DEVELOPMENT OF LASER CONDUCTING LANDING SYSTEM

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Abstract

In a worse visibility weather there always are some difficuties even some accidents when aeroplane is landing as the pilot can not look for the runway well.Using visual laser shows the direction that the aeroplane get into the airport and the descending slope.When the pilot saw the two laser beams as if found a "air-way" from sky to ground,so long as the aeroplane descend along this way,it can ensure that the landing point is just located at the correct position of the runway.Under the support of microelctronic technique this system can adjust the descending slope along with different type of aeroplane and the intensity of laser self-adopt to variable visibility ,In order to prevent the eyes of pilot from hurting by laser, the safe watching window is designed carefully in the system.This system will be self-adjuted variable of laser intensity to self-adapt along with the distance between the aeroplane and the light sourse.In order to direct the descending locus by the straight laser beams,there is a program adjustment of the laser beams in the system for adjusting the slope of laser beams along with the distance between the aeroplane and the light soursce.The programs are changeable in accordance with the different type of aeroplane.

Introduction

Landing is the the last stage of aviation at which pilots must perform many precise operations within a little while.It is a troublesome stage because of limited time and bad visibility due to overcast day,dense fog,low clouds and rain etc.In particular military airports are often built in moutain area even in cavens,aircraft accidents are likely happened.So it is very necessary for us to solve the problem of safety landing under vile weather condition.

I. Principle of Operation

Landing can be divided into two parts definitely,guiding (or approach) and landing course,as shown in Figure 1.When a plane begins to land ,it glides down first from a distance of 30-50 kilometers till at a height of 20-30 meters above the extension of the runway.This course is called approach. The landing course includes curvilinear flying in the vertical plane,touching ground,slipping along the runway till stoping completely.The laser guidance utilizes visible laser beams to show the gliding direction and slope that can be adjusted in accordance with types of planes,as if provided a precise and clear light-slide for landing.The pilot can control his plane to drift down the slide.This ensure safety landing on bad visibility condition.

The block diagram of the conducting system is shown in Figure 2.Two fully identical main laser system are erected separately on both sidelines of the starting point.They emit two parallel laser beams slanting upwards along the extension of the sidelines.The beams are widened and collimated,and their intensity can be adjusted.Their projections on the ground are just on the sidelines of the runway.

With the support of microcomputer control system the intensity and the frequency (for pulse laser) can be controled on the basis of the information fed via a main control console.And the intensity can adapt to the variable visibility according to the information supplied by a noise detecting system and a visibility detecting system.The worse the visibility and the longer the distance between the plane and the light sourse,the smaller is the intensity;the better the visibility and the shorter the distance,the greater is the intensity.The distance is measured with a simple noise monitoring system on plane.

The widening-collimaring system and enoscope are also controled by the microcomputer. The experiments show that if we change the beam size and make them sway the beams will easy to be found by pilots. Therefore we change the size and make them sway within a limited range with program to help the pilots finding the laser beams more easily in higher altitude and longer distance.When the pilot finds the laser,we fix the size of the laser beams and descending slope in the light of type and speed of the plane.The so-called slope is the tangent of the angle between the direction of laser beams and the horizontal plane.The angle is adjusted by turing the enoscope. The number of the angle is set up with pre-instruction of the main control console.

II. Selection of The Laser and Protections

To satisfy the above-mentioned requirements,the intensity of the laser beams must be sufficient,the adjusting system must be easy to operate,and the laser is visible.In order to observe the laser from enough long distance,the laser must have sufficient illumination which is not only determined by intensity but also by its divergent angle and widening-collimating system. On the other hand,because the pilots have to use their own eyes to look for the laser,we must adapt a series of protections to prevent the eyes from hurting by the laser.

To choose suitable laser,we test various lasers.First we ask the manufactures to write a detailed list as follows:
1. The manufacture's name.

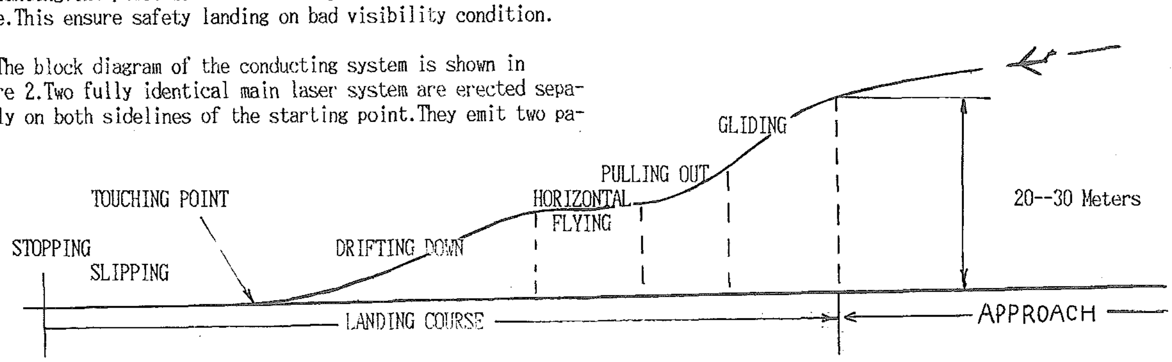

Figure 1. Approach and Landing

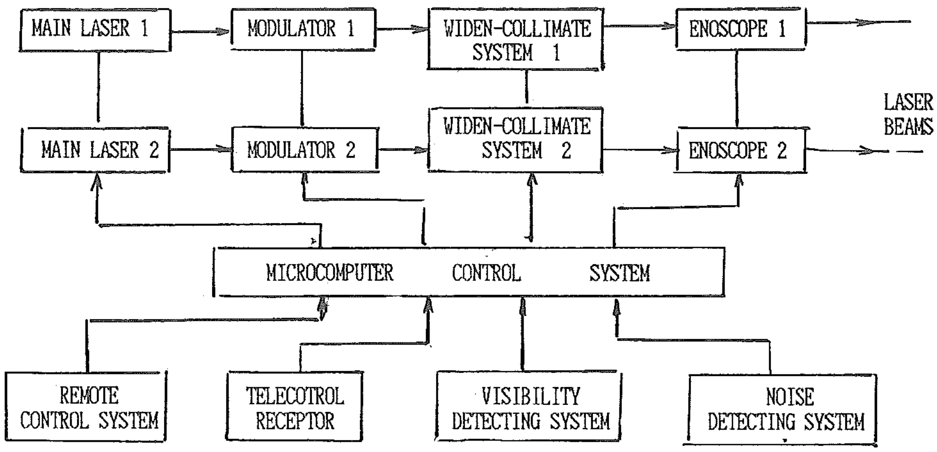

Figure 2 . Block Diagram of Laser guidance Landing System

2. The laser type and the name
3. The use for original design.
4. Wavelength and its range (for multimode laser have to indicate the ratio between the output power of every wavelength and the total)
5. The colour of the laser or the light-wavelength.
6. The divergent angle
7. The shape and size of the laser beam
8. Diverge (field angle)
9. Maximum average outpower
10. Maxmum intensity of transmitted power (measuring condition:measuring distance,diameter of the diaphragm)
11. Successive operating time
12. Duration without breakdown
13. Service life (whole and parts)
14. Supply voltage
15. The consuming power of the source
16. The unit price

The following are added to pulse laser:

1. pulse peak power (or energy)
2. Maximum and minimum frequency
3. Maximum and minimumu pulse width

Checking the listed properties of the supplied lasers item by item before acceptance,we make in-situ simulated experiment at the airports mainly to decide the transmission distance and the side-looking distance of the laser beams,which are influenced by chinging weather.The lasers are tested separately at different times (morning,noon,towards evening and midnight)under different weathers (clear,cloudy,foggy and rain day).Note that we must choose the southern airports and changeable climates, and wait patiently for proper oppertunity to do these experiments.

Basing on the simulated experiments,we select several kinds of lasers tentatively for flying-observing experiment.At a descending angle of three degrees or so two interior-parallel laser beams are emitted towards into the sky with their interior distance equaling to the width of the runway.The angle trembles with a range of not more than 0.01 degrees in the horizontal and vertical plane The transmission distance should be greater than 1.5 kilometers upon the worst weather conditions,that the clouds are 80 meters high,the horizontal visibility is one kilometer in the day,and the clouds are 100 meters high ,the horizontal visibility is 1.5 kilometers in the nighttime.When mid-air plane is on SIDE 4,the minimum visible distance should be less than one kilometer (shown in Figure 3).

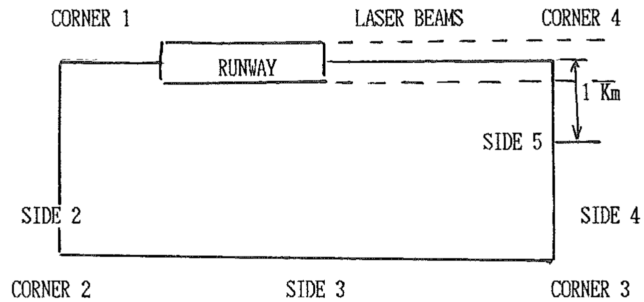

Figure 3 . Configuration of Laser Guidance

To protect the pilots' eyes,a safety harbour technique is adapted by adding a large-area light filter on the flying helmet which is characteristic of wedged absorption.Its absorption property changes with the extent that the pilot pulls down.At the center the filter absorbes the most, and at the edge the least. So if the pilot can not find the laser through the center he can observe on the edge and can find the laser more easily.For this reason,the pilot's eyes are absolutely safe.After above experiments and comparisions,we have grounds and confidence in choosing which laser is the most suitable.We also get a lot of experience in preventing pilot'seyes from hurtiňg.Another important protection is that we control the illuminance of the laser to decrease as the plane descending,with the support of microcomputer control system and the noise detecting system. In addition,we also employ a laser-warning sensor on flying helmet which can remind him that the plane has been in the laser-illuminating area,he has to pull down the filter so that his eyes can get into the safe harbour.

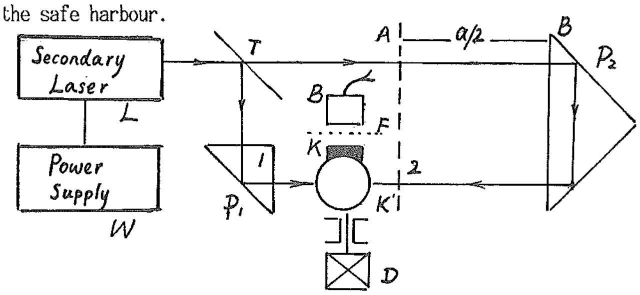

Figure 4. Visibility Detecting System

T- spectroscope
P1 , P2 - total reflection mirror
P - integrating-ball
K'- inlet
K - outlet
F - light filter
B - photoactor
D - stepper motor
L - secondary laser
W - source supply

III. The Visibility-Detecting System and Its Principle

This system is shown as Figure 4. Let's assume that P_o is the laser power, K is the air absorption coefficient. then

$$\frac{P_o \exp(-Ka)}{P_o} = b$$

Where a denotes the transmission distance, b denotes the air transmittivity, then:

$$b = \exp(-Ka) \quad (1)$$

from $$e = 1 + X + \frac{X^2}{2!} + \frac{X^3}{3} + \cdots$$

and because K is usually very small, $Ka \ll 1$, we have

$$b \approx 1 - Ka$$

and

$$K = (1 - b) / a \quad (2)$$

According to the definition of visibility, when the target brightness is 2% of that of the background, this is the lowest brightness of visible light. So as the target moves L meters from the near to the distant, the brightness reduces to 2%. At this moment. L is the longest visible distance, we call L the visibility. Hence we can draw a conclusion from Eq(1)

$$0.02 = \exp(-KL)$$

$$L = (\ln 50) / K = (a \ln 50) / (1 - b) \quad (3)$$

Seting a = 100 m, b = 0.9, then:

$$L = (100 \times 0.3912) / (1 - 0.9)$$

$$= 3912 \text{ m} \approx 4 \text{ Km}$$

In fact, the item of aln50 can be regarded as a constant. So the relationship between L and b can be given as follows:

$$L = 4 / (1 - b) \quad (\text{Km}) \quad (4)$$

Eq(4) can be considered as an experimental formula, b indicates the transmittivity of one hundred-meter-long horizontal air pole nearby the ground. And b can be measured in following steps:

(一). Calibrate the instruments as shown in Figure 4, put the lens P2 at a site nearby the entrance of the integrating ball by rotating the integrating-ball, Ray 1 and Ray 2 can enter it separately. So we get photocurrents I1 and I2 which are adjusted to be equal, i.e I1 = I2.

(二). Move P2 to site B at a distance of a/2 from A. Be careful to ensure all reflected-rays enter the integrating ball (of course deducting what the air absorbs and scatters). This can be achieved by aligning, and on the other hand, by making the diameter of the entrance of the integrating-ball be not less than that of the beams. Otherwise, compensation should be done, and the means is described in Error Analysis

(三). After calibrating the instruments, I1 and I2 are measured in order. so

$$b = I1 / I2 \quad (5)$$

Error Analysis

We denote α the divergent angle of the laser. If the diameter of Ray 2 (i.e d) is greater than that of the inlet, the diameter of the light-spot is:

$$d = \alpha \cdot a \quad (6)$$

Therefore the ratio g between the energy that enters the integrating ball and the total energy of the light-spot can be given:

$$g = \frac{s}{\pi \cdot (d/2)^2} = \frac{4 \cdot s}{\pi \cdot \alpha^2 \cdot a^2} \quad (7)$$

where s is the area of the inlet. Because s, α and a are all constants, g is also a constant, and $g < 1$. In order to compensate the loss of I2, we should substitute I2 / g for I2, or change Eq (5) into:

$$b = \frac{I2 / g}{I1} = \frac{I2}{I1 \cdot g} = \frac{\pi \cdot \alpha \cdot a \cdot I}{4 \cdot s \cdot I1} = \frac{K \cdot I2}{I1} \quad (8)$$

where K is a constant

$$K = 1 / g = (\pi \cdot \alpha \cdot a) / (4 s) \quad (9)$$

This correction can be achieved easily with software From Eq (2) we have:

$$\triangle b = \triangle K \cdot a + K \cdot \triangle a \quad (10)$$

Thus under good visibility, we can conclude that: $K \rightarrow 0$, $\triangle K \rightarrow 0$. So the error is very small and can be neglected. Because $\triangle a \cdot K \leqslant \triangle K \cdot a$, the error can be reduced if we reduce the distance a properly. Experiments show that when $Ka \leqslant 0.1$, the relative error is fewer than 0.5%.

IV. Microcomputer. Control System

In the computer control system a self-designed Z-80 single board computer is used, with an AD574 as the A/D converter. The AD574 is a high-integrated, low price successive approximation A/D converter made in the Analog Device Inc. The on-chip interface circuit makes it convenient to interface with Z-80 and other kinds of microcomputers.

The AD574 provides five control lines (CE, $\overline{CS}$, R/$\overline{C}$, 12/$\overline{8}$ and A_o). These lines are used to control the functions of Time Address, Start and Write. The operation of the ADC is determined by CE, $\overline{CS}$ and R/$\overline{C}$, while CE and $\overline{CS}$ are valid, R/$\overline{C}$ = "1" forces the ADC into the READ MODE, and R/$\overline{C}$ = "0" forces it into the CONVERTING MODE. The conversion length and data format are determined by line 12/8 and line A ; the latter is connected to the least significant bit (LSB) of the address bus. During conversion, when A_o = "0", 12-bit conversion is performanced; when A_o = "1", 8-bit conversion is performanced. During reading, when A = "0", one 8-bit output in the tri-state buffer is availible; when A_o = "1", one low 4-bit output is availible followed by 4-bit zeros. Line 12/$\overline{8}$ must be tied to the Digital Ground or to Digital Circuit Source to determine the format of the output data. If line 12/8 is connected to the Digital Ground, the ADC will provide a 12-bit data with a single output. But if the line is connected to the Digital Circuit Source, it will require two outputs to provide a data, first come a high 8-bit output, then a low 4-bit output. Notice that line 12/$\overline{8}$ is not compatible with TTL. In the AD574 there is a output line STS which indicates the state of conversion.At the beginning of conversion STS will go high and stay high till a coversion circle is completed.Figure 5 illustrates the method of interfacing an AD574 to a Z-80 computer.By connecting A to the LSB of the address bus,the 12-bit output data is divided into a high 8-bit data and a low 4-bit data.THe pins of the low 4-bit and the the high are connected respectively to D4~D7 of the data bus.The state of STS is read from D7 via a tri-state buffer (the address is B0H).R/$\overline{C}$ and CE are controled by RD and WR of the Z-80 chip.This ensure CE = "1" and R/$\overline{C}$ = "0" during conversion,and ensure CE = "1" and R/$\overline{C}$ = "1" during reading.The address decode signal of port A8H is gated with $\overline{ICRQ}$ of the processor to generate the chip select signal $\overline{CS}$.To keep the input voltage stable during conversion,a sample-hold circuit U7 (LF398) is used.The opration state of U7 is determined by writing the control code on to the the control output port BCH.If pin 8 is high ,U7 will work in sample mode;if pin 8 is low,U7 will work in holding mode. When the conversion begins,STS goes high,the processor keeps on enquiring port B0H.Once STS goes low,a read operation is performanced.A full conversion and reading circle is showed in Figure 6,and the routine as follows:

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2000        LD     A,     08H ;      Sampling
2002        OUT    (BCH),  A
2004        LD     (IX),   2200H
2008        LD     A,     00H ;      Holding
200A        OUT    (BCH), A
200C        OUT    (A8H), A    ;     Start ADC
200E LOOP   IN     A,     (BCH) ;    Converting ?
2010        AND    80H         ;     Finished
2012        JR     NZ,    LOOP
2014        IN     A,     (A8H) ;    Reading high 8-bit
2016        LD     (IX),  A
2019        INC    IX
201B        IN     A,     (A0H) ;    Reading low 4-bit
201D        LD     (IX),  A
2020        HALT
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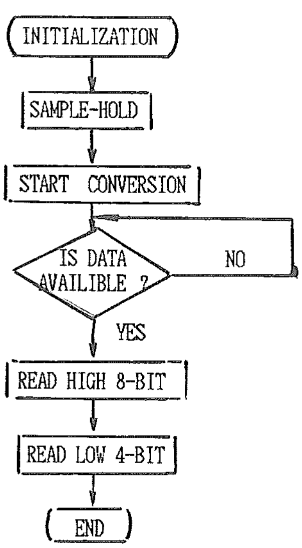

Figure 6. Flow Diagram of A/D Conversion

THe computer control system receives START and STOP instructions,along with other informations such as the kinds of the landing planes,the sorties and the landing time,from the central console.The informations about weather,distance and instructions sent out by pilots are obtained respectively from the visibility detecting system,the noise detecting system and the remote-controled receiver.The computer processes the information and then gives out instructions to control the laser.

The operation of the laser includes:

- Adjusting and fixing the slope
- Adjusting the frequency and intensity
- Changing the size and swaying the beams.

When finishing guiding an aeroplane,the system will guide the others,or stop guiding in accordance with sorties.

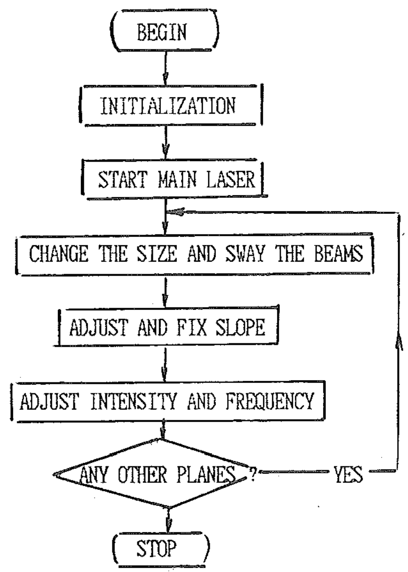

Figure 7. Flow Diagram of The Computer Control

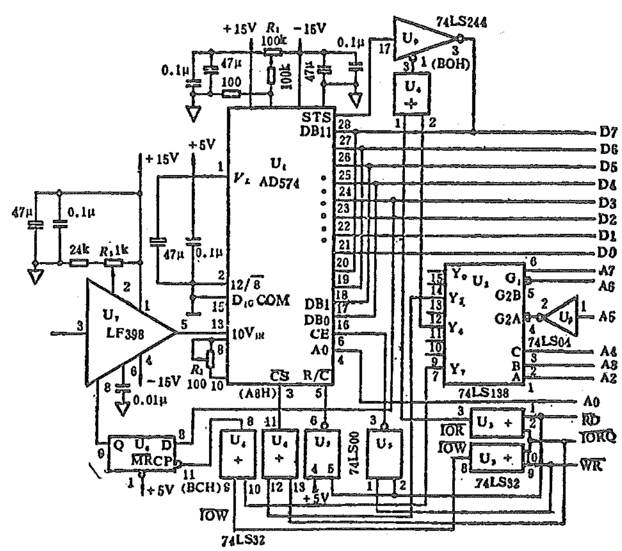

Figure 5. AD574 Interface to Z-80

Ⅵ: Comparison

In general,microwave guidance can only solve problems about course instead of descending height.But laser guidance can alter the slope of the laser beams according to descending curves of different types of planes. So it can show the pilot the height security-line all the way,help him to control descending height so as to ensure safety.

Microwave guidance is fan-guiding, When the visibility is very bad,it can only show the course and position of the runway appoximately,therefore it can not help the pilot to correct his operation in time,as well ensure the landing point is jusat correct position of the runway.Then the descending curve may make an angle with the midline.As a result, the plane may rush away or diverge from the runway ,bring about vile accidents.The laser guidance is linear guiding,even if the visibility is bad , we can conduct the plane down with laser beams like flying a kite. This can effectively prevent the plane from diverging from the runway.Microwave guidance does not have the features of indicating the sidelines, finding barriers during blind landing. But laser beams travel in line, we can use them to show the sidelines,the midline,and nearby barriers,etc;hence the poilt can be clear at a glance about the condition of the runway,and operate with facility.

Microwave guidance is easily interfered by enemy electronic jamming and stray electromagnetic wave with a result of the system being out of order.At present,laser guidance can not be interfered effectively by other methods except destroying directly.So laser guidance is more desirable for actual combat.

When laser guidance system is employed in concealed airports used at wartime,or in roads which are used as runways,it has the advantages of fine security,high flexibility and convenience,and training pilots easily,etc,By turning blind landing into distinct flying,the pilot can release his nerves and bring into play his subjective initiative and skill.So it is more acceptable by pilots and commanders.These specialities are beyond comparison to microwave guidance.

But this doesn't mean that the microwave guidance can be replaced by the laser guidance.The sphere of action of microwave guidance is large,guiding distance is long and the weather has no effect on it.These are its clear superiority to laser guidance.Therefore, these two systems should complement each other and exist simutaneously. When conducting a plane, first microwave guidance gives full play to its superiority, guides the plane to SIDE 4 and SIDE 5 till the pilot finds the guiding laser beams,then the laser beams guide the plane to land smoothly and safely.

Ⅶ. Prospects for the Laser Guidance

As the first generation of laser guiding system,we don't change or mount any parts on the plane.The second generation of laser guiding system will employ infrared-laser besides visible laser.They are emitted in parallel and received by infrared-laser receptors mounted on the wings of the plane.Under the support of modulation and demodulation technique,we can conveniently get vertical and horizontal deviation signals.The signals are separated and amplified,then delivered to autopilot to rectify the deviation.Therefore once the plane enters the laser area,it can land fully automatically.The principle block diagram is shown in Figure 8.

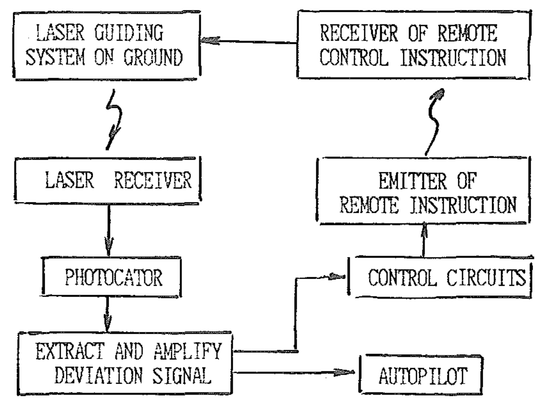

Figure 8. Laser Conducting System in Future

The infrared-laser has lots of merits,such as great energy, little harm to human eyes,high stability and reliability,long life,and cheap etc.It will play an important role in guidance in the future.Further experiments will solve the problems left.