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.

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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.

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

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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