Satellite Payloads 2024-2025 - Lesson's log

#	date	time	Topic	Teaching material
COM #01-02	24/09/2024 Room 32	13:00-15:00	- Introduction to the course, web page, teaching material, "in itinere" tests and final exam structure - The three main payload categories: TLC, Satellite Navigation, and Earth Observation. - Common characteristics, specific orbital requirements, and peculiarities.	Slides: 01_Payload_intro https://youtu.be/sgCQyhzWl1o
	26/09/2024 Aula 32	10:00-12:00	- Lecture postponed	
	26/09/2024 Room 9	13:00-15:00	- Lecture postponed	
	27/09/2024 Online	09:00-11:00	- Lecture postponed	
COM #03-04	01/10/2024 Room 32	13:00-15:00	- Example of Satellite Communication Systems - Geostationary satellites, Sir Clarke, example: the Inmarsat constellation - Global Antenna Beam from GEO, MEO, LEO: Beamwidth and Gain. Beamwidth to Gain relationship for symmetric conical antenna beams. - % of coverage of the Earth surface from the different orbits	Slides: 02_Payload_link_budget_intro https://youtu.be/swI9jb2G__0
COM #05-06	03/10/2024 Room 32	10:00-12:00	- Equation for the received density and received power. Impact of the ground receiving antenna equivalent area on the required satellite transmitted power. - Comparison of received power density from GEO, MEO, LEO global beams - Beam persistence from GEO, MEO, LEO - Approximate antenna directivity/gain for rectangular and elliptical antennas - Satellite elevation and coverage limitations when requiring a non-zero elevation	Slides: 02_Payload_link_budget_intro https://youtu.be/CRHZjbNZ8vQ
GNSS #01-02	03/10/2024 Room 9	12:00-14:00	- Principles of operation of the global navigation satellite systems - Positioning in 1D, 2D, 3D and the required hypotheses - Pseudorange measurements, clock errors and synchronization problems. 4D solution and PVT estimation	Slides: 31_GNSS_2024_principles_v7 https://youtu.be/knZWy9vXLL0
RAD #01-02	04/10/2024 Online	09:00-11:00	- Introduction to space-based radar systems and to the ground-based radar for space surveillance. - Radar equation, dynamic range; pulsed vs. CW radar. - The radar detection. - Range resolution - The power problem for the detection in the far-range and the need to increase SNR / received echo energy	Slides: 21_Payload_2024_Radar_fundamentals https://youtu.be/pbV-P5r6MoM

COM #07-08	08/10/2024 Room 32	13:00-15:00	- Global Earth coverage with minimum assigned elevation angle - A look at the Starlink constellation plan for global coverage - The hertzian dipole antenna and its radiation characteristics in the far field - Field linear polarizations: V and H - The dipole antenna pattern - Using the dipole as a basis for 1D and 2D antennas	Slides: 02_Payload_link_budget_intro 04_Payload_Antenna https://youtu.be/CJ2OLHWCp5k
COM #09-10	10/10/2024 Room 32	10:00-12:00	- Isotropic and directions TLC antennas: gain and directivity - Hertzian dipole, - Electric field amplitude, direction of propagation and polarization - antenna patterni - Long dipole linear antenna: size and beamwidth	Slides: 04_Payload_Antenna https://youtu.be/bOuGlpoWPyE
GNSS #03-04	10/10/2024 Aula 9 PL	12:00-14:00	- Estimation of satellite positions and clock errors from the Earth: Reference/Monitor stations, Master Control Station and the inverse GNSS equations. - Transferring the required data to the user receivers: predictions, fitting to parametric functions, upload and update every 2 hours. - Global structure of the Ground Segment.	Slides: 31_GNSS_2024_principles_v7 https://youtu.be/RWTBrOILqNA
RAD #03-04	11/10/2024 Online	09:00-11:00	- Range resolution - The power problem for the detection in the far-range and the need to increase SNR / received echo energy - Radar coherent pulse integration - Radar tracking of space objects from the Earth - Example of Inverse SAR images with TIRA	Slides: 21_Payload_2024_Radar_fundamentals https://youtu.be/vVSFO_fwNNU
COM #11-12	15/10/2024 Room 32	13:00-15:00	- lambda/2 linear antenna - rectangular aperture antennas: pattern, beamwidths, and directivity - circular planar antennas - parabolic reflector antennas	Slides: 04_Payload_Antenna https://youtu.be/Y-jLWybgqcQ
COM #13-14	17/10/2024 Room 32	10:00-12:00	- Receiver scheme with RF, IF and BB sections - Filtering needs at RF, IF and BB - Filter selectivity and insertion loss at RF, IF and BB - Equivalent Base Band transfer function of RF and IF filters - Global receiver Equivalent Base Band transfer function - Optimizing the Equivalent BB transfer function of the receiver to provide maximum output SNR - Maximum achievable SNR as energy over Noise power spectral density	Slides: 03_Payload_matched_filter https://youtu.be/nfMy30ooQo0
GNSS #0506	17/10/2024 Aula 9 PL	12:00-14:00	- Keplerian orbits and GNSS ephemeris - Satellite position reconstruction from Keplerian parameters (also with corrections) - Clock scheme and oscillator models - Clock errors: its behavior and its correction	Slides: 31_GNSS_2024_principles_v7 https://youtu.be/5OrxMU9VTmQ

RAD #05-06	18/10/2024 Online	09:00-11:00	- Radar for launch vehicle monitoring at Kourou - Radar measurement of angles: azimuth and elevation; the monopulse antenna - Radar tracking based on monopulse and conical scan - Radar detection and its performance parameters: Pfa and Pd; Neyman Pearson Criterion and Pd as a function of SNR	Slides: 21_Payload_2024_Radar_fundamentals https://youtu.be/EURdkWxuTNc
COM #15-16	22/10/2024 Room 32	13:00-15:00	- Derivation of the Matched Filter Transfer (MF) function - Interpretation of the resulting H(f) in the frequency domain - Need of the delay t_0>= pulse length to make the MF causal - Signal at the output of the matched filter in frequency domain and in time domain - MF output as a translated and scaled waveform autocorrelation - Behaviour of the rect pulse	Slides: 03_Payload_matched_filter https://youtu.be/AzsaEXSQ5Xc
	24/10/2024 Room 32	10:00-12:00	- Lecture postponed	
	24/10/2024 Aula 9 PL	12:00-14:00	- Lecture postponed	
	25/10/2024 Online	09:00-11:00	- Lecture postponed	
COM #17-18	29/10/2024 Room 32	13:00-15:00	- Gain vs Aperture: received power formulation; - EIRP & G/T merit figures; - Directional antennas: beam steering/attitude control requirements - Temporal and spectral characteristics of thermal noise - Equivalent thermal noise level at the receiver input - Thermal noise power and SNR definition Real vs. ideal noiseless receiver; noise contribution from the receiver - Equivalent noise temperature - Example of Satellite Communication Systems - Geostationary satellites, Sir Clarke, example: the Inmarsat constellation - Global Antenna Beam from GEO, Beamwidth and Gain. Beamwidth to Gain relationship and loss at the beams border - Parameters for Global Beam operation in C-Band; Saturated power and transmit backoff, evaluation of EIRP, Free Space Losses (FSL) and received power in clear sky conditions. - CNR in clear-sky conditions and margin	Slides: 05_Payload_2024_linkbudget_core_v2 https://youtu.be/ZsQ6qB9OvQE

COM #19-20	31/10/2024 Room 32	10:00-12:00	- SNR vs E/N_0 vs C/N_0 for the link budget description and relationship to the matched filter optimum output: matched filter gain G. - Discussion of an Example of Link budget evaluation for GEO Global Beam downlink - Description of the Global digital transmission scheme: Coding – Modulation – Transmission – Demodulation – Decoding - The 3 phases of the Coding (& Decoding): Source Coding; Encryption, Channel Coding with their purposes.	Slides: 05_Payload_2024_linkbudget_core_v2 06_Payload_2024_Global_Scheme https://youtu.be/SGh7wJQ_QAg
GNSS #0708	31/10/2024 Aula 9 PL	12:00-14:00	- Propagation errors and their correction - Effect of the atmosphere on the pseudorange measurements - Analytical expression of the error as a function of the refraction index - Tropospheric effects and compensation - mask angle - Effect of ionosphere on phase propagation - correction with navigation message coefficient and exploiting dual-frequency measurements dispersivity of ionosphere and relationship between phase and group propagation speed and delay.	Slides: 32_GNSS_atmosphere_and_solution https://youtu.be/rxRdpUtlkeQ
	01/11/2024	09:00-11:00	- Holiday – NO lecture	
COM #21-22	05/11/2024 Room 32	13:00-15:00	- I&Q modulator - I&Q demodulator	https://youtu.be/DFHh6etdoW4
COM #23-24	07/11/2024 Room 32	10:00-12:00	- Ideal and multipath propagation channel - Carrier phase shift caused by the propagation delay in the ideal propagation channel - Doppler frequency; its presence in the received signal and its effect on the output of the I&Q demodulator - Need for a phase estimation (Phase Lock Loop) to synchronize the I&Q demodulation - Mapping and demapping: from bit sequences to points in the I&Q constellation plane	Slides: 06_Payload_2024_Global_Scheme https://youtu.be/Yo7-dFqgRto
GNSS #0910	07/11/2024 Aula 9 PL	12:00-14:00	- The three Segments: Space, Ground and User - Initial idea of global positioning performance - Navigation message structure and timing - Navigation Solution via Taylor series expansion - Selection of the initial guess - Derivation of matrix H - Iterative algorithm and stopping criterion	Slides: 32_GNSS_atmosphere_and_solution https://youtu.be/DBAo2lCUYE4
RAD #07-08	08/11/2024 Aula 25	11:00-13:00	- Range accuracy of surveillance function vs range accuracy of tracking function - Examples where tracking radar require precision (prediction of location and time of impact of re-entry/launcher trajectory prediction) - Angular accuracy of radar measurements (tracking vs surveillance - High accuracy of angle estimation using antenna scan - Monopulse antenna and its principle of operation - Dependency of range and angular accuracies on SNR	Slides: 21_Payload_2024_Radar_fundamentals https://youtu.be/m6Cg-V35rFg

COM #25-26	12/11/2024 Room 32	13:00-15:00	- Mapping binary streams into sequence of symbols; symbol rate vs bit rate - D/A conversion with holding and bandwidth requirements - PSK constellations, QAM constellations - AM/AM and AM/PM distortion of Power amplifiers and the need of backoff & predistorsions - Satellite APSK constellations	Slides: 06_Payload_2024_Global_Scheme https://youtu.be/ho3wfr3EyGI
COM #27-28	14/11/2024 Room 32	10:00-12:00	- Digital transmission using a basic pulse shape: rect pulse, matched filtering and sampling on receive. - Transmission filtering and emission mask - Global Transfer function of the TX-Channel-RX - Effect of the global transfer function and the problem of the InterSymbolic Interference (ISI) - Sample spectral emission mask for DVB-S - Zero ISI condition in time and frequency domain - Symmetric characteristic of the Zero-ISI Transfer Function	Slides: 06_Payload_2024_Global_Scheme 07_Payload_ISI https://youtu.be/DxdRl62UZAU
GNSS #11-12	14/11/2024 Aula 9 PL	12:00-14:00	- GPS carrier generation and frequency allocation - Spectrum of GPS signal - Usage of GNSS waveforms for ranging - Requirements for GNSS waveforms - FDMA, TDMA, CDMA - Orthogonality of the waveforms and their separation in the code-domain	Slides: 33_GNSS_signal.p*df* https://youtu.be/ibBLsbrHRbY
RAD #09-10	15/11/2024 Aula 25	11:00-13:00	- From MF output high resolution requires wide bandwidth waveforms - Search for long, constant envelope waveforms that provide a high compression ratio -	Slides: 22_Radar_pulse_compression https://youtu.be/cibruCqmXrg
COM #29-30	19/11/2024 Room 32	13:00-15:00	- Symmetric characteristic of the Zero-ISI Transfer Function - Minimum bandwidth, triangular and trapezoidal shape function - Raised-cosine transfer function family and roll-off parameter - Splitting the raised-cosine shape between TX and RX filter to apply matched filtering	Slides: 07_Payload_ISI https://youtu.be/zehZxxXKFJ4
COM #31-32	21/11/2024 Room 32	10:00-12:00	- De-mapping operation - Noise at the output of the I&Q demodulator - Joint PDF of the noise components and error probability dependent on the modulus - Minimum distance criterion - Decision regions and their definition - Conceptual evaluation of the symbol error probability by integration of the joint PDF	Slides: 08_Payload_BER https://youtu.be/vc06mI4wSuU
GNSS #13-14	21/11/2024 Aula 9 PL	12:00-14:00	- LMS codes and their generation with shift registers - Properties of LMS and their cyclic autocorrelation - Generation of the C/A codes and their properties - Basic receiver scheme	Slides: 33_GNSS_signal.p*df* https://youtu.be/PpRSq-oW15Q

RAD #11-12	22/11/2024 Aula 25	11:00-13:00	- Search for waveforms with high compression ratio: the phase modulation (discrete or analog) - Range resolution as a function of the pulse bandwidth and the different ways to obtain a wide band waveform - Phase codes. Example of the Barker codes providing compression - Barker codes and MLS codes: properties of their autocorrelation especially for sidelobes - Chirp signal to guarantee a desired bandwidth: its frequency and phase characteristic - Spectrum of the Chirp waveform	Slides: 21_Payload_2024_Radar_fundamentals 22_Radar_pulse_compression https://youtu.be/G9y9wkzGzQQ
COM #33-34	26/11/2024 Room 32	13:00-15:00	- Probability of symbol error for the most common digital modulations : BPSK, QPSK & M-PAM by integration of the 2D Gaussian PDF	Slides: 08_Payload_BER https://youtu.be/PCucNtvM3f4
COM #35-36	28/11/2024 Room 32	10:00-12:00	- Probability of symbol error for M-PSK and M-APSK - From symbol error to bit error - Expressions as a function of Eb/No - Communication link sizing starting from BER - The bent-pipe transponder - The SNR of up&downlink connection with the bent-pipe transponder	Slides: 08_Payload_BER https://youtu.be/hF7wH_BaaPQ
GNSS #15-16	28/11/2024 Aula 9 PL	12:00-14:00	- Error budget for the pseudorange errors - Positioning error vs pseudorange error and the Dilution of Precision (DOP) - Positioning error covariance matrix derivation - Positioning accuracy improvement by reducing the DOP: Geo, pseudolites, doubling constellation, joint use of multiple constellations	Slides: 35_GNSS_performance 36_GNSS_accuracy https://youtu.be/_WgIyZsU4Bo
RAD #13-14	29/11/2024 Aula 25	11:00-13:00	- Compressed chirp waveform: MF output and sidelobes - Sidelobe Control filters and its effects - Spectral windows and their performance - Fresnel sidelobes	Slides: 22_Radar_pulse_compression https://youtu.be/yoFd4F9nBbw
RAD #15-16	03/12/2024 Room 32	13:00-15:00	- Relationship between cross-range position and Doppler frequency inside the antenna footprint - Exploitation of Doppler resolution to provide cross-range resolution - Maximum integration time and maximum cross-range resolution in STRIP-map mode - Spotlight SAR mode	Slides: 24_SAR_fundamentals.pdf https://youtu.be/JETczasYENo
COM #37-38	05/12/2024 Room 32	10:00-12:00	- Bent pipe transponder scheme: global amplification, change of frequency, channel separation before amplification - Applications served by Bent-pipe transponders: broadcast and fixed links (or limited flexibility)	Slides: 11_Payload_Coding 09_Payloads_2024_Transponder Video recording not available

			- Regenerative transponders scheme with digital demodulation and re-modulation. - Performance of multiple links path with regenerative transponders - Applications served by regenerative transponders, allowing address management and satellite network operation: the LEO satellite mobile communication constellations	
GNSS #17-18	05/12/2024 Aula 9 PL	12:00-14:00	- Fixed and variable Geometry - Positioning accuracy in 1D - 2D and 3D Gaussian PDF characteristics - 2D and 3D regions with High PDF values - GNSS Positioning accuracy in 2D & CEP - Probability ellipse and its derivation	Slides: 35_GNSS_performance 36_GNSS_accuracy https://youtu.be/WScQRxkZwt0
RAD #17-18	06/12/2024 Aula 25	11:00-13:00	- Synthetic Antenna approach, as alternative interpretation of cross-range resolution - Synthetic Antenna aperture length, Synthetic beamwidth and synthetic footprint (ceross-range resolution) - Improved Stripmap resolution with smaller antenna length	Slides: 24_SAR_fundamentals.pdf https://youtu.be/1SqM1aEGR40
GNSS #19-20	10/12/2024 Room 32	13:00-15:00	- Performance parameters: Accuracy, Availability, Integrity and Continuity - Pseudorange error removal using Local Area Differential approach: SV clock, ionospheric and tropospheric errors - Correction of equivalent error in the ephemeris prediction and its effectiveness - Ground Based Augmentation System (GBAS) scheme - Need for wide area correction for route navigation and problems to extend corrections to a Wide Area - WAAS & EGNOS	Slides: 35_GNSS_performance https://youtu.be/Sh86b29jkfI
RAD #19-20	11/12/2024 Room DIET09	10:00-12:00	- Satellite iso-range and isodops: best antenna pointing strategy & left-right ambiguity - Frequency change for the individual scatterer as a function of slow time and the cross-range chirp - Duration, bandwidth, slope and compression ratio of the slow-time chirp - Compression of the slow-time chirp to focus the SAR image and achievable resolution	Slides: 24_SAR_fundamentals.pdf https://youtu.be/aYHbPxYiU18
COM #39-40	12/12/2024 Room 32	10:00-12:00	- Single parity bit for error detection - Automatic Retransmission Request in half & full duplex modes: PRO's and CON's - Block codes and their characteristics - Hamming distance between bit sequences - Forward Error Correction exploiting redundancy bits - Error detection and correction as a function of the Hamming distance - Matrix implementation of block coding and decoding and the syndrome - Perfect codes	Slides: 11_Payload_Coding https://youtu.be/3dAHm4LKYWk
GNSS #21-22	12/12/2024 Aula 9 PL	12:00-14:00	- Galileo signals and interoperability with GPS - Galileo offered services - Performance of the offered services - Galileo system architecture for integrity	Slides: 37_GNSS_Galileo https://youtu.be/C0ZW8Q2waUg

	13/12/2024	11:00-13:00	- Lecture anticipated to 11/12/2024	
RAD #21-22	17/12/2024 Room 32	13:00-15:00	- Chirp matched filter as a way to compensate the time-varying Doppler of the chirp - Near field antenna interpretation of SAR quadratic phase compensation - Changing slope and aperture inside swath, with constant Doppler Bandwidth - Range cell migration - Range cell migration compensation - Radar PRF: azimuth ambiguity, range ambiguity	Slides: 24_SAR_fundamentals.pdf https://youtu.be/3c37XT-n9cQ
RAD #23-24	18/12/2024 Room DIET09		- PRF selection diagrams - Bounds for Radar PRF selection and bounds on antenna area and/or information - Range cell migration and its compensation - SAR quality parameters - SAR Constellations - Radar altimetry and Sounding	22_Satellite_RADAR24 25_SAR_quality_parameters 26_SAR_constellations 27_Radar_Altimetry_and_Sounding https://youtu.be/YL94XTIZBzA
COM #41-42	19/12/2024 Room 32	10:00-12:00	- Hamming codes and their ratio - The cyclic code families: BCH and Reed-Solomon with their characteristics - Convolutional codes: coding and decoding approaches - Concatenated codes, Turbo-Codes and LPDC	Slides: 11_Payload_Coding https://youtu.be/Inr4sBIUJLk
COM #43-44	19/12/2024 Aula 9 PL	12:00-14:00	- Evaluation of BER with error correction coding and performance comparison of coding and modulation approaches. - Mention to the Shannon Coding Theorem - Evolution of the GEO DVB-S standards, including variable coding and modulation schemes - Adaptive Coding and ModulationM - LEO Internet Satellites	13_Payload_Shannon 12_Payload_ACM_SatTV_and_Internet https://youtu.be/6QdQTwsUK20
	20/12/2024	11:00-13:00	- Lecture anticipated to 18/12/2024	