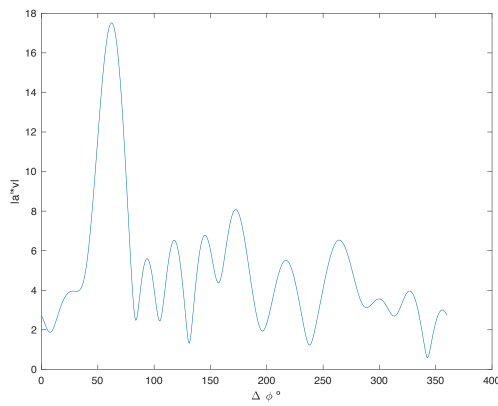
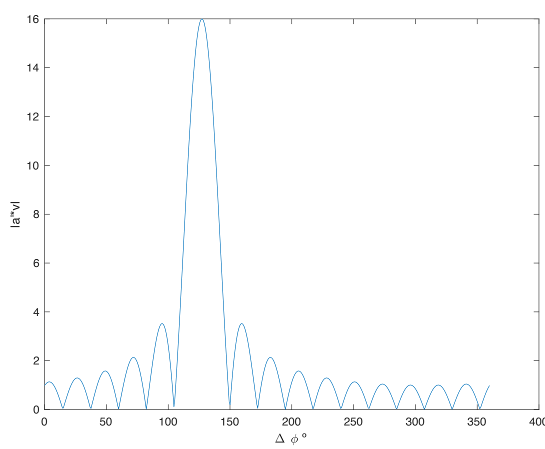
EECE 5612 HW7
4.14.2022
Stav Rones

For every possible delta_phi from 0 to 2π, the steering vector is calculated and the value for $|a' * v|$ is calculated. The delta_phi that maximizes this function is found to be 62.04 degrees, and when plugging in values for frequency, speed of wave and the distance between array recievers, theta is found to be **20.16 degrees**. A plot of delta phi vs the GML function is shown below



To test this method, a noiseless signal was constructed as $e^{-jm\Delta\varphi}$ for m = 0:16. When plotting the delta_phi vs GML function, we see the beam pattern below. The value that maximizes the GML function is when delta_phi is 126.97 degrees, or when theta is 44.86 degrees. This validates the method since theta was chosen to be 45 degrees.



APPENDIX

```
function hw7

    clc;

    % -------------- Load data --------------
    v = load("hwk7-1.mat").Y;
    m = length(v);

    % -------------- Find delta_phi GML --------------
    delta_phi = linspace(0, 2*pi, 500); % search space

    GML = zeros(1,500);
    for i = 1:length(delta_phi)

        % calculate steering vector
        a = exp((0:m-1)' * -1j * delta_phi(i));

        % calculate delta phi estimate
        GML(i) = abs(a'*v);
    end

    [~, i_max] = max(GML);
    delta_phi_gml = delta_phi(i_max);

    fprintf("Noise:\ndelta_phi_gml (deg): %6.2f\n", rad2deg(delta_phi_gml));

    % -------------- visualize GML function --------------
    plot(rad2deg(delta_phi), GML);
    xlabel("\Delta \phi º");
    ylabel("|a'*v|");

    % -------------- delta_phi -> Theta --------------
    f0 = 3E9;
    c = 3E8;
    d = 0.05;

    theta_gml = asin(delta_phi_gml*c / (2*pi*f0*d));
    fprintf("theta_gml (deg): %6.2f\n", rad2deg(theta_gml));

    % ----------------------------------------
    % -------------- Noiseless ---------------
    % ----------------------------------------

    d = .05;                 % distance between sensors
    c = 3E8;                 % wave speed
    f0 = 3E9;                % 3 KHz frequency (what is this)?

    theta_true = pi/4;
    delta_phi_true = 2*pi*f0*d/c*sin(theta_true);

    % -------------- Generate observed array --------------

    V_t = zeros(16,1);
```

```
    for m = 1:16
        V_t(m) = exp(-1j*(m-1)*delta_phi_true);
    end


    % -------------- Find GML delta phi --------------
    delta_phi = linspace(0, 2*pi, 500); % search space

    GML = zeros(1,500);
    for i = 1:length(delta_phi)

        % calculate steering vector
        a = exp((0:15)' * -1j * delta_phi(i));

        % calculate delta phi estimate
        GML(i) = abs(a'* V_t);
    end

    [~, i_max] = max(GML);
    delta_phi_gml = delta_phi(i_max);

    fprintf("\nNoiseless:\ndelta_phi_gml (deg): %6.2f\n",
rad2deg(delta_phi_gml));

    % -------------- visualize GML function --------------
    plot(rad2deg(delta_phi), GML);
    xlabel("\Delta \phi º");
    ylabel("|a'*v|");

    % -------------- delta_phi -> Theta --------------
    f0 = 3E9;
    c = 3E8;
    d = 0.05;

    theta_gml = asin(delta_phi_gml*c / (2*pi*f0*d));
    fprintf("theta_gml (deg): %6.2f\n", rad2deg(theta_gml));


end
```