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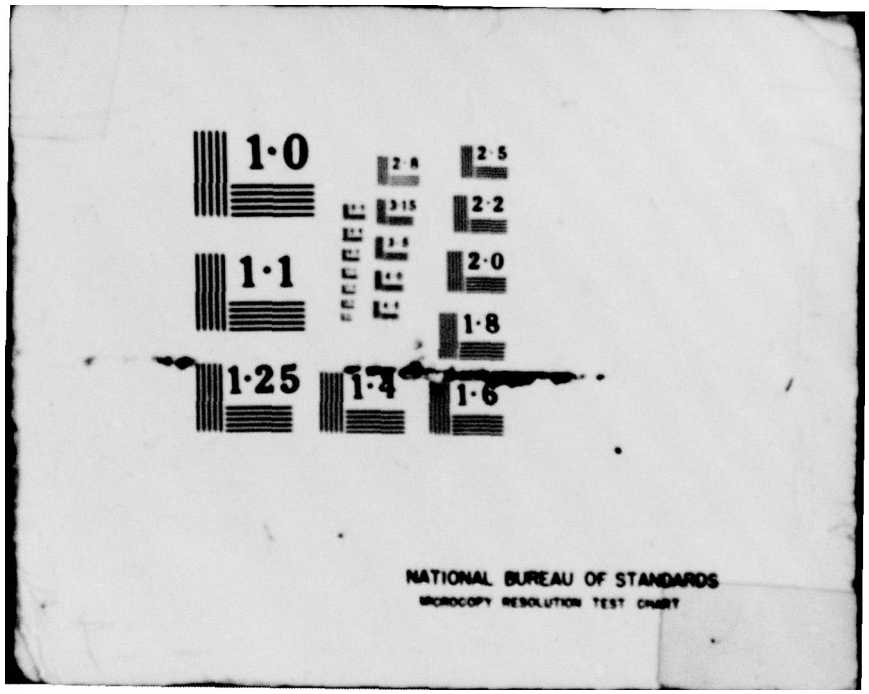
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Report No. FAA-RD-79-102

(12) LEVEL II

FAA LIGHTNING PROTECTION STUDY: REPORT OF INVESTIGATIONS RELATIVE TO PROVIDING LIGHTNING PROTECTION FOR CONTROL LINES FOR THE REMOTE CENTER AIR-TO-GROUND (RCAG)

Richard M. Cosel

May 1979

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

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Prepared by Post Doctoral Program, Rome Air Development Center

16. Abstract

The purpose of the Lightning Protection Study is to determine the degree of susceptability of FAA electronic systems to induced electromagnetic pulse effects due to lightning and to propose protective devices adequate for low voltage solid state systems. This Report covers the RCAG.

While the RCAG does contain solid state circuitry with potentially susceptible components, they are sufficiently isolated from transients so that effects are apparently negligable. Two separate reviews of four RCAG's in Florida failed to surface any outages directly attributable to lightning induced transients on control lines.

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METRIC CONVERSION FACTORS

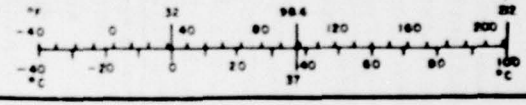
Approximate Conversions to Metric Measures

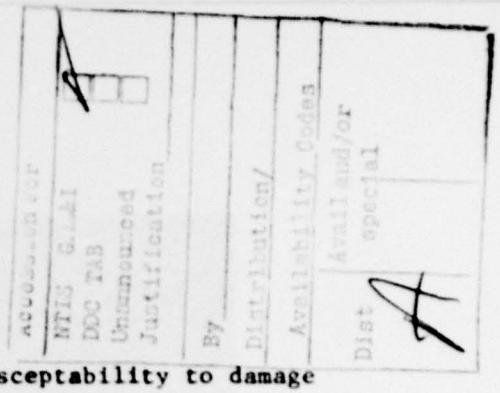
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F





This report covers the investigation of the susceptability to damage from lightning induced transients to the Remote Center Air-to-Ground (RCAG) facilities. The study has been part of a larger study program to provide protection for communications electronic equipment belonging to the FAA and conducted under the Post Doctoral Program.

Investigation of the susceptability to damage from lightning induced transients of Remote Center Air/Ground Facilities (RCAG) has been part of a larger study program to provide protection for communications electronic equipment.

Generally, newer solid state equipments, operating at much lower voltage levels than vacuum tube equipments have shown increased sensitivity to transients induced on both power and control lines causing problems ranging from complete failure to faulty and misleading data outputs. Certain Instrument Landing System (ILS) remoting circuits with control lines directly interfacing solid state components were found to be particularly susceptable. A series of reports summarized in Reference 1 have documented the problems and specific recommended solutions.

The Remote Center Air/Ground System (RCAG) is one of the two types of facilities in the enroute air/ground (A/G) VHF/UHF communication system. A typical installation is shown in Figure 1A, and its system function block diagram in Figure 2. It provides a medium of communication between a controller and pilot for air traffic control purposes. It has the following general characteristics:

1. The system is designed to transmit and receive double sideband amplitude modulated voice signals with an audio bandwidth of approximately 3000 cps.

2. The RF channel bandwidth is 50 to 100 kc for VHF service and 100 kc for UHF service.

3. The radio frequency bands for air/ground communications are 118-136 mc for civil aviation service and 225-400 mc for military service.

Figure 1A. A Typical RCAG Installation (Melbourne, Florida)

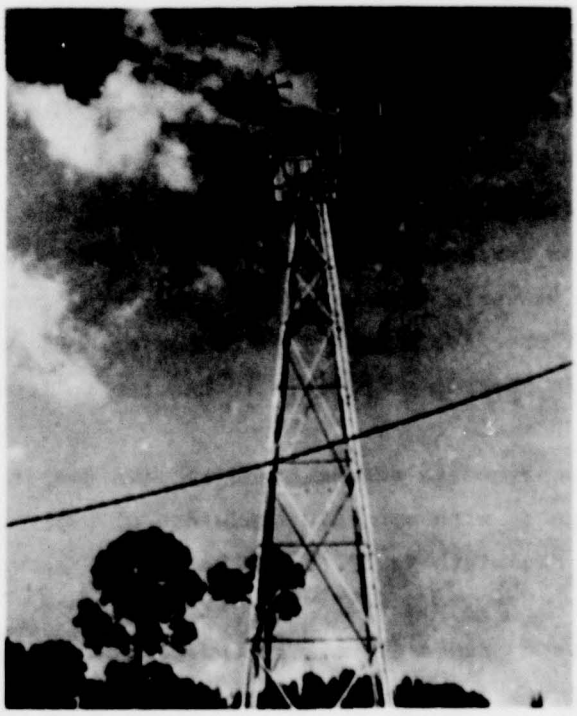


Figure 1B. Typical RCAG Antenna System Tower. In general there are four towers in each RCAG facility. (Melbourne, Florida)

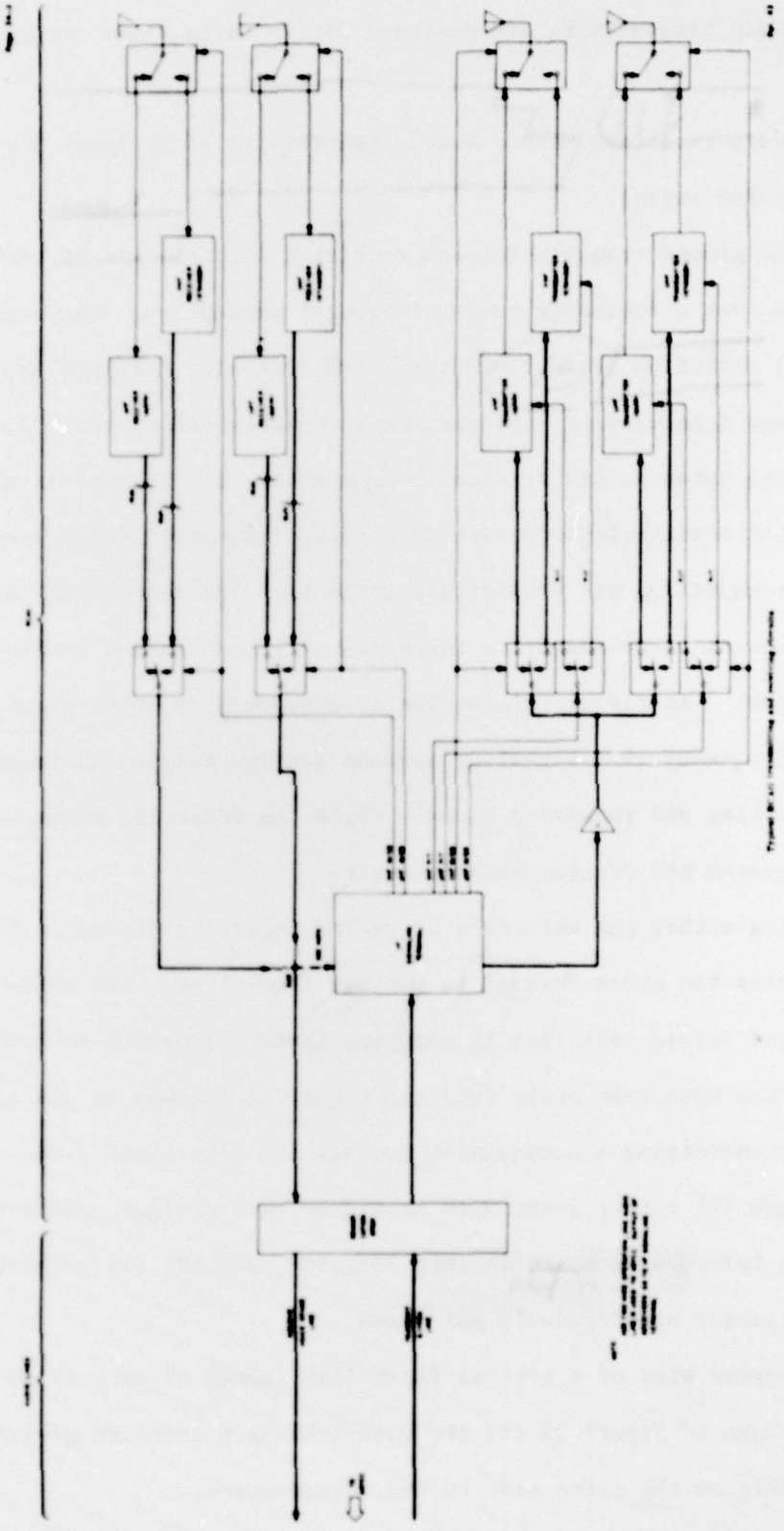


Figure 2. Typical RCAG Transmitting and Receiving Circuits

4. Radio transmitters are designed for 10 watts power output or optional 50 watts.

5. Radio receivers have a usable sensitivity of at least 5 μv (at 10-dB signal to noise ratio).

6. The ground transmitting and receiving antennas are of the broadband type useful over a frequency range of several megacycles. They also have omni-directional radiation characteristics. VHF receiving antennas are vertically polarized and transmitting antennas are circularly polarized. UHF transmitting and receiving antennas are vertically polarized. See Figures 1A and B.

The RCAG essentially consists of a voice frequency signal system and separate transmitting and receiving equipments. The system can operate in one of the following three modes: a split channel, a selective channel, and a paired channel. As far as utilization is concerned, a split channel must use two voice frequency (VF) signaling systems and two FAA-S-1142 telephone circuits for transmitting and receiving signals while the other two modes use one VF signaling system and one telephone circuit.

In using either the selective or paired selective channels, keying one channel denies the other channel to another controller. The difference between selective and paired selective is that the latter transmits both VHF and UHF signals at the same time while only one signal is allowed in the first case.

Both transmitting and receiving systems are connected to the outside world through (1) either a two wire or a four wire circuit, which is leased to FAA by a telephone company in that locality, and (2) the antennas which are either vertically or circularly polarized.

An exterior view of a typical FAA-S-1142 leased circuit is shown in Figure 3A. Also shown in Figure 3B are the carbon-block protective devices in the terminal strip on the telco side of the interconnect.

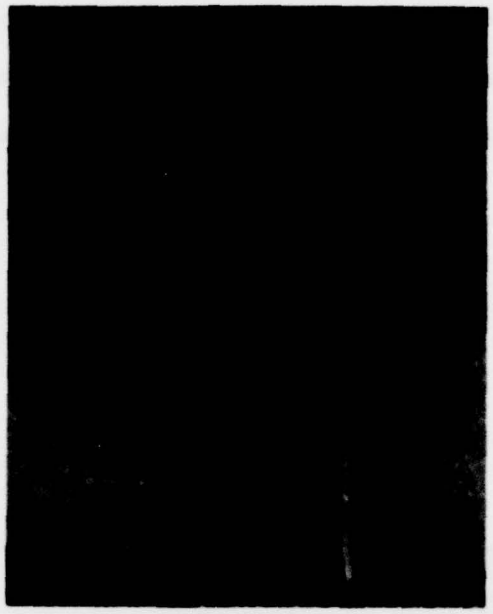


Figure 3A Exterior View of a Typical FAA-S-1142 Circuit Terminal

Figure 3B. Interior View of the Terminal Showing Carbon Block Holders (Vertical Strip, Right Side)

During the time frame that the overall investigation were taking place, the FAA was in the process of upgrading RCAG installations in the Southern Region. The existing tube type equipments were being replaced by new, largely solid state equipments. The receivers and 10 watt transmitters are completely solid state and only where 50 watt amplifiers are installed are any vacuum tubes used. Hence the word 'largely'. Specifically, these equipments, either in use or being installed were:

Voice Frequency Signaling System, FA-8187 (4) Figure 4.
Transmitting Set, Radio AN/GRT-21 (VHF) consisting of Transmitter, Radio T-1108/GRT-21, the exciter and amplifier and Amplifier, Radio Frequency, AM-6154/GRT-21, the power amplifier (2) Figure 5.

Transmitting Set, Radio AN/GRT-22 (UHF) consisting of Transmitter, Radio T-1109/GRT-22, the exciter and amplifier and Amplifier, Radio Frequency, AM-6155/GRT-22, the power amplifier (2) Figure 5.

(In both cases where only 10 watt output is required, the power amplifier is not used.)

Receiver, Radio, AN/GRR-23 (VHF) (3) Figure 6.

Receiver, Radio, AN/GRR-24 (UHF) (3) Figure 6.

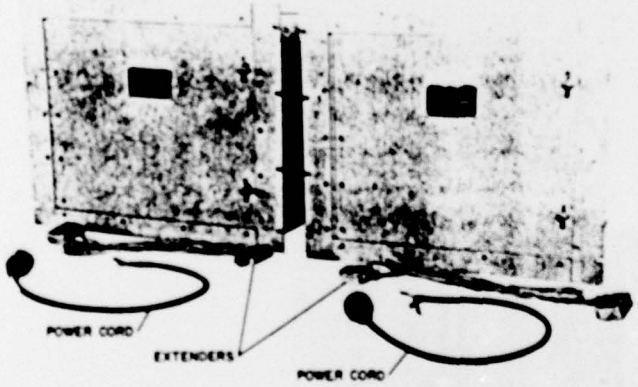


Figure 4. Voice Frequency Signaling System, Type FA-8187

The RCAG investigation begun in 1975 covered Miami (two installations), West Palm Beach, and Melbourne, all in Florida. Other than primary power failures, or external telephone line failures, no record of outages directly attributable lightning induced transients were found.

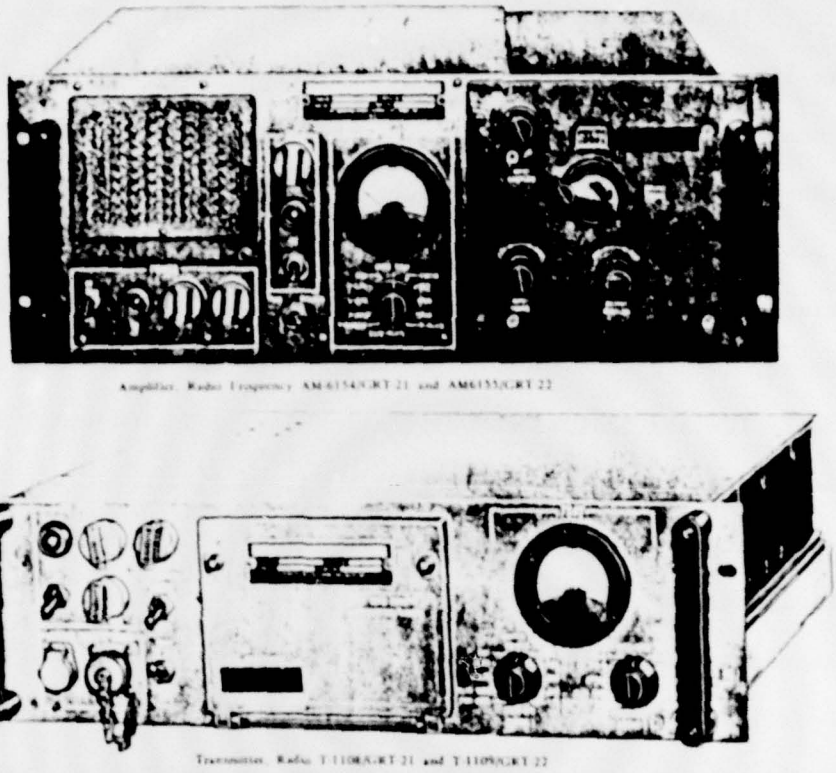


Figure 5. Transmitting Set, Radio AN/GRT-21 and AN/GRT-22

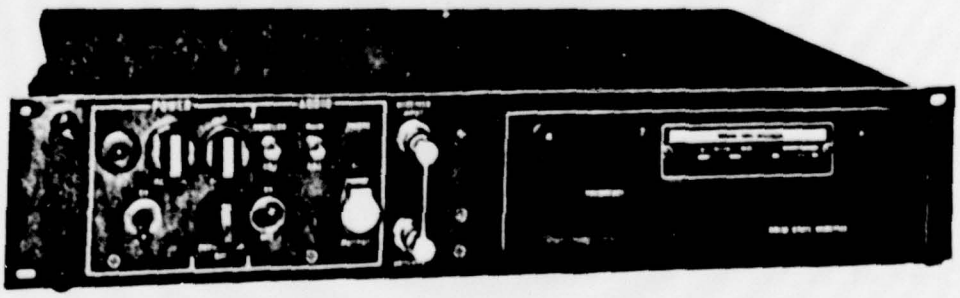


Figure 6. Receivers, AN/GRR-23 and AN/GRR-24

It should be noted, however, that experience with the new equipments was limited. Installation at Melbourne was just underway at that time. A paper analysis of susceptability indicated no problem. However, it was felt that rather than a negative report, the problem should be given a reasonable time to assert itself. A review was made again in May 1979. The same stations were contacted and again a negative report was received. Negative evidence not withstanding, during this interim period, change 234 to AF P 6500.1 (Communications Facilities and Equipment Modification Handbook - General) dated 7/28/76 was issued by FAA, AAF. (5) Chapter 279 is a modification to "Provide Lightning Surge Protection Circuits for Control Lines at Remote Center Air-to-Ground (RCAG) Facilities."

This change, directive in nature, states this modification applies to all RCAG facilities. In the background paragraph the change notes that "The RCAG contains equipment susceptible to damage by transients. Many component failures and facility outages have been traced to lightning strikes, which induce abnormally high voltage transients onto control lines. Damage can be minimized by installation of lightning protection circuits (LPC's) between FAA equipment and the telephone company (telco) demarcation terminal strip."

Actually all solid state devices are susceptible. However, the nature of the RCAG installation itself and the design of the equipment in this case tends to provide protection against all but a direct strike. Incoming lines have the usual telco protection plus that provided by the natural inductance of hybrid circuit and impedance matching devices. Antenna matching networks also provide a measure of protection against all but direct strikes. Again it should be noted that investigations conducted at the selected sites, all located in the highest thunderstorm incidence area, gave no history of outages directly attributable to lightning induced transients on control lines.

An additional change, No. 272 dated 11/22/77 (6), effectively reduced the requirement for installation of LPC's by deleting the requirement for RCAG facilities that have telco line automatic sensing and switching (LASS) equipment or at any other RCAG facility where landline inputs pass through telco solid state amplifiers at the RCAG facility before interfacing FAA equipment.

Unless more specific evidence of a need for protection for the RCAG develops, it is felt that no further action should be taken.

APPENDIX A

References

1. Cosel, R.M., "FAA Lightning Protection Study: Handbook of Installation Procedures for Selected Solid State Equipments," Report No. FAA-RD-77-170, October 1977.

2. Air Force Technical Manual, Service and Circuit Diagrams Transmitting Set, Radio, AN.GRT-21 and AN/GRT-22 T.O. 31R2-2GRT-102, 30 June 1971 and Change 4, 30 June 1973, International Telephone and Telegraph Corp. Aerospace/Optical Division. Also published as NAVELEX 0967-429-5010.

3. Air Force Technical Manual, Service and Circuit Diagrams, Receiver, Radio, AN/GRR-23 and AN/GRR-24, T.O. 31R2-2GRR-112, 31 August 1970, International Telephone and Telegraph Corp., Aerospace/Optical Division.

4. FAA-TI-6510.8 Preliminary Instruction Book, Voice Frequency Signaling System Type FA8187, Orbitronics Inc., Denver, Colo.

5. Department of Transportation, Federal Aviation Administration AF P 6500.1, CHG 234 dated 7/28/76, Subj: Communications Facilities and Equipment Modification Handbook-General, Chapter 279. Provide Lightning Surge Protection Circuits for Control Lines at Remote Center Air-to-Ground (RCAG) Facilities.

6. Revision to Reference 5, CHG 272 dated 11/22/77.