Performance of an Ultra Wideband Radar for Detection of Water Accumulation in the Human Bladder

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***Abstract*—This paper presents an Impulse Radio Ultra Wideband (IR-UWB) radar for detecting water accumulation in the human bladder. The goal is to monitor the level of urine in patients who suffer from urinary incontinence. This is achieved by detecting the reflected UWB signals from the boundaries of human tissues such as muscle and urine. The reflection properties are investigated both in a simulator with a bladder model and through measurements with a phantom model. The performance of the vivaldi antenna is investigated with regards to the pulse distortion due to the near field effect and signal attenuation in the far field. The simulation and the measurement results show the potential of water detection of the human bladder by using UWB pulses.**

I. Introduction

Lately there has been more and more interest of scientific research in radar applications using the Ultra Wideband (UWB) technology. The UWB technology opens a new spectrum for the radar sensors with high resolution by combining the UWB and the radar technology. UWB offers a promising solution to achieve fine range resolution and high data-rate for radar and communication applications. Applications of the UWB technology were focused on short-range high data-rate communications since the 1990s. Due to its very low radiation power, UWB devices with minimal interference are allowed to coexist with current RF systems. Benefiting from the fine temporal resolution, low complexity of system and good penetration capability, UWB is nowadays widely investigated for many applications such as through-wall detection, indoor navigation, ground penetration and medical applications [1] with improved performance.

The development of medical applications based on UWB signals has shown large potential. Different from the X-ray imaging, UWB radar probes use non-ionizing electromagnetic waves. Also, some unique features of UWB such as fine range resolution make it very suitable for medical diagnostics [2]. In recent times many publications have been presented dealing with the monitoring of human functions (respiration, heart beating, etc) [3] and identification of diseases (breast cancer detection) [4]. Together with these medical applications, where the UWB radar method is already applied, there are also other diseases, whose monitoring and detection can take advantage of the usage of a UWB radar.

The detection and the monitoring of water accumulation in the human body is a very important topic in various medical fields [5]. Monitoring the water accumulation in human organs (e.g. bladder) using a UWB radar, will be of help to people suffering from particular illnesses (e.g. urinary incontinence). In this way, a permanent catheterization can be avoided. The relative dielectric properties of living tissues are very different from one organ to another and this fact offers large potential of the detection and of identification of organs by using UWB signals. This paper presents the performance of the UWB radar technology for detecting the presence of urine in the human bladder. Salted water is used as urine for the phantom model because of their similar permittivity values.

This paper is organized as follows: In Section II, the scattering mechanism of the multilayer medium is discussed. The system design is shown in Section III. Section IV provides simulation and measurement results.

II. Reflection analysis of multilayer dielectric

For the detection of water accumulation of the human bladder, electromagnetic (EM) waves in the UWB band are utilized. The UWB pulses propagate into the human body and the backscattered signals are measured. A detection algorithm is used to detect the volume of urine in the human bladder.

The abdomen of a human body can be modeled as a multilayer structure. Different body tissues (e.g. muscle, fat, skin, etc) has a different relative permittivity [6] [7]. Hence, the transmitted EM waves undergo numerous reflections from the boundary between two tissues/organs that have a different relative permittivity ε_{r}. Therefore, the proposed method to detect the presence of water in the human body is based on the fact that the value of the relative permittivity of the water (e.g. urine) is much larger than the values of the relative permittivity of the surrounding organs and tissues. Hence, a large reflection of the incident UWB pulses occurs. The presence of water in the human bladder can be estimated through the time delay of the reflections [8].