Microwave-Spectral Signatures Would Reveal Concealed Objects

This technique should prove superior to conventional ground-probing radar.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed technique for locating concealed objects (especially small antipersonnel land mines) involves the acquisition and processing of spectral signatures over broad microwave frequency bands. This technique was conceived to overcome the weaknesses of older narrow-band electromagnetic techniques like ground-probing radar and low-frequency electromagnetic induction.

Ground-probing radar is susceptible to false detections and/or interference caused by rocks, roots, air pockets, soil inhomogeneities, ice, liquid water, and miscellaneous buried objects other than those sought. Moreover, if the radar frequency happens to be one for which the permittivity of a sought object matches the permittivity of the surrounding soil or there is an unfavorable complex-amplitude addition of the radar reflection at the receiver, then the object is not detected. Low-frequency electromagnetic induction works well for detecting metallic objects, but the amounts of metal in plastic mines are often too small to be detectable.

The potential advantage of the proposed technique arises from the fact that wideband spectral signatures generally contain more relevant information than do narrow-band signals. Consequently, spectral signatures could be used to make better decisions regarding whether concealed objects are present and whether they are the ones sought. In some cases, spectral signatures could provide information on the depths, sizes, shapes, and compositions of objects.

An apparatus to implement the proposed technique (see Figure 1) could be assembled from equipment already in common use. Typically, such an apparatus would include a radio-frequency (RF) transmitter/receiver, a broad-band microwave antenna, and a fast personal computer loaded with appropriate software. In operation, the counter would be turned on, the antenna would be aimed at the ground or other mass suspected to contain a mine or other sought object, and the operating frequency would be swept over the band of interest.

For success in detection, (1) at least a small portion of the electromagnetic wave radiated by the antenna must penetrate the soil or other mass, must impinge on the sought object, and must be either scattered or reflected back to the antenna; and (2) there must be a suitable frequency-dependent mismatch of impedances, as explained next: If, for example, the object sought were a plas-

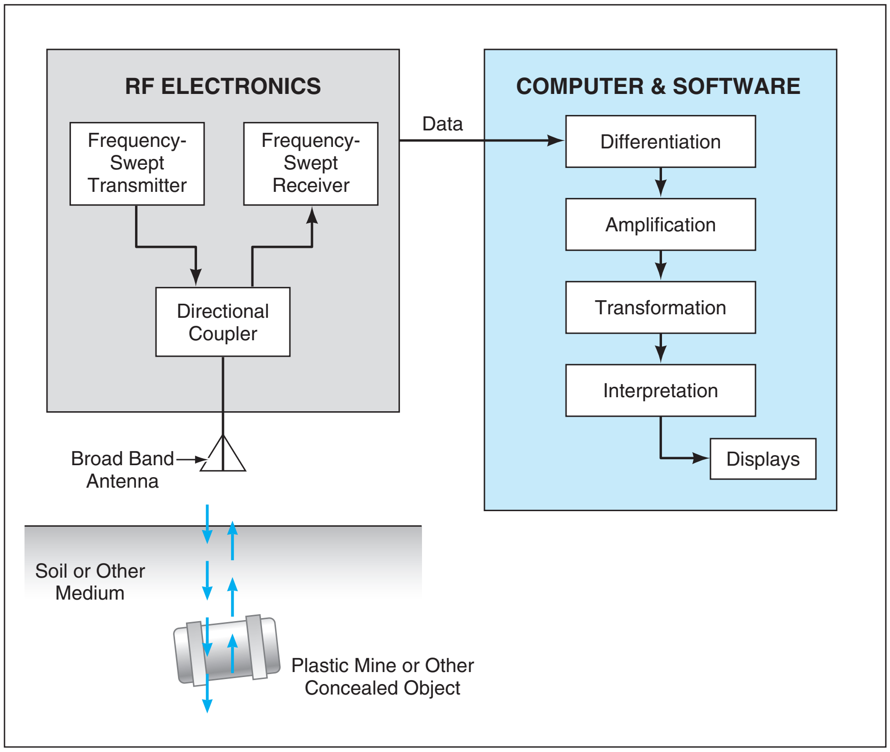

Figure 1. **Microwave Reflections From the Concealed Object** would contribute to the frequency-dependent input impedance of the antenna. The impedance would be measured by the network analyzer, and the frequency dependence would be processed to extract information about the concealed object.

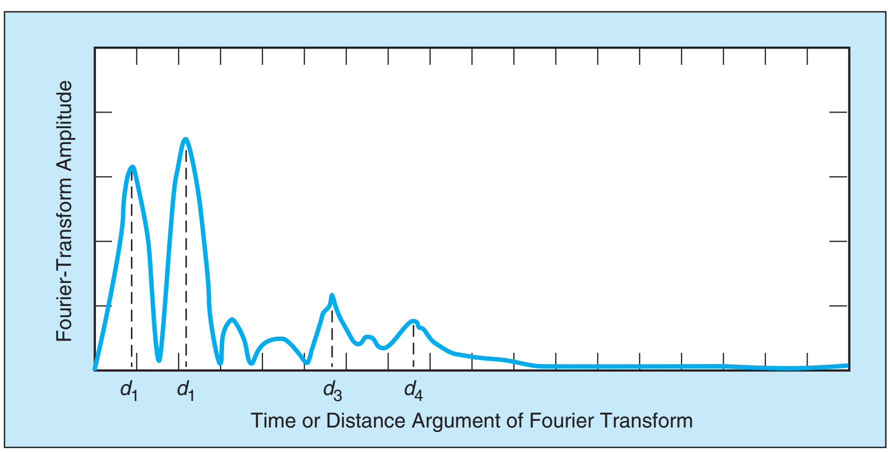

Figure 2. This **Plot Is the Fourier Transform** of a processed spectral signature, calculated theoretically for the case of a small buried plastic mine.

tic mine or other dielectric object, then some microwave energy would penetrate the object, would undergo one or more internal reflections, and would then be scattered or reflected back toward the antenna. The magnitude and phase of each of these reflections would depend on frequency and would contribute to the spectral signature of the object and the surrounding material. The spectral signature would manifest itself as the frequency dependence of the input impedance of the antenna. This impedance would be measured by the computer.

The impedance-vs.-frequency data must be processed to extract useful information on the location and nature of the sought object. One algorithm that could be used for this purpose can be summarized as follows:

1. Proceeding across the frequency band, calculate a running average of the magnitude of input impedance vs. frequency.
2. Compute the difference between the magnitude of impedance and the running average at each frequency.
3. Uniformly digitally amplify the difference data for all frequencies over the band.
4. Compute the Fourier transform of the difference-vs.-frequency data to obtain a plot that is intuitively easy to interpret because its abscissa is proportional to time and is thus related to signal-propagation distance and permittivity.

Figure 2 presents such a plot calculated theoretically for an apparatus operating in the frequency band of 1 to 10 GHz with its antenna aimed toward soil in which a plastic mine 3 in. (7.6 cm) in diameter and 1-1/2 in. (3.8 cm) thick is buried. The first spectral peak is caused by reflection of the microwave signal from the antenna input terminal and is located at d_1, which is proportional to the length of a coaxial cable from the network analyzer to the antenna. The second peak, located at d_2, is associated with the reflection of the microwave signal at the surface of the ground. The largest next two peaks, located at d_3 and d_4, are attributable to reflection from the top and bottom surfaces of the mine; thus, d_3 and d_4 are measures of the depth of burial of the mine.

This work was done by G. Arndt and P. Ngo of **Johnson Space Center***, J. R. Carl of Lockheed Martin, and K. Byerly and L. Stolarcyzk.*

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-22839.

Digital Averaging Phasemeter for Heterodyne Interferometry

One instrument performs functions for which separate instruments were previously needed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A digital averaging phasemeter has been built for measuring the difference between the phases of the unknown and reference heterodyne signals in a heterodyne laser interferometer. This phasemeter performs well enough to enable interferometric measurements of distance with accuracy of the order of 100 pm and with the ability to track distance as it changes at a speed of as much as 50 cm/s. This phasemeter is unique in that it is a single, integral system capable of performing three major functions that, heretofore, have been performed by separate systems: (1) measurement of the fractional-cycle phase difference, (2) counting of multiple cycles of phase change, and (3) averaging of phase measurements over multiple cycles for improved resolution. This phasemeter also offers the advantage of making repeated measurements at a high rate: the phase is measured on every heterodyne cycle. Thus, for example, in measuring the relative phase of two signals having a heterodyne frequency of 10 kHz, the phasemeter would accumulate 10,000 measurements per second. At this high measurement rate, an accurate average phase determination can be made more quickly than is possible at a lower rate.

Figure 1 schematically depicts a typical heterodyne laser interferometer in which the phasemeter is used. The goal is to measure the change in the length of the optical path between two corner cube retroreflectors. Light from a stabilized laser is split into two fiber-optic outputs, denoted P and S, respectively, that are mutually orthogonally polarized and separated by a well-defined heterodyne frequency. The two fiber-optic outputs are fed to a beam launcher that, along with the corner-cube retroreflectors, is part of the interferometer optics. In addition to launching the beams, the beam launcher immediately diverts and mixes about 10 percent of the power from the fiber-optic feeds to obtain a reference heterodyne signal. This signal is detected, amplified, and squared to obtain a reference square-wave heterodyne sig-

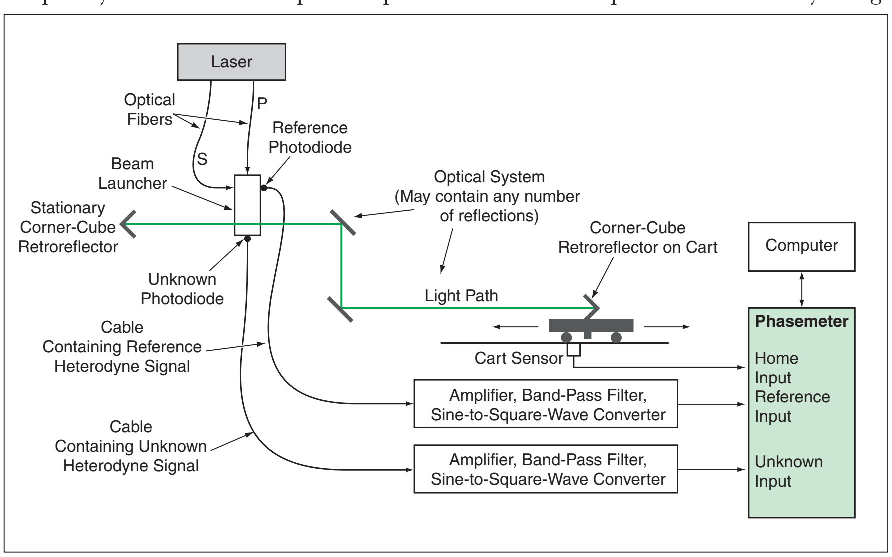

Figure 1. A **Heterodyne Laser Interferometer** is used to measure changes in the length of the optical path between the corner-cube retroreflectors. These changes are proportional to changes in the phase difference between the reference and unknown signals, which are measured by the phasemeter.