Chapter 9
Modeling of Aircraft and RPAS Data Transmission via Satellites

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ABSTRACT

This chapter is devoted to the modeling of aircraft data transmission via low-orbit satellites. Satellite communication channel models were designed, which allow to investigate BER dependencies on the type of signal modulation, information transfer rate, signal power, antenna diameters, and nonlinearity of a high power amplifier. Impact of a modulation type (BPSK, QPSK, 8PSK, 16QAM), E_b / N_0, satellite transponder amplifier gain without and with coding on a BER was investigated. Effectiveness of error detection and correction was analyzed using classic linear block and convolutional codes. Free space path loss, AWGN, and radio frequency satellite channels were considered. MIMO 2 × 1 and 3 × 2 fading uplink/downlink channels with antenna diversity were analyzed. Results were compared with AWGN uplink/downlink channels. On the base of these models, channels integrity was investigated.

INTRODUCTION

Aeronautical Telecommunication Network

The Aeronautical Telecommunication Network (ATN) has been designed to provide data communications services to Air Traffic Service (ATS) provider organizations for ATS communication, aeronautical operational control, administrative communication, and aeronautical passenger communication (Doc. 9880-AN/466, 2005; Doc. 9896, 2011). The ATN comprises application entities and communication services, which allow ground-ground, air-to-ground and air-to-air data subnetworks to interoperate using satellite subnetwork (Roddy, 2006).

Satellite communication systems are used for sending data from aircraft to a ground stations accessible to Aeronautical Operation Control (AOC), Air Traffic Management (ATM) and Air Traffic Control (ATC). Wide application of satellites in aviation is connected with the possibility of communication with a considerable amount of aircraft irrespective of a distance, with independence of expenses on a

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distance between planes, with insignificant influence of atmosphere and sites of land stations on reliability of communication.

A satellite tracking of aircraft is a technology available to aircraft operators that has huge benefits and relatively low costs. An aircraft can report its position via an Aircraft-Satellite-Ground Station data link. Automatic Dependent Surveillance – Broadcasting (ADS-B) – is a technology, which allows pilots and air traffic controllers to track aircrafts with high accuracy (EUROCONTROL, 2013; ADS-B, 2014). ADS-B can make flight safe and allows using of air space more effective. An aircraft equipped with ADS-B avionics transmit their exact position in space by means of digital communication channels. The digital code which contains this information is updated several times per second and transmitted by aircraft on discrete frequencies. ADS-B systems based on Low Earth Orbit (LEO) satellites are of special interest (Osborne, & Xie, 2009).

It was found (Aircraft-to-Satellite Links, 2003) that the most critical factors for all systems using aircraft are the transmitting antenna and the data rate that the communications system is required to carry. The maximum rate for any system in use today is set by the transmit power available from the ground (or aircraft) transmitter and the sensitivity of the satellite receiver. Therefore, it is necessary to determine the amount of data that must be transmitted and the time period in which the transmission must occur. Problems connected with the performance of satellite aeronautical communication channel are very important. Even small degradation of communication channel parameters influences a rate of data transmission, a time delay and a coverage. These factors at once impact on safety of flights and operational expenses. It is necessary to have the system parameters optimized before implementation (Elbert, & Elanix, 2009) and when things go wrong, a simulation model can be used to track down the offending element. The imitation modeling also may be useful for pre-testing any corrective action before attempting it either in space or on the ground. At the same time the role of a satellite transponder as a part of the microwave repeater and antenna system is significant. A transponder is used to amplify carriers on the downlink side. Each transponder is amplified by either a traveling wave tube amplifier or a solid state power amplifier.

Iridium System

Previous Iridium system included 66 LEO satellites at an altitude of 785 km and equally divided into 6 orbital planes. The orbits are circular with an inclination angle of 86.4˚ degrees (Irid743ium, 2007). Each satellite communicates with the Airborne Earth Station (AES). Each satellite uses three phased-array antennas for the user links, each of which contains an array of transmit/receive modules. These arrays are designed to provide user-link service by communicating within the 1616-1626.5 MHz band. The gateway connects the Iridium satellite network to ground communication networks, such as the terrestrial Public Switched Telephone Networks (PSTNs) and Public Switched Data Networks (PSDNs), and communicates via ground-based antennas with the gateway feeder link antennas on the satellite. The gateway can also serve as a gateway to the ATN for forwarding ATN messages from the aircraft to the required ATC or AOC unit or vice versa.

Channels are implemented in the Iridium Satellite Network using a hybrid Time Division Multiple Access/Frequency Division Multiple Access (TDMA/FDMA) architecture based on Time Division Duplex (TDD) using a 90-millisecond frame.

All L-Band uplink and downlink transmissions used in the Iridium Satellite Network employ variations of 25 Kilosymbols-per-second (ksps) Quadrature Phase Shift Keying (QPSK) modulation and are