THE BATTLE OF THE BANDS

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Abstract

Exclusive and globally allocated radio spectrum is essential for safe and efficient air travel. This paper will focus on the impact of changes in both U.S. and international radio spectrum policy, describe the issues these changes have raised for the aeronautical community, and examine a few proposed solutions.

First, the paper will put the Federal Aviation Administration in the context of the test and evaluation community. Common frequency usage will be examined and the major interactions between the Federal Aviation Administration, Department of Defense, and commercial sector test and evaluation activities.

The paper will provide a review of several U.S. spectrum policies from the early-to-mid 90's which set the stage for the current domestic spectrum policy debates. For example, spectrum auctioning was formally established in the Omnibus Budget Reconciliation Act of 1993 and further expanded in the Balanced Budget Act of 1997. Both of these Acts directed the transfer of radio spectrum that was allocated solely for Federal Government use to the private sector. These reallocations also set the stage for more recent domestic spectrum policy debates, such as that over ultrawideband devices, broadband service over powerline carrier, third generation wireless, and other new technologies that claim the ability to "share" radio spectrum with other existing users.

The paper will also review international spectrum policy changes that were made within the International Telecommunication Union and their impact on aeronautical radio spectrum. These include reallocation of aeronautical radio spectrum for uses such as wireless local area networks and fixed satellite links.

Yet another cause of reduction in the amount of aeronautical radio spectrum will be reviewed…that is, the increase in aeronautical requirements with no attendant increase in the overall aeronautical radio spectrum available. These increasing requirements include such critical spectrum needs as Global Navigation Satellite System modernization, growing applications which use very high frequency (VHF) air/ground radio spectrum, new automatic dependent surveillance-broadcast services, increased aeronautical telemetry needs, and use of unmanned aerial vehicles in the national airspace. This growth has resulted in increasing spectrum congestion in bands that support critical safety services for international civil aviation.

Finally, the paper will consider potential solutions to the shortage of aeronautical radio spectrum. These solutions include use of new advanced technologies, "splitting" the current channelization, and changes in radio regulations and frequency engineering criteria. Examples of what the Federal Aviation Administration is doing to implement these solutions will also be briefly addressed.

Overview

The United States, like many other countries, has "discovered" something that radio spectrum engineers have known for quite some time. That is, that the radio spectrum is a scarce commodity; that the radio spectrum is valuable; and that there is not any more of it being made. As in any economic system where the law of supply and demand holds, this allows the radio spectrum to be considered a resource, just like oil or minerals, and demands that it be used for the public welfare. While countries have reacted to this issue differently, the United States provides one model for how to utilize the radio spectrum, and has lead to a true "battle of the frequency bands".

It is interesting to review why the U.S. Federal Aviation Administration cares about this highly contentious radio spectrum debate; some of the history on how the United States got where it is today; and why it is so important to work within the international community – especially within the international civil aviation community – to ensure that the future needs of test and evaluation spectrum requirements in general, and civil aviation spectrum requirements in particular, are satisfied. We have many common interests.

Federal Aviation Administration's Interest in the Radio Spectrum

In the United States, the Federal Aviation Administration is the second largest Federal Government user of radio spectrum…after the Department of Defense…therefore, we are a major stakeholder in the spectrum policy debate. This shouldn't be a surprise, because civil aviation provides tremendous social, cultural, and economic benefits to the country. For example, one study (Ref 1, page 6) concluded that civil aviation has over a $900 billion impact on the United States economy in 2000.

It's also clear that civil aviation cannot do its job without liberal access to the radio spectrum. Understanding this, the International Telecommunication Union over the years has provided aviation with exclusive and global radio spectrum allocations so that we can provide communications, navigation, and surveillance services to our user community. I cannot over-emphasize the importance of two words here…"exclusive" and "global". It is very difficult to share radio frequencies between civil aviation users…who require high degrees of integrity and reliability to meet stringent requirements…and non-aviation users. There are many reasons for that. First, equipment built to such stringent requirements is expensive and there are few other users who want the expense or strict standards development activities that are integral elements of developing new civil aviation systems. Second, the mobile nature of aviation requires that aeronautical spectrum be available for use anywhere an airplane might fly. Allowing other users access to the aeronautical radio spectrum would limit aviation users. Finally, civil aviation is global. An aircraft taking off from Washington Dulles airport on a flight to Dakar, Senegal, cannot afford to carry two different communications systems for use at each airport. That's why the International Civil Aviation Organization plays such a central role in providing global interoperability for the aviation community.

It goes without saying that civil aviation must keep close ties with many others in the aviation community also. In the United States, about 15% of the air traffic is military and we consider it to be one of our most important users. In fact, in time of war, the Federal Aviation Administration becomes part of the Department of Defense. It is essential that the military be allowed to train and exercise to keep their combat skills honed. The Federal Aviation Administration plays a key role in making this happen. For example, under Steve Zaidman's leadership, the Air Traffic Control Spectrum Engineering Services Office is the focal point for military electronic jamming exercises including those which impact the Global Positioning System. Although the Federal Aviation Administration must often restrict such training to certain times of the day and sometimes limit their duration, we are proud to have a 100% success record in allowing such military training to proceed. The Federal Aviation Administration has a long history of doing whatever it takes to make sure our military forces are able to "train like they fight" as they sharpen their combat effectiveness.

Civil aviation also requires close ties to the test and evaluation community. New civil aviation systems are necessarily tested using the same frequencies they would use in actual operation. Therefore, in the case of development of new aeronautical systems, the Federal Aviation Administration plays a key role in providing radio spectrum in which to perform this testing and evaluation…and in some cases, is itself the test and evaluation agency.

In the United States, we are also closely aligned with the Aeronautical Flight Test Radio Coordinating Council that advocates and manages aeronautical flight test radio spectrum in the United States. While in the past, the Federal Aviation Administration has mainly served as simply an advocate for aeronautical telemetry spectrum, several recent decisions have demanded that we get more involved. Just one area which provides an opportunity for mutual support and cooperative efforts between civil aviation and the test and evaluation communities are two agenda items for the 2007 World Radiocommunication Conference. One of these agenda items will review the need for additional aeronautical telemetry radio spectrum and the other will study the future requirements for the aeronautical mobile communications safety services.

Spectrum Policy Decisions

If you had to point to one event that began the spectrum policy debate in the United States, it would probably be the Omnibus Budget Reconciliation Act of 1993 (Ref 2). You may remember what was happening in the United States at that time. There were large Federal budget deficits requiring significant cuts in Federal Government programs, while initiatives were being proposed to raise tax revenues in new ways. One proposal that offered an innovative revenue source was the auctioning of radio spectrum. The Omnibus Budget Reconciliation Act of 1993 was Congressional direction for the Federal Government to identify at least 200 MHz of Federal Government radio spectrum and transfer it to the private sector. This legislation was to, "benefit the public by promoting the development of new telecommunications technologies, products, and services that use the spectrum" (Ref 2, Executive Summary). But first, a little background…

In the United States, we have two radio regulatory authorities and each of these has their own version of the radio spectrum allocation table. The Federal Communications Commission is responsible for addressing the radio spectrum requirements of the private sector while the Department of Commerce's National Telecommunications and Information Administration is responsible for administering the Federal Government use of radio spectrum, although the National Telecommunications and Information Administration does have some responsibilities towards the private sector also.

Both the Federal Communications Commission and the National Telecommunications and Information Administration have their own allocation tables. These two allocation tables are very similar because most radio spectrum is shared between the private sector and Federal Government. It was from the small percentage that is allocated solely for Federal Government use that the Federal Government had to find the 200 MHz to transfer to the private sector.

The Federal Aviation Administration faired reasonably well in this legislative debate. Federal Aviation Administration arguments that spectrum supporting safety-related services and that spectrum identified for global civil aviation (often subject to international treaty agreements) should be exempted from transfer were largely accepted. The Federal Aviation Administration did, however, spend approximately $30 million; modifying radars and changing frequencies on radio communications links; to transfer this non-safety spectrum to the private sector (Ref 3). The aeronautical telemetry bands, especially for military telemetry, were reduced both by the Omnibus Budget Reconciliation Act of 1993 and the subsequent Balanced Budget Act of 1997, which directed that an additional 20 MHz of Federal Government radio spectrum and 100 MHz of private sector spectrum be identified for auctioning (Ref 4). Spectrum auctioning receipts were, "estimated netting $36.1 billion over a 5 year period" (Ref 4, page 1-1). This legislation also addressed reimbursement of relocation costs by the private sector to Federal Government users who were affected.

But the real impact of this legislation was to develop a framework for auctioning radio spectrum to the highest bidder and to create an environment wherein existing users may be vulnerable to radio frequency interference from new technologies, because of increased "sharing" of the radio spectrum. In recent years, this has lead to increased sharing of radio spectrum with initiatives such as broadband carrier over powerline, approval of ultrawideband technology, and other largely consumer-oriented and unlicensed use of the radio spectrum. Along with this, an atmosphere has developed where the burden of proof has shifted from the new user proving compatibility with existing spectrum usage; to a requirement of current users having to demonstrate that the new user will cause harmful interference.

International Spectrum Policy

At the international level, mostly by changes in the table of global spectrum allocations by the International Telecommunication Union, both international civil aviation and aeronautical telemetry spectrum have been lost or forced into additional sharing arrangements with other users. For example, at the 1997 World Radiocommunication Conference, the aeronautical radionavigation allocation from 5150-5250 MHz was proposed (and later adopted) for use by the fixed satellite service. At a later Conference, mobile services were added to this allocation to support wireless local area networks. These additional sharing arrangements have resulted in this former aeronautical radio spectrum not being suitable to support future aeronautical safety services. A similar fate likely awaits the aeronautical radionavigation spectrum from 5090-5150 MHz if civil aviation doesn't make use of this band soon. In recent years, civil aviation has also lost exclusive use of radio spectrum that had been reserved for aeronautical satellite safety communications and has accepted increased sharing of its radar frequency bands.

Due to the explosion of new telecommunications technologies, many proposed new services must be accommodated in radio spectrum that is already used, in some cases heavily used. Because of this, there are a variety of new technologies that claim that they can operate in the same frequency bands as existing systems, but without interfering with these existing services. At least one of these technologies, called ultrawideband technology, in some cases operates across wide swaths of radio spectrum. This results in low power unlicensed devices being allowed to use radio spectrum that was formerly designated as "restricted" from extraneous transmissions. Many of these restricted bands are used for aeronautical safety communications, navigation, and surveillance systems.

In general, civil aviation has been a solid supporter of new technologies…in many cases adapting them for civil aviation applications. However, many of these new technologies are primarily directed at the consumer market with the attendant lack of operating standards and emphasizing a focus on low cost.

Reduction in Spectrum Capacity

Actual loss of radio spectrum and "encroachment" of consumer devices to radio spectrum are not the only threats, however. Spectrum capacity can also be lost because of increased spectrum usage. This situation is especially insidious for civil aviation because it is increasingly difficult to expect to obtain additional global, exclusive allocations for any radio service. That forces civil aviation to become increasingly spectrum efficient so that we can continue to operate within our existing allocations…even as growth in air traffic continues unabated.

There are many examples of this situation. The 108-118 MHz aeronautical radionavigation band supports several civil aviation systems, including very high frequency (VHF) omniranges and instrument landing systems. New systems being implemented in this band include ground based augmentation systems to supplement the Global Navigation Satellite System as well as next-generation aeronautical surveillance systems. There are many issues with the 108-118 MHz band, however, not the least of which is its proximity to high power FM broadcast stations (from 88-108 MHz) that can interfere with sensitive instrument landing systems and VHF omnirange equipment onboard aircraft in critical phases of flight. In the 1970s, the civil aviation community forecast that there were insufficient instrument landing system channels to satisfy future demand. Based on this forecast shortage, the microwave landing system was developed and plans were prepared to decommission instrument landing systems and implement microwave landing systems. For a variety of reasons, microwave landing system implementation has been largely abandoned in favor of the Global Navigation Satellite System in the United States. In the meantime, instrument landing systems continue to be installed and more-and-more restrictions on these installations are required to allow them to operate compatibly. In some geographic areas, there are very few, if any, opportunities for frequency support of new instrument landing systems.

Another band that suffers from congested spectrum capacity is the 118-137 MHz band used for air-to-ground air traffic control communications. Over the years, civil aviation has achieved greater and greater spectrum efficiency in this band by adding spectrum to the band (the last being in 1990 when the band was extended from 118-136 to 118-137 MHz) and by implementing closer channel spacing. The latest action to increase spectrum efficiency was the result of decisions made at the 1995 International Civil Aviation Organization Communications/Operational Divisional Meeting. At this meeting, there were two options selected. First was a reduction in channel spacing from 25 kHz to 8.33 kHz, theoretically yielding a three-fold increase in capacity. The other option selected was implementation of a new digital system based on time division multiple access technology. The civil aviation community has already begun work on the next-plus-one generation of air traffic control communications systems.

There are other examples of reduction in spectrum capacity due to increased usage. Radar bands are becoming increasingly congested, and airport fixed links supporting low level windshear systems and remote maintenance monitoring require increasing bandwidths of spectrum. More-and-more, it is becoming difficult to increase the efficiency of airspace because of lack of adequate radio spectrum to support optimum plans for airspace re-design.

The Way Forward

There are many potential solutions to the dearth of radio spectrum to support aeronautical and information technology future requirements. Each of these need to be individually analyzed before they are implemented to determine their feasibility, economic viability, and efficiency in meeting future needs. We will now examine a few of these potential solutions.

First, is to develop and implement more spectrum efficient technologies. From a practical standpoint, this is usually the most inviting of the alternatives. The downside is that a favorable cost-to-benefit argument must be developed. With the cost of research and development of new technologies being very high, and oftentimes these technologies are application specific and don't have the benefit of large market share, it is often difficult to justify a favorable cost-to-benefit ratio. Also, in the civil aviation community in particular, new technologies usually involve considerable expense because of the need to certify compatibility of the new system onboard the aircraft. These, and many other factors, often lead to evolutionary new technologies in civil aviation rather than revolutionary new technologies.

Second, is "splitting the bandwidth" of the channels used for various applications. This has successfully been done to increase capacity of instrument landing systems and air-to-ground air traffic control communications radios over the years. For example, instrument landing systems have evolved from 100 kHz channels to the current 50 kHz channels. Air traffic control communications radio spectrum has undergone a four-fold increase in capacity as it has evolved from 100 kHz channels, then to 50 kHz channels, and then to the current 25 kHz channels (NOTE: in core Europe, this increase has been 12-fold due to their implementation of 8.33 kHz channels due to severe air traffic control communications spectrum congestion in Europe). While such "bandwidth splitting" is often a tempting method of solving spectrum shortage issues, it has the disadvantage of using the identical existing, often outmoded, technology and offers no new benefits which come from transition to a more modern technology.

Another method of addressing lack of sufficient radio spectrum is to design systems to allow "dual usage" of the spectrum. In civil aviation, this has been done several times in recent years. For example, in the late 1990's, international civil aviation identified a need for a second signal on the Global Navigation Satellite System that would be suitable for aeronautical safety use. Because there was little hope of identifying new spectrum for this proposed service, it was decided to design the Global Navigation Satellite System signal to operate in the 1164-1215 MHz portion of the 960-1215 MHz band, which is currently used by critical aeronautical safety systems such as distance measuring equipment, the air traffic control radar beacon system, and Mode S. An extensive study was undertaken to determine what technical characteristics such a new Global Navigation Satellite System signal would have. The results were a design that will allow the new planned Global Navigation Satellite System signal to operate without interference to these current systems. In some congested airspaces (notably parts of the United States, core Europe, and some areas of Japan) there may be a need to re-frequency some of the distance measuring equipments to allow the new Global Navigation Satellite System signal to be used to its fullest capabilities. If such action is needed (and studies are currently being done to determine if this will be needed), it may be a small price to pay to more fully realize international civil aviation's vision of a space-based global navigation system.

Another example of civil aviation's "dual usage" of a frequency band is the design of the ground based augmentation system used to supplement the Global Navigation Satellite System for precision landings. This augmentation system was designed to operate in the 108-118 MHz band that was already used to support the instrument landing system. In many cases, such "dual usage" of frequency bands allows use of existing antennas onboard the aircraft…an important consideration due to the high cost of installation of new antennas on existing airframes.

Yet another method of making more efficient use of existing radio spectrum is to closely review frequency engineering criteria, perform necessary testing to determine if the criteria is too stringent, and then to implement new frequency engineering criteria, if possible, which allows more flexible use of the available radio spectrum. This was done by the United States to increase the capacity of its air-to-ground air traffic control communications system. The international standard for many years had been a frequency engineering criteria that required that the undesired signal (of a same frequency transmission from a different location) be at least 20 decibels lower than the desired signal. After exhaustive study and human factors analysis (i.e., air traffic controllers and pilots judging the voice quality of the proposed new frequency engineering criteria), the United States implemented a new criteria that required only 14 decibels difference between the desired and undesired signals. This action greatly increased the capacity of the air traffic control communications band and was eventually adopted by the international civil aviation community. The Federal Aviation Administration is currently analyzing frequency engineering criteria for other civil aviation systems, such as distance measuring equipment and air traffic control radars, to determine if there are spectrum efficiencies to be gained by modifying criteria for those systems. All these, and other, "tricks of the trade", are being used to increase the capacity and make more efficient use of allocated aeronautical radio spectrum.

One method of increasing available radio spectrum is often overlooked…that is, changing radio regulations to increase efficiency. Oftentimes, this alternative is considered "too tough to take on", however, it can provide significant capacity enhancement at little or no cost. The Federal Aviation Administration took this approach when studying the possible methods of extending the useful life of the radio spectrum, from 118 to 137 MHz, that supports the air-to-ground air traffic control communications system. Since 1990, the

Federal Aviation Administration had been working in the international civil aviation community to address the serious issue of lack of radio spectrum to support current and projected growth of air traffic control communications circuits. In these international forums, there has been a concerted effort to identify candidate technologies for the next generation air traffic control communications system, to select the best technology to satisfy current and future requirements for the system, and to work within the International Civil Aviation Organization to agree on a design for the new system.

Because of the global financial situation of the airlines and the high cost of the proposed new system, the implementation of this next generation system has been put on hold in the United States. This has made it imperative that we extend the spectrum life of the current 25 kHz amplitude modulated system. Many of the potential solutions (referred to as the "25 Initiatives") involve changes to current United States' radio regulations. For example, many radio frequencies in the 118-137 MHz band in the United States are set aside for special use. Examples of such use include flight test, flight inspection, flight service station, and other such needs. While all of these requirements are essential to a safe and efficient national airspace system, some of them are used very little in actual day-to-day operations. For example, there were three frequencies set aside for "air carrier advisory" use on which there were only three stations throughout the United States. The Federal Aviation Administration believed that these three reserved frequencies could be more efficiently used for general air traffic control requirements, and that spectrum needs for the air carrier advisory could be met on other non-reserved frequencies. Based on Federal Aviation Administration input, the Federal Communications Commission changed the domestic spectrum policy concerning these three frequencies that are now being used for critical air traffic control communications requirements.

Conclusions

Radio spectrum is a critical resource; a resource that cannot be replenished and which is 100% in use today. Accommodating a new service or expanding an existing service either requires displacement of other users; such as was done when implementing cellular telephone systems; or developing suitable sharing arrangements to allow disparate users to simultaneously use the spectrum.

The international civil aviation community has implemented a variety of innovative methods of using its radio spectrum in a flexible manner. These range from "low tech" solutions such as "splitting" channels into smaller bandwidths, to developing new cutting edge technologies to satisfy increasing aeronautical requirements. As any of these solutions are implemented, they must necessarily meet the stringent civil aviation needs of integrity, reliability, availability, and accuracy to become successful.

Recommendations

Both the international civil aviation and the test and evaluation communities should fully participate in the development of their countries' positions for the 2007 World Radiocommunication Conference. Special emphasis needs to be placed on Conference Agenda Items 1.5 and 1.6. Conference Agenda Item 1.5 addresses the future needs of radio spectrum to support aeronautical telemetry and associated telecommand. Conference Agenda Item 1.6 addresses the future requirements for aeronautical safety communications.

The international civil aviation, international telemetry, and the international test and evaluation communities need to work closely together to provide mutually supportive positions to appropriate international forums which address radio spectrum policy. Such activities include those of the International Civil Aviation Organization, the International Telecommunication Union, the International Consortium for Telemetry Spectrum, the International Test and Evaluation Association, and others.

References

Ref 1: DRI-WEFA, Incorporated; The National Economic Impact of Civil Aviation; July 2002.

Ref 2: National Telecommunications and Information Administration; Preliminary Spectrum Reallocation Report, Response to Title VI – Omnibus Budget Reconciliation Act of 1993; February 1994.

Ref 3: National Telecommunications and Information Administration; Spectrum Reallocation Final Report, Response to Title VI – Omnibus Budget Reconciliation Act of 1993; February 1995.

Ref 4: National Telecommunications and Information Administration; Spectrum Reallocation Report, Response to Title III of the Balanced Budget Act of 1997; February 1998.