

Specific Targeted Research or Innovation Project

**BROADBAND VHF AERONAUTICAL COMMUNICATIONS SYSTEM  
BASED ON MC-CDMA**



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# B-VHF - FINAL EXECUTIVE SUMMARY

## 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.

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## 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.

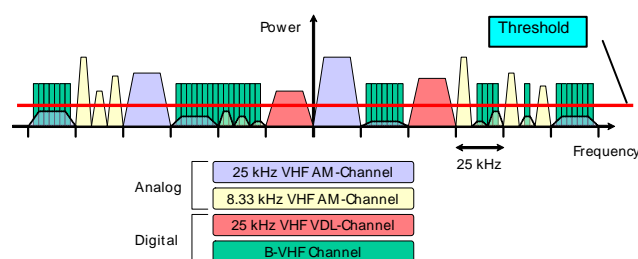


Figure 1: B-VHF overlay concept

The starting hypothesis for the B-VHF overlay concept (Figure 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), 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 have been further processed, analysed and used for B-VHF system design decisions.

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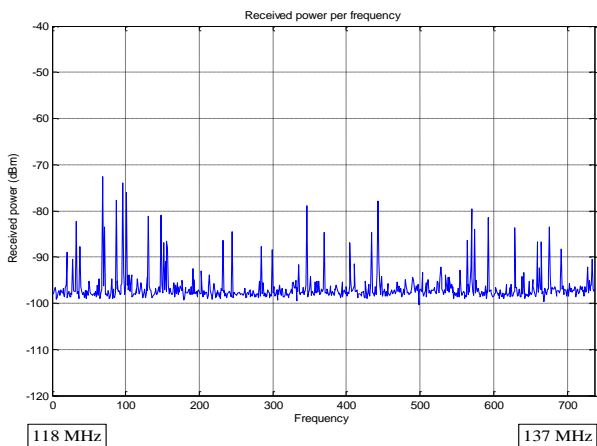


Figure 2: Instantaneous VHF COM spectrum occupancy

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.

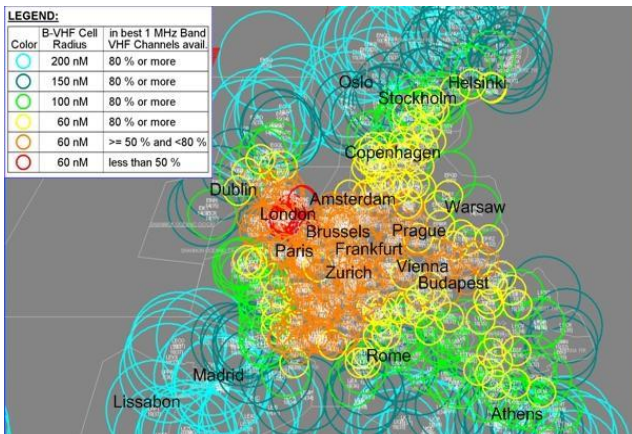


Figure 3: Simulated VHF COM spectrum availability for selected ground locations

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 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.

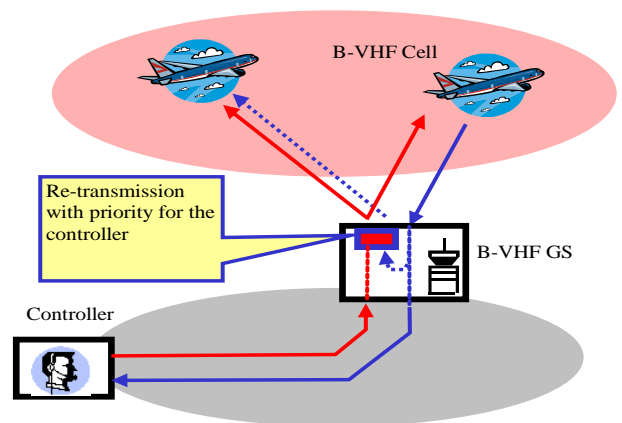


Figure 4: Party-line realisation via re-transmission within a cell

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 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

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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 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.

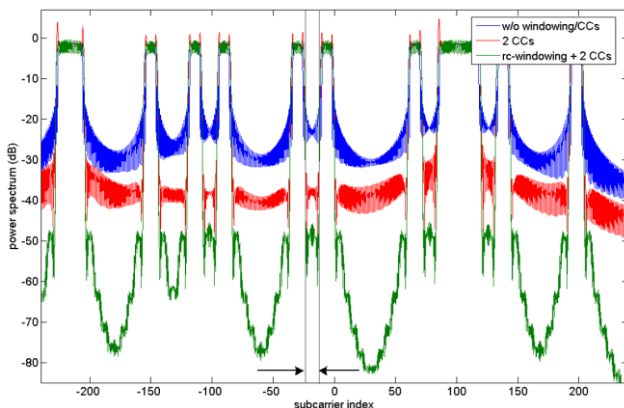


Figure 5: Simulated B-VHF transmitter spectrum for different sidelobe suppression techniques

Figure 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.

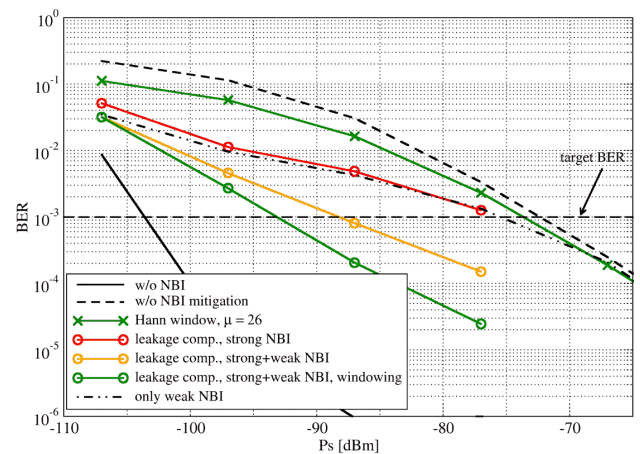


Figure 6: BER performance for en-route scenario with voice transmission

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 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.

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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 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.

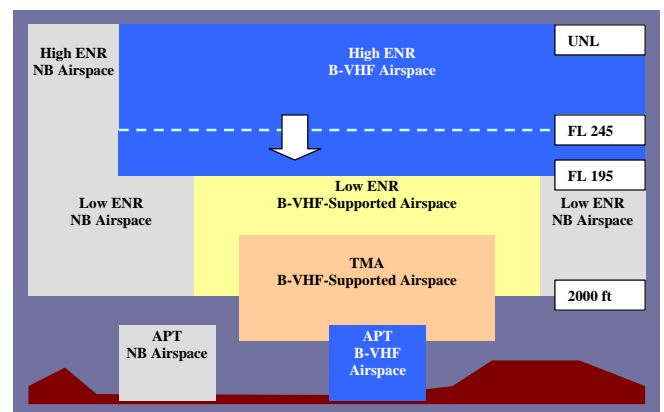


Figure 7: B-VHF system deployment in different airspace types

## 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 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

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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 8.

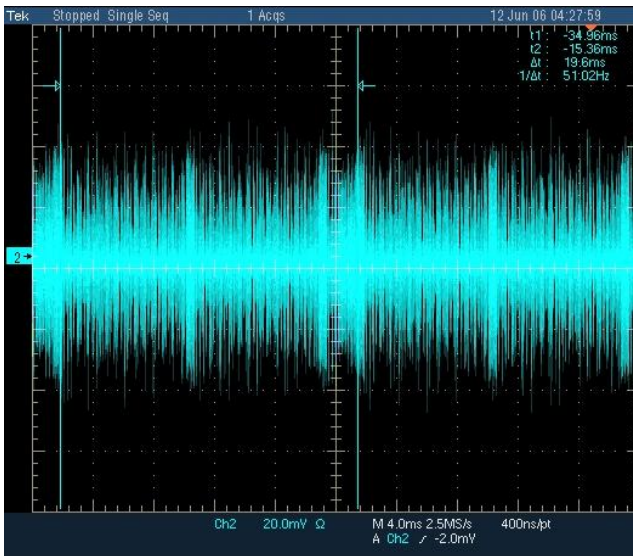


Figure 8: Time domain signal of the B-VHF system

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](http://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. 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.