Forward-Looking IED Detector Ground Penetrating Radar

This convoy-mounted IED detector radar could be used on route-clearing vehicles.

NASA's Jet Propulsion Laboratory, Pasadena, California

There have been many developments of mine or metal detectors based on ground penetrating radar techniques, usually in handheld or rover-mounted devices. In most mine or metal detector applications, conditions are in a stationary mode and detection speed is not an important factor.

A novel, forward-looking, stepped-frequency ground penetrating radar (GPR) has been developed with a capability to detect improvised explosive devices (IEDs) at vehicular speeds of 15 to 20 mi/h (24 to 32 km/h), 10 to 20 m ahead of the vehicle, to ensure adequate time for response. The GPR system employs two horn antennas (1.7 to 2.6 GHz, 20 dBi) as transmit and receive. The detector system features a user-friendly instantaneous display on a laptop PC and is a low-power-consumption (3 W) compact system with minimal impact on vehicle operations. In practice, the whole GPR system and a laptop PC can be powered by plugging into a cigarette lighter of a vehicle.

The stepped-frequency continuous-wave (CW) radar scans frequency from 1.7 to 2.6 GHz in 1,000 steps of 0.9 MHz, with the full frequency scan in 60 ms. The GPR uses a bi-static configuration with one horn antenna used as a transmitter and the other used as a receiver so that isolation between transmitter and receiver is improved. Since the horn antennas (20 dBi) are mounted on the roof of a vehicle at a shallow inclination angle (15 to 25° with respect to horizontal), there is a first-order reduction in ground reflection so that a significant amount of the total reflected power received by the GPR comes from the scattering of RF energy off of buried objects.

The stepped-frequency technique works by transmitting a tone at a particular frequency, while the received signal is mixed with the transmitted tone. As a result, the output of the mixer produces a signal that indicates the strength of the received signal and the extent to which it is in phase or out of phase with the transmitted tone. By taking measurements of the phase relationship between the transmitted and received signals over a wide frequency range, an interference pattern is produced showing all target reflections. When a Fourier transform is performed on this pattern, the result is a time-domain representation of targets. Among the advantages of this technique over impulse radar is the ability to transmit and receive much more total energy, and to use non-damped, highly focused horn antennas.

The novelty of the IED detector GPR has been achieved by miniaturization of GPR electronics (single electronics board, 10×5×2 cm), low power consumption (3 W), faster signal processing capability, and minimal impact on vehicle operations.

This work was done by Soon Sam Kim and Steven R. Carnes of Caltech, and Christopher T. Ulmer of Ulmer Systems, Inc. for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. Refer to NPO-47028.

Fully Printed, Flexible, Phased Array Antenna for Lunar Surface Communication

Applications include RFID tags, sensors, smart cards, electronic paper, and large-area flat-panel displays.

John H. Glenn Research Center, Cleveland, Ohio

NASA's future exploration missions focus on the manned exploration of the Moon, Mars, and beyond, which will rely heavily on the development of a reliable communications infrastructure from planetary surface-to-surface, surface-to-orbit, and back to Earth. Flexible antennas are highly desired in many scenarios.

Active phased array antennas (active PAAs) with distributed control and processing electronics at the surface of an antenna aperture offer numerous advantages for radar communications. Large-area active PAAs on flexible substrates are of particular interest in NASA's space radars due to their efficient inflatable package that can be rolled up during transportation and deployed in space. Such an inflatable package significantly reduces stowage volume and mass. Because of these performance and packaging advantages, large-area inflatable active PAAs are highly desired in NASA's surface-to-orbit and surface-to-relay communications.

To address the issues of flexible electronics, a room-temperature printing process of active phased-array antennas on a flexible Kapton substrate was developed. Field effect transistors (FETs) based on carbon nanotubes (CNTs), with many unique physical properties, were successfully proved feasible for the PAA system.

This innovation is a new type of fully inkjet-printable, two-dimensional, high-frequency PAA on a flexible substrate at room temperature. The designed electronic circuit components, such as the FET switches in the phase shifter, metal interconnection lines, microstrip transmission lines, etc., are all printed using a special inkjet printer. Using the developed technology, entire 1×4, 2×2, and 4×4 PAA systems were developed, packaged, and demonstrated at 5.3 GHz.

Several key solutions are addressed in this work to solve the fabrication issues. The source/drain contact is developed using droplets of silver ink printed on the source/drain areas prior to applying CNT thin-film. The wet silver ink droplets allow the silver to "wet" the CNT thin-film area and enable good contact with the source and drain contact after annealing. A passivation layer to protect the device channel is developed by bonding a thin Kapton film on top of the device channel. This film is also used as the media for transferring the aligned CNT thin-film on the device substrate.

A simple and cost-effective technique to form multilayer metal interconnections on flexible substrate is developed and demonstrated. Contact vias are formed on the second substrate prior to bonding on the first substrate. Inkjet printing is used to fill the silver ink into the via structure. The printed silver ink penetrates through the vias to contact with the contact pads on the bottom layer. It is then annealed to form a good connection. One-dimensional and two-dimensional PAAs were fabricated and characterized. In these circuits, multilayer metal interconnects were used to make a complete PAA system.

This work was done by Harish Subbaraman of Omega Optics, Inc., Ray T. Chen of the University of Texas at Austin, Xuejun Lu of University of Massachusetts – Lowell, and Maggie Yihong Chen of Texas State University 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-19035-1.

Battery Charge Equalizer with Transformer Array

Lyndon B. Johnson Space Center, Houston, Texas

High-power batteries generally consist of a series connection of many cells or cell banks. In order to maintain high performance over battery life, it is desirable to keep the state of charge of all the cell banks equal. A method provides individual charging for battery cells in a large, high-voltage battery array with a minimum number of transformers while maintaining reasonable efficiency. This is designed to augment a simple high-current charger that supplies the main charge energy.

The innovation will form part of a larger battery charge system. It consists of a transformer array connected to the battery array through rectification and filtering circuits. The transformer array is connected to a drive circuit and a timing and control circuit that allow individual battery cells or cell banks to be charged. The timing circuit and control circuit connect to a charge controller that uses battery instrumentation to determine which battery bank to charge. It is important to note that the innovation can charge an individual cell bank at the same time that the main battery charger is charging the high-voltage battery.

The fact that the battery cell banks are at a non-zero voltage, and that they are all at similar voltages, can be used to allow charging of individual cell banks. A set of transformers can be connected with secondary windings in series to make weighted sums of the voltages on the primaries.

This work was done by Francis Davies of Johnson Space Center. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-1003. Refer to MSC-25026-1.

An Efficient, Highly Flexible Multi-Channel Digital Downconverter Architecture

This technology can be used for any digital recording device that requires a flexible way to break a large input bandwidth into many smaller channels.

NASA's Jet Propulsion Laboratory, Pasadena, California

In this innovation, a digital downconverter has been created that produces a large (16 or greater) number of output channels of smaller bandwidths. Additionally, this design has the flexibility to tune each channel independently to anywhere in the input bandwidth to cover a wide range of output bandwidths (from 32 MHz down to 1 kHz). Both the flexibility in channel frequency selection and the more than four orders of magnitude range in output bandwidths (decimation rates from 32 to 640,000) presented significant challenges to be solved.

The solution involved breaking the digital downconversion process into a two-stage process. The first stage is a 2× oversampled filter bank that divides the whole input bandwidth as a real input signal into seven overlapping, contiguous channels represented with complex samples. Using the symmetry of the sine and cosine functions in a similar way to that of an FFT (fast Fourier transform), this downconversion is very efficient and gives seven channels fixed in frequency. An arbitrary number of smaller bandwidth channels can be formed from second-stage downconverters placed after the first stage of downconversion.

Because of the overlapping of the first stage, there is no gap in coverage of the entire input bandwidth. The input to any of the second-stage downconverting channels has a multiplexer that chooses one of the seven wideband channels from the first stage. These second-stage