Simulcast digital mobile radio networks

Version 2v3

Radio Activity S.r.l.

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Summary

INTRODUCTION ON DMR MULTISITE SYSTEM

ABOUT RADIO ACTIVITY

Radio Activity is a young and dynamic electronic engineering company specialized on design and production of wired and wireless communication equipments and systems.

The engineering team has completed more than 20 years of experience in RF, DSP and networking at major telecommunications companies. Radio Activity has developed advanced techniques for analog and digital simulcast mobile radio networks and numerous products for data transmission and communications management.

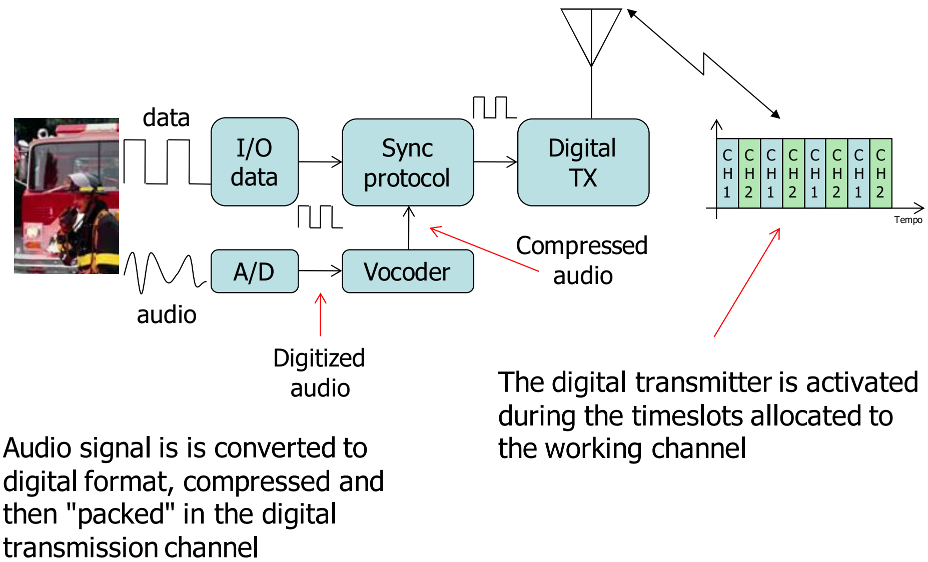
Radio Activity is a node of a network of excellence’s partners. The research and the development carried out inside the Company involves Radio Frequency, Digital Signal Processing and IP networking fields. The Company, taking advantage of external professionals of highest level with multidisciplinary skills, is able to create, each time, work groups in order to solve the most complex projects and to satisfy the most demanding Customer’s requirement. The result is a flexible and light structure, to reduce the fixed costs and to allow to always take advantage of the best available technology.

Radio Activity in few years has furnished more than 1500 base stations for emergency and essential services applications to a number of important Customers: Agip, Wind, Enel, Edison, Fire Brigades, Police, Motorways, Railway, Civil Protection, Rätia Energie AG, RWE, etc...

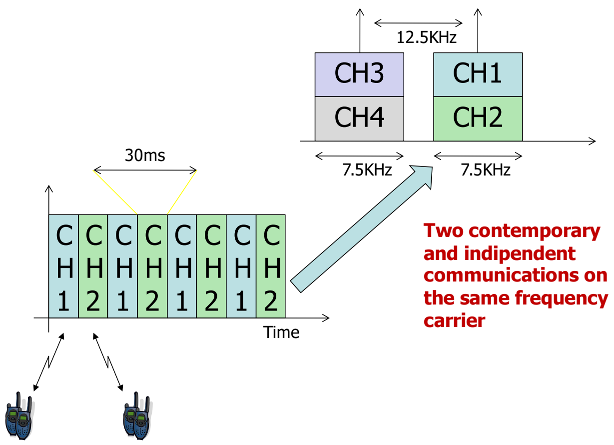
DIGITAL MOBILE RADIO (DMR) IN BRIEF

DMR standard (ETSI TS 102 361/2/3) has been defined in ETSI environment, by a working group composed by main PMR equipment manufacturers worldwide.

Digital Mobile Radio is able to give “added value” to current analog systems and at the same time it grants a gradual migration between the two technologies, safeguarding investments and specific existing operational requirements. DMR system can coexist with conventional analog systems on adjacent channels, without any performance loss of each of systems.



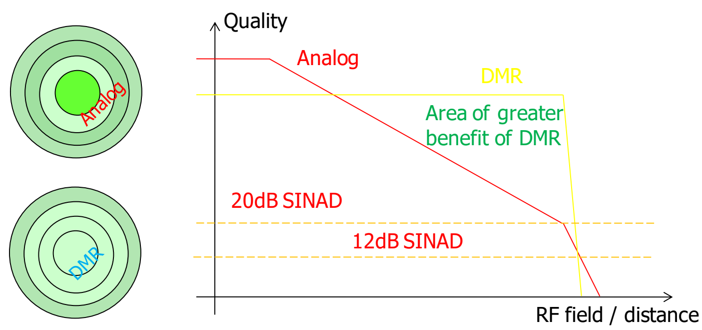
Frequency modulation has constant envelope (unlike the TETRA which does not have a constant envelope). Transmitters are very similar to their traditional analog version, because expensive linearization techniques are not needed: they can work in saturation (clipping) mode (C class o superior) with very low consumption => solar panels can be used.



DMR standard performs the transportation of both data and voice. Audio signal is converted into digital format, compressed, “packed” into digital transportation channel, differently “marked” than the data digital signal.

Audio/data channels are managed with two TDMA (Time Division Multiple Access) timeslots sharing the same radio 12.5 KHz wide channel. The two audio/data channel are perfectly separated and independent each from the other, as if they worked in a conventional mode on different frequency (carriers). The transmitter becomes active only during timeslots belonging to their working channel.

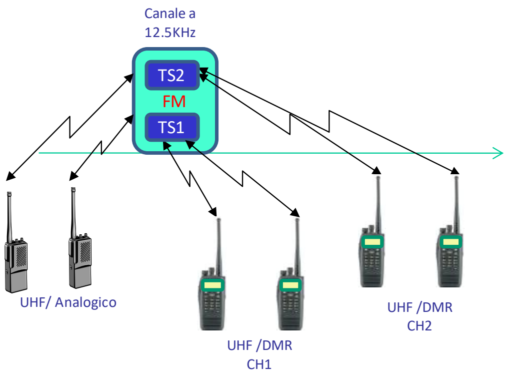
DMR system can live together with conventional analog systems on adjacent channels without any performance degradation for both ones. DMR system has a spectral efficiency of 1CH/6.25KHz, the same as TETRA and double in comparison with conventional systems.



Only one radio head (only one transmitter) gives 2 CH without the need of RF coupling systems, with the effect of lower costs and consumptions and greater available power. Furthermore, DMR system allows the direct communications between terminals. In this case only one channel per 12.5KHz will be available because the synchronization is missing, made by repeater/network.

The sensitivity of a DMR receiver is about the same as the one of a traditional analog system, but the audio quality remain constant up to the sensitivity limit and the coverage is slightly bigger than 12.5 KHz analog systems.

DMR terminals can work in “open channel” mode like traditional systems for emergencies, but individual calls and group calls are available: obviously selective callings are addressed in a digital format between DMR equipment. Network access of DMR terminals is regulated by a “colour code” which replaces sub-tone sub-audio tone.



The Radio Activity base stations are “**multi-protocol**” analog/digital with the automatic switch between the analog/DMR services. This reduces the migration impact: the old analog terminals may operate with the new digital one through the same network.

When an analog terminal accesses to the network, the other analog terminals listen him (obvious) and also the DRM terminals can listen the communication in the analog mode channel. For inter-operability Analog/DMR, it is necessary to set a sub-audio tones squelch on the receiver of the terminals (it stops the noise in case of DMR signaling into the analog receivers).

When a DMR terminal accesses the network using the Slot 1 or 2, the other DMR terminals can hear him and the analog terminals don't listen noise. Our network/repeater switches automatically DMR/Analog mode according to the terminal access mode.

We suggest to set-up the DMR terminals with scanning functions on two channels with the same frequency but one as analog and the other as DMR. In this case both analog and DMR incoming communications are listened.

The DMR terminals may implement a GPS based positioning system. The channel resources of the network could be used both to carry out voice and GPS positioning data. For best overall performance it is suggestible to use one channel (timeslot_1) for dispatching voice and the second (timeslot_2) for GPS positioning and for sporadic telephone communication.

The DMR standard allow many features for the user:

- to make a private (user to user) or a group (user to multi-user) or an "all call" (all user involved) or an emergency communication
- to assign more than 16 millions of terminal identification addresses
- to compose more than 16 millions of terminal groups
- to send/receive text messages or "raw data" for telemetry applications
- to send positioning data automatically
- to be included in a running communication (late entry)
- to identify the ID source and ID destination of any communication
- to encrypt audio and data
- and a lot more …

To differentiate adjacent networks operating on the same frequency it is required a color code access key that could be viewed similar to the sub-audio tone coded squelch used in analog.

Radio Activity tested successfully the DMR protocol compatibility with Motorola Mototrbo™ terminals.

To learn more about DMR standard we suggest to see:

- the latest edition of ETSI documents:
  - **ETSI TS 102 361-1: the DMR air interface protocol**
  - **ETSI TS 102 361-2: the DMR voice and generic services and facilities**
  - **ETSI TS 102 361-3: the DMR data protocol**
  - **ETSI TS 102 361-4: the DMR Trunking protocol**
  - **ETSI TR 102 398: DMR General System Design**
- the latest edition of the documents on **Radio Activity** web site:
  - ENV1 - DMR overview
  - ENB20 - DMR repeater

- ENB23 - DMR FAQs
- ENB26 - DMR vs TETRA comparison
- ENB29 - Alarm Messages
- ENB33 - Soft diversity reception

∞ The "white papers" on the web site of the **DMR Association**.

MULTISITE DMR SYSTEMS – MULTICAST/SIMULCAST

The digital mobile radio (DMR) standard appears very attractive for the professional mobile radio applications. It is a powerful digital solution that meets the major needs of users: digital encryption, good and constant audio quality, reliable data, GPS positioning without any disturb in audio, text messaging, telemetry, two TDMA channels in 12.5KHz (6.25KHz/ch equivalent), soft migration from analog to digital, low power consumption, etc..

DMR has all the advantages of a digital radio at the cost of an analog (conventional) one. These benefits may be partially missed when the coverage requested by the radio system exceeds one repeater. Some "key points" have to be understood to design an affordable, stable and user-friendly radio system.

The multisite system approach allows a radio to be in coverage area changing position and to participate in a call originating at any site. In multisite system configuration, repeaters communicate among themselves using a back-end network. A call originating at a repeater is transmitted by all the repeaters of the system.

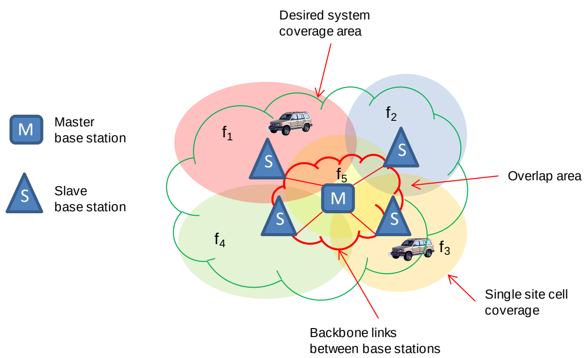
Currently (2010) there isn't any manufacturer able to supply a DMR trunking system following the ETSI standard. The solutions available to cover a wide area with more than one repeater may be multicast or simulcast.

To learn more about DMR multisite solutions we suggest to see:

∞ the latest edition of the documents on **Radio Activity** web site:

- ENB25 - DMR multisite sys design
- ENV2 - TCP-IP simulcast

MULTISITE MULTI FREQUENCY APPROACH



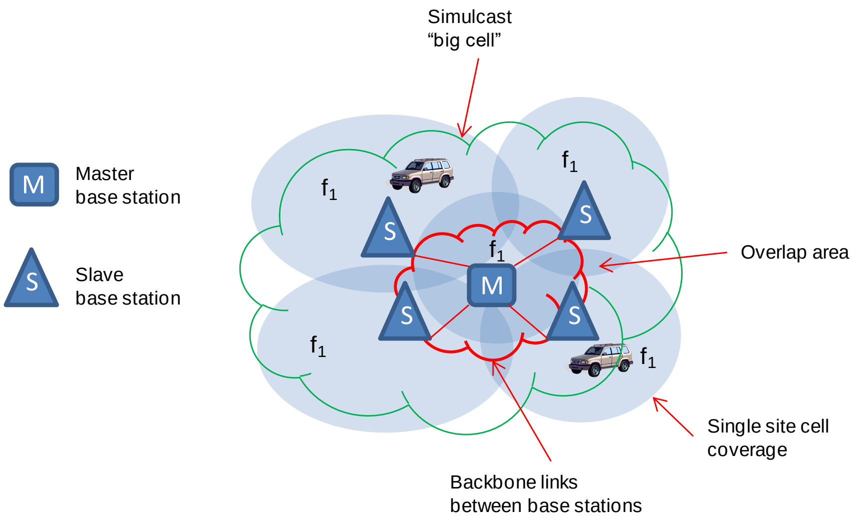
In multicast approach, the geographically adjacent repeaters should use different frequencies. Their color code can be either same or different. It is not advisable to keep the same frequencies because in areas of overlap, without special precautions (see simulcast paragraph), there will be destructive interference.

The main problem is the cell <u>handover</u> (site coverage changing) and <u>roaming</u> (research of desired group of users) in non trunking systems. These functions are not real time performed by DMR (tier II non trunking) over the air protocol: the available mobiles/portables should scan frequencies to look at the best “home” base station. Due to the scanning and validation time during handover, a mobile may be “missed” for relative long time (minutes). This problem may be unacceptable in an urban environment in which the cells are changed frequently.

MULTISITE SIMULCAST APPROACH

A robust and powerful solution that removes all multi-site limitations is to implement a single “big cell” with the same frequency over all the coverage area: this reduce to zero the time requested to reach a mobile or to find the correct base station. Simulcast solution permits the “click-less“ base station changing during a communication also.

A simulcast radio network is a very powerful radio network in which all the repeaters are active on the same frequency and at the same time. To obtain this result it is necessary to implement a number of algorithms to assure perfect alignment between the signals broadcasted by different base stations.



Main advantages:

- No terminal scanning needed;
- Automatic and continuous roaming and hand-over => Easy to use, fast set-up time;
- Functioning like single “big repeater” => automatic and simple conference call operation;
- All stations directly connected to the network => Integrated communication sys;
- The same RF channel over all Network => no change of channel in the coverage area;
- Maximum spectral efficiency due to use the same frequency in the overlap area.

The simulcast solution is the best in case of emergency due to easy and fast “open channel” mode of operation:

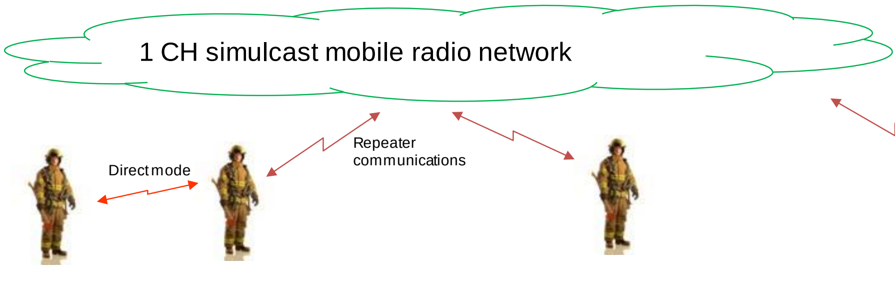
- all people involved in emergency situations can listen all communications so they are continuously informed about the critical situations;
- the regulation of network access is made by user, absolutely more intelligent and efficient than a trunking SW logic.

The coverage area of every single simulcast channel could be expanded easily by adding some simulcast base stations. These simulcast base stations will be integrated in the network with few operations at network level only (nothing is requested on mobile terminals).

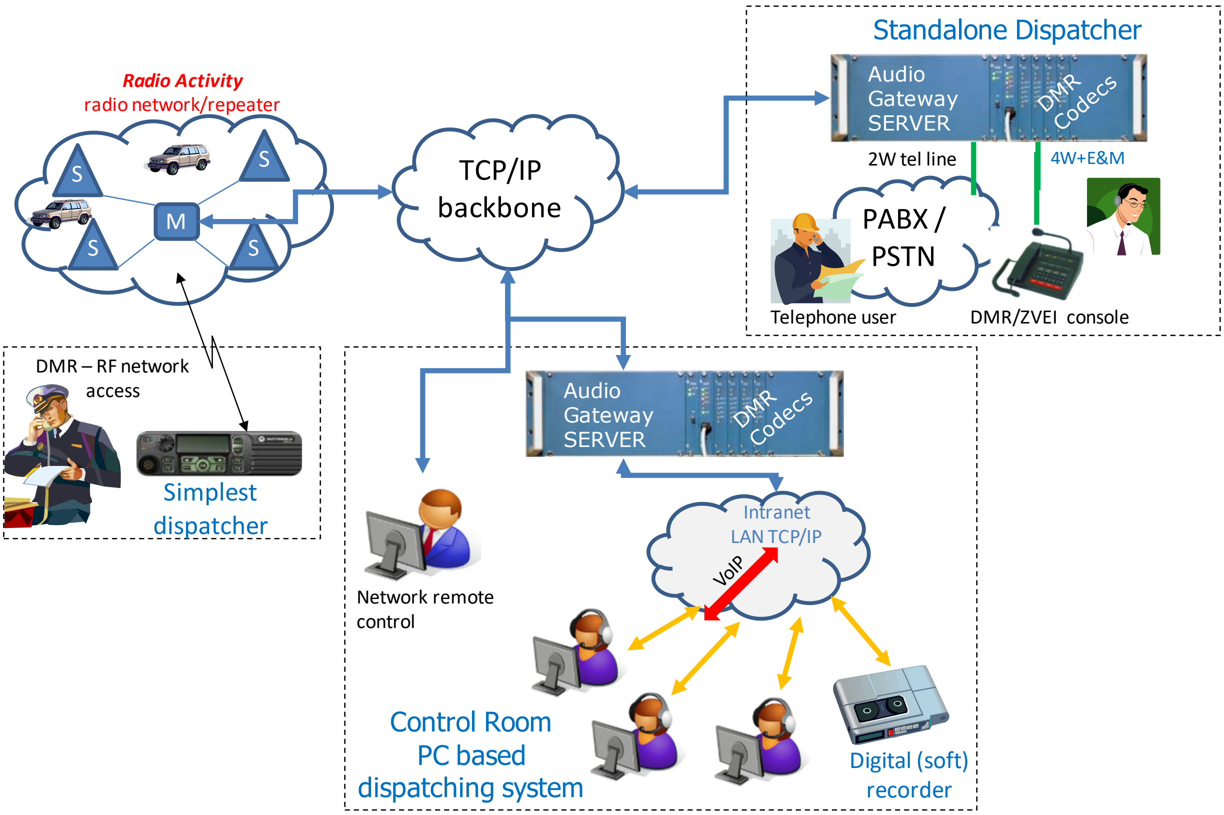
<u>**The simulcast network removes the need of scan on mobiles and portables, assures real time roaming and hand over during the call and reduces license costs.**</u>

The communications (private or group type) inside the mobile radio system may be:

- mobile to mobile in direct mode (short range). Normally they operate in the output frequency of the network so they can speech among them and, at the same time, they can listen the communications coming from the network
- mobile to mobile in repeater mode (long range). The mobile equipments use a frequency to access the network and a second frequency to listen the communications coming from the network (semi-duplex). The network is equal to a single "big" repeater.
- mobile to dispatcher in repeater mode. The communications are in semi-duplex mode as the previous case. The dispatcher has the priority in the communication. All the communications from the mobile and from the dispatcher could be listen by all equipments.
- mobile to dispatcher in private mode. It is the same of previous case but the communications from the mobile could are listen only by dispatcher.
- mobile to telephone line in group or private mode. It is possible from a mobile to perform or receive a telephone call from a PABX or a PSTN line (it needed the RA-TI-XX option).



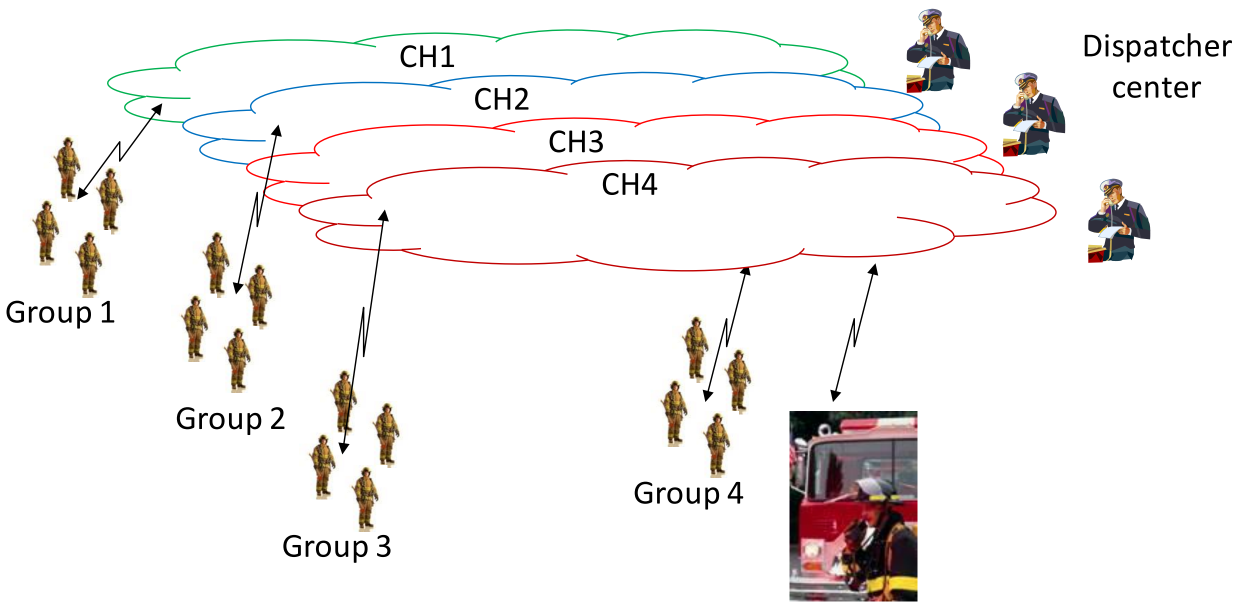
The network has its natural termination in the Control Room/Dispatch Center where all communications are managed. A Dispatch Center can be connected directly to the network through an Audio Gateway or can be connected through a radio path using fixed radio station. Many solutions are available depending on IP availability, cost and needs of the user. The following figure explains some application examples.



SIMULCAST SOLUTION -> EXPANDABILITY

Every channel of the system is independent from the other channel. The communications in one channel can be transfer to another channel only by a junction at master/Central Office level.

A system with N channel is the easy overlap of N separated simulcast networks. Note that a channel may be a single frequency (analog) or ½ of frequency (digital DMR). The following drawing explain this concept:



Every group of users communicate in exclusive mode in the own channel. In every channel can operate more than 1 group but, normally, they should have similar operative functions.

Every new simulcast channel can be added (with the necessary RF branching operations) without modify the other existing channels and without service interruptions.

There are virtually no limits in the number of channels of a system, the problem could be the branching system and the number of antennas required on sites.

The area of coverage of every single simulcast channel could be expand easily by adding some simulcast base stations. These simulcast base stations will be integrated in the network with few operations at network level only (nothing is request on mobile terminals).

FORGET THE PAST EXPERIENCES OF TROUBLE SIMULCAST

The simulcast networks are not very popular in the entire world due to the difficulty in achieving the right level of matching in the base stations. A lot of system integrators tried to assemble simulcast network from conventional repeaters adding synchronizer and (analog) delay line. The result was often a network with a lot of difficulties during set-up operations, with frequent and onerous maintenance operations, and, at the end, with low customer satisfaction.

In Italy, like other countries, the geographical constitution and other factors forced the constructors and the system integrators to find good simulcast solution. The revolution in simulcast performances was built in the 90' with the use of Digital Signal Processor (DSP) devices directly inserted in the analog base station. The performances of the network were so good that the most part of professional mobile radio networks in Italy are simulcast one!

The latest challenge is digital simulcast network. Starting from analog experiences, Radio Activity modified its DSP based software radio, to perform DMR protocol. All development was done to achieve optimum performance of digital simulcast and the field confirms this design. Sophisticated algorithms recover accurate sync (time and frequency), allowing (automatically) for adjustments of the delays and the alignment of the Protocol to achieve emissions at the bit accuracy. DSP includes the real time voting system and the network base station control layer.

The digital communications has the advantage respect to the analog one of forward error correction and adaptive filtering functions. These functionalities reduce the amount of bit error rate with a consistent improvement of audio and data quality in the overlap areas.

Digital or analog functioning is automatically selected from the incoming signals modulation to facilitate a smooth transition from analog to digital. A lot of base station configurations permit to realize simulcast networks with various backbone Links: TCP/IP (also wireless one), E1/T1, twisted wires, narrowband radiofrequency link, and mixed also.

All necessary functions (synchronism, voting, VoIP, remote control, network management, call control, etc.) are integrated in the base station without the need of external expensive and tedious to cabling devices.

The Radio Activity simulcast network is a really "plug and play" solution for professional users.

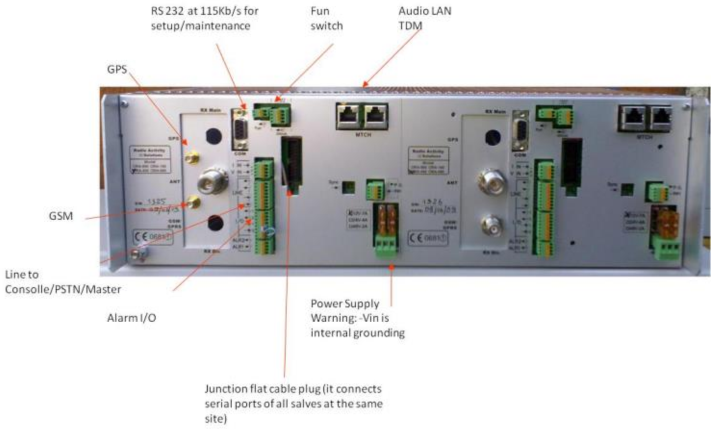
MAIN CARACTERISTICS OF RADIO ACTIVITY SIMULCAST SOLUTIONS

RA-XXX BASE STATIONS FAMILY

The simulcast systems of Radio Activity based on RA-XXX transceivers, use the latest RF hardware, integrated with sophisticated algorithms for the digital processing of the signals. The RA-XXX is designed to maximize the performances in terms of simplicity, flexibility, power consumption, reliability and cost. The base stations are inherently digital and have been designed specifically to achieve simulcast solutions. The strong investment made in the design of equipment, the continuous hardware and software updating and the widespread deployment in the field (**over 1500 installations in Italy and abroad**), guarantees the **highest quality and reliability** of our systems over time. Most critical functions are automatically set-up by the equipments. This fact guarantees a drastic simplification in installation and maintenance operations that require few manual adjustment on the apparatus.

The stations are modular, based on 5 different modular units only (PSM, TX, RX, DSP, I/O), which allow you to make all network and link configurations simply by combining necessary "blocks" and setting their parameters. The transceiver has a **very compact size** allowing two base stations with branching system in a single 19”/3TU standard rack. The power requirements of the RA-XX base station are in the lower level of the category.

Thanks to the **full digital approach**, the group and absolute delay are perfectly aligned. With the help of the **GPS integrated receiver**, the stations are able to equalize automatically phase and amplitude of the analog and digital signals even in the presence of variations in the response of the link. A new algorithm, developed in our laboratories, allows you to automatically equalize the transmission lines even in tunnels or in areas where there is no visibility of the GPS system.



An **GSM/GPRS integrated transceiver** may give an alternative communication way in the case that the main transportation link goes in failure.

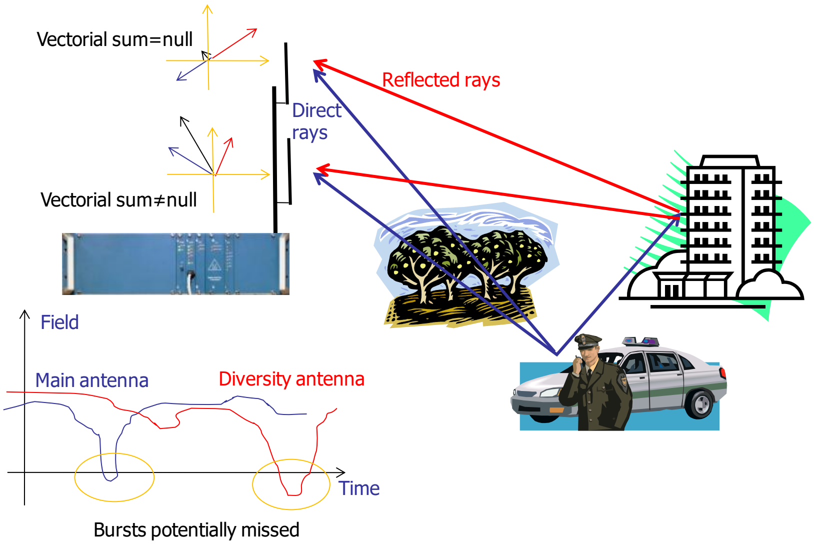
SOFT RADIO TO SOFT DIVERSITY RECEPTION

The transceivers were developed using the technique known as "soft radio" in which the front-end radio is followed by the mo-demodulation processes achieved through algorithms included in Digital Signal Processing (DSP) devices. Radio-electric performances are at the top of the category and meet widely as required by national and international directives.

Thanks to the “soft radio” approach, the receiver system implement a “soft diversity reception” extremely useful in any digital mobile communication system. The soft diversity is a receiving technique based on the vector treatment of the incoming signals. The soft diversity reception gives a number of benefits on the receiver capability of the base station:

- it gives 3 dB more of sensitivity
- it contrasts the multipath fading
- it removes long interruptions in the digital communications
- it reduces the de-sensitivity effect in the repeater placed at high altitude
- it increases significantly the coverage area of a repeater

The diversity algorithms work properly in digital and in analog mode. For analog modulations, the obtained benefit by this technology is significant, but non determining, while for systems with digital modulation, it becomes a crucial requirement, as it is also shown by the standardized use by all digital systems producers (TETRA, GSM, GPRS, etc.).



The full programmability of algorithms allows you to build different solutions not only for transmitting analog signals, but also for data transmission, recovery sync, etc., simply acting on SW, even remotely upgradable. This will help to **save the investment for the future**, because new services or capabilities (switchover to digital system (DMR), special fleet management, access protocols modification,…) can be added at any time.

LINUX CORE

The functions of communication and control of the RA-XXX are demanded to an integrated computer that manages the communications between the external word and the radio part. This processor use the open source operative system LINUX in the “full” version, where were developed all the SW applications for the local and remote control and managing of the radio. This operative system allows to operate on the physical level of the elaboration device giving “stability” of performances difficult to perform in a Windows or proprietary operative systems. Integrating a real computer in the base station allows to easy implement a variety of applications for audio and data communications and for control purpose.

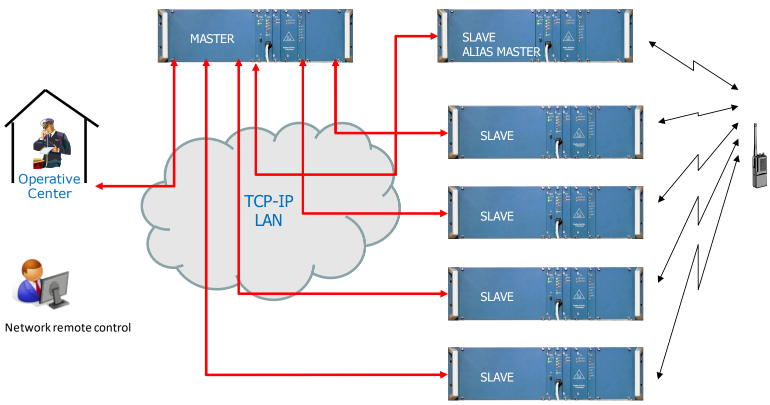
IP NATIVE

The use of LINUX in the “full” version allows a strong flexibility and it is the best solution in every IP based application. Thanks to the LINUX core, the RA-XXX is an “IP native” transceiver target for high level of performance in a distributed elaboration system. The main control and communication interface of the RA-XX is a standard IP Ethernet, one of the most common and cheap in the telecommunications world. The RA-XXX device is seen in the IP network as a peer with an own IP address and with many IP communication ports. Thanks to the “IP native” approach, the bandwidth requirement on the IP backbone is very low due to the packet protocol. Differently from a E1 G703 based solutions that requires constant link presence, each base station sends packets in the backbone in the case of valid signals only. When no traffic is present in the network, the bandwidth used by the base stations goes down to 1Kb/s or less. In a radio system few base stations contemporary may receive an access signal, therefore **the bandwidth requirement is a fraction of the E1 based solution**.

The base station can directly manage a LAN Ethernet 10BT/100TX (auto MDI/MDI-X) on an RJ45 socket or, as option, an Ethernet 100FX on SC-SC socket interface for optical fibre.

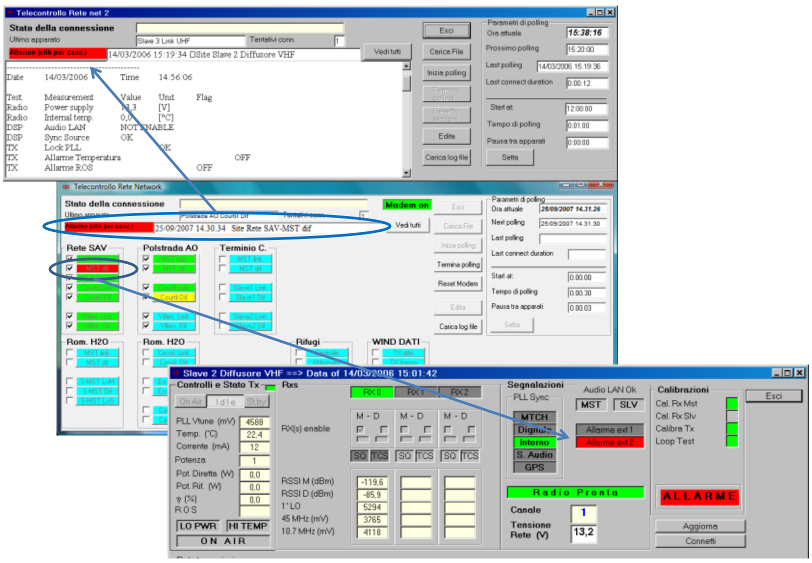
MAXIMUM SYSTEM RESILIENCY AND REDUNDANCY

Thanks to the LINUX powerful engine, the entire radio system is designed to **automatically react to failure situations** and seek the configuration of minimum possible disruption (progressive degradation). The system can integrate an "**Alias Master**" station placed in different position respect to the main Master. The "Alias Master" operate normally as a Slave base station until the Main Master is present in the IP network. When the main Master disappears from the IP network, every base station change the registration to the "Alias Master" automatically restoring the network functionality. The network reacts, depending on events, re-directing the paths of the signals on the transport network, creating sub-autonomous networks, it turns an isolated base station as a simple repeater (local bridge) up to reduce power consumption in the event over temperature.



POWERFUL REMOTE CONTROL

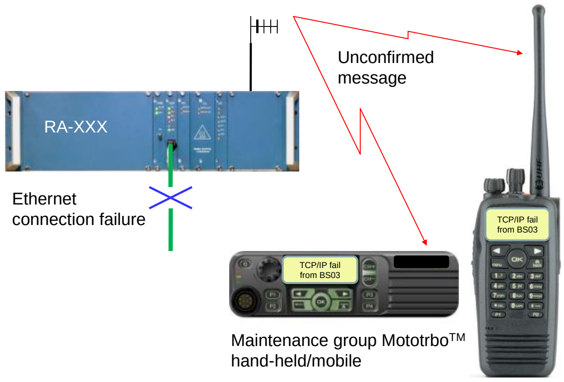
The powerful remote control tools gives a real full control of the base station and of the radio entire system. The features offered by the remote control are extremely large. All the setup (and SW develop tools also!) operations are available from remote. The remote control system, in addition to the classic change of radio parameters and the diagnostic services as audio and RF loop tests, temperature, absorption, etc.: it allows also **full software remote upgradability** (Operating system, LINUX applications, DSP applications and microcontrollers Firmware), IP networking parameters and a great number of useful features. It can use multiple connection routes (Ethernet IP, V.24 serial, internal GSM/GPRS modem, external modem, DMR embedded, …) with back up of each another. Through remote you can change in just a few minutes the structure of the network by creating autonomous sub-networks at the level of a province or even at the level of a single valley, and changing, if required, the



channel operation. This simplifies and speeds up operations for placing into service and maintenance of the network.

DESIGNED TO SIMPLIFY OPERATIONS

Many events, internal or user defined, can be set as alarms via the configuration form of the Base Station. **When an alarm occurs the base station sends automatically a DMR text message** to inform about its state. This new feature is particularly useful because allows the user to receive on his mobile terminal (or on a group of user terminals) short text messages at the occurrence of certain events. So, a continuous monitoring of the Remote Control utility is no more needed: the events will be dispatched in real time, even if the user is kept busy in other activities.



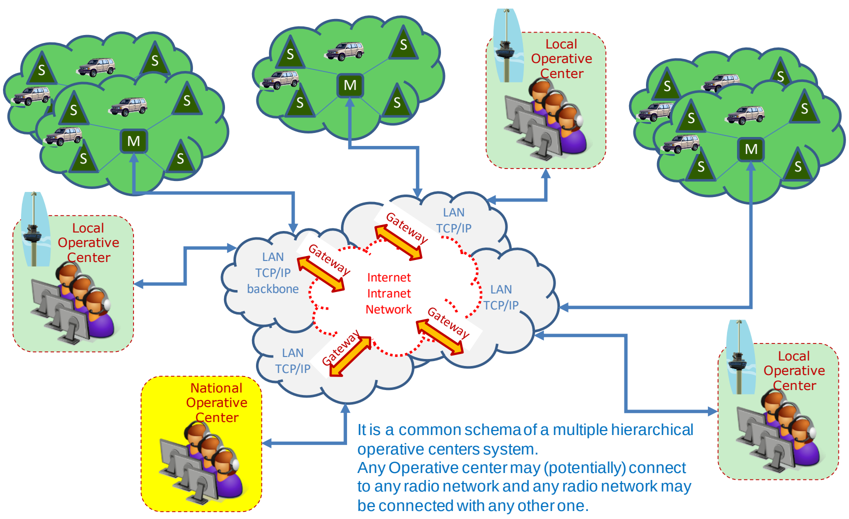
FULL ALGORITHMS INCLUSIVE

The simulcast systems of Radio Activity have on board all the necessary algorithms (voting system, equalization, protocol coherence, …) to ensure a perfect operation in any geometry of use and on any carrier transport (IP, SDH/PHD on fiber optic or microwave link, XDSL modem on copper pair, UHF narrowband, …). In the base stations are implemented **many different timing/synchronization systems** (GPS, OCXO, digital signals correlation, super-audio tone, digital strings, external clock) with automatic backup between the sources. The precision in timing and synchronization, the high performance graphic equalization and the built-in algorithms guarantee an **optimal functionality even overlap areas**.

Please refer to technical documentation detail below for a precise and comprehensive description of the special features of the Radio Activity base station RA-XXX family.

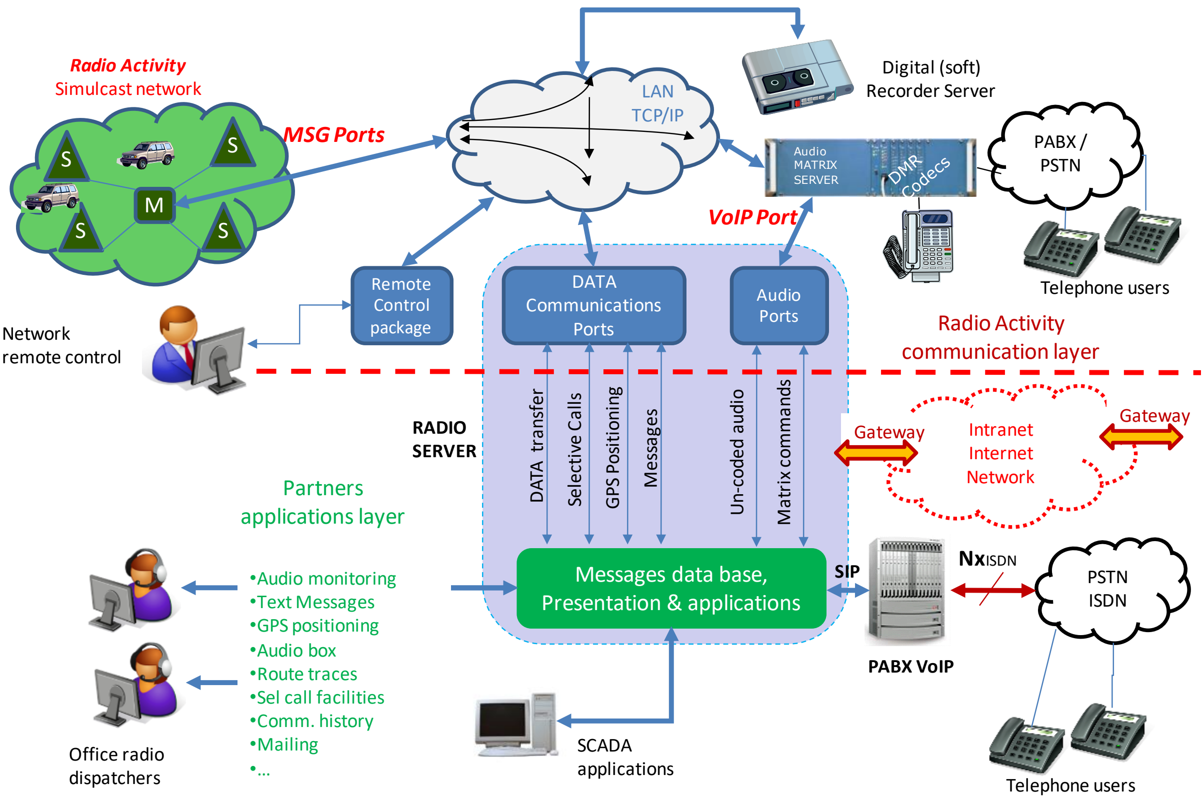
NATIONAL WIDE SYSTEM SOLUTIONS

The Radio Activity simulcast solution permits to create a number of applications target to Communication Center purpose. The IP protocol used to transport audio and data information gives a standard platform to implement easy several solutions spreading from a single dispatcher desk up to national wide Communication Centers network.



The simplified schema above illustrate a common approach to realize a large size infrastructure. The radio networks will serve local area like a town, a province or a region. Each Operative Center can manage the communications of one or more radio networks. The communications will be easy transported and managed through the IP backbone with standard IP network elements. Using appropriate server/client solutions it is possible to associate any radio network to one or more Operative Center. These associations can be moved in few seconds following the needs of the User: e.g. to use an Operative Center only during the night or to moving the control operation from a site to another site during an emergency.

Radio Activity has develop the **RA-TI-XX Audio Gateway** that can be used as **standalone DMR telephone interface** or it can convert the audio DMR streaming in PCM uncoded format. This audio can be easy managed using standard audio program and application on a PC. Radio Activity will provide the protocol descriptions to allow his partners to develop their own applications. The layer borders between Radio Activity and the partners SW applications is shown in the following figure.



The data communication ports permit to manage messaging, selective calls, GPS positioning and other data services.

The RA-TI-XX is connected to one IP only (e.g. Master station IP). In the case of Master failure, the audio gateway connect itself automatically to the "Alias Master" IP which ensures constant communication between a dispatcher, radio and telephone terminals.

There are three main functionalities in Audio Gateway: Phone Bridge, Analog Console and IP Dispatch.

Phone Bridge Features:

- Full duplex connection eliminates telephone/radio communication delays and other instabilities that may occur with VOX (important for Phone Bridge Applications)
- Direct IP connection with the repeater
- All DMR calls management (private, group, broadcasting)
- Phone selection of the DMR user/group via DTMF digit
- Programmable line release tone detection to meet most telephone standards
- Priority "over the air" output and control of the communication flow

- Emergency Call Management
- Call logging, Voice recording and reporting
- Text messaging, emails and positioning reports available on dedicated IP ports

Analog Console applications:

The RA-TI-XX manage automatic cross-coding of conventional radio calls (ZVEI/CCIR) to DMR MOTOTRBO™ protocol. A conventional console or dispatching system may be easily re-used in a DMR network saving costs and reducing trouble during migration. Console port accesses the radio network directly (not from a mobile terminal) with priority respect to the mobile terminals. It operates in automatic multi-protocol analog/DMR audio gateway.

IP dispatching applications:

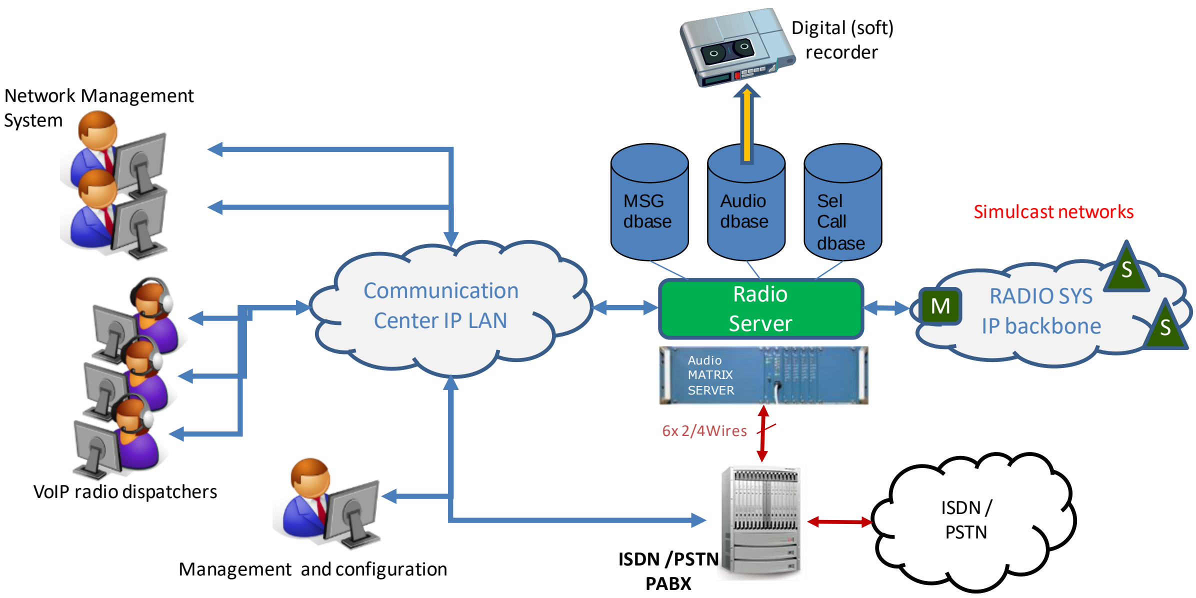
The audio ports of the RA-TI-XX operate in UDP-IP streaming (standard mu-law 64kb/s digital audio over IP) to create PC based dispatching system. These IP audio ports have similar functioning as the analog ones with more powerful features to allow a number of applications. Due to the full management of DMR protocol, the Audio Gateway can open all communications of the radio network, including private. This feature is ideal for full recording purpose in most emergency situations.

DISPATCHING CENTER

The IP traffic between Networks and the Communication Center will contain:

- Audio communications in analog or digital (DMR coded) format
- TXT messaging (DMR coded)
- Selective call
- Network management controls
- Optional services (GPS positioning, terminal remote control, …)

The Communication Center detail is explained in the following figure:



The Radio Server will store all audio communication in a database of audio file “Audio dbase”. The Audio dbase will be automatically updated at every communication coming from terminals (through simulcast networks) or coming from VoIP radio dispatchers. The “DMR private” calls will be stored in the Audio dbase also. This Audio dbase performs a virtual **Digital Voice Recorder** allowing recording of calls occurring on all radio channels and Dispatchers, with daily automatic archiving of recorded calls to DVD or CDROM, with local search and playback functions available from the Dispatcher workstations based on channel number, Caller ID and time of call. Each track will support at least 1000 hours of recordings.

The Radio Server will store the text messages and the selective calls in similar dbase structure. These data will be available from the Dispatcher workstations using channel number, Caller ID and time of call as research keys.

The Radio Server may implement an optional functionality that permit also the recording of the GPS positioning of the terminals. In this case GPS is needed in the DMR terminals.

The Audio Gateway or "Digital Audio Matrix"performs the audio trans-coding from DMR to PCM standard. This function permits to implement a Central System with PC based operator desks. The digital audio coming from DMR terminal is coded with the AMBE II+™ (Advanced Multi-Band Excitation) developed by Digital Voice Systems. The audio received on the master station of the network, through HDSL modem and the Radio Server, reaches the Digital Audio Matrix in the Communication Center. The Audio Gateway, housed in a 19" rack, works as a Slave of the master station of the radio network and converts the DMR audio in analog format.

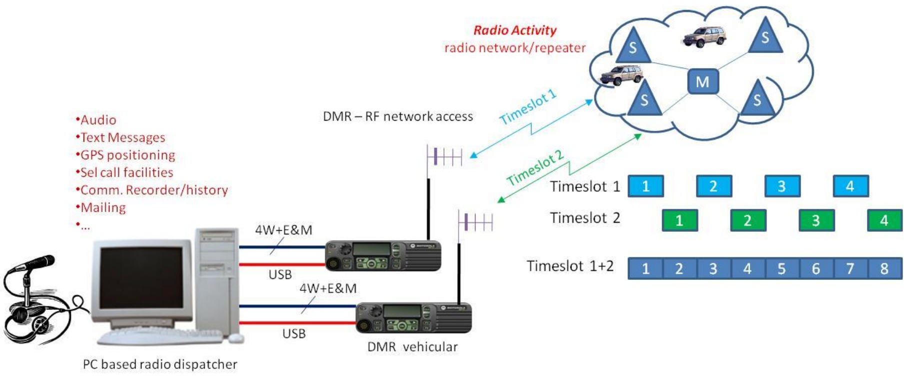
The audio signals are available in analog (2 or 4 wire balanced format) and in digital also: the Digital Audio Matrix converts it into the PCM format for the audio applications on the PC of the operator desk. This PCM flux is available from the Digital Audio Matrix through the Communication Center IP LAN.

The Digital Audio Matrix may operate as 2 wire automatic telephone interface (in this case without specific communication with the radio server) or as 4 wire E+&M analog interface for console. In both cases the analog audio coming from network (DMR) and coming from line (analog) may be sent to the radio server in PCM format (8bit@8KHz) for record purpose.

The Operators in the Communication Center will operate on **LAN-based VoIP local Dispatchers**. These dispatchers will be implemented on Personal Computer with a specific communication SW package and they will include highly ruggedized accessories.

Every dispatcher shall be assigned to a specific channel of the radio network. It will function as clients of the Radio Server device through a multi-level password access strategy.

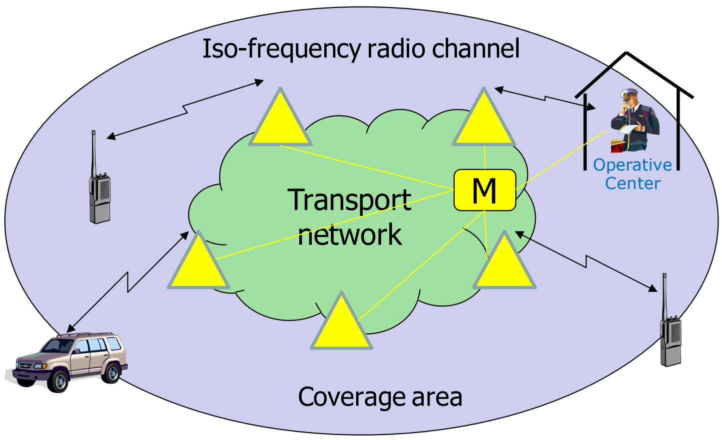
Alternatively the Radio Dispatchers could be realized through vehicular based fixed stations (many Motorola application partner can offer this low cost solution). In this case the Dispatchers shall access the network through the radio channels losing priority over the other terminals. The access shall be realized with fixed radio instead then the Audio Gateway.



UNDERSTANDING SIMULCAST BASIS

SYSTEM KEY ELEMENTS

A generic simulcast system may be represented as follow:



The base stations are connected each other by a **transport network**. A lot of type of transport networks may be used: IP, E1, microwave links, fiber optics, UHF links, 4 wire copper, …

One base station of the radio system assumes a "**Master**" role and manages all the communications and the signaling inside the network.

The other base station assume a "**Slave**" role and accept commands from the master station.

The master station performs the **voting process** that is the method by which the best signal received from each base stations of the network is continuously selected. In analog mode the Master station is able to "extract the good" of each signal received from RBS and to create a summary one with an improvement of input signal to noise ratio. In Digital mode (DMR) every timeslot received from all the base stations is selected to found the error free timeslot or the maximum likelihood one in absence of CRC (e.g. voice). An high performance, real time voting system performs a "very large diversity reception" over all the base stations involved in the call. The global effect on quality compared with the multi-frequency approach is superb.

The best signal (analog or digital) is sent back to all slave base stations in "IP multicast" mode. This procedure reduces significantly the bandwidth required to the backbone interconnection network.

The Slave station must **synchronize and equalize the signal** incoming from the master before broadcast it. The signal sent from the Slave to the Master should also be synchronize and equalize to avoid glitch during the real time selection operated by the Voting system on the Master.

The synchronisation and equalisation is mandatory for right operation in overlap area. An **overlap area** is a part of the coverage territory in which two or more transmitters arrive with similar RF field. These areas are critical in the simulcast broadcasting as it will explain in the next paragraphs.

TO DEBUNK URBAN LEGENDS ABOUT SIMULCAST

One of the main question about simulcast network is: "when I'm in a overlap area of two transmitters with same RF field and phase opposite I should produce a null in the receiver signal".

This sentence may be true considering this simple model with two rays but the reality is very different.

First of all, to produce a null it is needed exactly the same amplitude and a phase opposite. This situation is clearly very unlikely. Any other condition produces an attenuation only: a typical value of extra attenuation in strong overlap areas gives peaks of about +6dB/-15dB, moving in time and in space.

In addition, a land mobile environment may be modeled as a number of rays with random phase and amplitude. The propagation of the RF field suffers of reflections (buildings, hills, rocks, …) and attenuation (trees, borders, …) that “scatters” the rays. A statistical approach only may predict the global effect of this environment.

CONCLUSIONS

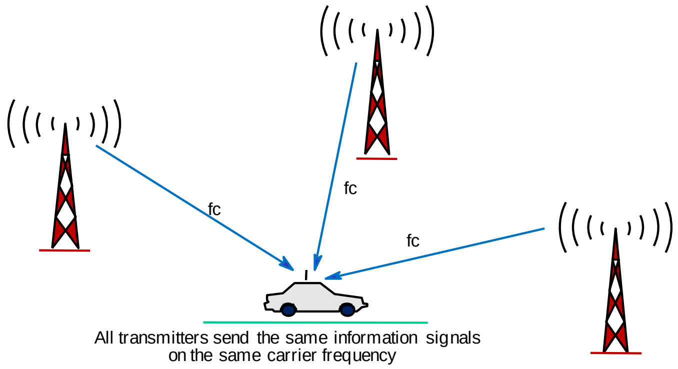
A simulcast network will perform better when:

- ∞ the matching of the base stations is very high => select professional digital radio from simulcast skilled manufacturer
- ∞ in the overlap area may occur more frequently additional attenuation of some dB => use good signals in the overlap area with 15/20 dB over the threshold of the mobile receiver
- ∞ the mismatch of the signals follow the physical law of propagation => avoid to realize very large cells that may introduce propagation mismatch
- ∞ a fine propagation delay adjustment is performed to “move” the overlap area into non-operative zones; generally this operation is not requested in network with radio cells less than 20-25Km of radius.

RADIO ACTIVITY SIMULCAST SOLUTIONS

INTRODUCTION

Simulcast type networks operate on the same radio channel on the whole coverage area. Communications can be both open and selective channel, semiduplex mode between mobile terminals or duplex mode between Central and terminals. The network will make the automatic selection of accessing terminals and will broadcast the signal on the same frequency throughout the coverage area. The terminals are served regardless of their position as if they were covered by a single repeater.



Radio Activity has a very powerful product to make simulcast network. The networks are based on the standard radio product RA-080 / RA-160 / RA-450 / RA-900. These radio implement all the necessary functions for high performance simulcast networks (timing and synchronization recovery, delay and response equalization, voting system …).

The Radio Activity base station is the ideal "basic block" to build simulcast or multicast radio networks based on the most common media supports. The network will operate in analog or digital (DMR) or in multi-protocol mode with automatic selection.

The base stations of the RA-XXX family are configurable to work in simulcast network with many different connection links (backbone network):

- General purpose IP backbone (microwave, fibre optics, LAN, …)
- Narrowband duplex radio links (UHF/VHF)
- 2/4 Wire leased/PSTN lines
- Mixed IP / radio link / wired

The flexibility of the RA-XXX base station allows a very large applicability of simulcast solutions over a number of real cases. The most used network structures may divided on the base of the backbone characteristics in two main groups:

- IP based backbone
- Narrowband RF linked

In the following chapters it will be explained the main common algorithms and the peculiarities of these simulcast solutions.

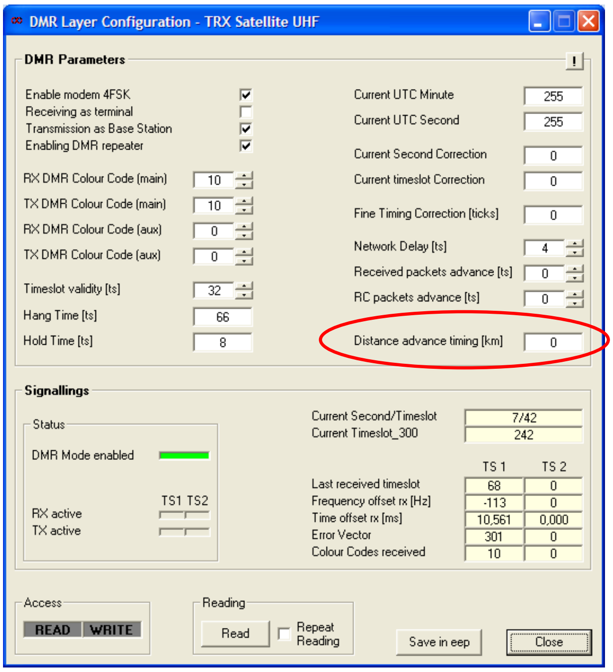
BUILT-IN SIMULCAST ORIENTED ALGORITHMS

MATCHING AND SELF ALIGNAMENTS

Thanks to the full digital approach, the group and absolute delay of the RA-XXX base stations can be perfectly aligned. At any power on or reset, the base station performs in few seconds a complete calibration of all internal parameters. In order to guarantee this feature also if radio modules are replaced and considering the spread of transmitters, Radio Activity stations are equipped with a digital self-regulation of deviation of transceivers. Transmitter frequency deviation is directly programmable from DSP module of the equipment. The actual modulation index is automatically calibrated across the entire audio band by looping the transmission synthesizer on to vector receivers. The measure of deviation is the result of a mathematical calculation, which is independent from components tolerance or temperature variation.

EQUALIZATION

Simulcast type networks require particular attention in the choice of lines linking the various stations, therefore one of the main tasks to do is the equalization of the signals to broadcast. The characteristics of these lines must be such as to make as much as possible identical signs of low frequency (audio) that each station must retransmit. Simulcast networks made by Radio Activity employ equalization devices based on Digital Signal Processing, which are able to automatically minimize the differences between the line paths.
The equalization process is carried out in a few seconds simultaneously in all repeater stations. With the help of the GPS integrated receiver, the stations are able to equalize automatically phase and amplitude of the analog and digital signals even in the presence of variations in the response of the link. A new algorithm, developed in our laboratories, allows you to automatically equalize the transmission lines even in tunnels or in areas where there is no visibility of the GPS system.



This feature allows to use a large family of communication lines, including time-varying IP backbone, pupinized copper lines that present considerable variations in temperature, or PSTN telephone lines subjected to variations of delay and BF response.

The signal equalization may be completed adding a delay to compensate the propagation effects that may be occur in some overlap areas. The compensation delay capability is equivalent of more than 1.000Km.

The automatic equalization can always get a network in **<u>perfect alignment without having to manually act on the stations</u>**.

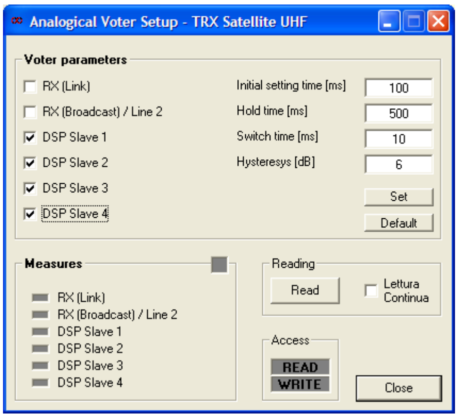
VOTING SYSTEM

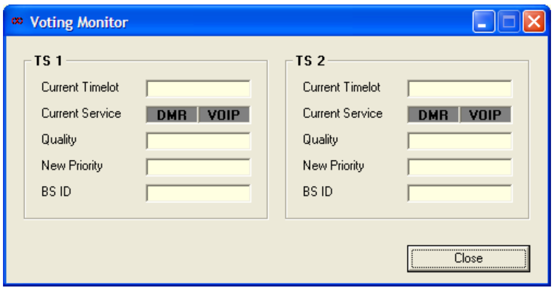
Another essential function of Radio Activity simulcast networks is the soft voting implemented in the Master station which is the method by which the best signal received from the network is continuously selected. The DSP devices are able to extract the best from each signal received from RBS and to create a “macro receiver diversity” effect with an improvement of input signal quality.

The voting system selects the incoming signals continuously on the basis of signal/noise (analog) or maximum likelihood (digital DMR) changing mode automatically following the incoming signal format.

Working in analog, the contribution of noise + distortion is extracted by each input channel. The noise, averaged, allows to select the best input signal and to return it to the output. The Voter can be configured in an optimal way for data transmission networks. In this case it is possible to set:

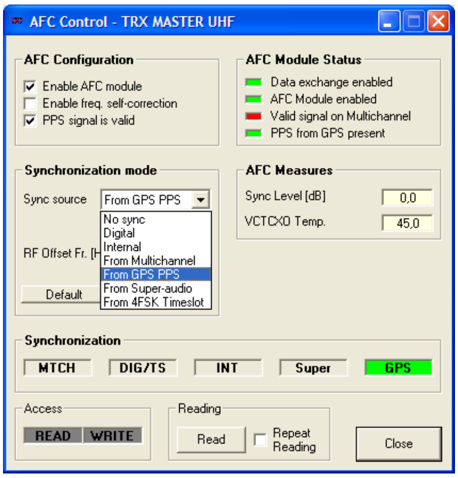
- setup time during which the Voter freely choose the best input signal (switching between channels is possible)
- selected channel hold time during the setup time (no switching is permitted, transit of the any data telegram)
- switching time between channels during the conversation
- switching hysteresis between channels with 3 dB step





Working in digital (DMR) mode, the voting system performs the selection of the best signals with the choice of the error free packet (CRC matched) in case of data transmission and measuring the error vector of the incoming signals in case of DMR coded voice communication (no CRC available during voice communication).

SYNCHRONISMS



In a digital simulcast network it is mandatory to recover an accurate synchronism on both frequency and time.

Frequency synchronism of the Radio Activity station can be extracted from multiple sources depending on network needs and the references availability. The resulting synchronism, except in case of external clock, is not "coherent", that is, it is not phase locked and introduces a "creep" between the carriers of the various satellites, normally less than 1Hz. It is possible to freely set a maximum frequency offset between satellites of + / - 20Hz to resolve any prolonged zero field in the equal field strength areas (sea, lakes,…).

The accurate timing is recover in different way, depending on the source selected as frequency synchronism as shown in the following paragraphs.

<u>Digital automatic frequency control (DAFC/4FSK/GMSK)</u>

The typical application is in case of Narrowband RF linked simulcast networks. Slaves equipment are able to regenerate a synchronization signal almost coherent using the embedded data streaming signalling transmitted by the master of the network.

The master, during network set-up time, send to satellites a digital synchronization signal, locked to its internal frequency reference. Each satellite receives the same encrypted signal by the master and reset its reference clock according to acquired signal. In this way all satellites are zeroed in frequency and time compared to master and then zeroed between them.

Appropriate algorithms implemented into DSP devices of satellites ensure to store the state of the frequency reference and to integrate and maintain it over time.

The synchronism updating time requires few timeslots so the process do not disturb communications.

The process of synchronism synthesis is entirely digital and provides an excellent synchronization for the retransmission carrier of a simulcast network. Furthermore, "refreshing" the value of relative-zero at each master transmission, periodic adjustments are non needed, while, instead, they are in case of other synchronism sources (high stability oscillators).

Internal

The synchronism source is a crystal oscillator placed inside the DSP module, which has a stability better than 0.5 ppm in the thermal range of functioning. On demand, higher stability oscillators can be used. The frequency tuning is digitally controlled and the setting can be stored. An internal self calibration function allows to correct the natural aging of the oscillator, by simply connecting the receiver to a calibrated external source.

This source is generally selected on a repeater or on a Master station in Narrowband RF linked simulcast networks.

Audio LAN

Selecting "Multichannel synch" the synchronism is obtained from Audio LAN connection clock (patch cord on the rear of the rack). This synchronism is required for systems with more digitally linked together radio stations or in Narrowband RF linked simulcast networks.

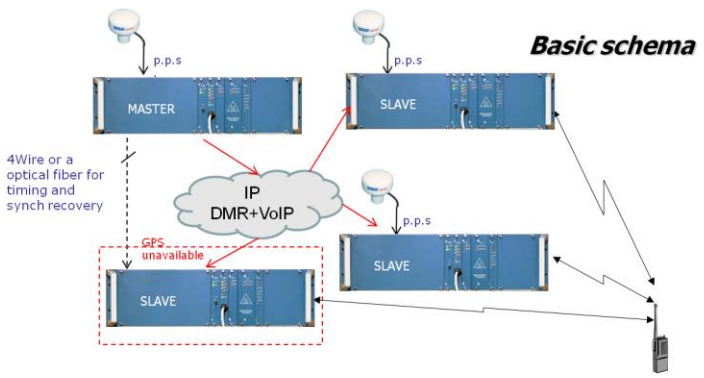
PPS GPS

The GPS receiver integrated in the station provides a pulse every second, which is used by the DSP to clear its frequency and time reference. The time reference allows automatic equalization of absolute delays of the links (useful in IP network or in SDH links with automatic reconfiguration of routes in case of backbone failure).

The synchronization procedure requires less than 1-2 minutes to reach the requested precision after a "cold start up". Thanks to the very high stability of internal clock sources in conjunction with sophisticated network algorithms, the synchronism remains good enough up to 8 hours after GPS missing.

Super-audio

Where the GSP signal is not available or it is "too evanescent", it is possible to recover all precise synchronisms via a twisted pair of copper or a 4Wire interface (e.g. from a fiber optics MUX). Radio Activity had develop other methods for synchronism recovery inserting a digital signalling in the audio band. Any synchronized base station can send a digital signalling in the 300-3400 Hz band on connection line, as the reference for the remote DSP to lock its internal clock.



External clock

An external 12.8 MHz signal with level between -10 and 0 dBm can be used to synchronize the station. Other frequencies are available on demand.

NETWORK FAMILIES

Simulcast networks made by Radio Activity base stations may be divided in two basic family, depending on their backbone connecting system:

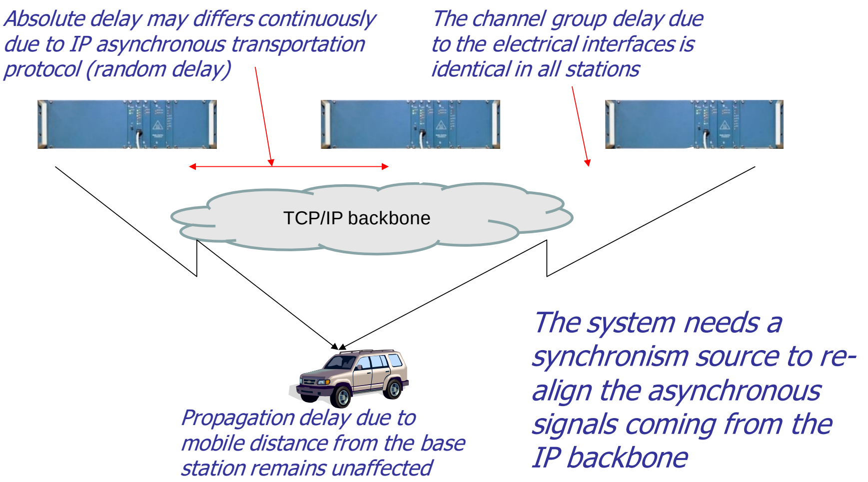
- IP based backbone
- Narrowband RF linked

IP BASED NETWORK

The IP based network is the ideal solution when an affordable IP backbone is available. This is the most common application of the Radio Activity base stations. Every base station runs in a full LINUX operative system that allow a very powerful and stable connections to a LAN backbone network through the local Ethernet port.

An important distinction between an over-IP system and a conventional (switch-based) one is that with a IP system there is no central switch, thus eliminating a critical point of potential failure. Instead, full signaling is made by IP (Internet Protocol) network technology to provide reliable data routing between network components. This combination of IP technology and the advanced DMR communication standard produces a feature-rich solution with a surprising degree of flexibility and resilience.

The synchronism are normally recover by the internal GPS receiver and the algorithms inside the base station perform all the needed functions for a best quality simulcast system. A TCP-IP backbone connectivity is very attractive to build professional radio networks. Since today it was very hard to implement a simulcast network over IP due to the instability of delay and time inaccuracy.



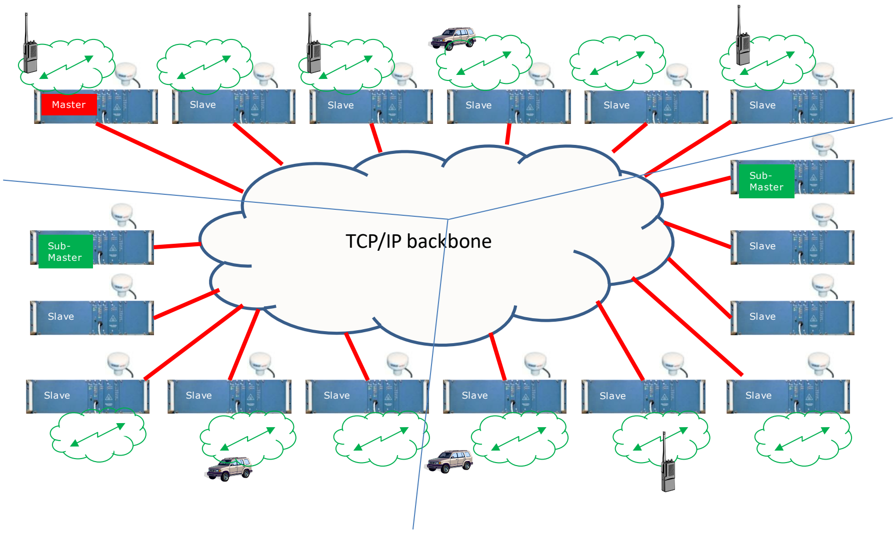
Now Radio Activity has open the way to do it with many advantages:

- UDP/TCP-IP is the most common protocol in the world: standardization reduces dramatically the costs
- the IP world is well known and a lot of technicians are able to operate efficiently on it
- the communication redundancy is intrinsically assured by the protocol
- every base station is identified by an address (IP) instead then a (fixed) connection: it is easy to expand a network adding new base stations!

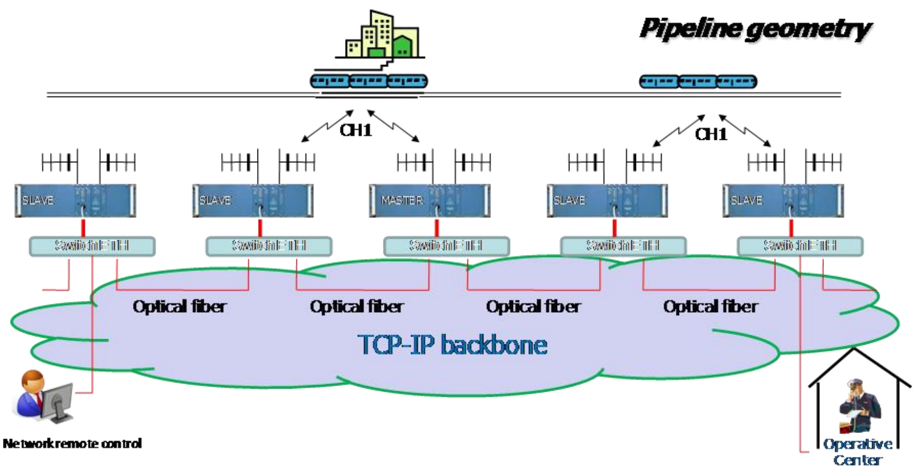
- all communications are carried out in the same digital format (the analog one also) without any noisy conversion and avoid periodic tediously audio level adjustments
- a unique ETH port connects several base stations: this cuts the cabling costs and reduces the probability of failure
- lower cost and lower bandwidth requirement respect to E1 solution
- a lot of customers has got a proprietary IP infrastructure for video-surveillance, remote controls, and other services: using the same infrastructure reduces the maintenance costs
- Simple redundancy implementation with “Alias Master” base station

Due to the intrinsic “relocation” of the peers in a IP network, this kind of solution is geometry independent and matches very well the common configurations as:

- Tree networks composed of nodal stations from which more "arms" depart towards stations downstream. This approach is hierarchic with a main Master station following to some level (nesting) of Sub Master and Slave stations.



- Linear networks consisting of a chain of stations, placed in series and connected via optical fibre or twisted pairs or multiplexes, to cover areas along highways, railways, pipelines, power lines and so on.



This solution presents a very good overall cost figure using very common and cheap IP network devices often just present in the Customer infrastructure.

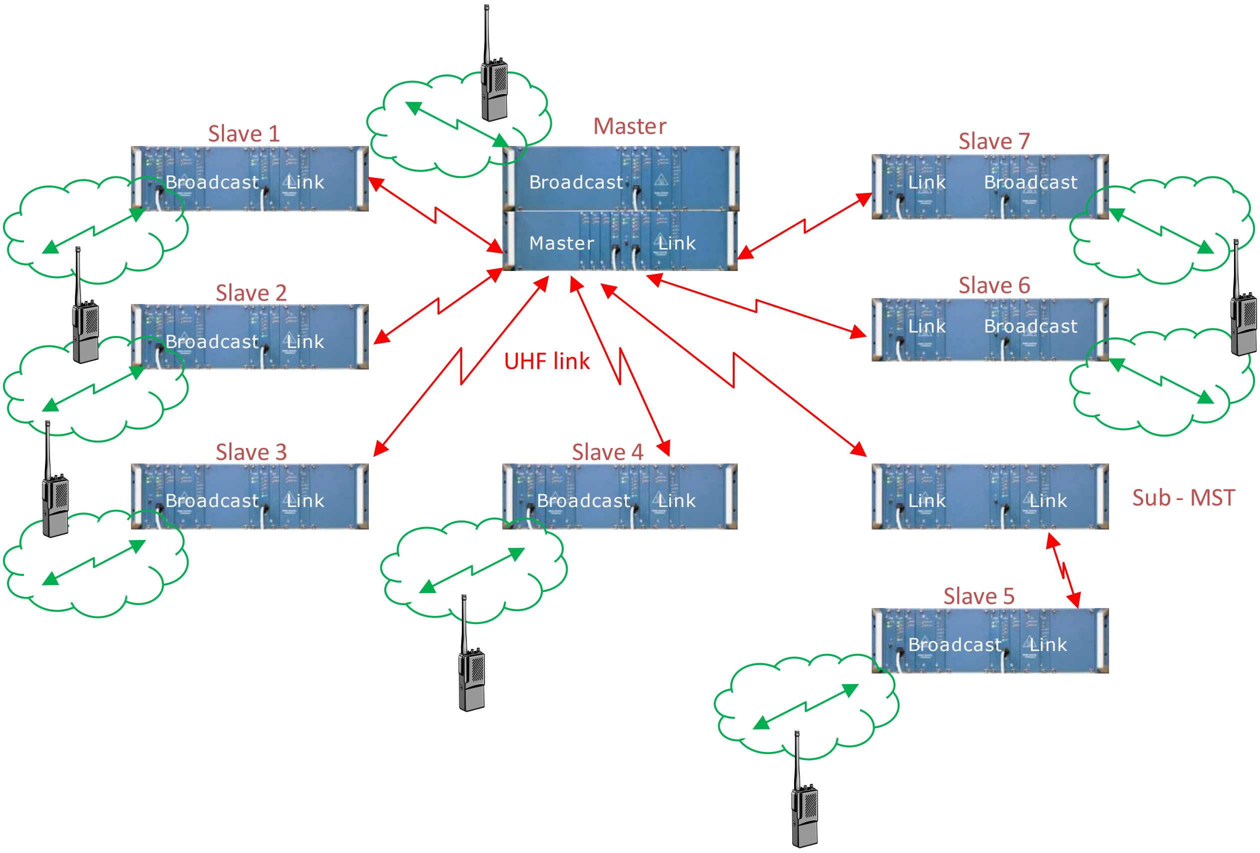
NARROWBAND RF LINKED NETWORK

In this kind of network the connections between the base stations are made by point to point radio links between Master and Slaves, with the ability to route through Secondary Masters.

The use of narrowband radio link allows to realize networks when the distance to connect is very large (100Km or more) or when the radio path isn't in direct visibility.

The radio stations are very compact, making audio connections between link and local transceivers directly in a 4Mb/s digital format. All required functions (Voting, compensation for delays, synchronization) are integrated in the station.

The standard configuration is a star networks with Master station in the centre links with the Slave ones implemented by radio devices in the UHF range integrated in the same radio stations. The Master station uses multiple receivers array (one receiver each Slave/Sub-Master) and a single transmitter to send back to the Slaves the best signals.

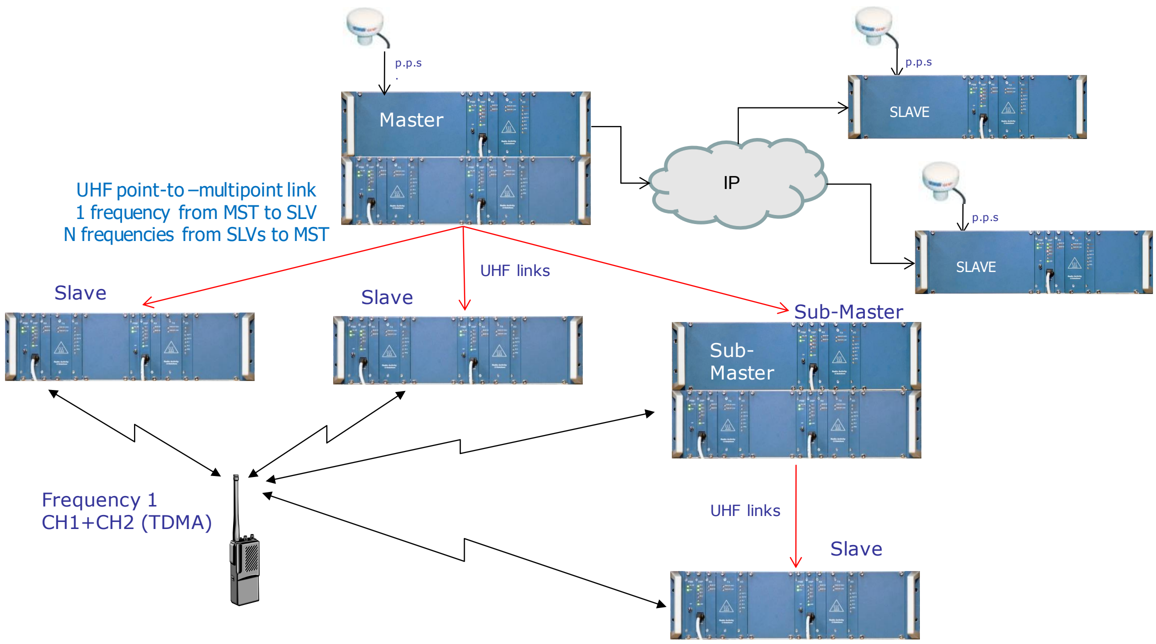


Carriers and time synchronization are carried out by extracting the information from the data streaming coming from the Master station. No GPS receiver is required.

The delays compensation is also obtained through the techniques described in the preceding paragraphs.

MIXED RF/IP NETWORK

Thanks to the algorithms implemented on DSP units for automatic equalization of signals and synchronism recovery, It is possible to realize simulcast radio networks with some base station connected through IP backbone (fibre optic or radio) and some other connected with narrowband radio links.



The same base station in an infinite ∞ application's variety

This topology may be useful to extend coverage area starting from a main IP backbone. A main IP connection from microwave or optical fibre support may connect a part of the base stations (included Master) and some RF links may connect remote base stations.

Some care has to be take in the synchronism and delay matching of this kind of network.

NETWORK CONFIGURATIONS

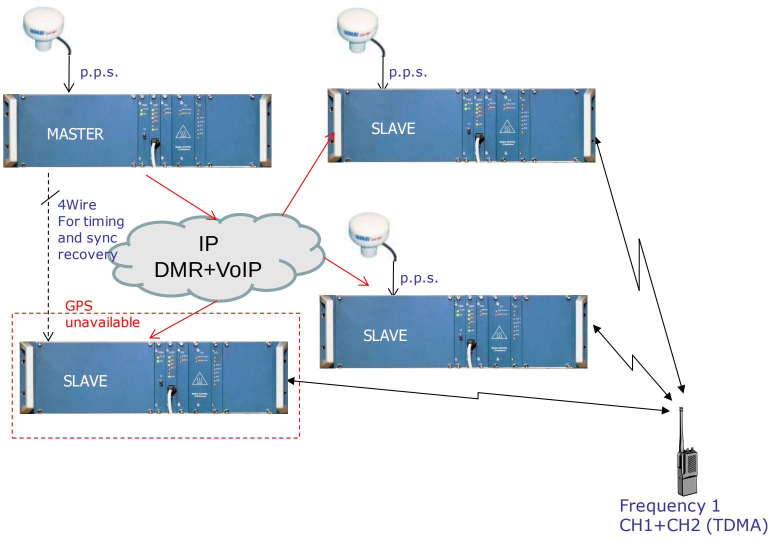
IP BASED NETWORK

This is the most common application of the Radio Activity base stations. Every base station has got an Ethernet port to connect to a LAN backbone network. An important distinction between an over-IP system and a conventional (switch-based) one is that with an IP system there is no central switch, thus eliminating a critical point of potential failure. Instead, full operating is made in IP (Internet Protocol) network technology to provide reliable data routing between network components. This combination of IP technology and the advanced DMR communication standard produces a feature-rich solution with a surprising degree of flexibility and resilience.

BASIC FUNCTIONING DESCRIPTION

One base station of the radio network works as "Master" station. It require a fixed IP address. The other base stations are configured as "Slave" stations with an IP static or not.

Through the LAN, the Slave base stations search the Master one and then they log themselves to it.



The master governs the radio network sending timing and related information to the slaves.

The incoming signal from a terminal equipment is received from one or more base stations. All base stations receiving a valid signal send it to the master station via the Ethernet interface through the LAN backbone. The master station waits the arrival of all signals and then performs the selection of the best signal (voting system). The master selects the incoming signals continuously on the basis of signal/noise (analog) or maximum likelihood (digital DMR).

The master station sends back the best signal to all the slaves via the Ethernet interface through the LAN backbone utilizing a multicast IP protocol.

All the slaves synchronize the signals received from master on the local GPS signaling base. All the base stations synchronize also their timing, protocol history and carrier frequency to the GPS. The synchronization procedure requires less than 1-2 minutes to reach the requested precision after a "cold start up". Thanks to the very high stability of internal clock sources in conjunction with sophisticated network algorithms, the synchronism remains good enough up to 8 hours after GPS missing.

Where the GSP signal is not available or it is "too evanescent", it is possible to recover all precise synchronisms via a twisted pair of copper or a 4Wire interface (e.g. from a fiber optics MUX). Radio Activity develops other methods for synchronism recovery, contact Factory for details.

Note that the GPS is not needed in the case of multicast (non simulcast) applications. In this case the algorithms based on the TCP-IP time stamps, corrected by Radio Activity "fine timing over IP" methods, perform a sufficient synchronizations of the base stations.

The Radio Activity simulcast or multicast network supports multi-protocol operation, that is, it can recognize if the incoming signal from a terminal equipment is analog or digital and configure itself as analog or DMR simulcast network. In the first case the voice will fill the entire channel (no other contemporary communication is allowed) and it will be compressed in quasi-linear format to be exchanged between stations through Ethernet connection. In the latter case the network will support two contemporary DMR communications (both data and voice) over the two timeslots. Full DMR features are supported.

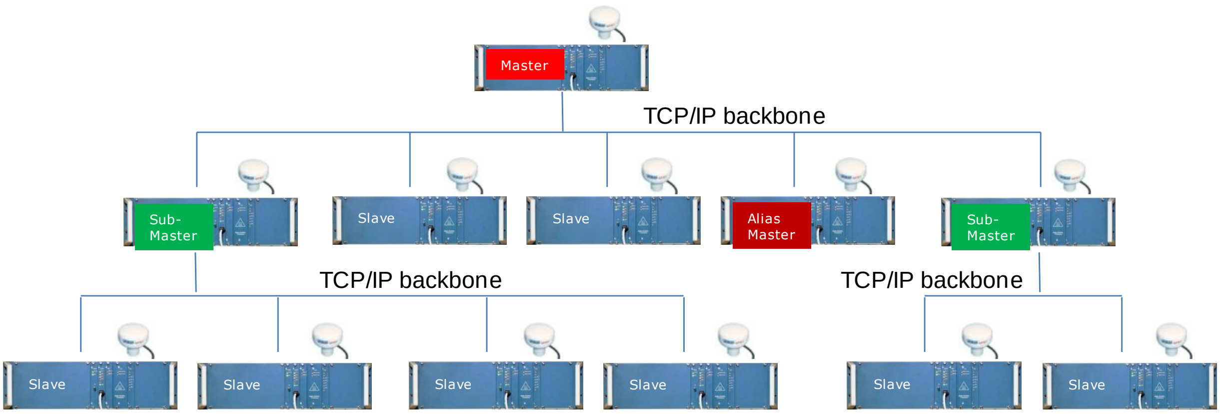
If DMR terminals are programmed in scan mode, they can perform communication both with analog terminals in analog mode and with DMR terminals in digital mode.

NETWORK REDUNDANCY

A Master or a Sub-Master station is able to **manage up to 32 IP peers** where the IP peers may be Slaves base stations, Sub-Master base stations or RA-TI-XX audio interfaces.

Combining one Master with some Sub-Master in a hierarchical structure, it is clear that the number of base stations insertable in a network may be enormous as 32^N where N is the nesting index.

The Sub-Master station may be useful to realize the network with a some redundancy, where it is preferable to use more than 1 Master station to maintain the communications in the case of failure.



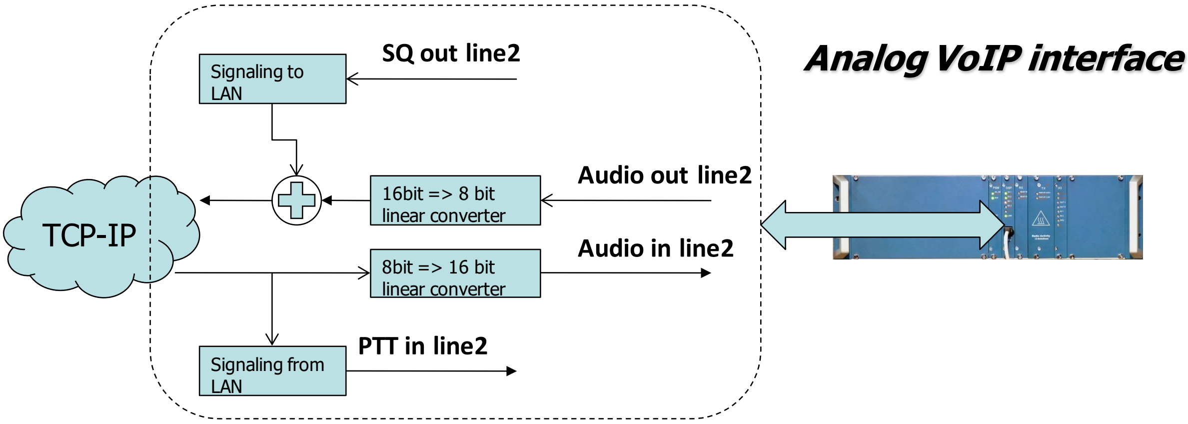
A very interested feature implemented in the Radio Activity IP based simulcast network is the "**reserve Master**" station or "**alias Master**" entity. Where the extension of the network is large or when a very reliable radio service is needed, it is possible to create a redundancy setting two Master base stations placed in different geographical position. The "alias Master" operate normally as a Slave base station until it doesn't receive the "alive" messages from the Main Master. In this case it change its role in Master. Every Slave base station knows the IP address of the main Master and the IP of the "alias" one. When the main Master disappears from the IP network, every base station change the registration to the "alias Master" automatically restoring the network functionality.

Radio Activity is able to furnish the radio **base station in 1+1** (main + spare) configuration. These equipment are made of two complete radio transceivers 1+0 sharing the same branching therefore all the functions, RF and IP routing, are doubled. The 1+1 equipment provide two line connectors in which input and output lines are physically paralleled, two Ethernet port with different IP addresses. By an internal algorithm a base station surveys the other and changes status in case of failure or on timeout request. The timeout is useful to equilibrate the use of the two base station and to be sure that the spare will be ready when effectively needed.

Finally, in the event of a single radio site becoming isolated from the network it can continue to operate in standalone mode until such time as normal network communications are restored. Any sites still able to communicate with each other can also continue to work together whilst temporarily isolated from the main part of the network. The base station remains synchronized therefore a communication involved two local base station may be correctly broadcasted during a LAN interruption also.

IP BACKBONE AND BANDWIDTH REQUIREMENTS

The simulcast network based on IP backbone is an extension of a 4 wires based one. Considering first the analog signal, the Slave base stations create on the IP backbone a virtual connections with the Master station. Over this virtual connection it is sent the audio signal encapsulated in UDP-IP multicast or unicast packets.

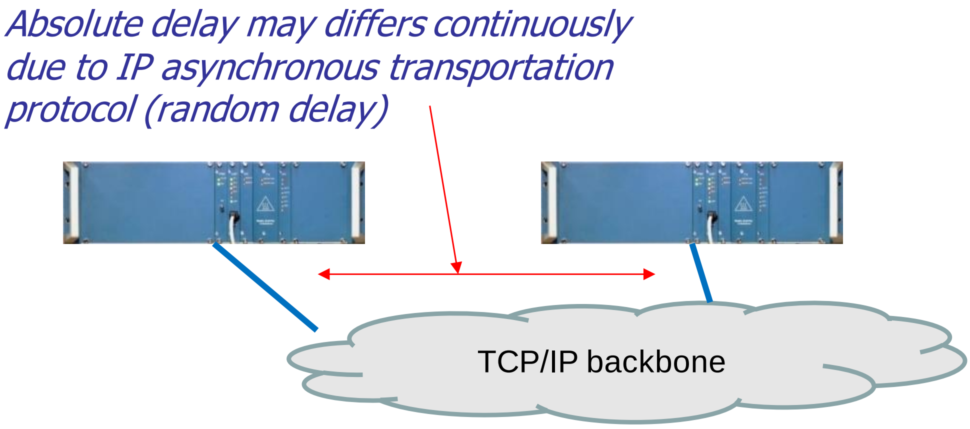


The figure above explain the IP transport mechanism. The audio signals come from the radio in digital format, typical 8KHz sampling/16bits sampling resolution, and then it is compressed linearly in a 8KHz 8bit format to preserve the full analog information. In fact some signals like selective call, FFSK modem and special tone advising can't be compressed differently from linearly without pay a total loss of information.

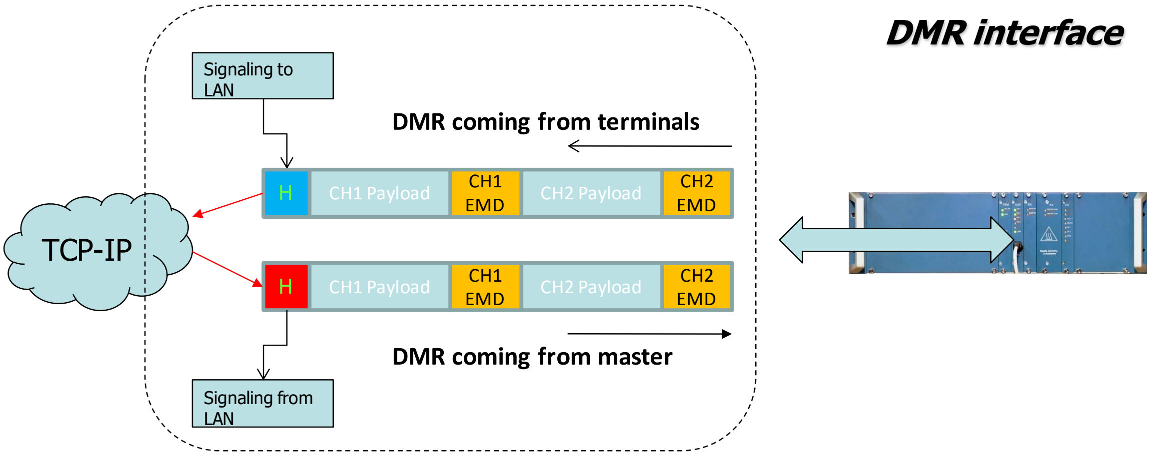
The audio samples are then collected in 60ms frames of 480 samples each and put in an UDP/IP packet addressed to the IP of the Master station. The radio signaling like squelch, PTT, TCS, S/N ratio and similar are also inserted in the packet.

The packet are accurately time marked to allow perfect reconstruction before voting on the Master station and before broadcasting in the Slave stations. This method of transport of the signals create a transparent audio connection in the 0-4KHz band between the base stations very similar to an analog 4 wires copper line.

The packet into the IP backbone will suffer by a fixed delay plus a random delay produced by the IP routing devices and depending of the load of the backbone. The base station can correct at the same time the variable and the fixed delay up to a maximum of 900ms round trip delay solving most of the problems that may appear in a real IP backbone.



The case of DMR signals is similar to the analog one. The main differences are that the audio is coded in DMR format and some data signaling are super imposed on it.



The payload of a DMR timeslot is 27 bytes every 30ms. Some information and auxiliary data channels must add to the streaming increasing the total length of it to 52 bytes. Adding the IP header and the CRC, the bandwidth requirement is about 20 kb/s to carry out both timeslots. There are two different ways to pack the DMR signals, an IP packet each timeslot or one for the two timeslots (as reported in the figure above). This choice allows the user to select low delay and a greater bandwidth on the IP backbone (single timeslot on each packet) or greater delay and lower bandwidth requirement.

The bandwidth requirement for the analog functioning is a little more than 64 kb/s due to the IP header and the superimposed signaling therefore it to consider a 70 kb/s as right value. This bandwidth will be allocated in presence of valid signal only. The packets from the Slave to the Master are sent in unicast format from each Slave while the packets from Master to the Salve are sent in multicast format. In fact the signal sent from the Master is the same for all the Slaves than the more convenient format is multicast or broadcast.

At this bandwidth shall be add the network control traffic that is done with the TCP/IP protocol. This protocol is used by the base stations for:

- timing recovery process
- registration of base stations
- remote control
- keep-alive and failure react processes
- other network control related signaling

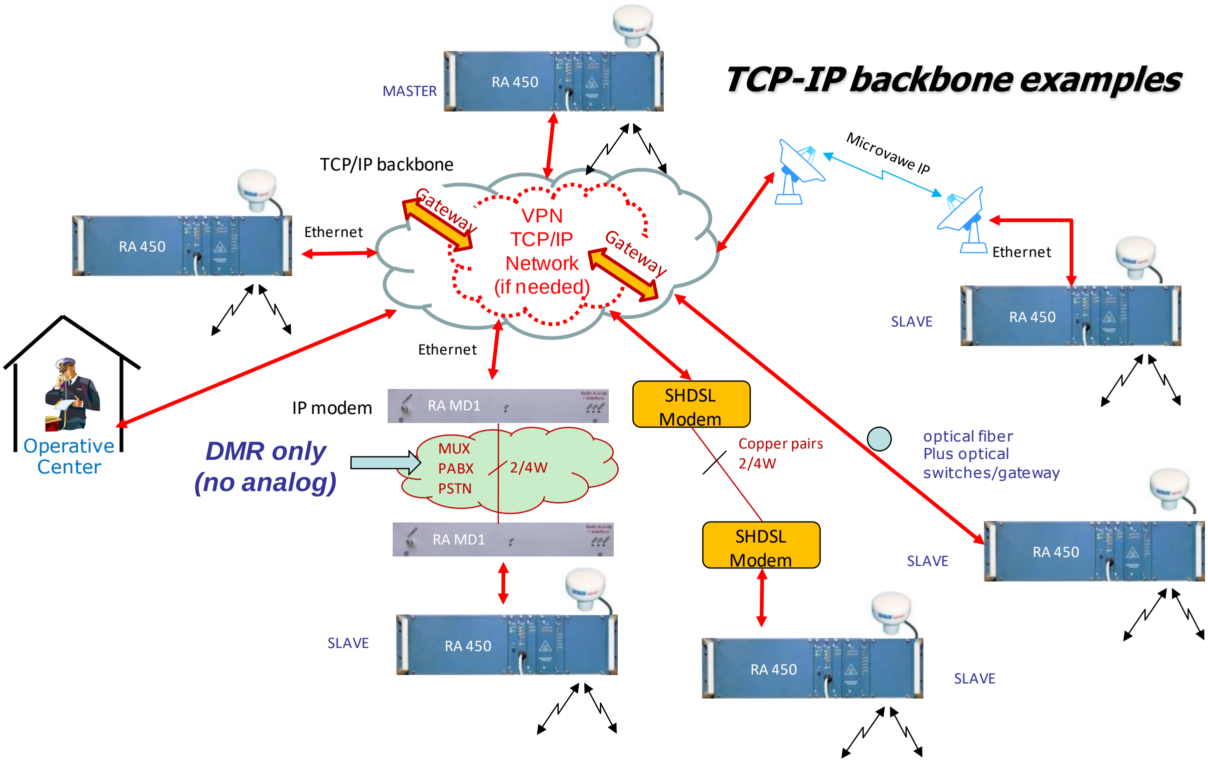
These IP processes need very low bandwidth of few some Kb/s, giving a QoS and a total BW requirement summarized in the following table:

Protocols for voice packets:	UDP/IP (ipv4), unicast (from slaves to master) and multicast (from master to slaves), with DSCP set to "**EF**" (*Telephony* service class), according to RFC 4594
Protocols for BS "internal" network control:	UDP/IP (ipv4), unicast and multicast, with DSCP set to "**CS6**" (*Network Control* service class), according to RFC 4594
Protocols for remote control, setup and surveillance:	UDP/IP and TCP/IP (ipv4) unicast and broadcast with DSCP set to "**AF13**" (*High-Throughput Data* service class), according to RFC 4594
Jitter (deviation of averaged packet time delay):	The Base Station is able to compensate Jitter delay up to 200 ms. The total delay averaged + jitter must not exceeds 400ms (each way)
Maximum delay:	The Base Station is able to compensate round trip delay less then 900ms (jitters included)
Packet loss	< 0.1 %
Audio format	Analog: 64 kb/s – 8 bit x 8 KHz linear coded DMR: AMBE II+™ (Advanced Multi-Band Excitation)
Audio frame block net payload	Analog: 60 ms – 480 bytes/samples DMR selectable single/double timeslot: 60 ms – 27 bytes each timeslot
Minimum bandwidth (network signaling and remote control polling inclusive):	SLAVE: 70 kb/s in analog to/from Master 24 kb/s in DMR to/from Master (both timeslots)
	MASTER to serve **N** SLAVES (both timeslots): 70 kb/s in analog to Slaves, 70 kb/s x **N** from Slaves 24 kb/s in DMR to Slaves, 24 kb/s x **N** from Slaves

It is to underline that the bandwidth requirement on the IP backbone is very low due to the packet protocol. Differently from a E1 G703 based solution that requires constant link presence, each base station sends packets in the backbone in the case of valid signals only. When no traffic is present in the network, the bandwidth used by the base stations goes down to few kb/s. In addition it is to consider that in a radio system few base stations contemporary may receive an access signal, therefore **the bandwidth requirement is a fraction of the E1 based solution**.

This fact allows the use of a wide selection of IP media supports. Generally the IP links gives Mb/s of bandwidth therefore the needs of a Radio Activity system is easy satisfied.

The following figure illustrates some IP links giving the right performances to build up a simulcast network.

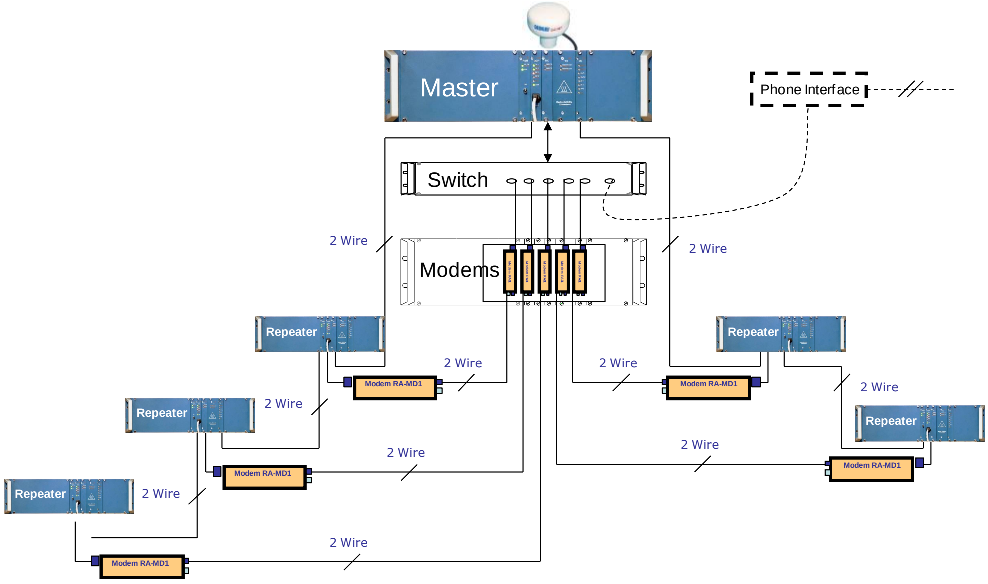


When some links between the slaves have to be realized by analog lines, Radio Activity suggests two possible solutions to choice depending on the type of available line connection:

- to use a pair of SHDSL IP modem able to create an IP connection over a physical copper line. In this case the bandwidth should be 128Kb/s or more, therefore it is enough to carry out DMR and analog communications.
- to use a Radio Activity IP modem model **RA-MD-1** to perform a LAN connection over a 300-3400Hz channel of a twisted pair of wires (leased line or PSTN) or a 4Wire interface (e.g. from a fiber optics MUX). The resulting LAN may have a reduced bandwidth (e.g. 33.6Kb/s or less) and introduces a significant delay (about 50-60 ms). Thanks to the low bandwidth requirements of the DMR Radio Activity base stations, it is possible to use this solution but in digital mode only (DMR) non in analog.

In case of E1 connection, the base station requires an external E1 to IP converter device with at least 1x64kb/s channel for DMR only or 2x64Kb/s for analog. Very often the E1 source has got an Ethernet port built in.

The following figure illustrates an example of DMR simulcast network full realized with wired lines.



BASE STATIONS CONFIGURATION

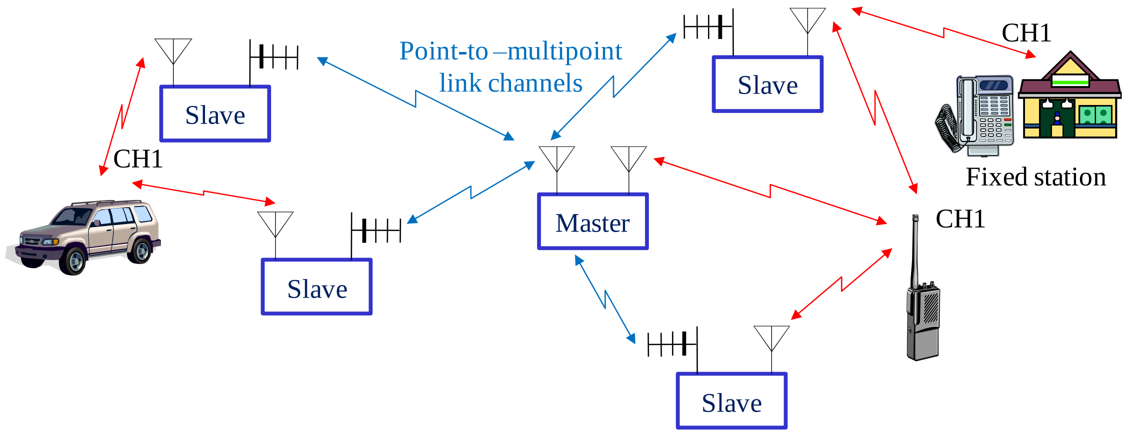
SLAVE: duplex radio base station series RA080/RA160/RA450/RA900 with “Multi-protocol” functioning for completely automatic working mode according both analog standard (8K50F3E) and digital DMR – TDMA standard. Equipment is housed into a **19” rack**, 3TU high, powered by 13.8 Vdc supply with negative ground. It is provided with needed SW-DSP algorithms to operate in a analog/digital **SIMULCAST** mode. Slave station is equipped with: GPS receiver for time and synchronism recovery (without external antenna), 4 Wire connection for external time and synchronism recovery (no DMR audio), I/O module to remotely control local commands and alarms (2 ON/OFF type opto-isolated input, 2 analog input, 2 relay type output, 2 status alarms output) and to remotely control the complete stations through internal embedded GSM/GPRS modem (SIM excluded) or besides ETH port, optional internal duplexer.

MASTER/SUB-MASTER: duplex radio base station series RA080/RA160/RA450/RA900 with “Multi-protocol” functioning for completely automatic working mode according both analog standard (8K50F3E) and digital DMR – TDMA standard. Equipment is housed into a **19” rack**, 3TU high, powered by 13.8 Vdc supply with negative ground. It is provided with needed SW-DSP algorithms to operate in an analog/digital **SIMULCAST** mode. Master station is equipped with: up to 32 channels multi-protocol voting system, Services IP ports for Operative Centers connections, network management system, GPS receiver for time and synchronism recovery (without external antenna), 4 Wire connection for time and synchronism recovery to Slave (no DMR audio), I/O module to remotely control local commands and alarms (2 ON/OFF type opto-isolated input, 2 analogical input, 2 relay type output, 2 status alarms output) and to remotely control the complete stations through internal embedded GSM/GPRS modem (SIM excluded) or besides ETH port, optional internal duplexer.

NARROWBAND RF LINKED NETWORK

A lot of users need narrowband radiofrequency link to connect the base stations of the network. These links operate typically in licensed UHF band, they can perform rugged and stable communications in “non visibility” conditions also.

The “RF linked” solution has the following geometry:

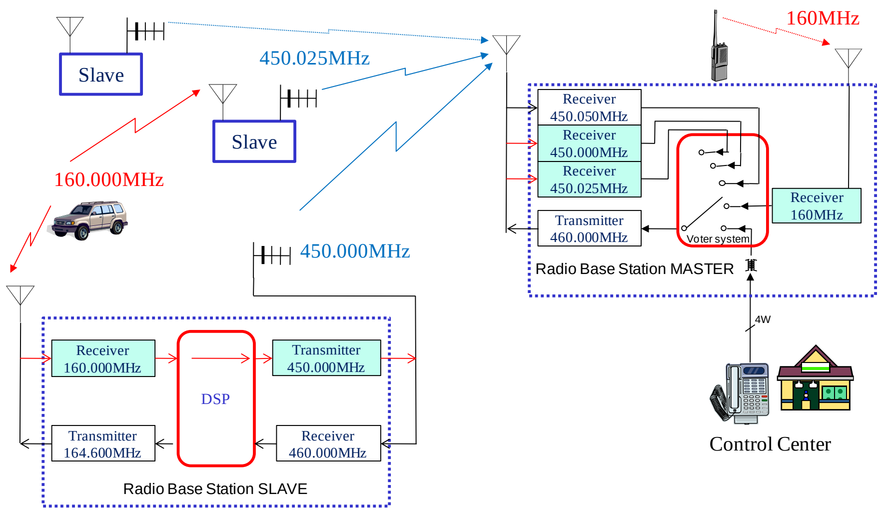


The operation of this type of network may be summarized as follows:

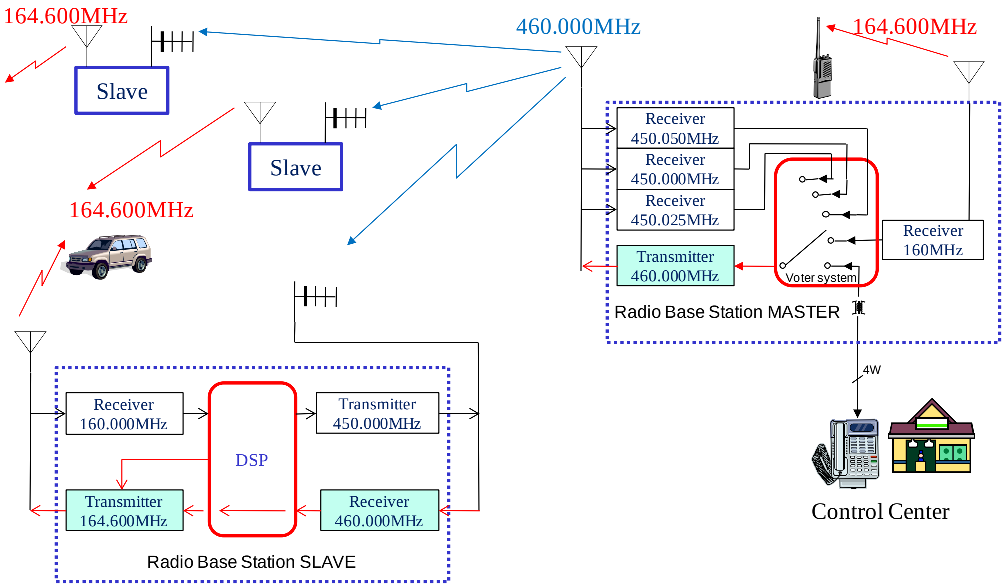
the radio signal emitted by a peripheral device is received by one or more receivers on the network, all tuned on the same frequency, and sent via UHF links to a comparator, which is located on the master (or sub-master), which in turn shall continuously select the best one in terms of signal/noise (analog) or maximum likelihood (digital DMR).

Selected signal is then sent back simultaneously on a frequency, obtained by the digital synchronism clock worked out by DSP, to the various transmitters of the network which provide to broadcast to the area of coverage of the system. Radio mobile coverage areas become in this way very wide, well beyond the capabilities of a single repeater, offering at the same time to users of the network the same operational ease as a single repeater.

In more detailed view, it can be see the up-link signal path in the next example:



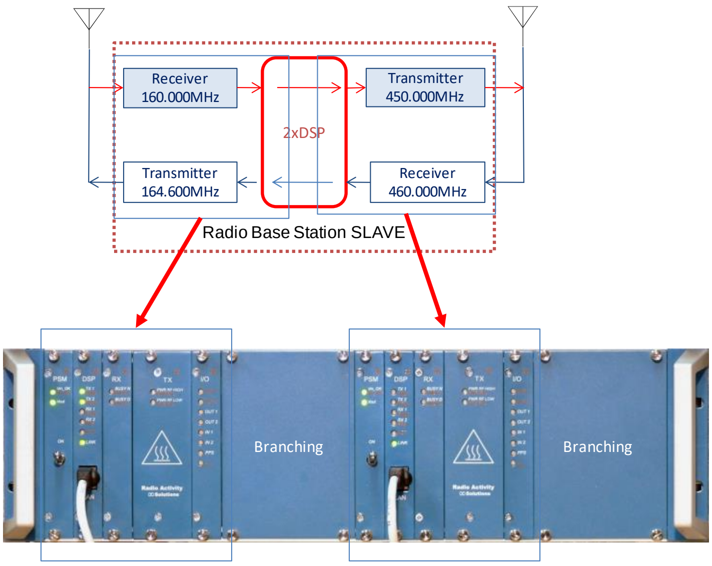
The real – time DSP voting selector on the master station chooses the best signal (greater S/N for analog or maximum likelihood for digital) incoming from the SLAVEs and sends it back to all the SLAVE stations. One different frequency is needed in the links from every slave station. Only 1 frequency is needed from the master station to the slave ones (the information is the same for all slaves) :



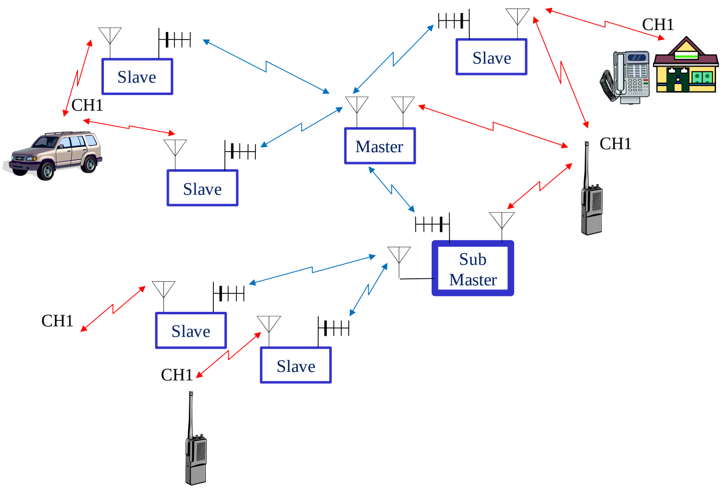
The DSP on the SLAVE stations perform automatic carrier and timing synchronization (it is recovered from a short digital burst from the master station), delay compensation and audio equalization. The GPS receiver is not required in this application due to the constant delay offered from the digital radio links.

The master station could be equipped up to 9 receivers (it can "see" up to 9 slave/secondary master stations).

A very integrated base station with two transceiver in the sample 19" rack is available for this applications. Radio stations are very compact, making audio connections between link and local transceivers directly in a 4Mb/s digital format. All required functions (Voting, compensation for delays, synchronization) are integrated in the station.



It is available the sub-master station for very large coverage area:



The sub-master station operates like a master station with an additional transceiver that perform the link with the primary master station. The sub-master send the best signal selected from its salves to the primary master and it sends back to its salves the signals receiving from the primary master.

The sub-master recovers and regenerates all synchronism and signaling for correct simulcast operation.

UHF LINKED SLAVE STATION

Example of Slave station

The basket acts both as the local transceiver VHF broadcasting (left side) and UHF link transceiver to the primary master (right side).

The signal received from the local receiver is sent to the main master through the links transmitter (UHF). The signal received from the main master, after delay equalization, is forwarded to the local broadcasting transceiver (VHF).

The stations includes the following functions:

1. managing of the received and transmitted signals to/from master
2. managing of the received and transmitted signals to/from mobile terminals
3. equalization of absolute and group delay on both directions in down-link (from Master) and in up-link (to the Master)
4. reclosing of the output signal in the absence of liaison with the primary master (this feature is enable in mask configuration and receiver dissemination (VHF) in box "Repeater mode ena." The repeater indicates the state of reclosing hanging a pitch to 400 Hz time programmable (typ = 500ms) at the end of each commitment to the network.

The sync and audio signals are distributed through LAN to 4 Mb / s synchronous (MTCH). The figure below shows schematically routes audio signals inside the station.

UHF LINKED MASTER STATION

Master station is made of two 19” 3TU rack, equipped like following.

Example of Master station for 4 slaves

The lower rack performs the functions of Master station, with automatic selection between receivers and transmitter towards the slaves. The upper rack perform the functions of local broad casting transceiver.

The Master-Link rack includes a RA-450 base station plus a number of receivers as needed. A DSP module is requested every 3 receivers to perform demodulation and voting. An RF active splitter is included in the standard configuration to distribute the UHF signals to all the receivers.

The stations includes the following functions:

1. voting between UHF receivers from its own satellites and local VHF receiver
2. receivers RF active splitter
3. digital synchronism forward to the slaves
4. group and absolute delays equalization on local broadcasting transceiver (VHF)
5. loop back of the best signal output from voting towards the slave
6. output signal loop back in the event of failure of the link to the Central Office

The link to the Central Office can be realized by an IP connection or by a radio point to point link, adding a duplex transceiver.

Audio signals and synchronisms are distributed through a 4Mb/s synchronous serial LAN (MTCH).

UHF LINKED SUB-MASTER STATION

SUB-Master station is made of two 19” rack, equipped as following.

Example of sub-master station for 4 slaves

The lower rack performs the functions of Sub-Master station, with automatic selection between receivers and transmitter towards the slaves. The upper rack perform the functions of local broad casting transceiver and of link towards main Master.

The Master-Link rack (the lower one in the figure above) includes a RA-450 base station plus a number of receivers as needed to manage the local Slaves of the Sub-Master. A DSP module is requested every 3 receivers to perform demodulation and voting. An RF active splitter is included in the standard configuration to distribute the UHF signals to all the receivers.

The stations includes the following functions:

1. voting between UHF receivers from its own satellites and local VHF receiver
2. receivers RF active splitter
3. digital synchronism recovery from main Master station
4. digital synchronism forward to the slaves
5. group and absolute delays equalization on local broadcasting transceiver (VHF)
6. loop back of the best signal output from voting towards the slave
7. output signal loop back in the event of failure of the link with main master (this function can be enabled through the configuration mask of the local broadcasting transceiver (VHF) in the “Repeater mode enable” box. The repeater will reveal its loop back status by sending a 400Hz tone of programmable length (typ=500ms) at the end of each network operation.

REMOTE CONTROL

INTRODUCTION

The remote control is a very important feature to assure the grade of services needed in a mobile radio network. The Radio Activity base station was designed to give the maximum grade of remote controllability. Remote control system is very flexible and powerful; it can work through different connecting means, also with back up each other. The same features may be available from the User or the local Technical Assistance or from the Factory directly. In fact Radio Activity sends its products over the world, in many cases placed in very uncomfortable site, therefore the possibility to control, observe, correct and modify parameters or the internal SW is a must.

Remote control is useful also during installation and maintenance, because allows remote radio station parameters check and tuning. From remote or through a local PC it is possible to setup each working parameter of transceiver (sub-audio settings, fine frequency tuning, digital filters corner frequency, RF deviation, input/output audio levels, PTT tone, …) and to perform a wide set of measurements (audio levels, distortions, delays, received field strength, emitted RF power, …). Remote control system, in addition to normal diagnosis tools like audio and RF loop test, temperature, current absorption, etc., allows complete remote down-loading of ever resident SW in the equipment.

The base stations has got a local intelligence to survey its state and the state of the neighbor network elements. These information are used to react to failure or specific situation and are available on the remote Network Managing Center.

There are some SW tools able to allowing changing setup parameter of each repeater stations:

- the **DMR_Manager** is a setup-tools giving a full control over the base station parameters. This SW package is intended for local setup and test by an expert user. It is able to connect manually to a remote base station through the IP backbone or through the local serial port or through the internal GSM/GPRS modem.
- the **DMR_NetControl** is a remote network surveillance tools. This SW package is intended for a continuous monitoring of the network functionality (Network Managing Center) by the User or by the local Technical Assistance. This package polls regularly the base stations of the network and display the status in a summary windows on the screen of a PC. The DMR_NetControl, under a password key, permit to access remotely to the same detailed setup menu of the DMR_Manager and then to performs the same features.
- the **DTI_Manager** is a setup-tools giving a full control over the RA-TI-XX telephone interface parameters. As the DMR_Manager, this SW package is intended for local setup by an expert user. It is also able to connect manually to a remote device

PERIPHERAL DEVICE

The DSP module inside the base station collects the diagnostic information from the other modules through a serial port at 115 Kb/s and through direct sampling of some signals.

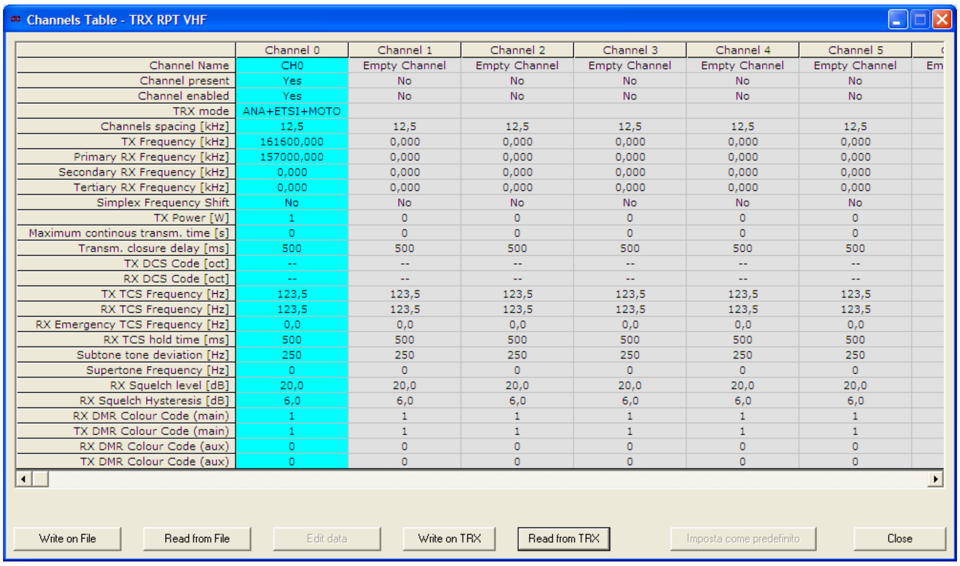
In the receiver, in the transmitter and in the GPS/GSM IO module there is a microprocessor that manage all the functioning of the module. These local data are continuously sent to the DSP module through the serial connection. The DSP adds some measurements and, on request, send all to the Network Managing Center through the Ethernet port or through the local serial port or through the internal GSM/GPRS modem or through the DMR connection.

The setup configuration can be saved permanently on the flash memory of the base station.Thanks to the digital elaboration of the signals, the base station integrate a powerful and precise “test set” collection of functions. These functions are very useful both to self calibrate the RF and audio parts and to test the arrival signals from the terminals or from the audio lines.

The collection of available parameters is very wide and it changes according to the particular application and increases at every new SW release. The list below, not exhaustive because it requests several pages, gives an idea of the diagnostic capability of the Radio Base Station.

TRX PROGRAMMABLE PARAMETERS

- Inhibit RX Main and Diversity
- Inhibit TX
- RX frequencies, squelch threshold, speed and hysteresis, sub-audio/super-audio access tone
- TX frequencies, RF power, timeout, deviation, sub-audio/super-audio access tone, hold time, ending communication tone
- 12.5 / 20 / 25 KHz channelization
- Equalization delay of broadcasting and receiving signals (by steps of 3,3 µs, which corresponds to 1Km)
- Modulation / demodulation type (FM/PM/DATA)
- synchronism source selection
- Equipment self-test function enable
- Switch between Active and hot Backup equipment
- Equipment power down, reset and restart



	Channel 0	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	
Channel Name	CH0	Empty Channel	Empty Channel	Empty Channel	Empty Channel	Empty Channel	Em
Channel present	Yes	No	No	No	No	No	
Channel enabled	Yes	No	No	No	No	No	
TRX mode	ANA+ETSI+MOTO						
Channels spacing [kHz]	12,5	12,5	12,5	12,5	12,5	12,5	
TX Frequency [kHz]	161600,000	0,000	0,000	0,000	0,000	0,000	
Primary RX Frequency [kHz]	157000,000	0,000	0,000	0,000	0,000	0,000	
Secondary RX Frequency [kHz]	0,000	0,000	0,000	0,000	0,000	0,000	
Tertiary RX Frequency [kHz]	0,000	0,000	0,000	0,000	0,000	0,000	
Simplex Frequency Shift	No	No	No	No	No	No	
TX Power [W]	1	0	0	0	0	0	
Maximum continous transm. time [s]	0	0	0	0	0	0	
Transm. closure delay [ms]	500	500	500	500	500	500	
TX DCS Code [oct]	--	--	--	--	--	--	
RX DCS Code [oct]	--	--	--	--	--	--	
TX TCS Frequency [Hz]	123,5	123,5	123,5	123,5	123,5	123,5	
RX TCS Frequency [Hz]	123,5	123,5	123,5	123,5	123,5	123,5	
RX Emergency TCS Frequency [Hz]	0,0	0,0	0,0	0,0	0,0	0,0	
RX TCS hold time [ms]	500	500	500	500	500	500	
Subtone tone deviation [Hz]	250	250	250	250	250	250	
Supertone Frequency [Hz]	0	0	0	0	0	0	
RX Squelch level [dB]	20,0	20,0	20,0	20,0	20,0	20,0	
RX Squelch Hysteresis [dB]	6,0	6,0	6,0	6,0	6,0	6,0	
RX DMR Colour Code (main)	1	1	1	1	1	1	
TX DMR Colour Code (main)	1	1	1	1	1	1	
RX DMR Colour Code (aux)	0	0	0	0	0	0	
TX DMR Colour Code (aux)	0	0	0	0	0	0	

REMOTELY CHECKABLE RADIO PARAMETERS

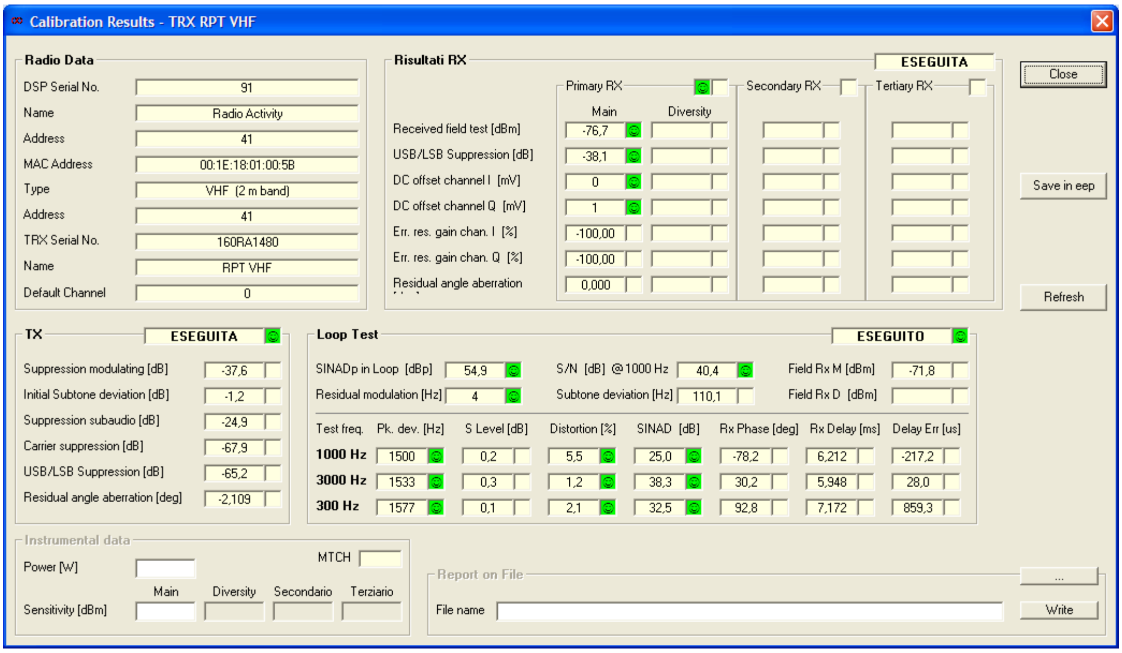
- RF received field strength, expressed in dBm (for both Main and Diversity receiver)
- Direct and reflected power and transmitter SWR
- Lock status and voltage of TX PLL and RX PLLs

- Lock status of station main synchronism
- Active station (Active or hot Backup in the 1+1 configuration)
- Temperature, efficiency and current consumption of RF transmitter
- External general purpose alarms (site housebreaking, main supply failure, …)
- DC/DC converters working status (Power good), voltage indication
- GPS synchronism presence
- Correct communication between radio units CPUs and DSP
- RBS resident SW versions

TRANSCEIVER SELF-TEST

On local or remote polling, the equipment is able to loop back the modulator onto the receiver and to perform a set of calibrations and tests which carry out the following diagnostic information:

- Receivers S/N @ -70 dBm
- Residual modulation
- Antennas noise floor, expressed in dBm
- Carrier and image suppression of vector demodulators (RX) and modulator (TX), expressed in dBc
- Modulator frequency deviation, expressed in Hz (@ 300-1000-3000 Hz)
- Total harmonic distortion RX+TX with a 0.1% resolution (@ 300-1000-3000 Hz)
- Group delay and SINAD (@ 300-1000-3000 Hz)



CALIBRATION SIGNALS

To speed-up and to simplify tests and checks of stations on site, the following automatic functions are provided, which can be both locally and remotely enabled:

- Continuous or sweep tone generation, with programmable frequency by 1 Hz steps or DTMF/ZVEI/CCIR/EIA signalling
- Received from lines signal level measure with 0.1 dB resolution
- Received from lines signal distortion and SINAD (available for sinusoidal signals in the 300-3400 Hz range, by 50 Hz steps)
- Received audio frequency measure with 1 Hz resolution
- Level and frequency measure of signalling super-audio tones
- BF loop back switch
- Not modulated carrier generation
- RF carrier generation with sinusoidal modulation at programmable frequency by 1 Hz steps with programmable nominal deviation by 1 Hz steps
- RF carrier generation with sweeping or patterned sinusoidal modulation to evaluate delay and frequency response
- SINAD and field strength received measures
- Received audio signal frequency and distortion measures (automatic on the full audio bandwidth by 50 Hz steps)
- Received sub-audio tones frequency and deviation measures
- Received DMR error vector and timing access measure

REMOTELY CHECKABLE LINES PARAMETERS

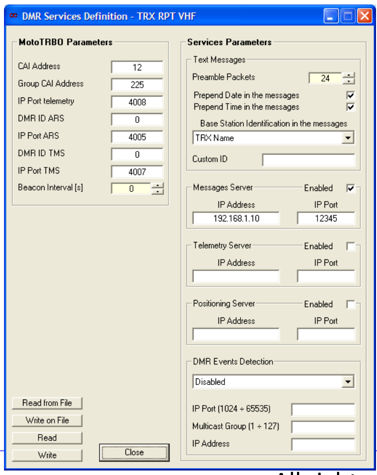
- Synchronism absence (interruption of upstream line)
- Loop back status enabled
- Total delay including lines and transits
- Positive result of equalization process

LINES PROGRAMMABLE PARAMETERS

- Audio lines level settings (both input and output by 0.1 dB step)
- Automatic lines equalization procedure enabling
- Synchronism source selection
- Upstream line transparent/equalized configuration
- Lines configuration set-up (enabling)

IP BACKBONE INTERFACES

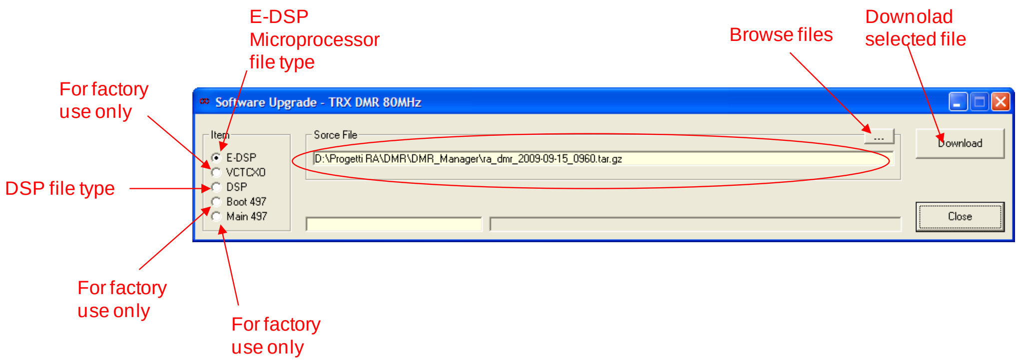
- Local IP address, gateway and subnet mask
- Master/Sub-Master/Alias Master IP addresses
- IP ports for remote control and messaging services
- UDP/IP communication formats
- Presence of Ethernet and an "alive" Master



- Network delay parameters
- Voting system setup and real time selection

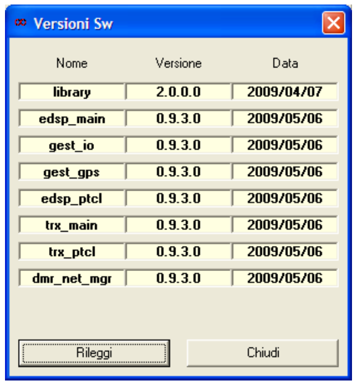
SOFTWARE DOWN-LOADING

The Network Managing Center can run the down-loading of any software included in RBS. Upon complete and error free receipt of the new SW version, the supervisor unit proceeds to locally up-grade involved devices. The up-loading operations provide for the creation of a copy of the new SW before removing the previous one. The correct completion of the operation is secured even though it is interrupted and the risk of "losing" connection with RBS during this operation is avoided. Although it is advisable to carry out the SW up-grading during a network standby period, the operation takes place without blocking the network (except in case of the use of a common communication channel) nor the concerned station. At the end there will be an out-of-service period which is limited to the time of restart of the RBS of few tens of seconds.



All the software and firmware inside the base station are stored in the DSP module. At any reset or power on, the DSP module checks the SW/FW versions in each module and upgrade it if different from the stored one. By this way an old module (e.g. a spare part) inserted on a new base station will be automatically aligned to the current version of SW.

On polling from Central, current SW versions can be read to check the alignment of RBS.



REMOTE CONTROL CONNECTIONS

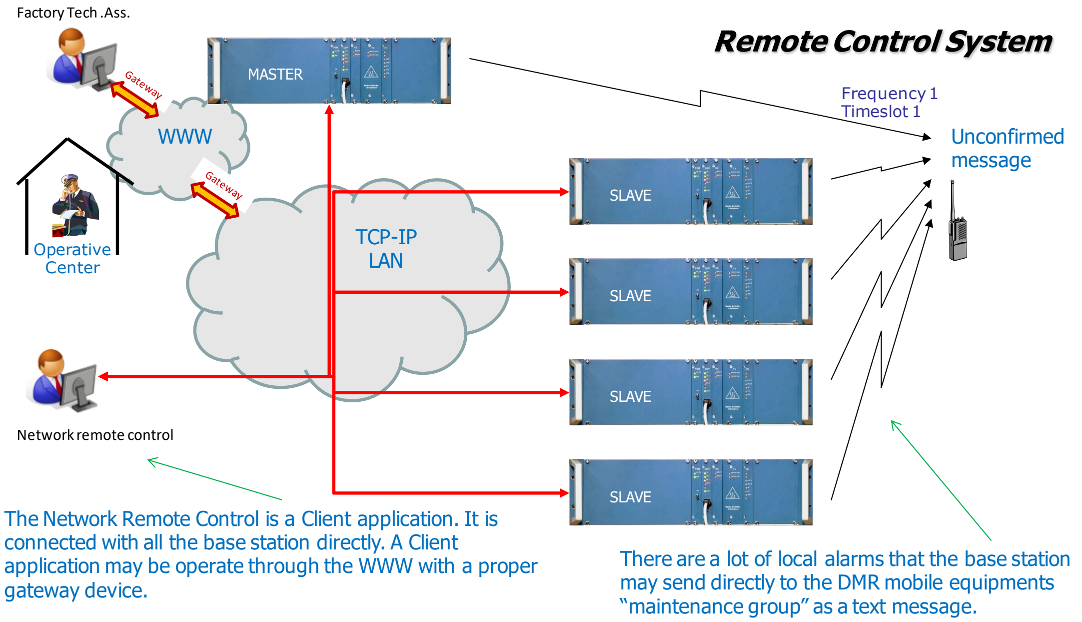
The Remote control facility permits the remote connections through some different way depending on what media it is available locally:

- Ethernet port with TCP/IP protocol
- RS232 V.24 local serial port
- internal GSM/GPRS modem
- external PSTN modem directly connected to the stations
- through the internal DMR modem in the same communication channel of the network. In this case the remote control doesn't disturb the current communications and is available also when the main connection links are out of service.

- in mixed mode, through GSM/PSTN modem or through serial port or through TCP/IP and, from that, bouncing with the internal DMR modem to the desired station

REMOTE CONTROL THROUGH THE IP BACKBONE

The remote surveillance through the IP backbone is the most suggestible way to perform an affordable control of the network functionality. The following figure illustrates the remote control system concept.

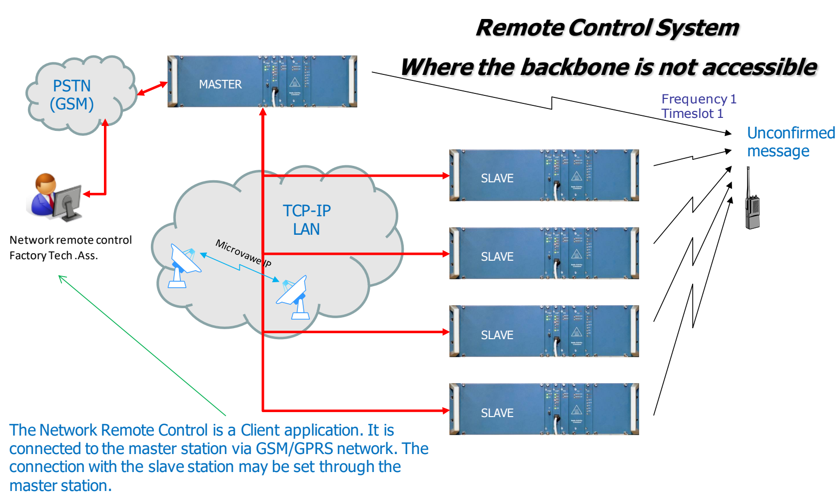


Every base station is directly accessed by the Network Managing Center. The connection is generally fast due to the IP backbone bandwidth, therefore full functionality are available. In fact the base station doesn't distinguish between a local or remote Ethernet connection.

Opening a firewalled access to the WWW, it is possible to request a external sourced Technical Assistance, up to have a support directly from Factory. Through the WWW access it will be possible (not yet implemented) for the Base Stations to automatically upgrade their software connecting to the Radio Activity website.

REMOTE CONTROL THROUGH INTERNAL (GSM) OR EXTERNAL MODEM

This solution solves the remote control connection problem when an IP backbone network is not available or when it is not possible to open an access to the WWW for the external sourced Technical Assistance or to have a mobile access to the network.

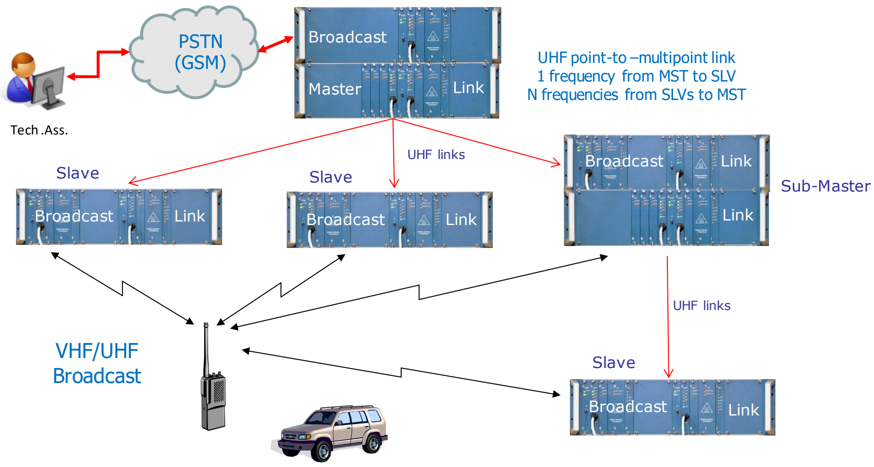


In this case the Network Managing Center should connect to the Master station through a GSM or a PSTN connection (external modem required). The

Master station will route the TCP/IP control packets to themselves or to the other stations (Slaves) as a gateway.

This approach is very useful to control the RF-linked DMR simulcast networks; in fact this kind of network is used when there isn't easy IP connectivity then the network may be accessed through the GSM modem.

It is suggestible to use one GSM modem in every base station to assure remote controllability even when some transceiver is out of service.



Alternatively, in case of GSM out of coverage in some sites, it is possible to use one GSM connection only on the Master station. The Master station will route the control packets to the other stations (Slaves) as a gateway using the DMR data link. In this case the Remote Control packets use the same traffic channel of the network that can be set in the "timeslot 1" or in the "timeslot 2" of the DMR channels. The remote control packets, as data packets, hasn't priority to the user communication therefore they wait when the network is busy. But the sending of a packet can't be interrupted from a user call, then this fact implies some considerations:

- the remote control uses traffic bandwidth then it is suggestible to keep polling cycles not very frequent (e.g. every 4-8 hours)
- the bandwidth available in DMR data link is limited then it is not suggestible to perform heavy software upgrading
- a base station may be un-accessible in case of failure of the UHF DMR link, and this is the case in which the remote control is mainly needed!

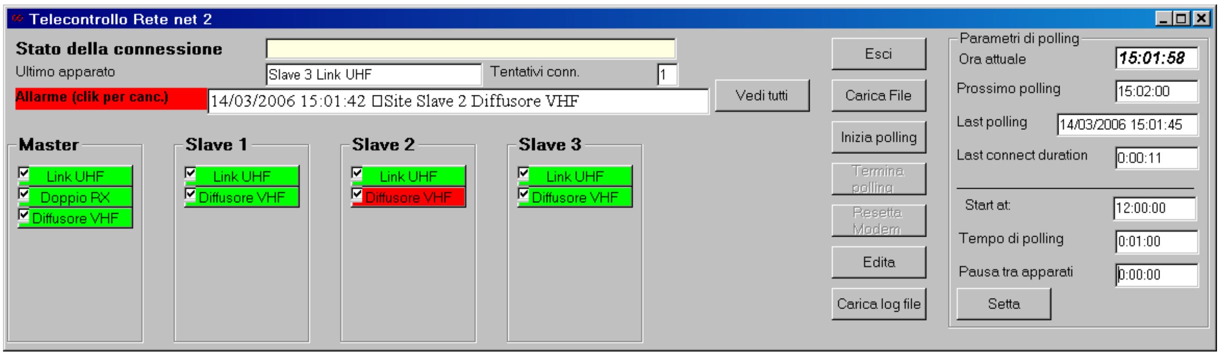
SUPERVISION SW PACKAGES

The Network Managing Center should be equipped with the DMR_NetControl surveillance tools. It consists of a software package in Windows that provides a simple user interface for surveillance functions. This package (shown in the following paragraphs) can be installed both on the PC of the User, for a local surveillance, and on the Technical Assistance Center PC.

This SW package is intended for a continuous monitoring of the network functionality. It polls regularly the base stations of the network and display the status in a summary windows on the screen of a PC. The DMR_NetControl, under a password key, permit to access remotely to the same detailed setup menu of the DMR_Manager and then to performs the same features.

Similarly the same software package may be installed on a laptop with a GSM modem for maintenance and activation of the network (e.g. adjustment of the propagation delays) that has to be made on the field.

The network is represented schematically in the main window:



The devices are interrogated separately and the color represents the state:

- green = operate normally
- red = presence of alarms
- blue = no status acquired
- black = connection failed (Attempts to link up to three)

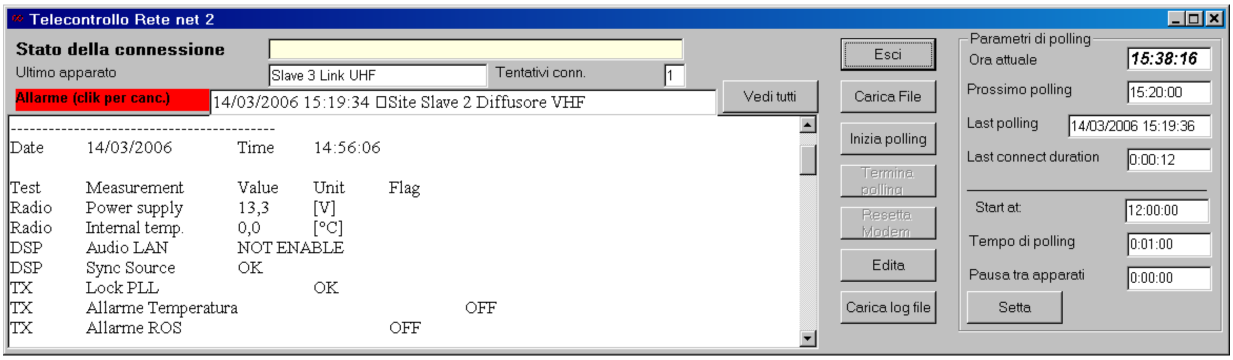
To include a machine in the polling cycle requires a click on the selection icon matched with the machine.

The writing of each unit are displayed directly on the icon up to 160 stations, otherwise the icon narrows to a single box and the writing appears when the mouse is moved on the icon.

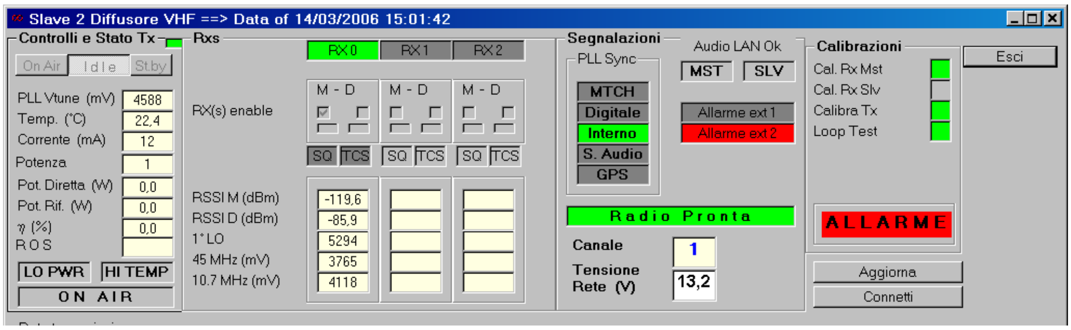
The alarm window lists the devices found in alarm with date and alarm time.

Normally the system is programmed for automatic polling equipments at fixed hours (for example once a day during the night). The connection parameters (e.g. the IP addresses or the GSM telephone numbers) can be immediately set from the main window.

The names of the sites and equipments can be freely set by the user through masks ("Edit" button). Reports are stored only in case of malfunction and can be accessed with the button "Load log file" or through a file .csv viewer (e.g. EXCEL). Report files are created daily in a Failure Report" folder for each device that has an alarm.



By selecting the icon of the device it is possible to access the last detected state (equipment status window):



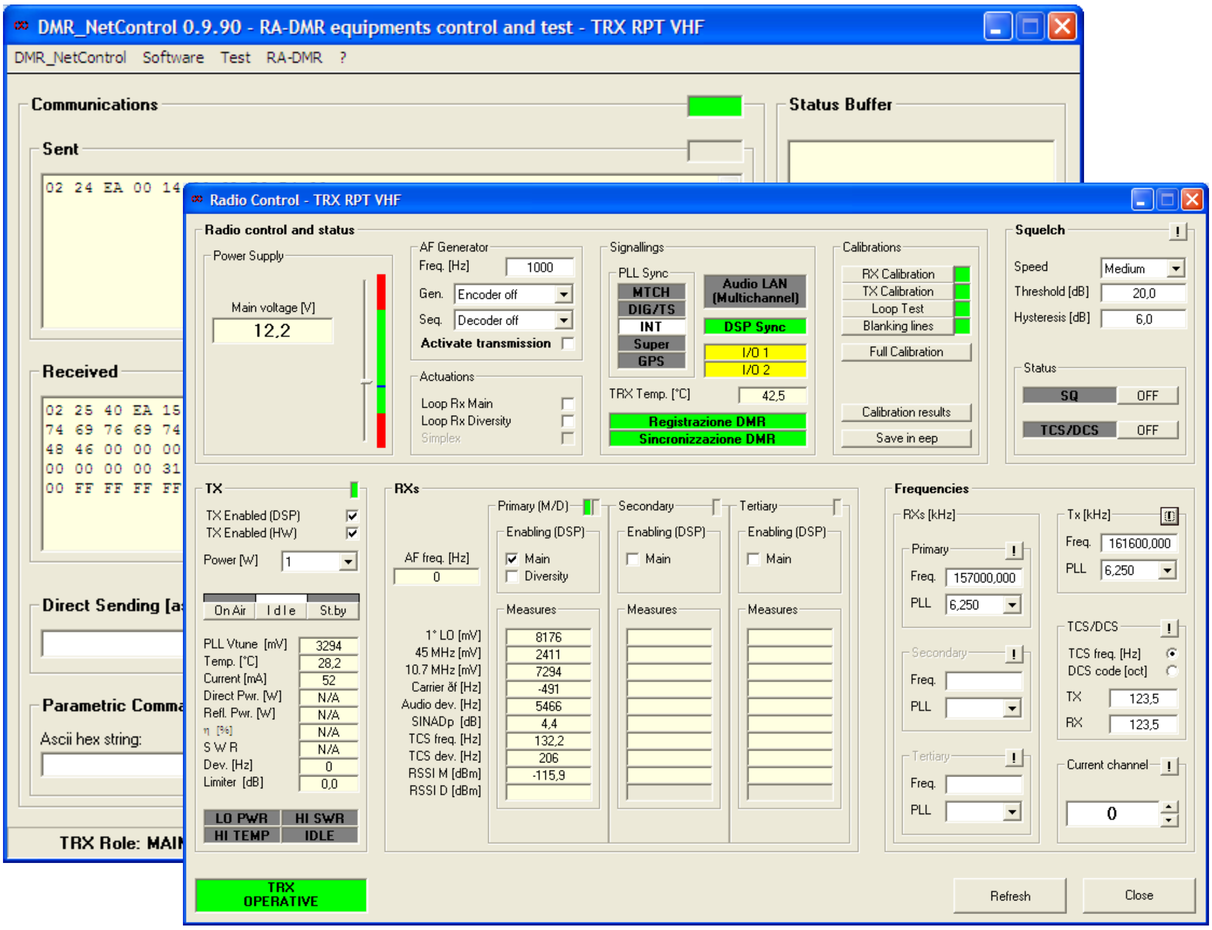
In this example is shown that the input “extern alarm 2” is on. This input is optoisolated and can be connected to the site opening switch or to the 220V voltage drop or to other states of interest.

The mask on the top shows the date and the time at which the data shown are referred to. To refresh data it is just necessary to activate the update button. The update is done through the “Update” button, which is very fast (a single data packet) and allows a clear view of the state of the apparatus.

The “**Connect**” button allows to know further details about the set up or the control of the stations. This command starts the connection mask and the other mask, which are described in the DMR_Manager manual.

The connection to the remote device activate the DMR_Manager tools that permits to full modify the parameters of the base stations. This feature is regulated by a password.

The first mask that will appear is the “main menu” selection windows:



The DMR_Manager features are too long to describe in this document then see the related user manual for a detailed description.

FACTORY REMOTE ASSISTANCE

Radio Activity offers on demand a remote technical support to help the User or the Reseller to maintain, upgrade, detect failure and repair the network. These operations should be available through when an access port is grant from the network IP backbone and the Internet or when is available a GSM/GPRS access.

The Radio Activity Technical Assistance Center may be able to make a precise remote diagnosis of the network status; then it could solve problems (if possible) or it could drive the Local Service Maintenance during system recovery. On site operation can be performed by technical staff not specifically trained in RBS knowledge which are considerably complex machines. Once on site, the operator will be led by the Radio Activity Technical Assistance Center to replace failed sub-unit with spare one. The failed unit will be repaired or replaced by the factory to restore the stocks.

The remotely SW up-grading function is useful for new features addition or to update the capabilities with new versions developed in Factory. This feature is particularly crucial and it is suggested to do it under the supervision of the Radio Activity Technical Assistance Center only.

Contact your Reseller or Factory for these services.

INTERNATIONAL DIRECTIVES COMPLIANCE

The devices are compliant with existing European telecommunication regulations, in particular respond to:

- **ETS 300 086**: Technical characteristics and test conditions for radio equipment for analog speech.
- **ETS 300 113**: Technical characteristics and test conditions for non speech radio equipment for the transmission of data.
- **ETSI 300-230**: Radio Equipment and Systems (RES); Land mobile service; Binary interchange of Information and Signalling (BIIS) at 1.200 bit/s (BIIS 1.200).
- **ETSI TS 102 361-1 V1.4.5 (2007-12) Air Interface.** Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 1: DMR Air Interface (AI) protocol
- **ETSI TS 102 361-2 V1.2.6 (2007-12) voice and generic services.** Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 2: DMR voice and generic services and facilities
- **ETSI TS 102 361-3 V1.1.7 (2007-12) Data protocol.** Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 3: DMR data protocol
- **FCC Part 90**. Private land mobile services compliance according with ANSI TIA-603-B-2002 (conducted test), ANSI C63.4-2003 (radiated test).
- **FCC Part 15 Subpart B, 15.107 and 15.109**. Unintentional radiators.
- The product is compliant with 1999-5-CE directive.
- The product is compliant with 2002/95/CE directive - RoHs (“ro-has”), not containing concentrations exceeding the permitted limits for the following substances:

  - Lead (Pb)
  - Mercury (Hg)
  - Cadmium (Cd)
  - Hexavalent chromium (Cr(VI))
  - Bifenile polybrominated (PBB)
  - Polybrominated diphenyl ethers (PBDEs)

