THE ROLE OF SATELLITE SYSTEMS IN FUTURE AERONAUTICAL COMMUNICATIONS

INTRODUCTION

1. Aeronautical Communications Systems must be reliable and efficient. Connection to Aeronautical networks is considered to be achieved by satellites with large coverage areas especially over oceanic regions during long-haul flights. The service concept needs to take into account today’s peculiarities of satellite communications, thus it must cope with the available or in near future available satellite technology and interworking must be performed at aircraft interface level with the satellite segment. Only restricted satellite data rates will be available in the near future, thus the bandwidth that is requested by standard interfaces of the wireless standards needs to be adapted to the available bandwidth (typically: 432 kb/s in down-link, 144 kb/s up-link (Inmarsat), or 5 Mb/s in down-link, 1.5 Mb/s in up-link. Furthermore, dynamic bandwidth management is needed to allocate higher bit rates from temporarily unused services to other services. Currently, few geostationary satellites such as the Inmarsat fleet are available for two-way communications that cover the land masses and the oceans. Ku-band may be used on a secondary allocation basis for Aeronautical Mobile Satellite services (AMSS) but bandwidth is scarce and coverage is mostly provided over continents. K/Ka-band satellites will be launched in the near future again here continental coverage is mainly intended.

2. The scenario must thus consider the use of different satellite systems, which will probably force the support of different service bearers and handover between satellite systems. Asymmetrical data rates in satellite up and down-links, that may also be caused to operate in conjunction with different satellites systems for up-and down-link. The service portfolio in the cabin and the service integration needs to cope with this possibility. The demand for making air traveling more pleasant, secure and productive for passengers is one of the winning factors for airlines and aircraft industry. Current trends are towards high data rate communication services, in particular Internet applications. In an aeronautical scenario global coverage is essential for providing continuous service. Therefore, satellite communication becomes indispensable and together with the ever increasing data rate requirements of applications, aeronautical satellite communication meets an expansive market.

3. In future Aeronautical Communications Systems, data links have to fulfill very stringent performance requirements. The nature of the information they carry which is bound to become the first mean of air traffic control make their availability critical to the safety of air transportation in the future. Satellite communication systems have many differentiating arguments when compared to terrestrial solutions. In high-density areas, satellite could also be useful either as a primary means of communication or as a secondary one in order to improve the overall communication System's availability. A satellite system, by nature is able to cover large regions of the earth and can thus provide a cost effective solution to the coverage of both high and low density areas such as oceanic regions where reliable terrestrial coverage is nonexistent.
SATellite Aeronautical Communication System: General Architecture

4. The general architecture of a satellite system for providing aeronautical communication services is discussed in succeeding paragraphs. After presenting the role of the different segments, the integration of such systems in the Aeronautical Telecommunications Network (ATN) is specified.

5. **Ground, Space And User Segments.** A typical satellite communication system is divided into three different segments. These are respectively the ground, space and user segments. The ground segment is responsible for interfacing the satellite communication system with the rest of the communication network infrastructure to which the satellite system constitutes an access network. Networking infrastructures are structured with a core network to which several access networks interconnect in order to allow end users to connect. In the ground segment of a satellite communication system, the information stream that arrives through the ground infrastructure is adapted in order to be sent out on the air interface of the satellite network gateway which in aeronautical communication systems is known as a **Ground Earth Station (GES)**.

6. The space segment is composed of the satellite itself. The role of the space segment is to either serve as a transparent reflector for the signals sent from the ground or to receive process and re-generate a signal towards the ground in which case the satellite is called regenerative. A regenerative satellite can be used in the case where the equipment on the ground and user segments doesn’t use the same modulation and coding rate for example. Another example of regenerative satellites are those used in constellations such as Iridium for which the signal is decoded in the space segment in order to be routed towards the appropriate satellite towards its destination.

7. Satellite system for aeronautical communications architecture is illustrated in figure shown above. The user segment as its name indicates is where the users of the satellite communication system are located. In the case of an Aeronautical Communication Satellite System, the user segment is known as the **Aeronautical Earth Station (AES)**. The role of the user segment is to provide an interconnection mechanism between the on-board networks and systems and the satellite access network. In a way that is similar to the ground segment. The user segment provides the interface between the streams of
data that are under the control of the satellite system (implementing a specific communication standard) and the outside world.

8. **Satellite System Integration to the Aeronautical Telecommunications Network.** The objective is to replace progressively voice communication for air traffic management by data communication services for safety reasons and because it supports increased automation in the aircraft and on the ground. Potential resource savings should also be possible when replacing voice by data communications. These data communications should then become the primary means for safety air-ground communication. These data link oriented communication services will be supported by new communication infrastructures.

9. Functionally, no processing exists on board the satellite, neither on the data nor on the frames, such a payload only handles a frequency conversion function. A satellite system appear as being an active element of the network (an IP router) or it can operate completely at layer in which case it constitutes a transparent bridge equipment between several segments of the same IP network. In future satellite systems for aeronautical communications, it is foreseen that their operation is performed at layer 3 for reasons which are linked to mobility requirements amongst others.

10. Aeronautical communication systems used for the transport of ATC/AOC are considered as safety critical in their frequency allocation by the ITU while systems used for APC communications. The principle of transmission in the safety satellite system consists of following:

    (a) The mobile link, between the satellite and the aircraft which is built on a safety satellite spectrum allocation.

    (b) The satellite is in charge of signals frequency conversion, simultaneously from C or Ku band to L band for the forward link and from L band to C or Ku band for the return link.

    (c) The fixed link between the ground and the satellite built on a fixed satellite spectrum allocation is based on FSS standard.
11. **L Band Situation.** The L band is defined as the Mobile Satellite Service allocation in the frequency ranges of 1525-1559 MHz and 1626.5-1660.5 MHz. Although, the whole band is generically for Mobile Satellite Service (MSS) use, in certain portions of the band, safety related services are afforded a specific status in the ITU radio regulations, as shown on Figure below. In the sub-band 1646.5-1656.5 MHz and 1545-1555 MHz, the communications are afforded by priority over other types of communications, through the footnote 5.357A of the Radio Regulations.

![L Band Allocation Diagram]

**Fig 3: AMS(R)S L band allocation for SATCOM**

12. The concerned communications are those falling under categories 1 to 6 of Article 44 of the Radio Regulations, as listed below:

(a) Distress calls, distress messages and distress traffic.
(b) Communications preceded by the urgency signal.
(c) Communications relating to radio direction finding.
(d) Flight safety messages.
(e) Meteorological messages.
(f) Flight regularity messages.
(g) Messages relating to the application of the United Nations Charter.
(h) Government messages for which priority has been expressly requested.

(i) Service communications relating to the working of the telecommunication service or to communications previously exchanged.
(j) Other Aeronautical Communications.

13. In the specific context of the L band, given the technical nature of satellite systems involved, it has been felt more efficient to have multilateral meetings among the concerned parties instead of solely relying on Article 9 of the Radio Regulation (ITU, 2008). In effect, the terminals in the L band have poor directivity which impacts any satellite network operating in visibility of that terminal which leads to segmentation of the
spectrum among systems. Given the high demand for spectrum in the L band, it is
difficult for a new entrant to have spectrum granted, even if this is for safety services. For
non-safety services, it is seen as impossible to have significant spectrum allocated for a
new entrant.

14. **Ku Band Situation.** Here, discussion is limited to the downlink portion of
the Ku band, i.e. the portion dedicated to the reception by the aircraft. The downlink
portion of the Ku band is divided in allocations to various services as follows:

(a) **FSS planned band.** These bands are regulated by Appendix 30B of the
Radio Regulations. In these bands, every country member of the ITU has access
to a reserved orbital position for national coverage. There are only few operational
systems in this band.

(b) **FSS unplanned bands.** These bands host most of the Ku band satellite
systems because of the flexibility of its regulation. In many areas, this band is fully
occupied by operational systems.

(c) **BSS planned bands.** These bands are regulated by Appendix 30 of the
Radio regulations (RR, 2008). In these bands, every country member of the ITU
has access to a reserved orbital position and determined number of TV channels
for national coverage. There are a significant number of operational systems in this
band.

15. Most of operational Ku band satellites operate in the Ku FSS unplanned band (in
blue). Therefore, it is likely that the capacity for APC services could be found in this
portion of the spectrum, although the others are not excluded. It should be noted that it
would be more correct from a regulatory point-of-view to use Mobile Satellite Service
allocations for the service since an aircraft can be considered as a mobile terminal.
However, it is possible to use FSS allocations, as long as the services do not entail
regulatory requirements higher than those of a classical FSS use.

**EXISTING SATELLITE SYSTEMS IN OPERATION
FOR AERONAUTICAL COMMUNICATIONS**

16. **Inmarsat And Mtsat.** The Inmarsat service was initially targeted to provide a
maritime communication service to the community for safety of life related issues.
However, Inmarsat soon began to provide service to other communities such as aircraft
and mobile users. The space segment of the Inmarsat system is a constellation
composed of several geostationary satellites (the number of satellites depend on the
service as not all of them support all the services) that cover the earth with the exception
of the poles. These can either be used through the legacy Classic Aero service or the
recently introduced Swift Broadband service. The Inmarsat satellites use three different
types of spot beams, one global spot beam for initial signaling and specific services, a set
of regional spot beams (since the 3rd generation satellites) and very small spot beams
(radius in the order of hundreds of kilometers) used for allowing for smaller antennas to
be used on the handheld terminals. In terms of frequencies, the Inmarsat system
operates the feeder link in Ku bands and the user link in reserved portions of the L band.
The Classic Aero service is mainly used for establishing circuit oriented connections for
low and medium quality voice and fax. In addition to these services, packet data services
can also be used.
17. **Iridium.** In addition to the Inmarsat and MTSAT satellite systems, the Iridium low earth orbit constellation of telecommunication satellites also provides Aeronautical Communication Services. The Iridium constellation is comprised of 66 active satellites that provide complete coverage, including the earth poles. The feeder and inter-satellite links are operated in Ka frequency band while the user link is operated in the L band. Services offered by the Iridium constellation are based on the GSM standard and include both voice and data oriented communications. In addition to these services, one-way paging services are also possible. The Iridium constellation and services has recently been undergoing the authorization process. However, initially, the system will be used to provide voice-oriented communication between controllers and pilots for the needs of ATS services.

**THE FUTURE SATELLITE LINK: CHALLENGES**

18. Currently, in continental areas, mobile communications use a narrowband VHF voice system combined with a VHF digital data link e.g. **VDL (VHF Digital Link)** Mode 2 (Fig 4 represents a VDL network architecture). The VHF network is composed of terrestrial antennas connected with gateway routers to a backbone network in which the services are located. Although, VHF is a very mature and reliable technology, it presents some disadvantages. It requires several remote ground stations to achieve the coverage that implies high operating cost due to links between ATC centers and remote radio stations.

19. In remote areas and over oceans, HF and SATCOM voice and data link systems are used. HF network has the same architecture as the VHF one but it is not limited to line of sight propagation. It can also be used with ground wave propagation and sky wave propagation. The main drawback of HF communications is its poor link overall quality due to fading. HF tends to be replaced by satellites links in oceanic areas because of the higher quality of satellites communications. But the currently implemented satellites links are not efficient enough to be economically viable on a large-scale deployment.

20. The evolution from voice to data links for ATC is motivated by safety reasons and by saturation of voice links in dense areas. Data transmission allows using less bandwidth and safer communications. With the considerable increase of the air traffic last few years and the expected increase in the next coming years the current ATM network will not be able to handle all the traffic with the requirements associated to ATC services.
In dense area managed airspace the objective is thus to increase the ATM capacity while having even higher level of safety and getting rid of aeronautical routes. In low density managed airspace the objective is to have a higher communication quality and more flexibility in trajectories of aircrafts.

21. Future Aeronautical Communication architectures will allow for onboard end systems to communicate with other end systems located on the ground through potentially more than one radio link at a given time. On the airborne side of the network, several functional entities are represented from passenger end systems which will mainly use the network architecture in order to access the Internet and specific passenger services which will communicate with service providers on ground through the use of potentially multiple access networks technologies including the satellite link. On the ground side of the network, the counterpart to several of the airborne side functional entities is presented. In order to provide its service, the network architecture relies on functionalities provided on the ground by Mobility Information Services as well as Security Services. In order to maintain a global connectivity between airborne and ground networks, the network layer shall be implemented.

![Diagram](https://example.com/diagram.png)

**Fig 5: Example of satellite link integration in the Future Aeronautical Communications**

22. The constant quality of service on the covered area required by such systems will be possible by the mean of a global coverage that only satellites can provide. Besides, the satellite can provide high safety guarantees along with a constant deployment and maintenance cost all over the coverage (conversely to terrestrial technologies) and permits to get rid of aeronautical routes. For all these reasons, the satellite shall play a major role in the future Aeronautical Communication Network. Either the satellite will be used as a primary mean for future ATM communications in all areas ensuring a constant quality of service and safety communication that could potentially be backed by
terrestrial technologies or the terrestrial access could be used as a primary means of ATM communication in the dense area managed airspace while the satellite could be used as a primary communication mean in low-density area managed airspace and as a backup communication mean in dense areas. A last option would be to use concurrently several access technologies including satellite access to provide future ATM communications. This last solution would permit to increase the overall availability of the network while reducing handover delay in case of a technology breakdown as all available technologies would be used in parallel. This approach could also permit to maintain a constant QoS for ATM communications as the access technology the most adapted to the QoS requirements would be used.

CONCLUSION

23. There are well-founded concerns that current Aeronautical Communications Systems will not be able to cope with their expected growth. Current processes, procedures and technologies in Aeronautical Communications do not provide the flexibility needed to meet the growing demands. In the future, airliners will provide a variety of entertainment and communications equipment to the passenger. Since people are becoming more and more used to their own communications equipment such as mobile phones and laptops with Internet connection, either through a network interface card or dial-in access through modems, business travelers will soon be demanding wireless access to communication services.

24. However, the role of Satellite Systems in future Aeronautical Communications is important and growth of air transportation in the upcoming years will change the way communication systems are used by pilots and crew. From a voice-centric paradigm, the convergence is likely to be a data-centric paradigm where voice is maintained only for highly critical situations for which text oriented transmissions are not adapted. In this context, the transmission delay which is the main drawback of geostationary satellite communication systems becomes less important than for highly interactive video/voice. The advantages of satellite systems, on the other hand are interesting for Aeronautical Communications. The large coverage, high availability, low maintenance costs, high flexibility in resource allocation and usage as well as the ability to provide similar service in remote areas are arguments in favor of such systems. While the regulatory framework imposes some constraints on the overall capacity and system design, a satellite component not only supports the services in oceanic and remote areas but that some of the characteristics of satellite systems make them a first choice for certain services also in higher density continental regions.

Read More:-

(a) http://en.wikipedia.org/wiki/Aircraft_Com munications_Addressing_and_Reporting_System.


(c) http://www.aerospace.org/.