"On the integration of terrestrial and satellite systems in future 5G networks: a waveform perspective"

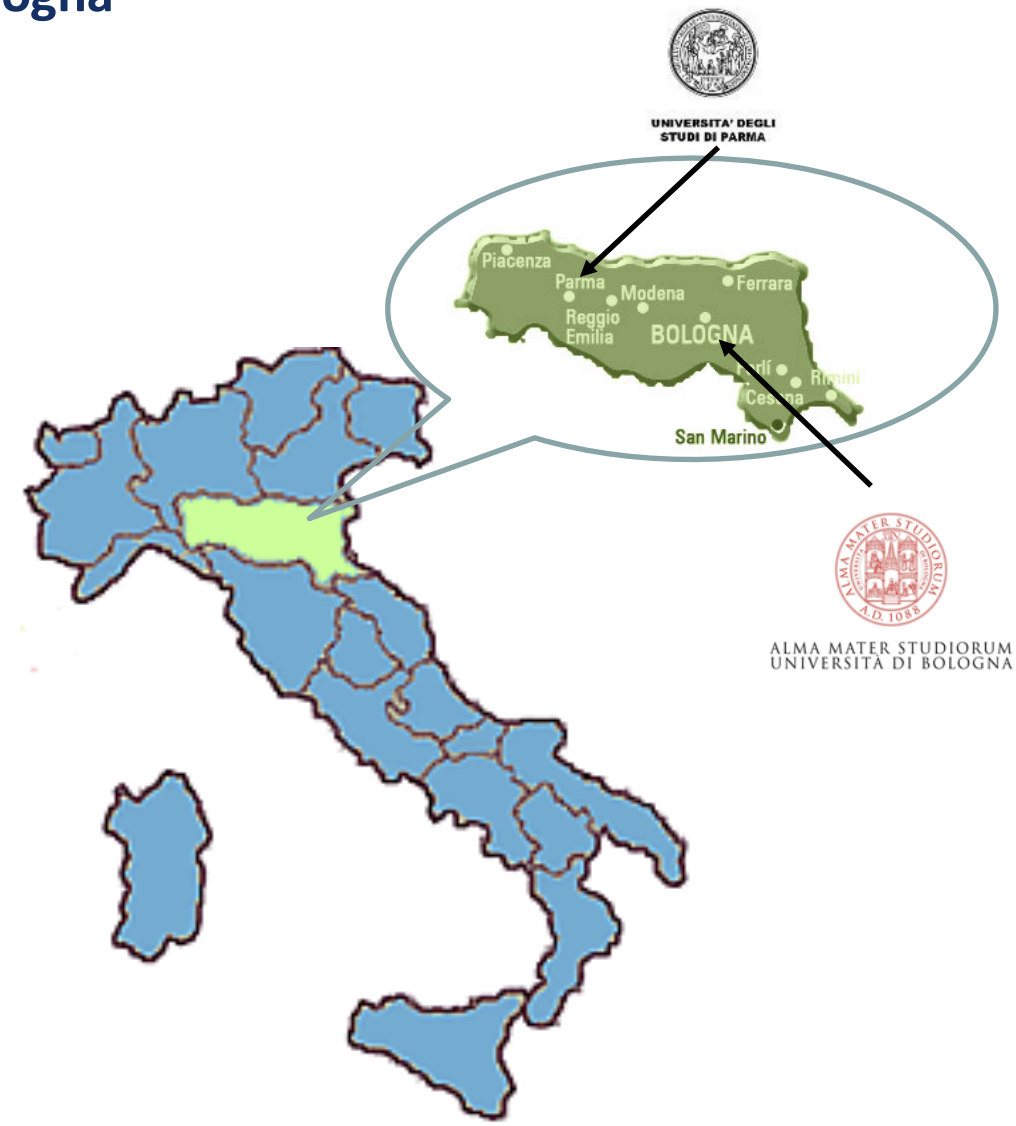
A. Guidotti (Univ. of Bologna), G. Colavolpe (Univ. of Parma),
A. Vanelli-Coralli (Univ. of Bologna), and G. E. Corazza (Univ. of Bologna)

Joint Expert Group and Vision Group Workshop 2016
Bologna, March 16, 2016

Presentation

- University of Parma and University of Bologna
  - Satellite and Terrestrial Communications
  - Waveform design
  - Interference Management
  - Synchronization and Estimation
  - Impairment countermeasures
  - Signal processing
  - Cognitive Radio

- Coordinator and Responsible for
  - European Space Agency studies
  - European projects
  - …



Context

- In 5G, very different use cases are converging, which pose mixed requirements
  - eMBB, mMTC, uRLL
- New Air Interfaces and waveforms are required to address
  - Frequency assignments from 300 MHz up to 100 GHz
  - Single- and multi-carrier solutions
  - Licensed/shared/unlicensed spectrum access
  - Orthogonal vs. non-orthogonal access
  - …
- 5GPPP, ETSI-SCN, and ITU (WG4B-4/40-E) groups advise for the integration of a satellite component into the 5G Architecture
  - e.g., coverage extension, backhauling/fronthauling, C-plane handover, etc.

SatCom in 5G

- Thanks to their inherent characteristics, satellites can contribute to enhance 5G service capabilities and to address major challenges
  - Ubiquitous coverage for areas/applications where terrestrial delivery not possible/efficient
    - Rural areas, emerging countries, etc.
    - 5G network management, synchronization, signalling,…
    - Efficient hierarchical backhauling
    - Multimedia delivery
  - M2M communications
  - Mission critical scenarios

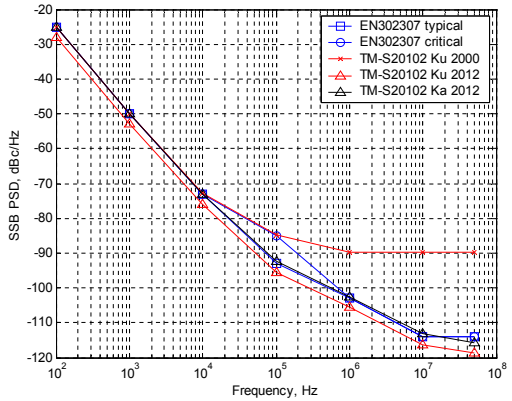
SatCom: current systems and future trends

- **SatCom scenarios**
  - **GEO constellations - HTS**
    - **Currently operating at 100 Gbit/s**
    - **100 beams in Ka-band**
    - **Future GEO-HTS systems**
      - Use of exclusive & shared Ka-bands, flexible power distribution, dynamic beamforming, beam hopping, etc.
  - **Non-GEO constellations**
    - **Existing LEO constellations target lower capacity global services**
    - **Mega-constellations are being developed (services foreseen by 2020)**
      - Global market with high capacity, low latency services
      - Interference issues with GEO
      - OneWeb (640), LeoSat (80-100), SpacEx (4000), Samsung (4600), SSI (80), etc.

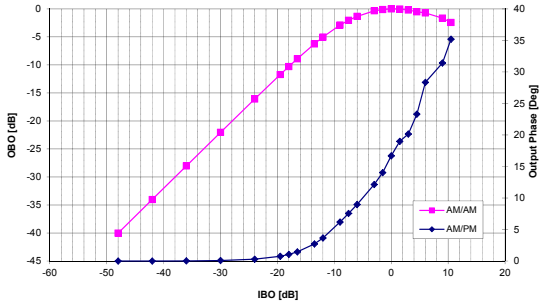
Source: B. Evans, "Future Network Concepts & Challenges", SPECSI workshop, London, March 2, 2016

Satellite channel characteristics

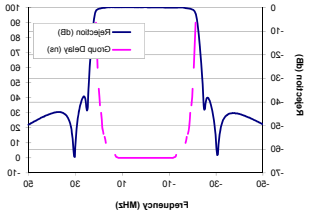
- There are several impairments on a satellite channel to be dealt with
  - Phase Noise

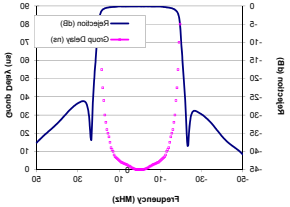


  - Non-linearities (not-colocated with the transmitter)



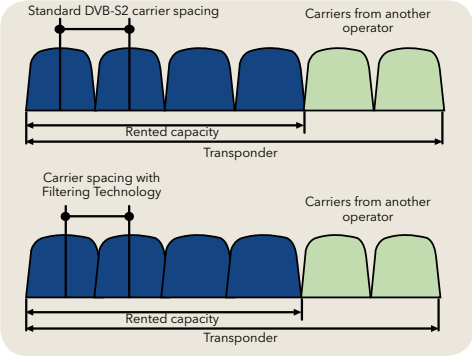
  - On-board filtering





SatCom Waveforms: SoA

- **DVB-S2(X)**
  - **Single-carrier waveform**

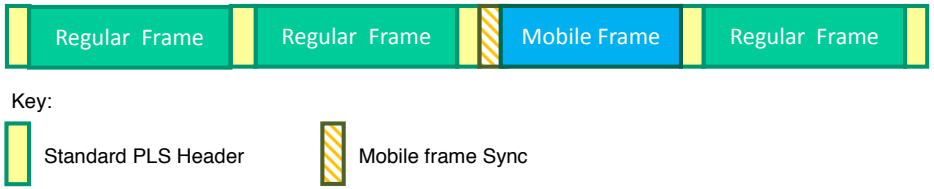


Sources

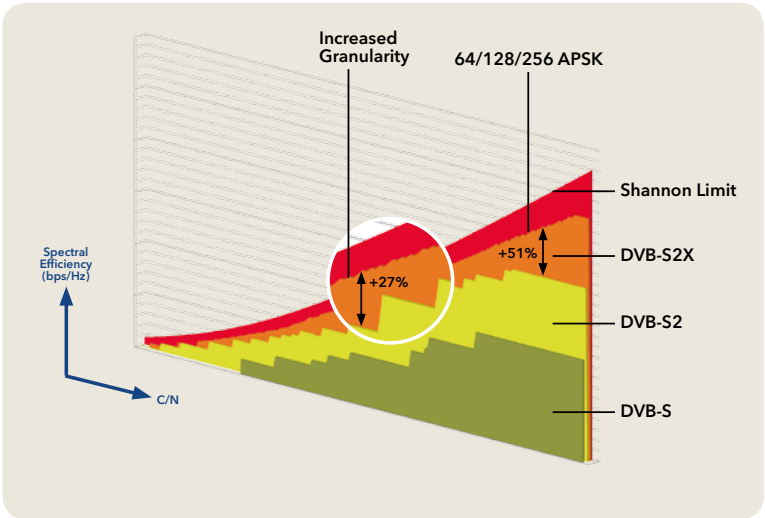
- "White Paper on the use of DVB-S2X for DTH applications, DSNG & Professional Services, Broadband Interactive Services and VL-SNR applications"

- Newtec white paper "DVB-S2X demystified"

  - **Regular framing structure**



  - **Multiple MODCODs from very low SNR to high spectral efficiency**
    - **BPSK, QPSK, 8-PSK**
    - **8-APSK, 16-APSK, 32-APSK, 128-APSK, 256-APSK**
    - **Rate 1/4, 1/3, 2/5, 1/2, 3/5, 9/10, 9/20,…**



5G discussed waveforms

- Single- and multi-carrier waveforms
  - Multi-carrier: optimal equalization efficiently performed in the frequency domain
  - Single-carrier: development of high-performance and low-complexity equalizers
- Orthogonal and non-orthogonal approaches
  - Orthogonality ensures the absence of interference
    - OFDM-like waveforms
    - Limited spectral efficiency: CP, OOB
  - Non-orthogonality to improve efficiency
    - interference shall be then dealt with
      - Faster-than-Nyquist/Time-Frequency Packing
      - Non orthogonal multicarrier
      - …
- Several waveforms proposed and to be considered for SatCom
  - e.g., P-OFDM, F-OFDM, UF-OFDM, FBMC, etc.

Question to be addressed

- Satellite positioning in the 5G architecture for
  - integrated satellite terrestrial network management and control approaches
  - Hierarchical backhauling
- Compatibility studies on radio interface (waveform, framing structure, etc.) and developed impairments countermeasure
  - How do the proposed air interface(s) performs in the presence of typical satellite channel impairments?
  - How do proposed countermeasures devised for terrestrial channel impairment fit satellite architectures?
  - Which are the complexity/flexibility/efficiency/costs trade offs?
    - A single air interface/multi RAT including satellite
- Channel models and interference management models
- Feasibility and demonstrations of efficient integration of Satellite and Terrestrial networks

THANK YOU

A. Guidotti (Univ. of Bologna), G. Colavolpe (Univ. of Parma),
A. Vanelli-Coralli (Univ. of Bologna), and G. E. Corazza (Univ. of Bologna)

alessandro.vanelli@unibo.it