Setup of a microwave reflectometer for the subsurface survey of masonry structures

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Electromagnetic waves are widely used for the assessment of architectural structures, like walls, wood beams, stone, and concrete. Ultrasound, Ground Penetrating Radar, and impedance tomography are commercially available and largely used for deep investigation, but the resolution on the first range of 10-20 cm is not particularly effective. The interest of authors is the development of a robust and user-friendly non-destructive measurement system to diagnose the materials used in masonry until 20 cm in depth, with a resolution less than 2cm. A similar system could be crucial to diagnose hidden defects within the material in order to prevent damages and to properly design remedial intervention.

The proposed system is based on a microwave reflectometry to determine the location of anomalies embedded in a host material. The system is essentially based on a continuous wave (CW) transmitter/receiver and an antenna/probe, working like a Step Frequency CW radar system. The acquired reflection coefficient in the frequency domain is transformed in the time domain by using an inverse Fourier series:

$$\Gamma(t) = \sum_{n=0}^{+\infty} c_n \, e^{j2\pi f_0 nt}$$

where:

$$c_n = f_0 |\Gamma(\omega_n)| e^{j \arg(\Gamma(\omega_n))} \, rect(\frac{f + f_c}{B})$$

$\Gamma(\omega_n)$ are *n*-th sample of the reflection coefficient at the frequency f_n, and f_c is the center frequency.
The measurement is performed in the microwave range 1-6 GHz by putting in contact the antenna/probe (coaxial to double ridged waveguide adapter WRD200) with the material under test. The choice of the probe is crucial from two points of view:
(1) it must be able to radiate in the medium a sufficient electromagnetic energy in order to give a reliable signal at the detector (good matching between probe and medium);
(2) then, the frequency band must be sufficiently wide to allow the detection of interfaces slab embedded in the host medium until 2 cm from z=0.

The measured data along each scanning line are presented as cross-sectional images useful for a preliminary on-analysis of the masonry structures. The results obtained on several case studies on laboratory samples and real objects will be presented.

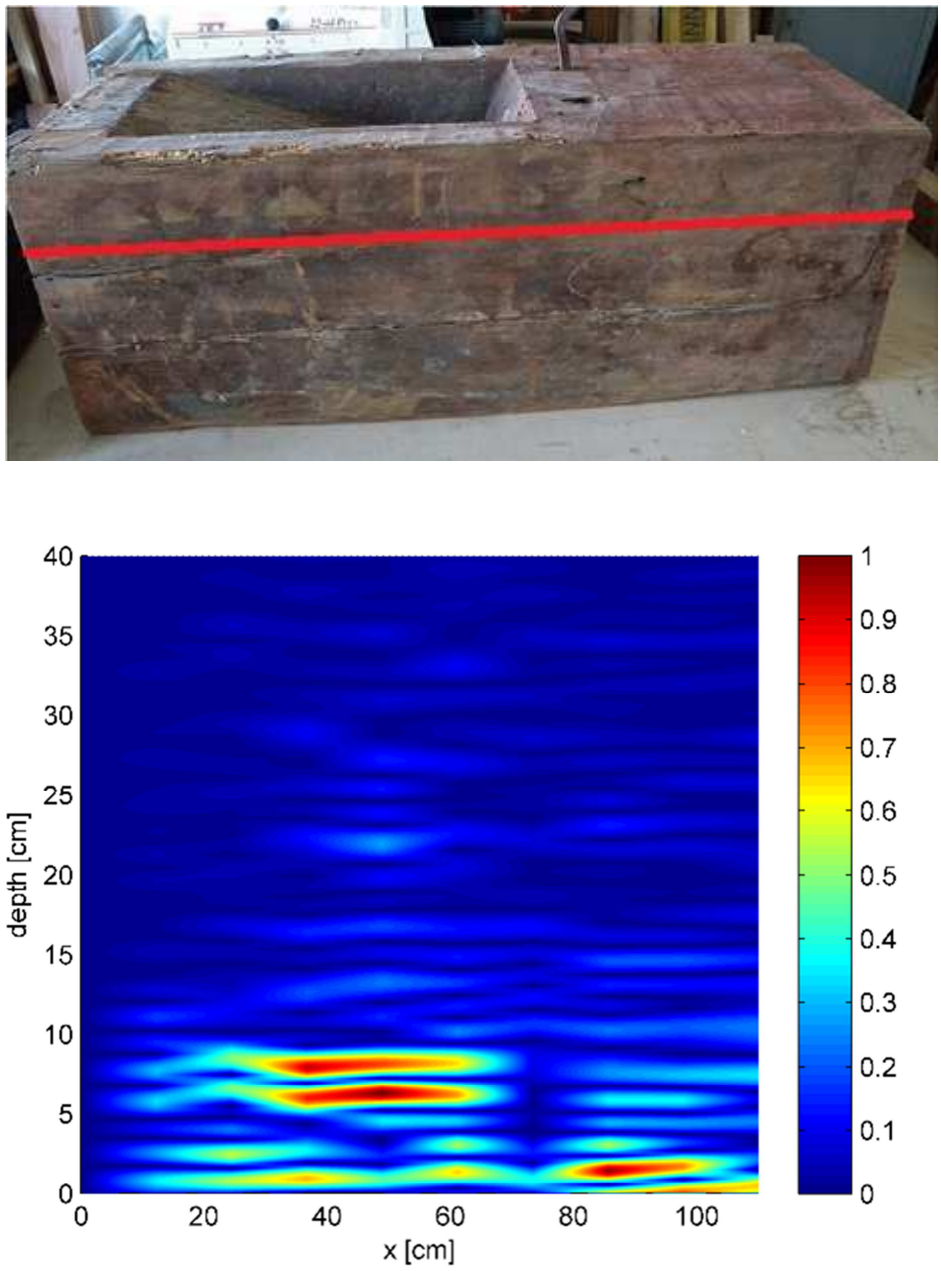

Fig. 1 – Cross-sectional image along the red line on the photo of the end section of a tie beam.