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To	Traffic and Weather Surveillance Subcommittee	**Date**	January 24, 2020
From	P. J. Prisaznuk AEEC Executive Secretary *pjp@sae-itc.org* tel 1-240-334-2579	**Reference**	20-009/WXR-105 lth

Subject

Strawman Circulation
Strawman for ARINC Project Paper 7xx: *Airborne Weather Radar with Advanced Antenna Technology*

Summary

The AEEC Executive Committee activated the Traffic and Weather Surveillance Subcommittee to develop several ARINC Standards, among them **ARINC Project Paper 7xx:** *Airborne Weather Radar with Advanced Antenna Technology.* The activity is authorized by APIM 19-008.

ARINC Project Paper 7xx is expected to define new weather radar equipment and installation intended for new aircraft designs. The document will include new material as follows:

- Airborne Weather Radar Architecture
- Weather Processor Unit (WPU) form, fit, function and interfaces
- Weather Radar Antenna Unit (WRAU) form, function and interfaces
- Control/display interfaces
- Advanced antenna function, interfaces, and installation envelope capable of single and dual antenna configurations
- ARINC 664 Ethernet interfaces
- Leverage ARINC 708A Weather Radar and ARINC 768 Integrated Surveillance System (ISS) definitions where applicable
- Other content as needed

Action

This document will be reviewed via web conference and at the next in-person meeting to be held March 19-20, 2020 in Phoenix, Arizona. Comments on this strawman should be submitted in writing to Paul Prisaznuk before March 14, 2020.

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Strawman for

ARINC Project Paper 7xx

Airborne Weather Radar with Advanced Antenna Technology

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1.0 INTRODUCTION

1.1 Purpose of this Document

This document defines an airborne pulse Doppler Weather Radar system intended for installation in all types of commercial aircraft. Its primary purpose is weather detection, forward looking windshear detection, ranging and analysis. Its secondary purpose is ground mapping to facilitate navigation by display of significant land contours. Its tertiary purpose is detecting weather events with turbulence. Weather radar equipment is intended to be capable of displaying auxiliary information from external sources such datalink.

1.2 Scope

This ARINC Standard was prepared to take advantage of technical advances in airborne weather radar and its associated components. Emphasis is placed upon windshear and weather detection/analysis capability and performance, reliability, installation ease, and reduced cost of ownership.

COMMENTARY

The ARINC Standard defines a new generation of weather radar equipment as an adjunct to existing ARINC 708 and ARINC 708A weather radar systems. The equipment built to those standards represent a large installed base at the airlines and the equipment performs well. The weather radar system described in this document maintains all the functionality of ARINC 708A systems. However, it does so in a distributed equipment architecture using units with smaller form factors and interfaces that minimize wire runs.

As much freedom as possible is given to equipment designers to provide the required performance in the most efficient manner and to meet individual airlines' preferences provided standard packing and interwiring are used. It is to be understood, however, that mechanical design is the responsibility of the airframe manufacturer.

The weather radar design should consider growth capability for emerging functions such as integrating uplinked weather information and/or interfacing with other sensors for clear air turbulence, wake vortex detection and other growth functions.

1.3 System Description

1.3.1 System Architecture

This document describes a weather sensor consisting of an antenna system with integrated RF components and a digital signal processing unit that interfaces to the flight deck control/display devices. The control elements may be provided by a separate unit or integrated into a multi-function device. The display may part of an integrated display system or may be a dedicated weather radar display.

1.3.2 System Configuration

The standardized units described by document consist of the following:

a. Weather Processor Unit (WPU)
b. Weather Radar Antenna Unit (WRAU)
c. Control Panel
d. Display

All units should be designed for an installation that includes single or dual transmitter-receivers, single or dual controls and/or displays and a single antenna. Block diagrams of typical configurations are shown in Attachment 11.

The input signals from other aircraft systems, control information and display data is expected to be serial digital data. The input signals from other systems should conform to appropriate ARINC Characteristics. The control information bus is defined to be a low-speed ARINC 429 bus as specified in **ARINC Specification 429:** *Digital Information Transfer System (DITS)*. The Display Data Bus should conform to the characteristics described in Appendix A of this document.

1.4 Unit Description

1.4.1.1 Weather Processor Unit (WPU)

The Weather Processor Unit (WPU) is expected to contain all circuitry necessary for the reception and processing of the radar data. Control and data interfaces to the WPU will be digital. The unit should accommodate single or dual control inputs and provide for the interface of up to three displays. Section 4.0 provides further details.

1.4.1.2 Weather Radar Antenna Unit (WRAU)

The Weather Radar Antenna Unit (WRAU) consists of the X-band antenna, antenna scanning control mechanism or electronic steering circuitry (if an electronic steering antenna is used), as well as all the X-band RF modules. The RF signal should be processed in the WRAU to allow transmission to the WPU using standardized cable, eliminating the requirement for a waveguide connection between the WRAU and the WPU.

The antenna mount, connections, and aircraft interwiring are fully standardized to assure the desired level of interchangeability is achieved. Section 5.0 provides further details.

1.4.1.3 Control Panel

The Control Panel may be dedicated to weather radar or it may be integrated with an existing control panel implemented in accordance with the requirements of the airframe manufacturer.

The Control Panel should use standard Dzus mounting. A typical configuration is shown in Attachment 7-2. This item may be integrated with EFIS. Section 6.0 provides further details.

1.4.1.4 Display

It is expected that weather radar images will be presented to the flight drew on an integrated display system using the capabilities of **ARINC Specification 661:** *Cockpit Display Interfaces to User Systems*.

1.5 Interchangeability

1.5.1 General Requirements for Interchangeability

One of the primary functions of an ARINC Characteristic is to designate, in addition to certain performance parameters, the interchangeability desired by users of equipment produced by various manufacturers.

1.5.2 Generation Interchangeability Considerations

The development of this ARINC Standard (ARINC 7XX) represents an evolutionary step-change in equipment architecture compared to previous generations of weather radar equipment defined by ARINC 708 and ARINC 708A. In particular, this latest equipment will use a distributed architecture moving RF components closer to the antenna, thus eliminating the need for waveguides and exotic media.

The air transport industry has chosen to deviate from the traditional form and fit previously specified in ARINC 708 and ARINC 708A. Accordingly, the industry desires that no specific provisions be made in this equipment for backward compatibility with previous generations of equipment.

Unchanged, however, is the industry's long-established desire that future evolutionary equipment improvements and the inclusion of additional functions in new equipment in the next few years do not violate the interwiring and form factor standards defined by this document. Provisions to ensure forward-looking generation interchangeability (as best can be predicted) are included in this document to guide manufacturers in future developments.

1.5.3 Interchangeability Requirements for ARINC 7XX Equipment

Users have expressed the desire for interchangeability of the weather radar system installation and performance. Manufactures should ensure interchangeability among their own Weather Processor Unit (WPU), Weather Radar Antenna Unit (WRAU), and dedicated Control Panel (if used).

COMMENTARY

ARINC 7XX weather radar system are intended to be installed in new aircraft type designs. This standard was not developed with retrofit in mind, though it does not preclude retrofit should there be a compelling reason to do so.

Due to the nature of interface between the WPU and the WRAU, it is neither practical nor desirable to expect interchangeability among different suppliers' equipment. The airlines do, however, expect full compliance by the manufacturers in providing overall system interchangeability in installations designed in accordance with this ARINC Standard. Further, all units produced by a given manufacturer must be fully interchangeable with other units having the same part numbers.

Airline experience has shown that these characteristics are often interpreted differently. Therefore, prior to any installation design, it would be prudent for the designer to ensure interface compatibility. It is often too late and too expensive to modify an aircraft due to an interface incompatibility problem.

1.6 Regulatory Approval

The weather radar equipment must meet all applicable EASA, FAA, and Federal Communications Commission (FCC) requirements. This ARINC Standard does not and cannot set forth the specific requirements which an equipment manufacturer must follow to be assured of regulatory approval under the Technical Standard Order (TSO) program or FCC approval. Such information must be obtained from the FAA and FCC.

1.7 Reliability

The airlines desire reliability in all phases in the design, production, installation and operation of this weather radar equipment.

COMMENTARY

The users do not normally state how much reliability they are willing to accept in new equipment -- they always want all they can get within the bounds of reasonable equipment complexity and cost. However, in the case of weather radar equipment, the users have expressed a need for antennas that will stay on the aircraft for at least five years. That means the antenna must be highly reliable and the maintenance people must be certain it is an antenna failure before removing it.

1.8 Reference Documents

Unless otherwise noted, the latest versions of the following documents apply:

ARINC Specification 429: *Digital Information Transfer System (DITS)*

ARINC Specification 600: *Air Transport Avionics Equipment Interfaces*

ARINC Report 604: *Guidance for Design and Use of Built-In Test Equipment (BITE)*

ARINC Report 609: *Design Guidance for Aircraft Electrical Power Systems*

ARINC Report 624: *Design Guidance for Onboard Maintenance System*

ARINC Characteristic 704: *Inertial Reference System*

ARINC Characteristic 705: *Attitude & Heading Reference System*

ARINC Characteristic 706: *Subsonic Air Data System*

ARINC Characteristic 707: *Radio Altimeter*

ARINC Characteristic 708A: *Airborne Weather Radar with Forward Looking Windshear Detection Capability*

ARINC Characteristic 735: *Traffic Alert and Collision Avoidance System (TCAS)*

EUROCAE ED-12: *Software Considerations in Airborne System and Equipment Certification*

EUROCAE ED-14: *Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments*

FAA TSO-C63c: *Airborne Weather and Ground Mapping Pulsed Radars*

FAA TSO-C92c: *Airborne Ground Proximity Warning Equipment*

FAA TSO-C112c: *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*

FAA TSO-C117a: *Airborne Windshear Warning and Escape Guidance System for Transport Airplanes*

“General Certification Methodology and System Level Requirements – Airborne Short and Long Range Windshear Predictive Systems (Forward Looking Windshear Systems)” – (Exemption 5256)

RTCA DO-160: *Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments*

1.0 INTRODUCTION

RTCA DO-173: *Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radar*

RTCA DO-178: *Software Considerations in Airborne System and Equipment Certification*

RTCA DO-213: *Minimum Operational Performance Standards for Nose Mounted Radomes*

RTCA DO-220: *Minimum Operational Performance Standards for Airborne Weather Radar with Forward Looking Windshear Capability*

RTCA DO-254/EUROCAE ED-80: *Design Assurance Guidance for Airborne Electronic Hardware*

2.0 INTERCHANGEBILITY STANDARDS

2.1 Introduction

This section describes the specific form factors, mounting provisions, connectors, interwiring, input and output signals, and power supply requirements for the weather radar system. These standards are necessary to ensure the concurrent design of the weather radar equipment and the aircraft installation.

Manufacturers should note that although this ARINC Standard does not preclude the use of different form factors and interwiring, the practical problems of re-designing what will then be a standard installation to accommodate a special system could very well make the use of that other design prohibitively expensive for the customer. Thus, manufacturers should recognize the practical advantages of developing equipment in accordance with the form, fit, function, and interfaces specified in this document.

2.2 Form Factor, Connector, and Index Pin Coding

The weather radar systems should comply with ARINC Specification 600 to enable the interchangeability of complete systems provided by different manufacturers. Specifically, equipment manufacturers are encouraged that their units conform to all statements concerning dimension tolerances, handles, projections, cooling and limits on weight and center of gravity, as specified in ARINC Specification 600.

2.2.1 Weather Processor Unit (WPU)

The Weather Processor Unit (WPU) should comply with the electrical and mechanical installation standards provided in ARINC Specification 600 for the 4 Modular Concept Unit (MCU) form factor. The physical characteristics needed for the interchangeability of mounting trays is provided in Attachment 4.

The WPU should use a low insertion force ARINC 600 Size 1 service connector located on the center grid of the rear panel. The index code is specified as #TBD. The index pins on the WPU rear connector should be set as follows per ARINC 600. The position is specified from the point of view of each unmated connector. Attachment 4 provides detailed connector drawings.

Position	Left	Center	Right
WPU	6	6	3
Aircraft	2	5	5

2.2.2 Weather Radar Antenna Unit (WRAU)

The Weather Radar Antenna Unit (WRAU) consists of the antenna and all related RF components. A digital interface is provided to between the WRAU and the WPU. Antenna mounting standards, maximum swept volume, form factors, connector types, and RF connectors are defined in Attachments 8 through 10.

The WRAU mounting standards, maximum swept volume, form factors, connector types and locations are shown in (Attachment 4 in ARINC 768). The mounting footprint and swept volume are identical to those defined in ARINC 708A.

COMMENTARY

The standard aircraft provisions for antenna mounting and swept volume will accept the standard antenna configuration shown in Attachment 10.

2.2.2.1 Standard Attachment Hole Pattern

The standard aircraft installation includes the antenna mounting hole pattern defined in Attachment 8.

2.2.2.2 Mounting Adjustments

The standard mounting provisions to be incorporated in the aircraft installation should provide a means for adjustment of the antenna approximately ±2° in the pitch axis by means of shims under the mounting pads and in the roll axis by means of the slots contained in the one mounting plate or equivalent means. It should be possible to check the alignment of the mounting pads through the use of an accurate spirit level prior to the actual installation of the antenna. In service, the airlines should be able to check the antenna alignment by means of the electrical provisions defined in Section 5.0.

2.2.3 Control Panel

Pilot control of weather radar functions may be provided on a dedicated WXR control panel or integrated with another control panel such as the Integrated Surveillance System (ISS) control panel defined by ARINC Characteristic 768. Guidance on the design of a suitable control panel is provided in Section 6.0 of this document.

The standard Control Panel, when used, should comply with the Dzus mounting dimensions as shown in MS 25212. Further details, including size, connector type and pin assignments are defined in Attachments 7-1 and 7-2.

2.3 Weights

This document specifies the maximum weight desired of each component of the weather radar system. Manufacturers are encouraged to develop equipment within these limits and keep the AEEC staff informed of any deviations to this standard. The need for appropriate changes will be determined at that time.

Table 2-1 - Weather Radar Equipment Weights (maximum)

Unit	Weight (lbs)	Weight (kg)
WPU	10	4.5
WRAU	30	13.6
Control Panel	2	0.90

2.4 Standard Interwiring

The standard interwiring to be installed for the weather radar system is provided in Attachment TBD of this document. This interwiring is intended to provide the degree of interchangeability specified in Section 1.5 of this document. Manufacturers are cautioned not to rely upon special wires, cabling or shielding for use with particular units, because they will not exist in the standard installation.

COMMENTARY

Standardized interwiring is perhaps the heart of all ARINC Characteristics. It is this feature which allows the airline customer to complete negotiations with the airframe manufacturer so that the latter can proceed with engineering and initial fabrication prior to airline commitment on a specific source of equipment. This provides the equipment manufacturer with many valuable months in which to put the final “polish” on his equipment in development.

2.5 Power Circuitry

2.5.1 Primary Power Input

The aircraft power supply characteristics, utilization, equipment design limitations and general guidance material are provided in ARINC Report 609: Design Guidance for Aircraft Electrical Power Systems.

2.5.2 WPU Power Input

The equipment should be designed to use 115 (+5%) Vac 400 Hz single phase power as the primary input for all circuits including the antenna. The primary power should be protected by circuit breakers of the size shown in Attachments 2-1 and 2-2.

COMMENTARY

Regulatory authorities require compatibility with the electrical power characteristics specified in the latest version of RTCA DO-160.

The equipment should be designed to use two 115 Vac 360-800 Hz variable frequency power inputs. One of these inputs, identified as the Emergency Bus Input, should be used to power only the circuitry necessary for the transponder function in order to minimize the power requirement from the essential bus. The other input should be used for functions not required to support transponder operation.

In the WPU, care should be given to maintain a maximum level of isolation between two power inputs. These inputs are protected by a single circuit breaker for each input, situated in the aircraft power distribution center. Power to the WRAU should be supplied by the WPU. Power to the control panel may come from the WPU or may come directly from a circuit breaker or the power distribution system.

2.5.3 Power Control Circuitry

There should be no master on/off power switch within the weather radar system. Any user desiring power on/off control for the unit should provide, through the medium of a switching function installed in the airframe, means of interrupting the primary AC power to the equipment. It may be noted that primary power on/off switches should not be needed in most installations and power should be wired directly to the equipment from the circuit breaker panel or power distribution system.

COMMENTARY

Although only one WPU of a dual installation may be operating at a time, users desire the inoperative unit to be held in a powered-up “standby” condition so that it’s Built In Test Equipment (BITE) may detect and annunciate any failures that would render it incapable of providing service when called upon.

2.5.4 The Common Ground

The wires connected to the WPU connector pins labeled "Chassis Ground" should be employed as the dc ground return to aircraft structure. It is not intended as a common return for circuits carrying heavy ac currents. Equipment manufacturers should design their equipment accordingly.

2.5.5 The AC Common

The wires connected to the WPU connector pins labeled "115 Vac Ret" should be grounded to the same structure that provides the dc chassis ground but at a separate ground stud. Airframe manufacturers are advised to keep ac ground wires as short as practicable in order to minimize noise pick-up and radiation. These pins should not be grounded internal to the WPU.

2.5.6 Internal Circuit Protection

The basic master power protection means for the WPU will be external to the unit (utilize a circuit breaker or power distribution relay). Within the equipment, no master power protection means is to be provided, although circuit protection is acceptable where the set manufacturer feels this would improve the overall reliability of the equipment.

COMMENTARY

Airlines prefer protection means other than fuses and circuit breakers. However, if internal protection by fuses is employed, these fuses should not be accessible when the set is installed in the aircraft radio rack but should be replaceable only when the equipment goes through the service shop.

If circuit protection is provided by means of circuit breakers, the majority prefer that these be accessible on the front panel of the equipment so that they can be reset in service.

2.6 Standard Interfaces

The weather radar system sends and receives data on several interfaces. Interoperability of equipment from different manufacturers requires that all communication interfaces are compatible with each other from the electrical and protocol point of view. Interfaces in this respect are interfaces to the avionics buses as well as the interfaces to the onboard applications requiring communication services.

2.7 Standardized Signaling

Electrical signal inputs and outputs of the weather radar system should be in the form of a digital format or switch contact. Standards should be established exactly to assure the desired interoperability of equipment.

Basic standards described below are applicable to all signals. Unless otherwise specified, signals should conform to the standards set forth in the sections below.

2.7.1 Digital Interfaces

The WPU should contain necessary digital interfaces and adequate spares to support growth functions over the foreseeable future. The recommended equipment ID for WPU is TBD. This ID may be used with ARINC 429 and other data transfer mediums. See ARINC Specification 429 for additional information on this topic.

2.7.1.1 ARINC 429 Data Bus

ARINC Specification 429 and applicable ARINC Characteristics (e.g., ARINC 702A, 708A, 718A, 735A, 735B, 762) define data word formats, refresh rates and resolution.

2.7.1.2 ARINC 664 Ethernet Bus

ARINC Specification 664 defines the physical layer definitions for copper and fiber optic media used in aircraft installations. Exact data word formats, refresh rates and resolution, are to be defined by the airframe manufacturer. The WPU should be designed to accept different data formats and rates used by software data loading equipment.

2.7.1.3 AEEC 453 Radar Bus

As an option, the WPU should provide a Weather Radar Display bus output compliant to AEEC Project Paper 453.

2.7.2 Discrete Interfaces

2.7.2.1 Standard Open

The standard “open” signal is characterized by a resistance of 100,000 ohms or more with respect to signal common.

COMMENTARY

In many installations, a single switch is used to supply a logic input to several Line Replaceable Units (LRUs). One or more of these LRUs may utilize a pull-up resistor in its input circuitry. The result is that an “open” may be accompanied by the presence of 27.5 Vdc nominal. The typical signal range is 18.5 to 36 Vdc.

2.7.2.2 Standard “Ground”

A standard “ground” signal may be generated by either a solid state or mechanical type switch. For mechanical switch-type circuits, resistance of 10 ohms or less to signal common represents the “ground” condition. Semiconductor circuitry should exhibit a voltage of 3.5 Vdc or less with respect to signal common in the ground condition.

2.7.2.3 Standard “Applied Voltage” Output

The standard “applied voltage” is defined as having a nominal value of 27.5 Vdc. This voltage is considered “applied” when the actual voltage under the specified load conditions exceeds 18.5 volts (36 Vdc maximum) and is “not applied” when the equivalent impedance to the voltage source exceeds 100,000 ohms.

2.7.2.4 Standard Discrete Input

A standard Discrete Input should recognize incoming signals with two possible states, “open” and “ground”. The characteristics of these two states are defined in Sections 2.10.2.1 and 2.10.2.2 of this document. The maximum current flow in the steady “ground” state should not exceed 20 milliamps.

The “true” state may be represented by either of the two states (ground or open) depending on the aircraft configuration.

The maximum input capacitance to ground should be less than 1 microfarad.

COMMENTARY

The maximum input capacitance is specified because excessive input capacitance can cause current spikes of over 1 amp.

The logic sources for discrete inputs to the WPU are expected to take the form of switches mounted on the airframe component (flap, including gear, etc.) from which the input is desired. These switches can either connect the discrete input pins on the connector to airframe DC ground or leave them open circuit as necessary to reflect the physical condition of the related components.

The WPU is expected to provide the DC signal to be switched. Typically, this is done through a pull-up resistor. The WPU input should sense the voltage on each input to determine the state (open or closed) of each associated switch.

The values of voltages (and resistance) which define the state of an input is based on the assumption that the discrete input utilizes a ground-seeking circuit. The input may utilize an internal pull-up to provide for better noise immunity when a true “open” is present at the input. This type of input circuit is favorable among both manufacturers and users.

Because the probability is quite high that sensors (switches) will provide similar information to a number of users, unwanted signals may be impressed on the WPU inputs, especially when the switches are in the open condition. For this reason, equipment manufacturers should base their logic sensing on the “ground” state of each input. Manufacturers should ensure adequate signal isolation to prevent sneak circuits from contaminating the logic. Typically, diode isolation is used in the avionics equipment to prevent this from happening.

2.7.2.5 Standard Discrete Output

A standard Discrete output should exhibit two states, “open” and “ground” as defined in Sections 2.10.2.1 and 2.10.2.2. In the “open” state, provision should be made to present an output resistance of at least 100,000 ohms. In the “ground” state provision should be made to sink at least 20 milliamps of steady state current. Non-standard current sinking capability may be defined.

COMMENTARY

It is recognized that not all Discrete output needs can be met by the Standard Discrete output defined above. Some Discrete outputs may need to sink more current than the standard value specified above and will be defined in the appropriate section of this document.

The designer is cautioned that discrete input capacitance and discrete output slew rates can caused current spikes of over 1 amp.

Discrete outputs that need to source current should utilize the standard “Applied Voltage” output defined in Section 2.10.2.3. These special cases are noted in the text describing each applicable Discrete output function and in the notes to interwiring.

Although defined here, discrete outputs which provide a current output rather than a current sink are not “Standard Discrete Outputs.”

2.7.2.6 Standard Program Pin Inputs

Program pins may be assigned on the WPU service connector for the purpose of identifying a specific aircraft configuration or to select (enable) optional performance. The optional operational function may be in effect at all times or only under certain conditions, such as when the aircraft is on the ground (identified by the enabling of the Air/Ground Discrete input). Every effort should be made to minimize the number of program pins used for weather radar.

Program pins may be used for a variety of purposes. Program pins enable a piece of equipment to be used over a greater number of airframe types. One way this is done is by identifying the unique characteristics of the airframe in which the unit is installed. Another is to identify the location (left, right, center) of the unit. Often program pins are used to enable (turn on) options for alternate or extended performance characteristics.

The encoding logic of the program pin relies upon two possible states of the designated input pin. One state is an “open” as defined in Section 2.10.2.1 of this document. The other state is a connection (short circuit i.e., 10 ohms or less) to the pin designated as the “Program Common” pin.

COMMENTARY

Normally, the “primary” location or “usual,” “common” or “standard” function is defined by the “open” logic and the optional response is programmed (encoded) by connection to Program Common.

One means of reducing the program pins to make use of an Airplane Personality Module (APM) (see Section 2.10.4) and another is to make the programmable aspects of the system to be encoded in the onboard loadable software.

2.7.3 Analog Interfaces

2.7.3.1 DC Panel Backlight Dimming Bus Input

0 to 10 Vdc signal input should be used to control the brightness of the control panel back lighted legends.

2.7.3.2 AC Panel Backlight Dimming Bus Input

As an alternate to the dc Backlight Dimming Bus, 0 to 5 Vac (360-800 Hz) can be used for panel backlighting.

2.7.3.3 Audio Output

The system should provide synthesized voice outputs for windshear alerts. One of these outputs is intended for driving a speaker (8 ohm). The other is for interfacing with the aircraft audio system (600 ohms). See Attachment 1, Note 23.

Audio outputs should be programmable to deliver 0.625 to 80 mW into 600 ohm load at 1000 Hz. Default audio outputs settings should provide 10 mW (nominal) into 600 ohm load per RTCA DO-214. Audio levels should be customer programmable.

2.8 Interwiring and Program Pins

The aircraft interwiring should be in accordance with the “Standard Installation” defined in Attachments 2-1 and 2-2. The special interwiring notes are listed in Attachment 1.

2.8.1 System Configuration Programming Pins

The standard installation has provisions for jumpers between the “common” and the appropriate “System Configuration Programming” pins as defined in Attachment 16.

COMMENTARY

This document defines a system capable of several configurations using standardized units. The equipment designers are encouraged to automatically determine the installation configuration without using the program pins.

2.8.2 Windshear Performance Programming Pins

The standard installation should have provisions for jumpers between the “common” and the appropriate “Windshear Performance Programming” pins as defined in Attachment 16.

COMMENTARY

The current definition has one threshold for windshear alerts that is to be used by all aircraft regardless of performance capabilities. Windshear Performance Programming Pins are reserved as provisions for future use if variations of windshear threshold is defined based on aircraft performance. These pins should not be used until its definitions are approved.

2.8.3 Audio Output Level Programming Pins

Three program pins are assigned to designate the audio output volume (power) level. The logic for these three pins is defined in Note 23 of Attachment 1 to this document.

2.8.4 Onboard Maintenance System Program Pins

A program pin is assigned to designate the type of maintenance system interface employed as described in Section 8.0. The logic for this pin is defined in Note 20 of Attachment 1 to this document.

2.9 Input Signal Characteristics

Digital data bus signals should be provided in the standard installation as shown in Attachments 2-1 and 2-2. These signals should comply with ARINC Specification 429 and other applicable ARINC Standards.

2.9.1 Digital Data Bus Inputs

Digital data inputs include Aircraft Attitude, Radio Altitude, Air Data, and interface requirements for the maintenance system are defined in Section 8.0. Provisions are made for dual inputs for the other data buses. In the case of the Attitude Input, a source select signal (Attitude Discrete) input is provided. The logic for this source selection is defined in Note 8 of Attachment 1. For the Radio Altitude and Air Data, the second inputs are included for redundancy.

The data to be provided on the data bus inputs is shown in Table 2-2 below.

Table 2-2 - Digital Data Bus Inputs

Attitude Input Bus (IRS/AHRS/ADIRS)	ARINC 429 Label
Roll	Label 325
Pitch	Label 324
Ground Speed	Label 312
Heading Magnetic	Label 320
Heading True	Label 314
E/W Velocity	Label 367 or 374
N/S Velocity	Label 366 or 373
Track Angle	Label 317
Drift Angle	Label 321
Radio Altitude	Label 164
True Air Speed	Label 210
Uncorrected Altitude	Label 203
Corrected Altitude	Label 204
Computed Air Speed (CAS)	Label 206

If interfacing with an ADIRS, the data required from the Air Data Computer can be transmitted on the Attitude Input Bus.

2.9.1.1 Altitude Digital Bus Input

The Right or No. 2 Low Range Radar Altimeter (LRRA) bus is connected to the R-T(s) for purposes of redundancy. Normally the Left or No. 1 LRRA is used as the prime input by the #1 or #2 R-T and the Right or No. 2 LRRA.

2.9.1.2 General Input Bus

Two bus inputs (General Input Bus #1 and #2) are defined to be used for multiple functions. The following are potential usage of these inputs:

a. For aircraft equipped with ARINC 575 Air Data Systems, the General Input Buses #1 and #2 may be used to accept ARINC 575 Air Data in lieu of the normal ARINC 706 Air Data defined for DACD #1 and #2 input buses.
b. For standard installations, General Input Bus #1 should be connected to the Terrain Avoidance Warning System (TAWS) enabling a terrain based automatic radar antenna tilt control function. The required data to be provided is shown in Table 2-3 below.

Table 2-3 – Additional Data Bus Inputs

General Input Bus Data	ARINC 429 Label
Display Terrain Selected	Label 060
Sector 1 tilt angle	Label 061
Sector 2 tilt angle	Label 062
Sector 3 tilt angle	Label 063
Sector 4 tilt angle	Label 064
Sector 5 tilt angle	Label 065
Pseudo Radar Altimeter	Label 067

The bit assignments are further defined in Attachment 21.

For an installation that can provide windshear related discrete inputs in a digital bus format, the General Input Buses #1 and #2 may be used for these inputs. The bit assignments for the Windshear Discrete Input are defined in Attachment 15-4.

2.9.2 Combined Digital Data Bus Input

For aircraft using integrated avionics, all of the required data listed in Section 2.8.1 can be combined on a single bus connected to the Attitude Input. In this case, the bus can also contain a data word for all the desired discrete inputs, as described in Section 2.8.4. This data word is further described in Attachment 15-4.

2.9.3 Digital Input Signal Loading

The loading on the digital bus inputs should not exceed that specified for a single receiver input impedance as defined by ARINC Specification 429.

2.9.4 Discrete Inputs

The discrete inputs described in the following sections should be provided in the standard installation, unless the data is provided in the digital format on the Attitude Input as described in Section 2.8.2.

2.9.4.1 Qualifier Inputs

To facilitate automatic activation of windshear mode (Section 3.1.6), and to prevent the radar from turning on and radiating at the gate area or in maintenance hangers, two types of Qualifier Input signals are desired.

Qualifier-A: These inputs should be connected to sources which provides a ground signal (Less than 3.5 Vdc or 10 ohms) when the aircraft is on the runway or in the air. These signals should provide an open (more than 100,000 ohms) or 28 Vdc when the aircraft is at the gate area and when people might be present within the safe radiation distance of the radar. One candidate source for this signal is the transponder is ON. The Qualifier-A #1 should be connected to the #1 source and, #2 to the #2 source. A Qualifier-A program pin is provided to reverse the logic of the Qualifier-A inputs. If the program pin is grounded (connected to the program pin Common), Qualifier-A input is considered “valid” when it is not a ground signal.

Qualifier-B: These inputs should be connected to sources which provides a ground signal when the aircraft is not in the maintenance hangar. These signals should provide an open or 28 Vdc when the aircraft is in the maintenance hangar when maintenance personnel might be near the radar antenna. One candidate source for this signal is the Oil Pressure Normal which provides a ground signal when engine oil pressure is at normal operating level. The Qualifier-A #1 should be connected to the #1 source and, #2 to the #2 source. Qualifier-B program pin is provided to reverse the logic of the Qualifier-B inputs. If the program pin is grounded (connected to the program pin common), Qualifier-B input is considered “valid” when it is not a ground signal.

2.9.4.2 Gear Down Input

Two inputs should be provided in the standard installation for Gear Selected Down signal input. They should be connected to an aircraft source which provides either positive (28 Vdc) or negative (Ground) logic Gear Selected Down signal. Only one input is needed. This signal is used to determine transition to takeoff mode from landing mode in the case of a go-around.

2.9.4.3 Windshear Alert Audio Inhibit

One input pin has been assigned for inhibiting the windshear alert audio output. The prioritization scheme is shown in Table 2-4 below.

Table 2-4 - Audio Inhibit Priorities

Priority	Apply Ground to Inhibit
1	Reactive Windshear (if installed)
2	GPWS Mode 1 Warning
3	GPWS Mode 2 Warning
4	EGWS Terrain Warning
5	Predictive Windshear Warning
6	GPWS Mode 1-5 and EGPWS Caution
7	Predictive Windshear Caution
8	TCAS RA
9	TCAS TA

2.9.4.4 Air/Ground Discrete Input

The ground/air logic input to the equipment should be assigned for application as the user sees fit. It should be wired to a logic source in the aircraft which presents a standard open circuit (100,000 ohms or more resistance from this pin to airframe dc ground or a voltage between 18.5 and 36.0 Vdc) while the aircraft is on the ground 2.8.4.4 Air/Ground Discrete Input and a standard ground (less than 10 ohms resistance from the pin to airframe) while the aircraft is in the air. Equipment manufacturers are cautioned to provide sneak circuit protection for this input so that malfunctions of their equipment connected to the same logic source do not affect the weather radar operations. See Attachment 1, Note 17.

2.9.4.5 Attitude Discrete Input

An Attitude Discrete Input is provided to select the attitude source. When open, the unit uses the on-side input. Normally on-side attitude for R-T #1 is the #1 (left) attitude source. On-side for R-T #2 is the #2 (right) attitude side. See Attachment 1, Note 8.

2.10 Environmental/EMI Requirements

Weather radar components should comply with the environment test requirements of RTCA DO-160 latest version. Because components may be located in different areas of the aircraft, different levels of environmental testing may be required. Further, tested at ambient pressure altitudes up to 20,000 feet in accordance with RTCA DO-160, it should not cause a fire or other hazardous condition. Attachment 14 to this ARINC Standard tabulates the relevant environmental categories.

COMMENTARY

Airplane manufacturers may conduct additional tests for certification.

2.11 Cooling

The WPU should be designed to accept forced air cooling. Airframe manufacturers should configure the installation to provide cooling as defined in ARINC 600 (220 kg/hr per kW of power dissipation).

Unit Size	Air Flow (kg/hr at 40 deg C)	Average Power (watts)
4 MCU	16.5	100

The coolant air pressure drop through the equipment should be per ARINC 600, which specifies level 1 cooling (5 ±3 mm) or level 2 cooling (25 ±5 mm) at standard conditions of 101.3 kPa. This pressure drop does not include the drop through a returning orifice when such orifice is located external to the equipment case. A loss of in-flight cooling air for 345 minutes should not cause any loss of functionality. A partial reduction in duty cycle is acceptable during periods of no cooling air for higher ambient air temperatures or longer periods of no cooling air.

Other components, such as the WRAU and control panel, should be designed for convection and conduction cooling. These units should not require forced-air cooling.

COMMENTARY

The specified cooling air flow rate is based on estimated average power dissipation. However, it should be noted that power dissipation during RF signal transmission will be higher than the estimated average. Thus, the specified air flow rate will be less than the rate recommended in ARINC 600 for the maximum dissipation.

Equipment failures in aircraft due to inadequate thermal management have plagued the airlines for many years. Section 3.5 of ARINC 600 contains information needed by airframe and equipment suppliers to prevent such problems in the future. The airlines regard this material as “required reading” for all potential suppliers of weather radar equipment as well as airframe manufacturers.

Equipment designers should make it a goal to minimize the loss of operating life even considering the most severe ambient conditions of ARINC Specification 600.

2.12 Grounding and Bonding

The attention of equipment and airframe manufacturers is drawn to the guidance material in Section 3.2.4 of ARINC Specification 600 on the subject of equipment and radio rack grounding and bonding.

COMMENTARY

A perennial problem for the airlines is the location and repair of airframe ground connections whose resistances have risen as the airframe aged. A high resistance ground usually manifests itself as a system-level problem that is difficult to troubleshoot and therefore consumes an unreasonable amount of time and effort on the part of maintenance personnel to fix. Airframe manufacturers are urged, therefore, to pay close attention to assuring the longevity of ground connections. Close attention to the above-referenced material should be the first step.

2.13 Radome

The radome should be optimized for X-band frequency (9.3 to 9.5 GHz) and meet RTCA DO-213 Class B or better specifications. However, the installation should be designed to be certifiable with Class C radomes to make allowance for field degradation of the radome. The radome should meet the electrical performance requirements defined in Section 7.0. The airlines recognize the need for the installation designer to control the mechanical, structural and lightning protection characteristics of the radome.

3.0 SYSTEM DESIGN AND PERFORMANCE REQUIREMENTS

3.1 Performance

The performance requirements for weather detection range, windshear detection, and ground mapping range are specified separately in the following sections. The turbulence detection capability is an optional feature. Since there are no industry standards for the turbulence detection, performance is not specified.

3.1.1 Weather Performance

Weather phenomena of operational significance should be displayed with good discernibility with sufficient performance margin ahead of the aircraft. By both airline experience and technical analysis, adequate performance in this sense is achieved by meeting the following quantitative relation:

$$PI = 113 + L_a R + 40\ \mathrm{Log}_{10} R$$

Where:

PI = Minimum Performance Index (dB)

R = Maximum system range (nm)

L_a = Two-way free air attenuation 0.024 dB/nm (9300 to 9500 MHz)

Table 3-1 provides calculated PI values for various ranges and frequency bands using the PI equation.

Table 3-1 Minimum Performance Index (PI)

Aircraft Cruising Speed (kt)	System Range (nm)	Minimum Performance Index (dB) 9360 to 9560 MHz
up to 100	22	170
up to 200	50	182
up to 350	75	190
up to 500	100	195
up to 650	125	200
> 650	150	204

The ranges shown in Table 3-1 were chosen as being generally suitable for aircraft having cruising speeds as shown above. The relationship of Minimum Performance Index to system range allows for a radome loss of 3 dB and a transmission loss of 4 dB. When the total two-way loss from these sources is other than 7 dB, the above figures should be modified accordingly. The Performance Index (PI) for ranges other than those given in the table may be calculated from the PI formula.

3.1.2 Weather Performance Index

The weather performance index should be calculated in accordance with the following formula:

Weather Performance Index = P_t + 2G + K + T P_r

Where:

P_t = 10 $\log_{10}$ of the transmitter peak power in watts at the transmitter/ receiver RF connection

G = The antenna gain in decibels, referred to an isotropic radiator

K = Frequency factor. This factor takes into account the effect of the frequency of transmission on radar reflection characteristics and includes an allowance for precipitation attenuation. The effect of frequency on antenna gain is included in term G.

Table 3-2 lists the K factor for the frequency bands indicated.

Table 3-2 - Performance Index K Factor

Transmitted Frequency (MHz)	**K Factor**	
	Penetration	Avoidance
9300 to 9500	-6 dB	+6 dB

Where:

T = 10 $\log_{10}$ transmitted pulse length in sec between the 3 dB points

P_r = MDS power at antenna port in dBm

For digital displays MDS should be measured with a maximum probability of false alarm of 10-3 and a probability of detection of 30% for an individual display element.

The effective screen area integrated by the signal processing should be limited to the following values to ensure sufficient resolution is retained:

Range resolution – 5% of displayed range or 3 nm whichever is smaller

Azimuth resolution – Not less than the antenna horizontal beam width

Scan-to-scan time – Maximum of ten seconds

COMMENTARY

The weather performance calculation is based upon conventional pulse radar techniques. By using the radar display to establish system sensitivity, many of the challenges previously encountered when using the Performance Index have been overcome. It should be pointed out, however, that the processing techniques used to improve system sensitivity in the laboratory may not always apply to the weather signals whose characteristics usually differ considerably from fixed or “hard” reflecting surfaces due to the de-correlation times of the weather signals.

The objective is to provide an adequate means of comparing the weather detection range performance of one equipment with another. The equations provided in this section provide a means of relating the Performance Index, which may be determined by the equation in Section 3.1.1 to the Maximum Operational Range likely to be achieved by a given weather radar equipment. The equations of both sections are based upon actual airline and radar meteorology scientists' experience. Thus, the manufacturer of a prospective customer may utilize this mathematical model to effectively determine the operational range capability of a given design for the storm model used in its development.

Although this section does not specify range requirements, the equipment designer should take note of the fact that most airlines need a minimum range of 150 nm range for subsonic aircraft.

Antenna gain and beam width varies with design, frequency, and size. Assuming flat plate radiators, generally round in shape, the approximate values are provided in Table 3-3.

Table 3-3 – Antenna Performance

Antenna Size	X Band	
	Gain (dB)	Beam Width
35.5"	-	-
30"	35.0	2.9º
24"	33.0	3.7º
22"	32.2	4.1º
18"	30.5	5.0º
15"	28.9	6.0º

3.1.3 Windshear Detection Performance

RTCA DO-220 defines the Minimum Operational Performance Standards for Airborne Doppler Weather Radar with Forward Looking Windshear Detection Capability. In summary, the radar system should be capable of detecting dry (as low as 0 dBz outflow reflectivity) and wet (more than 40 dBz core reflectivity) microbursts with hazard factors exceeding 0.13 averaged over 0.54 nm (1 km) range.

3.1.4 Ground Mapping Performance

This weather radar system should be capable of ground mapping within the same range as is used for weather display, with the aircraft flying at the upper flight levels. Sensitivity Time Control (STC) and Automatic Gain Control (AGC) may be disabled or modified, and the transmitted RF pulse characteristics may be changed when the Map mode is selected. The flight crew should use the manual gain control, if possible, to adjust system sensitivity to match the desired ground mapping range.

COMMENTARY

The normal pencil beam pattern as described in Section 5.5 provides sufficient illumination for adequate ground mapping to the extent needed by most airlines for their limited radar navigation. However, some users have expressed a continuing need for a special beam shape in the Map mode to meet their more extensive use of this radar for navigation purposes.

3.1.5 Automatic Activation of Radar

The radar is automatically turned on when radio altimeter is less than 2300 feet with at least one of the Qualifier-A and one of the Qualifier-B inputs are valid. The valid conditions for these inputs are defined in Section 2.8.4.1.

If suitable signals are not available, automatic enabling should be deactivated by leaving qualifier inputs open. In this case, the radar should be turned on manually prior to take off and approach by making it a checklist item.

Provisions should be provided such that dual systems should not be turned on simultaneously.

3.1.6 Windshear Mode Activation

The windshear detection capability should be active below 2300 feet Above Ground Level (AGL) any time the radar is “ON,” but not in the test mode. In the test mode, when the radio altimeter is less than 2300 feet with at least one of the Qualifier-A and one of the Qualifier-B inputs valid, the windshear detection mode should be activated.

3.2 Display Characteristics

3.2.1 Display Interface

The display system interface is a function of the aircraft installation. Display data and system mode/status information should be transmitted using a display bus and interface in accordance with **ARINC Specification 661:** *Cockpit Display System Interfaces to User Systems*. **ARINC Specification 664:** *Aircraft Data Network* (ARINC 664 Ethernet) may be used for the physical layer.

3.2.2 Ranges

A weather radar range selection feature must be provided. The display system should be so designed that it automatically erases the weather data image being displayed when the range is changed. The mechanism used to sense a change in range must include suitable protection from inadvertent image erasure due to noise.

This document does not specify the indicator display ranges. Control Word 2 described in Attachment 15-2 makes it possible for the equipment to select up to 64 different ranges in any combination of 5-mile increments for a full display range from 5 nm to 320 nm; however, ranges of 5, 10, 20, 40, 80, 160, and 320 nm should be used whenever possible.

COMMENTARY

The number of ranges and the value of each range is not standardized. Most of the later generation of aircraft use 10, 20, 40, 80, 160, and 320 nm as standard ranges. The industry might want to consider these ranges as de facto standards. Standardization will help reduce equipment complexity and reduce cockpit training differences. It is desirable to have a 5 nm range for the windshear icon display.

Designers may wish to facilitate configuration changes by providing an internal “patch panel” or firmware (switches are not acceptable) for the range bit pattern (bits 29-24 in Attachment 15-1) for each selected range.

The transmitter and/or receiver characteristics (such as pulse length) may be changed at longer ranges. This may present problems if used in installations with dual displays having independent range selection.

3.2.3 Display Sector (Scan Angle)

3.2.3.1 Normal Angle

The operational desire for weather radar scan angle or display sector varies greatly among the airlines. The needs of most operators can be adequately satisfied with a sector scan of ±90º each side of the aircraft longitudinal axis. Thus, this type of antenna is described herein.

3.2.3.2 Reduced Sector Scan

The weather radar system should also provide the capability to reduce the scan angle to ±45º each side of the aircraft. Control of this function is defined in Note 3 of Attachment 15-1.

COMMENTARY

The purpose of this function is to provide more rapid target/display data update rate. Users who do not desire this function need not provide the associated cockpit control.

3.2.3.3 Windshear Detection Scan

The windshear azimuth coverage should be at least ±25º each side of the aircraft longitudinal axis.

3.2.4 Accuracy of Display

With zero pitch and roll signals applied to the antenna the displayed data should correspond in angular position within ±2º to the antenna angular position which that data represents. The error in indicated range should not exceed ± 5% of the selected range including range mark accuracy and display linearity.

3.2.5 Display Visibility

The display should provide adequate lighting under ambient conditions. Adjustment of overall display brightness and brilliance by the flight crew should be possible.

3.2.6 Display Color

For weather targets, green, yellow, and red should be used for Levels 2, 3, and 4, respectively. Magenta should be used for displaying turbulence areas. Optionally, magenta can be used for displaying Level 5 targets. In this case white should be used for turbulence indication.

3.2.7 Iso-Echo-Contour

Iso-echo-contour is desired from weather targets having “Z” values of 104 (40 dBz) and greater when the target lies within the STC range as defined in Section 3.8. Signals greater than the Iso-echo-contour threshold should be painted as red. This reflectivity data should be encoded in the respective range bin as defined in Attachment 15-3 with “Level 4” corresponding to Z-4.

3.2.8 Auxiliary Data Bus

The transmission of auxiliary data for display should be by means of a data bus defined by ARINC Specification 429. The word formats and bit interpretations are provided in Attachment 18 to this document. The bit transmission rate should be 100 kbps.

COMMENTARY

Users have expressed a desire for display of data from more than one external device. They expect that this may be accomplished by the use of a switch external to the Display Unit (DU).

3.2.9 Traffic Display

It is the desire of some users to have the DU display information obtained from other sensors. This may include information from Airborne Collision Avoidance System (ACARS), Traffic Collision Avoidance System (TCAS) (both TAs and RAs traffic), etc., in addition to weather and windshear. Consideration should be given to the human factors so that the information presented is timely, correct, not misleading and easily interpreted (see the TCAS high speed bus defined in ARINC 735 for traffic display).

3.2.10 Icon

The symbol used to represent the location of a windshear event consists of alternating red and black arcs. The depth of each red or black arc should be eight range bins (out of 512 range bins) when 5 nm range is selected. The depth may be scaled for other range selections. The icon should cover the area of the windshear event where F-factor exceed the alert criteria defined in Section 3.1.3. The warning area (1.5 nm on Approach and 3 nm on takeoff).

For range selections above 10 nm, yellow and black radial lines from the edges of the icon area should be displayed to aid flight crews with identification of the direction of the windshear event which might not be visible due to small area of the event at the origin. The width of the yellow and black radial lines should not exceed three degrees. These radial lines may be used for all ranges, if the display is also used for traffic display.

The windshear icon, including the yellow/black radial lines, should be superimposed on radar returns. The TCAS traffic should not be blanked by the windshear icon or radial lines.

COMMENTARY

There are 512 possible range bins.

3.3 Controls

3.3.1 Control Data Bus

The communication of system control functions should be provided by a standard ARINC 429 low speed data bus. The word labels have been selected from those set aside in ARINC 429 for transmitting discretes. Therefore, the specific bit encoding is fully defined in Attachment 15-1 to this document. Additional information on the manner in which the Control Data Buses are used may be found in Attachment 11-7 to this document.

COMMENTARY

The basic design parameters and operating protocol for the Control Data Bus are defined in ARINC Specification 429. Any such material in ARINC Specification 429 should take precedence over similar descriptions herein in the event of a conflict between the two.

3.3.2 ON/OFF Control

Provision of a front panel ON/OFF control is a manufacturer option. The windshear detection mode should be active even if the system is put into OFF condition by the ON/OFF control. If the ON/OFF control option is exercised, the WPU should continue to provide an active interface with the Central Fault Display System (CFDS) as described in ARINC Report 624 even in the OFF condition. The WPU should be capable of making automatic fault reports and declaring itself to be OFF should a BITE request be made to which it is unable to respond without being fully energized. Pins are provided on the connector for an ON/OFF Discrete input. See Attachments 2-1 and 2-2. The logic of the ON/OFF Discrete is described in Note 6 of Attachment 1.

Provisions should be provided such that dual systems should not be turned on simultaneously.

COMMENTARY

Some portions of operational circuitry may need to be energized to meet the status monitoring provisions of ARINC Report 624.

3.3.3 Antenna Tilt Control

3.3.3.1 Manual Tilt Control

The system should include a means for the flight crew to manually select the desired antenna tilt within the range defined in Section 6.2.2 for weather and ground mapping modes.

Note: The extent of tilt adjustment should be such that the axis of the beam may be set to positions from at least 14o below to at least 14o above a plane perpendicular to the antenna rotation axis.

3.3.3.2 Automatic Tilt Control

Automatic tilt control for the windshear mode is required to set the antenna tilt at the optimum level for detecting outflows from microbursts. Additionally, the equipment designer may, at his option, include means for automatic adjustment of tilt for weather and ground mapping modes compensate for changes in flight conditions, such as the selection of a different display range. Crew selection of automatic tilt control for weather radar and ground mapping is transmitted as described in Note 3 to Attachment 15-1.

COMMENTARY

Because technical and operational details are manufacturer options, the Automatic Tilt Control is not defined.

3.3.4 Self-Test

A self-test facility should be provided that will give positive information about overall system performance.

In the case of low or nil performance, the test should also give substantial aid to maintenance personnel in locating a faulty unit without having to pull the system apart.

For further information, refer to Section 4.10 and Section 8.0.

3.4 X-Band Radio Frequency

The equipment should be designed to operate at a center frequency anywhere within the 9300 to 9500 MHz frequency band.

COMMENTARY

The frequency band 9300 to 9500 MHz is allocated to the Radio Navigation Service by International Telecommunication Union (ITU), Article 8. Footnote 825 specifically addresses airborne weather radars. Within the U.S., airborne weather radars are covered by FCC Rule 87.187(t), inter-alia. This is only a “short-list” of the applicable rules. Others, such as FCC Rules 2.106 and Part 15, cover other aspects.

The regulatory bodies involved are the ITU for international allocations, the FCC for U.S. frequency assignments and equipment type certification, and the FAA for coordination of aeronautical services and TSO of equipment. Other countries may regulate use of these frequencies and equipment in an entirely different manner. However, they generally are in conformance with the ITU allocation.

The general ITU allocation rule wording is as follows:

“The frequency band 9300 to 9500 MHz is allocated for use by airborne weather radars by ITU Article 8, footnote 825. Assignment of frequencies and equipment approval are further regulated by the aviation and/or radio communication authorities of the aircraft’s country of registry.”

3.5 Operating Conditions

Manufacturers should note the guidance material on environment and information on cooling requirements in ARINC Specification 600.

Equipment manufacturers should note that their Mean Time Between Failures (MTBF) promises may be turned into reliability warranty requirements by their prospective customers.

3.6 Dual Operation

The ARINC 7XX equipment may be used in either single or dual installations including dual displays. Customers desiring single installation should use Attachment 2-1. Those needing dual installations should use Attachment 2-2.

3.7 Sensitivity Time Control (STC)

Sensitivity Time Control (STC) is required for radar operation in the weather mode. It should cause the radar loop gain to increase with range so as to compensate for the increasing normal path losses and thus provide a weather return whose intensity is relatively unchanged over the distance for which the STC has control. STC action should become effective at the first receive time and continue out to a range where the signal level starts to fall off and there is no more gain to control. For this system, it is anticipated that the STC range should function up to 70 nm.

COMMENTARY

In the past it was common to correlate the STC with a beam filling target situation with a 3 nm size cloud. While it may be argued that this is a valid theoretical, and maybe in some cases, a valid practical circumstance, it really does not state the objective which is to retain a constant level weather return over a nominal range so that relative intensities may be compared and analyzed.

For some systems, practical experience indicates that the STC should function to at least 170% of the range as calculated using the beam filling 3 nm theory. Otherwise, the radar is over sensitive to calm weather returns. In nature, droplet returns are usually extended horizontally more than vertically, and thus form a horizontal band of scintillating echoes. Their vertical extent is usually limited by temperature. Thus a 3 nm circular cloud with constant radar echoes is unusual and, except for very close ranges, most weather returns do not involve beam filing conditions. Also, for most paths at flight levels in which we operate, the path loss due to atmospheric attenuation caused by humidity, dust and gasses is somewhat higher than that for free space. The lower the frequency, the less the effect. So as might be expected, the “C” band radar, with its slightly wider horizontal beam width and lesser path loss does require a longer range over which signal normalization (STC) is applied for a given loop gain.

3.8 Turbulence Detection

The manufacturer should optionally make provisions for incorporation of direct detection of turbulence.

3.9 Anti-Clutter

Terrain clutter rejection can be used in the weather mode as an optional feature. Annunciation and control of this function is described in Attachments 15-1 and 15-2.

3.10 Alert Outputs

3.10.1 Windshear Alert

The weather radar system provides three levels of alerts for windshear conditions exceeding the criteria defined in Section 3.1.3. These alert levels conform to the definitions of alerts in SAE ARP 4102/4.

3.10.1.1 Windshear Warning Alerts (Level 3)

Windshear Warning alerts are generated for windshear events located within ±0.25 nm from the longitudinal axis of the aircraft and within ±25o of the aircraft heading. On the ground, the maximum range for Windshear Warning alerts is 3 nm. In the air, the maximum range is 1.5 nm.

Automatic range scaling should be provided to prevent annunciation of Windshear Warning alerts beyond the Touchdown zone of the runway during landing. Events beyond the range calculated using the following equation should not generate a Windshear Warning alert.

R = 3.14x10-3 h + 0.337

Where:

R = Range in nm

h = Distance Above Ground Level (AGL) in feet

During takeoff, Windshear Warning should be inhibited from the time the aircraft attains 100 knots airspeed until the aircraft reaches 50 feet AGL. During landing, it should be inhibited below 50 feet AGL. There should be no Windshear Warning alert above 1200 feet AGL.

Windshear Warning alert condition is transmitted on the weather radar data bus, as defined in Attachment 15-2, and the Hazard Bus, output as defined in Attachment 15-3.

3.10.1.2 Windshear Caution Alerts (Level 2)

Windshear Caution alerts are generated for windshear events located outside the Windshear Warning alert region but within ±25º of the aircraft heading and 3 nm from the aircraft.

During takeoff, Windshear Caution alert should be inhibited from the time the aircraft attains 100 knots airspeed until the aircraft reaches 50 feet AGL. During landing, it should be inhibited below 50 feet AGL. There should be no Windshear Caution alert above 1200 feet AGL.

Windshear Caution alert condition is transmitted on the weather radar data bus, as defined in Attachment 15-2, and the Hazard Bus, output as defined in Attachment 15-3.

3.10.1.3 Windshear Advisory Alerts (Level 1)

Windshear Advisory alerts are generated for windshear events located outside the Windshear Warning and Caution alert regions but within scan limit of the windshear mode and 5 nm from the aircraft. The only output for the Windshear Advisory alerts is icons transmitted on the weather radar data bus as defined in Section 3.2.10. There should be no Windshear Advisory alert above 1200 feet AGL.

COMMENTARY

Some airlines desire to have advisory (Level 1) alerts up to 1800 feet AGL. If such operation is permitted by the FAA, the advisory alerts should be inhibited above 1800 feet AGL, instead of 1200 feet.

3.10.2 Aural Alert Outputs

For Windshear Warning alerts (Level 3), the radar system should generate aural alert output using a synthesized phrase: “WINDSHEAR AHEAD, WINDSHEAR AHEAD.” The aural warning should be repeated only when a different event causes a new Level 3 alert. Two different audio outputs should be provided as described in Section 2.9 and Attachments 2-1 and 2-2.

For Windshear Caution alerts, the radar system should generate an attention (chime) or a synthesize phrase consisting of “MONITOR RADAR DISPLAY”. A program pin is provided to inhibit the chime only. The internally generated chime consists of a tone with swept frequency from 800 Hz to 400 Hz. The tone starts at 800 Hz. Its frequency is linearly lowered to 400 Hz over 300 msec time period. Then, the frequency jumps to 800 Hz and swept down to 400 Hz again over next

300 msec period. After a 300 msec gap, this two-cycle sweeping from 800 Hz to 400 Hz is repeated. The total time period for aural alert outputs should not exceed three seconds. Two program pins are provided to select the type of Windshear Caution aural alert, or to inhibit it. They are described in Attachment 1, 2-1, and 2-2.

3.10.2.1 Inhibiting Windshear Aural Alert Input

The weather radar system should accept a discrete input to inhibit the windshear aural alert output from the reactive windshear system. When this input is below 1.2 volts the audio output should be inhibited. When the input is high impedance, greater than 100k ohms, or more than 3.5 Vdc, the audio output should be enabled.

The weather radar system should respond to the Windshear Aural Alert inhibit in less than 100 msec. The system should wait two minutes before it declares this input faulted, if it stays in the inhibit state continuously.

The system should generate alert audio within 500 msec of inhibit release if a valid alert condition exists at time of inhibit release. If the audio alert is in progress when the inhibit is set, the system may complete the duration of the audio alert.

This inhibit should not affect the generation of lamps and alert data on output buses.

3.10.3 Visual Alert Outputs

Two separate discrete outputs should be provided for Windshear Warning (Level 3) and Windshear Caution (Level 2) alert conditions as shown in Attachments 2-1 and 2-2. These outputs can be used to energize alert lamps directly. Each one of these outputs should be capable of sinking 1 amp steady state (less than 1.0 volt output). Leakage current should be less than 1 milliamp when external 40 Vdc is applied to the output.

3.10.4 Windshear Discrete Alert Output

The weather radar system should provide an alert discrete output any time alert audio is active. This discrete output can be used to inhibit TCAS and Ground Proximity Warning System (GPWS) aural alerts.

The discrete output should be a ground for alert conditions capable of sinking 0.1 amps with maximum output voltage of 1.0 Vdc. In the non-alert condition, the output should sink less than 100 microamps when connected to 40 Vdc.

The system should set this output between 200 and 500 msec prior to audio output and hold this output between 200 and 500 msec after audio output has ended.

The system should set this output between 0 and 500 msec after the alert level has been transmitted on the Hazard Bus.

The audio inhibit output setup and hold times specified above are not required during manual self-test.

3.10.5 Hazard Bus Output

The weather radar system should provide a Hazard Bus output. This bus should be a high-speed ARINC 429 data bus. All the windshear related information should be encoded on this data bus according to Attachment 15-3.

The Hazard Bus should be active whenever the WPU is receiving input power (i.e., bus activity should not be dependent on WRAU selection or windshear detection mode).

The Hazard Bus activity should be interrupted for no more than one second during normal mode transitions.

3.10.6 Turbulence Alert Option

The manufacturer may, at his option, include the capability to automatically detect a "Turbulence" alert condition and provide an alert indication for the flight crew. Where provided, this information should be transmitted on all Display Data Buses encoded as defined in Attachment 15-2.

COMMENTARY

The efforts to mechanize the turbulence alert function in earlier generations of weather radar proved less than fully acceptable to the flight crews. This document does not define any of the technical or operational characteristics of this feature.

Older weather radar may contain a weather alerting indication option. In those installations, Bit 15 of the display bus is defined to be used for providing weather alert indication to the display systems.

Bit 15 was redefined in ARINC 708A to be used for indication of automatic tilt control selection to the display system. The display system manufacturers and installer should be aware that if the display system is upgraded to annunciate automatic tilt control selection, there could be an interchangeability problem with older weather radars that use bit 15 for the weather alert option.

3.11 LRU Failure

The weather radar system should incorporate failure monitoring circuitry or Built In Test Equipment (BITE) capable of indicating which Line Replaceable Unit (LRU) should be replaced to correct a detected failure condition. Failures in the various LRUs should be coded independently to allow simultaneous indication of multiple failures. This information should be transmitted continuously to the display on each Display Data Bus encoded as defined in Attachment 15-2. The display unit or system should "OR" Bits 20-25 for displaying radar System failures. Dedicated Bits are assigned to encoded windshear function related failures. The windshear related failures are also encoded on the Hazard Bus output as described in Attachment 15-3. The radar maintenance word (Label 350) may be transmitted on the Hazard Bus, also.

COMMENTARY

The failure annunciation provided for the flight crew should indicate the radar system is no longer operating properly.

3.11.1 Windshear Mode Fault Indication Lamp

The failure monitoring circuitry or BITE should provide an output driving a fault indication lamp with the following parameters any time a system failure prevents it from generating a Windshear alert. This output can be used to drive a fault indication lamp.

Type of Output	Switch closure to ground
Signal Status	Switch “contacts” open for system in normal operating condition, closed for failed condition
“Open” voltage hold-off	30 Vdc
Potential across “closed” switch	1 Vdc max
Current handling capability load	0.5 amperes steady state lamp

3.12 Master/Slave Operation (Optional)

A master/slave operation may be provided by the weather radar system. The slave control mode should be shown by the status of bits 30 and 31 of the control word. See Attachment 11-7 for details.

4.0 WEATHER PROCESSOR UNIT (WPU)

4.1 General

This section defines the form, fit, function, and interfaces applicable to the Weather Processor Unit (WPU). The WPU is intended as a digital processing computer located in the traditional avionics Electrical and Electronics (E/E) bay

4.2 Weather Surveillance Function

The WPU is expected to provide the following functions:

- Precipitation detection
- Convective activity detection
- Basic turbulence detection
- Predictive windshear detection

COMMENTARY

Reactive windshear detection capability is assumed to be implemented with the Terrain Awareness and Warning System (TAWS) or Integrated Surveillance System (ISS).

4.2.1 Weather Radar Function

The weather radar function should meet the requirements specified in TSO-C63c for basic precipitation detection and RTCA DO-220 for predictive windshear detection.

4.2.1.1 Radio Frequency

The weather radar equipment should be designed to operate at a center frequency anywhere within the band of 9300 to 9500 MHz.

4.2.1.2 Precipitation and Convective Activity Detection Performance

Weather phenomena of operational significance should be displayed with good discernibility with sufficient performance margin ahead of the aircraft. The Performance Index (as defined in RTCA DO-220) for the weather radar function should exceed 204 dB.

4.2.1.3 Windshear Detection Performance

The weather radar should meet the windshear detection performance as specified in RTCA DO-220.

The radar system should be capable of detecting dry (with as low as 0 dBz outflow reflectivity) and wet (with more than 40 dBz core reflectivity) microburst with hazard factors exceeding 0.13 averaged over 0.54 nm (1 km) range.

The IWPU should generate both Warning and Caution level alerts as defined in the RTCA DO-220. It may also generate Advisory level alerts as a customer selectable option.

4.2.1.4 Turbulence Detection Performance

At the time of this writing, there are no industry standards for turbulence detection. As a goal, turbulence detection performance should exceed the capability available in the previous generation (ARINC 708A) radars.

4.2.1.5 Ground Mapping Performance

Although it is not a weather surveillance function, the weather radar system should be capable of ground mapping within the same range as is used for weather display, with the aircraft flying at the upper flight levels. The transmitted RF pulse and other radar characteristics may be changed when the Map mode is selected.

4.2.1.6 Automatic Activation of Radar

The radar may be automatically turned on to minimize delays to provide suitable radar data to the display system based on selected input parameters. The criteria for automatic activation should be selected to prevent radar turning on inadvertently at the gate or during maintenance. Means should be provided to ensure that dual systems are not powered simultaneously.

4.2.1.7 Windshear Mode Activation

The windshear detection capability should be activated automatically below 2300 feet AGL. In the air, the activation should be based on the Radio Altimeter input or other source of AGL. On the ground, the criteria used for automatic activation of the radar for the predictive windshear detection should be selected to prevent the radar from turning on inadvertently at the gate or during maintenance. Means should be provided such that dual systems should not be turned on simultaneously.

4.2.2 Weather Surveillance Growth Functions

Current ARINC 708A radars based on current technology, have limited turbulence detection capability. Emerging technology is expected to provide enhanced turbulence detection capability. Data from various onboard sensors as well as data-linked meteorological data should provide means for making enhanced turbulence information available to the flight crews. Unlike the current radar systems that can detect turbulence only associated with weather phenomenon containing sufficient reflectivity (moisture), enhanced turbulence information is expected to include all types of turbulence including clear air. The WPU should have provisions to receive and process data from other external sensors and sources for enhanced turbulence detection. It should also have provisions for weather data fusion to provide integrated turbulence information to the display and alerting systems.

4.3 Digital Inputs for Windshear Detection

For the windshear detection mode, the unit should accept aircraft heading, ground speed, and longitudinal axis data from the attitude data bus. It should also accept radio altitude information from the Radio Altimeter data bus per ARINC 429 and use this data for automatic tilt control of the antenna and signal processing for the windshear detection. It should also accept airspeed information from the ARINC 429 data bus. For additional information, refer to Sections 2.8.1 through 2.8.3.

4.4 Serial Digital Control Inputs

The WPU should accept control data from up to four sources, and operationally respond to the conditions dictated by the applicable control data. The inputs control data bus should be compatible with ARINC 429 and formatted in accordance with

Attachments 15-1 control bus format. The WPU should also accept serial digital data inputs from the maintenance system per Sections 2.8.1 and 8.

4.5 Serial Digital Data Outputs

The WPU should output display data on two output buses; one dedicated to Radar Display No. 1, and the second to Radar Display No. 2. A third optional bus may be provided to serve additional multi-function display systems. These buses are shown in Attachments 11-1 and 11-2.

The output data should consist of control and radar data or color data formatted in accordance with Attachment 15-2, describing the data bus format.

Electrical characteristics should be those specified for the high speed bus described in Appendix A. The WPU should output serial data to the maintenance system per Section 8.2. An additional data bus is provided for windshear hazard output per Section 3.11.5.

4.6 Test Facilities

The storage of fault data should be provided for use by shop-level maintenance. The system should provide a test capability such that undetected failure rate of the windshear function should be less than 10-5 failures per flight hour. Refer to Section 8.0.

4.6.1 Manual Self-Test

A self-test feature should be provided and be selectable on the control panel. The test should verify system calibration and performance capability and should isolate substandard performance to the most probable LRU. Results of the test should be presented to the operator as a standard test pattern. A standard test pattern consists of color bands for all colors use and any turbulence symbols, if applicable. The windshear icon may be displayed during self-test. All discretes and aural alert outputs should be tested.

4.6.2 Auto Test

An automatically initiated self-test should be performed at the time of equipment turn-on. The system should have continuous monitoring capability for windshear detection.

4.6.3 Flight Line Maintenance BITE

The weather radar system should provide internal Built-In Test Equipment (BITE) capable of detecting and annunciating on the front panel of WPU a minimum of 95% of faults or failures detected during operation of the system. Refer to Section 8.0 for more details.

4.7 Service Adjustments

Equipment should be designed such that no service adjustments will be required when the equipment is installed in an aircraft, or during the service of the equipment in the aircraft.

4.8 Cooling

Cooling of the WPU is defined in Section 2.7.

5.0 WEATHER RADAR ANTENNA UNIT (WRAU)

5.1 Design Criteria

The Weather Radar Antenna Unit (WRAU) will include the weather radar antenna, its controlling mechanisms, and as a minimum, the X-Band transmitter/receiver. The unit will be installed in the unpressurized radome area of the aircraft, thus special care should be exercised in the design of this unit. Since replacement of the WRAU will likely require opening the radome, airlines are very concerned with the reliability of the WRAU.

The antenna unit tilting mass should be supported in such a manner (preferably in a center of gravity axis) as to minimize aircraft vibration and acceleration (±1 G in aircraft pitch axis) effects upon antenna positioning, thereby improve stabilization accuracy. The antenna stabilization should be capable of maintaining the proper orientation of the antenna during pitch and roll rates of 20 deg/sec in each axis.

COMMENTARY

The antenna unit designer should devote particular attention to maintaining adequate stabilization throughout the prolonged periods of acceleration (particularly in the pitch attitude) encountered by aircraft in the turbulent conditions frequently encountered during operation of the weather radar equipment. The airlines recognize this requirement presents some testing difficulties, but it is of significant operational importance in the environment in which this weather radar system is to be used.

5.1.1 Active RF Circuitry

The WRAU should contain the X-band elements of the radar transmitter/receiver to eliminate the need for a waveguide connection between the antenna and RF components. However, the active RF circuitry should be kept to a minimum to achieve this purpose. Airlines desire to have the highest achievable reliability for the WRAU.

5.1.2 Single/Dual Considerations

The WRAU should be designed to accommodate single and dual configurations. For dual installations, there should be as much redundancy as possible in antenna control mechanisms as well as transmitter/receiver circuitry. For dual configurations the design should make probability of a single failure causing total radar functionality loss nearly improbable.

All RF switching should be internal to the WRAU. There should not be any requirement for external signal switching for dual installations.

For single configurations, the redundant circuitry and the second connector can be omitted.

5.2 Antenna Control

The antenna control parameters include scan angle and rate, elevation and stabilization. They are described in the following sections.

5.2.1 Scan Angle and Rate

The antenna scan angles and scan rates are to be determined by the manufacturer to suit their particular implementation.

5.2.2 Elevation

Mechanical elevation scan freedom of the antenna should be sufficient to accommodate the aircraft attitudes of up to ±30 deg of roll and ±20 deg of pitch.

5.2.3 Stabilization

An external inertial platform or other attitude sensor system capable of providing stabilization signal with attitude accuracy of ±0.25 deg should be used as a vertical reference for the antenna stabilization system. The antenna stabilization system should maintain the beam axis within ±0.25 deg of the desired pointing angle exclusive of attitude sensor signal and mounting errors.

Latency between aircraft movement and stabilization data arriving at the rear connector of the WPU should not exceed 72 ms. Two ARINC 429 inputs should be supported for a direct connection to an external inertial platform, for use when either the latency specification cannot be met by the installation, or where the latency produces undesirable operation.

COMMENTARY

Installation designers are cautioned as to the effects of stabilization data signal latency. At 10 deg/sec aircraft roll (a typical value) attitude data that lags 100 ms will yield a pointing error of 1 degree. Routing IRU data through data concentrators can add to this latency.

However, some system installations have demonstrated the ability to exceed this latency in dynamic conditions and also meet aircraft operational requirements. Therefore, the weather radar should be designed to minimize the effect of data latencies of at least 120 ms.

5.3 Beam Width and Shape

The beam width is largely dependent on the feasible size of the antenna which in turn is dictated by the space available in the airframe nose section. For a 30 inch diameter antenna, the beam width will be approximately 2.9 degrees. Additional beam widths are provided in Table 3-3. The antenna design should keep side lobes down at least 25 dB at all pitch, roll and azimuth angles.

Radome performance standards are provided in Section 7.0.

5.4 Installation

The antenna should be installed using best commercial practice with specific considerations described below.

5.4.1 Mounting

The antenna mount should fit the standard installation provisions of Attachment 8. Mounting holes should be positioned with sufficient accuracy so that the antenna may be mounted without the necessity of flight line adjustment.

5.4.2 Cable Losses

For equipment utilizing coaxial medium, the system design parameters and frequencies used for the interface between the WRAU and the WPU should be selected such that the system can tolerate cable losses, capacitance, and impedance of 100 ft of RG-400 type cable (or equivalent). The WRAU and WPU should be designed such that there is no requirement for any RF cable matching, neither phase nor amplitude.

5.5 Interface

The WRAU should interface with the WPU using ARINC 429, coaxial signal or fiber optic signals. The communication should be bi-directional.

5.6 WRAU Power

The WRAU should be powered from a signal commanded by the WPU. The characteristics of this power are to be determined by the manufacturer.

5.7 Automatic Gain Control (AGC)

An automatic gain control should be provided in the WRAU. It may be deactivated from the control panel when one wishes to examine special conditions, such as ground mapping. If deactivated in the weather mode, annunciation should be provided on the display.

In the automatic gain circuitry (normal) mode of operation the receiver gain should be kept constant at an optimum value independent of temperature, aging, and other variables.

5.8 Range Resolution

Range resolution for weather and ground mapping modes should be less than 3 nm for range selections exceeding or equal to 80 nm. It should be less than 1.5 nm for range selections less than 80 but more than or equal to 40 nm. It should be less than 1 nm for range selections less than 40 nm.

For the windshear detection mode the effective range resolution should be less than 0.2 nm.

The WRAU transmits 512 range bins and the indicator should accept 512 range bins.

The WRAU may choose to use only 128 or 256 range elements in the basic data processing but in these cases the reflectivity data is repeated without change in each block of four or two range bins respectively to provide the standard 512 bin interface.

Equally the display may choose to process only 128 or 256 bins instead of the full 512 by collapsing the input information in blocks of four and two, respectively. To ensure interchangeability data should be repeated by the WRAU and or display in blocks of 1, 2 or 4 bins only and reflectivity bin No. 1 should always contain the start of the first block.

5.9 Dynamic Range

Dynamic response of the receiver for weather and ground mapping modes should be essentially linear or predictable for input levels up to at least 60 dBz as exhibited at the display encoder output.

COMMENTARY

Although the maximum encoded level is 50 dBz, the 60 dBz requirement is intended to assure that receiver saturation at the higher input levels will not detrimentally affect the ability of the receiver to faithfully respond to subsequent lower levels which fall in the encoded range.

For the windshear detection mode, the processing dynamic range should be such that 0 dBz targets can be detected in the presence of clutter exceeding equivalent of 65 dBz in the surrounding area.

5.10 Design Criteria

The antenna should be designed to support a wide range of dynamic conditions that the aircraft can experience in its flight envelope over the life of the airframe.

A scale should be provided that allows reading of the beam elevation position of the antenna. Calibration should be in degrees of electrical beam tilt.

The antenna should include provisions or actual measuring devices to determine errors in mounting alignment.

The antenna tilting mass should be supported in such a manner (preferably in a center of gravity axis) as to minimize aircraft vibration and acceleration (±1.0 G in aircraft pitch axis) affects upon antenna positioning, and thereby improve stabilization accuracy.

The antenna stabilization should be capable of maintaining the proper orientation of the antenna (±0.5º attitude) during pitch and roll rates of 20º per second in each axis.

COMMENTARY

The antenna designer should devote particular attention to maintaining adequate stabilization throughout the prolonged periods of acceleration (particularly in the pitch attitude) encountered by aircraft in the turbulent conditions frequently encountered during operation of the weather radar equipment. The airlines recognize this requirement presents some testing difficulties, but it is of significant operational importance in the environment in which this weather radar system is to be used.

5.11 Scan Angle and Rate

This document describes only the conventional sector scan type of antenna used by most airlines.

5.11.1 Sector Scan

Mechanical details of two types of conventional sector scan antennas are provided in Attachment 10-1 and 10-2, including the RF and interwiring connectors. These antennas should provide a scan angle of at least ±90º as described in Section 3.2.3.

5.11.2 Scan Rate

The scan rate for the ±90º sector should be at least 15 looks per minute. Certain implementations may require decreased looks per minute when certain combinations of multiple modes are used, such as windshear detection mode simultaneously with weather mode.

5.12 Tilt

Mechanical tilt freedom of the antenna should be sufficient to accommodate the stabilization requirements of Section 5.4 plus the ±14º of manual tilt control provided for the pilots' use. The mechanical tilt freedom is measured from a plane perpendicular to the antenna rotation reference axis, and at any azimuth angle at which the antenna is operational. The accuracy of the antenna tilt mechanism and the associated servo system should be sufficient to make use of the 0.25º least significant bit (LSB) data provided by the pilots' control. See Section 6.2.2.

COMMENTARY

The +14º of tilt (up) is frequently used by the pilots while the aircraft is on the ground awaiting take-off. This capability to assess the local weather picture is especially important since many traffic controllers do not have adequate weather information.

5.12.1 System Accuracy

The antenna stabilization system should maintain the beam axis at any given manually selected tilt angle within +0.25º exclusive of attitude sensor signal and mounting errors. The radar system's total dynamic accuracy under the stated combinations of pitch, roll, and tilt plus the roll and pitch accelerations (see Section 5.1 above) but exclusive of the radome should be:

Combined Pitch, Roll, & Tilt	**Beam Error (Max RSS)**
0º to 20º	0.5º
20º to 40º	1.0º

Note: The above dynamic accuracy is stated for system operation with the aircraft attitude sensor presumed to provide an error contribution of 0.25º (maximum).

A summary of the tolerances is provided in Attachment 13.

COMMENTARY

The tolerance (error) budget prescribed for this system and summarized in Attachment 13 is intended to realize the highest degree of performance, especially with regard to minimizing ground return during aircraft maneuvering. The users recognize the "Attitude Accuracy" of 0.25º likely will not be achieved in installations which lack inertial quality attitude signals. In such cases the total beam pointing error will be higher than that shown in Attachment 13.

5.12.2 Improved Line-of-Sight Antenna

Antennas using improved line-of-sight stabilization should meet the performance and accuracy requirements of Section 5.4.1 under the following conditions:

Operational Conditions	
Pitch	±20º
Roll	±30º
Manual Tilt	±14º
Combined Pitch, Roll, & Tilt	±35º

5.12.3 Independent Roll Stabilization

Antennas using an independent roll stabilized (split-axis) antenna should meet the performance and accuracy requirements of Section 5.4.1 under the following conditions:

Operational Conditions	
Pitch	±25º
Roll	±40º
Tilt	±14º
Combined Pitch & Tilt	±25º

5.12.4 Stabilization Limit Annunciation

The antenna stabilization system should provide an indication to the flight crew when the combination of aircraft attitude and antenna tilt selection exceeds the system's design limits. In such conditions the antenna control circuitry can no longer properly position the Radar beam. The data for this indication should be transmitted on each Display Data Bus encoded as defined in Attachment 15-2.

COMMENTARY

This is a normal system condition which results from large excursions in combined aircraft pitch, roll and selected tilt. The annunciation is provided because some display distortion will occur under this condition.

5.13 Environmental Considerations

The WRAU will be mounted in the radome. Refer Attachment 14 of this document for detailed environmental conditions applicable to the WRAU.

6.0 CONTROL PANEL

6.1 General Design Criteria

The Control Panel design should be suitable for installation in both single and dual installations. It is expected that weather radar controls will be integrated with the Cockpit Display System (CDS) used in new aircraft. However, for aircraft with dedicated controls, three different types of control panels are defined in **ARINC Characteristic 768:** *Integrated Surveillance System (ISS)*. The control panel selection depends on the configuration. The control panels are defined as follows (for ISS):

Type I: Controls all surveillance functions. This control panel is intended for ISS configurations that contain weather radar, TAWS and TCAS/Transponder functions.

Type II: Controls TCAS/Transponder functions. This control panel is intended for ISS configurations with TCAS and transponder functions.

Type III: Controls weather radar functions. This control panel is intended for ISS configurations with radar.

Type II and III control panels may be used for ISS configurations that contain both radar and TCAS/Transponder functions, if it is desirable to maintain cockpit commonality with aircraft without ISS. The form factor is shown in Attachment 6-1.

6.2 Form Factors and Connectors

Control panels should be packaged as a 5.75 inch wide Dzus mounted panels. Detailed outline drawings with example panel layouts are shown in Attachment 2 of ARINC Characteristic 768. The standard connectors are specified in Table 6-1.

Table 6-1 – Control Panel Connectors

CONTROL PANEL CONNECTOR DEFINITIONS				
	System #1 Connector	System #1 Mating Connector	System #2 Connector	System #2 Mating Connector
Type I	MS3472W16-23P	MS3476W16-23S	MS3472W16-23PW	MS3476W16-23SW
Type II	M83723-72R16247	M83723-75R16247	M83723-72R16248	M83723-75R16248
Type III	MS-3122E-18-32P-N	MS-3126F-18-32S-N	MS-3122E-18-32P-W	MS-3126F-18-32S-W

6.3 Control Functions

The following are typical controls that might be incorporated in a standard integrated control panel per ARINC Characteristic 768:

- System selector
- Transponder standby/on switching
- Transponder code selectors
- Transponder “Ident” pulse On/Off
- Transponder altitude reporting On/Off
- Self-Test On/Off for various functions
- TAWS control for various functions

- Radar modes
- Radar gain
- Radar elevation/tilt
- Vertical profile direction control
- Traffic control for various functions
- TCAS Mode function
    - TA ONLY
    - TA/RA
- Flight ID

6.4 Interface

The control panel should interface with each WPU using two ARINC 429 buses, one input and one output.

6.5 Brightness Control

6.5.1 Panel Light Brightness Control

The control panels should be designed to accept a 0-10 Vdc sense input or 0-5 Vac, 360-800 Hz, lamp input for controlling the backlighting of the legends on the control panel. Separate pins are assigned for these inputs. The 0-10 Vdc input is primarily intended for panels employing Light Emitting Diodes (LED) for panel lighting. 0-5 Vac is intended to power the incandescent panel lighting directly. This input can also be used as a sense input for panels employing the LED lighting.

COMMENTARY

Traditionally the control panel is connected to the aircraft dimming bus for back lighting of the legends using incandescent light bulbs. Current LED technology allows much more reliable means of backlighting with much lower power dissipation, compared to incandescent. This also allows simplification of aircraft dimming control by generating a low power dc sense voltage to be used by the panels. LED panel lighting with sense voltage input is recommended for new aircraft designs.

6.5.2 Annunciation Brightness Control

If the control panel contains annunciations, its brightness can be controlled by discrete input, either open/ground or 12-26 Vdc. The open/ground is primarily intended for panels employing Light Emitting Diodes (LED) for annunciators. The 12-26 Vdc discrete is intended to power the incandescent annunciators directly. This input can also be used as a sense input for panels employing the LED annunciators.

6.6 Control Panel Power

Type I and III control panels should be powered from the WPU. The characteristics of this power are to be determined by the manufacturer.

The Type II control panel should be powered from the aircraft 115 Vac, 360-800 Hz primary supply. Power supply transients of the amplitudes and duration defined in ARINC 413A and RTCA DO-160D should not result in the control panel output containing false setting of the control functions.

6.7 Human-Centered Design

The control panel selection should be of a type that minimizes inadvertent operation.

6.8 Windshear Auto Turn-On Inhibit

Selection of the Windshear Auto Turn-On Inhibit function should provide “Windshear Inhibit” annunciation to the flight deck. The BITE capabilities should continue to be monitored and annunciate a fault indication only if a failure is detected.

6.9 Controls

The Control Panel should contain controls as indicated in the following sections.

6.9.1 Display Controls (Typical)

Intensity Controls brightness of display

Range Selects display range of display via WPU

Hold (Optional) Stops update of display memory

Range/Azimuth Marks ON/OFF

Function Selects display of basic radar only, windshear only, radar or windshear with auxiliary data overlaid or auxiliary data only.

6.9.2 System Controls (Typical)

PWR System power ON/OFF

STAB Antenna stabilization ON/OFF

WX Weather Mode

MAP Map Mode

TEST Test Mode

Gain Manual adjustment of receiver gain

CAL Selects preset receiver gain for weather

TILT Adjusts antenna position ±14o. Resolution should be consistent with the requirements of Section 5.3.

W/S Only Manual selection of Predictive Windshear (PWS) prior to the qualifiers’ activation may be desirable.

It is desirable to have a control unit that is protected against inadvertent turn-on.

6.10 Screen

The display should cover a sector of at least 180º in accordance with the system capability (see Sections 3.2 and 5.2).

An effective contrast enhancement filter may be provided.

6.11 Panel Lighting

The panel lighting should be energized from the associated integral lighting system of the aircraft. Therefore, no specific dimmer is needed. Provisions should be made to accommodate 5 volt lighting supplies.

Normally only white lighting need be provided. However, it should be possible to alter the panel lighting color (white or red).

6.12 Shielding

Adequate magnetic shielding should be provided to eliminate harmful effects from Electro Magnetic Interference (EMI). Any disturbance should not exceed ±1° at a distance of 24 inches in any direction or orientation from the display. The shielding should also provide sufficient protection of sensitive components within the indicator from exterior magnetic fields from other devices on the aircraft.

6.13 Control Data Bus

Serial digital control data per ARINC 429 should be used for the interface to the WPU. Format for the 32-bit control word is shown in Attachment 15-1.

6.14 Display Interface

A high-speed serial bus should be used to send data from the WPU to the display. This dedicated bus should be formatted in accordance with Attachment 15-2.

6.15 TCAS Interface (Optional)

As an optional feature, the display unit can function as a Traffic Display Unit for TCAS per ARINC Characteristic 735 and ATA Recommended Standards for TCAS II Displays and Symbology. The interface definitions for the capability are per ARINC 735 and interwiring as defined in Attachments 2-1 and 2-2.

6.16 Auxiliary Data Display Functions (Optional)

The Display Unit (DU), when in the auxiliary data mode, should provide for the functions in the following sections. The control and data word formats are provided in Attachment 18.

6.16.1 Character Font (Optional)

The alphanumeric font coding should be stored internal to the display unit. The data from the external source(s) will be pre-formatted. The set of ISO-5 character codes listed in Attachment 19 should be used for decoding the ARINC 429 words.

6.16.2 Display Size (Optional)

The DU should display a maximum of 12 lines with 32 characters per line.

6.16.3 Modes of Operation (Optional)

The DU should exhibit three modes of operations:

a. Weather Radar Only
b. Weather Radar with Auxiliary Data
c. Auxiliary Data Only

When weather information and auxiliary data are displayed simultaneously, the auxiliary data should overlay the weather information in lines 5 through 10 of the DU. The DU should provide for erasing the overlaid material and replacing it with a new page.

In the Weather Radar Only mode, the DU should not respond to a “request-to-send” discrete with a “clear-to-send” indication. The DU should provide a “Message Waiting” indication.

COMMENTARY

In the Auxiliary Data Only mode, the weather information is normally locked out. Some users may have the need to annunciate an unsafe weather condition while the auxiliary data is displayed.

6.16.4 Special Use of Characters (Optional)

The ISO-5 “NUL” and “SP” characters may be used for special functions. The “NUL” character may be used to generate multiple colors per line and position characters horizontally on the line. The “SP” character can be used to “flash” characters on the display.

6.17 Caution and Mode Indicators (Optional)

Manufacturers may provide weather radar systems that may be operated in an uncalibrated mode. Where this facility is provided, annunciation should be provided on the display to alert the aircrew.

7.0 RADOME DESIGN

7.1 General

Design and performance of the radome are critical elements in operation of the weather radar system. Designers are reminded of the users' long-term needs. Radomes should be designed to provide high performance throughout a long useful life. The design should cope with all mechanical problems including erosion, water entrapment, lightning strikes, bird strikes, decorative trim and repair of physical damage.

Radome performance described in this document represents a carefully drawn compromise between engineering and maintenance needs. Designers are encouraged to give special attention to those problems that could increase maintenance costs or limit the useful life of the radome. The fully finished radome with primer, paint, anti-static system, rain erosion, lightning protection and other systems installed should have the minimum electrical performance characteristics shown in the following paragraphs.

7.2 Transmission Efficiency

The radome performance should be in accordance with RTCA DO-213.

COMMENTARY

It is the responsibility of the airlines to maintain their radomes in accordance with RTCA DO-213 and manufacturer's guidance. It is beneficial for the airlines, radome manufacturers and radar suppliers to maintain suitable margins for performance degradation. Consideration should be given for total system capability to achieve the required system performance.

7.3 Reflection

Power reflected back into the radar system by the radome should be less than 0.5% of the impinging energy throughout those portions of the window area at all positions of the system antenna within its mechanical limits. See RTCA DO-213.

7.4 Side Lobe Levels

The side lobe levels should exhibit the following characteristics when measured with an appropriate system antenna and the fully finished radome, including the installation of lightning protection, all trim finish materials, and the associated nacelle structure:

a. No side lobe should exceed the level of –21 dB with respect to the main beam.
b. Side lobes with levels in the range of –21 to –25 dB with respect to the main beam with the radome installed should not have been increased by more than 3 dB of the levels with the radome not installed.
c. Side lobes with energy levels below the –25 dB with respect to the main beam requirement as measured with the radome installed may be disregarded.

Tests for these performance requirements should use a system antenna which has side lobe levels about 25 dB below the main beam. If the test antenna has significantly lower side lobes, the performance must be adjusted accordingly.

When the term “side lobe” is used, it refers to any kind of RF energy that may get back into the weather radar system.

Side lobes are further defined in RTCA DO-213.

7.5 Anti-Icing

Anti-icing should not be included in the radome design.

COMMENTARY

Users emphatically restate the industry view that radomes should not include provisions for anti-icing because this is known to create more problems than it solves.

7.6 Beam Deflection Errors

The beam deflection errors should not exceed 0.50º (8.72 milliradians) in both azimuth and elevation due to the radome’s presence. See RTCA DO-213.

7.7 Beam Width

The radome should not cause the half power (-3dB) main beam width, within the window area, to be increased by more than 10%. See RTCA DO-213.

8.0 BUILT-IN TEST

8.1 General

The weather radar system should support at least one of the following Built-In Test Equipment (BITE) capabilities as defined by ARINC Standards:

- ARINC Report 624
- ARINC Report 604

The WPU is expected to interface to the aircraft's central maintenance system. It should report the status of the weather radar system to an appropriate maintenance display device for the purpose of providing a fault log formatted in accordance with either ARINC 624 or ARINC 604. The fault logging method should be compatible with maintenance philosophy used on the aircraft. A means should be provided for the flight crew and/or maintenance crew to print the maintenance log on the cockpit printer.

There should be no cockpit annunciation of failure unless it causes loss of function. Sufficient margin should be used to preclude nuisance failure messages. Discrepancies in weather radar operation caused by power bus transients, EMI, ground-handling, servicing interference, abnormal accelerations or turbulence should be recorded as events, not as faults.

8.1.1 Fault Classification

Weather radar faults should be classified based on their effect on the system as debilitating or non-debilitating. Fault displays should also indicate the most probable correction of the problem.

A system debilitating failure is any non-recoverable failure which prohibits the weather radar from performing any basic required function. Cockpit failure annunciation is provided for a system debilitating failure. A system debilitating failure will be logged in BITE memory. If recoverable, crew action may be necessary.

A non-system-debilitating failure is any BITE-detected failure which is auto-recoverable within specified/acceptable operational limitations (of short duration and requiring no crew action for recovery) and which has no adverse impact on the required functions of the weather radar system. A non-system-debilitating failure will be logged in BITE memory but need not be cockpit annunciated.

8.1.2 BITE Capability

BITE should be capable of detecting at least 95% of the faults or failures which can occur within the weather radar units, and as many faults as possible associated with other interfaces.

BITE should be initiated from the flight deck. All functions should be tested with BITE.

BITE should be functioning to the extent practical when the weather radar is in "standby" mode. Failures should be stored in non-volatile memory and reported to the on-board maintenance system.

BITE should operate continuously during flight. Monitoring of the results should be automatic and the BITE should automatically test, detect, isolate and record intermittent and steady state failures. The BITE should display system condition and indicate any faulty Line Replaceable Unit (LRU) upon activation of the self-test routine. In addition, BITE should display faults which have been detected during in-flight monitoring.

BITE should closely relate to bench testing. Error modes encountered on the aircraft should be reproducible in the shop. Error messages recorded by BITE should assist bench testing.

No failure occurring in the BITE subsystem should interfere with the normal operation of the weather radar system.

8.1.3 Return to Service Testing

When a weather radar unit is installed on the aircraft, some form of end-to-end system testing should be available for two primary reasons:

- To provide an operational verification of the system functions prior to return to service.
- To reduce unnecessary removals of the weather radar when the fault was actually in another part of the system.

As an end-to-end test, the procedure should verify integrity of all LRUs as well as their interfaces with other systems.

COMMENTARY

Airlines prefer test results to indicate the probable cause of a failure. Emphasis on end-to-end system testing leads to a desirable increase in Mean Time Between Unscheduled Removal (MTBUR), especially for removals that are not related to an LRU fault.

8.2 Radar Functional Test

The WPU should monitor all the radar processing circuitry in the WPU as well as all the circuitry in the WRAU. The radar functional test should verify operation of the antenna control, receiver and transmitter functions. A test pattern might be generated during the initiated test mode to test the display interfaces.

The weather radar system should incorporate failure monitoring circuitry and BITE capable of indicating which LRU should be replaced to correct a detected failure condition. Failures in the various LRUs should be coded independently to allow simultaneous indication of multiple failures.

8.3 Fault Reporting Protocol

8.3.1 OMS Fault Reporting Protocol

The weather radar system should contain fault reporting protocol in accordance with ARINC Report 624, Section 6.0, “OMS Communication Protocol”, and particularly Section 6.5, “Upper Layer Protocol”.

Since the weather radar system may be installed in aircraft with different type of On Board Maintenance System (OMS), the equipment should support both “Fault Status” protocols as described in Sections 8.3.2 and 8.3.3.

8.3.2 Character Oriented BITE Fault Status Protocol

The weather radar system should provide character-oriented fault status protocol.

Attachment 15-6 contains the list of BITE fault messages which should be used for ARINC 708A weather radar character-oriented fault status protocol.

COMMENTARY

New equipment designs should be produced in accordance with ARINC Report 624. ARINC Report 624 was prepared by the AEEC as the successor to ARINC Report 604.

8.3.3 Bit-Oriented Fault Transmission

The ARINC 708A weather radar should provide bit-oriented fault status protocol. Attachment 15-5 contains a typical list of BITE codes which should be used for ARINC 708A weather radar bit-oriented fault status protocol.

8.4 Automatic Test Equipment

To enable Automatic Test Equipment (ATE) to be used for bench testing and maintenance, internal circuit functions (those not available at the unit service connector and considered by the equipment manufacturer necessary for ATE) may be brought to pins on an auxiliary connector of a type selected by the equipment manufacturer. This connector should be fitted with an adequate number of contacts needed to support ATE functions. The connector should include a protective cover suitable to protect these contacts from damage, contamination, etc., while the unit is installed in the aircraft. The manufacturer should refer to ARINC Specification 600 for unit projections, etc., when choosing the location for this auxiliary connector.

APPENDIX A GLOSSARY

Acknowledgement

Indication to the sender of a message that the message has arrived at its destination and has been recognized.

APPENDIX B ACRONYMS

ACARS	Airborne Collision Avoidance System
ACR	Avionics Computer Resource
AEEC	Airlines Electronic Engineering Committee
AGC	Automatic Gain Control
AGL	Above Ground Level
APM	Airplane Personality Module
ATE	Automatic Test Equipment
BITE	Built In Test Equipment
CAS	Computed Air Speed
CFDS	Central Fault Display System
DACD	TBD
DC	Direct Current
DU	Display Unit
EASA	European Aviation Safety Agency
EE	Electrical and Electronics
EMI	Electro Magnetic Interference
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GPWS	Ground Proximity Warning System
ISS	Integrated Surveillance System
ITU	International Telecommunication Union
LED	Light Emitting Diodes
LRRA	Low Range Radar Altimeter
LRU	Line Replaceable Unit
MCU	Modular Concept Unit
MDS	TBD
MTBUR	Mean Time Between Unscheduled Removal
MTBF	Mean Time Between Failures
OMS	On Board Maintenance System
PI	Performance Index
PWS	Predictive Windshear
RF	Radio Frequency
RSS	Root Sum Square
STC	Sensitivity Time Control
TAWS	Terrain Avoidance Warning System
TCAS	Traffic Collision Avoidance System
TCAS RA	Traffic Collision Avoidance System Resolution Advisories
TCAS TA	Traffic Collision Avoidance System Traffic Advisories
TSO	Technical Standard Order

APPENDIX B
ACRONYMS

WPU	Weather Processor Unit
WRAU	Weather Radar Antenna Unit