MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS
DEPARTMENT OF AVIONICS

ALLOW TO DEFEND
Head of the Graduating Department
_________Y.V. Grishchenko
«___»___________2024 p.

QUALIFICATION WORK

(EXPLANATORY NOTE)

BACHELOR'S DEGREE GRADUATE

SPECIALTY 173 "AVIONICS"

Theme: «Testing the Quality of Cartographic Data and Video Information Reproduction by the Aircraft`s On-Board Display System»

Done by: 410-AV group, Potapenko Vasyl Kostyantinovich

Supervisor: PhD, As. Prof., V.N. Belinskiy

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(signature)

Kyiv 2024

NATIONAL AVIATION UNIVERSITY
Faculty of Air Navigation, Electronics and Telecommunications
Department of avionics
Specialty 173 ‘Avionics’

APPROVED
Head of department
__________ YURII Hryshchenko
‘___’ ____________2024

TASK
for execution graduation work
Vasyl Potapenko

1. Theme: «Testing the Quality of Cartographic Data and Video Information Reproduction by the Aircraft's On-Board Display System», approved by the order of the rector dated 14. 03 2024 p. № 385/st.

2. Duration of which is from May 13, 2024 to June 16, 2024

3. Input data of graduation work: Aircraft's On-Board Display System

4. Contents of the explanatory note (list of issues to be developed): Analysis of flight technical characteristics of passenger aircraft and their electronic display systems, Research of the structure cartographic data and functional for display systems, Research of methods for assessing the quality of the image on the display system, Development of a method for researching the quality of reproduction of cartographic data and video images.

5. List of mandatory graphic material: Table of aircraft performance characteristics, dysplay system diagrams, laboratory setup diagram, measures for testing the quality images.

6**. Planned schedule**

№	Task	Duration	Signature of supervisor
1.	Analysis of flight technical characteristics of passenger aircraft and their electronic display systems	13.05.2024	Done
2.	Research of the structure cartographic data and functional for display systems.	16.05.2024	Done
3.	Research of methods for assessing the quality of the image on the display system	23.05.2024	Done
4.	Development of a method for researching the quality of reproduction of cartographic data and video images	25.05.2024	Done
5.	Labor protection	27.05.2024	Done
6.	Environmental protection	30.05.2024	Done
7.	Preparation of graphic material	31.05.2024	Done
8.	Preparation of an explanatory note	01.06.2024	Done
9.	Introduction to the department. Elimination of deficiencies, preparation of an explanatory note	05.06.2024	Done

7. Consultants individual chapters

Chapter	Consultant (Position, surname, name, patronymic)	Date, signature	
		Task issued	Task accepted
Labor protection	Associate Professor Kateryna KAZHAN		
Environmental protection	Associate Professor Larysa Cherniak		

8. Date of assignment: 14.03.2024

Supervisor _______________ Valerii Bielinskyi

The task took to perform _______________ Vasyl Potapenko

ABSTRACT

Explanatory note to the qualification work «Testing the Quality of Cartographic Data and Video Information Reproduction by the Aircraft`s On-Board Display System»: 80 pages, 70 pics., 4 tables, 6 literature source.

The object of the research: On-board Information Display System (EFIS) for A320neo and A321 aircraft, including their displays and cartographic data.

The subject of the research: The quality of the display of cartographic data and video information on the on-board display system of the A320 neo and A321 aircraft, as well as testing the characteristics of the displays (color change, viewing angle, sharpness).

Research Method: To assess the quality of reproduction of cartographic data and video information on the displays of the onboard display system of A320 neo and A321 aircraft, as well as to identify defects in the display matrix that may affect the accuracy and clarity of information display.

Scientific novelty: Research of the technical documentation and characteristics of the EFIS system of A320 neo and A321 aircraft. Conducting tests for color changes, viewing angles, and clarity of displays using specialized software. Processing and analysis of the obtained data to determine the presence of defects and their impact on the display of information.

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REFERENCES

List of Abbreviations and Terms

A320neo – Airbus 320 New Engine Option

A321 – Airbus 321

EFI(S) - Electronic Flight Instrumentation (System)

PFD – Primary Flight Display

ND – Navigational Display

FCU – Flight Control Unit

DMC – Display Management Computer

EIS – Engine Indicating System

ECAM – Electronic Centralized Aircraft Monitor

UDU – Upper Display Unit

EWD – Engine/Warning Display

ECP – Electronic Centralized Panel

FWC – Flight Warning Computers

BSCI – Onboard cartographic information system

Introduction

In the early days of aviation, pilots flew without modern conveniences such as LCD monitors. Their instrument panels were equipped with analog instruments based on mechanical and electromechanical principles. Basic instruments included compasses, altimeters, speed indicators, and gyroscopic instruments for navigation and orientation. These instruments provided pilots with the basic information needed to fly, but required a high level of skill and care.

Early airplanes had open cockpits, which made flying especially difficult due to exposure to weather conditions and the need to rely on visual cues. In the absence of sophisticated navigation systems, pilots often relied on maps, landmarks, and even roads to navigate. Flying at night or in poor visibility conditions was extremely dangerous and required pilots to have excellent spatial awareness and the ability to make quick decisions.

With the development of aviation, instrument panels have become more complex. In the 1930s, radio navigation systems such as radio bands and radio compasses were introduced, greatly improving the accuracy of navigation. During World War II, aviation technology made great strides: autopilots, radar, and the first electronic flight control systems were developed and implemented to help pilots navigate and reduce workload.

The real revolution came with the advent of digital technology and LCD monitors in airplane cockpits. The 1970s and 1980s ushered in the era of glass cockpits, as analogue instruments began to be replaced by digital displays. These displays provided pilots with more accurate and varied information in an easy-to-read format. Data that previously required many separate instruments can now be displayed on a single screen. This not only reduced the number of instruments on the instrument panel, but also improved ergonomics and increased flight safety.

Modern LCD monitors allow you to integrate data from a wide variety of systems: navigation, meteorological, engine control systems and others. This allows pilots to have a complete picture of the aircraft and its surroundings in real time. Thanks to these technologies, today's pilots can effectively plan routes, avoid dangerous weather conditions and make informed decisions, which significantly improves the safety and efficiency of flights.

Thus, the transition from analog instruments to digital LCD monitors was a significant step forward in aviation, significantly facilitating the work of pilots and improving their ability to navigate in space.

CHAPTER 1. Analysis of flight technical characteristics of passenger aircraft A320neo and A321. Their electronic display systems.

1.1 Features and dimensions of the A321 and A320neo

1.1.1 Description and purpose of aircraft

	A320neo	**A321**
Description	The Airbus A320neo is a family of improved versions of medium-haul narrow-body passenger jets. The abbreviation "NEO" stands for "New Engine Option".	The Airbus A321 is a narrow-body aircraft with a tricycle landing gear, equipped with two engines.
Appointment	The A320neo is designed for use in short and medium distance passenger air transportation.	The A321 is designed for use in medium and long range aircraft

1.1.2 Structure and dimensions.

The A320neo cabin variant provides a two-class layout with simultaneous seating for up to 164 people, including 8 business class seats and 156 seats for passengers in economy class.

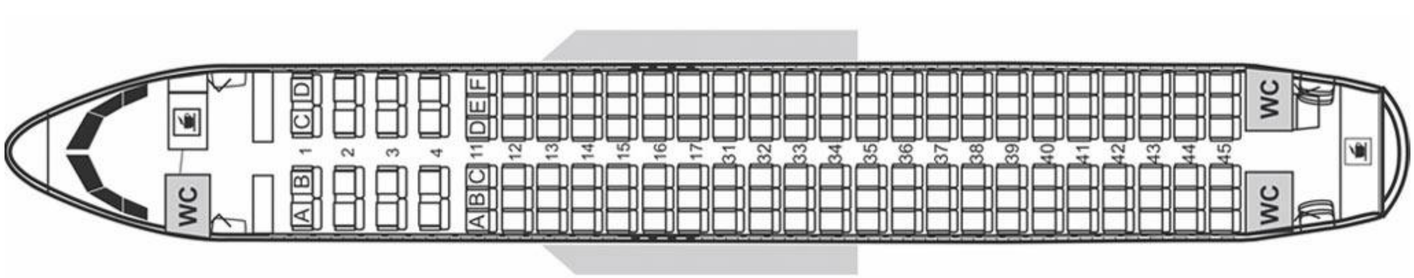

Fig 1.1.1

1-4 rows. Business Class. Comfortable wide and comfortable chairs, an increased level of service and a beautiful view from the porthole. To accommodate in such seats, you need to purchase special air tickets in Business Class, the cost of which is much higher than in Economy Class.

Round 11. The seats have increased legroom. However, there are also disadvantages - the gaze rests on the wall of the Business Class cabin, opposite is the engine, which creates increased noise.

Round 17 Comfortable seats with good space in front thanks to being close to the emergency exit. The disadvantage of the seats is the limited view - the wing blocks the view from the porthole.

Rows 38-41. Places that are convenient for their view from the porthole and are quite remote from toilets and engines. The disadvantage is the long disembarkation from the plane after the arrival of the flight. In the event that the disembarkation will be carried out only through one front jet bridge.

The cabin layout of the A320neo aircraft is extremely unique. Airlines can rebuild the cabin of the aircraft to suit any needs. A320 NEO seats range from 150 passengers in a two-class cabin (2+2 seats in Business Class and 3+3 seats in Economy Class) to 180 people in a single-class cabin.

For a more detailed understanding, a diagram of the dimensions of the main components of the aircraft is given:

1) Fuselage length 37.57 m

2) Wingspan 35.80 m

3) Fuselage height 11.76m

4) Cab width 3.7m

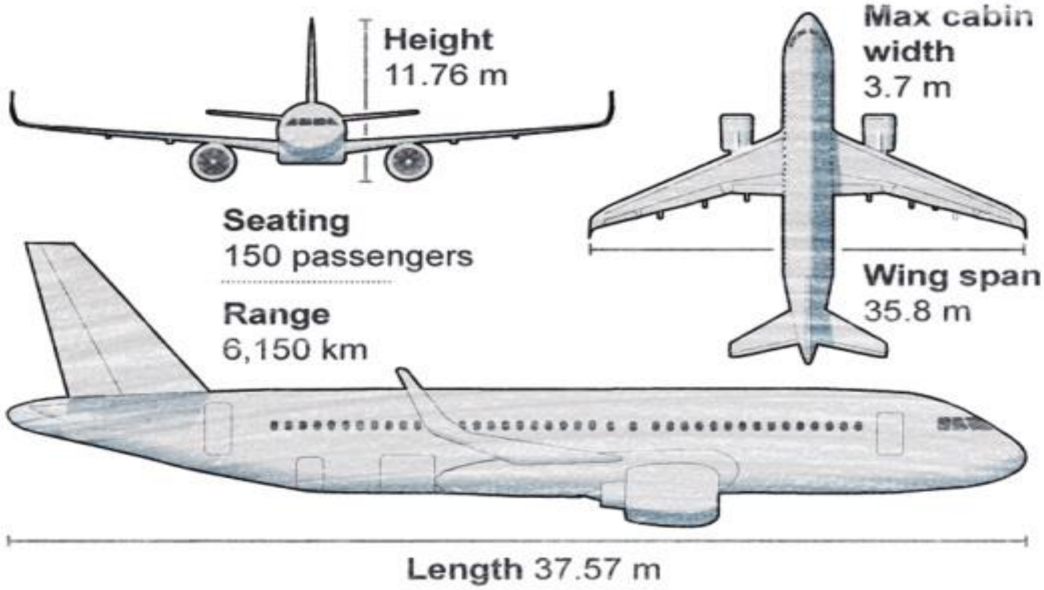

Fig 1.1.2

Unlike the A320neo, the A321 is the longest member of Airbus' best-selling single-aisle family, seating between 180 and 220 passengers in a standard two-class cabin layout and up to 244 passengers with a tighter seating arrangement.

Sizes

Total length 44.51 m

Cabin length 34.44 m

Fuselage width 3.95 m

Maximum cab width 3.70 m

Wingspan (geometric) 35.80 m

Height 11.76 m

Track 7.59 m

Wheelbase 16.90 m

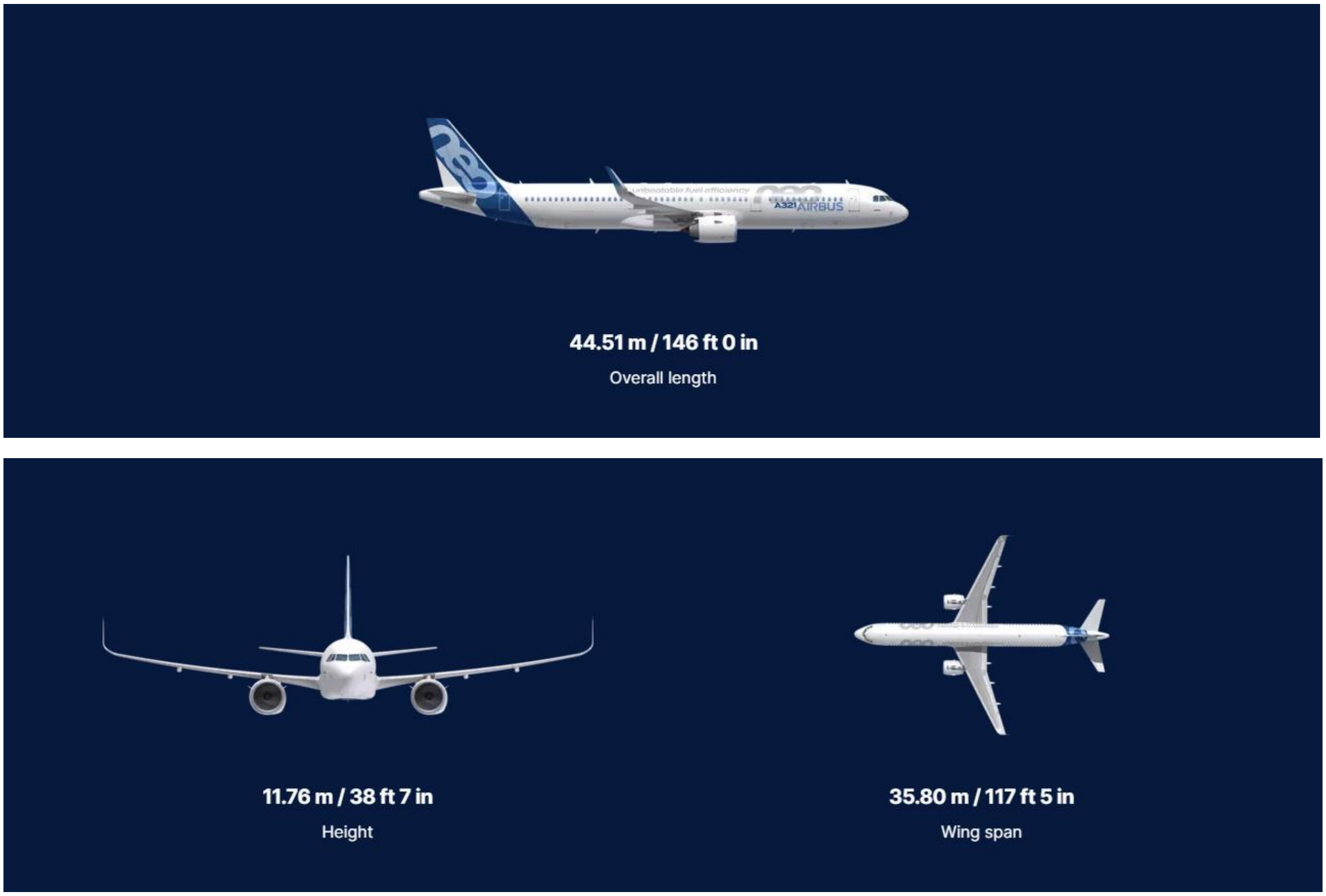

Fig 1.1.3

Capacity

Maximum number of seats: 244

The typical number of 2-class seats is 180-220

Load Capacity LD3 Under Floor 10 LD3-45W

Max. Number of pallets under the floor 10

Water volume 59 m³

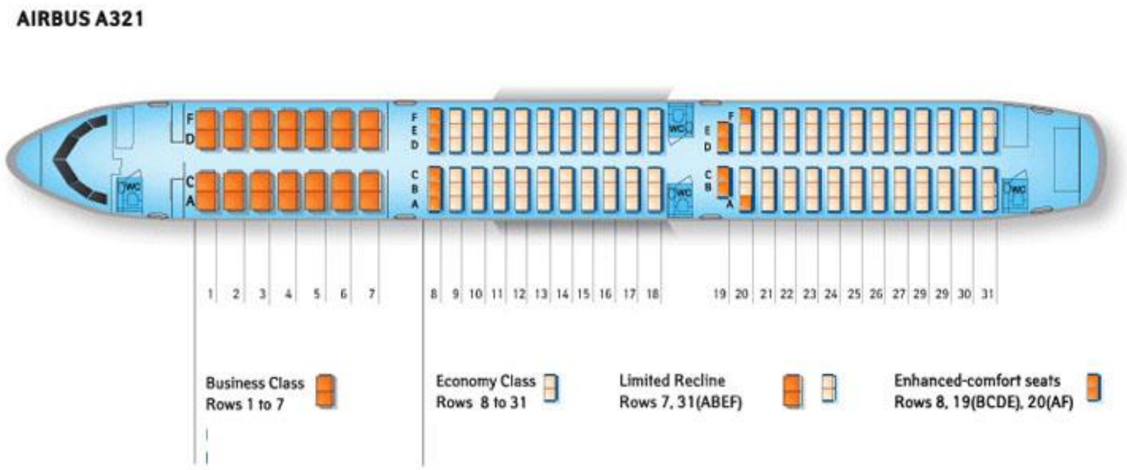

Fig 1.1.4

Fig 1.1.5

Characteristics

Flight range 7400 km

Maximum speed in Mach M0.82

Maximum curb weight 97.40 t

Maximum take-off weight 97.00 t

Maximum take-off weight 79.20 t

Maximum weight of zero fuel 75.60 t

Maximum fuel capacity 32,940 litres

Fig 1.1.6

1.2 Flight characteristics

1.2.1 Types of aircraft operating speeds

A320neo

MAXIMUM OPERATING SPEED	DEFINITION	EXAMPLES OF QUANTITIES SPEEDS FOR A320 NEO AIRCRAFT
Maximum Operating speed V0/M0	V0 or M0 are speeds that must not be intentionally exceeded in any flight mode (climb, cruising or descending).	V0 = 350 knots (IAS) M0 = M0.82 (Mach)

Flight speed with flaps extended V	V must be installed so that it did not exceed the design speed flight with flaps extended.	CONF1 230-215 knots CONF2 200 knots CONF3 185 knots CONFFULL 177 knots
Speed flight with extended gears VL0 / VLE	VL0: Landing Gear Speed VL0 must not be allowed to exceed the speed limit flight that ensures safety both during and during the retraction of the chassis. If the speed of at the time of release is not equal to the speed during cleaning, these two Speeds must be marked accordingly VL0(EXT) and VL0(RET).	VL0 RET (gear up) 220 knots. (IAS) VL0 EXT (gear down) 250 knots. (IAS) VLE (extended gears) 280 knots. / M 0.67

A321

MAXIMUM OPERATING SPEED	**DEFINITION**	**EXAMPLES OF QUANTITIES SPEEDS FOR A321 AIRCRAFT**
Maximum Operating speed V0/M0	V0 or M0 are speeds that must not be intentionally exceeded in any flight mode (climb, cruising or descending).	V0 = 450 knots. (IAS) M0 = M0.82 (Mach)
Flight speed with flaps extended V	V must be installed so that it did not exceed the design speed flight with the flaps extended.	CONF1 240-225 knots. CONF2 210 knots. CONF3 195 knots. CONFFULL 185 knots.
Speed flight with extended gears VL0 / VLE	VL0: Landing Gear Speed VL0 must not be allowed to exceed the speed limit flight that ensures safety both during	VL0 RET (gear up) 225 knots. (IAS) VL0 EXT (gear down)

	and during the retraction of the chassis. If the speed of at the time of release is not equal to the speed during cleaning, these two Speeds must be marked accordingly VL0(EXT) and VL0(RET).	255 knots. (IAS) VLE (extended gears) 285 knots. / M 0.67

1.3 Analysis of electronic display systems

1.3.1 EFIS (Electronic Flight Instrument System)

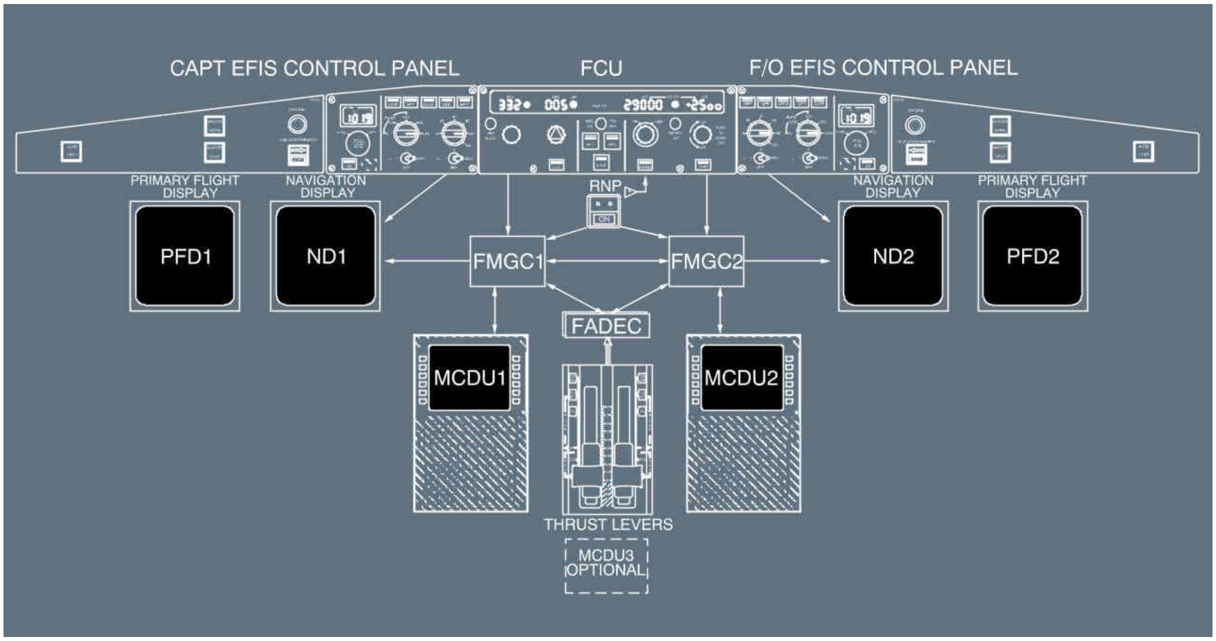

Fig 1.3.1

The **EFIS system** in the **A320neo** and **A321** uses electronic displays to show important flight metrics such as speed, altitude, angle of attack, heading, vertical speed, and more. This allows pilots to get the information they need quickly and accurately.

EFIS Consists of:

1) Two Primary Flight Displays

Fig 1.3.2

The Primary Flight Display (PFD) is the primary flight data display, which is designed to display critical information about the flight and condition of the aircraft. Here are the main properties and functions of the PFD:

1. **Basic Information Display: The** PFD displays basic flight parameters such as altitude, speed, angle of attack, vertical speed, and engine, fuel, and avionics information.
2. **Graphical representation:** The information on the PFD is represented graphically, making it easily readable and understandable to the pilot, even under high load conditions.
3. **Alarm and Warning Message Indication:** The PFD also displays messages about emergency and warning conditions such as collision threats, low altitude, system anomalies, and other critical situations.
4. **Integration with Autopilot and Navigation System:** The PFD is integrated with the autopilot and navigation system, allowing for automatic flight control and route tracking.

5. **Display Modes: The** PFD typically has multiple display modes, such as navigation mode, engine display mode, synchronization mode with other displays in the cockpit, etc., allowing pilots to choose the most appropriate display format.

Overall, the PFD is a key element in the Electronic Flight Indication System, which provides pilots with important information to operate the aircraft safely and efficiently.

2) Navigational Display

Fig 1.3.3

Navigational Display (ND) is an element of the electronic flight indication system that displays information about the route, navigation points, airspace map, as well as other information necessary for navigation during flight. Let's take a look at the main properties and functions of a navigation display:

1. **Display of route information:** ND displays the flight plan, including the route, viewpoints, entry and exit points of air routes, aerodromes and other key facilities.
2. **Graphical representation of navigational information:** The information on the ND is represented graphically, usually against the background of a map or airspace plan, making it easier to navigate and navigate in space.

3. **Display of navigation data:** ND also displays data on radio navigation (such as data from GPS or VOR), distance to points, speed, heading, altimetrical altitude, and other parameters required for navigation.

4. **Integration with other systems:** The ND is integrated with the autopilot, flight control systems, and other elements of the electronic display system, allowing it to automatically monitor the route and adjust it as needed.

5. **Display Modes: ND** typically has multiple display modes such as map mode, nearby aerodrome display mode, weather mode, etc., enabling pilots to choose the most appropriate information display format depending on the situation.

The navigation display plays an important role in ensuring safe and efficient navigation during flight, providing pilots with the necessary information to correctly complete the route and navigate in space.

3) Two EFIS control section on Flight Control Unit

Fig 1.3.4

Flight Control Unit - responsible for controlling the parameters of the Electronic Flight Indication System (EFIS) during flight. The main properties and functions of this section are:

1. **Display Mode Control:** EFIS control section on FCU allows pilots to select display modes on Primary Flight Displays (PFD) and Navigation Displays (ND). This includes choosing between map, navigation, weather, radio navigation, and more modes.
2. **Changing Flight Parameters:** With the EFIS control section on FCU, pilots can change various flight parameters such as altitude, heading, speed, vertical speed, etc., enabling them to effectively control the flight according to the operational situation.

4) Display Management Computer

Fig 1.3.5

The Display Management Computer (DMC) is a component of the Electronic Flight Indication System (EFIS) that is responsible for managing and coordinating the displayed information on aircraft screens. Here are the main properties and functions of DMC:

1. **Display Management: DMC** is responsible for managing the graphical representation of data on EFIS displays such as Primary Flight Display (PFD), Navigation Display (ND), and other screens.
2. **Data processing and interpretation:** DMC takes information from various aircraft systems, such as navigation data, flight parameters, engine control systems, etc., and processes it for further display on screens.
3. **Monitoring and diagnostics:** DMC monitors the operation of displays and their proper functioning, as well as provides diagnostic and data analysis capabilities to identify any malfunctions or errors.

With that been said, **the Display Management Computer (DMC)** plays an important role in ensuring that the information displayed on the aircraft's displays is effectively managed and coordinated, helping pilots make informed decisions during flight.

CONCLUSIONS TO THE CHAPTER 1

For the Electronic Flight Display System (EFI) on the A320 NEO and A321 aircraft, it can be summarized and after analysis that the EFI consists of three main elements: two Primary Flight Displays (PFDs), two Navigational Displays (ND) and an EFI Flight Control Unit (FCU).

Primary Flight Displays (PFDs): These displays display basic flight information, including flight parameters, engine status, fuel, and avionics. They also provide a graphical representation of data, including alarm and warning messages, and integrate with the autopilot and navigation system.

Navigational Displays (ND): These displays show route information, navigation data, radio navigation, and other parameters needed for in-flight navigation. They also integrate with other systems and have multiple display modes.

EFIS control section on Flight Control Unit (FCU): This section is responsible for controlling the display modes on the PFD and ND, changing flight parameters, selecting navigation parameters, and integrating with the autopilot.

CHAPTER 2. Research of the structure cartographic data and functional for display systems.

2.1 Analysis of the principles of geoinformation data formation and structure of the BSCI system.

Geo-information data includes information on terrain (relief, settlements, roads), air routes, weather conditions and tactical features of the areas. To manage this information, a BSCI system is used on board the aircraft. This system is designed to store and display geo-information data on indicators in the airplane. Despite the availability of various technical solutions for BSCI, the automation of geoinformation processes remains insufficient. Thus, an important task is to develop more automated methods for handling this data on board the aircraft.

The principles of geoinformation data formation are related to the information need of the airplane crew, which depends on the mode and conditions of flight. Digital representation of the terrain map is used to display actual geoinformation data.

A digital terrain map is created from the original paper map, which is converted into electronic form using geodetic data and satellite positioning technologies. This data is stored in special databases and consists of various layers such as relief, vegetation, roads, etc.

Objects on a digital terrain map are linked to different layers according to their type and characteristics. For example, they may be associated with aeronautical information, object size, or time of year. These data are stored in DFX or SXF formats, which provides the possibility of processing the information in various computer-aided design systems.

Thus, the formation of geoinformation data is based on the conversion of a paper map into electronic form with the subsequent binding of objects to different layers according to their characteristics and the needs of the airplane crew.

Cartographic data is organized as different layers on a digital terrain map. Each layer represents a particular type of information or characteristics of objects. For example, a map may have layers representing terrain, vegetation, roads, aeronautical data, and so on. These layers can be overlaid on each other to create a complete and informative map of the area. This approach allows to efficiently manage a large amount of information and make the map more understandable and useful for users, including the airplane crew.

Layer 0 - contains part of the semantic data of the terrain model that tells the pilot the names of settlements in the flight area.

Fig 2.1.1

Layer 2 - contains the terrain model metric data representing the world map at a given scale.

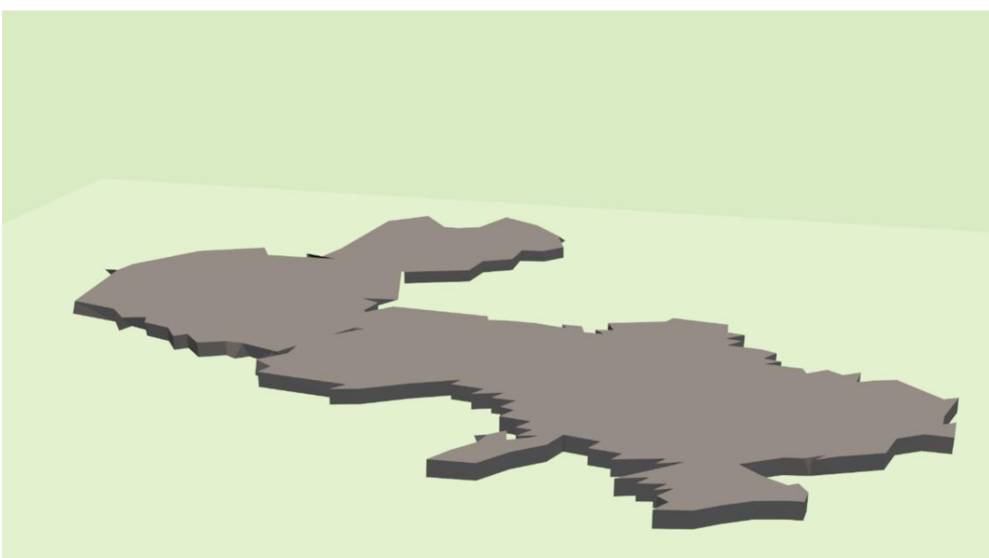
Fig 2.1.2

The information frame obtained as a result of layer overlapping gives an idea of the mutual location of geoinformation objects. Such representation makes it possible to redraw only separate map layers when the tactical situation changes.

Fig 2.1.3

To display geospatial data based on the introduced data structures, the following principles of image formation on on-board display means are used:

- inline reading of metric data with selection of types of data displayed in each data layer;
- formation of the list of data to be displayed based on the analysis of semantic information of objects falling into the display frame and the scale of geospatial data representation;
- identification of objects by specified coordinates, determination of object properties and their semantic parameters;
- determination of metric data, semantic parameters and object properties by given identification information.

The described data structure is realized as a part of the computing module, which is a part of the onboard mapping system.

The structure of BSCI system

The onboard cartographic information system (BSCI) performs information interaction with onboard radio-electronic equipment systems (BRES) and also provides storage, reading, preparation, transformation and output of digital terrain map, navigation and operational-tactical information (in the overlap mode) to onboard information displaying means.

BSCI consists of the following functional units:

- computing module (CM) - used as a module of the BSCI central processor;
- discrete information exchange module - is used for information exchange with the BRES subscribers via the serial exchange channel;
- graphic module (MG) - used to generate and output a digital map of the terrain in TV format to the display means of the BDMS;
- external memory module (IM) - used for recording and storing geo-information data recorded from an external carrier;
- exchange module (ME) - used for information exchange with the DDR subscribers via multiplexed exchange channel;
- voltage module (VM) - used for power supply of modules included in the BSCI.

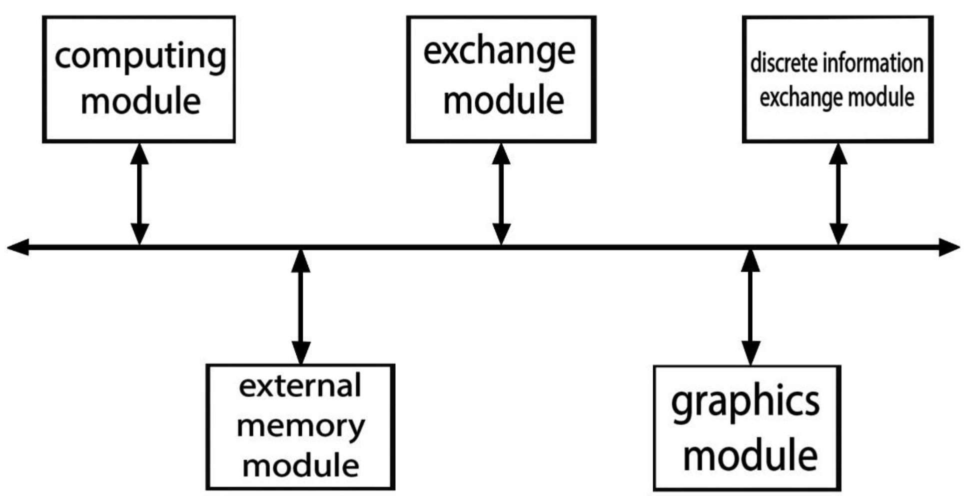

Fig 2.1.4

The BSCI provides:

- interaction with onboard radio-electronic equipment via multiplexed channel of information exchange, serial codes and one-time commands;
- storage, reading, conversion and transmission of the combined television image of the digital terrain map and operational-tactical information for display onboard indication means.

2.2 Investigation of the accuracy of visual determination of the location of the map object on the display of the indicator.

In the course of aircraft flight, the onboard navigation complex evaluates the values of pilotage and navigation parameters - latitude and longitude of object positioning in a given coordinate system, aircraft speed, relative and barometric pressures. To inform the crew about the location of the aircraft, the values of estimates of a number of navigation parameters are displayed onboard indication means. The main element of indication of modern navigation complexes are onboard indicators of MFCI class (multifunctional color indicators) made on the basis of flat liquid crystal display (LCD) panels. The display of estimates of navigation parameter values on board an airplane can be realized in two ways:

1) directly - the numerical value of the parameter is displayed on the MFCI screen;

2) mnemonic - the MFCI screen displays the silhouette of the object against the background of the substrate, which is a graphic image of the terrain map in the flight area (in projections “view from the ground to the airplane” or “view from the airplane to the ground”). The direct method of displaying the values of navigation parameter estimates is easy to use by the crew, but requires the navigator to perform additional operations of positioning the aircraft on the terrain.

The mnemonic method of display is more visible for the crew, because in the combined mode both the terrain map and the object location are simultaneously displayed, but it is less accurate and is used today for geo-information support and increasing situational awareness of the crew about the geographical terrain in the flight area. The purpose of this paper is to present to a wide range of readers the results of scientific research results of the author's team in the field of obtaining estimates of the accuracy of the object location display in geoinformation systems and indication systems of modern manned aircraft navigation complexes for the mnemonic method.

Navigation parameters mapping error

Synthesis and display of geoinformation data on the MFCI screen, which has a discrete (pixel) screen structure, is carried out in the combined mode.

The combined mode implies simultaneous display of navigation information and cartographic information, which is a digital array of the terrain map in the aircraft flight area, on one display medium.

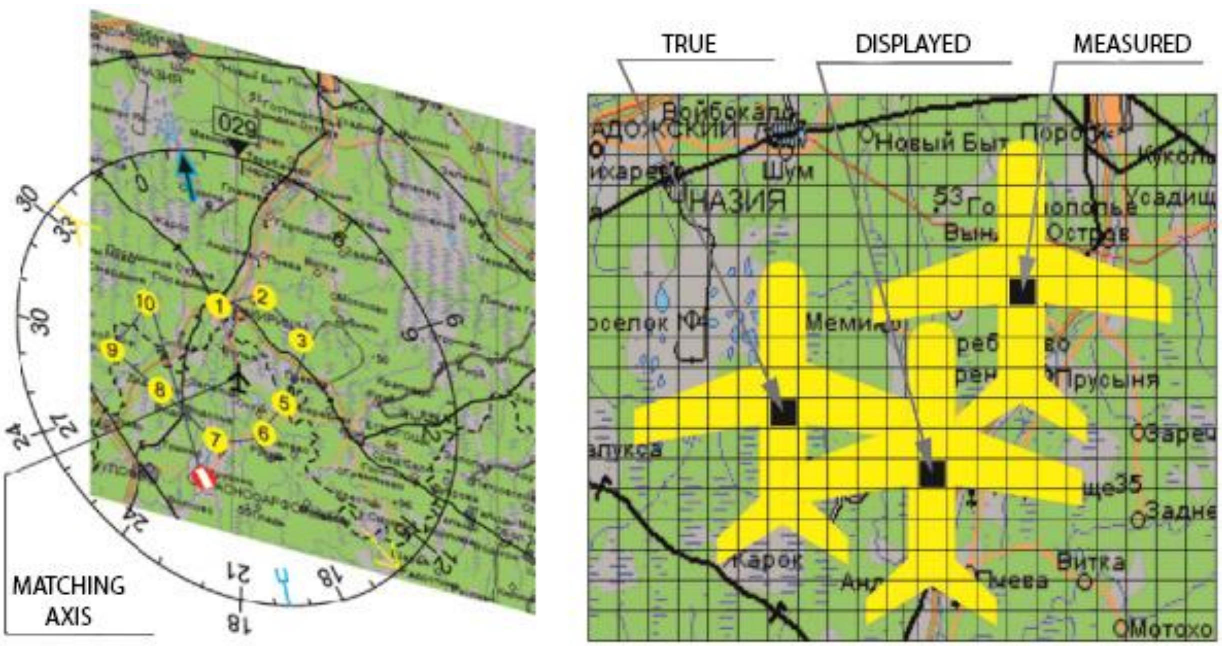

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Fig 2.2.1

To combine two types of dissimilar images, the following is used reference point, which can be the starting point of the LCD panel coordinate system, as well as geographic coordinates of latitude and coordinate system of the LCD panel, as well as geographic coordinates of latitude and longitude of the object measured (estimated during the flight).

It is customary to distinguish between:

1) **TRUE** position of the airplane in geographic coordinates. The true position of the aircraft is determined by the projection of the object's center of mass on the physical map of the area.
2) **MEASURED** position of the airplane in geographic coordinates. The measured aircraft position is determined by the projection of the estimated values of latitude and longitude of the aircraft position on the terrain map, taking into account the existing errors of measurements and program-algorithmic processing.
3) **DISPLAYED** position of the airplane in geographic coordinates. The displayed aircraft position is determined by the projection of the reference point of the mnemonic pattern of the object on the indicated terrain map. In the absence of systematic errors, the displayed and estimated aircraft positions on the MFCI screen overlapping.

The accuracy of the visual location of an object on the indicator display depends on several factors, including the scale of the map display, type of LCD screen, screen size, and screen resolution (number of vertical and horizontal pixels). Depending on these parameters, a single pixel can represent different distances on the map.

The following map display scales are commonly used in the aviation industry: 1:0.25 km; 1:2 km; 1:5 km; 1:10 km; 1:15 km. This means that one centimeter on the map corresponds to 0.25 km, 2 km, 5 km, 10 km, or 15 km on the ground, respectively.

The LCD screens used on board have different sizes and resolutions. The screen sizes (in inches) can be 5″×5″, 6″×6″, 6″×8″, 7.2″×9.6″, 9″×12″, and the screen resolutions can be as follows: 480×480, 640×480, 768×576, 800×600, 768×768, 1024×768, 1400×1050, 1600×1200.

An accuracy research is to determine how accurately the location of an object on a map can be determined with different combinations of these parameters.

Example:

Suppose a 1:5 km scale map is displayed on a 6″×8″ display with a resolution of 800×600 pixels. In this case, one pixel represents a terrain area of approximately 6.25 meters (5 km / 800 pixels). If a pilot needs to locate an airport on such a map, the accuracy will depend on the size and resolution of the screen as well as the scale of the map. The larger the screen and higher the resolution, the more accurate the location of the object can be determined.

The division value of one pixel of the LCD screen of the MFCI indicator when displaying a digital terrain map on board the aircraft shall be determined according to the table below:

Screen Size (inches)	**Resolution (pixels)**	**Scale 1:0.25 km**	**Scale 1:2 km**	**Scale 1:5 km**	**Scale 1:10 km**	**Scale 1:15 km**
5″×5″	480×480	0.52 m/pixel	4.17 m/pixel	10.42 m/pixel	20.83 m/pixel	31.25 m/pixel
6″×6″	640×480	0.39 m/pixel	3.13 m/pixel	7.81 m/pixel	15.63 m/pixel	23.44 m/pixel
6″×8″	768×576	0.33 m/pixel	2.60 m/pixel	6.51 m/pixel	13.02 m/pixel	19.53 m/pixel
7.2″×9.6″	800×600	0.31 m/pixel	2.50 m/pixel	6.25 m/pixel	12.50 m/pixel	18.75 m/pixel
9″×12″	1024×768	0.24 m/pixel	1.95 m/pixel	4.88 m/pixel	9.77 m/pixel	14.65 m/pixel
9″×12″	1400×1050	0.18 m/pixel	1.43 m/pixel	3.57 m/pixel	7.14 m/pixel	10.71 m/pixel
9″×12″	1600×1200	0.16 m/pixel	1.25 m/pixel	3.13 m/pixel	6.25 m/pixel	9.38 m/pixel

This table shows how many meters on the ground correspond to one pixel on the screen for different combinations of screen sizes, resolutions, and map scales. The higher the screen resolution (i.e., the more pixels per inch), the smaller the area on the ground that corresponds to a single pixel. This allows you to display a more detailed and accurate picture on the screen.

Calculation of the division price of one pixel of the LCD panel was made by the formula:

$$m = \frac{M \cdot L}{l \cdot c},$$

where ***m*** - division price of one pixel of the LCD panel, m;

M - scale of the displayed terrain map, m;

L - side of the LCD matrix, m;

l - number of pixels in side L of the LCD-matrix;

c = 0.01 - dimensional coefficient, m.

Example Calculation

Suppose we have the following parameters:

1) Scale of the displayed terrain map

   M = 1:5000 (or 5000 meters).

2) Side of the LCD matrix

   L = 0.15 meters (which is 6 inches).

3) Number of pixels along side

   l = 800 pixels.

4) Dimensional coefficient

   c = 0.01 meters.

$$M := \frac{1}{5000} \quad \text{(or 5000 meters)}$$

$$L := 0.15 \text{ meters} \quad \text{(6" inches)}$$

$$l := 800 \text{ pixels} \quad \text{(along side L)}$$

$$c := 0.01 \text{ meters} \quad \text{(Dimensional coefficient)}$$

$$\boxed{m := \frac{1}{M} \cdot \frac{c}{l \cdot L}}$$

$$m = 0.417 \quad \text{(meters/pixel)}$$

Fig 2.2.2

CONCLUSIONS TO THE CHAPTER 2

Cartographic data is organized as different layers on a digital terrain map. Each layer represents a particular type of information or characteristics of objects. This approach allows to efficiently manage a large amount of information and make the map more understandable and useful for users, including the airplane crew.

BSCI system automates many processes related to the preparation, storage, and display of geographic data. This reduces the workload on the flight crew and minimizes the risk of human error.

The higher the screen resolution (i.e., the more pixels per inch), the smaller the area on the ground that corresponds to a single pixel. The division value of one pixel of the LCD screen of the MFCI indicator when displaying a digital terrain map on board the aircraft shall be determined according to the table.

<u>**CHAPTER 3. Research of methods for assessing the quality of the image on the display system.**</u>

3.1 Explore of the technology for testing the image quality of LCD indicators of modern aircraft.

There are 3 types of Built-In Test:

- Power-On Self Test (POST): this includes software and hardware testing activated at power on. The objective of the POST is to ensure of the validity of the equipment

- Continuous Built-In Test (CBIT): the CBIT includes recurrent tests. The objective is to detect internal or external, to memorize the abnormal event, to analyze it and then to transmit the failure report to the centralized maintenance system i.e. the CFDIU (Centralized Fault Interface Unit)

- Initiated Test (IBIT): interactive test called IBIT are activated while the aircraft is on ground, the CFDS (Centralized Fault Display Display System) switched to MENU mode, the INST (Instrument) page selected and finally the EIS 1 (2) or (3) page has been selected by the MCDU operator.

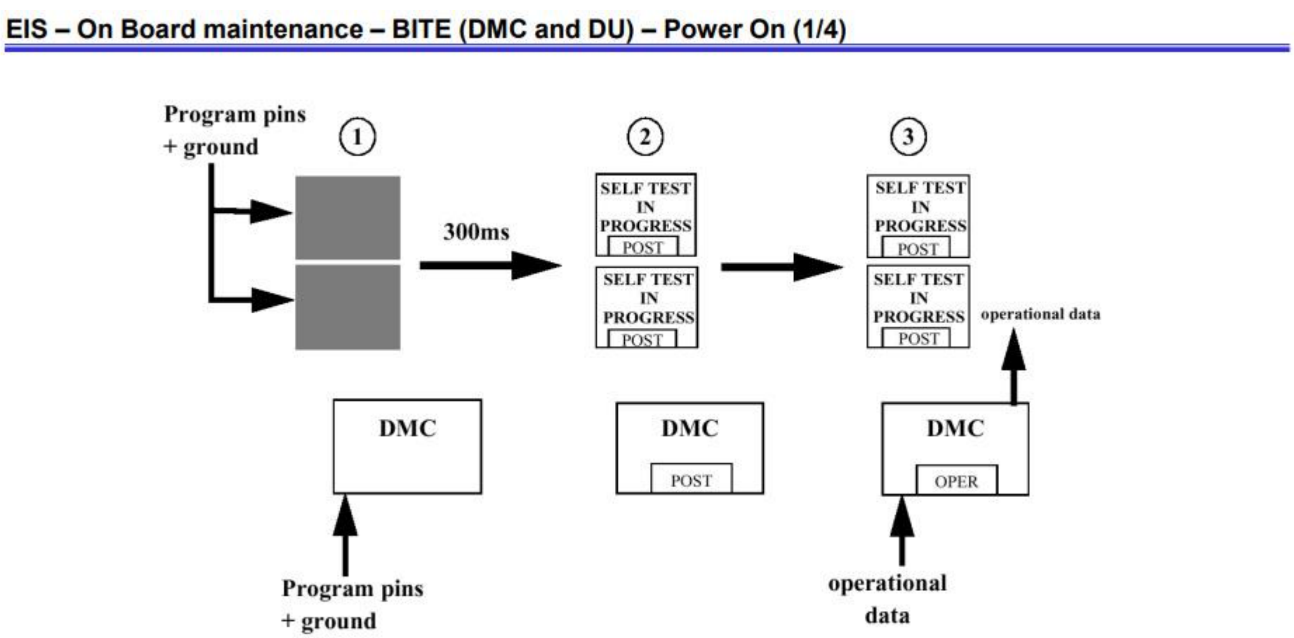


Fig 3.1.1

1 : after power-on, DMC and DU acquire flight/ground information during 300 ms and pin-programming.

2 : after 300 ms, DMC and DU activate the POST mode. DUs display the SELF TEST IN PROGRESS green message.

3 : DMC, after correct completion of the POST mode, activates the OPER mode and sends operational data to DUs. DUs, because of their internal hardware tests duration, are always activating the POST mode tests and displaying the SELF TEST IN PROGRESS green message.

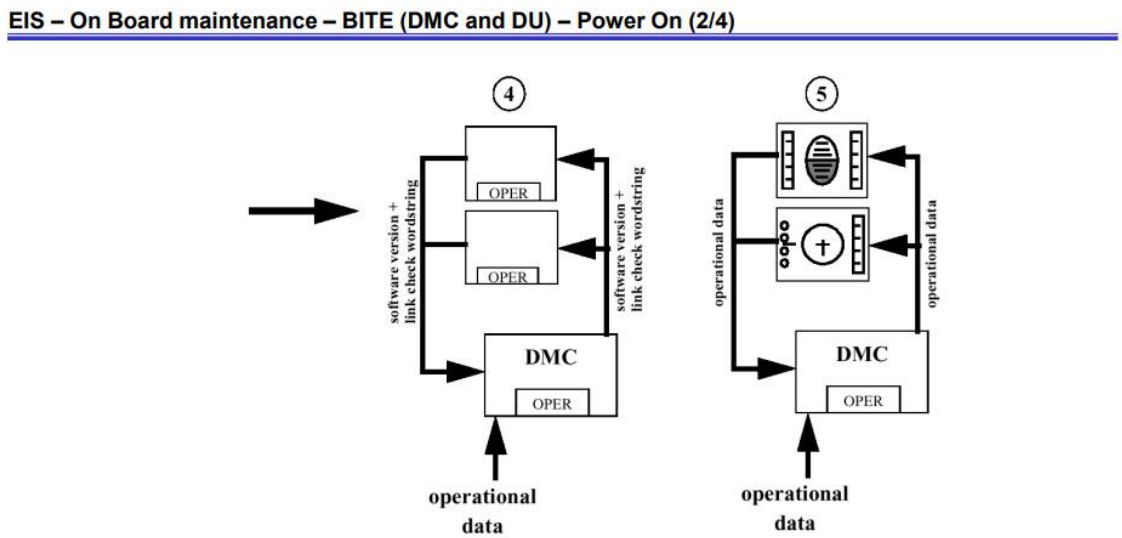


Fig 3.1.2

4 : DUs, after correct completion of the POST mode, activate the OPER mode. During this phase, DUs send software version and link check wordstring and activate the software version check process and the A629 inputs validity check process. During this phase (short test), nothing is displayed on DUs. DMC is always sending operational data to DUs.

5 : after correct completion of theses checks, DUs display an operational image.

The duration of these tests is equal to 40 seconds for the LCDU and 35 seconds for the DMC.

During the POST mode, or in case of interruption during the POSTs, when the DU starts again and if the results of the previous POST was OK, the **SELF TEST IN PROGRESS (MAX 40 SECONDS)** green message is displayed, when the required resources are available.

Fig 3.1.3

If the required resources are available, the **INVALID DISPLAY UNIT** amber message is displayed when: - a fatal failure is detected during the DU POST, - or in case of interruption during the POSTs, when the DU starts again and if the results of the previous POST was KO.

Fig 3.1.4

If the hardware resources to display a failure message, are not available, the hardware pattern **F** is displayed in amber. If any failure is detected during the start-up phase (for instance if one of the two graphic channels is out of order), the software orders directly to the hardware the display of the hardware pattern **F**.

Fig 3.1.5

In case of DMC POST activity n° 1, 2, 3, or 5 failure the DU displays the **INVALID DATA** amber message.

Fig 3.1.6

In case of DMC POST activity n° 4 failure the DU displays the **DMC VERSION INCONSISTENCY** amber message.

Fig 3.1.7

The POST mode activities and their sequence for DMC are:

1) hardware P/N compatibility check (complete),

2) pin program parity check (complete),

3) equipment location check (complete),

4) engine type validity check (complete),

5) internal hardware tests (complete/light).

The POST mode activities and their sequence for DU are:

1) hardware P/N compatibility check (complete),

2) pin program parity check (complete),

3) equipment location check (complete),

4) internal hardware tests (complete/light).

In-Depth Guide to LCD Status Monitoring

LCD Status refers to the functionality within a system that allows users to check and verify the operational status and wear level of LCD (Liquid Crystal Display) units. This is typically part of a diagnostic or maintenance feature that helps ensure the displays are functioning correctly and helps identify any issues that may need attention.

The LCD Status page, activated by key 5L of the Pin Prog/Status and Xload menu, allows to verify the wear level of the LCD displays. Three test patterns could be displayed on the LCDU.

<u>• LCD Status Activation:</u>

- On LCDU STATUS command reception from the active DMC, the DU:

- Displays the test image corresponding to the selected key.

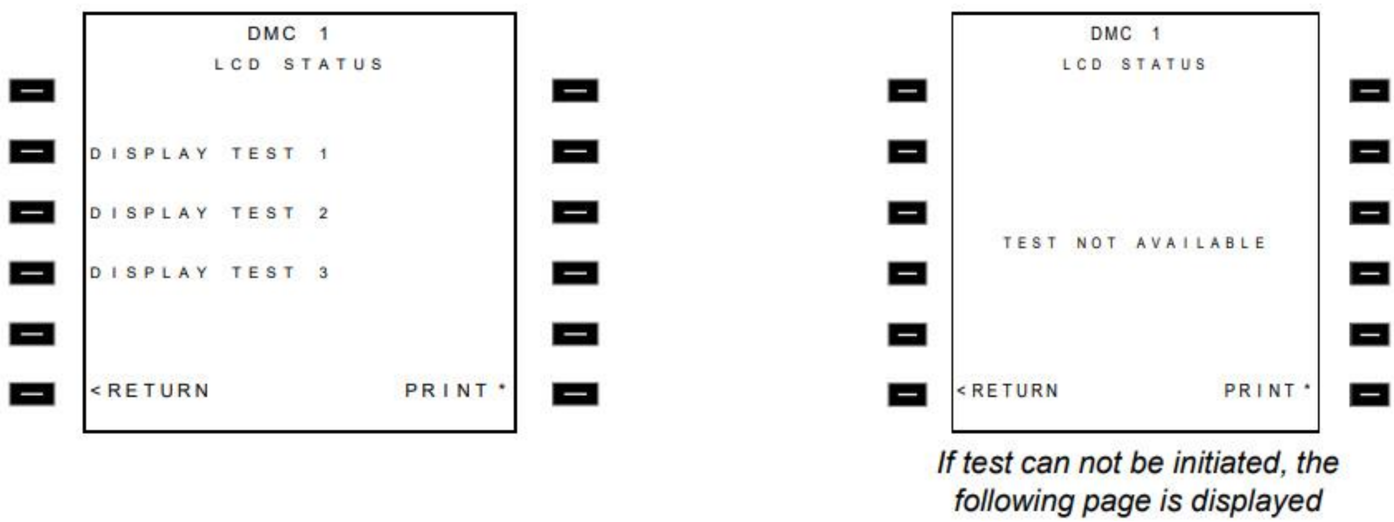


Fig 3.1.8

The **Display Test 1** is used during on-board maintenance step, in order to evaluate the graphic drawing capability of the LCDU725. A specific pattern is used which is composed of:

- a color palette which presents the 8 basis colors,

- a gray scale from Black to White in order to check the addressing chain of the LCD panel,

- the LCDU725 Part and Serial Number,

- the EIS Software Part Number.

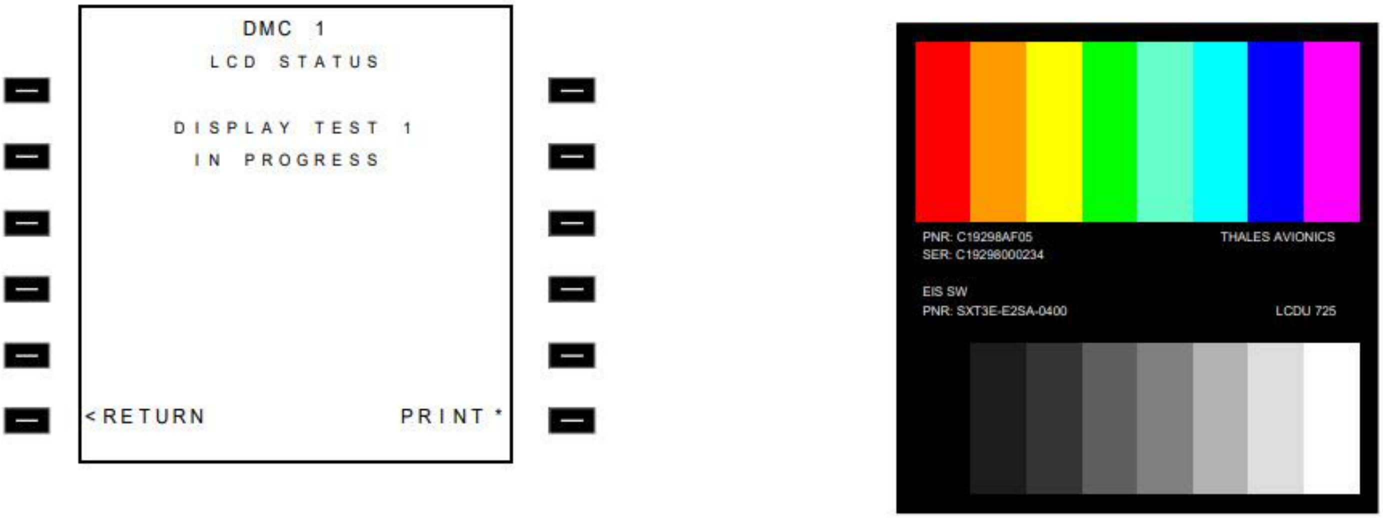


Fig 3.1.8

The **Display Test 2** is used to check the Pixels defect OFF and ON by a visual control of a dedicated checkerboard gray and white colored.

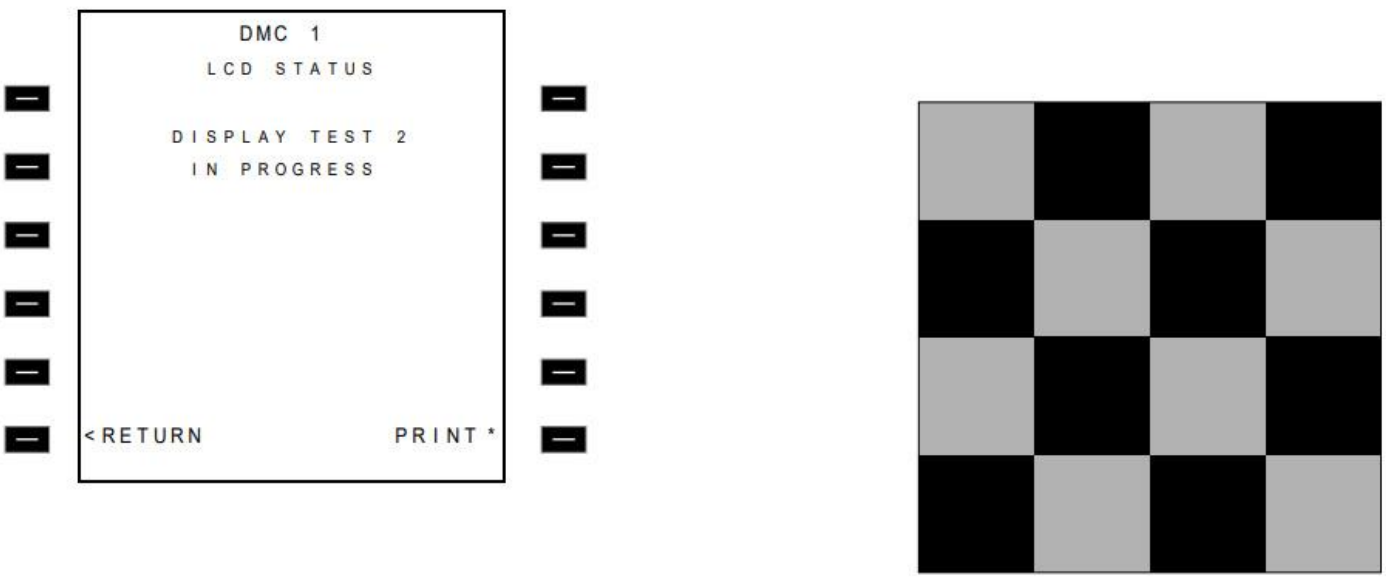
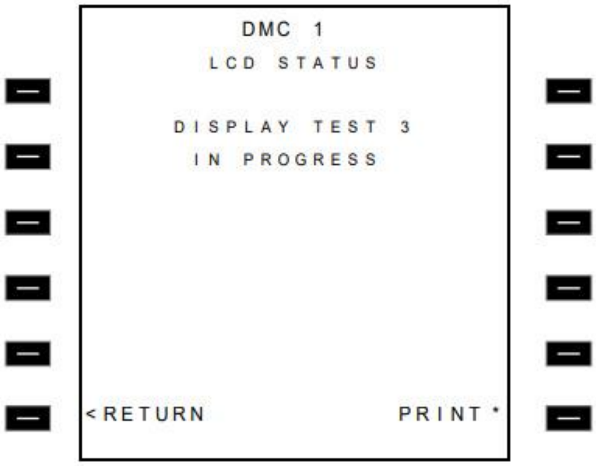


Fig 3.1.9

The **Display Test 3** is used to check the Pixels defect OFF and ON by a visual control of a dedicated checkerboard gray and white colored.



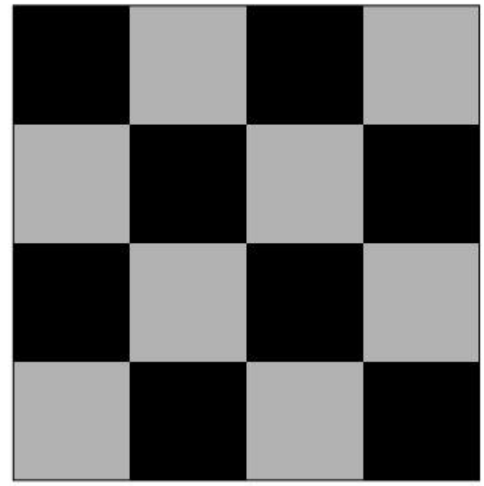


Fig 3.1.9

INDICATING AND RECORDING SYSTEMS EIS BITE SYSTEM

EIS MCDU MENU DESCRIPTION

Functionality The SYSTEM REPORT/TEST page enables to select INST DISPLAY function in order to interrogate the EIS SYSTEM for failure, report display and testing.

The selection of one of the 3 DMCs will give access to the related DMC BITE page. Each DMC is a type 1 computer with a BITE menu providing a GROUND SCANNING and the following specific functions. The SYSTEM TEST function allows an automatic test of the EIS and an operator display visual check. The system test performs in the following order:

1) a DMC self test,
2) a DMC/DUs A629 link test,
3) a connected DUs self test,
4) a display check.

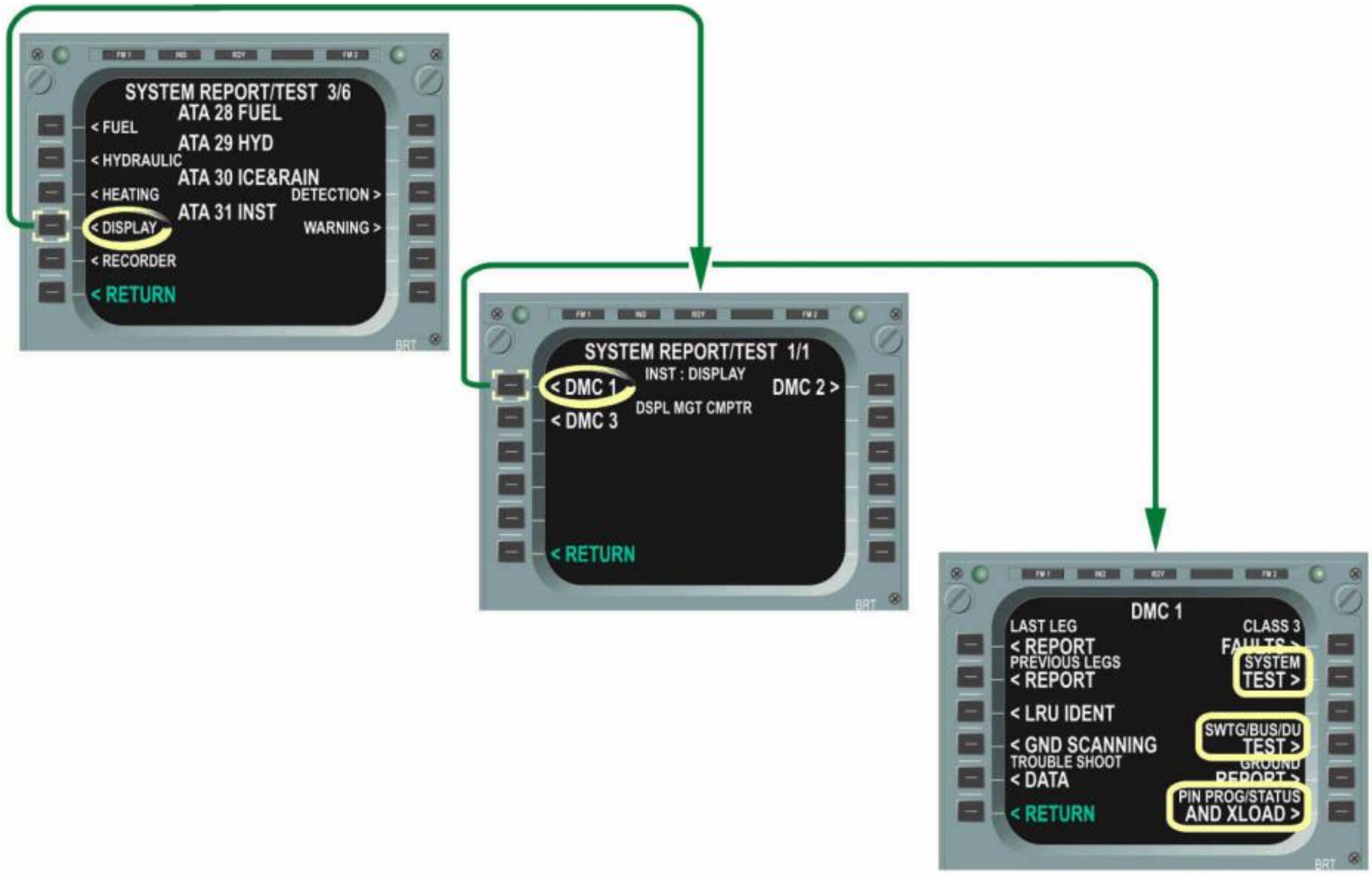


Fig 3.1.10

DMC BITE

SYSTEM TEST PROCEDURE

During the SYSTEM TEST the DMC are in the INTERACTIVE mode. Throughout the duration of the test the DMC sends a page, held on the MCDU by the CMC, indicating TEST IN PROGRESS ”Xs”. The length of time ”Xs” is the time in seconds required to execute all the above−defined tests, taking into account a reasonable maximum execution time for each test.

DMC self test equivalent to:

1) **DMC POST**

2) **DU POST**

3) **A629 TEST**

These tests are the same as those run after a power rise following a long power cut on the ground. The fault messages and associated TSD concerning A629 and DU internal faults are stored in zone 3 of the EEPROM (storage of internal faults on the ground). The fault messages and associated TSD concerning external bus faults are stored in the RAM.

Test Procedure

1) set initial conditions,

2) start test

3) color pattern display on the captain PFD and ND

The operator checks that the color pattern is actually displayed on the PFD and ND. This operation is repeated three times as there are three different patterns available.

1) first pattern: **Color display**

2) second pattern: **White/Black display**

3) third pattern: **Black/White display**

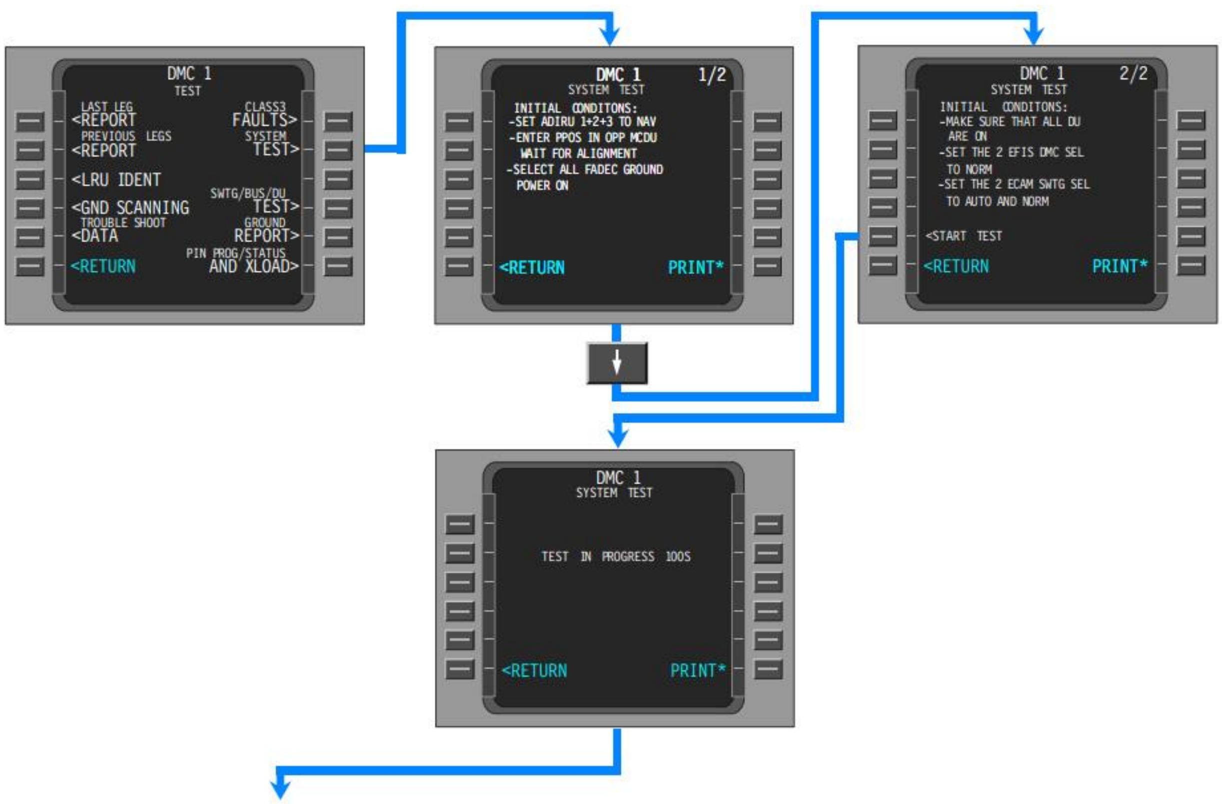
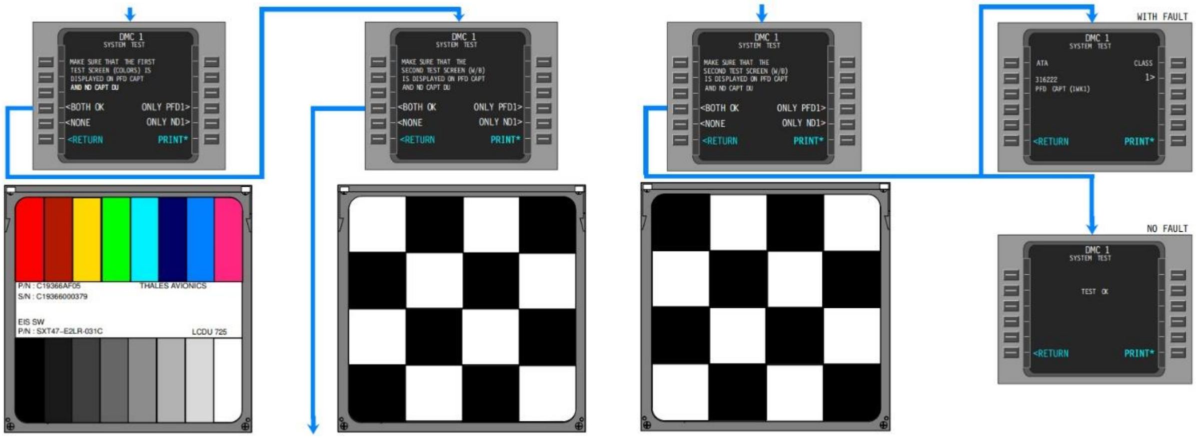


Fig 3.1.11



The first test pattern displayed is a full spectrum color pattern. This pattern is used to check the color accuracy, uniformity, and overall performance of the display. The goal is to identify any issues with color rendering or inconsistencies across the screen.

This pattern is the inverse of the White/Black pattern, focusing on the same areas of contrast and brightness but from a different perspective. This pattern consists of alternating white and black areas, providing a stark contrast that makes it easier to spot problems related to brightness and contrast.

3.2 Analysis and justification of the choice of television test tables.

Test table #1

Siemens Star Test Chart

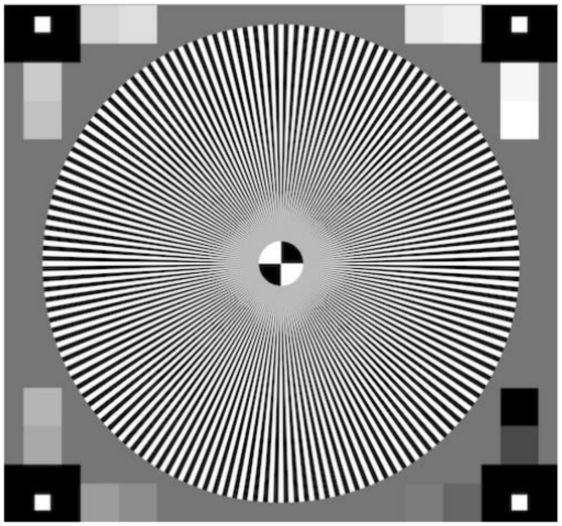


Fig 3.2.1

Evaluation of resolution (as well as digital artifacts, moire, etc.). Version for computer analysis systems. Complies with ISO-12233:2014 standard.

Circular world type Siemens Star. Available in two versions: contrasting solid black and white stripes and sinusoidally modulated black and white stripes. The first option is used primarily for assessing contrast parameters (CTF contrast transfer function), identifying image processing artifacts, assessing moiré, astigmatism, and adjusting optics. The second option (Sinusoidal Siemens Star) is used to evaluate the real MTF resolution without the influence of various image “enhancers” (contour correction, dynamic range correction, etc.) The tables allow you to evaluate and measure parameters in any direction at any angle.

Test table #2

Siemens Star Test Chart

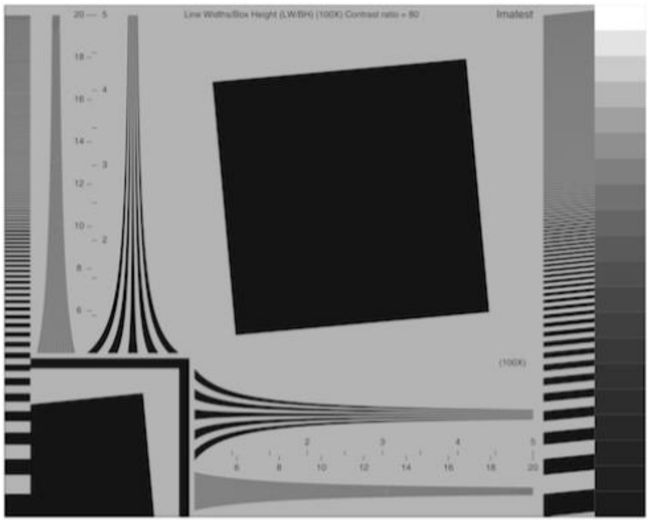


Fig 3.2.2

Evaluation of resolution (as well as digital artifacts, moire, etc.). Version for computer analysis systems. Complies with ISO-12233:2014 standard.

Circular world type Siemens Star. Available in two versions: contrasting solid black and white stripes and sinusoidally modulated black and white stripes. The first option is used primarily for assessing contrast parameters (contrast transfer function CTF), detection of image processing artifacts, assessment of moiré, astigmatism, optics settings. The second option (Sinusoidal Siemens Star) is used to evaluate the real resolution of the MTF without the influence of various image “enhancers” (contour correction, dynamic range correction, etc.) The tables allow you to evaluate and measure parameters in any direction at any angle.

Test table #3

Log Frequency-Contrast Test Chart

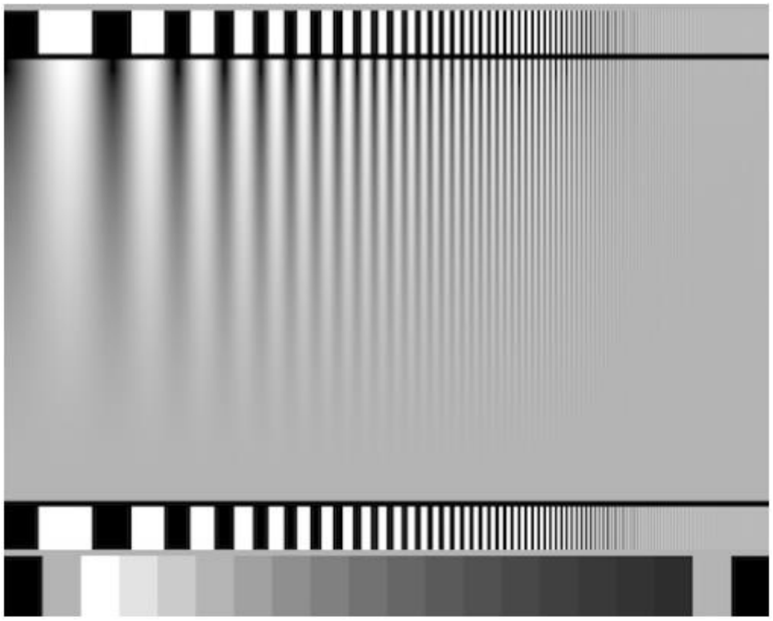


Fig 3.2.3

Comprehensive assessment of resolution (MTF and SFR), as well as assessment of the impact of noise reduction systems on image clarity, texture and contrast.

The main part of the table is a sinusoidally modulated world with a logarithmically increasing frequency from left to right and a linearly decreasing contrast from 1 to 0 from top to bottom (Campbell-Robson CSF (Contrast Sensitivity Function)).

Above and below are unmodulated line worlds of the same frequency as the central pattern. At the bottom of the table is a 16-step “gray wedge” flanked by black and medium gray patches.

Test table #4

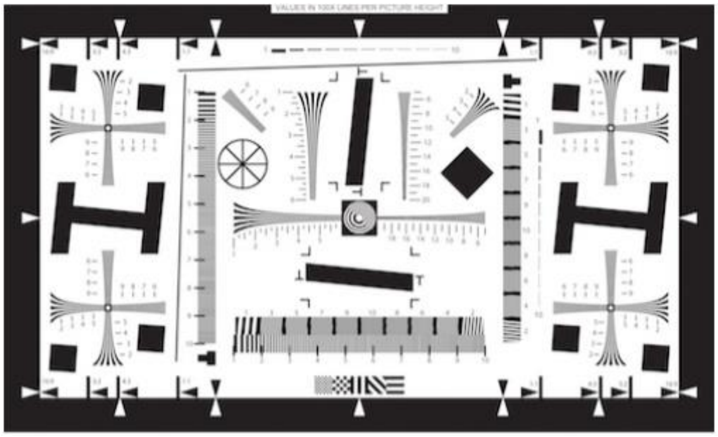


Fig 3.2.4

ISO-12233 SFR/MTF Test Chart The main table for evaluating the images generated by digital cameras.

Comprehensive assessment of resolution, contrast/dynamics, digital artifacts. The first table is according to the ISO-12233 standard. Contains all the test images necessary for visual, instrumental and computer analysis of the modulation transfer function (resolution).

- Hatch worlds of continuously increasing frequency for MTF and moiré assessment.
- Slant Edge objects for SFR analysis

Test table #5

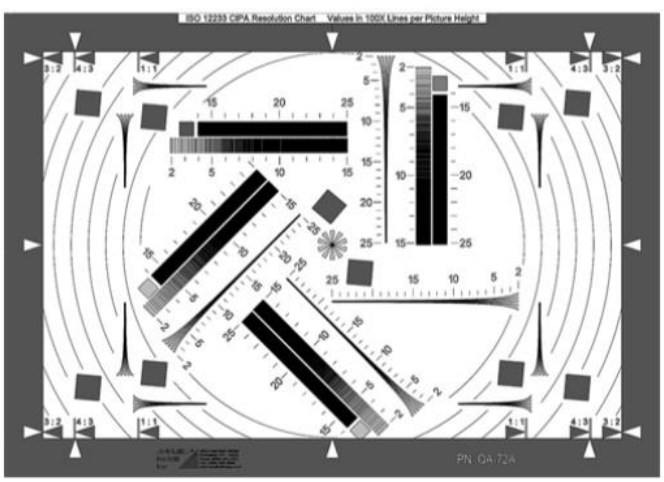


Fig 3.2.5

ISO-12233 CIPA Resolution Chart (QA-72A) Combined test pattern for visual and instrumental quality control of digital systems. Provides measurement of resolution, upper cutoff frequency, MTF based on CIPA recommendations. The table specification is set out in ISO-12233:2014, Annex A. ISO-12233 CIPA Resolution Chart Contains a wide range of test elements:

- markers for frame formats 1:1, 4:3 and 2:2
- central star for focusing
- hyperbolic line worlds 200~2500 LW/BH
- Line worlds (vertical, horizontal, 45o) 200~2500 LW/BH - inclined (5o) SFR squares
- Diagonal (50o) SFR squares

Test table #6

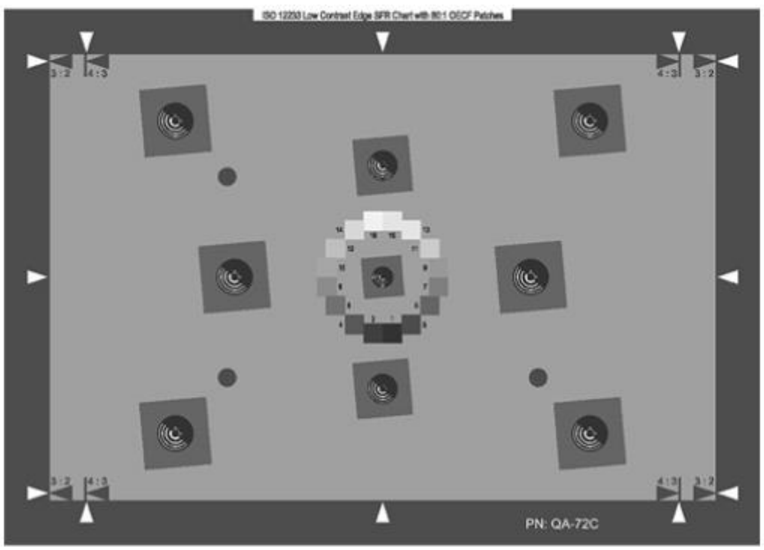


Fig 3.2.6

ISO-12233 Low Contrast Edge SFR Chart (QA-72C) Test chart for computer analysis and measurement of resolution, upper cut-off frequency, MTF of digital cameras based on the slanted edge technique outlined in ISO-12233:2014, Annex C.

The low contrast table contains 9 slanted edge objects spaced evenly across the table. In the center of the table is an OECF gray scale in the form of square patches arranged around a circle, intended for illumination settings and linearity checks.

Test table #7

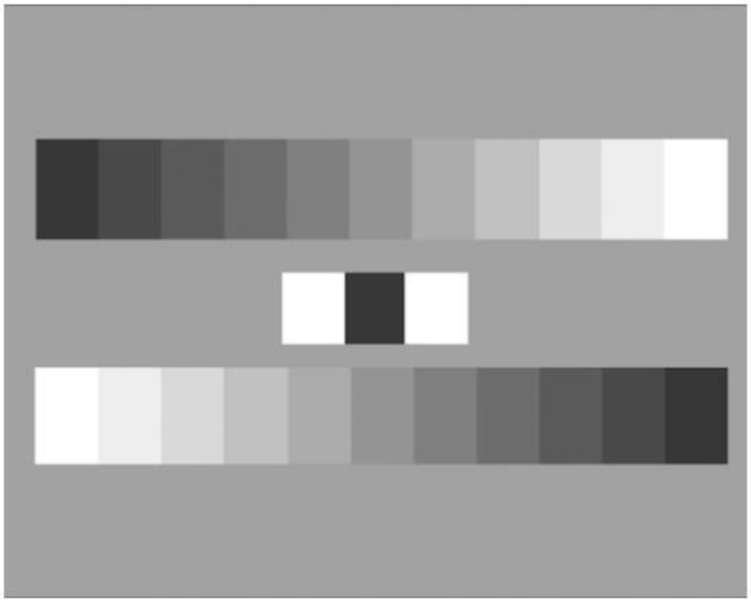


Fig 3.2.7

LOG Gray Wedge

The basic table is designed to evaluate the color balance and transmission of the grayscale and contains two counter-directed horizontal gradation wedges (11 gradations, logarithmic). In addition to evaluating the dynamic range, it allows to estimate the accuracy of matching of gamma curves of separate colors, the occurrence of stretching continued colors, occurrence of stretched extensions, set exposure, brightness, contrast.

Test table #8

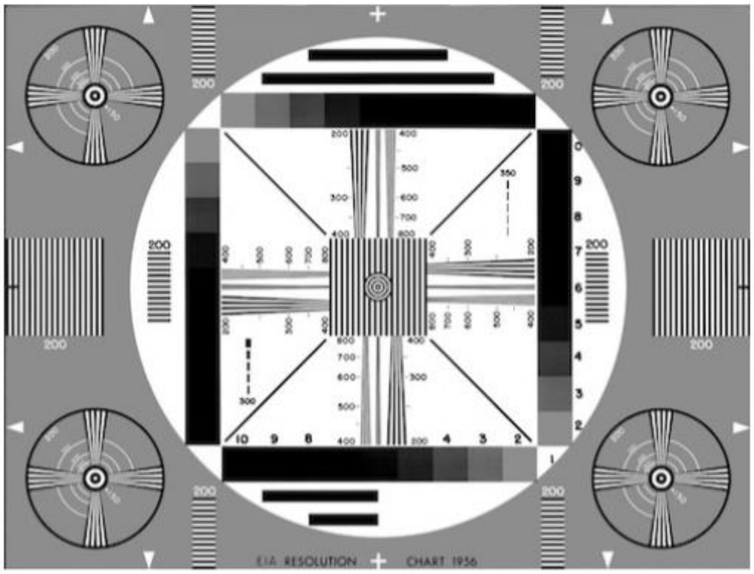


Fig 3.2.8

EIA1956 Universal Table

Basic image evaluation table for standard definition systems.

Comprehensive evaluation of resolution, contrast/dynamics in the luminance channel.

Contains:

1) Center and corner circles for geometric distortion evaluation

2) Horizontal and vertical gray gradation wedges from d=0.15 to d=1.50 in increments of 0.15

3) Stroke gradation wedges with smooth transition 200 ~ 800 TVL

4) Reference dashed worlds 200 TVL full field

5) Diagonal lines for interlace control

Test table #9

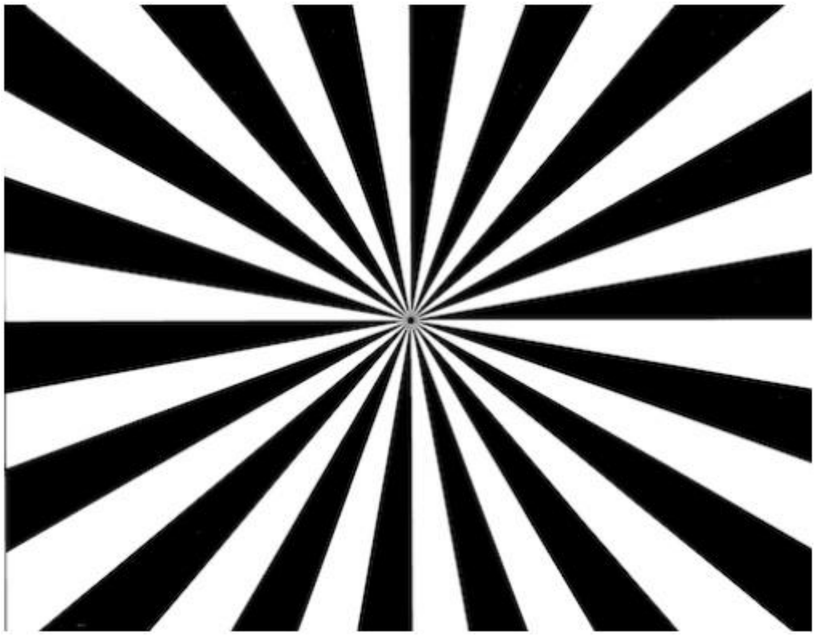


Fig 3.2.9

Focus star

Standard table for lens back alignment, lens testing and focusing.

Test table #10

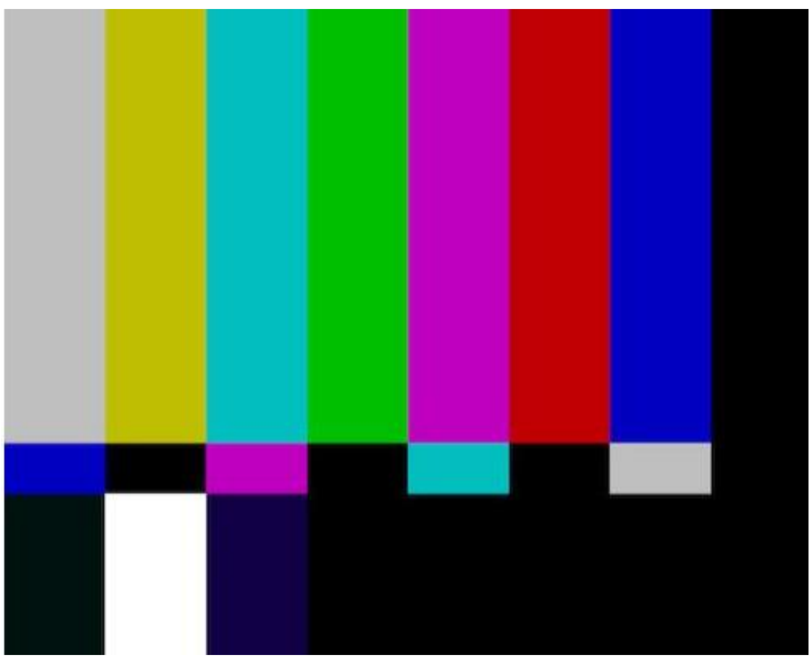


Fig 3.2.10

SMPTE Color Bars

SMPTE RP 219-2002 color bars table for the evaluation and adjustment of camera colorimetry and calibration of display devices (monitors).

Standard test signal for NTSC equipment. Contains at the top

8 color bars 75% (3 primary colors, 3 complementary colors, 75% white, black).

Below them there is a strip with color bars separated by black blocks.stripes with the same blue component (for blue only mode), but different green and red. The lower part of the table in the electronic form contains in the left part 100% white strip on the sides of which are located bands with color subcarrier -I +Q. In the right part there is a PLUGE signal for adjusting the black level.

Test table #11

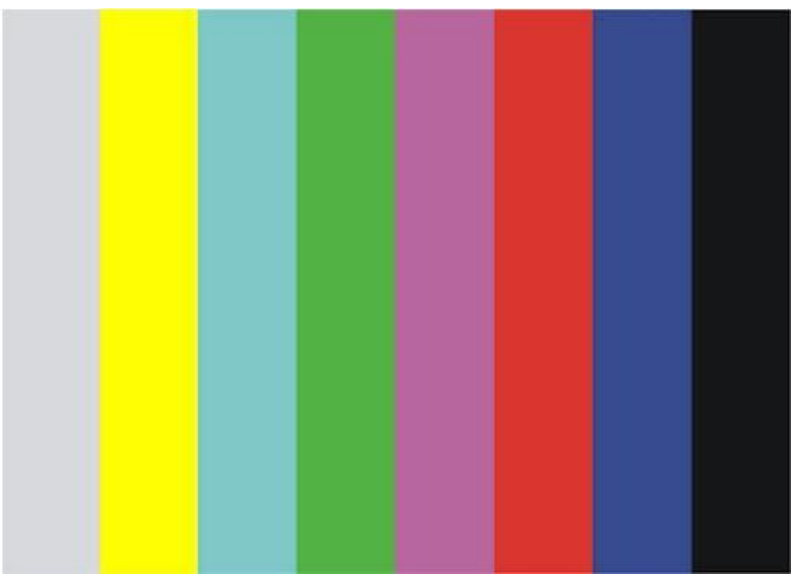


Fig 3.2.11

EBU 75% Color Bars

Standard test signal for PAL equipment. Contains 8 75% color bars (3 primary colors, 3 secondary colors, 75% white, black). The colors of the bands are chosen so that they are inside the triangle of colors transmitted in television when illuminated by light sources with both Tzv 3200 K (incandescent lamps) and Tzv 5500 - 6500 K (daylight).

Test table #12

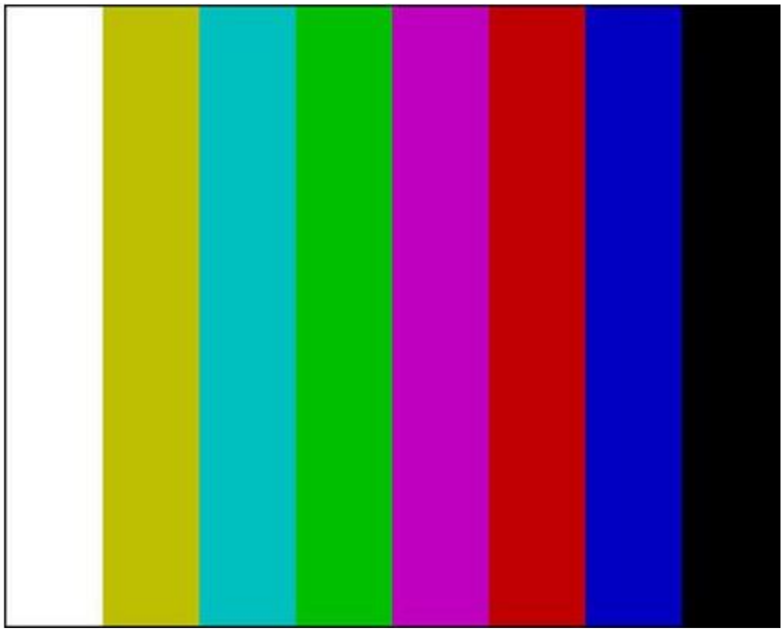


Fig 3.2.12

EBU Color Bars

Standard test table for control and adjustment of PAL TV cameras. Corresponds to the EBU 100/75 Bars test signal. Contains 6 color bars of 100% saturation 75% intensity (3 main colors, 3 additional colors), 100% white, black. It is used for objective and subjective assessment of the color rendering quality of a color television image, as well as, for example, for comparison of several cameras by color rendering by visual comparison of table images from two cameras separated by a curtain in one frame.

Test table #13

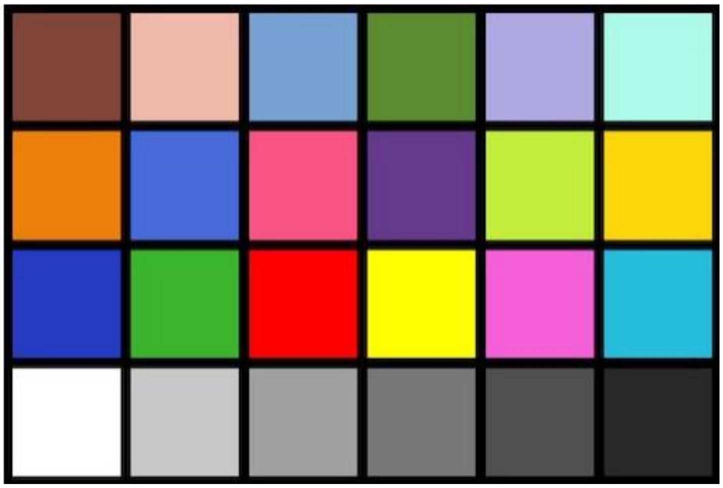


Fig 3.2.13

X-Rite Gretag Macbeth ColorChecker The classic camera colorimetry evaluation table. Used in photography, film and television. Contains 18 color cells (3 primary and 3 complementary colors, 12 critical colors such as facial skin tones, sky, etc.) and 6 gray wedge steps).

Test table #14

Fig 3.2.14

X-Rite Digital ColorChecker SG Advanced Camera Colorimetry Evaluation Table. Digital ColorChecker Semi Gloss (SG) is specifically designed for testing digital cameras. It allows you to check and compare the accuracy of the cameras' image reproduction, adjust white balance, and create camera profiles. It is an extended version of the classic Gretag

Macbeth ColorChecker table. It contains a wide range of natural colors, including facial skin, vegetation, sky, gray patches of different densities. The table colors are standardized and their parameters are available in LAB and XYZ values.

Test table #15

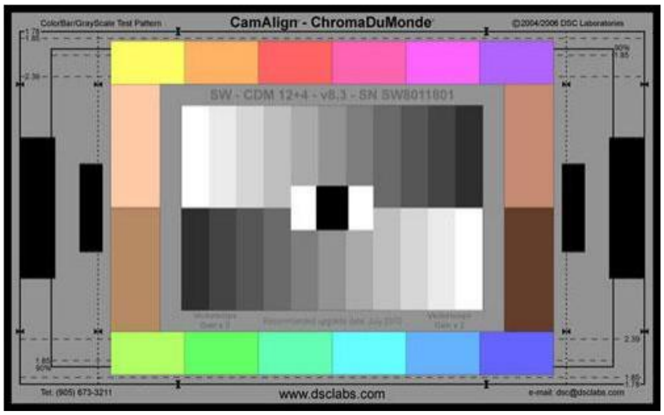


Fig 3.2.15

ChromaDuMonde 12+4 CamAlign Chart One of the most popular charts used in video production. Provides color and brightness/contrast adjustment of the camera both visually and with the help of oscilloscope and vectoroscope. Complies with SMPTE 274M (ITU-R BT.709). Contains 12 base colors (4 primary, 4 complementary + 4 intermediate) + 4 facial skin tones and 2 counter 11-step gray wedges. Additionally contains frames and marker lines for different frame formats: 16:9 (1.77, 90% and100%), 1.85 (90 and 100%) and 2.35 (100%)

Test table #16

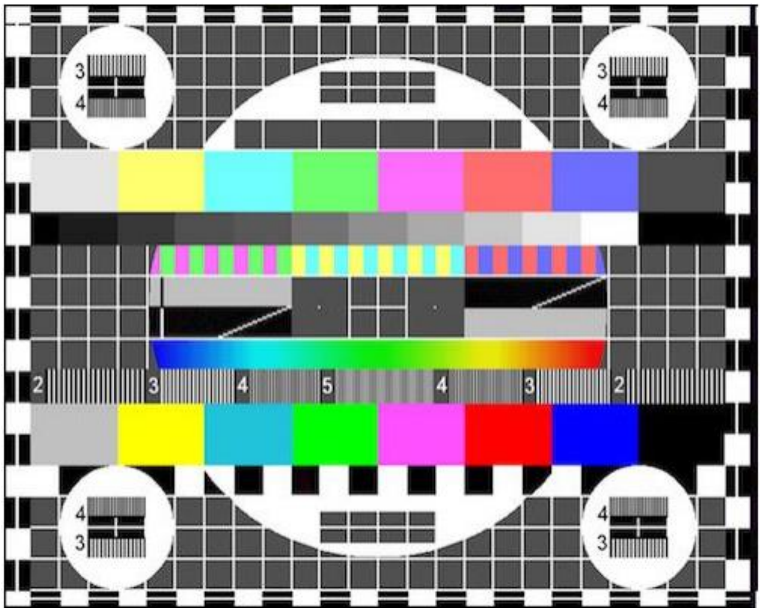


Fig 3.2.16

Universal Electronic Test Table (UEIT) Universal measurement table for SECAM standard devices. Evaluation of resolution, colorimetry, contrast, AFC, information, etc.

Main parts:

- Grid field - table background. Allows you to adjust the ray convergence, as well as visually divides the table into rows and columns;
- Circles for control of geometrical distortions of the image. In the center of the circles crosshairs for centering the image and for adjusting the convergence;
- Color bars of 75% saturation (horizontals 6-7) and 100% saturation (horizontals 14-15) to control color reproduction.
- Gray scale (horizontal 8) for setting brightness, contrast, white balance and black level;
- Contrast color bars (9 horizontal) for adjusting the sharpness of color transitions;
- Smooth color transition (12 horizontal) to check the linearity of the color channel.
- Vertical strokes on the 13th horizontal and in small circles to evaluate the resolution and dynamic focus of the color channel.

They are formed by packets of sinusoidal signals with frequencies of 2, 3, 4, and 5 MHz, correspond to the resolution of 220, 330, 440, and 550 tv lines;

- Slanted bars in 10-11 horizontals to monitor the accuracy of interlaced scanning;
- Contrast marks in the same lines to control stretched extensions and repetitions;
- Alternating black and white squares (line 16) - to evaluate the AFC of the video path on all channels

3.3 Research of software products for video image quality assessment

High-quality display of information on a multifunctional indicator is an important component of safe aircraft flight. The information on the indicator should be easy and clear for the pilot to read, regardless of the type of lighting, viewing angles, temperature, day or night, and other factors. To this end, any indicator requires a thorough assessment of its optical parameters before it is put into operation. In this section, we have developed a methodology for testing optical parameters using special software tools.

Since the comparison of monitors according to the technical characteristics specified by manufacturers is not entirely correct, since different manufacturers use different measurement standards, test methods, instruments and test equipment, and the results will differ accordingly. If several indicators are tested using the same methodology, then it is possible to correctly compare them with each other.

Technical means used to test the optical parameters of the indicator:

- LCD indicator;

- I Liked Color program - a tool that contains only one window and is designed to determine the color of each pixel on the screen. With this program, it is possible to determine the results in three formats: HEX (for direct use in Web site development and Web programming), TColor (for programming in Delphi and C++Builder) and RGB (for use in vector and graphic editors);

- LCD Color Error Check program - a tool that allows you to check the LCD screen for defective pixels.

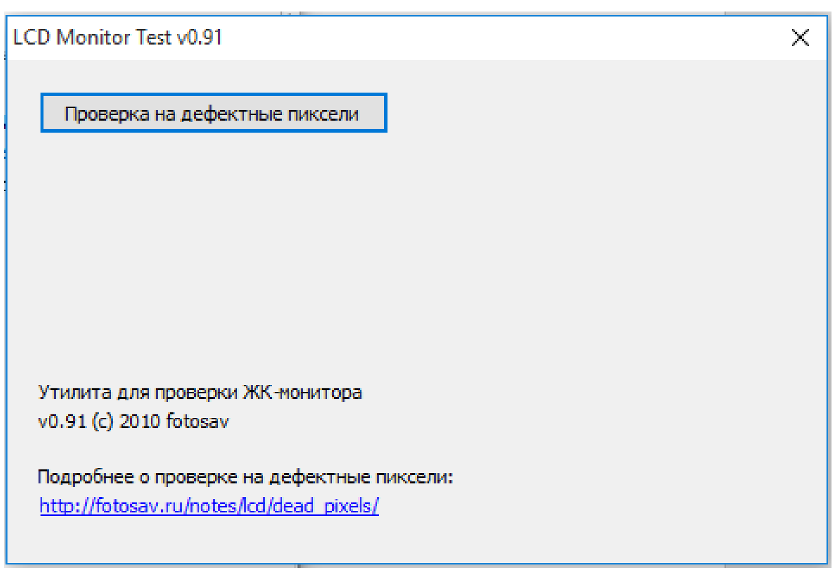
The check consists in a thorough inspection of the screen to identify abnormal pixels. The inspection is carried out sequentially and separately for the main colors: black, white, red, green, blue, cyan, magenta and yellow;

- TFT Test Monitor 1.52 is a universal utility for checking LCD monitors for defective pixels, image processing speed, color bars, gradient, fonts, etc;

- PixPerAn program - a foreign program for evaluating the properties of LCD monitors and determining their characteristics with an accuracy that is achieved without the use of special measuring devices.

Determining pixel defects using the LCD Color Error Check program

To determine pixel defects, you need to display the image of the LCD Color Error Check program on the working field of the working window indicator.



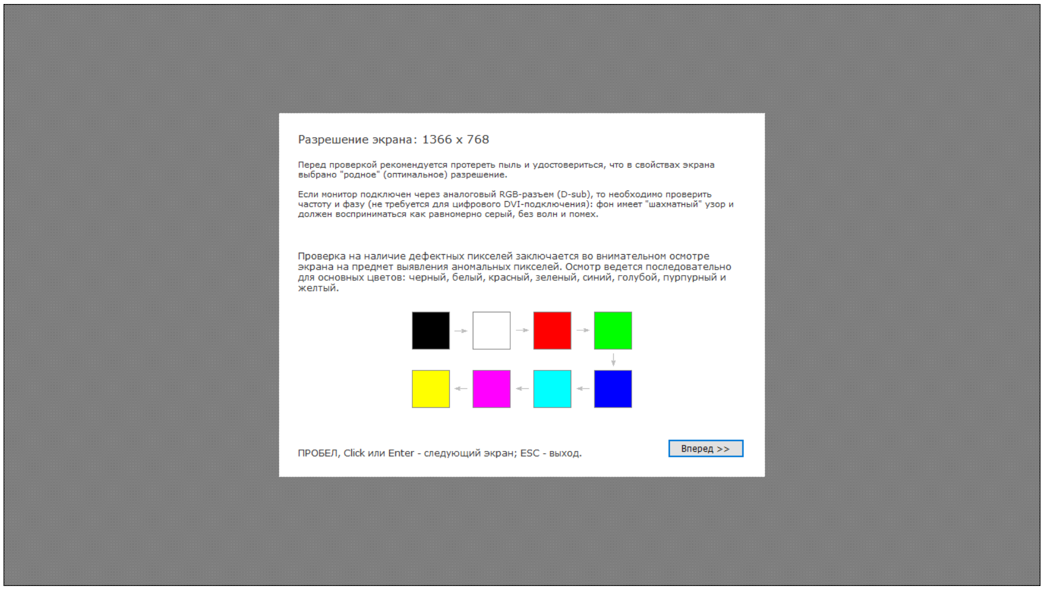


Fig. 3.3.1 The working window of the “LCD Color Error Check” program.

The test is performed after pressing the “Go” function by visually inspecting the screen for pixel anomalies in sequence on screens of different colors, namely black, white, red, green, yellow, pink, blue, and cyan.

Determining the visibility of brightness gradation using the “I Liked Color” program

To determine this parameter, you need to display an image of a black and white halftone transition on the indicator screen.

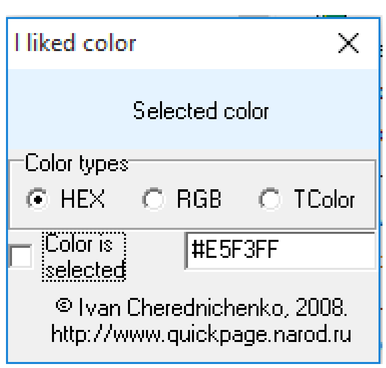


Fig. 3.3.2 Working window of the program "I Liked Color"

Open the "I Liked Color" application, select the format in which the brightness of the pixel will be measured (HEX, RGB, TColor) and, enlarging the image, measure the brightness at several boundary areas of different tones.

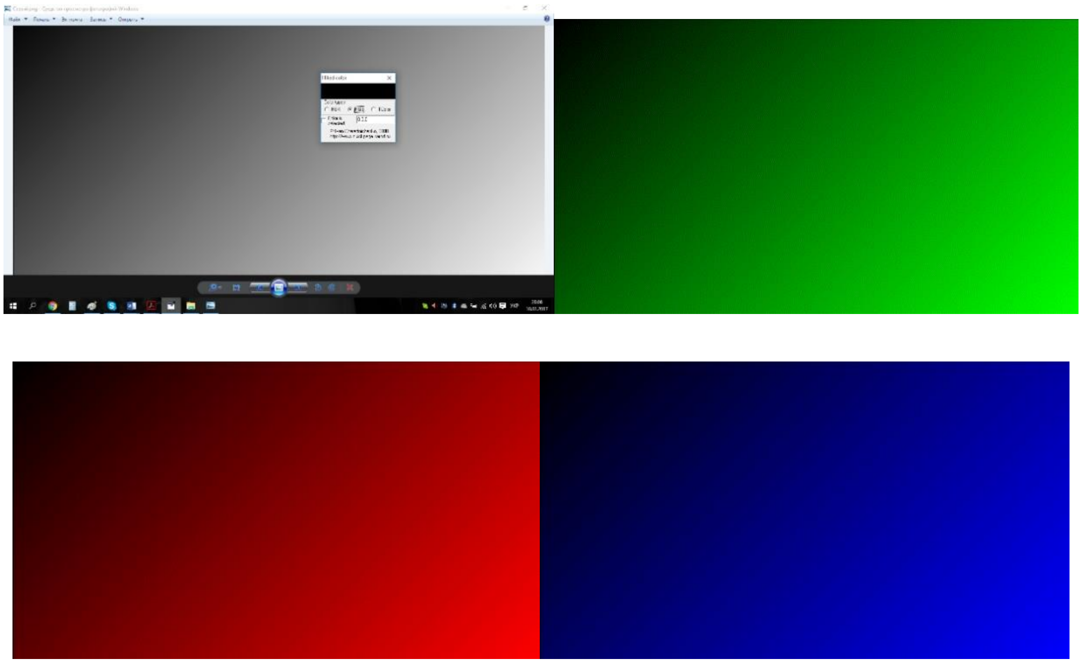


Fig. 3.3.3 Image of a halftone transition of black, green, red and blue colors

Then repeat the steps for the red, blue, and green images. The change in the intensity of the brightness signal of each color component is depicted in the form of a graph.

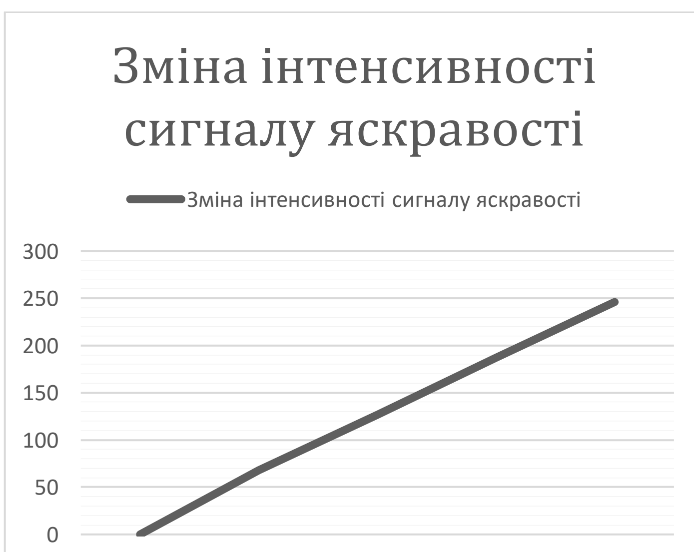


Fig. 3.3.4 Graph of changes in the intensity of the brightness signal

Contrast detection using TFT test monitor 1.52 and "I Liked Color"

Contrast can be defined as the ratio of the brightness of the maximum white pixel to the black. With the help of THE TFT program Test Monitor 1.52, we display an image of a stepped gradient on the monitor screen

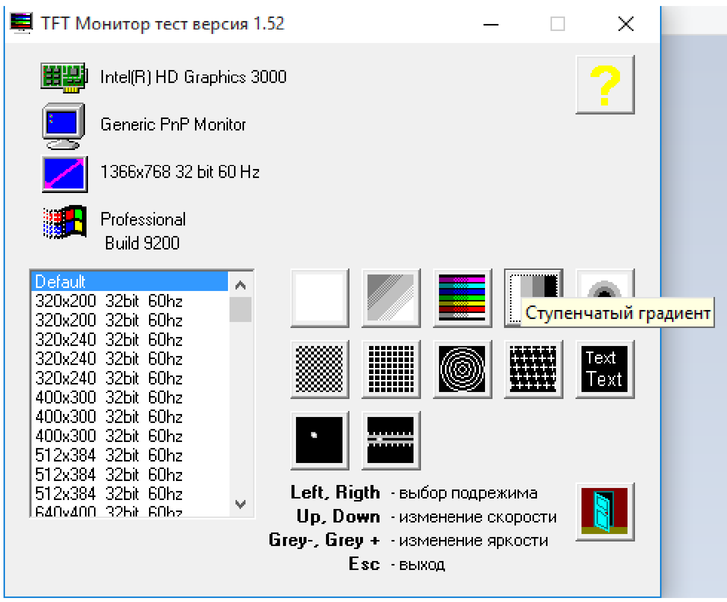


Fig. 3.3.5 TFT Program Working Window Test Monitor 1.52

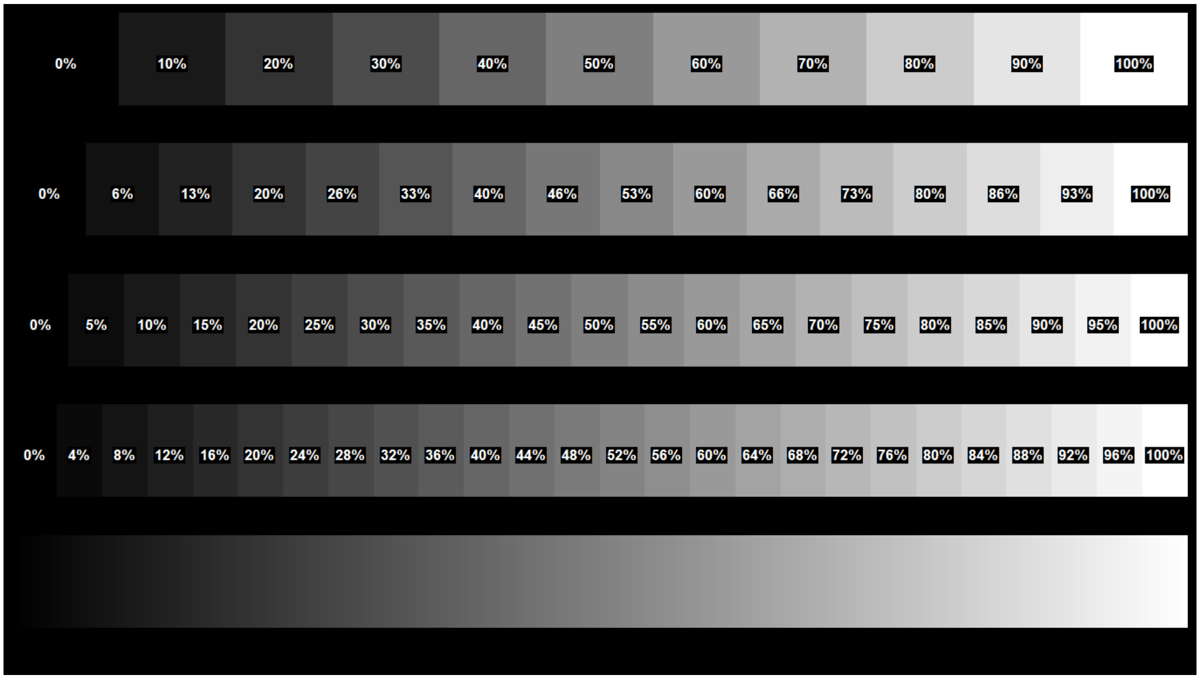


Fig. 3.3.6 Image of a step gradient

Open the "I Liked Color" window and measure the brightness of the black and white pixels.

Fig. 3.3.7 Monitor contrast measurement

The ratio of measured values in white and black (255:1) is taken as the contrast value.

Determine the color change that is reproduced when you change the angle of view of an image

With the help of THE TFT program Test Monitor 1.52, display the working window of the program on the monitor.

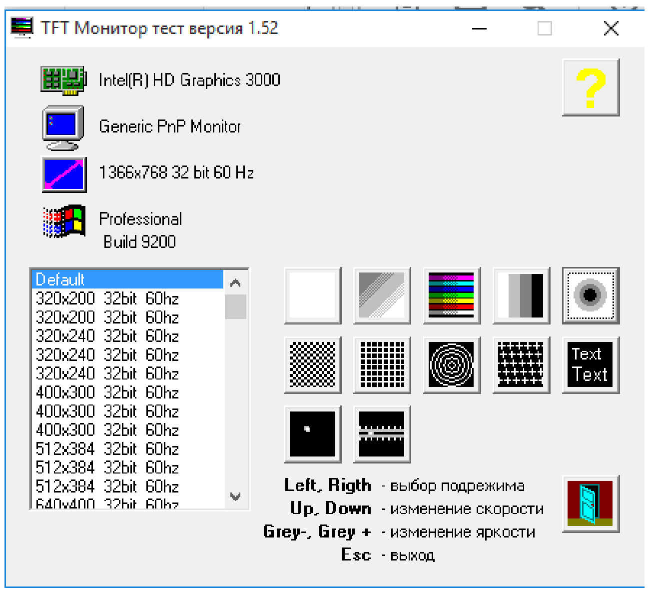


Fig. 3.3.8 TFT Program Working Window Test Monitor 1.52

Select the appropriate resolution of the monitor under test or use the "Default" function to set it automatically.

Select the Ring Gradient mode and display an image of a circular gradient of different colors on the monitor.

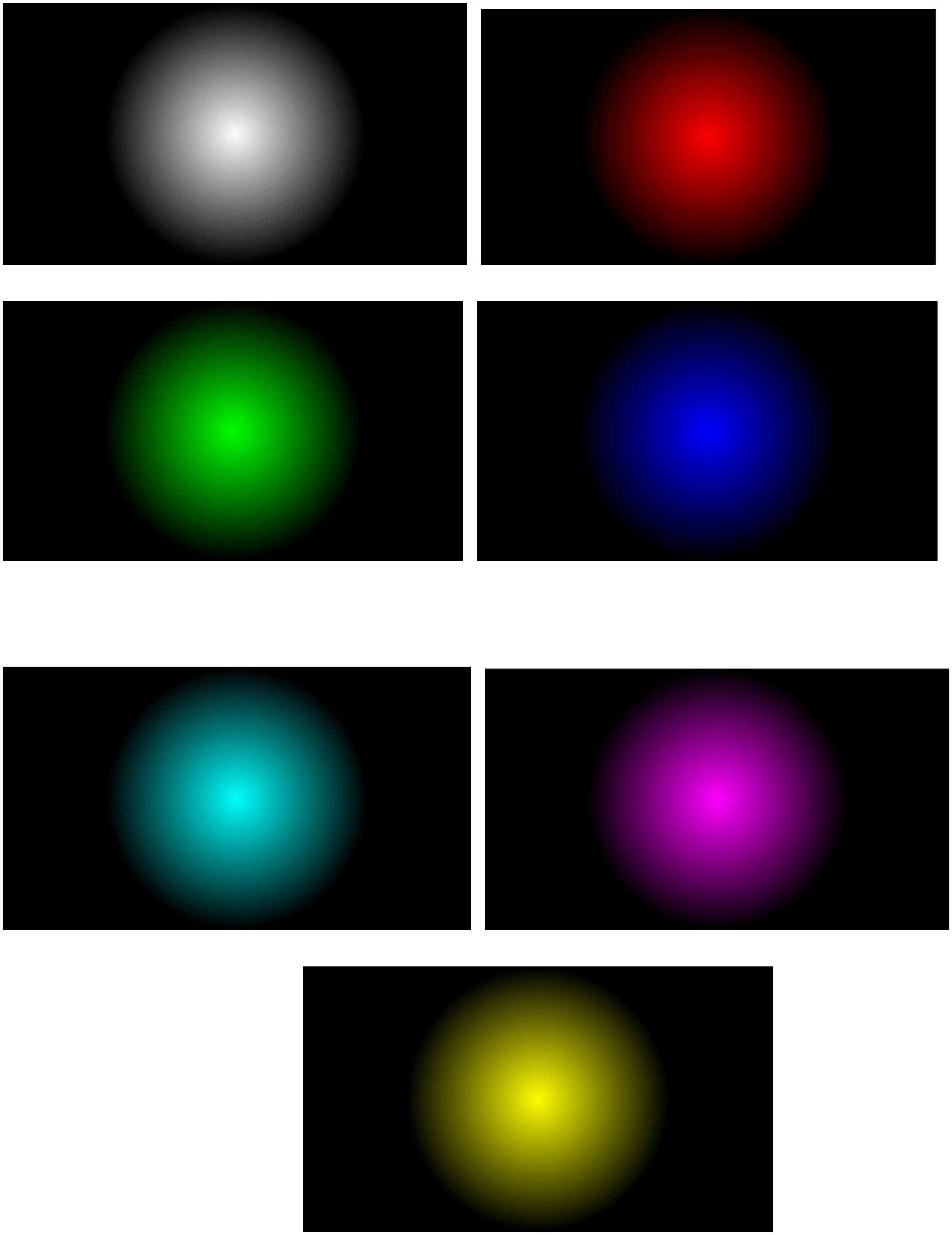


Fig. 3.3.9 Image of a circular gradient of different colors

Conduct an inspection by giving subjective ratings (in percentage) of the quality of color display for three values of viewing angles: 0, 30 and 60 degrees with a deviation of the position vertically and horizontally from the frontal position.

Determining the characteristics of the monitor using the "PixPerAn" program

The program "PixPerAn" is designed to determine the speed of the monitor, i.e. the speed of drawing frames. With its help, it is possible to characterize such feature monitor as the pixel response time. To do this, the developers have prepared six tests in which different figures move at different speeds, while this speed is defined as the speed of drawing frames.

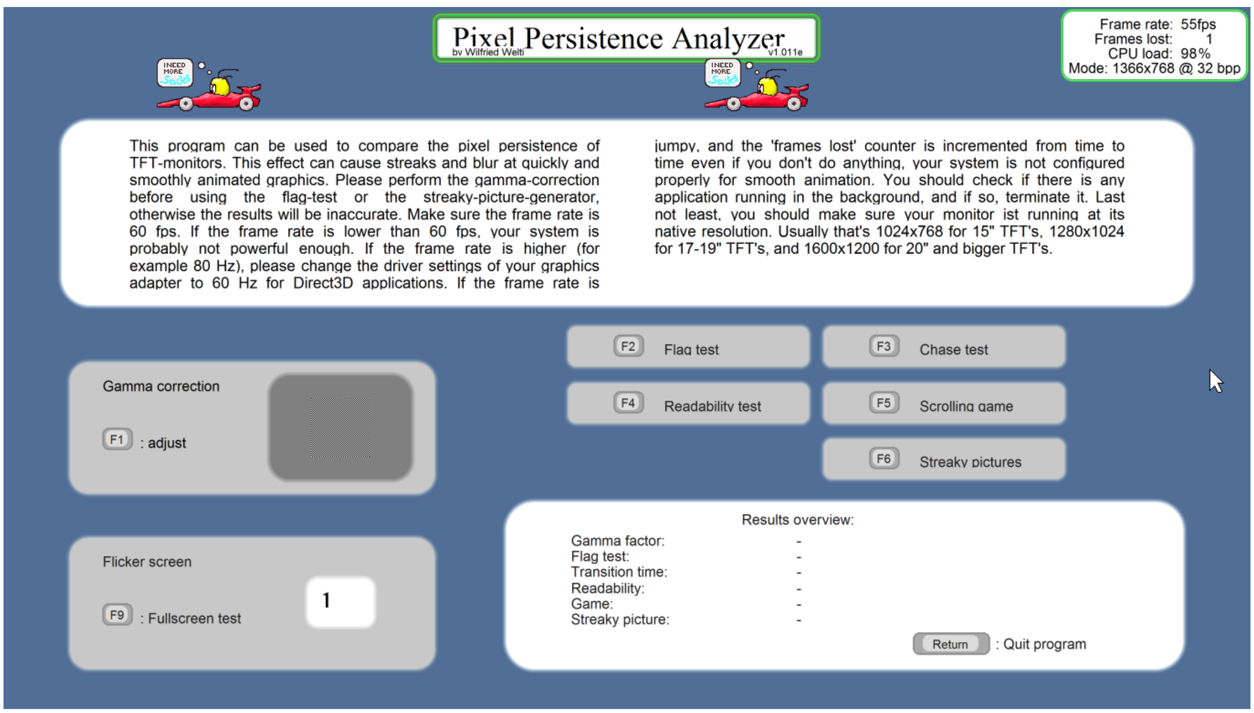


Fig. 3.3.10 Interface of the program "PixPerAn"

In the upper right jacket, in a green frame, there is data on the screen refresh rate (Framerate), which is expressed by the number of frames per second (fps), the number of "lost" frames (Frameslost), the degree of processor load (CPU load) as a percentage, the selected mode (Mode) of the screen resolution, as well as the "depth" of color representation – in the number of bits per image element (bpp). This data is displayed when performing any of the tests performed using the PixPerAn program.

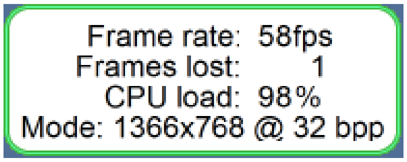


Fig. 3.3.11 Indicator of the "PixPerAn" program

Testing with the help of the program is carried out as follows:

Adjusting the Monitor's Gamma Response

- Before starting work, you need to check if the frame rate corresponds to the value of 60 Hz.

- Make sure that the monitor under test is set to the optimal resolution.

- Carefully examine the red "car" that constantly passes on the screen. Its movement should be smooth, without jerks.

- Adjust the monitor's gamma response (key ≪F1≫) to ensure that the results are repeated for the rest of the tests. An incorrectly set gamma value will lead to incorrect results for the rest of the tests: ≪with checkboxes≫ and with a ≪blurred≫ image.

At the bottom of the screen there is a knob that allows you to change the value of the monitor's gamma indicator from 0.1 in the far left position to 4.0 in the far right. At the bottom of the screen there is also a halftone scale with 32 grayscales, which clearly demonstrates the reflection of halftones when changing the gamma characteristic. It is necessary to set the brightness and contrast of the monitor in such a way that all parts of the halftone scale are well displayed and occupy the entire dynamic range of screen brightness. Set the gamma coefficient using the red bar so that the brightness of the squares in the background coincides with the brightness of the gray background as much as possible. Ideally, the squares disappear at a distance of 2-3 meters from the screen. In many monitors, the value of the gamma coefficient depends on the viewing angle, so it is impossible to make all the squares invisible, in which case it is worth choosing the coefficient in such a way that at least in the middle of the screen the squares disappear.

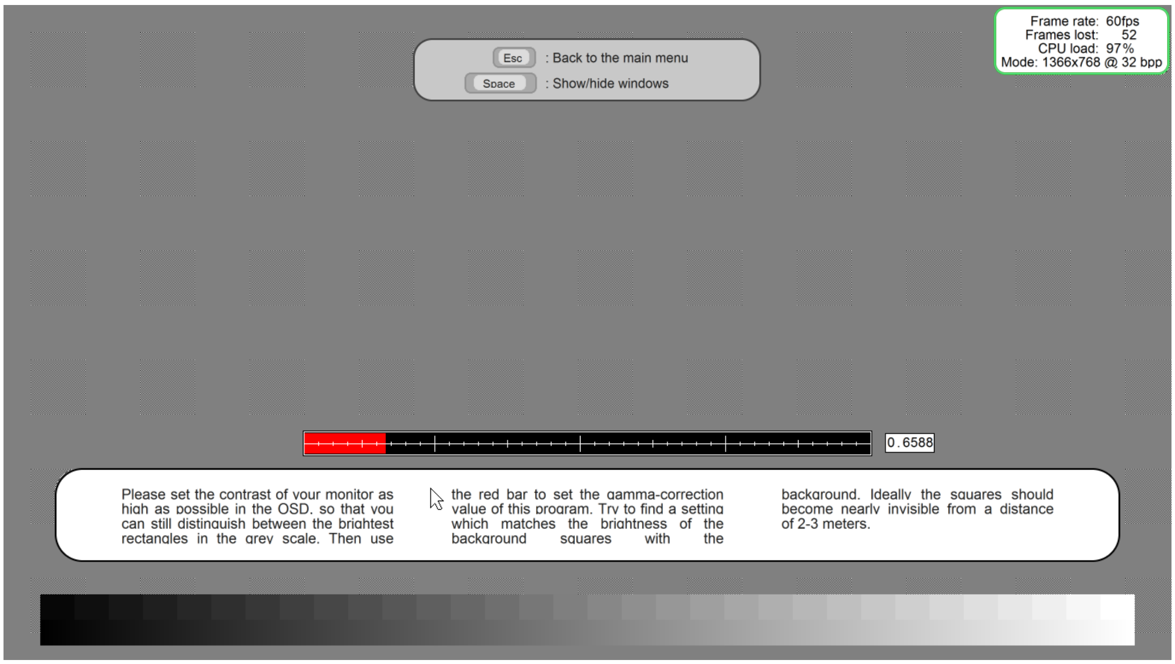


Fig. 3.3.12 PixPerAn program window with gamma correction display

Checkbox test

To perform a test "with flags", after pressing the F2 key, a program window opens, in the middle part of which the flags located on a contrasting background are moved to the left. The F1 and F2 keys allow you to change the color scheme of objects. Two long knobs at the bottom of the screen change the brightness of the top and bottom rows of flags, respectively. To the right of them is a short knob for the speed of the flags («Tempo:»), below it is a switch that changes the boundaries of the flags' brightness adjustment from white to gray.

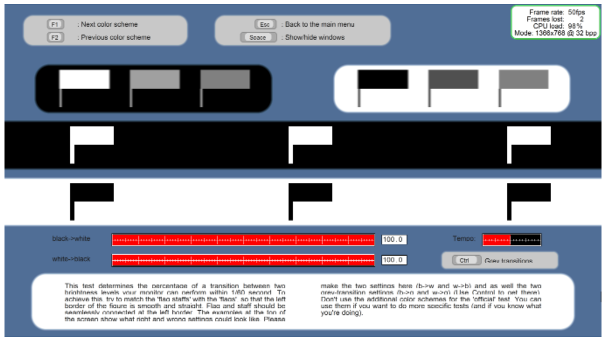


Fig. 3.3.13 PixPerAn program window with the display of the test "with checkboxes"

The "checkbox" test allows you to determine what percentage of the transition between two brightness levels the monitor performs in one display cycle (1/60s). The test is performed as follows: it is necessary to first set the brightness of the flags for both knobs in the display mode of black-white flags and at an average speed of their movement so that it is equal to the brightness of the flagpoles. Three examples are shown above, the middle installation option depicts the correct option. It is important that at the junction point of the flag and flagpole there is no noticeable difference in their color. After that, you need to switch to the gray color mode (Ctrl key) and perform the same installation, fulfilling all the conditions. The result of the test is 4 numbers (regulators).

The "Harassment" Test

The test is run by pressing the ≪F3≫ key. The purpose of the test is to assess the inertia of the LCD monitor, which is noticeable when moving objects change. First of all, the boundaries of the image perpendicular to the direction of their movement suffer from the inertia of the monitor. The program displays two rectangles moving across the screen against a contrasting background at a certain speed.

Fig. 3.3.14 PixPerAn program window displaying the "pursuit" test

The distance between the rectangles can be adjusted with the "Distance (pixels)" knob. It is necessary to set the minimum value of this distance, at which it is still possible to recognize the undistorted background color in the gap between moving figures. At the same time, the knob is moved below "Transitiontime(ms)", which means the interval between both rectangles (transition time), the indicators of which are a quantitative result of the test. Above the moving rectangles are Three columns of knobs, which allow you to set the colors of the first rectangle, the second and the background. The test results are one number for each color scheme for which the test was performed.

"Sign Recognition" Test

The test is used to determine the effect of the inertia of the monitor on the perception of the image on it, namely reading the test from the screen. Reading becomes more difficult if the letters move and, as a result, are "blurred" in the direction of movement. The test is started by pressing the F4 key. After running the test, slowly move on the screen for 1 minute. A random sequence of letters of the Latin alphabet is moved, which must be recognized on the typed keyboard into a light rectangle in the center of the screen.

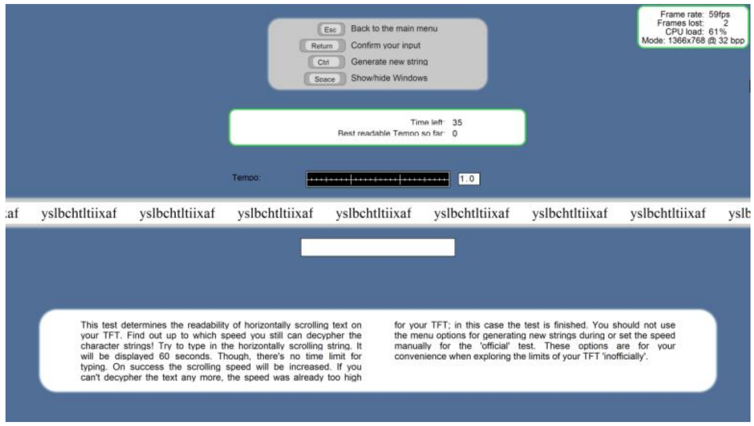


Fig. 3.3.15 The window of the program "PixPerAn" with the display of the "sign recognition" test

There is no time limit for entering text. After entering all the letters, press the ≪Enter≫ key on the keyboard or the ≪Return≫ key on the screen. If the test is successful, the inscription ≪Inputcorrect≫ will appear, and the speed control (≪Tempo:≫), located in the middle of the screen above the letters, goes to the next (more right) position. The speed increases. In the event that one mistake is made when you enter the letters, the inscription "Input Incorrect" will appear. If more than one letter is read and entered, the test is considered complete. An inscription appears in the upper rectangle showing the number of the test that gave a positive result at a low speed of text ("BestreadableTemposofar:X" –X test number) – this is the final result of the test.

CONCLUSIONS TO THE CHAPTER 3

In this section, we explored how to perform tests on a manufactured LCD monitor. Also we analyzed the possible defects in the operation of this product. The defects are divided into: broken pixels, uneven backlighting, color distortion.

CHAPTER 4. Development of a method for researching the quality of reproduction of cartographic data and video images.

4.1 Researching of video system resolution in "still" frame mode.

The researching of the technology for obtaining high-quality video image is to measure the frequency-contrast characteristics (FCC) of a digital aerial camera (DAC). The purpose of this experiment is to practically research and master the technique of measuring the frequency-contrast characteristics (FCC) of a digital camera under semi-natural conditions.

To perform this experiment we will need the following equipment

1. A digital camera.
2. A tape measure.
3. Test object (EIA1956 electronic and paper target).
4. RMVA utility.

The sequence of the experiment:

1) During the independent work in preparation for the practical lesson to receive from the teacher guidelines for the operation of the digital camera Olympus C-370, to find out personal tasks, as well as to analyze:

- purpose, parameters and technical characteristics for the use of digital camera;
- the procedure for making calculations for the use of digital cameras;
- the procedure for testing and preparation for operation of a digital camera;
- safety measures during operation;
- lighting conditions at the place of photography;

2) After analyzing the task of digital photography, operating instructions and safety measures, get the equipment, research and practice:

- the procedure for compiling theoretical calculations for the use of the device:
- the order of preparation of the device for work;
- the procedure for determining the field of view and angular distinction using a test object;
- the procedure for determining the distance to the object under different shooting conditions;
- the procedure for adjusting the exposure under different shooting conditions;
- the order of viewing images stored in the camera's memory on the display of a personal computer.

3) After taking a photo, analyze the photos and determine the resolution digital camera.

To understand what is happening, let’s clarify the basic theoretical information data of the experiment:

Frequency-contrast characteristic or modulation transmission function in optics and photography is one of the parameters that characterize the quality of the image reproducing system (such systems, in particular, are optical devices and light-sensitive materials, semiconductor matrices, etc.).

Frequency-contrast characteristic $T(\nu)$ is a dimensionless value, which is defined as the ratio of the value of contrast in the reproduction of the test object (measure) to the contrast of the corresponding area of the original, i.e. the measure itself.

The value of the frequency-contrast characteristic $T(\nu)$ depends on the spatial frequency of the details of the original ν: the higher the frequency ν, the smaller the value of T. Therefore, the frequency-contrast characteristic is also called the graph of T on ν, measured by some standard test object (Fig. 4.1.1).

$$T(\nu_i) = \left\{\frac{I_{max}(\nu_i) - I_{min}(\nu_i)}{I_{max}(\nu_i) + I_{min}(\nu_i)}\right\}_{вих} : \left\{\frac{L_{max}(\nu_i) - L_{min}(\nu_i)}{L_{max}(\nu_i) + L_{min}(\nu_i)}\right\}_{вх} = \frac{M_{вих}(\nu_i)}{M_{вх}(\nu_i)}$$

where I max , I min - maximum and minimum brightness of the photographic image of the white and black bars of the measure; Lmax, Lmin - maximum and minimum brightness of the white and black stripes of the original (measure); νi is the spatial frequency of the i-th harmonic. Periodic gratings (measures) with a linear structure of different spatial frequency of absolute contrast M m (ν) = 1.0 are used as the original when estimating the frequency-contrast characteristic.

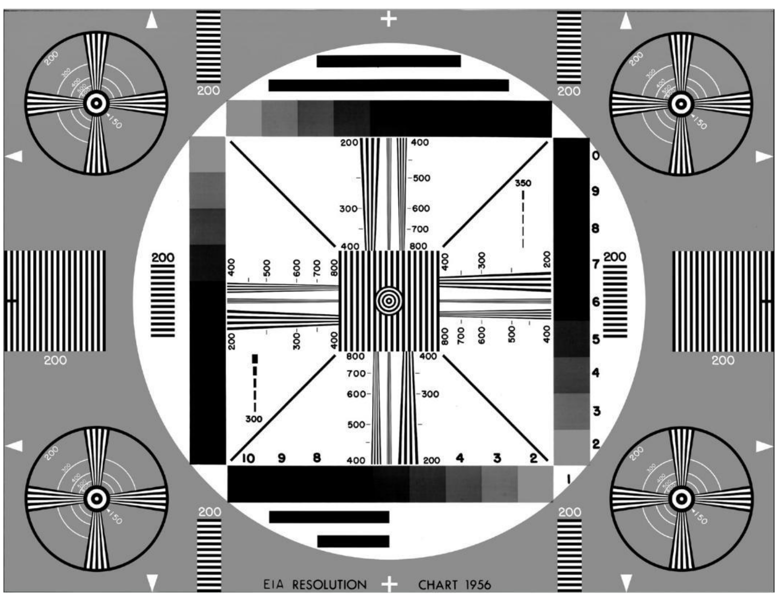


Fig 4.1.1 Test table (measure EIA1956).

Based on the measurement results, a graph of the frequency-contrast characteristic is constructed as the dependence of the modulation depth in the image - M sm (ν) = T (ν) on the spatial frequency ν. The Right Mark Video Analyzer (hereinafter RMVA) program will be used to calculate the camera's HF in the laboratory, which allows to objectively assess the image quality obtained by the camera, including optics, matrix, ADC, video processor and compare the original with the obtained image. Video Analyzer builds a graph of the frequency-contrast response of the test object - the bar measure EIA1956 and its image.

The resulting graph is convenient for detecting distortions in the transmission of large, medium and small parts. Also FCC allows to estimate precisely horizontal resolution of the chamber (a place on a vertical wedge measure where strips merge) as the subjective method gives a big error. Existing methods of constructing FCC require the use of several programs and a large number of manual operations. A traditional bar chart is used as the test image. The measure contains not one continuous test area with stripes preceded by an increase in spatial frequency, but three narrow wedge measures for the clarity range Nt = 200-1600 TvL (television lines) or approximately N bw = 100-800 pairs of black and white lines in width (height) frame. Photographic resolution is defined as

$$R_{\mathrm{Phx}} = N_{\mathrm{bwx}} / b_{\mathrm{fr}} \text{ та } R_{\mathrm{phy}} = N_{\mathrm{bwy}} / h_{\mathrm{fr}}$$

The white field is taken as 100% of the brightness (averaging the brightness of the array of points on a large white circle in the center of the table). If the camera uses artificial sharpening (sharpening, from the English. To sharpen - sharpen, sharpen), the contrast may exceed 100%. In the future, for the correct construction of the HF, the correction of the zero level of brightness should be introduced (averaging the brightness of the points of the darkest part of the density gradient in the table).

Carrying out the experiment

1) **Preparation for measuring the MTF along the longitudinal axis (T(νx)):**

Set the EIA1956 test table on the wall and provide sufficient and uniform illumination. Position the camera on a tripod so that the table image occupies the entire screen horizontally (horizontal reference triangles touching the vertical frame border) at medium zoom setting.

Fig 4.1.2

Set exposure in the automatic mode so that all 10 halftones of the optical wedge of the table were reproduced in the image. Fix the camera and take a test photo of the table, save it in JPEG format.

2) Preparation for measuring MTF along the vertical axis (T(vy)):

Move the stand with the test table so that the table image occupies the entire screen vertically at the same zoom value. Set the automatic exposure mode and take a photo of the table and save it. Ensure that the reference triangles at the top and bottom of the table touch the frame boundaries by monitoring the image on an external monitor to ensure 100% coverage of the frame.

3) Using the RMVA program to analyze images:

Open the RMVA utility.

Use the "ZOOM" command to set the scale of the optical wedges image to 100% and drag the white field and optical wedges image into the RMVA window.

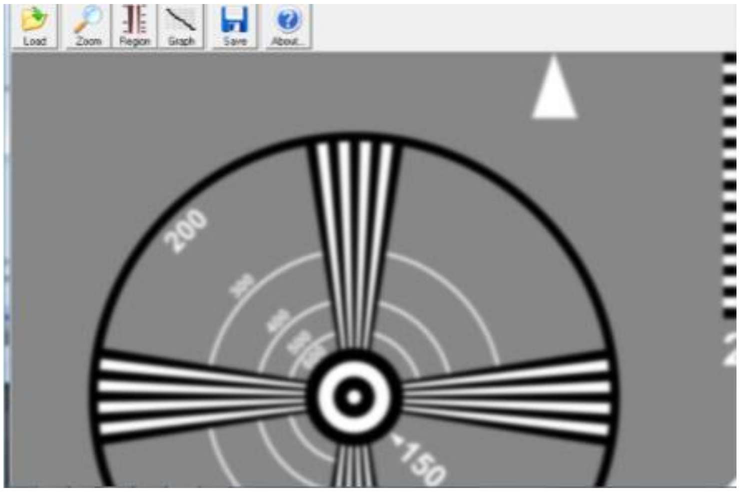


Fig 4.1.3

After clicking the "Region" command, select "Select White Sample" from the drop-down menu and drag the red square onto the white field.

The tvl values are chosen from a standard set of spatial frequencies used to estimate the resolution of video systems. They represent the number of black and white lines that can be distinguished at a certain image width.

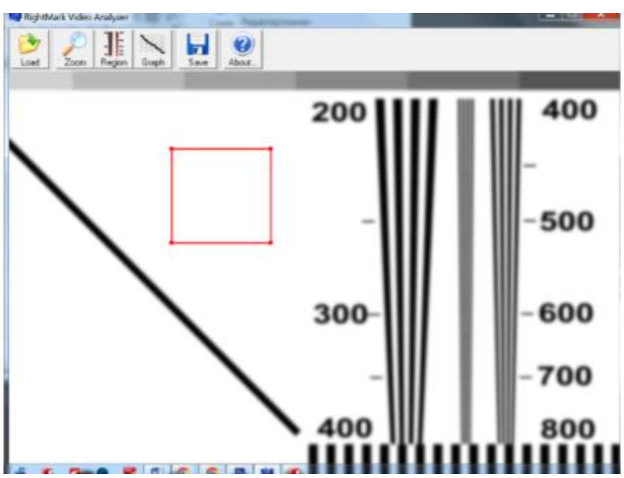


Fig 4.1.4

If necessary, correct the zero brightness level at the darkest semitone of the optical wedge to properly plot the longitudinal MTF T(νx).

Plot the longitudinal MTF T(νx) using the "GRAPHIC" command.

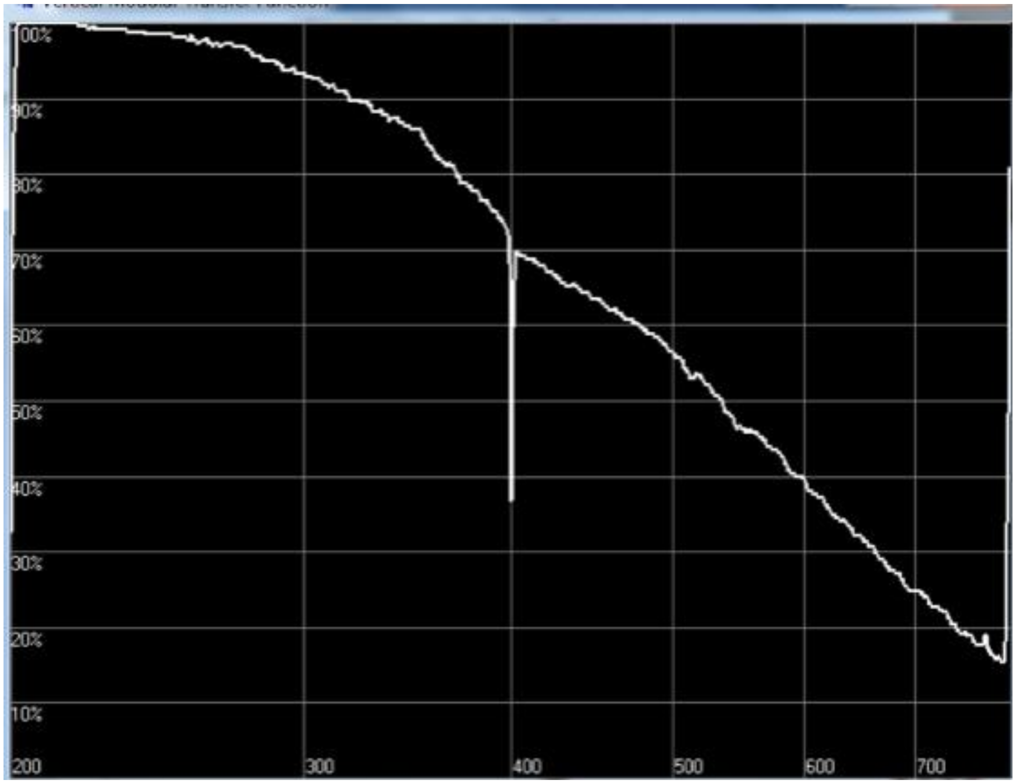


Fig 4.1.5

Save the table of results of MTF T(νx) measurement using the command "SAVE" and transfer the data to the first two rows of the results table. Analyze the graph of the image and calculate the values of T(νx).

Calculate the values and fill in the table of results of the frequency contrast response (FCR) of the camera. To do this we need the values of T(νx), Tid(νx), T lens(νx). for different spatial frequencies expressed in TV lines.

The values **T lens(νx)** are calculated as the ratio of the measured values of the frequency contrast response **T(νx)** to the values for the ideal camera **T id(νx)** .These values show how well the camera lens renders contrast details compared to the ideal camera

After analyzing the data from the experiment and using the formula,

$$T_{\text{lens}}(\nu_x) = \frac{T(\nu_x)}{T_{\text{id}}(\nu_x)}$$

we get:

$$\frac{1.00}{0.92} = 1.09$$

$$\frac{0.93}{0.87} = 1.07$$

$$\frac{0.37}{0.82} = 0.45$$

$$\frac{0.56}{0.76} = 0.74$$

$$\frac{0.396}{0.71} = 0.56$$

$$\frac{0.25}{0.66} = 0.38$$

$$\frac{0.15}{0.61} = 0.25$$

Result

tvl	**T(vx)**	**Tid(vx)**	**T lens(vx)**
200	1.00	0.92	1.09
300	0.93	0.87	1.07
400	0.37	0.82	0.45
500	0.56	0.76	0.74
600	0.396	0.71	0.56
700	0.25	0.66	0.38
793	0.15	0.61	0.25

4.2 Determination of matrix defects and characteristics of the LCD monitor

1. Dead-pixel check

Fig 4.2.1

Conclusion: There is no dead pixels

2. Viewing angle check

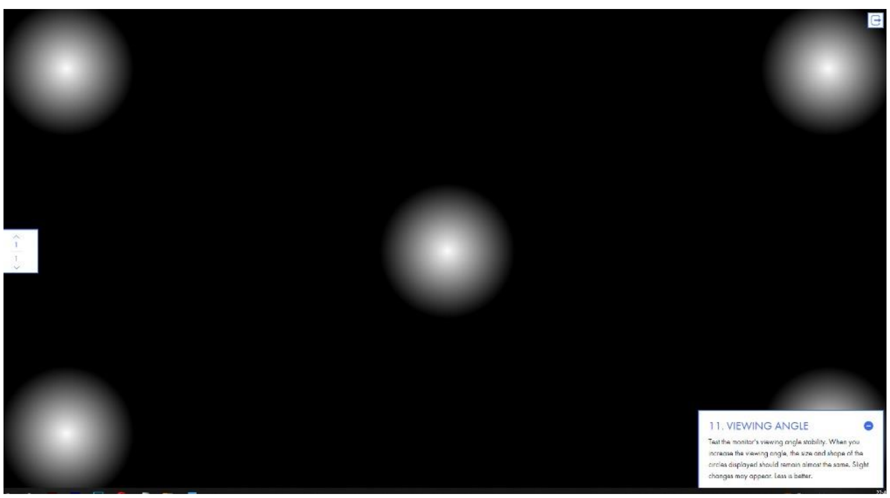


Fig 4.2.2

Conclusion: At 0 viewing angle, the elements on the monitor are clear, clearly visible, color does not change. At a significant viewing angle, there is a loss of visibility of the object, its color, as well as transparency.

3. Sharpness check

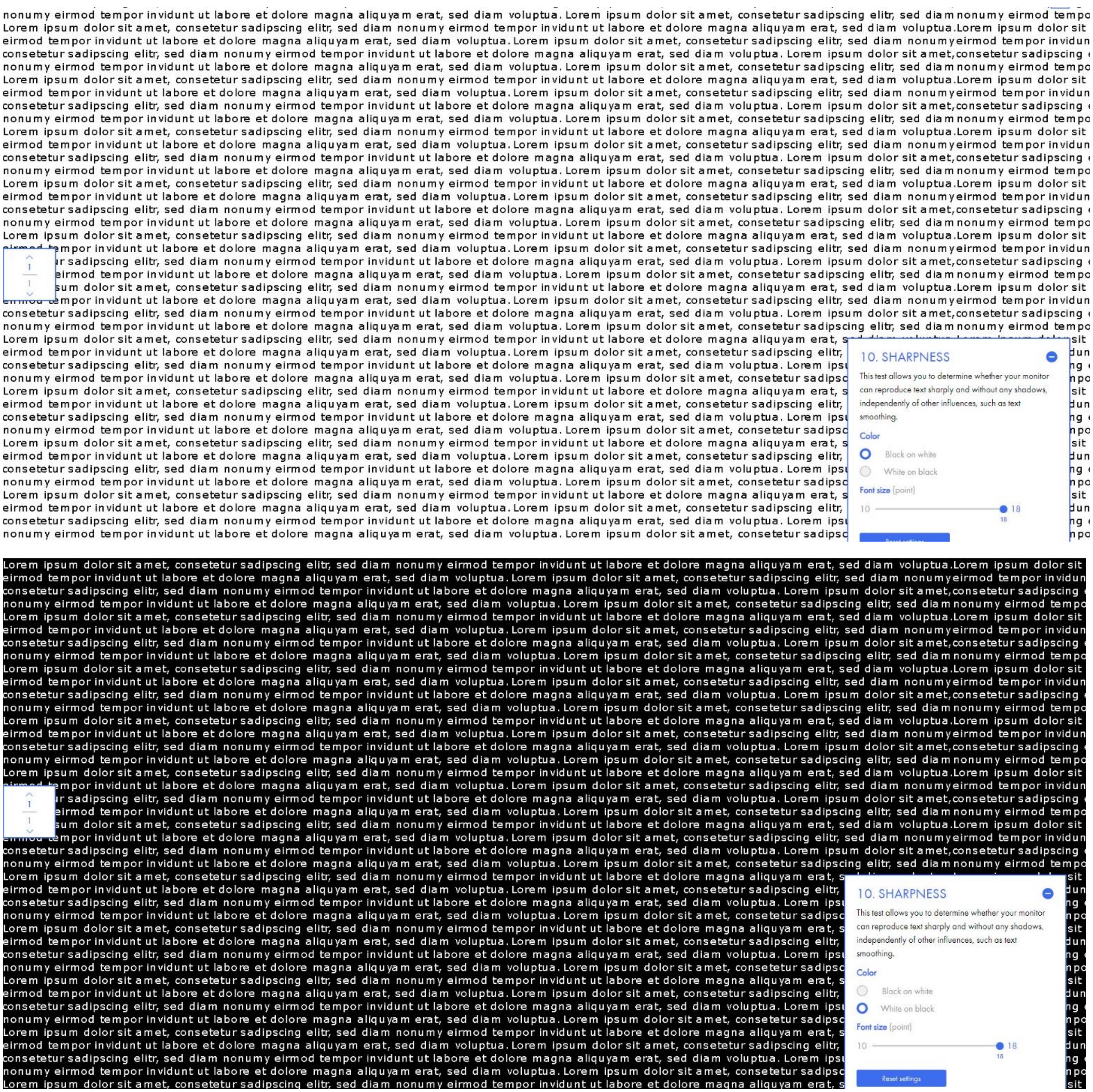


Fig 4.2.3

Conclusion: While increasing the font of the text, change its color, as well as the color of the background. Loss of sharpness of the image and elements present on it is not observed.

CONCLUSIONS TO THE CHAPTER 4

In this section, we explored the method of technology for obtaining high-quality video image by measuring the frequency-contrast characteristics (FCC) of a digital aerial camera video system resolution in "still" frame mode. We compared the experimental value of frequency-contrast characteristic with an ideal value of frequency-contrast characteristic. After filling in the table, we obtained results of **T lens** for each **tvl** (Television Lines).

Also we made a test for LCD monitor to determine the matrix defects inside it.

REFERENCES

1. A320neo ATA 31 Technical Notes are brief and to-the-point information on the Airbus A320 Indicating and Recording Systems, including its components and their functions.

2. A320neo ATA 06 (Technical Notes) – DIMENSIONS AND AREAS.

3. Principle of formation and display of geoinformation data array on the screen of on-board display – Mark Luzin,

4. Realization of the data structure used in the formation of the indication frame in on-board cartographic information system - P.P. Paramonov.

5. Concepts and Methods of Mathematical Statistics - James E. Gentle Wolfgang Karl Härdle, Yuichi Mori.

6. Avionics development and implementation - Cary R. Spitzer.