Modular Wireless Data-Acquisition and Control System

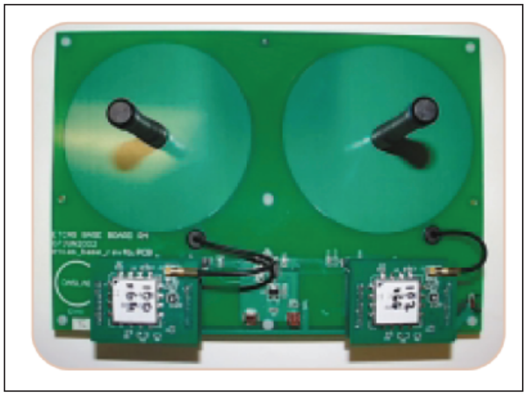
This system can be used to build an autonomous, highly reliable instrumentation network.

John F. Kennedy Space Center, Florida

A modular wireless data-acquisition and control system, now in operation at Kennedy Space Center, offers high performance at relatively low cost. The system includes a central station and a finite number of remote stations that communicate with each other through low-power radio-frequency (RF) links. Designed to satisfy stringent requirements for reliability, integrity of data, and low power consumption, this system could be reproduced and adapted to use in a broad range of settings. Examples of potential applications include industrial instrumentation, home automation, wireless intrusion-detection systems, remote reading of meters, medical instrumentation, telecommunications, automotive systems, homeland security, and military reconnaissance.

The central station has been implemented on several platforms, such as single board computers, personal computers, and the like, running custom software developed by NASA. Through its RS-232 port (a standard port for asynchronous serial data communication), the central station is connected to radio-transceiver modules (see figure) identical to the corresponding modules in the remote stations.

The remote stations contain programmable microcontrollers that can be easily reconfigured to perform many functions, depending on the application. For example, the microcontrollers can buffer data, process data, provide excitation for sensors, perform signal-conditioning and -conversion functions, and control local equipment. The microcontroller architecture can easily accommodate local "smart sensor" instrumentation that has self-calibration and self-diagnosis capabilities. Moreover, by suitable processing of data, the microcontrollers gain the ability to make decisions regarding operation and regarding the selection of relevant information to send to the central station; as a result, the bandwidth needed for communication is reduced and the system can be made less complex than it would otherwise be.



The **Central Station Hardware** includes communication modules that contain generic RF circuit boards. Identical communication modules are used in the remote stations.

The remote stations include power-management modules. An efficient power-management scheme enables the remote stations to operate on batteries for several years (sampling rate dependent). Each remote station stays in a low-power-consumption mode until either it receives a message from the central station or another event triggers its power-management module to supply power to the other modules.

The output power of the radio transmitter in each station is made low (≈10 mW) to minimize interference. The range of each station is 300 feet (about 90 m) with a small whip antenna and can be increased by use of a directional antenna. The system is based on a spread-spectrum transceiver and uses an in-house developed algorithm to central communication over more than 100 frequency pairs on a 433- or 918-MHz base frequency. The wireless links currently operate at a data rate of 19.2 kb/s, but are capable of 115 kb/s.

The central station normally communicates with all remote stations directly, but the system can reconfigure itself to restore communication when a remote station moves out of range or interference occurs. Upon loss of the RF signal from a remote station, the central station initiates a routine to determine which remote station(s) can become a relay for the lost station. The routine can occur on multiple levels to create a chain of stations and thereby enable long-distance communication using relatively low power.

This work was done by José Perotti and Angel Lucena of **Kennedy Space Center** *and Pedro Medelius, Carlos Mata, Anthony Eckhoff, and Norman Blalock of ASRC Aerospace. For further information, contact the Kennedy Commercial Technology Office at (321) 867-8130.*
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Microwave System for Detecting Ice on Aircraft

This system can distinguish among ice, water, and ice/water mixtures.

John H. Glenn Research Center, Cleveland, Ohio

A microwave-based system has been developed as a means of detecting ice on aircraft surfaces, with enough sensitivity to provide a warning before the ice accretes to a dangerous thickness. The system can measure the thickness of ice from a few mils (1 mil = 0.0254 mm) to about 1/4 in. (≈6 mm) and can distinguish among (1) ice, (2) water (or deicing fluid), and (3) a mixture of ice and water (or deicing fluid). Sensors have been ruggedized to withstand the rain erosion environment.

The system (see Figure 1) includes a microwave module that contains a con-

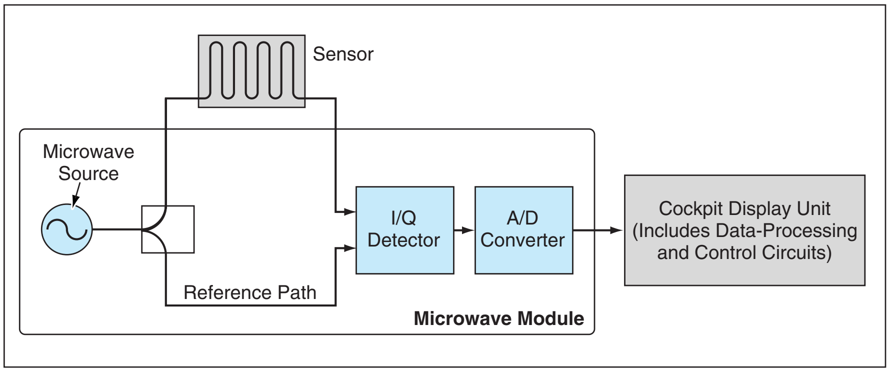

Figure 1. The **Sensor Is a Section of CPW or SL Transmission Line** flush with an aircraft surface. The magnitude and phase of the microwave signal arriving at the I/Q detector is affected by the amount of ice and/or water coating the sensory section of the transmission line.

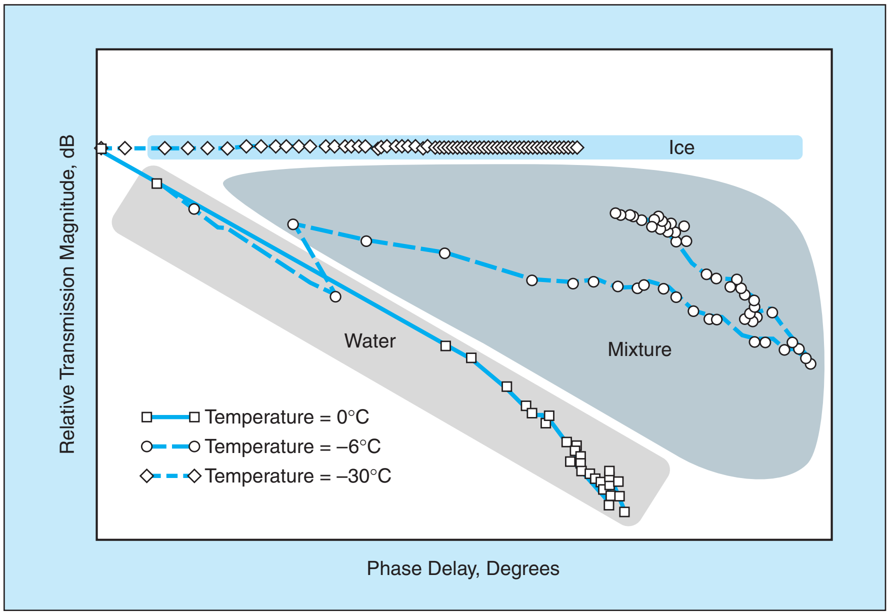

Figure 2. This **Normalized Response in the Magnitude/Phase Plane** was obtained in tests of a slot-line sensor at three temperatures. Three distinct regions of the magnitude-vs.-phase plane make it possible to distinguish among coats of ice, water, and mixtures thereof. In the important case of pure ice, the amplitude shift is negligible and the thickness of ice is indicated by the amount of phase shift.

tinuous-wave microwave signal source, the output of which is split onto a sensor path and a reference path. The sensor path consists of a microwave transmission line that includes a sensory portion of either the ground-plane coplanar-waveguide (CPW) type or the slot-line (SL) type. Whichever type is used, the sensory portion of the transmission line is mounted flush with the aircraft surface at the desired ice-detection location. With the exception of the sensory portion of the transmission line, the aforementioned circuitry is enclosed within an electrically conductive box. The sensor- and reference-path outputs are processed through an in-phase/quadrature (I/Q) detector, then through an analog-to-digital (A/D) converter. The output of the A/D converter is sent to data-processing and control circuitry in a cockpit display unit.

The data-processing subsystem computes the magnitude and phase of the sensor signal relative to those of the reference signal, and uses the sensor signal obtained when the sensor is bare to normalize the response of the system when water and/or ice are present. The normalized magnitude and phase response of the system serves as an indication of the thickness of ice and or water (see Figure 2).

This work was done by Philip J. Joseph, Dennis P. Glynn III, and John C. Joseph of Dedicated Electronics, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17135.

Routing Algorithm Exploits Spatial Relations

This algorithm is competitive with two prior algorithms.

NASA's Jet Propulsion Laboratory, Pasadena, California

A recently developed routing algorithm for broadcasting in an *ad hoc* wireless communication network takes account of, and exploits, the spatial relationships among the locations of nodes, in addition to transmission power levels and distances between the nodes. In contrast, most prior algorithms for discovering routes through *ad hoc* networks rely heavily on transmission power levels and utilize limited graph-topology techniques that do not involve consideration of the aforesaid spatial relationships. The present algorithm extracts the relevant spatial-relationship information by use of a construct denoted the relative-neighborhood graph (RNG).

The RNG algorithm is best described by reference to, and comparison with, two prior algorithms: one based on a construct denoted the minimum-radius (minR) graph, the other based on a construct denoted the minimum spanning tree (MST). The minR algorithm starts from the assumption that every node must use the same transmission radius, *d*. [As used here, "transmission radius" does not signify radius as the term is commonly understood; instead, it signifies an effective radius that depends on the ratio between the transmission power and the bit rate.] An iterative binary search is performed to find the smallest *d* that guarantees connectivity of the network. On each iteration, a graph with transmission radius *d* is computed. If the graph is found to be connected, then *d* is decreased for the next iteration. The algorithm stops at the finding of the value of *d* such that the graph is connected but at the next smaller