Electronics/Computers

Digitally Controlled Slot Coupled Patch Array

John H. Glenn Research Center, Cleveland, Ohio

A four-element array conformed to a singly curved conducting surface has been demonstrated to provide 2 dB axial ratio of 14 percent, while maintaining VSWR (voltage standing wave ratio) of 2:1 and gain of 13 dBiC. The array is digitally controlled and can be scanned with the LMS Adaptive Algorithm using the power spectrum as the objective, as well as the Direction of Arrival (DoA) of the beam to set the amplitude of the power spectrum. The total height of the array above the conducting surface is 1.5 inches (3.8 cm).

A uniquely configured microstrip-coupled aperture over a conducting surface produced supergain characteristics, achieving 12.5 dBiC across the 2-to-2.13-GHz and 2.2-to-2.3-GHz frequency bands. This design is optimized to retain VSWR and axial ratio across the band as well. The four elements are uniquely configured with respect to one another for performance enhancement, and the appropriate phase excitation to each element for scan can be found either by analytical beam synthesis using the genetic algorithm with the measured or simulated far field radiation pattern, or an adaptive algorithm implemented with the digitized signal.

The commercially available tuners and field-programmable gate array (FPGA) boards utilized required precise phase coherent configuration control, and with custom code developed by Nokomis, Inc., were shown to be fully functional in a two-channel configuration controlled by FPGA boards. A four-channel tuner configuration and oscilloscope configuration were also demonstrated although algorithm post-processing was required.

This work was done by Thomas D'Arista and Jerry Pauly of Nokomis, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18540-1.

Reconfigurable Robust Routing for Mobile Outreach Network

The envisioned lunar network comprises many heterogeneous assets integrated by various protocols and technologies.

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The Reconfigurable Robust Routing for Mobile Outreach Network (R3MOON) provides advanced communications networking technologies suitable for the lunar surface environment and applications. The R3MOON technology is based on a detailed concept of operations tailored for lunar surface networks, and includes intelligent routing algorithms and wireless mesh network implementation on AGNC's Coremicro Robots.

The product's features include an integrated communication solution incorporating energy efficiency and disruption-tolerance in a mobile *ad hoc* network, and a real-time control module to provide researchers and engineers a convenient tool for reconfiguration, investigation, and management.

A new routing protocol extends existing routing methods such that more alternate routes can be found between the source and the destination. This leads to better packet delivery rate as well as larger extent of delivery. Alternate routes can also be used for route optimization wherein the most energy efficient route is chosen. The criterion of energy efficiency can be readily reconfigured to accommodate different design objectives and network requirements.

When disruption occurs, a data buffering mechanism is established so that the undeliverable packet is stored at a dynamically selected storage node while awaiting redelivery. Since the undeliverable packet is not discarded but buffered, robustness is achieved. A proper storage node is chosen by considering its buffer space, battery power, and location.

A hardware prototype network is developed based on AGNC's product solutions such as Coremicro Robot and Coremicro 40 GIS. The multi-robot demonstration scheme incorporates mesh and relay networking. With three network nodes, routing capability is tested, verified, and monitored on this platform with a real-time Coremicro 40 GIS based robot Operator Control Unit (OCU). Multimedia data is exchanged in the network through effective communication and routing, even upon disruption. When one of the direct links is disrupted, an alternative two-hop path can be used to accomplish the communication.

R3MOON offers the following novel features in a complete and comprehensive communication solution:

- Energy-efficient routing achieved through path selection. This approach is highly feasible and implementable.
- Disruption-tolerant routing achieved through data buffering and retransmission mechanism. This approach is also based on AODV (*ad hoc* on-demand distance vector) routing protocol. Retransmission from the storage node achieves more graceful packet discarding rate, faster restoration, and higher redelivery rate than retransmission from the source node.
- Implementation and performance demonstration through software and hardware realization. The simulation shows animation for the route discovery process, and validates the performance of the proposed method in vari-

ous simulated network settings.

- An actual implementation of a mesh network architecture that integrates network control and optimization functionalities. The integral approach combines communication, navigation, control, and other functions needed to perform the mission. Each network node (e.g., robot) houses modules such as robot control processor, sensor fusion processor, and image processor, which are all interconnected through a communication module. The communication module connects all the nodes in the network. The configuration can be customized for designer's needs such as reduction of power consumption or simplification of wiring. In the higher level of the R3MOON architecture, a human/machine interface is embedded for executing AGNC's 4D-GIS and for monitoring and management of the network.
- A communication module that can be configured with different routing algorithms to run the mesh network. Both proactive [e.g., OLSR (Optimized Link State Routing)] and reactive (e.g., AODV) based routing protocols can be used in the module. A mesh wireless network with optimized routing algorithms enhances system reliability and performance.

This work was done by Ching-Fang Lin of American GNC Corp. for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18501-1.

Fiber-Scanned Microdisplays

Lyndon B. Johnson Space Center, Houston, Texas

Helmet- and head-mounted display systems, denoted fiber-scanned microdisplays, have been proposed to provide information in an "augmented reality" format (meaning that the information would be optically overlaid on the user's field of view). A system of this type would include laser diodes feeding light into the input ends of optical fibers. The output ends of the fibers would be vibrated in prescribed patterns (scanned), in synchronism with excitation of the laser diodes, to trace out the patterns to be displayed. Lenses would form virtual images of the patterns and project the images directly (or by reflection) into the viewer's eyes.

The effective object distance of the images could be set to approximate the distances of other objects in the field of view, so that the viewer need not refocus to view the display. The display units could be positioned to present the displays at the margin of the field of view, thereby minimizing distraction when the user needs to concentrate attention elsewhere. Alternatively, the display units could be mounted so that a turn of the eye or a slight turn of the head from a nominal straight-ahead orientation would be necessary for viewing the displays.

This work was done by Janet Crossman-Bosworth and Eric Seibel of the University of Washington for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-23847-1

Reconfigurable Fault Tolerance for FPGAs

FPGAs can be reconfigured to provide higher capacity or fault-tolerant redundancy.

Lyndon B. Johnson Space Center, Houston, Texas

The invention allows a field-programmable gate array (FPGA) or similar device to be efficiently reconfigured in whole or in part to provide higher capacity, non-redundant operation. The redundant device consists of functional units such as adders or multipliers, configuration memory for the functional units, a programmable routing method, configuration memory for the routing method, and various other features such as block RAM, I/O (random access memory, input/output) capability, dedicated carry logic, etc. The redundant device has three identical sets of functional units and routing resources and majority voters that correct errors. The configuration memory may or may not be redundant, depending on need. For example, SRAM-based FPGAs will need some type of radiation-tolerant configuration memory, or they will need triple-redundant configuration memory. Flash or anti-fuse devices will generally not need redundant configuration memory. Some means of loading and verifying the configuration memory is also required. These are all components of the pre-existing redundant FPGA.

This innovation modifies the voter to accept a MODE input, which specifies whether ordinary voting is to occur, or if redundancy is to be split. Generally, additional routing resources will also be required to pass data between sections of the device created by splitting the redundancy. In redundancy mode, the voters produce an output corresponding to the two inputs that agree, in the usual fashion. In the split mode, the voters select just one input and convey this to the output, ignoring the other inputs. In a dual-redundant system (as opposed to triple-redundant), instead of a voter, there is some means to latch or gate a state update only when both inputs agree. In this case, the invention would require modification of the latch or gate so that it would operate normally in redundant mode, and would separately latch or gate the inputs in non-redundant mode.

For fault tolerance, it is assumed that only one fault will occur within a voting group within one voting cycle, and thus, the fault can be eliminated by majority voting. Three voters are often used, providing three values to the next voting group, and so on, with the