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2023 World Radiocommunication Conference
Agenda Item 1.7

Space Based VHF Studies

VOICE project: outcomes of technical studies and test/validations

ESAF/WACAF Regional Workshop
Preparation for WRC-23
26-27 April 2022
ENAIRE/Indra/EUROCONTROL/SITA//STARTICAL

Contents

Introduction.

- The first objective is Ensure a better understanding of Space Based VHF proposal by Indra & Startical and address outstanding questions on implementation from the US VHF community.
- The results of the technical studies and laboratory tests performed by the VOICE project in support of the space based VHF concept will be presented.

Contents

VOICE Project – Validation approach

- **Objective:**
  - Evaluate the feasibility of Space based VHF communications in oceanic and remote airspaces in order to provide VHF voice and Data services and ensure the possibility to provide complementary and continuous coverage for VHF voice and Data services from Continental to oceanic Airspaces.
- **Validation approach:**
  - Aircrafts in the area of interest of the exercise will be asked to communicate using pre-assigned frequencies (1 for VHF voice and 1 for Data) in areas where normally no VHF coverage is available.
  - Communication with ATCO from Canarias and SAL FIRs will be stablished using assigned VHF frequencies.
  - No operational instructions will be given during this demonstration.
- **Technical aspects:**
  - VHF frequencies for VHF voice and data has been selected considering that they are not repeated in the affected envelope of the possible satellite positions used for Tx.
  - Transmitted power in Satellite is dynamically configurable based on satellite position (LAT-LONG) and based in command and control orders, in order to ensure that there´s no impact outside the exercise envelope.
  - Satellite is configured in Rx mode as default, and will switch to Tx mode only when commanded by the system and with the power levels in order to ensure there´s no impact outside the exercise envelope.

VOICE Project – End to End Test

VOICE

Reduced separations and improved efficiency based on Vhf cOmmunICations over LEO satEllites

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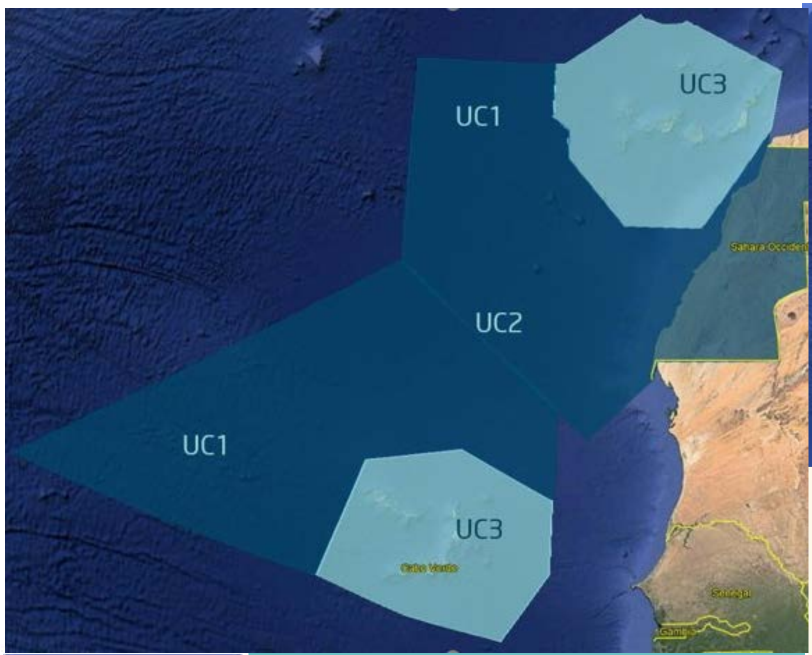

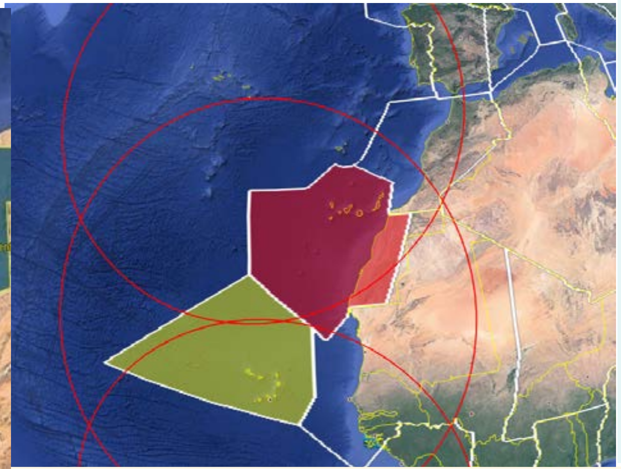

Objectives

The main objective of this project is to perform a proof of concept for this technology in real environment by end 2022.

- Demonstrate that use of VHF comms with LEO satellites is successful and does not interfere with existing installations.
- Provide real data for approval of use of VHF in LEO satellites in the next WRC2023

Consortium partners

- **Indra (consortium leader)**
  - Subcontractors: SITA, INTA, UPM
- **Enaire**
  - LTP: CRIDA, ASA-Cape Verde
- **GomSpace**
  - GomSpace A/S
  - GomSpace Lux
- **Eurocontrol**

Advisory Board

- Air Europa
- IATA
- AESA
- JOTRON

This project has received EUR 3.989.808,75 funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101017688.

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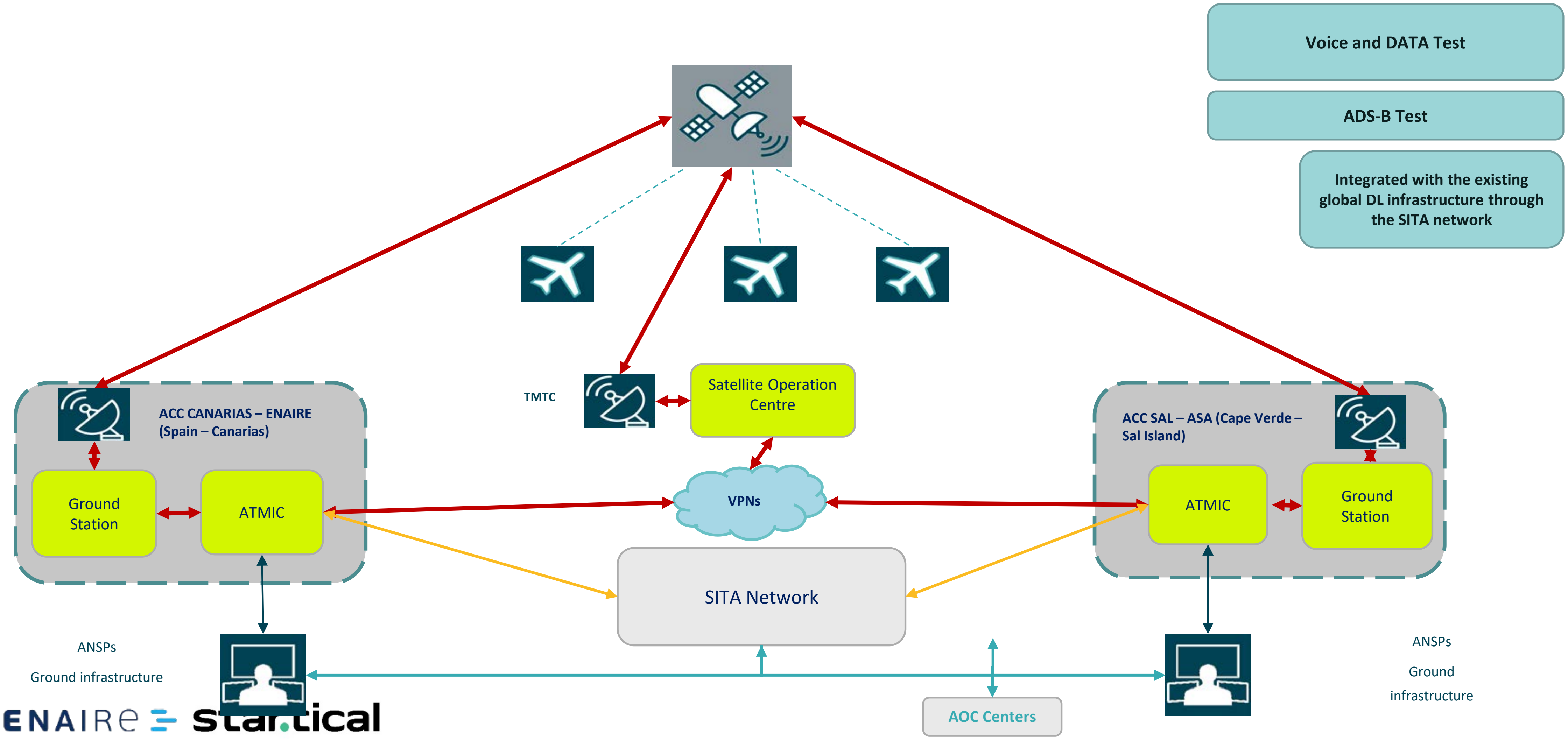
VOICE Project – Infrastructure

VOICE

VHF – Data and Voice - System Definition for VOICE project



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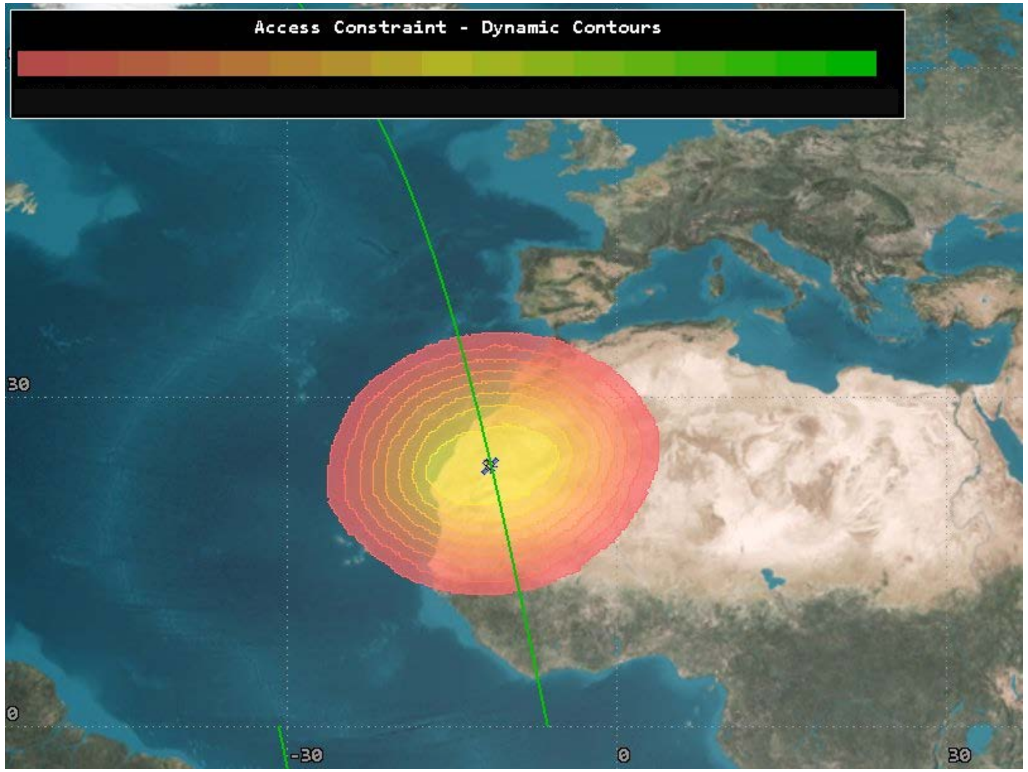
VOICE Project – Theoretical Coverage

VOICE

Orbit Type: Sun-Synchronous 550 km

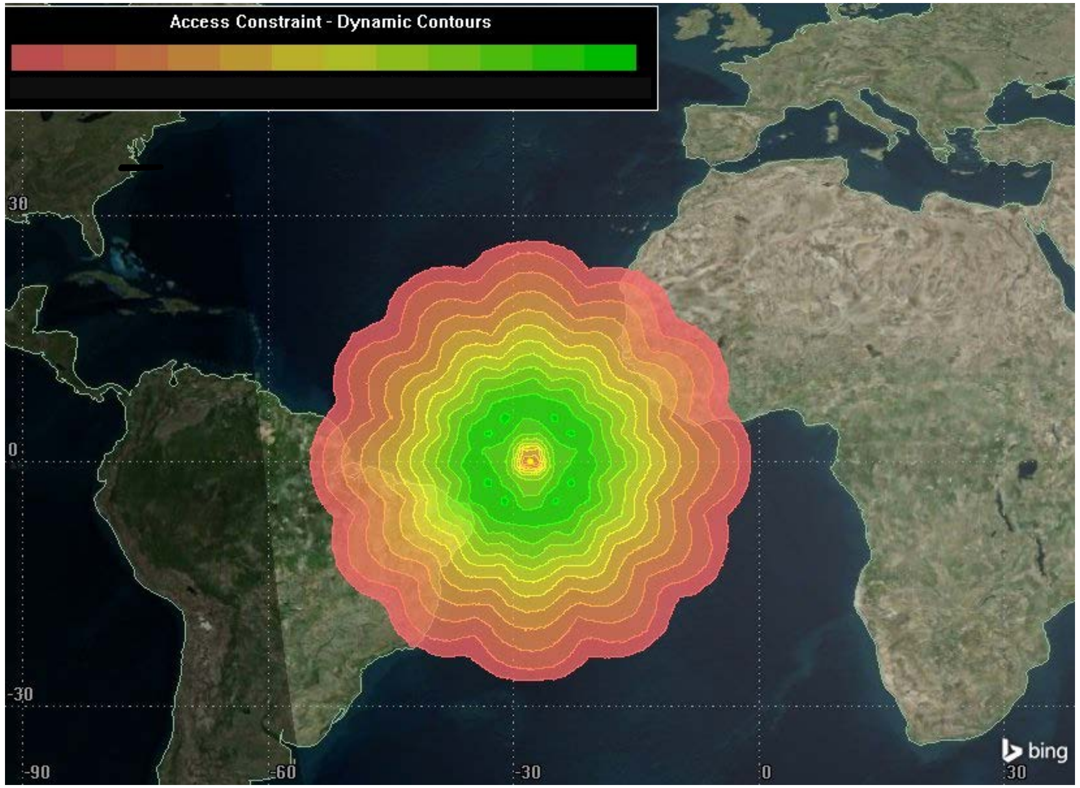
VHF Antenna Type: Isoflux Nadir pointing
VHF Tx Coverage (configurable): Maximum 1500 km



VHF link budget for Data and Voice Satellite to Aircraft

(PFD, Scintillation, Doppler, Faraday, Antenna ….)

ADS-B Antenna type patch



ADS-B - Aircraft to Satellite (Rx) Coverage

(S/N, Detectability, Antenna ….)

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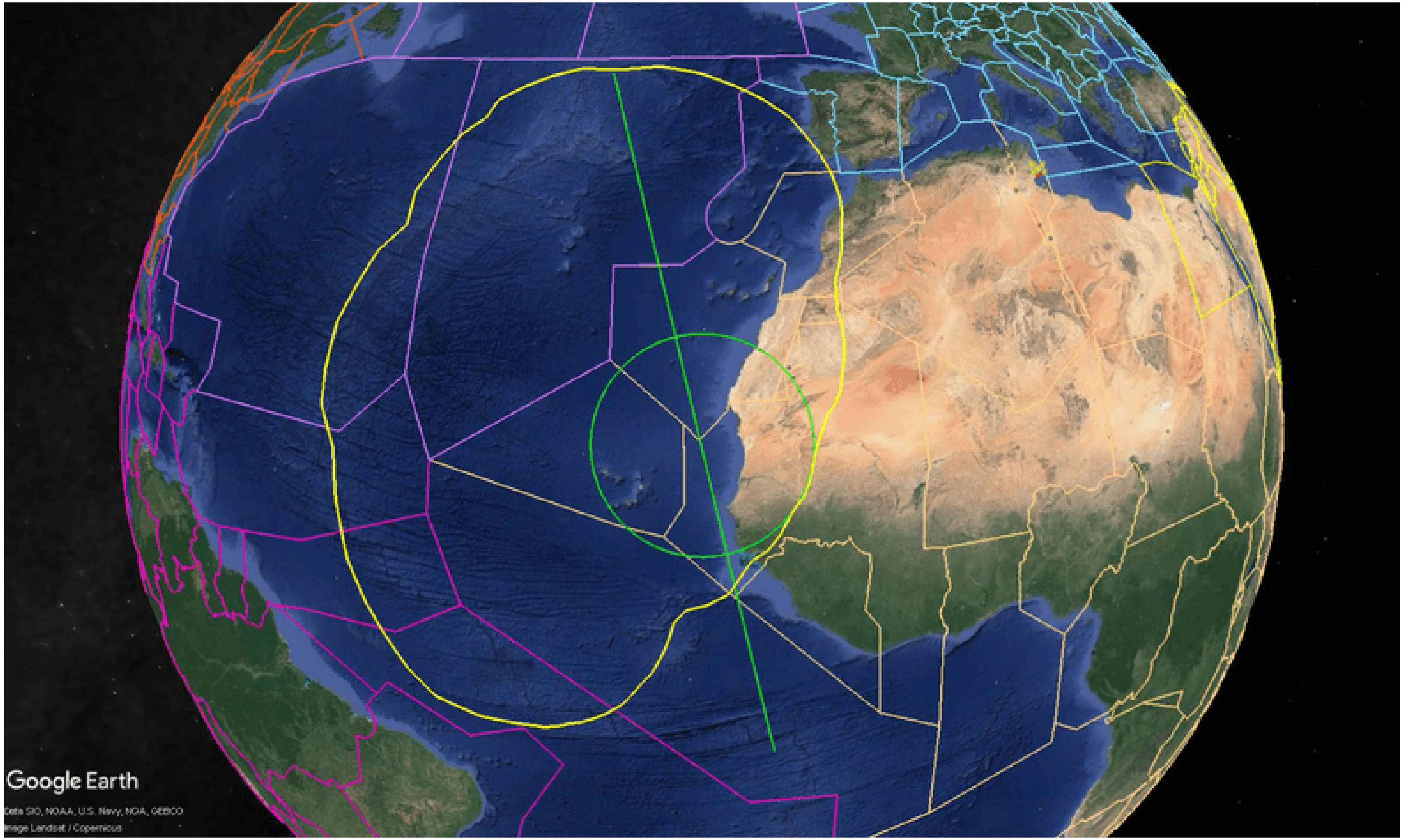
VOICE Project – Technical Test

VOICE



N-S passes marked in red.

S-N passes marked in green

Satellite Footprint is dynamically configurable based on satellite position (LAT-LONG) and based in command and control orders, in order to ensure that there´s no impact outside the exercise envelope.

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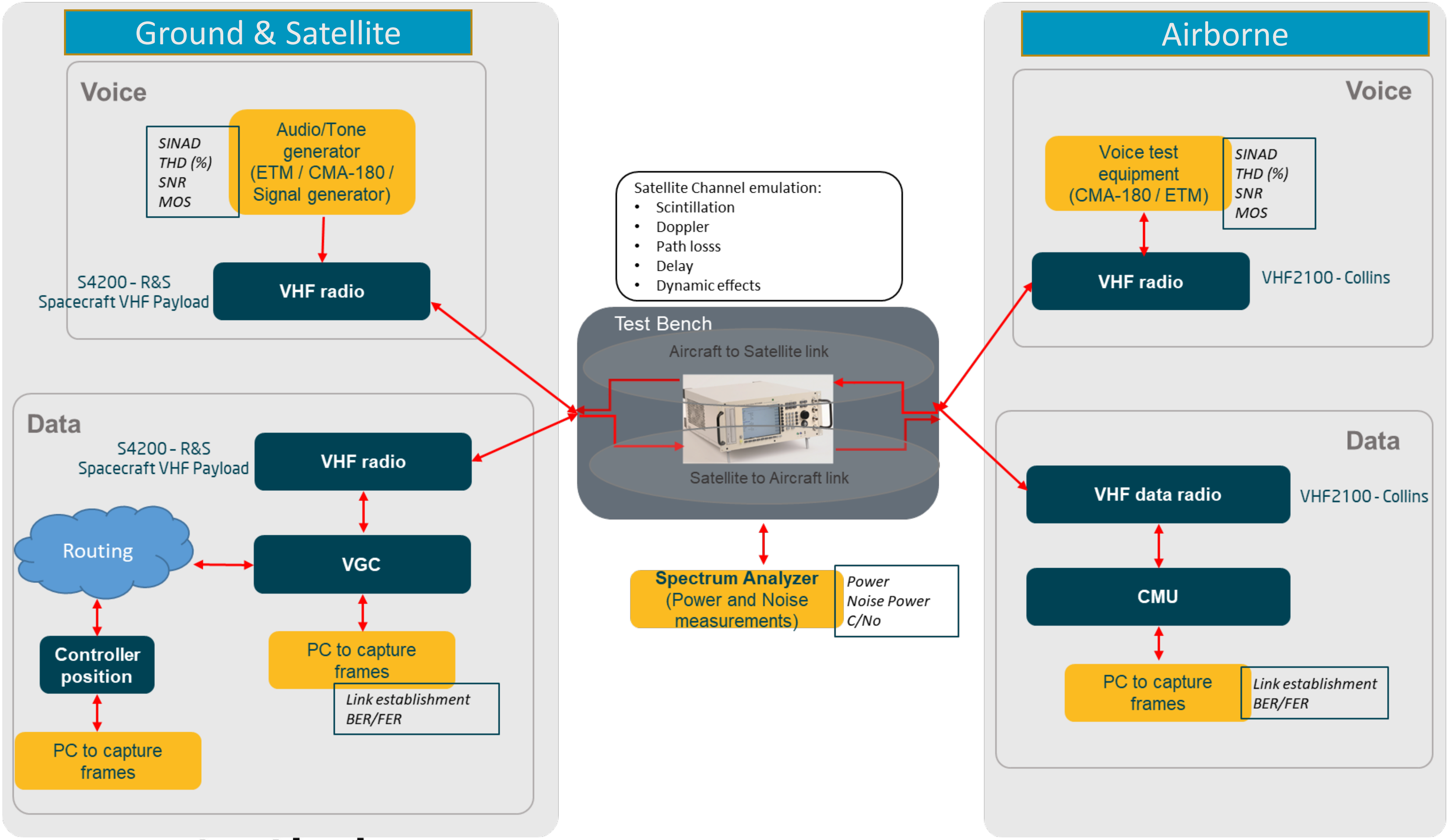
Test Bench for global communications



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Contents

Signal propagation - impact on VHF link

- **Objective:** Evaluate impact of **higher satellite channel propagation attenuation and scintillation effect** to verify PFDs and SNRs for VHF Voice and VHF Data links requested in ICAO SARPS.
- **Studies / Analysis:**
  - Analysis considering variable propagation conditions, scintillation and the typical aircraft antennas characteristics and by taking into account the relevant ITU-R Recommendations/Reports for these studies
- **Tests / Measurement:**
  - Laboratory Test environment
    - Composed of commercial VHF equipment (both airborne from Collins and ground sides) deployed in ENAIRE test facilities.
    - Satellite Channel Emulator to introduce representative attenuation patterns and scintillation effect.
    - Scintillation emulated based on ITU-R models and generated through computed time series.
  - SESAR VOICE project to carry out flight tests with a LEO satellite.

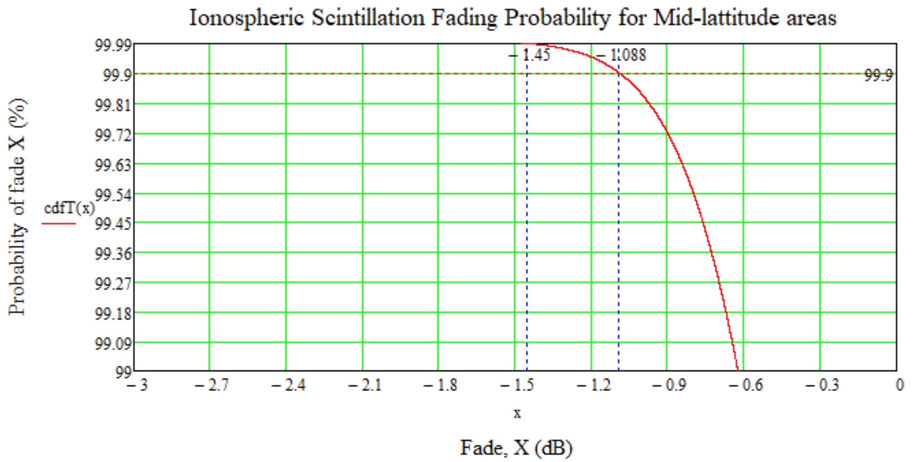
Signal propagation -Impact of satellite channel propagation on VHF links. Scintillation Analysis

ITU 5B group Inputs

- **Document 5B/112-E – ITU-R WP 3L**
  - **link to ITU-R P.531-14:** Ionospheric propagation data and prediction methods required for the design of satellite networks and systems.

- **Annex 29 to Document 5B/355-E:**
  - "…. Depending on satellite system design trade-offs, **it may be of interest not to dimension the satellite system to account for the worst-case propagation loss**, which is transient and highly dependent to time, weather and location, and to compensate with appropriate measures (like appropriate flight planning) over the concerned regions when affected. "
  - "…Based on these considerations, it is proposed to retain in this report the assumptions corresponding to the low and medium levels of scintillation losses, I.e. 1 dB and 5 dB respectively, and to establish link budgets under both of these assumptions."

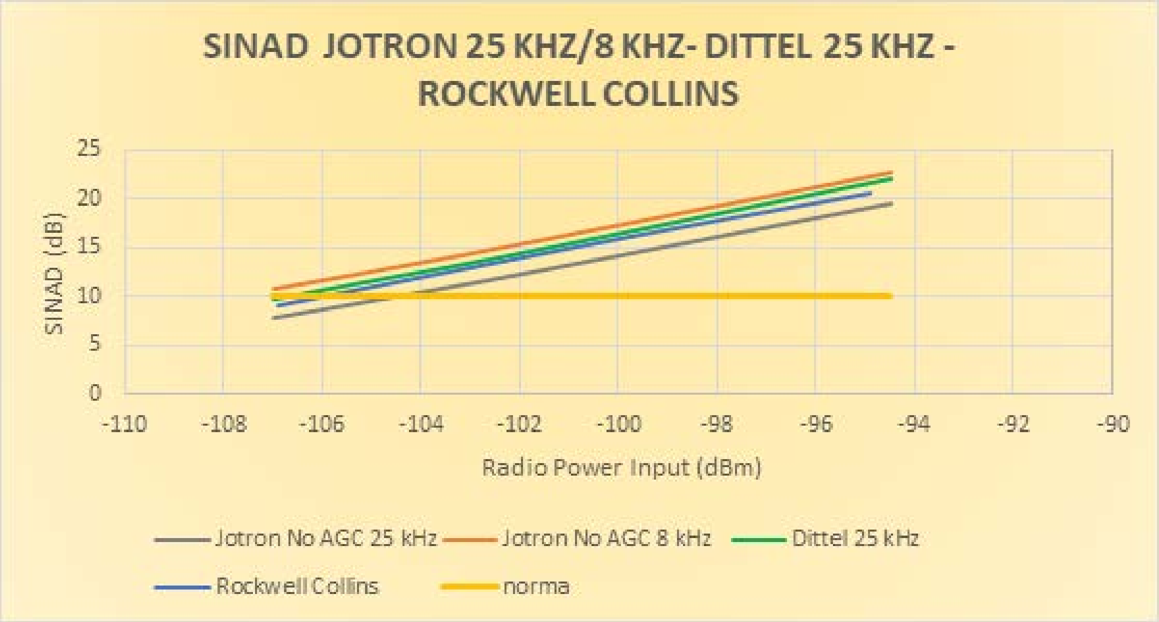
- **Document 5B/372-E – WP 3L**
  - "… The value of 1 dB seems to be appropriate for middle latitude regions…".

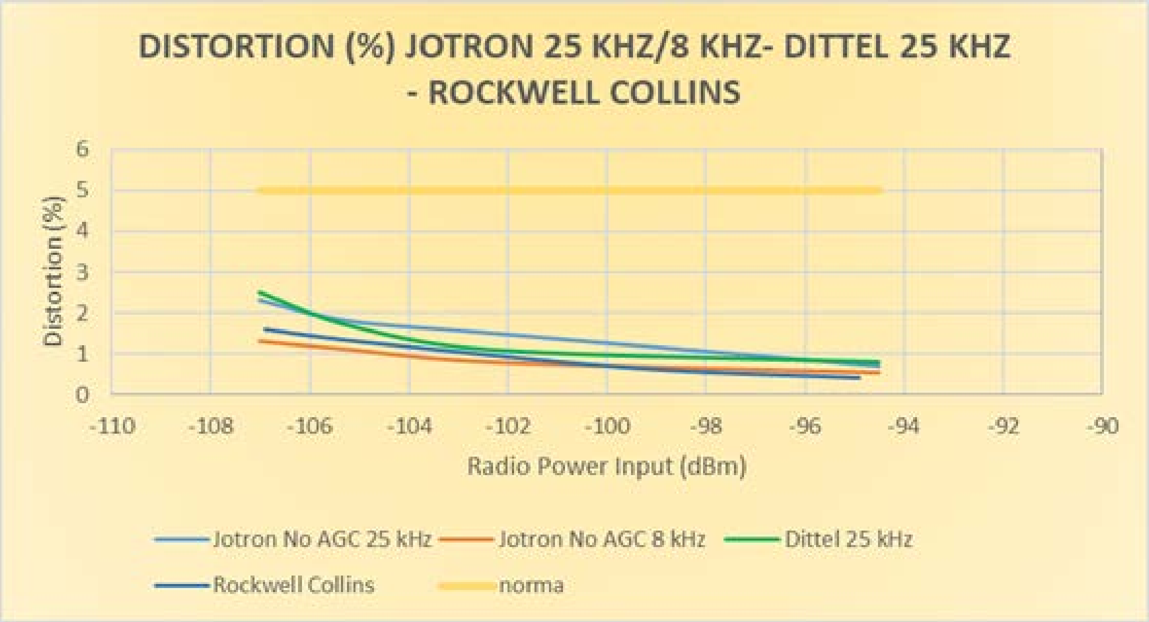


Outcomes:

- Using Nakagami formulation, it can be mathematically modeled by a distribution function for middle latitudes areas considering existing scintillation bibliography and statistical data around 138MHz. Therefore, as was discussed with ITU-R Working Party 3L and according to Nakagami model, **1 dB of fading effect for 99,9% of cases in middle latitudes is considered**.

Signal propagation - Impact of satellite channel propagation on VHF links. Voice Calibration Tests: C/No and sensitivity

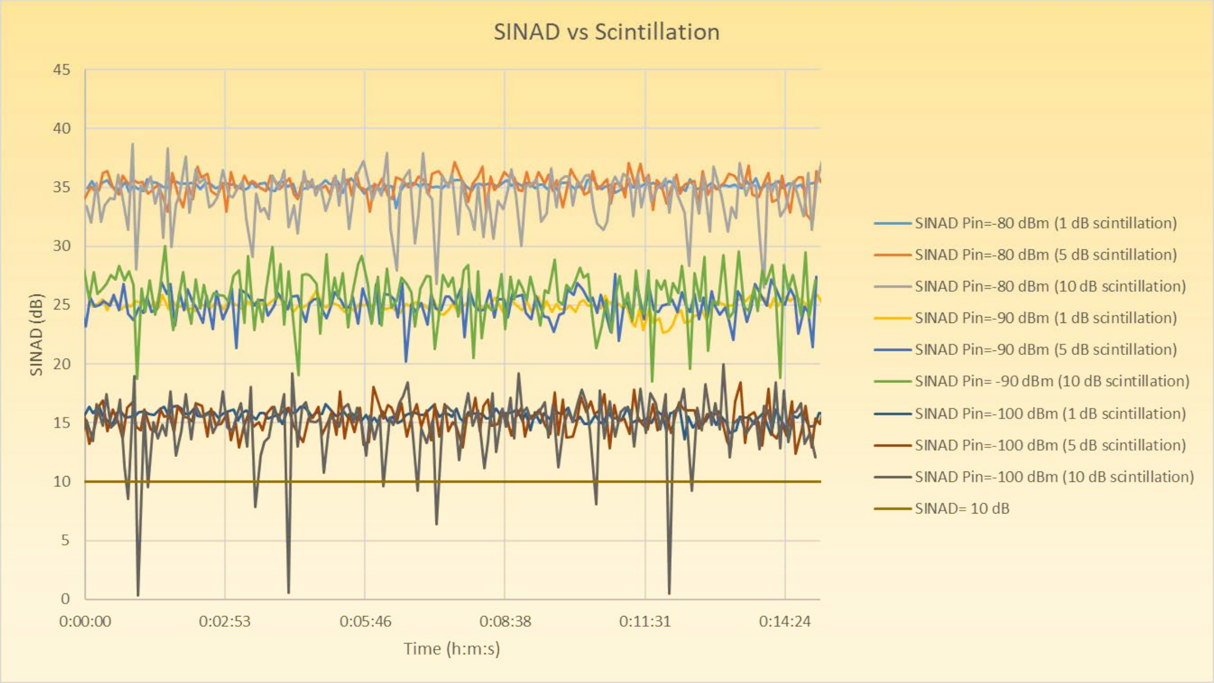


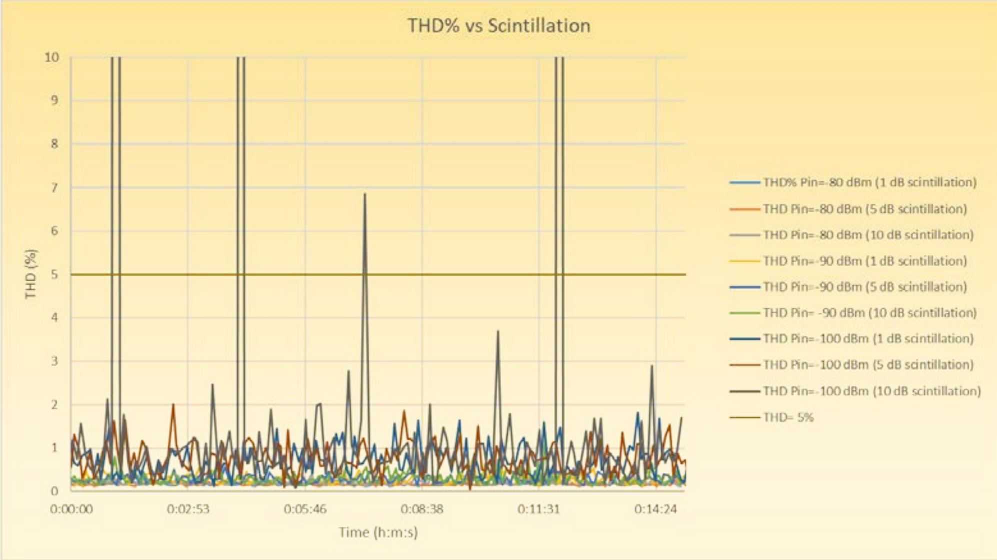


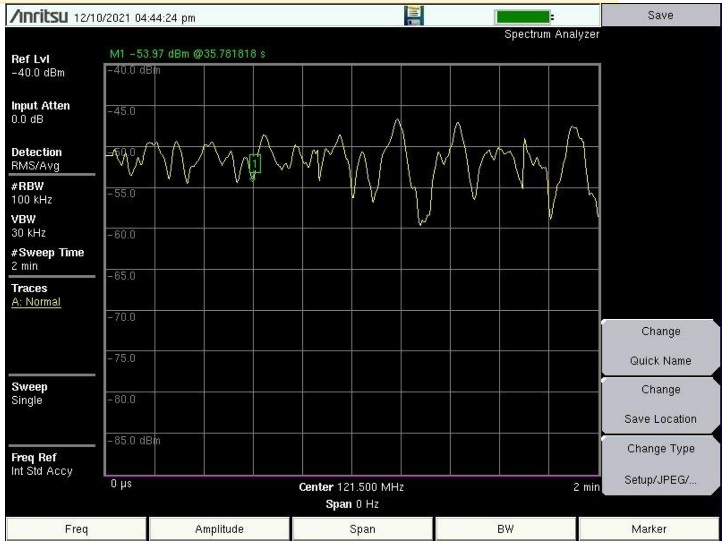
- Calibration based on power levels from Link budget computation. Reference results to compare with the ones when satellite channel effects are introduced.
- **Performance of demodulated audio is above the values specified** in ICAO SARPS (SINAD >10 dB and THD<5%) for the expected range of input powers.

SINAD: Signal-to-noise and distortion ratio

Signal propagation - Impact of satellite channel propagation on VHF links. Voice Tests: Scintillation



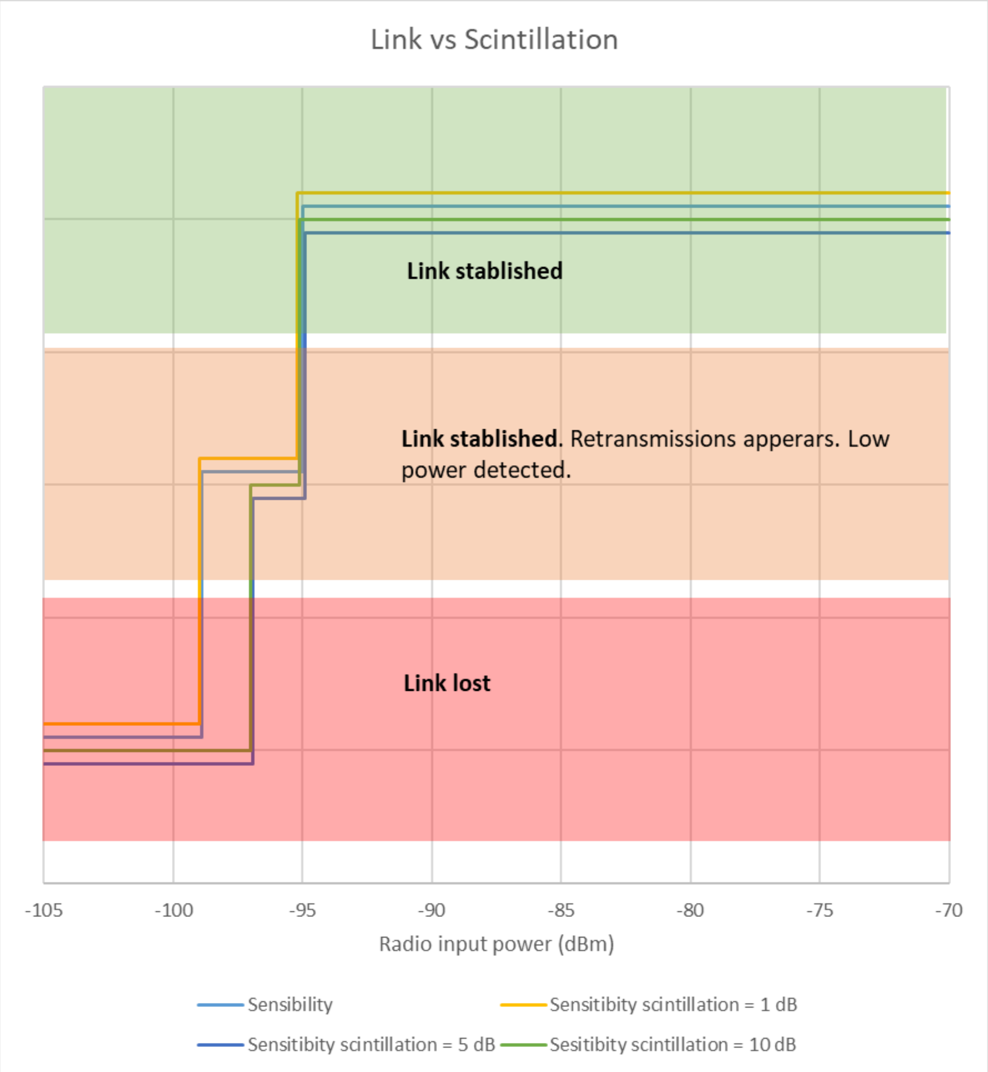




- Tests of 3 scintillation time series with different attenuations (1 dB middle latitudes, 5 dB high latitudes) and 10 dB (equatorial)
- **SINAD and THD% are over values specified** in ICAO SARPS (SINAD >10 dB and THD<5%) when scintillation is applied, except a few instants for the 10 dB scintillation case.

SINAD: Signal-to-noise and distortion ratio

Signal propagation - Impact of satellite channel propagation on VHF links. Preliminary DATA link Tests: sensitivity & Scintillation



- Calibration was done with power level from Link budget computation. **Data link was established until a power level of –99 dBm**.
- VDLM2 retransmissions avoid some scintillation effects minimizing its effects in the link behaviour.
- No degradation is observed for 1 dB scintillation case with respect no scintillation. For 5 dB and 10 dB cases, there is no degradation for inputs levels higher than -97 dBm.

Contents

Doppler effect on VHF link

- **Objective:** Evaluate the **impact of the satellite Doppler effect in airborne VHF radios**, taking into account currently defined ICAO SARPS specification for carrier frequency acquisition range. To be assessed for VHF Voice and VHF Data (focus on VDLm2).

- **Studies / Analysis:**
  - Computation of the aggregated frequency offset over the Satellite footprint with the main contribution of the Satellite Doppler shift.
  - Study of the impact on VHF Data reception and assess the necessity of a pre-compensation mechanism.
  - Study of the impact on VHF Voice reception for 25 kHz channel.

- **Tests / Measurement:**
  - Laboratory Test environment
    - Composed of commercial VHF equipment (both airborne and ground sides) deployed in ENAIRE test facilities.
    - Representative satellite Doppler effect profiles introduced in the VHF links by a Satellite Channel Emulator.
    - Evaluate the maximum Doppler shift tolerated, both for voice and data that a commercial airborne VHF radio.
  - SESAR VOICE project to carry out flight tests with a LEO satellite.

Doppler effect on VHF link – Analysis Spacecraft -> Aircraft Doppler effect

- **VDL Mode 2 Standards Specifications**
- **ED-92C** Minimum Operational performance standard for **an airborne VDL Mode-2 system** operating in the frequency range 118-136.975 MHz

2.2.1.2.7 Frequency Capture Range

The receiver willbe capable of acquiring and maintaining a lock to the desired signal tuned to any selected channel at or above the sensitivity level (Section 2.2.1.2) with the maximum permitted signal frequency offset defined below.

The receiver will achieve the error rate requirement (Section 2.2.1.2) when the desired signal at the reference signal level (Section 2.2.1.2) is subject to a frequency offset of ± 967 Hz at the room temperature.

NOTE: *This value is composed of the maximum transmitter frequency error at 136.975 MHz (± 685 Hz) and the maximum Doppler shift (± 282 Hz).*

- **VHF Voice Standards Specifications**
- **Annex 10:** Volume III Communications Systems Part II – Voice Communication Systems
- Effective **acceptance bandwidth for 25 kHz** channel spacing (including Doppler shift)

2.3.2.3 *Effective acceptance bandwidth for 100 kHz, 50 kHz and 25 kHz channel spacing receiving installations.* When tuned to a channel designated in Volume V as having a width of 25 kHz, 50 kHz or 100 kHz, the receiving function shall ensure an effective acceptance bandwidth as follows:

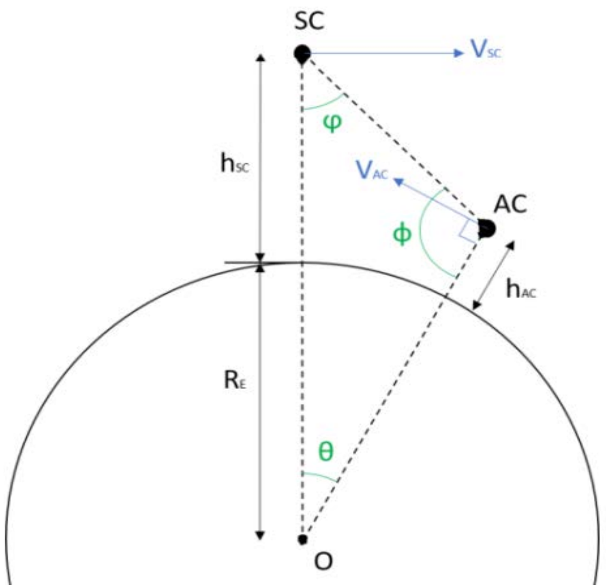
a) in areas where offset carrier systems are employed, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 has a carrier frequency within 8 kHz of the assigned frequency;

b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 has a carrier frequency of plus or minus 0.005 per cent of the assigned frequency.

	VDLM2 (Hz)	Voice 25 kHz offset carrier	Voice 25 kHz no offset carrier
Frequency stability [ppm]	±5	±30	±5
Frequency stability [Hz]	±685	±4110	±685
Acceptance bandwidth [ppm]	**±7**	**±58**	**±50**
Acceptance bandwidth [Hz]	**±967**	**±8000**	**±6850**

Doppler effect on VHF link- Analysis Spacecraft -> Aircraft Doppler effect

- **Frequency error budget computation**
- Maximum expected shift ±3.2 kHz.
- Maximum Doppler shift experienced with a direct overflight. Doppler shift attenuated as maximum spacecraft elevation decreases.
- For a Doppler estimation, uncertainties on Doppler shift contributions are also considered. (around 60 Hz from aircraft and spacecraft position accuracy, delay in error computation)

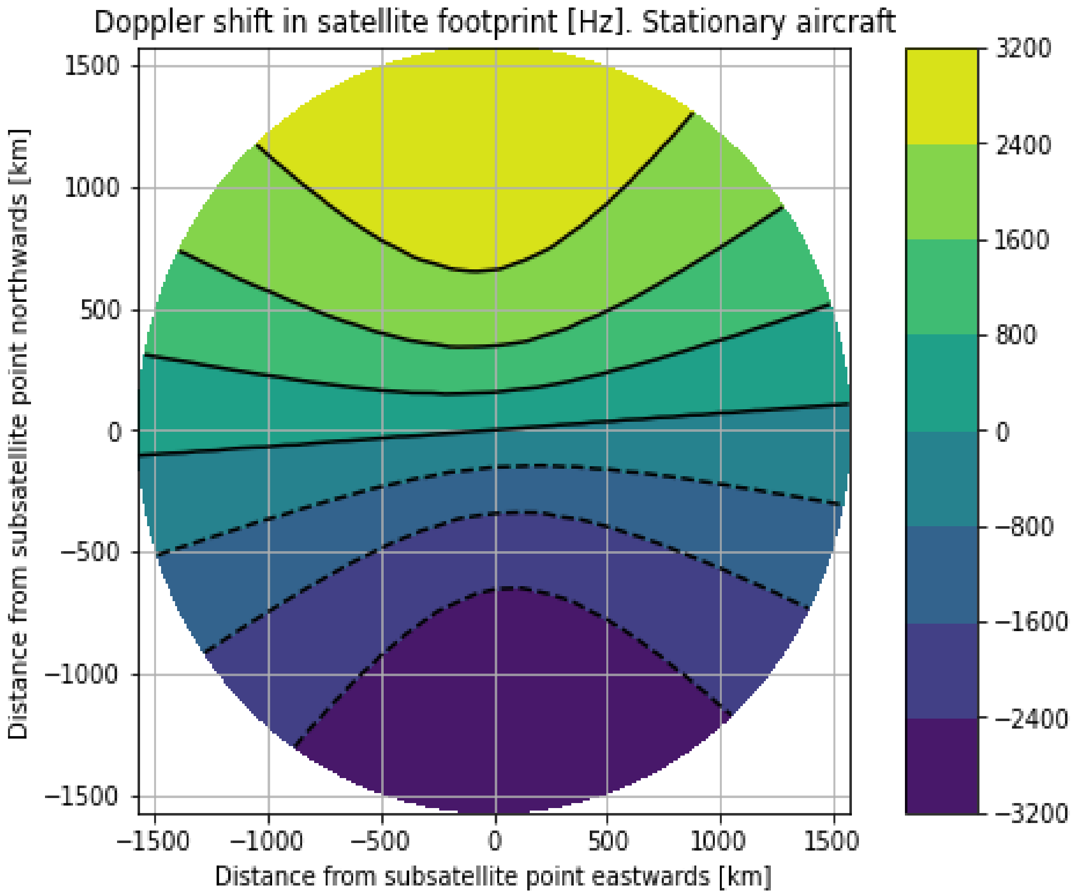


	Frequency error [Hz]	Comments
Spacecraft oscillator	±15	
Spacecraft-aircraft velocity	±3170	It can be estimated
Aircraft oscillator	±685	Not to be considered
Uncertainty in aircraft & spacecraft position / velocity	±60	

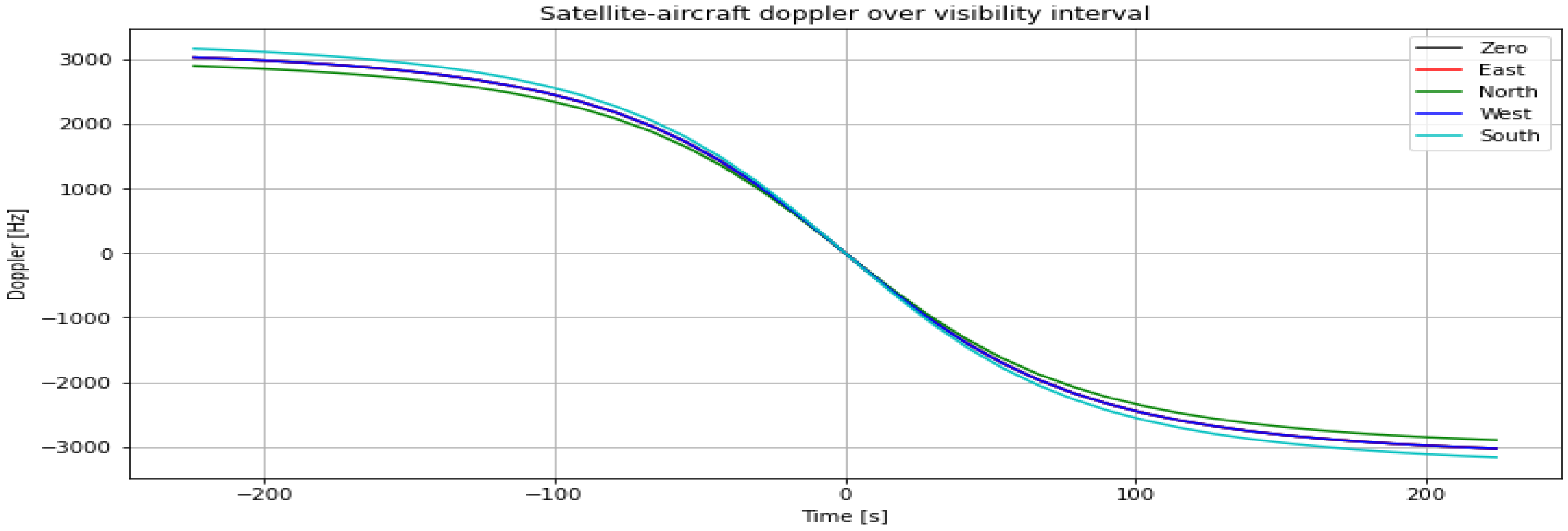
Doppler effect on VHF link- Analysis Spacecraft -> Aircraft
Doppler effect

Example of Doppler shift experienced by an aircraft in the footprint

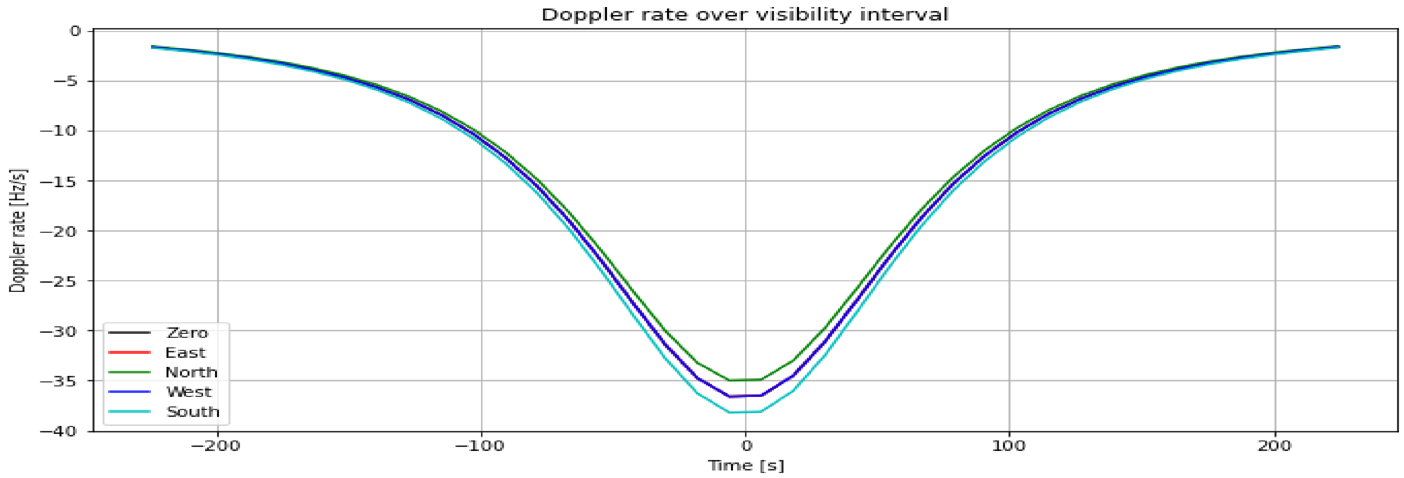
- Orbit: polar or SSO orbit at 650 km
- Orbital period approx. 100 min.
- Evolution on visibilities is highly dynamic due to spacecraft motion.
- Every few minutes, each spacecraft reaches the position of the preceding spacecraft, i.e. its covered region is completely renewed with this frequency
- Doppler Frequency of +/- 3.2 kHz



Doppler effect on VHF link- Analysis Spacecraft -> Aircraft Doppler effect



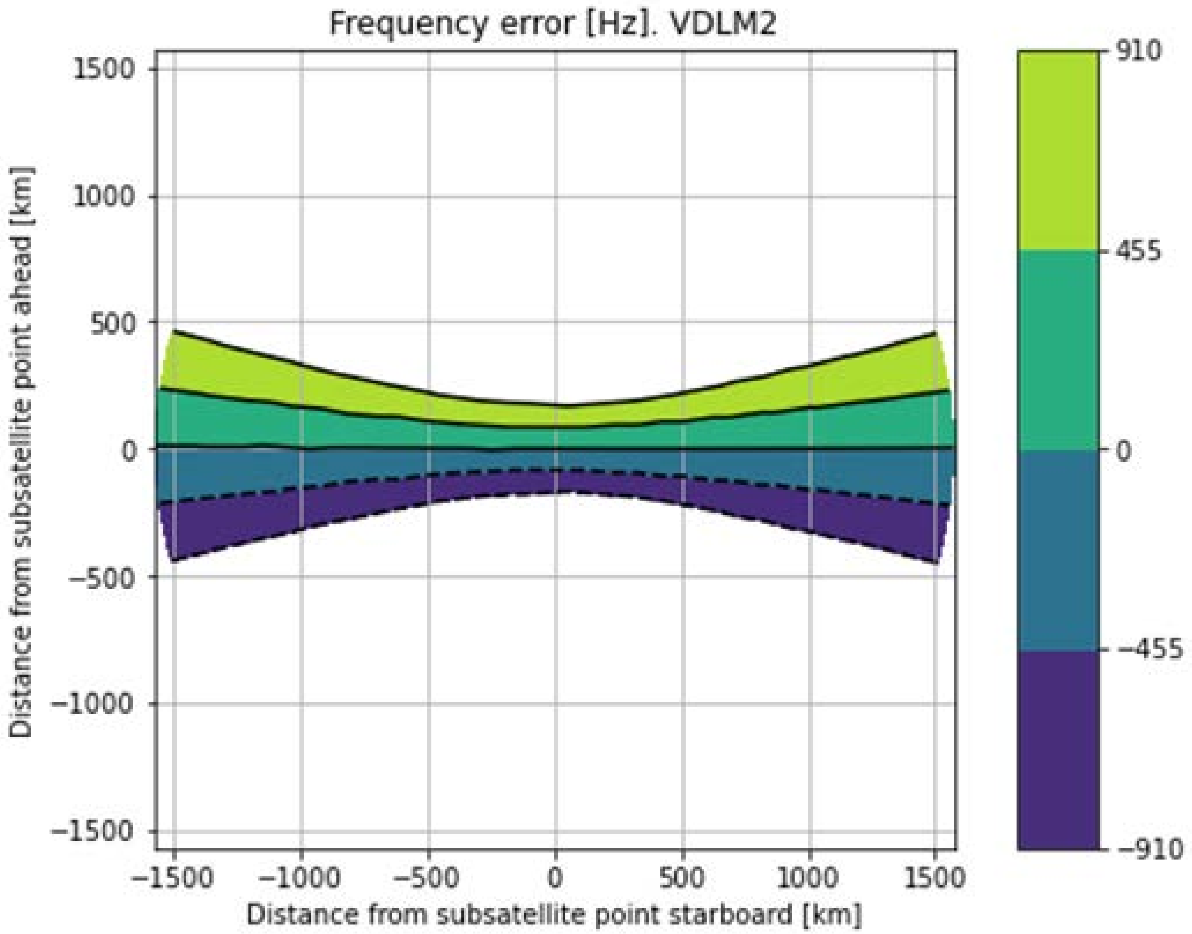
Doppler shift and Doppler rate experienced by an aircraft as function of time in a spacecraft overflight when flying from North to South



Doppler effect on VHF link- Analysis Spacecraft -> Aircraft Doppler effect

Frequency offset at transmission. No offset

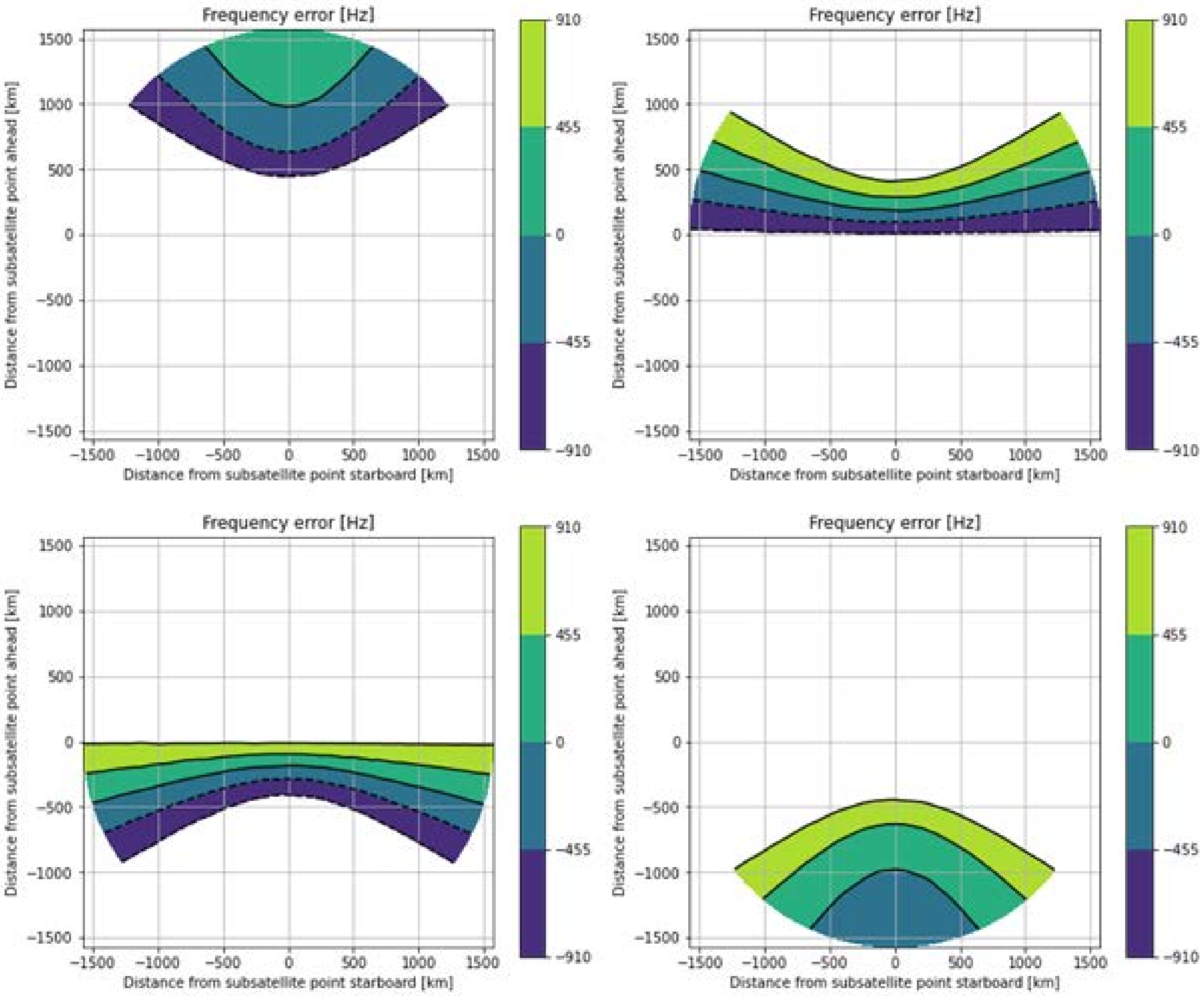
- The transmitting satellite does not apply any frequency offset to the transmitted signal and the receiver in the aircraft have an frequency acceptance threshold of 910Hz (VDLM2 minus SC uncertainties), only a small fraction of the footprint will be able to receive the message
- Area receiving low frequency offset is 300 km in direction of satellite velocity and complete footprint (3000 km) in direction perpendicular to satellite velocity



Doppler effect on VHF link- Analysis Spacecraft -> Aircraft Doppler effect

Frequency offset at transmission. Offset

- If the transmitting satellite applies an offset to the frequency transmitted, the reference frequency is received at positions located ahead or behind the satellite
- Figure shows region in footprint which has a frequency error lower than ±910 Hz when satellite applies different offsets to the central frequency (2730, 910, -910, -2730 Hz)
- Area receiving low frequency offset is 400 km in direction of satellite velocity and complete footprint (3000 km) in direction perpendicular to satellite velocity



Doppler effect on VHF link- Analysis Spacecraft -> Aircraft Doppler effect

Example of VHF Voice concept of operation based on previous analysis and to demonstrate the technical feasibility of the approach

- Message will be transmitted by as many spacecraft as needed to cover the FIR
- Messages will be transmitted with a frequency offset of ±5kHz (± 4.8kHz can be considered)
- Sign for the offset will be the same for each orbital plane and opposite for adjacent planes

Doppler effect on VHF link- Analysis Spacecraft -> Aircraft Doppler effect

Example of VDL2 concept of operation based on previous analysis and to demonstrate the technical feasibility of the approach.

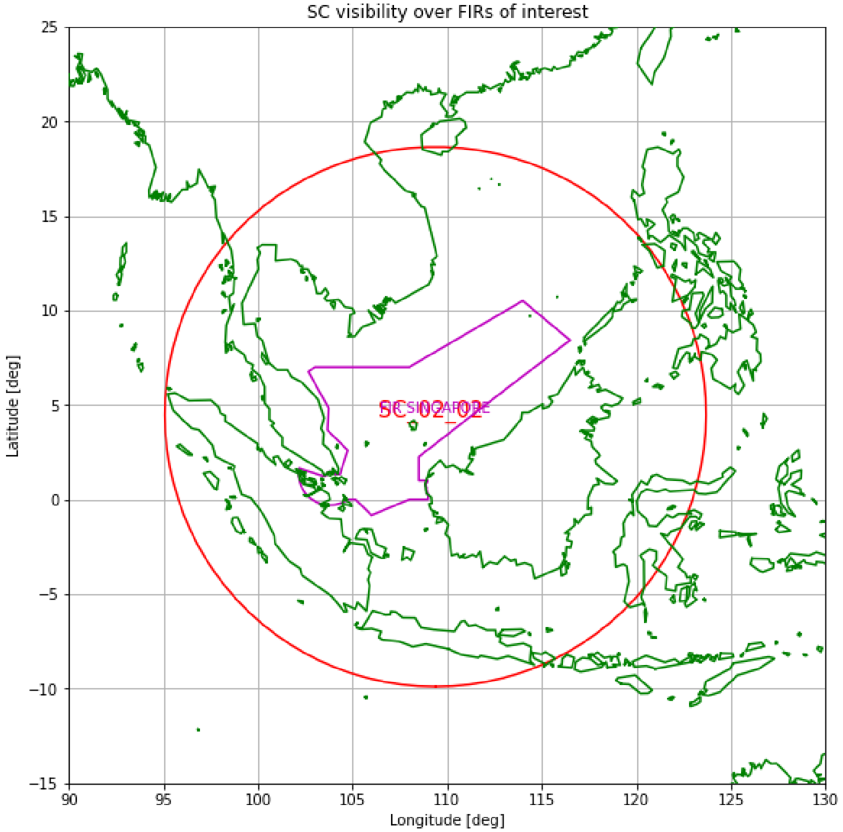
- Satellite which has best visibility of target aircraft (or region for the broadcast) shall transmit the message
- If the burst is broadcast, the same burst will be transmitted several times(4) times with different frequency offsets_
  - Broadcast with frequencies +2700,+900,-900,-2700 Hz guarantees reception for Doppler shifts up to ±3600 Hz, enough for supersonic aircraft
  - Repetition is not expected to impact the capacity significantly as broadcast messages are `not frequent enough.
- If the burst is targeted to a specific aircraft, the frequency offset shall be added to compensate the expected Doppler shift based on known spacecraft-aircraft position/velocity
- Several frames targeted to different aircraft might be grouped in the same burst if the required frequency compensation is similar for all aircraft

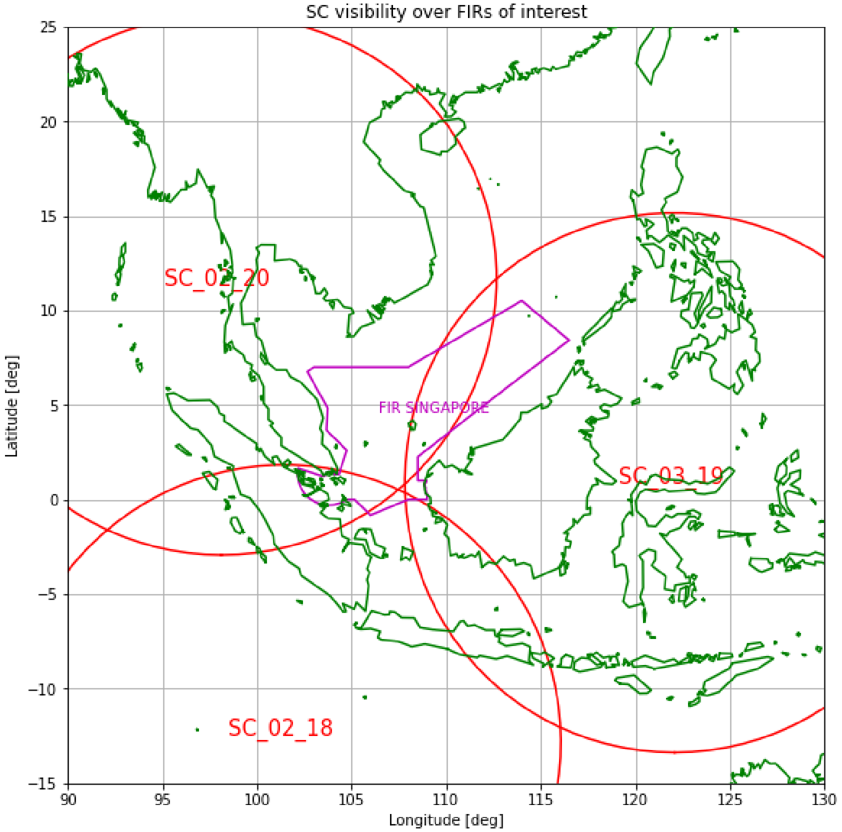
Constellation setup

- Orbit: polar or SSO orbit at 650 km
- Global coverage for TX and RX roles independently
- Visibilities of adjacent satellites with the same role have some overlap to guarantee smooth spacecraft handover
- Orbital period approx. 100 min.
- Evolution on visibilities is highly dynamic due to spacecraft motion.
- Every few minutes, each spacecraft reaches the position of the preceding spacecraft, i.e. its covered region is completely renewed with this frequency

Constellation setup. Use case

- Singapore FIR is detailed
- Best case, one SC covers complete FIR.
- Worst case, a combination of 3 SC cover FIR completely





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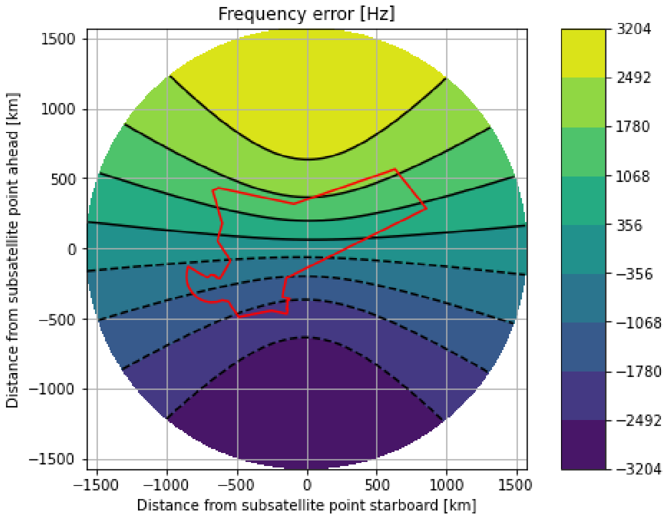
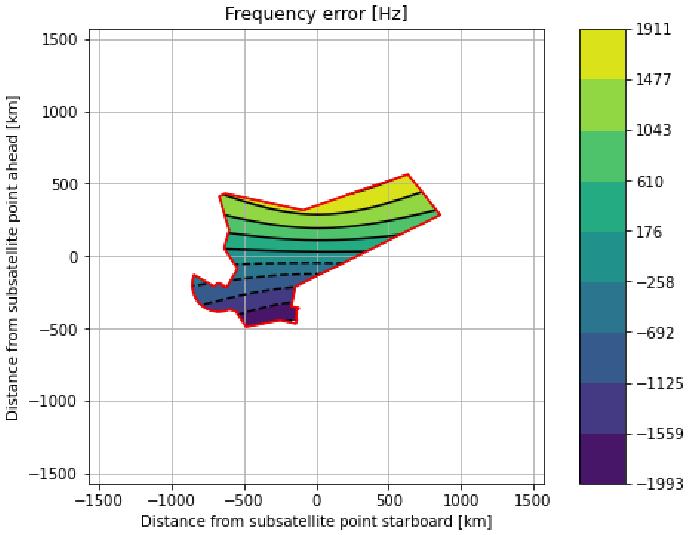
Voice 25 kHz. Use Case. No offset carrier

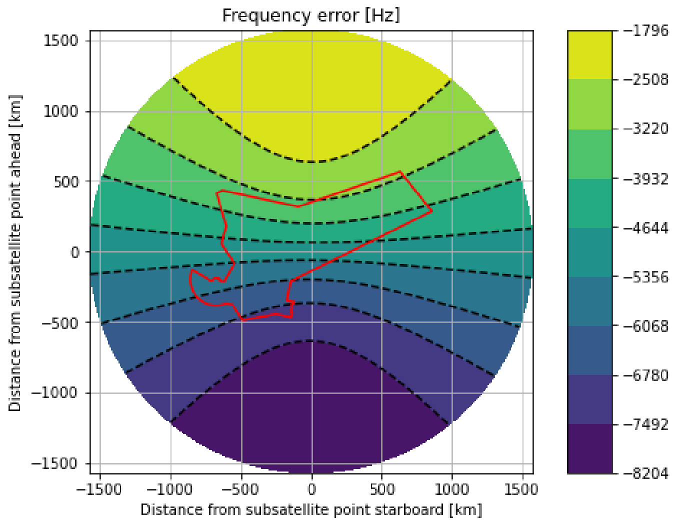
- Complete FIR covered by a single satellite
- Maximum frequency error experienced in both FIRs is ±1.9kHz
- Frequency error within acceptance bandwidth of radios with offset carrier and without offset carrier.

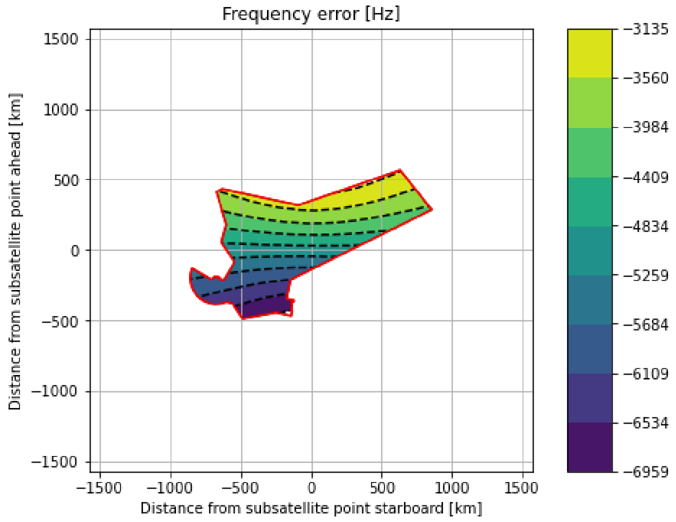




Voice 25 kHz. Use Case. With offset carrier

- Complete FIR covered by a single satellite
- Maximum frequency error experienced in the FIR is ±7kHz (For positive and negative offsets)
- Frequency error within acceptance bandwidth of radios with offset carrier but exceeding the acceptance bandwidth for radios without offset carrier.





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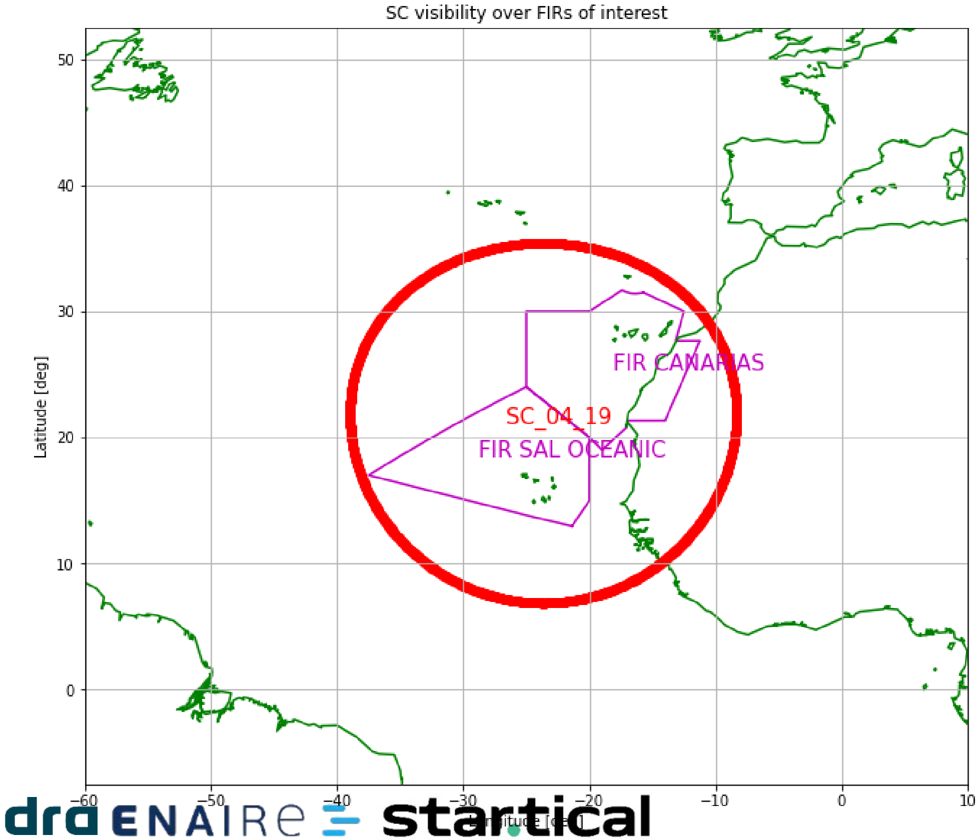
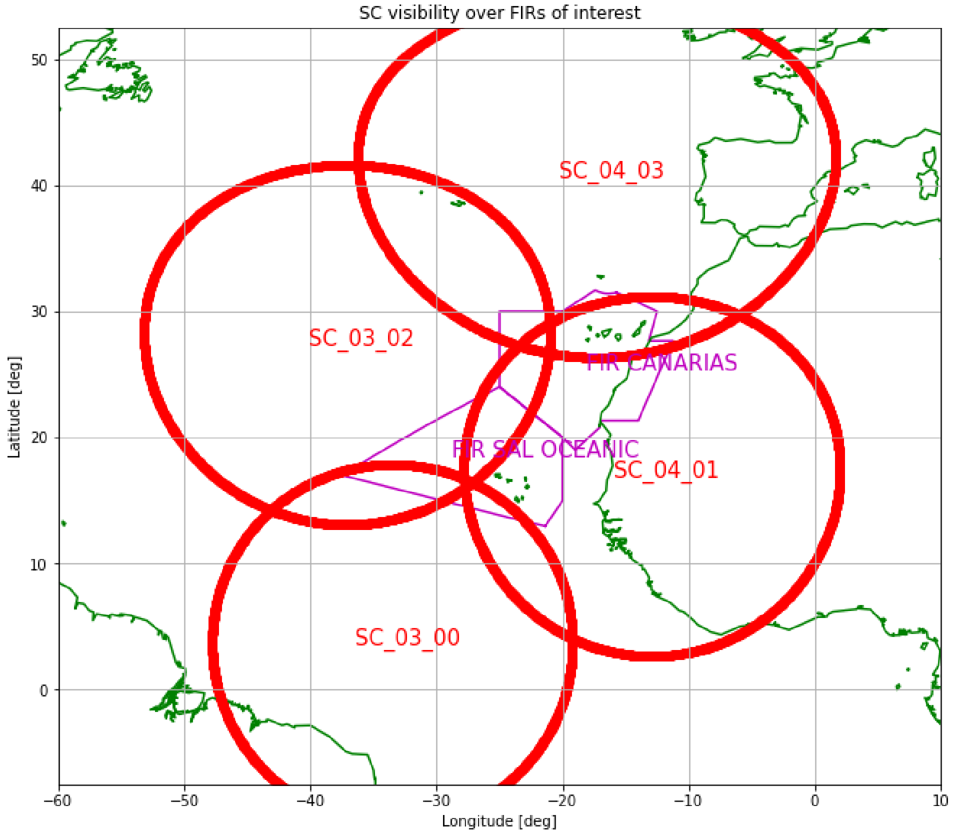
Constellation setup. Use case

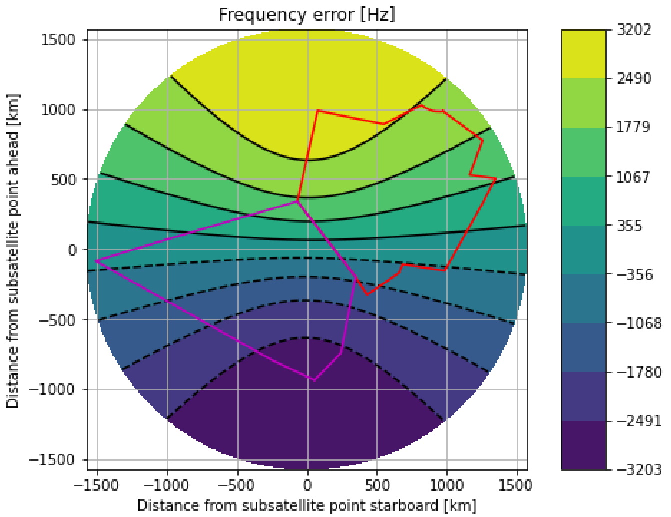
- Canarias and Cape Verde FIRs are detailed
- Best case, one SC covers complete FIR.
- Worst case, a combination of 3 SC cover each FIR completely

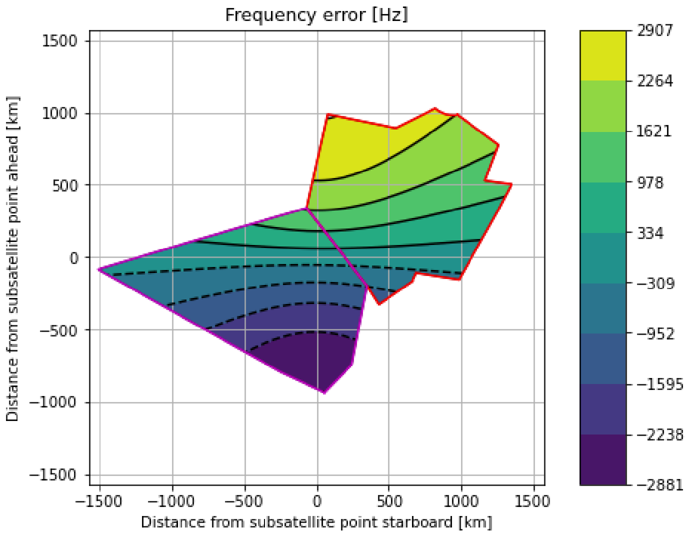




Voice 25 kHz. Use Case. No offset carrier

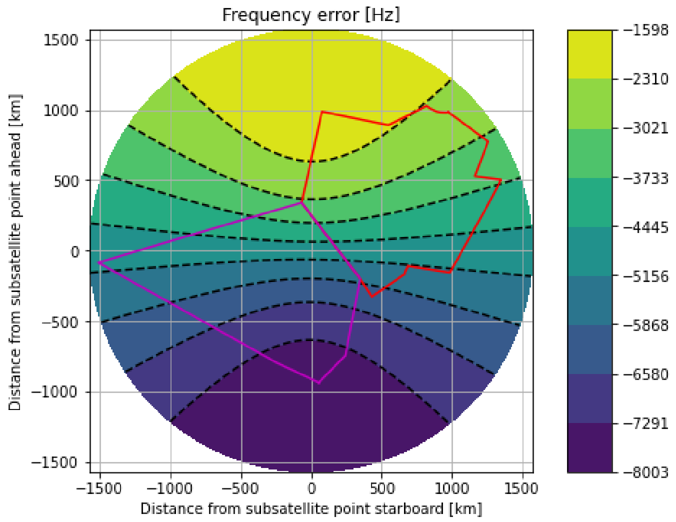
- Complete FIR covered by a single satellite
- Maximum frequency error experienced in both FIRs is ±3kHz
- Frequency error within acceptance bandwidth of radios with offset carrier and without offset carrier.

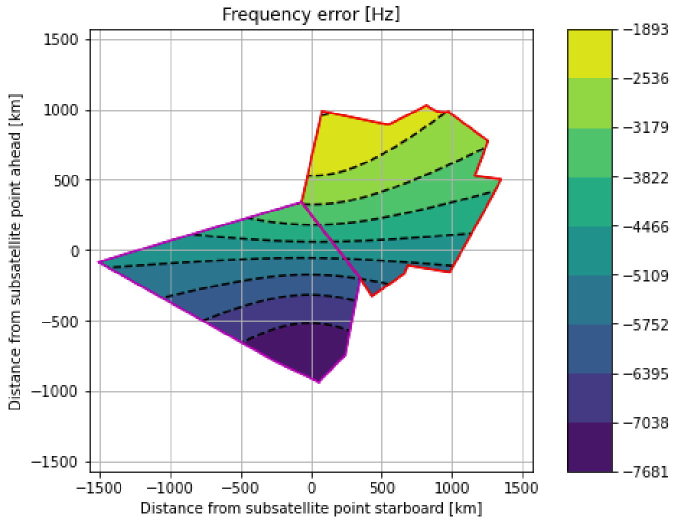




Voice 25 kHz. Use Case. With offset carrier

- Complete FIR covered by a single satellite
- Maximum frequency error experienced in both FIRs is ±8kHz (For positive and negative offsets)
- Frequency error within acceptance bandwidth of radios with offset carrier but exceeding the acceptance bandwidth for radios without offset carrier.





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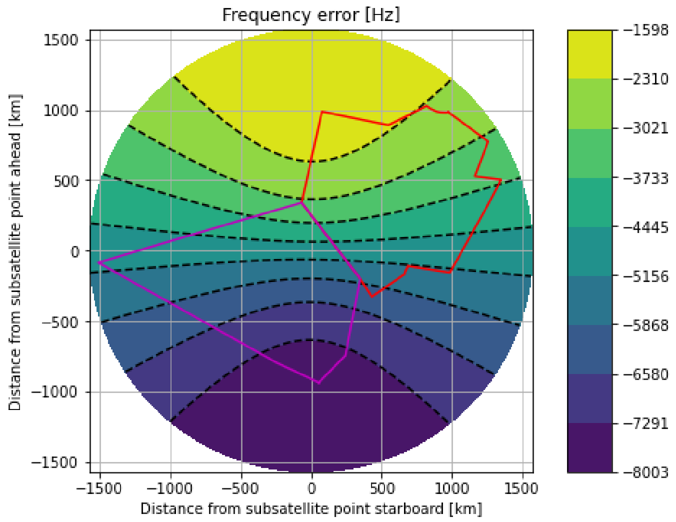
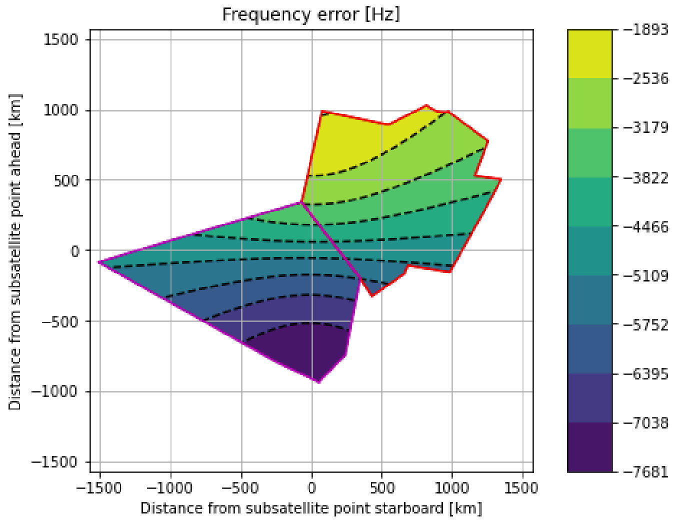
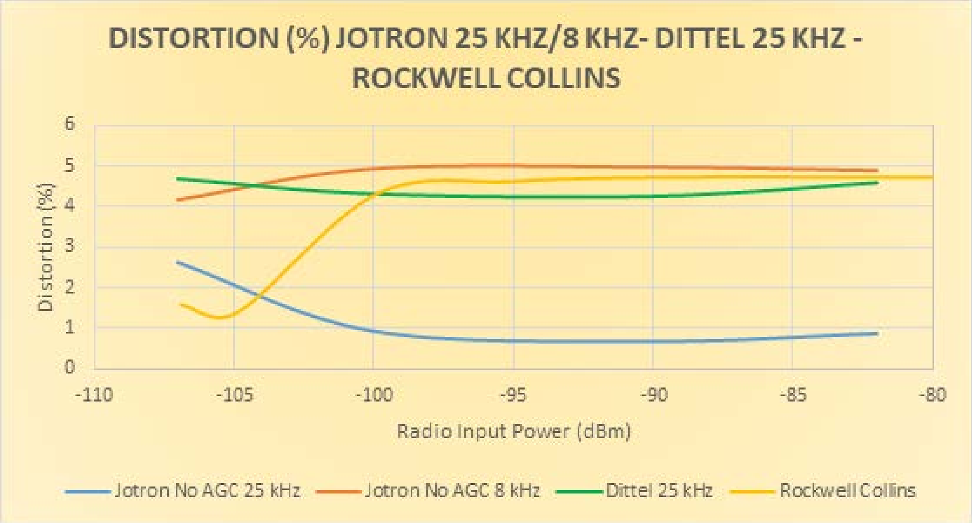
Voice 25 kHz. Use Case. With offset carrier

- Complete FIR covered by a single satellite
- Maximum frequency error experienced in both FIRs is ±8kHz (For positive and negative offsets)
- Frequency error within acceptance bandwidth of radios with offset carrier but exceeding the acceptance bandwidth for radios without offset carrier.





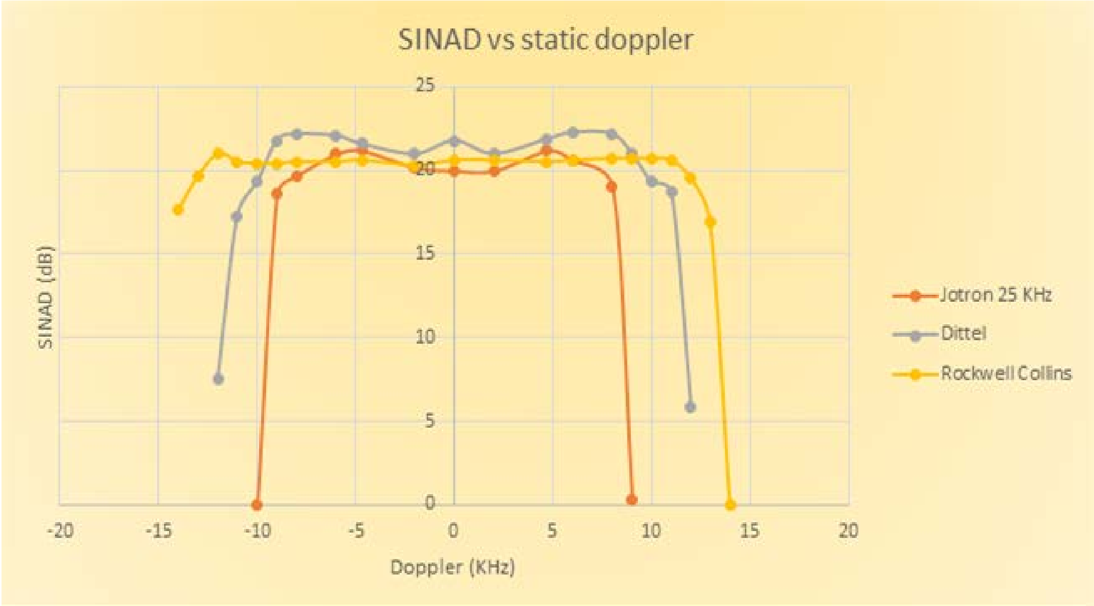
Doppler effect on VHF link- Impact of satellite channel Doppler on VHF links. VHF Voice Tests: Static Doppler



- In the radio tested, **25 KHz channels support Doppler shifts higher than the maximum Doppler shift expected** due to satellite movement (3.2 kHz).
- The behavior of the **audio demodulated when Doppler is applied is within the limits specified** in ICAO SARPS (SINAD >10 dB and THD<5%).

Maximum Doppler shift for a SINAD> 10 dB and THD<5%

SINAD vs Doppler for fix radio input power



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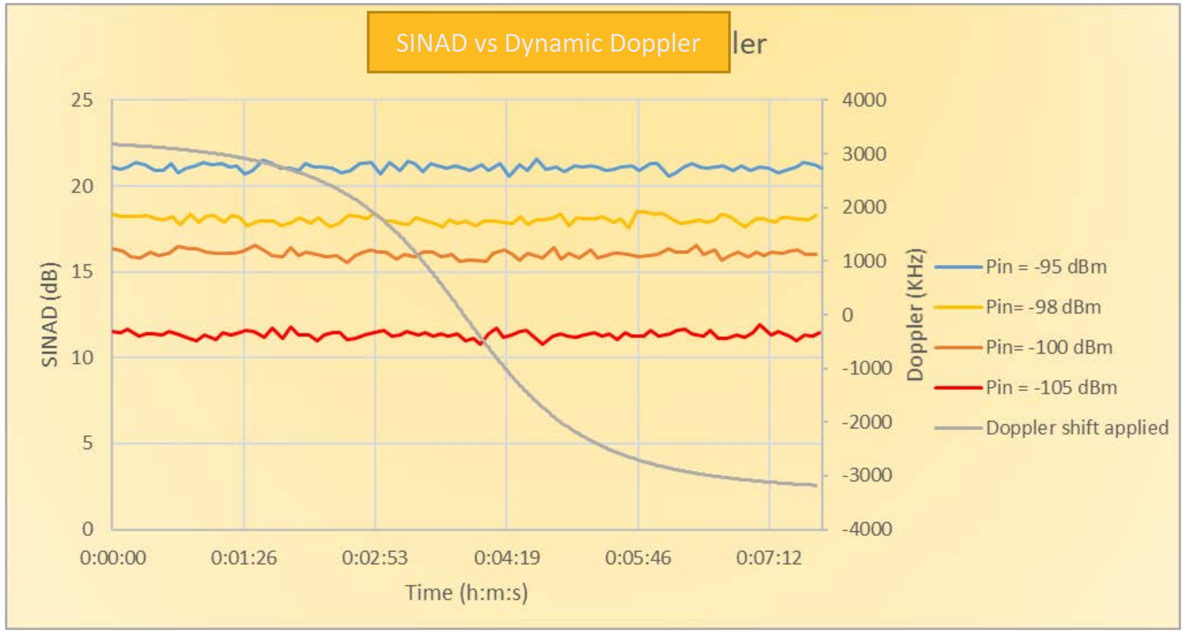
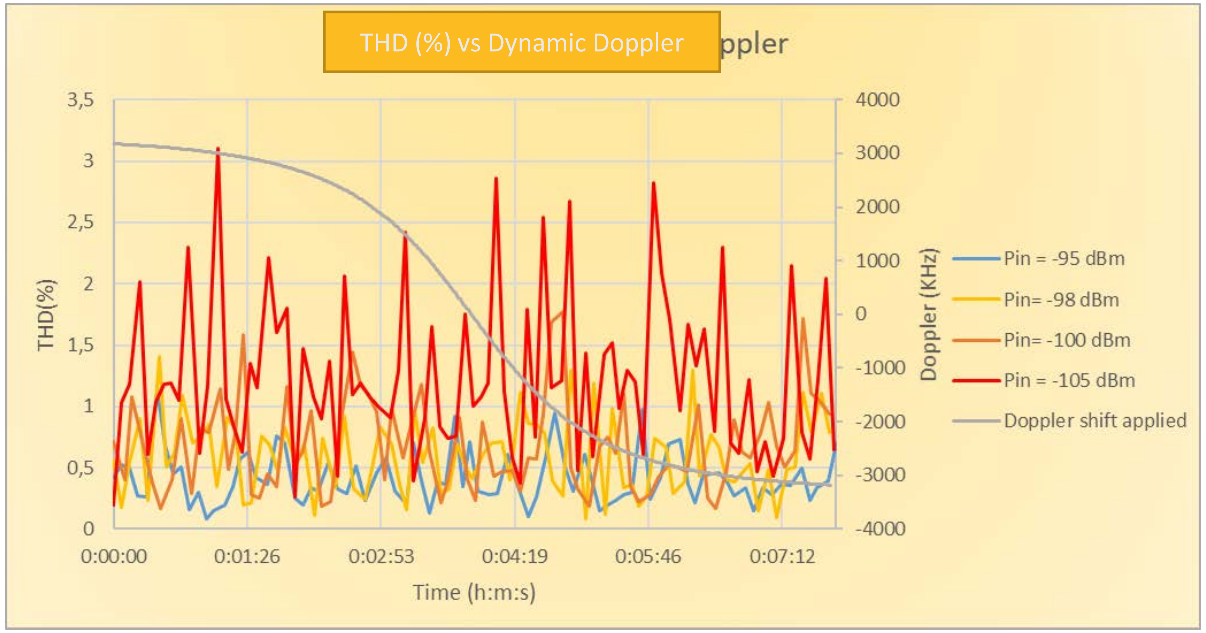
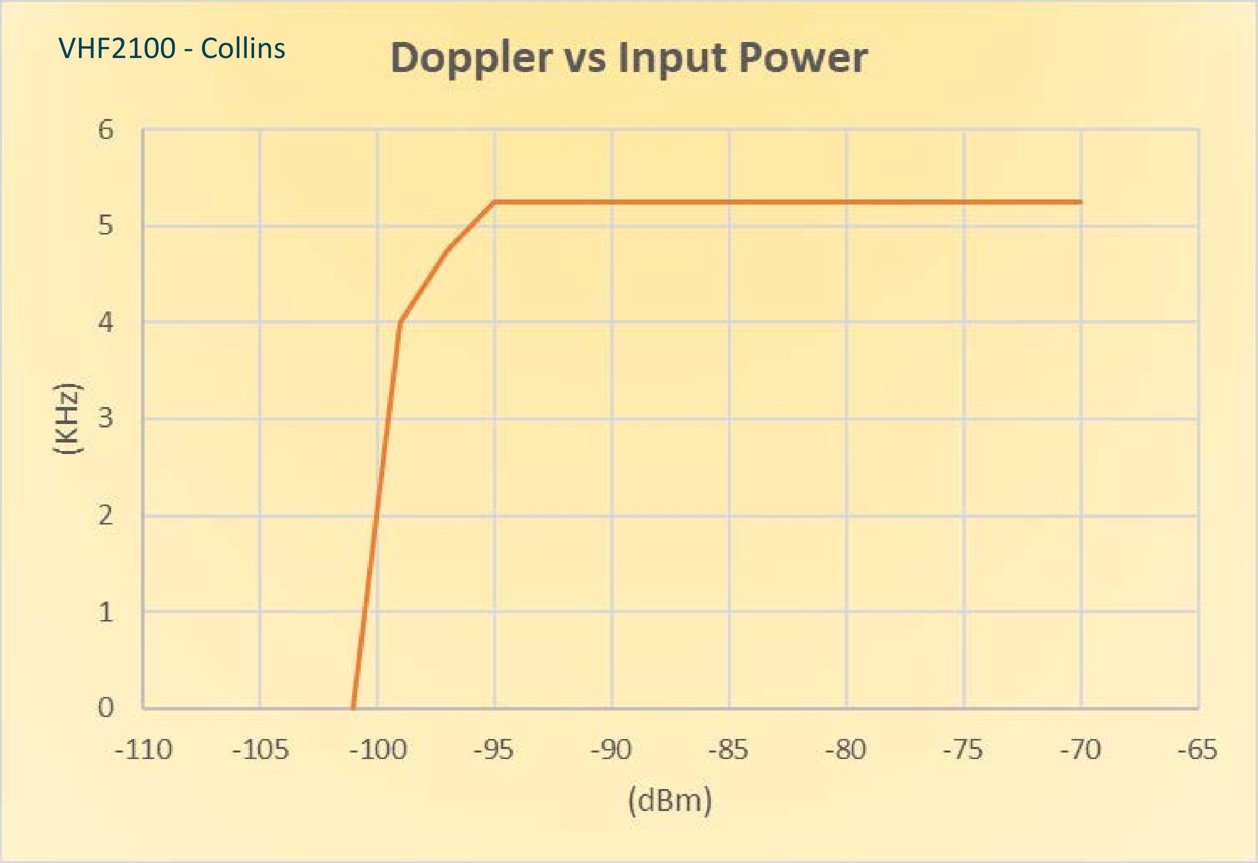
Doppler effect on VHF link- Impact of satellite channel Doppler on VHF radio. VHF Voice Tests: Dynamic Doppler





- Radio behaviour is not affected by dynamic Doppler shift.
- The performance of the audio demodulate when Doppler is applied is above the values specified in ICAO SARPS (SINAD >10 dB and THD<5%)

Doppler effect on VHF link - Impact of satellite channel Doppler on VHF radio. Data Link Tests: Doppler



Maximum Doppler shift at the receiver input for which the VDL2 link is established and maintained for different input powers

- Airborne Radio tested **(Collins VHF2100) supports Doppler shifts** due to satellite movement (3.2 kHz) that produces a **maximum frequency offset higher** than specified (ED-92C: 967 Hz).
- The Airborne radio behavior is the same when introducing dynamic Doppler effect (one satellite overflight)
- This Airborne radio is one of the most commonly installed on board aircraft

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Spectrum compatibility

- **Objective:** Study the compatibility between the space-based VHF system and systems operating inside the band 117.975-137MHz, below the band <117.975MHz and above the band >137MHz. The considered channels will be both, 25 kHz channels with AM Voice Signal and D8PSK Data Signal. The interference levels at different bands will be studied at aircraft and ground levels transmitting VHF carriers and measuring in band and out of band interference levels. Power Flux Density (PFD) and absolute value (dBW) on ground will be the key parameters involved.

- **Studies / Analysis:**
  - Analysis of ITU-R regulations affecting the harmful interference protection and determine the required level of protection to be implemented if required.
  - Analyze interference over adjacent channels coming from spectrum shift due to satellite Doppler.

- **Tests / Measurement:**
  - Test in the lab transmitter spectrum mask behavior using a real VHF amplifier.

Spectrum compatibility – Below 117.975MHz

Compatibility of Unwanted AMS(R)S Out-Of-Band and spurious emissions below 117.975 MHz to be ensured by ICAO Frequency management

ITU-R Draft Report for AI 1.7, paragraph 7.3: "… ICAO has outlined that there is also no need to perform a comprehensive compatibility study within ITU-R between the AMS(R)S and aeronautical radionavigation services. The same frequency planning and coordination works on-going within ICAO will be performed to ensure compatibility between AMS(R)S and aeronautical radionavigation services."

Spectrum compatibility – In band 117.975MHz-137 MHz

According to the summary in ITU-R Draft Report for AI 1.7 of ITU-R WP5B November meeting:

- Section 9.1 for in the frequency band 117.975-136 MHz and Section 9.2 for in the frequency band 136-137 MHz :

“Protection of in-band systems operating under AM(R)S and AM(OR)S, and of adjacent band systems below 117.975 MHz under ARNS would be resolved through conventional frequency planning exercise, involving the relevant aeronautical authorities including ICAO, and assigning frequencies to the satellite system over interested regions in a manner that ensures compatibility between ground and satellite facilities.”

Spectrum compatibility above 137MHz

Based on the summary in Draft Report for AI 1.7 of ITU-R WP5B November meeting:

- Section 9.1 for operating of the space-based VHF system in the frequency band 117.975-136 MHz:

"Protection of adjacent-band systems operating above 137 MHz in the Mobile satellite service (space-to-Earth), Space operation service (space-to-Earth), Space research service (space-to-Earth), and Meteorological satellite service (space-to-Earth) would be ensured, thanks to the 1 MHz guard band in 136-137 MHz."

- Section 9.2 for operation of the space-based VHF system in the frequency band 136-137 MHz:

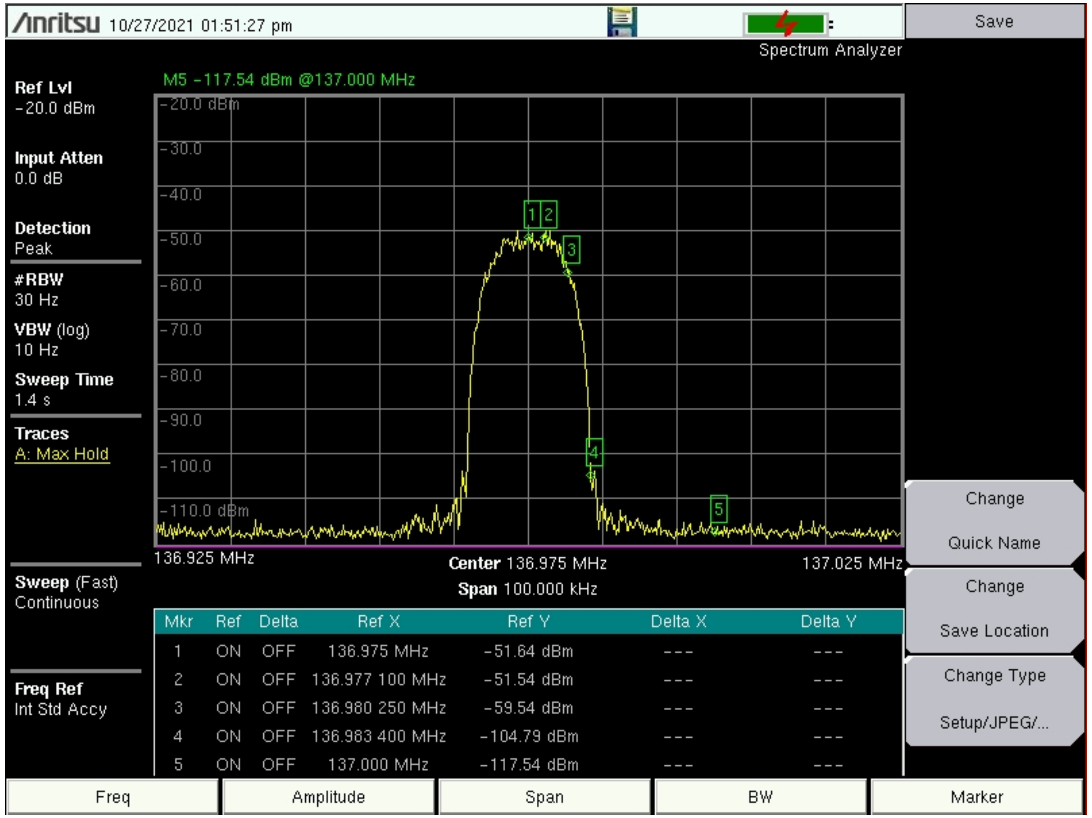
"Protection of adjacent-band systems operating above 137 MHz in the Mobile satellite service (space-to-Earth), Space operation service (space-to-Earth), Space research service (space-to-Earth), and Meteorological satellite service (space-to-Earth) would be ensured by a spectrum roll-off in order to achieve a maximum emission above 137 MHz not more than -156.3 dB(W/(m^2 · 14 kHz)) or the equivalent -197.7 dB(W/(m^2 · Hz))."

Spectrum compatibility above 137MHz

Actual ground VHF radio measurements on a VHF D8PSK frequency modulation 10,5Ksymbols/s

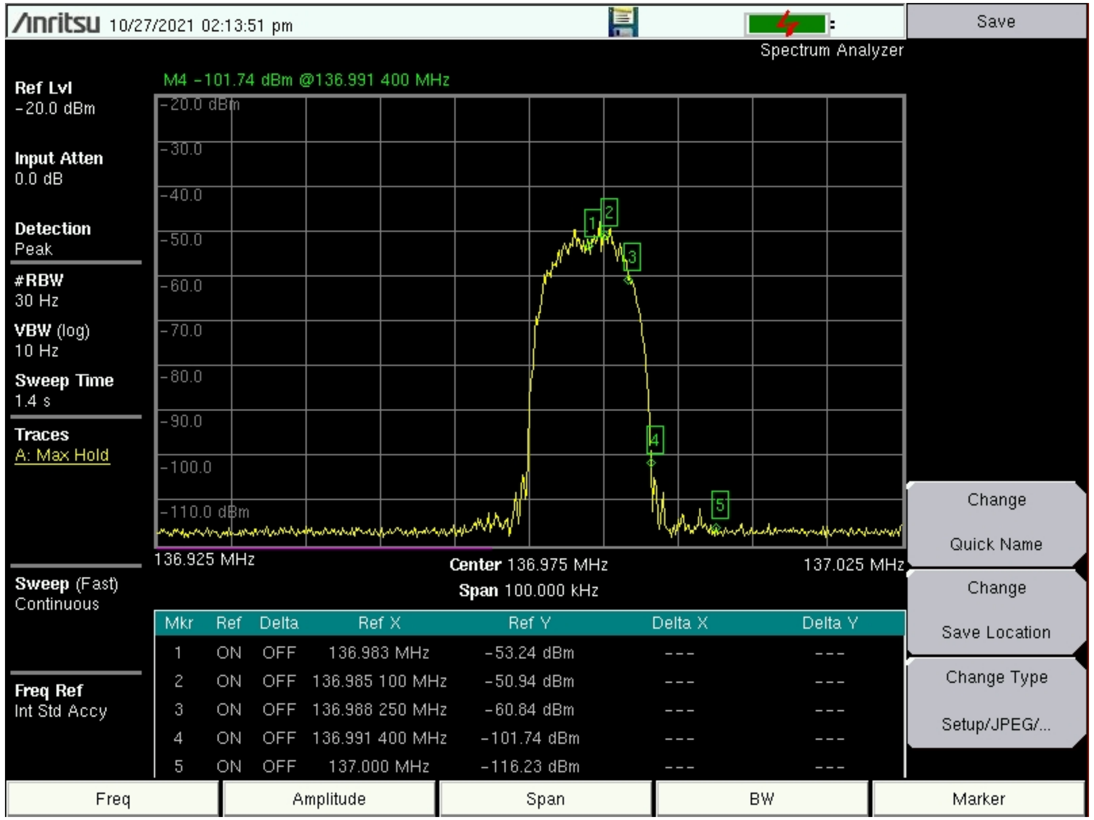
Without Doppler

- **@136.975MHz**
- **Out of Band power < -60dBc spurious**



With Worst case Doppler

- **@136.975MHz+8KHz (2 * times Doppler shift)**
- **Out of Band power < -60dBc spurious**



Out of Band (OoB) power at 137 MHz is attenuated higher than 60 dB from the In band AMS(R)S signal

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Operation of space-based VDLm2 system

- The satellite system is similar to the ground station in term of behaviour :
  - CSMA protocol
  - D8PSK modulation
  - Agnostic to the protocols running on top of the AVLC layer. Use of the same AVLC protocol as Ground Based VDLm2. GSIF will indicate the available services (AOA and/or ATN) over Space Based VDL.
  - CVME to assign to the radio a dedicated channel as specified by ICAO
  - The ground stations and the space-based VHF system will be visible each other. As a result, this will avoid the issue of the hidden transmitters in the event that they use the same channel (CSC)
  - As both system are similar (same modulation, same CSMA protocol), both system will co-exist as this is already the case for the ground-based VDL stations which use the same channel.

- Satellite coverage over oceanic and remote areas:
  - Satellite is complementary component to the ground-based VDL network, meaning that in area where it is impossible to deploy a ground-based VDL station, hence no coverage from the ground, the space-based VHF station will take the hand-over
  - Channel to be coordinated and assigned by ICAO
  - Other specific channels to be considered depending on the traffic
  - Minimum overlaps with ground stations operating close to the coastline to ensure continuity of service
  - Seamlessly transition from a ground station to the satellite component

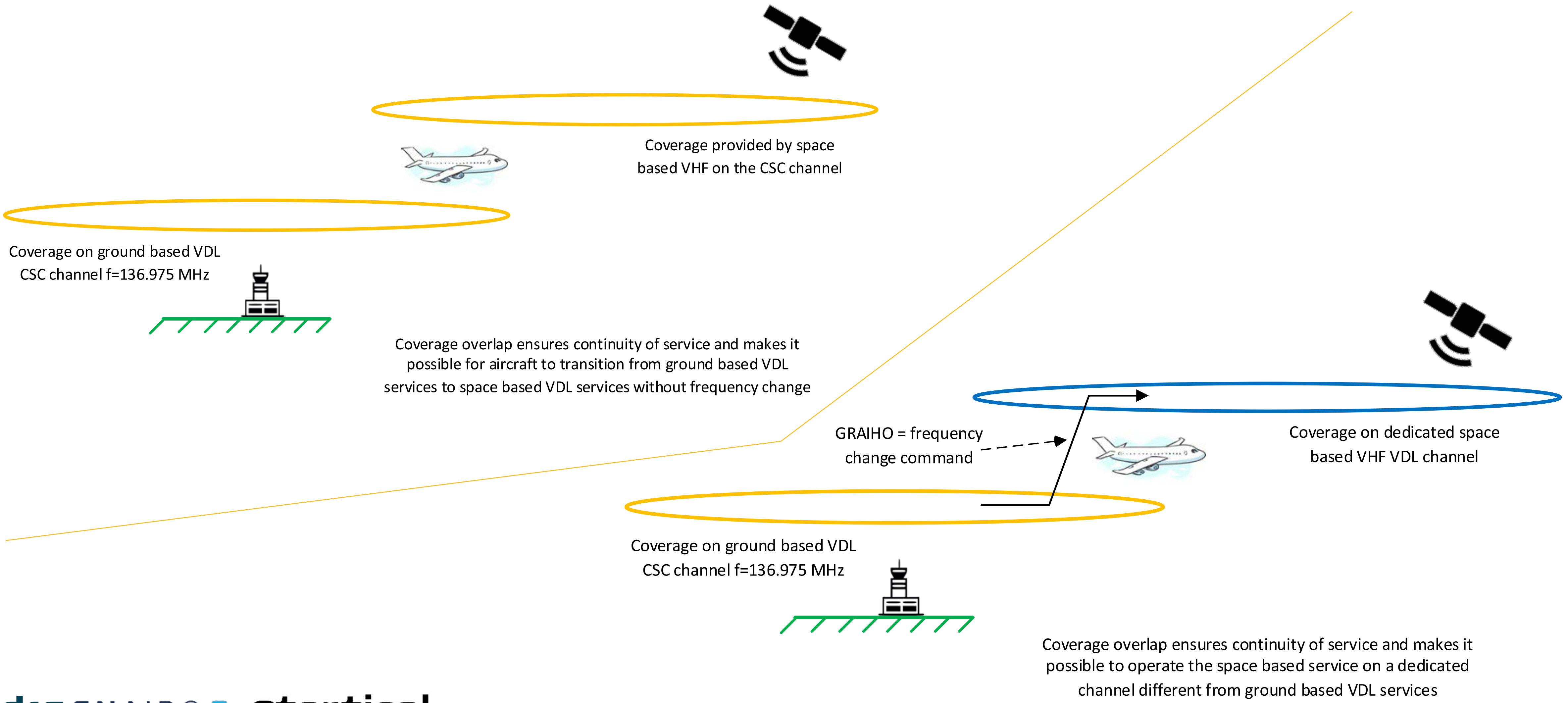
Operation of space-based VDLm2 system

- In case of oceanic coverage, it should be mentioned that as this area is considered as international, an alternate frequency can be different to the one used in the USA and Europe.
- For coverage near the coasts of continents the space-based VDL station allows the VDL service to be extended out to the oceanic region in a seamless fashion. The space-based VDL service can be provided on the same frequency as the terrestrial-based VDL stations or it can be provided on an alternate frequency to which the aircraft would be commanded to switch by the CVME, as it is done currently in the scope of VDL multi-frequency management.
- The "same DSP ID" approach is preferred as no changes required in avionics configuration (no software modifications would ever be needed in the avionics).

  In the event the space-based VDL service is required to operate with its own DSP ID that is different from the existing DSP IDs then the transfer from satellite-based to terrestrial based would happen exactly the same way as transfers which occur currently when an aircraft that is configured to be allowed to access the VDL service of different service providers, for example ARINC and SITA, loses datalink service when it flies outside the coverage area of one service provider but then detects the availability of VDL service from the other service provider. This mechanism is already actively being used on the current aircraft fleet.

- Space-based VDL stations will be managed by the CVME just as the existing terrestrial-based VDL stations are already managed. The space-based VDL stations will be simply added to the inventory of VDL stations managed by the CVME with their own, appropriate coverage maps.

Operation of space-based VDLm2 system



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Technical Summary

VHF Voice. Initial results show that:

- Actual aircraft radios exhibit performances as specified in ICAO for the Sensitivity and SNR range of the satellite channel and also for several cases of scintillation.
- Radios tested, working in a 25 KHz channel, can manage the Doppler effect added to the VHF link due to satellite movement.

VHF Data. Initial results show that:

- Actual aircraft radios behaves as expected in terms of Sensitivity for the expected satellite channel range. In addition, preliminary tests with scintillation show good behaviour for moderate cases.
- The radio tested (Collins VHF2100) shows very good performances when Doppler is applied, behaving better than the specified requirement in ICAO SARPS.
- A pre-compensation mechanism in the satellite is required to reduce the frequency error to the range specified in the requirements.

Spectrum. Initial results show that :

- Outcomes of the compatibility studies demonstrate that the space-based VHF satellite does not create harmful interference to services operating above 137 MHz.
- Compatibility of Unwanted AMS(R)S Out-of-Band and spurious emission below 117.975 MHz and compatibility in the frequency band of 117.975 MHz-137MHz is ensured by ICAO Frequency management.

VDL-Mode 2

- Compatibility between AMS(R)S and AM(R)S is accomplished by frequency allocation for the operation of the space-based VHF system.
- The Space-based VHF system will be complementary component to the actual terrestrial networks, providing seamlessly transition from a ground station to the satellite component.
- To address sharing studies under ICAO umbrella, but not under ITU-R.

General Summary

- **WRC-19 approved the Resolution 428:** *"Studies on a possible new allocation to the aeronautical mobile-satellite (R) service within the frequency band 117.975-137 MHz in order to support aeronautical VHF communications in the Earth-to-space and space-to-Earth directions***"**

- **Resolution 428 noting b):** *"that the development of compatibility criteria between new AMS(R)S systems proposed for operations in the frequency band 117.975-137 MHz and ICAO-standardized aeronautical systems in this frequency band* ***is the responsibility of ICAO*** *"*

- **Resolution 428 invites ITU-R:** *"to take into account the results of the studies to provide technical and regulatory recommendations relative to a possible new AMS(R)S allocation within the frequency band 117.975- 137 MHz, taking into consideration the responsibility of ICAO referred to in noting b)"*

- **Resolution 428 invites ICAO:** *"to participate in the studies by providing aeronautical operational requirements and relevant available technical characteristics to be taken into account in ITU Radiocommunication Sector (ITU-R) studies and to take into account the sharing and compatibility conclusions reached at ITU-R in the SARPs to be developed for the AMS(R)S,"*

Considering outcomes from works done concludes that the new allocation of AMS(R) are:

- Technically feasible.
- Operationally feasible.
- Compatible with services in adjacent band.

ICAO and their States members should promote and support the activities in ITU-R and ICAO in order to achieve the new allocation for all AMS(R)S in the whole VHF aeronautical band 117.975-137MHz, under ICAO responsibility, AI 1.7 at WRC-2023.

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