an electrical connection through the ground plane, a coaxial connector can be optimized to maintain shielding.

- Because the microstrip line and the antenna are printed on different dielectric substrates, the aforementioned limitation on available area no longer applies.
- Also, because the microstrip line and the antenna are printed on different substrates, the substrate for the transmission can be thin and of high relative permittivity (typically between 2 and 10), as needed for a low-leakage transmission line, while the antenna patch can be printed on a thick, low-relative-permittivity substrate to maximize bandwidth and suppress surface waves.

This work was done by Richard Hodges and Daniel Hoppe of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-30605, volume and number of this NASA Tech Briefs *issue, and the page number.*

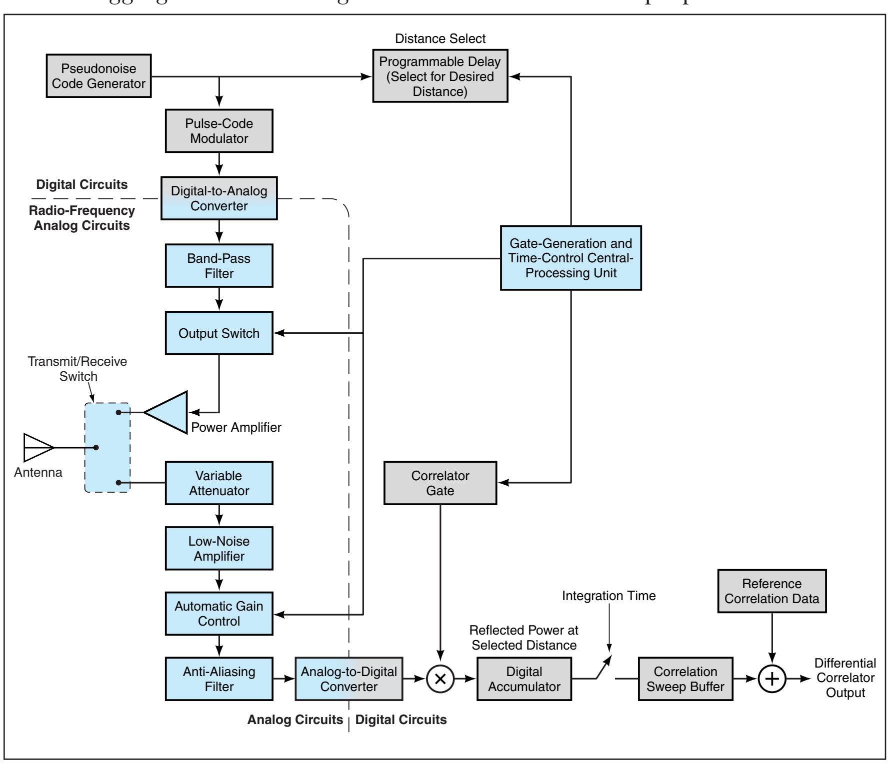
Medium-Frequency Pseudonoise Georadar

It would not be necessary to trade away resolution against penetration distance.

Lyndon B. Johnson Space Center, Houston, Texas

Ground-probing radar systems featuring medium-frequency carrier signals phase-modulated by binary pseudonoise codes have been proposed. These systems would be used to locate and detect movements of subterranean surfaces; the primary intended application is in warning of the movement of underground water toward oil-well intake ports in time to shut down those ports to avoid pumping of water. Other potential applications include oil-well logging and monitoring of underground reservoirs.

A typical prior georadar system operates at a carrier frequency of at least 50 MHz in order to provide useable range resolution. This frequency is too high for adequate penetration of many underground layers of interest. On the other hand, if the carrier frequency were to be reduced greatly to increase penetration, then bandwidth and thus range resolution would also have to be reduced, thereby rendering the system less useful. The proposed medium-frequency pseudonoise georadar systems would offer the advantage of greater penetration at lower carrier frequencies, but without the loss of resolution that would be incurred by operating typical prior georadar systems at lower frequencies.



A **Medium-Frequency Pseudonoise Georadar System** would contain a combination of digital signal-generating and -processing circuits and analog radio-frequency transmitting and receiving circuits to implement a pseudonoise ranging technique for locating underground water fronts and possibly other interfaces.

The figure is a block diagram of a system according to the proposal. The transmitter would operate at a carrier frequency chosen primarily according to the electrical conductivity and permittivity of the underground region of interest; ordinarily, one would use a frequency <1 MHz in a high-conductivity region or > 1 MHz in a low-conductivity region. The carrier signal would be phase-modulated with pseudonoise pulses representing "0" or "1" phase states. Between pseudonoise pulses, the transmitter would be turned off and the receiver turned on to detect reflections. Signal-propagation times, and thus distances to interfaces, would be determined by processing the demodulated received signals with various delays to find correlations between the received signals and the transmitted pseudonoise code.

Propagation of medium-frequency electromagnetic signals in the underground environment involves dispersion and frequency-dependent attenuation, which introduce spectral distortion. The receiver would include filters that would compensate for this distortion.

The time gating of the transmitter and receiver would reduce the probability that the high power and short delay of reflections from nearby interfaces would degrade the response of the receiver to low-power reflections from distant interfaces. A further contribution to the needed dynamic range would be made by automatic gain control and/or an electronically controlled variable attenuator.

Much of the system would be digital. The system could be configured digitally to function in a wide variety of geological formations that may be encountered at depths from zero to thousands of meters. For example, the length of the pseudonoise code could be chosen according to how much processing gain is needed to extract the desired return signal from the noise-corrupted received signal. A longer code entails longer detection time. Because of the slowness of motion of underground water fronts, there is usually sufficient time for processing a long code.

This work was done by G. Dickey Arndt of **Johnson Space Center**, *J. R. Carl of Lockheed Martin, Kent A. Byerly of Spacial Acuity Co., and B. Jon Amini of Winn Fuel Systems.*

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) 483-0837. Refer to MSC-23029.