CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Transportation Sciences

Department of Air Transport

Analýza kvality radiokomunikace v provozu General Aviation

Analysis of radiocommunication quality in General Aviation operations

Bachelor Thesis

Study Programme: PIL

Study Field: Profesional Pilot

Supervisor: Ing.Vladimír Machula

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Semen Kiriutin

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děkan
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K621 .... **Ústav letecké dopravy**

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

(PROJEKTU, UMĚLECKÉHO DÍLA, UMĚLECKÉHO VÝKONU)

Jméno a příjmení studenta (včetně titulů):

Semen Kiriutin

Studijní program (obor/specializace) studenta:

bakalářský – PIL – Profesionální pilot

Název tématu (česky): **Analýza kvality radiokomunikace v provozu General Aviation**

Název tématu (anglicky): Analysis of Radiocommunication Quality in General Aviation Operations

Zásady pro vypracování

Při zpracování bakalářské práce se řiďte následujícími pokyny:

- Cílem práce je vytvořit analýzu přechodu letecké radiové komunikace z kanálového dělení 25 kHz na 8,33 kHz. Dále identifikovat problémy spojené s přechodem na kmitočtové dělení 8,33 kHz a navrhnout možnosti řešení problémů kvality.
- Další požadavky na zpracování bakalářské práce:
- Analyzujte základní problematiku, popište účelu přechodu na kanálové dělení 8,33 kHz. Definujte uživatele radiokomunikačních služeb v oblasti GA, podmínky provozu a legislativu.
- Popište používané radiokomunikačního vybavení.
- Identifikujte problémy radiokomunikace v oblasti GA po přechodu na kanálové dělení 8,33.
- Zhodnoťte dopad identifikovaných problémů na bezpečnost v oblasti GA. Vytvořte návrhu pro rešení problémů kvality.

ČVUT FD

Rozsah grafických	Dle instrukcí vedoucího bakalářské práce
Rozsah průvodní	minimálně 35 stran textu (včetně obrázků, grafů a tabulek, které jsou součástí průvodní zprávy)
Seznam odborné literatury:	https://www.eurocontrol.int/sites/default/files/publication/files/201707-8.33-vcs-user-handbook%201.1.pdf Bailey, D.. (2003). Practical Radio Engineering and Telemetry for Industry. 1-284. Spitzer, Cary. (2006). Avionics: Development and Implementation. 10.1201/9781315222233.

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(datum prvního zadání této práce, které musí být nejpozději 10 měsíců před datem prvního předpokládaného odevzdání této práce vyplývajícího ze standardní doby studia)

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b) v případě odkladu odevzdání práce následující datum odevzdání práce vyplývající z doporučeného časového plánu studia

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V Praze dne............ 2. prosince 2021

Abstract:

Starting in the early 1990s, ICAO had been pondering upon the possibility of narrowing channel spacing to aid an ever-increasing number of flights worldwide and mending those limitations inflicted by voice radio communications. In the mid-2000s, the European aviation community had kicked off the solution implementation: a transition to the 8.33 kHz spacing which replaced the 25 kHz that was in use previously.

The goal of this bachelor's thesis is to analyse the transition to the new voice channel spacing in the European region, in order to identify problems in the implementation process of this project. Additionally, this research aims to propose possible solutions to the problems that have occurred during the transition.

A survey engaging the main radio communication groups in general aviation has been chosen as the method to solve this problem. Together with a review of available literature and documentation.

Results that were obtained could help avoid delays and misunderstandings in subsequent changes in frequency spacing

Keywords: radiocommunication, transition, voice channel spacing

Abstrakt:

Od počátku 90. let minulého století se ICAO zabývala možností zúžení odstupu kanálů, aby pomohla stále rostoucímu počtu letů po celém světě a odstranila omezení způsobená hlasovou radiokomunikací. Na začátku 21 století zahájila evropská letecká komunita implementaci řešení: přechod na rozestup 8,33 kHz, který nahradil dříve používaný rozestup 25 kHz.

Cílem této bakalářské práce je analyzovat přechod na nový rozestup hlasových kanálů v evropském regionu, aby bylo možné identifikovat problémy v procesu implementace tohoto projektu. Kromě toho si tento výzkum klade za cíl navrhnout možná řešení problémů, které se během přechodu vyskytly.

Jako metoda řešení tohoto problému byl zvolen průzkum, do něhož byly zapojeny hlavní radiokomunikační skupiny ve všeobecném letectví. Spolu s přehledem dostupné literatury a dokumentace.

Klíčová slova: rádiová komunikace, přechod, rozteč hlasových kanálů

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I would like to thank my supervisors Ing. Vladimir Machula and Ing. Terézia Pilmannová, MBA for their patience, effort and work, as well as their invaluable advice and guidance on completing this thesis.

I would also like to thank my family and friends: Yurii Kiryutin, Tatiana Kiryutina, Regina Kiryutina as well as Christina Tyutyunikova for their moral support and faith in me.

Declaration of Honour

I declare that I have prepared the bachelor's/diploma thesis entitled Analysis of radiocommunication quality in General Aviation independently and have used a complete list of citations of the sources used, which are given in the list attached to the bachelor's/diploma thesis.

I have no serious reason against the use of this schoolwork within the meaning of §60 of Act No.121/2000 Sb., on Copyright, on Rights Related to Copyright and on Amendments to Certain Acts (Copyright Act).

Prague, 08.08.2022

Signature

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List of abbreviations

ACC – Area Control Centre

ADF – Automatic Direction Finder

AES – Artificial Earth Satellites

ANSP – Air Navigation Service Provider

ARAMB – Autonomous Repeater of Aeronautical Mobile Air Communications

ARB – ground omnidirectional Azimuth VHF Radio Beacon

AS radar – Airfield Survey radar

ASR – Airport Surveillance Radar

ATC – Air Traffic Control

ATS – Air Traffic Service

CRB – Course Radio Beacon

CTR – Control Zone

DOC – Designated Operational Coverage

EANPG – European Air Navigation Planning Group

FDPN – Flight Data Processing Systems

FDPS – Flight Data Processing System

FL – Flight Level

GPB – Glide Path Beacon

ICAO – International Civil Aviation Organization

IR – Implementation Regulation

LR – Landing Radar

LRRB – Long-Range Marker Radio Beacon

MSC – Message Switching Centers

NMRB – Near Marker Radio Beacon

RBLS – Radio Beacon Landing Systems

RRB – ground omnidirectional Rangefinder VHF Radio Beacon

RRC – Receiving Radio Center

RSR – Air Route Surveillance Radar

SDRS – Separate Drive Radio Station

TMA – Terminal Control Area

TRC – Transmitting Radio Center

VCS – Voice Channel Spacing

VFR – Visual Flight Rules

VHF – Very High Frequency

1. Introduction

The problem of improving flight safety has always been and will be one of the most critical tasks facing developers in general aviation. The analysis of the causes of aviation accidents and incidents indicates a decrease in the proportion of events, which accounts for problems directly related to the state of aviation equipment and airborne and ground equipment. However, even with the most modern electronic equipment, a situation may arise when general aviation, the crew piloting strictly according to the readings of the instruments, is involved in an accident. Therefore, one of the main requirements for flight operations is to ensure safety when operating general aviation. Ensuring the safety of general aviation flights is carried out by a complex of organisational and technical measures and means in accordance with the relevant structures. General air transport control from the ground is carried out with the help of various radio equipment, including air-ground radio communications. Thus, it is necessary to fulfil all the requirements for the composition, placement, operation, and periodic monitoring of the technical characteristics of radio equipment and aviation telecommunications.

At the same time, the ever-increasing saturation of free space with radio waves of various ranges, with multiple types of modulation and manipulation, leads to a constant increase in the likelihood of a dangerous effect of this kind of unintentional electromagnetic interference on the radio-electronic equipment of general aviation. Moreover, the presence of electromagnetic radiation leads to the fact that working instruments have begun to give false readings since they perceive obstacles as valuable signals, based on which they will make the wrong decisions on piloting general aviation. [53]

The motivation for choosing this topic for writing a bachelor's thesis was the lack of research on problems during or after transfer on a new spacing of 8.33 kHz, the absence of any literature, and poor disclosure in the regulatory documentation. Moreover, this bachelor thesis aims to analyse the transition of aeronautical radio communication from 25 kHz to 8.33 kHz channel division to identify problems related to the transition to frequency division 8.33 kHz and design possible solutions to quality problems.[31]

A vast amount of information is required for and from pilots to ensure flight safety. Data on aircraft service performance includes information on the situation in the vicinity of the plane and ground communication like different permissions, meteorological reports, or traffic information. In this respect, radio communication is a critical implementation, enabling an agreement with its fellow pilots and an agreement by Air Traffic Service officers. In many cases, it is no longer possible to imagine flying without the use of radio, especially concerning operations in Control Zone (CTR), Terminal Control Area (TMA), and possibly in congested spaces. The development of aviation and the affordability of aircraft and vehicles led to an increase in the number of flights. Especially with the development of air transport in the European territory, the requirements for free frequencies are growing.

2. Current state of the art

The 8.33 kHz channel is created by dividing the 25 kHz channel into three parts, where one carrier frequency is the same as the 25 kHz carrier frequency but with a channel width of 8.33 kHz, and the other channel will have a carrier frequency of + 8.33 kHz, or -8.33 kHz.

If we have 25 kHz channeling, the channel frequencies, for example, are 119.975 MHz, 120.0 MHz, 120.025 MHz, and 120.05 MHz. For example, in the case of 8.33 kHz frequency, 120.0 MHz is divided into the following frequencies: 119.99167 MHz, 120.0 MHz, and 120.00833 MHz. This step brings three 8.33 kHz channels into the original channel width of 25 kHz. [9] This action increases the capacity of the frequency band by 66%. [9]

The frequency band reserved for air transport is already filled, and we get into a situation where other free frequencies are not easily available. This shows in Figure 2. Other frequency bands suitable for aviation are fully occupied by other applications, and their release is impossible. The easiest solution seems to be to increase the capacity of the aviation frequency band. Currently, the only solution on offer is to narrow the transmission channel width from 25 kHz to 8.33 kHz. [20] For example, approximately ten frequencies are currently in use after the transition to the new channel spacing in Prague Ruzyně Airport. [26] Figure 1 shows the number of available VHF channels in the European region.

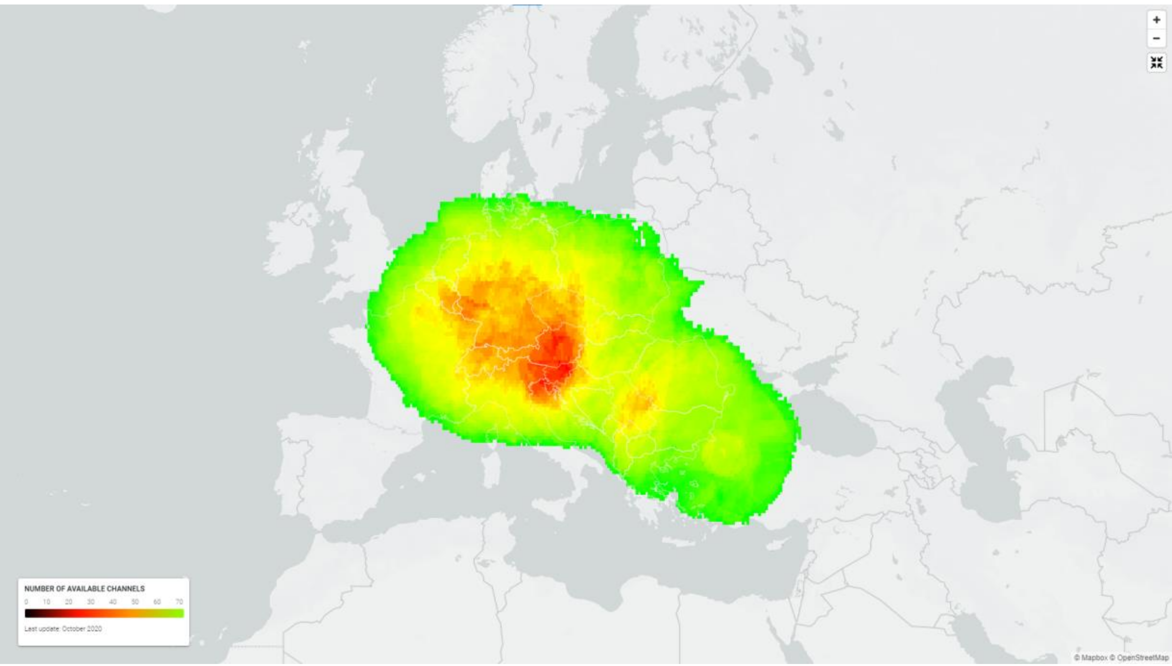

Figure 1- Map of available VHF voice channels in Europe [24]

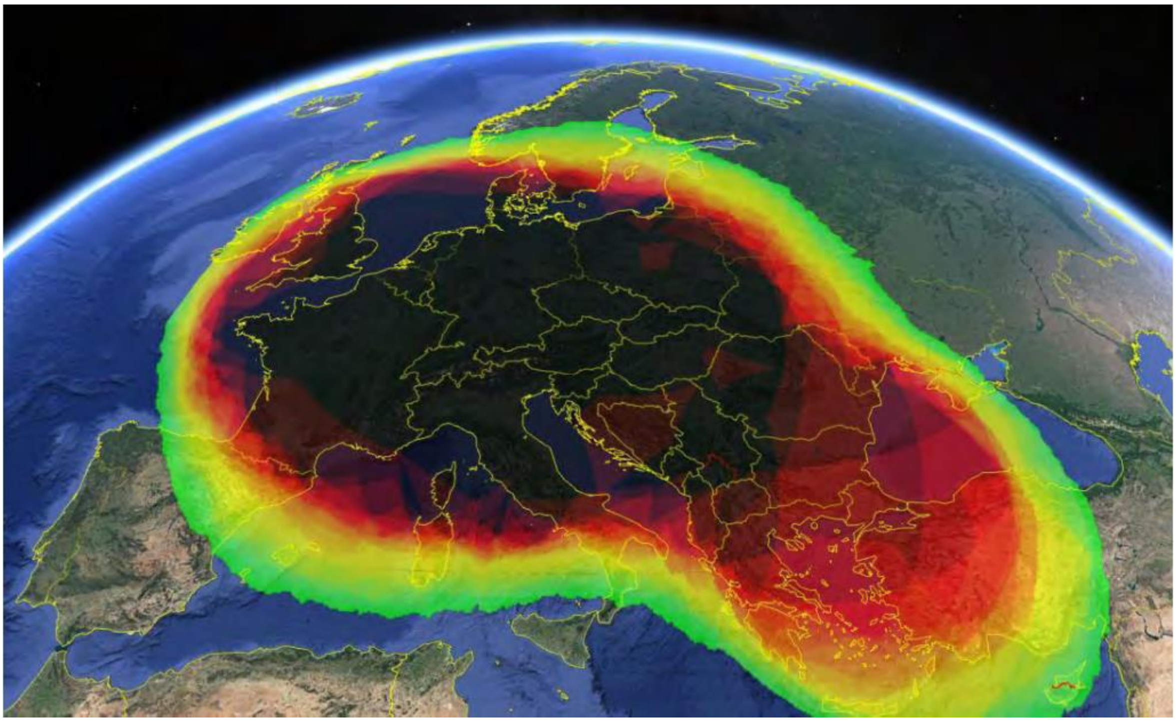

Figure 2 - Number of available frequencies for a 25 kHz sector [38]

This step increased the capacity of the frequency band by about 66%. It is a significant step that enabled the further development of flying or its management. In theory, this step increased the capacity of the frequency band by 66%, but in practical implementation this number is much smaller. Eurocontrol and ICAO have been working on the issue of the 8.33 kHz switchover for several years, and this switchover is now broken down into several steps. [9]

First, a channel width transition of 8.33 kHz was made at altitudes above FL 195. Now this operation has been performed at altitudes from GND to FL 195. However, this operation is not as simple as it may seem. Equipment had to be replaced at aeronautical and aircraft stations (i.e., radio stations operating in the ground band or on the aircraft), as stations with a current channel width of 25 kHz could potentially cause problems during communication on the frequency with a channel width of 8.33 kHz and vice versa. [9]

3. Theoretical and historical background

In this chapter, the technical characteristics of the use of radio waves and their history of formation and change will be considered. In particular, the essence of electromagnetic waves will be revealed, frequency and modulation definitions will be given, factors affecting the quality of transmission will be listed, and the current situation with the use of intervals will be considered.

3.1 Electromagnetic waves

Information is a set of facts about an object's specific events, phenomena, and states. The concept of a message is everything that contains information about a phenomenon or an event that needs to be transmitted (speech, text, image, etc.). In this context, a message is a carrier of information, its material embodiment. The transmission of a message over a distance is carried out using material carrier (paper, magnetic tape) or a physical process (sound or electromagnetic waves). The physical process representing (carrying) the transmitted message is called a signal. [6]

In radio engineering, signals for one purpose or another (telegraph, telephone, television, etc.) are transmitted from sender to receiver using electromagnetic waves. The main goal pursued here is that the received signals are, as far as possible, precisely similar to the sent ones. This is also known as undistorted transmission, and the effect of unavoidable external interference is minimal. In this case, energy considerations are downgraded to the background. [12]

The signal at the output of the message's source is, as a rule, non-electrical: speech, photography, instrument readings. Therefore, a device that converts a non-electrical signal into an electrical one is needed, for example, a microphone. The received electrical signal contains low frequencies, so it cannot be transmitted over long distances without wires, even after amplifying it. One of the reasons is that the size of the antennas must be commensurate with the wavelength. Considering that it is possible to build antennas with dimensions not exceeding hundreds of meters, then waves of several kilometers in length can be used for communication, and their frequency significantly exceeds audio frequencies. [6]

At the same time, vibrations with a frequency of 100 kHz and higher can be radiated quite efficiently. Therefore, high-frequency vibrations are used as a carrier of the message. For this purpose, one or several parameters of high-frequency oscillations: amplitude, frequency, and phase, are changed. This process is called modulation and is done in a device called a modulator. The carrier frequency generator generates the high-frequency oscillation. Depending on the parameter being changed, there are three main types of modulation - amplitude, frequency, and phase. There are also various methods of pulse modulation based on changing the parameters of the pulse sequence. Oscillation from the output of the modulator is fed through the power amplifier to the antenna, through which the electric current is converted into an electromagnetic field radiated into space. The power of the wave supplied to the antenna can range from a few milliwatts to hundreds of kilowatts. [11]

Electromagnetic waves can be divided into the following frequency groups: super long waves, long waves, medium waves, short waves, ultrashort waves, high frequencies, and extremely high frequencies. Due to the ability to bend obstacles and excellent penetrating, ultrashort waves are widely used in broadcasting. On the other hand, this type of electromagnetic wave has the disadvantage of fast attenuation when meeting obstacles. [11]

3.2 Frequency

Depending on the type of radio lines used, there are line-of-sight radio communication systems, tropospheric, ionospheric, space, and radio relay communication systems. Communication lines are classified according to their length, frequency range, and the mechanism of radio wave propagation used. [13]

In terms of length, radio lines are divided into global, long-range, medium-range, and short-range communication lines. Global communication lines allow communication with objects within the globe. Lines with a length of 3,000 to 10,000 km are called long-distance communication lines. Medium-range lines provide communication in the range from 400 km to 3000 km. Short-distance communication lines have a length of 400 to 500 km. [11]

According to the mechanism used for the propagation of radio waves, communication lines can be divided into lines using: the process of bending around the Earth's surface by electromagnetic waves; wave propagation within the line of sight; reflection from the ionosphere; ionospheric scattering; reflection from meteor trails; tropospheric scatter; retransmission through artificial earth satellites (AES). [6]

For VHF voice radiocommunication purposes, space wave type of propagation is used. It is made up of two paths, as shown in figure 3. The first path is a direct wave that travels directly through the air from the transmitter to the receiver. The second path is a reflected wave called reflected wave cause of its reflection from the ground before reaching the antenna. [35]

Starting from VHF, radio waves behave like light. Moreover, just like a beam of light, the radio wave propagates in a line of sight. [35]

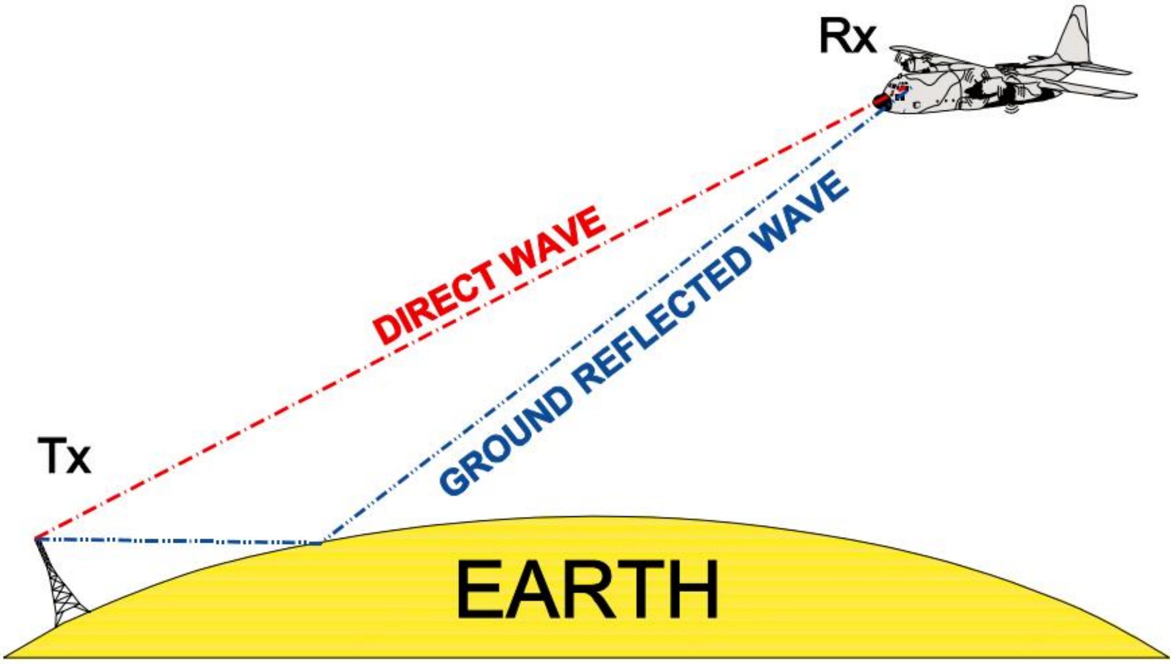

Figure 3- Space wave propagation [35]

3.3 Modulation

Modulation is the process of changing the parameters of a radio frequency oscillation in accordance with a change in the information parameter of the primary signal, also known as a message. [33]

The unmodulated harmonic signal is called the carrier. The energy of the primary signals is concentrated mainly in the low-frequency region; therefore, the spectra of the primary signals are transferred to the high-frequency region by modulating the high-frequency carrier in the transmitter with the primary signal. The average carrier frequency is much larger than the message bandwidth. [5]

In radio communication systems, the transmitted message modulates one or a set of parameters of the high-frequency carrier. The carrier parameters changed during modulation are called informative parameters. The very high-frequency carrier's informative parameter determines the modulation type's name. The number of possible modulation types for a given carrier type is determined by the number of its parameters.

As a carrier, high-frequency harmonic oscillations, pulse sequences, complex composite sequences, etc., are used.[31]

In single-channel radio communication systems, direct modulation of a harmonic carrier by a transmitted message is most often carried out. [5] The signal in such systems has one modulation stage. In this case, three main types of harmonic carrier modulation are possible: amplitude, frequency, and phase. Versions of amplitude modulation are suppressed carrier dual-band modulation and single-sideband modulation. For an angle, two main possibilities exist frequency modulation and phase modulation. [31]

In the modulation process, the spectrum of the primary signal is transferred to a given frequency region, which allows each frequency range allocated for radio communication to orderly place the spectra of signals from various radio communication systems. [11]

3.4 History of spacing

Aeronautical Telecommunication Standards and Recommended Practices were first adopted by the Council on 30 May 1949 in accordance with the provisions of Article 37 of the Convention on International Civil Aviation (Chicago, 1944) as Annex 10 to the Convention. They entered into force on 1 March 1950. The Standards and Recommended Practices were based on the recommendations of the Third Session Division held in January 1949. [34] Up to and including the seventh edition, Appendix 10 was published in one volume, which consisted of four parts with appropriate additions, namely: Part I "Equipment and Systems," Part II "Radio Frequencies," Part III "Regulations," and Part IV "Codes and Abbreviations." [19]

As a result of the adoption of Amendment 42, Part IV was deleted from the Annex; the codes and abbreviations contained in this part have been submitted as a new document (Doc 8400).[25]

On 31 May 1965, due to the adaptation of Amendment 44, the seventh edition of Annex 10 was published in volumes. Volume divided into Part 1 "Equipment and Systems" and Par, t 2 "Radio Frequencies", Volume 2 "Communication Rules". [34]

The channel spacing for voice communications in the air band was originally 200 kHz until 1947, providing 70 channels from 118 to 132 MHz. Some radio stations of that time provided coverage only for a reception at frequencies below 118 MHz, a total of 90 tracks. From 1947 to 1958, the interval became 100 kHz; from 1954, it was again divisible by 50 kHz, and the upper limit was extended to 135.95 MHz (360 channels) and then to 25 kHz in 1972 to accommodate 720 usable channels. On 1 January 1990, frequencies between 136,000 and 136.975 MHz were added, resulting in 760 channels. [19]

In order to reduce the shortage of VHF radio frequencies for ATS in the congested upper levels of airspace in Europe, the September 1994 navigation meeting (EUR RAN, Vienna) recommended the introduction of 8.33 kHz channel spacing.[1]

On 4 November 1996, this plan was approved by the European Organization for the Safety of Air Navigation. From 1 January 1999, in the European region above Flight Level (FL) 245, the aircraft already required 8.33 / 25 kHz - compatible equipment for radiotelephone communication, and from 15 March 2007 - above FL195. The final regulation (Voice Chanell Spacing Regulation) was published in the Official Journal of the European Union (№ 1079/2012 or L320 / 14) on 16 November 2012, as amended in July 2013 (EU) № 657/2013. [20]

3.5 Actual situation with spacing

Worldwide aviation traffic has grown steadily year after year, up to 2020 and COVID-19-related restrictions. Despite various natural and artificial disasters, passenger traffic in the European Union has doubled between 1990 and 2019, as shown in Figure 4.

Along with this growth, the demand for available voice radio frequencies has also increased. Figure 5 shows the available frequencies, and it can be seen that since the 1990s, a shortage of frequencies has been a big problem. The decrease in 2020 and 2021 is caused by a special Block Planning exercise performed for appropriate one mew frequency to the VHF Data Link band.

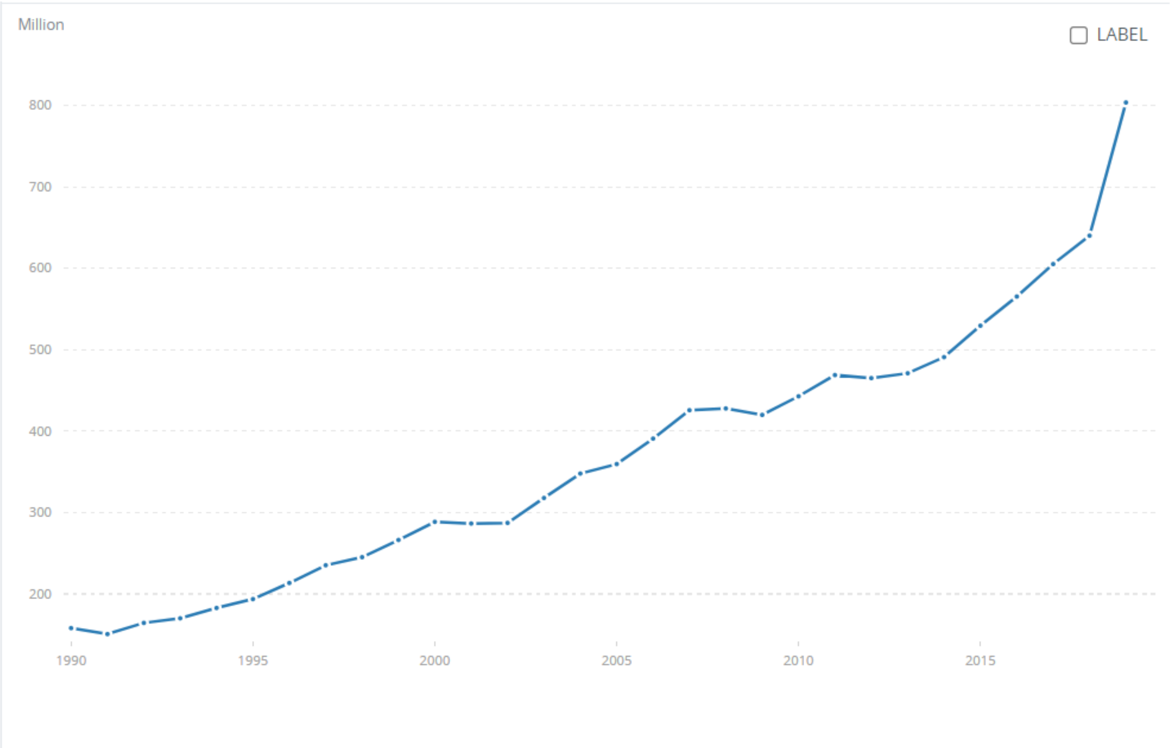

Figure 4- Number of passengers carried by air transport between 1990-2019 in millions [36]

A plan was therefore developed to move to a new voice channel spacing of 8.33kHz. With this step, the number of free frequencies increased, as seen in Figure 1.

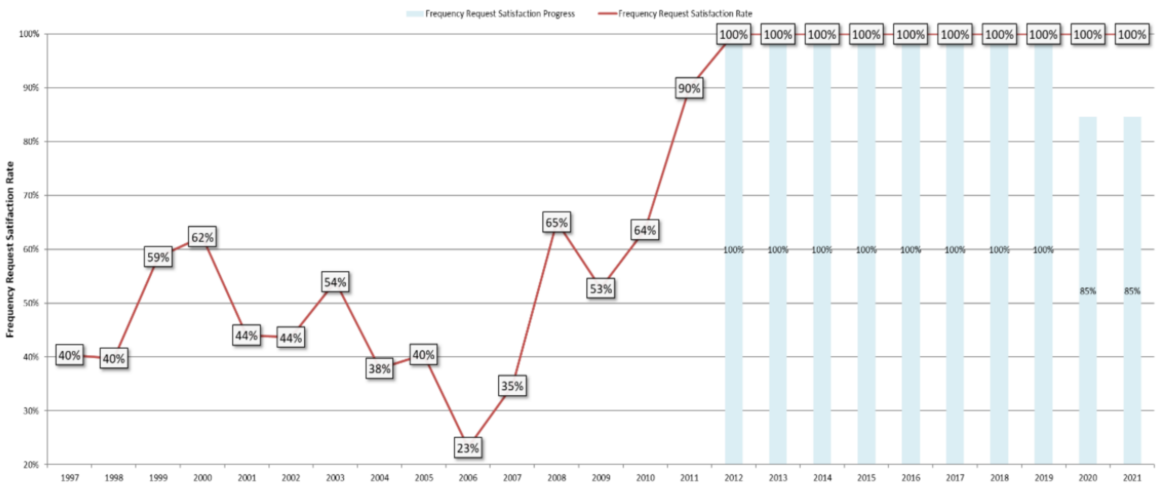

Figure 5- Frequency request satisfaction rate in most congested areas [38]

3.5.2 Frequency Conversions

The introduction of 8.33 kHz channel spacing involves the conversion of existing 25 kHz channels to 8.33 kHz channels. An 8.33 kHz channel has a reduced bandwidth compared to its 25 kHz counterpart. This allows for creating two adjacent 8.33 kHz channels on the so-called "shoulder" frequencies. [1] Graphically illustrated in figure 6

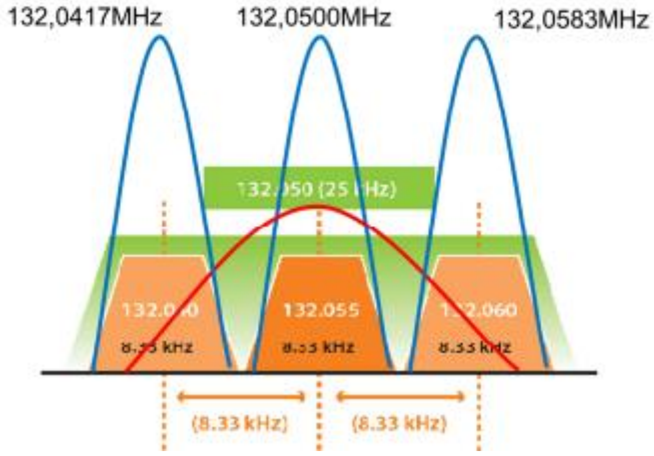

Figure 6- Channel separation [1]

The VHF frequency assignments classified as Area Control Centers (ACC) are mostly used in ACC but also at times to cover en-route ATC sectors. However, some of these assignments are also used for backup frequencies, military frequencies, approaches (APP), and Flight Information Services (FIS). Past studies concluded that if a comparison is made for the demand covered between 2008 and 2012, a linear model can be considered the best assumption for ACC frequency requirements. An analysis of the historical data based on the Network Strategic Tool (NEST) has been performed. This study looked at the number of elementary and operational sectors from 2012 to 2015. It consisted of two Aeronautical Information Regulation and Control (AIRAC) cycles per year. For the frequency demand forecast consolidation, between 2015 and 2019, information regarding the maximum number of sectors with a 25kHz configuration was derived from the information reported by Network Operations Plan (NOP) Service Providers. Three scenarios: high, medium, and low, were developed depending on different strategies for allocating assignments to the new planned sectors. This information is shown in figure 7. Based on expert judgment, the resulting scenarios were adjusted by applying a de-multiplication factor: High – 67% Medium – 75% Low – 50% taking into account the possibility of frequency allocation already in place or re-use of current assignation. [1] The derived values are shown in Table 1.

Table 1–Frequency evolution

Additional Frequency demand trend – baseline 2015	2016	2017	2018	2019
Area 1 High	18	23	26	27
Area 1 medium	14	17	19	20
Area 2 High	25	34	42	51
Area 2 medium	15	20	25	30

The following conclusions can be drawn by looking on a figure 7:

- The growth of the number of frequencies and the number of sectors can be considered linear for more than a decade.

- The analysis shows that the linear growth of ACC frequencies and ACC sectors have almost the same slope in each analysis area.

- the linear growth of ACC frequency assignments cannot continue forever (due to the limited operational dimensions of an ACC sector);[1]

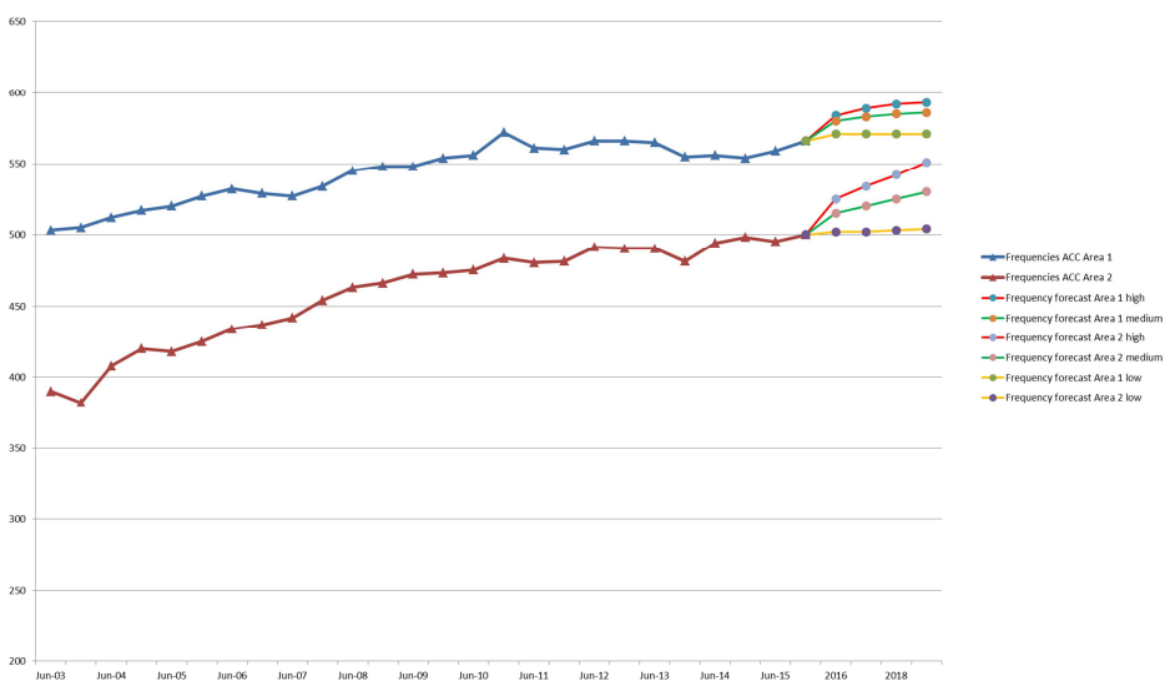

Figure 7 - Area 1 and 2: Frequency evolution between 2003-2015 and forecast scenarios between 2015-2019

3.6 Factors affecting the quality of radio communication

The following factors affect the radio communication quality and propagation:

- Attenuation

Loss of signal strength during movement of radio waves outward from the transmitter. This factor can be caused by two main aspects:

a) The space where a radio wave travels include different particles, such as water vapour, dust and air molecules. These particles absorb the energy of the radio waves. The effect is also known as absorption. Higher the frequency, the higher the effect of absorption.

b) Figure 8 shows the second aspect of an attenuation, called a law of inverse square. The electromagnetic radiation spreads as a sphere surface; this means that with increasing distance from a transmitter, the available power decreases. In other words, the power available is proportional to the inverse of the square of the range. [35]

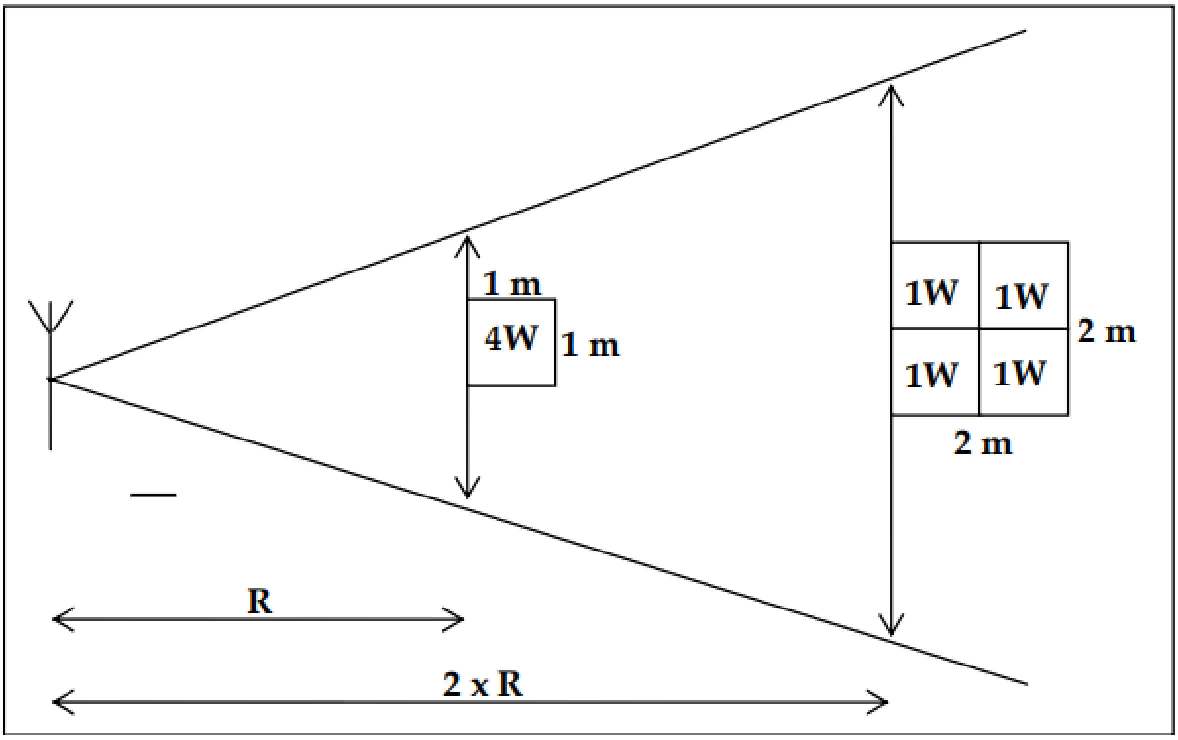

Figure 8- Law of inverse square [35]

- Power

Higher power means a higher range within the limits of the law of inverse square. [35]

- Wavelength

Long waves (LW) are electromagnetic waves longer than 3000 m (oscillation frequency less than 100 kHz). They bend around the Earth's surface comparatively well due to the phenomenon of radio wave diffraction. As the wave lengthens, the energy losses in the soil (water) decrease and the conditions for the reflection of radio waves from the ionosphere improve, which leads to an increase in the range of the radio station. At less than 100 km distance to the radio frequency transmitters, signals propagating along the Earth's surface prevail. At large distances, the signals reflected from the ionosphere play a decisive role. [14]

- Height of "suspension" of antennas (receiving and transmitting)

The area of reliable VHF reception is determined by the line-of-sight distance from the transmitting antenna to the receiving one. Since the Earth's surface is spherical (radius 6370 km), you can use an approximate formula to the determine the maximum range corresponding to the line of sight, shown in equation 1.

Equation 1 – Maximum range

$$D(NM) = 1{,}23 * \left(\sqrt{h1} + \sqrt{h2}\right)$$

where: D - maximum line-of-sight range, h1 and h2 antenna heights [52]

- Terrain

The formula does not consider the terrain and assumes that the antennas are installed on a perfectly smooth surface. In addition, during the propagation of VHF radio waves, diffraction and refraction of radio waves still occur. The area within which it is possible to receive a radio signal confidently can be divided into two zones: line of sight and penumbra. [14]

- Environmental influences (solar activity, season, time of day, etc.)

Thus, we find that the propagation of the VHF radio signal is influenced to a greater extent by the height of the antenna suspension. Therefore, to increase the propagation range of the VHF range in the penumbra region, it is necessary to use highly efficient directional antennas, highly sensitive transceiver equipment, and low-loss cables.

4. Regulations, legislations, and requirements

This chapter will consider the legal and legislative features of radio frequency regulation in aviation. The basic rules, legislation, and requirements for the use of radio frequencies will be disclosed here separately.

4.1 Regulations

According to Eurocontrol, in 2016, the assessments forecasted a 16% growth in flight numbers by 2022. [27] Despite implementing 8.33kHz VCS in the airspace above FL 195 and the halt in flight average annual growth due to the pandemic and other factors, Europe is continuing to experience the effects of a deficiency of voice communication frequencies. The outcomes could be critical: expansion in air traffic delays, failure to execute security upgrades, and loss of adaptability for presenting functional improvements bringing about a compelled European economic development. Broadening the utilisation of 8.33kHz voice channel spacing beneath FL 195 is the main demonstrated approach to meeting the European aeronautical mobile communication frequency needs in the medium to the long haul. To encourage this expansion, the Commission Implementing Regulation (IR) (EU) № 1079/2012 (VCS Regulation) set out the prerequisites for a coordinated presentation of air-ground voice interchanges in light of 8.33kHz channel spacing has been embraced. It applies to all voice correspondence radios working in the aeronautical VHF band, flight information handling frameworks serving general air traffic, and all flights working as broad air traffic. The regulation comprises requirements for interoperability and execution, as well as sending commitments, with pertinent application dates for Air Navigation Service Providers (ANSP), administrators, and different users of radios, for the Member States and the Network Manager.[1] [7]

The transition from channel spacing of 25 kHz to 8.33 kHz when conducting voice communications in the VHF range is intended to increase the number of available frequencies. In addition, this will improve the airspace's operational aspects, particularly its restructuring.

The following countries were the first participants in the 8.33 kHz voice channel spacing below FL195: Bosnia and Herzegovina, The Former Yugoslav Republic of Macedonia, Hungary, Denmark, Ireland, Spain, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, United Kingdom, Federal Republic of Yugoslavia, Finland, Croatia, Czech Republic, Sweden, and Estonia. Effective by 31 October 2002, most of these states will remove their 8.33 kHz channel spacing exemptions in force. [9] Figure 9 depicts the 8.33 kHz conversion rate in Europe Operators who fail to ensure strict compliance with the mandatory equipment and exemption requirements on aircraft may jeopardise flight safety. In the event of such a situation, ATC will ensure that aircraft that are found not to be equipped with 8.33 kHz spacing equipment fly outside the specified channel spacing sectors and take appropriate action on notification of such situations.

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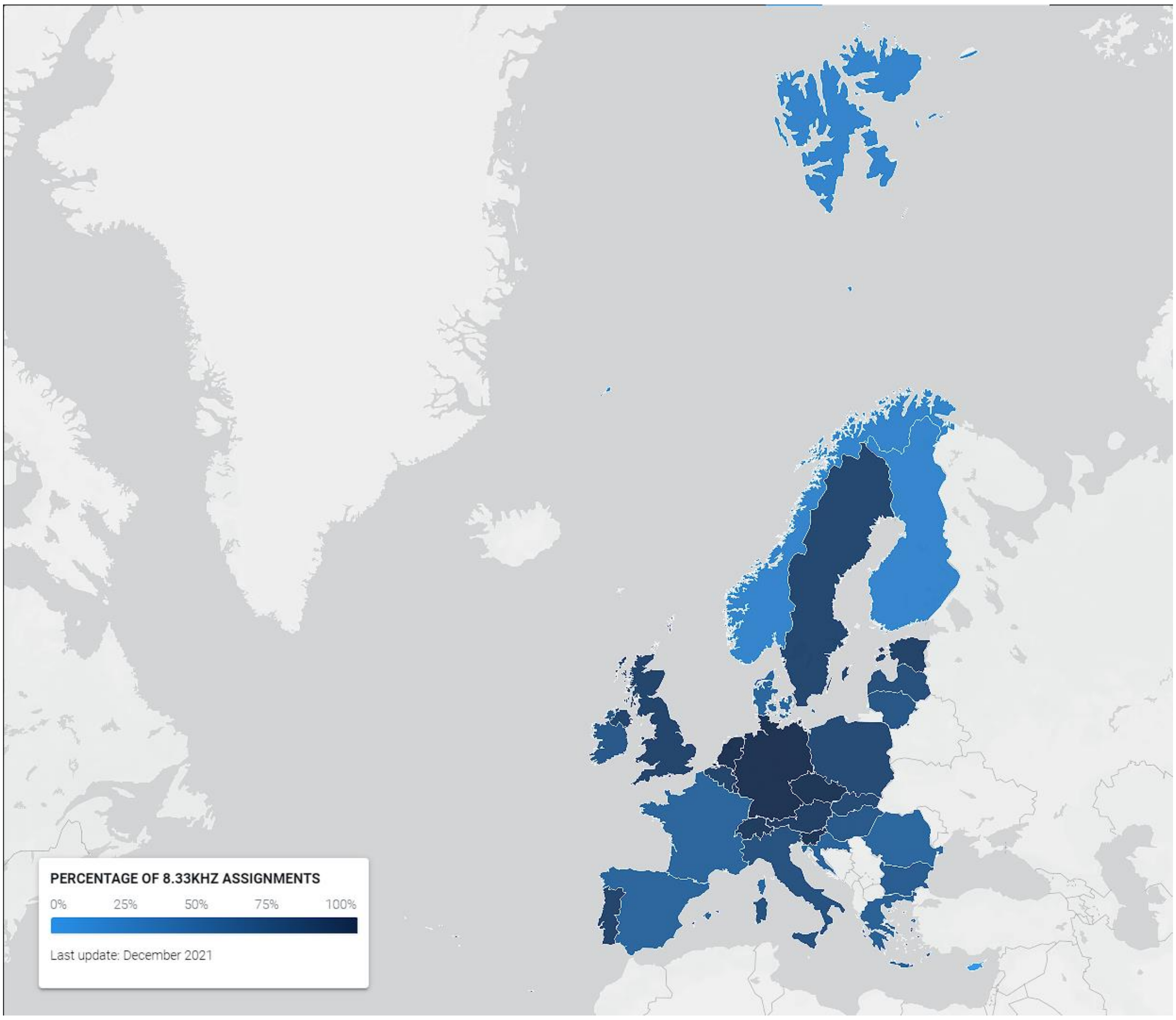

Figure 9 - 8.33 kHz conversion rate [24]

4.2 Legislation

Multiple institutional provisions support the advent of 8.33 kHz VCS in the European airspace and extend its applicability range. These provisions consist of ICAO recommendations, European (Implementing Rule) and national legislation, and agreed with Eurocontrol targets. [2]

It was in 1994 at the Special European Regional Air Navigation meeting (EUR RAN) and in 1995 at the Special Communications / Operations Division meeting (SP COM/OPS/95) that the first decisions and suggestions were made to introduce 8.33 kHz as an answer for VHF congestion inside of the ICAO EUR region. Shortly after, on 7 October 1999, it was made mandatory for aircraft operating above FL245 to carry and operate 8.33 kHz channel spacing capable radio communication equipment in the region. In December 2002, it was decided at EANPG 44 to expand the 8.33 kHz mandatory carriage requirement in the ICAO EUR region in an attempt to progressively lower flight levels (below FL245). ICAO has approved the Amendment to the Regional Supplementary Procedures – Doc 7030/4 EUR/NAT-S 04/10 – EUR RAC/3 [28] to incorporate the mandatory carriage requirement of 8.33 kHz above FL195 within the ICAO EUR region. [14]

In 2005, the European Commission ordered EUROCONTROL to develop a draft enforcing the rule on Air-Ground Voice Channel Spacing to provide an appropriate regulatory framework for the EU deployment of the 8.33 kHz technology. This order included two parts:

- the deployment of 8.33 kHz channel spacing within the airspace above flight level 195. This part was met with the release of the Commission Regulation (EC) No 1265/2007 in the Official Journal of the European Union on 27 October 2007.
- the extension of the deployment of 8.33 kHz channel spacing to the airspace beneath flight level 195

Commission Implementing Regulation (EU) No 1079/2012, amended by Commission Implementing Regulation (EU) No 657/2013 of 10 July 2013, introduces requirements for the coordinated advent of air-ground voice communications based on 8.33kHz channel spacing. It also includes the lower airspace (below FL195) requirements, originally covered in Regulation (EC) No 1265/2007, for the coordinated introduction of air-ground voice communications primarily based on 8.33 kHz channel spacing. [29]

The states inside the ICAO EUR area hold responsibility for their national 8.33 kHz implementations and the amendments of their respective policies. The IR 1079/2012 is relevant to the EU Member States and through global agreements with Norway and

Switzerland; numerous neighbouring states, however, may determine to transpose and consequently apply the VCS Regulation requirements in their personal airspaces. [1]

Airspace users are supplied with improved notification by states via an Aeronautical Information Circular (AIC) publication. The individual states are obligated to amend their National Aeronautical Information Publications (AIP) to reflect the 8.33 kHz carriage requirements, eventual exemptions from equipage, and the guidelines for managing State aircraft (Annex A of this document provides 8.33 kHz associated content for all aeronautical publications).

Due to the deployment of 8.33VCS communications below FL195 requiring stronger local/national coordination, to make sure the achievement of such activities, it was decided by the EC through the EU Member States Single Sky Committee to invite the Member States to appoint a competent person, authority, or corporation as "8.33 VCS National Co-ordinator."

4.3 Requirements

This chapter will consider the legal and legislative features of radio frequency regulation in aviation. The basic rules, legislation, and requirements for the use of radio frequencies will be disclosed here separately, and factors affecting the quality of transmission will be listed.

4.3.1 General requirements

The frequency band 117.975 - 137 MHz is meant specifically for aeronautical radio communication. ICAO EUR Doc 011 sets out planning guidelines that are designed to ensure that each system element is adequately protected from interference from other compliant aeronautical radio services. These rules are based on the assumption that all systems and equipment comply with current standards. [32]

8.33 kHz conversion is defined as the replacement of a frequency assignment registered in the central register and using 25 kHz channel spacing by a frequency assignment with 8.33 kHz channel spacing. The channel spacing for 8.33 kHz channel assignments equals 25 kHz divided by three, which equals 8.333[3] kHz. [30]

During the conversion process, if the frequency of the former 25 kHz assignment is centred in the new 8.33 channel and the Designated Operational Coverage (DOC) stays without change, international coordination is not required. Suppose the new 8.33 channel chosen for conversion is not the former 25 kHz central frequency, or there is a change in the DOC. In that case, international coordination is required to ensure that the new submitted assignment can be used without crossing the existing assignments. A reasonable ground for completing a conversion is when the old frequency in 25 kHz spacing is removed, and the new 8.33 channel is in Assigned or Operational status. [2]

4.3.2 Requirements for ground stations

On a technical level, the ANSPs will have to make sure that the radio equipment on the ground meant to be used for 8.33 kHz channel spacing communications is properly installed and certified before converting the assigned 25k Hz frequency to an 8.33 kHz channel. Furthermore, ANSPs must provide coverage so that all traffic subjects to the air traffic service provided are in the right position to maintain communications in the selected area of responsibility and perform testing to exclude any possible technical issues (e.g., interferences, etc.). [2]

IFR-operated flights within the ICAO EUR Region must include all equipment and capability information in the flight plan. [2]

The aircraft operator is expected to ensure that the information is given in the flight plan (i.e., 8.33 kHz equipage information or the presence of the exemption indicator) is consistent with the aircraft to be used and airspace with the applicability of the GAT 8.33 kHz requirement. Flight Data Processing System (FDPS) is in charge of providing real-time flight information to the air traffic controllers and enabling automated coordination between adjacent air traffic control centres. [2]

4.3.3 Requirements for airborne stations

Based on the 8.33 Regional Implementation Plan, below are listed some requirements for airborne stations. First and foremost, according to onboard avionics, all flights subject to an air traffic service need to be properly equipped and confirm the right positioning of exemption procedures. Also, contingency, and fallback activities should be prepared for communications in case of interferences.[2]

Additionally, early advance notice is set to minimise costs in the case of the aircraft retrofit. With 8.33 kHz capability as an option on all new aircraft, this advancement could benefit the airspace users of the EUR Region. Those general aviation aircraft require a high cost for older generation aircraft retrofit. [2]

Starting 01 January 2018, an aircraft shall not be operated in the airspace where radio carriage is required unless the aircraft radio is equipped with the 8.33 kHz channel spacing. An aircraft cannot operate in a region where 8.33 kHz channel spacing is applied without suitable equipment onboard. This requirement entered effect on 01.01.2018. Member States can take local measures granting exemptions from equipage and frequency assignment conversions for cases resulting from a safety requirement or if the impact on the network is limited. Frequency assignments designated to accommodate non-8.33kHz equipped state aircraft may also be exempted from conversion. [1]

The Implementation Regulation (IR) 965/2012 states the number of radio communication systems required on board and describes conditions that apply depending on the operations and aircraft type.

The VCS Regulation includes such arrangements as regulatory provisions related to 8.33kHz radios State aircraft equipage and measures to ensure the handling of non-equipped State aircraft by the Air Traffic Service (ATS) Providers:

• Transport-type State aircraft operating flights above FL 195 must be equipped with 8.33 kHz channel spacing capable radios.

• When it is impossible to comply with paragraph 1, transport-type State aircraft operating flights above FL 195 shall be equipped with radios with 8.33 kHz channel spacing capability before 31 December 2012.

• Non-transport-type State aircraft operating flights above FL 195 shall be equipped with radios with 8.33 kHz channel spacing capability.

• New State aircraft entering service from 1 January 2014 require equipment with radios having the 8.33 kHz channel spacing capability.

• Since 1 January 2014, whenever the radios installed onboard the State aircraft are upgraded, the new radios have the 8.33 kHz channel spacing capability.

• All State aircraft have been equipped with radios with 8.33 kHz channel spacing capability by 31 December 2018.

Operating as general air traffic with the lack of dual independent 8.33 kHz airborne radios and operating with single VHF and UHF radio configurations can be hazardous when done in areas without UHF coverage and a VHF radio failure occurs (some countries do not have UHF coverage and alternative handling can only be ensured on VHF 25 kHz).

Specific VHF 8.33 kHz equipage aspects such as the required number of independent radio sets for fighters are not yet clearly harmonised at a European level for State aircraft. Some military stakeholders still choose to fill in a flight plan as "8.33 kHz compliant" and not as "Exempted State aircraft." In the last case, they may face operational restrictions dictated by safety limitations. Military operators continue to question the possibility of claiming compliance when a State aircraft is only equipped with one VHF 8.33 kHz radio and one independent UHF transceiver (which could be used as a "backup" where coverage exists).

Flights operated under VFR can be granted temporary derogations from airborne carriage obligations above FL 195 (VCS Regulation Art 14(1)). Also, in cases of limited impact on the network or caused by a safety requirement, aircraft may be granted exemptions from the equipage requirements (VCS Regulation Art 14(2)). State aircraft expected to be withdrawn from operations by 31/12/2025 are not required to be equipped with 8.33 kHz channel spacing capable radios. State aircraft which cannot be equipped in line with the provisions of the VCS regulation due to compelling technical, budgetary, and procurement constraints are also met with specific exemptions. [1]

5. Problems of the transfer

The move to the new 8.33kHz spacing is a huge project, requiring enormous international coordination and regulation. Like any other project, it may contain some shortcomings and ambiguities. This chapter will outline similar problems which may have been encountered by pilots or FIC officers and heads of departments, both during and after the transition to the new VCS.

5.1 Problems during transfer

From the communicative point of view, the original 25 kHz channel will be overlapped by other 8.33 kHz channels. If a receiver with a channel width of 25 kHz is used compared to a transmitter with a channel width of 8.33 kHz, the reception is disturbed by the transmitters of adjacent channels that fall within the channel width of 25 kHz. Conversely, if a transmitter with a channel width of 25 kHz is used compared to receivers with a channel width of 8.33 kHz, this will interfere with the reception of devices operating on adjacent channels. [1]

Organisational problems that could be observed during the transition. For example, installing new equipment in Maastricht and Bordeaux provoked at least 110,000 and 18,000 minutes of delays, respectively.[40]

The activities of the working group have been running since November 2009. The proposed transition plan is specified in the meetings of this group. At its regular meetings, about once every six months, the PSG Group refines and modifies this plan, according to most countries.

The financial side of the problem should also be borne in mind. Certified rags are expensive, and many aviators or even companies cannot afford new equipment and must buy used ones. Table 2 shows the prices in October 2021 of the most common models of radio equipment. Models differ in terms of functionality, power, and other similar characteristics. However, the average price is $1814.6. [41]

Table 2 - Price of the new radio stations in October 2021. [41]

Model	Price ($)
Becker	
AR-6023	1300
AR-6201	1300
RT-6201	1408
Garmin	
GTR200	1199
GTR200B	1395
GTR225	2295
GTR225B	4095
ICOM	
A220	1199

TKM Avionics	
	1828
TRIG Avionics	
TY96A	1865
TY97A	3048
TY91	1100
TY92	2943
Val Avionics	
COM 2000	1285
COM 2KR	949

Of course, channel spacing cannot affect some problems, but those problems still have a big influence on aviation. For example, the human factor is the most common factor that causes 80% of all incidents in aviation.[22] Humans' errors against communication are the following:

- Poor communication skills in consequences, misunderstanding, and high crew workload [23],
- Interference in transmissions, in this case, caused by aircraft not equipped with 8,33 kHz VCS. However, it can also be caused by an incorrectly installed or tuned transmitter or receiver. The data in Figure 10 indicates that in 2018 the number of open interferences increased from three in 2017 to fifteen in 2018. [1] [47]
- incorrect setting of frequency [1],
- a large number of aircrafts in an ATC sector. [1]

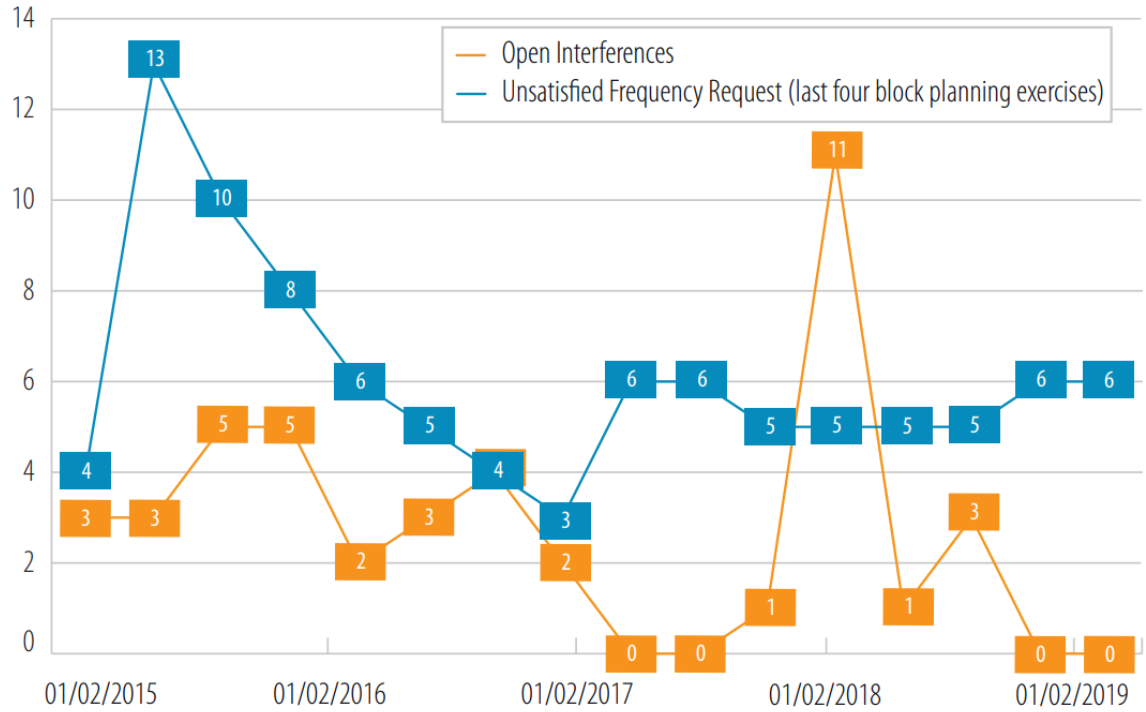

Figure 10 - Evolution of interference cases and unsatisfied frequency demand in the period between 2015 and 2019. [47]

5.2 Problems after transfer

In air communications, a frequency-shifted carrier system, also known as Climax, Offset Carrier, or Multi-carrier System, is often used. This system is used to cover the required area when parts of the area are in the radio shadow due to mountainous terrain or to cover larger sectors. In such cases, it is then necessary to transmit from several locations on the same frequency channel. If 25 kHz channel separation is applied, the transmission frequencies are shifted relative to each other according to Table 3 so that they still fit in the assigned 25 kHz frequency channel. [21]

Table 3 - Transmission frequency offset when using the Climax system. [21]

Offset Carrier	-second offset	-first offset	carrier	+1nd offset	+2st offset
2-carrier system	x	-5kHz	x	+5kHz	x
3-carrier system	x	-7,3kHz	Carrier	+7,3kHz	x
4-carrier system	-7,5kHz	-2,5kHz	X	+2,5kHz	+7,5kHz
5-carrier system	-8kHz	-4kHz	carrier	+4kHz	+8kHz

If it were transmitted simultaneously without a carrier shift, the onboard receiver would degrade or even lose reception due to the phase shifts of the individual signals. A minimum of 2 and a maximum of 5 transmitters are used for ground-to-air transmission at a channel spacing of 25 kHz. If we use a channel spacing of 8.33 kHz, and in this case, we can use a maximum of 2 transmitters for the use of Climax, while the transmission frequencies are shifted from the carrier by +/- 2.5 kHz. [21]

Therefore, if we wanted to apply Climax, for example, in the upper UIR Karlsruhe airspace described above, at 8.33 kHz, a frequency-shifted carrier system could not be used because it would require five transmitters to cover the airspace above FL375 in the Karlsruhe area. In practice, this means that at a channel spacing of 8.33 kHz, we use the Climax in a sector less concept only in a limited smaller space. The second option is to return to 25 kHz channel separation, which can be done relatively easily, as new radio equipment operating with 8.33 kHz channel separation can operate with both 8.33 kHz channel spacing and 25 kHz spacing. It depends purely on the choice of the user. For example, if a user selects a frequency with 25 kHz separation, such as 132,000, such a new device will operate exactly like old devices with 25 kHz channel separation, but if the user selects a channel such as 132.005, the radio will operate in channel separation mode of 8.33 kHz. In most cases, these radios are equipped with a switch that allows users to easily switch between 25 kHz and 8.33 kHz modes. Of course, it is essential that such a device be configured in the correct mode in order to be able to select the desired correct channel or frequency. [3]

Table 4 shows examples of pairing between channels and carrier frequencies for channel separation of 25 kHz and 8.33 kHz. [3]

Table 4 - Channel and frequency pairing examples for 25 kHz and 8.33 kHz channel separation

Old 25kHz radio	New 8.33kHz radio				
	Dial selection			Real Tx/Rx frequency	
Frequency	Dial	25 kHz frequency	8.33kHz Channel	Frequency (Mhz)	Spacing (kHz)
118.000	118.000	118.000		118.0000	25
	118.005		118.005	118.0000	8.33

	118.010		118.010	118.0083	8.33
	118.015		118.015	118.0167	8.33
118.025	118.025	118.025		118.0250	25
	118.030		118.030	118.0250	8.33
	118.035		118.035	118.0333	8.33
Etc					

For the problem of communication in the sector less concept, which, at least in the initial stages, will be implemented only in the upper airspace, means the possibility of using one radio station in 25 kHz and 8.33 kHz channel separation, increasing the chances of using CLIMAX in sector less environment, as in locations where 8.33 kHz channel separation is already commonly used, the use of the Climax concept with 8.33 kHz channel spacing would not be sufficient to cover the area and, thanks to compatible radio stations capable of operating with both 8.33 kHz and 25 kHz channel separation, we were able to return relatively easily, using the current infrastructure, to 25 kHz separation and thus cover larger areas.

Other problems include the need to improve or replace some equipment on the ground. The equipment requires debugging, and sometimes malfunctions and failures can occur. Table 5 contains data on breakdowns of communication systems and time delays in air traffic flow in minutes between 2014 and 2018, i.e. years before and during the transition. The average value of these delays is 3006.5 minutes.

Table 5 - Communication Issues 2014-2018 [42] [43] [44] [45] [46]

Date	Place	Issue	Delay in minutes
20.09.2014	The airspace between Makedonia ACC and Istanbul ACC	Voice communication problems	5889

28.08.2016	Vienna	COM system failure	2523
28.12.2016	London TMA	COM system failure	2845
23.05.2017	Lisbon ACC	COM failures between Lisbon ACC and Santa Maria ACC	2395
27.10.2017	Munich ACC	COM failure	1144
15.11.2017	Langen ACC	COM failure	6464
08.06.2018	Reims ACC	Communication system failures	1088
09.07.2018	Brest ACC	Communication system failures	2099
15.08.2018	Amsterdam	Instability of communication	2047
30.08.2018	Airspace between Karlsruhe and Vienna	Communication system failures	3363
23.09.2018	Maastricht ACC	VCS failure	1232
26.09.2018	Karlsruhe UAC	Communication system failures	1620
18.10.2018	Brussels CANAC	Communication system failures	1319
26.10.2018	Lisbon ACC	Communication system failures	4654

26.10.2018	The airspace between Lisbon and Madrid	Communication system failures	3113
10.04-11.04.2017	Brest ACC	COM system failure	6309
		Total value	48104
		Average Value	3006,5

Table 6 contains similar data for the period between 2019 and 2021. The average value is 3,730.4 minutes, an increase of 19.4%.

Table 6 - Communication issues 2019-2021 [47] [48] [49]

Date	Place	Issue	Delay in minutes
10.04.2019	Shannon ACC	Radio communication failure	1379
21.05.2019	Stockholm ACC	Radio communication failure	4417
24.06.2019	Maastricht ACC	Radio communication failure	2253
20.09.2019	Marseille ACC	Communication issues	2095
01.10.2019	Bordeaux ACC	Radio communication failure	1317
01.10.2019	Brest ACC	Radio communication failure	1852

29.10.2019	Geneva ACC	Radio communication failure	1875
18.02.2020	Lisbon ACC	VCS problem	1972
01.10-31.10.2019	Marseille TMA	Radio communication failure	11660
01-30.09.2021	Santorini	Communication system failures	3169
08-09.10 22-24.10.2021	Palma de Mallorca	Communication system failures	5356
16-16.05.2019	Paris ACC	Radio communication failure	1511
20-21.12.2021	Bremen ACC	Communication system failures	9639
		Total Value	48495
		Average Value	3730,38462

As shown in Figure 9, some Member States are still in the implementation phase of a new VCS, which could be an issue. For example, a pilot with inadequate pre-flight preparation can field a flight plan via 8,33 kHz airspace, and during the flight, this pilot may have to divert unexpectedly. This fact may pose a threat to the safety of aircraft. [1] EUROCONTROL estimates the worst-case scenario effect of this situation at 4 (severe incident). [1]

Even if the above situation is unlikely and most pilots are aware of the changes and requirements, this could lead to increased traffic in Class E or G airspace where establishing two-way radio communications is not mandatory. This problem could result in an increased pilot workload as he will have to spend more time ensuring clearance from other aircraft. In the worst-case scenario, a comparable situation could result in a major incident (3 on the EUROCONTROL scale). [1]

6. Assessment of the actual quality of radiocommunication

This chapter draws on the theoretical background revealed earlier in this thesis and showcased the assessment of the actual quality of radiocommunication as reported by its practitioners.

6.1 Goals of the quality assessment

Collecting and utilising the survey results facilitates a deeper analysis of the transition. Through the prism of assessing reflections of practitioners who constitute frontline users of the transitioned new radio frequency spacing, this chapter aims to uncover insights from their experiences.

Throughout this thesis, several issues regarding the transition to the new radio frequency spacing for general aviation at 8.33 kHz were identified. To maximise the value of current research, a questionnaire that covered issues was developed and circulated. In order to get an independent opinion and uncover further practical insight on the topic under study survey invited multiple groups of respondents, which ranged from private or commercial pilot license holders to flight information service staff.

This questionnaire is focused on identifying radio communication practitioner experiences of the aeronautical mobile service in air-ground communication operations. It also uncovers potential problems associated with the transition to 8.33 kHz channel division and compares the newly utilised system with the original solution. Assessment of survey responses assists this research in exploring the question from the inside. To access the full list of questions, please see Annex A.

6.2 Methodology of the quality assessment

The specificity of this research relies on qualitative methods, in this case – a questionnaire. For the study, a survey was designed for the beneficiaries and potential beneficiaries of radio communication services, which included multiple choice and open-ended questions.

In order to delve deeper into the methodologies of qualitative research, this thesis analyses the works of Disman, Handle, and Rachel to draw on their definitions for the best design of the practical section. Disman views qualitative research as a non-numerical study and interpretation of social reality using inductive logic. Inductive logic implies that first, a social phenomenon is observed, and then data is collected and further analysed. [16] Hendl defines qualitative research as "the process of seeking understanding, based on different methodological traditions of studying a given social or human problem. It creates a comprehensive, holistic picture, analyses different types of texts, informs research participants, and conducts research in natural settings. The main objective of such research is "to clarify how people in a given environment and situation understand what is happening, why they act in a certain way, and how they organise their daily activities and interactions." [17] As Reichel writes in his publication, in qualitative research, the main questions are usually supplemented or changed during the research itself, that is, during the collection of information and its analysis. In other words, it can be said that data collection occurs concurrently with its evaluation. In this situation, the researcher constantly revises his procedure. [18]

For the selection of the research sample for the purposes of this work, the following criteria were established. The respondents should work as employees of aviation companies or study to become pilots and have practical experience of flying. The selected sample of practitioners represents pilots and other professionals associated with implementing radio communications.

An anonymous questionnaire with 21 questions and 2 to 10 multiple choice answers was developed. Only a fraction of the questions had an option for a freeform answer. It was also possible to select several options from the proposed answers (2 or more). The full version of the questionnaire is in the Annex 1.

The survey was created and distributed electronically via a link to the dedicated website https://cns.fd.cvut.cz. After collecting and counting the questionnaires, all data from them was entered into an Excel spreadsheet. It was utilised in analysing inputs and creating a table of individual questions and sections. All the data was visually transformed into several types of graphs and pie charts. The response collection was open for one month.

7. Questionnaire

In this chapter, the received data will be presented based on the answers compiled from the questionnaire. The survey is divided into four main groups of respondents: pilots, FIS employees, aviation technicians, and flight school managers. For each of these categories, different questions were designed with different objectives. For example, based on the answers from pilots or FIS service personnel, it is possible to assess the quality of radio communication based on practice. On the other hand, flight school supervisors/managers can help to understand the problems related to the purchase of radios and the enforcement of new rules applicable to radios. The technicians can give an assessment of the technical part of the new radios, or the differences related to the installation of new equipment. In the end, 30 respondents participated in this survey. The survey includes both multiple-choice and open-ended questions, where respondents needed to elaborate on their own answers. The number of questions also differed for each group, from one (for technicians) to ten or more (for pilots and FIS officials).

The first part of the questions concerned the section on the experience of using radio stations with a frequency of 25 kHz. The second question determined what percentage of respondents had experience using radio stations with a frequency of 25 kHz.

Based on the answer, shown in figure 11, to the question about the experience of using radio stations with a frequency of 25 kHz, 83% of the respondents (or 25 people) answered positively. Five respondents had no experience with 25 kHz radios. 17 out of 30 were student pilots and started flying after implementing the new VCS.

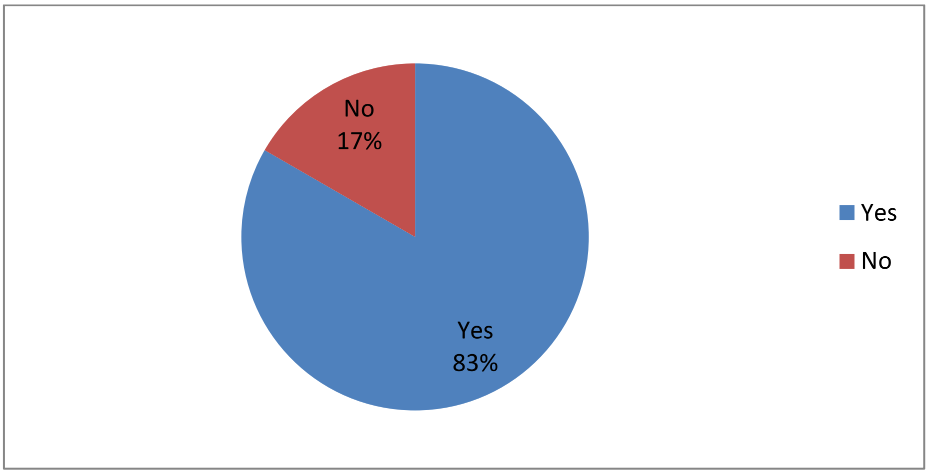

Figure 11 - Do you have any experience with 25 kHz radio stations?

The next question in the questionnaire aimed to determine how often the respondents encountered problems while using radio stations with a frequency of 25 kHz and was aimed at pilots.

Figure 12 shows that only 13% had any problems during their work. The absolute majority (87%) did not have such issues during their practice as a pilot.

Connected to the above eventuality of issues occurring in 13% of practitioners' experiences, the next question posed a crucial question of the frequency of such problems.

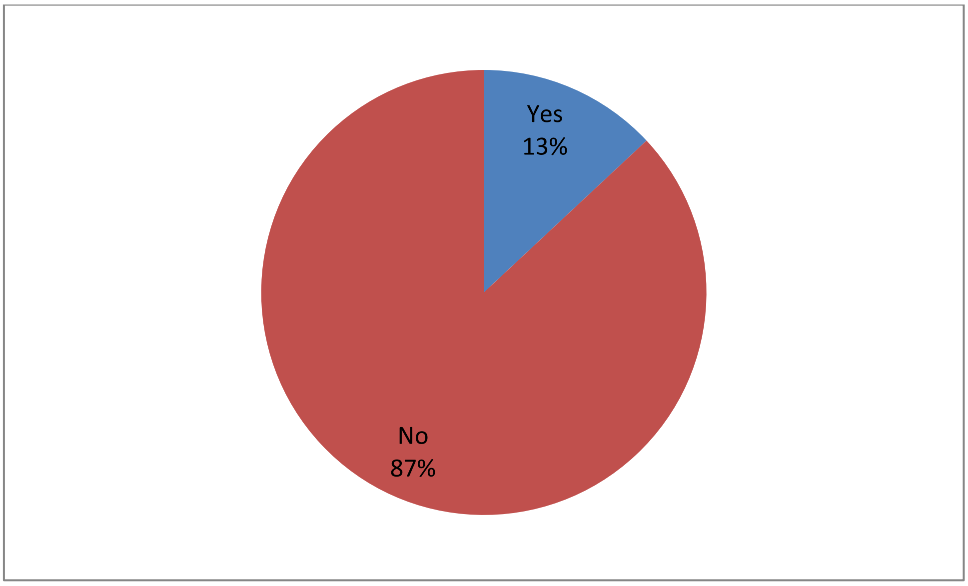

Figure 12 - In your experience, have you had any problems with radios that had a frequency spacing of 25 kHz?

When answering the question, one could indicate 1, which meant that the problems were one-time or extremely rare, and 10, when the problems occurred systematically. Figure 13 shows that the respondents chose answers 2 and 3, which means that, in general, problems with the operation of radio stations are generally quite rare.

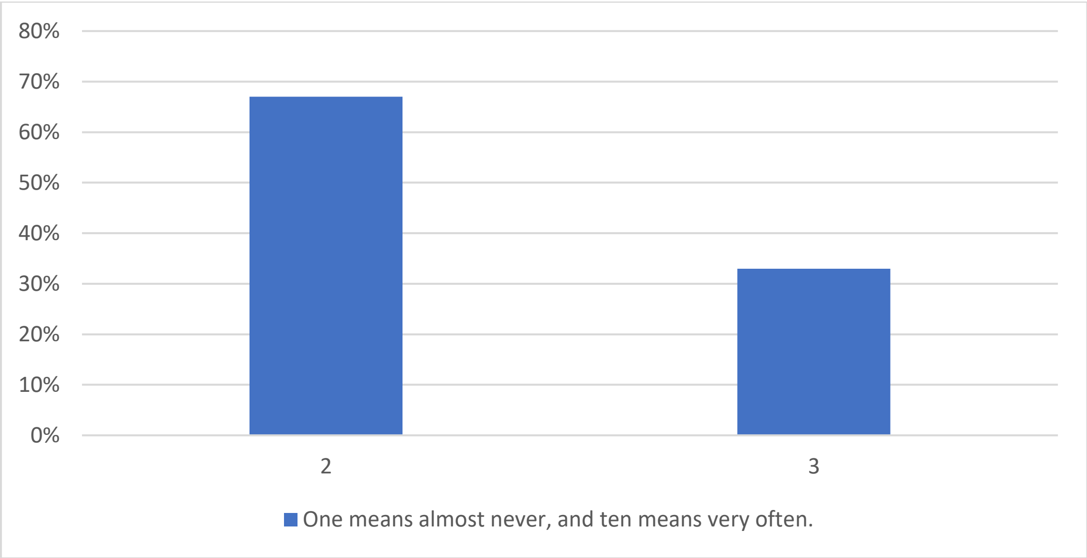

Figure 13 - How often did this event happen? One means almost never, and ten means very often.

In the next part, respondents were interviewed using similar questions but concerning their experience of using the new frequency spacing of 8.33 kHz

Figure 14 contains the answers to the next question. Only 70% of the respondents (21 pilots) answered that they had any experience with new radios. The remaining seven replied that they have not yet used this frequency in their work. The respondents without experience have been eliminated from the survey.

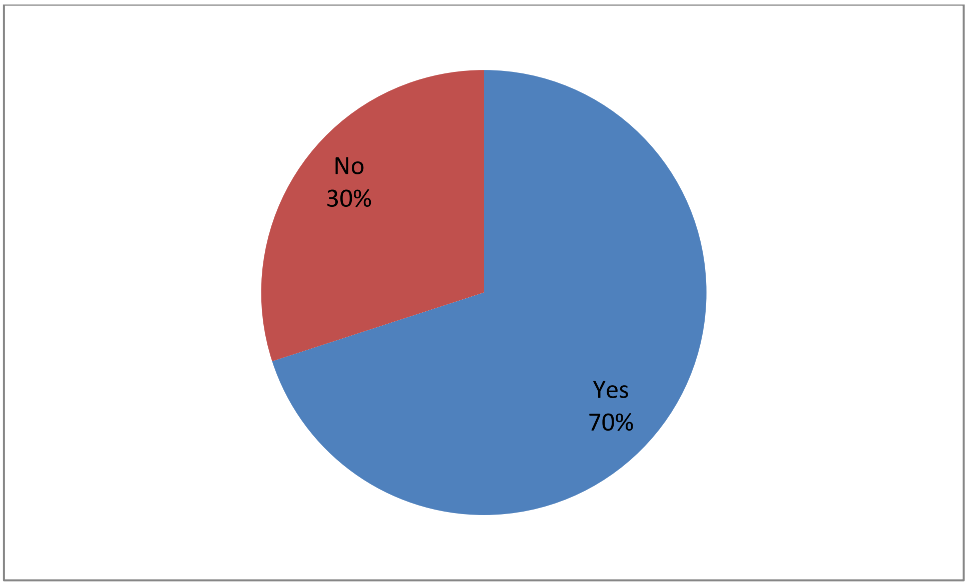

Figure 14 - Do you have any experience with 8.33 kHz radio stations?

The next question aimed to determine how satisfied the pilots were with the new VCS. The answers are very divided, as seen in figure 15: only 33% of respondents are completely satisfied with using the new VCS. At the same time, in general, another 27% are quite enough, which in total amounts to 60% of positive responses regarding the satisfaction of work with a new frequency. Another 20% of respondents indicated that they have a neutral attitude or are not very happy, and 20% are completely unhappy. This indicated that a majority of practitioners are onboard with the frequency and are satisfied with their experience.

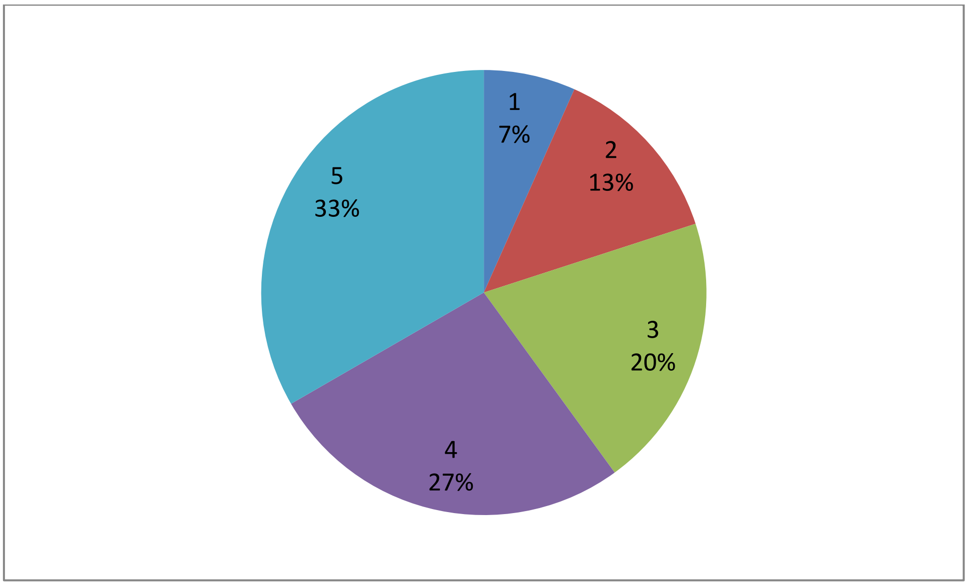

Figure 15 - How satisfied are you with the new frequency spacing? 5- very satisfied, 1- very dissatisfied

The next question was designed to determine whether the respondents had any problems using the 8.33 kHz frequency. Results are shown in figure 16.

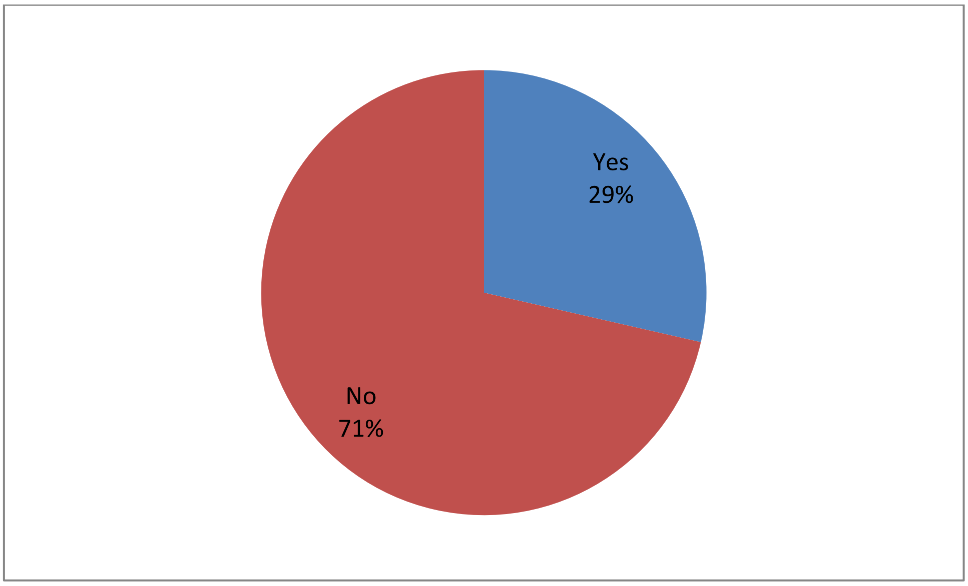

Figure 16 - In your experience, have you had any problems with radios that had a frequency spacing of 8.33 kHz?

Despite the majority of users indicating their satisfaction with the previous question, almost a third of the respondents answered that they had problems with the new VCS.

The next question delves deeper into the field of issues practitioners experienced and sets out to determine what the main problems were. Options were considered during the survey design and presented to respondents as multiple choices.

In figure 17 summarising the answers above, it is evident that the issue of a weak signal was encountered frequently - this option was marked four times. A close second was taken by the loss of connection or its violation - indicated in 3 cases. Furthermore, in two cases, problems with frequency variability were noted.

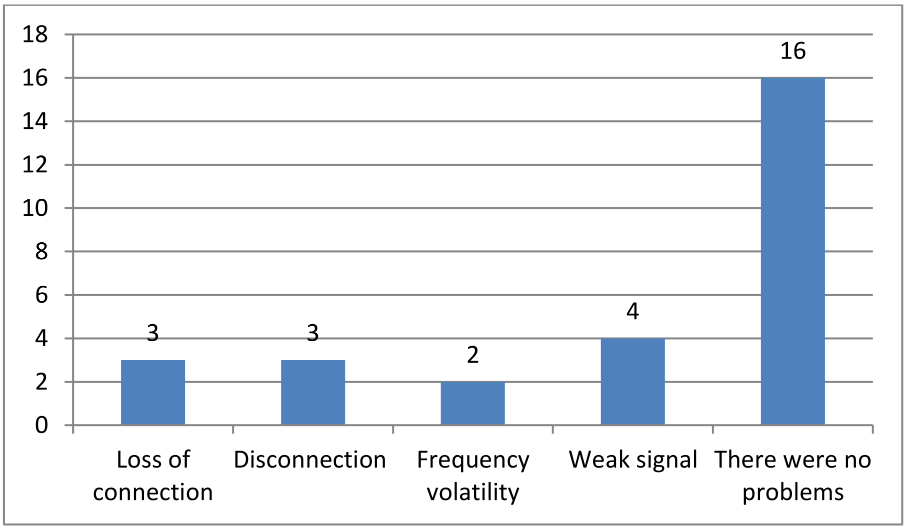

Figure 17 - What specific problem did you encounter (you can choose several options)

Figure 18 explored what pilots believed to be the underlying cause of issues occurring and shows whether the problem originated from the ground service side or the aircraft itself.

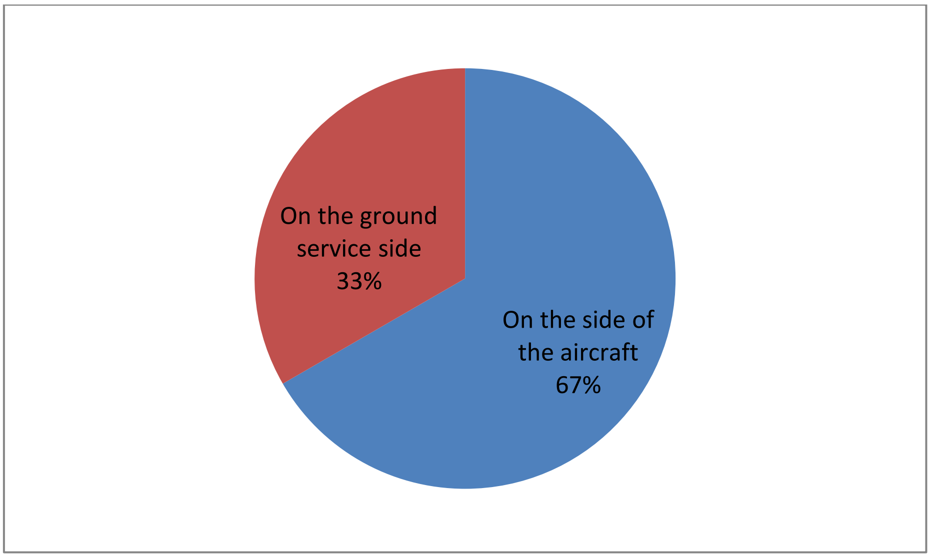

Figure 18 - According to you, was the incident caused by you or the ground service?

It is evident that, in most cases, according to respondents, the problem was with the radio equipment on the aircraft side – as marked by 67% of pilots. However, in roughly every third response practitioner pointed out that the problem was on the side of ground services.

Figure 19 explored how often such problems arose.

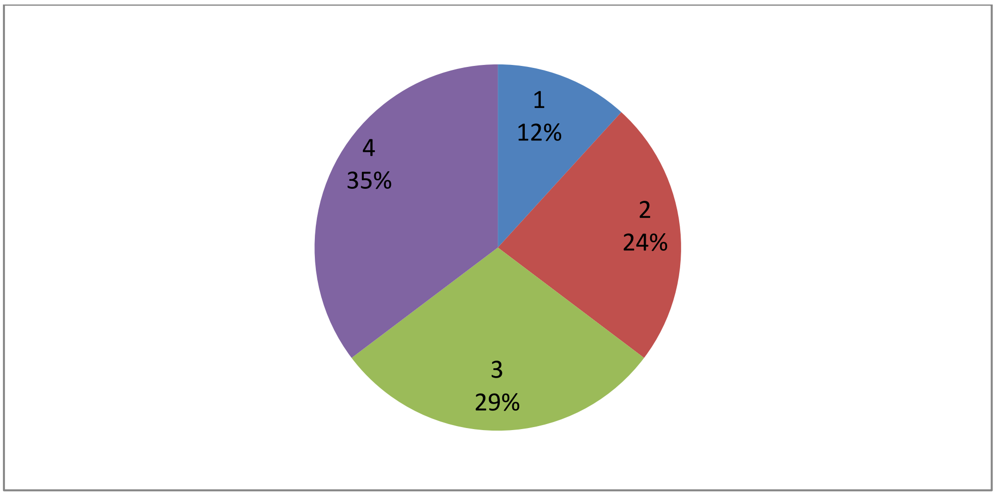

Figure 19 - How often did this event happen? One means rarely, and ten means very usually.

According to the above figure, problems arose moderately infrequently, with 35% of respondents in agreement. In addition to this quantitative data, an open-ended question was posed on which scenarios the problems occurred. Some of the answers pointed to the mountainous terrain, bad weather and even airspaces of certain countries.

When answering the question about what problems arose when using new radio stations, the majority answered that there were no problems as such since their functionality is the same as that of radio stations with a frequency of 8.33 kHz. At the same time, two people indicated that it was not always possible to access the frequency, and with the slightest error, the signal was lost or became very weak.

The following figure 20 indicates which problems were the most dominant in the transition to the new radio as a new way of working. Respondents could choose from three major areas that prevented a comfortable, trouble-free transition: financial (the cost of refitting equipment) and legislative (uncertainty in requirements).

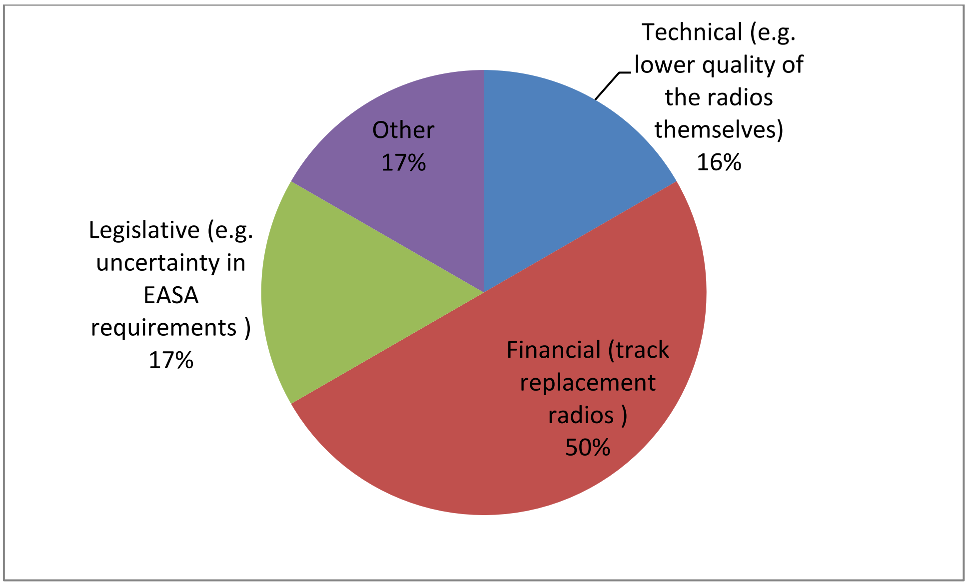

Figure 20 - Which aspects cause the most trouble? (you can choose several options)

The majority of respondents were preoccupied with the high cost of replacing equipment - 50% of the answers. Legal and technical problems were also classified as problems - 17% each. Another 17% also referred to other problems (such as cooperation with state departments etc.).

When asked how the respondents assessed innovations in radio stations, the majority indicated that they noticed largely positive changes as previously the signal was often busy. It was not possible to resolve issues with ground services quickly. At the same time, many pointed to problems with these innovations: weak signal coverage, not all countries supporting this radio signal, both 8.33 kHz and 25 kHz frequencies being in operation. Additional inconveniences were experienced in the process of re-equipment for both aircraft and ground services, which caused frequent misunderstandings.

8. Conclusion

This bachelor thesis analysed the quality of radio communications in general aviation. The work focused on identifying problems associated with implementation of the new frequency spacing. It also proposes possible solutions to the problems identified.

In developing this thesis, certain limitations were identified, which, to a certain extent, influenced the quality of the achieved goals. First and foremost, the small number of respondents and their status. It must be noted that almost all 30 respondents to the survey happened to be pilots, which narrows the overall picture showing only one of many sides faced by aviation practitioners. Perhaps, the results were also affected by the general reluctance of people to participate in the survey, despite its anonymity. Additionally, the relative novelty of the introduced innovations and probably the lack of experience of the respondents with the new radio stations also had some impact.

Despite the limitations mentioned above, the necessary goals were achieved. The most significant problem is the following: respondents largely noted an improvement in communication quality. A substantial 71% have not experienced any issues utilising the new radios, and out of those who did face issues, the majority cited them as infrequent and mainly due to the aircraft's own fault as opposed to pinning those down on ground services. The most sizeable holistic issue uncovered by the survey was the cost of updating equipment to meet the new standards and clarifying the European and country-level standards.

When comparing the new spacing (8.33 kHz) use to the outgoing one (25 kHz), 87% of the respondents said there were no issues with 25 kHz at any time. While reflecting on the same question for 8.33 kHz, as many as 30% indicated that it had certain problems. Nonetheless, the discrepancy can be attributed to the transitional period and so-called "teething issues".

Among other negative points when using the 8.33 kHz frequency, the dilemma with the high cost of replacing the equipment was quite often indicated. As a recommendation, it is worth offering to start funding. An example of this would be the British Aviation Authority announced in the summer of 2016 that it received 2.65 million Euros from EASA to equip British aircrafts with new radios with a frequency grid of 8.33 kHz. [50] A less successful example of the rollout of the similar initiative is the AOPA’s (Aircraft Owner and Pilot Associations) effort to fully or partially cover aircraft owners' costs caused by this transition which did not achieve optimal results and eventually was shutdown. [51] Additional issues were attributed to legal and technical difficulties. In general, the respondents were positive about the transition.

The review of the literature also shows a general increase in the timing of introduction and a lack of harmonisation of civil aviation departments at the international level. Consequently, it would be worthwhile in the future to establish more international links within individual regions. This step could qualitatively improve the speed and overall result of implementation as well as reduce the potential negative impacts of change.

In the future, this work could delve deeper into assessing transition’s impact on safety. Using the principles of the Safety Management System as well as Annex 19. Using this work, a better method of overcoming these problems for pilots and controllers could be created. [54] [55]

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Annex 1: Full version of the questionnaire

Page 1

V jaké roli v současné době působíte? *

- Pilot CPL
- Pilot PPL
- Provozovatel
- Technik
- Dispečer

Další

Page 2

Máte nějaké zkušenosti s radiostanicemi s rozestupem 25kHz? *

- Ano
- Ne

Previous Další

Page 3

Měli jste ve své zkušenosti nějaké problémy s radiostanicemi, která měli kmitočtový rozestup 25kHz? *

- Ano
- Ne

Previous Další

Page 4

S jakým druhem radiostanic? (můžete si vybrat několik možností)

- Dittel Avionik KRT2
- TRIG TY91
- Garmin GTR 225a
- Becker AR6201
- Other

S jakým konkrétním problémem jste se setkali (můžete si vybrat několik možností)? *

- [ ] Ztráta spojení
- [ ] Rušení spojení
- [ ] Nestálost frekvence
- [ ] Nefunkční radiostanice
- [ ] Slabé vysílaní
- [ ] Nízká kvalita spojení
- [ ] Other

Jakým způsobem jste vyřešili tuto situaci? *

- [ ] Náhodně, bez pozemní přípravy
- [ ] Pozemní příprava
- [ ] Problém se vyřešil sám
- [ ] Jiným způsobem

Podle Vás byl ten incident způsoben z Vaši strany nebo ze strany pozemní služby *

- [ ] Na straně letadla
- [ ] Na straně pozemní služby

Jak často se tato událost stávala? 1 znamená skoro nikdy, 10 znamená hodně často *

1 2 3 4 5 6 7 8 9 10

V jaké lokalitě jste se nacházeli? Uveďte přibližnou polohu letadla *

Previous Další

Page 5

Máte nějaké zkušenosti s radiostanicemi s rozestupem 8,33kHz? *

- [ ] Ano
- [ ] Ne

Previous Další

Page 6

Měli jste ve své zkušenosti nějaké problémy s radiostanicemi, která měli kmitočtový rozestup 8,33kHz? *

- [ ] Ano
- [ ] Ne

Jak jste spokojený s novým frekvenčním rozestupem? 5- velmi spokojen, 1- velmi nespokojen

1 2 3 4 5

Previous Další

Page 7

S jakým druhem radiostanic? (můžete si vybrat několik možností)

- Dittel Avionik KRT2
- TRIG TY91
- Garmin GTR 225a
- Becker AR6201
- Other

S jakým konkrétním problémem jste se setkali (můžete si vybrat několik možností) *

- Ztráta spojení
- Rušení spojení
- Nestálost frekvence
- Nefunkční radiostanice
- Slabé vysílaní
- Nízká kvalita spojení
- Other

Jakým způsobem jste vyřešili tuto situaci

- Náhodně, bez pozemní přípravy
- Pozemní příprava
- Problém se vyřešil sám
- Other

Podle Vás byl ten incident způsoben z Vaši strany nebo ze strany pozemní služby *

- Na straně letadla
- Na straně pozemní služby

Jak často se tato událost stávala? 1 znamená skoro nikdy, 10 znamená hodně často *

1 2 3 4 5 6 7 8 9 10

V jaké lokalitě jste se nacházeli? *

Jakou podporu byste potřeboval(-a) pří řešení zmíněných problémů? *

Previous Další

Page 8

S jakými potížemi se setkáváte při používání nových radiostanic(Například, během prvních měsíců jste se set... (ID 38)

Které aspekty způsobují největší potíže? (můžete si vybrat několik možností) *

- Technické (např. nižší kvalita samotných radiostanic)
- Finanční (dráha výměna radiostanic)
- Legislativní (např. neurčitostí v požadavcích EASA)
- Other

Jakou podporu byste potřeboval(-a) při řešení zmíněných problémů? *

Previous Odeslat

Page 9

Jak vnímáte nové radiostanice? Z technického pohledů, jaký změny přinesly dané radiostanice. *

Page 10

Máte nějaké zkušenosti s radiostanicemi s rozestupem 25kHz? *

- Ano
- Ne

Previous Next

Page 11

Měli jste ve své zkušenosti nějaké problémy s radiostanicemi, která měli kmitočtový rozestup 25kHz? *

- Ano
- Ne

Previous Next

Page 12

S jakým druhem radiostanic? (můžete si vybrat několik možností)

- ☐ Dittel Avionik KRT2
- ☐ TRIG TY91
- ☐ Garmin GTR 225a
- ☐ Becker AR6201
- ☐ Other

S jakým konkrétním problémem jste se setkali (můžete si vybrat několik možností) *

- ☐ Ztráta spojení
- ☐ Rušení spojení
- ☐ Nestálost frekvence
- ☐ Nefunkční radiostanice
- ☐ Slabé vysílaní
- ☐ Nízká kvalita spojení
- ☐ Other

Jakým způsobem jste vyřešili tuto situaci

- ☐ Náhodně, bez přípravy
- ☐ Byl jsem připraven předchozím výcvikem
- ☐ Problém se vyřešil sám
- ☐ Other

Podle Vás byl ten incident způsoben z Vaši strany nebo ze strany pozemní služby *

- ☐ Na straně letadla
- ☐ Na straně pozemní služby

Jak často se tato událost stávala? 1 znamená skoro nikdy, 10 znamená hodně často *

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

V jaké lokalitě jste se nacházeli? Uveďte přibližnou polohu. *

Previous Next

Page 13

Máte nějaké zkušenosti s radiostanicemi s rozestupem 8,33kHz? *

- [ ] Ano
- [ ] Ne

Previous | Další | (ID 71)

Page 14

Měli jste ve své zkušenosti nějaké problémy s radiostanicemi, která měli kmitočtový rozestup 8,33kHz? *

- [ ] Ano
- [ ] Ne

Jak jste spokojený s novým frekvenčním rozestupem? 5- velmi spokojen, 1- velmi nespokojen

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Page 15

S jakým druhem radiostanic? (můžete si vybrat několik možností)

- [ ] Dittel Avionik KRT2
- [ ] TRIG TY91
- [ ] Garmin GTR 225a
- [ ] Becker AR6201
- [ ] Other

S jakým konkrétním problémem jste se setkali (můžete si vybrat několik možností)? *

- [ ] Ztráta spojení
- [ ] Rušení spojení
- [ ] Nestálost frekvence
- [ ] Nefunkční radiostanice
- [ ] Slabé vysílaní
- [ ] Nízká kvalita spojení
- [ ] Other

Jakým způsobem jste vyřešili tuto situaci?

- [ ] Náhodně, bez přípravy
- [ ] Byl jsem připraven předchozím výcvikem
- [ ] Problém se vyřešil sám
- [ ] Other

Podle Vás byl ten incident způsoben z Vaši strany nebo ze strany pozemní služby * (ID 79)

- [ ] Na straně letadla
- [ ] Na straně pozemní služby

Jak často se tato událost stávala? 1 znamená skoro nikdy, 10 znamená hodně často *

1 2 3 4 5 6 7 8 9 10

V jaké lokalitě jste se nacházeli? Uveďte přibližnou polohu. *

Jakou podporu byste potřeboval(-a) pří řešení zmíněných problémů? *

Odeslat