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1 Project Execution

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VHF SPECTRUM SHORTAGE THREATENS AIR TRANSPORT GROWTH

Air transport has been identified as a dominant factor for sustainable economic growth world wide, and A/G communications are extremely critical for achieving an ATM system that is capable of matching all future air traffic demands.

The VHF COM spectrum (118 – 137 MHz) has been globally allocated for aeronautical safety communications over continental areas. This spectrum is currently organised in voice channels of 25 kHz or 8.33 kHz and a unique voice VHF channel is assigned to each Air Traffic Control (ATC) sector or function.

Relatively small parts of the spectrum have been allocated to the aeronautical data links like ACARS (Aircraft Communications Addressing and Reporting System) and VDL (VHF Digital Link). VHF communications provide good cost to service figures and will remain very attractive for the aviation community on a mid or long term perspective.

Studies clearly indicate that the future communication systems - including VHF communications - will have to provide more communications capacity and increased capabilities to cope with the expected air traffic growth.

Existing VHF voice communications system, ACARS and VDL data links may not be able to provide the capacity and performance required in the long term. Radical improvements are necessary to cope with the expected air traffic growth.

B-VHF AS AN INNOVATIVE APPROACH

The B-VHF research project, which has been co-funded by the European Commission under the Sixth Framework Programme, has investigated a new approach to overcome the VHF spectrum bottleneck. The main focus of the B-VHF project was initially put on the feasibility analysis of a broadband VHF aeronautical communications system based on MC-CDMA (Multi-Carrier Code-Division Multiple-Access) technology.

A modern, fully-digital broadband B-VHF system has been designed at a high level, to match the future aeronautical communications requirements gathered from strategic ATM documents. The B-VHF system design covers both voice and data link services in a safety-related ATS and AOC environment.

Based on the high-level system design, an operational concept has been developed, accompanied by the deployment concept focused on the initial system deployment, i.e. operating the B-VHF system together with other systems in the crowded VHF COM range and on subsequent transition towards the fully deployed B-VHF system. Both the operational concept and deployment concept allow the system to be deployed and used in the VHF COM range and in other spectrum ranges anticipated for aeronautical communications.

Starting from the high-level system design, simulation scenarios and a simulation framework have been developed, allowing for the verification of project goals via detailed simulations at different layers of the communications protocol stack. The simulation campaign started with separate simulations of the B-VHF physical layer and ended with system-wide simulations. The results have demonstrated that the B-VHF system is capable of operating under different scenarios with that number of users corresponding to expected future air traffic densities and under changing communications demands while providing higher aggregate channel throughput, broader scope of services and a higher performance level than today's legacy VHF systems.

The project consortium has presented the benefits of this innovative approach to the aeronautical community via broad dissemination of selected project achievements.

KEY PROJECT OBJECTIVES

The main objectives of the B-VHF project were to prove:

- Suitability of multi-carrier technology for aeronautical communications

The B-VHF project identified and resolved the most significant technological challenges of the MC-CDMA technology when applied to aeronautical communications.

In order to be able to assess the suitability of the proposed multi-carrier technology, a real-time testbed for the B-VHF forward and reverse link has been implemented.

- Increased communications performance and flexibility

The B-VHF system has been designed to support an increased number of users within the same VHF spectrum and to provide higher aggregate channel throughput than the sum of legacy systems occupying the same spectrum. In each deployment phase it supports a mixture of communications services with varying Quality of Service (QoS) expectations and is easily configurable, following changing user needs.

- Increased security

Laboratory measurements on B-VHF forward- and reverse link test-bed have demonstrated the robustness of the adopted multi-carrier physical layer to narrowband interference. The designed system allows the integration of end-to-end security concepts and applications. However, such concepts need a very precise knowledge about the used data services in order to perform an adequate threat analysis. This time-consuming task could not be designed or followed within the B-VHF project.

- Operational feasibility of deployment concept

The project produced a set of scenarios for an initial system deployment in VHF and other ranges, both with voluntary and mandatory equipage, with smooth transition towards final deployment scenarios. The proposed scenarios are well aligned with previously developed concepts of operation for the introductory phase and for the time period ten years after an initial introduction.

- Feasibility of overlay concept in the VHF band

The main objective of the B-VHF project was to investigate the technical feasibility of the overlay deployment concept within the VHF COM band. Narrowband VHF systems must be able to continue operating within the broadband B-VHF channel if the users of the two systems remain separated by some protection distance. This offers a possibility for the B-VHF system to locally re-use spectral resources that were allocated to the narrowband systems which continue to operate beyond some defined co-channel-sharing range.

As an overall result, the feasibility of the B-VHF overlay concept in the VHF band has been successfully proven. It is possible to establish a B-VHF overlay system in the VHF band. However, ensuring coexistence with the legacy systems considerable effort has to be taken to reduce sidelobes of the B-VHF transmission signal and, in particular, to mitigate interference from legacy VHF systems at the B-VHF receiver. This is based on the assumption that not any change in the existing systems, infrastructure, frequency planning, operational concepts, etc. will be made to make the deployment of B-VHF as an overlay system easier.

PROJECT SCIENTIFIC ACHIEVEMENTS

During the B-VHF project following valuable scientific results have been obtained:

- System requirements were defined
- B-VHF functional scope, architecture and high-level system design were defined
- B-VHF system operational concept was developed
- Ground- and airborne measurements of the VHF spectrum occupancy were conducted
- VHF spectrum occupancy for Europe was modelled and simulated
- Detailed B-VHF system design has been elaborated and verified via separate simulations
- Based on the ground measurements a narrowband interference simulator for DSB-AM and VDL mode 2 was developed
- Broadband VHF channel model was developed
- B-VHF simulation framework has been developed (lowest two layers of the ISO-OSI model)
- Performance simulations of the B-VHF system were carried-out
- B-VHF deployment scenarios were elaborated
- Test-bed, comprising B-VHF forward and reverse links, has been implemented and evaluated in laboratory

SYSTEM REQUIREMENTS, FUNCTIONAL SCOPE AND OPERATIONAL CONCEPT

The requirements for the B-VHF system have been derived from the EUROCONTROL Operating Concept of the Mobile Aviation Communication Infrastructure Supporting ATM beyond 2015 (MACONDO) and other public documents. Both functional and performance requirements of an integrated voice and data link B-VHF system have been taken into account.

The B-VHF functional scope, system design and the operational concept take specific requirements of ATS (Air Traffic Services) and AOC (Airline Operational Communications) voice and data link services into account.

At a high-level, the B-VHF system is designed as a cellular terrestrial broadband full-duplex system. TDD (Time-Division Duplex) is used as duplex scheme. The combination of TDD access with the multi-carrier OFDM physical layer provides capacity and robustness combined with operational flexibility that is required for future ATM communications.

Like other terrestrial VHF systems, B-VHF system provides line-of-sight coverage. B-VHF communication concept assumes star-topology where aircraft within a certain volume of space, called B-VHF cell, are connected to the controlling Ground Station (GS). Each B-VHF GS provides multiple voice and data communications services to its users by using a dedicated broadband VHF channel. The channel bandwidth can be configured in a flexible way to provide the necessary number of communication channels.

Physical coverage of a B-VHF cell can be designed independently from the required service operational coverage. The operational coverage for an operational service (e.g. ATC sector) is achieved by installing the service at an certain number of B-VHF cells. In contrast to the operational handoff between voice channels that

remains human-controlled, the handover between involved B-VHF cells is automatic and fully transparent to the users.

The voice part of an integrated B-VHF system provides a dedicated party-line voice channel to each ATC function and supports a broadcast service as well. The system design also comprises a selective voice service supporting that voice circuits are established on demand upon explicit air- or ground user's request. When providing voice services, the B-VHF system re-uses the vocoder algorithm that has been validated and accepted for the VDL Mode 3.

The B-VHF data link sub-system comprises bi-directional acknowledged point-to-point air-ground data link suitable for integration as an ATN sub-network, non-ATN point-to-point data link and non-ATN broadcast/multicast data link.

VHF SPECTRUM AVAILABILITY AND OVERLAY CONCEPT

Different types of communications systems are currently operated within the VHF COM band (118- 137 MHz), like DSB-AM 25 kHz and 8.33 kHz voice systems, ACARS data link, VDL Mode 2 and VDL Mode 4 data links.

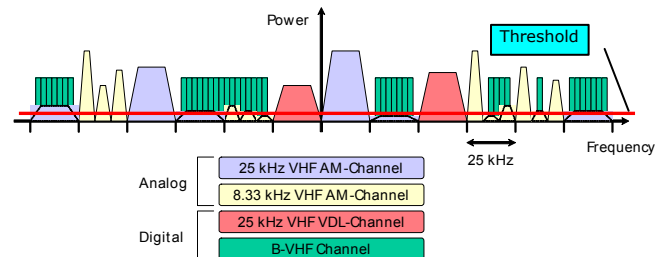


Figure 1-1: B-VHF overlay concept

The starting hypothesis for the B-VHF overlay concept (Figure 1-1) was that the B-VHF system can locally re-use VHF channels carrying weak signals from distant narrowband transmitters.

It is distinguished between weak (W) and strong (S) interferers depending on whether the received interference power in a given narrowband channel is below or above the specified threshold.

The narrowband channel containing weak interferers may be re-used by the B-VHF system. A group of OFDM carriers of the B-VHF system can be placed in that channel, but the B-VHF system must tolerate the remaining weak interference from distant narrowband transmitters. The channel containing strong interferers cannot be re-used as the B-VHF system would jam close narrowband receiver operating in that channel.

This decision procedure can be applied to each narrowband channel. Finally, a local broadband B-VHF channel can be composed from non-contiguous OFDM carrier groups (green bars in Figure 1-1), providing additional communications capacity without causing interference towards legacy narrowband systems.

The B-VHF project assessed via measurements and simulations the current usage of the VHF COM band spectral resources and the spectrum availability for interference-free operation, assuming the overlay concept.

The measurement campaign produced detailed data about VHF spectrum occupancy in Europe, comprising several hours of ground measurements at representative ground locations around Heathrow Airport in the UK as well as more than 12 hours of dedicated measurement flights carried out during peak traffic hours at different flight levels over UK and Central Europe. The raw data captured with a spectrum analyser at a two sample per second rate

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have been further processed, analysed and used for B-VHF system design decisions.

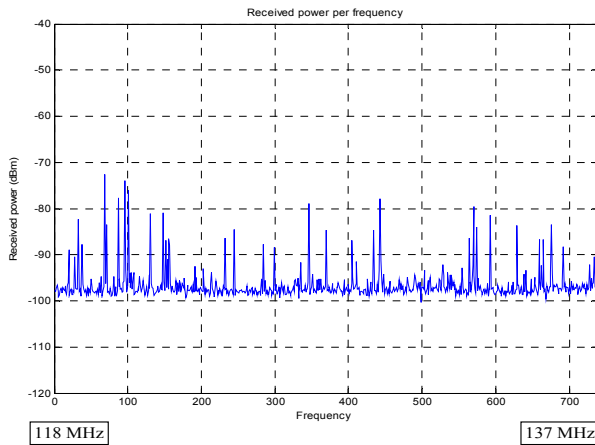


Figure 1-2: Instantaneous VHF COM spectrum occupancy

In parallel with the measurement campaign, a theoretical interference analysis has been performed using the NAVSIM tool. This investigation is based on the deterministic worst-case users' topology.

Towards the end of the project, several supplementary simulations have been performed in order to obtain worst-case spectrum availability at representative airports in Europe.

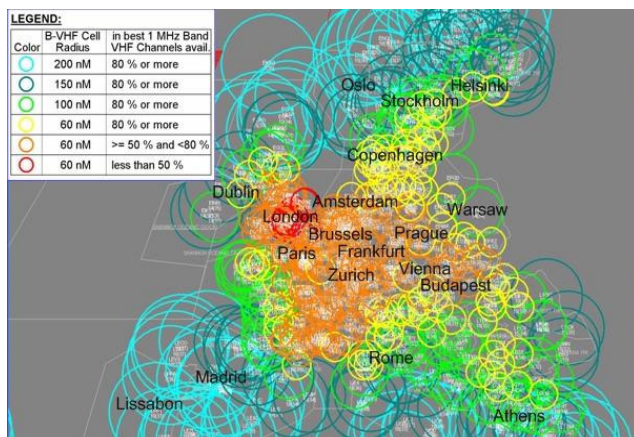


Figure 1-3: Simulated VHF COM spectrum availability for selected ground locations

The results of these activities lead to the conclusion that the overlay concept is feasible, but the local spectrum availability, which will under overlay conditions determine the achievable size and communications capacity of a hypothetical B-VHF cell, strongly varies within the European airspace. Furthermore, the results of physical layer simulations and laboratory measurements have shown that with overlay specific measures must be implemented within the B-VHF system (careful spectral shaping of the transmitted B-VHF signal-in-space and interference suppression techniques at the B-VHF receiver).

DETAILED B-VHF SYSTEM DESIGN

The detailed B-VHF system design was based on the previously established system requirements and comprises B-VHF system-specific, user-transparent methods that are required for the system

itself to work, including the system initialisation, automated net entry, automated seamless handover for wide-area coverage voice and data services, as well as internal procedures for service selection and resource allocation. The B-VHF system design comprises a broad scope of aeronautical communications services, with different priorities and quality of service as required for a specific application.

All important features of existing voice and data link systems are re-built within the B-VHF system. As an example, the party-line feature that is today based on direct air-air connectivity has been realised within the B-VHF system (Figure 1-4) via re-transmission of pilot's voice received via a dedicated GS to all other aircraft within the coverage range of this GS (and eventually other involved GSs). Due to the implemented access arbitration feature, the controller's voice transmission will always interrupt any ongoing re-transmission (the controller has the highest priority).

The B-VHF data sub-system comprises an ATN-compatible air-ground data link, as well as non-ATN point-to-point and broadcast data links in support of extended surveillance and autonomous aircraft operations. An option for a non-ATN air-air data link is provided as well. The ground data link architecture assumes that the B-VHF system would be used as an ATN sub-network, with an optional support for IP communications.

Opposite to the voice communications that mainly use permanent physical channels, the B-VHF system allocates resources for a data link only upon explicit user request. This improves the system communications capacity and provides the flexibility required on the transition path after an initial system deployment.

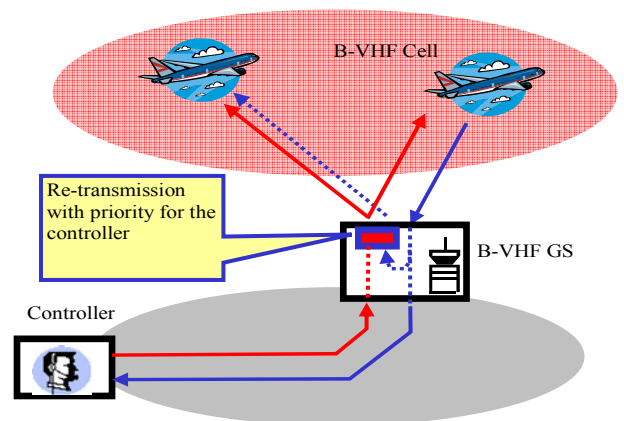


Figure 1-4: Party-line realisation via re-transmission within a cell

The multi-carrier B-VHF physical layer is based on OFDM. MC-CDMA has been selected as the multiple access scheme for the B-VHF forward link, whilst the reverse link uses OFDMA (Orthogonal Frequency-Division Multiple-Access). Physical OFDM carriers are organised into different types of physical transport channels that can be allocated for different types of communications services.

The B-VHF Data Link Layer (DLL) solution comprises multiple types of logical channels and transport channels. The Media Access Control (MAC) sub-layer maps the system and user data from the transport channels to physical transport channels and finally to appropriate forward- and reverse link time slots within the so called B-VHF super-frame.

The system end-to-end architecture takes multiple constraints into account. The concept of the B-VHF airborne architecture avoids the need to substantially change existing avionics. As long as only

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basic voice features are required, no changes to existing Voice Communications Systems (VCS) are needed.

PERFORMANCE SIMULATIONS

The design of the B-VHF physical (PHY) layer has been validated by means of simulations of the proposed algorithms. Overall system performance in presence of interference from legacy VHF systems towards the B-VHF system has been simulated as well.

Simulation scenarios consider different flight phases with appropriate broadband channel models, e.g. take-off and landing, parking, and en-route flights, taking typical and worst-case interference situations into account. The corresponding interference scenarios have been retrieved from the measurement flights as well as from the NAVSIM simulation tool.

The NAVSIM tool calculates the worst-case VHF channel occupancy at a certain location, for a certain cell size, and for a certain time. For this purpose, all GS are considered to be active and for each ATC sector one representative interfering A/C is placed as close as possible to the simulated victim A/C. Moreover, a duty cycle of 100% for GS and A/C transmissions is used. With that setting, the worst-case in terms of interference (maximum interference) and in terms of the number of available VHF channels (lowest number) is obtained.

As not all VHF systems in these broadband channels are active and used at the same time, the actual interference is modelled according to the results retrieved from the measurement campaign.

The design of the PHY layer and the overlay concept itself are evaluated by means of software simulations. The performance of the B-VHF physical and data link layer has been evaluated by means of bit error rate (BER) and frame error rate (FER) in dependence of the total received power for a given interference scenario and noise floor.

A specific synchronisation approach in a high-interference environment has been investigated, taking selected representative broadband VHF channel models into account. For reasons of simplicity perfect synchronisation and channel estimation has been assumed when conducting the simulations.

Multiple options for interference suppression by the B-VHF receiver and spectral shaping in the transmitter have been investigated.

Figure 1-5 shows the proposed spectrum shaping method (green line) that allows for efficient suppressing the B-VHF signal outside the B-VHF bandwidth and thus reducing the interference caused by the transmitted B-VHF signals on the narrowband legacy systems.

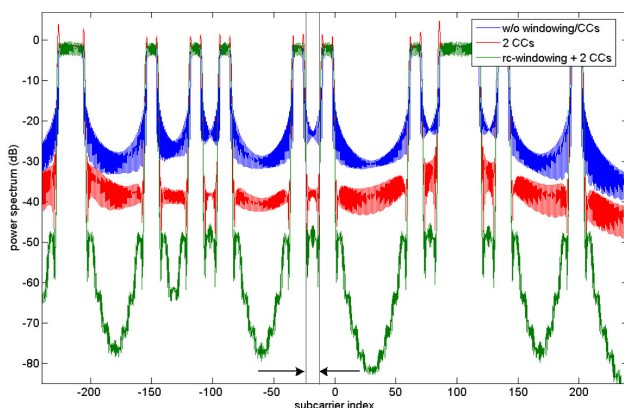


Figure 1-5: Simulated B-VHF transmitter spectrum for different sidelobe suppression techniques

Figure 1-6 depicts the BER performance of the B-VHF receiver for voice transmissions in the FL en-route scenario. On the x-axis the total RX power P_s of all used subcarriers is plotted in dBm, assuming a total noise power within the one MHz band equal to -110 dBm and an interference scenario, which is characterised by two strong and two weak interferers.

The results are shown for different mitigation methods, but also for the reference cases without narrowband interference (w/o NBI, solid black line) and with narrowband interference present, but without any mitigation mechanisms implemented within the B-VHF receiver (w/o NBI mitigation, dashed black line).

Receiver windowing (upper green line) can slightly reduce the performance loss due to NBI when compared to the reference case where NBI was not mitigated.

In to further reduce the impact of narrowband interference (NBI), first leakage compensation has been applied only to strong interferers (red line), but only slight improvement has been achieved. This is due to the remaining undesirable impact of the two weak interferers. In particular, the target BER for voice services (10^{-3}) could not be achieved within simulated P_s range.

When leakage compensation was applied to both strong and weak interferers (yellow line), a significant improvement was achieved. The best result was obtained by applying both windowing and leakage compensation to strong and weak interferers (lower green line). The required RX power required for achieving target BER = 10^{-3} for voice services could be significantly reduced compared to the case without NBI mitigation.

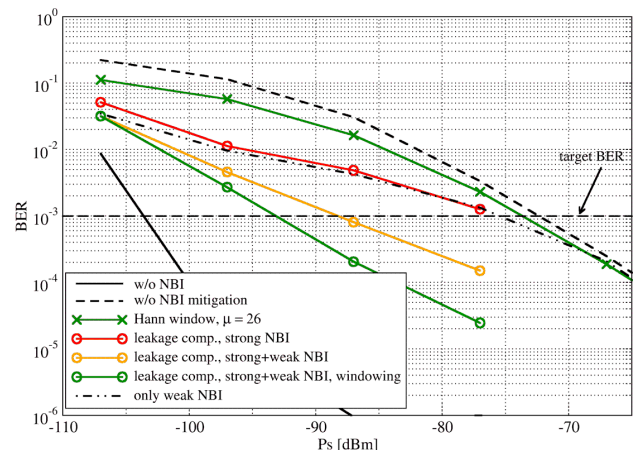


Figure 1-6: BER performance for en-route scenario with voice transmission

It can be concluded that with leakage compensation of strong and weak interferers combined with windowing the impact of NBI can be reduced such that the number of interferers and the total interference power has only a low effect on the system performance. The overall system performance can be improved by further reducing NBI, e.g. by means of a more accurate NBI estimation or with an improved windowing function. The required TX power can be derived from the simulation results by simple link budget calculations taking into account e.g. antenna gain and propagation losses.

The B-VHF higher layer protocols have been designed to provide several voice and data services, e.g. broadcast and party line voice communications or connection-oriented and connectionless data transfer.

In the course of the B-VHF project a wide range of simulation setups were investigated. Each simulation setting comprised one

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B-VHF cell with up to 255 registered A/C. An appropriate A/C population (arrival and departure) has been generated for the three base scenarios: Parking, Take-Off and Landing, and En-route.

Data traffic patterns were defined for all three air traffic scenarios and for the years 2015, 2020 and 2025. The BER retrieved from the PHY layer simulations, which varies with the used modulation technique (implying coding rate, spreading sequence, etc.) has been converted into the FER and further has been applied to assess the system performance for different transport channels.

Two modulation schemes, namely QPSK and 64-QAM, have been investigated. For each of the three scenarios different levels of aircraft population have been defined.

As voice traffic is not influenced by data traffic, the end-to-end performance of the voice system has been evaluated in a custom scenario.

In order to simulate party line functionality, this special scenario comprised a varying number of aircraft communicating with each other (via relay) and with the GS. Statistics have been collected for every completed one-way transmission, which implies that every relayed A/C transmission has been seen as two distinct voice messages: one message from A/C to ground and the other message from GS to all A/C. The simulation results have shown that the B-VHF system is able to support digital voice services with the quality of service (QoS) as defined in requirements for the voice system.

The medium access delay introduced by the used algorithm has been evaluated through simulations for net entry and resource acquisition. Capacity requirements, when using 64-QAM and the quality of service (QoS) for voice and data transmissions could be met. This has been proven by end-to-end simulations of the link establishment time and latency.

DEPLOYMENT SCENARIOS

Different scenarios have been developed for the deployment of the B-VHF system in both the VHF COM range, as well as in other spectrum ranges (NAV-band, L-band, C-band) anticipated to be used by new aeronautical communications systems.

During the work on B-VHF deployment scenarios some issues were identified that should be considered in future activities. In particular, as no mature radio hardware was available, some assumptions had to be made about the B-VHF RF front-end performance. Significant further specification/validation work will be required towards system standardisation.

Those B-VHF system parameters, which are relevant for the frequency planning (e.g. transmitter power, receiver sensitivity), have been estimated as accurate as possible at that time. This assessment is based on the results of different simulations and laboratory measurements. As it is expected that an airborne B-VHF transmitter operating in the VHF range will be an extension of the existing airborne VHF Data Radio (VDR) standard, it has been proposed to limit the maximum allowed total signal power of an airborne B-VHF transmitter to the level used by existing VDR radios (25 W).

When developing the frequency planning criteria for the broadband B-VHF system a mature RF front-end would be required. As the existing results of laboratory measurements might be not representative for the mature B-VHF system, only an outline of the frequency planning approach has been provided.

All deployment scenarios and associated airborne and ground B-VHF system architectures are well aligned with the B-VHF operational concept. The scenarios have been produced for an

initial B-VHF system deployment, for the transition phase and the full deployment.

In the early deployment phase B-VHF system offers basic voice services and an ATN-compatible air-ground data link. Selective voice services, surveillance data link and downlink of aircraft parameters have been postponed to the transition/final deployment phases.

Scenarios consider aircraft that is equipped with B-VHF radios ("B-VHF aircraft") and aircraft carrying narrowband equipment ("NB aircraft"). In addition to the current situation where the entire airspace is "narrowband-one" (NB airspace), two other options have been identified: B-VHF airspace, where B-VHF equipage is mandatory for all aircraft and B-VHF-supported airspace, with voluntary B-VHF equipage (Figure 1-7).

All VHF scenarios are based on a strict overlay concept, which characterised that not any change of the legacy systems is mandated, and assume an integrated voice/data system. The preferred deployment options are a mandatory introduction in the upper En-route airspace and a voluntary equipage in other airspace types. In scenarios with mixed B-VHF/NB population gateways must be realised within the ground voice system to preserve party-line between the B-VHF voice channel and the corresponding DSB-AM voice channel.

Non-VHF scenarios, i.e. scenarios which consider the deployment of the B-VHF system in other bands than VHF, are based on dedicated channels (without overlay) and are related to the data-only B-VHF system. In that scenario, voice services are assumed to be provided by the DSB-AM system in the VHF range.

Scenarios for an initial B-VHF system deployment have been used as a starting point for the transitional phase and final system deployment. During the transition more and more airspace becomes converted to B-VHF operation. At the same time new services are successively added to the system, including selective voice for AOC usage, downlink of aircraft data and powerful ATS services for trajectory-based ATM. In the final deployment phase improved spectrum occupancy would allow the air-air data link and broadcast surveillance services (ADS-B, TIS-B) to be deployed in addition to existing services.

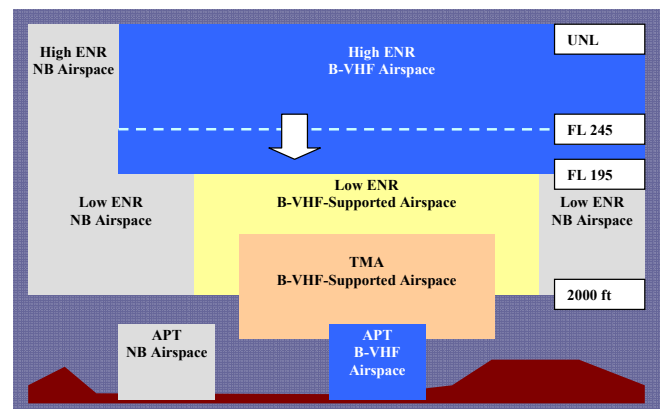


Figure 1-7: B-VHF system deployment in different airspace types

TEST-BED EVALUATION

As a first step towards a prototype a simplified B-VHF testbed has been implemented to demonstrate the technical feasibility of a B-VHF radio.

The B-VHF testbed consists of a B-VHF transmitter and a receiver implemented in digital signal processing (DSP) technology and of a

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simple low-power TX and RX front-end. On the transmitting side, the baseband signal processing is conducted in the DSP and the analogue signal at the intermediate frequency is fed to the TX front-end input. The TX front-end converts the signal into the VHF COM band (118 - 137 MHz). The B-VHF receiver RX front-end converts the incoming RF signal to the intermediate frequency and forwards it to the receiving DSP board where the A/D conversion, the baseband signal processing and the evaluation take place.

In B-VHF laboratory measurements only the FL (from GS to A/C) has been investigated. Three airborne radios and one ground DSB-AM radio have been used as DUT (device under test) equipment. For measurement purposes, the DSB-AM channel under test has been adjusted such that it coincides with the centre frequency of the broadband B-VHF FL transmitter signal.

In some measurements, the B-VHF spectrum comprised all OFDM carriers within the RF bandwidth. In other measurements a defined number of OFDM carriers around the DSB-AM channel has been excluded (turned-off). The interference tests have been performed with a continuous interfering B-VHF signal, i.e. without any gaps in time, ignoring the realistic B-VHF super-frame structure.

For demonstration purposes, a B-VHF test-frame has been implemented, comprising 128 OFDM carriers, where 112 carriers are used for transmission and 8 carriers on each side of the transmission spectrum serve as a guard band. With the carrier spacing of 2.083 kHz the system RF bandwidth has been set equal to 267 kHz. The resulting time domain signal for two subsequent B-VHF frames is shown in Figure 1-8.

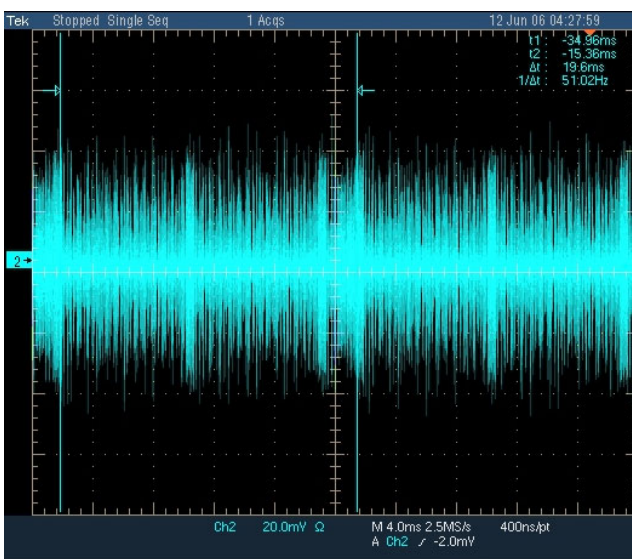


Figure 1-8: Time domain signal of the B-VHF system

The interference measurements with B-VHF system transmitting over the reception bandwidth of the DSB-AM receiver comprised the following scenarios:

- All OFDM carriers are active - 12 carriers may appear within the IF bandwidth of the DSB-AM receiver.
- A variable number of OFDM subcarriers is cancelled (left-out) around the carrier of the DSB-AM signal in order to suppress interference with the AM signal.

In the latter case the B-VHF transmitter provides, without using any spectrum shaping algorithm, a notch of a certain size within the B-VHF spectrum. By inserting and then broadening the gap around the DSB-AM signal it is possible to investigate the interference mechanisms between the two systems.

The impact of a VHF DSB-AM voice communications system on the B-VHF system and vice versa has been determined via laboratory measurements using several test procedures, comprising the following tests:

- B-VHF power spectrum measurements
- B-VHF receiver sensitivity evaluation
- Evaluation of B-VHF interference imposed on analogue voice DSB-AM receiver
- Evaluation of DSB-AM interference on B-VHF victim receiver

During above measurements, the interference limit for the victim DSB-AM receiver has been defined by the undesired squelch break or by degradation of a desired signal which is intolerable to the user.

The interference limit for the victim B-VHF receiver was defined by the BER of uncorrected voice exceeding 10^{-3} .

From the obtained results preliminary values for the maximal acceptable interference power received from legacy VHF systems and the required sensitivity of the B-VHF receiver (RX) were derived. In addition, the maximal allowed power of the B-VHF transmitter (TX) has been determined that guarantees that the legacy VHF system is not disturbed by the B-VHF system.

The results within the testbed evaluation have been obtained without interference suppression and NBI mitigation at TX and RX, respectively. Significant improvements are expected if the respective algorithms – as done within the PHY layer simulations – are integrated in the B-VHF implementation. Further improvements regarding the B-VHF interference on the DSB-AM can be achieved with a professional front-end design and a higher resolution D/A converter (the current resolution is 14 bits). Using a higher system bandwidth, as designed, the interference could be further reduced. Furthermore, with a more enhanced B-VHF receiver which applies NBI mitigation techniques, the B-VHF output power could be reduced and thus, also the interference on DSB-AM.

POTENTIAL FOR FURTHER IMPROVEMENTS

The simulations conducted within the B-VHF project have shown that a B-VHF overlay system in the VHF band is feasible. At the same time it was shown that interference conditions in the VHF band are severe. Therefore, further improvement/optimisation of proposed interference mitigation techniques and their validation with an improved B-VHF system demonstrator are required.

According to Eurocontrol and FAA roadmaps, aeronautical data communications should be preferably realized in the L-band, while voice communications should remain in the VHF band. The results of B-VHF system simulations allow for a conclusion that it may be possible to operate the B-VHF system in the L-band while maintaining the main characteristics.

The detailed assessment of the feasibility of the data-only B-VHF system for an application in the L-band and an assessment of necessary modifications of the system design should be investigated in detail in future work.

DISSEMINATION OF RESULTS AND FEEDBACK

The results of the B-VHF activities have been presented at the recent ATC Maastricht exhibitions and at several international conferences in Europe and the USA (for further details, please refer to the project's web-site at www.b-vhf.org).

In 2004, EUROCONTROL and FAA together launched the Future Communications Study (FCS), aiming to identify the most promising technologies that could cover future aeronautical needs.



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B-VHF is one of the technologies which have been assessed by this study, and it has been ranked by both independent FCS evaluators (NASA/ITT and QinetiQ) amongst the most promising future technologies for aeronautical communications in continental airspaces.

The project has established a close relationship to EUROCONTROL and accordingly the final project achievements have been presented to EUROCONTROL.

2 Dissemination and Use

This section sets out the terms of use and dissemination of the knowledge arising from the project. This plan is an evolving document and has been regularly updated every half a year to give a cumulative overview of the project's undertaken and planned activities.

Now the project is finished and thus the plan represents the final status of the activities already carried out and planned in the near future.

2.1 Exploitable knowledge and its use

Table 1 presents the exploitable results, defined as knowledge having a potential for commercial application in research activities.

Exploitable Knowledge	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
B-VHF System Design	Knowledge about how to establish an aeronautical communications system based on broadband multi-carrier technology that may be applied in protected frequency bands, like VHF-, L- or C-band, to be used for detailed specifications and implementations of the prototype B-VHF system in a field trial scenario towards operational usage	Aeronautical Communications	After creation of a framework for follow-on activities and acceptance of commercial approach	N/A	B-VHF Consortium & Frequentis, DLR
B-VHF Test-bed	Physical layer demonstrator usable for laboratory measurements and dissemination	Aeronautical Communications	After acceptance of commercial approach	N/A	B-VHF Consortium & DLR, ULPGC
B-VHF Protocol Laboratory Prototype	Data flows between the Data Link Layer and Upper Layers can be visualised considering different inherent functionalities of the B-VHF system (e.g. handover).	Aviation authorities and aeronautical industry	After acceptance of commercial approach	N/A	B-VHF Consortium & UniSBG
Frequency Management Guidance	Guidelines for B-VHF cell/frequency planning and system design (within the VHF band or in other bands, e.g. DME band).	Frequency Management and Allocation	After acceptance of commercial approach	N/A	B-VHF Consortium & Frequentis, DFS, DLR
B-VHF Measurement results over UK airspace and Core Europe	B-VHF database for future VHF channel management activities	Aviation	Immediately	N/A	B-VHF Consortium

Table 1: Overview of Exploitable Knowledge and its Use

2.1.1 Exploitable Results

The B-VHF project was proposed and accepted as an initial step on the way to the new commercial solution that would strengthen the European position on the global aeronautical market.

As a feasibility study of a new broadband technology, the B-VHF project created valuable results, including an initial B-VHF system design, B-VHF system test-bed and B-VHF protocol demonstrator together with the results of systematic measurements of spectrum occupancy in the VHF range and development of preliminary guidelines for frequency management. All together, these achievements represent the solid basis for the further detailed B-VHF system development and, finally, its commercial use.

However, the use of B-VHF project results – including the knowledge accumulated during the project - is conditioned by the acceptance of the new proposed aeronautical communications technology and by establishing the framework for follow-on activities by institutions and bodies outside the B-VHF Consortium (e.g. EUROCONTROL, ICAO, FAA).

The way forward towards possible commercialization of below listed results heavily depends on the decision of EUROCONTROL and FAA, which future aeronautical communications system will be further promoted by them.

Provided that B-VHF will pass this final threshold and will be one of the selected technologies, some commercialization issues have to be reconsidered.

Barriers to commercialization are the acceptance of this new system by aeronautical community as maybe the operational concepts have to be slightly adapted.

B-VHF System Design

During the B-VHF project new knowledge has been gained, which can be further used to establish a broadband communications system based on multi-carrier technology for aeronautical communications in protected frequency bands, like VHF-, L- or C-band. This knowledge is a baseline for future detailed specification and implementation of the B-VHF system in a prototype or a field trial scenario finally leading to its operational usage.

The partners, which are primarily interested to refine the existing knowledge on the B-VHF system design, are Frequentis, DLR and UniSBG. For that reason further additional research has to be carried out in that field, which requires further collaboration between these three partners.

The B-VHF consortium does not comprise any company, which manufactures airborne or ground radios. Therefore, the B-VHF consortium alone cannot proceed towards commercialisation of this achievement. The knowledge for the B-VHF System design has to be refined within the follow-on framework and then used as basis for manufacturing first B-VHF radio prototypes.

B-VHF Test-bed

The Physical Layer Demonstrator is usable for laboratory measurements and for demonstrating the functionality of a future B-VHF system, based on overlay, in a simplified manner. It is upgradeable in the sense that it could embrace new capabilities and features that may emerge and may have to be verified during follow-on activities.

The partners, which contributed to the production of this B-VHF Testbed were DLR (assisted by Frequentis) and ULPGC.

This B-VHF test-bed has already been demonstrated to EUROCONTROL on September 8th, 2006.

B-VHF Protocol Laboratory Prototype

The implementation of the B-VHF protocol layer can be exploited for demonstrating the functionality of the B-VHF system and the data exchange - especially ATC digital voice and CPDLC data communications - between ATC controllers and aircraft via B-VHF ground stations. It can be extended to embrace new protocol capabilities and features that may emerge and may have to be verified during follow-on activities.

For an unambiguous description of the developed B-VHF system and its specific protocols, and in order to implement the B-VHF protocol functionality demonstrator, a detailed SDL specification of the Data Link Layer (DLL) Protocols has been carried out and is now available. This is important for the further development, prototype implementation, standardisation, and commercialisation of the B-VHF system by IT/radio manufacturers.

The partner, which is primarily interested in further improving the currently available Protocol Demonstration environment for promotion aspects, is UniSBG.

This B-VHF protocol demonstrator has already been shown to EUROCONTROL on September 8th, 2006.

Frequency Management Guidance

B-VHF results comprise guidance for B-VHF cell/frequency planning and system design (within the VHF band or in other bands, e.g. DME band). Such guidance can be used when dealing with B-VHF and other broadband communications systems. In order to carry out the VHF occupancy evaluations significant extensions and adaptations to an available tool, called *NAVSIM*, have been made, which is intended to be exploited in further cell / frequency planning tasks for future aeronautical communication systems.

The partners, which contributed in elaboration of these criteria, are Frequentis, DLR, DFS and UniSBG.

B-VHF Measurement results over UK airspace and Core Europe

Raw data gathered during VHF band occupancy measurements as well as statistics values calculated for the purpose of B-VHF project can be provided to be used by other interested research projects/programmes, e.g. to these dealing with statistics of VHF ATC voice communications.

2.2 Dissemination of knowledge

2.2.1 Overview of dissemination activities

Table 2 shows an overview of both past and planned future dissemination activities.

Planned / actual Dates	Type of Activity	Event	Target audience	Size of audience	Countries addressed	Partner responsible / involved
10 / 11 Feb 2004	Exhibition Flyer	Maastricht ATC 2004	Supplier of ATC and ATM equipment and services Key specifier and buyer in that market	> 1500	global	FRQ
19 –23 Apr 2004	Regular Meeting	7 th ICAO ACP Working Group C	ATSP, Aerospace industry, Research institutes (Members of ICAO ACP WG-C)	> 50	global	DLR (FRQ)
26 – 30 Apr 2004	Presentation, Publication	4 th ICNS Conference and Workshop	Industry and academic communities performing research and technology development for advanced digital communications supporting air transportation systems	> 100	global	FRQ (DLR)
10 –16 May 2004	Exhibition Flyer	ILA (Internationale Luftfahrtausstellung)	Industry, airline and airport authorities	> 1000	global	DLR
20 – 24 Sep 2004	Regular Meeting	8 th ICAO ACP Working Group C	ATSP, Aerospace industry, Research institutes (Members of ICAO ACP WG-C)	> 50	global	DLR
24 – 28 Oct 2004	Presentation, Publication	23 rd Digital Avionics Systems Conference (DASC)	Key personnel involved in avionics, aircraft systems, or air traffic management Research Institutions and Industry	> 100	global	DLR (FRQ)
31 Oct – 3 Nov 2004	Exhibition	ATCA 49 th Annual Meeting, International Technical Program and Exhibits	Aviation community members	> 750	global	FRQ
31 Oct – 3 Nov 2004	Panel discussion	ATCA 49 th Annual Meeting	Aviation community members	> 150	global	FRQ
01 – 03 Feb 2005	Exhibition Flyer, Poster	Maastricht ATC 2005	Supplier of ATC and ATM equipment and services Key specifier and buyer in that market	> 1500	global	FRQ
05 – 12 Mar 2005	Presentation, Publication	2005 IEEE Aerospace Conference	Leading experts and researchers	> 50	global	FRQ (DLR)
04 – 08 Apr 2005	Regular Meeting	9 th ICAO ACP Working Group C	ATSP, Aerospace industry, Research institutes (Members of ICAO ACP WG-C)	> 50	global	DLR (FRQ)

Planned / actual Dates	Type of Activity	Event	Target audience	Size of audience	Countries addressed	Partner responsible / involved
02 – 05 May 2005	Presentation, Publication	5 th ICNS Conference and Workshop	Industry and academic communities performing research and technology development for advanced digital communications supporting air transportation systems	> 100	global	FRQ (UPM)
09 May 2005	Presentation	1 st Meeting of EUROCONTROL's Air Ground Communications Focus Group	ATSP, Aerospace industry, Stakeholders from across the aviation industry	> 30	Europe	FRQ (DLR)
16 – 20 May 2005	Presentation	IEEE International Conference on Communications ICC'05	Leading experts and researchers	> 100	global	UGent
30 May – 01 Jun 2005	Presentation	IEEE 61 st Semi-annual Vehicular Technology Conference (VTCSpring2005)	Leading experts and researchers	> 100	> 50	UGent
21 – 29 Jun 2005	Regular Meeting	1 st ICAO ACP Working Group of the Whole	ATSP, Aerospace industry, Research institutes (Members of ICAO ACP Working Groups)	> 50	global	DLR
14 – 16 Sep 2005	Presentation	5 th Workshop on Multicarrier Spread-Spectrum (MC-SS05)	Leading experts and researchers	> 50	global	UGent
19 – 21 Sep 2005	Presentation	7 th IFIP International Conference on Mobile and Wireless Communication Networks (MWCN'05)	Leading experts and researchers	> 50	global	UGent

Planned / actual Dates	Type of Activity	Event	Target audience	Size of audience	Countries addressed	Partner responsible / involved
26 – 29 Sep 2005	Presentation, Publication	Deutscher Luft- und Raumfahrtkongress	Key personnel involved in avionics, aircraft systems, or air traffic management Research Institutions and Industry	> 50	national	DLR
30 Oct – 02 Nov 2005	Exhibition	ATCA 50 th Annual Conference & Expo	Aviation community members	> 750	global	FRQ
30 Oct – 02 Nov 2005	Publication in ATCA Annual Conference Proceedings	ATCA 50 th Annual Conference	Aviation community members	> 150	global	FRQ (FRQ)
30 Oct – 03 Nov 2005	Presentation, Publication	24 th Digital Avionics Systems Conference (DASC)	Key personnel involved in avionics, aircraft systems, or air traffic management Research Institutions and Industry	> 100	global	DLR (FRQ)
14 – 16 Feb 2006	Exhibition Flyer, Poster, Presentation, Demonstration	Maastricht ATC 2006	Supplier of ATC and ATM equipment and services Key specifier and buyer in that market	> 1500	global	FRQ, UniSBG, DLR, (UPM)
08 March 2006	Presentation	2 nd Meeting of EUROCONTROL's Air Ground Communications Focus Group	ATSP, Aerospace industry, Stakeholders from across the aviation industry	> 30	Europe	FRQ (DLR)
04 Mar – 11 Mar 2006	Presentation, Publication	2006 IEEE Aerospace Conference	Leading experts and researchers	> 50	global	DLR
13 Mar - 17 Mar 2006	Regular Meeting	10 th ICAO ACP Working Group C	ATSP, Aerospace industry, Research institutes (Members of ICAO ACP WG-C)	> 50	global	DLR
03 Apr – 07 Apr 2006	Presentation	4 th International Symposium on Turbo Codes	Leading experts and researchers	> 100	global	UGent

Planned / actual Dates	Type of Activity	Event	Target audience	Size of audience	Countries addressed	Partner responsible / involved
10 Apr – 12 Apr 2006	Presentation	1 st Southeastern Europe Broadband Conference and Exhibition	Leading vendors, technical and marketing experts, service provider executives, regulators, government, officials, enterprise customers and solution providers	> 100	South-eastern Europe	FRQ
01 May – 03 May 2006	Presentation, Publication	6 th ICNS Conference and Workshop	Industry and academic communities performing research and technology development for advanced digital communications supporting air transportation systems	> 100	global	FRQ (UniSBG, DLR)
11 Jun – 15 Jun 2006	Presentation	IEEE International Conference on Communications, ICC06	Leading experts and researchers	> 100	global	UGent
19 – 21 Jun 2006	Presentation	Fifth Community Aeronautical Days 2006 Conference	CEO, industry R&D managers, project co-ordinators, researchers, engineers, academics, government officials from RTD and transport ministries and journalists from all over Europe as well as the global aeronautics community	~ 1000	global	FRQ (DLR)
19 – 21 Jun 2006	Exhibition Flyer, Poster, Presentation, Demonstration	Fifth Community Aeronautical Days 2006 Exhibition	CEO, industry R&D managers, project co-ordinators, researchers, engineers, academics, government officials from RTD and transport ministries and journalists from all over Europe as well as the global aeronautics community	~ 1000	global	FRQ (UniSBG)
08 Sep 2006	Demonstration	Presentation of Project's Results to Eurocontrol	Frequentis, DLR, UniSBG and EuroControl	~ 10	global	FRQ (DLR, UniSBG)
18 Sep – 19 Sep 2006	Presentation	3 rd Meeting of EUROCONTROL's Air Ground Communications Focus Group	ATSP, Aerospace industry, Stakeholders from across the aviation industry	> 30	Europe	FRQ (DLR)

Planned / actual Dates	Type of Activity	Event	Target audience	Size of audience	Countries addressed	Partner responsible / involved
18 Sep – 22 Sep 2006	Regular Meeting	11 th ICAO ACP Working Group C	ATSP, Aerospace industry, Research institutes (Members of ICAO ACP WG-C)	> 50	global	DLR
15 Oct – 19 Oct 2006	Presentation, Publication	25 th Digital Avionics Systems Conference (DASC)	Key personnel involved in avionics, aircraft systems, or air traffic management Research Institutions and Industry	> 100	global	DLR (UniSBG, UGent)
03 Mar – 10 Mar 2007	Presentation, Publication	2007 IEEE Aerospace Conference	Leading experts and researchers	> 50	global	DLR
	Project web-site www.b-vhf.org				global	

Table 2: Overview of B-VHF's Dissemination Activities

Description of dissemination activities

Maastricht ATC 2004

Frequentis attended the Maastricht ATC 2004 fair, which took place from 10th to 11th February, 2004. Frequentis produced B-VHF flyers, which were available at the Frequentis booth.

The costs related with the attendance of this exhibition were not charged to the B-VHF project.

Seventh ICAO ACP Working Group C

DLR is a member of ICAO's ACP Working Group C, and therefore participates in the regular meetings. The 7th meeting took place from 19th to 23rd April 2004 in Montreal and DLR presented a working paper entitled "Overview on B-VHF" about technical details of the B-VHF overlay concept. FRQ assisted DLR in preparation of the working paper.

The costs related with the attendance of this meeting were not charged to the B-VHF project.

Fourth ICNS Conference and Workshop

This conference took place in Fairfax, Virginia, USA from 26th to 30th April, 2004. Frequentis presented a paper entitled "B-VHF – A MULTI-CARRIER BROADBAND COMMUNICATIONS CONCEPT FOR AIR TRAFFIC MANAGEMENT IN THE VHF BAND", which has been incorporated into the conference proceedings.

The costs related with the attendance of this conference were not charged to the B-VHF project.

ILA ("Internationale Luftfahrtausstellung")

This exhibition took place in Berlin from 10th to 16th May, 2004. DLR attended the fair and presented a poster describing the B-VHF project at the DLR booth. Moreover, flyers about the B-VHF project were distributed.

The costs related with the attendance of this exhibition were not charged to the B-VHF project.

Eighth ICAO ACP Working Group C

DLR is a member of ICAO's ACP Working Group C and therefore participates in the regular meetings. The 8th meeting took place in Munich from 20th to 24th September, 2004.

One agenda item of this meeting was the introduction of the Future Communication Study, which is a joint FAA/EUROCONTROL research plan (Action Plan 17). The objective of this study is to define a common and globally-applicable next generation air-ground communications system.

Activity Task 3.1 of AP17 outlines an activity to pre-screen potential technologies that "are under development in the industry" and to assess their "high level capabilities, projected maturity ..., and their potential applicability to aviation." One of the pre-screened technologies is B-VHF.

The costs related with the attendance of this meeting were not charged to the B-VHF project.

23rd Digital Avionics Systems Conference (DASC)

This conference took place in Salt Lake City, Utah, USA from 24th to 28th October, 2004. DLR presented a paper entitled "B-VHF - An Overlay System Concept for Future ATC Communications in the VHF Band", which has been incorporated in the conference proceedings. FRQ assisted DLR in preparation of the conference paper.

ATCA 49th Annual Meeting, International Technical Program and Exhibits

Frequentis attended the 49th ATCA, which took place from October 31st to November 3rd, 2004, and participated in a panel discussion on future communications.

The costs related with the attendance of this exhibition were not charged to the B-VHF project.

Maastricht ATC 2005

Frequentis attended the Maastricht ATC 2005 fair, which took place from February 1st to February 3rd, 2005. Frequentis produced B-VHF flyers about the current status of the B-VHF project and the achievements so far. The flyers were available at the Frequentis booth.

2005 IEEE Aerospace Conference

Frequentis and DLR have attended the 2005 IEEE Aerospace Conference and presented a paper entitled "B-VHF – A Multi-Carrier Based Broadband VHF Communications Concept for Air Traffic Management", which has been incorporated in the conference proceedings. The conference took place in Big Sky, Montana, USA from 5th to 12th March, 2005.

Frequentis did not charge the costs related with the attendance of this conference to the B-VHF project.

Ninth ICAO ACP Working Group C

DLR is a member of ICAO's ACP Working Group C and therefore participates in the regular meetings. The 9th meeting took place in Montreal from 4th to 8th April, 2005.

DLR presented a working paper entitled "B-VHF – Channel Occupancy and Capacity Analysis" about the VHF channel measurements and B-VHF system capacity analysis. FRQ assisted DLR in preparation of the working paper.

The costs related with the attendance of this meeting were not charged to the B-VHF project.

Fifth ICNS Conference and Workshop

This conference took place in Fairfax, Virginia, USA from 02nd to 05th May, 2005. Frequentis presented a paper entitled "VHF CHANNEL OCCUPANCY MEASUREMENTS OVER CORE EUROPE", which has been incorporated into the conference proceedings. This paper was produced in co-operation with UPM and ULPGC.

The costs related with the attendance of this conference were not charged to the B-VHF project.

First Air Ground Communications Focus Group Meeting

The Future Communication Study (Activity Task 3.1 of AP17) has carried out a pre-screening of promising technologies, and the B-VHF showed excellent scores in some evaluation criteria. For that reason, Frequentis was invited by the EUROCONTROL to present the B-VHF in general and the achievements made so far. This meeting took place in Brussels at EUROCONTROL premises on May 9th, 2005.

First ICAO ACP Working Group of the Whole

The ICAO ACP Working Group of the Whole is a joint meeting for all ICAO ACP Working Groups where the results of the different working groups are presented and the working program for the working groups are defined. As member of the ICAO ACP Working Group C DLR participates also in these meetings to give inputs on future work plans for the Working Group C.

The costs related with the attendance of this meeting were not charged to the B-VHF project.

IEEE International Conference on Communications ICC'05

UGent presented a paper entitled "On soft multiuser channel estimation of DS-CDMA uplink using different mapping strategies" at the conference in Seoul, South Korea. The conference took place from 16th May 20th May, 2005.

IEEE Vehicular Technology Conference (VTCSpring2005)

UGent attended the conference in Stockholm, Sweden, which took place from May 30th to June 1st, 2005. B-VHF flyers were distributed.

Fifth Workshop on Multicarrier Spread-Spectrum

UGent presented a paper entitled "Performance Evaluation and Parameter Optimization of MC-CDMS" at the conference in Oberpfaffenhofen, Germany. The conference took place from 14th to 16th September, 2005.

Seventh IFIP International Conference on Mobile and Wireless Communication Networks

UGent presented a paper entitled "Code-aided ML frame synchronization in a downlink MC-CDMA" at the conference in Marrakech, Morocco. The conference took place from 19th to 21st September, 2005.

Deutscher Luft- und Raumfahrtkongress

This national German conference took place in Friedrichshafen from 26th to 29th September 2005. DLR presented a paper entitled "B-VHF – Ein 'Overlay'-System für die aeronautische Kommunikation im VHF-Band", which has been incorporated into the conference proceedings.

ATCA 50th Annual Conference and Expo

Frequentis attended the 50th ATCA, which took place from October 30th to November 2nd, 2005, and submitted a paper called "Future Aeronautical Communications Concepts and Their Impact on ATM Procedures", which has been published in the conference proceedings. This paper was produced together with DLR.

The costs related with the attendance of this exhibition were not charged to the B-VHF project.

24th Digital Avionics Systems Conference (DASC)

This conference took place in Washington, D.C., USA from 30th October to 3rd November, 2005. DLR presented a paper entitled "Physical Layer Design for a Broadband Overlay System in the VHF Band With In-band Transition", which has been incorporated in the conference proceedings. FRQ assisted DLR in preparation of the conference paper.

The costs related with the attendance of this conference were not charged to the B-VHF project.

Maastricht ATC 2006

The B-VHF consortium presented the achievements made at an own "B-VHF Stand". Frequentis, UniSBG and DLR attended the Maastricht ATC 2006 fair, which took place from February 14th to February 16th, 2006. Frequentis represented the B-VHF consortium, UniSBG demonstrated the VHF Occupancy Simulation Results and the actual status of the protocol demonstrator, whilst DLR presented the detailed physical layer design and the specific measures implemented to suppress the interference at the B-VHF transmitter.

Frequentis produced B-VHF flyers about the current status of the B-VHF project and the achievements so far. The flyers were available at the Frequentis booth, too.

Second Air Ground Communications Focus Group Meeting

The Future Communication Study (Activity Task 3.1 of AP17) has carried out a pre-screening of promising technologies, and the B-VHF showed excellent scores in some evaluation criteria. For that reason, Frequentis has been invited by EUROCONTROL to present the B-VHF in general and the achievements made so far. This meeting took place in Toulouse at Airbus premises on March 8th, 2006 and the presentation was held by DLR.

2006 IEEE Aerospace Conference

DLR has attended the 2006 IEEE Aerospace Conference and presented a paper entitled "Techniques for Ensuring Co-existence Between B-VHF and Legacy VHF Systems", which has been incorporated in the conference proceedings. The conference took place in Big Sky, Montana, USA from March 4th to March 11th, 2006.

DLR did not charge the costs related with the attendance of this conference to the B-VHF project.

10th ICAO ACP Working Group C

DLR is a member of ICAO's ACP Working Group C and therefore participates in the regular meetings. The 10th meeting took place in Montreal from 13th to 17th March, 2006. DLR presented a working paper entitled "B-VHF – Current Achievements and Outlook". FRQ assisted DLR in preparation of the working paper.

The costs related with the attendance of this meeting were not charged to the B-VHF project.

International Symposium on Turbo Codes (ISTC 06)

UGent presented a paper entitled "Code-Aided Channel Tracking for OFDM" at the conference in Munich, Germany. The conference took place from April 3rd to April 7th, 2006.

The costs related with the attendance of this conference were not charged to the B-VHF project.

First Southeastern Europe Broadband Conference and Exhibition (SEEB 06)

Frequentis presented the B-VHF project goals, achievements made so far and gave an outlook on activities to be carried out in the future at this conference in Belgrade, Serbia and Montenegro. The conference took place from April 10th to April 12th, 2006.

The costs related with the attendance of this conference were not charged to the B-VHF project.

Sixth ICNS Conference and Workshop

This conference took place in Baltimore, Maryland, USA from May 1st to May 3rd, 2006. Frequentis presented a paper entitled "TECHNICAL AND OPERATIONAL ASPECTS OF MIGRATION CONCEPTS OF A BROADBAND VHF COMMUNICATION SYSTEM (B-VHF)", which has been incorporated into the conference proceedings. This paper was produced in co-operation with DLR and ULPGC.

Additionally, in course of this conference detailed information concerning actual status of the Future Communications Study has been given.

IEEE International Conference on Communications (ICC'06)

UGent presented a paper entitled "Effectiveness Study of Code-Aided and Non-Code-Aided ML-Based Feedback Phase Synchronizers" at the conference in Istanbul, Turkey. The conference took place from June 11th to June 15th, 2006.

Fifth Community Aeronautical Days 2006 - Conference

This event took place in Vienna from June 19th till June 21st, 2006. Frequentis presented on behalf of the B-VHF consortium the B-VHF project.

Fifth Community Aeronautical Days 2006 - Exhibition

Frequentis and UniSBG presented at this exhibition on behalf of the B-VHF consortium the achievements made within the B-VHF project. Additionally, UniSBG presented the update of the B-VHF functionality demonstrator (improved since ATC Maastricht 2006).

This B-VHF test-environment allows B-VHF data exchange (via LAN) using two (generic) ATC controller work stations, two (generic) pilot work stations, some supporting work station for generating a realistic air traffic scenario and a B-VHF functionality visualisation work station for demonstrating the functionality of the B-VHF system and the data exchange between ATC controllers and aircraft via B-VHF ground stations. The B-VHF demonstrator set-up allows the demonstration of handovers between different ATC sectors within one single B-VHF cell, as well as a B-VHF handover within one (large) ATC sector between two B-VHF cells / ground stations.

Demonstration of Achievements made to EUROCONTROL

Frequentis, DLR and UniSBG presented on September 8th in Oberpfaffenhofen the final project results to EUROCONTROL. In the course of this demonstration the B-VHF Testbed (baseband implementation of the physical layer for the B-VHF Forward- and Reverse Link) and the B-VHF functionality demonstrator were presented. By means of the B-VHF testbed it was shown that the B-VHF technology can cope with interference coming from DSB-AM legacy systems.

Third Air Ground Communications Focus Group Meeting

The Future Communication Study (Activity Task 3.1 of AP17) has carried out a pre-screening of promising technologies, and the B-VHF showed excellent scores in some evaluation criteria. For that reason, Frequentis has been invited by EUROCONTROL to present the final B-VHF results. This meeting took place in Brussels at EUROCONTROL premises from September 18th to September 19th, 2006.

11th ICAO ACP Working Group C

DLR is a member of ICAO's ACP Working Group C and therefore participates in the regular meetings. The eleventh meeting took place together with the Third Air Ground Communication Focus Group Meeting in Brussels from 18th to 22nd September, 2006. Frequentis presented the final results of the B-VHF project. DLR assisted Frequentis in preparing the presentation.

25th Digital Avionics Systems Conference (DASC)

This conference took place in Portland, Oregon, USA from 15th to 19th October, 2006. DLR presented a paper entitled "B-VHF – Selected Simulation Results and Assessment", which has been incorporated in the conference proceedings. FRQ, UGent, and UniSBG assisted DLR in preparation of the conference paper.

The costs related with the attendance of this conference were not charged to the B-VHF project.

2007 IEEE Aerospace Conference

In addition, DLR will attend the 2007 IEEE Aerospace Conference and present a paper entitled "Final Assessment of the B-VHF Overlay Concept", which will be incorporated in the conference proceedings. The conference will take place in Big Sky, Montana, USA from 3rd to 10th March, 2007.

All conference papers and flyers distributed by the B-VHF consortium are available for download via the project's web-site (www.b-vhf.org).

2.3 Publishable results

The descriptions of these project results, which are anticipated for further exploitation (see Table 1), are listed in the following.

2.3.1 B-VHF System Design

Within this project, an initial system design – PHY layer and complete protocol stack – for an aeronautical communications system based on broadband multi-carrier technology that may be applied in protected frequency bands, like VHF-, L- or C-band, has been developed. From this study work, deep insight and knowledge how the multi-carrier technology can be applied within aeronautical communications has been gained. Knowledge has been gathered about the high-level system design responding to the aeronautical communications requirements (aligned with [EATM- Operating Concept of the Mobile Aviation Communication Infrastructure Supporting ATM beyond 2015, Ed. 1.0, July 2002 (nicknamed MACONDO Study)] and [Final Communications Operating Concept and Requirements for the Future Radio System; Draft 0.1 issued by EUROCONTROL/FAA on April 24th, 2005]). B-VHF specific methods have been developed to ensure that the system can cope with the special conditions of respective channels, as well as the required countermeasures to ensure co-existence with legacy systems operating in the same frequency band.

The study results are well-suited to be used within the ongoing ICAO activities on the development of future aeronautical communications systems mainly performed within the joint FAA and EUROCONTROL Future Communications Study [AP 17-04-Wp04-v1.0].

The current B-VHF system development stage comprises a complete simulation software package which supports detailed PHY layer and protocol simulations. Moreover, a laboratory test-bed for demonstration purposes is available.

Collaboration is sought especially among the radio manufacturers to improve the existing system design and to build a prototype system.

With respect to IPR, several patent applications for sidelobe suppression techniques have been issued but not yet granted.

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2.3.2 B-VHF Test-bed

Within this project, a laboratory test-bed for the B-VHF system comprising the PHY layer has been developed, which is usable for laboratory measurements and demonstration purposes. The laboratory test-bed consists of two DSP boxes (TX and RX) for digital signal processing of all relevant PHY layer functions, up/downconverters for conversion into/from IF band at 10.7 MHz from/to digital baseband, and VHF front-ends for up/downconversion into/from VHF band from/to IF band.

The current development stage might be described as a laboratory test-bed which is a good starting point for the development of a B-VHF prototype.

Collaboration is sought especially among the radio manufacturers to improve the laboratory test-bed and to build a prototype system. The main tasks to be performed are the development of a broadband RF front-end for the respective frequency band (VHF-, L-, C-band) which shows low noise floor, high resolution A/D and D/A conversion, high sensitivity, high linearity and good sidelobe suppression capabilities.

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2.3.3 B-VHF Protocol Laboratory Prototype

A B-VHF functionality demonstrator has been developed and tested in order to verify the developed B-VHF Data Link Layer protocols and MAC algorithms as well as some selected B-VHF applications (ATC voice, CPDLC data). This B-VHF test-environment allows B-VHF data exchange (via LAN) between peer B-VHF systems in the following set-up configuration:

- ▶ Two (generic) ATC controller work stations, with connected ATC voice board (converting analogue ATC voice into digital voice using a VDLM3 compliant vocoder) and tablet touch input device monitors (for generating CPDLC data messages)
- ▶ Two (generic) Pilot work stations, with connected ATC voice board (using the same VDLM3 compliant vocoder) and monitors (for generating/responding to CPDLC data messages)
- ▶ Supporting work station generating a realistic air traffic scenario
- ▶ B-VHF functionality visualisation work station for demonstrating the functionality of the B-VHF system and the data exchange between ATC controllers and aircraft via B-VHF ground stations. The B-VHF demonstrator set-up allows the demonstration of handovers between different ATC sectors within one single B-VHF cell, as well as a B-VHF handover within one (large) ATC sector between two B-VHF cells / ground stations. Although, initially not planned (stipulated in the Technical Annex I), it has been considered important for the final performance evaluation, results and further exploitation of the B-VHF project that these functionality visualisation and protocol demonstrations of the B-VHF system have to be implemented. Several aspects became only obvious and solutions could be provided, when actually implementing and testing the developed protocols on target pre-prototype hardware and software platforms.

For an unambiguous description of the developed B-VHF system protocols, and in order to implement the B-VHF protocol functionality demonstrator, a detailed SDL specification of the Data Link Layer (DLL) Protocols has been carried out and is now available.

It is intended to establish co-operations with IT/radio manufacturers either in the context of future European or national research programmes or in direct bi-/multilateral co-operations with industrial partners in order to develop further versions of B-VHF demonstrators with fully integrated PHY layer functions, as well as the Data Link Layer and higher layer protocols.

This type of intended co-operation with IT/communication equipment manufacturers would also be important with regard to future standardisation of the B-VHF system by

standardisation bodies like ICAO, EUROCAE and/or ETSI. It is intended to provide input to such organisations within the next two years.

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2.3.4 Frequency Management Guidance

In order to develop realistic introduction and deployment strategies of the B-VHF system taking suppression and mitigation of interference to and from existing narrowband legacy systems into account, intensive VHF spectrum occupancy evaluations have been carried out within the B-VHF Project. These B-VHF results comprise guidance for B-VHF cell/frequency planning and system design (within the VHF band or in other bands, e.g. DME band). These guidelines have to be further refined to be in accordance with the B-VHF system design improvements.

In order to promote the commercialisation of the developed B-VHF system or other broadband communication systems these results are considered as the basis for comprehensive cell/frequency planning in the VHF band or other bands (e.g. DME).

For this reason it is intended to establish co-operations with ATC stakeholders and aeronautical communication service providers either in the context of future European or national research programmes or in direct bi-/multilateral co-operations with such partners within the next year.

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2.3.5 B-VHF Measurement results over UK airspace and Core Europe

Raw data gathered during VHF band occupancy measurements as well as statistics values calculated by using these raw data are available. These raw data comprise the received power values obtained during measurement flights in the South-eastern part of UK and around Core Europe (including the exact geographical position of the measurement aircraft at that point in time when the power has been measured), as well as during ground measurements nearby London Heathrow. These data has been further processed to retrieve probability density functions of the received power in all 760 25 kHz channels within the VHF COM band.

These data can be used for occupancy assessments of the VHF COM band as required for any broadband communications system to be operated within this frequency range.

For this reason it is intended to establish co-operations with ATC stakeholders and aeronautical communication service providers either in the context of future European research programmes or in direct bi-/multilateral co-operations with such partners within the next years.

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