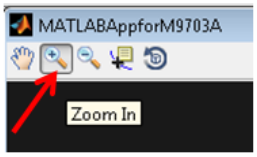
- The app can now be run by pressing the green **Acquire Data button.**

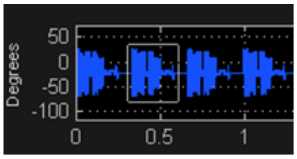
- Look at both the Individual Channel Phase plots and the Cross Channel Phase plots by using the radio button control above the plot display grids.



Explore Measurement Features

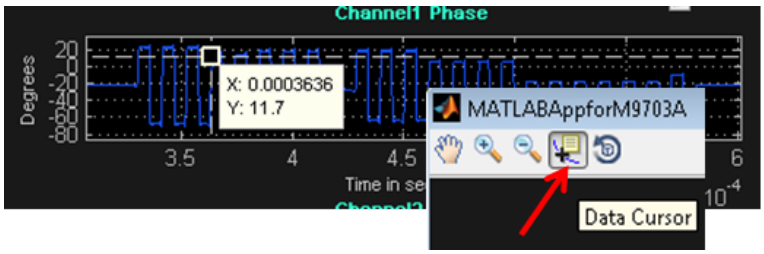
- First, in the **Individual Channel Phase** window, zoom in on one of the waveforms to see the phase modulated waveform with more detail.

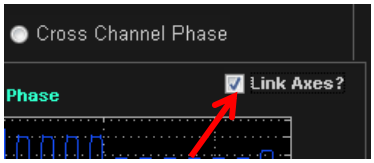




After using the **drag and drop** of a **zoom box** around one of the bursts of the phase modulated waveform, you will see all channels zoom to the same scale and plots like below.

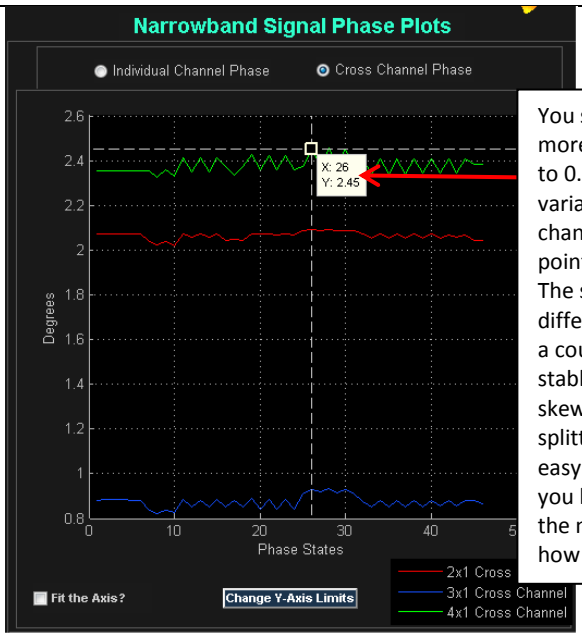
- Use the **data cursor tool** to **track values** of phase over time in the individual channel phase plots.
- **Pan** the waveforms (either together or separate) using the **hand tool**. Waveform scaling tracks all four channels by default, but you can check and then uncheck (double click) the **Link Axes box** to release the grids for independent panning and zooming.





Cross-ch Phase Variance vs Skew

- Place data cursor on the cross channel phase plots. Look for the pk-pk variation by moving the cursor from high to low peak excursions. This gives you in indication of the variance you would expect for a phase measurement at that frequency (narrowband signal at 300MHz CF).
- Think about how the phase response might vary at different frequencies…
  Hint: wideband measurements are covered in the next experiment using this MATLAB app.

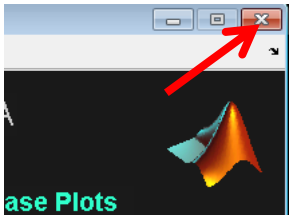


You should see no more than about 0.1 to 0.2 degrees of variation in the cross-channel phase from hi points to low points. The skew or absolute differences are within a couple degrees and stable (some of this skew is from the splitter), so those are easy to correct for… you have to wait until the next lab to see how ☺

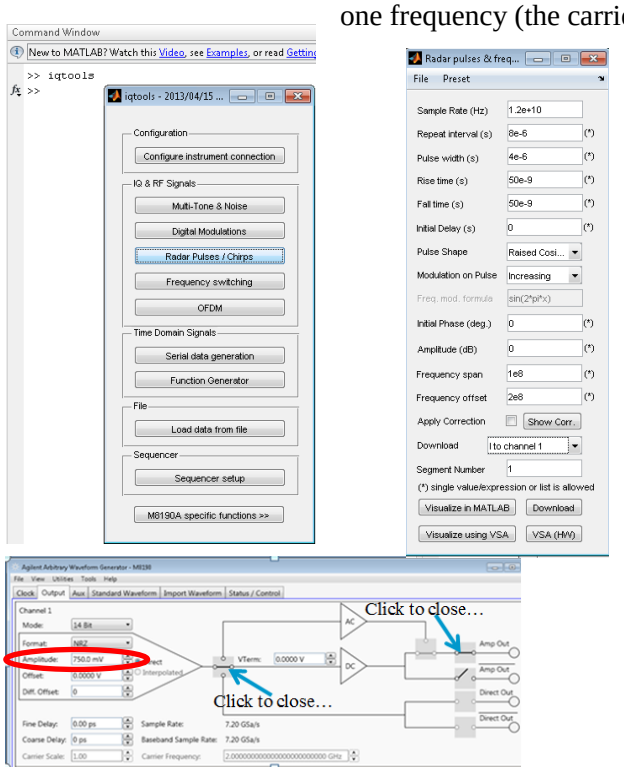
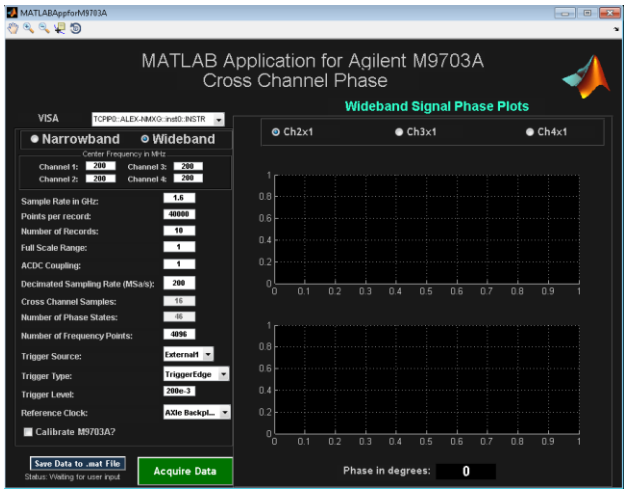
The point of this experiment is to see how you can compute intra-channel phase and cross-channel phase on the I&Q data from the M9703A's DDC. You can see the digitizer offers excellent phase variance performance and the ability to analyze 3.2 ms of phase modulation in only 10K points of acquisition data (decimation of 2^9 to reduce sample rate into memory and improve SNR/ENOB). For more info on the algorithms used for these measurements, please refer to the appendix topics **individual channel phase** and **cross channel phase**.

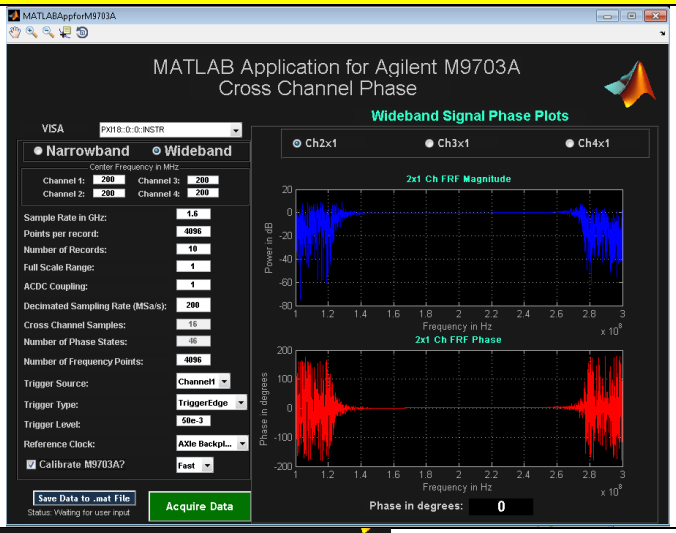
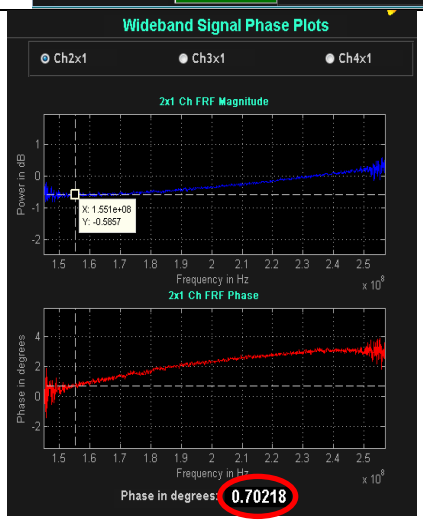
Finish Lab Part 1

- **Close the MATLAB APP** to release the session and start fresh for lab part 2 (you should keep MATLAB itself open).



Lab part 2 – Broadband techniques for making cross-channel FRF measurements

Procedure	Results / Explanation
Configure M8190A with IQTools • Go back to IQTools (if already closed then type iqtools at the prompt in MATLAB command window). • Click the **Radar Pulses / Chirps** button. • Configure parameters as follows (all others leave default values): Pulse width (s): **4e-6** Frequency span: **1e8** Frequency offset: **2e8** Download: **I to channel 1** • **Press Download** **M8190A SFP** • Make sure the output is set to **Amp out** as in the previous narrowband experiment from M8190A SFP (output tab). **Also ensure the amplitude is 1.0V.**	Now, using a wideband approach to making phase and magnitude measurements permits us to analyze the response at multiple frequencies simultaneously. In the previous measurement scenario we were only really considering phase at one frequency (the carrier). 
Configure MATLAB App – Wideband • Again, Start M9703A Cross Channel Phase Analysis APP • Set VISA address to the M9703A • Select “Wideband” radio button → you should see the plots change as the picture on the right (Ch2x1, Ch3x1, Ch4x1). • Configure parameters as follows (other should remain at default values): Points per record: **4096** Trigger Source: **Channel1** Trigger Level**: 50e-3** **Check Calibrate M9703A? -> fast**	

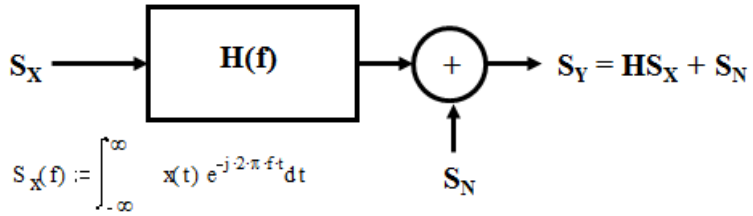
Procedure	Results / Explanation
Run MATLAB App • The app can now be run by pressing the green **Acquire Data button.** 	
Analyze Results • You can use the **zoom and data cursors** like in the narrow-band experiment.	 Also notice that there is some magnitude and phase mis-alignment between the frequency responses of both channels so using an IF magnitude & phase correction could be beneficial. You will notice that when you enable a data cursor you will see the value for the other parameter in the display at the bottom (exp. select a point on the magnitude plot, see corresponding phase reading below).

Lab summary – What have we learned?

1) How to use MATLAB demo APP to measure intra-channel and cross-channel phase from digitized data out of the M9703A digitizer with option –DDC (digital down-converter).
2) The M9703A, once calibrated using the built-in self-calibration, provides low channel to channel phase variance and therefore excellent coherence. However, just like with any instrument (source or receiver), base-line frequency response characteristics often can be improved upon for specific measurement solution configurations. And of course, in system configurations the digitizer itself cannot compensate automatically for whatever RF conversion and/or conditioning you do to the signal before it reaches the digitizer. **That is why we are presenting in MODIN_S13_Lab3 a systematic way of approaching solution level multi-channel wideband corrections**.

3) Finally, as programming example, you have a MATLAB APP (w/ editable source code) to understand and develop your own real-world implementations of the cross channel phase algorithms in the appendix.

Appendix – supplemental material

MATLAB APPS	http://www.mathworks.com/discovery/matlab-apps.html
Where MATLAB APPS source is installed by default:	C:\Users\<username>\My Documents\MATLAB\Apps
Individual channel phase (θ)	$\theta = \tan^{-1}(imag(z), real(z))$ Where z is a complex sample (or an array of complex samples). Each sample having the form of z = real(z) + j*imag(z).
Cross channel phase ($\theta_1 - \theta_2$)	Narrow-band: Let X = [x_0 x_1 x_2 … x_{n-1}] be N complex samples of x(t) Let R = [r_0 r_1 r_2 … r_{n-1}] be N complex samples of r(t) $\boldsymbol{G1} = \frac{XR'}{RR'}$ where R' is the conjugate transpose of R G1 = Complex ch-ch ratio (I&Q) Use this to compute relative mag and phase using: $\text{Mag} = \sqrt{Im(G1)\text{^}2 + Re(G1)\text{^}2}$ $\text{Phase} = \tan^{-1}\frac{Im(G1)}{Re(G1)}$ **Note: G1 can be implemented with a sum notation to average over multiple adjacent samples of stable phase/magnitude if oversampling sufficiently to improve sensitivity. Wide-band: 

	$\mathbf{H_{est}} = \overline{\mathbf{G_{YX}}} / \overline{\mathbf{G_{XX}}}$ $G_{YX} = S_Y S_X^*$ $G_{XX} = S_X S_X^*$ * conjugate operation $\mathbf{G_{YX}}$: Cross-Spectrum $\mathbf{G_{XX}}$: Average-Spectrum VSA software: Built-in freq response measurement
Using MATLAB to generate phase modulated waveform for IQTools	There are two *.m files (fillntoggle.m is a function called by the primary phmod.m script). Using these two in conjunction, you can generate a square-shaped pulse modulation pattern with discrete phase states like the one in the first narrow-band example. This allows you to test out the ability to average over multiple adjacent samples. The MATLAB app assumes that each phase transition (from min to max) occupies 1 decimated sample period and you can set the number of phase states and cross-channel samples per phase state in the GUI.