RADIO ACOUSTIC TECHNIQUE FOR FOREST FIRE DETECTION

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ABSTRACT

Several technologies are mentioned in literature to detect the forest fire. Radio Acoustic Sound System (RASS) technique of wildfire detection is important emergent technology, with fine space and time resolution capabilities for continuous monitoring and early detection of fires. This technology is an early detection system for crown and surface fires of vegetation, based on RASS, allowing remote temperature measurements and thermal sensing of a particular forest region. The RASS technique with its high-resolution volume, can directly and continuously measure air temperature profiles, including temperature increase due to fire.

INTRODUCTION

Worldwide forests are prone to high risk of forest fires and large areas of forest are affected by these phenomena every year. Forest fires usually occur in areas remote from inhabited places, so that their detection at an early phase and timely reports to the extinguish authorities are of extreme importance. Wildfire due to anthropogenetic origin is reason of enormous environmental, social, and commercial damage. Wildfire not only causes an excessive loss to valuable natural resources but also pose more risk to life of human being. Various forest fire detection technologies are described in literature. Particular technology depends on many factors, whether the detection device is immobile or mobile, the method of providing power to the detection device, whether the system is providing the fire spread information, whether the system is suitable for detection of fire in a particular region or can it cover the entire forest, the time difference between detecting onset of fire incident and reporting it to the control center, whether the system is capable of differentiating the exact occurrence of fire from the symptoms of fire, the error between the exact location point of fire to the point given by the system. Numerous technologies mentioned in literature to detect the wildfire are classified in different manners. A Review on Forest Fire Detection Techniques described in literature are classified as[1]: (I) Sensor Based Techniques (Wireless Sensor Networks)[2] (ii) Camera Based Techniques[3] (Image and Video Processing) (iii) Neural Networks Based Techniques[4] (iv) Satellite Based Techniques[5] (v) UAV/ Air Borne Techniques[6] (vi) Fuzzy Logic Based Techniques[7] (vii) Animals as mobile sensors[8-9] (viii) Radio Acoustic Sound System (RASS) techniques[10]. Our present investigation is focused on RASS techniques. RASS technique is an early detection system for crown and surface wildfires allowing remote temperature measurements and thermal sensing of a particular forest region. RASS technique is highly sensitive to temperature changes and can remotely provide more accurate air temperature measurement, crucial to early detection of fire, than any other above mentioned remote sensing systems. RASS create thermal maps of forest areas for detection of potential fires. Further, RASS is able to continuously monitor simultaneous multiple ranges with fine spatial and temporal resolution. RASS is a more efficient and cost-effective solution than a distributed network of multiple static sensors.

METHOD: RADIO-ACOUSTIC SOUNDING SYSTEM (RASS)

The use of radio wave to acquire information about atmospheric structure and parameters has been applied since a long time. Scientists have recognized that sound wave propagation is sensitive to atmospheric temperature and wind; one can easily obtain information about atmospheric temperature and wind velocity with the help of sound wave propagation[11]. Therefore, acoustic parameters characterizing sound propagation through the atmosphere, such as sound velocity, can carry information providing a spatial description of atmospheric properties such as virtual air temperature and fluid motion (wind turbulence). The air temperature and wind turbulence are greatly affected by occurrence of forest fire. Hence, forest fire can be detected with the help of propagating sound property. The maximum altitude range of RASS systems is typically 750 meters, although observations have been reported up to 1.2 km in moist air[12].

A radio acoustic sounding system (RASS) is a system for measuring the atmospheric lapse rate using backscattering of radio waves from an acoustic wave front, to measure the speed of sound at various heights above the ground. This is possible because the compression and rarefaction of air by an acoustic wave changes the dielectric properties, producing partial reflection of the transmitted radar signal. Hence, from the speed of sound, the temperature of the air near the Earth surface boundary layer can be computed[13].

RASS system consists of two main device types: (i) Radars with fire observation tower, (ii) Acoustic sources. While acoustic sources produce sound waves with a certain frequency and a certain power level, Radar continuously scans for acoustic waves. Sound wave velocity is affected by air temperature and humidity. Radar can scan the differences in speed of acoustic waves, generated by acoustic sources, periodically measuring air temperatures immediately above the trees, software embedded in Radar creates a thermal map of the region and stores thermal data for future use. Then the software checks for instant changes in temperature, and when sudden increases are found, it establishes communication with the relevant fire watchtower and warns staff of the location.

According to RASS theory[10], acoustic waves are transmitted into the atmosphere at approximately half the wavelength of the radar (Bragg matching condition) and the speed can then be calculated by the Doppler Effect at the radar receiver, provided that the acoustic and radar beams overlap. The method relies on the enhancement in electromagnetic backscatter due to the Bragg resonant scattering from acoustic waves. In practice, a spectral range of acoustic frequencies are to be used to satisfy the Bragg matching condition for the range of expected speeds of sound, since, it varies due to temperature and wind variations with range. The temperature and wind vector field can thus be determined from analysis of the intensity and the Doppler frequency shift of the return signal. Thus, principle of operation behind RASS is as follows: Bragg scattering occurs when acoustic energy is transmitted into the vertical beam of a radar such that the wavelength of the acoustic signal matches the half-wavelength of the radar. As the frequency of the acoustic signal is varied, strongly enhanced scattering of the radar signal occurs when the Bragg match takes place. When this occurs, the Doppler shift of the radar signal produced by the Bragg scattering can be determined, as well as the atmospheric vertical velocity. Thus, the speed of sound as a function of altitude can be measured, from which virtual temperature profiles can be calculated with appropriate corrections for vertical air motion. The virtual temperature of an air parcel is the temperature that dry air would have if its pressure and density were equal to those of a sample of moist air.

Radio-acoustic sounding system (RASS) is capable of measuring virtual temperature profiles (with range) using a Doppler radar to measure the propagation speed of a sound wave, which is directly related to the square root of virtual temperature[14]. Several researchers[15-16] have designed and presented systems using sound signals in the audio and near-audio frequency range to characterize meteorological flow and heating phenomena from near-surface layers to a height of several kilometers in the atmosphere. However, due to the inability of monostatic Sodar to directly measuring temperature, a radio-acoustic sounding technique has been developed as a reliable tool for remotely measuring virtual temperature. It has been both theoretically and experimentally demonstrated that the two- or three-dimensional distributions of temperature and flow fields can be remotely measured and estimated by bistatic acoustic or radio-acoustic remote sensing systems employing different techniques and algorithms.

LIMITATIONS OF RASS:

Restrictions and constraints must be considered, and these are the scanning area of the radar, and frequency and the power level of acoustic sources. The scanning area of radar should be restricted to a certain level of altitude immediately above the trees. In addition, the determination of the frequency and power of the acoustic sources should take into careful consideration of factors such as forest surface and density, distance between Radar and acoustic sources, etc. The frequencies of acoustic sources and radar should be matched. Moreover, the power level of acoustic sources is directly related with the coverage area and there is a correlation between the frequency and the power level of the sound waves.

CONCLUSION

RASS technology is capable to generate thermal maps of woods for detection of potential fires. The main basis is the fact that the radio-acoustic sounding technique is highly sensitive to the temperature changes and can remotely deliver more accurate air temperature measurement, crucial to early detection, than any of the other aforementioned remote sensing technologies useful for detection of forest fire. Additionally, the RASS technique is able to continuously monitor simultaneous multiple ranges with fine spatial and temporal resolution, and hence is a more efficient and economical solution than a distributed network of multiple static sensors.

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