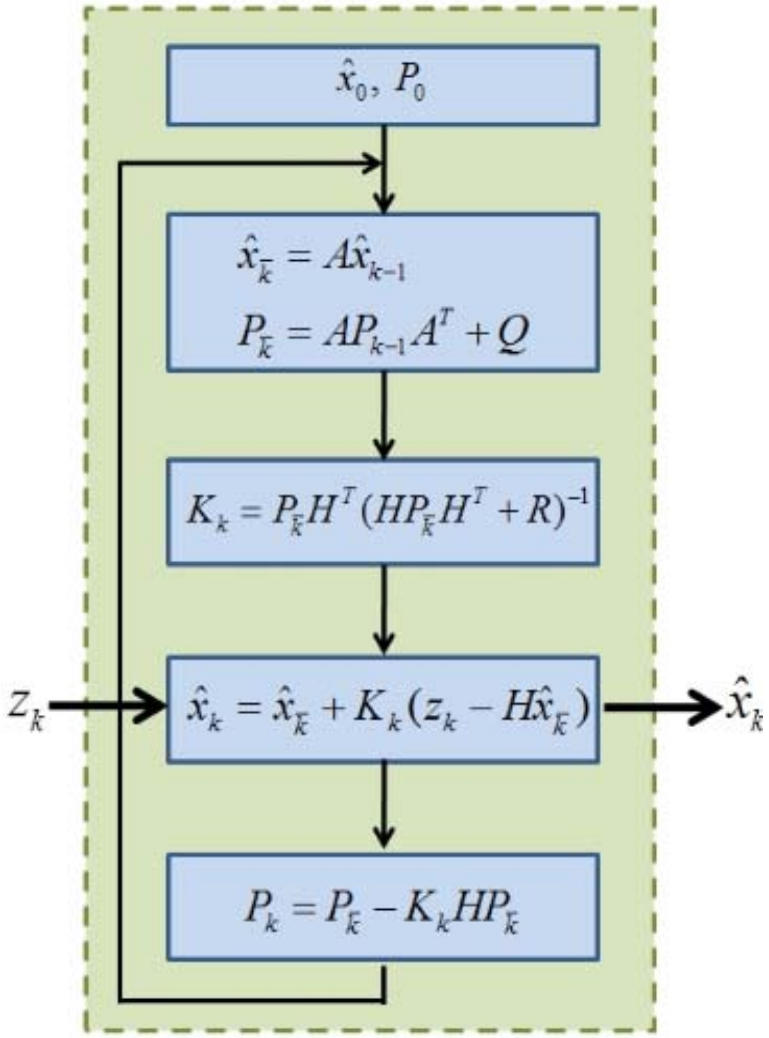
Extended Kalman filter

2019.04.04

차례

1. Linearization Kalman Filter

1. Linearization Kalman Filter



Kalman Filter algorithm

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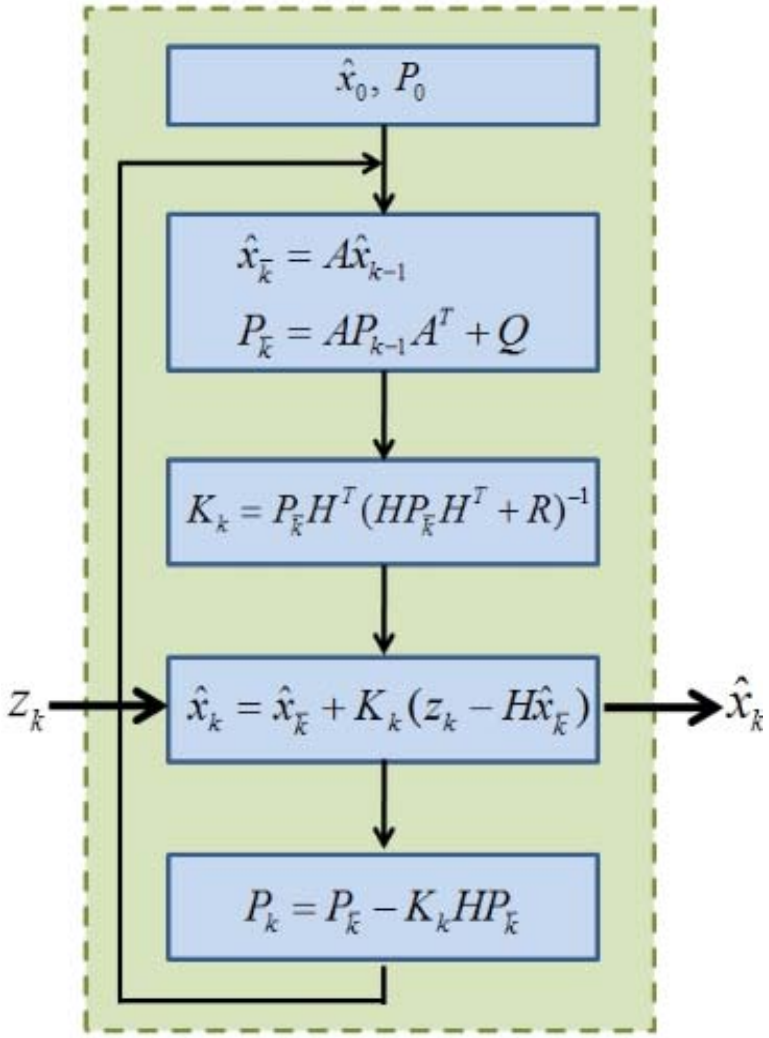

Kalman Filter algorithm

$x_{k+1} = Ax_k + w_k$ $Q = w_k$의 공분산 행렬

$z_k = Hx_k + v_k$ $R = v_k$의 공분산 행렬

x_k는 상태 변수

z_k는 측정값

A는 상태전이행렬

H는 mXn 행렬

w_k는 잡음

w_k는 측정 잡음

2. Extended Kalman Filter

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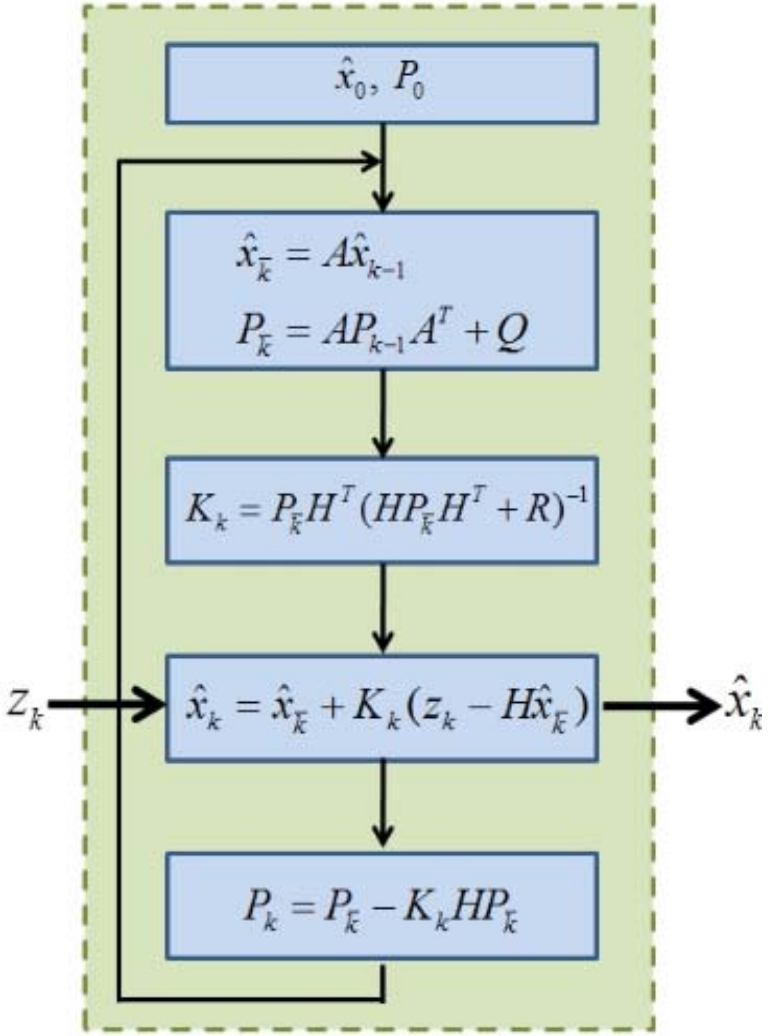

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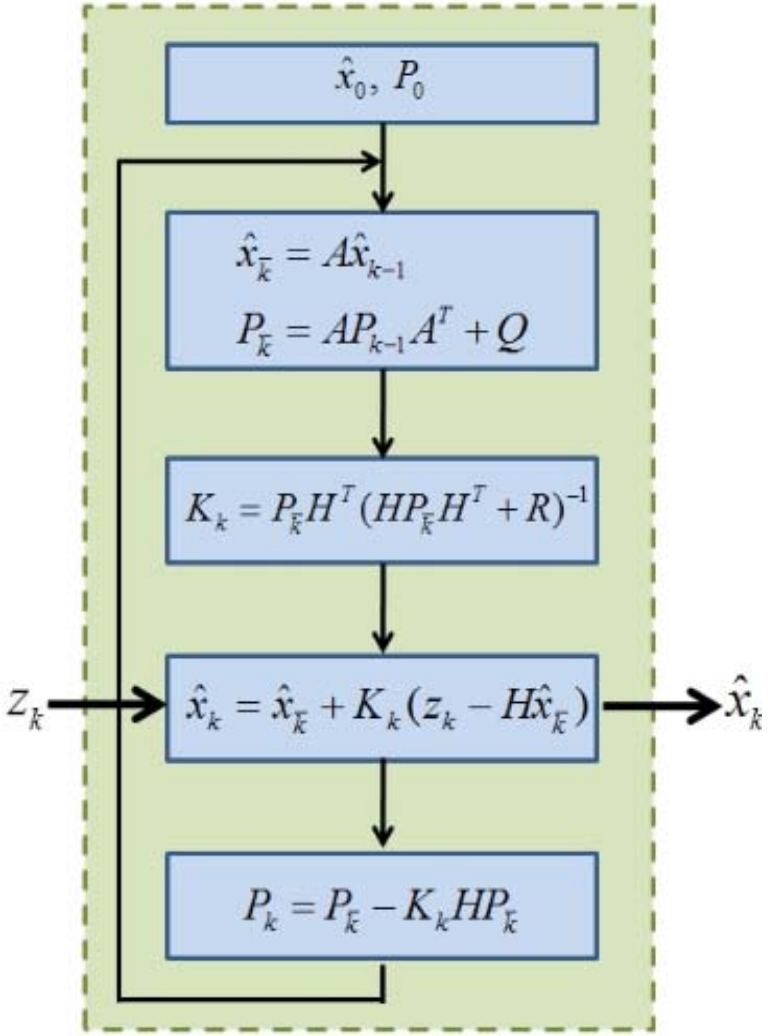

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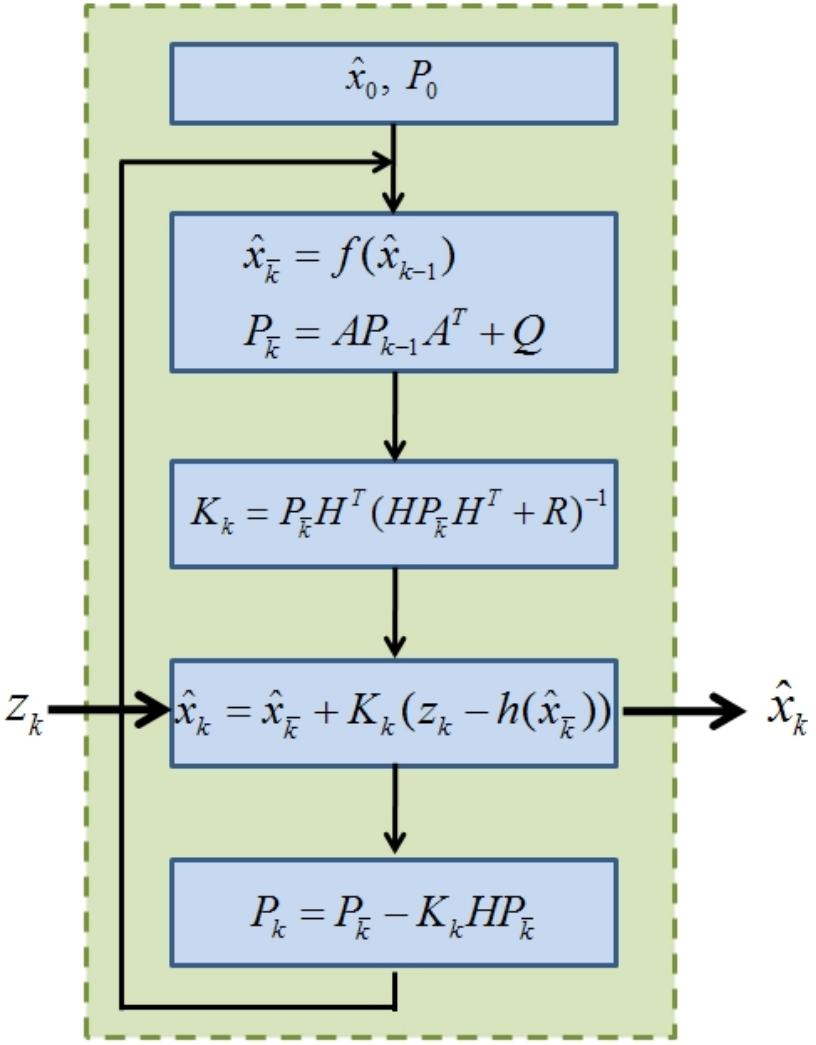
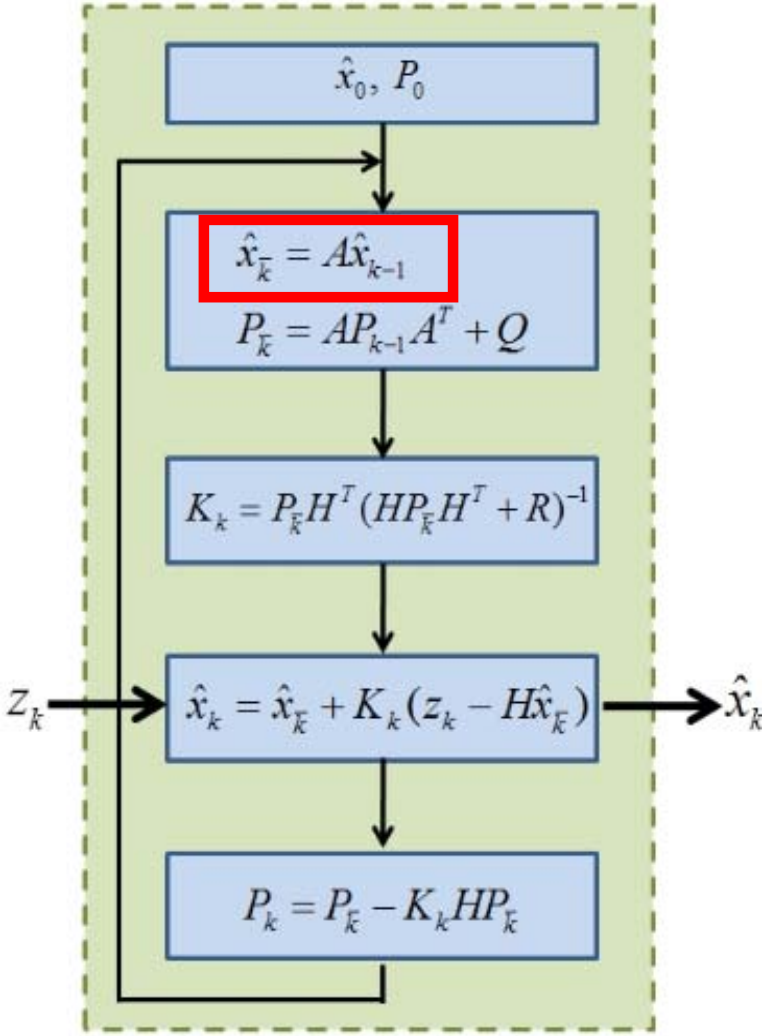


EKF algorithm

2. Extended Kalman Filter



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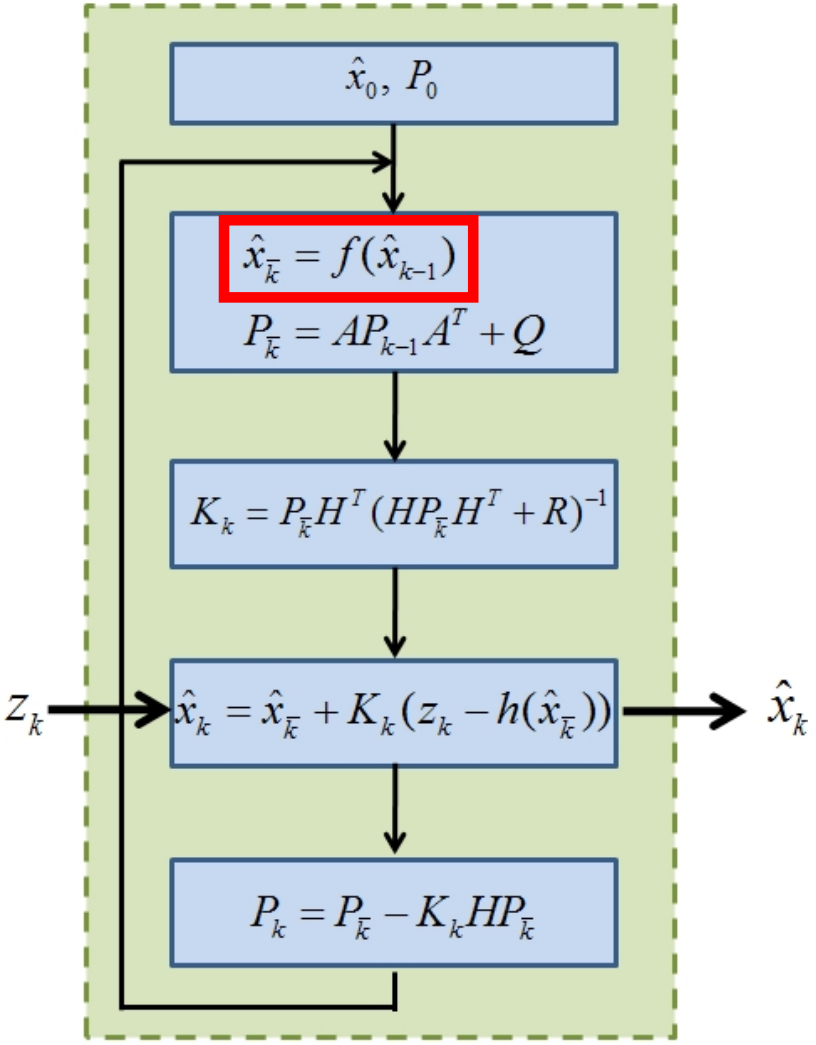

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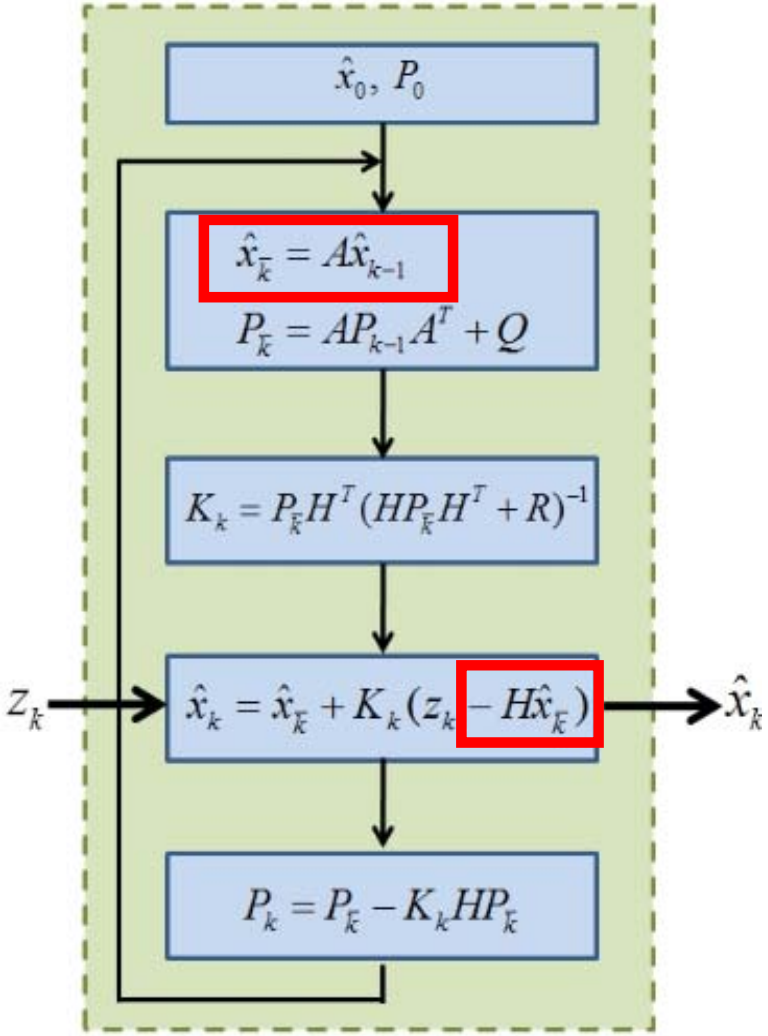

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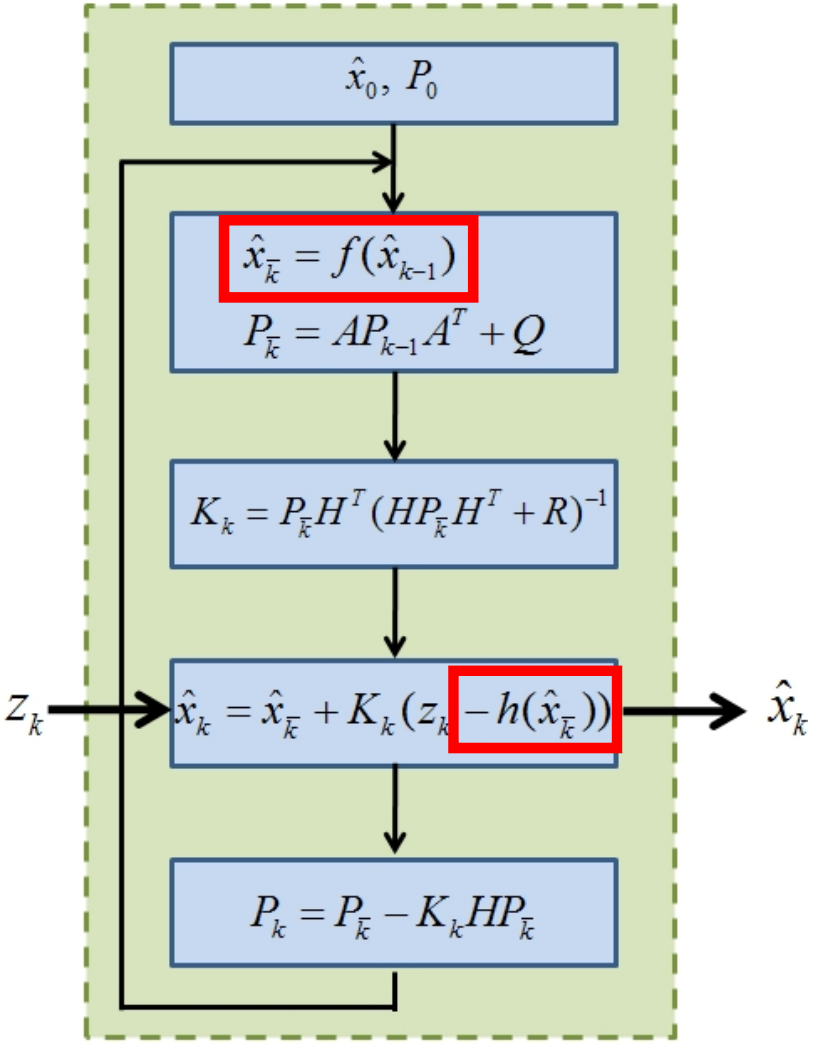

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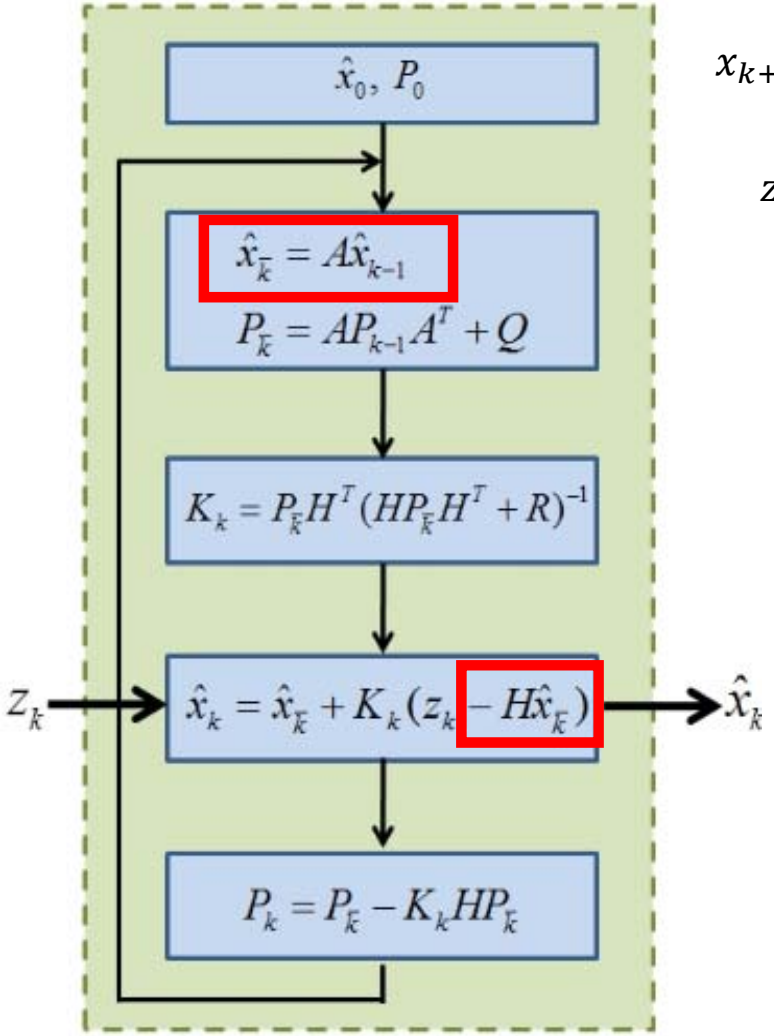

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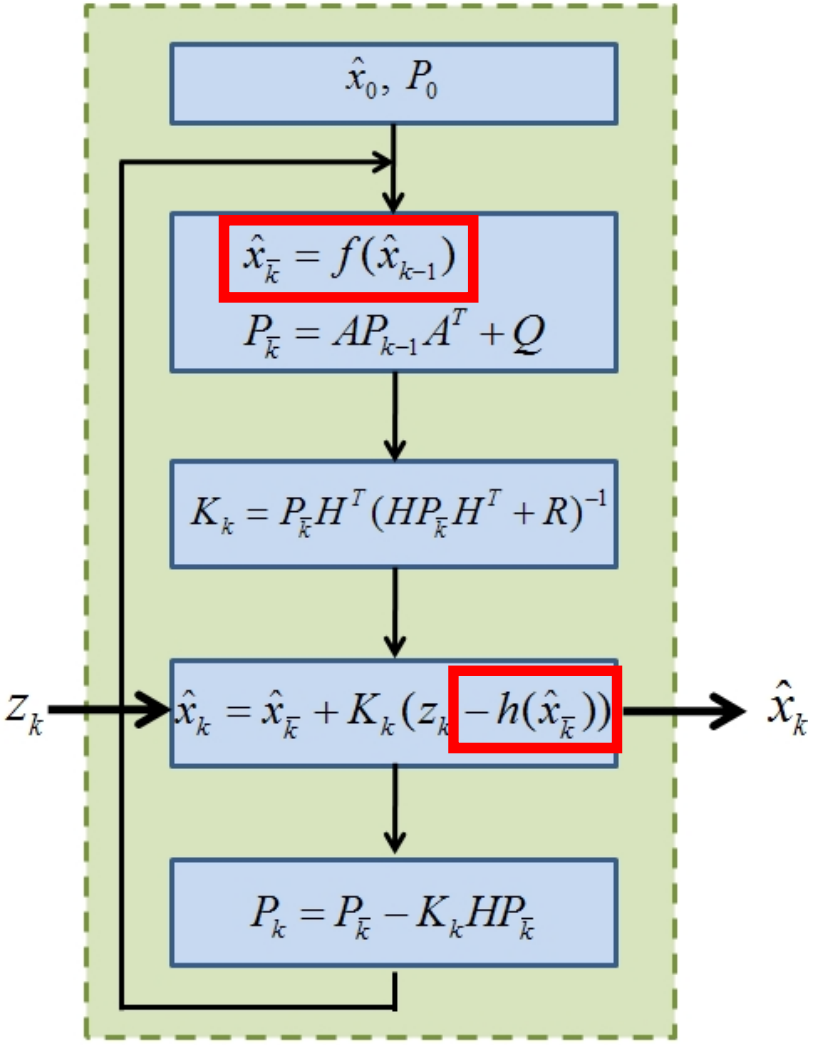

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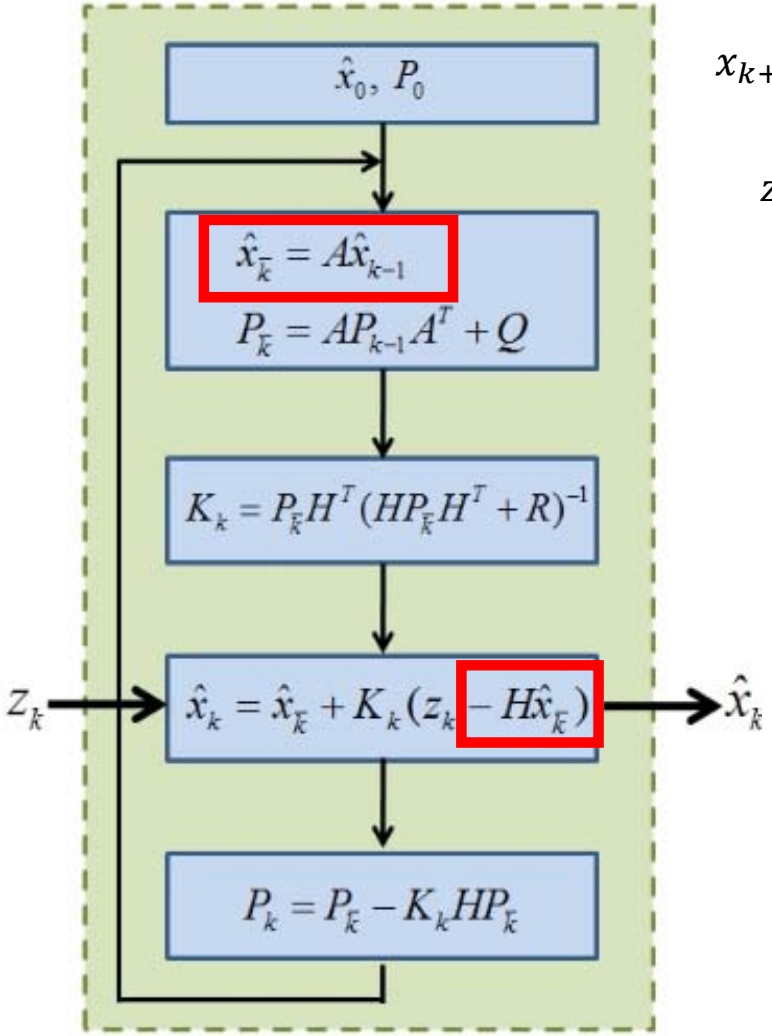

Kalman Filter algorithm

$$x_{k+1} = f(x_k) + w_k$$

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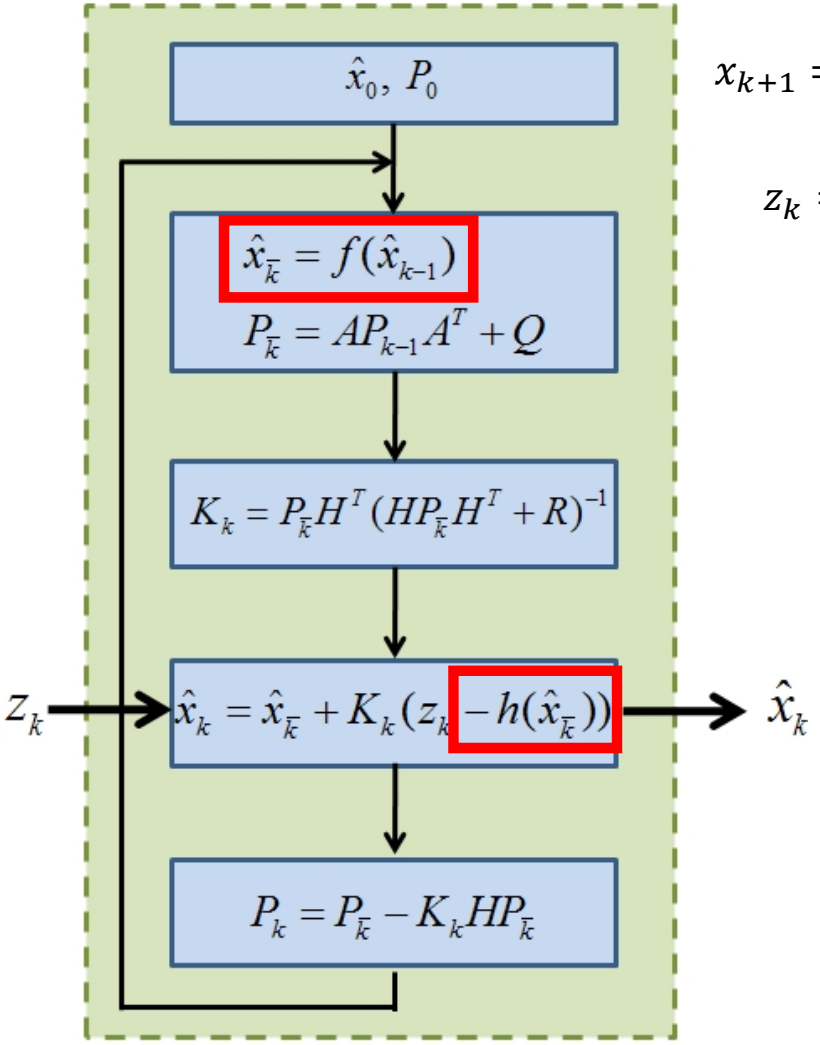

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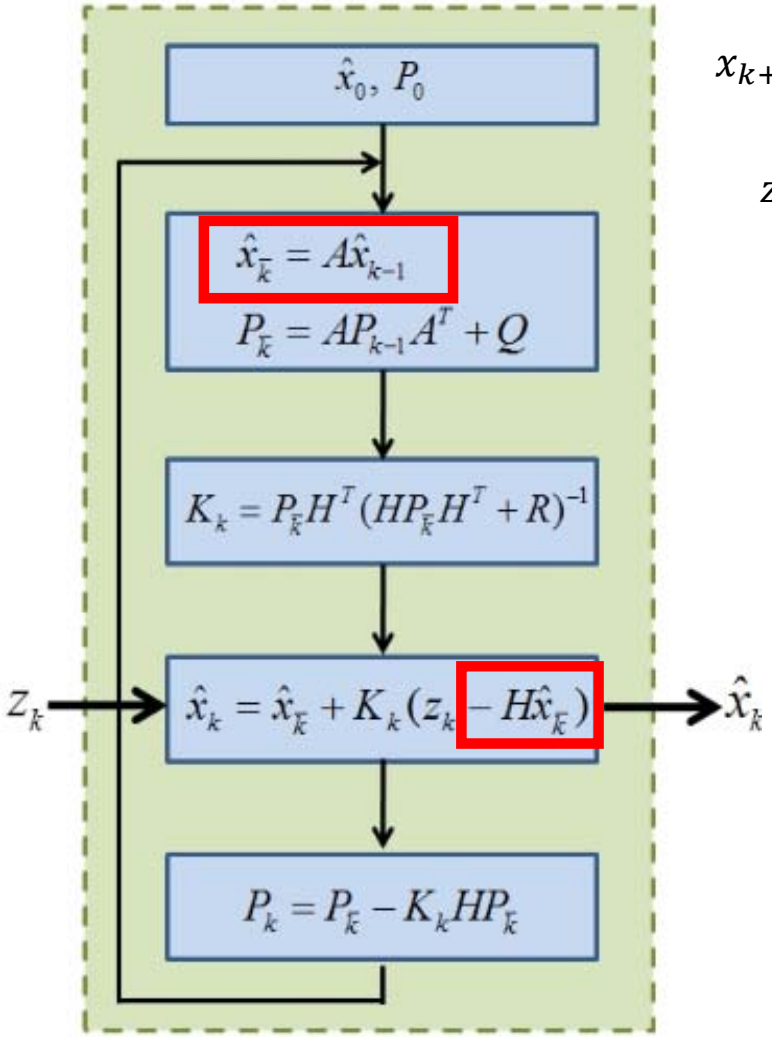

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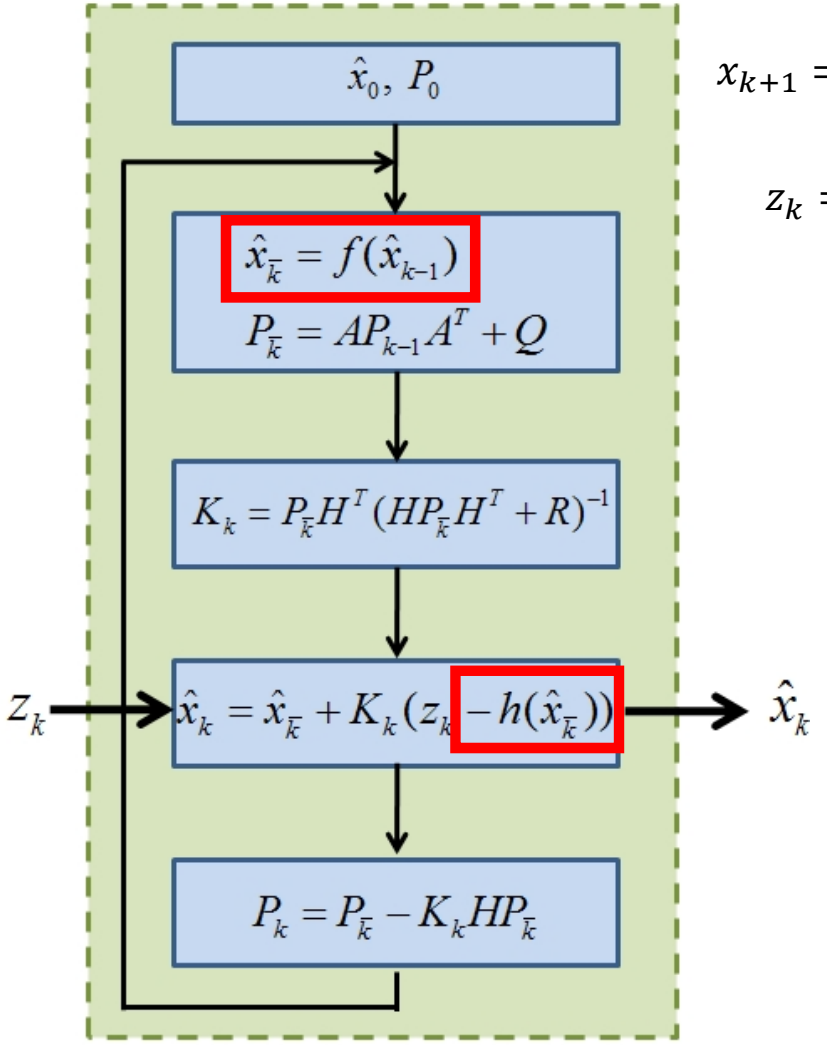

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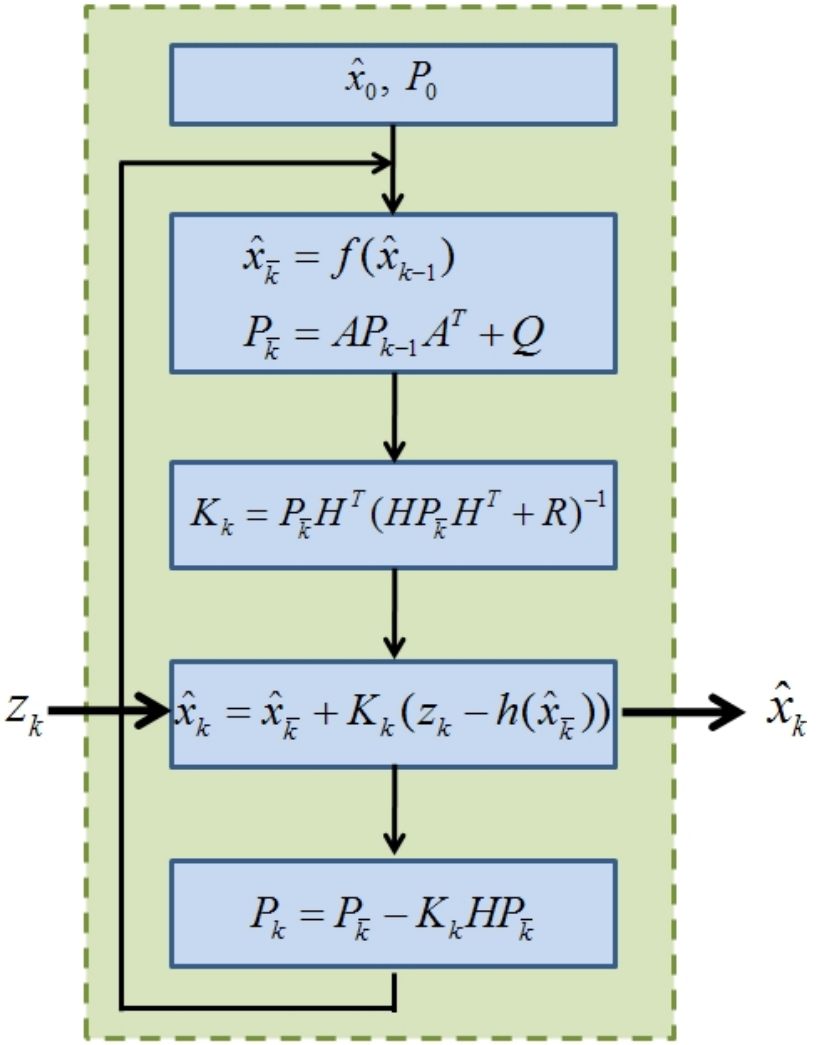

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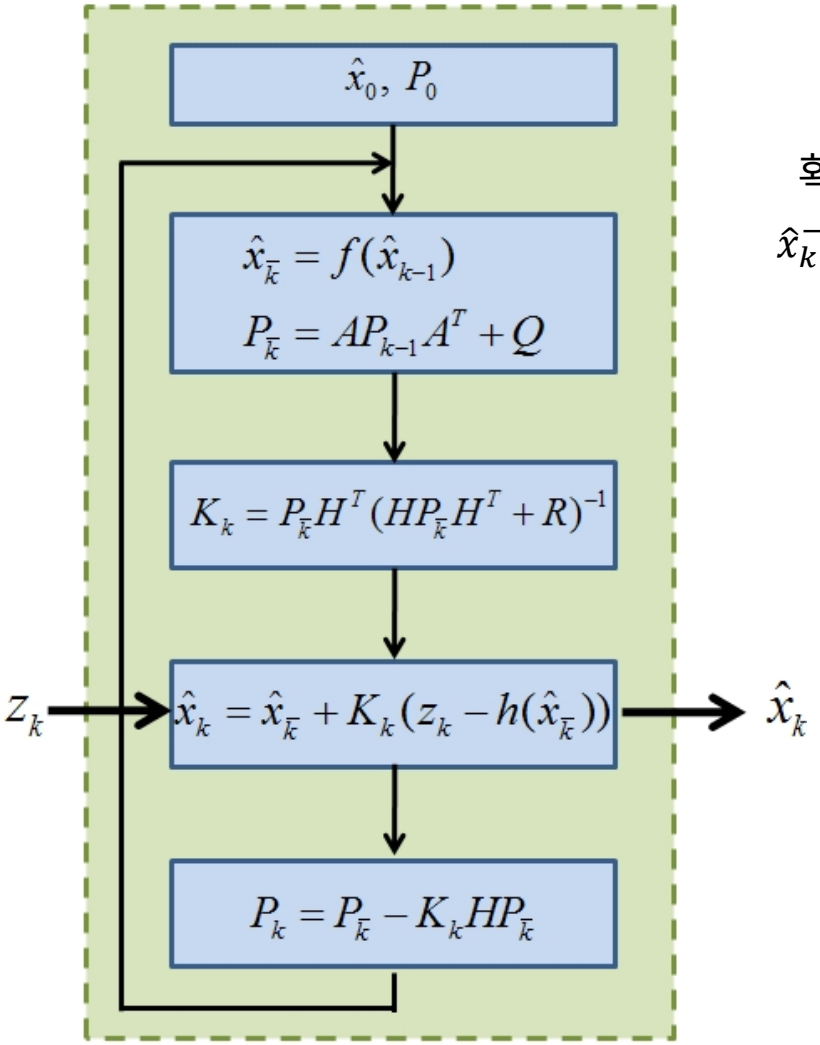
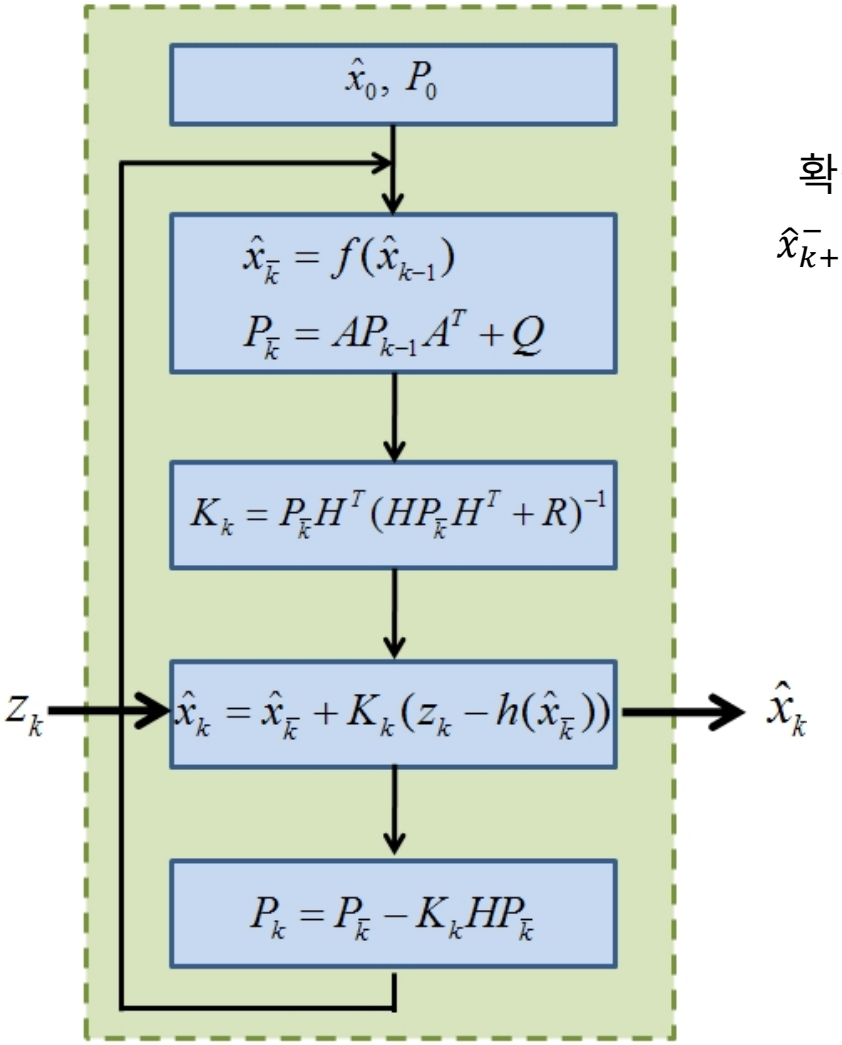


EKF algorithm

확장 칼만

$\hat{x}_{k+1}^{-} = f(\hat{x}_{k-1})$

2. Extended Kalman Filter



EKF algorithm

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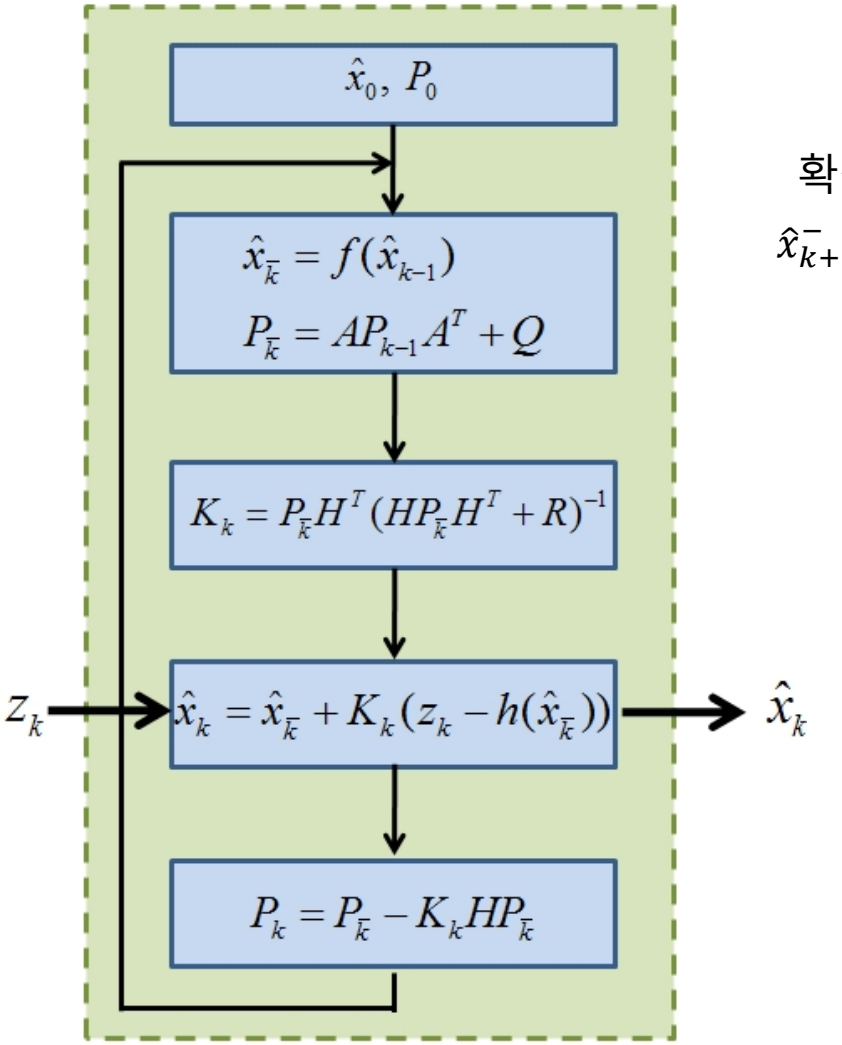
$\hat{x}_{k+1}^- = f(\hat{x}_{k-1})$

확장 칼만

$\hat{x}_k = \hat{x}_k^- + K_k\{z_k - h(\hat{x}_k^-)\}$

2. Extended Kalman Filter



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선형 칼만

$\hat{x}_{k+1}^- = A\hat{x}_{k-1}$

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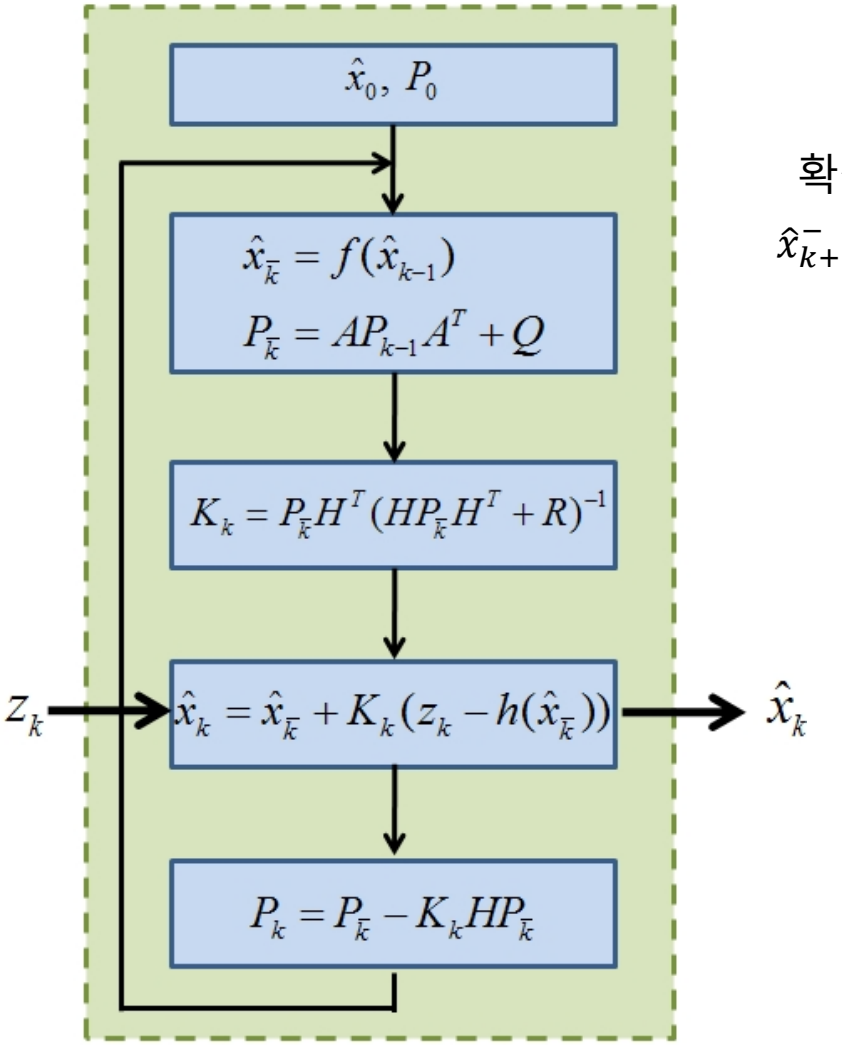

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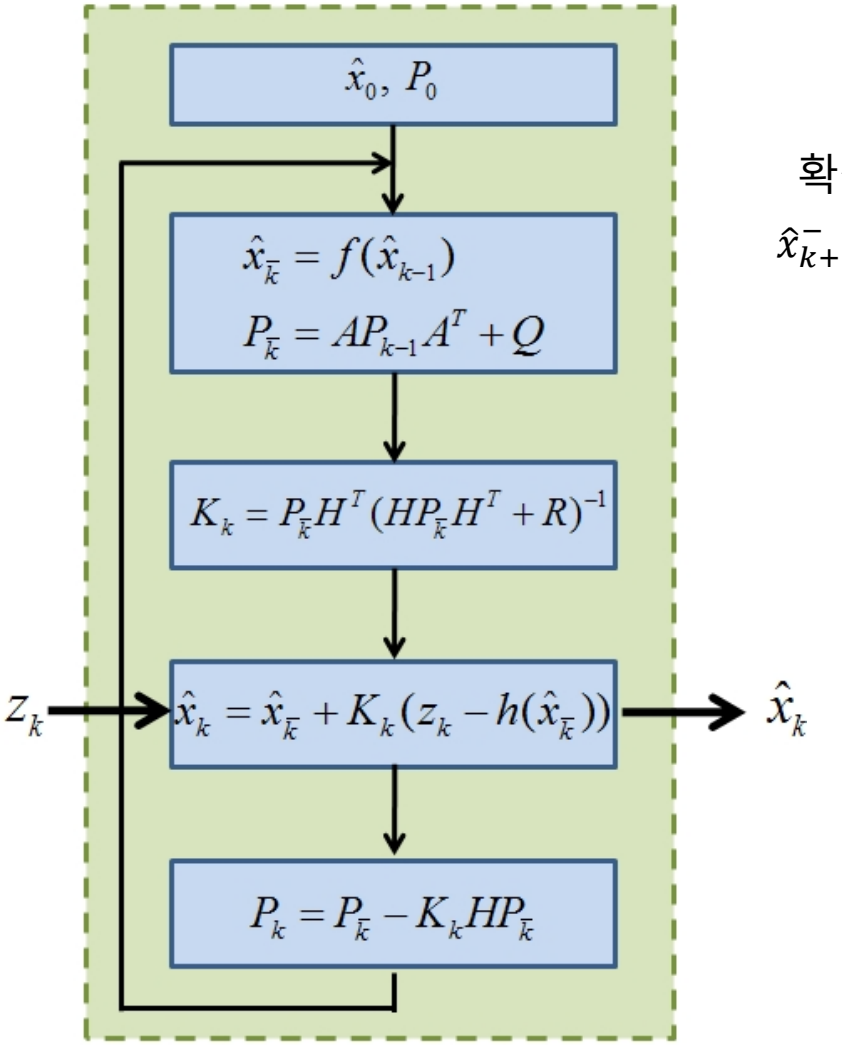

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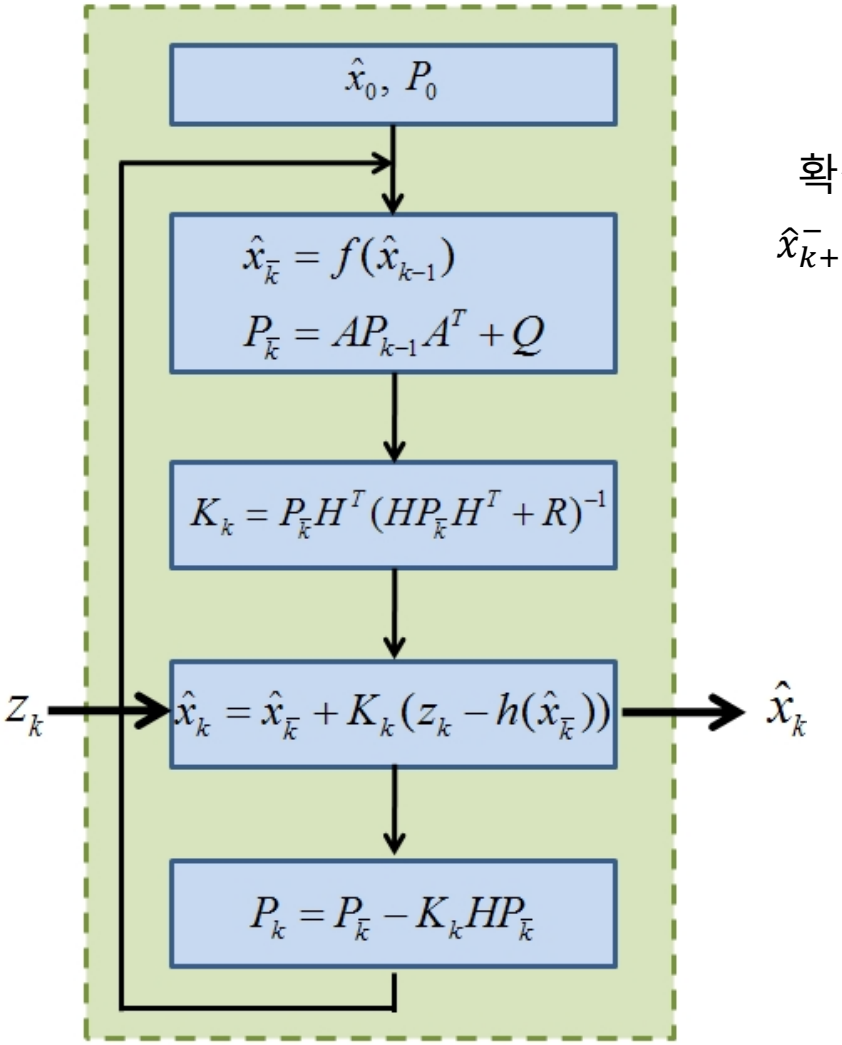

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$f(\hat{x}_{k-1}) \Leftrightarrow A\hat{x}_{k-1}$

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$h(\hat{x}_k^-) \Leftrightarrow H\hat{x}_k^-$

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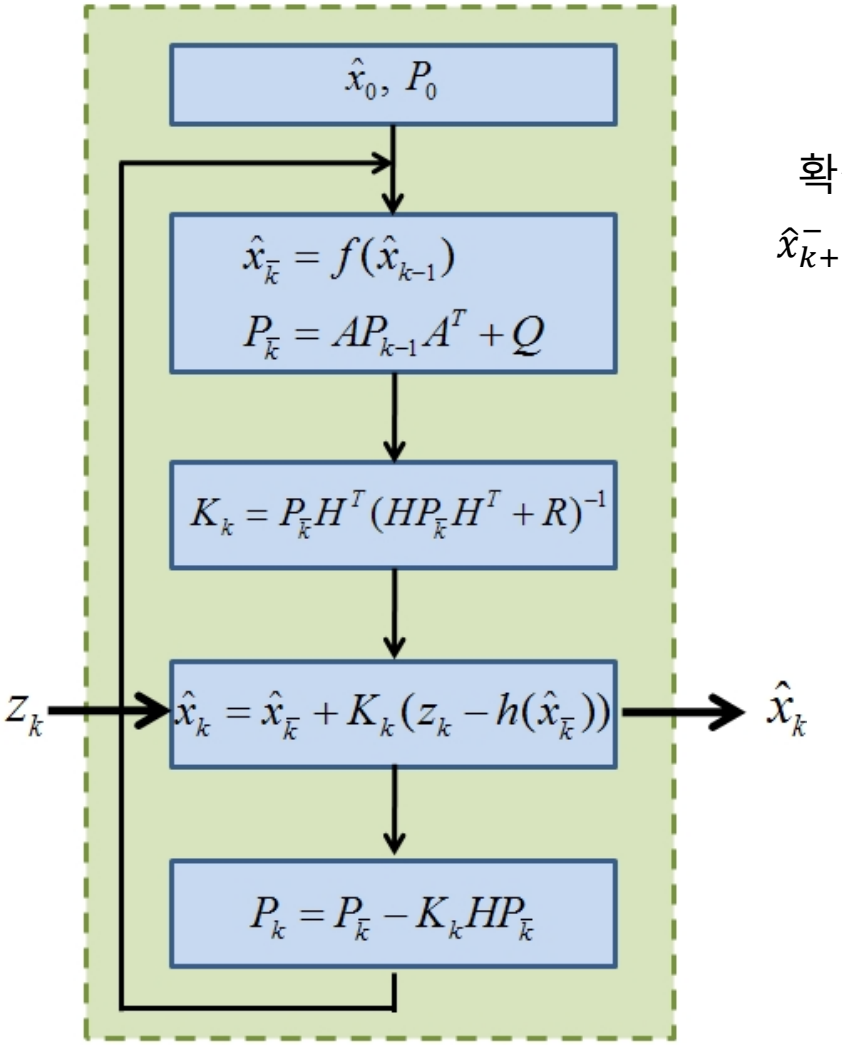

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$$A \equiv \left.\frac{\partial f}{\partial x}\right|_{\hat{x}_k}$$

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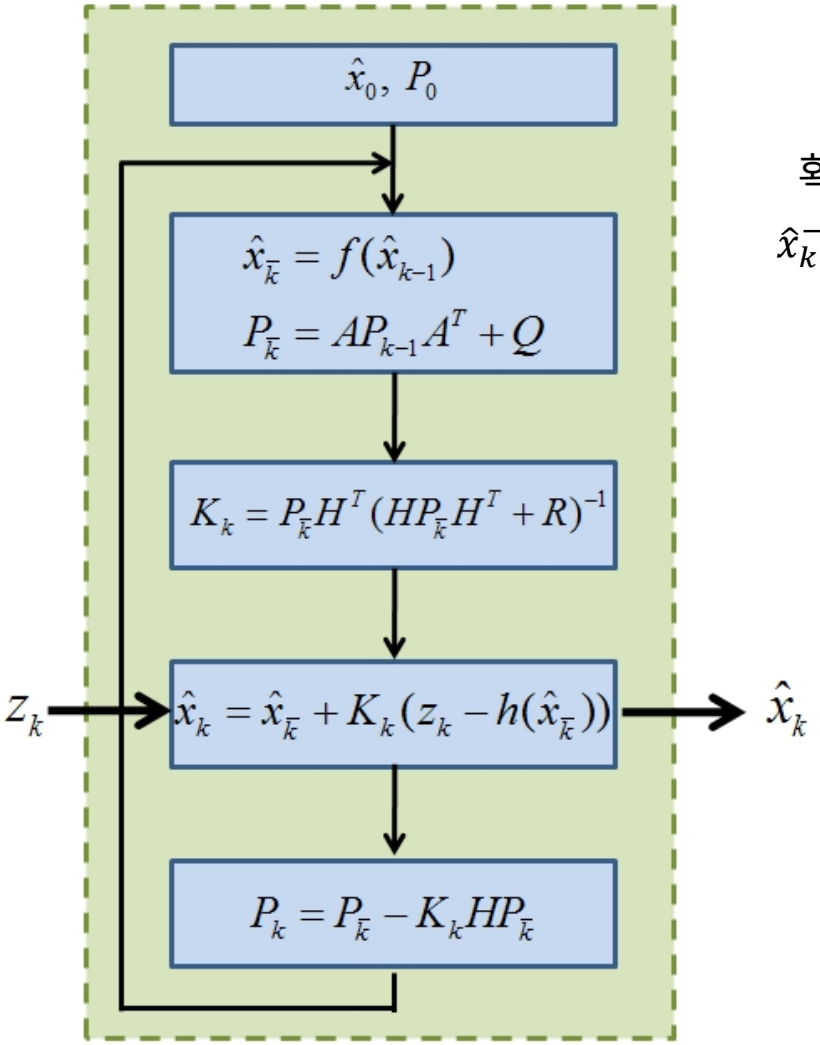

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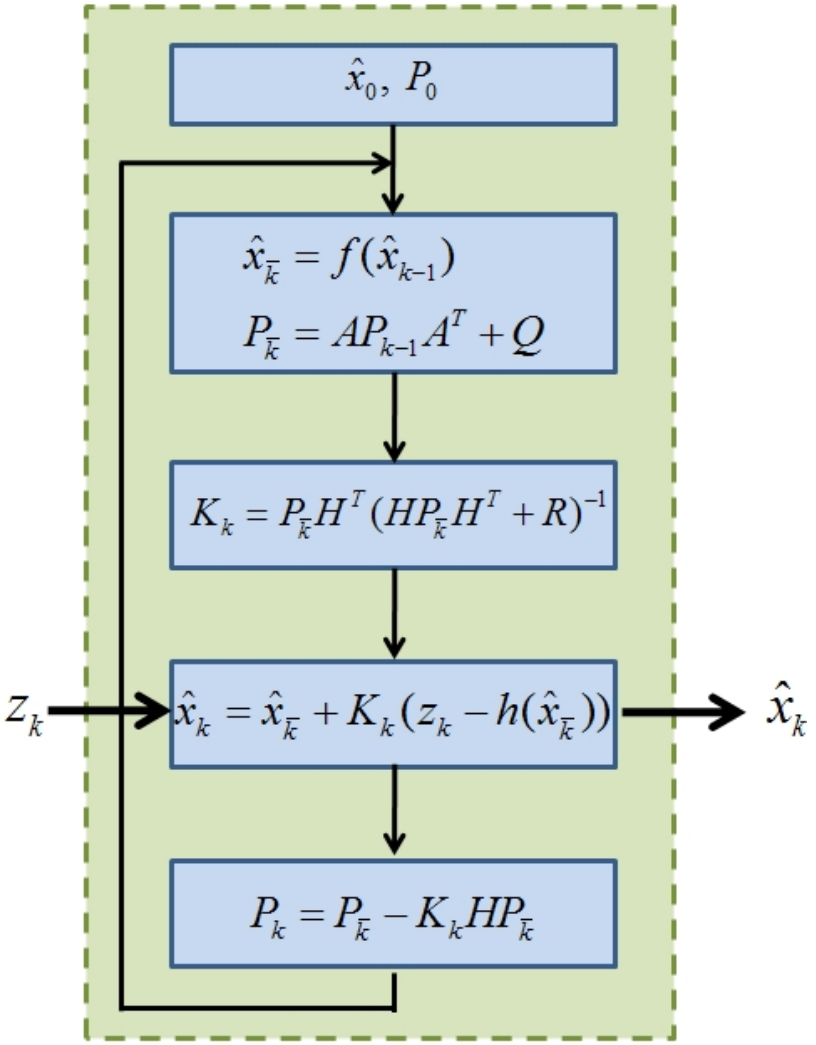

EKF algorithm

$$A \equiv \left.\frac{\partial f}{\partial x}\right|_{\hat{x}_k} \qquad H \equiv \left.\frac{\partial h}{\partial x}\right|_{\hat{x}_k}$$

직전 추정값을 기준으로 선형 모델을 구한다.

3. what is RADAR?

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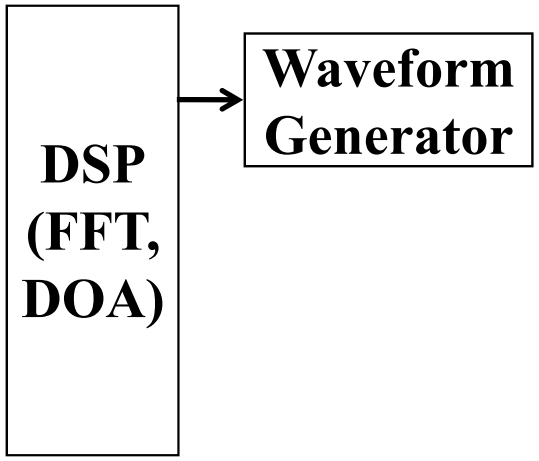

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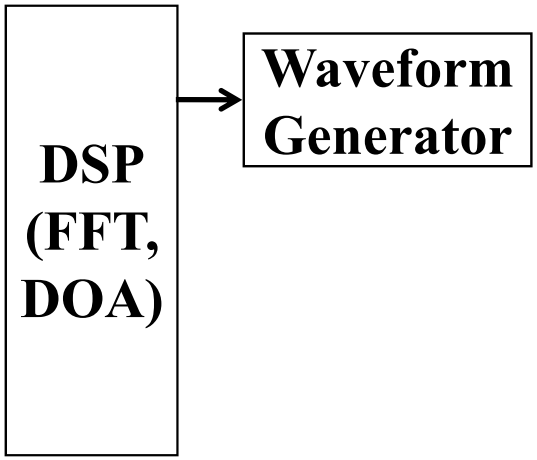

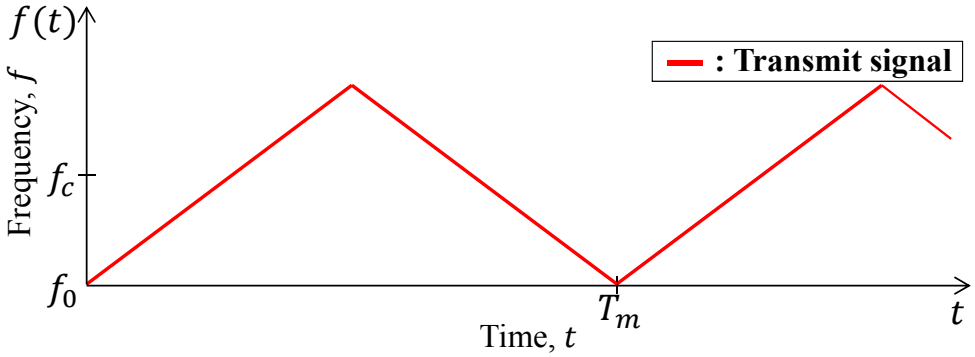

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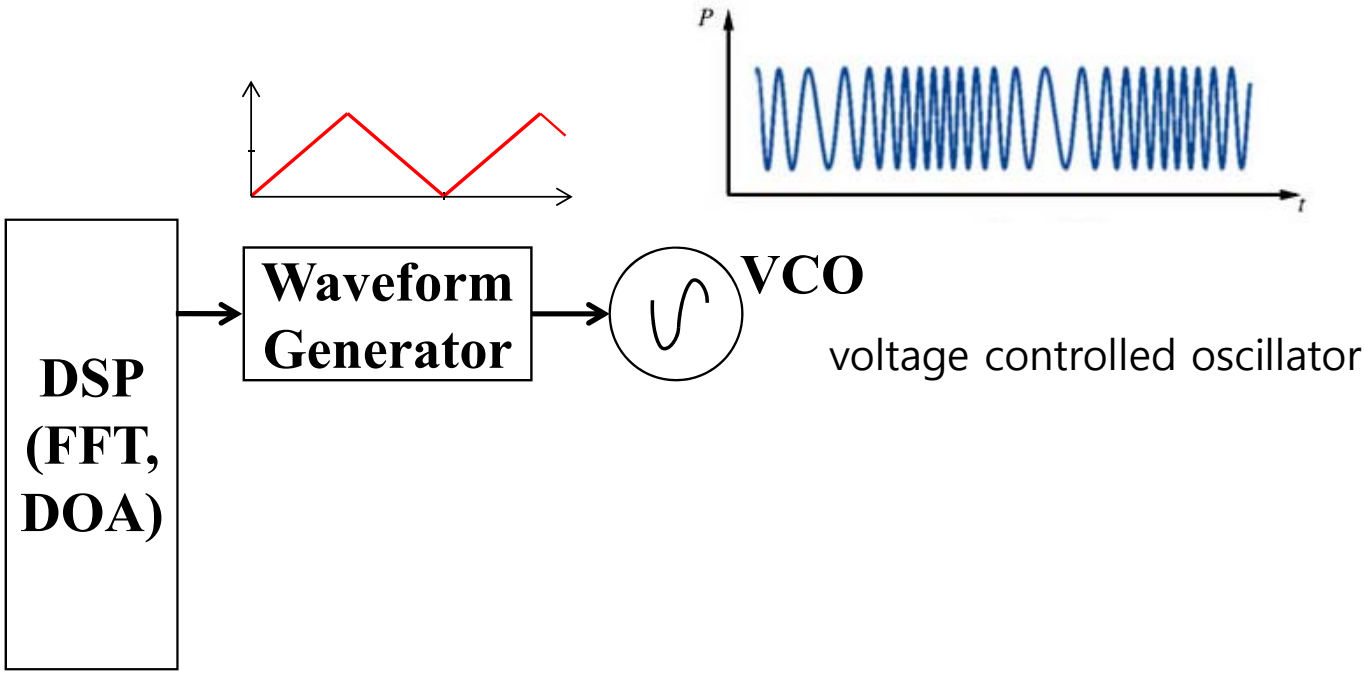

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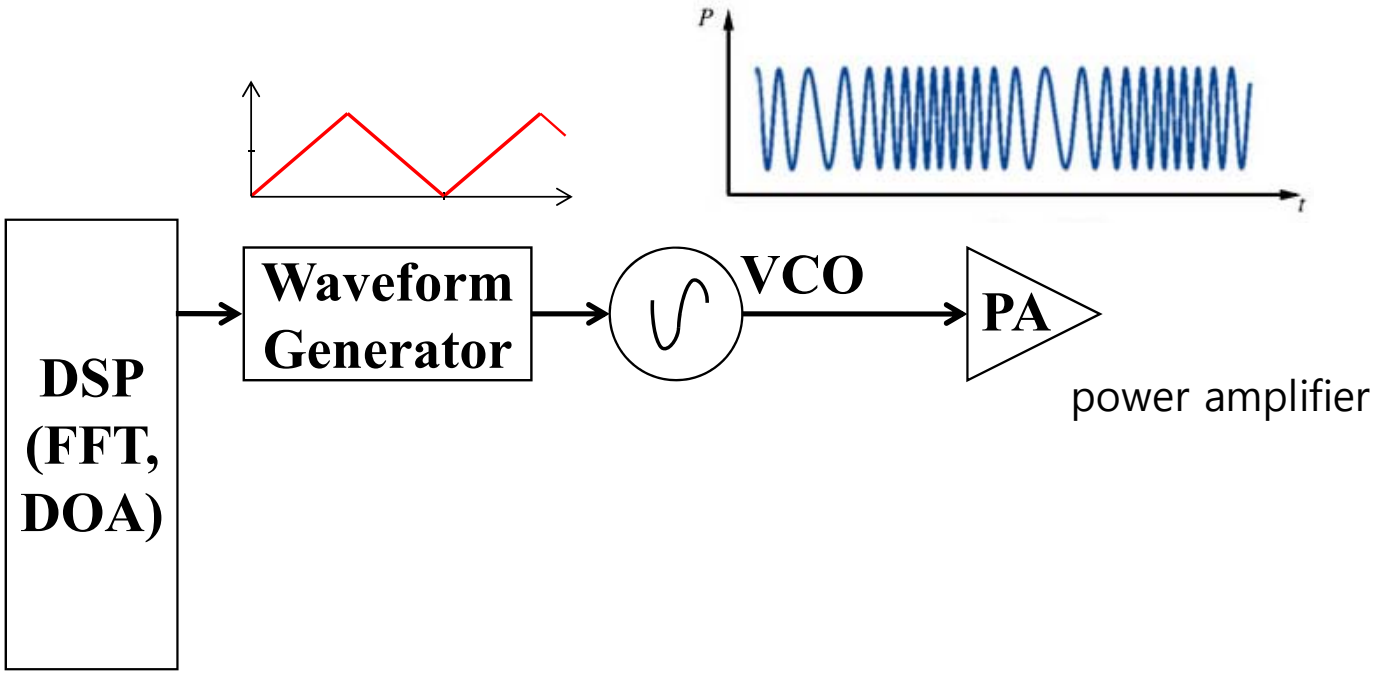

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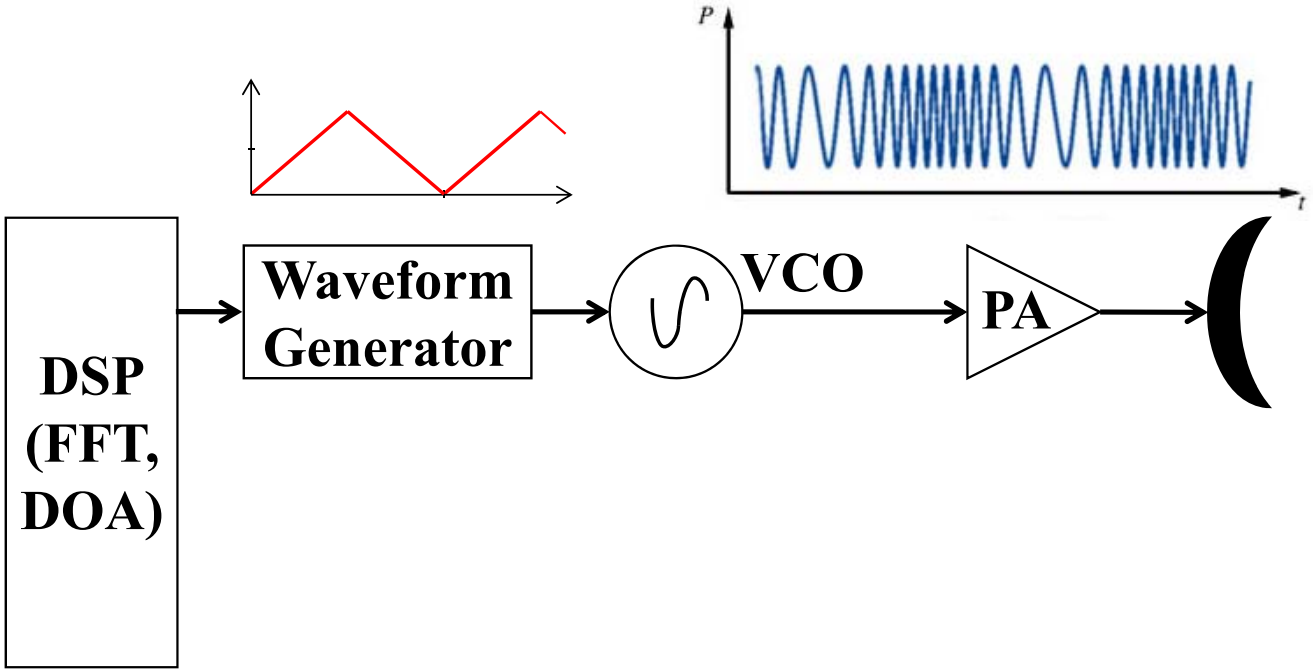

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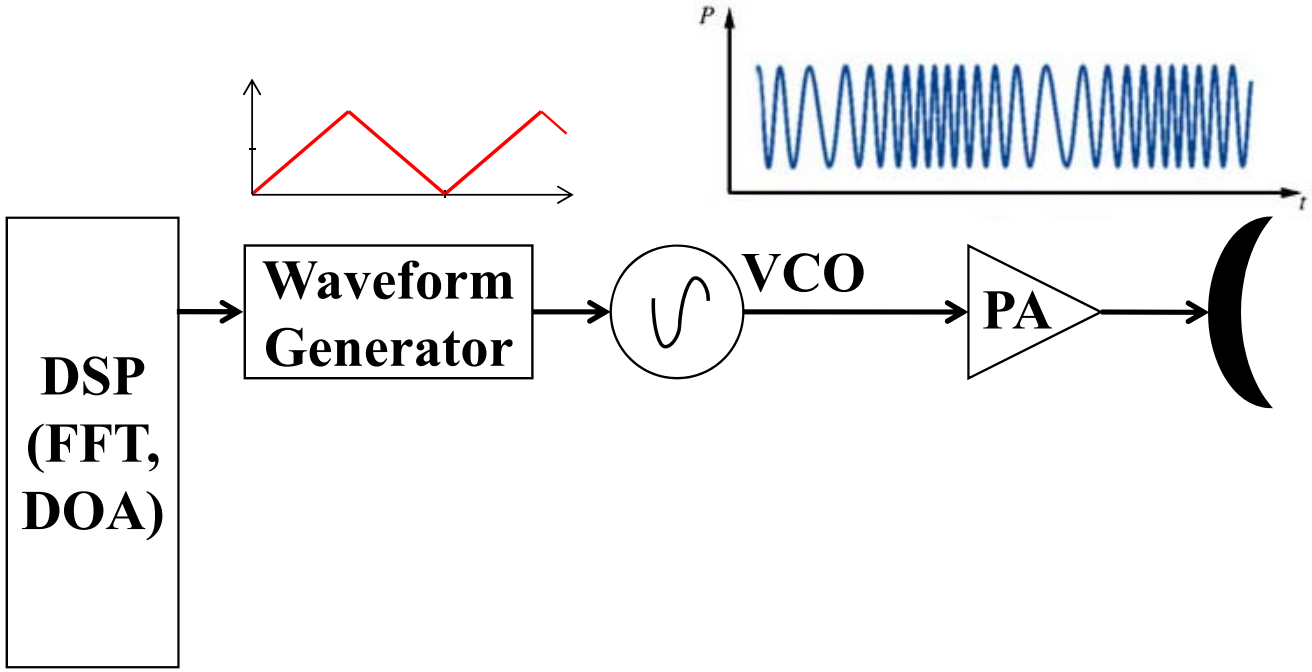

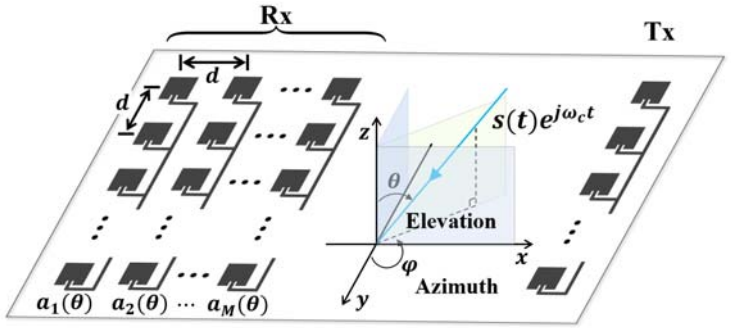

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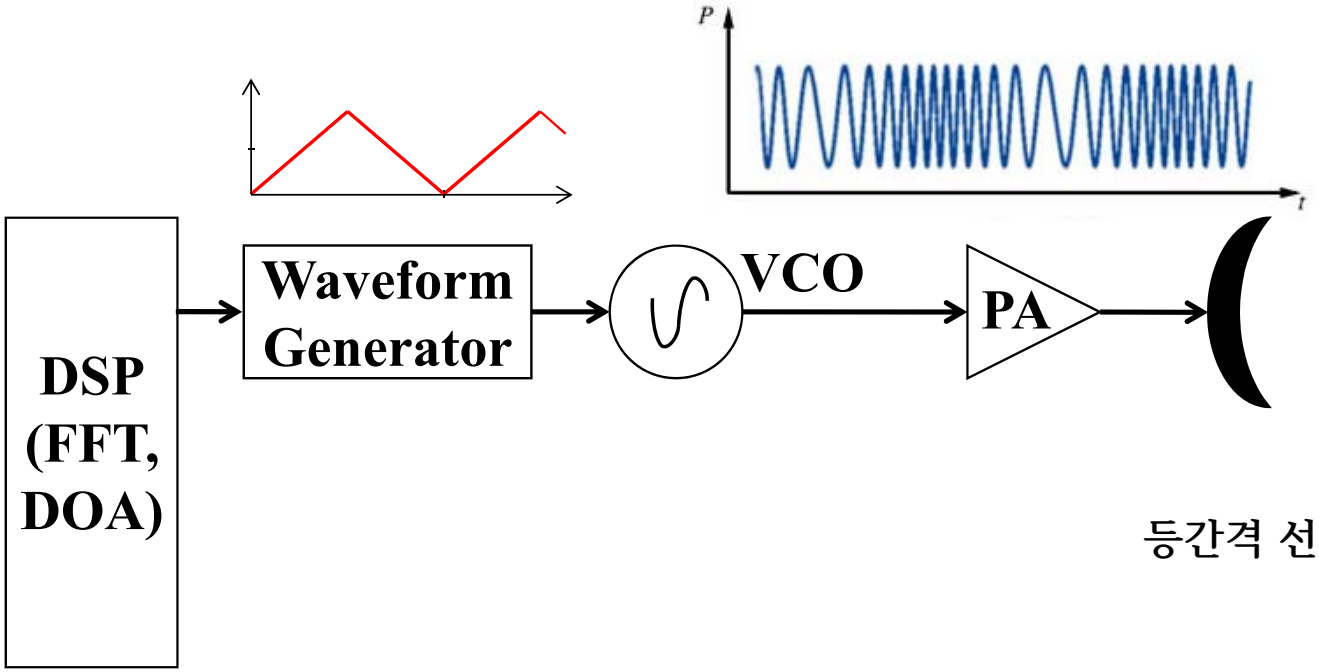

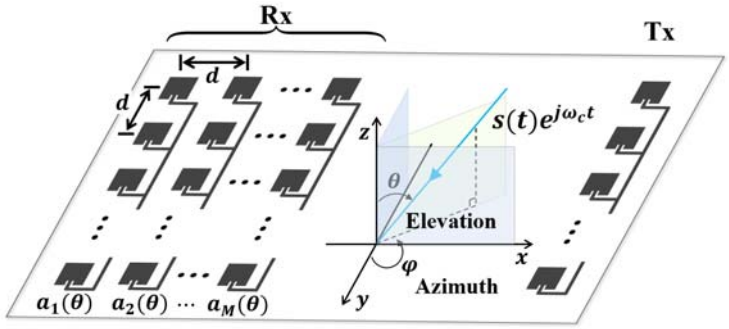

등간격 선형 어레이 (Uniform Linear Array : ULA)

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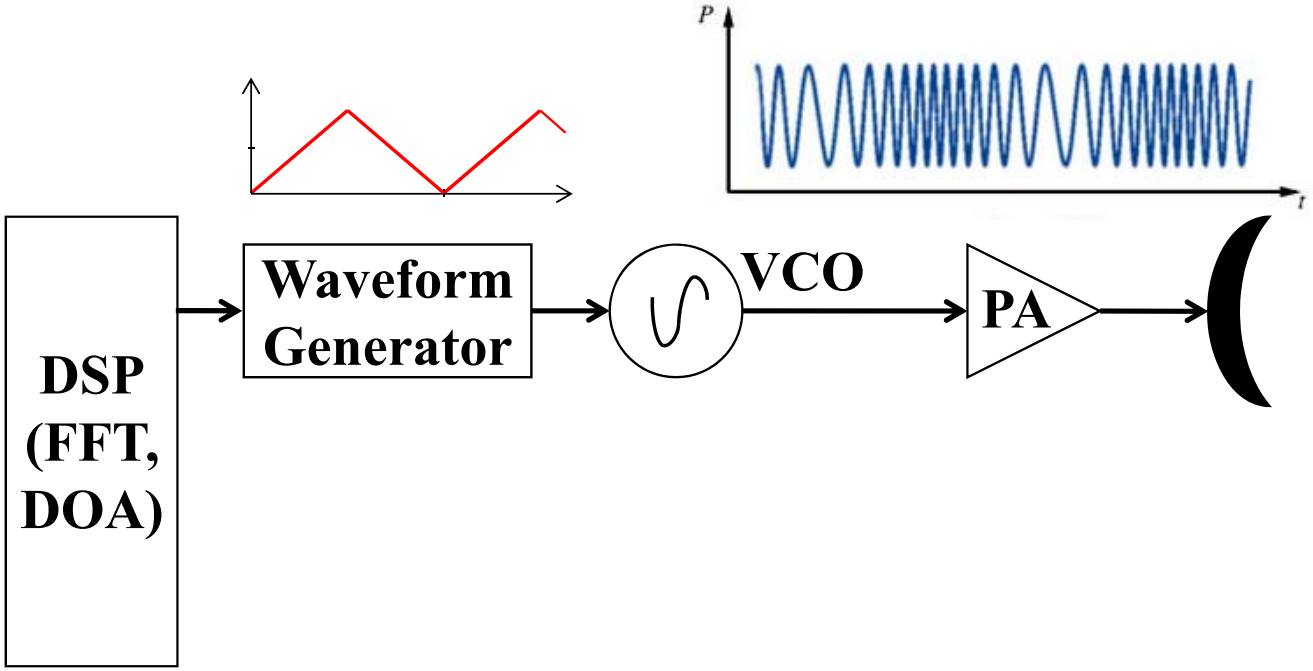

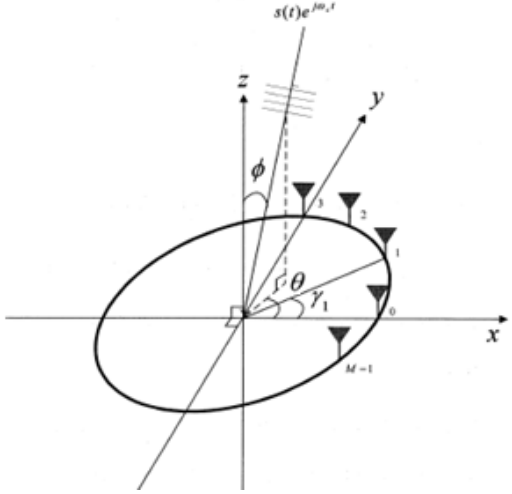

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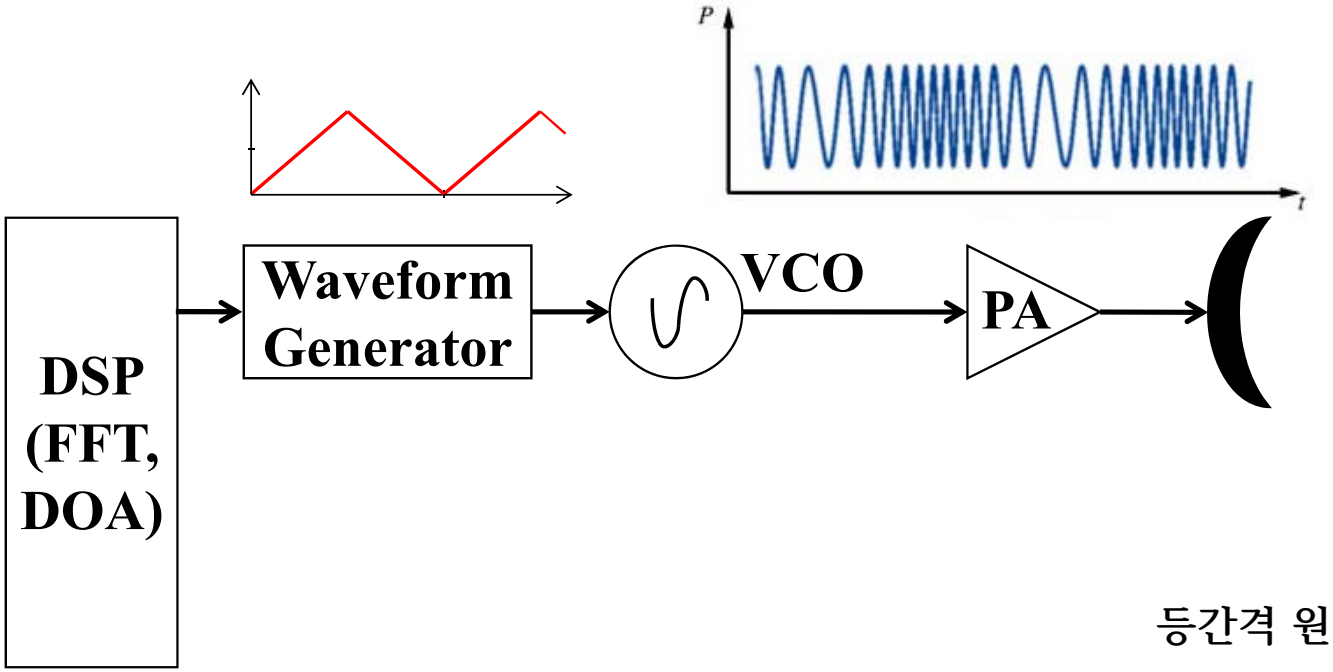

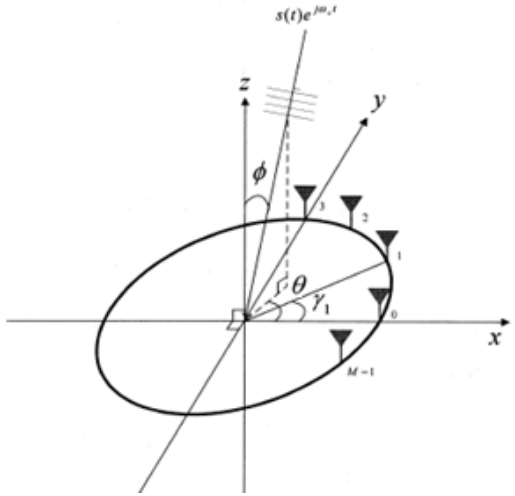

등간격 원형 어레이 (Uniform Circular Array : UCA)

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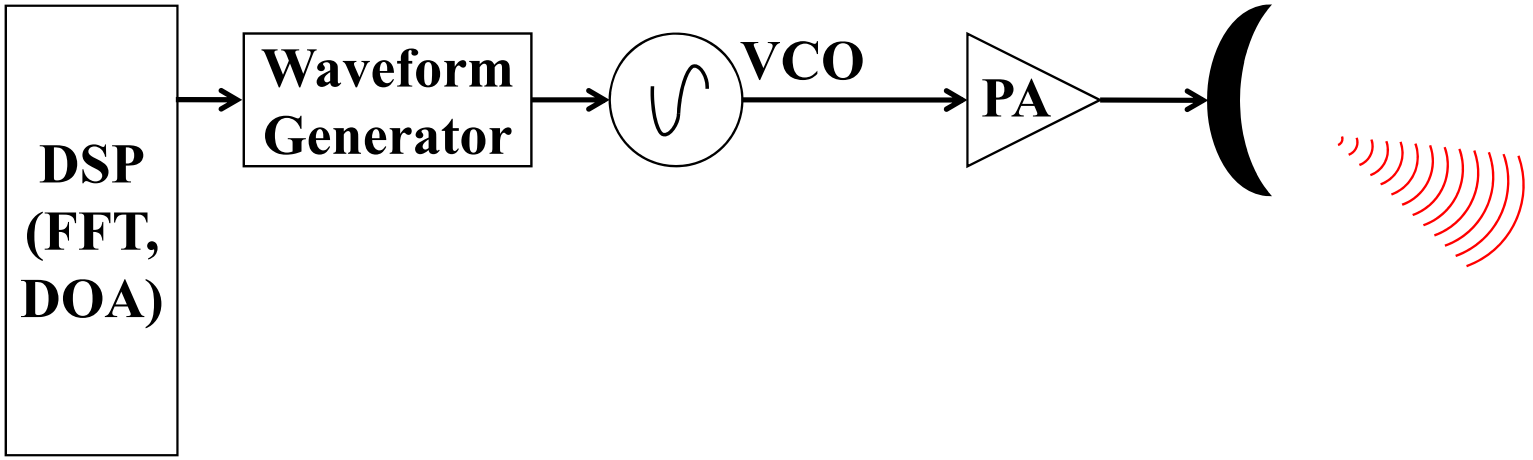

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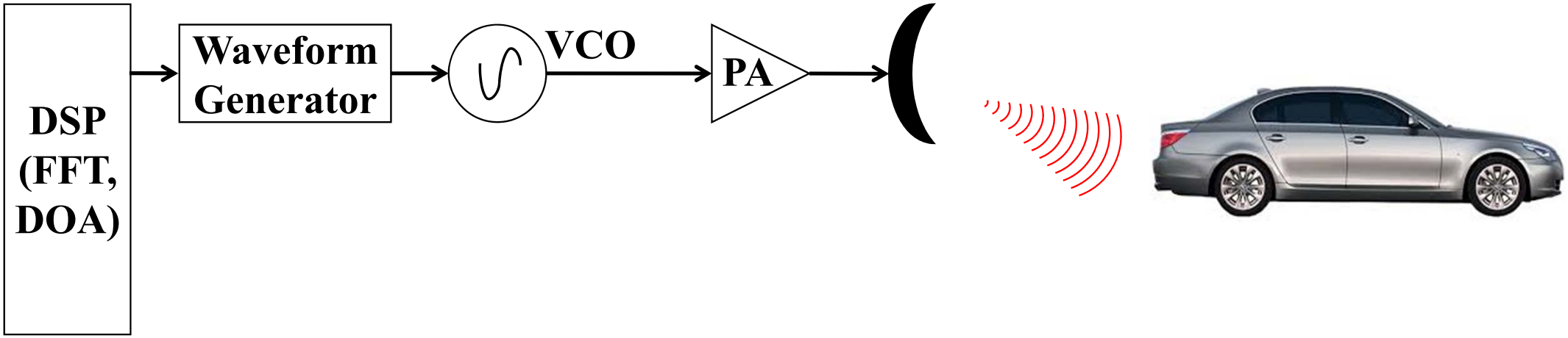

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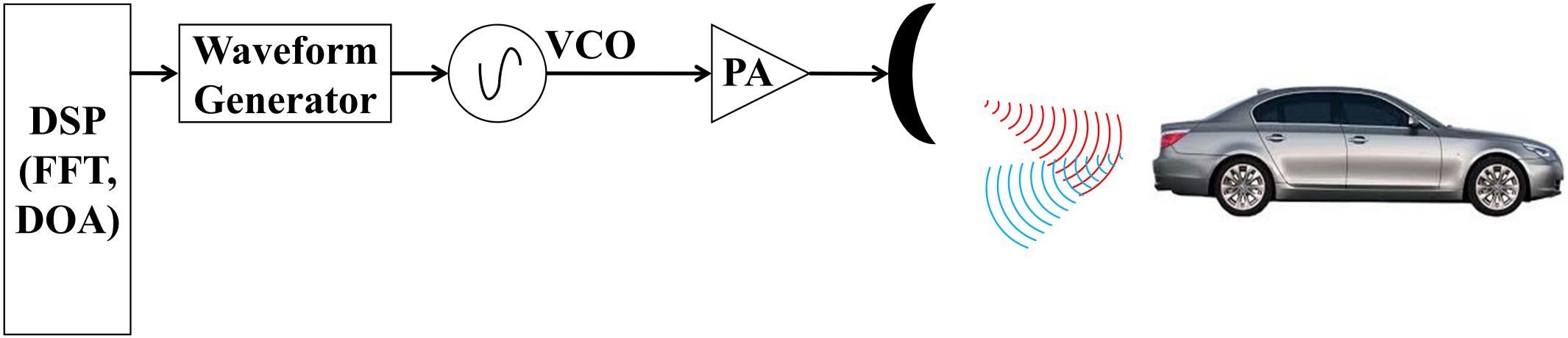

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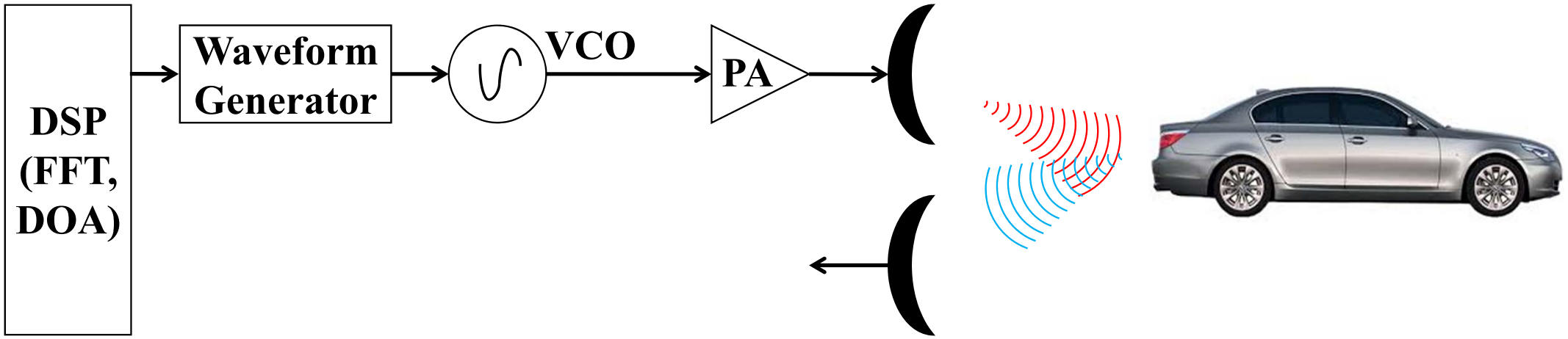

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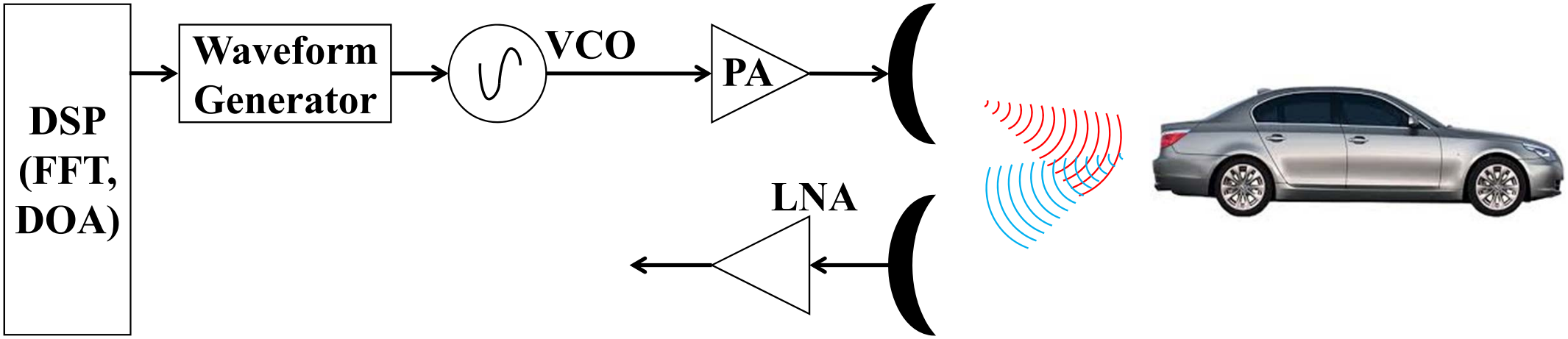

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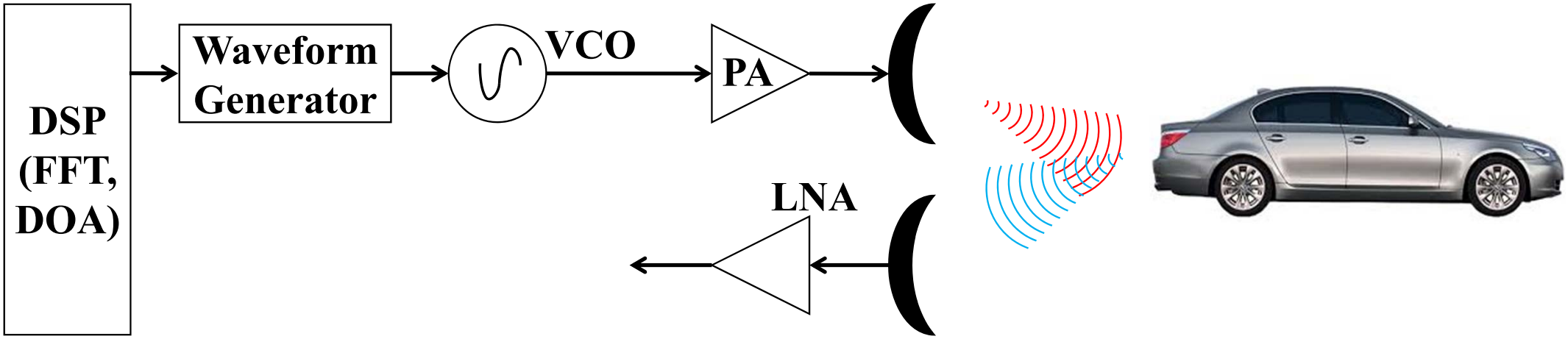
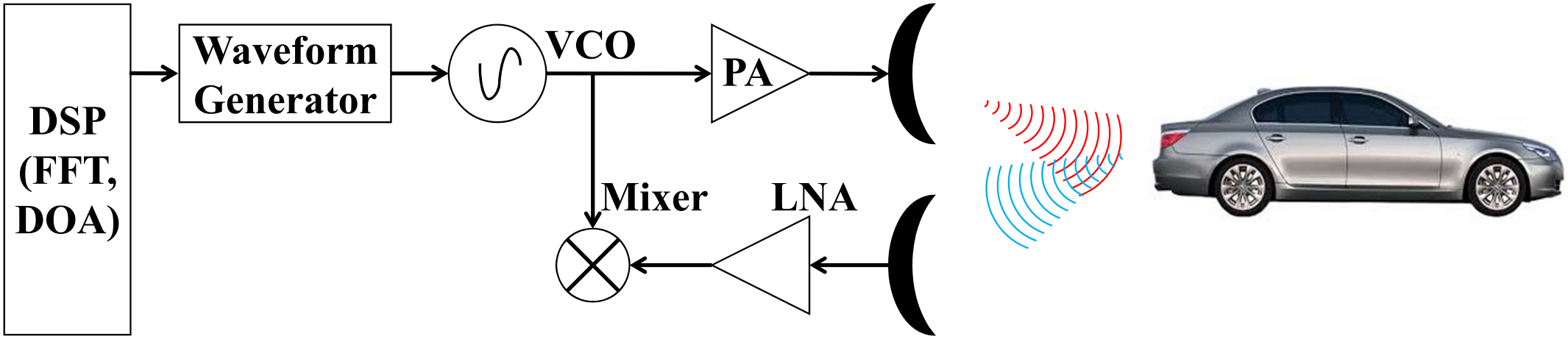


Low Noise Amplifier

3. what is RADAR?



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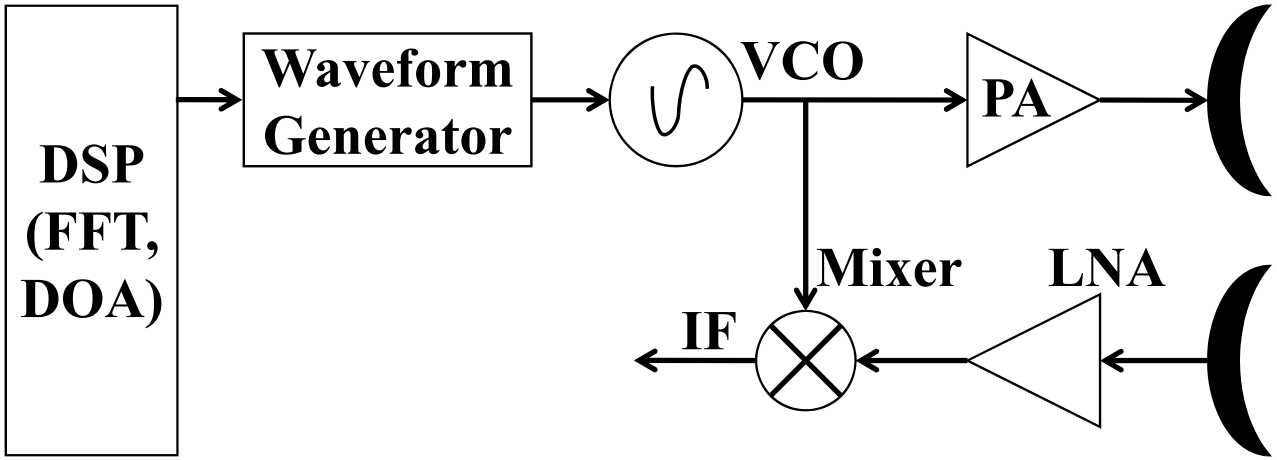

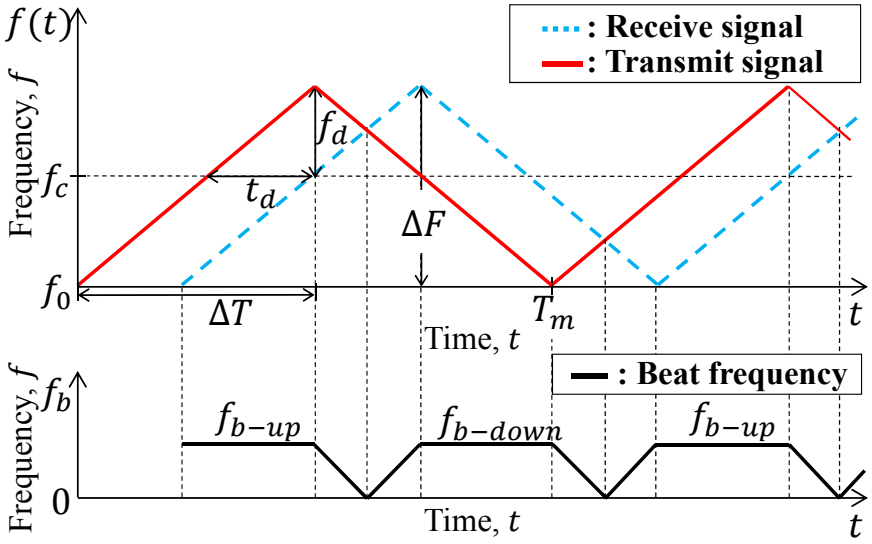

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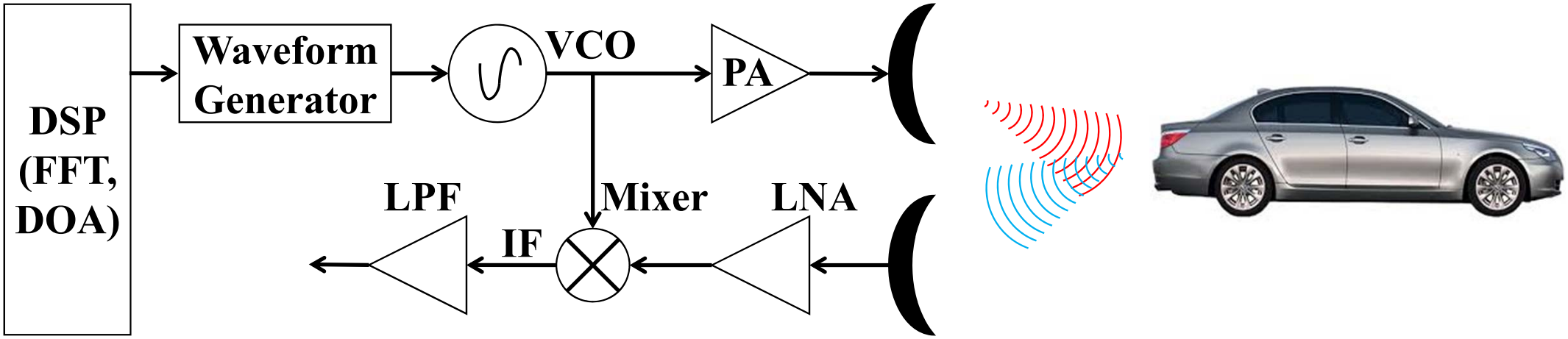

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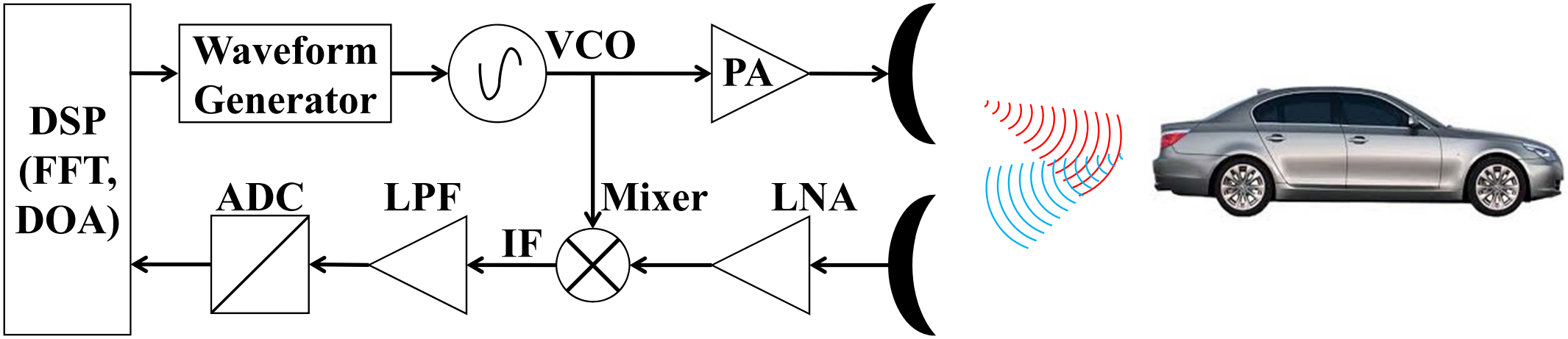

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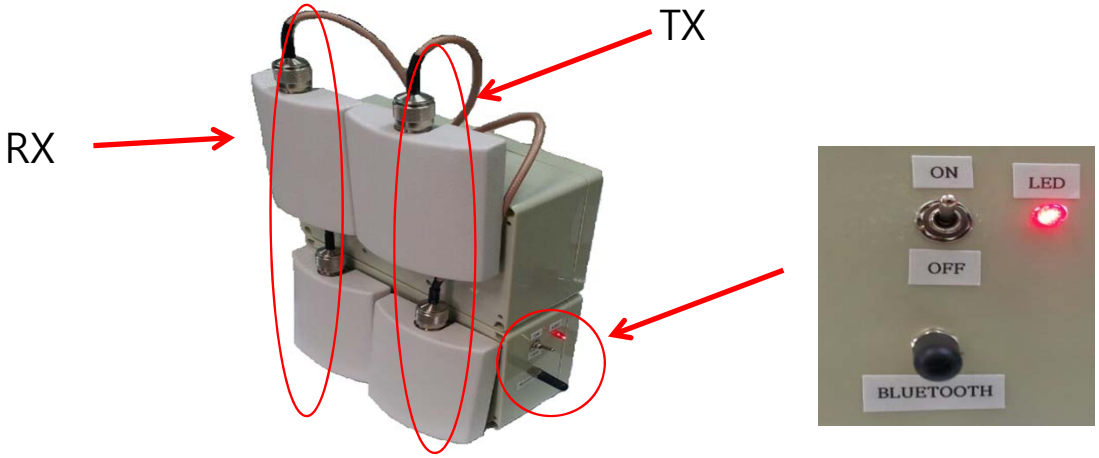

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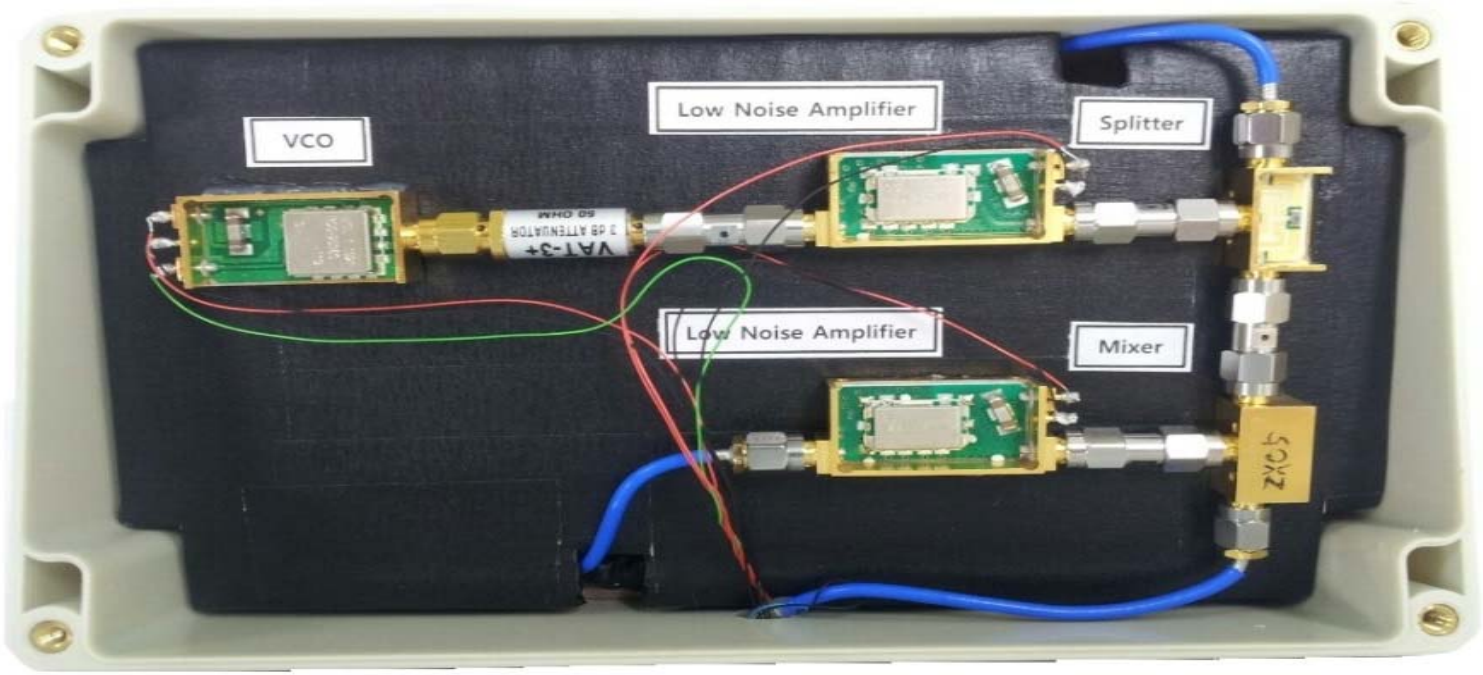

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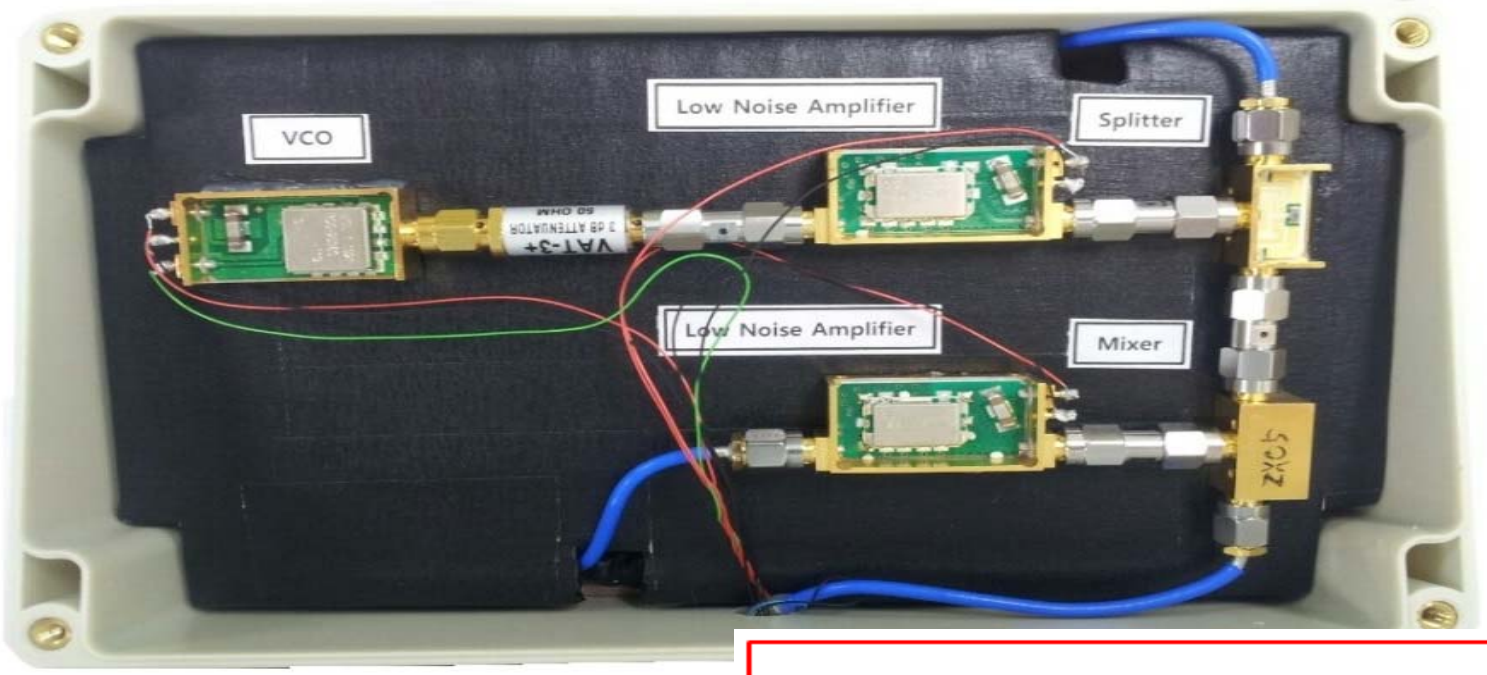

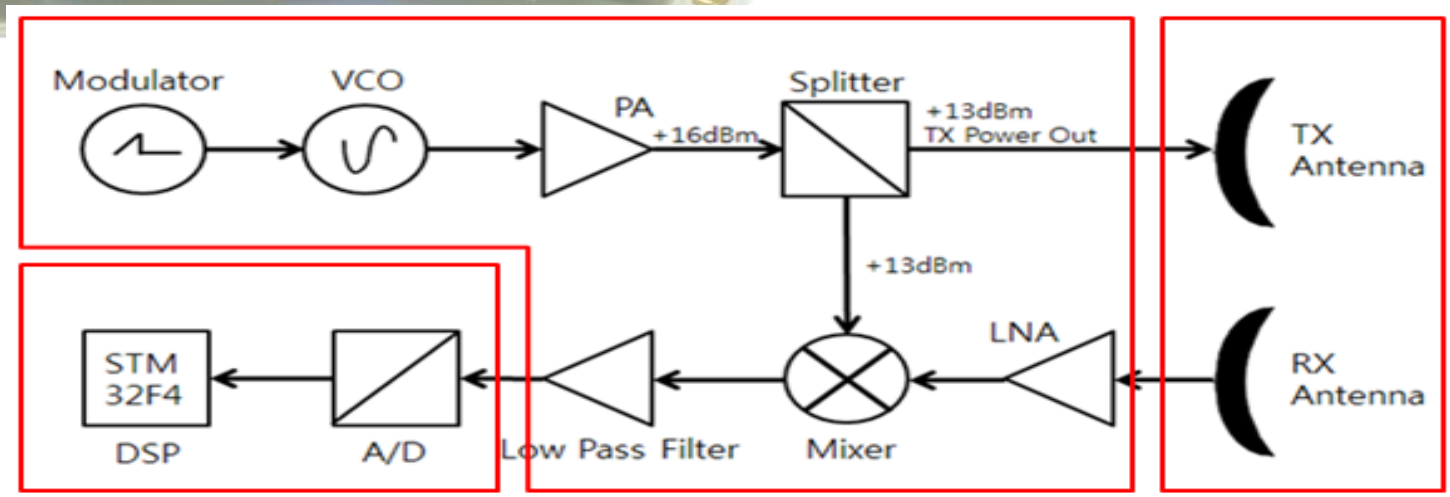

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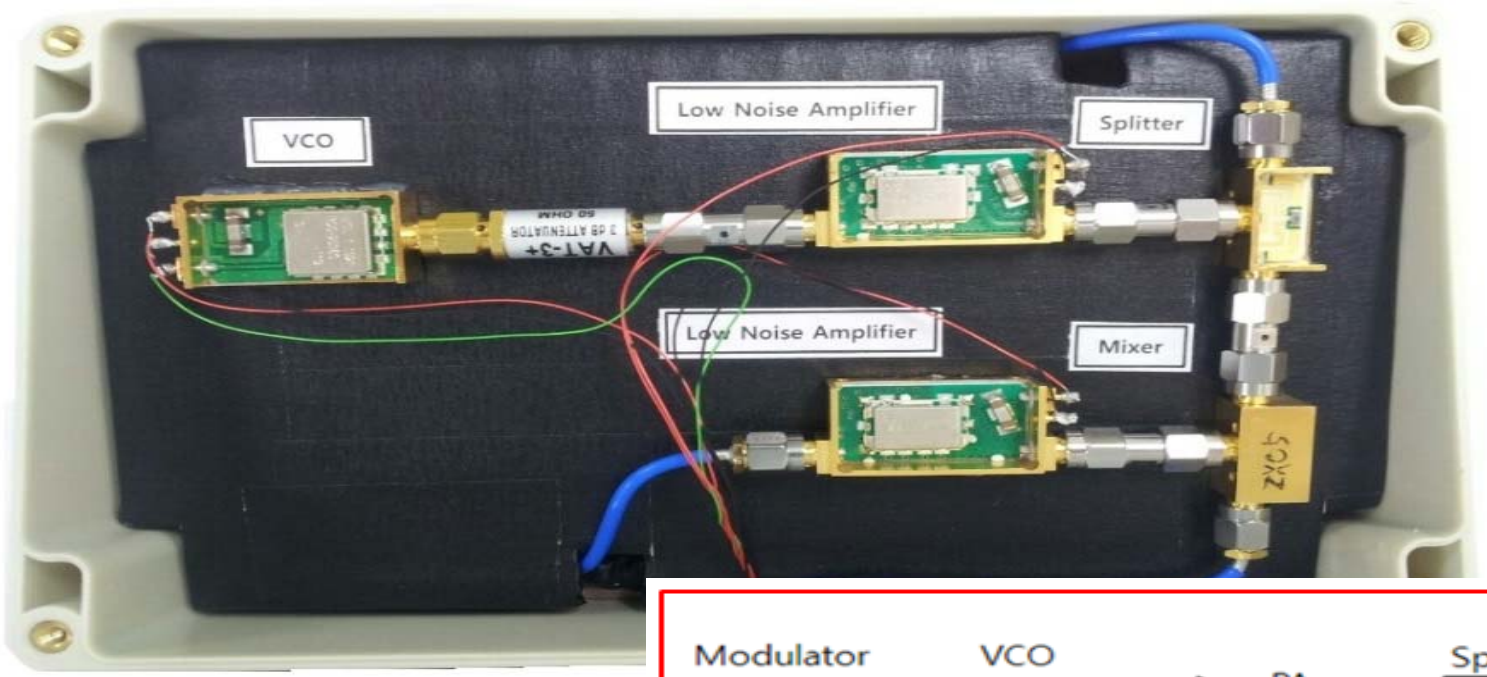

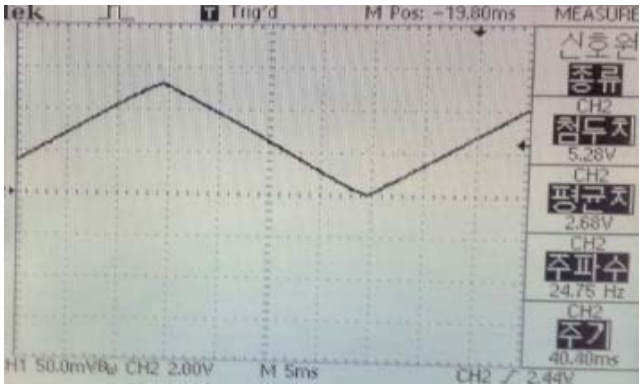

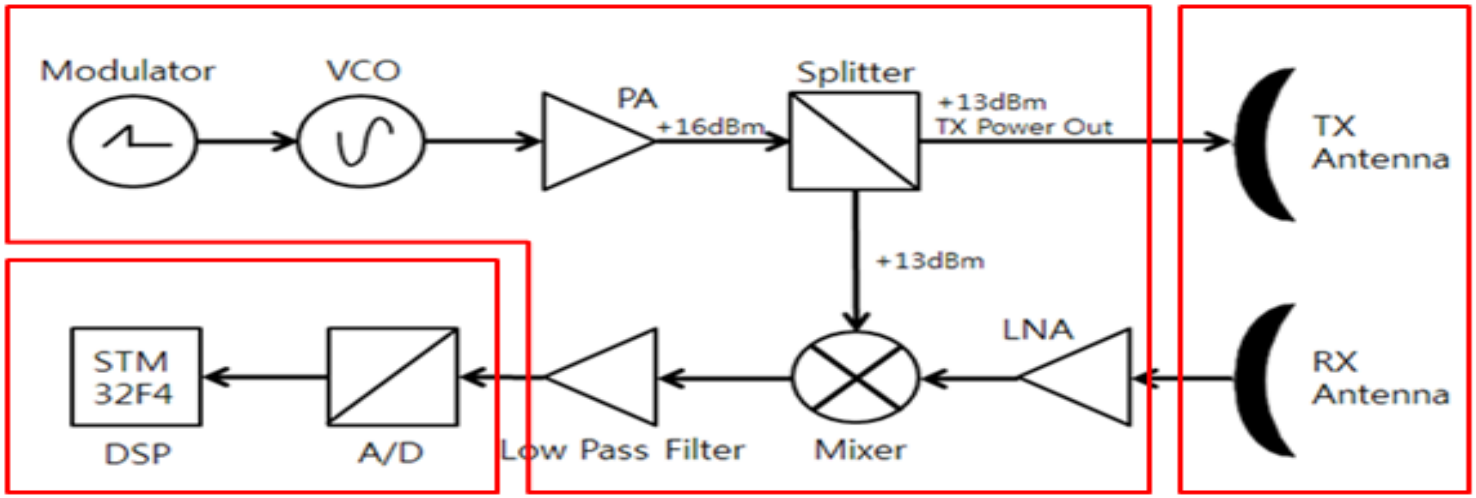

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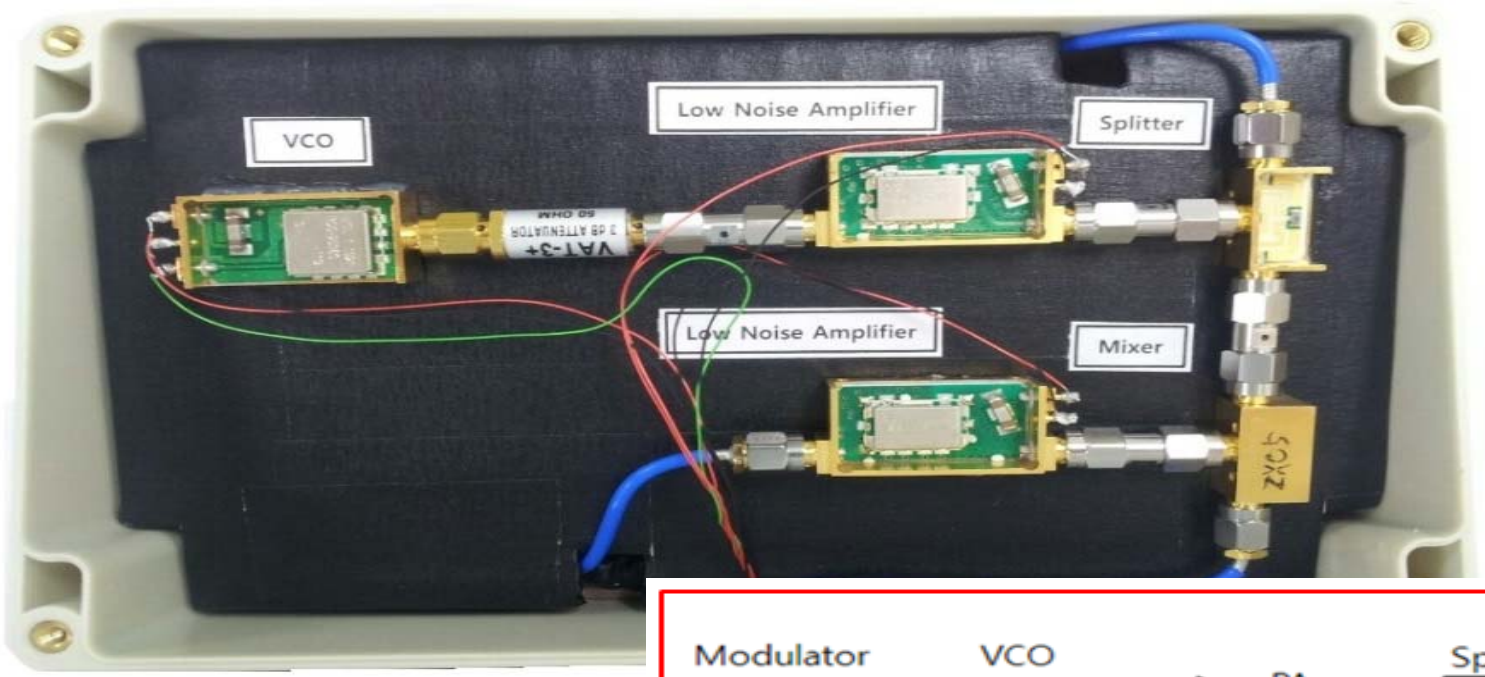

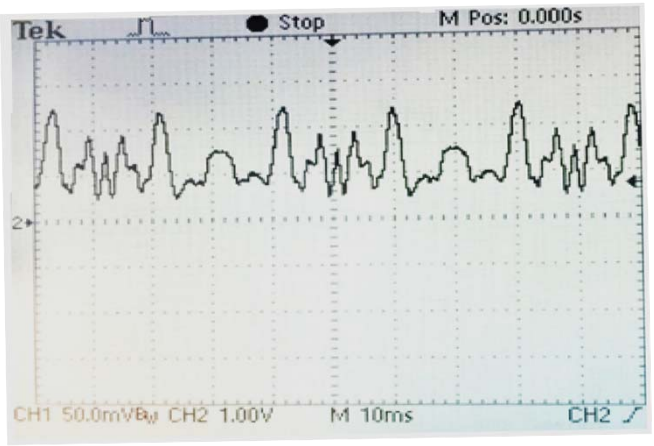

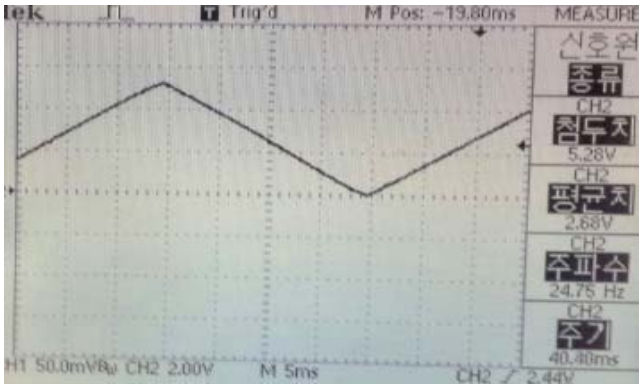

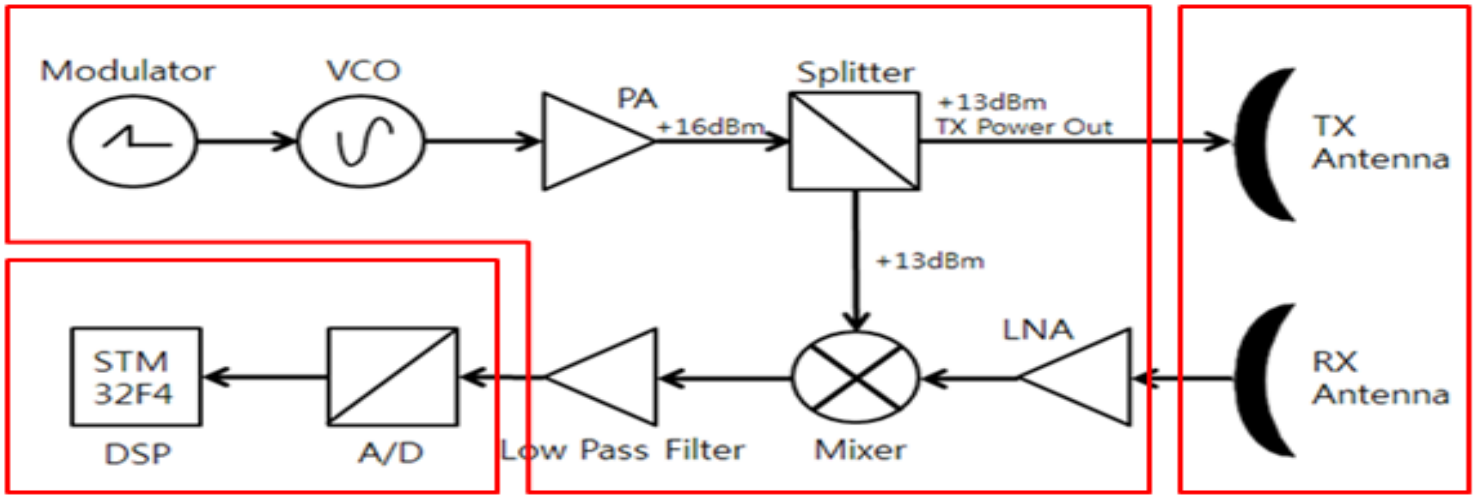

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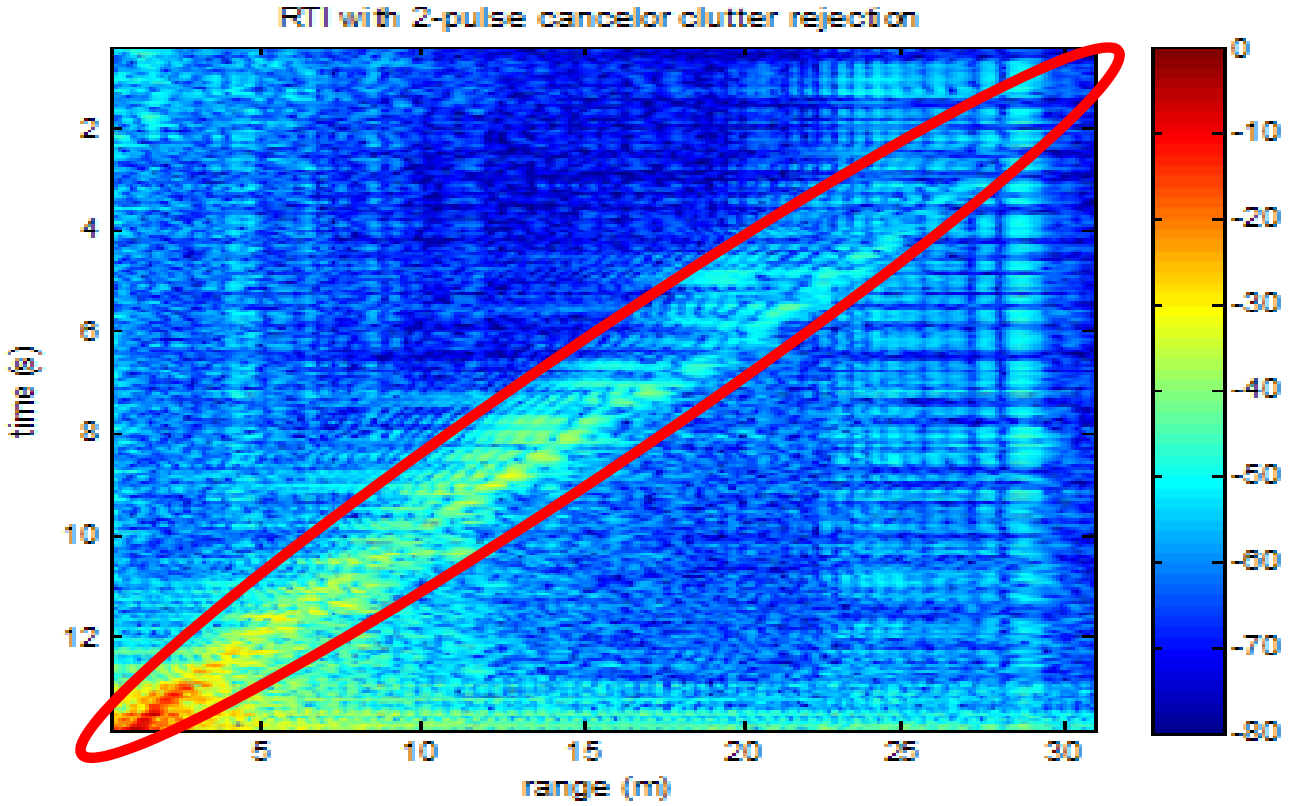

4. RADAR Program using EKF

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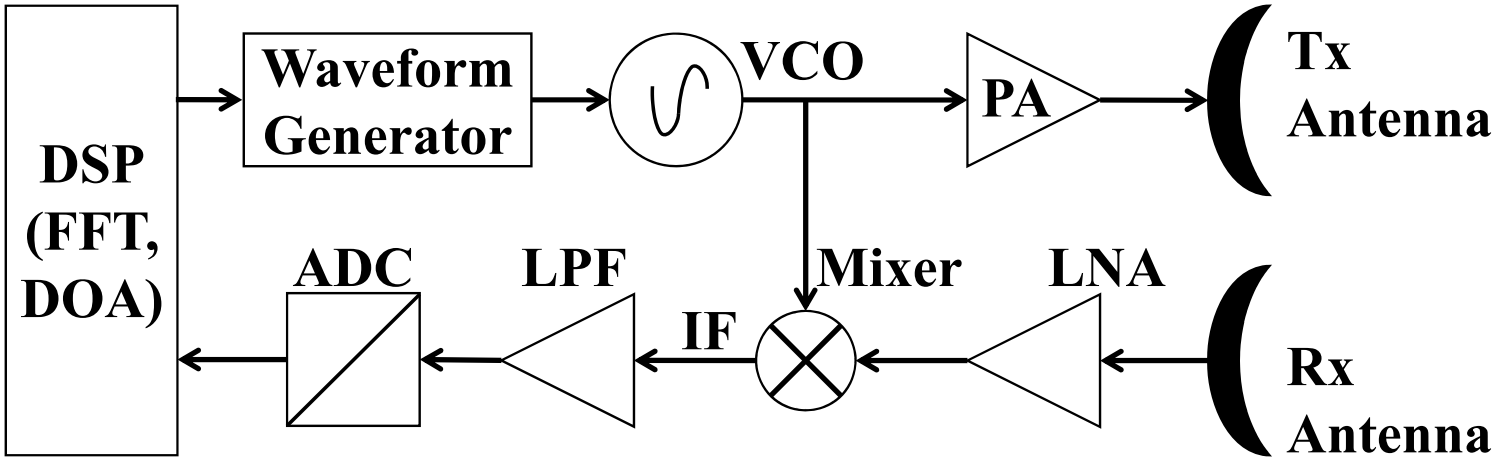

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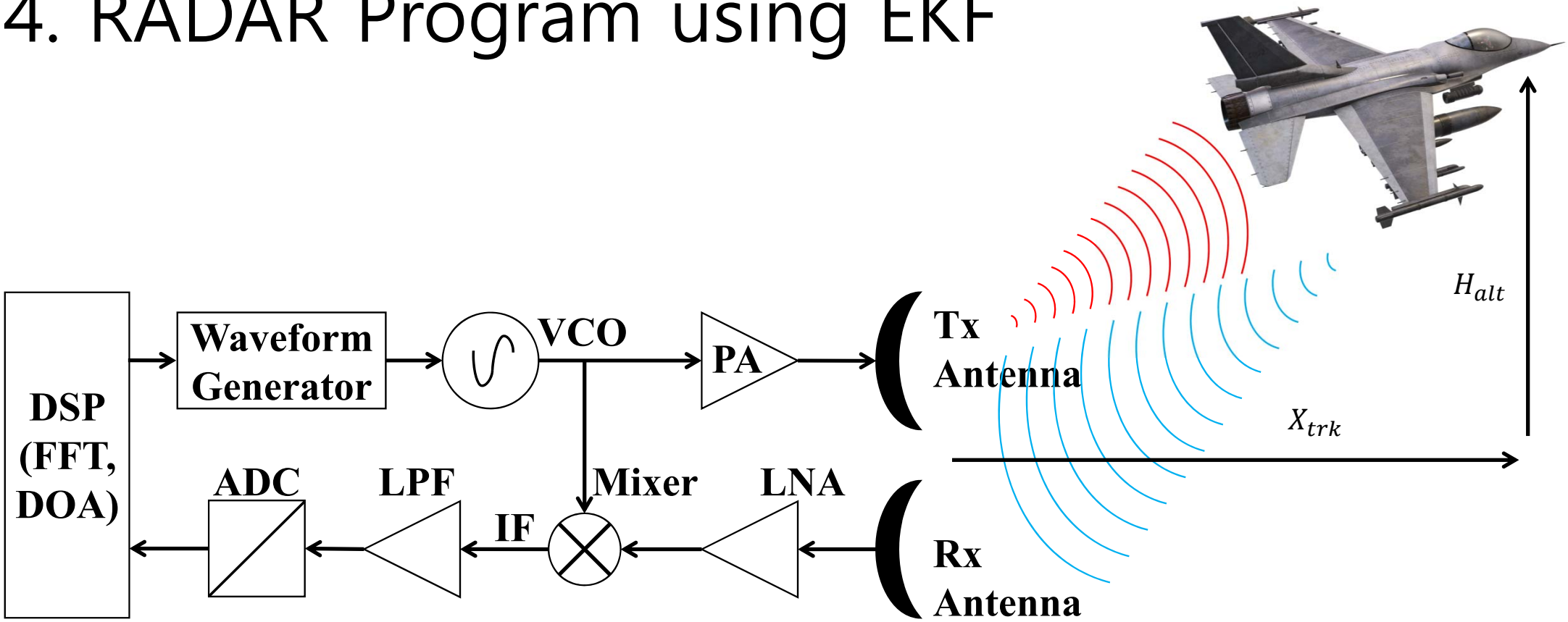

4. RADAR Program using EKF

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수평거리 미분

$$\dot{x}_1 = x_2$$

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수평거리 미분	이동속도 미분	고도 미분
$\dot{x}_1 = x_2$	$\dot{x}_2 = w_1$	$\dot{x}_3 = w_2$

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측정 모델 설계

- 레이더가 측정하는 값은 이동 물체까지의 직선 거리이다.

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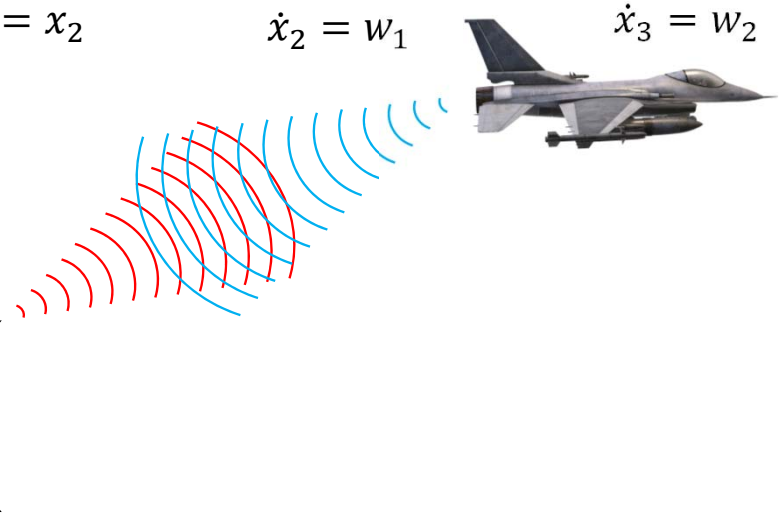

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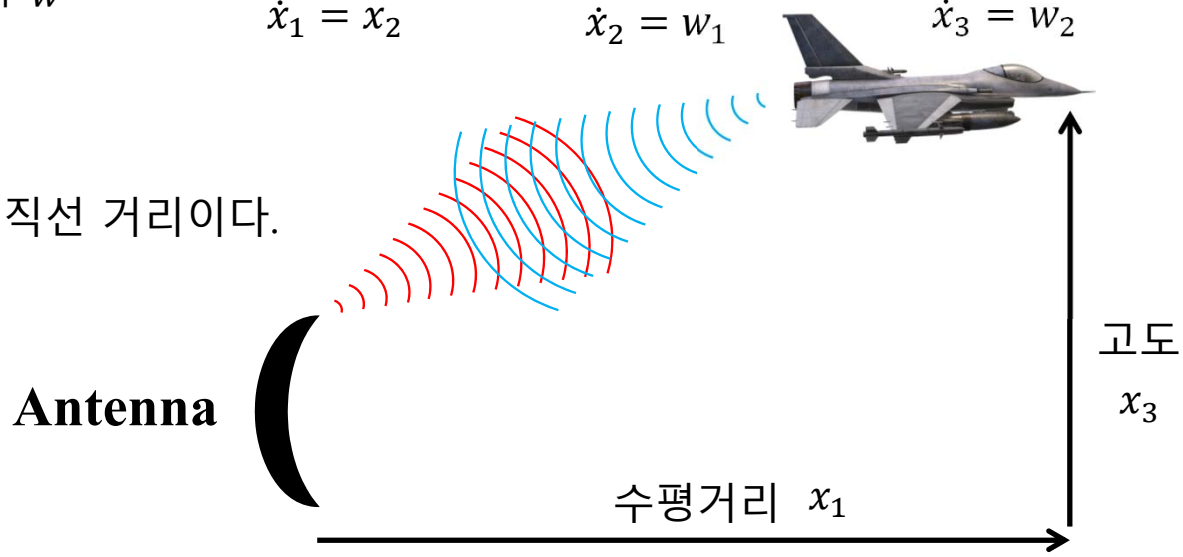

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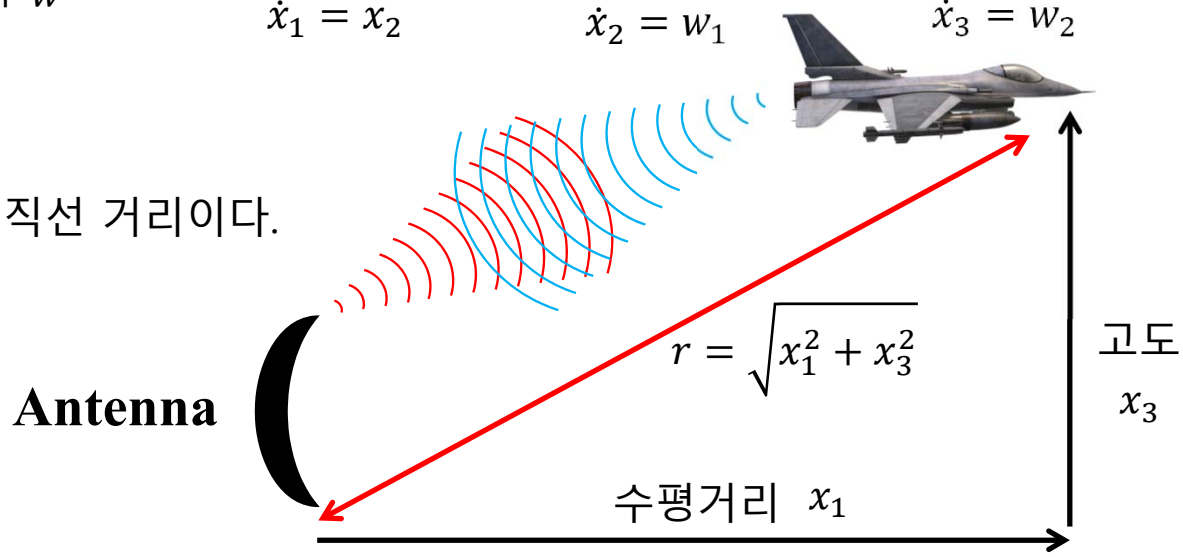

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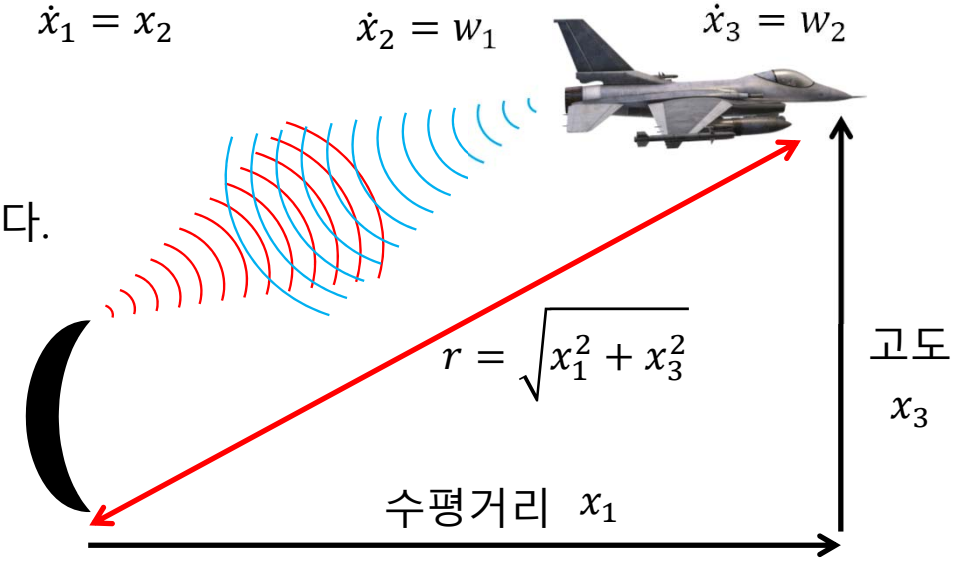

측정 모델 설계

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$$r = \sqrt{x_1^2 + x_3^2} + v \equiv h(x) + v$$

4. RADAR Program using EKF

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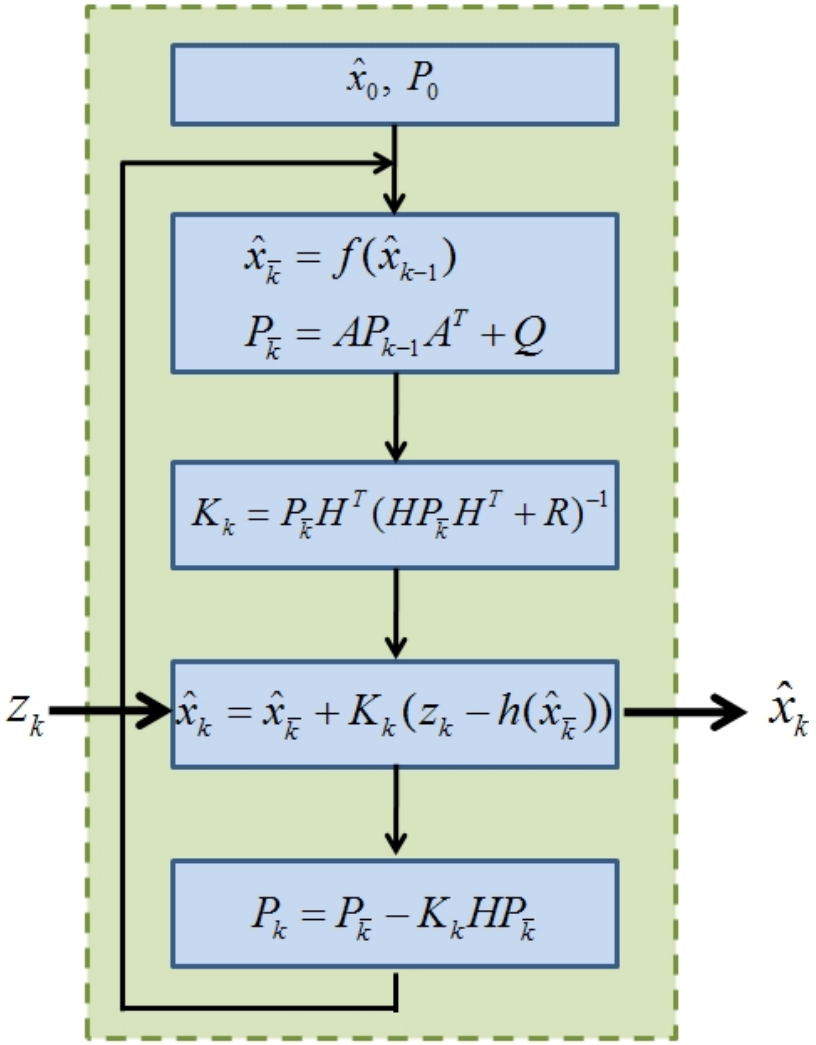
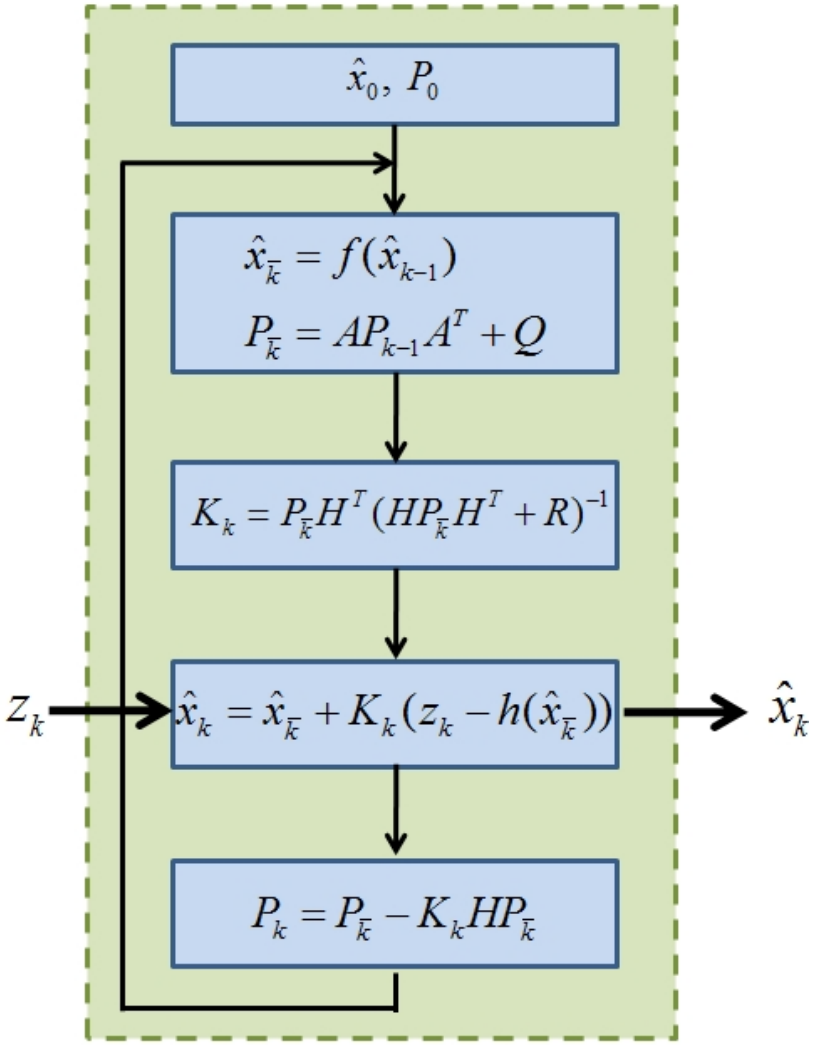


EKF algorithm

4. RADAR Program using EKF



EKF algorithm

$x_{k+1} = f(x_k) + w_k$ $Q = w_k$의 공분산 행렬

$z_k = h(x_k) + v_k$ $R = v_k$의 공분산 행렬

x_k는 상태 변수

z_k는 측정값

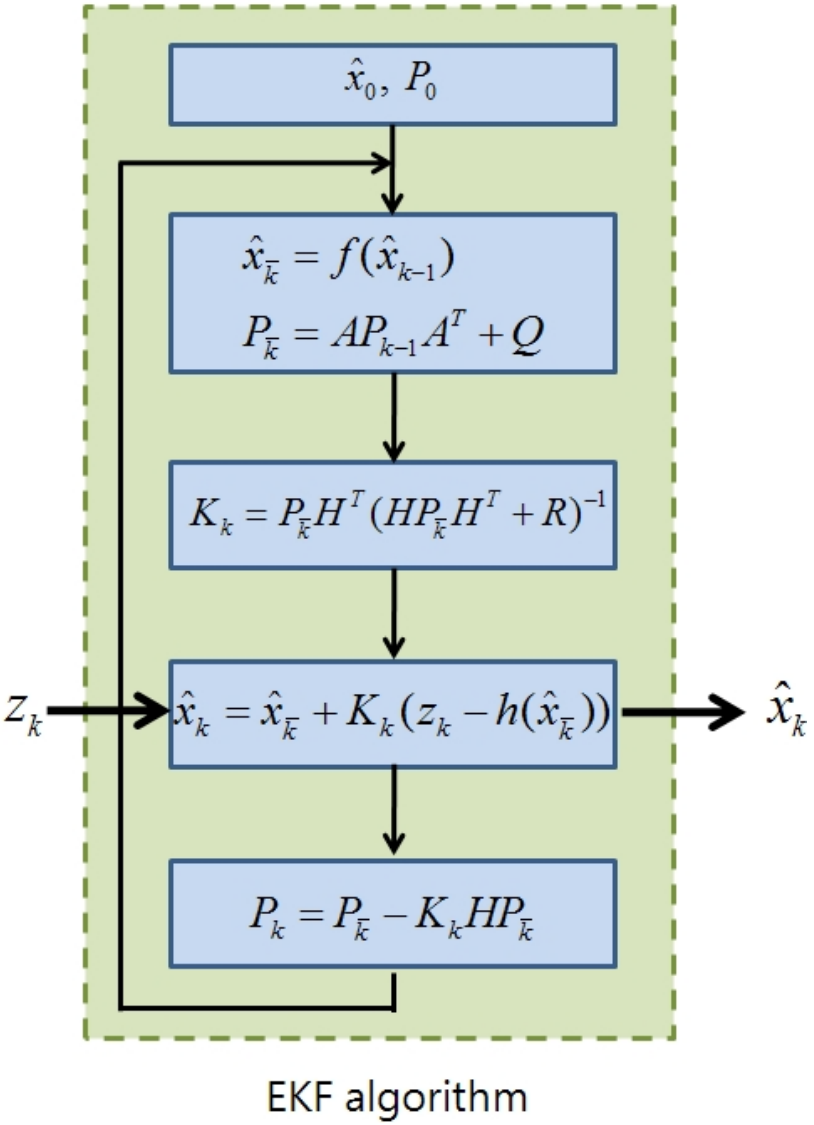
A는 상태전이행렬

H는 mXn 행렬

w_k는 잡음

w_k는 측정 잡음

4. RADAR Program using EKF



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$f(\hat{x}_{k-1}) \Leftrightarrow A\hat{x}_{k-1}$

$h(\hat{x}_k^-) \Leftrightarrow H\hat{x}_k^-$

x_k는 상태 변수

z_k는 측정값

A는 상태전이행렬

H는 mXn 행렬

w_k는 잡음

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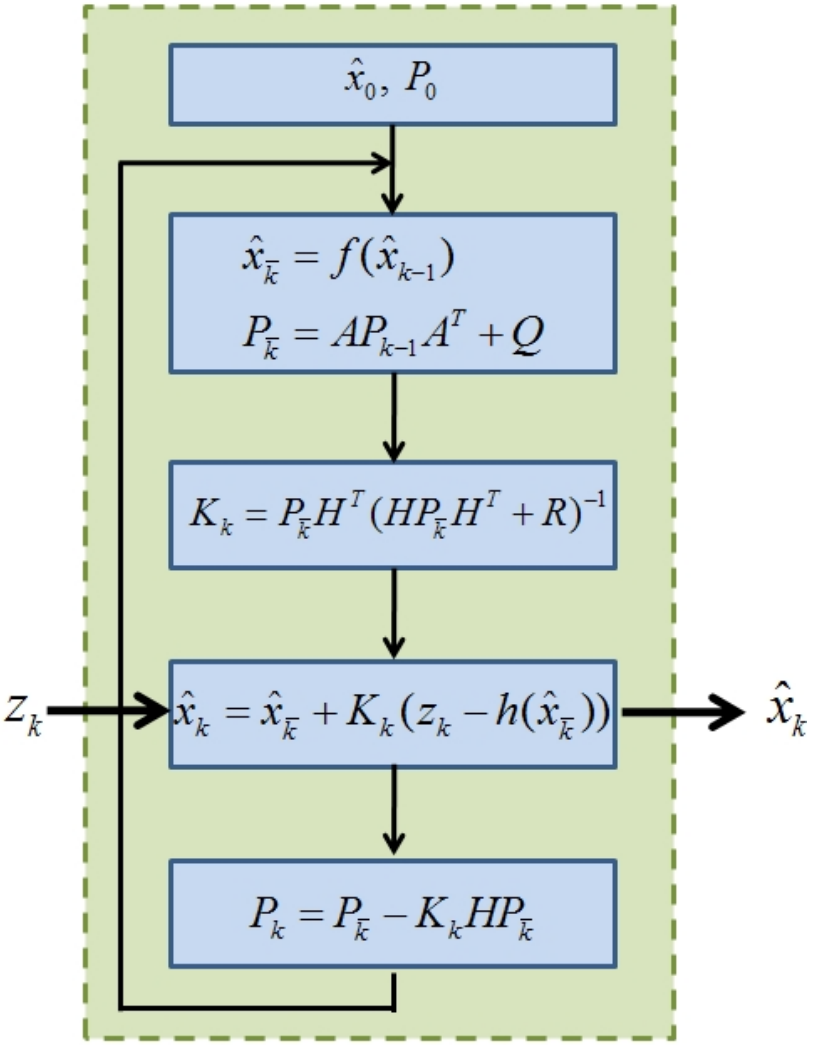
4. RADAR Program using EKF



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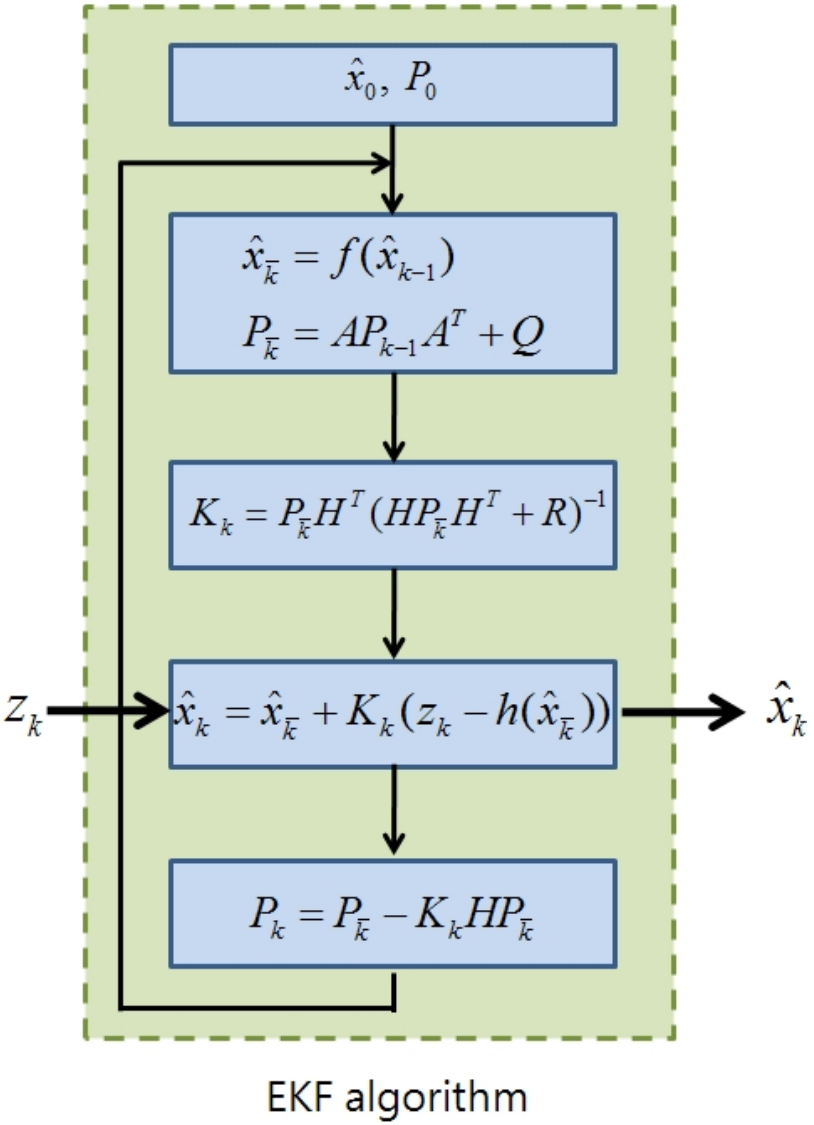

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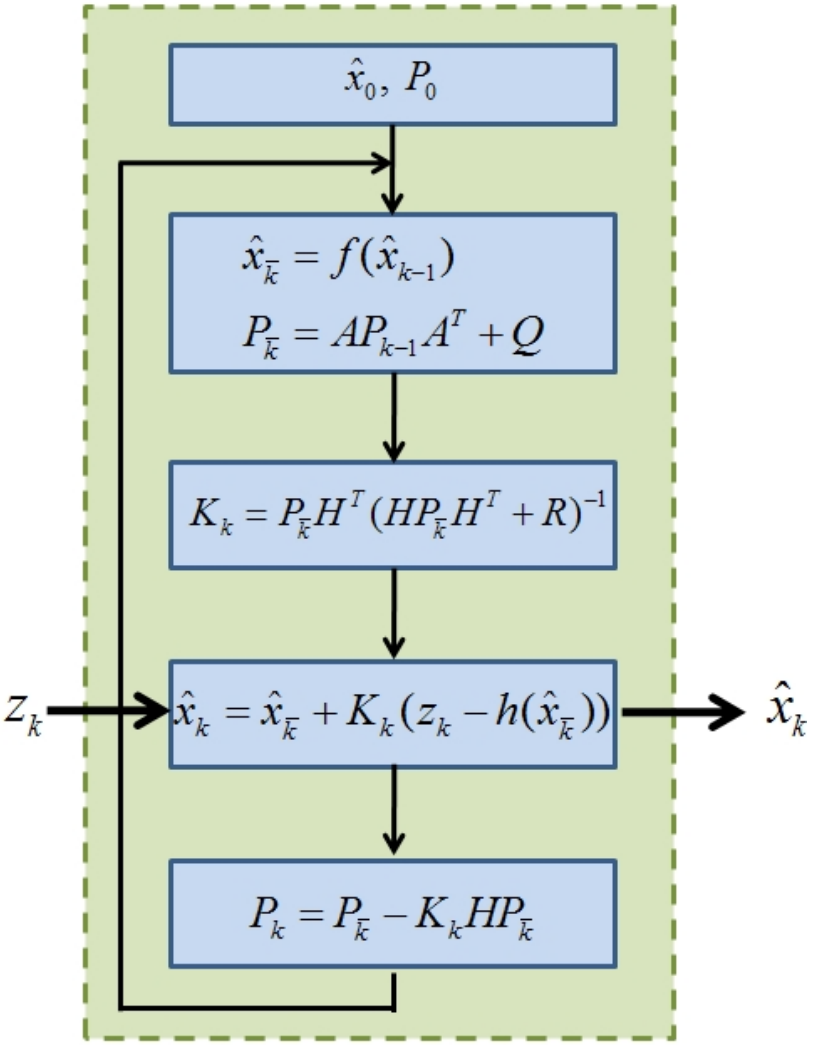
4. RADAR Program using EKF



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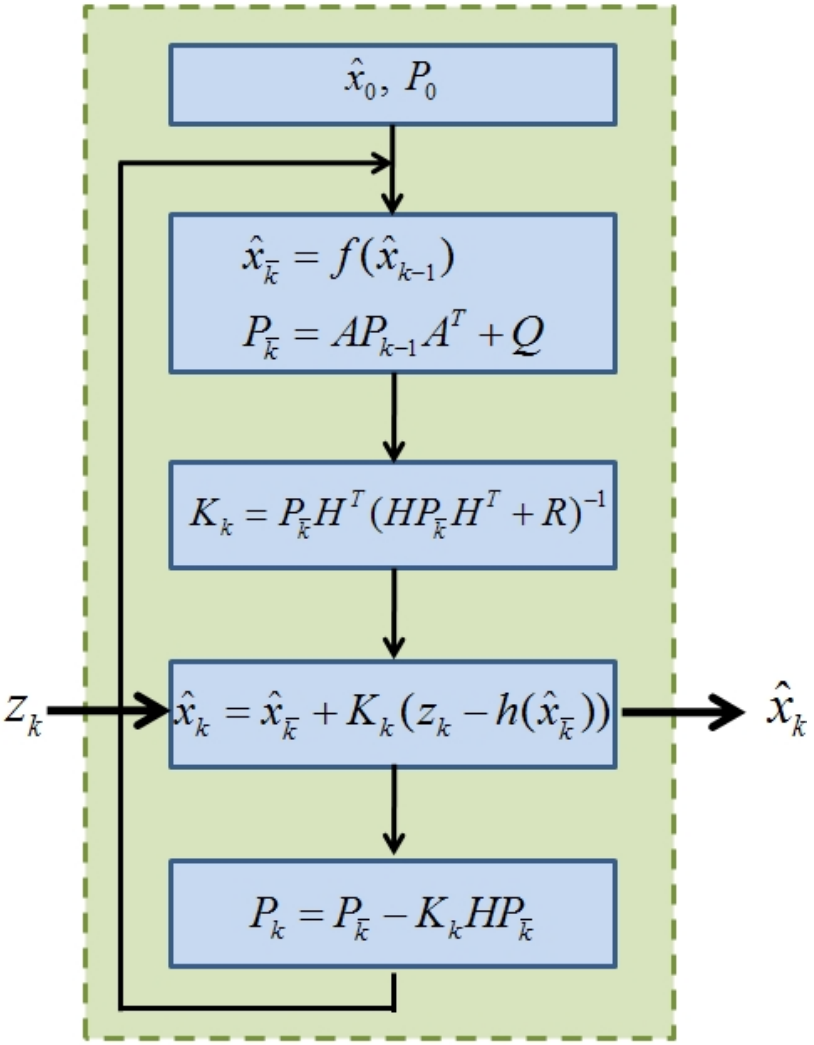

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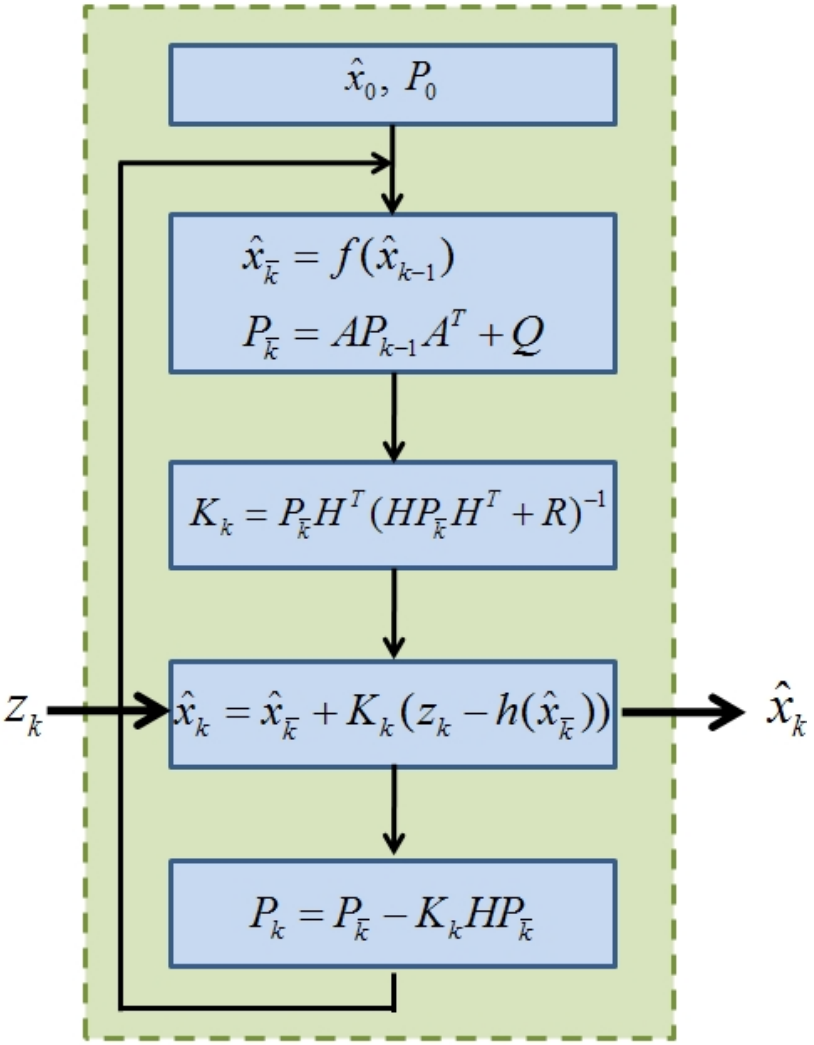

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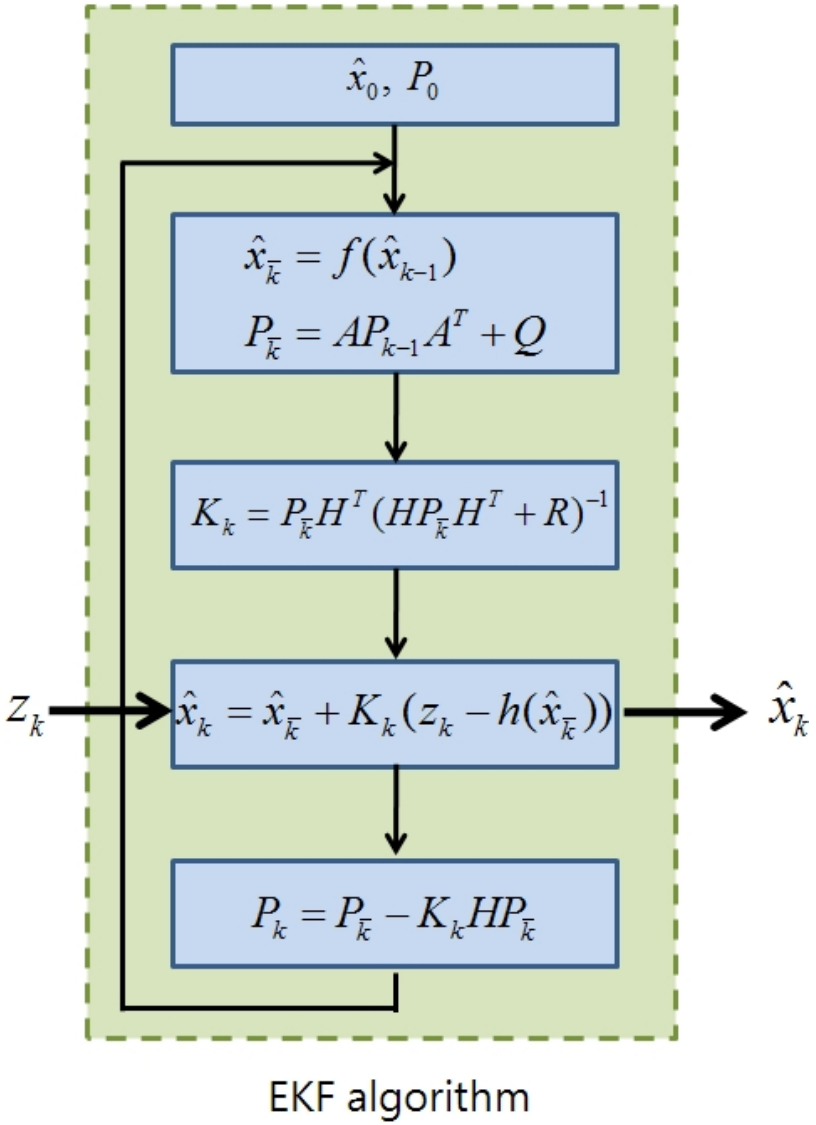
$$H = \begin{bmatrix}\frac{\partial h}{\partial x_1} & \frac{\partial h}{\partial x_2} & \frac{\partial h}{\partial x_3}\end{bmatrix}$$

4. RADAR Program using EKF



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$$H = \begin{bmatrix} \frac{\partial h}{\partial x_1} & \frac{\partial h}{\partial x_2} & \frac{\partial h}{\partial x_3} \end{bmatrix} = \begin{bmatrix} \frac{x_1}{\sqrt{x_1^2 + x_3^2}} & 0 & \frac{x_3}{\sqrt{x_1^2 + x_3^2}} \end{bmatrix}$$

4. RADAR Program using EKF

```
clear all

dt = 0.05;
t  = 0:dt:20;

Nsamples = length(t);

Xsaved = zeros(Nsamples, 3);
Zsaved = zeros(Nsamples, 1);

for k=1:Nsamples
  r = GetRadar(dt);

  [pos vel alt] = RadarEKF(r, dt);

  Xsaved(k, :) = [pos vel alt];
  Zsaved(k)    = r;
end
```

```
PosSaved = Xsaved(:, 1);
VelSaved = Xsaved(:, 2);
AltSaved = Xsaved(:, 3);

t = 0:dt:Nsamples*dt-dt;

figure
plot(t, PosSaved)

figure
plot(t, VelSaved)

figure
plot(t, AltSaved)
```

4. RADAR Program using EKF

```
function r = GetRadar(dt)

persistent posp

if isempty(posp)
  posp = 0; % 초기값
end


vel = 100  +  5*randn; % 100m/s의 속도 + 오차범위 5%
alt = 1000 + 10*randn; % 1Km의 고도 + 오차범위 10%

pos = posp + vel*dt;

v = 0 + pos*0.05*randn;

r = sqrt(pos^2 + alt^2) + v;

posp = pos;
```

4. RADAR Program using EKF

```
function [pos vel alt] = RadarEKF(z, dt)
persistent A Q R
persistent x P
persistent firstRun

if isempty(firstRun)
  A = eye(3) + dt*[ 0 1 0;
                    0 0 0;
                    0 0 0 ];
  Q = [ 0  0      0;
        0  0.001  0;
        0  0      0.001 ];
  R = 10;
  x = [0 90 1100]';
  P = 10*eye(3);

  firstRun = 1;
end

H = Hjacob(x);
xp = A*x;
Pp = A*P*A' + Q;
K = Pp*H'*inv(H*Pp*H' + R);
x = xp + K*(z - hx(xp));
P = Pp - K*H*Pp;

pos = x(1);
vel = x(2);
alt = x(3);
%------------------------------
function zp = hx(xhat)

x1 = xhat(1);
x3 = xhat(3);

zp = sqrt(x1^2 + x3^2);
%------------------------------
function H = Hjacob(xp)

H = zeros(1, 3);

x1 = xp(1);
x3 = xp(3);

H(1) = x1 / sqrt(x1^2 + x3^2);
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$$A = I + \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \times dt$$

```
x = xp + K*(z - hx(xp));
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$$A = I + \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \times dt$$

측정값의 영향을 덜 받고 변화가 완만한 추정값을 얻고 싶다면 행렬 R을 키우고 Q를 줄려야한다.

```
x = xp + K*(z - hx(xp));
P = Pp - K*H*Pp;

pos = x(1);
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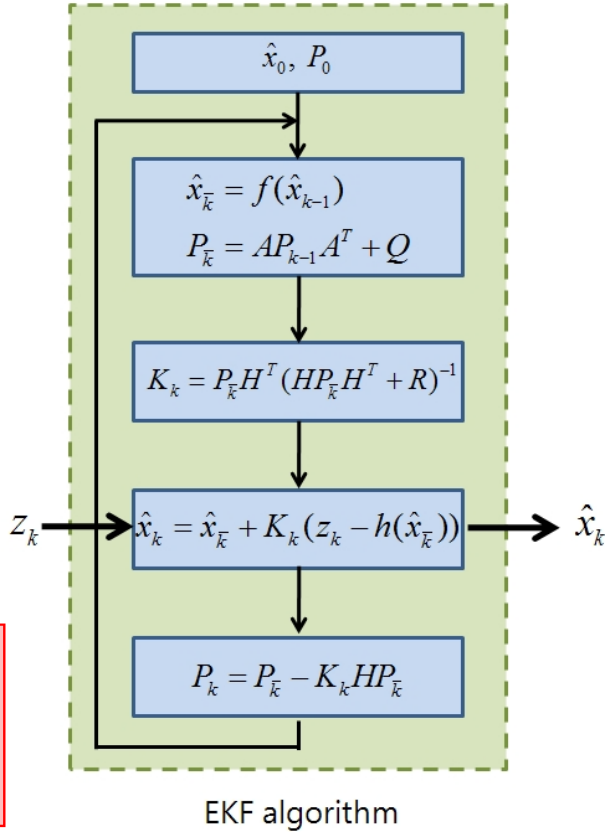

EKF algorithm

```
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```

```
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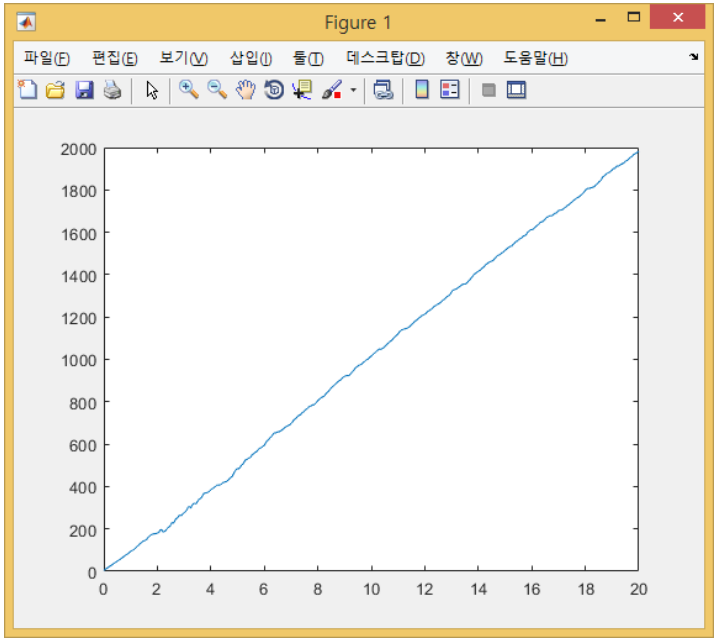
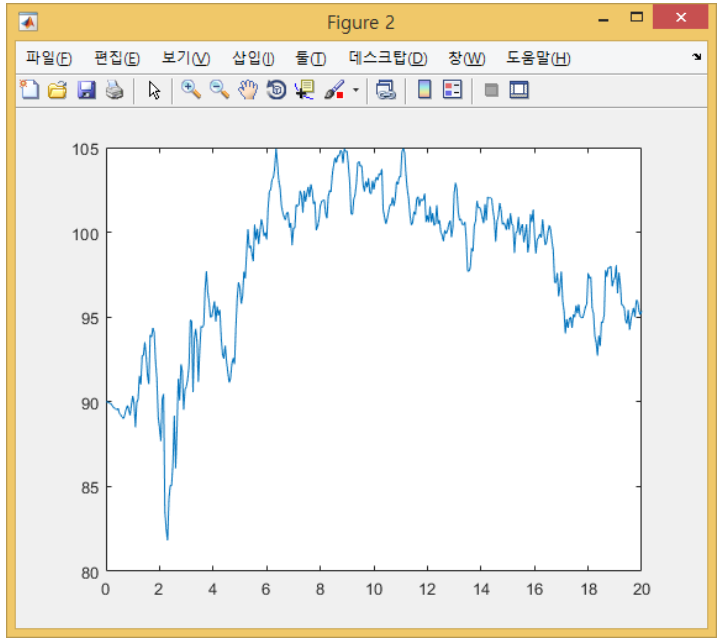
4. RADAR Program using EKF

거리



속도



고도