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An Embedded Web based Real Time Application for Remote Monitoring & Controlling of MST RADAR Transmitters

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Abstract: An embedded web based radar transmitters control & interlock system is developed in the present work. This research activity facilitates controlling and monitoring 53-MHz, 2.5 Mega-watt peak power MST radar triode based transmitters via internet. This radar is a prime instrument for atmospheric science research with 32 transmitters powering 1024-element antenna array. A comprehensive safety interlock is built in to protect expensive devices; by sensing anode voltages, heater currents and airflow etc. It automatically prevents fatal damages by switching transmitter / RF off. The system is designed and developed using RISC microcontroller ARM LPC 2148 based on a 32- bit ARM7 TDMI-S CPU with real-time emulation and embedded trace support and 512 kB high speed flash memory. The microcontroller is a blend of serial communication interface, dual 10-bit ADC's and fast GPIO. Ethernet controller LM3S6432 is used to send sensors' digitalized data over internet. *Copyright © 2012 IFSA.*

Keywords: ARM7LPC2148, MST radar transmitter, Ethernet controller LM3S6432

1. Introduction

Fundamental scientific research in atmospheric and space sciences is being conducted at NARL, Gadanki by various collocated instruments. NARL is obtaining atmospheric parameters about different atmosphere dynamical process with very high resolution instruments. Statistical description of atmospheric motions over the earth, their role in transporting the constituents of the atmosphere and the transformation of different forms of energy is studied with sophisticated MST radar [1]. The 53 MHz MST radar operating since 1991 is a prime instrument for atmospheric science research with 32 transmitters powering a 1024-element square grid antenna array. Transmitters are four stage amplifiers, with first solid-state amplifier followed by three stages of triode based amplifiers with a total gain of nearly 81 dB. The four amplifier stages in the transmitter use expensive devices, hence a web based comprehensive safety is built into the system with this embedded web based real time remote monitoring and controller to protect them against supply variations, failures, cooling etc. This system monitors the status of all the 32 radar transmitters' health parameters and automatically acts upon to safeguard the systems in case of malfunctions. System personnel can access, monitor and maintain on-site system through the network without the limit of region and time. It greatly simplifies the system testing methodology. Development of Ethernet technology facilitates the installation of remote monitoring of the transmitters and real-time performance of radar is improved. This research activity provided facility to control and monitor the MST radar transmitters via internet with this embedded web based radar transmitters control & interlock system.

The remote control and monitoring system is designed and developed using RISC microcontroller ARM LPC 2148. This microcontroller is based on a 32 bit ARM7 TDMI-S CPU with real-time emulation and embedded trace support with 512 kB high speed flash memory. It is ideal for applications like access control due to tiny size and low power consumption. The microcontroller is a blend of serial communication interface, dual 10-bit ADC's to read analog data and fast GPIO lines are used to control transmitter. Serial communication port is used to send sensors' digitalized data to web using Ethernet converter LM3S6432. This system connects the triode based transmitters to internet to control and monitor health of amplifier stages. Thus 'Embedded Web based Real Time Application for Remote Monitoring & Controlling of MST RADAR Transmitters' allows scientists to operate and control the transmitters from remote client webpage.

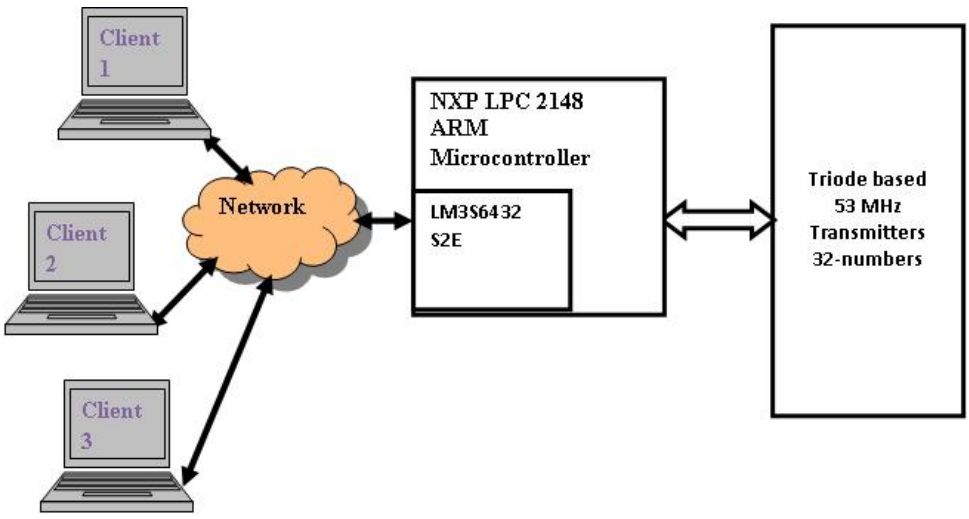

Fig. 1. Experimental setup for transmitter parameters acquisition over internet.

2. Hardware Description

The hardware of the ARM based centralized control and interlock system consists of LPC2148 based 16/32 bit ARM7TDMI-S™ core microcontroller board, relay driver board and LM3S6432 Ethernet controller integrated in a single unit.

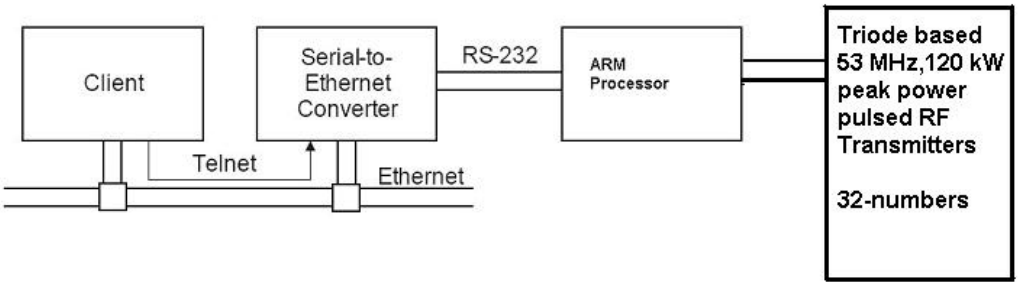

Fig. 2. The connectivity of system and to network.

The main application, sensors analog parameters reading from transmitters is performed by ARM7TDMI-S core microcontroller that is a 64 Pin (LQFP) LPC2148 from Philips (NXP). It includes USB, ADC, DAC, timer/counter, capture, I2C, SPI, UART etc. This microcontroller consists of real-time emulation and embedded trace support. Together with 128/512 kilobytes of embedded high speed flash memory, with on-chip 4 MHz internal oscillator, 32 kB SRAM make the device very well suited for this type of applications. Various 32-bit timers, an improved 10-bit ADC, 10-bit DAC, a CAN control unit, and up to 70 fast GPIO lines with up to 12 edge or level sensitive external interrupt pins make this microcontroller particularly suitable for control systems.

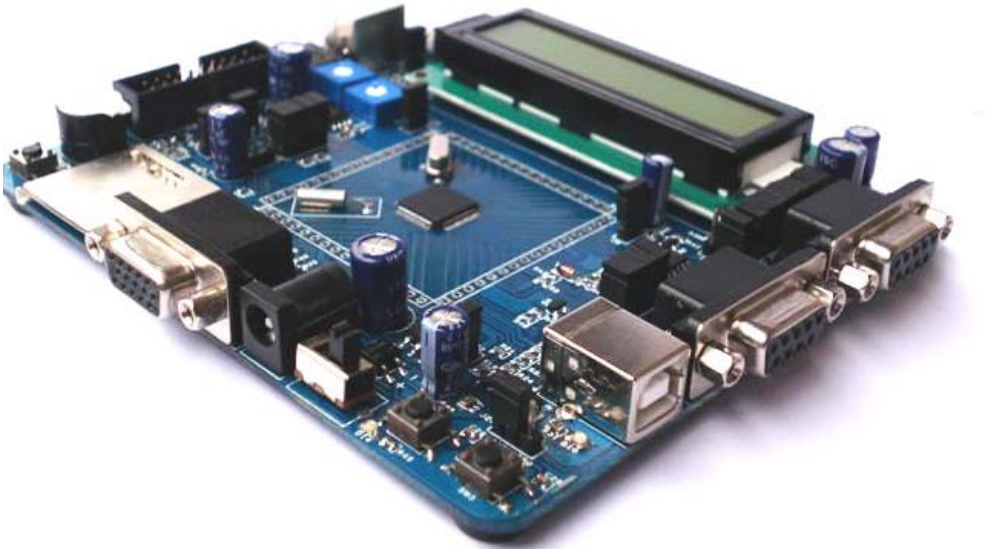

Fig. 3. LPC 2148 ARM controller board.

Ethernet application is developed using LM3S6432 microcontroller for sending the parameter values to a central computer system. LM3S6432 is a highly integrated ARM® Cortex–M3 microcontroller with integrated 10/100 Ethernet MAC and PHY. It has efficient network traffic handling with 50-MHz performance and ample single cycle on-chip Flash and SRAM memory. This S2E module includes one

10/100 Ethernet port and two serial ports with flexibility that includes both RS-232 and CMOS/TTL level signaling, flow control, and hardware support for both synchronous and asynchronous serial communication.[3]

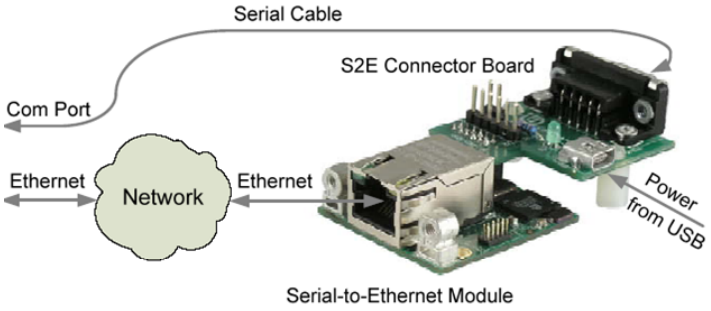

Fig. 4. The connectivity of s2e module and to network.

A 4-channel TTL relay board with 5V with solid state relays switches high-current loads of transmitter electrical systems like cathode, filament voltages, anode voltages and RF ON OFF module. The relay needs the input control signals and has no effect on the output voltage with the relay contacts. The active driver circuits allow lower current input signals such as 5V TTL to be used. The relay contacts are electrically isolated from the rest of the board, with status of each relay is indicated visually by LEDs.

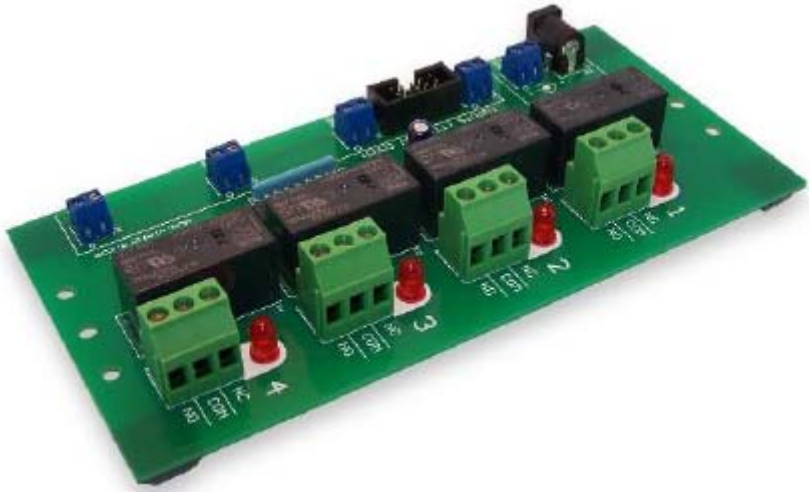

Fig. 5. Relay card board.

MST radar transmitters have four amplifying stages and associated power monitoring and controlling and safety interlock circuits. The input to the transmitter is 1milli watt pulse-modulated (coded / un-coded) signal at 53 MHz. The output powers of the amplifiers range from 0.05-0.1 kW [SSA], 0.3-1.2 kW [PDR], 3-15 kW [DR] and 36-120 kW [HPA] and the corresponding bandwidths are 3.5, 3.2 and 2 MHz respectively; the transmitters power across the 32 numbers is in correspondence with Taylor distribution to improve antenna sidelobe level better than -20 dB. The transmitters use triodes 3CX1500, 3CPX1500 and 3CPX5000 made by Varian / CPI with triode anode voltages of the order of 2.5 kV, 5.6 kV, and 6.2 kV. These devices need precise heater voltages, currents anode voltages and cooling systems for its working. Hence a comprehensive health monitoring and control system is built in transmitter.

Fig. 6. The snapshot of MST radar transmitters in a building.

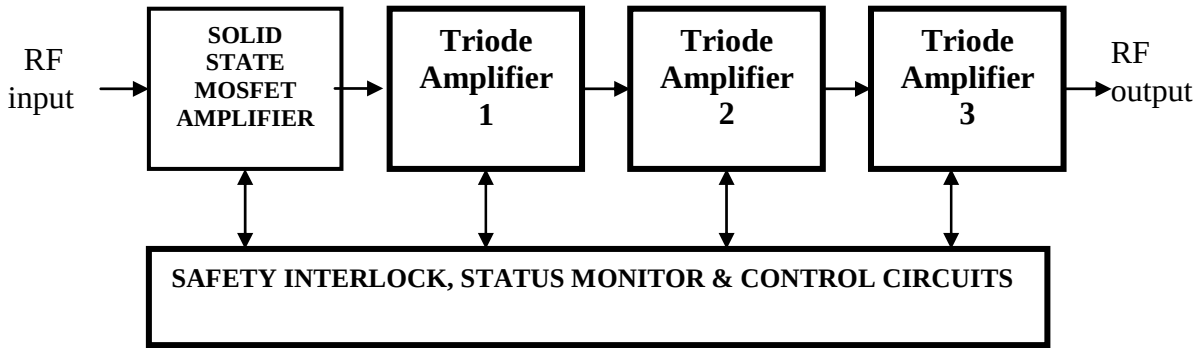

Fig. 7. Simplified radar transmitter showing RF amplifier chain, safety interlock circuits.

MST Radar transmitter triode amplifier operates in class-C mode. Heat dissipated in RF amplifier is driven away by fan/blower placed near triode (forced air-cooling system). Presence / absence of airflow are sensed by flap attached micro switch contact ON- OFF operation. Monitor voltage presence indicates obstruction in airflow and interlock operates to switch off heater, anode supply and RF switch.

Transmitter triodes' filaments/heaters are kept ON for at least 6 minutes before application of anode supply and RF signal. Filament heater current is monitored using current sensor (current transformer and associated circuits), which provides monitor dc voltage for rated heating load. Filament current drawn by the AC 5V, 5A (DR 5V, 5A and HPA 15V, 15 A) power supply is monitored using current sensors placed in the filament voltage connection to triode. If filament current is reduced due to arcing or increased triode filament resistance, filament draws less current than rated current. Interlock assumes abnormality in triode filament circuit, hence anode supply and RF OFF command are switched off. Presence / absence of anode supply in PDR (DR, HPA) RF amplifier cavity are monitored using potential divider/bleeder resistor network. This potential divider sensor provides DC voltage of about 4 V while Anode supply is ON. If the sensor voltage is less than reference voltage due to any reason, Interlock unit assumes absence of anode supply, LED indicates anode voltage absence, and RF OFF command is given to RF switch.

These analog monitoring signals are inputs of ARM microcontroller and transmitters are monitored continuously. Incase of malfunction of any, the anode supplies or RF switch are operated to safeguard the transmitters.

3. System Functionality

Embedded web based transmitters monitoring and controlling system directly connects each MST radar transmitter as a node to the network. The parameters measured are amplifiers, air flow, heater current, anode voltage, and SSA overload. These signals are monitored continuously and T_x are controlled. The sensed signals are fed to analog to digital converters for conversion to digital values. The ARM7LPC2148 chip controls the A/D conversions and the data transmission with ARM processor. The digitized data is displayed in the web page form by embedded web server.

Once transmitter auto operation is selected through the MAN/AUTO button on transmitter front panel for regular Tx operation, the transmitter is made sure to be ON using TX ON/OFF button on the webpage. All the heaters and HTs are powered-up automatically and the RF control is given on RF ON/OFF button. This button is used to bring the process to standby/active state only under the auto operation. In manual mode of operation, which is used for transmitter troubleshooting, it is essential that all the heaters and HTs be operated individually. These manual/auto operations are processed with the interlock parameters to evaluate the control actions. Interlock unit monitors the health condition of the heater currents, anode voltages, airflow etc. Fault status of any parameter automatically locks the concerned process and the RF transmission. During troubleshoot in the interlock section, the interlock conditions get bypassed and ARM evaluates control actions only based on the user choice. During troubleshoot in the ARM board all the relays permanently get energized in the relay driver board to continue the process.

The transmitters are connected to network via ARM processor through the RJ45 connector of Ethernet controller. The transmitters are active over the internet. The hardware can be accessible, from the remote place, by entering the IP address of the corresponding transmitter on the address bar (URL) of the internet browser.

4. Web Based System Description

The remote monitoring system completes the data collection in the embedded device and provides the data to remote host through the TCP/IP protocol from web server. Web server in embedded devices performs remote monitoring, diagnosis and controlling of all nodes on the network. Embedded system is a kind of special computer system which has limited resources and functions. To implement web server running in the client system, requests are processed by the ARM embedded system. Considering the need for large dynamic data exchange during equipment monitoring and controlling, the logic is implemented through C# (C-Sharp) and ASP.Net environment. ARM embedded system is a special kind of computer system which has limited resources and functions, hence to implement web server in embedded system is characteristic of itself.

Active socket provides an easy-to-use development interface to a variety of IP protocols. By using active socket, one can very easily create or enhance applications with network features. Active socket features ICMP, HTTP and HTTPs with support for proxy servers and secure web sites, Telnet, NTP time protocol, RSH remote shell script interface, SNMP (Simple Network Management Protocol), SNMP Traps, Sockets (TCP and UDP), WOL (Wake-On-LAN) etc. Active socket can be well integrated into ASP.NET environments.

The transmitters are active over the internet. The hardware is accessible from the remote place, by entering the IP address of the corresponding transmitter on the address bar of webpage. The webpage contains the information about which transmitter is connected, transmitters health and ON/OF control of transmitter parameters. In this webpage the RF ON/OFF button is used to switch on the RF power of transmitter. The health status of the each parameter and voltage levels are shown in Fig. 8.

Fig. 8. Screen shot of webpage contained T_x health parameter values.

Health status (good or bad) is indicated as a colour bubble. The RED is indicated as fault/bad condition of the corresponding parameter and GREEN indicates good condition. On clicking the RF ON/OFF and control ON/OFF buttons the respective command/data is sent by client browser to the server through the protocol layer of the TCP/IP stack. Then the server logically handles the data and sends to microcontroller. The web server loads transmitter current status automatically at few seconds refresh rate in webpage. ARM microcontroller will take the appropriate actions.

The software flow diagram is explained in Fig. 9. The first step is to initialize GPIO's, ADC, UART and TIMER. Timer interrupt is set to one second, hence ADC converts analog values every one second to digital form and frame a serial packet. All the parameters of the selected transmitter are placed in the serial packet in a predefined sequence. The serial packet contains STX, ETX, parameters health status and controls. The UART sends serial packet to Ethernet controller. The transmitter always sends updated data to centralized controller located at instrumentation room for webpage monitoring, transmitter status display and archival of transmitter health status.

Transmitter is controlled by the central computer with the help of ARM controller digital I/O lines. ARM read/accepts controls from webpage by Ethernet and then converts the same in serial communication mode to control transmitter via main ARM processor, to perform task corresponding to the commands from the webpage.

5. Results & Test Report

The design and implementation of ARM based interlock and fault monitoring system is thus carried out efficiently with advantages of high density code size, cost and power requirements. The combination of complexity and speed is finding ready applications for ARM systems in digital

processing and particularly in those application areas requiring sophisticated high speed digital control. Fig. 10 is a webpage snap shot of one of the 32 radar transmitters. T_x selection is at top left, drop down box. The webpage displays T_x output power in kW and antenna sub array health with help of reflected power indication.

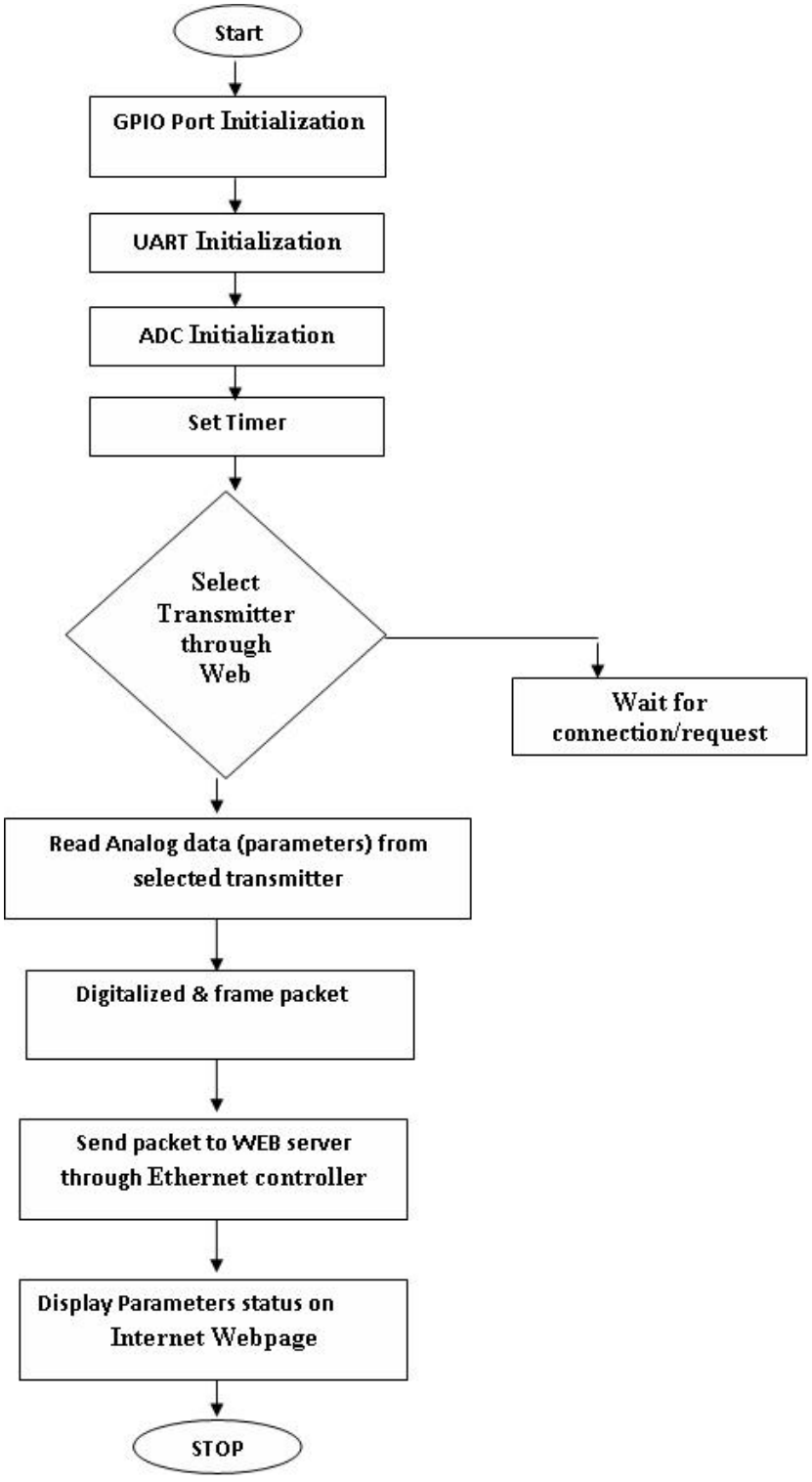

Fig. 9. System software flow diagram.

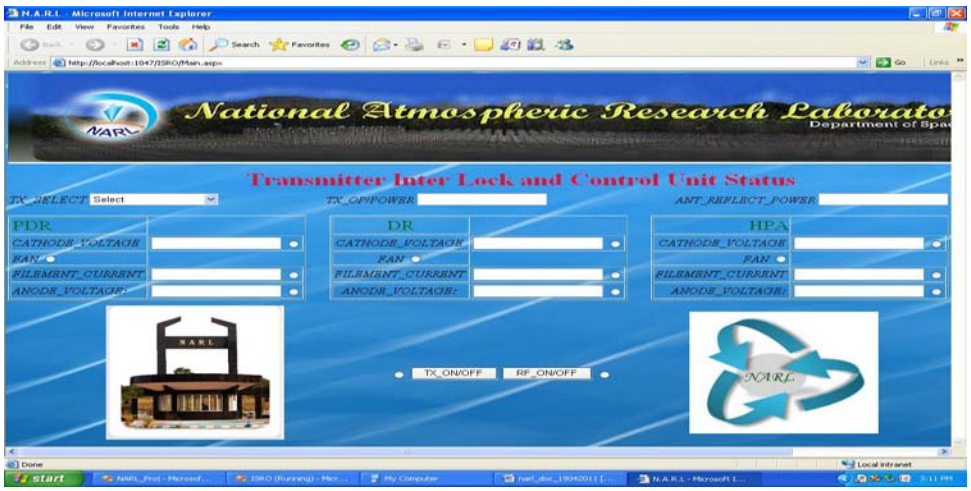

Fig. 10. Webpage snapshot for selection of one transmitter out of 32 transmitters.

6. Conclusions

Remote monitoring and controlling system based on web technology for embedded devices is designed and implemented in this work. The system adapts browser/server mode and realizes the interconnection of the embedded devices like ARM processor target board. Therefore, remote users can access, control and manage the embedded devices [ARM processor through MST radar transmitter] using a standard web browser over the internet. It has advantages of small size, data logger, system maintenance, longer work time and stable performance. It is applicable to a variety of fields like industrial control and automation, medical instrumentation etc.

Acknowledgement

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BIONATURE 2012

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
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