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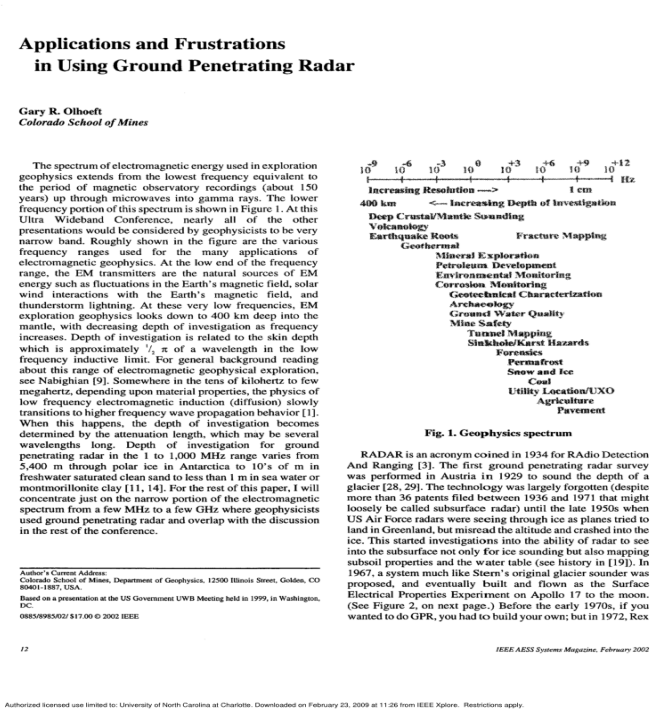

Applications and Frustrations in Using Ground Penetrating Radar

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The spectrum of electromagnetic energy used in exploration geophysics extends from the lowest frequency equivalent to the period of magnetic observatory recordings (about 150 years) up through microwaves into gamma rays. The lower frequency portion of this spectrum is shown in Figure 1. At this Ultra Wideband Conference, nearly all of the other presentations would be considered by geophysicists to be very narrow band. Roughly shown in the figure are the various frequency ranges used for the many applications of electromagnetic geophysics. At the low end of the frequency range, the EM transmitters are the natural sources of EM energy such as fluctuations in the Earth's magnetic field, solar wind interactions with the Earth's magnetic field, and thunderstorm lightning. At these very low frequencies, EM exploration geophysics looks down to 400 km deep into the mantle, with decreasing depth of investigation as frequency increases. Depth of investigation is related to the skin depth which is approximately $^1/_2 \pi$ of a wavelength in the low frequency inductive limit. For general background reading about this range of electromagnetic geophysical exploration, see Nabighian [9]. Somewhere in the tens of kilohertz to few megahertz, depending upon material properties, the physics of low frequency electromagnetic induction (diffusion) slowly transitions to higher frequency wave propagation behavior [1]. When this happens, the depth of investigation becomes determined by the attenuation length, which may be several wavelengths long. Depth of investigation for ground penetrating radar in the 1 to 1,000 MHz range varies from 5,400 m through polar ice in Antarctica to 10's of m in freshwater saturated clean sand to less than 1 m in sea water or montmorillonite clay [11, 14]. For the rest of this paper, I will concentrate just on the narrow portion of the electromagnetic spectrum from a few MHz to a few GHz where geophysicists used ground penetrating radar and overlap with the discussion in the rest of the conference.

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Fig. 1. Geophysics spectrum

RADAR is an acronym coined in 1934 for RAdio Detection And Ranging [3]. The first ground penetrating radar survey was performed in Austria in 1929 to sound the depth of a glacier [28, 29]. The technology was largely forgotten (despite more than 36 patents filed between 1936 and 1971 that might loosely be called subsurface radar) until the late 1950s when US Air Force radars were seeing through ice as planes tried to land in Greenland, but misread the altitude and crashed into the ice. This started investigations into the ability of radar to see into the subsurface not only for ice sounding but also mapping subsoil properties and the water table (see history in [19]). In 1967, a system much like Stern's original glacier sounder was proposed, and eventually built and flown as the Surface Electrical Properties Experiment on Apollo 17 to the moon. (See Figure 2, on next page.) Before the early 1970s, if you wanted to do GPR, you had to build your own; but in 1972, Rex

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