**Abstract**

Many approaches have been used to monitor landslides. The detection techniques vary and depend on the range between the area of interest and receiving devices. For ranges up to a few hundred meters, the laser light-based system and the wireless sensor-based transceiver system are used to monitor small-area landslides. A new landslide detection technique that installs a transmitter array at the area of interest to transmit signals to monitor near real time of small but critical area landslide in centimetre range. The dual-receiver system, apart at a small distance, demodulates the receiving signals independently but coherently. An ambiguity route, which corresponds to a landslide’s movement without change on phase difference, is defined and must be avoided. The proposed architecture provides the identification of landslide before it occurs. It can be found out during same time displacement and different time displacement.

**Keywords:** detection algorithm, displacement measurement, geophysical measurement system, land surface, remote monitoring.

**Introduction**

Every year there is great loss of life and property due to landslides. An early warning system for landslide prediction could help in preventing these losses. In this we proposed an architecture for landslide prediction using Wireless Sensor Network (WSN). The primary reasons for using WSN for landslide prediction are: (i) dense data, (ii) inexpensive long range communication to multiple locations, (iii) overall increased accuracy and robustness because of the dense deployment of sensors, and (iv) real time monitoring and prediction of events.

In this proposed system the relative high power for ranges over 100 m, the laser light-based measurement can be a safety hazard near a residential area. Its performance is also affected by the weather such as heavy fog or snow/rain. Monitoring the change in parameters like pressure transducer, geophones, soil moisture sensor inside the area of interest. It is relatively expensive for large-area monitoring when multiple sensors are needed. The principle of differential synthetic aperture radar(SAR) interferometry (DInSAR) has been used to monitor large area of longer distance landslide in satellite- and airborne-based SAR applications. The DInSAR-based system utilize phase shifts between pairs of ground images, obtained at different time frames, to measure displacements in millimetres. The disadvantages are that the monitoring time interval is excessive, from hours(airborne) to weeks(satellite), and is expensive for daily or hourly monitoring. Also in severe weather, the airborne-based system cannot safely be used to perform the surveillance. The ground-based SAR is used for ranges from a few hundred meters to a few kilometres, was developed to reduce the aforementioned concerns. Nevertheless, when high bandwidth signal(for high resolution along range direction) is used, expensive instrument will be needed.

![Fig 1. Overview of landslide monitoring system.](image-url)
distance and demodulate the receiving signals independently but coherently. It can detect the early landslide for small but critical areas with ranges up to 250 m. The collected land deformation data can be sent back to the control centre for further action. This technique is cost effective as multiple antennas can share the same transmitting circuitry. The landslide detection system based on a single Tx will be described first, followed by a discussion of how the relative range and phase information are applied to compute the land movement. Multiple transmitter-based systems are also described. An ambiguity route is defined, and the math equation will be derived. The receiver block diagram and signal analysis then follow. Simulation examples in a 3-D model are given to illustrate land movement. Multiple transmitter-based systems are also described. An ambiguity route is defined, and the math equation will be derived. The receiver block diagram and signal analysis then follow. Simulation examples in a 3-D model are given to illustrate land movement.

Wireless Transceiver System Model Description

Fig. 1 shows an overview of a landslide monitoring system. The area of interest is located on the hillside above a residential area.

![Fig. 2. Single Tx landslide detection model](image)

and an array of Tx is installed inside the area of interest. Each Tx, labelled as T1-T6, is hardwired to coordinate the transmitting sequence to the dual-receiver system. They are programmed to transmit signals at regular time intervals. Multiple Txs, each with its own antenna, can share the same transmitting circuitry to reduce the cost. Away from the area of interest and foothill, there are two synchronised receivers R0 and R1 with their antennas placed apart at a small distance.

Sensor Interfaces

The interfaces for the sensors have to be designed so that different sensors can be added to the final wireless sensor node. The sensors are connected to the MOTE using either SPI or I²C interface. A library consisting of all the sensors that can be integrated to the wireless sensor has to be designed.

System with Tx Array

The single Tx system can be easily be extended to a 2-D Tx array to cover a wider area for monitoring landslides. An example of a 2×3 Tx array can be seen in previously described Fig. 1. Each Tx of the array will send signal in sequence and can be programmed or hardwired to send the same signal for the same time duration at fixed time intervals. For complicated terrain, each Tx may have its own hill slope. The Tx array can also be implemented with multiple antennas sharing one transmitting circuitry through a multiplexer to reduce hardware costs. The two synchronised receivers will demodulate the received signals, identify the Tx, and compute the land deformation accordingly.

Block Diagram and Signal Analysis of Transceiver System

The overall functional block diagram of a transceiver system consists of one Tx and two receivers. A typical Tx that generates a gated constant carrier signal is used in this letter, while the block diagram of two synchronized receivers is shown in Fig. 3. The Tx carrier frequency \( f_c \) is different from that in the receivers. The typical performance requirement is ±25-ppm all-inclusive frequency stability (as in 802.11x applications); therefore, the maximum error of \( f_c \) between the Tx and receiver will be 50 ppm. Letting the Tx carrier frequency be \( f_c + f_{ch} \), then, the receiver carrier frequency is \( f_r \), with a maximum frequency deviation of \( f_r = 0.5 \cdot f_c/10^8 \).

As shown in Fig. 3, the two receivers share one local oscillator, which generates two frequencies, \( f_s \) and \( f_r \), with \( f_s \) as the intermediate frequency. The amplified receiving signals \( m_0(t) \) and \( m_1(t) \) are independently demodulated by frequency \( f_s - f_r \). These two signals are then low pass filtered to become \( s_0(t) \) and \( s_1(t) \). Two of the in-phase-quadrature-phase (I–Q) demodulators are used to produce the baseband signals \( v_0(t) \) and \( v_1(t) \), which, in turn, are used to generate the phase information of two received signal.

Ambiguity Route

An ambiguity route is defined as the land deformation route where the range difference between two receivers from the moving Tx \( T^{-}(x_1, y_1, z_1) \) stays unchanged. That is, if the range difference \( r_0 - r_1 \) (at setup) equals \( r_0^{-} - r_1^{-} \) (after landslide), then ambiguity occurs. The detection technique described in Section II fails if \( T^{-}(x_1, y_1, z_1) \) moves in the direction as the ambiguity route.
Fig. 4. Single Tx with dual-receiver system in x–y plane.

Computer-Simulated Land Deformation Examples Based On Multiple TX System

Fig. 5 Simulation output for same time node displacement

Here the change in displacement is calculated on the left side of the slope, when the multiple number of transmitter experience an overall displacement change means it sends an information to the dual receiver system in order to control the landslide before it occurs.

Fig. 6. Simulation output for right side displacement

Conclusion
A new technique of detecting land displacement based on a Tx array in AOI and a dual-receiver system has been presented. The dual receiver is set apart at a small distance and demodulates the receiving signals independently and coherently. The relative phase difference from two demodulated signals is used to monitor the land deformation. This technique can be applied to detect small but critical landslide area with centimetre accuracy in near real time and is not climate sensitive. An ambiguity route that causes no phase change of Tx movement is defined and must be avoided. Dual-receiver block diagram, together with signals at each stage, is described and analyzed. Tx array used to cover a wider land area is described. Three computer-simulated 3-D land deformation detection examples based on a single Tx system are illustrated. The future work involves the implementation of multiple transmitter with dual receiver system involves the wireless sensor node.

References


