



## Front-Side Microstrip Line Feeding a Raised Antenna Patch

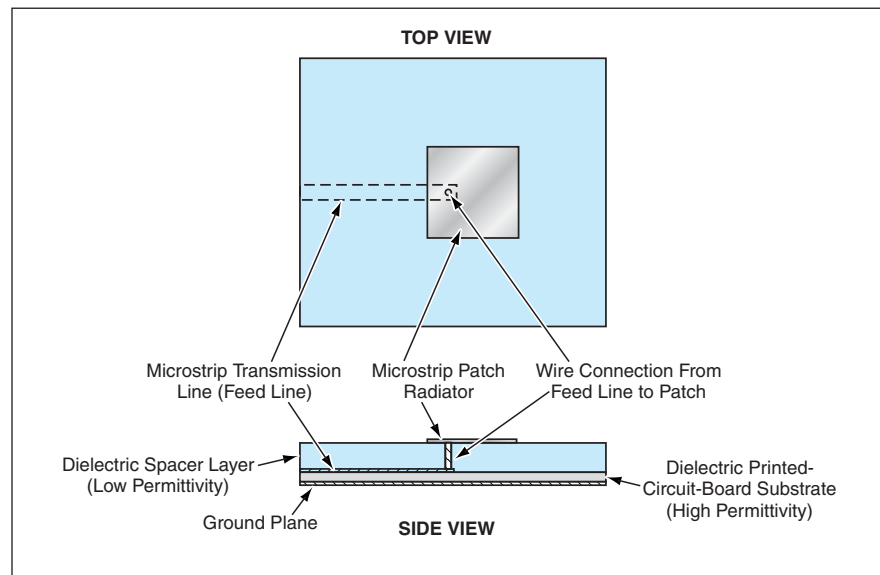
Relative to prior patch antennas, this is simpler, thinner, and less expensive.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved design concept for a printed-circuit patch antenna and the transmission line that feeds the patch calls for (1) a microstrip transmission line on the front (radiative) side of a printed-circuit board based on a thin, high-permittivity dielectric substrate; (2) using the conductor covering the back side of the circuit board as a common ground plane for both the microstrip line and the antenna patch; (3) supporting the antenna patch in front of the circuit board on a much thicker, lower-permittivity dielectric spacer layer; and (4) connecting the microstrip transmission line to the patch by use of a thin wire or narrow ribbon that extends through the thickness of the spacer and is oriented perpendicularly to the circuit-board plane. The thickness of the substrate is typically chosen so that a microstrip transmission line of practical width has an impedance between 50 and 100  $\Omega$ . The advantages of this design concept are best understood in the context of the disadvantages of prior design concepts, as explained below.

One prior design concept involves the use of a probe feed, in which the coupling between a transmission line behind the ground plane and an antenna patch on the front side of the circuit board is effected by a small wire that passes through a coaxial hole in the ground plane and the printed-circuit-board substrate. In another prior design concept, a transmission line on the back and an antenna patch on the front are coupled magnetically via slots. In yet another prior design concept, the antenna patch and its microstrip feed line are both formed on the front surface of the printed-circuit board along with the rest of the printed circuitry.

Probe- and slot-coupling designs exhibit a tendency toward leakage of radiation from the transmission-line region behind the antenna. Leakage can be reduced by shielding the microstrip or making it asymmetrical, but this undesirably increases the thickness of the antenna and causes excitation of parallel-plate modes that have a zero cutoff frequency, contribute spikes to the re-



This Relatively Simple Patch Antenna performs as well as or better than does a more complex and expensive prior patch antenna.

turn-loss spectrum, and sometimes make the antenna "blind" in some directions. Special mode-suppression pins, or vias, can be used in probe coupling to suppress the parallel-plate modes, but this significantly increases the cost, complexity, and size of the antenna. In addition, fabrication of the feed line at the thickness and permittivity that optimize connection to the patch antenna tends to make coupling to the next layer behind the feed circuit very difficult.

The prior design concept in which the microstrip feed is printed on the same surface as that of the antenna patch is seldom implemented and is fraught with drawbacks. First, the thickness and permittivity needed for a microstrip transmission line tend to result in a very narrow-band and inefficient microstrip radiator. To increase the radiative bandwidth of the patch, one must increase the substrate thickness, but this increases the percentage of power launched into the lowest order transverse magnetic surface wave mode, resulting in greatly reduced efficiency and loss of control over the radiation pattern. A second drawback is that the patch takes up so much space on the circuit board that there is very little area

available for placement of feed lines. The only alternative is to place the feed lines close together and close to the patch, leading to undesired cross coupling between lines and patches, scattering of radiation, and consequent loss of control of the radiation pattern.

In the improved design concept, the low-permittivity thick-spacer and direct-connection features, taken together, result in a good impedance match with suppression of unwanted cross-coupling and scattering. By eliminating the feed circuitry from behind the ground plane and eliminating all holes through the ground plane, this design concept eliminates the leakage-suppression problem and, hence, the drawbacks of the leakage-suppression techniques. Moreover, because there is no feed circuitry behind the ground plane, the overall antenna package is much thinner than it would otherwise be. Other advantages of this design concept include the following:

- Any desired additional electronic circuits can be placed behind the ground plane with little or no risk of electromagnetic interference because these circuits are inherently shielded by the ground plane. If it is necessary to make

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).*

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## 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 un-

derground reservoirs.

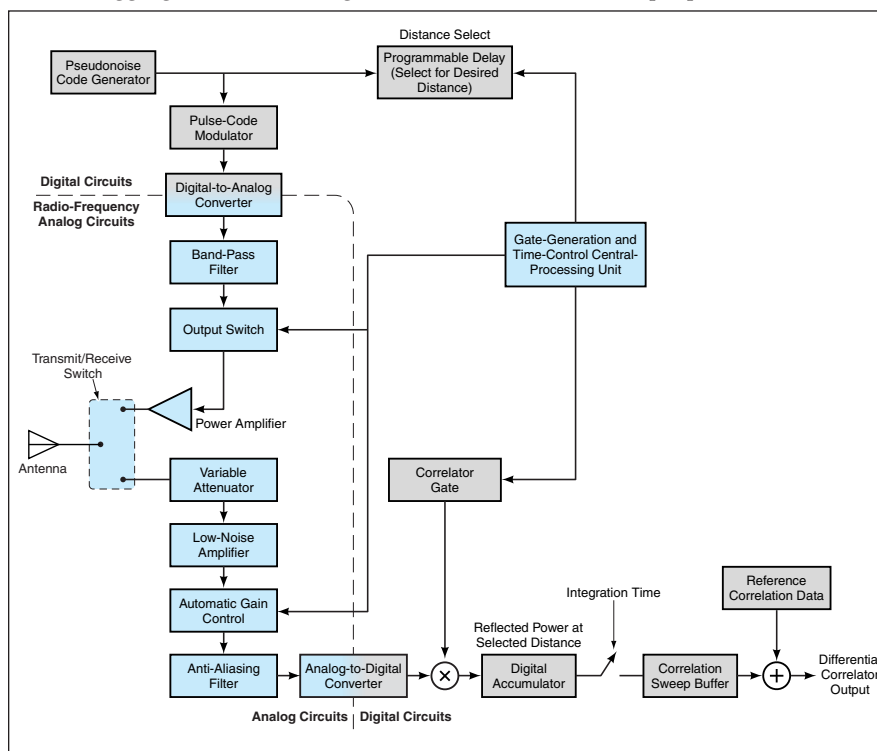
A typical prior georadar system operates at a carrier frequency of at least 50 MHz in order to provide useable range resolution. This frequency is too high for adequate penetration of many underground layers of interest. On the other hand, if the carrier frequency were to be reduced greatly to increase penetration, then bandwidth and thus range resolution would also have to be reduced, thereby rendering the system less useful. The proposed medium-fre-

quency 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.

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 dis-



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.