TECHNICAL AND OPERATIONAL ASPECTS OF MIGRATION CONCEPTS OF A BROADBAND VHF COMMUNICATION SYSTEM (B-VHF)

Bernhard Haindl, Miodrag Sajatovic, Christoph Rihaceck, Frequentis GmbH
Carl-Herbert Rokitansky[1] University of Salzburg
Michael Schnell PhD, DLR

Abstract

This paper describes several deployment concepts including the transition strategies starting from the existing VHF systems to a fully deployed B-VHF system. It presents the main constrains, which affect different migration strategies. The B-VHF project deals with the investigation, design, and evaluation of a broadband overlay communications system for aeronautical communications in the VHF band. This overlay concept facilitates in-band transition from the current to a future ATC communications system and, thus, allows this future system to remain in the advantageous and protected VHF band. Beside this straight transition in the VHF band this paper presents alternative B-VHF system deployment scenarios, which have no or only partly overlay character. For a few selected deployment scenarios a first estimation about the available bandwidth and the possible cell sizes was performed. This first approximation for the B-VHF system capacity was performed for the whole airspace over Europe using the NAVSIM tool.

I Introduction

Aeronautical air-ground voice and data communications systems are reaching their capacity limits as air traffic grows and the airspace is subdivided into smaller areas each requiring a dedicated VHF radio frequency. The problem is most severe in areas with high traffic density and complex airspace configuration, i.e., in Central Europe and in parts of the United States. Currently, 25 KHz channel spacing is being used in the USA. Europe additionally started to introduce 8.33 KHz spacing to provide the needed capacity. However, the strategy of subdividing both the airspace and the VHF band into smaller and smaller segments does not offer a final solution for future Air Traffic Management (ATM) needs.

A global solution shall take into account the requirements for current as well as for emerging operational concepts, taking care of spectrum availability and utilization, transition strategies, economics and national needs. Such a future system will be capable of supporting both data and voice communications.

The introduction of a new ATM communications system is a difficult task since ATM operational functions have to be supported continuously. Thus, a new system has to be introduced gradually and already existing equipment should be able to operate in parallel with the new one to ensure continuity of service during the transition period. This parallel operation will be needed until all users are completely migrated to the new equipment. Therefore, a smooth transition from existing to new technology is a key requirement for any new system.

The B-VHF project within the EC's 6th Framework Program develops one candidate technology for a future aeronautical communications system, where a focal point of the project is the operational feasibility of different deployment concepts during the transition phase. The system requirements are based on current and expected ATM operating concepts. Both functional and performance requirements of voice and data link are taken into account. The B-VHF system is designed as a multi application technology, which provides a flexible air-ground communication infrastructure with capabilities optimized for ATS voice and data service classes (CoS) [1]. The coverage and the communication concept are based on a star-topology where aircraft within certain airspace - so-called B-VHF cell - are connected to the controlling Ground Station (GS). The B-VHF GS uses a dedicated broadband VHF channel to provide multiple communications services to all users within the cell. The multi-carrier B-VHF physical layer is based on OFDM (Orthogonal Frequency Division Multiplexing). This approach allows for exploiting this

---

[1] Main affiliation: RWTH Aachen University / Communication Networks

bandwidth in the VHF spectrum that remains unused by the current narrowband systems by establishing an overlay system in the VHF band. For more detailed information refer to [2] and [3].

B-VHF Cellular Concept

In contrast to the current ATC communication solutions, the B-VHF system is assigned to a cylindrical cell (blue frames in Figure 1) instead of covering only a single ATC sector. With a cellular approach, one B-VHF cell might provide coverage for several ATC sectors, on the other side, one ATC sector might belong to several B-VHF cells/systems.

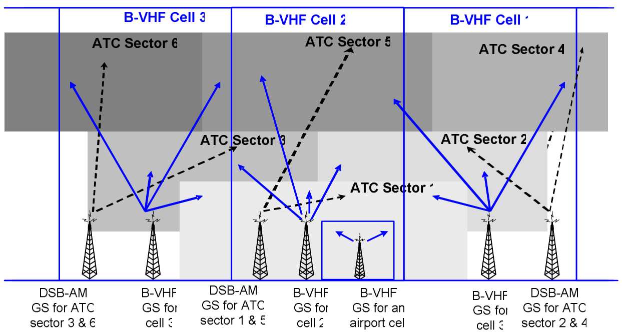

Figure 1: Mapping of B-VHF cells onto ATC sectors

This cell based B-VHF system approach gives a high flexibility with respect to the ground infrastructure due to the arbitrary mapping between ATC sectors and B-VHF cells. It makes a rapid (even dynamic) change of the ATC sector boundaries possible. Only the mappings of services onto ground stations have to be changed, but not the B-VHF GS infrastructure. This approach enables the realization of a multi application communications platform.

B-VHF cells may have different sizes and serve different types of continental airspace: airport (APT), TMA or en-route (ENR). The cell designed operational coverage (CDOC) is defined by the cell radius and cell height. Each cell has a broadband RF channel according to the frequency planning criteria assigned. As long as these criteria are fulfilled, the cell designed operational coverage CDOCs may overlap or a CDOC of a cell may even be entirely contained within a CDOC of another cell.

Within a CDOC, the cell offers multiple operational services. Each operational service has its own Designed Operational Coverage (DOC) that is independent of the B-VHF CDOC. TMA/ENR cells (e.g. GS_1 shown in Figure 2) will provide their services to different ATC sectors and aircraft flying at different Flight Levels (FL) within TMA/ENR airspace, respectively.

A particular cell located at an airport (e.g. GS_2 shown in Figure 2) may have APT services like delivery, ATIS, ground control and RWY control assigned, but its tasks also comprise voice party-line circuits for TMA ATC sectors. In such a case, the GS TX per-carrier forward link power must be designed for the "maximum service DOC" (TMA services), but in order to reduce interference to APT narrowband systems the GS TX may use reduced per-carrier power for carriers dedicated to APT services.

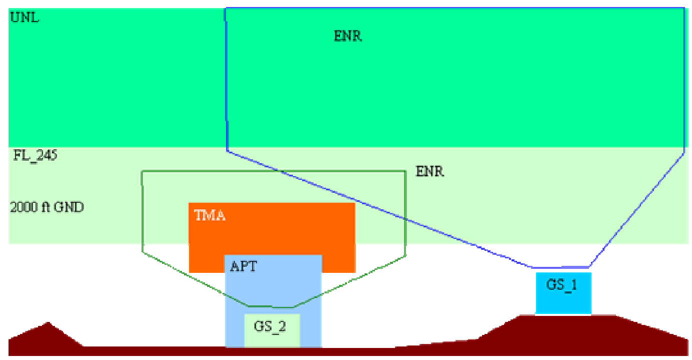

Figure 2: B-VHF Cell DOCs (CDOCs)

II Overlay Concept

An interesting advantage of multi-carrier communications is its flexibility and adjustability to certain spectrum restrictions, which comes from the fact that multi-carrier systems are designed in the frequency domain. The sub-carriers are the basic elements and the data symbols to be transmitted are assigned to the sub-carriers according to some mapping rules. With multi-carrier technology it is possible to realize transmission systems, which do not need a continuous transmission band. Hence, an MC-CDMA system has an internal capability to organize non-contiguous parts of spectrum into a single broadband channel.

B-VHF uses this possibility of "ignoring" selected sub-carriers in order to establish an overlay system in the VHF band, assuming the legacy narrow-band systems within the considered frequency band do not use the whole frequency band for the whole time, but leave some frequency gaps. Additionally, the B-VHF overlay system itself will produce only a small (tolerable) amount of interference power towards the legacy VHF systems without jeopardizing existing protected signal levels of narrowband systems.

Areas within the B-VHF bandwidth, which are already occupied by transmissions of legacy VHF systems operating close to the deployed B-VHF cell, are left unused. The resulting VHF band occupancy picture, reflecting the co-existence of the B-VHF system with the legacy VHF systems, is schematically shown in Figure 3.

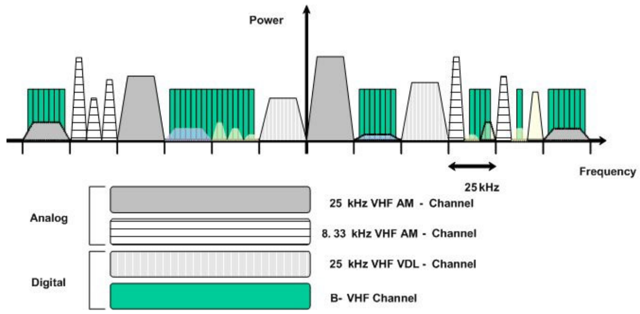

Figure 3: B-VHF overlay concept

The anticipated operating concept for the B-VHF system is based on the a-priori knowledge of these DSB-AM channels which are active or which could be operated within a given region. The line-of-sight propagation conditions in the VHF aeronautical channel allow predicting the received power for each given location in a simple manner. Dependent on the received power level, some DSB-AM ground- or airborne stations can be considered as "strong/local" interferers, while the others belong to the "weak/ distant" category. According to Figure 4, there are three possible constellations of narrowband (NB) VHF signals with respect to the B-VHF (BB) channel:

"S" constellation denotes a STRONG NB in-band signal (channel) that operates within the B-VHF RF bandwidth under overlay conditions and is received with a power above WEAK/STRONG threshold. Narrowband channels classified as "S" are not used by the B-VHF system. In order to protect close ("S") NB receivers, the B-VHF TX shall never transmit on these channels. A B-VHF RX must suppress received interference coming from a close NB "S" transmitter by notching-out these signals.

"W" constellation denotes a WEAK in-band NB signal that operates within the B-VHF RF bandwidth but is received with a power below the WEAK/STRONG threshold. Such channels are considered to be "available" and are effectively used by the B-VHF system in a "real" overlay mode. B-VHF TX may put its carriers into "W" channels; B-VHF RX does not apply filtering, but still must use interference suppression techniques (e.g. windowing) to reduce received interference coming from a distant NB "W" transmitter.

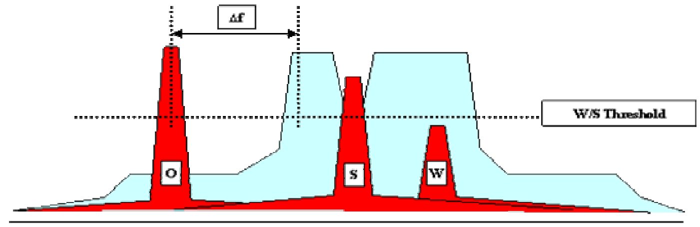

Figure 4: Relative Position of B-VHF and Narrowband Signals

"O" constellation denotes a NB signal (channel) that operates outside the B-VHF RF bandwidth. "S" and "W" constellations apply to the overlay concept where different signals may overlap in the spectral domain.

Opposite to "S" and "W" constellations, which require specific criteria to be developed and applied for interference-free operation, for "O" constellation classic "FDM" frequency protection reasoning applies, based on the required spatial distance to achieve satisfactory performance at a given frequency spacing Δf between involved signals (see Figure 4).

"O" channels are not affected by the WEAK/STRONG threshold (they may be either STRONG or WEAK, with the received power either above or below the threshold).

The particular importance of identifying STRONG interferers is that the B-VHF system will have to consider such narrowband channels as "close" ones that require additional treatment at the transmitter and receiver. The investigations related to this threshold value are based on the link budget analysis given in [6]. In order to calculate the maximum allowed transmission power for the new B-VHF overlay system the smallest possible distance to the legacy narrowband VHF receiver has to be determined that still preserves the protected narrowband signal level at the receiver input. In order to calculate this distance, first the interference power level, acceptable for the victim receiver, has to be estimated which is acceptable for the victim receiver, i.e., which guarantees that the normal communications performance of the victim receiver is not degraded due to the B-VHF system operation. A standard DSB-AM receiver is considered to be used for the victim receiver. Furthermore, we assume the following system and environment parameters:

- The B-VHF system bandwidth B is between 500 KHz and 1 MHz
- For en-route and approach scenario a rice channel model with a rice factor of K = 15 dB applies

- The B-VHF power spectral density is assumed to be flat within the measurement bandwidth.

ICAO Annex 10, VOL III defines the minimum field strength of the DSB-AM signal at the airborne receiver antenna as E_{min} = -75 μV/m, which results in a minimum signal at airborne receiver input of -85 dBm. It is assumed that a Desired to Undesired ratio of 10 dB will be sufficient for the quality of the received signal at a DSB-AM receiver, if the frequency spectrum of the undesired signal is uniformly distributed over the receiver bandwidth[2]. This results in an acceptable interference power level of -95dBm within the equivalent noise bandwidth of the narrowband airborne receiver. This interference threshold is independent of forward or reverse B-VHF link. The IF bandwidth of the typical DSB-AM radio receiver is typically much wider (~16 KHz) than the bandwidth of each single transmitted RF signal.

The threshold between strong and weak interferers is dependent on the B-VHF parameters transmitter power and bandwidth and can be calculated for an airborne victim DSB-AM receiver by using the following equation.

$$P_{Threshold} = -95dBm + P_{DSB-AM} - P_{B-VHF} + FDR(\Delta f < \frac{B}{2} - 16KHz)$$

, where PDSB-AM is the transmission power for AM radio and PB-VHF is the transmission power of the B-VHF radio. FDR (Δf) is the frequency depended rejection for a frequency separation Δf and it is for the different B-VHF bandwidth between 14 to 18 dB for the forward link and 4 to 7 dB for the reverse link. FDR is the rejection provided by a receiver to a transmitted signal as a result of the limited bandwidth of the receiver with respect to the transmitted signal and the detuning between the receiver and the transmitter. Since the link margin is above 12 dB for 200 nm cell radius, transmission power and threshold value should be considered during system design, and will be in the range between -75 dBm to -85 dBm in order to have enough VHF channels available.

[2] In ICAO Annex 10 the allowed desired to undesired signal ratio in a DSB-AM receiver is defined with 14 dB. This ratio is defined for Co-Channel interference, where the undesired signal is also a DSB-AM signal. The reduction of the protection ratio assumed here is based on the fact that we can assume the power of an MC-based signal is distributed uniformly so the filters at the receiver will add an additional attenuation of~ 3 dB, since the DSB-AM signal bandwidth is only 7KHz

III Deployment Concept

This chapter captures aspects that are common to all B-VHF deployment scenarios and defines some terms that will be used in the following sections of this paper. The main focus of the B-VHF project is to asses the feasibility of the overlay deployment concept in the VHF COM band. The success of such an in-band migration scenario is strongly influenced by the interference on the B-VHF system from the legacy VHF system and on the number of "available" VHF channels which can be re-used from the B-VHF system without deteriorating the performance of the legacy VHF systems. Thus, with an overlay deployment concept, the B-VHF system – more precisely the B-VHF cell size - would basically be interference-limited. Due to the B-VHF cellular concept the coverage of a B-VHF cell is independent of the designed operational coverage of a given communications service.

These services are currently provided in the narrowband mode, by using a number of ground stations (GSs) placed at appropriate locations. As each GS comprises not only radio equipment, but also other expensive infrastructure (like buildings, antenna towers, power supply and access to the network infrastructure), the coverage of a particular B-VHF cell should be comparable to the coverage provided by an existing narrowband GS.

As under overlay conditions this condition may not always be achievable in the VHF range, alternative deployment scenarios should be considered that include additional frequency ranges. Therefore, also B-VHF system deployment scenarios, which have no or only partly overlay character, have been investigated.

There are some other aeronautical bands that may become available for the implementation of future aeronautical mobile services (AMS). In [4] the 960 – 1024 MHz (DME) and the 5091 – 5150 MHz (MLS) frequency bands where identified as suitable candidates for future AMS. In addition, the upper part of the VOR range (116- 118 MHz) has been indicated as a possibility to deploy a new system for AMS [5].

Taking these additional opportunities into account, the B-VHF system may be deployed in:

VHF COM range (118–137 MHz)

VOR range (target range: 116–118 MHz)

DME range (target range: 960–1024 MHz)

MLS range (target range: 5091–5150 MHz)

An initial system deployment concept for the VHF COM band is currently being developed within B-VHF project. Starting with an initial deployment of B-VHF services, first B-VHF ground infrastructure must be deployed. The required airborne equipage depends on the initial deployment mode of the airspace. In general we can distinguish between three different airspace types:

B-VHF-supported airspace, where the B-VHF ground infrastructure must be deployed, but the airborne deployment of the B-VHF system is voluntary. Within B-VHF-supported airspace a mixed ground NB/B-VHF infrastructure and mixed NB/B-VHF aircraft population would exist. B-VHF system would be operated in parallel with the existing narrowband DSB-AM and VDL systems, providing some B-VHF services in addition to the already available narrowband services. For some services special precautions must be taken on the ground (gateways) to assure interoperability between NB and B-VHF aircraft.

B-VHF airspace, where the B-VHF ground infrastructure must be deployed and the deployment of the B-VHF system is mandatory for all aircraft that intend to enter such airspace. B-VHF airspace would be segregated from B-VHF-supported airspace or NB airspace. With this option (that is very similar to the 8,33 kHz system introduction policy), a defined scheduled switchover to the new system would be required. Moreover, after the switchover, the B-VHF system would remain the sole terrestrial air-ground communications system operated within that airspace, replacing all services that were previously provided by DSB-AM and VDL.

NB airspace, where no ground B-VHF system is deployed (only NB ground infrastructure exists). Within NB airspace mixed NB/B-VHF aircraft population may exist, but only NB VHF systems are used to provide communications services. NB airspace may be visited by B-VHF aircraft, but aircraft radios (even if B-VHF-capable) would always be operated in NB mode due to the lack of ground B-VHF support. Therefore, NB airspace is actually out of scope with respect to the B-VHF system deployment, but B-VHF airspace or B-VHF-supported airspace would always be surrounded by the NB airspace.

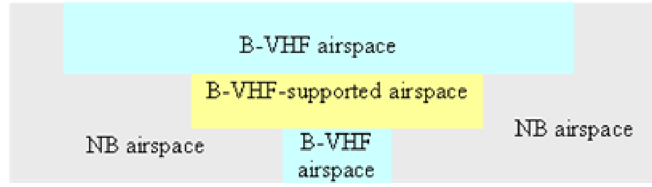

Figure 5: Airspace Regimes

An example of three airspace types (vertical view) is shown in Figure 5. In this example, it is assumed that an airport and a part of the upper-space have been converted to B-VHF operation.

Spectrum Usage Options

Basically, B-VHF system deployment in any frequency range may be based either on overlay or on the usage of dedicated channels. By the dedicated channel approach, other systems operate “out-band” with respect to the B-VHF broadband channel, without spectrum sharing. Traditional frequency planning criteria for that frequency range are applied.

With an overlay approach, the B-VHF system shares the spectrum with other systems (these systems operate “in-band” with respect to the B-VHF broadband channel). The B-VHF system can tolerate some amount of interference from other systems (DSB-AM, VDL, etc.) operating within the same part of the spectrum that is used by the B-VHF system while it produces no visible interference towards these systems itself. “Extended” frequency planning criteria must be developed, taking into account all traditional FDMA aspects for that range, as well as specific aspects due to an overlay approach.

The basic B-VHF cellular concept, developed for the VHF band, requires that B-VHF cells operate within the B-VHF system as frequency-protected service volumes. For a single cell, only one broadband channel is required, for wide-area coverage a certain minimum number of broadband channels must be allocated. Frequency planning criteria assure that with appropriate spatial separation of service volumes no B-VHF to B-VHF interference can occur that could jeopardize the required voice and data QoS.

IV Migration Scenarios

This chapter addresses selected migration scenarios for the B-VHF system in the European airspace. With the number of possible aeronautical frequency bands, the different airspace types, the way of using the spectrum and the type of services that should be supported by a B-VHF system (voice and data services integrated system or data only system), exists a large number of potential migration scenarios. We will present three of the most important scenarios:

VHF-COM Transition: B-VHF System Deployment in the VHF COM band

VHF- COM - DME Transition: B-VHF System Deployment in the VHF COM and DME band

VHF- COM - NAV Transition: B-VHF System Deployment in the VHF NAV and COM band

In the VHF-COM Transition the B-VHF system concept provides an integrated voice/data system. The preferred VHF deployment scenario is based on overlay. A deployment in the VHF COM range without overlay is not realistic due to the fact that each B-VHF GS requires a separate broadband channel that would – without overlay – have to be completely free from any in-band narrowband channels. Therefore, the B-VHF system operating in the VHF range would remain an overlay system until the last in-band VHF narrowband channel has been abandoned within a local area of interest. It is likely that NB emergency channels (e.g. 121.5MHz) will continue to be operated within the VHF COM range for the foreseeable future. Additionally, there will always be a boundary to the non-B-VHF airspace where the specific overlay constraints and specific frequency planning criteria would apply under any conditions.

The VHF- COM-DME Transition has a partly overlay character, where the VHF COM band and the DME band are used for implementing the B-VHF system. For example, the approach and tower VHF channels in high density areas might be transferred to the DME band and the gained VHF band capacity facilitates the B-VHF system deployment. Currently, the DME band (960-1215 MHz) has been reserved and protected for aeronautical navigation services. Due to higher operating frequency modifications must be done at the physical layer (e.g. the transmission power has to be ~20 dB higher than in the VHF COM band in order to cover the same area). No changes are expected in other parts of the B-VHF protocol stack. Within this scenario, a B-VHF system operates as an integrated system, providing both voice and data services to the equipped users.

Dependent on the preferred local deployment policy, this scenario can be applied within the B-VHF supported airspace, with mixed B-VHF and NB aircraft population and voluntary airborne equipage. Alternatively, B-VHF system deployment may start within a dedicated B-VHF airspace. Assuming an appropriate number of dedicated broadband channels is available in the target DME band (as required for the frequency planning), an integrated voice/data B-VHF system can be deployed in this band without overlay. As the DME range is sufficiently separated from the VHF range, no interference is expected between the B-VHF radios operating within the DME range and the "classical" DSB-AM voice radio system operating in the VHF range. Simultaneous B-VHF/DSB-AM operation from the same aircraft (e.g. emergency channel) should be possible without significant problems.

The VHF- COM-NAV Transition scenario has similar features as the VHF- COM-DME Transition approach. The supported services and the combined usage of different frequency bands are identical. Furthermore, the mixture of overlay and dedicated spectrum usage are similar, only the available bandwidth in the VHF NAV band is far smaller than in the DME band.

In order to get for the different transition concepts first estimates about the available bandwidth and the possible cell size allocation within a representative airspace, a worst case VHF band occupancy simulation was performed. This estimation considers only the overlay part of the different transition scenarios - which is in all three scenarios the VHF COM band.

Approach for Cell Size Evaluation

This first B-VHF system capacity analysis was performed considering the whole airspace over Europe and using the NAVSIM[3] tool, with a model that includes among other things a complete list of ATC sectors, radio stations and assigned VHF frequencies. The modeling approach to determine the available bandwidth and cell size allocation are based on (worst case) VHF channel occupancy calculations in [6]. With the NAVSIM tool the maximum cell size and the 1 MHz/ 500 KHz frequency band with the lowest number of interferers – "best candidates" to become a local B-VHF RF channel - where determined for more than 500 reference points all over Europe.

Therefore, a channel occupancy simulation for the whole VHF COM band has been performed for the European airspace. The maximum interference power levels were calculated taking into account worst-case scenarios for both ground station and aircraft transmissions. For the ground station transmissions the

[3] NAVSIM is an Air Traffic / ATC & CNS Simulation Tool

worst-case scenario assumed that all ground stations transmit on their respective frequency with a duty cycle of 100%. Aircrafts were represented by one interfering aircraft per ATC sector placed at a “worst-case” (closest) position with respect to the victim receiver. This aircraft is located at the edge of the ATC sector which is nearest to the victim receiver. Moreover, the duty cycle of the worst-case interfering aircraft is also set to 100%. Applying that approach, the worst possible interference scenarios are created for the VHF band occupancy simulations. The interference power level in each VHF channel is calculated using a link budget analysis based on free space propagation. All aircraft and ground stations within the radio horizon are taken into account assuming the EIRP power levels for transmission as specified in Table 1. Since the victim receiver might in each VHF channel receive narrowband signals from several different sources, e.g. a ground station and an aircraft transmitter, the strongest interference signal has been retained and with that the maximum interference power level is calculated.

Aircraft EIRP	Aerodrome EIRP	TMA EIRP	En Route EIRP
41 dBm	39 dBm	46 dBm	46 dBm

Table 1: EIRP levels of the different transmitter types.

The VHF channels which can be re-used for B-VHF have to be available not only at a certain geographical point, but within the whole B-VHF cell. For simplicity, B-VHF cells are assumed to be cylindrical and are characterized by their cell radius.

Figure 6 to Figure 11 show results of these simulations on over 500 selected reference points in Europe. For each of the reference points possible B-VHF cell size ranges of 60 nM, 100 nM, 150 nM and 2000 nM, with threshold values of -75dBm and-80dBm have been evaluated.

Figure 6 and Figure 7 show for the VHF-COM Transition scenario the cell size allocation over Europe with a threshold value of -75 dBm and a bandwidth of 1MHz and 500 KHz, respectively. For each reference point the largest of the above mentioned cell sizes is used, where more than 80% of the bandwidth is available. In this scenario no modification on the existing system has been carried out. This means that this would be fully seamless transition, without any effort for the existing system. The cyan and grey circles (cell sizes of 200 and 150 nM) represents the Low-Density area of Europe. The green circles mark the Medium-Density area and the yellow and orange circles indicate the High-Density area. The red circles around London mean that in these areas no seamless transition is possible without changing the existing system. Figure 8 shows for the same transition scenario the results with a threshold value of – 80 dBm. In Figure 9 the same situation as in Figure 8 was simulated, but now only the forward link situation is presented. It can bee seen that for the available bandwidth the limiting factor is the reverse link.

Figure 10 and Figure 11 give for the VHF-COM DME Transition scenario the cell size allocations over Europe with threshold values of -75 dBm and -80 dBm, respectively. In these simulations all approach and tower VHF channels are transferred to the DME band. This approach would ease the channel assignment and coverage demands in the whole European airspace.

Finally, in Figure 12 to Figure 14 the histogram of the B-VHF cell size distribution is presented for different threshold values (75 dBm. -80 dBm and -85 dBm).

V Conclusions

In this article, we have presented selected aspects of different deployment scenarios for the B-VHF system. Worst case interference simulations, with different threshold values for the tolerable interference, have been performed for the European airspace over the whole VHF COM band. These simulations have revealed first results about the available bandwidth and the cell sizes of a B-VHF system in Europe. That facilitates the classification of the airspace into categories; High-, Medium-, and Low-density areas. The simulation results indicate that pure in-band transition is feasible if a threshold value of -75 dBm proves to be sufficient for the B-VHF system operation. However, even in this case the initial deployment would be easier if additional VHF bandwidth could be made locally available (additional number of VHF channels made available for B-VHF) in High-density areas. This could be realized by an extension of the VHF COM band towards the VHF NAV band, or by transferring existing approach and tower frequencies to the DME or MLS band.

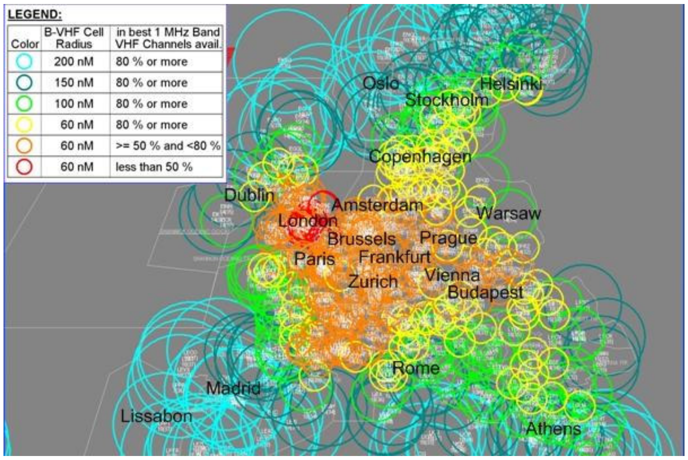

Figure 6: 1MHz, all stations, threshold -75 dBm

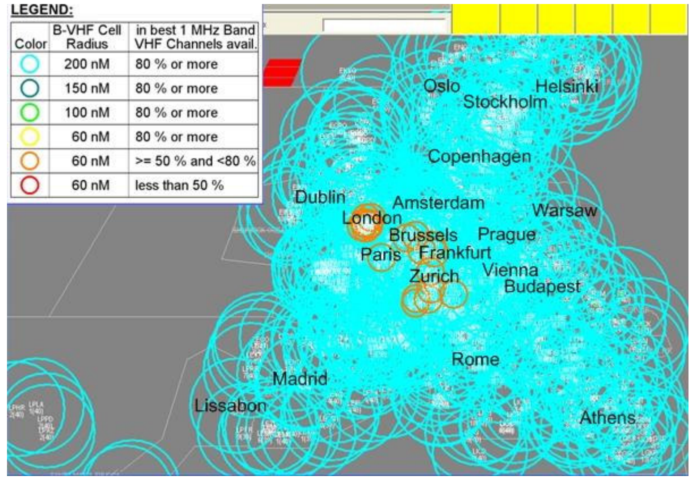

Figure 9: 1MHz, all stations, victim receiver 300ft above ground, threshold -80 dBm

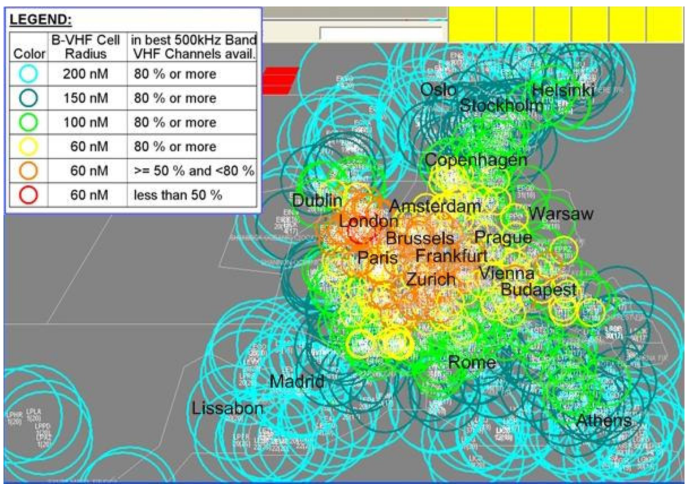

Figure 7: 500kHz, all stations, threshold -75 dBm

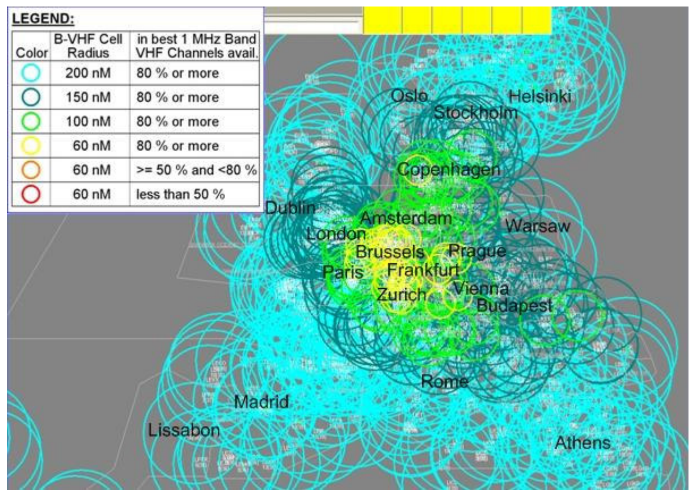

Figure 10: 1MHz, en-route stations only, threshold -75dBm

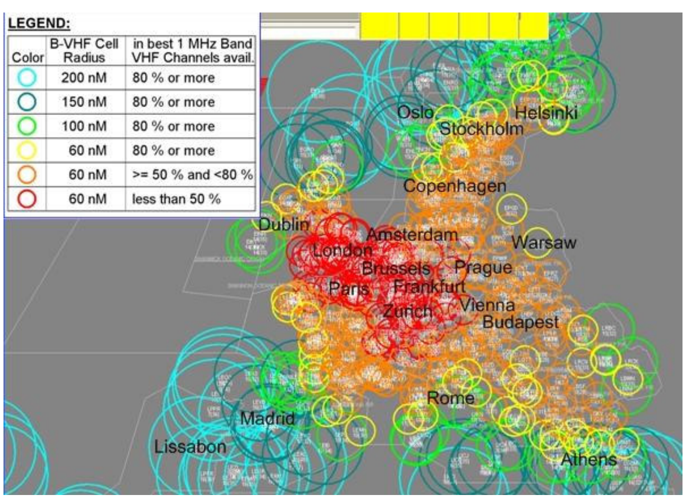

Figure 8: 1MHz, all stations, threshold -80 dBm

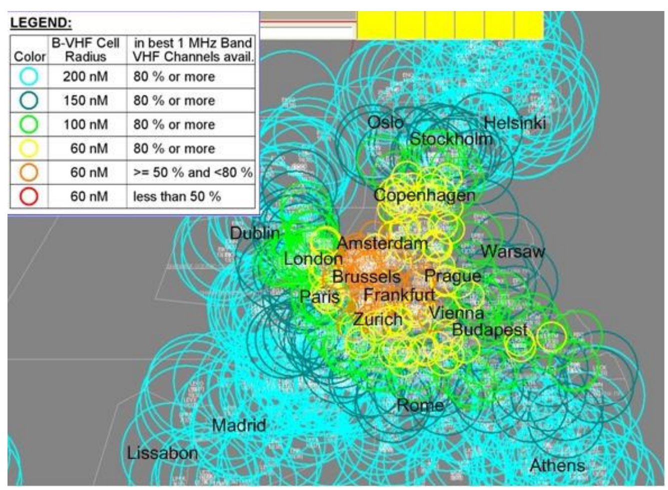

Figure 11: 1MHz, en-route stations only, threshold -80dBm

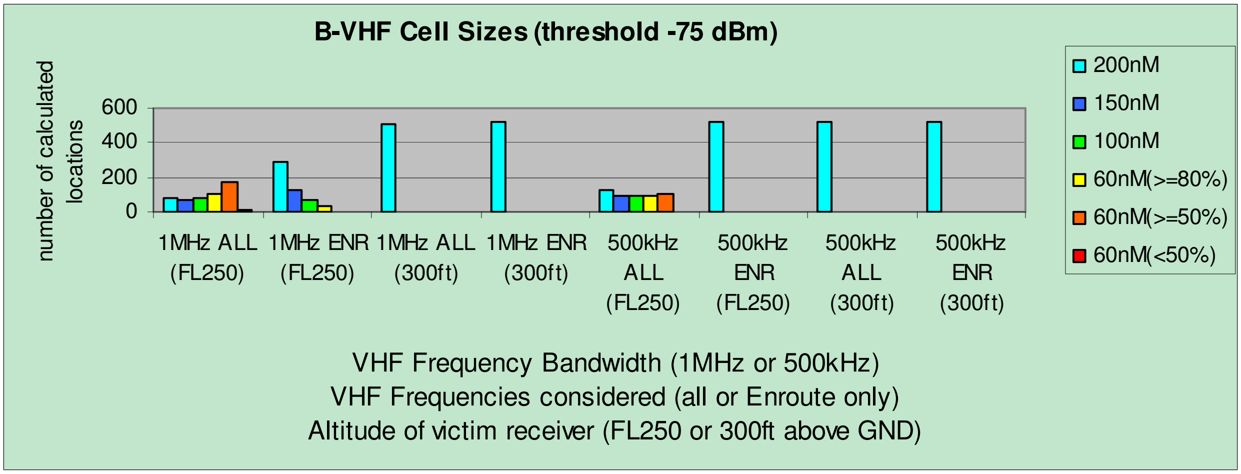

Figure 12: B-VHF Cell Sizes, threshold -75 dBm

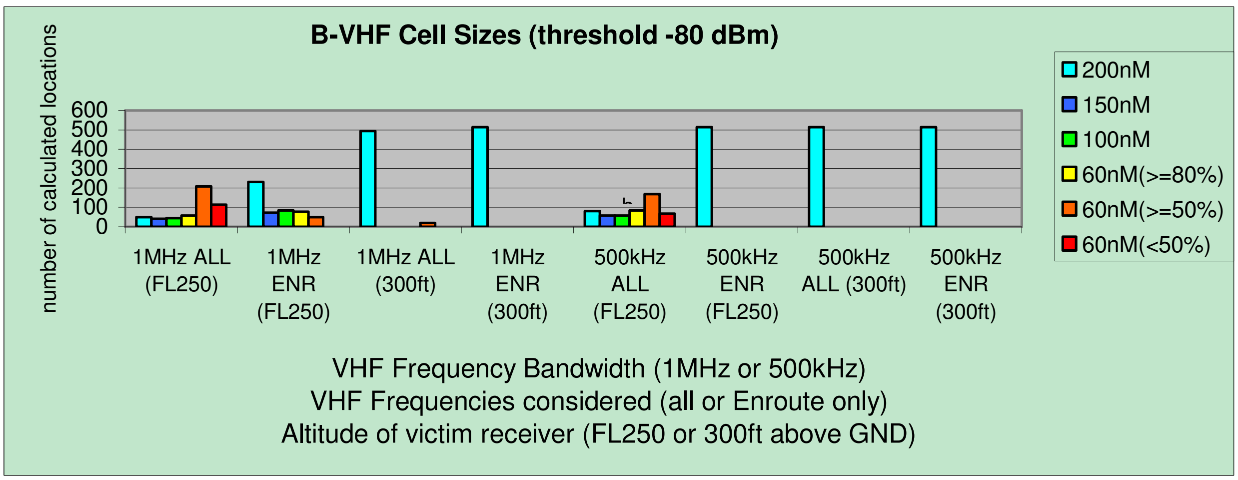

Figure 13: B-VHF Cell Sizes, threshold -80 dBm

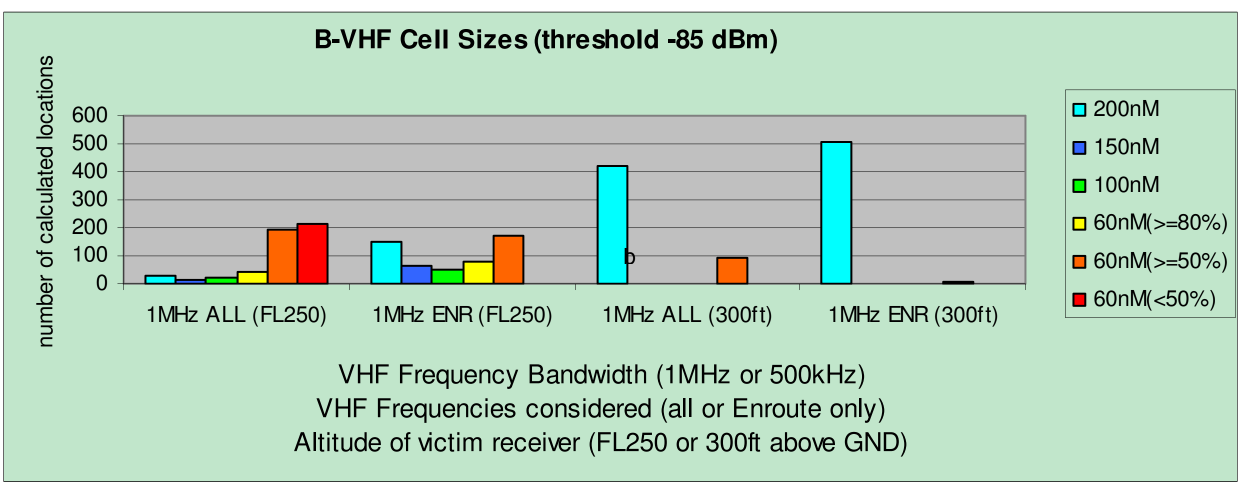

Figure 14: B-VHF Cell Sizes, threshold -85 dBm

References

[1] EATM,- "Operating Concept of the Mobile Aviation Communication Infrastructure Supporting ATM beyond 2015," Ed. 1.0, July 2002

[2] B-VHF Project, " B-VHF Functional Principles and Architectures," Report D-06, www.b-vhf.org, April 25, 2005.

[3] B. Haindl et al., "A Multi-Carrier Based Broadband VHF Communications Concept for Air Traffic Management," IEEE Aerospace Conference March 2005.

[4] ACP-WGF14/WP14 – ITU WRC-07, "Agenda Item 1.6 – Allocations to the Aeronautical Mobile (R) Service", Malmö, Sweden, 22-26 August 2005

[5] ACP-WGF14/WP21 – ITU WRC-07, "Agenda Item 1.6 – Feasibility of VOR/DME Re-planning in Europe to Free the Sub-band 116-118 MHz for AM(R)S Usage" , Malmö, Sweden, 22-26 August 2005

[6] B-VHF Project, "Interference on the B-VHF Overlay System," Report D-09, www.b-vhf.org, November 15, 2005.

Biographies

Bernhard HAINDL: He received his communications degree from University of Technology Vienna in 1995 .and the Ph.D. degree in electrical engineering from University of Technology Vienna in 2005. He joined Frequentis in 1995 as scientific researcher. From April 1999 to December 2001 he was research assistant at the Institute of Computer Technology at the Vienna University of Technology with a strong focus on aeronautical communications. He has participated in international aeronautics research activities, with a focus on radio and IP communications.

Miodrag SAJATOVIC: He received his MSEE from the Electrotechnical Faculty of the University of Zagreb, Croatia in 1976. He has successfully participated in international aeronautics research activities where his focus was on communications and operational concepts (F-VHF, MA-AFAS). His special expertise are radio communications, in particular VHF and he holds a patent for secure VHF communication.

Christoph RIHACEK joined Frequentis GmbH in 1999. Mr. Rihacek is responsible for managing research projects and programmes at Frequentis GmbH. Mr. Rihacek has a strong expertise in guiding the development of new and innovative systems with development teams residing in different countries. Currently Mr. Rihacek is responsible for co-ordinating the "B VHF" project, which is co-funded by the European Community within the Sixth Framework Programme. Mr. Rihacek has a degree in Control Engineering and Industrial Electronics from Vienna University of Technology.

Carl-Herbert ROKITANSKY: He studied economics / mathematical statistics at the University of Vienna and Computer Science at the University of Vienna and Technical University of Vienna (1977 – 1982). From 1983 to 1986 and from 1987 to 1988 he was within "Institut für Nachrichtentechnik" at DFVLR (former name of DLR) Oberpfaffenhofen . During academic year 1986/1987 he was Visiting Professor at University of Lawrence, KS, USA. From 1988 to 1991 he was within the "Institut für Datenverarbeitungstechnik" at "Fern-Universität" Hagen, Germany. Since 1991 he is within the Institute of Communication Networks, RWTH Aachen University of Technology, Aachen, Germany. He is currently Hon. Prof. for "Technical Informatics" at University of Salzburg, Institute (FB) for Computer Sciences where since 1989 he is giving lectures on mobile communication, stochastic modeling and simulation, performance analysis using Markov chains, encryption and data security.

Michael SCHNELL: He received his Dipl.-Ing. Univ. degree in electrical engineering from University of Erlangen-Nuremberg, Germany, in 1987, and the Ph.D. degree from University of Essen, Germany, in 1997, respectively. In 1990, he joined the Institute of Communications and Navigation of the German Aerospace Center (DLR), Oberpfaffenhofen, Germany, where he is currently group leader and project manager of the Aeronautical Communications Group. He is lecturer for multi-carrier communications at the University of Karlsruhe, Germany, member of IEEE (M'96-SM'04) as well as VDE/ITG, and serves as selected advisor to the German Aviation Authority (DFS) for ICAO/ACP.