Analysis and Measurement of GPR Signal with Superimposed Noise

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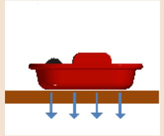
ABSTRACT

Ground Penetrating Radar (GPR) is a safe, advanced, non-destructive and non-invasive imaging technique that can be effectively used for the inspection of composite structures and subsurface. GPR provides high resolution images of the investigated scenario through wide-band electromagnetic waves. It is capable of probing down to a few tens of meters, depending on the system characteristics and on ground conditions. This paper aims at investigating two aspects: first the evaluation of electromagnetic radiation intensity to which humans operating with ground penetrating radar have been exposed; second topic is to investigate effects of electromagnetic interferences of specific devices, as cellular phones, and XBee transceiver built on the IEEE 802.15.4 MAC/PHY

DEVICES

Ground Penetrating Radar: GSSI SIR2000, single channel general-purpose system requiring a 12 VDC power input at 3 A

Antenna: Radarteam SUB-ECHO HBD 300
Central frequency: 300 MHz
3-dB BW: 120-780 MHz
4 kg, 72x36x16 cm



The SIR-2000 can be used with antennas from 2000 MHz to 16 MHz, providing penetration depths ranging from a few cm to tens of m

EQUIPMENT

Spectrum Analizer Rohde Schwarz FSP30 9 KHz – 30 GHz

Spectrum Analizer Agilent E4440A 3Hz – 26.5GHz

Lecroy Wavemaster 8500A Oscylloscope up to 6 GHz

Preamplifier HP8447F 9 KHz – 1300 MHz

Shuner Sukoflex 100 Microwave Cables 104 & 106

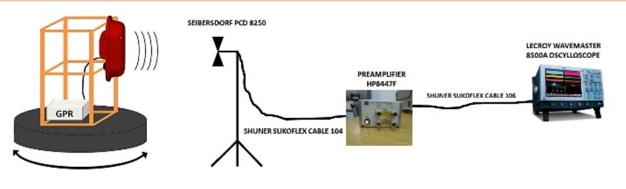
Seibersdorf PCD 8250 30 MHz – 1 GHz

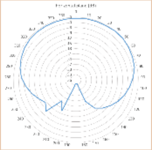
Anechoic Chamber

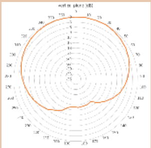
Size: 9 x 6 x 5.4 m,
Frequency: 300 KHz - 18 GHz

Electric shielding efficiency:
300 kHz –30 MHz : 120 dB
30 MHz –400 MHz : 105 dB
400 kHz –18 GHz: 100 dB

Magnetic shielding efficiency:
10 kHz : 60 dB
100 kHz : 90 dB



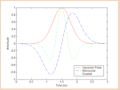


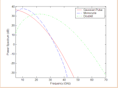


EM EXPOSURE OF GPR OPERATORS

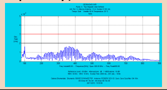
Normally, a GPR operator is exposed to the back lobe of transmitting antenna, and to the signal reflected from soil under investigation. In the present analysis we consider a Worst case: evaluation of electric field transmitted from GPR directly to receiving antenna, located about at 2 m of distance. Results have been carried out by organizing the measurement in a controlled room, supposing that all radiated energy reaches the operator, along direct line of maximum electromagnetic radiation, and disregarding back lobe transmission.

In figures are shown typical pulses generated by UWB GPR, respectively in time, and in frequency domains.

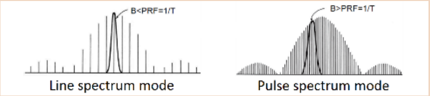




SIR2000 Georadar generates single pulses that have a time duration of about 2.7 ns and a variable Pulse Repetition Time (PRT=T). Measures carried out in the controlled room confirm the presence of spectral traces separated among them by a constant PRF=1/T (Pulse Repetition Frequency).



Spectrum analyser (SA) allows to examine signal spectra globally, and to identify ones that are generated by radar equipment, measuring their peak and average intensities. Furthermore, by means of Resolution Bandwidth (RBW) of SA we can put in evidence the actual radar pulses. Two SA modes are permitted in the literature, depending on the ratio between bandwidth at 3 dB of IF filter (RBW), and frequency distance between contiguous spectral rows. These two procedures are named: line spectrum mode and pulse spectrum mode.



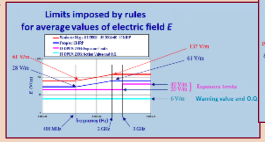
Line spectrum mode Pulse spectrum mode

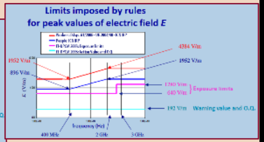
The norm CEI 211-7B regulates how to measure the electric field peak: is the dB value, estimated by means of analyzer at carrier frequency, corrected by adding the de-sensitivity factor $\alpha L[dB]=-20\log10(\tau/T)$, where τ is the peak duration time. Frequency, peak value, and average intensities of electromagnetic field (V/m rms) are entities that must be measured for this purpose.

Intensity of electric field E is evaluated by means of equation $E = ACF \cdot Va = ACF \cdot AttCable \cdot Vr$, where Va,, AttCable, Vr and ACF are respectively: the voltage value across output of receiving antenna, cable attenuation, intensity of voltage measured by receiver, and the Antenna Calibration Factor. GPR's setup can be changed. In the case of setup as 900TAS, 300S, 2500HHS, we measured a PRT of 12 µs, different from that shown when setup is 500DPH (PRT=23.3 µs). In our experimental results the value of electrical field peak has been measured equal to Epeak = 1.7 mV. Consequently, the rms values of electrical field are:

$E_{RMS} = E_{peak} \cdot \sqrt{\tau/T} = 0{,}025$ V/m, for setup: 900TAS, 300S, 2500HHS.

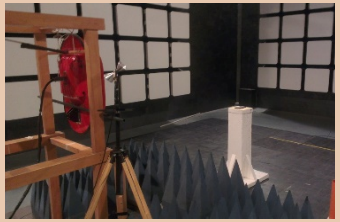
$E_{RMS} = E_{peak} \cdot \sqrt{\tau/T} = 0{,}018$ V/m for setup 500DPH. In any case, these measured values are very little, lower than limits imposed by rule. The following figures exemplify rules.





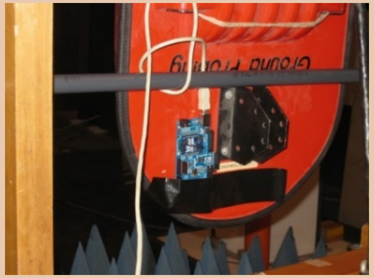
INTERFERENCE TESTING ANALYSIS FOR A GPR

In order to evaluate interferences generated by transmitters located near the GPR antenna, we organized two different measurements, that include one at a time cellular phone, and XBee transceiver. First test considers an UMTS cellular phone. The distance between GPR antenna and phone is 1.4 m. The phone transmits LOS.



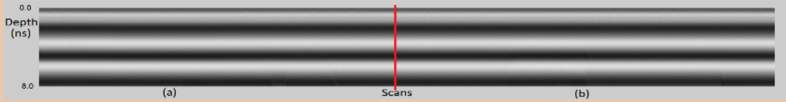
Measure with cellular phone

For the second test a transceiver XBee PRO-S2, international variant by Digi International, is arranged on the top at direct contact with GPR's antenna. Specifications of the RF module are: transmitting power output 10 mW, outdoor RF LOS range 1500 m, operating frequency band ISM 2.4 GHz, RF data rate 250 kbps, 14 direct sequence channels.

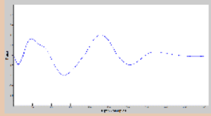


XBee on the top of antenna

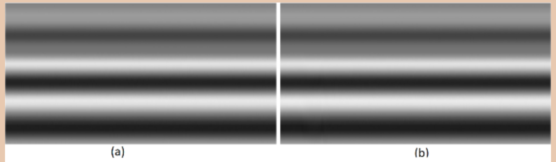
Figure shows radargram output (3849 scans) which includes record of data in absence (a) and in presence (b) of the cellular transmission. The oscilloscope representation allows to put in evidence very limited spread of traces.



Radargram: (a) absence of transmission (b) with cellular phone transmission



Cellular phone: maximum spread of traces.



Radargram in the case of XBee transceiver: (a) with transmission; (b) in absence of transmission.

The radargram shows a first interval of data acquisition with XBee in the state off, and a following interval characterized by XBee that continuously operates in transmission. Both tests demonstrate low interference generated by these two transmitters on the GPR detection, due to different operating frequency bands among devices. So, the design for adding wireless communication devices to the GPR is justified.