Detecting Negative Obstacles by Use of Radar

Changes in diffraction and reflection would be used to detect abrupt downslopes.

NASA’s Jet Propulsion Laboratory, Pasadena, California

Robotic land vehicles would be equipped with small radar systems to detect negative obstacles, according to a proposal. The term “negative obstacles” denotes holes, ditches, and any other terrain features characterized by abrupt steep downslopes that could be hazardous for vehicles. Video cameras and other optically based obstacle-avoidance sensors now installed on some robotic vehicles cannot detect obstacles under adverse lighting conditions. Even under fa-
vorable lighting conditions, they cannot
detect negative obstacles — at least in
part because they cannot see around cor-
ers. Other obstacle-avoidance sensors
that utilize thermal-infrared radiation
from terrain features cannot detect ob-
stacles when temperatures change too
rapidly, as they often do at dusk and
dawn. The proposed radar systems would
not be subject to these limitations.

Radar systems partly similar to the pro-
posed ones are already used in some cars
and trucks to warn drivers during backing
toward objects that cannot be seen from
the drivers’ positions. However, those sys-
tems are not designed to detect negative
obstacles. A radar system according to
the proposal would be of the frequency-mod-
ulation/continuous-wave (FM/CW) type.
It would be installed on a vehicle, facing
forward, possibly with a downward slant
of the main lobe(s) of the radar beam(s)
(see figure). It would utilize one or more
wavelength(s) of the order of centimeters.

Because such wavelengths are compar-
able to the characteristic dimensions of ter-
rain features associated with negative haz-
ards, a significant amount of diffraction
would occur at such features. In effect, the
diffraction would afford a limited ability to
see corners and to see around corners. Hence, the system might utilize diffraction
to detect corners associated with negative
obstacles. At the time of reporting the infor-
mation for this article, preliminary analyses of
diffraction at simple negative obstacles had
been performed, but an explicit description
of how the system would utilize diffra-
tion was not available.

Alternatively or in addition to using dif-
fraction, the system might utilize the
Doppler effect and/or the radiation pattern of
the radar antenna for
detecting negative obstacles. For example, if
the forward speed of the vehicle were known,
then the approximate direction from
the radar apparatus to a reflecting ob-
ject could be determined from the differ-
cence between the Doppler shift of the re-
flection and the Doppler expected of a
reflection from an object straight ahead.

For another example, if the main lobe of
the radar beam were horizontal or nearly
so, then the amount of power reflected
from a nearby negative obstacle would be
less than that reflected from level ground
at the same horizontal distance from the
vehicle. Combining these two examples, it
might be possible to detect approaching
negative obstacles through changes in the
reflected power and/or in the spectral dis-
tribution of the reflected power.

This work was done by Anthony Mitskus
and James Lux of Caltech for NASA’s Jet
Propulsion Laboratory. Further informa-
tion is contained in a TSP (see page 1).

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Cryogenic Pound Circuits for Cryogenic Sapphire Oscillators
Thermomechanical instabilities and associated frequency instabilities are reduced.

NASA’s Jet Propulsion Laboratory, Pasadena, California

Two modern cryogenic variants of the
Pound circuit have been devised to in-
crease the frequency stability of microwave
oscillators that include cryogenic sapphire-
filled cavity resonators. Invented in the
1940s and named after its inventor (R. V.
Pound), the original Pound circuit is a mi-
rowave frequency discriminator that pro-
vides feedback to stabilize a voltage-con-
trolled microwave oscillator with respect to
an associated cavity resonator. Heretofore,
Pound circuits used in conjunction with
cryogenic resonators have included room-
temperature electronic components cou-
pled to the resonators via such intercon-
nections as coaxial cables. The thermomechanical instabilities of these in-
terconnections give rise to frequency insta-
Bilities. In a cryogenic Pound circuit of the
present improved type, all of the active
electronic components, the interconnec-
tions among them, and the interconnec-
tions between them and the resonator re-
side in the cryogenic environment along
with the resonator and, hence, are thermo-
mechanically stabilized to a large degree.
Hence, further, frequency instabilities are
correspondingly reduced.

The active microwave devices required
in a Pound circuit are two amplitude detec-
tors and a phase modulator. A Pound cir-
cuit generates a frequency-error signal by
converting a phase modulation (PM) to an
amplitude modulation (AM). The AM in
question is generated when a microwave
signal that is reflected from a resonator
has a high value of the resonance quality
factor (Q) and the signal frequency differs
from the resonance frequency. A pure PM
signal is required because any AM at the
input terminal of the resonator would
generate a frequency error.

In the present cryogenic Pound circuits
(see figure), the active microwave devices
are implemented by use of state-of-the-art
commercially available tunnel diodes that
exhibit low flicker noise (required for
high frequency stability) and function
well at low temperatures and at frequen-
cies up to several tens of gigahertz. While
tunnel diodes are inherently operable as
amplitude detectors and amplitude mod-
ulators, they cannot, by themselves, in-
duce significant phase modulation.
Therefore, each of the present cryogenic
Pound circuits includes passive circuitry
that transforms the AM into the required
PM. Each circuit also contains an AM de-
tector that is used to sample the micro-
wave signal at the input terminal of the
high-Q resonator for the purpose of veri-
fying the desired AM null at this point.
Finally, each circuit contains a Pound signal
detector that puts out a signal, at the mod-
ulation frequency, having an amplitude
proportional to the frequency error in the
input signal. High frequency stability is
obtained by processing this output signal
into feedback to a voltage-controlled os-