In-Class Exercises for Beamforming

These problems are part of the beamforming lecture. You can complete each problem after the corresponding section in the class.

For each problem, complete the sections labeled TODO.

Contents

- Problem: Simulating RX combining on QPSK symbols
- Problem: Measuring the SNR with an BF error

Problem: Simulating RX combining on QPSK symbols

To illustrate RX combining, we do the following simple simulation of transmitting and receiving QPSK symbols with beamforming

```
% Consider an array with the following parameters
fc = 37e9;      % frequency
lambda = physconst('LightSpeed')/fc;
nant = [8,8];
dsep = 0.5*lambda;

% TODO:  Construct the URA with the above parameters
%   arr = ...

% TODO:  Generate nb=1e4 bits using the randi command.
%   bits = ...

% TODO:  Modulate the bits using QPSK with the qammod command
%
%     x = qammod(bits,...);
%
% Set the 'InputType' to 'bit' in the qammod command
% and the 'UnitAveragePower' to true


% Assume the angle of arrival, ang0 = [30; 45];
% TODO:  Compute the steering vector, u.
ang0 = [30; 45];

% TODO:  Compute the receive symbols.  This will be a matrix,
%  r0(:,i) = RX vector for TX symbol x(i).
% Assume the path loss is 40 dB
pathLoss = 40;

% TODO:  Add noise so that the SNR per antenna is 10 dB
%  r = r0 + noise
% Be careful how you scale noise!


% TODO:  Compute the optimal BF vector.  This is the normalized
% steering vector

% TODO:  Compute the linear combined symbols, z.

% TODO:  Plot the symbols before and after combining.
% -- subplot(1,2,1):  Plot the the constellation of r(1,:),
%    the receive symbols on the first antenna
```

```
% -- subplot(1,2,2):  Plot the the constellation of z,
%    the received symbols after beamforming
```

Problem: Measuring the SNR with an BF error

We will now: * Simulate symbols being received from a beam that is misaligned to the angle of arrival * Compute the resulting SNR * Compare the SNR with the prediction from the array factor

```
% Using the array from above, generate the array
% directed in the following angle that is slightly off from the
% true angle
angbf = ang0 + [15; 15];  % 15 deg error in az and el

% TODO:  Compute, w = the BF vector for the angle angbf


% TODO:  Apply w to the RX symbols to get z.
% Convert z to a column vector and plot the symbols

% TODO:  Plot the constellations in z
```

We next compute a channel estimate. We suppose the first nsymRef=100 symbols are known to the RX. That is, they are reference symbols. We know

```
z(i) = h x(i), i=1,...,nsymRef
```

We can then estimate h from

```
hhat = xref'*zref/(xref'*xref);
```

where xref and zref are the TX and RX reference symbols. This formula is the LS estimates. See the equalization section in digital comm.

```
% TODO:  Compute the estimate hhat from the scalar equiv channel
nsymRef = 100;


% Now suppose the remaining symbols x(i), z(i), i=nsymRef,...,nsym
% are for data.
% TODO:  Compute xdat, zdat, the TX and RX data symbols

% TODO:  Compute the equalized data symbols
%    xhatdat = zdat / hhat

% TODO:  Plot the equalized symbols

% TODO:  Measure the SNR after BF:
%  snrBF = 10*log10(Ex/Eerr)
%  Eerr = mean(abs(xdat-xhatdat).^2)
%  Ex = mean(abs(xdat).^2)

% TODO:  Compare to the expected SNR predicted by the
% array factor
```