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Design of a radar system based on compact cavity-backed ultra wide band slot antennas for ground penetrating applications

F. Sagnard
IFSTTAR, Universite Paris-Est, Paris, MACS, France (florence.sagnard@ifsttar.fr)

Antennas with broadband characteristics have recently found various applications in modern ultra wide band (UWB) communication systems and in ground penetrating radar (GPR). Our applications are focused on imaging the subsurface of a large range of civil engineering structures at several depths using a bistatic GPR positioned on or close to the ground surface. The development of a compact (34*29 cm2) broadband pair of antennas operating in the frequency band from 0.27 to 3.1 GHz, whose radiation characteristics have been preliminary studied theoretically in details in different configurations, is to allow the probing of the subsurface in several frequency sub-bands using a step frequency (SF-GPR) acquisition mode.
Microstrip patch antennas (MPAs) are one of the most basic and important types of planar antennas because they offer many advantages such as compact size, low-cost, ease of fabrication, light weight, and various shapes design. However, a low bandwidth and a low gain are the main shortcomings for such planar structure. The microstrip antenna has now reached maturity and many techniques have been suggested for achieving a high bandwidth such as using more complex shapes, parasitic elements, multilayer configurations and the tuning of the feed line. In this paper, an original printed rectangular slot antenna fed by a 50 Ohms CPW (coplanar waveguide) transmission line tuned by a E-shaped patch is presented. Presently, little work has been made to lower the operating frequency band of microstrip antennas at frequencies less than 0.8 MHz and to reduce the antenna size at these frequencies because major applications concern UWB wireless communications. By choosing a relative combination of a E-shaped patch, a linear feed line and a rectangular slot, we have designed an antenna structure on a FR4 substrate (h=1.5mm) with a very wide operating bandwidth whose nearly half of the spectrum covers frequencies lower than 1 GHz. A partial shield, only opened towards the ground, and coated with an inner layered absorbing material has been added to eliminate undesirable reflections from the upper environment particularly at low frequencies; moreover, in a GPR system, the antenna shielding will allow to reduce the coupling between the transmitting and the receiving units.
The proposed rectangular slot antenna has been designed and simulated using the 3D commercial software EMPIRE based on the finite difference time domain (FDTD) technique. A detailed parameter study has allowed to define the several geometrical parameters of the unshielded slot antenna which are the result of a compromise on the frequency bandwidth (S11<-10 dB) and compact dimensions. Afterwards, the antenna radiation characteristics have been studied in the presence of a shield (conductive box coated with a multi-layered lossy material) and a common soil (epsilon=5.5, sigma=0.01 S/m). A pair of antennas has then been considered to form a bistatic radar link positioned on the soil surface, where the soil can included buried objects (pipe or crack) met in civil engineering structures. First measurements made on a sandy box have allowed to validate the simulation results