Satellite Communications Class Project:
mm-wave Satellite Links – Satellite Communications as Inherent Part of 5G Systems?

ECE 6390 – Fall 2019

Introduction:

The vision of 5G mobile communications is driven by the predictions of up to 1000 times data requirement by 2020 and the fact that all traffic could be video embedded. If one compares this with the mobile spectrum available now (about 500 MHz) there is, what is referred to as the 'spectrum crunch'—there is not enough bandwidth to satisfy the demands. Thus the conclusion is to move to a more dense networks and increase the area spectral efficiency by orders of magnitude. This leads to a network of much smaller cells, all of which will not be solely homogeneous but a flexible heterogeneous network where the resources can be adapted dynamically (on demand) as the users demand in space, time and spectral resources and even between operators varies.

Mobile satellites today provide services to air, sea and remote land areas via GEO operators (e.g., Inmarsat, Thuraya) and non GEO operators (e.g. Iridium, Globalstar, O3b). These operate in L, S and more recently Ka bands, to both handheld and vehicle mounted as well as some fixed terminals. Air interfaces and network functions have tended to be proprietary although some integration with MSS and 3GPP network interfaces exist. Fixed satellites today provide backhaul services to cellular in C, Ku and Ka bands, and also services to moving fixed terminals on vehicles in C-, Ku-, X- and Ka-bands. Satellite has been an overlay, rather than integrated system except in S band where an integrated satellite and terrestrial MSS standard has been adopted. 3GPP like services exist via satellite to individual users, but as yet these have not been extended to 4G. Satellite services to ships, aircraft and fast trains using FSS satellites provide a full range of mobile and broadcast services to passenger vehicles. A growing area of interest is in the transport sector where safety services and V2V (Vehicle To Vehicle) are seen as ideal for satellite delivery.

Since research into V2V systems proposes use of higher frequencies such as 76 GHz radar and communication integrated systems, the objective of this project is to investigate feasibility of using satellite links for V2V communications.

Objective:

The objective of this project is to develop and validate communication link models over the 71 – 76 GHz and 81 – 86 GHz frequency bandwidths. This technical objective necessitates a higher level of sophistication as bi-directional, modulated data signal measurements are required. Key measurements include bit-error-rate, link margin, Doppler shift, and availability. The approach to meet this objective is to operate a transponder at a geostationary orbit over the continental United States. The transponder will receive (uplink) signals from a ground transceiver in the 81 – 86

GHz frequency band and retransmit (downlink) signals to the ground transceiver in the 71 – 76 GHz frequency band.

To accomplish meaningful research and experimental data collection, the system design criteria listed in Table 1 should be considered as a starting point for the beacon payload and companion ground data collection instruments. Clear-day link margins are suggested so as to provide ample signal strength to facilitate rain-fade measurements. Table 2 lists additional information and assumptions that should be considered in the design.

Table 1: Beacon Experiment Design Criteria

Duration of data collection	Threshold: 36 months; Objective: 60 months
Ground data collection sites	Multiple – exact number to be determined
Clear-day link margin	Threshold: 30 dB; Objective: 36 dB
Signal	Threshold: single tone at 73.5 GHz; Objective: three tones (e.g., at 71 GHz, 73.5 GHz, and 76 GHz)
Supplemental K-band beacon	Threshold: not included; Objective: Included
Transmit power	Design parameter to be determined
Transmit aperture size	Design parameter to be determined
Receive aperture	Design parameter to be determined

Table 2: Beacon Experiment Assumptions

Space segment	Assume that the flight unit will be a hosted payload on a primary spacecraft/bus to be determined by the Government
Size, weight, and power constraints	To be determined once host spacecraft is identified, but size, weight and power should not be considered to be limiting design requirements at this stage of development; power will be provided by host spacecraft
Orbit	Assume geostationary over CONUS (~100 degrees west longitude)
Aperture pointing	Assume nadir deck location for pointing transmit aperture location on host spacecraft
Telemetry	Assume that flight unit command, control, health and status will be accomplished through a communications link to the host spacecraft bus
Environment	Transmit aperture will be mounted on nadir deck of host spacecraft; electronic system will be mounted inside of spacecraft bus, which offers some thermal control and radiation protection

In addition to above constraints, additional the system design criteria listed in Table 3 should be considered as a starting point for the transponder payload and companion ground transceiver instruments. Given the increased difficulty of the transponder experiment, clear-day only operation may be the only feasible design approach. Information and assumptions given for the beacon are applicable to the transponder. To insure interoperability and to reduce technical risk, it can be assumed that the ground receivers (and / or transceivers) would be designed in parallel with the space segment.

Table 3: Transponder Experiment Design Criteria

Duration of data collection	Threshold: 36 months; Objective: 60 months – both intermittently (~10% duty cycle)
Ground sites	Threshold: single transceiver station; Objective: multiple transceiver stations (potentially using existing ground stations / antenna)
Clear-day link margin	Design parameter to be determined
Signal bandwidth / data rate	Threshold: bandwidth and signal-to-noise to support at least 19.2 kbps data rate; Objective: bandwidth and signal-to-noise to support at least 10 Mbps data rates
Number of carrier frequencies	Threshold: a single carrier frequency in the W-band (uplink) and a single carrier frequency in the V-band (downlink); Objective: three carriers in the W-band (uplink) (e.g., 81 GHz, 84.5 GHz, and 86 GHz), and a single V-band (downlink) carrier
Transmit power	Design parameter to be determined
Transmit aperture size	Design parameter to be determined
Receive aperture	Design parameter to be determined

Team-Member Assignments:

I will assign ~7 teams with 4-5 members. I expect everyone to contribute to the final design and documentation and will solicit internal rankings of team-member efforts.

System Components:

Due to the multiplicity of talents within each group and the "systems"-nature of the class, *all* aspects of the mission design should be explored in the final proposal. Communication systems should receive the most design focus, but the final project should address all of the following systems:

- Communication Systems – antennas, RF hardware, modulation, spectral usage, peak data output, bit rate, coding, etc. A key aspect will be demonstrating that the proposed transmission can make it through the atmosphere of Venus for reliable communications.
- Propulsion System – engine type, trajectory, and voyage time, single craft system or additional (and more expensive) relay orbiter
- Power Systems – power source, peak power output, estimated lifetime, etc. Thermal-proofing the power system is critical.
- Resiliency of Electronics – Discuss strategies for space-hardening and heat-hardening the electronics for the duration of the mission. Identify the likely points of failure.
- Budget and Timeline – total research and development costs broken into materials, equipment, supplies, people costs, space resources, and other miscellaneous costs.

This list is not necessarily exhaustive. The level of detail for each system is left up to the groups. However, increased descriptions will enhance the competitiveness of your design. *Verbose* descriptions will degrade the competitiveness of your design.

Deliverables:

You must prepare a concise, well-written technical report in IEEE conference paper style detailing your team's mission design. The report should be in pdf format with all files (simulations and calculations) submitted through e-mail. **Projects must be submitted by noon on Friday, December 6 2019.** Late projects will not be accepted. In the technical report, as a minimum, please address the following aspects of your design:

1	System Requirements Review
2	Modeling and simulation to demonstrate that the proposed concept is feasible and will meet mission requirements (propagation channel, link, RF systems, size, weight, power requirements)
3	Risk identification and management
4	Sub-system design descriptions (space segment, ground segment, hardware, software)

Grading:

Your final proposal will be graded on the technical criteria listed above. Deductions from these base scores will then be made based on the following areas: Completeness, Technical Writing, Professional Content, Research/References, and Conciseness. Each team member may also receive a small, variable downward adjustment to their individual project scores based on internal rankings of contribution and effort – each team will conduct internal evaluation of their members.

Distance Learning Student Grading:

Distance-Learning students will perform the same project individually (no groups) with the following changes to the grading/submission scheme: 1) expectation of a *much* shorter PDF write-up on your proposed design is expected and 2) no peer-review or team-member component/requirement. **Distance Learning students may submit their project reports on December 13 2019.**