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Design approach for avoiding airplanes landing accident based on Embedded cockpit display

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Abstract—this paper presents a new approach about avoiding airplanes landing related accident based on Embedded Electronics System (EES) display and installed in cockpit. This new automation or animation based cockpit display will develop to provide optimum guidance information's to the pilot in a manner that is compatible with pilots and easily can control capabilities for safety landing. Main reason for landing accidents, when the Pilots are unable to see the runway or refer the information because of bad weather conditions, inaccuracy of runway distance information and speed of the airplanes.This all information's are displayed in EES based cockpit display. In this EES based cockpit display has divided into four parts and it's shown like Engine parameters, live status of airplanes movement in runway, control surfaces and important parameters related to landing operations.This achievement of displaying the parameters and commands are controlling by Microcontroller.Microcontrollers will get information from sensor sources and its give the landing related parameters information to pilot through cockpit display. Radio Frequency (RF) signal used to identify the airplanes Altitude and Longitude parameters. Based on the RF Received Signal Strength (RSS), the airplanes altitude and longitude will be detected and displays the aircraft movement in every meter like animations.EES display will show exact distance from one end of runway to other end of runway information and status of the airplanes. If this system is implemented, pilots are no need to refer the runway information from Air Traffic Control (ATC) and status of runway; through EES based cockpit display, pilots can easily land the airplanes at any environmental conditions.

Index Terms— Cockpit Display, Embedded System, RF Signal Strength, Landing Parameters and Safety landing

1 INTRODUCTION

GENERALLY, airplanes are always diverted from current airport to another airport, if the visibility level is below the allowable limit or when pilots cannot see the runway. At Low visibility operations, increase the workload on the pilot to scan several instruments and form a mental picture of the aircraft situation. As it approach runway more accuracy is required since the limit for mismatching the touch point should not exceed meter level. Airplanes approach and landing are of the most hazardous portions of flight. Accidents records indicate that approximately 50 percent of the accidents occur during airplanes landing [1].

The aviation industry is developing rapidly to occupy the increasing needs for faster, comfortable and safe transportation. Aircraft landing is a critical phase and high accuracy in required especially when flying under bad weather and low visibility conditions. The zero accident policy announced by Federal Aviation Authority (FAA) requires airliners to have essentially perfect navigation from take-off to landing. International Civil Aviation Organization (ICAO) has divided landing systems into three categories according to decision height, visibility and runway visual range. Also Category III C in ICAO Standard is not in operation yet anywhere in the world because of systematic limitations of landing systems in service. It requires landing with no visibility or runway visual range.Currently, the limits of integrity and accuracy of ground equipments have not been able to match ICAO standards and recommended practices.

Nevertheless, they are still in use due to the lack of better alternatives.The main current equipments limitations are: inaccuracy, unreliability, vulnerability to multipath, obstruction in signal broadcasting, cause ground service cognition, lack of integrity and high cost. In this paper presents a new approach about to meet ICAO standards (i.e) avoiding landing related accidents and safety landing.

2 SYSTEM OVERVIEW

Especially for airplanes landing related and present systems are like Instrument Landing System (ILS), Microwave Landing System (MLS), Global Positioning System (GPS) and Differential Global Positioning System (DGPS). This system information's are not able to match the ICAO standards. Currently, GPS is the main navigation system used all over the world for aircraft navigation, approach and landing. However, in aircraft approach and landing phase, the accuracy of GPS is not sufficient to perform a perfect landing due to the possibility of aircraft to be drifted out of the runway [2]. Also these systems are difficult to maintenance and high cost.

In 2012, FAA has published Next Generation Implementation Plan ("Next Generation GPS Operational Control Segment," 2012). FAA plan to use Ground Base Augmentation System (GBAS) for civil aviation local augmentation to support all flight phases including aircraft approach and landing. The use of GPS-based system for aircraft landing did not satisfy researchers and operators as well and the results have proved the lack of reliability and inaccuracy of the system [3]. The other GPS limitations are: Satellite unavailability, Satellite Geometry, Low vertical accuracy, Satellite signal broadcasting travel time is longer than signals transmitted from ground surface, GPS receiver update rate is low,

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Signal weakening and degradation, Ionosphere effects, GPS lack of high accuracy.

In order to overcome GPS limitations, even though many systems have been designed to augment GPS and improve the accuracy, no system can be relied on to achieve a high accuracy in a range of less than 1 m for high speed applications with high integrity and reliability [4]. EES based display system proposes an animation and/or automatic information about airplane position and its displays all information, related airplanes landing in any weather conditions. This system is not based on GPS; it depend only RF Received Signal Strength (RSS) and displays the parameters as per gathering information.This proposed system designed for increase the accuracy, reduce the pilots work load and safety landing. The design of EES based system shown in Fig 1. This EES based system concept is based on RF signal strength levels and runway information's as per airplane models/types.

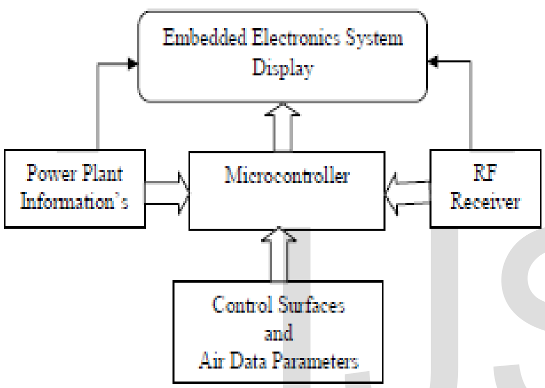

Fig 1: Functional block diagram of EES based Cockpit Display

3 SYSTEM OPERATIONS

3.1 LANDING OPERATION

This EES based system is proposed to be used for airplanes landing where the area is considered small relatively and high accuracy. So a very High Frequency (VHF) band could be used to cover the required area for airplanes approaching and landing. The chosen frequency should be in a high range where the signal propagation is not influenced by weather phenomena like, rain, snow or clouds. The characteristics of VHF propagation are ideal for short distance terrestrial transmission. VHF radio does not reflected by the ionosphere and thus transmissions are restricted to the local area. It does not interfere with transmissions thousands of kilometres away. Therefore, it is less affected by atmospheric noise and interference from electrical equipment than lower frequencies [5]. VHF ranges from 108 to 118 MHz is used for Air navigation beacons VOR and ILS [6].

The selected RF frequency is important consideration for to cover the entire runway. In this system, the data's are broadcasted to receiver via any frequencies from Transmitter (Tx).Receiver (Rx) on the airplanes receives the transmitted signals from Ground station or Tx and measures the time delay that the signal takes between transmission and reception [7].The location of the transmitter is placed before the 500meters in end of the runway. The overview of EES based display shown in Fig 2.

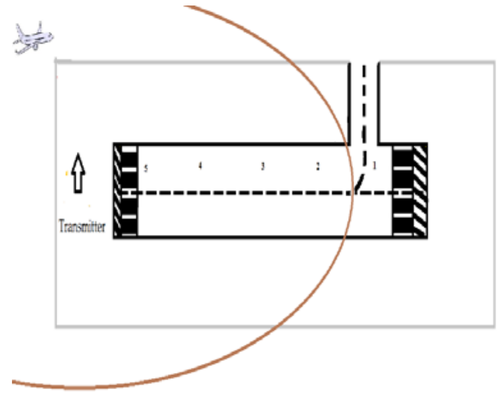

Fig 2: EES system overview of operating modes

In this cockpit display, runway is marked as numbers and it indicate the distances in meter. Here numbers are mentioned up to five and it indicates that total length of runway is 5 kilo meters. Based on runway length numbers will vary. The RF signal coverage area is marked as light brown colour and it shows the signal coverage area and it depends on selected frequency range. The received signal range can be obtained by Equation 1.

$$\text{Range} = (\text{speed}) \times (\text{Time}) \quad (1)$$

Where the speed of the signal is the speed of light and time is the time that the signal takes between transmitter and receiver [8]. Then receiver can calculate the coordinates (longitude and altitude) of the airplanes, depending on the received signal strength ranges.

Normally, in ILS the Outer Marker (OM) beacon is located at 7.4 to 13 kilometers from the ILS threshold to mark the point at which glide slope altitude is verified or at which the airplanes descent ("Terminal Area Separation Standards: Historical Development", 1997). The first signal that an airplane receives from ILS is from outer marker when it is about 7-13 km from runway threshold [9]. In EES system will give entire runway information form Transmitter location point to Signal coverage areas. Based on signal, airplane will positioned at centre of the runway (i.e line). If any deviation in received signal levels, the airplane position also will change as per deviation range. So pilot can observe the exact position and movement of the airplane.

3.2 COCKPIT DISPLAY

Cockpit display is based on LCD screen, because it will consume less power consumption and better brightness.In this EES based cockpit display has divided into four parts and displays different parameters like Power Plant, Landing related Power Plant warning information's, Control surfaces parameters and live animation about airplanes movements according to real observing information's from sources. Airplanes movements and runway information's like Runway distances (runway total distance, touch point location and remaining distance), Altitude, Airplanes symbol movement and Commands are displayed in centre part of the EES based Cockpit display. These sets of cockpit display shown in below Fig 3.

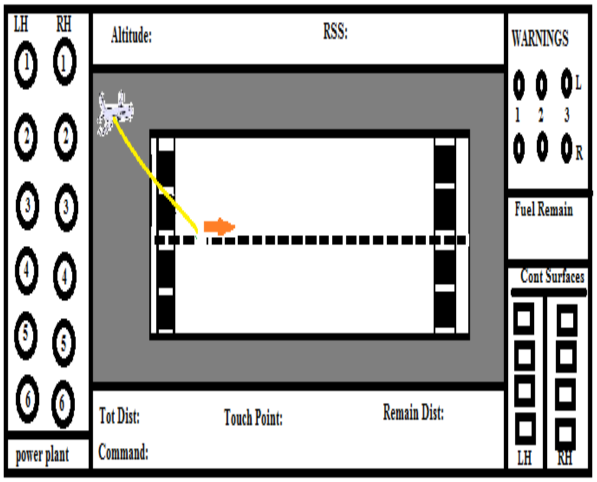

Fig 3: EES based Cockpit Display

In Power plant parameters like Engine speed, Fuel flow Rate, Inter Turbine Temperature (ITT), Oil Temperature, Fuel and Oil flow Pressures of the both sides (LH and RH) of engines are shown in Left side of cockpit display. This all information is mentioned numbers in display shown in above the Fig. Right side of the cockpit display divide into three parts and displays only waring information's. Warning information's is landing related important parameters in Power plant, Fuel quantity and Control surfaces. All warning indications are like LED blinking and it will vary different colours. Mostly three colours are used to indicate the warning information.

If any one of the parameter is critical condition means it display will show RED colour and normal means GREEN colour. Before the critical condition means display will show YELLOW or AMBER colour. This all operations are controlled by Microcontroller and display operations are based on Visual Basic and National Instruments. Fuel remaining quantity also mentioned and it will shows in digital format. All these waring parameters are arranged in as per primary and secondary controller parameters.

4 INFORMATION CONTROL

4.1 Time Difference

Both transmitter and receiver have a precise clock and transmitted signal contains information about signal transmission time. So the receiver uses its clock to compare time of transmission in the transmitted code with time of reception to calculate time difference. Clocks are synchronized between receiver and transmitter. As receiver receives signal containing time code, it generates its time code internally and uses it to compare between two codes. The receiver determines the range between airplanes and transmitter or base station [10]. This time difference calculation expressed in below Fig 4.

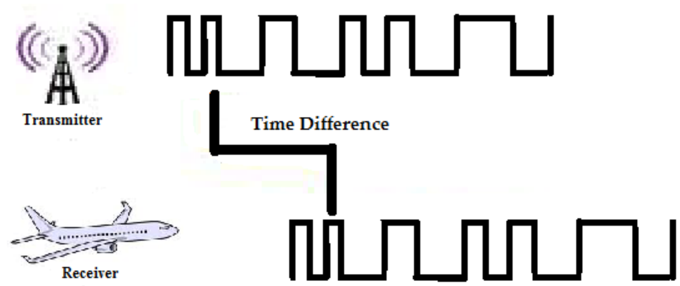

Fig 4: Time Difference calculation between Transmitter and receiver

4.2 Distance and Altitude Calculation

The distance from the runway where the airplanes starts to descend differs for airports. Therefore, the best glide speed and the glide ratio depend on the airplanes. Normal descents take place at a constant airspeed and constant angle of descent (3-4 degree final approach at most airports). In this system altitude determination is referenced to the height of the runway. The angle of decent between airplane touch point and airplane position is showed in Fig 5.

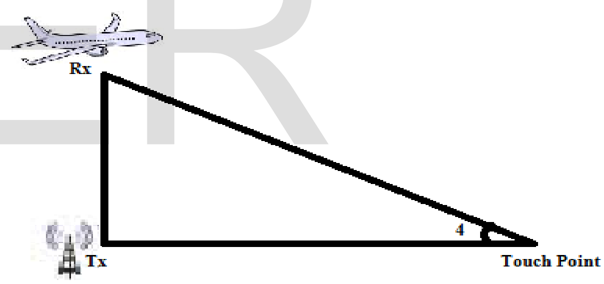

Fig 5: Distance and Altitude calculation form transmitter to airplane touch point

At a distance of 13km from runway touch point with a descend angle of 4°:

$$\text{Cos } \theta = 13/H \quad (2)$$

$$H = 13.0317$$

$$\text{Sin } \theta = \text{Altitude}/H \quad (3)$$

Where H is referred to height of the runway and θ is descend angle.

As per equation (2) and (3), altitude ranges are shown in TABLE.1. Altitude ranges are measured form transmitter to aircraft position. These ranges are referred as exact height of the airplane from ground level, not in sea level.

TABLE 1: Descend Angle versus Altitude ranges based

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on 13km runway distance

Descend Angle (degree)	H=13/Cos θ	Altitude= Sin θ * H (meters)
4	13.0317	909.04
3.8	13.0286	863.45
3.6	13.0257	817.89
3.4	13.0229	772.34
3.2	13.0203	726.81
3	13.0178	681.12

EES based system distance calculation is need to subtract 500 meters from normal distances. Because EES based system transmitter is placed before the 500 meters from end point of runway. Similarly, the altitude range calculation of the airplane position is based on transmitter height. During altitude measurement need to subtract with transmitter height. Also graphical comparison between Normal and EES based system shown in Fig 6.

EES display Distance = (Normal distance – 500) (4)

Altitude Distance= (Measured Distance-Tx Height) (5)

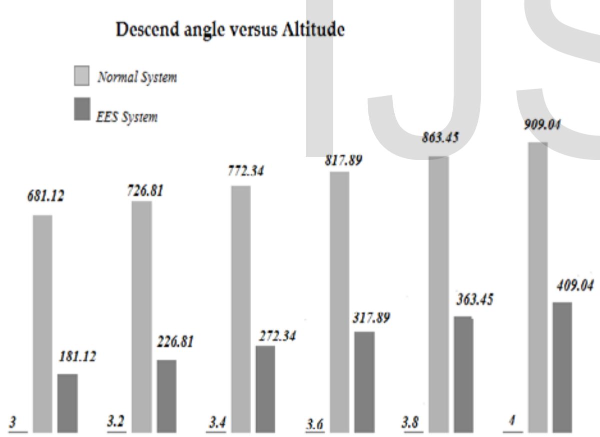

Fig 6: Graphical comparison about Noramal and EES Display system landing accuracy

4.3 Transmitter Power

The general rule of transmitter power is it will take four times the power to double the transmission distance. Transmission range could be increased by increasing antenna height without increasing power. Raise the height significantly increase broadcast distance. Typically, transmission power is measured in dBm. The greater transmission power, the greater distances can be achieved. Friis transmission equation is used to calculate transmitted and received power ratio (Pr/Pt). Whereas, equation 5 is used to calculate the power received.

$$Pr / Pt = Gt\, Gr\, (\lambda / 4 \Pi R)^2 \qquad (6)$$

Where **Gt** and **Gr** are transmitter and receiver antennas gains respectively, **Pt** and **Pr** are transmitted and received power respectively, **λ** is the wavelength, and **R** is the distance.

4.4 Microcontroller

PIC based microcontrollers are best performance for control system operations. In EES based cockpit display, microcontroller is heart of the instrument. It will control the display the information's based on observing data or information's from source [11]. Mostly it will used to control the warning information's and control surfaces parameters. Also it will control the command words as per user conditions (i,e if any one of the parameter is not in condition means, command will appear). Commands are used for to understand the status about airplanes conditions and levels. Commands in displays would be helpful in reducing flight deck workload and ensuring safety especially by reducing the scan time for searching all parameters.

Based on the collected information's form source, the commands display will brings challenges such as potential increase in error rate, loss of sensory feedback, and difficult operation during confusion. In order to evaluate the effectiveness of interfaces depends on ICAO standards and designer of the airplanes. Microcontroller will observe the data's from source and it performs as per user codes [12]. All codes are based on C and C++ in Embedded Technologies.

5 EES ADVANTAGES

This system is proposed to overcome the majority of aircraft landing systems limitations. It has many advantages over current systems. The main purpose of this study is to design a system to reduce some positioning errors and eliminate others. This study aims to meet ICAO standard for the ability to land in bad weather and low visibility conditions. In addition, this system gives the real and accurate altitude of the aircraft since it refers to the real height of the runway, not the mean sea level nor the earth ellipsoid like GPS. Moreover, the signal broadcasted from satellites takes about 0.07 second to reach to earth whereas it takes about 0.000004 second if the signal is transmitted from earth surface. Besides that, signal transmitted from Ground-based system will be stronger.It can penetrate construction in vicinity of airport.

Additionally, satellites unavailability due to satellites distribution or construction blockage is a serious problem in critical stages of landing, this system is designed to be available continuously within the approach and landing area. Also, due to the distribution of satellites the vertical accuracy is always less than horizontal accuracy. More than that it causes an accuracy reduction when the visible satellites are all clustered together in a single quadrant, this narrows satellites visibility angle and consequently reduce the positioning accuracy.

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6 Conclusion

Airplanes landing is a very difficult and it risk for airplanes to be drifted out of the runway or crash building. So a superior accuracy is required to guide the airplanes from runway touchdown point to entire runway distance. In bad weather conditions when visual range does not exist, airplanes rely on full automatic system to land systematically. Currently, no system is able to provide this reliability all over the world. In this system has been proposed to reduce and eliminate the airplanes landing accidents. This System characteristic is to enhance the airplanes to land in all weathers safely with high accuracy guidance.

The airplanes altitude determination has become more reliable since it refers to the real height of the airplanes, not the mean from sea level. Overall, this system is completely autonomous. It does not depend on GPS satellites such as DGPS. This system provides an accurate airplanes deviation from recommended route points and enhancing the airplanes to land in all weather conditions. Finally, the system results show that visibility, integrity, availability and accuracy have been considerably increased.

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