Global Instrumentation Network for Broadband RF Spectrum Monitoring

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Abstract **- The aim of the paper is to present a global instrumentation network designed and implemented to perform the broadband RF spectrum monitoring. Instruments such as RF receivers/analyzers, CTCSS tone decoders, antenna switching systems, azimuth and polarization controllers, and IP audio communicators, part of them designed and implemented by the authors, materialize the network nodes that corresponds to different ANACOM's spectrum monitoring centers located at Portuguese islands and continental Portugal. The remote control, analysis and data logging software fully developed in LabVIEW assures a high degree of integration of different functionalities, transparency and reliability.**

I. INTRODUCTION

ANACOM, National Authority for Communications, is the Portuguese organization in charge of monitoring and controlling the RF spectrum in Portugal. For that purpose, ANACOM has spectrum monitoring and control centers (SMCCs) not only in continental Portugal but also in Azores and Madeira. For logistic and efficiency increase reasons, a global instrumentation network connecting the different ANACOM centers was proposed and its implementation has been an interesting challenge to the authors. An important component of the development of the instrumentation network is related to the hardware interfaces that assure the integration of different SMCCs instruments in ANACOM's global RF monitoring network.

Starting with the Azores SMCC, which was elected as the prototype node, the collaboration between Instituto de Telecomunicações and ANACOM went on and automation and integration of other SMCCs was carried.

The following paragraph presents the hardware and software of the implemented instrumentation network. Additionally, are reported the design and implementation of the antenna control (switching, polarization control and azimuth control), of a CTCSS decoder and of a smart interface for local control of different instruments based on a touch panel unit.

II. INSTRUMENTATION NETWORK ARCHITECTURE

To implement a global instrumentation network to connect specific instruments from different SMCCs both hardware and software aspects must be carefully considered. Thus, the first thing to do was to assess the performance of the existing equipment from both those points of view. Considering that instrumentation limitations such as no communication interface and no remote control software can affect the performance of monitoring tasks, additional hardware and software was designed and implemented [1] [2]. Based on hardware that can be connected in a network the proposed and implemented architecture is presented in Fig. 1.

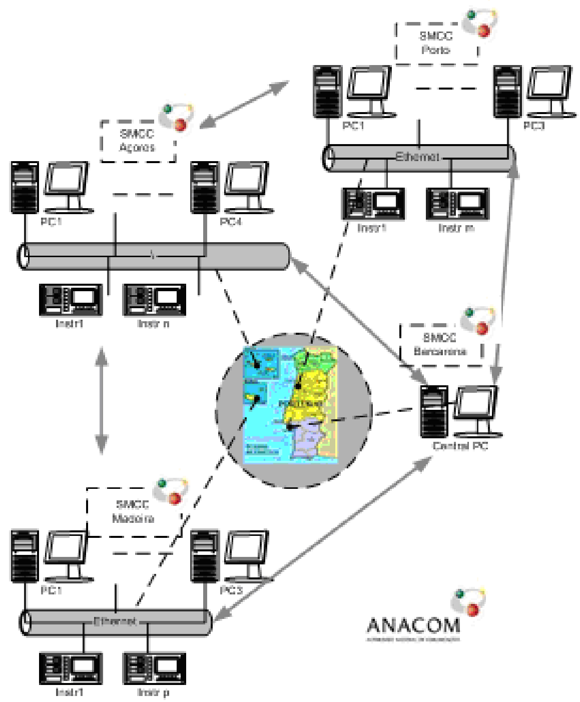

Fig. 1 ANACOM Global Instrumentation Network Architecture

As can be observed in Fig.1, the used protocol for the implemented network was Ethernet taking into account that the ANACOM centers were already networked using that protocol. Considering that a high degree of reliability of the instrumentation network is required, the possibility to develop RF monitoring tasks using equipments from other SMCCs during critical situations associated with one or more centers (e.g. instruments failure in the local center, no operational personnel in one SMCC for a given time interval) imposes the design and implementation of a system where the instruments of a SMCC (e.g. instr1…., inst n) are connected to the network and can be directly accessed by remote computers without intermediary local computer usage. For logistic and operative reasons, the Ethernet capable instruments of the ANACOM centers are organized in operational positions ($OperPOS_J$) according to the specific RF monitoring activity (e.g. RF measurements: offset frequency, modulation index; radiogoniometry). Each position includes two human-machine interfaces (HMIs) materialized by a PC for instrument control and a touch screen used for antenna control. Referring to hardware design and implementation, an important part of the work was to assure its compatibility with the network protocol and secondary was to include new functionalities such as antenna control (switching, polarization and azimuth control) and IP audio communication associated with RF audio emission monitoring tasks. The software it is installed in all PCs and presents the similar user interface for different kind of controlled instruments using the virtual instrumentation principle “multiple instruments – one software interface”.

In the following paragraphs will be described authors’ contribution to the hardware setup and also the developed software regarding the implemented functionalities. Additionally, embedded software was developed using LabVIEW Touchscreen toolkit.

III. INSTRUMENTATION NETWORK HARDWARE

To implement distributed instrumentation working under remote control, the interfacing capabilities of the existing instruments was investigated. Meanwhile, and because some instrumentation limitations that affected the performance of operators were detected, the equipment was complemented with interfacing blocks developed using microcontroller interfacing cards [1] (e.g based on PIC16F74 - RS232 compatible) and/or using RS232 – Ethernet bridges. Several implementations were already reported [2,3] and new ones more recently concluded, namely: a CTCSS decoder characterized by Ethernet interface, a polarization antenna controller, 4×RS232 to Ethernet interfacing modules, a smart interface for local operation of the antenna controllers such as R&S HSRV azimuth controller, an IT-GB016 polarization controller and an antenna switching system from DowKey. The smart interface permits to monitor the CTCSS detected frequencies received through communication with the CTCSS decoder.

In the following paragraphs are presented elements related to the operational positions of the SMCCs as part of the spectrum monitoring distributed system.

A. ANTENNA CONTROL ARCHITECTURE

In order to integrate the RF monitoring functionalities of different RS232 or Ethernet capable receivers assuring flexible operation from different instrumentation network locations, fully antenna control is mandatory. In the ANACOM Azores center were develop a set of HMIs (4 units) that assures antenna remote switching through the control of a set of RF relays using 24V digital signals. The implemented HMI for antenna control permits to locally visualize the switched antenna and he controller has an RS232 interface. The Ethernet compatibility of the developed controller is assured with the utilization on each position of an NI ENET-RS232/4 server that provides RS232 – Ethernet fully transparency. Taking into account that the SMCCs of Madeira and Porto have a large number of antennas (e.g. 14 antennas) characterized by different polarizations, the decision was to use a set of antenna switching systems from DowKey (DowKey 4201-20-ENET). The architecture of the antenna control units including switching system, azimuth controllers and antenna polarization controller are presented in Fig.2.

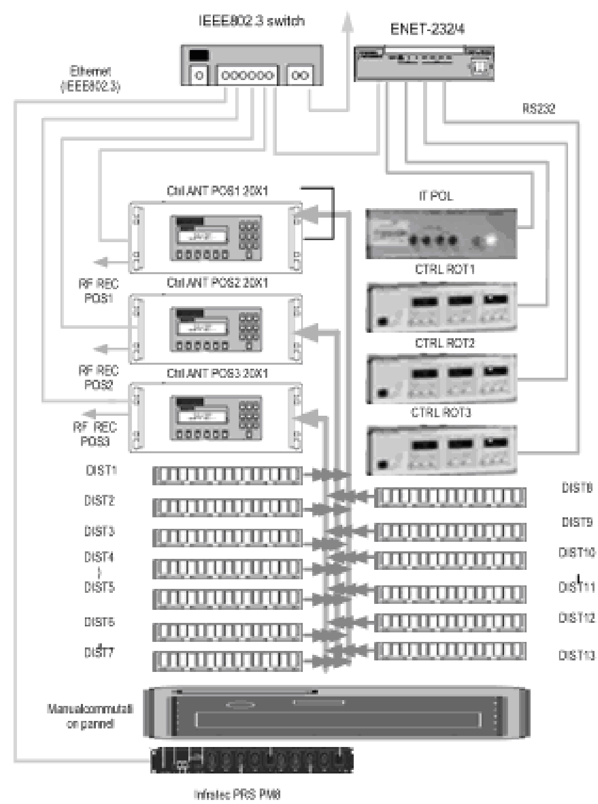

Fig. 2 Antenna control architecture based on Dow-Key 4201-20-ENET antenna control

The antenna switching control can be performed remotely from a PCs or by smart interfaces based on NI TPC2006 of the SMCCs.

Infratec 230V Ethernet compatible modules are included in the antenna control position of the ANACOM centers for remote on/off switching of the position equipments.

B. CTCSS DECODER

RF spread spectrum monitoring tasks, such as spectrum scanning with audio monitoring, digital scanning and RF emissions measurements, are performed using the RF receivers of the operational positions. The receivers used, R&S EK890, R&S ESVN40, and R&S ESMB are connected to the instrumentation network. Tasks such as CTCSS tone decoding can not be done by the operational position receivers. CTCSS tone decoder architecture with Ethernet interface was developed by the IT team and uses a multiprocessor architecture that is presented in Fig.3.

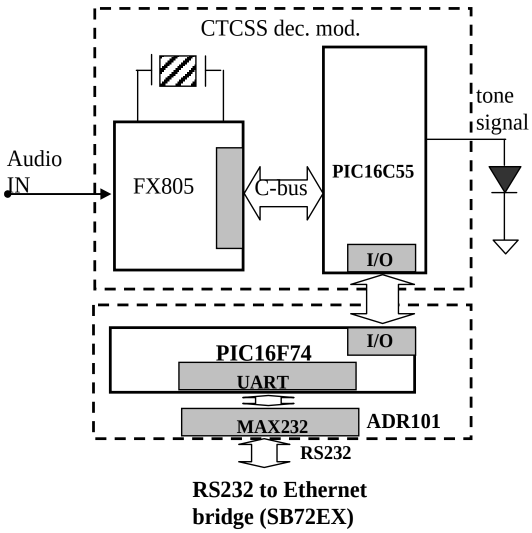

Fig. 3 Multiprocessor CTCSS tone decoding block diagram

The audio signal provided by the RF receivers is applied to the audio input of the CTCSS decoder based on the FX805 sub-audio signaling processor and PIC16C55 microcontroller. The detected tone is signalized using LEDs and is connected to one of digital output of the decoder module. During operation, 8 bit binary words are generated by the decoding module through an I/O port. The binary values are read by PA digital port of remote control interface ADR101 that is based on PIC16F74. The Ethernet compatibility is assured by the SB72EX RS232-to-Ethernet bridge from Netburner that can be configured (9600bps, 8 data bits, 1 stop bits, no parity) using a configuration web page.

III. INSTRUMENTATION NETWORK SOFTWARE

The instrumentation network software was fully developed in LabVIEW [4] and assures a global semi-automatic or/and automatic operational position control. The implemented graphical user interface for the particular case of ANACOM Porto center is shown in Fig. 4. The operational positions are represented using *text&pic ring* LabVIEW objects that permit to the user the visualization including the names of the instruments connected in a particular operational position.

A. *OPERATIONAL POSITION SOFTWARE*

Remote operation for one or multiple operational positions can be carried out using the position selectors and the RUN POS button. The operational position user interface appear as a pop-up window and includes the controls for all the instruments of the selected position as well as the control of the equipments related to the antenna switching, antenna polarization control and antenna azimuth control (Fig. 5).

Fig. 4 Graphical user interface for SMCC's operational position control (ANACOM Porto Center case)

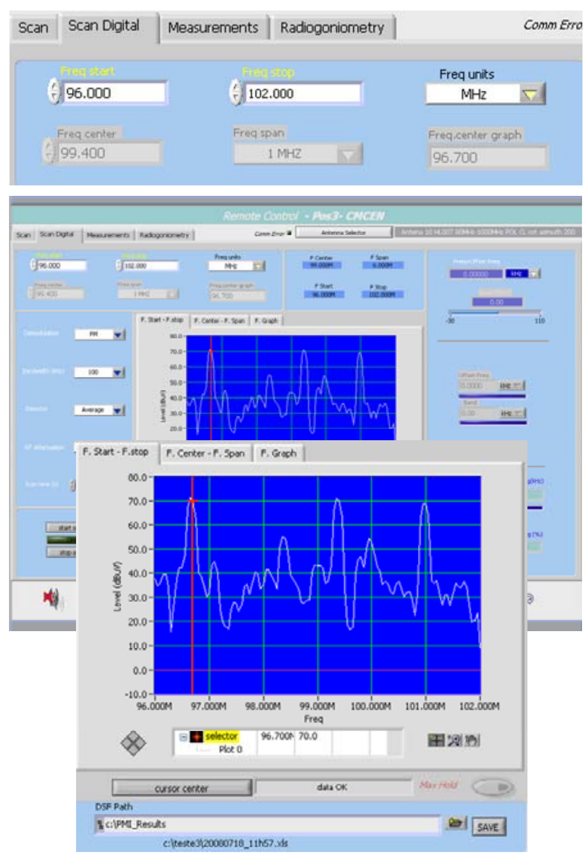

Fig. 5 Front panel of the operational position software ($POS3_{oper}$ ANACOM Porto Center)

Different LabVIEW *tab* objects assure the optimal organization of the user interface permitting the selection of different operating modes for the RF receiver according to the selected tasks. In Fig. 5 the digital scanning of the RF emissions for an imposed $f_{min} \div f_{max}$ band is selected. This kind of RF scanning is selected when a RF spectrum occupation testing must be carried out. For different tests, additional frequency band selection, such as f_{center}, f_{span} and f_{graph}, f_{span} is available. RF receiver configuration parameters can be selected using the digital controls associated with different tabs. RF receiver independent setting, such as antenna selection, selected antenna azimuth, and selected antenna polarization, are performed using the *antenna selector* while receiver audio or power supply on/off switching are performed using the buttons included in the lower part of the user interface. Radiogoniometry tasks are performed joining the capabilities of antenna rotor controlled and an RF receiver. The implemented user interface for a radiogoniometry testing system is presented in Fig.6.

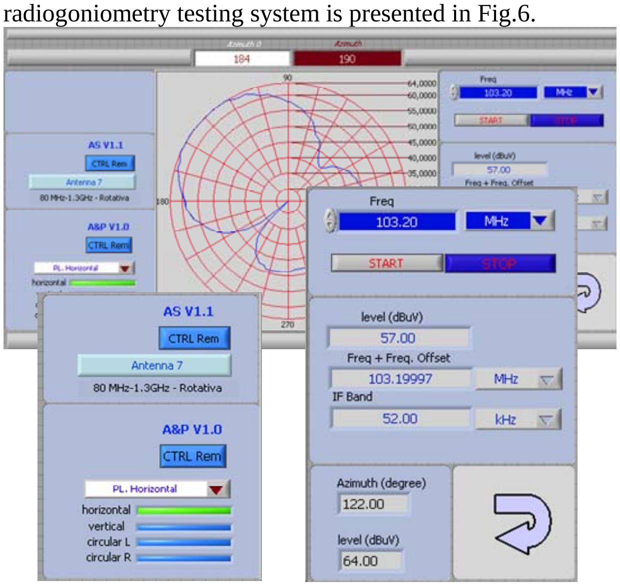

Fig. 6 Radiogoniometry software user interface

Referring to the CTCSS tone decoder, a software component was embedded on the RF emission measurement component of the software implemented for the operational positions. The software permits to view the emission frequency and the tone frequency as well as elements of tone occupancy. The software permits also to visualize the CTCSS tone occurrence for an imposed monitoring period.

B. HMI EMBEDDED SOFTWARE

The local control of antennas from an operator at an SMCC position during the utilization of receivers hardware interface was considered with the inclusion of an HMI smart interface based on NI TPC-2006. The interface is characterized by a touch panel and is programmed using LabVIEW Touch Panel module. Several tabs of the graphical user interface permit to select the following functionalities: a) WinCE password; b) antenna selection; c) antenna azimuth control; d) antenna polarization control; e) CTCSS tone monitor. The implemented user interface for the touch screen embedded software is presented in Fig. 7.

Fig. 7 Antenna azimuth control *tab* of the embedded software for touch screen interface

From Fig. 7, the azimuth angle setting is based on the utilization of numeric (0 to 9) and functional (C, GO, START) buttons. A possible error in the communication between the touch screen module and the controlled antenna selector is signaled through two LEDs: green LED – no error, red LED – error.

IV. CONCLUSION

The implementation of a global instrumentation network that permits automatic and semi-automatic control of the instruments used to monitor and control the RF spectrum in ANACOM centers of Azores, Madeira and Porto represents an important part of the project. Such network including the above mentioned SMCCs and future remote stations simplifies and enhances the tasks of ANACOM as the national authority in charge of the spectrum control. As main realizations of the project until now can be underlined the design and implementation of antenna controllers, interfacing units and CTCSS tone decoders. Different versions of the instrumentation network software was developed during the last years with good results making possible the fully control of the three network nodes from the ANACOM Barcarena Center.

IV. REFERENCES

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