IN-SITU RADARS FOR SOUNDING OF MARS AND EUROPA

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1. Introduction

One of the fundamental problems in the Mars science is the determination of Martian volatile budget. Of primary importance is the knowledge of the planetwide distribution of ground ice. It has become apparent, from years of research, that the only realistic means of addressing this problem is through electromagnetic sounding of Martian subsurface by ground penetrating radars. Based on the operations scenario of the present US and international Mars programs, it is possible that, as part of the future Mars rover missions, a set of small, light weight ground penetrating radars (GPRs) will be deployed with the rovers to "sample" the planetwide vertical distribution of ground ice cm Mars. However, due to the latitudinal variation in the depth of the cryolithosphere and ground ice, the penetration depth and vertical resolution requirements for sounding at different Martian latitudes can differ significantly.

Another fascinating problem in planetary science that recently received much attention is the possible existence of liquid ocean in Europa - the second of the galilean satellite. Recent optical images of complex, fractured terrain of Europa from the Galileo spacecraft point to the possible existence of liquid ocean below the icy surface of Europa (McKinnon, 1997). The sounding measurements acquired by the in-situ GPRs (e.g., lander deployment) would once again help to address this issue. Based on current speculation, the depth of the ice/rock or the possible ice/water interfaces would range from several to several tens of kilometer below the surface. As such, the GPRs would be required to penetrate a substantially different depths on Europa than on Mars.

In the past, such a diverse set of required penetrating capabilities would result in a set of dedicated, and therefore more costly, instruments each built solely for a given mission. With the recent technological advances in radar electronics, it is now possible to implement a GPR that, once built, possesses varying penetration and resolution capabilities by simply changing the radar instruction software and reloading it to the computer, and by a slight antenna modification. As such, a similar and more cost-effective in-situ GPR (ISGPR) system can be used for a number of Mars Rover and Europa Lander missions. In this paper, the system concept for such an robust instrument is presented.

2. System Design Overview

The ISGPR system is a frequency modulated - continuous wave (FM-CW) radar. It will measure the range to a scatterer by transmitting a digitally-generated FM pulse. The frequency $f(t)$, as a function of time, is given by:

$$f(t) = f_0 + \frac{B}{T} t \qquad \text{for} \quad 0 \le t \le T,$$

where B is the transmit pulse bandwidth, T is the pulse duration, and f_0 is the initial starting frequency, The echo from the scatterer at a distance r has a round-trip propagation time of $2r\sqrt{\varepsilon}/c$ where ε is the relative dielectric constant of the medium and c is the propagation speed in free space. In the proposed ISGPR the received echo is heterodyned with the attenuated transmit signal, resulting in an output signal whose frequency f_r is proportional to pulse propagation time $f_r = 2rB\sqrt{\varepsilon}/cT$.

Using the assumed attenuation coefficients and the proposed ISGPR system parameters (see Table 1), we have computed a set of representative SNRs and the results are shown in Figure 1. Within the limitations on our assumptions, we have shown in this figure that the sounding performance of the ISGPR system is indeed adequate to address the science issues as required. A summary of the ISGPR system performance parameters, such as range resolution, blind zone (this is the distance from the surface that the radar cannot detect because a radar pulse is transmitted at that time period), and penetration depth, are given in Table 2.

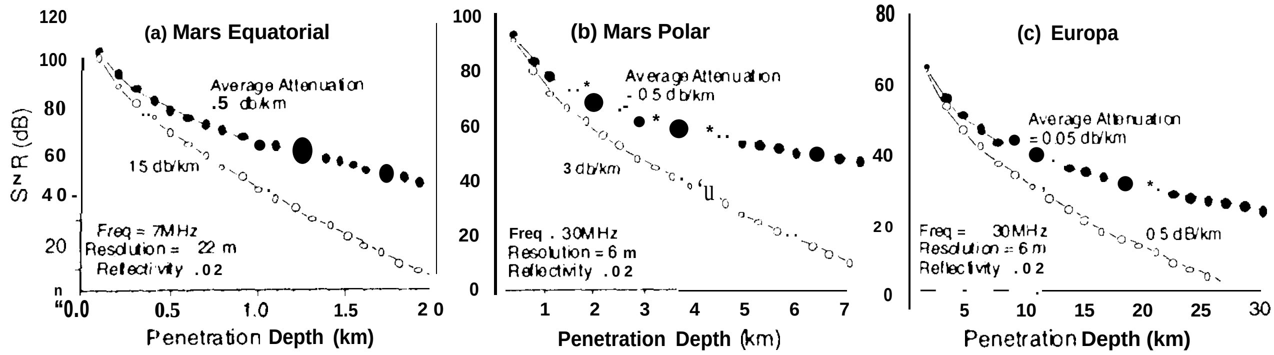

Figure 1. Expected SNR as a function of subsurface penetration depths for sounding at: (a) the Mars equatorial region; (b) Mars polar region; and (c) Europa.

	Mars Equatorial Region	Mars Polar Region	Europa
Penetration Depth	2 km	7 km	30 km
Range Resolution	22 m	6 m	6 m
Blind zone	104 m	90 m	1300 m

Table 2. Nominal performance characteristics of the ISGPR system.

4. Summary

In this paper, we have presented a system concept for an in-situ ground penetrating radar for subsurface sounding of Mars and Europa. Its tunable design allow optimized operations at a specific subrange of penetrating depths. For deployment with roving vehicles, it is expected to penetrate Martian subsurface ranging from 2 km near the equatorial region to 7 km near the polar regions, It is also expected to penetrate at least 30 km for sounding of Europa.

References

Barbin Y., F. Nicollin, W. Kofntan, V. Zolotarev, and V. Glotov, 'Mars 96 GPR Program,' *J. Appl.Geophys.* **33** (1995), 27.

Chuah, T. S., S. Gogineni, C. Allen, B. Wohletz, Y. C. Wong, P. Y. Ng, and E. Ajayi, 'Radar Thickness Measurements over the Southern Part of the Greenland Ice Sheet,' University of Kansas, RSL Technical Report 10470-2 (1996).

Chuah, T. S., S. Gogineni, C. Allen, B. Wohletz, 'Radar Thickness Measurements over the Nouthern Part of the Greenland Ice Sheet,' University of Kansas, RSL Technical Report 10470-3 (1996).

McKinnon, W. B., 'Sighting the Seas of Europa,' *Nature* **386** (1997), 768

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