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Design Interface of Radar Equation by Using MATLAB

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Abstract: *In recent years, the radars of all kinds have become the focus on attention of all countries in peace and war. In addition the radar equation is a fundamental tool to analyze the detection range of radar, So in this paper and with this equation I have designed a graphical user interface (GUI) for radar equation to compute the range by using MATLAB application .The aim of this design it's detect the target as soon as possible by enter the inputs and compute the impotent parameters such as signal-to-noise ratio, bandwidth ……etc.Because the radar equation is more complicatedthan other equations for that reason we are going to try design the interface for that equation by using MATLAB.*
Keywords: *Radar equation, Radar operating frequency, Range of radar.*

I. INTRODUCTION

The radar equation is very successful fundamental tool for analysis of radar operating range and is widely applied in system design for both searching radar and tracking radar[1]. And as we said previous the radar equation is more complicated than others because it contains many important parameters such as, received power, peak transmit power, Transmitter gain.....etc. So We start the paper by design interface form in MATLAB by using 'guide' command which use to create a form and we submit all parameters in Radar equation by using some tools such as ' Edit text , Static text , Push Button ' whatever you want depend on your design , so we are starting by write guide in command window in MATLAB and choose the tools that you need .

II. DETAIL OF WORK

First of all we should write the radar equation to know all input parameters that we are going to insert to the radar equation as important data .Fig 1 show all these parameters.

$$R_{max} = \left(\frac{P_t G^2 \lambda^2 \sigma \;\; n\, E_j(n)}{(4\pi)^2 k T_e B F_n (S/N) L_f(n_e)} \right)^{\frac{1}{4}} \quad [2] .$$

Figure 1. Radar Equation

where the terms in the equation are:
P_t — Peak transmit power in watts.
G — Gain of antenna .
λ — Radar operating frequency wavelength in meters.
σ — Target's nonfluctuating radar cross section in square meters.
k — 1.38e-23
T_e — noise temperature
B — bandwidth
F— noise figure
SNR— signal to noise ratio
R_{max} — Range from the transmitter to the target.
n — number of pulses
Ei— integration improvement pulses

III. DESIGN IN MATLAB

In this step we start design the interface of radar equation in MATLAB by using guide commend but before starting we should divide the parameters in two groups:-

- First group for the parameters which have specific values.
- Second group for the parameters which need to compute.Fig 2 shows these groups and also shown the final interfacedesign.

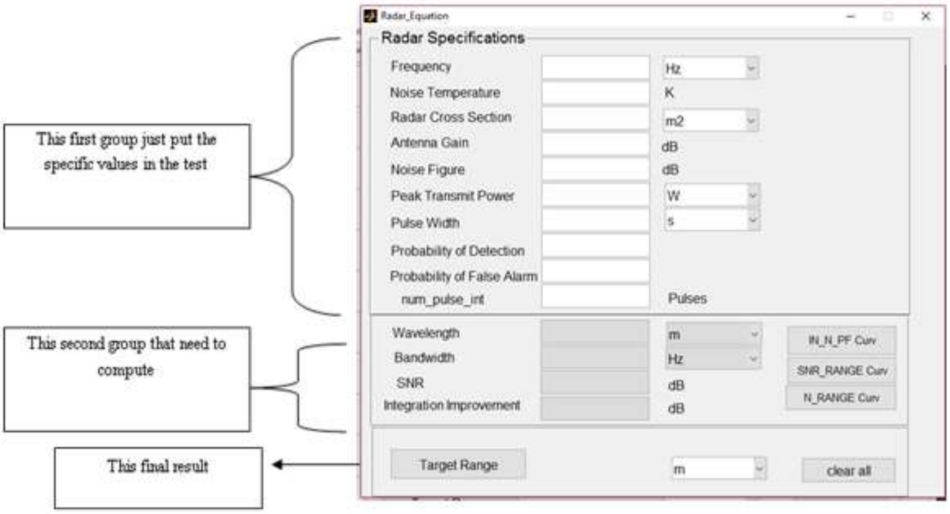

Figure 2.GUI design used to insert data as inputs[3]

IV. THE STEPS IN MATLAB TO DESIGN THE INTERFACE RADAR EQUATION

In this stage we have many steps to starting design interface radar equation in MATLAB First group for the parameters which have specific values.

For first group we need to use these steps below to implement this part:

- First we use the (guide) commend in MATLAB window.
- After use previous commend we will run the GUIDE Quick Start. See fig 3.

Figure 3. GUI first step to start design[3]

Next choose the (Blank GUI (Default)) option then press OK

- Then we will see this window in fig 4.

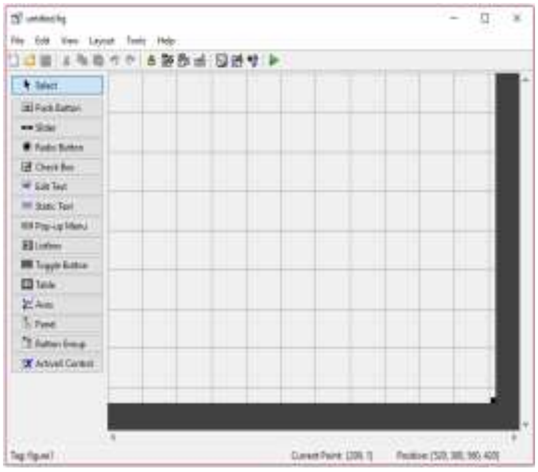

Figure 4. GUI shows the second step design[3]

- As we see in figure 4,there are several tools such as Push Button , Slider ,.......est.
- For first group we have ten differences parameters :

1. Frequency we need ("Static Text", "Edit Text", and "Pop-up Menu") .
2. Noise Temperature we need ("Static Text" and "Edit Text") .
3. Radar Cross Section we need ("Static Text", "Edit Text", and "Pop-up Menu") .
4. Antenna Gain we need ("Static Text" and "Edit Text") .
5. Noise Figure we need ("Static Text" and "Edit Text") .
6. Peak Transmit Power we need ("Static Text", "Edit Text", and "Pop-up Menu") .
7. Pulse Width we need ("Static Text", "Edit Text", and "Pop-up Menu") .
8. Probability of Detection we need ("Static Text" and "Edit Text") .
9. Probability of False Alarm we need ("Static Text" and "Edit Text") .
10. Number of Pulse Integration we need ("Static Text" and "Edit Text")[4].

For second group we should compute all these parameters:

- Wavelength $= \frac{3*10^8}{f_0}$ where $3*10^8$ is velocity and f_0 is frequncy opration[2] .

  we need ("Static Text", "Edit Text", and "Pop-up Menu")
- Bandwidth $= \frac{1}{\text{Pulse width}}$[2].

  we need ("Static Text", "Edit Text", and "Pop-up Menu")

- SNR= $\frac{P_{av}T_iG^2\lambda^2\sigma}{(4\pi)^3R^4kT_eFL}$[1].we need ("Static Text" and "Edit Text")

  where :

P_{av} — Average Power .
G — Gain of antenna .
λ — Radar operating frequency wavelength in meters.
σ — Target's Nonfluctuating Radar Cross Section in Square Meters.
k — 1.38e-23
T_e — Noise Temperature
L — Radar Losses
F— Noise Figure
R— Range from the transmitter to the target.
Ti — Time on Target

SNR= $\frac{P_{av}T_iG^2\lambda^2\sigma}{(4\pi)^3R^4kT_eFL}$[3] .we need ("Static Text" and "Edit Text")

Integration Improvement =

$$[I(n_p)]_{dB} = 6.79(1+0.235P_D)\left(1+\frac{(1/P_{fa})}{46.6}\right)\log\left(1-0.140\log(n_p)+0.018310(\log n_p)^2\right)$$ [3].

where ,
P_D — Probability of Detection .
P_{fa} — Probability falsealarm .
n_p — Number of Pulses.

V. RELATIONSHIP BETWEEN SOME PARAMETERS SHOWN BY MATLAB

- Relationship Between The integration Improvement ,Probability of Detection, Probability False and Number of Pulses shown in fig 5. For this work we need to write this script code 1 in MATLAB.

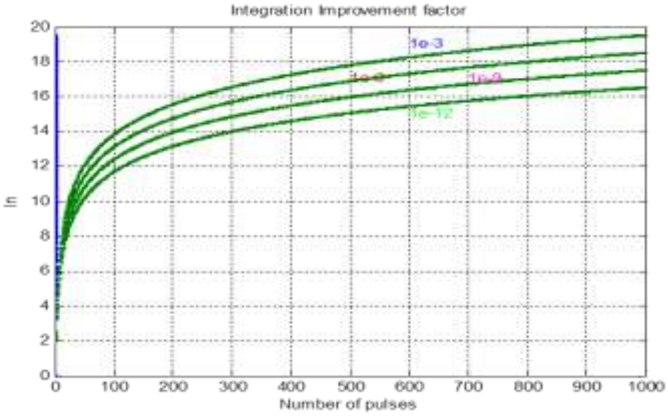

Figure 5. Graphshows relationship between integration Improvement, P_D , P_{fa}andn_p[5] .

- Relationship Between The SNR and The Range of Radar shown in fig 6 .To plot this figure we need to write this script code2 in MATLAB.

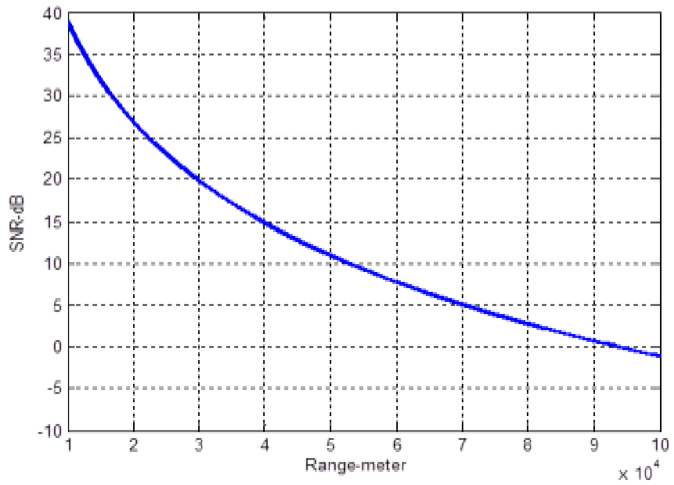

Figure 6. Graphshows relationship between SNR and the range[5].

- Relationship between Number of Pulses and The Range of Radar shown in figure 7. In this figure we need to write this code3 below in MATLAB.

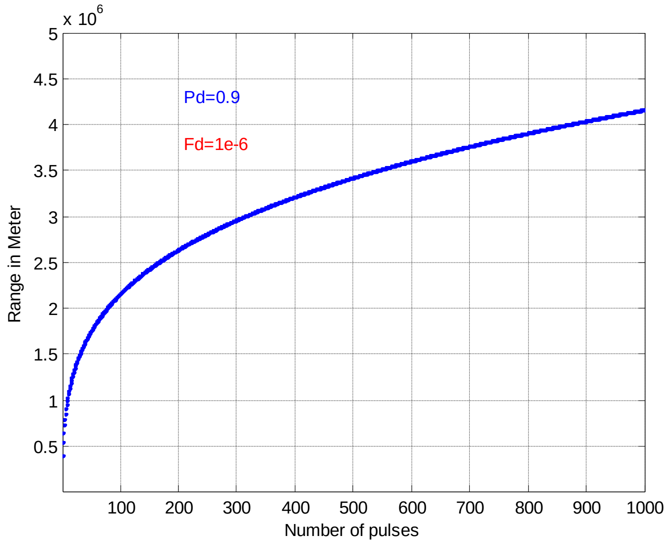

Figure 7. Graphshows relationship between n_p and the range [5] .

VI. THE FINAL DESIGN

Finally, we designed the interface of the radar equation and now ready to compute the range just enters the specific values of parameters and get the result which shown in fig 8.In MATLAB to compute the range of radar we need ("pushbutton", "Static Text", "Edit Text", and "Pop-up Menu") and then write code 4 in MATLAB .

Figure 8.GUI final design used to obtain the result[3] .

VII. CONCLUSION

In this article we have deal with radar equation and we designed the GUI interfaces in MATLAB to calculate the range of radar and get the results .MATLAB has great ability in design and dealing with complex equations to obtain the important calculations .And also by MATLAB we plotted some graphs to show the relationship between many parameters. Finally by MATLAB we solve some problems in radar equation such as calculate SNR. The task is to calculate the range of the radar accurately by its own equations in MATLAB.

REFERENCES

[1] B. R. Mahafza, *Radar Systems Analysis and Design Using MATLAB*, 3rd ed., 2013.
[2] M. I. Skolnk, *Introduction to Radar Systems*, 3rd ed., 2001.
[3] B. R. Mahafza and A. Z. Elsherbeni, *MATLAB Simulations for Radar System Design* 2003.
[4] A. K. Gupta, *Numerical Methods using MATLAB*, 2014.
[5] G. Walter, *Learning MATLAB Aproblem Solving Approach*, 2014.

Code 1

```
% --- 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)
figure
PPf=1e-3
for N=1:1000
    for PPd=0.1:0.99
In=6.79*(1+0.235*PPd)*(1+(log10(1/PPf))/(46.6))*(log10(N))*(1-
0.140*log10(N)+0.018310*(log10(N))^2)
plot([PPd,N],In)
hold on
plot(PPf)
hold on
    end
end
grid
xlabel('Number of pulses')
ylabel('In')
text(600, 19, '1e-3', 'Color', 'b');
hold on
PPf=1e-6
for N=1:1000
    for PPd=0.1:0.99
In=6.79*(1+0.235*PPd)*(1+(log10(1/PPf))/(46.6))*(log10(N))*(1-
0.140*log10(N)+0.018310*(log10(N))^2)
plot([PPd,N],In)
hold on
plot(PPf)
hold on
    end
end
```

```
text(500, 17, '1e-6', 'Color', 'r');
hold on
PPf=1e-9
for N=1:1000
    for PPd=0.1:0.99
In=6.79*(1+0.235*PPd)*(1+(log10(1/PPf))/(46.6))*(log10(N))*(1-
0.140*log10(N)+0.018310*(log10(N))^2)
plot([PPd,N],In)
hold on
plot(PPf)
hold on
    end
end
text(700, 17, '1e-9', 'Color', 'm');
hold on
PPf=1e-12
for N=1:1000
    for PPd=0.1:0.99
In=6.79*(1+0.235*PPd)*(1+(log10(1/PPf))/(46.6))*(log10(N))*(1-
0.140*log10(N)+0.018310*(log10(N))^2)
plot([PPd,N],In)
hold on
plot(PPf)
hold on
    end
end
text(600, 15, '1e-12', 'Color', 'g');
title('Integration Improvement factor')
```

Code 2

```
% --- 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)
figure
Fc=5.6e9; % carrier frecuancy
Pav=30e3;   % average power
Pav_dB=log10(Pav)*10;
Ti=2;        % dwell interval
Ti_dB=log10(Ti)*10;
Gtt_dB=20  % antenna gain
lamda = 3e8/Fc; % wavelenght
lamda_dB=(log10(lamda)*10)*2
Rcs=0.01   % radar cross section
Rcs_dB=log10(Rcs)*10;
Te=400  % noise tempeature
K=1.38e-23;  % constant
KTe_dB=log10(K*Te)*10;
Fnn_dB=5  % noise figure
Loss_dB=8   % loss figure
Pi_dB=log10((4*pi)^3)*10;


for R=10000:100000
SNR__dB=(Pav_dB+(Gtt_dB*2)+lamda_dB+Rcs_dB+Ti_dB)-
(Pi_dB+(log10(R^4)*10)+KTe_dB+Fnn_dB+Loss_dB)
plot(R,SNR__dB)
hold on
    end
axis([10000,100000,-10,40])
grid
xlabel('       Range-meter')
ylabel('SNR-dB')
```

Code 3

```
% --- Executes on button press in pushbutton5.
function pushbutton5_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
figure;
Pf=1e-6;
Pd=0.9;
Fcc=5.6e9; % carrier frequency
K=1.38e-23; % constant
Wave_lenght_sq_dB=(log10(3e8/Fcc)*10)*2; %wave length;
Pulsewidth=0.2e-6;
Bandwidth=1/Pulsewidth
Te=290; % noise temprature
K_Te_B_dB=log10(K*Te*Bandwidth)*10
RCS=0.1; % radar cross section
RCS_dB=log10(RCS)*10
G_sq_dB=45*2 % gain antenna
Noise_Fig_dB=3
Ptt=1.5e6; % noise figure
N_pulses=100
N_pulses_dB=log10(N_pulses)*10
P_transsmit_dB=log10(Ptt)*10  % peak power
four_PI_cube_dB=10*log10((4*pi)^3)
for N_pulses=1:10000
    SNR=-
5*log10(N_pulses)+(6.2+(4.54/(N_pulses+0.44)^0.5))*log10(log(0.62/Pf)+0.12*log(0.62/Pf)*
log(Pd/(1-Pd))+1.7*(log(Pd/(1-Pd))))%%SNR=?5log10N+[6.2+4.54/(N+0.44)^0.5]log10(A+0.12AB+1.7B)
Int_improvementin_dB=6.79*(1+(0.235*Pd))*(1+(log10(1/Pf))/46.6)*log10(N_pulses)*((1-
(0.140*log10(N_pulses)))+(0.018310*(log10(N_pulses))^2))
Range_in_dB=(P_transsmit_dB+G_sq_dB+Wave_lenght_sq_dB+RCS_dB+Int_improvementin_dB+N_pulses_dB)
-(four_PI_cube_dB+K_Te_B_dB+SNR+Noise_Fig_dB);  %// Maximum Range in dB
Rmax_in_meter=(10^(Range_in_dB/10))^0.25       %// Maximum Range in meter
plot(N_pulses,Rmax_in_meter)
hold on
end
    grid
axis([1,1000,10000,5000000])
xlabel('Number of pulses')
ylabel('Range in Meter')
text(210, 4300000, '    Pd=0.9', 'Color', 'b');
text(210, 3800000, '    Fd=1e-6', 'Color', 'r');
```

Code 4

```
% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
Frq_op=str2num(get(handles.edit1,'string'));           %// Frequency Operation
Noise_temp=str2num(get(handles.edit2,'string'));       %// Noise Temperature
RCS=str2num(get(handles.edit3,'string'));              %// Radar Cross Section
A_Gain_dB=str2num(get(handles.edit4,'string'));        %// Antenna Gain
Noise_Fig_dB=str2num(get(handles.edit5,'string'));     %// Noise Figure
SNR=str2num(get(handles.edit6,'string'));              %// SNR
P_transmit=str2num(get(handles.edit7,'string'));       %// Peak TrnsmitPowew
PW=str2num(get(handles.edit8,'string'));               %// Pulse Width
Wave_lenght=str2num(get(handles.edit9,'string'));      %// Wavelenght
Bandwidth=str2num(get(handles.edit10,'string'));       %// Bandwidth
Pd=str2num(get(handles.edit11,'string'));              %// Probability of Detection
Pf=str2num(get(handles.edit12,'string'));              %// Probability of False Alarm
N_pulses=str2num(get(handles.edit13,'string'));        %// Number OF pluses integration
Int_improvement=str2num(get(handles.edit16,'string')); %// Integration Improvement
Frq_op=str2num(get(handles.edit14,'string'));     %
P_transmit=str2num(get(handles.edit15,'string'));%
N_pulses_dB=log10(N_pulses)*10;
SNR=-5*log10(N_pulses)+(6.2+(4.54/(N_pulses+0.44)^0.5))*log10(log(0.62/Pf)+0.12*log(0.62/Pf)*
log(Pd/(1-Pd))+1.7*(log(Pd/(1-Pd))))%%SNR=?5log10N+[6.2+4.54/(N+0.44)^0.5]log10(A+0.12AB+1.7B)
%Int_improvementin_dB=6.79*(1+0.235*Pd)*(1+(log(1/Pf)))*log10(N_pulses)*((1-
0.140*log(N_pulses))+(0.018310*log(N_pulses))^2)
```

```
Int_improvementin_dB=6.79*(1+(0.235*Pd))*(1+(log10(1/Pf))/46.6)*log10(N_pulses)*((1-
(0.140*log10(N_pulses)))+(0.018310*(log10(N_pulses))^2))
set(handles.edit16,'string',Int_improvementin_dB)
set(handles.edit6,'string',SNR)
Wave_lenght_sq_dB=log10(Wave_lenght)*10*2         %// ? (wavelenghtsquer) in dB
K_constant=1.38e-23;                              %// K constant
K_Te_B_dB=log10(K_constant*Noise_temp*Bandwidth)*10        %// K_Te_B (constant*noise
temperature * bandwidth) in dB
P_transsmit_dB=log10(P_transsmit)*10                %// Pt (peak transmit power) in dB
G_sq_dB=A_Gain_dB*2                         %// G^2 (antenna gain squer)in dB
RCS_dB=log10(RCS)*10               %// RSC (Radar Cross Section) in dB
Bandwidth_indB=log10(Bandwidth)*10;
four_PI_cube_dB=log10((4*pi)^3)*10 ;         %// (4*pi)^3 in dB
%Range_in_dB=(P_transsmit_dB+G_sq_dB+Wave_lenght_sq_dB+RCS_dB)-
(four_PI_cube_dB+K_Te_B_dB+SNR+Noise_Fig_dB);  %// Maximum Range in dB
Range_in_dB=(P_transsmit_dB+G_sq_dB+Wave_lenght_sq_dB+RCS_dB+Int_improvementin_dB+N_pulses_dB)
-(four_PI_cube_dB+K_Te_B_dB+SNR+Noise_Fig_dB);  %// Maximum Range in dB
Rmax_in_meter=(10^(Range_in_dB/10))^0.25;        %// Maximum Range in meter
set(handles.text19,'string',Rmax_in_meter)
```

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