■ 1176

Design of radar display of Indonesian airspace monitoring application

Sulistyaningsih*[1], Yussi Perdana Saputera[2], Mashury Wahab[3], Yudi Yulius Maulana[4]
[1,3,4]Research Center for Electronics and Telecommunication-Indonesian Institute of Sciences (PPET-LIPI),
Kampus LIPI, Sangkuriang St. Building 20, 4th Floor, Cisitu, Bandung 40135, Indonesia,
tel/fax: +62-2504660/+62-2504659
[2]Faculty of Engineering, Universitas Islam Nusantara
Soekarno-Hatta St. No. 530, Sekejati, Buah Batu, Bandung 40286, Indonesia, tel: +62-27509656
*Corresponding author, e-mail: sulistyaningsih@gmail.com, yussips@gmail.com

Abstract

In this research, the design and manufacture of radar display software using Plan Position Indicator (PPI) format for air surveillance radar application are presented. The PPI display shows interpretations of echo detections of radar signal reflected from the flying objects/targets. The detection results will be displayed on a circular 360º area, where the radar position is at the center. System configuration is done via interface from the display, by adjusting the level of transmit signal, by setting the gain for threshold, and by enabling moving target indicator (MTI) mode. The MTI mode only displays moving objects and no non-moving objects are shown such as mountains and buildings. Based on the results of this research, the PPI display shows the targets on the display according to its position, some desired targets can also be tracked, information on target, GPS location, target ID, required parameters, and some settings. The radar display fulfills all the required capabilities for air surveillance radar.

Keywords: air surveillance, display and MTI, PPI, radar

1. Introduction

Indonesia is one of the largest archipelagic countries and has vast territory. Indonesia uses a straight base line from the outermost point of the outer islands so that Indonesia, according to the 1982 Sea Law Convention, is called an archipelago state. This provision adds to the extent of Indonesia's airspace, as set forth in Article 1 of the Chicago Convention of 1944, that every state has full and exclusive sovereignty over the airspace above it, both on land and over the territorial sea [1]. The airspace of Indonesian territory is calculated from the air space above the 12 nm boundary of the outermost island coast as shown in the following Figure 1.
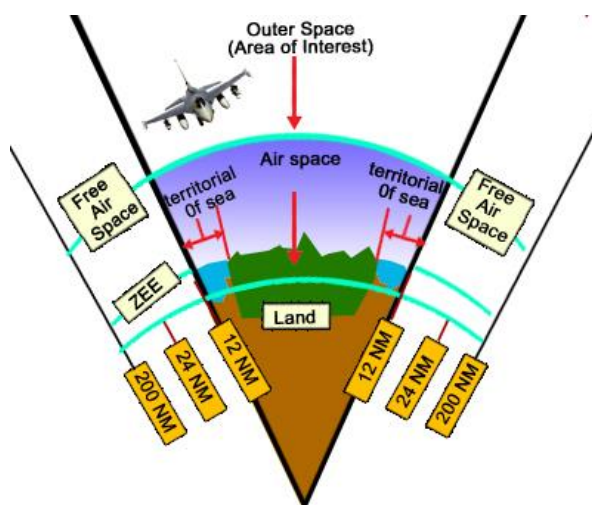

Figure 1. Area of Indonesian airspace

Radar has long been used in military and commercial applications [2]. The role of air surveillance radars for monitoring, defense and security in maintaining the sovereignty of the Indonesian republic is very important. The developed air surveillance radar presented in this study, is divided into two sub-sections of the system, namely hardware and software sub-systems. Software sub-system is divided into display software that serves as a graphical user interface (GUI) between the user and the radar, and signal processing software to process analog signal to become digital signal and also perform some computations. Display software as the GUI uses Plan Position Indicator (PPI) to show the detected target on the screen. This software was developed using QT creator software that runs on Ubuntu 14 (Linux) operating system. The role of radar displays is to observe and plot of the results of object detection including real objects, clouds, rain, and noise.

2. Basic Theory
2.1. Air Surveillance Radar

Air Surveillance Radars are designed for early warning, tracking, air, land and maritime surveillance [3-6]. The radars can be installed on fixed-wing aircrafts, helicopters, ground/land or on remotely piloted vehicles (RPV's) [7-9]. Over the years, radar has been used for many and varied military and non-military purposes [10, 11]. Most Federal Government radars are functionally classified as either surveillance or tracking radars, or some combination of the two. A surveillance radar is designed to continuously search for and detect new targets. The basic function of surveillance radar has a 2-dimensional (2-D) plot showing the target object position in degrees from North (azimuth) and range (distance) from the radar [12, 13]. Radars that can determine azimuth, distance, and elevation are called 3-dimensional (3-D) radars. A tracking radar calculates a path for individual targets by using radar return echoes from one scan to the next and are usually 3-D radars. Radars that perform both surveillance and tracking are loosely called multi-mode radars.

2.2. Radar Display

The information retrieved from the radar receiver has a large size of several mega bits per second and should be processed in real time. From these and other data, such as the angle/azimuth of the antenna, the indicator on the display should depict a continuous, easily understandable, graphical picture about the relative positions of radar targets. It should provide size, shape, and insofar as possible, indications of the type of targets. A cathode-ray tube (CRT) fulfils these requirements to an astonishing degree. The cathode-ray tube's principal shortcoming is that it cannot present a true three-dimensional picture. The fundamental geometrical quantities involved in radar displays are the RANGE, AZIMUTH ANGLE (or BEARING), and ELEVATION ANGLE. These displays relate the position of a radar target to the origin at the antenna. Most radar displays include one or two of these quantities as coordinates on the CRT monitor. The actual range of a target from the radar, whether on the ground, in the water, or in the air is known as SLANT RANGE. The majority of displays use as one coordinate the value of slant range, its horizontal projection (GROUND RANGE), or its vertical projection (ALTITUDE). Range is displayed by means of a linear time-base sweep, starting from a given point or line at a definite time in each pulse cycle. Thus, distances along this range sweep actually measure slant range. The sweep speed determines the scale factor, which relates the distance on the tube to actual range. The sweep length is the total represented distance. Distances are expressed in miles (statute or nautical) or yards. The origin of the range sweep may be on or off the tube screen [14].

2.3. Plan Position Indicator (PPI)

The PPI, also called the P-Scope, is by far the most commonly used radar display [15-18]. Example of PPI for air radar at airport ATC can be seen in Figure 2. It is an intensity modulated circular display on which echo signals are shown in plan position with range and azimuth angle displayed in polar coordinates. It is a polar coordinate display of the area surrounding the radar platform. The radar is represented as the origin of the sweep, which is normally located in the center of the scope, but may be offset from the center on some sets. The PPI uses a radial sweep pivoting about the center of the presentation. A long-persistence screen is used so that the display remains visible until the sweep passes again. The origin of

the polar coordinates is at the location of the radar, and is normally located at the center of the display. The PPI uses a radial sweep pivoting around the center. The result is a map-like display of the area covered by the radar beam. Azimuth angle to the target is indicated by the target's angular position in relation to a line extending vertically from the sweep origin to the top of the scope. Example of PPI for air radar made in Indonesia can be seen in Figure 3.

Figure 2. Example of PPI for air radar at airport ATC

Figure 3. Example of PPI for air radar made in Indonesia

3. Development, Results and Analysis

In this study, the manufacture of air surveillance radar is divided into 2 subsystems, software and hardware [19]. This research was designed of radar display of Indonesian airspace monitoring application. The design of airspace radar display software is based on the needs of Arhanud TNI-AD who need airspace radar to help monitor Indonesian airspace. In generally, the manufacture of display software for airspace radar is made by large companies based in Europe and America. This radar display software research used to answer the needs of Arhanud TNI-AD as a user. The hardware of air surveillance radar as shown on Figure 4.

3.1. Radar Software Flowchart

Main loop flowchart as shown on Figure 5. In designing the main display, load configuration data method is used. This method updates processes from command information which can generate feedback from RF (radio frequency) part when the RF receive commands. Therefore, data coming from RF and return to RF for emission through the process of data execution with the parameters of the variable that can be input manually. Data processing is

performed in accordance with each feature will result in appearance in the main window. In the main windows section, the user can give commands to the radar. The command is through variable calling and data construction process of automatic radar plotting aid (ARPA), where radar data is plotted to show the position of the detected object on the next line and distance, and this is also to show the intensity of the detected power level of the radar object. Color intensity degradation is known by the color, where red color show the very strong intensity while blue is the very weak object detection (can also be noise). One of the most important parameters in performing the process of plotting objects on a radar display is the time, where real time data processes should be performed on the PPI display. Radar display loop flowchart as shown on Figure 6.

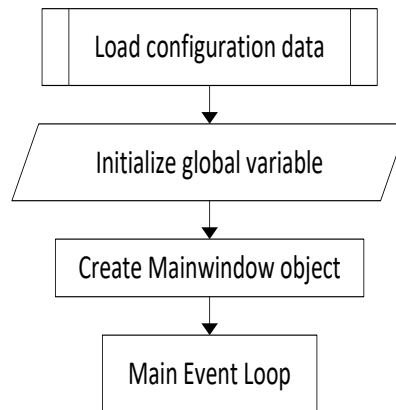Figure 4. The hardware of Air Surveillance Radar (made in Indonesia)
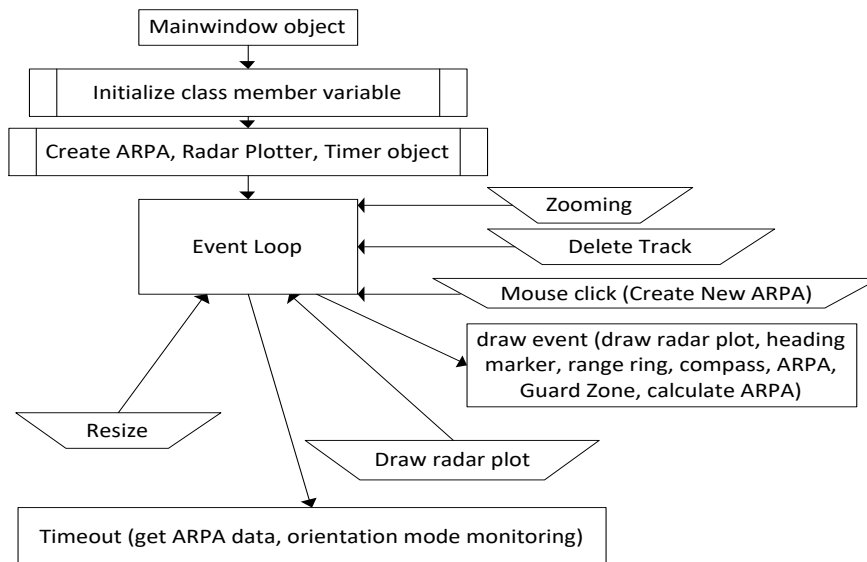
Figure 5. Main loop flowchart

Figure 6. Radar display loop flowchart

All the results of the objects detection can be obtained by the repetition process using these commands. With the input data looping start from the zooming process, delete tracking of the tracking object that has been done, delete can be done to each data, as well as all of data. Subsequent data entry is a command for ARPA data processing, and other input data in the form of radar plot command set the direction of point 0 in the north or 0 degrees, range rings, GPS data and Guardzone. The process of sorting data in the guardzone specified by settings

the distance and angle on guardzone. When an object enters the guard zone area, the radar display will perform the identification process, thus sending the message to the alarm and displaying a threat message.

Radar display settings are done by changing the ranges of detection to PPI, where this command will activate the resize command to the results of detection. When the object's detection distance is at close range, then the resolution generated from the object detection will be large in the corner, so that the object shown in the PPI is clearer. When the detection distance is far, the size of object will decrease as the resolution is set to 512. The range in the process starts from 1, 1.5, 3, 6, 16, 32, 64 and 72 km. Radar function that can be done repeatedly is on the event loop process, where the process of loop event produces data processing from the receive radar data that is already in the form of digital data. Then the process of slinging the trail on the selected object is executed. Radar Information (RI) can be seen in Figure 7.
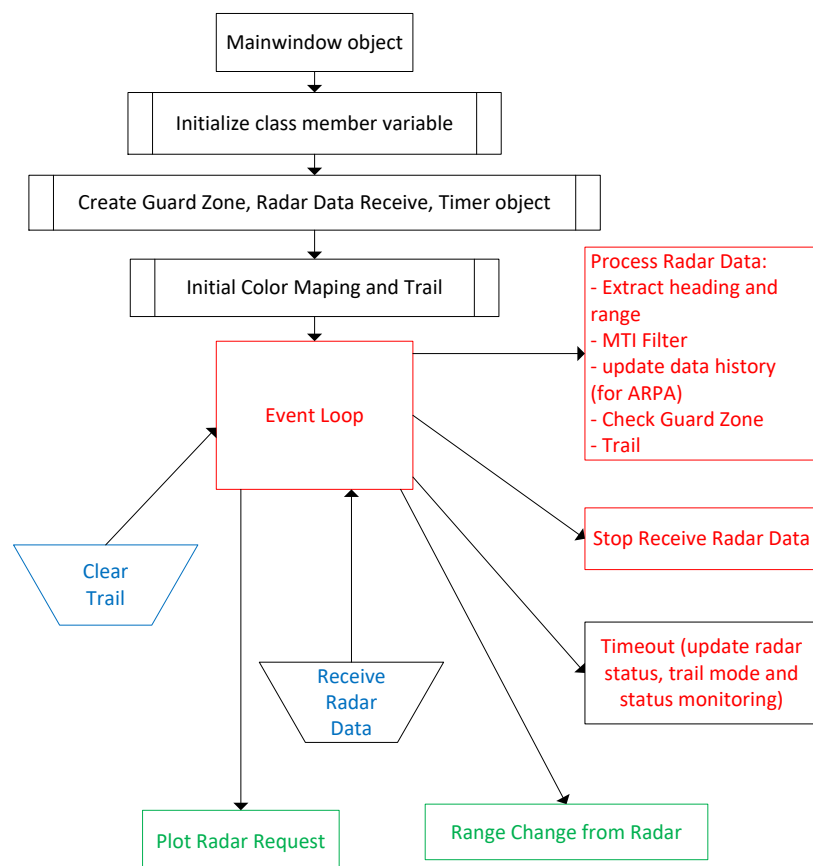

Figure 7. Radar information (RI) flowchart

The main process of the loop event produces a data extract heading and range, where the heading of the object will be exactly the same. This is based on the actual object position and then compressed with the data from the real object range generated from the reflection of the radar signal received on the receiver side. The next process that is not less important is the sorting process of echo radar reflection that is received between objects that relatively stasioner and fast moving such as aircrafts flying in the air. This process uses the moving target indicator method, by filtering the object relative not moving and eliminating the echo reflection. Furthermore, the resulting data is the updated ARPA data that has been obtained in the previous process, with the scanning rotation 24 rpm against the target sweep. ARPA data will be processed as additional data that can be sent as sensor data to other devices. And it has been already mentioned previously, the output data that is not less important are guardzone and trail. Input source data

obtained from radar data input that has been done post processing on the receive radar data in digitalization form of analog digital output converter (ADC) in the digital signal processing (DSP) module. For the mainwindow loop process, this can be seen in Figure 8.
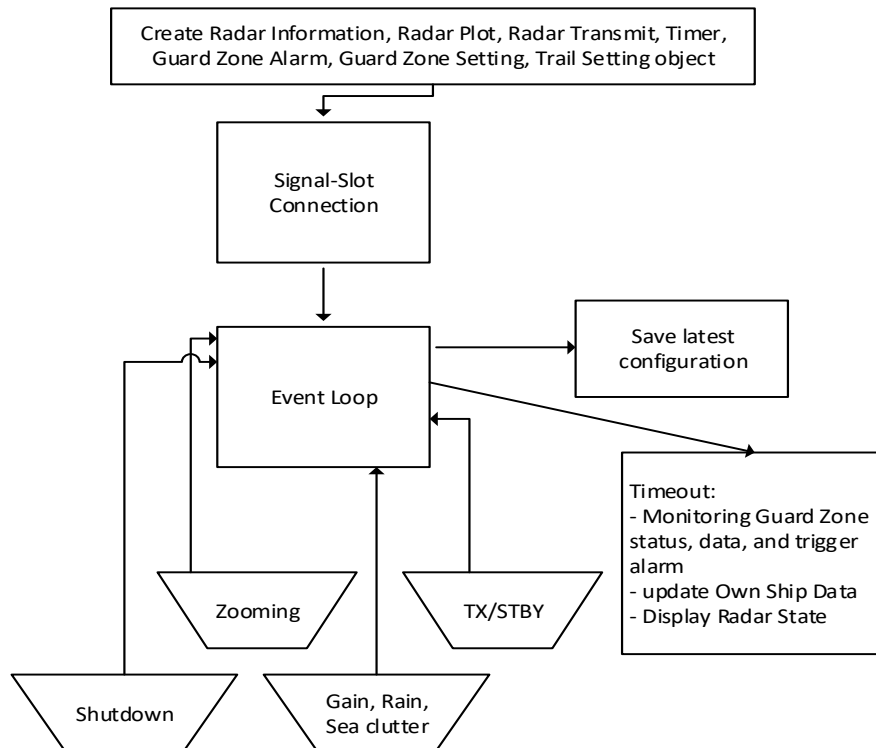

Figure 8. Mainwindow loop flowchart

Based on Figure 8, it can be seen that the suggestion given in the loop event is the command process of the connection-slot signal, where the process in this section is very involved between the connectivity of data obtained from the hardware that will be sent to the software, when the data connection is lost, and, then, it can be sure the loop event will not perform data processing, but only minor commands such as on/off radar display software. In the design of air surveillance radar, the use of tracking is one of the important parameters in monitoring the target that is indicated to be dangerous [20-24]. For the tracking ARPA, the flowchart can be seen in Figure 9. Tracking process begins when the object to be observed in selected by clicking using the mouse and directly convert the process into coordinates that are locked automatically. When the object selection process is still categorized in the limit of the ability of the radar data, it will be continued to the process of creating track, where, in this position, any objects that is being tracked will be followed wherever the object moves during the tracking process takes place. By using Kalman filter method as the main parameter in doing tracking process, it can be derived position and speed of target which is being tracked

The advantage of using this filter kalman is because this algorithm can estimate the next result based on the data that already existed before. This algorithm is usually used to estimate actual data based on observed data containing noise and some other factors of inaccuracy, and that is the meaning of the word filter. But in this case, the algorithm will be used to predict the future value, obtained from the filter value at the end of the calculation. The prediction process is done by filtering method Kalman filter is by doing matrix process to parameter data which got in before [25]. When the matrix process is running, then the optimum data will be updated tracking such as position, speed and course parameters. In the tracking process, there are 2 sub processes that occur continuously and complement each other. Between the track creation process that starts the tracking process and the refresh track process in which the process after creating with the data update, the process happens

continuously until the user intentionally stops tracking or inadvertently occurs lost target due to the distance of outer range from radar detection.
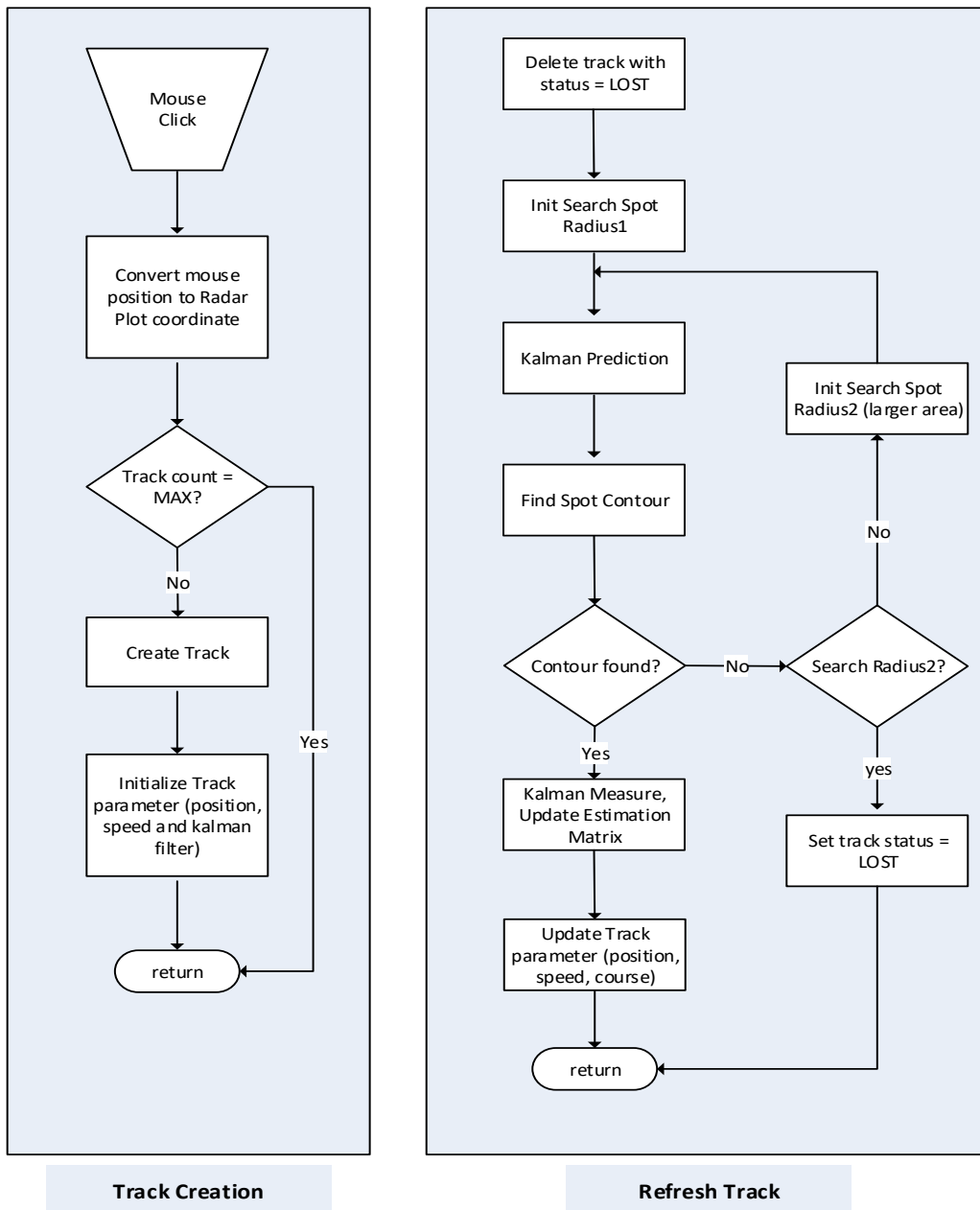

Figure 9. Tracking ARPA flowchart

The algorithm used is programming using C language [26], where the data displayed is obtained from the results of the process of digitizing the analog signal generated by the hardware (RF module) into a digital signal that can be processed with a voltage level of -5 Volts to +5 Volts with data format from the frame contains the head, data distance, reflection, and settings of the noise threshold (Gain, Land and Sea). The update in this study is the MTI method, where the radar detection results from the number of sweeps as many as n with the position that does not change or constant will increase the threshold, so that only moving objects will be displayed. Based on the ability of the Kalman filter process, it can be predicted the next movement of the object and it can do the tracking process correctly in accordance with

the original data obtained. The result of radar display design can be seen in Figure 10. The parameter description as shown on Table 1.

Table 1. Parameter Description

Number	Information
Number 1	Maximum Radar Distance Settings
Number 2	Radar Rings Settings
Number 3	Settings Transmit / Standby
Number 4	Shutdown
Number 5	Gain Settings
Number 6	Land Clutter Settings
Number 7	Sky Clutter Settings
Number 8	Setting the Moving Target Indicator Feature (MTI)
Number 9	Cursor Position Information
Number 10	Sensor Data Information
Number 11	Track Radar Object Information
Number 12	Object Information Track ADS-B
Number 13	Compass Settings
Number 14	Setting Heading Marker
Number 15	Display Orientation Settings
Number 16	Guardzone Settings
Number 17	ADS-B Settings
Number 18	Object Trail Settings
Number 19	Radar Settings

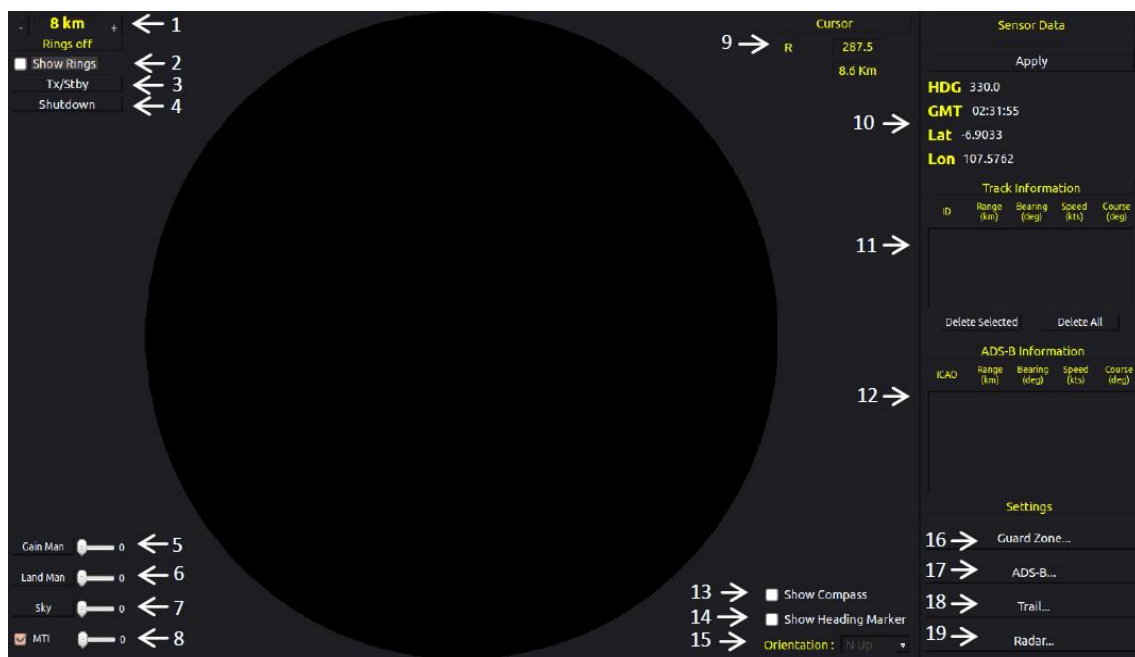

Figure 10. Design the main display of air surveillance radar

4. Conclusion

Research on the design and manufacture of radar display software using Plan Position Indicator (PPI) format for air surveillance radar application has been presented. The software algorithm uses windows main method, where all the commands can be done in this window and directly in the process on the event loop for command processing. The PPI display shows interpretations of echo detections of radar signal reflected from the flying objects/targets. The MTI mode only displays moving objects and no non-moving objects are shown such as mountains and buildings. The design of radar display software uses tracking parameters as a method of observing objects in detection. The process of tracking the object using the filtering process kalman filter. Based on the results of this research, the PPI display shows the targets

on the display according to its position, some desired targets can also be tracked, information on target, GPS location, target ID, required parameters, and some settings. The radar display fulfills all the required capabilities for air surveillance Radar.

Acknowledgment

References

[1] Komando pertahanan udara nasional. Air Defense Data of the Republic of Indonesia. (*In Indonesia Data Pertahanan udara Republik Indonesia*). TNI-AU. 2018.
[2] Implementing Digital Processing for Automotive Radar Using SoC FPGAs. Altera White Paper. 2013.
[3] Reintjes JF, Coate GT. Principles of Radar. New York. McGraw-Hill. 1952.
[4] Skolnik MI. Editor. Radar Applications. New York: IEEE Press.1987.
[5] Barton D, Leonov S. Radar Technology Encyclopedia. Norwood: Artech House. 1997: 320-321.
[6] Stimson GW. Introduction to Airborne Radar. 2nd Edition. SciTech Publishing.1998.
[7] Skolnik MI. Radar Handbook. McGraw-Hill. 1990. 2.1-3.32.
[8] Kouemou G. Radar Technology. India, In-the. 2009.
[9] Goodwin J. Types of Radar Systems. Presentation transcript, ELC 451E. 2015.
[10] Kurniawan D, Adhi P, Satyawan AS, Syamsu I, Praludi T. Object Detector on Coastal Surveillance Radar Using Two-Dimensional Order-Statistic Constant-False Alarm Rate Algoritm. *TELKOMNIKA Telecommunication Computing Electronics and Control*. 2015; 13(2): 624-631.
[11] Wahab M, Kurniadi DP, Estu TT, Mahmudin D, Maulana YY, Sulistyaningsih. Development of Coastal Radar Network at Sunda Strait. *TELKOMNIKA Telecommunication Computing Electronics and Control*. 2016; 14(2): 507-514.
[12] Wahab M, Daud P. *Image Processing Algorithm for FM-CW Radar*. TSSA/WSSA Conference ITB. Bandung. 2006.
[13] Radar Processing: FPGAs or GPUs. Altera White Paper. 2013.
[14] Kaushik P. Radar Display. *International Journal of Innovative Research in Technology (IJIRT)*. 2014; 1(7): 472 - 476.
[15] Kassotakis I. Modern Radar Techniques for Air Surveillance & Defense. *Journal of Computations and Modelling*. 2014; 4(1): 189-205. ISSN: 1792-7625 (print), 1792-8850 (online), Scienpress Ltd.
[16] Stamatović M, Jevtić M, Kisić U, Member, Tatarević M, Pajić T, Marković K. Modern Air Situation Picture Display for Air Surveillance Radar Applications. *Telfor Journal*. 2013; 5(1): 54-59.
[17] RadarView-Primary Radar Visualisation. Cambridge Pixel Ltd. 2012.
[18] Jevtić M, Stamatović M. *Radar Data Processing and Visualization on Desktop Platforms*. Proc. 17th Telecommunications forum TELFOR. 2009: 1315-1318.
[19] Radar Document Project. PT. Radar Telekomunikasi Indonesia. Arhanud TNI-AD Project. 2017.
[20] Kalman RE. A new approach to linear filtering and prediction problems. *Trans. of the ASME-Journal of Basic Engineering*. 1960; 82 (Series D): 35-45.
[21] Blackman SS. Multiple Target Tracking with Radar Applications. Norwood: Artech House. 1986.
[22] Bar-Shalom Y. Editor. Multitarget-Multisensor Tracking: Applications and Advances, Vol II. Norwood, MA: Artech House. 1992.
[23] Blackman S, Popoli R. Design and Analysis of Modern Tracking Systems. Norwood, MA: Artech House, 1999.
[24] Bath WG, Trunk GV. Automatic detection, tracking, and sensor integration. In Radar Handbook. 3rd ed. Skolnik MI. *Editors*. New York: McGraw-Hill. 2008.
[25] Sustika R, Suryana J. Nonlinear-Filtering with Interacting Multiple-Model Algorithm for Coastal Radar Target Tracking System. *TELKOMNIKA Telecommunication Computing Electronics and Control*. 2015; 13 (1): 211-220.
[26] Blanchette J, Summerfield M. C++ GUI Programming with Qt 4. 2nd ed. Prentice Hall. 2008.