Acoustic/Seismic Ground Sensors for Detection, Localization and Classification on the Battlefield

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ABSTRACT

The purpose of this paper is to present different acoustic and/or seismic systems designed and tested by Thales Underwater Systems(TUS) in the past few years, in order to detect, localize and classify a large panel of targets on the battlefield. The presented systems address mainly weapon fire detection and localisation, wheeled and tracked vehicles detection/localisation/tracking and aircraft (helicopters, drones) detection, localisation and classification. Depending on the application requirements, they include either stand-alone acoustic/seismic sensor, or networks of acoustic sensors. Firstly, TUS background is recalled, then drawbacks and advantages of acoustic and seismic system are briefly discussed. Some equipment dedicated to different kinds of battlefield target are then described in terms of operational requirement and implied design drivers for stand alone sensors and, when appropriate, for network architectures of unattended ground sensors. The principles of the signal and data processing implemented are outlined. All processing schemes used in Thales Underwater Systems build upon the synergy between Anti-Submarine Warfare and in-air acoustics, and are consistently focused on reliable automatic false alarm control. Actual implementations of this approach in Thales products and demonstrators are presented as well as some experimental results obtained during different ground tests or operational assessment trials: BACH &BARRE for helicopters, drones and blade propelled aircrafts, VEGA/ACSIS devices deployed in UGS-TG25 NATO trials for light/heavy wheeled/tracked vehicles, and BACCARA/SL2A for artillery guns (105-155mm), tank guns (105-120mm) and mortars (60-81-120mm). This paper concludes on the means to build upon these target-focused devices for providing an integrated multi-targets acoustic/seismic remote sensor for passive battlefield monitoring.

1.0 INTRODUCTION

1.1 Thales Underwater Systems background

THALES Underwater Systems (TUS) is a subsidiary of THALES dedicated to Anti-Submarine Warfare. This world leading company (2nd world rank, 1st for exports) has forty years experience in high-tech sonar design and development for surface ships and submarines.

TUS interest for in air acoustics began in the middle of 1980’s when the question of helicopter’s threat for SSBN submarines was raised. This potential threat led TUS R&D teams to first study air-water interface, in air acoustics propagation, and then acoustic helicopter detection feasibility.

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It rapidly appeared that false alarms control was a key point in order to design reliable automatic in-air acoustics detection systems : data and signal processing algorithms must be performing. At the early 1990's, the fast evolution of processor computation power has allowed the transposition of the most sophisticated ASW detection, localization and classification algorithms to in-air acoustics applications.

For more than fifteen years, TUS R&D's teams have then applied its state-of-the-art acoustic algorithms to in air acoustic detection, localisation and classification of battlefield targets. These works, mainly funded by the French DGA, have resulted in different demonstrators and products adapted to different kinds of targets : helicopters (with extension to blade propellers aircraft and drones), vehicles and pedestrians, and artillery/snipers.

1.2 Advantages and drawbacks of Acoustic and Seismic sensors

In Air Acoustics and Seismic sensors exhibit several interesting advantages for battlefield applications which among which **Non-Light-Of-Sight** (NLOS) detection, **Fully passive** (stealthy, low power) and **panoramic** (360°) coverage, **Non Cooperative Target Recognition** (NCTR) capabilities : acoustic and seismic signatures of some targets contain highly revealing features (e.g. helicopters) and **low cost** (potentially expendable).

These advantages are somewhat counterbalanced by the following drawbacks :

- Their performance are sensitive to the environment. For acoustic sensors, performance are weather sensitive, mainly because long range acoustic propagation, rather complex, depends on wind and temperature evolution with altitude. Wind also creates an additional low frequency non stationary noise. As a result, detection range is weather dependent and often anisotropic, especially at long distance. For seismic sensors, behaviour strongly depends on ground composition (attenuation, wave velocity, interaction with acoustic waves).
- The sound celerity in air is rather slow (340 m/s), which induces significant detection delay at long range. Seismic waves velocities are very variable (depending on ground, but also on range through the depth of propagation paths).

Acoustic/Seismic sensors can be used as stand alone systems, or can be coupled with other sensor technologies. Indeed, they can offer :

- Alert and target cueing for LOS passive sensors,
- A reduction of active sensors vulnerability,
- Complementarities for coverage, localisation and NCTR purposes.

Depending on the context, in-air acoustic and seismic sensors can therefore be considered as good complements (or even sometime alternatives) to more traditional battlefield sensors such as cameras or radars.

2.0 EXAMPLES OF THALES IN AIR ACOUSTICS UGS

2.1 Introduction

Though initial In Air Acoustics works of TUS in the beginning of the 90' were focused on straightforward applications of Anti Submarine Warfare algorithms, it soon became obvious that demonstrating the efficiency of sophisticated signal processing algorithms would quickly sidetrack the main issue : operational usefulness.

Following the Warsaw Pact demise, many modern armies have to deal with an ever growing complexity of equipments and the downsizing of their manpower. Any new technology is likely to be accepted if, and only if, its benefits are not obtained at the cost of overburdening the users. It is especially true with In Air Acoustics and Seismic sensors that, as previously stated, often to be used in complement of other sensor technologies. In most cases, deployment and use of IAA systems will thus be done as a secondary task as their main mission will focus most of their attention. As a corollary, deployment has to be fast, easy and safe. No operator should be needed for monitoring the system, his assessment being required only when reliable information is available concerning an existing threat. Last, but not least, this minimum manpower requirement has to be achieved not only in combat use, but also through logistics, support and training.

These simple “common sense” guidelines have many important consequences on the design of an In Air Acoustic piece of equipment, especially in a design-to-cost approach. Most of them have to be tackled at the hardware level (size, weight, autonomy) but some have to be taken into account at the algorithm level (very low false alarm rate and threat assessment) or at the network level when applicable (stealth, reliability,..). Depending on its primary mission, these guidelines will be derived in terms of design drivers that will be presented below for three classes of targets of interest for In Air Acoustic UGS. Though similar in some requirements, the hardware or system designs adopted by TUS were slightly different as feedback from numerous field tests and evaluation refined practical implementation.

2.2 Helicopters and extensions

2.2.1 Operational context

Helicopters were the targets of choice for applying ASW algorithms to In Air Acoustics as they represent a major threat for any submarine, and thus have been studied early by TUS in the context of SSBN protection. On the battlefield, helicopters are well suited to avoid detection from radar and optronic sensors as they are able to “hug the ground” and hide behind relief and vegetation, but their rotors radiate very distinctive very low and low frequency sounds that are not significantly attenuated by these obstacles. TUS studies and demonstrator in the early 90s involved hidden target detection and classification with an microphone antenna located immediately near the protected site, mainly in Very Short Range Air Defence scenarios. Though successful, this approach appeared to be less promising than sensors barrier deployed a few kilometres ahead of the protected area, and in 1995 DGA funded BACH, a UGS demonstrator intended to fulfil two main missions: Protection of a site from an incoming helicopter in tactical flight, and intelligence gathering on helicopter movements over a given area.

Both missions were subject to operational requirements given in broad terms such as : no constraints in sensor post location, deployment time of less than one minute by one soldier, autonomy over two days, no operator required, maximum stealth, very low false alarm rate, detection ranging from 2 km to 10 km, threat direction estimation, helicopter type recognition…Aside from these requirements, each sensor post was to be recovered after its mission, but inexpensive enough to afford leaving it on the battlefield, should the need arise.

2.2.2 Design drivers

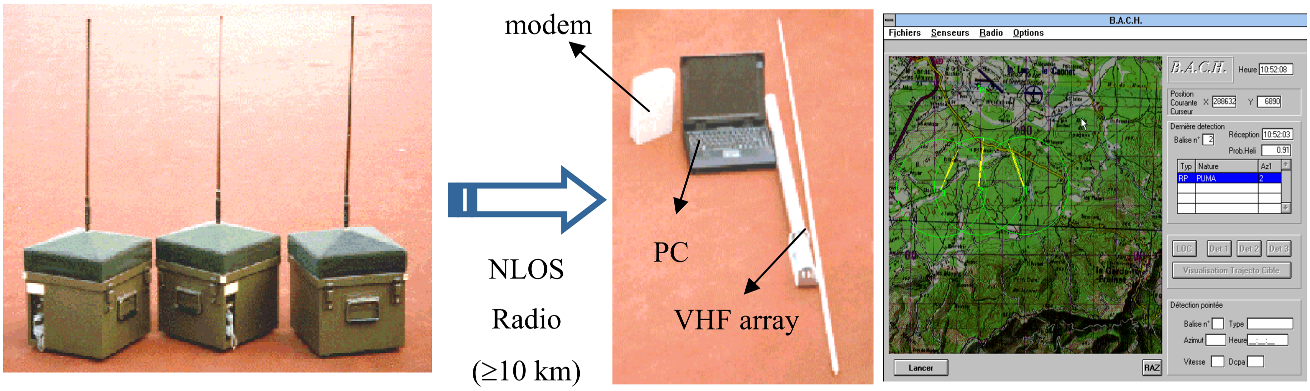
The global architecture consisted of multiple autonomous sensor posts (Unattended Ground Sensors) reporting to a distant command post through radio links. Operational inputs were then declined into the following design drivers : constraints on deployment time, manpower and cost dictated a compact design, involving a single load without any moving or folding parts. Minimising deployment time involved a squat box as Sensor Post, with a single on/off switch and with a compact array of microphones housed *inside* the Sensor Post : as location accuracy was not a premium, deployment consisted of putting the sensor post on the ground, rotating a marked corner toward North and turning it on. Into action time is thus less than twenty seconds. Avoiding constraints in deployment locations implied a powerful Non-

Line-Of-Sight radio link, which had to be efficiently managed according to power supply limitations as well as stealth requirement. As minimum UGS radio activity and Command Post security is insured by one way (SP to CP) burst transmission strictly limited to positively classified threats, it implies a fully automatic behaviour of the UGS, regardless of environmental conditions and acoustic environment of the SP. This requires a false alarm driven conception of the processing, requiring a lot of computing power with minimised energy requirement. Using floating point DSP enables to avoid compromise on algorithm implementation within a suitable energy budget : inexpensive lead batteries insures a few days of operation at full detection capabilities, and may offer extended operation time using a reduced awareness mode.

Using these design guidelines, a design-to-cost procedure led to the selection of the BACH SP hardware that is described further. A second step involved refined operational requirement on a much better location accuracy that led to the adjunction of an external array of microphones (into-action time as well as dimensional requirement were accordingly modified) connected to the SP.

2.2.3 BACH/BARRE presentation

The BACH system is composed of 1 to 8 sensor posts reporting to one PC (Command Post) by NLOS radio links (wire link also available). The command post is composed of a laptop PC, a modem and a VHF antenna. Radio range allows NLOS 10 km distance between SP and CP. Radio emission of each SP is controlled so that collisions are avoided. Figure 1 presents BACH system components.



3 BACH Sensor Posts (1 to 8)

Command Post

BACH MMI

Figure 1 : BACH System

Whenever an interesting target is detected, a sensor post sends synthetic information (such as target bearing, classifying features, helicopter type…) to the Command Post which automatically displays them both on a digital map and in an alphanumeric window.

Each BACH Sensor Post is a self contained unit that includes :

- An internal 5-microphones array,
- A compact electronic package (internal test and monitoring unit, AD signal converter unit and floating DSP board),
- A NLOS proprietary radio modem and short flexible antenna,
- A power pack and a GPS unit.

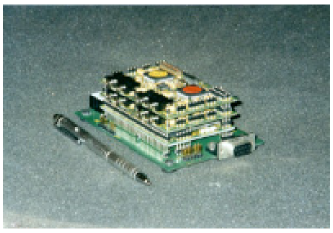


Figure 2 : BACH electronic board

Size and weight are mainly driven by the power pack: the overall dimensions of a BACH Sensor Post is around 33 cm in all dimensions in order to fit many SP in a single lightweight vehicle. Sensor Post weight is under 20 kg with a rechargeable power pack insuring one week of autonomy. The high performance Digital Signal Processor is able to cope with 40 simultaneous tracks. The BACH SP may be used in two modes involving a small built-in microphones array for very quick deployment (below 20 s) in difficult conditions, or a larger external microphones array (BARRE extension) for increase localisation accuracy (deployment requires a few minutes by a single man).

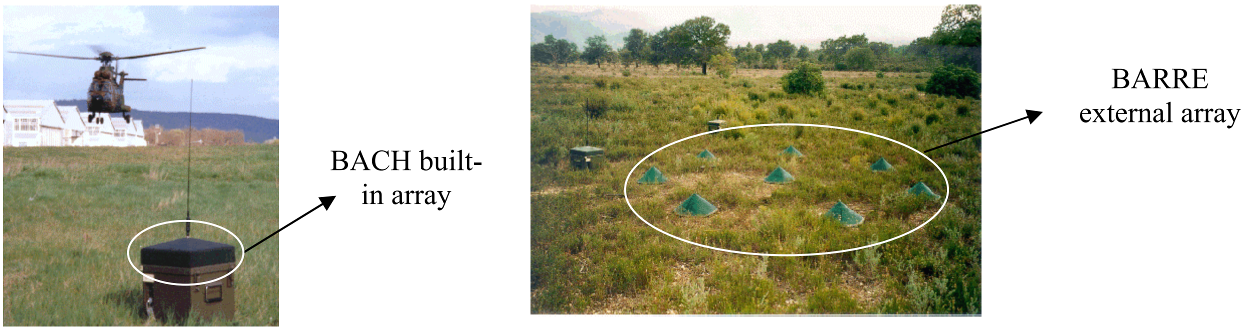


Figure 3 : BACH inner array and BARRE external array

2.2.4 Processing scheme

Processing inside SP is dedicated to stationary spectral lines extraction and derives from ASW algorithms. Special attention was given to false alarms (FA) rejection, which is achieved at different stages of the processing chain, as illustrated in figure 4. The more ambiguous the FA, the more complex the rejection process. Classification stage involves specific features extraction and neural classifier. Recognition of the helicopter type is eventually achieved using either rules or a neural net depending on extracted features. Helicopter type is found among ten predefined types (e.g. Alouette 3, Gazelle, Puma,…), but an "unknown type" class is available.

The processing is fully automatic: no operator tuning is required as the software automatically adapts to the acoustic and meteorological environment (CFAR detection via specific normalisation scheme).

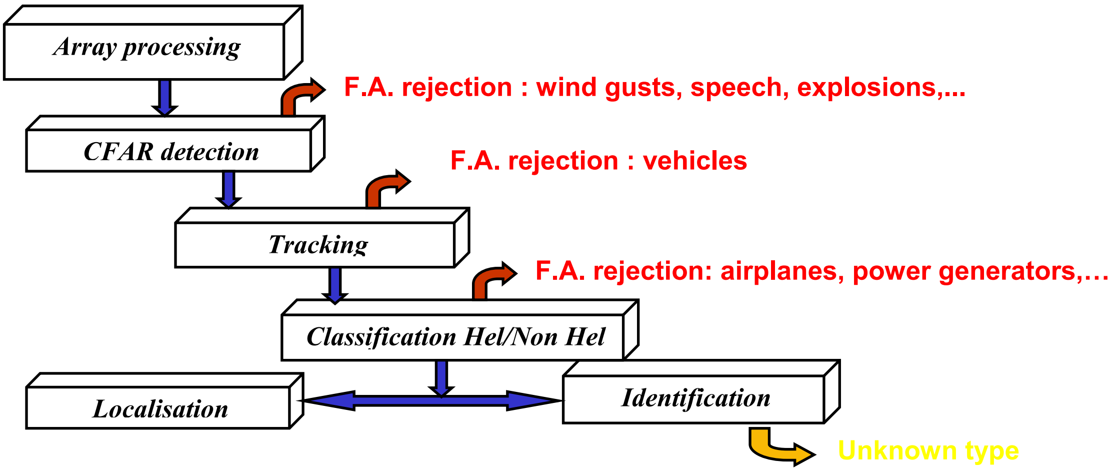


Figure 4: Principles of BACH Sensor Post processing scheme

2.2.5 Field tests results

The BACH/BARRE system has been tested on the ground at different places, under various met conditions. Detection range depends on helicopter type and met conditions. Typical BACH SP detection area (often anisotropic due to wind) is about 50 km² for light helicopters, and over 100 km² for heavy helicopters. In very difficult weather conditions, it remains superior to 10 km² for silent helicopters. Correct recognition of helicopter type (among ten) is superior to 90% (even in multiple targets environments), thanks to the reliable significant features extracted from acoustic helicopters signatures. Bearing estimation accuracy obviously depends on the acoustic array size. Figure 5 shows instantaneous bearings vs time measured with small BACH internal array (left picture) and with BARRE external array (right picture), on main rotor signature (red plots) and tail rotor signature (green plots). External larger array brings spectacular improvement at low frequency (see red plots), whereas bearing estimates remain correct even with the small array at higher frequency. Field trials tests assessed that at mid-range, BACH inner compact array leads typically to about 5° accuracy, whereas external array (few meters extension) allows 1°/2° accuracy. The use of the most suitable acoustic array will depend on operational need and constraint (compromise between required performance/deployment ease and rapidity).

Localisation in X-Y can be derived from at least 2 SP's by triangulation means. Distance estimation from a single sensor post is achievable using Doppler and bearing evolutions, but reliable estimation would be obtained only under restricted conditions (rectilinear uniform motion, low distance, high speed,…).

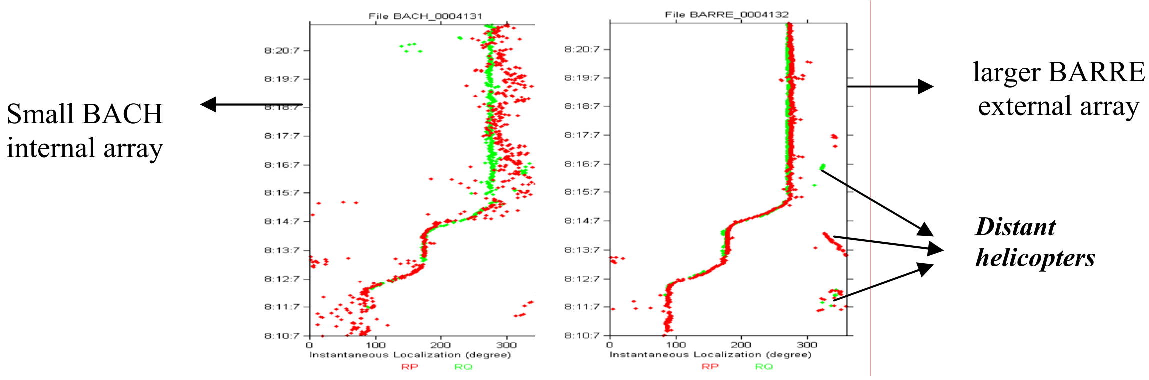


Figure 5: Instantaneous bearing measurements

Complementary field tests involving BACH sensor Post are worth to be mentioned:

- PATHFINDER trials conducted with DERA involved a BACH sensor post co-located with an IR sensor and a visible light camera. The obtained results proved feasibility and interest of acoustic sensor cueing a LOS sensor: NLOS early warning, efficient (< 10° with inner array) location cueing for LOS sensor orientation, very few false targets, highly reliable helicopter identification,
- Several trials proved that BACH/BARRE could be extended to other targets than helicopters: deactivating certain false targets rejection criteria, blade propelled aircrafts were tracked at several tens of km, and certain drones (equipped with rotor or blade) could be tracked over a few km.

2.3 Vehicles

2.3.1 Operational context

Preliminary work on acoustic vehicle detection and location in TUS were related to counter mobility in the context of a major invasion by a large number of tanks. The overall context was the Area Defence Weapon project which objective was to deploy new mines able to launch a smart submunition (able to relocate and attack a main battle tank, or MBT) over a designated area without restraints on mine-target inter-visibility. Given NLOS requirements, both in air acoustic and seismic sensors (as well as VHF/UHF radar) were natural contenders as part of the mine triggering system, and the concept was then studied and demonstrated in 1992/1993. As the threat declined, the operational requirements evolved towards :

- Enhanced surety for compliance with international treaties regarding mines : in this role, the acoustic/seismic sensors perform either as a full fledged NLOS vehicle detector /locator/mine trigger, or simply ensure that the target may not be a pedestrian.
- Zone surveillance by unattended sensors platforms. One could think that this mission basically translates in the same type of equipment as the mine triggering system minus the warhead and plus a network communication and management system. Nevertheless, this mission offers much more possibilities by alleviating timing constraints for warhead efficiency, and stresses cooperative use of multiple sensors.
- Short range protection of a soldiers unit : though seemingly unrelated, this application relies upon the same algorithms that the preceding missions.

2.3.2 Design drivers

In terms of design drivers, mine triggering devices are most demanding in terms of stealth (a counter mobility device is only useful so far that it cannot be easily located and neutralised), false alarm control, cost and autonomy (applications presented below were done using available DSP and eluded autonomy constraints, but current contracts focus on translating proven algorithms on specific boards ensuring up to two months of autonomy). Part of the stealth constraints translates into minimising the visual footprint of the sensor: this is simple enough for seismic (buried) sensors but becomes quite complicated for microphones when high location accuracy is required. When required, TUS choice is to use a seemingly large array of microphones (for accurate angular estimation), but lying flat on the earth and whenever possible hidden in vegetation (tall grass, bushes…). False alarm is a major constraint for the mine triggering application as spurious detection may void the efficiency of the device (one shot warhead) or negate the purpose (compliance with international treaties) and places a lot of stress on the classification functionality. Achieving extreme reliability depends on the nature of the false targets: quite easy when discriminating pedestrian from tracked vehicle, it may require additional sensors in complex situation, e.g. when dealing with counter measure devices. Thales explored with DGA various combinations of acoustic, seismic and NLOS radar sensors for robust vehicle detection, tracking and classification.

2.3.3 VEGA/ACSIS presentation

The VEGA/ACSIS sensor for vehicles comes in two versions associated to two different purposes:

- VEGA is an acoustic alerter that detects and localises in azimuth incoming vehicles. A threat assessment based on an internal classifier decides whether or not to trigger a low power NLOS VHF radar developed by Thales Air Defence (TAD). Target is then acquired both in acoustic and radar modes, and tracked through a multi-sensors fusion algorithm developed by THALES Daimler Aerospace Armements (TDA). An effective X-Y target position prediction enables to direct fire by either a co-localised smart munition or by a remote firing system.
- ACSIS combines both acoustic and seismic information originally to estimate target range in a fully passive mode (with a lesser accuracy that the one obtained in the radar-acoustics mode).

VEGA and ACSIS share the same hardware: figure 6 below shows the folding VEGA purely acoustic array. In ACSIS mode, central microphone is simply replaced by a seismic sensor.

2.3.4 Processing scheme

Implemented processing for vehicle detection is similar to that used for helicopters (see figure 4), with adaptations to cope with vehicles signatures (fuzzy unstable spectral lines, abrupt variations,…). In

VEGA/ACSIS application, identification stage is absent, and classification is oriented toward mine triggering application (forbidden/non-valid/doubtful/valid). In ACSIS mode, seismic signature is also exploited in order to help to deliver a distance estimation. As for BACH, processing automatically adapts to acoustical and met environment so that no operator tuning is required.

2.3.5 Field tests results

Performances of VEGA/ACSIS sensor have been assessed in multiple field tests. Detection range lies from several hundred of meters to several kilometres, depending on the vehicle (from light wheeled to heavy battle tank) and on weather conditions. Angular accuracy is of a few degrees at mid-range. Range estimation by a single sensor is possible in ACSIS mode, but only under specific trajectory condition and target nature.

VEGA/ACSIS sensor was deployed in NATO/TG25 UGS trials (Bourges, Oct.2002) in a stand-alone configuration and delivered bearing estimates in real-time via DGA SPIDER protocol. The obtained results turned out to be pretty satisfactory all along the two weeks trials, in terms of detection range and localisation (classification was not adapted to TG25 typology). Figure 6 shows an example where a P4 jeep was tracked by VEGA/ACSIS sensor over 1 km range under favourable conditions. Other example results are presented in [1], where the good behaviour of this sensor during TG25 trials can be viewed.

Figure 6 : VEGA/ACSIS array (left) and NATO/TG25 UGS trials results illustration (right)

2.4 Weapon location application

2.4.1 Operational context

An important field of interest for In Air Acoustic Unattended Ground Sensors is weapon detection and location ranging from heavy artillery down to small calibre weapons. An artillery fire locator demonstrator named BACCARA was designed by TUS closely following French Army operational requirements: it has evolved in the THALES SL2A product incorporating SMAD derived Command Post. The framework of this product development was closely related to the COBRA radar artillery locator (it is sometimes tagged as a “COBRA alerter”). SL2A is an artillery location system designed to fulfil three main missions, with minimum operational constraints:

- Autonomous artillery locator for quick tactical response against enemy fire,
- Surveillance and intelligence gathering in long-term peace keeping missions,
- Cueing system for other counter-fire systems such as the COBRA radar, which can further be detailed as:
  - Survivability: to cue the directional radar COBRA with precise information on artillery battlefield activity (number, density, location, nature…) optimising radar use and survivability by giving it before going active a valuable situation awareness.
  - Continuity of service: illuminating the battlefield makes COBRA a primary target of enemy fire and forces it operate briefly before moving to a new position. During COBRA transit, SL2A still operates and locates continuously enemy artillery activity.
  - Complementarities: relying upon a different physical phenomenon, COBRA and SL2A data can be corroborated to improve classification of events.

Though initially required for artillery location, the system has to be able to cope with lighter weapons threat, namely detection and location of small calibre mortars, firearms, but also antitank weapons shot in ballistic flight.

2.4.2 Design drivers

BACCARA/SL2A design drivers were focused upon operational efficiency, stealth and tactical mobility. They may be summarised as follows : **No specialised operators** : the system must require few operators, and they are usually not dedicated to this equipment. **Stealth** : Command post must be fully passive, and Sensor posts must be extremely difficult to detect (visible, infrared, radio). **Easy to deploy and to use, and mobile** : multiple sensor posts can be deployed and recovered in a few minutes by a single man with a light vehicle. Command post can be used on the move, and SP may be leapfrogged transparently. Vehicle may be fitted with a specific array to become a highly mobile opportunity SP. **Reliable** : The system must be accurate as well as sensitive with an extremely low false alarm rate and the global architecture must be robust versus destruction of some sensor posts. Multiple Command Post may share part or all Sensor Posts. **Low cost** : though sensor posts are designed to be recovered, they may be used as expendable assets whenever the tactical situation requires it.

2.4.3 BACCARA/SL2A presentation

BACCARA demonstrator used the same hardware as BACH system (see §2.2.3), with adjunction of a large external 3-microphones array for better false alarm control and high density firing environments.

SL2A sensor post External triangular array SL2A light CP

Figure 7 : SL2A system components

SL2A Sensor Post is a ruggedized and more compact evolution of BACH/BACCARA SP. Multiple channels are selectable for radio and rechargeable pack power is clipped for an easy change. Sensor Post weight is under 18 kg with a rechargeable power pack insuring 48 hours of autonomy. An enhanced Digital Signal Processor is able to cope with high firing rate environments (up to 5 events/s) with room to house extra multiple mission software (aircrafts, vehicles…). The external 3-microphones array is covert and easy to deploy on a triangle. A complete into-action time only requires less than five minutes with two soldiers. A vehicle mounted specific compact array can also been used instead of triangular one.

A full SL2A system is composed of 8 Sensor Posts reporting to a Command Post by NLOS radio link (≥10 km). For stealth reasons, no radio transmission is required from CP, and SP emission towards CP are limited to bursts sent only when validated events occur or when health report is required. Time sloting logic avoids any emission collision. Multiple Command Posts may use the same Sensor Posts network.

The command post is composed of a PC, and radio means. All located events are displayed to the operator both on a digital map and in an alphanumeric window. Along this main display, multiple functions are available to the operator such as remote sensor monitoring (SP locations, microphones, power and GPS status…), storage/prints of events reports, replay mode...

2.4.4 Processing scheme

The implemented processing in BACCARA/SL2A sensor post is dedicated to low frequency transients extraction. Once again, full automatic false alarm rejection is achieved at different stages of the processing chain, involving increasingly complex criteria: CFAR normalisation scheme, multi-channels coherency checks, neural classification gun/no gun... Sensor Post delivers multiple information such as bearing, time of arrival, classification features… The false alarm rejection is complemented at the CP level, by association algorithm which controls that detected events from several space apart sensor posts are coherent both in time and azimuths. These multiple false alarms rejection steps result in a very low false alarm rate at BACCAR/SL2A system level. At the CP level, sensor posts outputs are merged to derive an x-y location, together with a classification mark.

2.4.5 Field tests results

BACCARA and SL2A have been exhaustively tested on the field during numerous ground tests and operational assessment trials. SL2A is in service in the French Army since 2004.

Minimum detection ranges depend on met conditions and weapons charge but may summarised as follows:

- Artillery guns (105 mm, 155 mm) : >10 km (typically 15 km)
- Tank guns, 120 mm mortar : >10 km
- 81 mm, 60 mm mortars (and smaller calibre guns): ≥ weapons firing range

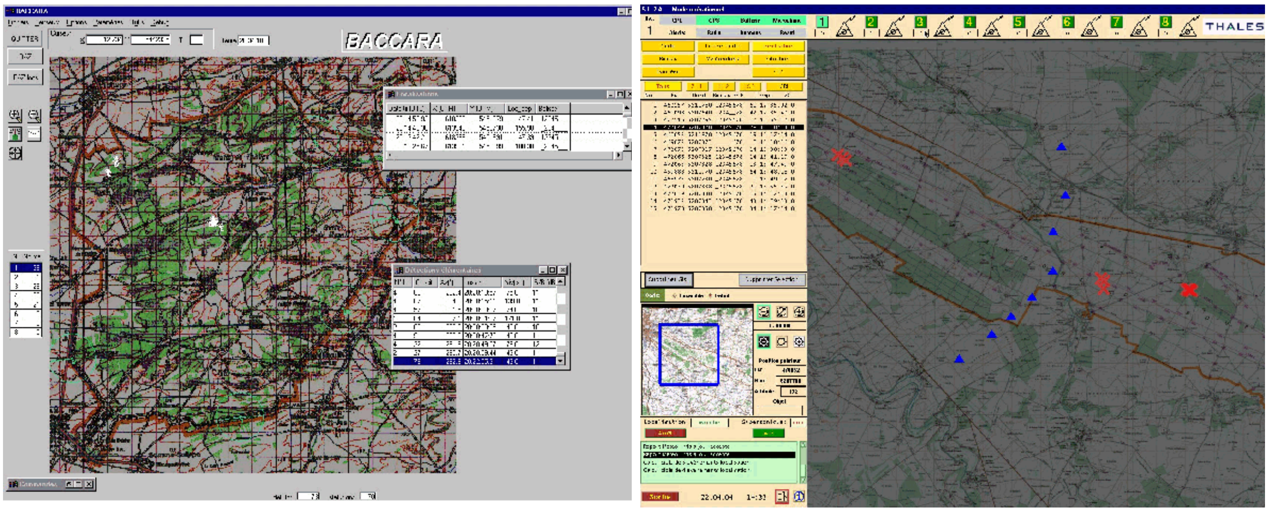
Of course, longer ranges have been observed under favourable conditions (> 25 km on artillery guns, > 15 km on 81 mm/120 mm mortars, > 20 km on tank guns).

Location accuracy also depends on sensor posts configuration (network extension). Though CEP of a few meters has been observed under very favourable conditions, CEP is more typically of 100 m under 8 km range, and 1%-2% of range at longer range.

False alarm rate is low (specified as 1/24 h, it is consistently lower than this value).

Besides, during complementary field trials, a specific compact folding acoustic array, mounted on a light vehicle, was substituted to the external triangular array and successfully tested as part of the SL2A system.

For illustration purposes, figure 8 below presents BACCARA and SL2A screen hardcopies obtained during field trials at Suippes and Bourges.



BACCARA MMI

SL2A MMI

Figure 8 : BACCARA and SL2A Command Post MMI

3.0 CONCLUSION

The logical development framework for previous work was to extract design guidelines from a specific operational context, then to develop a dedicated combination of software and hardware that match specific operational requirements. Though each final product is well suited to the application, this approach has drawbacks, mainly the cost and delay of possible UGS redesign and the lack of synergy between dedicated algorithms. From a hardware point of view, SL2A UGS platform is able to house all previous algorithms that may be downloaded during mission preparation and can be fitted with extra specific peripherals according to the target of choice.

Concurrently, TUS is looking into an alternate solution that would integrate all previous algorithms into a single multi-purpose multi-target software architecture that would rely upon a basic SL2A sensor post fitted with a single deployable acoustic/seismic sensor array similar in design to the VEGA array. The main software difference is that instead of running instances of each algorithm and merging final results, each process builds upon intermediate results of common sub-algorithms, instead of implement a more simple multiple hypothesis detection test. For example, primary detection of transient events (artillery, sniper, pedestrian) is very efficient at extracting signal time slices that exhibit non-stationary behaviour. Precise time stamping of these events is thus beneficial to enhance spectral lines detection common to vehicle and helicopter detection, by cancelling out time-frequency domain polluted by transient events. Another example lies in the spurious target classification modules: a lot of processing is done to separate vehicle signature from other spectral line generating targets. Using helicopter classifier output efficiently isolates all its spectral components, thus reducing the burden of "non-vehicle" classification module. SL2A computing power has been tailored to deal with simultaneous processing of the following targets: helicopters, vehicles, pedestrians and weapon fires (guns, mortars, tanks and light weapons).

Benefits of this approach are twofold : enhanced detection capability for a given false alarm rate within each application framework, and multi-threat detection/localisation/classification capability with a single UGS. It is to be noted that the second goal is not always desirable when dealing with actual in-service equipment. Care must be taken not to clutter the operator with information unrelated to his primary mission, though this approach enables to filter out non relevant alarms at the Command Post level.

Multi threat capability is especially interesting for zone surveillance, which implies efficient deployment of a network of such sensors, but it requires further analysis in how to deploy them efficiently as detection range will widely vary between target types: half a dozen sensor posts will efficiently monitor a 1000 km^2 area for heavy gun activity but will only detect pedestrians on a few thousand of square meters. Theoretical tools have been developed by TUS to investigate network efficiency for a given threat, and thus providing valuable insights on deployment strategies [2].

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