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# Communications in the Auger Observatory

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**Abstract.** The large coverage area and widely dispersed nature of the 1600 water Cherenkov detectors that form the surface array made a communications system based on radio technology the only economically viable solution for the Pierre Auger observatory. This paper describes the communications system together with the custom digital radio hardware that was necessary to meet the design goals of the project. The reliability of the radio network is of critical importance to the data taking operations of the observatory and the paper also describes the extensive network planning effort that has been undertaken to ensure that radio propagation conditions at the site are well understood.

## 1 Introduction

The Auger observatory data communications system consists of 2 integrated radio networks organised as a 2-layer hierarchy; a high capacity backbone network supports communications from the Fluorescence Detector sites and provides a series of distributed collection points for data from the surface detector wireless LAN network that services the surface detectors directly.

## 2 Backbone network

The backbone network uses a standard 34 Mbps telecommunications architecture based on commercially available microwave point-to-point equipment. Each link supports 16 digital E1 channels; with each channel having a data rate of 2.048 Mbps. These provide high capacity data links for the data coming from the surface array and from the fluorescence detector eye buildings. The 103 km total length of the backbone network terminates at the observatory central buildings located at the western edge of the surface array in the town

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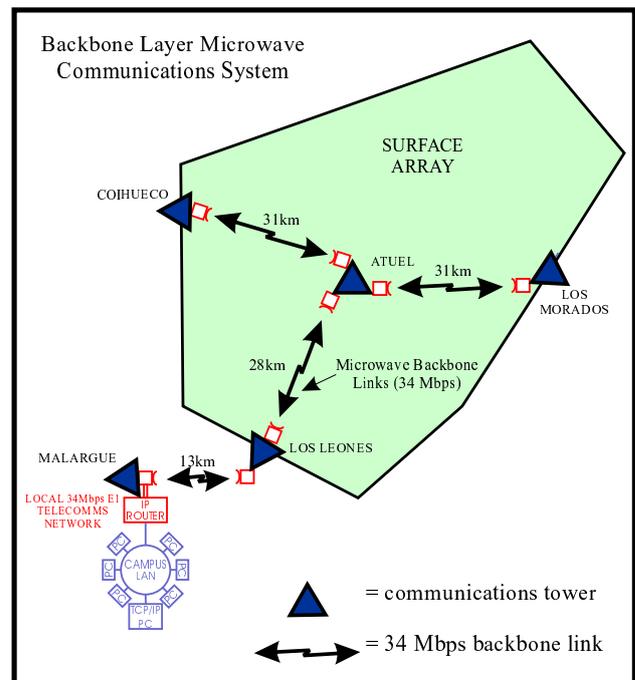(p.d.j.clark@elec-eng.leeds.ac.uk)



**Fig. 1.** The backbone layer communications system

of Malargüe. Fig. 1 shows the backbone links and the positions of the 4 main communications towers within the surface array.

## 3 Surface detector WLAN network

The surface detector wireless LAN network has been especially designed for the Auger project using custom radio hardware running proprietary network access protocols. This network operates in the 902-928 MHz ISM radio band and provides data recovery to and from the 1600 surface detector stations over a 3000 km$^2$ area. Data is concentrated at a small number of telecommunication towers distributed throughout
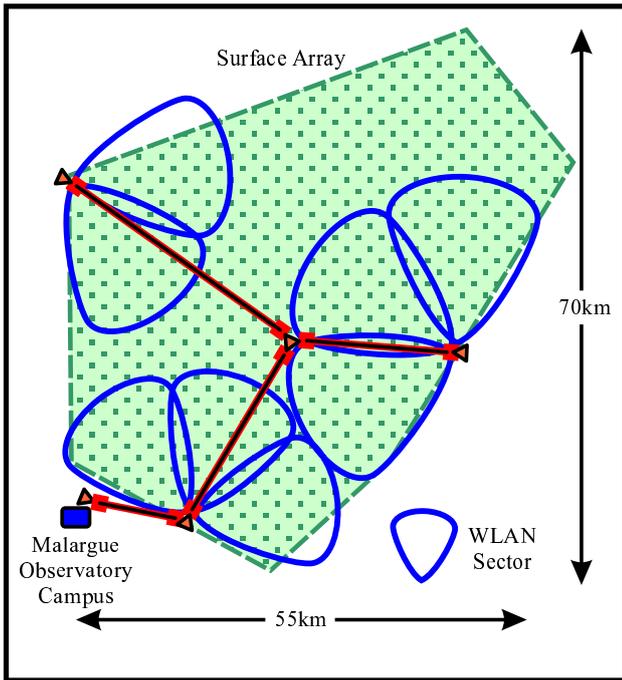
**Fig. 2.** Surface detector WLAN coverage.

the area of the observatory. Fig. 2 illustrates a simplified view of the overlapping base station sectors at each tower. It is planned that the final system will have 28 sectors in total.

## 4 Data path from surface detector to campus

Communication starts at each surface detector at a subscriber unit radio which communicates with the radio network via a directional Yagi type antenna mounted on a short integrated communications mast. Fig. 3 shows a typical tank installation with the Yagi antenna visible above the solar panel.

The antenna transmits data up to 30 km to a local data concentration tower where the signal is received via a high gain cellular base station type panel antenna. Each panel antenna is connected to a base station radio that covers a sector of up to 80 detector tanks.



**Fig. 3.** Surface detector comms mast and antenna installation.



**Fig. 4.** Panel antennas on 41 meter Los Leones comms tower.

A single tower concentrates data from several base stations onto the backbone microwave network for transmission to the central observatory buildings. The backbone system transmits in the 7 GHz band using a low power of 0.1 to 0.5 W. A high system gain is provided by the parabolic antennas used at each end of the link. Fig. 5 shows the microwave equipment fitted to the Malargüe campus tower.

From here, the data passes from the E1 microwave network into the central data acquisition system, CDAS, via TCP/IP running on a conventional Ethernet network.

**Table 1.** Key characteristics of the wireless LAN radios.

| | |
|---|---|
| Operating frequency: | 902-928 MHz |
| Channel spacing: | 500 kHz |
| Channel access method: | TDMA and FHSS |
| Modulation method: | coherent QPSK |
| On-air data rate: | 200 kbps |
| Receiver input for $1\times10^{-6}$ BER: | -101 dBm |
| Transmitter output power: | +27 dBm (500 mW) |

**Fig. 5.** 7 GHz microwave dish on 50 meter Malargüe comms tower.

## 5 Digital radio system hardware development

The need to provide many links over the long distances to the surface detectors, using a minimal amount of power, offered some unique equipment performance challenges that could not be met with existing communications equipment. To fulfill this requirement, a low power custom wireless LAN transceiver has been designed specifically for use at the surface detector sites. Fig. 6 shows the circuit board detail of the transceiver. The key characteristics of this radio transceiver are given in Table 1.

Both the subscriber unit and the corresponding tower mounted base station radios were custom designed for the Pierre Auger observatory and feature a modular, long range, multi-node capability that permits a network of 1600+ nodes to be formed.

The radios use very low power devices and a highly flexible architecture to provide reliable long range digital communications within the strict power budget of the solar powered surface detectors; consuming on average just 0.95 Watts of DC power.

Each surface detector requires a relatively low up-link data rate of 1200 bps, Nitz (1997). This is supplied continuously by the non-blocking data network. A return broadcast downlink of 2400 bps is provided to all detectors for the CDAS system to interrogate individual detectors for full download of interesting cosmic ray events.
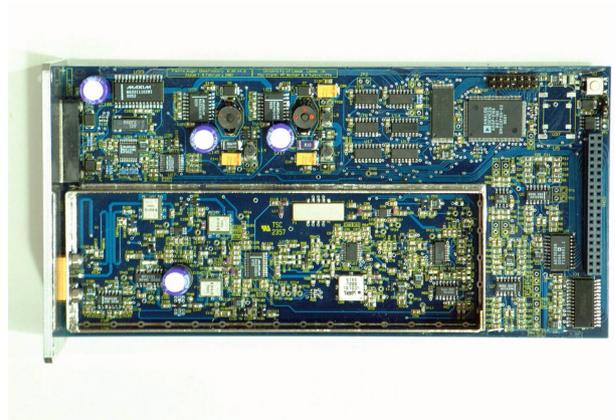


**Fig. 6.** Circuit board detail of subscriber unit radio.

## 6 Radio network planning

A campaign of on-site radio frequency (RF) measurements has been undertaken to gain an in-depth understanding of the expected performance of the radio network, prior to deployment at the site.

This campaign has been augmented by a detailed series of RF propagation modeling exercises. The technique uses standard radio propagation models combined with digital elevation terrain data of the site to produce accurate simulated radio coverage maps of the surface array area. These coverage maps greatly assist in the design of the layout of the final radio network.

Fig.7 gives an example coverage map where multiple transmitters are enabled simultaneously. The various colour bands denote decreasing received signal strength as the range from a given transmitter increases.

The radio coverage maps offer a powerful interactive tool to assist in the planning of the surface array radio network;

– The placement of data concentration towers may be readily optimised.

– Areas of poor coverage may be identified in advance of surface detector deployment. For example, Fig. 8 shows an area of severe radio signal shadowing due to local terrain features close to the Los Morados transmitter at the Eastern edge of the array. Advance knowledge of these problem areas permits alternative coverage plans to be implemented.

– "Best-service" sectors may be identified and assigned, i.e. which tower should a given surface detector use?

– The height of the 1600 surface detector radio masts could be minimised thereby leading to project cost savings.

The accuracy of the radio coverage maps was verified by a series of on-site roving spot measurements and via a long term static radio propagation measurement experiment.

Fig. 9 shows a series of simulated path-loss estimates compared with actual on-site measurements and gives an example
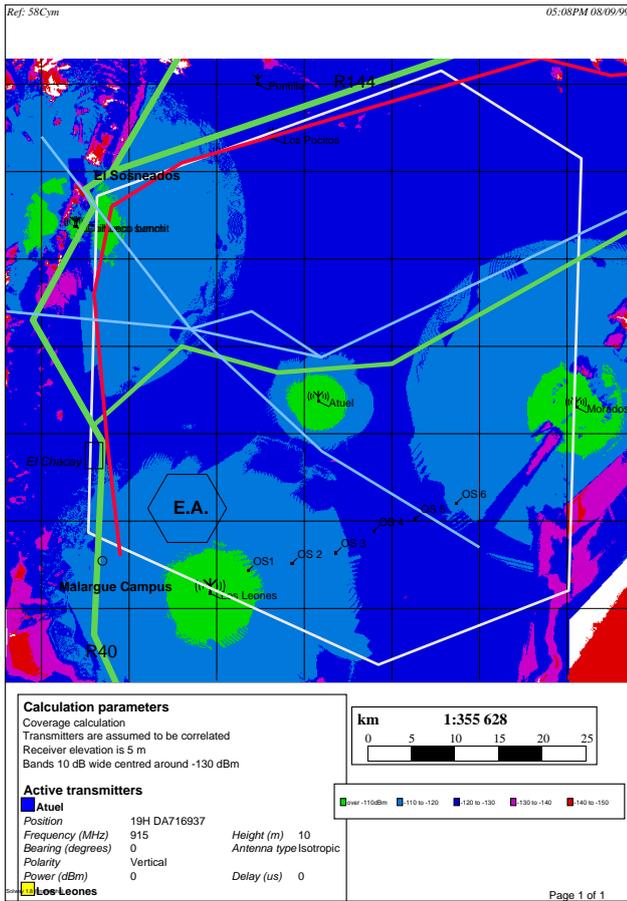
**Fig. 7.** Multi-transmitter radio coverage map of Southern site.



**Fig. 8.** Example of shadowed area revealed by coverage maps.
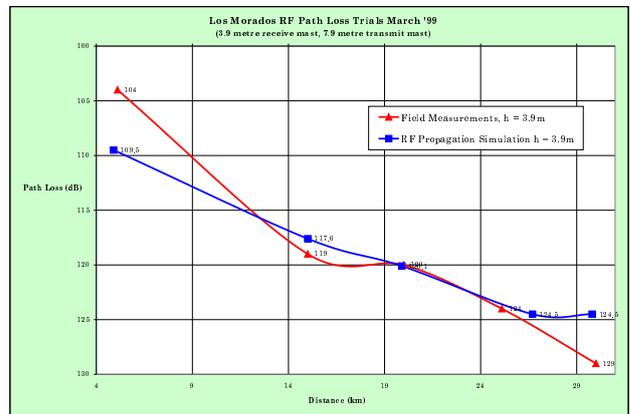


**Fig. 9.** Correlation of radio simulations and measurements.

of the good correlation between the simulated maps and the actual conditions found at the site.

## 7 Determining permitted path loss

It is necessary to implement reliable radio links under the conflicting requirements of providing a high reliability digital data service which is able to operate under variable radio path conditions and is also realised at minimum cost to the project as a whole.

The question arises as to how to establish a realistic baseline performance requirement upon which to base analysis of the propagation maps.

One standard design technique is to adopt an operating point for the permissible on-air uncorrected channel bit error rate (BER), and a standard figure of $1 \times 10^{-6}$ is often used. Note that this figure is for uncorrected on-air bit errors and does not represent the quality of the data delivered to the user, which undergoes additional error detection and correction processing.

The method determines what signal level must be available at the input to the receiver to deliver the designed channel error rate. The difference between this signal level and the average signal level achieve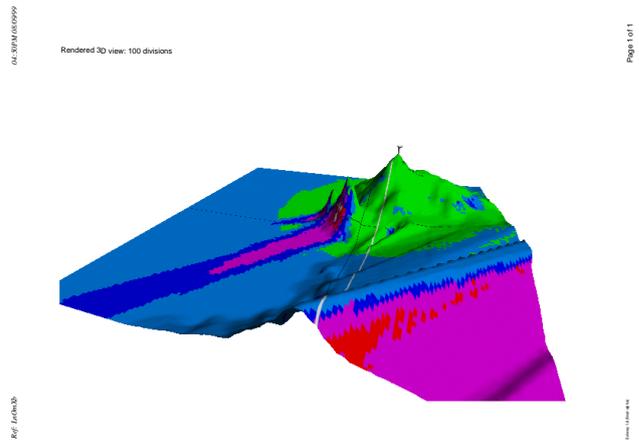d over a particular link is known as the fade margin available on the link. The higher this figure, the more reliable the link will be. In practice a fade margin of 20 dB is suitable for fixed terrestrial links such as those used in the surface array.

Once other parameters, such as the available transmitter power and antennas gains, are factored in a maximum acceptable path loss parameter is derived which may be used to determine the viability of a particular link.

Using figures for the Auger v4.0 wireless LAN transceiver gives 142 dB maximum permissible path loss, a figure that may then be used with the coverage maps in link planning.

## References

Nitz, D. for the Pierre Auger Observatory Collaboration, *Triggering and Data Acquisition Systems for the Auger Observatory*, $X^{th}$ IEEE Real Time Conference, Beaune, France, 1997.

Sklar, B *Digital Communications fundamentals and applications*, Prentice Hall, 1988, ISBN 0-13-212713-X, Chap. 7 pp. 384.