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Elimination of Screen-Flickering Phenomenon in Multi-Function Display During Flight of Fixed-Wing Aircraft

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Abstract

In this study, we aim to eliminate the flickering phenomenon in multi-function display (MFD) units during the flight of fixed-wing aircraft. To execute flight missions effectively, the video signals transmitted to MFDs must provide information accurately and seamlessly. Therefore, a method for addressing the flickering phenomenon—including cause analysis and failure diagnosis—is adopted; specifically, a wiring configuration with a direct connection between the video signal cables and with a short cable length is adopted. The proposed method is experimentally verified using a flight test.

Key Words : MFD (Multi-Function Display), Coaxial Cable, Disconnection, Signal Loss, Signal Attenuation, Mission Computer, Flickering, DVI (Digital Visual Interface), RGB (Red-Green-Blue), W/H (Wire Harness)

1. Introduction

In modern fixed-wing aircraft, video information provided by sub-systems during flights is shown on multi-function displays (MFDs) using the mission computer. Therefore, video and flight information must be displayed accurately and seamlessly to perform flight missions effectively. As shown in Fig. 1, sub-systems provide various types of video signals, such as red-green-blue (RGB) and digital visual interface (DVI) signals, to the mission computer, which converts these signals to video and symbol information and displays them on the MFD. However, the flickering phenomenon occurs intermittently on the screens of certain systems in which RGB video is shown on the MFD during aircraft operation. In this study, we developed a method to address this phenomenon through cause analysis and failure diagnosis [1-2].

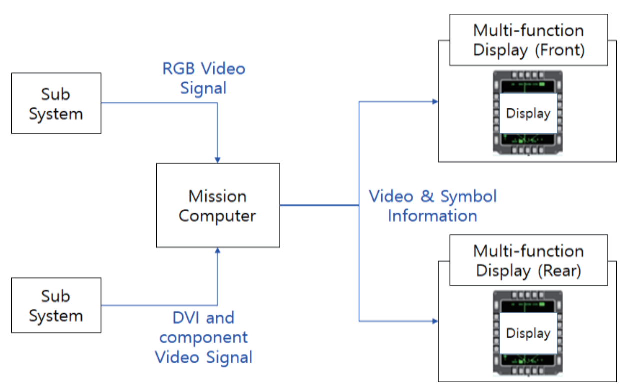

Fig. 1 Display of video and symbol information in MFD.

2. Discussion

2.1 Phenomenon Analysis

The MFD receives various types of video information from different sub-systems of the mission computer, and the information is displayed on different screens. An examination shows that flickering occurs only when the information is displayed on the screens of specific sub-systems using RGB videos, as shown in Fig. 2. Therefore, we examined the major factors involved in the transmission of video signals among sub-systems providing RGB videos, the mission computer, and the MFD.

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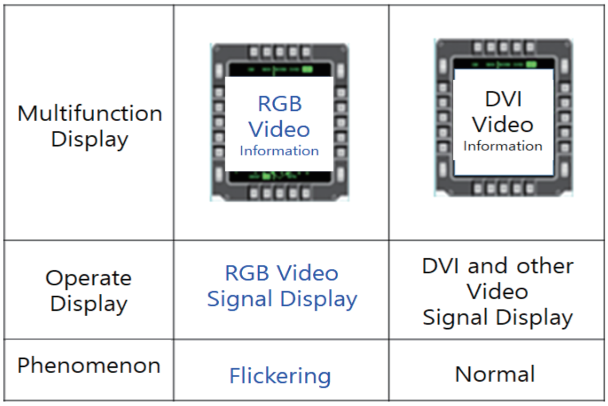


Fig. 2 Flickering phenomenon in RGB video signal.

Using fault tree analysis (FTA), as shown in Fig. 3, the avionics equipment (sub-system equipment, mission computer, MFD) and the wire harness path of the video signals were determined to be the major factors. First, the avionics equipment related to the occurrence of flickering was replaced sequentially. However, the phenomenon continued to occur. Even after performing function diagnosis for the individual units of the avionics equipment, the internal error that caused the flickering could not be identified. Therefore, an examination of the video signal and wire harness paths was required.

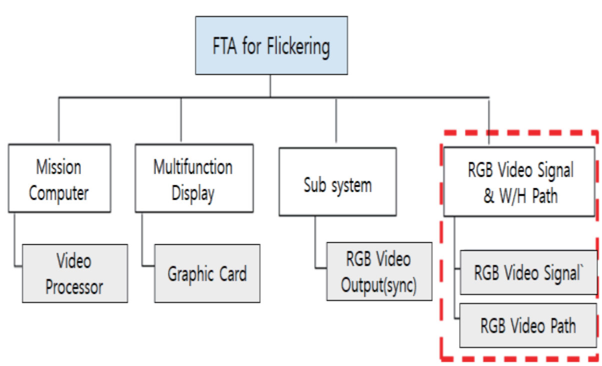


Fig. 3 FTA for flickering phenomenon.

2.2 Key Factor Analysis

As described previously, the video signals provided by other sub-systems from the mission computer were all displayed normally on the MFD. Therefore, an analysis of the cause was required for only the RGB video signals transmitted to the mission computer. RGB video signals, which consist of three colors (R, G, and B) are transmitted using three coaxial cables, as shown in Fig. 4; the Sync signals are sent with the green signals.

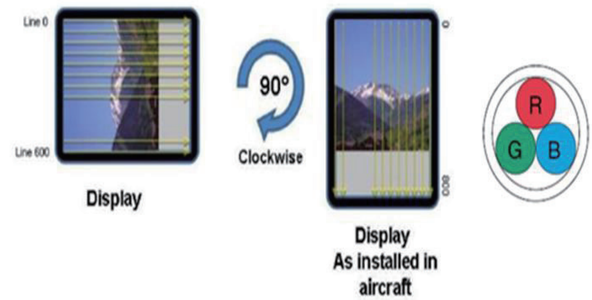


Fig. 4 Coaxial cable with RGB signals.

The video signals in aircraft need to be transmitted without loss or attenuation at any point. Therefore, coaxial cables are usually employed as the medium between the sub-systems and the mission computer; such cables are the best transmission medium for analog video signal transmission owing to their excellent transmission efficiency, as shown in Table 1 [3–4].

Table 1 Characteristics of coaxial cables.

Category	Characteristics
Interference	Electromagnetic interference prevention is effective as electromagnetic interference is offset by the interaction of the conductors in the cables.
Signal loss	Low signal loss due to field and magnetic field radiation to the exterior of the cable, and no external obstruction in terms of induction.
Accessibility	Easy to install, easy to use, easy to access with other components.
Caution note	Excessive loads, such as bending, can cause internal and external damage. Transmission loss may occur owing to improper disconnection point.

The signal attenuation is smallest at the characteristic impedance, and because the video signals should be transmitted as far as possible, the characteristic impedance is a crucial parameter for video cables. However, conductive loss, dielectric loss, and noise generation may occur even in a coaxial cable with excellent characteristics if there is an element that can cause image signal loss or attenuation, as shown in Table 2 [5].

Such losses and noise can cause transmission loss, resulting in abnormal display (flickering, etc.) owing to changes in the characteristic impedance, an increase in the insertion loss, etc. Therefore, a sequential examination of the causes of signal loss in the path of RGB video signals transmitted to the mission computer is required.

Table 2 Causes of signal loss in video cables.

Category	Details
Load	• Excessive loads such as bending and improper fixation • Use of non-standard materials • Poor soldering
Damage	• Internal/external damage
Video Sync	• Abnormal input of Sync signal
Disconnection	• Inappropriate disconnection point
Long length	• Signal attenuation across cable • Length increases

2.3 Analysis of Signal Loss Factors

First, the video cables in the aircraft suffering from screen flickering were disassembled, and the fabrication quality and workability of the cables were examined. It was determined that appropriate working methods had been used, as was the case for other sub-systems. Moreover, as shown in Fig. 5 and Table 3, no internal/external damage to the cables was found.

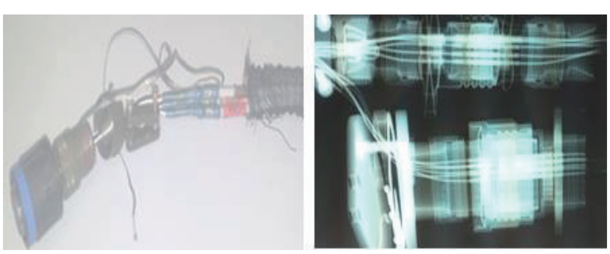


Fig. 5 Results of disassembly and examination of video cables.

Table 3 Video cable conditions.

Category	Details
Workability	• Contact, cable: Used specification • Cable work: Clear • Clamping, tapping: Clear • Connector mating: Clear
Damage	• No internal/external damage (X-ray result: Normal)

The application of excessive loads during the installation of video cables can cause internal/external damage to the cables [6]. As shown in Table 4, excessive loads were applied to test the cables, but no damage occurred. This implies that the problem was not due to the workability.

Table 4 Results of applying excessive loads on the video cables.

Category	Details	Result
Excessive load	• Tight tying with lacing tie: 10 times • Five soft bends: 90° • Five strong bends: 180°	No damage
Shield	• Disconnection of shield and checking the condition	No damage

When sub-system equipment provides RGB signals, the Sync signals are provided with the green signals to synchronize the video timing.

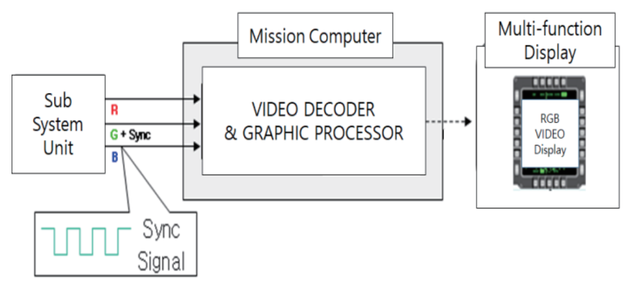


Fig. 6 RGB and Sync signal from sub-system.

Therefore, if the Sync signals of the RGB video are input abnormally, the video processing may be delayed within the mission computer. This may be recognized as an abnormal state and may subsequently cause phenomena such as flickering on the screen. Therefore, we analyzed the Sync signals in sub-systems affected by screen flickering. As shown in Table 5, the measurement results satisfied the signal standard specifications.

Table 5 Measurement result of RGB video Sync signal in the sub-system unit.

Sub-system	Sync signal level	Sub-system	Sync signal level
A	Satisfied specifications	B	Satisfied specifications

2.4 Effect of Signal Disconnection

Because we found no elements that may cause flickering in the individual sub-systems or the Sync signals from the technical analysis and failure diagnosis, we examined the wire harness path of the video cables. Upon checking the path of the cables transmitting the RGB videos from the sub-systems to the mission computer, it was confirmed that the cables were not connected directly, but a disconnection point had been added, as shown in Fig. 7. The design included a separate wire harness path with a disconnection to improve the serviceability by ensuring ease of installation/removal during the long-term operation of the aircraft. This is a normal design method because there is no separate restriction on the application or number of disconnection points for the wire harness, including the video cables, in the standard specifications regarding wiring in aerospace vehicles (MIL-W-5088L) [7]. However, if the impedance characteristics are affected by the addition of a disconnection point to the video signal cables, signal loss and distortion may occur. Furthermore, if the external shield is open at the disconnection point, noise may enter the cable, causing screen flickering. Therefore, a detailed examination was needed.

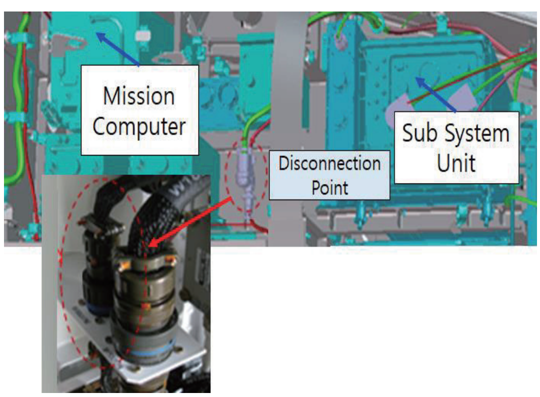


Fig. 7 Video signal path between the sub system and the mission computer.

3. Derivation of Improvement

3.1 Cause Analysis

Upon examining the disconnection point of the video signal cables, it was found that the point had a structure of two parallel lines, as shown in Fig. 8.

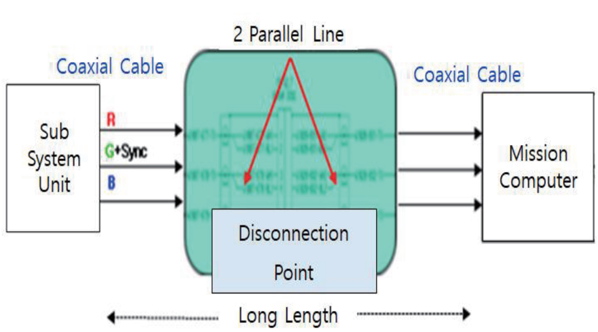


Fig. 8 Disconnection point in the video signal path.

These parallel transmission lines comprise a white lead and black lead in the solder sleeve, as shown in Fig. 9 [8].

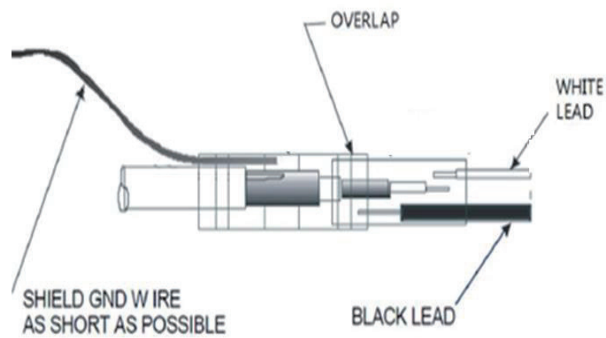


Fig. 9 Two parallel lines of lead configuration.

In a coaxial cable, the characteristic impedance is the intrinsic value of the line determined by the amplitude ratio of the voltage and current of the transmission signal, as shown in Eqs. (1) and (2) [9]. Because high-frequency signals propagate along the surface of the conductor, the outer diameter of the inner conductor and the inner diameter of the outer conductor are important variables. If the cable length and disconnection point are not characteristics of the coaxial cable, a characteristic impedance mismatch occurs owing to the difference in the characteristic impedance. Accordingly, only some of the energy is delivered, and the rest is reflected; this produces standing waves inside the cable, which may cause signal loss.

$$Z_O = \sqrt{\frac{R + j\omega L}{G + j\omega L}} = R_O + jX_O \tag{1}$$

$$Z_O = \sqrt{\frac{L}{C}} = \frac{60}{\sqrt{\epsilon_S}} \ln\frac{b}{a} = \frac{138}{\sqrt{\epsilon_S}} = \log_{10}\frac{D}{d} \tag{2}$$

D: Diameter of outer conductor
b : Radius of outer conductor
d : Diameter of inner conductor
a : Radius of inner conductor
ϵ_s : Relative dielectric constant

However, the disconnection point has a parallel wire structure and a characteristic impedance that are different from those of the coaxial cables, as shown in Eq. (3) and Fig. (10) [10]. As a result, the characteristic impedance may vary from 100 Ω to 300 Ω depending on the separation between the white and black lead wires at the disconnection point. Because the characteristic impedance does not match that of the coaxial cable (75 Ω), impedance mismatching may occur [11].

$$Z_O = 120\ln\frac{2D}{d} = 276\log_{10}\frac{2D}{d} \tag{3}$$

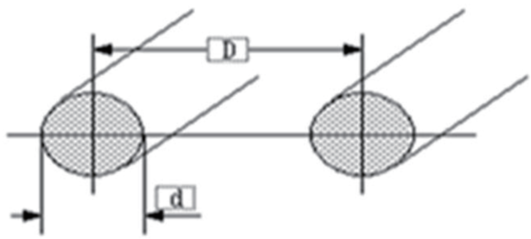


Fig. 10 Characteristic impedances of two parallel wires.

In particular, because high-frequency energy propagates along the surface of the conductor, the outer diameter of the inner conductor and the inner diameter of the outer conductor are important variables. If the cable length and disconnection point are not characteristics of the coaxial cable, a characteristic impedance mismatch occurs owing to the difference in the characteristic impedance. Accordingly, only a part of the energy is delivered, and the rest is reflected; this produces standing waves inside the cable, which may cause signal loss. Furthermore, the parallel wires have an open-shield structure, which can be affected by external noise, and the length of the video cable is increased significantly because a disconnection point is used instead of a direct connection. Thus, the cable is vulnerable to external noise. Therefore, the characteristics of the output signals transmitted from the mission computer to the MFD were measured, as shown in Fig. 11.

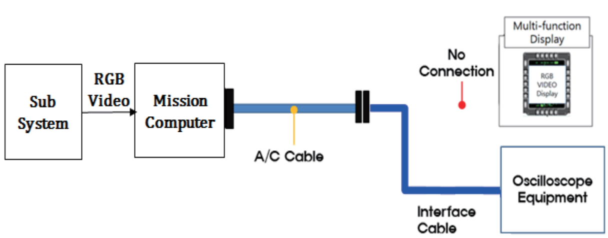


Fig. 11 Improvement in cable configuration.

Pulses at certain intervals were expected to be generated in the output signals. However, based on the measurement results, distorted and disconnected signals were observed intermittently, as shown in Fig. 12; this indicates that an improvement was required.

Fig. 12 Measurement result for disconnection point.

3.2 Improvement Method

Flickering in an MFD occurs mainly during flight. Therefore, the MFD performance should be assessed after improving the cable configuration (as shown in Fig. 13) to verify the signal loss resulting from the disconnection point and excessive cable length. We adopted the optimal path to prevent signal loss and distortion by drastically reducing the cable length and directly connecting the sub-system unit and the mission computer, without the need for a disconnection point on the wire harness for the RGB video signals [12].

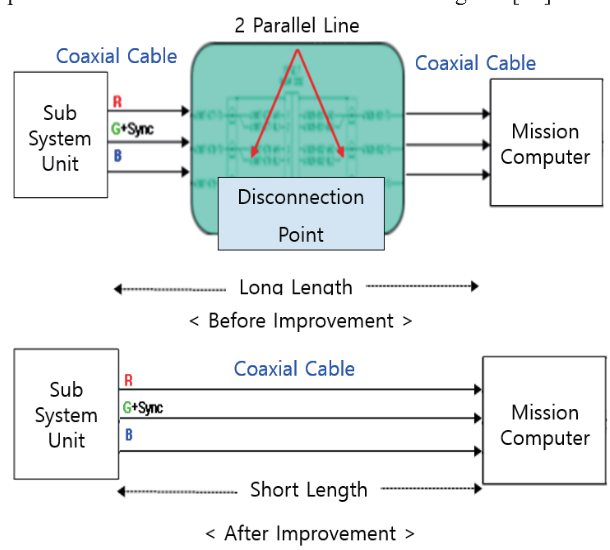


Fig. 13 Improvement in cable configuration.

The calculated values of the signal distortion before and after the improvement show that the shortened length of the video signal cable reduced the signal distortion (Table 6).

Table 6 Calculated results of signal attenuation.

Category	Attenuation
Before Improvement	dB/100 feet X Length (feet) / 100 = X.XX dB
After Improvement	dB/100 feet X Length (feet) / 100 = X.XX dB (significantly reduced ↓)
※ Video signal frequency = XX MHz, Attenuation (dB/100 ft.) Value = X.X dB	

4. Verification Result of Improvement Method

4.1 Attenuator Mounting Method

Figs. 14 and 15 depict the direct-connection configuration, which was implemented in an aircraft in which the MFD was affected by screen flickering due to signal loss. The MFD performance was analyzed after implementing the improved configuration.

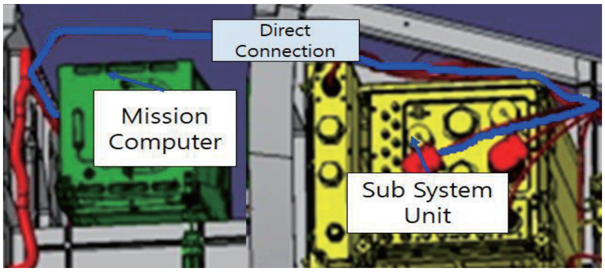


Fig. 14 Wire harness of RGB signal with direct connection.

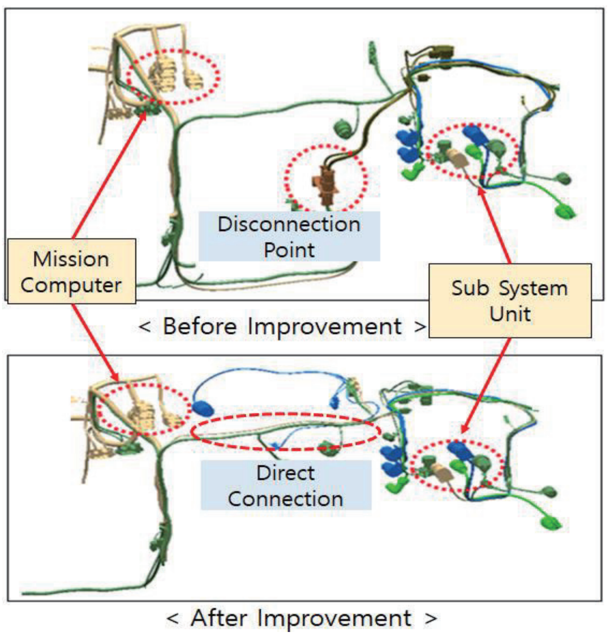


Fig. 15 Applied wire harness path in the system.

As shown in Table 7 and Fig. 17, the ground/flight verification for the improved configuration showed that the intermittent flickering phenomenon had been eliminated. Moreover, based on an interview with the operator, it was confirmed that the flickering had been resolved and that all of the MFDs functioned appropriately.

Table 7 Results of applying the improved configuration.

Aircraft	Before Improvement	After Improvement
A	Intermittent occurrence of flickering	No flickering
B		
C		
D		

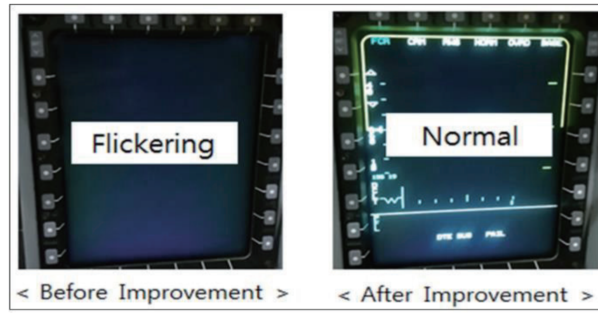


Fig. 16 RGB video display after improvement.

In addition, we measured the characteristics of the final signals provided by the mission computer to the MFD by using the method shown in Fig. 11. As a result, normal signals without distortion of disconnection were continuously measured in the output signals, as shown in Fig. 17, confirming the improvement in the output.

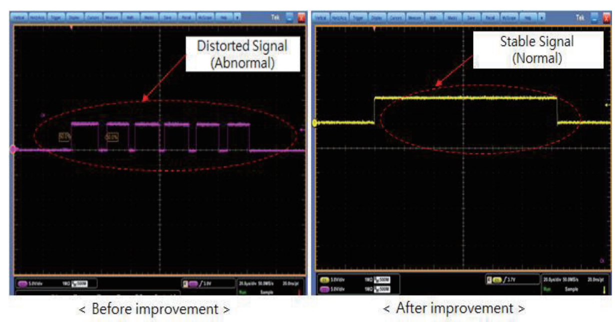
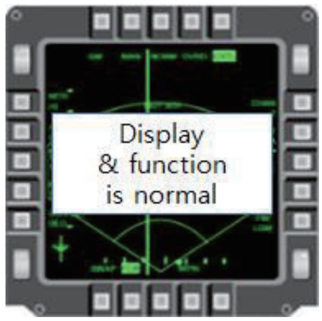
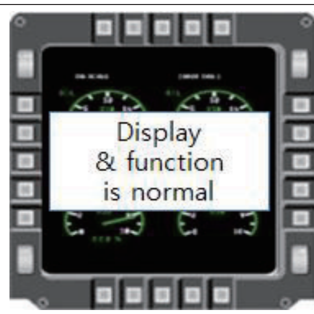


Fig. 17 Signal measurement result.

In the improved configuration, the wire harness path of the RGB video signals directly connects the mission computer and the MFD. Therefore, when the improved configuration (i.e., direct connection and a short wire harness path) is applied, the other display functions of the MFD and the video signals transmitted to the other sub-systems remain almost unaffected. Nevertheless, we sought to verify this by performing additional tests considering the effect of signal interference. Based on the results obtained, it was confirmed that the display functions and signals of other devices were unaffected, as shown in Table 8.

Table 8 Test result for video display.

Category	Test result
DVI or component signal video display	 Normal
RGB signal video display	 Abnormal

5. Conclusion

MFD screens flicker during the flight of fixed-wing aircraft because of the video signal loss and distortion caused by the impedance mismatch resulting from the use of disconnection points and the excessive length of cables transmitting RGB video signals from specific sub-systems to the mission computer. Therefore, based on the results of technical diagnosis and tests, we attempted to alleviate this flickering phenomenon by directly connecting the video signal cables and shortening the cable length. By eliminating the screen flickering phenomenon, the flight operation and aircraft reliability were improved. We used the results of this study to facilitate the cable installation design for a fixed-wing aircraft under development. It is expected that the results of the cause analysis and the failure diagnosis method used in this study will contribute to improving operability in similar types of aircraft.

References

[1] P. A. Shahady, "Military aircraft noise," *Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio,* vol. 12, no. 8, August 1975.

[2] K. Young, M. Jeong, S. G. Cho, J. Po, and H. Choi, "DVI cable improvement for preventing MFD abnormal display of a rotary-wing aircraft," *Journal of the Korean Society for Aeronautical & Space Sciences,* vol. 46, no. 9, pp. 782-789, September 2018.

[3] Burgt, Martin J. Van Der, "Coaxial Cable and Application," *Belden Electronics Division*, July 2011.

[4] Coaxial Cable Specifications for RG-6, https://www.rfcafe.com/references/electrical/coax-chart.htm

[5] MIL-DTL-3655D, "Connector, plug and receptacle, electrical (coaxial, series twin), and associated fittings, general specification", *Department of Defense*, July 2004.

[6] MIL-I-3190F, "Insulation sleeving, electrical, flexible, coated, general specification," August 2008.

[7] MIL-HDBK-83575, "General handbook for space vehicle wiring harness design and testing," *Department of Defense,* June 1998.

[8] R. A. Chipman, "Theory and Problems of Transmission Lines," *McGraw-Hill Book Company*, 1968.

[9] D. M. Pozar, "Microwave Engineering," Wiley, US, pp. 51-56, 2012.

[10] MIL-S-83519A, "Military specification: Shield terminate on, Solder style, Insulated, Heat-shrinkable, Environment resistant general specification for," *Department of Defense,* June 1984.

[11] MIL-W-5088L, "Military specification: Wiring aerospace vehicle," *Department of Defense,* May 1991.

[12] SAE-AS-50881, "Wiring aerospace vehicle," *Society of Automotive Engineer Aerospace Standard*, May 2015.