A radar information processing system is operable to process high bandwidth radar information received from a radar system into low bandwidth radar information that may be communicated to a low bandwidth connection coupled to an electronic flight bag (EFB). An exemplary embodiment receives radar information from a radar system, the radar information communicated from the radar system at a first bandwidth; processes the received radar information into processed radar information, the processed radar information configured for communication over a connection operable at a second bandwidth, the second bandwidth lower to the first bandwidth; and communicates the radar information from the radar system, the radar information communicated from the radar system at a first bandwidth.
References Cited

OTHER PUBLICATIONS


European Patent Office; Communication from the European Patent Office, Netherlands, EPO Form 1507N 08.10; European Search Report dated May 6, 2011; 6 pages.

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FIG. 1

- Display 122
- EFB Processing System
- Radar Data Decompression (RDD) Unit
- Electronic Flight Bag
- Radar Data Compression (RDC) Unit
- Aircraft Components
FIG. 2

RDC Processing System

Radar Data Compression (RDC) Unit

FIG. 3

Radar Data Decompression (RDD) Unit
FIG. 7

FIG. 8
SYSTEMS AND METHODS FOR RADAR DATA COMMUNICATION

GOVERNMENT RIGHTS

The invention described herein was made in the performance of work under NASA Contract No. NNL06AA22C (Subcontract No. 07-002) and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2457). The Government may have rights to portions of this invention.

BACKGROUND OF THE INVENTION

Aeronautical Radio, Incorporated (ARINC) standards define parameters for communications between aeronautical devices and systems. The standards support the physical and communication interfaces for transfer of digital information. Radio detection and ranging (RADAR, or commonly referred to as “radar”) systems typically output information that conforms to the ARINC 453 standard, which is a high-speed data protocol for weather radar. The ARINC 453 standard communicates radar information using a 1600 bit word communicated at 1000 kHz.

A radar system emits a directional radio signal along a relatively narrow beam. The radar system then detects returning radio signals reflected by weather phenomena and/or other physical objects. Analysis of the returning radar signals along the particular direction (radial) of the returning radio signal (corresponding to the direction of the emitted radio signal) allows determination of characteristics of the reflecting weather phenomena and/or other physical objects. For example, the distance range of weather phenomena and/or other physical objects from the radar system may be determined. For certain types of weather phenomena, the intensity of the weather phenomena at various ranges is determinable. For example, the radar system is capable of discerning between light cloud cover versus a heavy thunderstorm having lightning and hail.

As the radar system rotates (sweeps) the position of the radio signal emitter back and forth (or in a circle), the returning radar signals may be analyzed to construct an image of the weather in front of (or around) the aircraft. That is, image data for a plurality of adjacent radials is assembled to form information corresponding to the weather phenomena in front of (or around) the aircraft. The information is presented on a radar display.

The radar information for a radial is presented in a single ARINC 453 word. The 1600 bit ARINC 453 word begins with a 64 bit header followed by a series of 512 sub-words (3 bits each). The header specifies orientation of the radial. The relative location of each sub-word in the word corresponds to a range of a radial. The sub-words contain color information, which is indicative of the nature (e.g., severity) of the detected weather phenomena and/or other physical objects. For example, the color black indicates an absence of weather phenomena (no returning reflected radar signal at that range).

Aircraft personnel may use various types of portable auxiliary equipment. Such equipment may be commonly referred to as an “electronic flight bag” (EFB) or an “electronic travel bag” (ETB), generally referred to as EFBs herein. EFBs are connectable to aviation electronics of the airplane via ports, buses, or other suitable connectors. EFBs conform their connections to communicate under the ARINC 429 standard, which is a relatively low speed data protocol (particularly with respect to the ARINC 453 standard used by radars).

ARINC 429 supports a low speed data transfer mode (12.5 to 14.5 kHz) or a high speed data transfer mode (100 kHz) based upon a 32 bit word structure. EFBs may include a display. At times, it may be desirable to have the EFB display present radar information. However, weather radar information available under the ARINC 453 standard (1600 bit words communicated at 1000 kHz) cannot be communicated over a connector operating under the ARINC 429 standard with sufficient speed to present radar information on a real time basis. That is, the inherent delay in communicating the weather radar information (generated in 1600 bit words at a 1000 kHz rate) over the ARINC 429 connector (32 bit words communicated at the low speed or the high speed ARINC 429 rates) would be so great that the presented radar weather image on the EFB display would not be of any useful value to aircraft personnel.

SUMMARY OF THE INVENTION

Systems and methods of communicating radar information over a low bandwidth communication connection are disclosed. An exemplary embodiment has a radar data compression (RDC) unit coupled to a radar system and a connector coupled to the RDC unit. The RDC unit is operable to receive radar information from the radar system, and operable to process the received radar information into processed radar information corresponding to a low bandwidth. The connector is operable to communicate the processed radar information at the low bandwidth to an electronic flight bag (EFB).

In accordance with further aspects, an exemplary embodiment receives radar information from a radar system, the radar information communicated from the radar system at a first bandwidth; processes the received radar information into processed radar information, the processed radar information configured for communication over a connection operable at a second bandwidth, the second bandwidth lower than the first bandwidth; and communicates the processed radar information at the second bandwidth over the connection to an electronic flight bag (EFB) for presentation on a display.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred and alternative embodiments are described in detail below with reference to the following drawings:

FIG. 1 is a block diagram of an embodiment of the radar information communication system;
FIG. 2 is a block diagram of an embodiment of the radar information compression unit;
FIG. 3 is a block diagram of an embodiment of the radar information decompression unit;
FIG. 4 is a conceptual illustration of information corresponding to three radials of ARINC 453 data presented on a radar display;
FIG. 5 is a conceptual illustration of radar information generated under the ARINC 453 format;
FIG. 6 conceptually illustrates processed information prepared by an exemplary embodiment of the radar data compression unit;
FIG. 7 is a conceptual illustration of data granularity of a first and a second region of data in the ARINC 453 format; and
FIG. 8 is a conceptual illustration of the pixel data resolution on an EFB display for the first and the second regions of FIG. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a block diagram of an embodiment of the radar information presentation system 100. An exemplary embodi-
The radar system 104 emits and receives radio signals via one or more antennas 106. The returned radio signals, reflected from weather phenomena (and/or other physical objects), are processed by radar system 104 so that a radar image signal is generated. The radar image signal, generated in the ARINC 453 format, is communicated to a display 122, via a connection 112. The radar image is then displayed on the display 122. The radar system 104 may be configured to communicate information under the ARINC 453 format or another data intensive format.

A radar data compression (RDC) unit 110 receives radar information from the radar system 104, via a connector 114. Alternatively, the radar information may be received via a connection 114a, which is coupled to the connection 112. The RDC unit 110 compresses the received radar information into a low bandwidth format suitable for communication via a connector 124. In one embodiment, the RDC unit 110 processes the radar information received under the ARINC 453 format into the ARINC 429 format.

The FEB 116 includes, in this exemplary embodiment, a radar data decompression (RDD) unit 118, an FEB processing system 120, and a display 122. In alternative embodiments, the RDD unit 118 may be coupled to the RDC unit 110 via one or more additional connectors 126, which are also low bandwidth connectors.

The RDD unit 118 is communicatively coupled to the RDC unit 110 via the connector 114, which is a low bandwidth connector. In one embodiment, the connector 124 is operable to communicate information under the ARINC 429 format. In alternative embodiments, the RDD unit 118 is communicatively coupled to the RDC unit 110 via one or more additional connectors 126, which are also low bandwidth connectors.

The optional RDD unit 118 may decompress the radar information received from the RDC unit 110 into a format used by the FEB processing system 120. The radar information processed by the RDD unit 118 is communicated to the FEB processing system 120, via the connector 128. The FEB processing system 120 may further process the received radar information into a format that is receivable by the display 122. Thus, a radar signal generated by the radar system 104 is generated and is communicated to the display 122 for presentation.

As used herein, the term “compress” refers to any suitable processing whereby an amount of radar information is reduced. Similarly, “decompression”, as used herein, refers to any suitable processing whereby the previously “compressed” radar information is further processed. The radar information may be “decompressed” into its original amount or form, or may be processed into another amount or form. Further, the terms “compressed” and “decompressed” may be interchangeably referred to as “processed” herein.

In an alternative embodiment, the RDD unit 118 processes the radar information received from the RDC unit 110 into a format receivable by the display 122. The processed radar information is communicated to the FEB processing system 120 via the connector 128. Thus, the RDD unit 118 further processes the received radar information and communicates the processed radar information directly to the display 122 for presentation.

In some embodiments, the RDD unit 118 processes the radar information into a signal that is in a data presentation format used by the display 122. For example, the RDD unit 118 may generate rasterized line data or digitalized pixel data that is used by the display 122. Accordingly, the RDD unit 118 may be directly coupled to the display 122 via the connector 130.
hail, strong winds, or tornadoes, however such information needs to be interpreted carefully.

Following presentation of the first radial 402, a next radial 404 is next presented, followed by another radial 406. Presentation of the radials continues until the last radial is presented at the right side 414 of the radar display 108. Then, in an exemplary embodiment, the radials are refreshed in the reverse direction across the radar display 108, beginning at the right side 414 and continuing to the left side 416. Since the currently presented radial corresponds to a more recent acquisition of radar data than the preceding presented radials, the radar display 108 is refreshed with the most currently available radar information. Other embodiments may refresh the presented radials in other suitable manners.

Further, since the location of a bin along any particular radial corresponds to proximity to the detecting radar system 104, the viewer understands that the presented information corresponding to the group of bins 420 corresponds to the detection of reflecting weather phenomena (and/or other physical objects) relatively close to detecting radar system 104, and that the last of the bins 422 corresponds to the detection of reflecting weather phenomena (and/or other physical objects) relatively far away from the detecting radar system 104.

It is appreciated that the illustrated radar display 108 displays across a range of approximately 180°, with the arrow 418 corresponding to the front of the airplane in which the radar display 108 is installed. Other radar information presentation formats may be used, such as a 360° presentation wherein radar information surrounding the detecting radar system is displayed. Embodiments of the radar information presentation system 100 may be operable with any suitable radar device or system.

FIG. 5 is a conceptual illustration of the radar information 502 generated under the ARINC 453 format. Each radial i resides in a 1600 bit word that begins with a 64 bit header (Pi) followed by a series of 512 sub-words (3 bits each). The header (Pi) contains various presentation information pertaining to the radial, such as the angular orientation of the header on the radar display 108. For example, the header (Pi) may contain a specified angle at which the corresponding radial is to be presented on the radar display 108.

In the simplified example of FIG. 5, the location of the 3 bit sub-words in the word corresponds to the location along the radial i. For example, the first sub-word (indicated as “1”) contains the information that corresponds to presented first bin 408 (FIG. 4). The sub-words indicated as “1,” “2,” “3,” and “4” in FIG. 5 correspond to the first four presented bins 420 (FIG. 4). The last sub-word 512 corresponds to the last presented bin 412 (FIG. 4).

Further, the 3 bit sub-words contain color information corresponding to the characteristics of detected reflecting weather phenomena (and/or other physical objects). For example, a number in a bin may correspond to the color black to indicate that for that range bin, no reflections from weather phenomena (and/or other physical objects) were detected.

It is appreciated that other suitable radar information formats may be received and processed by various embodiments of the radar information presentation system 100. A different number of range bins may be used, for example. Further, additional or alternative colors may be used. Some radar systems 104 may use only black and white colors.

FIG. 6 conceptually illustrates processed radar information 602 prepared by an exemplary embodiment of the RDD unit 110. The RDD unit 110 receives the radar information from the radar system 104. In embodiments where the connection 124 (and connections 126 if present) communicates data under the ARINC 429 format, the RDD unit 110 processes the received ARINC 453 radar data into 32 bit words compatible with the ARINC 429 format. Other embodiments process the received radar information into a format appropriate for the connection 124 (and connections 126 if present).

The RDD unit 110 processes the received radar information 602. Then, the processed radar information 602 may be decompressed (further processed) for communication to the EFB processing system 120. The EFB processing system 120 then processes the received radar information into a format that is communicated to the display 122. For example, if the display 122 is an ARINC 453 compliant display, then the RDD unit 118 and/or the EFB processing system 120 processes the received processed radar information 602 back into the ARINC 453 format. The processing may be performed by the RDD unit 118 such that the ARINC 453 compliant radar information is communicated to the EFB processing system 120. Or, partial decompression may be performed by the RDD unit 118 such that the radar information is communicated to the EFB processing system 120, which then finishes the processing so that the ARINC 453 compliant radar information is communicated to the display 122. In embodiments where the RDD unit 110 decompresses the received radar information 602 into the ARINC 453 format, the radar information may be communicated directly to display 122 (via connection 130) or may be communicated onto connection 134 (via connection 132).

In some embodiments, the display 122 may not be ARINC 453 compliant. For example, the display 122 may require vectorized, rasterized, or pixel-based image data. For example, the display 122 may be a pixel-based flat screen display. Or, the display 122 may be a cathode ray tube (CRT) display that scans one or more electron beams from left to right, and from top to bottom, across its display screen. Accordingly, such data may be further processed by either the RDD unit 118 or the EFB processing system 120 into display information that is receivable by the display 122.

Various information compression and decompression techniques, interchangeably referred to as information processing techniques, used by embodiments of the radar information presentation system 100 are now described. The various embodiments may use one of, or a combination of, the information processing techniques described herein. The information processing techniques include run length encoding, elimination of redundant range cell data, conversion for polar to Cartesian coordinates, optimization of information based upon the display resolution, and/or use of multiple communication channels (between the RDD unit 110 and the RDD unit 118). The information processing techniques, alone or in combination, process the data intensive information generated by the radar system 104 (for example, ARINC 453 compliant radar information) into a less data intensive format (for example, ARINC 429 compliant radar information) for communication to the EFB 116.

Run-length encoding (RLE) is a form of information compression in which sequences of the same data value (consecutive data elements) are stored as a single data value and count, rather than as the original run of sequential like data elements. Common formats for RLE data includes, but is not limited to, PackBits, Pacific Exchange (PCX), or interchange file format (ILBM). RLE data may be processed using various techniques, such as Modified Huffman coding. Embodiments of the radar information presentation system 100 may employ any suitable RLE technique.

For example, returning to FIGS. 5 and 6, the data for radial i in the first four bins (1-4) may have black color information therein (corresponding to an absence of reflected weather
In some embodiments, the RDC unit 110 processes the ARINC 453 radar information 502 based on the resolution of the display 122. That is, the granularity of the predefined pixel size of the display 122 may be used to determine the amount of information reduction when the ARINC 453 radar information 502 is converted into Cartesian coordinate-based radar information 602. For example, the native display resolution of the display 122 may be 640x480. However, the ARINC 453 radar information 502 provides a higher degree of resolution, particularly near origin 410 (see display 108, FIG. 4). Accordingly, the amount of information to be communicated from the RDC unit 110 to the RDD unit 118 may be reduced by processing the ARINC 453 radar information 502 into information that corresponds to the display resolution of the display 122 which will be presenting the processed radar information.

In some embodiments, the radar information presentation system 100 may be operable to present information on different displays 122. For example, one EFB 116 may have a display 122 with a first display resolution, and a different EFB 116 may have a different type of display 122 with a second display resolution. The radar information presentation system 100 compresses the received ARINC 453 radar information 502 into variable sized pixel data that corresponds to the actual display resolution of the display 122. In one embodiment, the RDD unit 118 may detect the display resolution of the display 122, or may have the display resolution information stored therein. When the RDD unit 118 is coupled to the RDC unit 110 via the connection 124 (and the connections 126 if used), the RDD unit 118 may communicate the native display resolution of display 122 to the RDC unit 110. The RDC unit 110 may then adjust its processing of the ARINC 453 compliant radar information received from radar system 104.

Another processing technique is to process the ARINC 453 radar information 502 into a plurality of sub channels that are individually communicated between the RDC unit 110 and the RDD unit 118 over dedicated connectors. For example, a second connector 126 may communicatively couple the RDC unit 110 and the RDD unit 118. Accordingly, both connectors 124 and 126 may be used to transfer different portions of the radar information 502. Some embodiments of the radar information presentation system 100 may have a plurality of connectors 126, thereby providing a higher net transfer capacity between the RDC unit 110 and the RDD unit 118.

FIG. 7 is a conceptual illustration of data granularity of a first and a second region 702, 704 of data in the ARINC 453 format. Here, the granularity of the ARINC 453 compliant radar information is much finer near the origin 410. In contrast, FIG. 8 is a conceptual illustration of the pixel data resolution on the EFB display 122 for the first region 702 and the second region 704 of FIG. 7. Here, the resolution of the display 122 is finer for both the region 802 (corresponding to the above-described region 702) and the region 804 (corresponding to the above-described region 704). However, the resolution of the radar information as presented is not as fine as the native resolution of the display 122. That is, even if the radar information was provided based on the native resolution of the display 122, such presented radar information with the maximum degree of granularity would not be discernable by the viewer. If, discernable, the higher degree of granularity of the presented radar information may provide no significant benefit. That is, a lower resolution presentation of the radar information may be adequate for the viewer’s particular needs. Accordingly, embodiments of the radar information presentation system 100 may process the ARINC 453 radar information 502 received from radar system 104 to a pre-
The embodiment of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for communicating radar information, comprising:
   - receiving radar information from an aircraft radar system, the radar information communicated from the aircraft radar system in an ARINC 453 format to a remote radar data compression (RDC) unit coupled to the aircraft radar system;
   - processing the received ARINC 453 radar information into processed radar information at the RDC unit, the processed radar information configured for communication over a connection operable at a low bandwidth, the low bandwidth lower than a bandwidth of the ARINC 453 radar information;
   - communicating the processed radar information at the low bandwidth from the RDC unit over the connection to a radar data decompression (RDD) unit; and
   - processing the processed radar information at the RDD unit for presentation on an electronic flight bag (EFB) display.

2. The method of claim 1, wherein processing the received radar information comprises processing the ARINC 453 radar information by processing radar information of a first bin and duplicate radar information of an adjacent second bin into a single bin.

3. The method of claim 1, wherein processing the received radar information comprises processing at least one bin of a first radial of the ARINC 453 radar information and an adjacent bin of an adjacent radial of the ARINC 453 radar information into a combined bin.

4. The method of claim 1, wherein processing the received radar information comprises processing the received radar information from a polar coordinate system to a Cartesian coordinate system.

5. The method of claim 1, wherein processing the received radar information comprises processing the received radar information from a first resolution to a second resolution.

6. The method of claim 1, wherein communicating the processed radar information over the connection comprises: communicating a first portion of the processed radar information at the low bandwidth over a first connection; and communicating a second portion of the processed radar information at the low bandwidth over a second connection.

7. The method of claim 1, wherein the connection communicates the processed radar information under an ARINC 429 format.

8. The method of claim 1, further comprising:
   - receiving the processed radar information;
   - processing the received processed radar information into display information; and
   - communicating the display information to the EFB display.

9. The method of claim 1, further comprising:
   - receiving the processed radar information;
   - processing the received processed radar information into ARINC 453 radar information; and
   - communicating the ARINC 453 radar information to the EFB display.

10. An aircraft radar information processing system, comprising:
   - a radar data compression (RDC) unit coupled to an aircraft radar system, operable to receive radar information from the aircraft radar system communicated at a first bandwidth, and operable to process the received radar information into processed aircraft radar information corre-
11. A radar information processing system comprising:

- a connector coupled to the RDC unit and operable to communicate the processed radar information at the second bandwidth; and
- a radar data decompression (RDD) unit coupled to the connector, operable to receive the processed aircraft radar information communicated at the second bandwidth, and operable to process the received processed aircraft radar information into displayable radar information that is presentable on a display of an electronic flight bag (EFB).

12. The radar information processing system of claim 11, further comprising:

- an EFB processing system coupled to the RDD unit, operable to receive the displayable radar information, and further operable to process the presentable radar information into a display signal receivable by the display.

13. The radar information processing system of claim 11, wherein the display is coupled to the RDD unit and is operable to receive the presentable radar information.

14. The radar information processing system of claim 11, wherein the radar information received from the radar system is formatted in an ARINC 453 format, and wherein the radar information is formatted in an ARINC 429 format.

15. The radar information processing system of claim 11, wherein the connector is an ARINC 429 connector.

16. The radar information processing system claim 11, wherein the RDC unit processes the received radar information using run length encoding to generate the processed radar information.

17. The radar information processing system claim 11, wherein the radar information received from the radar system is formatted in an ARINC 453 format, and wherein the RDC unit processes the received ARINC 453 radar information by eliminating redundant range cell data.

18. The radar information processing system claim 11, wherein the radar information received from the radar system is formatted in an ARINC 453 format, and wherein the RDC unit processes the received radar information by converting the ARINC 453 radar information from a polar coordinate system to a Cartesian coordinate system.

19. The radar information processing system claim 11, wherein the connector is a first connector that is operable to communicate a first portion of the processed radar information at the second bandwidth to the EFB, and further comprising:

- a second connector coupled to the RDC unit and operable to communicate a second portion of the processed radar information at the second bandwidth to the EFB.