# REMOTE RADIATION MAPPING INSIDE THE VAULT OF THE KOLKATA K-130 CYCLOTRON USING MOBILE ROBOT

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*Abstract*

In order to estimate the accidental/worst scenario exposure to radiation in a cyclotron environment, it is necessary to have an idea of the distribution of the radiation dose rate during the operation of the cyclotron at different locations in the cyclotron vault as well as the experimental areas. A mobile robot-based dose rate mapping system has recently been developed for this purpose for the K-130 cyclotron at Kolkata. The robot is equipped with a single board computer that not only controls the motion of the robot (based on user commands given remotely) but also acquires data captured by a radiation (neutron and gamma) monitor mounted on the robot. The robot is tele-operated from a stationary computer located in the cyclotron control room over wireless-Ethernet and its position and orientation is visualized with the help of five cameras mounted at different positions in the cyclotron vault. As the robot keeps moving, it continues to send the measured radiation dose rate to the stationary computer for analysis and visualization by the health physicist. This mobile robot-based radiation monitoring system is currently being used to measure the dose rate at twelve pre-decided locations in the cyclotron vault when the cyclotron is delivering beams of different energies.

## INTRODUCTION

In many nuclear installations, monitoring and mapping of radiation level, as well as locating source of radiation are routine requirements. Mapping dose rate at inaccessible areas is necessary as it helps estimate the accidental human exposure due to say failure of interlocks. This is mandatory for a nuclear installation as per the guidelines of the regulatory body. Also, the data help in the betterment of beam transmission ratio. Deployment of mobile robots to perform these jobs is an attractive proposition [1]. The robots in these cases are usually operated from a remotely-located stationary computer. While the robot keeps doing its intended job, its performance is continuously watched by the operator on a TV or a computer screen. If necessary, the course of action of the robot is altered by the operator by dispatching commands to it wirelessly.

This paper describes the development of a mobile robot equipped with radiation survey meter, and user interface software to teleoperate the robot and monitor radiation level in the Kolkata K-130 cyclotron adjoining areas.

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## SYSTEM DESCRIPTION

The mobile robot (Fig-1) has two drive wheels and one castor wheel for support. Steering is achieved through differential motion of the drive wheels. It has a single board computer (SBC). A supervisor microcontroller is connected to the SBC through serial port. The control of mobile robot is performed by high level programs running on the SBC. This supervisor microcontroller receives commands from the high level programs running on the SBC and sends command packets to two different PID controllers of the motors for controlling the motion of the robot. Two DC motors with gearbox and encoder drive the wheels and feedback position signals to the PID controllers. For wireless communication with a Wireless access point, the robot uses a wireless adaptor module which works in IEEE802.1b/g standards (Fig-2).

A Gamma & Neutron Survey Meter is used for radiation monitoring. It is mounted on the mobile robot at a height of 1.2m because the beam lines are situated at this height at the Cyclotron vault. This meter communicates with the SBC using an RS-232 serial link (Fig-2).

Fig. 1. The mobile robot with a gamma and neutron survey meter mounted on it.

## EXPERIMENTAL SETUP

A 3-tier architecture is adopted for radiation profiling from the control room. The core mobile robot "server" processes are implemented in the supervisor microcontroller (Fig -2). These processes manage the more critical and time-sensitive low-level tasks of robot control and operation, including maintaining requested motion and heading state and estimating position from odometer. The robot firmware does not, however, perform any high-level robotic tasks. Rather, it is the job of an intelligent client program running on the SBC to perform these application-level robotic control strategies and tasks. An object-oriented applications-programming interface (API), written in the C++ language has been developed. This includes many useful utilities for general robot programming and cross-platform (Linux and Windows) programming as well. This can be accessed at different levels for simply sending commands to the robot and reading status of mobile robot and its sensors. Extensible framework for communication with remote programs over a network has been designed for application level programming. With the help of these APIs, an application program running on the cyclotron control room computer can maneuver the robot and take it to all reasonable locations where the health physicist desires to measure the radiation dose rate. An application program written in Visual Basic and running on the SBC continually fetches the radiation data measured by the radiation meter. For simplicity, the user interface of this program is teleported to the control room computer for noting the radiation level at a designated location.

Currently, we take the help of five cameras mounted on the inside of the cyclotron vault to figure out the location of the robot. Twelve pre-decided locations on the vault floor are identified by distinct markings (Fig.-3). These markings are clearly seen using the five cameras. The robot is teleoperated, and taken to each of these marked positions, where the radiation dose rate is recorded. For want of space, only one such set of readings taken recently is listed in Table 1.

## CONCLUSION

The described mobile robot based dose mapping system has been extensively used to measure dose rates at different energies of the beam, and many more such experiments shall be carried out shortly. Even though it is desirable to have a continuous radiation dose profile, in the present implementation, we have stuck to measuring the dose at twelve predecided locations only for want of a robust position estimation system of the robot. Imparting the robot with autonomous navigation capability, so that it can build a continuous dose profile without operator intervention, is a theme of our future research.

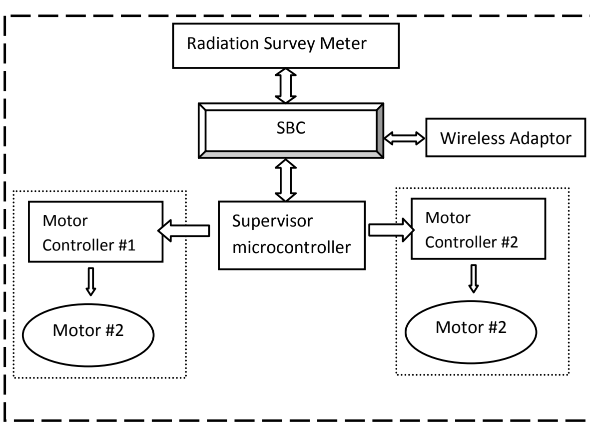


Figure-2. Components of the mobile robot

Table 1. Recorded dose rate with 30 MeV Alpha Beam for 3 – 5 uA on Faraday Cup #1 (FC-01)

| Locations (see Fig.3) | Neutron (mR/hr) | Gamma (mR/hr) |
|---|---|---|
| A | 1086.81 | 272.27 |
| B | 393.77 | 71.69 |
| C | 503.21 | 96.54 |
| D | 567.57 | 119.39 |
| E | 345.28 | 64.33 |
| F | 204.34 | 30.03 |
| G | 79.90 | 9.40 |
| H | 194.62 | 93.97 |
| I | 65.17 | 13.74 |
| J | 97.28 | 18.66 |
| K | 51.61 | 6.95 |
| L | 48.77 | 8.14 |

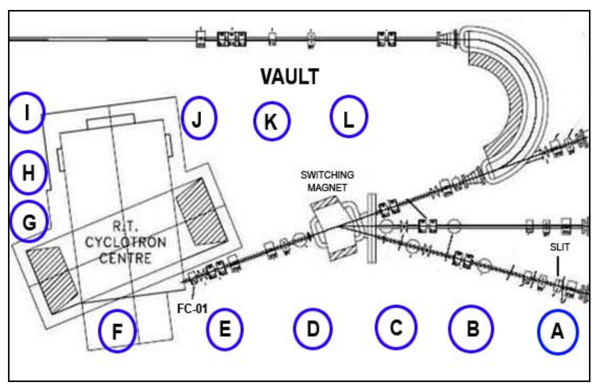


Figure-3. Different locations, marked A – L, inside the cyclotron vault where radiation measurements were taken.

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