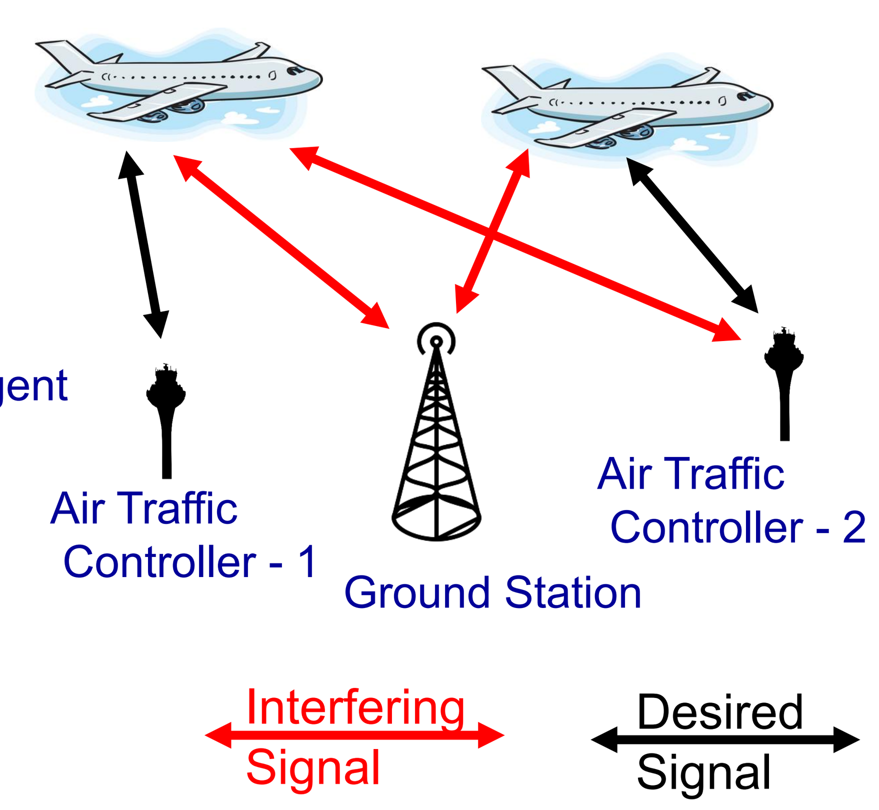
Dynamic Spectrum Access Enabled Cognitive Radio based Sustainable Air-to-Ground Communication System

Cognitive Radio for Aeronautical Communications: Motivation

- Air traffic is expected to be doubled by 2025.
- Increase in air traffic leads to congestion in the aeronautical spectrum
- Problem: Scarcity of the wireless spectrum
- Consequence:

  Interference-limited Systems

Interference Scenario in Aeronautical Communication Systems



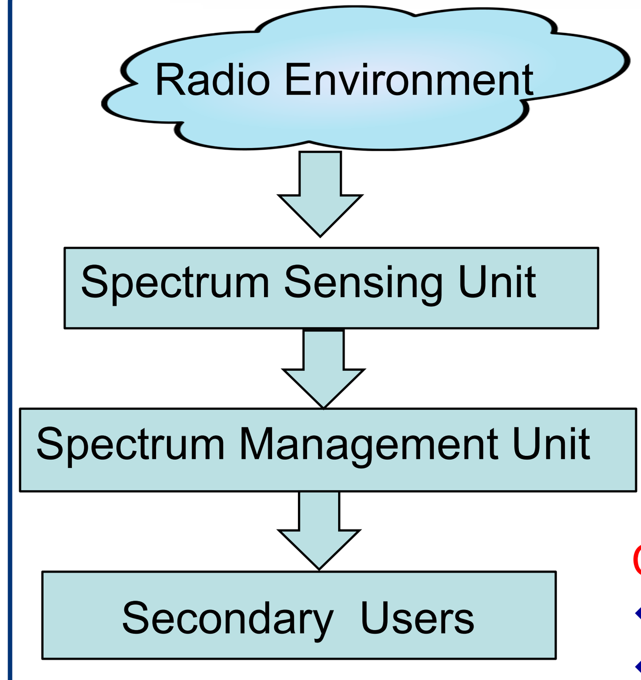
- Solution: Cognitive Radio based Intelligent Transmitters and Receivers

- ❖ Capable of sensing RF environment
- ❖ Able to avoid / harness the interference

- In Cognitive Radio, users are classified as Primary and Secondary users:
  - ❖ Legacy and Mission-Critical Services are Primary users
  - ❖ Non-critical services are Secondary users

Cognitive Radio based Aeronautical Communications: Specific Aim

Key Stages in Cognitive Radio



Challenge:
- ❖ Detection of the primary user
- ❖ Identification of the spectral holes

Challenge:
- ❖ Dynamic Frequency allocation to users

Challenge:
- ❖ Design of Encoding and Decoding Algorithms
- ❖ Design of the hardware

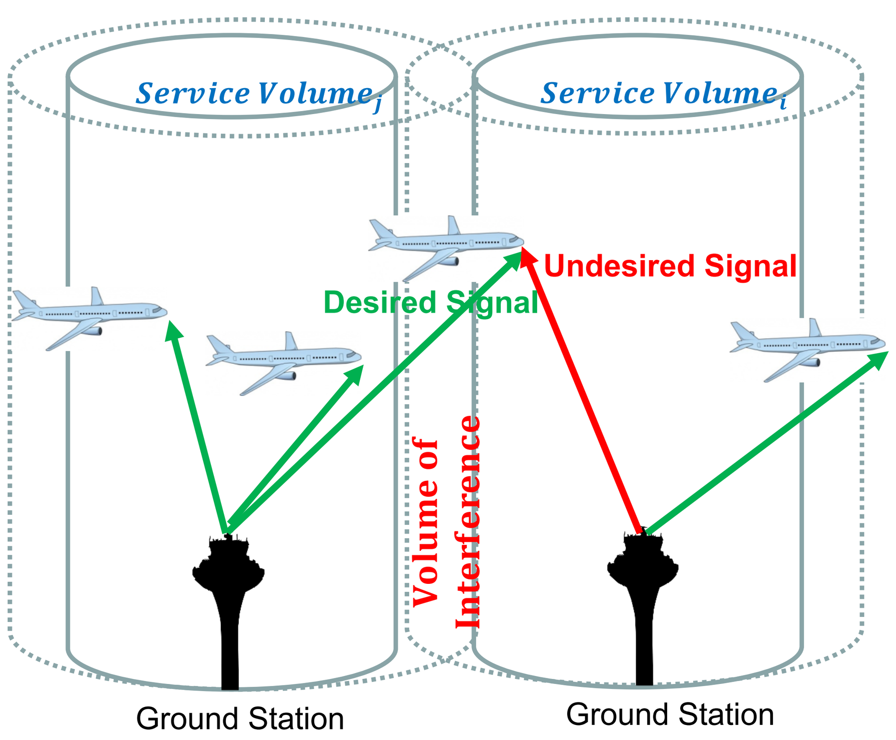
Objective:

To develop a Cognitive Radio based Air-to-Ground Communication network

Specific Aims:
- ❖ Develop an efficient spectrum sensing unit to effectively sense the wide band spectrum for vacant bands for cognitive radios to use.
- ❖ Propose a spectrum management unit to decide most suitable vacant band for each airplane depending on the Quality of Service (QoS) requirement and allocate these vacant bands to airplanes for dynamic spectrum access.
- ❖ Design a reconfigurable and low power on-board channel adaptation unit for Air-to-Ground data communication.
- ❖ Integrate above units to develop a cognitive radio based Air-to-Ground communication system.

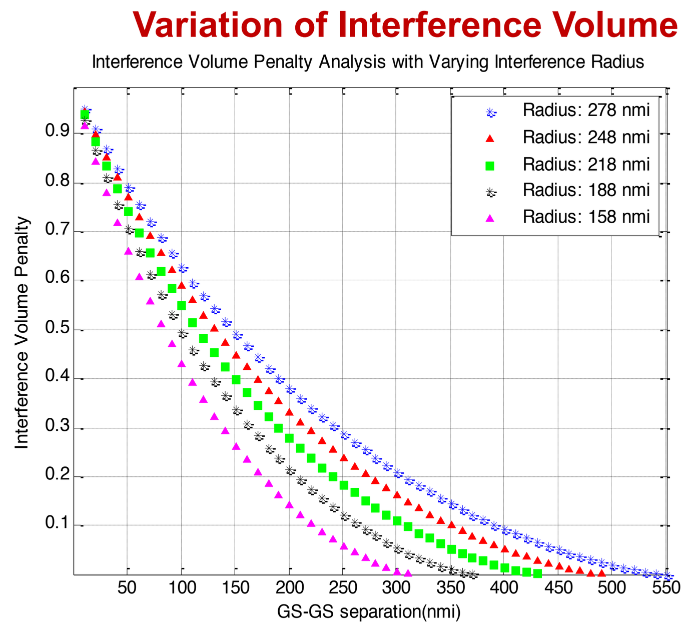
Contribution: Optimizing the system wide interference score (IS) through efficient Time-Frequency Unit (TFU) Allocation

System Model for Co-channel Interference Scenarios



- Ingenious algorithm for efficient and interference-limited Time Frequency Unit (TFU) allocation to aircrafts within adjacent service volumes (SV).
- Introduced the Interference volume (I_v) penalty parameter which is the ratio of volume of interference between adjacent SVs to total volume of the SVs.
- Allocation of TFUs to adjacent SVs are planned such that their I_v penalty is below a pre-determined value which curtails the system wide interference score within acceptable ranges.

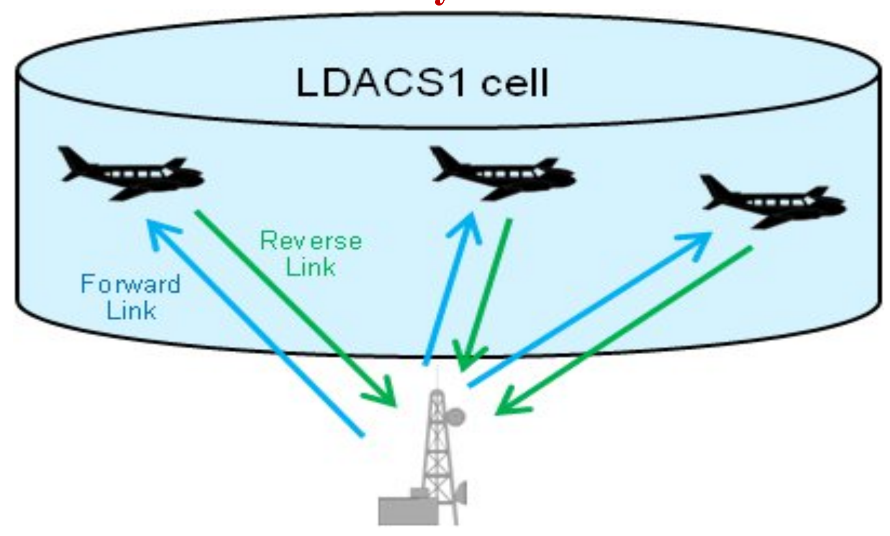
Variation of Interference Volume Penalty with Ground Station-to-Ground Station distance



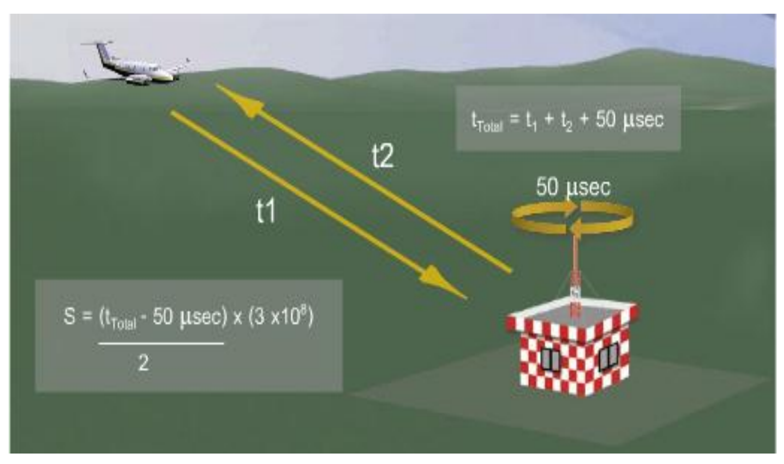
- Penalty can be determined from the positions of the victim aircraft, the ground stations of the source and the interfering SV.
- Based on this value, it is possible to determine the impact of co-channel frequency reuse at varying distance between adjacent SVs.
- Lesser value for penalty permits co-channel frequency reuse with higher DUSR and hence decreases the system wide IS.

Contribution: Distance Measuring Equipment (DME) Interference Mitigation for LDACS-1 Based on Decision-Directed Noise Estimation

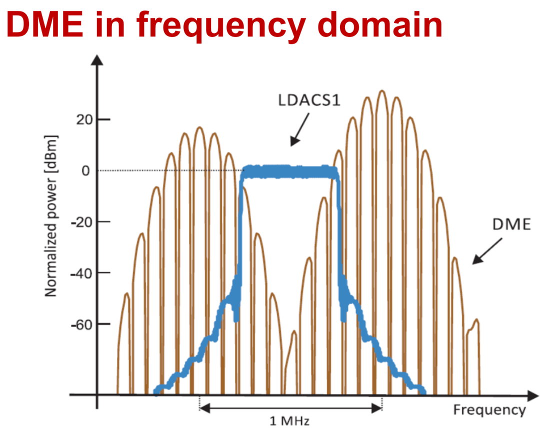
L-band Digital Aeronautical Communications System 1



Distance Measuring Equipment



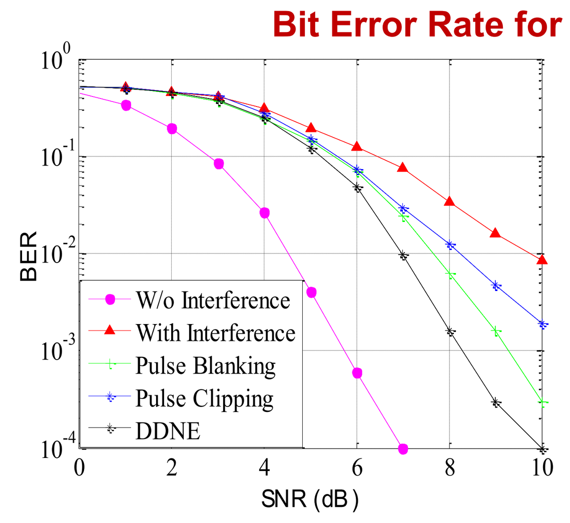
Interaction between LDACS 1 and DME in frequency domain



Key Steps involved in Decision-Directed Noise Estimation (DDNE)

- Estimate the DME interference in received signal of LDACS1 system.
- Subtract the DME interference from the received signal and demodulate the OFDM signal.

Bit Error Rate for DDNE: Comparison with Traditional Methods



- Proposed DDNE based LDACS1 system leads to:
  - ✓ an SNR performance improvement of about 1 dB for BER 10^{-3} when compared to the pulse blanking method with T^{pb}=0.3,
  - ✓ an SNR improvement of 2 dB is observed when compared to the pulse clipping method with T^{clip}=0.3.