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A Preliminary Design Of Application Of Wireless Identification And Sensing Platform On External Beam Radiotherapy

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Abstract

A linear accelerator (linac) is widely used as a means of radiotherapy by focusing high-energy photons in the targeted tumor of patient. Incorrectness of the shooting can lead normal tissue surrounding the tumor received unnecessary radiation and become damaged cells. A method is required to minimize the incorrectness that mostly caused by movement of the patient during radiotherapy process. In this paper, the Wireless Identification and Sensing Platform (WISP) architecture was employed to monitor in real time the movement of the patient's body during radiotherapy process. In general, the WISP is a wearable sensors device that can transmit measurement data wirelessly. In this design, the measurement devices consist of an accelerometer, a barometer and an ionizing radiation sensor. If any changes in the body position which resulted in incorrectness of the shooting, the accelerometer and the barometer will trigger a warning to the linac operator. In addition, the radiation sensor in the WISP will detect unwanted radiation and that can endanger the patient. A wireless feature in this device can ease in implementation. Initial analyses have been performed and showed that the WISP is feasible to be applied on external beam radiotherapy.

A Preliminary Design Of Application Of Wireless Identification And Sensing Platform On External Beam Radiotherapy

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Abstract. A linear accelerator (linac) is widely used as a means of radiotherapy by focusing high-energy photons in the targeted tumor of patient. Incorrectness of the shooting can lead normal tissue surrounding the tumor received unnecessary radiation and become damaged cells. A method is required to minimize the incorrectness that mostly caused by movement of the patient during radiotherapy process. In this paper, the Wireless Identification and Sensing Platform (WISP) architecture was employed to monitor in real time the movement of the patient's body during radiotherapy process. In general, the WISP is a wearable sensors device that can transmit measurement data wirelessly. In this design, the measurement devices consist of an accelerometer, a barometer and an ionizing radiation sensor. If any changes in the body position which resulted in incorrectness of the shooting, the accelerometer and the barometer will trigger a warning to the linac operator. In addition, the radiation sensor in the WISP will detect unwanted radiation and that can endanger the patient. A wireless feature in this device can ease in implementation. Initial analyses have been performed and showed that the WISP is feasible to be applied on external beam radiotherapy.

Keywords: Radiotherapy, Radiation dose, Accuracy, Wearable sensor.

1. Introduction
External beam radiotherapy is one of the most widely applied methods for modern cancer treatment [1][2][3][4]. Linear accelerator (linac) emits high energy photon output to patients who have a targeted malignant tumor. Unfortunately the normal tissue around the tumor also receives an abundance of external beam radiation from some shooting angles [1]. The intensity of radiotherapy and the accumulation of received doses have an impact on cell damage. Moreover, the normal tissue almost does not have a sufficient time to recover.

The above method of radiotherapy requires accurate calculation of depth-dose distribution between the target area and surrounding tissue to obtain an effective therapeutic process [2]. However, precise information about position and orientation of target is often not obtained during the treatment process. To deal with it, one of techniques is to increase the size of the target volume to accommodate the level of inaccuracy. As a result, the larger target size will extend more normal tissues receiving

unnecessary radiation dose as well. Therefore, external beam radiotherapy requires the smallest addition of target volume assumptions but effectively to kill tumor cell.

The greatest cause of such inaccuracy is the uncertainty of the patient's movement during therapy. An illustration of beam path from some shooting angles as shown in figure 1(a) and the movement of the patient that being performed radiotherapy process is shown in figure 1(b) (c). In this paper we will introduce radiofrequency (RF) based monitoring system that can overcome the above problem. This design is able to monitor movement of patients in real time during the treatment process. In addition, the radiation sensor can detect unwanted radiation that can jeopardize the patient.

This system utilizes a platform of Wireless Identification and Sensing Platform (WISP) which has been developed by Intel Research Network [5]. In general, this system is a wearable sensor that attached to an area around targeted tumor. Then the device will send the measurement signal from the sensor in the form of both position and radiation dose level to RF receiver device. The RF receiver will then forward the information to the linac operator.
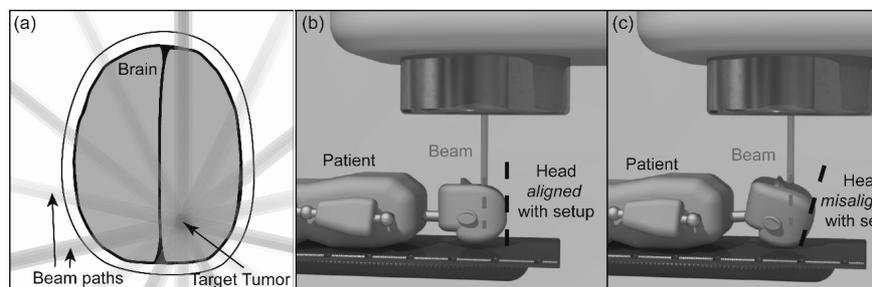

Figure 1. **(a)** External beam radiotherapy treatment for a targeted malignant tumor. **(b)** Initial position of the patient. **(c)** Uncertainty movement of the patient that can lead to receive unwanted radiation [1].

2. Methodology

WISP architecture harnesses Radio Frequency Identification (RFID) technology as a means of wireless communication. The RFID is an electronic device that uses a microchip and integrated antenna to transmit a unique identification data to the RFID reader or receiver. The advantage of WISP that conventional RFID does not have is a typical ability to program transmitted data [5][6][7][8]. The ability was used to transmit continuous measurement data from several sensors embedded in WISP [8]. In addition WISP also has an advantage to operate without battery that similar to conventional passive RFID tag.

A block diagram of the WISP architecture can be seen in figure 2. Antenna and impedance matching circuit are the initial and crucial part of receiving RF signals from RFID reader. The power harvester circuit converts the RF signal into a DC (Direct Current) voltage that used as a power supply for WISP. The demodulator circuit converts the RF signal into a data signal that can be read by a microcontroller. To perform data transmission, the microcontroller provides data to the modulator circuit by changing the antenna impedance. The WISP was designed to be compatible with standard commercial RFID device EPC class 1 generation 1 [5].
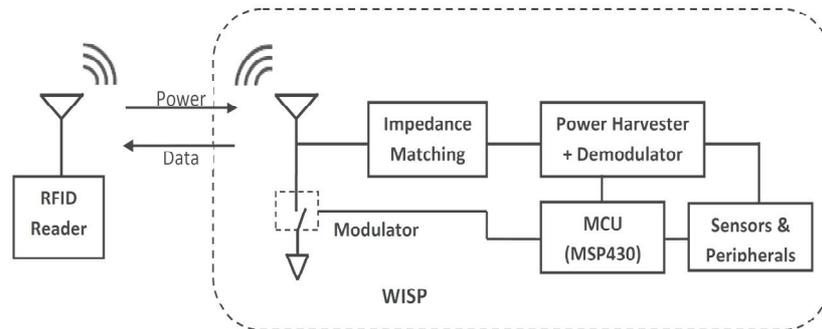
Figure 2. Blok diagram of WISP architecture

Due to limited power at the time of WISP operation, suitable circuit design and correct component selection are required. Ultra low power microcontroller MSP430F2132 is selected as the main controller of WISP system. This 16 bit microcontroller needs only a minimum voltage of 1.8 V and a current of about 600 µA for 4 MHz operation. This component can also perform flash memory operation and ADC (Analog to Digital Converter) task during operation. The microcontroller has several main functions in WISP such as sensor controller to perform measurements, power management and communication controller. The WISP hardware can be seen in figure 3.
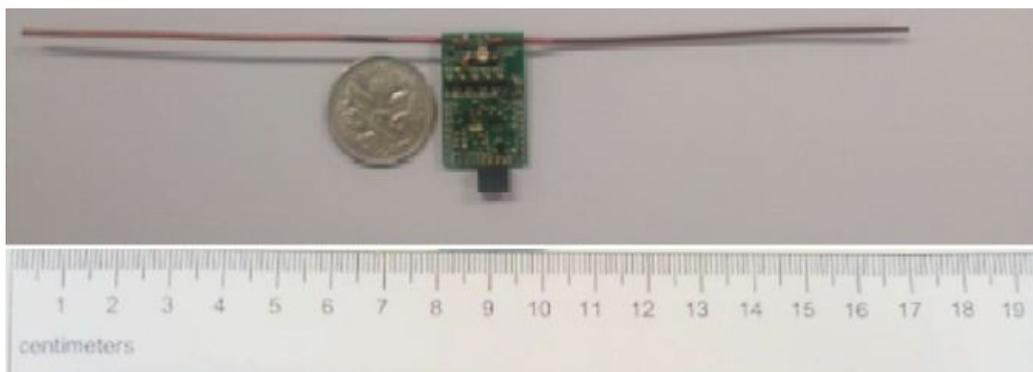

Figure 3. The WISP hardware

Embedded sensors of accelerometer and barometer in WISP are able to monitor body movements in real time. Accelerometer uses X, Y and Z axis as references. Changes in WISP positions will alter the accelerometer results of Xg, Yg, and Zg. [5][6]. In figure 4, it can be seen that there is a change in Xg variable value caused by the movement of body position of the patient from sitting to lying down and vice versa. By correct setting of sensitivity of these sensors, the WISP will be able to detect small body movements such as a nod of the head. As a result, combination both accelerometer and barometer will provide more accurate information of the movement [8].
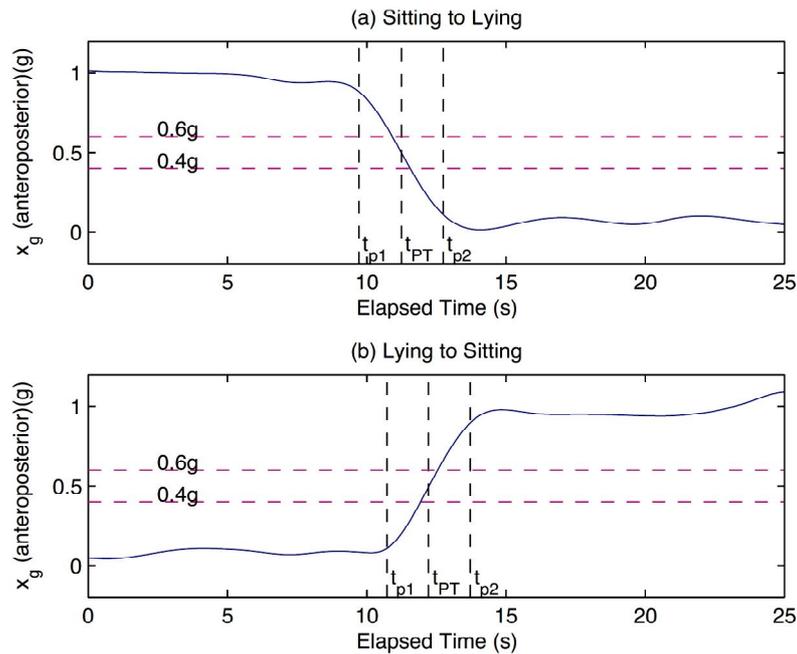
Figure 4. Detection of body movement using accelerometer [6]

In some circumstances, the microcontroller will deliver a warning signal to the operator in case of particular changes in body position that can endanger the patient. Afterwards, the shooting of linac can be adjusted precisely to the targeted tumor. Consequently, it can minimize damage to the surrounding normal tissue.

The WISP design also features a solid state sensor for ionizing radiation measurement. If ionizing radiation is detected by the sensor, it will generate changes in electrical charge.   Difference in radiation dose level will also result in difference in the output voltage. The advantages of this sensor are the dimension is quite small and the power consumption is also lower than other types of radiation sensors [9][10][11].

The RD2014 sensor developed by Teviso Sensor Technology is able to detect gamma radiation with a dose rate of 0.1 µSv per hour to 100 mSv per hour as shown in figure 5 [12]. By operating the voltage between 3 volts to 5 volts and the current consumption of about 400 µA, this sensor will be compatible to be integrated into the WISP system. A threshold value of safe radiation is programmed into the WISP system. As a result, if any excess radiation is detected, the WISP will transmit warning information to the linac operator. However, a Monte Carlo simulation will be necessitated to analyze depth-dose distributions extensively [13].
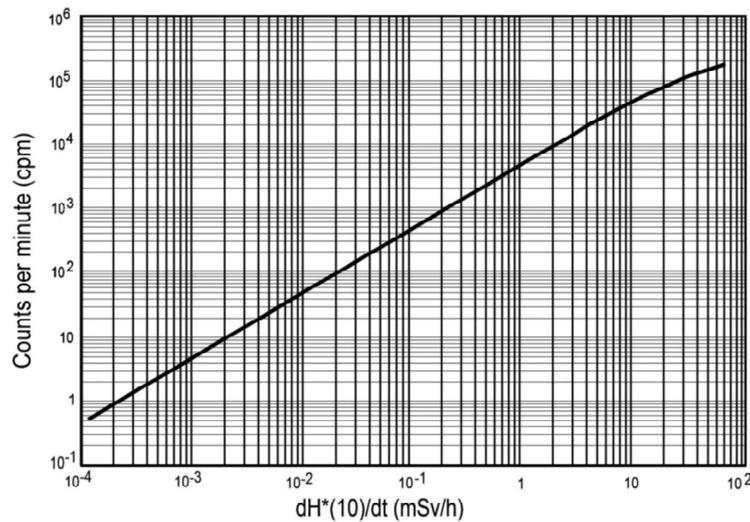
Figure 5. Radiation dose response of RD2014 [12]

3. Results and discussion

One of the most important things in this initial design is how to manage in such a way that the power harvested will be spent efficiently. For example MSP430F2132 working at 3 MHz frequency requires current consumption of 470 µA at 1.8 Volt, while the radiation sensor requires a current of about 400 µA and a working voltage of 3 volts. Eventually all components on WISP must be able to work with available power.

By using the minimum power input required for WISP activation, the working distance of WISP can be calculated by using Friis formula for path loss:

$$PRec = PTran - 20log\left(\frac{4\pi d}{\lambda}\right) + GTran + GRec - LPol \tag{1}$$

The power of the receiver device is PTran = 1 W = 30 dBm. With frequency EPC C1 G1 is 915 MHz, then the wavelength λ = 0.33 meters. Gain of transmitter antenna GTran = 6 dBi, which is an international standard. Gain of the receiver antenna GRec = 2 dBi, which is the standard gain for a dipole antenna. Loss of polarization, LPol is 3 dB.

By using a supply voltage of 3 Volts as shown in figure 6, then we get the working operation of WISP or Power received PRec = 6.1 dBm. The maximum working distance from WISP is about 3 meters. So it can be illustrated placement of WISP system on external file-based radiotherapy as in figure 7.
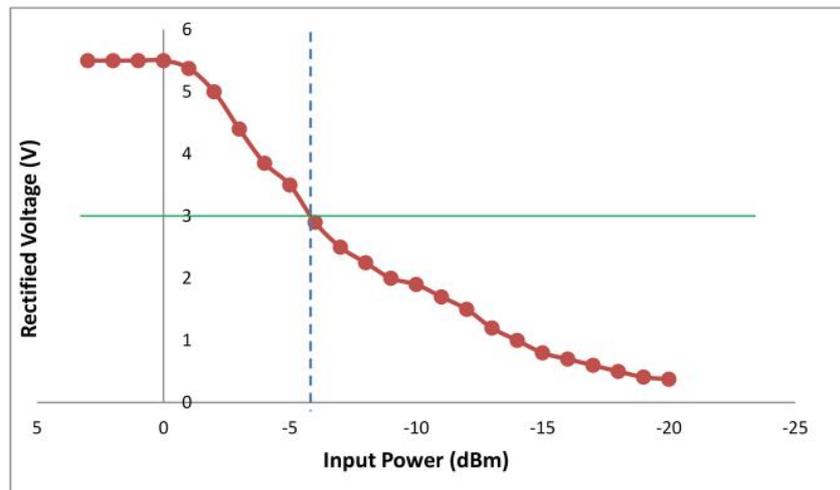
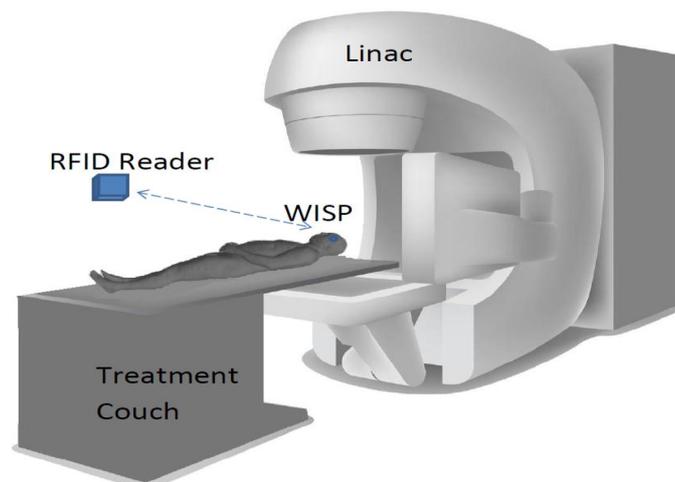**Figure 6**. The WISP simulation for input power (dBm) vs rectified voltage (V)

Figure 7. Design of WISP implementation for external beam radiotherapy treatment

4. Conclusion

In this initial design, it has been reported that WISP technology can support external beam radiotherapy treatment. Changes in body position of the patient can be monitored in real time with accelerometer and barometer embedded in WISP. Sensitivity of the accelerometer, which is measured in the variables Xg, Yg, dan Zg, can be set to obtain tolerable body motion thresholds. Radiation dose of the patient is also monitored by radiation sensors RD2014. The calculation with the Friis formula for path loss indicates that WISP can be placed near to the patient's body with the maximum distance of three meters from the receiver device or RFID reader.

The implementation of WISP to the radiotherapy treatment requires some further analysis. Among them are power management so that the WISP can run all the embedded sensors and components efficiently and also analysis of various positional changes of patients that affect the detection of the movement sensor. Furthermore, the Monte Carlo simulation will be required to simulate comprehensive depth-dose distributions. In addition, study of electronic component defect caused by received radiation should be considered.

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