Application Note

Anritsu

MATLAB Application

MG3700A
Vector Signal Generator

Application Note

- MATLAB® Application -

Anritsu

MG3700A

Vector Signal Generator

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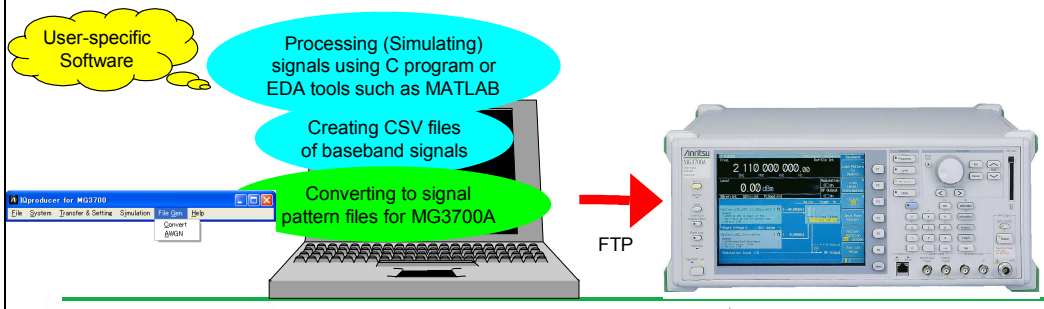
Contents

Introduction

- Electronic Design Automation (EDA) tools, such as MATLAB and Microwave Office, can save IQ simulation data to CSV text files.
  - » Easy comparison between simulation and measured data
- The IQproducer application software (MG3700A standard accessory) can import user I/Q sample data from CSV files into MG3700A, making it useful for various applications.
  - » R&D into next-generation wireless systems, RFID, PWM, analog modulation such as AM, FM, and PM

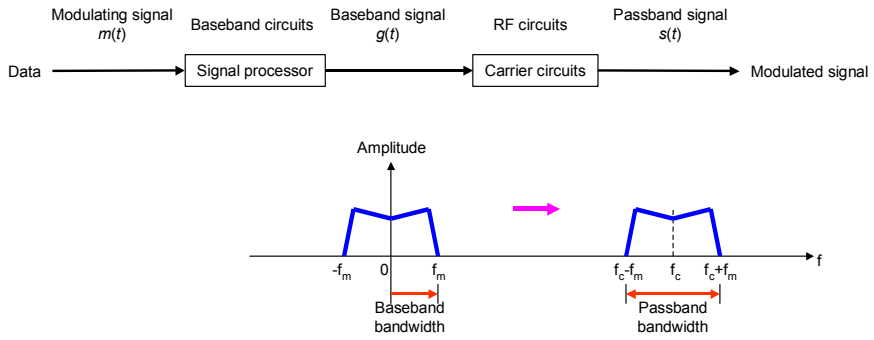


Introduction

- MG3700A supports Arbitrary Waveform Generator (AWG) features
  - » Sample rate (Fs)
    - – 20 k to 160 MHz
  - » Waveform memory
    - – 2× 128 Msample/channel (1 GB)
    - – 2× 256 Msample/channel (2 GB) * with Option Memory upgrade
      - Dual baseband memory
  - » DAC resolution
    - – 14 bits
  - » Marker output
    - – 3 definable TTL
- This document presents MATLAB usage examples.

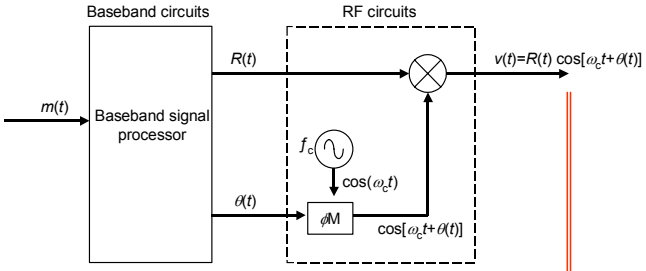
Modulation Basics

- Modulation imposes source data on a passband signal with carrier frequency f_c by using amplitude and/or phase perturbations.



Modulation Transmitter

- AM-PM technique

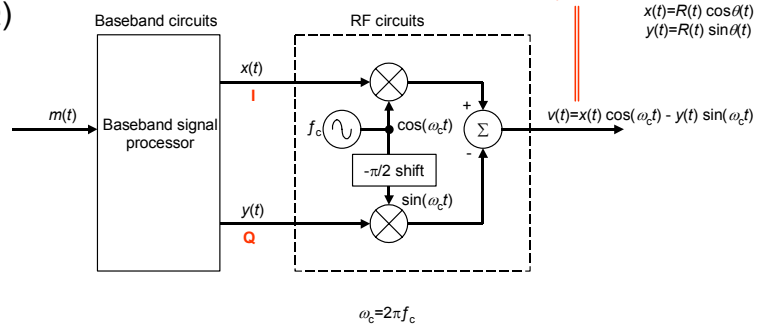


$$R(t) = \sqrt{x^2(t) + y^2(t)}$$

Equivalent

$x(t)=R(t)\cos\theta(t)$
$y(t)=R(t)\sin\theta(t)$

- Quadrature (IQ) technique



$\omega_c = 2\pi f_c$

Baseband Waveform

Modulation scheme	AM-PM		IQ modulation		Remark
	$R(t)$	$\theta(t)$	$x(t)$	$y(t)$	
AM	$A_c[1+m(t)]$	0	$A_c[1+m(t)]$	0	$m(t)=\mu\sin(2\pi f_m t)$ μ: Modulation depth f_m: Modulation freq.
PM	A_c	$D_p m(t)$	$A_c\cos[D_p m(t)]$	$A_c\sin[D_p m(t)]$	D_p: Phase deviation [rad/V]
FM	A_c	$D_f\int_{-\infty}^{t} m(\sigma)d\sigma$	$A_c\cos\left[D_f\int_{-\infty}^{t} m(\sigma)d\sigma\right]$	$A_c\sin\left[D_f\int_{-\infty}^{t} m(\sigma)d\sigma\right]$	D_f: Frequency deviation [rad/V·s]
QM	$A_c\sqrt{m_1^2(t)+m_2^2(t)}$	$\tan^{-1}\frac{m_2(t)}{m_1(t)}$	$A_c m_1(t)$	$A_c m_2(t)$	$m_1(t) = \pm 1$ $m_2(t) = \pm 1$

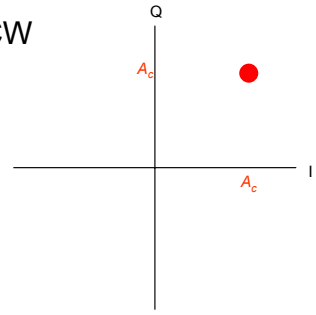
QM: Quadrature Modulation

Baseband Signal

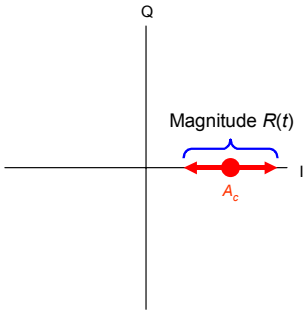
- Any type of modulated signal may be generated using either the AM-PM technique or quadrature technique.
- Any modulation scheme can be achieved by selecting the appropriate software algorithm.
- In a Vector Signal Generator (VSG), the passband signal $s(t)$ is often partitioned into two channels, one for $x(t)$ called the I (in-phase) channel and one for $y(t)$ called the Q (quadrature-phase) channel.
- In digital computer simulations of passband signals, the sampling rate used in the simulation can be minimized by working with the baseband signal, instead of with the passband signal $s(t)$, because the baseband signal is equivalent of the passband signal.

Fundamental I/Q Constellation

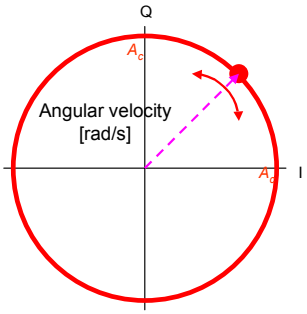
- CW



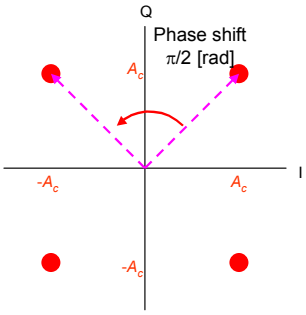
- AM



- FM

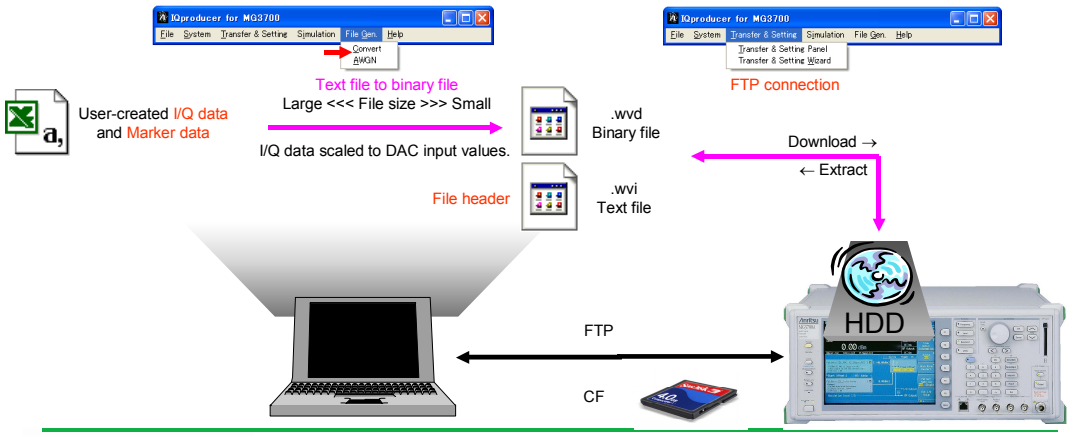


- PSK



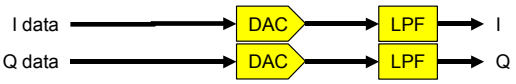
Understanding Signal Pattern File

- Signal pattern files consist of three data:
  - » IQ data
  - » Marker data
  - » File header



I/Q Data

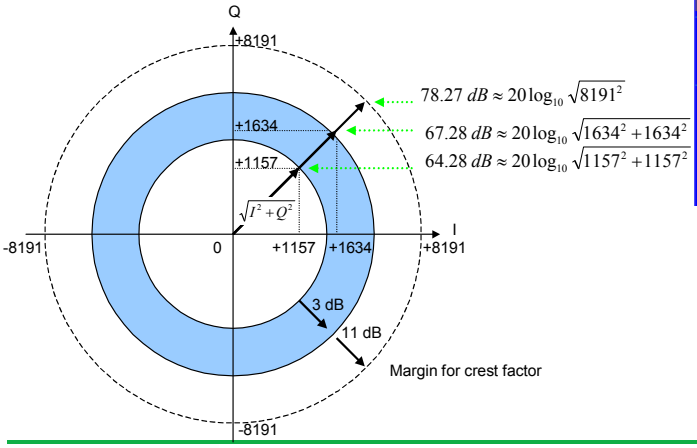
- The data file (.wvd) contains the I and Q data points (signed 14-bit integers for each I and Q data point). Each I/Q point equals one baseband waveform point.
- The MG3700A uses a 14-bit DAC to process each of the 2-byte integer values for the I and Q data points. The 14-bit DAC has a range of 0 to 16383, but MG3700A divides this range between positive and negative values.

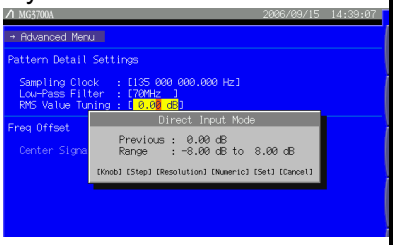


I/Q data range	DAC range	I/Q output voltage	
8191	16383	V_{max}	Positive (+) full scale
0	8191	0 V	
-8192	0	V_{min}	Negative (-) full scale

I/Q Data Range

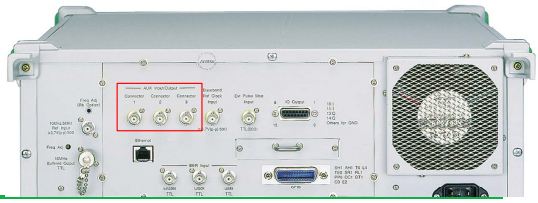
- The MG3700A performance is guaranteed within I/Q DAC RMS value 1157 to 1634.
  - » Tunable DAC RMS value considered crest factor (peak power/RMS power)
  - » Tunable $\sqrt{I^2+Q^2}$ RMS power on MG3700A display



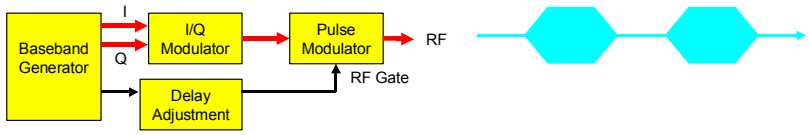


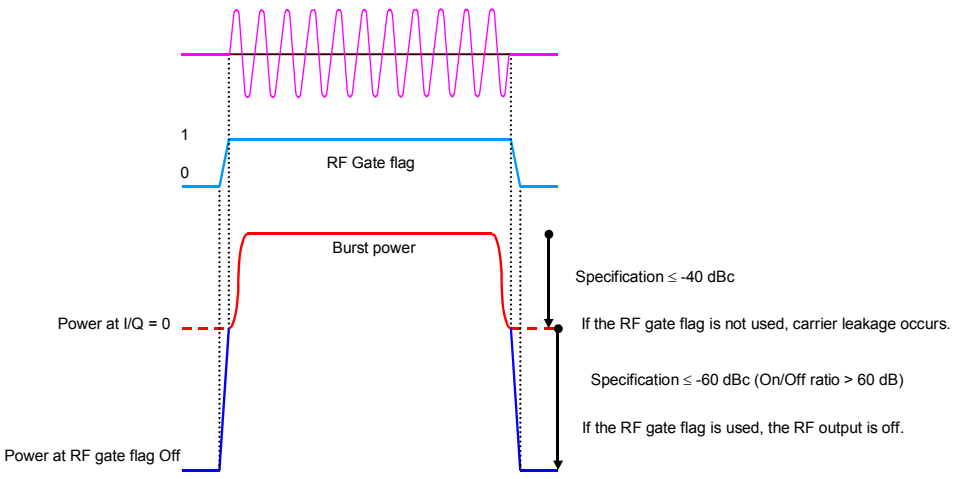
Marker Data

- The marker data uses 4 bits per I/Q data point to set the state of the four markers either On (1) or Off (0) for each I/Q data point.
- The marker data consists of three event markers and an RF gate flag.
- When an event marker is active (On), it outputs a trigger signal at the rear-panel marker connector corresponding to active marker number 1 to 3.
- An RF gate flag is used for pulse modulation and drives the internal pulse modulator.
  - » When I/Q data is imported without marker data, event markers are set automatically to inactive (Off), and the RF gate flag is set to active (On).



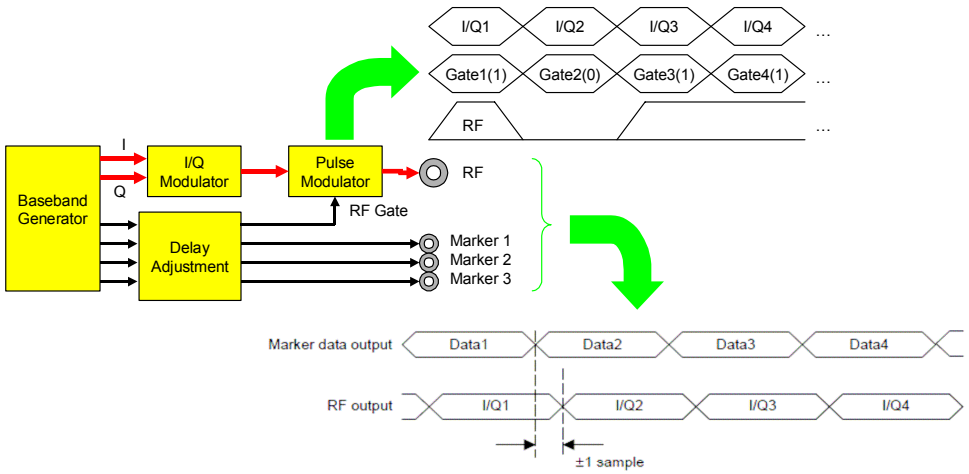
Internal Pulse Modulator





Timing

- Because markers are set at each I/Q data point, the marker data contains the same number of samples as I/Q data points.



- The time difference between the event markers output connector and RF connector is adjusted to be within ±1 sample.

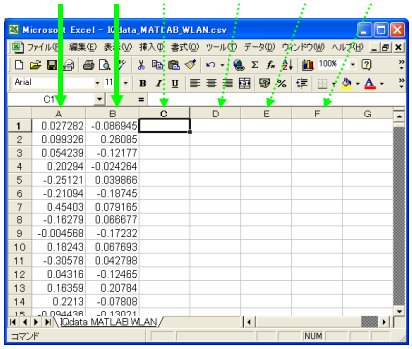
File Header

- The data file (.wvd) and file header (.wvi) have the same file name. The MG3700A stores the files in same package folder.
- The file header contains settings for the ARB modulation format, such as sample rate, number of samples, I/Q DAC RMS value, etc.
  - When the MG3700A finds unspecified header settings, it either uses the default settings, or the settings from previous signal pattern if a signal pattern was played previously.

Data File Size

- The data file (.wvd) is loaded into baseband memory, meaning that the occupied memory size equals the data file size.
- A baseband waveform consists of samples. One sample contains 4 bytes.
  - » I/Q Data + Marker Data = 1 Waveform Sample
    14 bits I 4 bits 4 bytes (32 bits)
    14 bits Q

Channel
I , Q (, Marker 1, Marker 2, Marker 3, RF gate flag)



Sampling rate (sample per second) Fs:
Sampling frequency expressed in Hz
Sampling interval Ts=1/Fs:
Time between samples in uniform sampling

Maximum of
256,000,000 sample
512,000,000 sample * with Option

Programming Examples to Create I/Q Data File

- There are various programming environments to create ARB I/Q data.

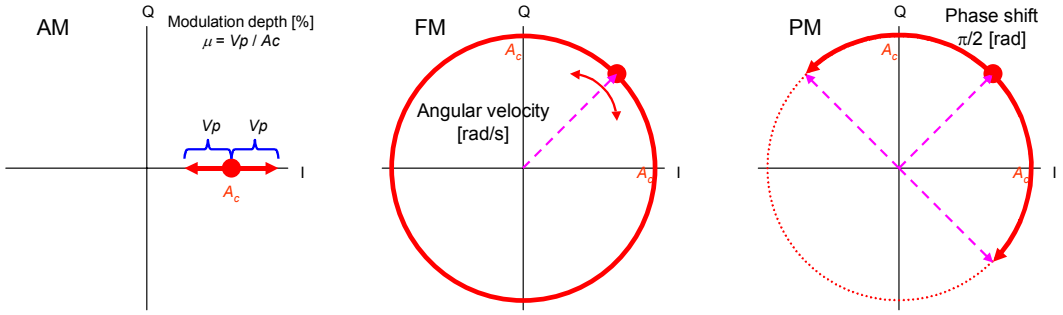
  Generally there are two types:
  - » Simulation software (EDA tool)
    - – MATLAB, Microwave Office, etc.
  - » Advanced programming languages
    - – C/C++, VB, LabView, etc.

- The example uses MATLAB, and shows the programmable M-files.
  M-file: MATLAB program for command script

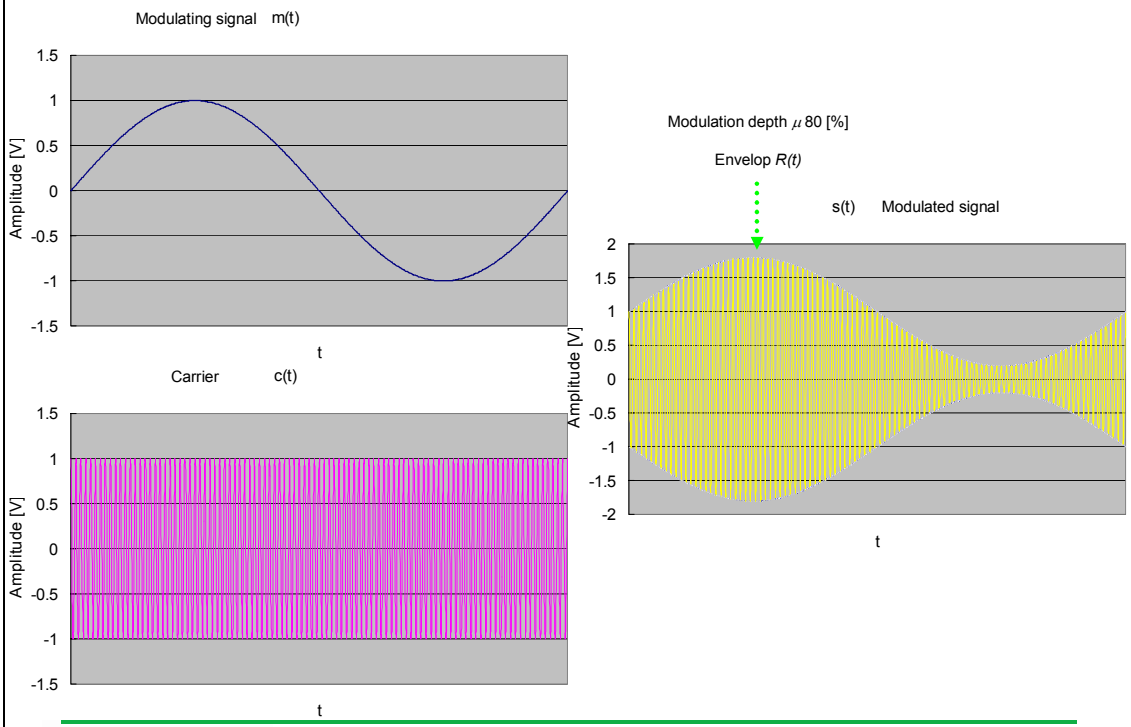
Analog Modulation

- Analog modulation schemes are most basic techniques and it is simple to create I/Q data.

  Basic analog modulation schemes:
  - » Amplitude Modulation (AM)
  - » Frequency Modulation (FM)
  - » Phase Modulation (PM)



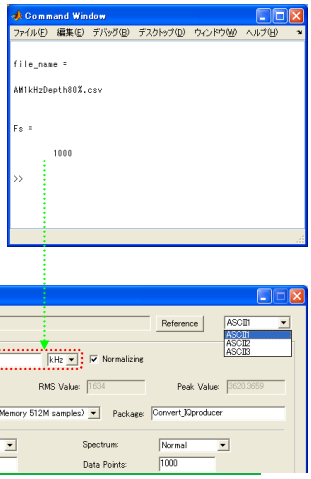
AM



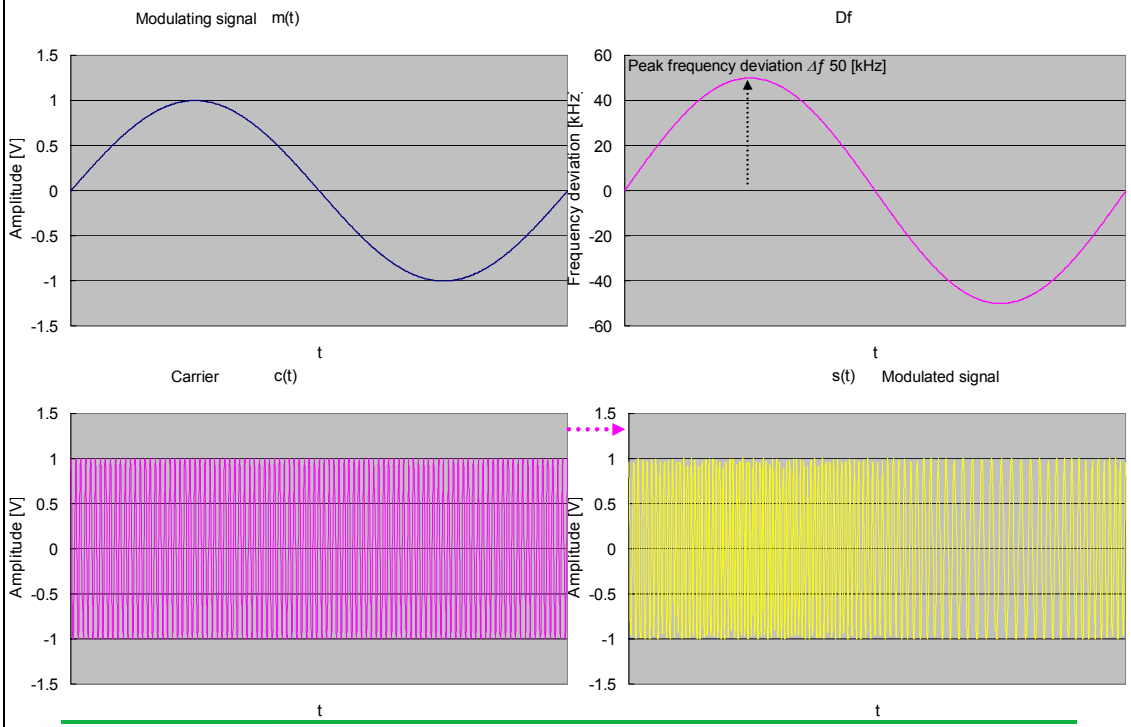
AM Programming Example

- I = $x(t) = Ac[1+m(t)] = 1+\mu \sin(2\pi f_m t)$
- Q = $y(t) = 0$
  - *Ac*: Carrier signal amplitude = 1
  - μ: Modulation depth = Modulating signal peak/Carrier signal peak (amplitude)

```
clear all, close all, clc

fm = 1;                    % Modulating frequency [kHz]
Depth = 0.8;               % Modulating depth
CSVfile = 'AM1kHzDepth80%.csv'

DataPoints = 1000;
Fs = fm*DataPoints         % Sampling rate [kHz]

t = 0:DataPoints-1;
I = 1+Depth*sin(2*pi*fm*t/DataPoints);
Q = zeros(1,DataPoints);
data = [I' Q'];
csvwrite(CSVfile,data);
```



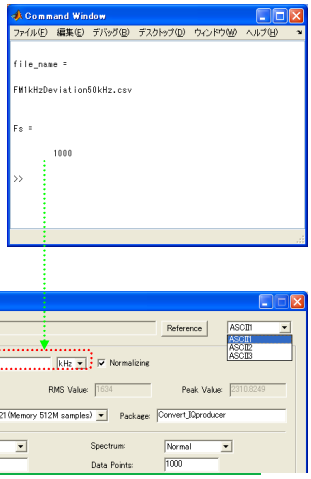
FM



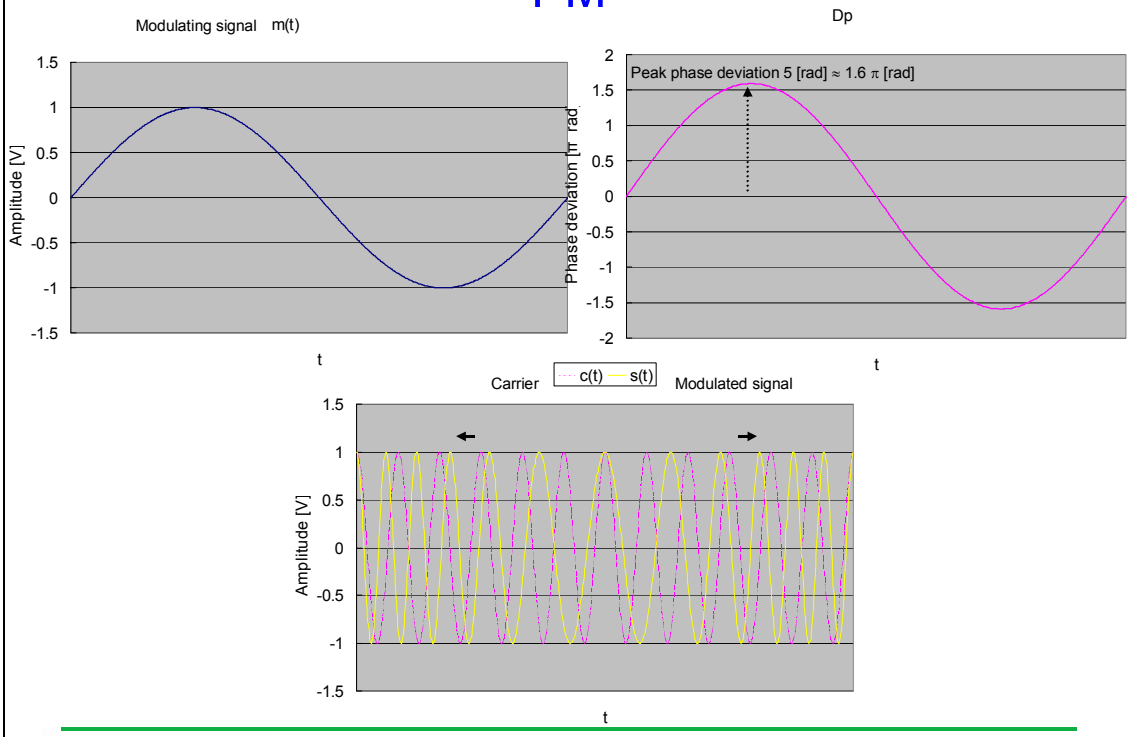
FM Programming Example

- I = $x(t) = A_c \cos\left[D_f \int_{-\infty}^{t} m(\sigma)d\sigma\right]$ = $\cos[\beta \sin(2\pi f_m t)]$
- Q = $y(t) = A_c \sin\left[D_f \int_{-\infty}^{t} m(\sigma)d\sigma\right]$ = $\sin[\beta \sin(2\pi f_m t)]$
  - *Ac*: Carrier signal amplitude = 1
  - β: Modulation index = $\Delta f / f_m$
  - Δf: Peak frequency deviation

```
clear all, close all, clc

fm = 1;                 % Modulating frequency [kHz]
Deviation = 50;         % Peak frequency deviation [kHz]
CSVfile = 'FM1kHzDeviation50kHz.csv'

DataPoints = 1000;
Fs = fm*DataPoints      % Sampling rate [kHz]

t = 0:DataPoints-1;
I = cos(Deviation/fm*sin(2*pi*fm*t/DataPoints));
Q = sin(Deviation/fm*sin(2*pi*fm*t/DataPoints));
data = [I' Q'];
csvwrite(CSVfile,data);
```



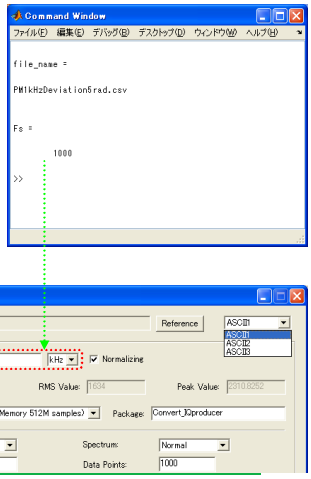
PM



PM Programming Example

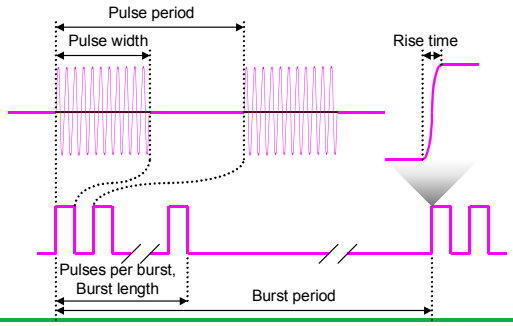
- I = $x(t) = Ac \cos[D_p\, m(t)] = \cos[D_p \sin(2\pi f_m t)]$
- Q = $y(t) = Ac \sin[D_p\, m(t)] = \sin[D_p \sin(2\pi f_m t)]$
  - *Ac*: Carrier signal amplitude = 1
  - Dp: Peak phase deviation

```
clear all, close all, clc

fm = 1;                 % Modulating frequency [kHz]
Deviation = 5;          % Peak phase deviation [kHz]
CSVfile = 'PM1kHzDeviation5rad.csv'

DataPoints = 1000;
Fs = fm*DataPoints      % Sampling rate [kHz]

t = 0:DataPoints-1;
I = cos(Deviation*sin(2*pi*fm*t/DataPoints));
Q = sin(Deviation*sin(2*pi*fm*t/DataPoints));
data = [I' Q'];
csvwrite(CSVfile,data);
```



Pulse Modulation

- Pulse modulation is used for radar and satellite signals using a combination with either FM or PM, and time-multiplexed burst signals.
  - PRF/PRR: Pulse repetition frequency, rate [pps], [pulse/s]
  - Pulse period [s]: 1/PRF
  - Pulse width, duration [s]: Including rise time
  - Duty ratio, cycle [%]: Pulse width/Pulse period
  - Pulses per burst [pulses/burst]
  - Burst length [s]
  - Burst period [s]
  - Rise time [s]



Pulse Modulation Programming Example

- I = $x(t) = Ac = 1$ (CW)
- Q = $y(t) = Ac = 1$
  - *Ac*: Carrier signal amplitude = 1
  - PRF: 700 [pps]
  - Pulse width: 1 [μs]
  - Pulses/burst: 18
  - Burst period: 10 [s]

```
clear all, close all, clc

PRF = 700;                  % [pps]
PulseWidth = 1E-6;          % [s]
PulsesPerBurst = 18;        % [pulses/burst]
BurstPeriod = 10;           % [s]
CSVfile = 'Pulse700ppsW1us18ppbB10s.csv'
zerofile = 'Pulse700ppsW1us18ppbB10sZero.csv'

Fs = LCM(PRF,1/PulseWidth)          % Sampling rate [Hz], LCM: Least Common Multiple
% Number of samples
W = PulseWidth*Fs;
PulseGap = (1/PRF-PulseWidth)*Fs;
```

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Pulse Modulation Programming Example

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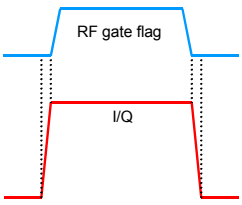
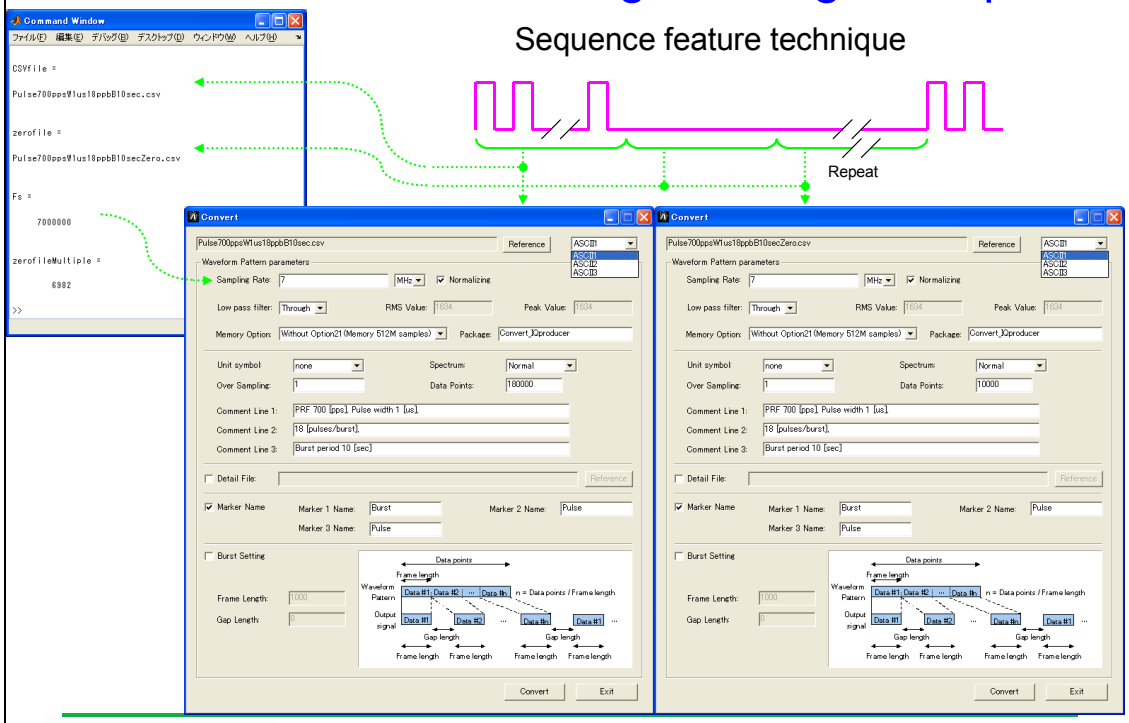
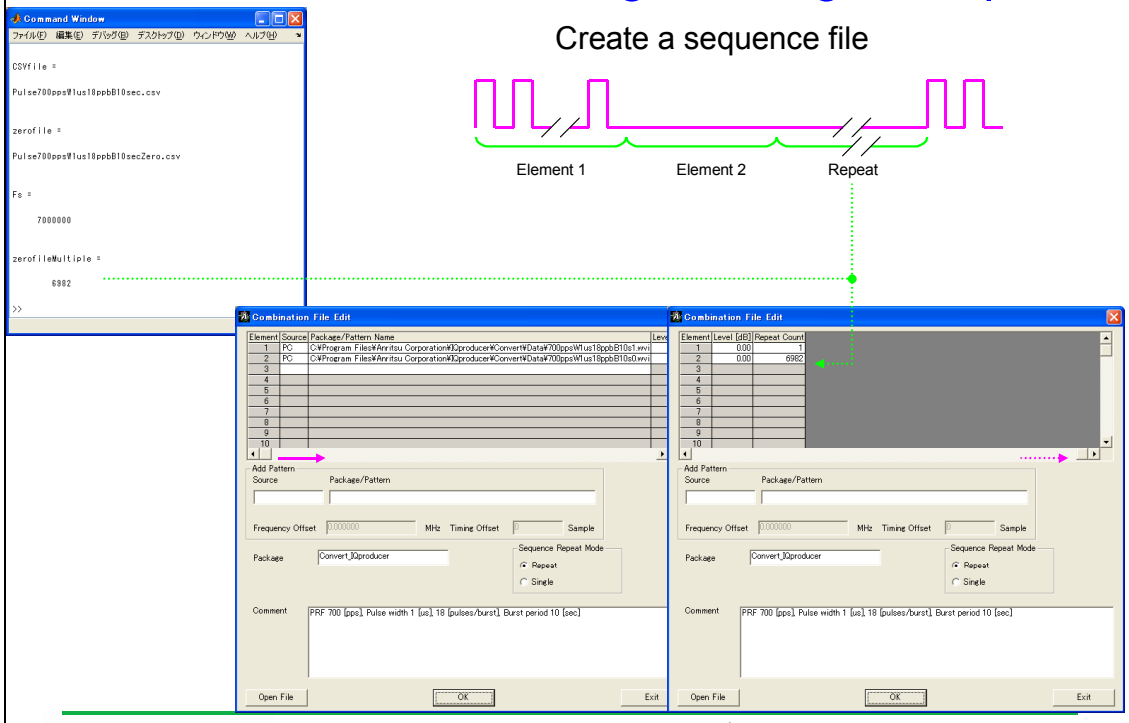



```
I = [ ones(1,W+2) zeros(1,PulseGap-2) ];
Q = [ ones(1,W+2) zeros(1,PulseGap-2) ];
RFgateFlag = [ zeros(1,1) ones(1,W) zeros(1,PulseGap) ];
Burst = [ zeros(1,1) ones(1,W) ];
for n = 2:PulsesPerBurst
    I = [ I ones(1,W+2) zeros(1,PulseGap-2) ];
    Q = [ Q ones(1,W+2) zeros(1,PulseGap-2) ];
    Burst = [ Burst ones(1,PulseGap+W) ];
    if n == PulsesPerBurst
            RFgateFlag = [ RFgateFlag ones(1,W) zeros(1,PulseGap-1) ];
    else
            RFgateFlag = [ RFgateFlag ones(1,W) zeros(1,PulseGap) ];
    end
end

Marker1 = [ Burst zeros(1,PulseGap-1) ];        % Burst
Marker2 = RFgateFlag;                           % Pulse
Marker3 = RFgateFlag;                           % Pulse
data = [I' Q' Marker1' Marker2' Marker3' RFgateFlag'];
csvwrite(CSVfile,data);

BurstGapPulseLength = PRF*BurstPeriod-PulsesPerBurst;
zero = zeros(1,Fs/PRF);  % samples/pulse
zerodata = [zero' zero' zero' zero' zero' zero'];
csvwrite(zerofile,zerodata);
zerofileMultiple = PRF*BurstPeriod-PulsesPerBurst  % Pulse length in Burst gap
```

Pulse Modulation Programming Example



Pulse Modulation Programming Example

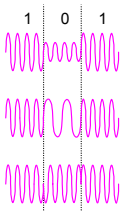


PSK, QAM

- Digital modulation schemes change the amplitude, frequency and phase of the carrier at regular time intervals, and sends a digital baseband signal.
  - » Analog modulation schemes change the carrier amplitude, frequency and phase continuously.

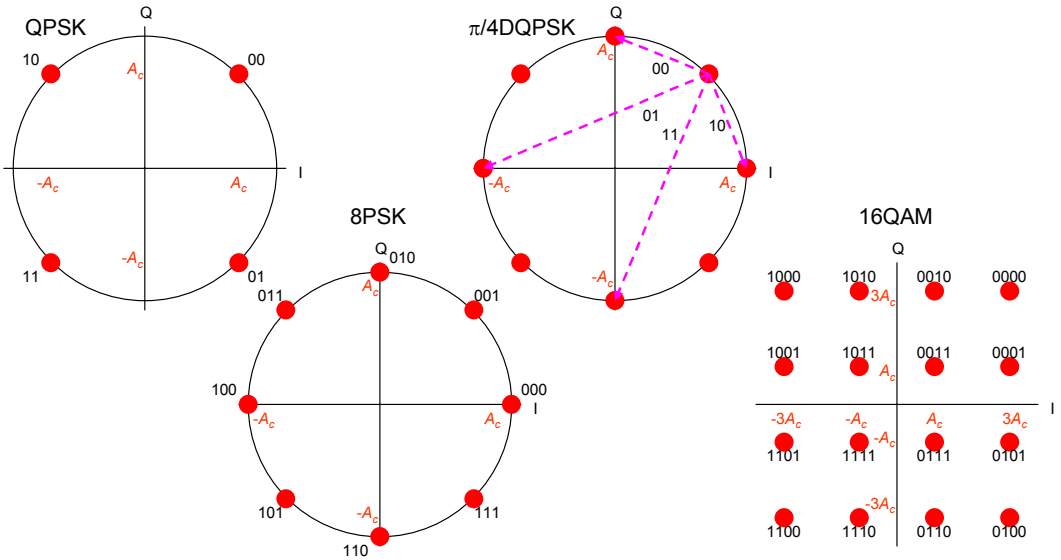
Basic digital modulation schemes:

- » Amplitude Shift Keying (ASK)
  - – The amplitude of the carrier varies linearly with the symbol sequence.
- » Frequency Shift Keying (FSK)
  - – The frequency of the carrier varies linearly with the symbol sequence.
- » Phase Shift Keying (PSK)
  Differential Phase Shift Keying (DPSK)
  - – The phase of the carrier varies linearly with the symbol sequence.
- » Quadrature Amplitude Modulation (QAM)
  - – The amplitude and phase of the carrier varies linearly with the symbol sequence.



PSK, QAM

- This chapter shows common examples for QPSK, π/4DQPSK, 8PSK, 16QAM.



QPSK

Complex envelop

- $g(t) = Ac[m_1(t)+jm_2(t)] = I(t)+jQ(t)$
  - Ac: Carrier signal amplitude = 1

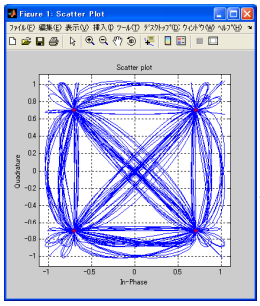
MATLAB requires:
Signal Processing Toolbox
Communications Toolbox

```
clear all, close all, clc

Fd = 1;       % Symbol rate [sps]
Fs = 10*Fd;% Oversampling rate
Pd = 256;   % Symbol points
repetition = 2;                % Repetition factor of data
R = 0.5;      % Rolloff factor for FIR filter
delay = 3;   % Filter's group delay
CSVfile='QPSK.csv'

M = 4;        % Point signal constellations
SymbolData = randint(Pd,1,M);          % Random data [Communications Toolbox]
% Duplicate the symbol data because of waveform phase continuity
DuplicateSymbolData = repmat(SymbolData,repetition,1);          % Replicate the symbol
    data [Fixed-Point Toolbox]
g = pskmod(DuplicateSymbolData,M,pi/4);              % Complex envelop g(t), Initial phase
    pi/4 rad [Communications Toolbox]
```

(Continued on the next page)

QPSK

(Continued from previous page)

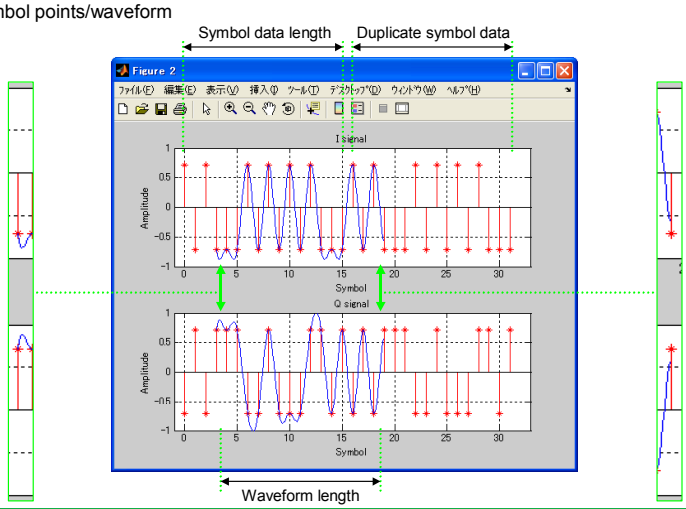



```
filtering = rcosflt(g,Fd,Fs,'fir/normal',R,delay);          % Filter input signal using FIR filter
    [Communications Toolbox]
OversampledData = filtering(Fs*delay*2+1:Fs*delay*2+Fs*Pd);     % Correct filter delay
data = [real(OversampledData) imag(OversampledData)];           % I/Q data
csvwrite(CSVfile,data);

scatterplot(OversampledData,1,0,'b-'),hold on,plot(g,'r*'),grid         % Signal constellation

figure        % Complex envelop
t_g = 0:Pd*repetition-1;   % g(t) symbol number
t_o = delay:Fd/Fs:delay+Pd-1/Fs;        % Oversampled symbol number
subplot(2,1,1),stem(t_g,real(g),'r*'),hold on,plot(t_o,real(OversampledData)),grid% In-phase
axis([-1 Pd*repetition+1 round(min(real(g))) round(max(real(g)))])
title('I signal'),xlabel('Symbol'),ylabel('Amplitude')
subplot(2,1,2),stem(t_g,imag(g),'r*'),hold on,plot(t_o,imag(OversampledData)),grid
                % Quadrature-phase
axis([-1 Pd*repetition+1 round(min(imag(g))) round(max(imag(g)))])
title('Q signal'),xlabel('Symbol'),ylabel('Amplitude')
```

Waveform Phase Continuity

- The MG3700A plays back a waveform of finite in length and repeats it continuously. Phase discontinuity between the end of one waveform and the start of the next repetition can lead to periodic spectral regrowth and distortion.
- Repetitions with abrupt phase changes result in high frequency spectral regrowth.

For Pd = 16 symbol points/waveform



π/4DQPSK

Complex envelop

- $g(t) = Ac[m_1(t)+jm_2(t)] = I(t)+jQ(t)$
  - *Ac*: Carrier signal amplitude = 1

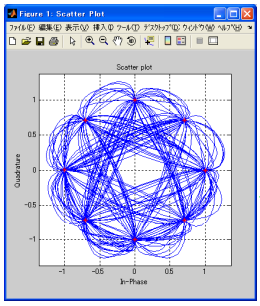
MATLAB requires:
- Signal Processing Toolbox
- Communications Toolbox

```
clear all, close all, clc

Fd = 1;       % Symbol rate [sps]
Fs = 10*Fd;% Oversampling rate
Pd = 256;   % Symbol points
repetition = 2;                % Repetition factor of data
R = 0.5;      % Rolloff factor for FIR filter
delay = 3;   % Filter's group delay
CSVfile='pi4DQPSK.csv'

M = 4;        % Point signal constellations
SymbolData = randint(Pd,1,M);          % Random data [Communications Toolbox]
% Duplicate the symbol data because of waveform phase continuity
DuplicateSymbolData = repmat(SymbolData,repetition,1);          % Replicate the symbol
    data [Fixed-Point Toolbox]
g = dpskmod(DuplicateSymbolData,M,pi/4);          % Complex envelop g(t) using phase
    shift pi/4 rad [Communications Toolbox]
```

(Continued on the next page)

π/4DQPSK

(Continued from previous page)




```
filtering = rcosflt(g,Fd,Fs,'fir/normal',R,delay);          % Filter input signal using FIR filter
    [Communications Toolbox]
OversampledData = filtering(Fs*delay*2+1:Fs*delay*2+Fs*Pd);     % Correct filter delay
data = [real(OversampledData) imag(OversampledData)];           % I/Q data
csvwrite(CSVfile,data);

scatterplot(OversampledData,1,0,'b-'),hold on,plot(g,'r*'),grid         % Signal constellation

figure          % Complex envelop
t_g = 0:Pd*repetition-1;    % g(t) symbol number
t_o = delay:Fd/Fs:delay+Pd-1/Fs;        % Oversampled symbol number
subplot(2,1,1),stem(t_g,real(g),'r*'),hold on,plot(t_o,real(OversampledData)),grid% In-phase
axis([-1 Pd*repetition+1 min(real(OversampledData)) max(real(OversampledData))])
title('I signal'),xlabel('Symbol'),ylabel('Amplitude')
subplot(2,1,2),stem(t_g,imag(g),'r*'),hold on,plot(t_o,imag(OversampledData)),grid
                % Quadrature-phase
axis([-1 Pd*repetition+1 min(imag(OversampledData)) max(imag(OversampledData))])
title('Q signal'),xlabel('Symbol'),ylabel('Amplitude')
```


8PSK

Complex envelop

- $g(t) = Ac[m_1(t)+jm_2(t)] = I(t)+jQ(t)$
  - Ac: Carrier signal amplitude = 1

MATLAB requires:
- Signal Processing Toolbox
- Communications Toolbox

```
clear all, close all, clc

Fd = 1;       % Symbol rate [sps]
Fs = 10*Fd;% Oversampling rate
Pd = 256;   % Symbol points
repetition = 2;                 % Repetition factor of data
R = 0.5;      % Rolloff factor for FIR filter
delay = 3;   % Filter's group delay
CSVfile='8PSK.csv'

M = 8;        % Point signal constellations
SymbolData = randint(Pd,1,M);           % Random data [Communications Toolbox]
% Duplicate the symbol data because of waveform phase continuity
DuplicateSymbolData = repmat(SymbolData,repetition,1);          % Replicate the symbol
    data [Fixed-Point Toolbox]
g = pskmod(DuplicateSymbolData,M);  % Complex envelop g(t) [Communications Toolbox]
```

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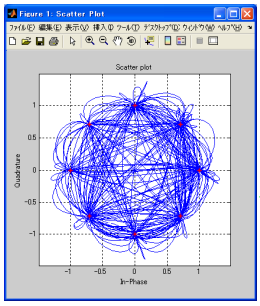
8PSK

(Continued from previous page)




```
filtering = rcosflt(g,Fd,Fs,'fir/normal',R,delay);          % Filter input signal using FIR filter
    [Communications Toolbox]
OversampledData = filtering(Fs*delay*2+1:Fs*delay*2+Fs*Pd);     % Correct filter delay
data = [real(OversampledData) imag(OversampledData)];           % I/Q data
csvwrite(CSVfile,data);

scatterplot(OversampledData,1,0,'b-'),hold on,plot(g,'r*'),grid         % Signal constellation

figure          % Complex envelop
t_g = 0:Pd*repetition-1;    % g(t) symbol number
t_o = delay:Fd/Fs:delay+Pd-1/Fs;        % Oversampled symbol number
subplot(2,1,1),stem(t_g,real(g),'r*'),hold on,plot(t_o,real(OversampledData)),grid% In-phase
axis([-1 Pd*repetition+1 min(real(OversampledData)) max(real(OversampledData))])
title('I signal'),xlabel('Symbol'),ylabel('Amplitude')
subplot(2,1,2),stem(t_g,imag(g),'r*'),hold on,plot(t_o,imag(OversampledData)),grid
                % Quadrature-phase
axis([-1 Pd*repetition+1 min(imag(OversampledData)) max(imag(OversampledData))])
title('Q signal'),xlabel('Symbol'),ylabel('Amplitude')
```


16QAM

Complex envelop

- $g(t) = Ac[m_1(t)+jm_2(t)] = I(t)+jQ(t)$
  - *Ac*: Carrier signal amplitude = 1

MATLAB requires:
- Signal Processing Toolbox
- Communications Toolbox

```
clear all, close all, clc

Fd = 1;       % Symbol rate [sps]
Fs = 10*Fd;% Oversampling rate
Pd = 256;   % Symbol points
repetition = 2;                 % Repetition factor of data
R = 0.5;      % Rolloff factor for FIR filter
delay = 3;   % Filter's group delay
CSVfile='16QAM.csv'

M = 16;      % Point signal constellations
SymbolData = randint(Pd,1,M);           % Random data [Communications Toolbox]
% Duplicate the symbol data because of waveform phase continuity
DuplicateSymbolData = repmat(SymbolData,repetition,1);          % Replicate the symbol
    data [Fixed-Point Toolbox]
g = pskmod(DuplicateSymbolData,M);  % Complex envelop g(t) [Communications Toolbox]
```

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16QAM

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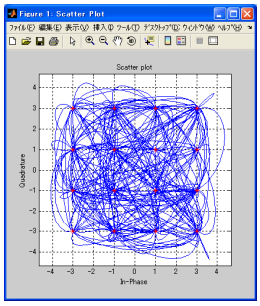
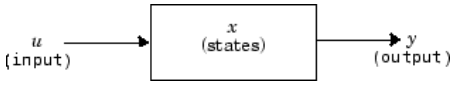



```
filtering = rcosflt(g,Fd,Fs,'fir/normal',R,delay);          % Filter input signal using FIR filter
    [Communications Toolbox]
OversampledData = filtering(Fs*delay*2+1:Fs*delay*2+Fs*Pd);    % Correct filter delay
data = [real(OversampledData) imag(OversampledData)];          % I/Q data
csvwrite(CSVfile,data);

scatterplot(OversampledData,1,0,'b-'),hold on,plot(g,'r*'),grid        % Signal constellation

figure        % Complex envelop
t_g = 0:Pd*repetition-1;   % g(t) symbol number
t_o = delay:Fd/Fs:delay+Pd-1/Fs;        % Oversampled symbol number
subplot(2,1,1),stem(t_g,real(g),'r*'),hold on,plot(t_o,real(OversampledData)),grid% In-phase
axis([-1 Pd*repetition+1 min(real(OversampledData)) max(real(OversampledData))])
title('I signal'),xlabel('Symbol'),ylabel('Amplitude')
subplot(2,1,2),stem(t_g,imag(g),'r*'),hold on,plot(t_o,imag(OversampledData)),grid
            % Quadrature-phase
axis([-1 Pd*repetition+1 min(imag(OversampledData)) max(imag(OversampledData))])
title('Q signal'),xlabel('Symbol'),ylabel('Amplitude')
```


Simulink



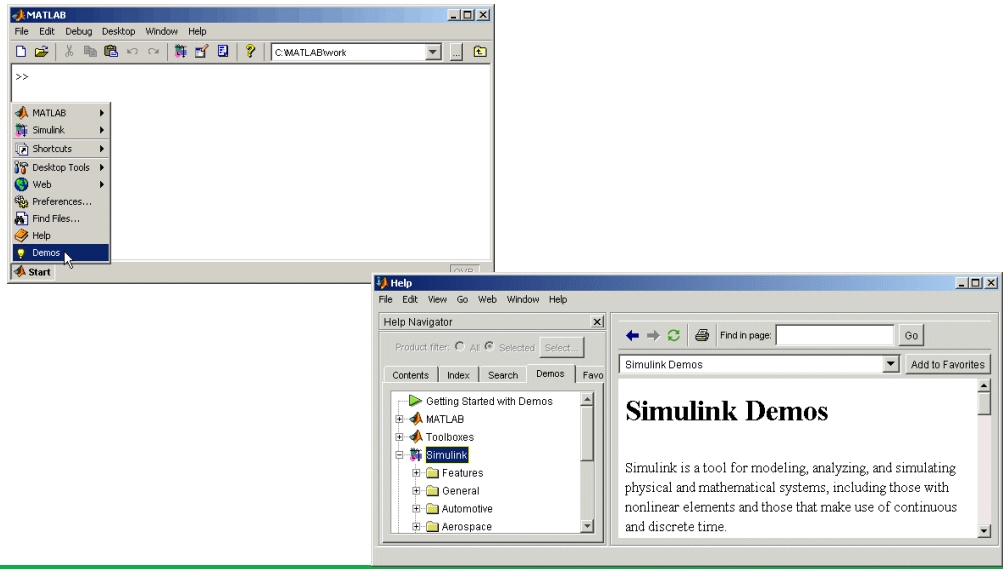
- What is Simulink?
  - » Simulink® is a software package for modeling, simulating, and analyzing dynamic systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two.
- Tool for simulation
  - » You can easily build models from scratch, or take an existing model and add to it. It offers instant access to all the analysis tools in MATLAB, so the results can be taken and analyzed and visualized.
- Tool for model-based design
  - » For modeling, Simulink offers a GUI for building models as block diagrams, using click-and-drag mouse operations. You can also customize and create your own blocks.
  - » Models are hierarchical, so they can be built using both top-down and bottom-up approaches.
  - » After defining a model, you can simulate it. Simulation results can be put in the MATLAB workspace for post-processing and visualization.

CSV file

For more information on Simulink, visit the MathWorks website.
http://www.mathworks.com/access/helpdesk/help/toolbox/simulink/

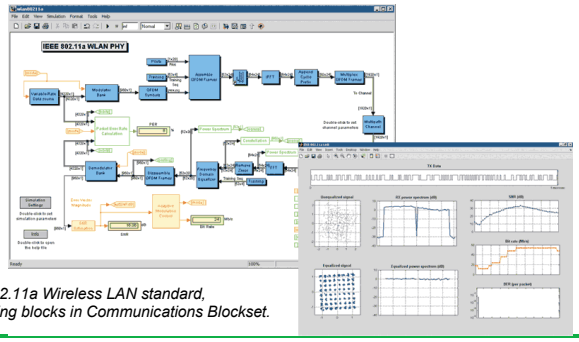
Simulink Demos

- Simulink demos illustrate useful modeling concepts. Access demos from the MATLAB Command Window.



Simulink Blockset Demos

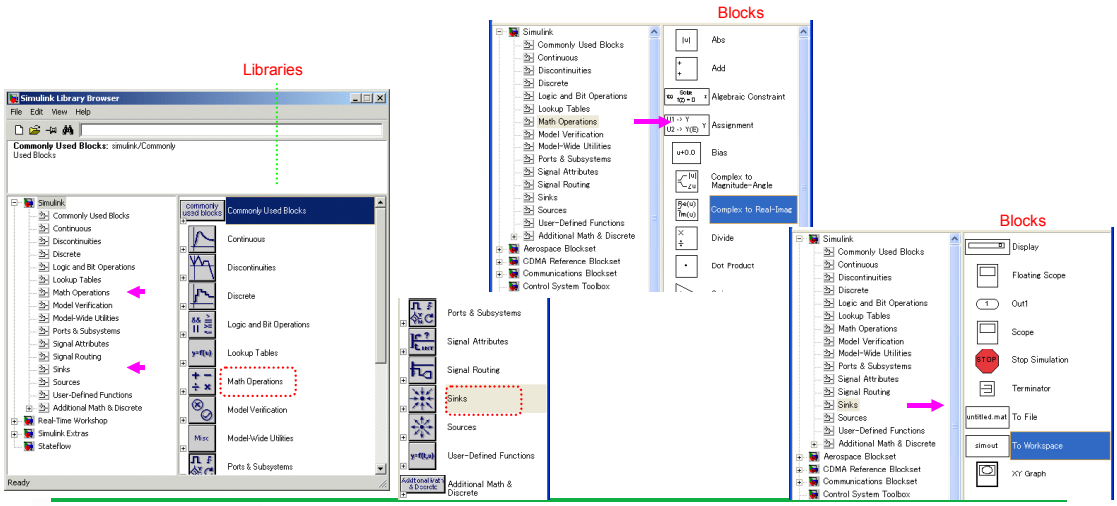
- The Blocksets are the collections of specialized Simulink blocks designed for design and simulation in a particular field.
- For example, the Communications Blockset extends Simulink with a comprehensive library of blocks to design and simulate the physical layer of communication systems and components. The blockset helps design for communications systems and their semiconductor components, such as commercial or defense wireless and wire systems.



Model of physical layer of IEEE 802.11a Wireless LAN standard, including adaptive modulation, using blocks in Communications Blockset.

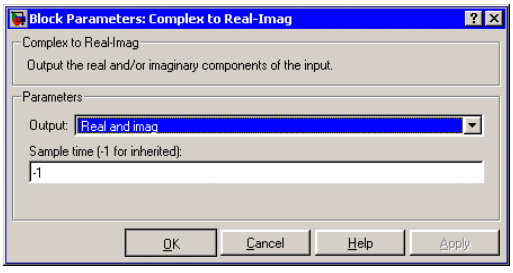
Simulation Data Save Technique

- Simulink Library Browser
  - » The *Math Operations* library contains blocks for modeling general mathematical functions.
  - » The *Sinks* library contains blocks that display or write block output.



Complex to Real-Imag

- Output real and imaginary parts of complex input signal
  - The Complex to Real-Imag block accepts a complex-valued signal of any data type supported by Simulink, including fixed-point data types. It outputs the real and/or imaginary part of the input signal, depending on the setting of the **Output** parameter. The real outputs are of the same data type as the complex input. The input can be an array (vector or matrix) of complex signals, in which case the output signals are arrays of the same dimensions. The real array contains the real parts of the corresponding complex input elements. The imaginary output similarly contains the imaginary parts of the input elements.



Complex to Real-Imag

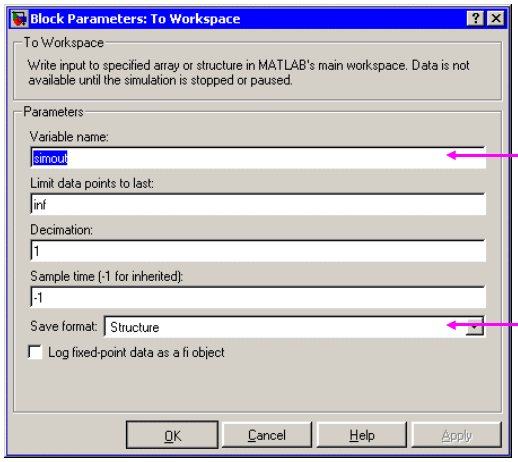
- Parameters
  - » Output
    - – This parameter determines the output of this block. Choose from the following values: ***Real and imag*** (outputs the input signal's real and imaginary parts), Real (outputs the input's real part), Imag (outputs the input's imaginary part).
  - » Sample time (-1 for inherited)
    - – This parameter specifies the time interval between samples. To inherit the sample time, set this parameter to ***-1***.

-1

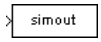
- – If the block is not in a triggered subsystem, this setting specifies that the block inherits its sample time from the block connected to its input (inheritance) or, in some cases, from the block connected to its output (back inheritance). If the block is in a triggered subsystem, set the SampleTime parameter to this setting.
  Note that specifying sample-time inheritance for a source block can cause Simulink to assign an inappropriate sample time to the block if the source drives more than one block. For this reason, avoid specifying sample-time inheritance for source blocks. If it is specified, Simulink displays a warning message when updating or simulating the model.

To Workspace

- Write data to workspace
  - – The To Workspace block writes its input to the workspace. The block writes its output to an array or structure with the name specified by the block's **Variable name** parameter. The **Save format** parameter determines the output format.



*inf: IEEE arithmetic representation for positive infinity

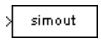


To Workspace

» Array

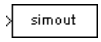
- Selecting this option causes the To Workspace block to save the input as an N-dimensional array where N is one more than the number of dimensions of the input signal. For example, if the input signal is a 1-D array (i.e., a vector), the resulting workspace array is two-dimensional. If the input signal is a 2-D array (i.e., a matrix), the array is three-dimensional.
- The way samples are stored in the array depends on whether the input signal is a scalar or vector or a matrix. If the input is a scalar or a vector, each input sample is output as a row of the array. For example, suppose that the name of the output array is simout. Then, simout(1,:) corresponds to the first sample, simout(2,:) corresponds to the second sample, etc. If the input signal is a matrix, the third dimension of the workspace array corresponds to the values of the input signal at the specified sampling point. For example, suppose again that simout is the name of the resulting workspace array. Then, simout(:,:,1) is the value of the input signal at the first sample point; simout(:,:,2) is the value of the input signal at the second sample point; etc.
- Block parameters control when and how much data the To Workspace block writes:

1. The **Limit data points to last** parameter indicates how many sample points to save. If the simulation generates more data points than the specified maximum, the simulation saves only the most recently generated samples. To capture all the data, set this value to *inf*.
2. The **Decimation** parameter allows you to write data at every nth sample, where n is the decimation factor. The default decimation, 1, writes data at every time step.
3. The **Sample time** parameter allows you to specify a sampling interval at which to collect points. This parameter is useful when you are using a variable-step solver where the interval between time steps might not be the same. The default value of -1 causes the block to inherit the sample time from the driving block when determining the points to write.



To Workspace

- For variable-step solvers, the **Output options** found on the **Data Import/Export** pane of the Configuration Parameters dialog box determine the original amount of data available to the To Workspace block. For example, to ensure that data is written at identical time points over multiple simulations, select the Produce specified output only option in the Configuration Parameters dialog box and enter the desired time vector. The To Workspace block begins with this specified time vector and further limits the amount of data written to the workspace based on its block parameters.
- During the simulation, the block writes data to an internal buffer. When the simulation is completed or paused, that data is written to the workspace. Its icon shows the name of the array to which the data is written.

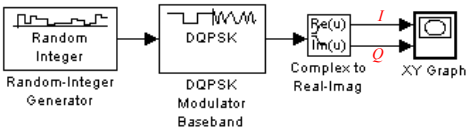


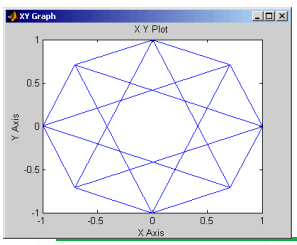
To Workspace

- Parameters
  - » Variable name
    - – Name of array holding data
  - » Limit data points to last
    - – Maximum number of input samples saved (The default is *inf* samples.)
  - » Decimation
    - – Decimation factor (The default is 1.)
  - » Sample time
    - – Sample time at which to collect points
  - » Save format
    - – Format in which to save simulation output to workspace (The default is *structure*.)
  - » Log fixed-point data as a *fi* object
    - – Select to log fixed-point data to MATLAB workspace as Simulink Fixed-Point *fi* object. Otherwise, fixed-point data is logged to the workspace as double.

Simulation Data Save Example 1

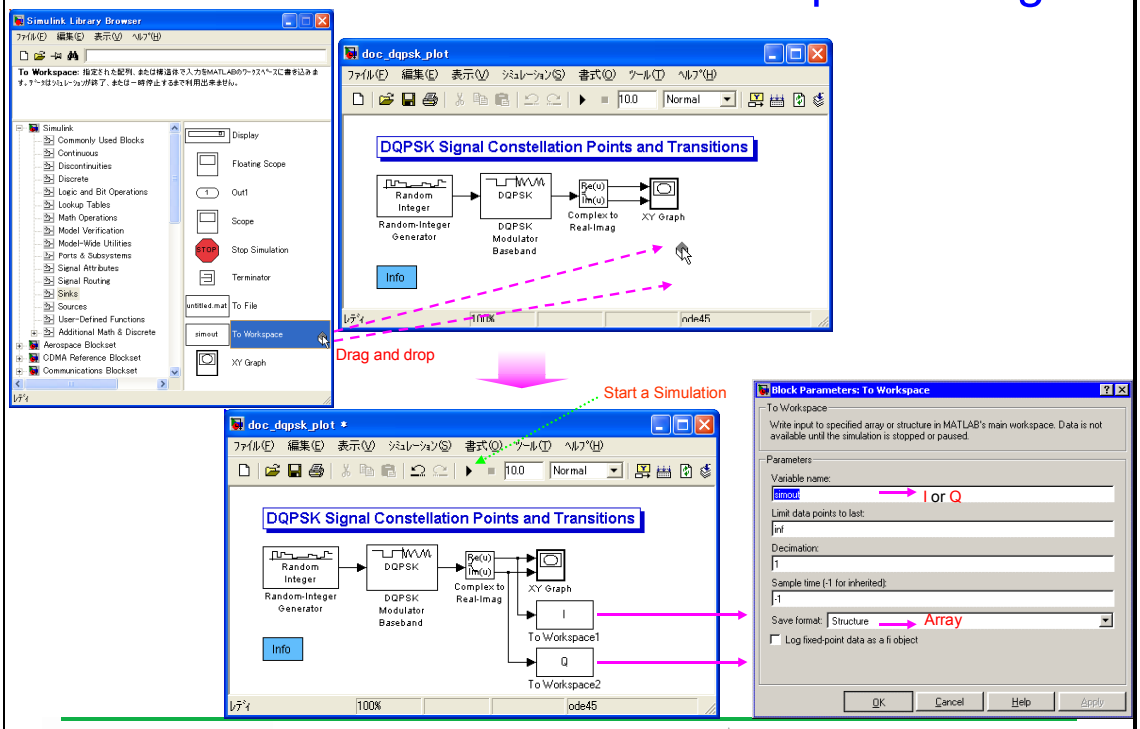
- Open completed model
  - • Communications Blockset Help
  - > Examples in Documentation
  - > Digital Modulation
  - > DQPSK Signal Constellation Points and Transitions
    - – open('/MATLAB701/help/toolbox/commblks/commblks_examples/doc_dqpsk_plot.mdl')
- The model plots the output of the DQPSK Modulator Baseband block. The image shows the possible transitions from each symbol in the DQPSK signal constellation to the next symbol.





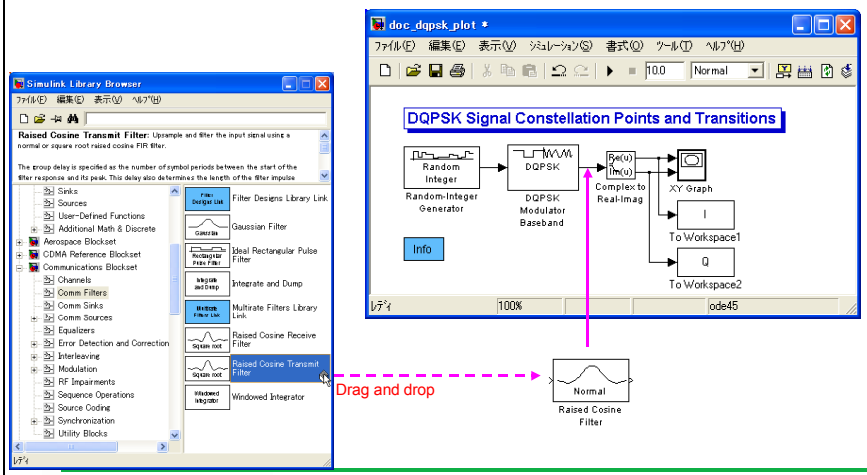
- – Running the model produces the plot. The plot reflects the transitions among the eight DQPSK constellation points.
- – This plot illustrates π/4DQPSK modulation, because the default **Phase offset** parameter in the DQPSK Modulator Baseband block is *pi/4*.

Communications Blockset Example Editing

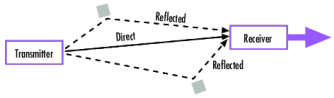


Note

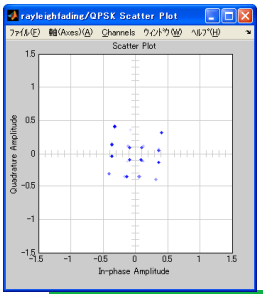
- When the MG3700A generates this I/Q signal, a raised cosine FIR filter block must be added to the model.
  - For more information about the raised cosine FIR filter block
    http://www.mathworks.com/access/helpdesk/help/toolbox/commblks/ref/raisedcosinetransmitfilter.html
    - Upsample and filter input signal using raised cosine FIR filter

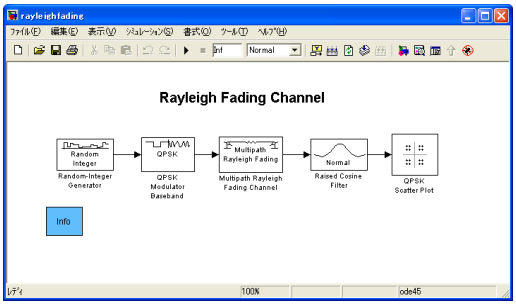


Simulation Data Save Example 2



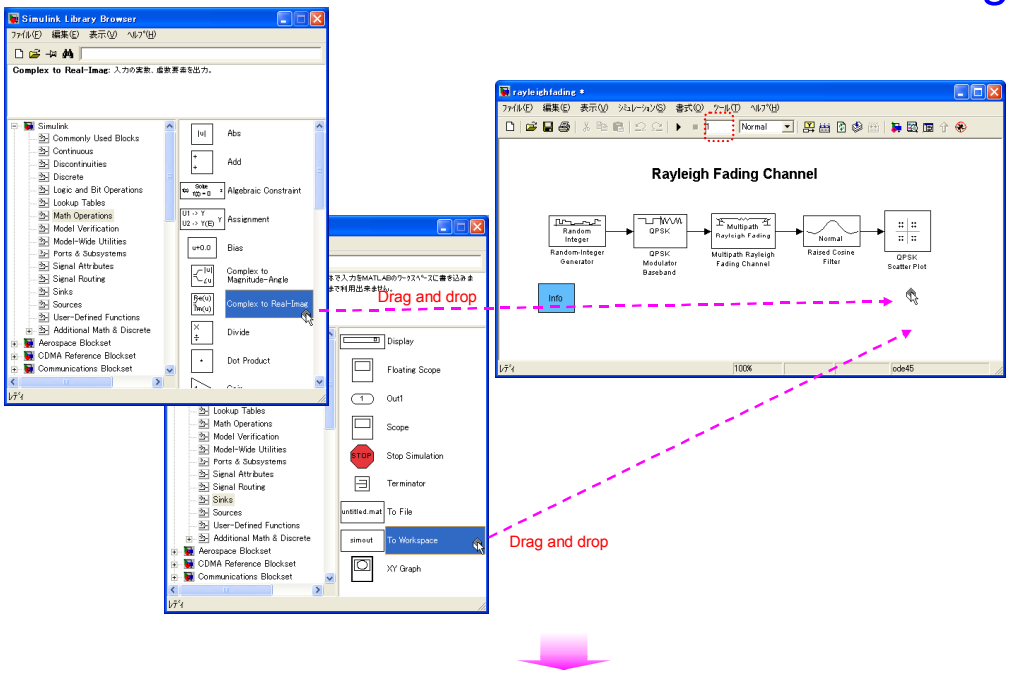
- Open completed model
  - Communications Blockset Demos
  > Channel Models and Impairments
  > Rayleigh Fading Channel
  - For more information about channels
    http://www.mathworks.com/access/helpdesk/help/toolbox/commblks/ug/fp62122.html
  - For more information about fading channels in general
    http://www.mathworks.com/access/helpdesk/help/toolbox/comm/ug/a1069449399.html
- The model illustrates the channel's effect on a QPSK modulated signal.



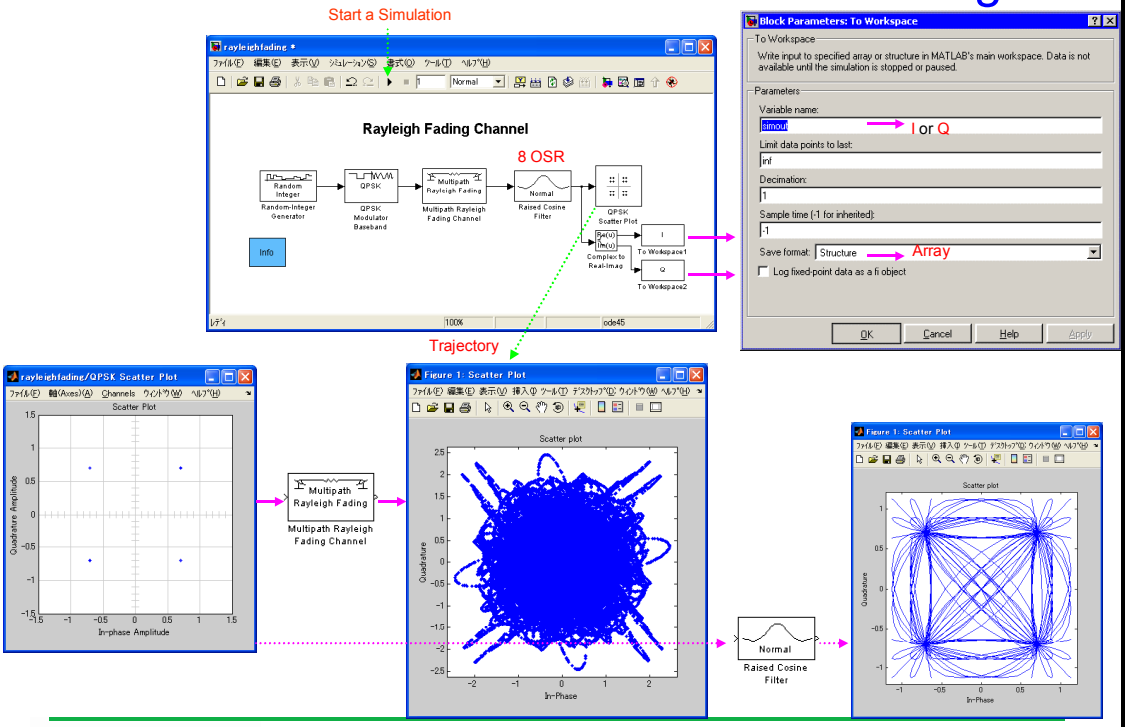


– Running the model produces the plot. The plot reflects the channel's effect on the QPSK constellation points.

Communications Blockset Demo Editing



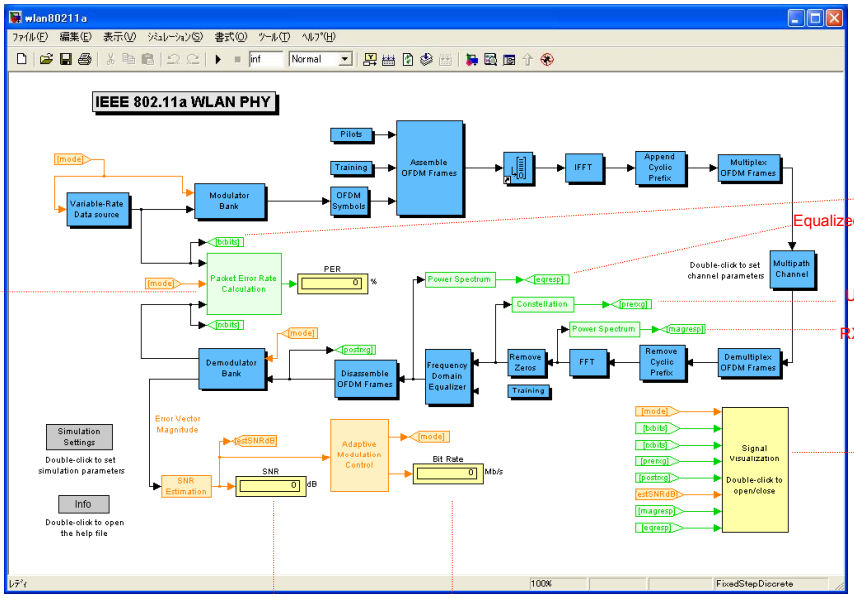
Communications Blockset Demo Editing



Simulation Data Save Example 3

- Open the completed model
  - Communications Blockset Demos
  > Application-Specific Examples
  > IEEE 802.11a WLAN Physical Layer
- IEEE 802.11a/g WLAN OFDM physical layer model demonstrating adaptive modulation and coding
  - Requirements: Communications Toolbox, Communications Blockset, Signal Processing Blockset, Signal Processing Toolbox
  - End-to-end 802.11a physical layer
  - All mandatory and optional data rates: 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s
  - BPSK, QPSK, 16QAM, 64QAM modulations
  - Forward error correction coding (convolutional; code rates 1/2, 2/3, 3/4)
  - OFDM transmission: 52 subcarriers, 4 pilots, 64-pt FFTs, CP (Cyclic Prefix)
  - Data interleaving
  - PLCP preamble (modeled as 2x2 long training sequences)
  - Receiver equalization
  - Viterbi decoding
  - Data rates selectable on-the-fly
  - Adaptive modulation demo over dispersive multipath fading channel

Communications Blockset Demo



BER (per packet)

TX Data

Equalized power spectrum

Unequalized signal

RX power spectrum

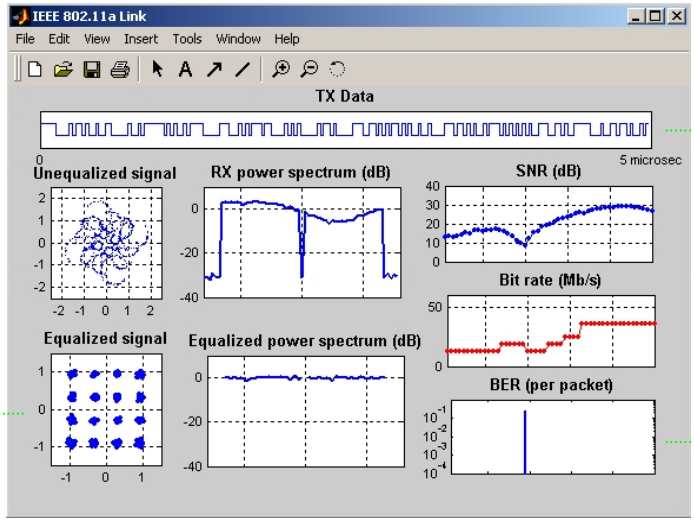
Signal Visualization

SNR

Bit rate

– Running the model and double-clicking Signal Visualization block produce the plot.

Communications Blockset Demo

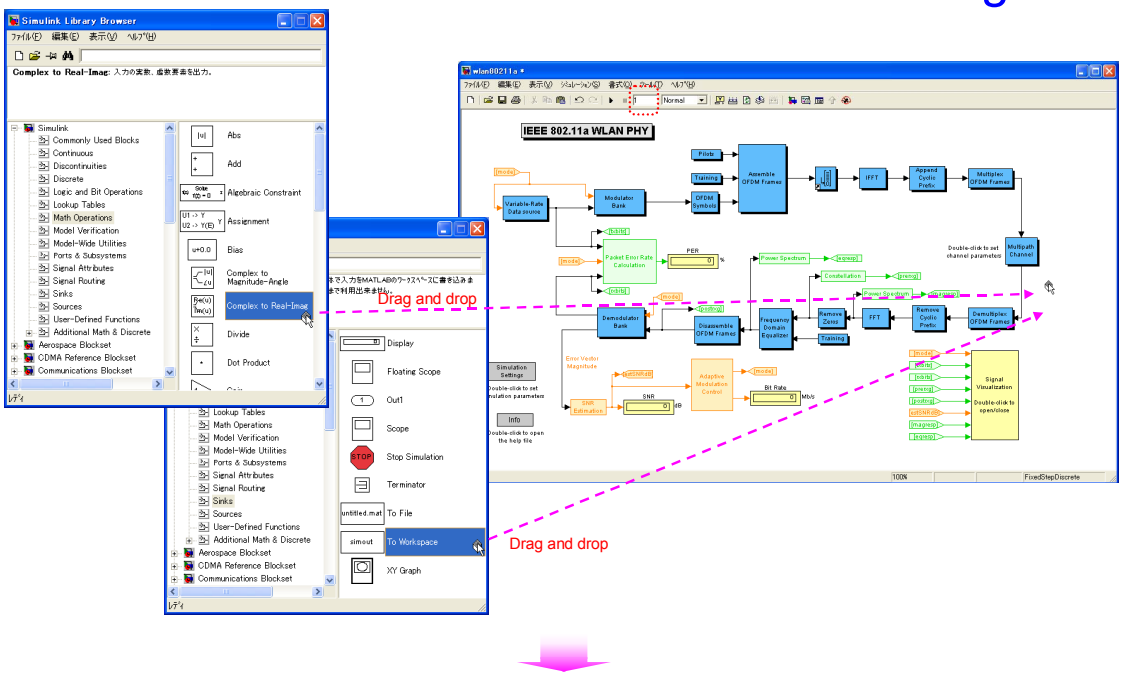


NRZ
(Non-Return to Zero)

16QAM
in this case

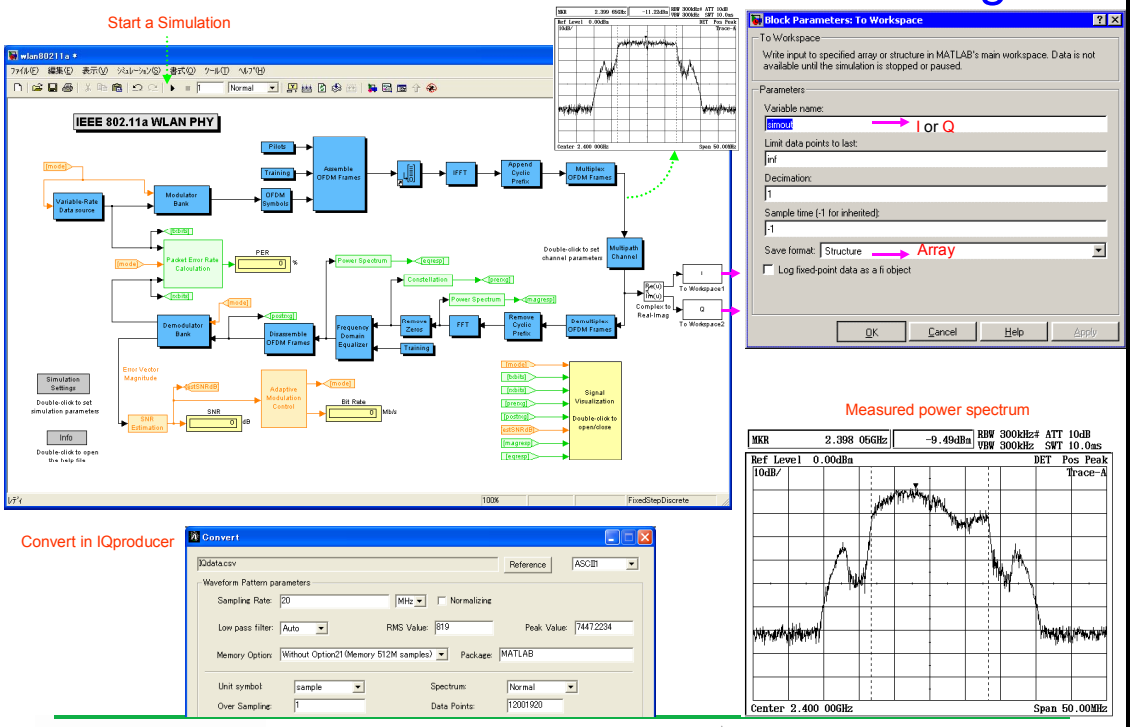
PER = 1/50 (2 %)
in this case

Communications Blockset Demo Editing



Communications Blockset Demo Editing

Start a Simulation

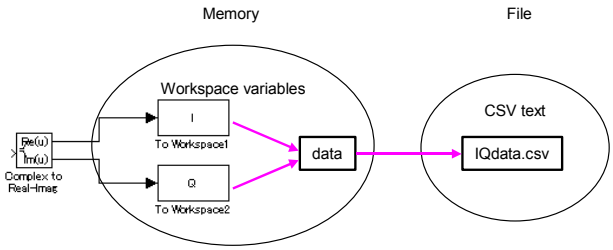


Measured power spectrum

Convert in IQproducer

Workspace Data Save

- To save the workspace variables as a CSV file, run the command by entering the following in the MATLAB command window:
  - » data = [I Q];
  - » csvwrite('IQdata.csv',data);
    - The workspace is the set of variables (named arrays) stored in memory during a MATLAB session.



Programming Example to Convert and Transfer I/Q Data File without IQproducer

- To download IQ data to the MG3700A, typically, it is easier to use "Convert" and "Transfer & Setting" in IQproducer, because MATLAB (simulation software) and C++ (advanced programming language) can usually save the data as a CSV file.
- This process takes more time because a text file is larger, and it is a bother.
- To minimize the time to convert a IQ data file, create a specific binary data file.
- This section examines how to facilitate downloading a complex data array from within the MATLAB environment.

1. Creating GUI with GUIDE
2. Executing [Convert]
3. Executing [Transfer] and [Play]

Creating GUI with GUIDE

» GUIDE, the MATLAB graphical user interface development environment, provides a set of tools for creating graphical user interfaces (GUIs). These tools simplify the process of laying out and programming GUIs.

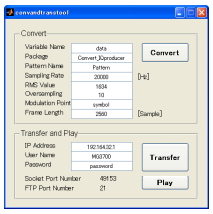
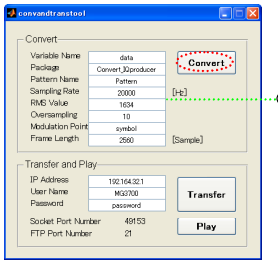
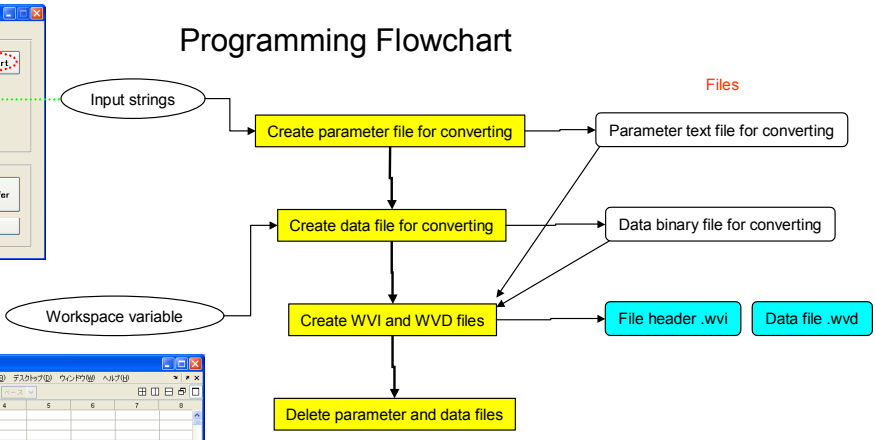


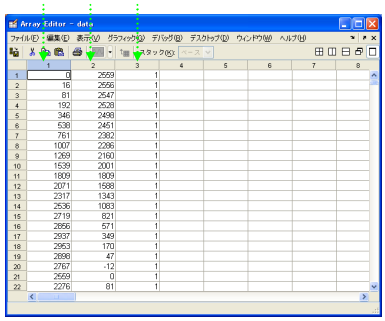
FIG-file

- GUI Layout
  - Using the GUIDE Layout Editor, populate a GUI by clicking and dragging GUI components, such as axes, panels, buttons, text fields, sliders, etc., into the layout area. You can also create menus and context menus for the GUI. The GUIDE saves a GUI layout to a FIG-file.
- GUI Programming
  - GUIDE automatically generates an M-file controlling how the GUI operates. This M-file provides code to initialize the GUI and contains a framework for the GUI callbacks -- the routines that execute when a user interacts with a GUI component. Using the M-file editor, add code to the callbacks to perform the required functions.
- For more information about GUIDE
  http://www.mathworks.com/access/helpdesk/help/techdoc/creating_guis/creating_guis.html

Executing [Convert]



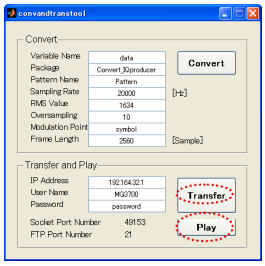


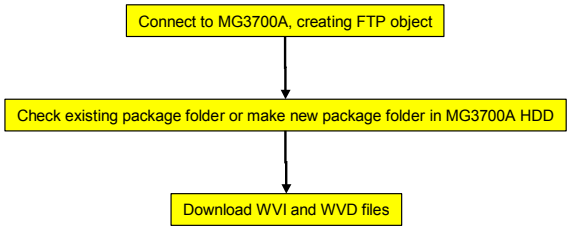


Executing [Transfer] and [Play]

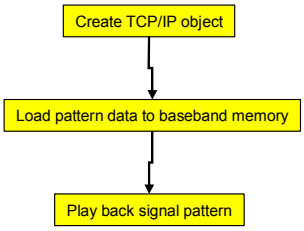
Programming Flowchart

– [Transfer]: Transfer files to MG3700A HDD using FTP





– [Play]: Load pattern data to baseband memory with TCP/IP remote control



Example of Creating GUI with GUIDE

- GUIDE saves GUI layout to *convandtranstool.fig*.
- GUIDE automatically makes *convandtranstool.m*.

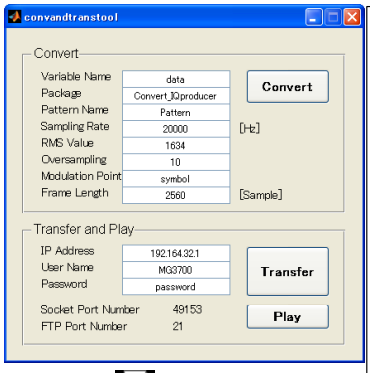


FIG-file

M-file function

```
function varargout = convandtranstool(varargin)
% CONVANDTRANSTOOL M-file for convandtranstool.fig
%      CONVANDTRANSTOOL, by itself, creates a new CONVANDTRANSTOOL or raises the existing
%      singleton*.
%
%      H = CONVANDTRANSTOOL returns the handle to a new CONVANDTRANSTOOL or the handle to
%      the existing singleton*.
%
%      CONVANDTRANSTOOL('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in CONVANDTRANSTOOL.M with the given input arguments.
%
%      CONVANDTRANSTOOL('Property','Value',...) creates a new CONVANDTRANSTOOL or raises the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before convandtranstool_OpeningFunction gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to convandtranstool_OpeningFcn via varargin.
%
%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help convandtranstool
```

M-file

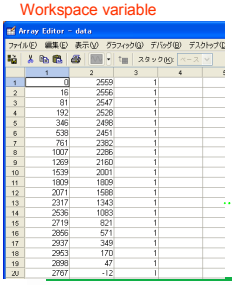
Call M-file Function

- M-files can be either *scripts* or *functions*. Scripts are simply files containing a sequence of MATLAB statements. Functions make use of their own local variables and accept input arguments.
- The name of a function, as defined in the first line of the M-file, should be the same as the name of the file without the .m extension.
- The variables within the body of the function are all local variables.
- When calling an M-file function from the command line or from within another M-file, MATLAB parses the function and stores it in memory. The parsed function remains in memory until cleared using the clear command or quitting MATLAB.

```
I_Q = [real(OversampledData) imag(OversampledData)];   % I/Q data
```

Equal to variable "data" in previous section

Workspace variable

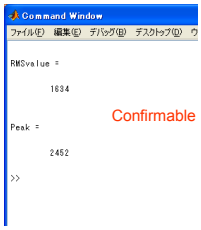


```
IQrms = sqrt((I_Q(:,1).^2 + I_Q(:,2).^2)/2);
RMSvalue = sum(IQrms)/length(IQrms(:,1));
I_Q = round(I_Q*1634/RMSvalue);
IQrms = sqrt((I_Q(:,1).^2 + I_Q(:,2).^2)/2);
RMSvalue = round(sum(IQrms)/length(IQrms(:,1)))
Peak = round(max(IQrms))

gate = ones(length(I_Q),1);          % RF gate flag
data = [I_Q gate];

convandtranstool
```

Set RMS Value "1634"



Confirmable

Call M-file function

Convert Programming Example

```
% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

- Create parameter file for converting

```
valname = get(handles.edit1, 'String');
package = get(handles.edit9, 'String');
patname = get(handles.edit2, 'String');
samprate = get(handles.edit10, 'String');
rmsval = get(handles.edit3, 'String');
oversamp = get(handles.edit4, 'String');
sysunit = get(handles.edit5, 'String');
framelen = get(handles.edit11, 'String');
if isempty(package)
    package = 'Convert_IQproducer';
End
```

Get input strings

(Continued on the next page)

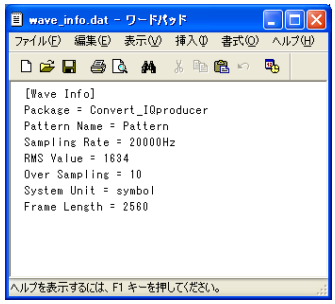
Convert Programming Example

(Continued from previous page)

```
fid = fopen('wave_info.dat', 'w');
fprintf(fid, '[Wave Info]¥n');
fprintf(fid, ['Package = ' package '¥n']);
fprintf(fid, ['Pattern Name = ' patname '¥n']);
fprintf(fid, ['Sampling Rate = ' samprate 'Hz¥n']);
if ~isempty(rmsval)
    fprintf(fid, ['RMS Value = ' rmsval '¥n']);
end
if ~isempty(oversamp)
   fprintf(fid, ['Over Sampling = ' oversamp '¥n']);
end
if ~isempty(sysunit)
   fprintf(fid, ['System Unit = ' sysunit '¥n']);
end
if ~isempty(framelen)
   fprintf(fid, ['Frame Length = ' framelen '¥n']);
end

fclose(fid);
```

Open file, or create new file, for writing



Close the open file

Convert Programming Example

- Create data file for converting

```
evalin('base', 'fid_r = fopen("wave_raw.dat", "w");');
evalin('base', ['fwrite(fid_r, ' valname ', "int16");']);
evalin('base', 'fclose(fid_r);');
evalin('base', 'clear fid_r');
```

Open file, or create new file, for writing
Write binary data with integer 16 bits to file
Close open file
Remove items from workspace, freeing up system memory

- Create WVI and WVD files

```
!MakeWvFile "./wave_info.dat" "./wave_raw.dat"
```

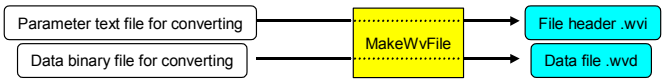
Execute EXE file

- Delete parameter and data files

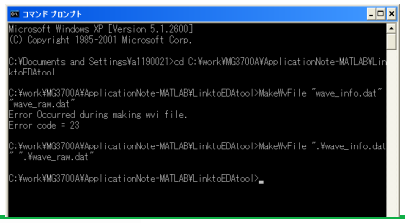
```
delete('wave_info.dat');
delete('wave_raw.dat');
```

Create WVI and WVD files: MakeWvFile

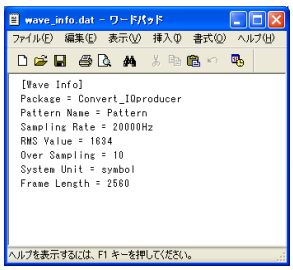
- The MakeWvFile.exe application software is provided by Anritsu.
- It creates the data file (.wvd) and file header (.wvi) from the specific binary data file.



- Function reference
  - » Syntax
    - MakeWvFile "ParameterFilename" "DataFilename"
  - » Arguments
    - "ParameterFilename" — Text filename for file header (.wvi)
    - "DataFilename" — Specific binary data filename for data file (.wvd)
      * Filename: Full pathname



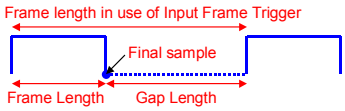
Parameter text file for MakeWvFile



- » Package
  - Folder name for pattern file
    - ≤ 30 characters
      - If the parameter is blank, *Convert_IQproducer* is set.
- » Pattern Name
  - ≤ 20 characters
- » Sampling Rate
  - Number of I/Q waveform samples per second (expressed in Hz and equal to reciprocal of sampling interval)
    - 20000 to 160000000Hz (20 kHz to 160 MHz), Resolution 0.001 Hz
- » RMS Value
  - $$RMS_{I/Q} = \sqrt{\frac{\sum_{n=1}^{N}(I_n^2 + Q_n^2)}{2N}}$$
    - 1 to 8191
      - If the parameter is blank, the value calculated from data file is set.
- » Over Sampling
  - Oversampling ratio (OSR): Ratio of sampling rate to modulation rate
    - 1 to 999
      - If the parameter is blank, *1* is set.

Parameter text file for MakeWvFile

- System Unit
  - Modulation point for modulation rate i.e. chip, symbol, sample
    - ≤ 6 characters
      - If the parameter is blank, *None* is set.
- Frame Length
  - Frame sample length
    Note: Frame length in use of Input Frame Trigger
    = Frame Length + Gap Length
    - 1 to 8388607
      - If the parameter is blank, Input Frame Trigger and Gap Length cannot be used.
- Gap Length
  - Burst gap sample length
    Note: This period holds the final sample data including event marker and RF gate flag in Frame Length.
    Example of burst signal



    - 0 to 8388607
      - If the parameter is blank, *0* is set.

Data binary file for MakeWvFile

- Specific binary data file format
  - Each data point needs 6 bytes (three integer values) as 2 bytes for the I point, 2 bytes for the Q point and 2 bytes for the RF gate flag.

  - Little Endian (byte order)
    - 0C F6 00 00 01 00 22 F7 02 00 01 00 … [HEX]

      I Q RF gate I Q RF gate

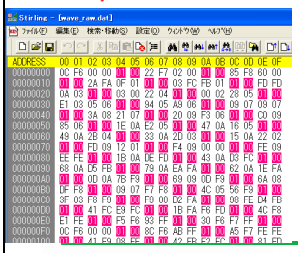
      -2548 0 1 -2270 2 1 … [Decimal]
      - For Big Endian (byte order) referred to as byte swapping

      F6 0C 00 00 00 01 F7 22 00 02 00 01 … [HEX]

  - I/Q binary data is 16-bit two's complement, representing signed integers.

	I/Q data range	Binary data	HEX data	I/Q output voltage
–	8191	00011111 11111111	1FFF	V_{max}
:				
–	1	00000000 00000001	0001	
–	0	00000000 00000000	0000	0 V
–	-1	11111111 11111111	FFFF	
:				
–	-8192	11100000 00000000	E000	V_{min}

Binary Editor



For more information on the I/Q data value, see slides 11 and 12.
For more information on the RF gate flag value, see slides 13 and 14.

Byte Order

- The little endian or big endian byte order depends on the type of PC processor.
  - » Intel and AMD processors use little endian.
  - » Sun and Motorola processors use big endian.
  - » The Apple PowerPC processor, while big endian oriented, also supports the little endian order.
    - – Always refer to the processor manufacturer to determine the order they use for bytes and, if they support both, to understand how to ensure that you are using the correct byte order.
- The byte order describes how the system processor stores integer values as binary data in memory.
  - » When outputting data from a little endian system to a text file (ASCII text), the values are the same as viewed from a big endian system.
  - » The order only becomes important when using binary data, as when downloading data to MG3700A.

Byte Order

- The LSB and MSB positioning changes with byte order.
- In little endian order, the LSB and MSB are next to each other in the bit sequence.

Example of -2548 signed integer

» Little endian

– 0C F6 [HEX] 0 0 0 0 1 1 0 0 (LSB) 1 1 1 1 0 1 1 0 (MSB) [Binary]

» Big endian

– F6 0C [HEX] 1 1 1 1 0 1 1 0 (MSB) 0 0 0 0 1 1 0 0 (LSB) [Binary]

- Most Significant Bit (MSB) is bit position in binary number with greatest value.
- Least Significant Bit (LSB) is bit position in binary integer determining whether the number is even or odd.
  - – In 2-byte data, the MSB appears in the second byte.

Two's Complement Integers

- Two's complement is a popular way to represent signed integers by counting backwards in computer. The MSB represents the sign of positive and negative values.

	HEX	Binary	Decimal
•	09 F4	00001001 11110100	+2548
+			
•	F6 0C	11110110 00001100	-2548
	= 1	00000000 00000000	0

  - Ignoring 17th bit (leftmost bit) gives actual answer "0".
  - » The decimal value of a two's complement binary number is calculated by taking the value of the MSB, where the value is negative when the bit is one, and adding the values for each power of two where there is a one.
    - F6 0C: 11110110 00001100 = $-2^{15} + 2^{14} + 2^{13} + 2^{12} + 2^{10} + 2^{9} + 2^{3} + 2^{2} = -2548$

Two's Complement Integers

- Calculating two's complement
  - » When finding the two's complement of a binary number, the bits are inverted and the value of 1 is added to the resulting value. Bit overflow is ignored.
    - Beginning with F6 0C (-2548):

      11110110 00001100
      - To convert to +2548 in two's complement notation, the bits are inverted; 0 becomes 1, and 1 becomes 0:

        00001001 11110011
        - This numeral is the one's complement of the decimal value -2548.
      - To obtain the two's complement, 1 is added:

        00001001 11110100
    - Beginning with 09 F4 (+2548):

      00001001 11110100
      - To convert to -2548 in two's complement notation, the bits are inverted; 0 becomes 1, and 1 becomes 0:

        11110110 00001011
      - To obtain the two's complement, 1 is added:

        11110110 00001100

MakeWvFile Error

- An error code is returned when an error occurs.
- Error code
  - » 0
    successful completion
  - » 16
    File writing failure
  - » 23
    Converting failure due to irregular Pattern Name in parameter text file
  - » 24
    Converting failure due to irregular Package name in parameter text file
  - » 25
    Converting failure due to irregular Sampling Rate in parameter text file
  - » 64
    WVD file opening failure
  - » 65
    WVI file opening failure
  - » 66
    Data binary file opening failure
  - » 67
    Parameter text file opening failure

Transfer Programming Example

```
% --- Executes on button press in pushbutton3.
function pushbutton3_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

- Connect to MG3700A, creating FTP object

```
ipaddress = get(handles.edit6, 'String');
username = get(handles.edit7, 'String');          ..... Get input strings
password = get(handles.edit8, 'String');

f = ftp(ipaddress, username, password);
```

Transfer Programming Example

- Check existing package folder or make new package folder in MG3700A HDD

```
package = get(handles.edit9, 'String');
patname = get(handles.edit2, 'String');          ..... Get input strings
if isempty(package)
    package = 'Convert_IQproducer';
end

cd(f, 'hdd0/PACKAGE');                           ..... Change directory in MG3700A HDD
buff = dir(f, package);                          ..... Directory listing
if length(buff) < 4
   mkdir(f, package);                            ..... Make new directory
end
```

- Download WVI and WVD files

```
cd(f, package);
mput(f, ['./' patname '.wvi']);
mput(f, ['./' patname '.wvd']);                  ..... Upload files

close(f);                                        ..... Close FTP object
```


Play Programming Example

```
% --- Executes on button press in pushbutton4.
function pushbutton4_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

- Create TCP/IP object

```
ipaddress = get(handles.edit6, 'String');        ..... Get input strings
t = tcpip(ipaddress, 49153);                     ..... Instrument Control Toolbox
fopen(t);                                        ..... Connect TCP/IP object to MG3700A
```

Play Programming Example

- Load pattern data to baseband memory

```
package = get(handles.edit9, 'String');
patname = get(handles.edit2, 'String');          ..... Get input strings
if isempty(package)
    package = 'Convert_IQproducer';
end

fprintf(t, ['LDFILE WMA,"' package '", "' patname '"']);

for n = 1:150                                    ..... Monitor END Event Status Register
    pause(1);
    fprintf(t, 'ESR2?');
    flag = str2num(fscanf(t));
    if bitget(flag, 5) == 1
            break;
    end
end
```

- Play back signal pattern

```
fprintf(t, 'PATCOMBMODE DEFINED');               ..... Pattern Combination Mode: Defined
fprintf(t, ['LOADEDFILESEL WMA,"' package '","' patname '"']);
fprintf(t, '*OPC?');                             ..... Operation Complete Query
fscanf(t);

fclose(t);                                       ..... Disconnect TCP/IP object
delete(t);
```

Anritsu

Specifications are subject to change without notice.

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