Millimeter-Wave Localizers for Aircraft-to-Aircraft Approach Navigation

Beyond aircraft refueling, this system can be used in automotive navigation and unmanned aerial vehicle refueling.

NASA's Jet Propulsion Laboratory, Pasadena, California

Aerial refueling technology for both manned and unmanned aircraft is critical for operations where extended aircraft flight time is required. Existing refueling assets are typically manned aircraft, which couple to a second aircraft through the use of a refueling boom. Alignment and mating of the two aircraft continues to rely on human control with use of high-resolution cameras. With the recent advances in unmanned aircraft, it would be highly advantageous to remove/reduce human control from the refueling process, simplifying the amount of remote mission management and enabling new operational scenarios.

Existing aerial refueling uses a camera, making it non-autonomous and prone to human error. Existing commercial localizer technology has proven robust and reliable, but not suited for aircraft-to-aircraft approaches like in aerial refueling scenarios since the resolution is too coarse (approximately one meter). A localizer approach system for aircraft-to-aircraft docking can be constructed using the same modulation with a millimeter-wave carrier to provide high resolution.

One technology used to remotely align commercial aircraft on approach to a runway are ILS (instrument landing systems). ILS have been in service within the U.S. for almost 50 years. In a commercial ILS, two partially overlapping beams of UHF (109 to 126 MHz) are broadcast from an antenna array so that their overlapping region defines the centerline of the runway. This is called a localizer system and is responsible for horizontal alignment of the approach. One beam is modulated with a 150-Hz tone, while the other with a 90-Hz tone. Through comparison of the modulation depths of both tones, an autopilot system aligns the approaching aircraft with the runway centerline. A similar system called a glide-slope (GS) exists in the 320-to-330MHz band for vertical alignment of the approach. While this technology has been proven reliable for millions of commercial flights annually, its UHF nature limits its ability to operate beyond the 1-to-2-meter precisions associated with commercial runway width.

A prototype ILS-type system operates at millimeter-wave frequencies to provide automatic and robust approach control for aerial refueling. The system allows for the coupling process to remain completely autonomous, as a boom operator is no longer required. Operating beyond 100 GHz provides enough resolution and a narrow enough beamwidth that an approach corridor of centimeter scales can be maintained.

Two modules were used to accomplish this task. The first module is a localizer/glide-slope module that can be fitted on a refueling aircraft. This module provides the navigation beams for aligning the approaching aircraft. The second module is navigational receiver fitted onto the approaching aircraft to be refueled that can detect the approach beams. Since unmanned aircraft have a limited payload size and limited electrical power, the receiver portion was implemented in CMOS (complementary metal oxide semiconductor) technology based on a super-regenerative receiver (SRR) architecture. The SRR achieves mW-level power consumption and chip sizes less than 1 mm^2. While super-regenerative techniques have small bandwidths that limit use in communication systems, their advantages of high sensitivity, low complexity, and low power make them ideal in this situation where modulating tones of less than 1 kHz are used.

This work was done by Adrian J. Tang of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48868

Impedance Discontinuity Reduction Between High-Speed Differential Connectors and PCB Interfaces

Lyndon B. Johnson Space Center, Houston, Texas

High-speed serial communication (i.e., Gigabit Ethernet) requires differential transmission and controlled impedances. Impedance control is essential throughout cabling, connector, and circuit board construction.

An impedance discontinuity arises at the interface of a high-speed quadrax and twinax connectors and the attached printed circuit board (PCB). This discontinuity usually is lower impedance since the relative dielectric constant of the board is higher (i.e., polyimide ≈4) than the connector (Teflon ≈2.25). The discontinuity can be observed in transmit or receive eye diagrams, and can reduce the effective link margin of serial data networks.

High-speed serial data network transmission improvements can be made at the connector-to-board interfaces as well as improving differential via hole impedances. The impedance discontinuity was improved by 10 percent by drilling a 20-mil (≈0.5-mm) hole in between the pin of a differential connector spaced 55 mils (≈1.4 mm) apart as it is attached to the PCB.

The effective dielectric constant of the board can be lowered by drilling holes into the board material between the differential lines in a quadrax or

twinax connector attachment points. The differential impedance is inversely proportional to the square root of the relative dielectric constant. This increases the differential impedance and thus reduces the above described impedance discontinuity. The differential via hole impedance can also be increased in the same manner. This technique can be extended to multiple smaller drilled holes as well as tapered holes (i.e., big in the middle followed by smaller ones diagonally).

This work was done by Sal Navidi, Rodell Agdinaoay, and Keith Walter of Honeywell Aerospace for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to Honeywell Aerospace. Inquiries concerning licenses for its commercial development should be addressed to:

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Refer to MSC-24855-l, volume and number of this NASA Tech Briefs *issue, and the page number.*

⚛ SpaceCube Version 1.5

This processing system is suited for any sub-orbital application that requires a compact solution with high-data-rate storage capability and high-performance processing.

Goddard Space Flight Center, Greenbelt, Maryland

SpaceCube 1.5 is a high-performance and low-power system in a compact form factor. It is a hybrid processing system consisting of CPU (central processing unit), FPGA (field-programmable gate array), and DSP (digital signal processor) processing elements. The primary processing engine is the Virtex-5 FX100T FPGA, which has two embedded processors. The SpaceCube 1.5 System was a bridge to the SpaceCube 2.0 and SpaceCube 2.0 Mini processing systems. The SpaceCube 1.5 system was the primary avionics in the successful SMART (Small Rocket/Spacecraft Technology) Sounding Rocket mission that was launched in the summer of 2011.

For SMART and similar missions, an avionics processor is required that is reconfigurable, has high processing capability, has multi-gigabit interfaces, is low power, and comes in a rugged/compact form factor. The original SpaceCube 1.0 met a number of the criteria, but did not possess the multi-gigabit interfaces that were required and is a higher-cost system. The SpaceCube 1.5 was designed with those mission requirements in mind.

The SpaceCube 1.5 features one Xilinx Virtex-5 FX100T FPGA and has excellent size, weight, and power characteristics [4×4×3 in. (≈10×10×8 cm), 3 lb (≈1.4 kg), and 5 to 15 W depending on the application]. The estimated computing power of the two PowerPC 440s in the Virtex-5 FPGA is 1100 DMIPS each. The SpaceCube 1.5 includes two Gigabit Ethernet (1 Gbps) interfaces as well as two SATA-I/II interfaces (1.5 to 3.0 Gbps) for recording to data drives. The SpaceCube 1.5 also features DDR2 SDRAM (double data rate synchronous dynamic random access memory); 4-Gbit Flash for storing application code for the CPU, FPGA, and DSP processing elements; and a Xilinx Platform Flash XL to store FPGA configuration files or application code.

The system also incorporates a 12 bit analog to digital converter with the ability to read 32 discrete analog sensor inputs. The SpaceCube 1.5 design also has a built-in accelerometer. In addition, the system has 12 receive and transmit RS-422 interfaces for legacy support. The SpaceCube 1.5 processor card represents the first NASA Goddard design in a compact form factor featuring the Xilinx Virtex-5. The SpaceCube 1.5 incorporates backward compatibility with the SpaceCube 1.0 form factor and stackable architecture. It also makes use of low-cost commercial parts, but is designed for operation in harsh environments.

This work was done by Alessandro Geist, Michael Lin, Tom Flatley, and David Petrick of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15936-1