Impulse Ground Penetrating Radar for Nondestructive Evaluation of Pavements

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Abstract **A novel impulse ground penetrating radar (GPR) has been developed and demonstrated for nondestructive evaluation of pavements. The GPR is completely fabricated using MICs. It has been used to measure the relative dielectric constants and thickness of various samples. Good agreement between the theoretical and measured results was achieved.**

I. INTRODUCTION

Ground penetrating radar (GPR) operates by radiating electromagnetic waves into a structure and examining the reflected signal for information about the subsurface objects. GPR is a promising technology and has shown great potential as an effective tool for nondestructive evaluation (NDE) of highway structures, e.g., [1]-[3]. During the past decade, the use of GPR for assessing highway structures has increased dramatically. Most existing GPRs are based on the pulse technique and employ wide-duration pulses, typically 1 *ns*, which result in low resolution and limit the systems' abilities for pavement assessment such as accurate determination of subsurface layer thickness. Additionally, they are realized using discrete components and are thus expensive and bulky.

In this paper, we report a novel all-integrated-circuit GPR prototype for NDE of pavements [4]. The GPR is based on the impulse radar technology and incorporates the transmitter, receiver, and antennas completely on printed circuits. The transmitter generates 333-ps monocycle pulses with a pulse repetition rate of 10 MHz. The receiver is based on sampling down-conversion and operates from 0–6 GHz. The transmit and receive antennas have an extremely wide bandwidth of several decades and relatively high gain.

II. SYSTEM DESIGN

Fig. 1 shows a block diagram of the GPR, consisting of a transmitter, a receiver, a timing control circuit, transmit and receive antennas, and a lap-top computer. This system employs a coherent sampling method to down-convert a high-frequency signal directly into a base band for signal processing. The transmitter generates a train of monocycle pulses which are radiated by the transmit antenna into the pavement. The illuminating signals are reflected off of the pavement's surface and subsurface objects due to changes of their dielectric properties. They are captured by the receive antenna and down-converted to a very low-frequency signal by the receiver. This base-band signal is then processed by the computer to reveal information of the pavement's subsurface conditions. The timing control circuit, consisting of Clocks 1 and 2, provides a simple and effective synchronization between the transmitter and receiver needed for the coherent sampling. These clocks are fed into the pulse triggering and buffer circuits to initiate operation of the transmitter and receiver. Using two clocks eliminates the need of a pulse delay generator.

Fig. 2 shows the integration of the complete system prototype with the transmitter/antenna and receiver/antenna modules separated by a common ground plane. The antennas are soldered directly to the output transmission lines of the transmitter and receiver. This integration provides seamless electrical connections between these subsystems and antennas without using any transitions or baluns. Design of the transmitter, receiver, and antenna is given in [5], [6], and [7], respectively.

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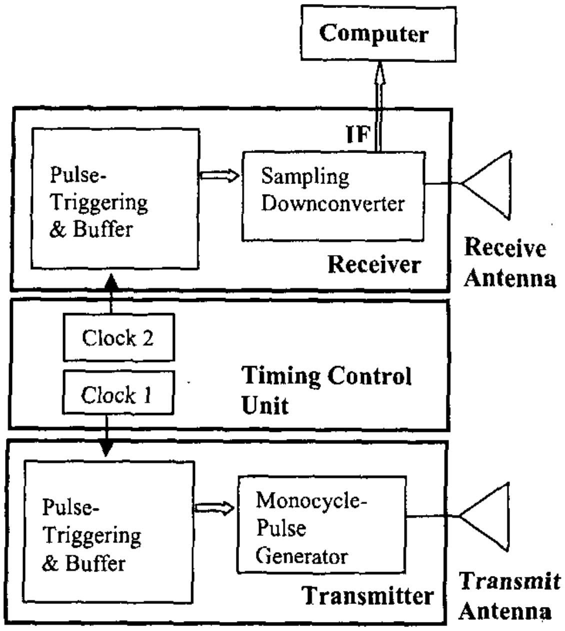

Fig. 1 Block diagram of the GPR.

III. SYSTEM INTEGRATION AND TEST

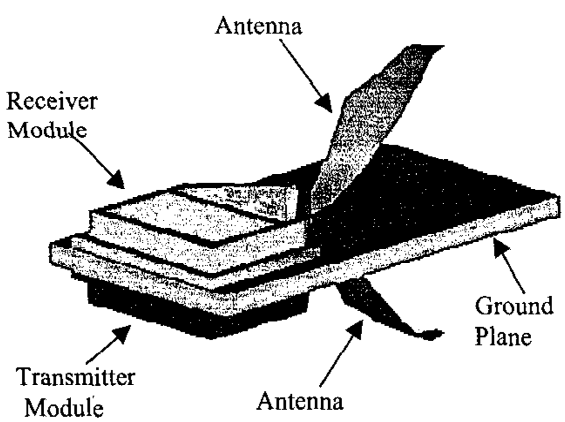

Fig. 2 Integration of the GPR.

Several tests were made to demonstrate the GPR prototype. In one test, a 32 in. x 32 in. asphalt sample of 4-in thick was suspended 3.7-in in air from the floor. The GPR was pointed directly onto the asphalt sample through air to measure the asphalt's relative dielectric constant and thickness. The transmitter transmitted a train of 333-ps monocycle pulses into the sample. Fig. 3 shows the signal reflected from the sample and measured by the receiver. As expected, this signal clearly shows the pulse P_1 reflected from the boundary between air and the top side of the asphalt layer and the pulse P_2 reflected from the boundary between the bottom side of the asphalt and air. The distinct time delay between the two reflected pulses determines the asphalt thickness. Table I shows the theoretical and experimental results of the asphalt's relative dielectric constant ε_r and thickness. These results agree well. The theoretical relative dielectric constant was obtained through measurements of various asphalt samples at 3 GHz using an HP automatic network analyzer and dielectric probe.

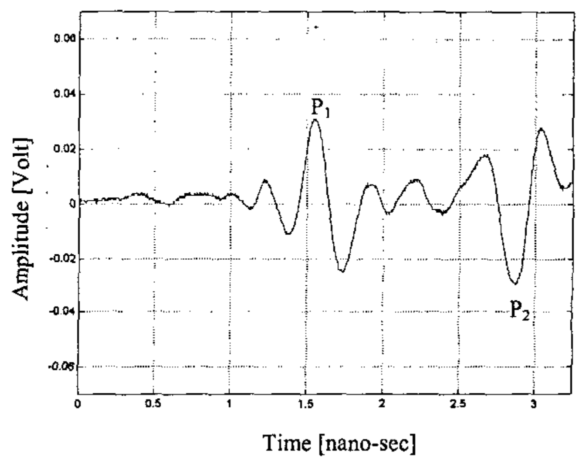

Fig. 3 Signal reflected from the asphalt sample.

TABLE I

RESULTS FOR AN ASPHALT SAMPLE

Parameter		Asphalt
Thickness	Theory	10.5 cm
	Experiment	10.6 cm
ε_r	Theory	5-7 at 3GHz
	Experiment	5.26

IV. CONCLUSION

A novel impulse GPR prototype has been developed for NDE of pavements using all microwave integrated circuits. The GPR employs a 333-ps monocycle-pulse transmitter, a 0-6-GHz sampling receiver, and antennas operating from 200 MHz to more than 20 GHz. It is based on the coherent sampling implemented using two highly stable clock oscillators to achieve a simple and effective synchronization between the transmitter and receiver. Measurements of various samples have been made to confirm the performance of this system prototype. Experimental data, obtained with this GPR prototype, also agree well with the theoretical results. The developed GPR is attractive and useful for assessing pavements or other structures for subsurface information.

ACKNOWLEDGEMENT

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