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SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

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ORBITER CCTV VIDEO SIGNAL NOISE ANALYSIS

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1.0 SUMMARY

This paper predicts the amount of steady state and transient noise which will couple to Orbiter CCTV video signal wiring in the cabin area. The primary emphasis is on the interim system. However, some predictions are made concerning the operational system wiring in the cabin area.

Noise sources considered are RF fields from on board transmitters, precipitation static, induced lightning currents, and induced noise from adjacent wiring. The most significant source is noise coupled to video circuits from associated circuits in common connectors. Video signal crosstalk is the primary cause of steady state interference, and mechanically switched control functions cause the largest induced transients.. Worst case crosstalk is 2.3 millivolts peak to peak for the interim system and 18.4 millivolts for the operational system. The worst case transient coupling is 149 millivolts for both systems. The analytic technique utilized is based on coupling equations described in Design Note 5B4 of AFSC Design Handbook DH1-4 (Reference 1). The results are considered to be worst case.

The significance of the predicted noise levels is not apparent since there is no specified allowable video noise. Therefore, it is recommended that a test be performed to inject known noise levels using existing hardware and subjectively evaluate picture quality degradation. An alternative would be to compare any noise level measurements on video signals of past programs to the predicted levels of this paper.

2.0 DISCUSSION

It is intent of this design note to assess the noise pick-up on the interim TV system video signal routed through the orbiter cabin area. In addition, noise pick-up on the same circuits will be examined for the operational TV system.

The video signal wiring to be analyzed consists of the following; Flight Deck Panel 019 (30J9192) to the VIU (Video Interface Unit) (30 P6), Mid Deck Panel M058 (80P9701) to the VIU (30 P6), and VIU (30 P6), and VIU (30P6) to the S-Band FM Signal Processor (83P76).

Noise sources to be considered are RF fields emanating from on board transmitters, precipitation static, induced lightning currents, and induced noise from adjacent wiring.

2.1 Precipitation Static and Lightning Effects

Since precipitation static and lightning can occur only in the atmosphere, and the CCTV system is not normally expected to operate during launch and landing, these noise sources will not have any effect on the video signal quality.

There may be concern that a lightning strike during launch could damage the video circuits and hamper system operations in orbit. Taking the worst case lightning induced magnetic field peak value (1200 AMP/M) in the flight deck area from Reference 2, assuming a 30 ft wire length and 2 inches above the ground plane, and applying the induced voltage equation from Reference 2, Appendix H yields;

$$E = (1200\ \text{AMP/M})(360\ \text{in.} \times 2\text{in.})(405 \times 10^{-6}) = 350\ \text{volts}$$

A conservative estimate of the shielding effectiveness for the multipoint grounded shields on the video circuits is 20 db. This results in a worst case common mode voltage on the video circuit of 35 volts. The video circuits should be capable of tolerating a 35 volt transient without sustaining damage.

2.2 Orbiter Transmitter Radiated Fields

Orbiter transmitter radiated fields should not interfere with the CCTV system operation since the lowest transmitter frequency is 225 MHz-ATC voice, and the TV system 3db bandwidth is specified as 1 Hz to 10 MHz (See Reference 3).

2.3 Noise Coupling from Adjacent Circuit Wiring

Analysis of noise coupling from associated circuit wiring to the video signal circuits requires the evaluation of a number of variable parameters. Specified or measured values are assigned when they are available. However, conservative assumptions are made where significant uncertainties are involved. This approach leads to results which tend to be worst case. Table I gives values for parameters used in calculating noise for each mode of coupling.

Inspection of the video signal wire routing reveals that the primary sources of steady state coupled interference are other video signals. These signals are given an EMC category of Class R and where practicable RI has maintained the appropriate wire separation by EMC class. As a result video signal wires are grouped together in bundles and connectors.

TABLE I NOISE PARAMETERS VS. COUPLING MODES

PARAMETERS AND RESULTING NOISE VOLTAGE \ NOISE COUPLING MODE	VIDEO/VIDEO COMMON CONNECTOR	VIDEO/VIDEO WIRE-TO-WIRE	MDM DISCRETE TRANSIENT (COMMON CONNECTOR)	MECHANICAL SWITCH TRANSIENT (COMMON CONNECTOR)
SOURCE IMPEDANCE-OHMS NOISE GENERATOR	75	75	100	50
LOAD IMPEDANCE-OHMS NOISE GENERATOR	75	75	25×10^3	50
SOURCE IMPEDANCE-OHMS NOISE RECEPTOR	75	10^6	75	75
LOAD IMPEDANCE-OHMS NOISE RECEPTOR	75	10^6	75	75
FREQUENCY-HZ	10^7	10^7	10^5	10^7
LENGTH OF COMMON ROUTING PATH - FT	0.333	17	0.333	0.333
WIRE SEPARATION DISTANCE - IN	0.103	0.25	0.19	0.19
HEIGHT ABOVE GROUND PLANE - IN	0.25	2.0	0.25	0.25
CONDUCTOR DIAMETER - IN	0.025	0.025	0.025	0.025
CONDUCTOR AND INSULATOR DIAMETER - IN	0.050	0.050	0.050	0.050
INSULATION DIELECTRIC CONSTANT	2.1	2.1	2.1	2.1
EFFECTIVE GENERATOR VOLTAGE - VOLTS	1.0	1.0	28	28
NOISE VOLTAGE ON RECEPTOR CIRCUIT - MV. PEAK TO PEAK	2.3	602*	0.4	149

* This value does not include the beneficial effects of shielding and common mode rejection.

For the interim system configuration, connector J1/30P6 on the VIU can have two video signal inputs (one from a flight deck camera and one from a mid deck camera) and has one video signal output to the S-Band Signal Processor. To predict the amount of video crosstalk in the connector, noise frequency and amplitude must be determined. Leading and trailing edges on the TV composite waveform contain the highest frequency components. Examination of the waveform shown in Figure 5.2.3.2.1-1 of Reference 3 reveals a maximum voltage excursion of one volt and a specified maximum risetime of 0.3 microseconds.

Since Reference 3 specifies an upper limit (3 dB point) of the video circuits of 10 MHz, it is assumed that the risetime could be as fast as 0.1 microsecond. Therefore, a frequency of 10 MHz is used for calculation of video crosstalk in connectors. For frequencies below 10 MHz, coupled noise decreases in linear proportion to the frequency. Common connector crosstalk is also a function of the distance between the pins carrying different video signals. Actual dimensions were taken from Sheet A-5 of Reference 4 and are included in Table I along with assumed values for all required parameters. The result obtained is 2.3 millivolt peak to peak coupled from the Panel O19 (Flight Deck) video signal to the video signal input for the S-Band FM Signal Processor. This level is taken as typical for common connector crosstalk.

There are nine video circuits in this connector for the operational system. It is assumed that all nine video signals will be in phase since all cameras will be drive by a master sync signal. Coupled noise will then be in phase and algebraically additive, resulting in worst case peak to peak crosstalk of 18.4 millivolts (8 circuits x 2.3 millivolts). This represents a peak to peak signal to peak to peak noise ratio of 35 dB.

2.3.2 Common Connector Transient Noise

Connector 30P732 carries the video signal into Forward Avionics Bay 3 to the S-Band Signal Processor. Sharing this connector are 36 MDM 28 volt discretes and eight mechanically switched control functions.

The MDM discretes were characterized in Reference 5 with respect to rise and fall times and load and source impedance. Rockwell has estimated a maximum switching rate of 3/minute for MDM discretes. Assuming a linear distribution from 0 to 3 discrete transitions per minute, the typical rate for any one discrete would be 1.5/minute. This result in an average transient rate on the video signal of 54 per minute. Table I gives the parameters used in calculating the coupled transient amplitude. Dimensions for wire separation were taken from Sheet A-11 of Reference 4 for the discrete in nearest proximity to the video signal. A frequency of 100 KHz is used since the MDM discrete have rise times>10μsec. The calculated coupled transient is 0.4 millivolts.

The mechanically switched control functions have uncontrolled rise and fall times. A conservative worst case noise frequency of 10 MHz was therefore arbitrarily selected. The switching rate from these functions is expected to be low. Since primary Bus power is applied through the switches, an impedance of 50 ohms is assumed for source and load. This is the nominal value measured by RI on SAIL Buses and documented in Reference 6. The calculated coupled transient is 149 millivolts.

2.3.3 Common Wire Bundle Crosstalk

Calculations of crosstalk between video circuits routed together in a common wire bundle is not straightforward since the degree of unbalance (common mode rejection) is undefined. The approach used assumes that the noise generator circuit is single-ended and the noise couples common mode to the receptor circuit. This yields 0.602 volts of common mode noise at 10 MHz. A conservative estimate of shielding effectiveness of the video circuit wiring is 20 dB for the noise generator circuit and the same for the noise receptor circuit. This will reduce the coupled common mode noise to 6.02 millivolts. As many as nine video circuits have been found to have a common routing path for the operational system. Since the operational system will have all composite waveforms in phase, the crosstalk noise will add. Eight circuits coupling to one circuit results in 48.2 millivolts. The fact that the video circuits are balanced will reduce the crosstalk noise in proportion to the square of the common mode rejection. For example, a commmon mode rejection figure for all video circuits of 20 dB will reduce the 48.2 millivolts to 0.482 millivolts and 40 dB will reduce to 0.00482 millivolts. Note that these values are worst case for frequency, length of cable run, and number of synchronized video circuits.

3.0 CONCLUSIONS

The most signficant source of steady state interference is video crosstalk in common connectors. Common connector crosstalk can be as high as 2.3 millivolts for the interim system and 18.4 millivolts for the operational system.

The most significant source of transient interference is common connector coupling of mechanical switch functions. These transients can be as high as 149 millivolts.

The significance of the predicted noise levels is not apparent since allowable noise is undefined in the Communications and Tracking Requirements Definitions Document (SD72-SH-0105), or in EIA Standards RS170 and RS330. The EIA standards only define the video composite waveform.

4.0 RECOMMENDATIONS

Evaluation of picture quality degradation should be performed on existing hardware by injecting known noise levels while observing picture fidelity. The results of such a test should be applicable to newly designed equipment also. If similar noise level tests have been performed on past programs, comparison of that data to the levels predicted in this paper would aid in evaluating present systems.

5.0 REFERENCES

1. AFSC Design Handbook DH1-4, Electromagnetic Compatibility

2. Orbiter Electromagnetic Effects Compatibility Control Plan, SD75-SH-0234

3. Requirements Definition Document, Communications and Tracking, SD72-SH-0105

4. Connectors, Electrical, Circular, Miniature, High Density, Environment Resisting, Specification For, 40M38277

5. MDTSCO Design Note 1.3-DN-C0204-019, Preliminary Orbiter Data Bus Noise Prediction Study

6. Rockwell Internal Letter, 382-230-BLG'77-068, SAIL DC Power Bus Measurements