Global Positioning System Receiver and Inter-Satellite Communications RF Design

*Soralis Pimentel*

National Oceanic and Atmospheric Administration (NOAA)-National Environmental Satellite, Data and Information Service (NESDIS), Office of Systems Development
National Aeronautics and Space Administration (NASA), Goddard Space Flight Center-Guidance, Navigation and Control Center (GNCC)
GOES Mission

- This constellation provides information about meteorological events in the Western atmosphere.
- GOES-R measurements will result in more accurate weather forecasts, atmosphere, climate, and ocean monitoring.
Global Positioning System (GPS)

- Satellite radio navigation system
- Passive system that uses trilateration positioning method
- Array of satellites to measure position, velocity and time
- Positioned on the middle earth orbit (MEO)
- Designed to measure on the lower earth orbit (LEO) down to earth’s surface
- GOES-R GPS application could be used to validate measurements
GPS orbits

Main lobe

First side lobe

42.6 degrees (L1)

GEO

LEO (below 3000 km)

HEO spacecraft

-130dBm

-145dBm

42.6 degrees (L1)

LEO (below 3000 km)

HEO spacecraft

First side lobe

Main lobe
Objectives

- To design, build and test Radio Frequency (RF) chains
  - Magnetospheric Multi Scale (MMS) mission, IRAS:
    - Down-conversion frequency receiver and power amplification
    - Up-conversion and phase modulator transmitter
- Global Positioning System:
  - Weak signal down-conversion frequency receiver and power amplification
- For future GOES-R applications and others
Design Requirements

- **GPS receiver:**
  Input of -111dBm at 1.57542 GHz for an output of +4dBm at 35.42MHz

- **IRAS communications system:**
  - Transmitter: pulse train from a Digital to Analog Converter (DAC) of 2V peak-to-peak of +10dBm input
  - Receiver: input of -111dBm at 2.05 GHz for an output of +4dBm at 35.42MHz

- **Power representation**

  $$dB = 10 \log(P)$$

  $$dBm = 10 \log\left(\frac{P}{1mW}\right)$$
Methodology

- Understanding of Electrical Engineering design skills
- Study information about RF design
- Know the requirements and specifications for the design
- Build and test the systems
- Data analyses about overall effectiveness of the chain
GPS Receiver

LO = 1.54GHz

-111dBm @1.57542GHz

LNA’s

+20dBm

BPF

-2dBm

LNA’s

BPF

-3dBm

Power Amplifier

+20dBm

Loss ?

BPF

-3dBm

Loss ?

Attenuator

+24.6dBm

LPF

-2dBm

-3dBm

+24.6dBm

+24.6dBm

+3.3dBm @35.42MHz

-2dBm

-8.5dBm

-2dBm
Receiver output
IRAS transmitter

**Input Signal**
-1V
+1V
+10dBm @1MHz

**LPF**
-2dBm
Cut-off Frequency: 2MHz

**LO=2.05GHz**
-2dBm
-4dBm

**BPF**
+2dBm
Center frequency: 2.05GHz
B=10MHz

+2.2dBm @2.05GHz
Low Pass Filter Design

- Cut-off frequency = 2MHz @ -1dB, Pass Band
- Frequency = 1.9MHz, Pass Band Ripple = 0.5dB

3rd Order Low Pass Chebyshev I

Pass Band Frequency = 1.900 MHz
Pass Band Ripple = 500.0 mdB
Acquired Knowledge

• Hands-on Engineering design
• System requirements and specifications
• RF principles and applications
• Filter design and implementation
• Overall system effectiveness analyses
References

- www.minicircuits.com
- Filter Free design software
Acknowledgments

- NOAA-EPP program, for the opportunity of this internship and the Kennedy Space Center trip
- ORISE
- Edward Miller, NESDIS-Office of System Development, for mentoring
- Greg Boegner, Miriam Wennersten, NASA-Goddard Space Flight Center, GNCC for the opportunity of interrelating a project between NOAA and NASA
- NWS Aviation Services Branch
Plans for next summer

Find a project that includes both Engineering and Atmospheric Science in order to integrate an interdisciplinary background for Graduate studies consideration.
Questions?
Backup Slides
Spacecraft

Electrical Power Subsystem (PSE)
- Solar Array
- Batteries
  - Power Distribution

Control and Data Handling
- Spacecraft computer
- Telemetry
  - Memory

Guidance and Navigation Center
- Position

Instruments
- Plasma instruments
  - Energetic particle detectors
- Electric field instruments
  - Magnetometers

- Range
- Velocity
- Interface
Inter Satellite Ranging and Alarm System (IRAS)

- IRAS is part of MMS
- Ranging:
  - It is used to measure the relative distances among four satellites forming a tetrahedron
- Alarm:
  - Passing packets of orbit data
  - Pass alarm messages between the observatories
Electrical Engineering Facts

- **Transmitter:**
  - Source of data information and process the signal for transmission to another medium

- **Receiver:**
  - Receives a signal from an external source to process the information

- **Amplifier:**
  - Integrated circuit that increases the power, voltage or current of a signal

- **Mixer:**
  - Mixes the RF signal with the local oscillator signal to obtain the IF output.
Electrical Engineering Facts

- **Filter**: sort out unwanted frequency ranges
  - Low Pass (LPF), High Pass (HPF), Band Pass (BPF), Band Reject (BRF)

- **Modulation**: alter a signal inserting a carrier
  - Phase Modulation (PM)
    - Encoding of information into a carrier wave by variation of its phase in accordance with an input signal

- **Power representation in decibels, dB or dBm**

\[
dB = 10 \log_10(P) \quad dBm = 10 \log_10\left(\frac{P}{1mW}\right)
\]
Materials

- Amplifiers
- Band Pass filters, Low Pass filters
- Mixer
- Power amplifiers
- Attenuators
- Coaxial cables
- Spectrum analyzer
- Power supply and signal generator