International Committee on
Global Navigation Satellite Systems

Exploration of ISL configuration for MEO constellation

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Introduction

Why Inter-satellite links (ISL) are required?

- Inter-satellite links are used for Orbit determination, time synchronization, commanding, telemetry and data transfer.
- Helps in reduced dependency on global ground network.
- Inter-satellite links are already being used by GNSS systems.

Objective of the study?

- To study the constraints of ISL payload antenna configuration, data rate, code rate, power required and onboard communication system and to derive a possible ISL payload configuration for MEO-MEO satellite constellation.

What analysis is done?

- The visibility analysis has been carried for MEO constellation (24 satellites, 3 planes, 24000km).The analysis parameters are variation of off-boresight angle, azimuth angle and slant range.
- The Doppler frequency variation also has been analyzed.
- The analysis has been carried out using STK and in-house developed Matlab modules.
- Various parameters effecting data rate and code rate has also been analyzed.

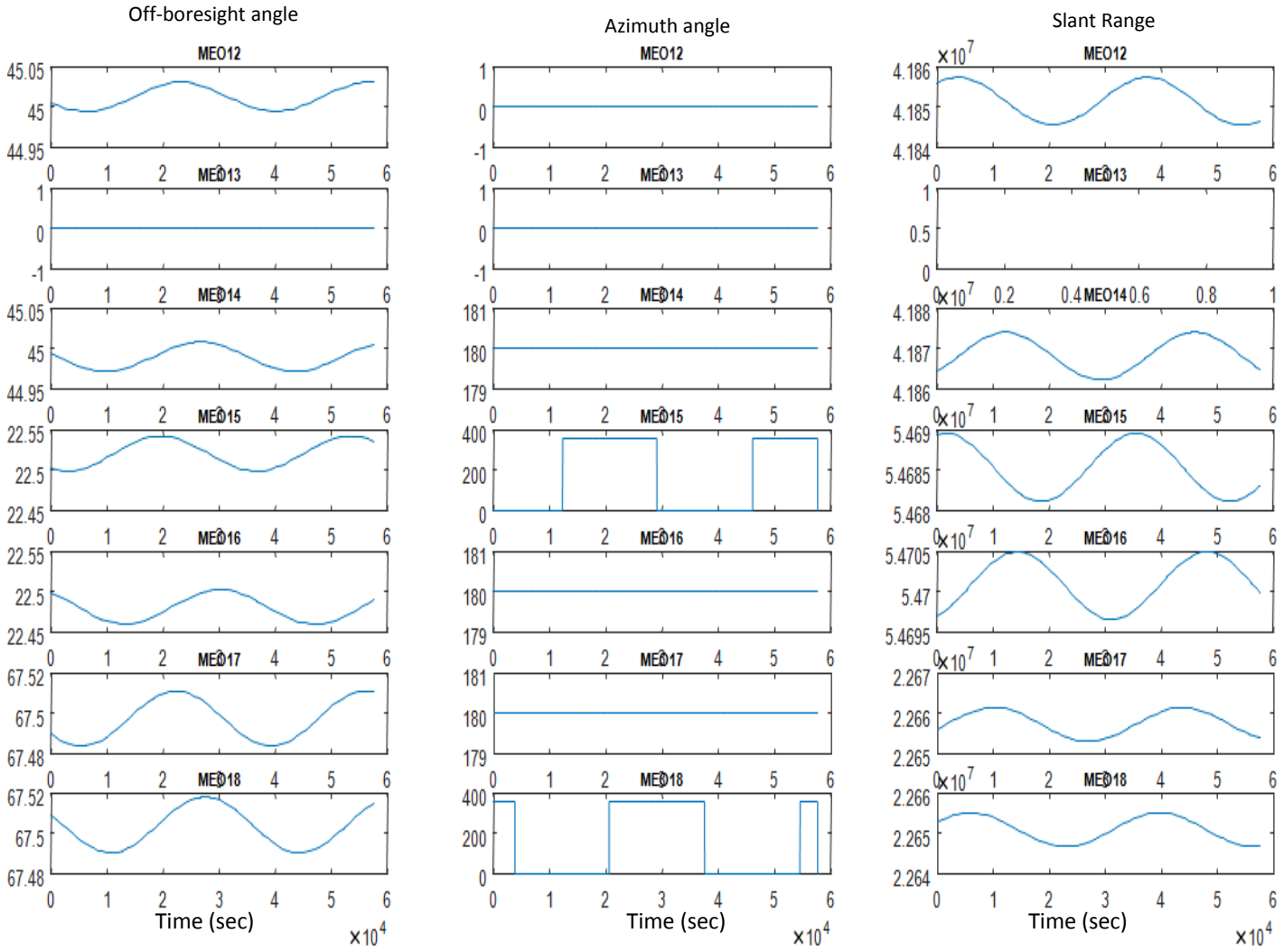
1. Frequency selection

- ITU allocated frequencies for ISL are UHF, S, C, Ka, V and other higher frequency bands.
- The main factors of frequency selection are complexity of antenna in terms of size, antenna pointing complexity and available components.
- Considering the above defined parameters the Ka frequency band from 22.55 to 23.55 GHz has been chosen.
- The frequency range from 23.38 GHz to 23.55 GHz has been chosen so that the selected range doesn't interfere with the already existing systems in this band.

The frequency in this band 23.38 GHz to 23.55 GHz has been chosen for further analysis.

2. Antenna configuration selection: In-plane satellite visibility

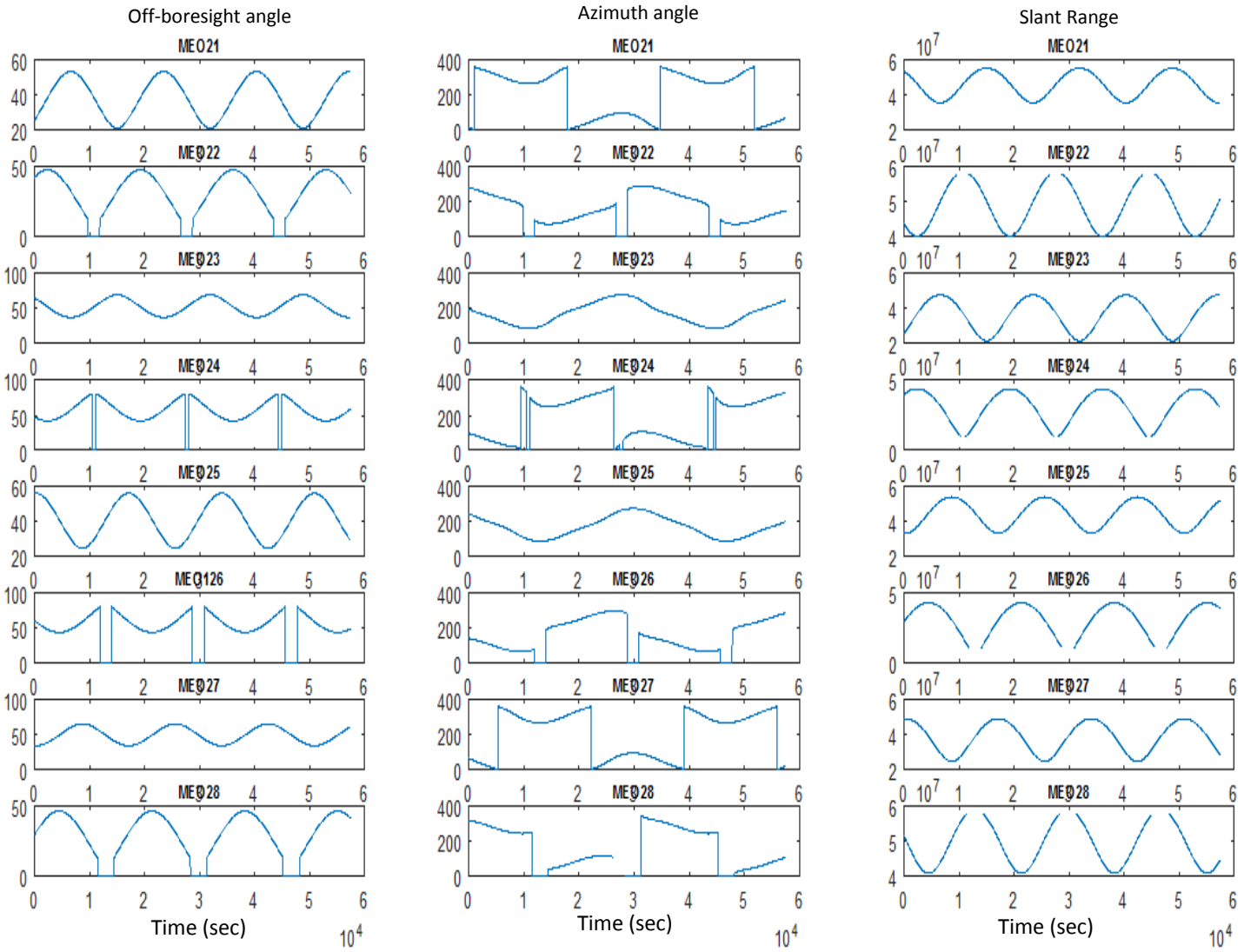
In-plane satellites MEO11 to MEO18...



- The slide shows the variation of off-boresight angle, azimuth and slant range of a in-plane satellite w.r.t MEO11.
- Always 6 in-plane satellites are visible.
- The in-plane satellites visibility starts at 22.5 deg approx.
- The range variation is from 22600km to 54700 km.
- Can be tracked using fixed antenna (i.e. no steering) with number of satellites to be tracked is equal to the number of antennas.

2. Antenna configuration selection: Out-of-plane satellite visibility

In-plane satellites MEO21 to MEO28...



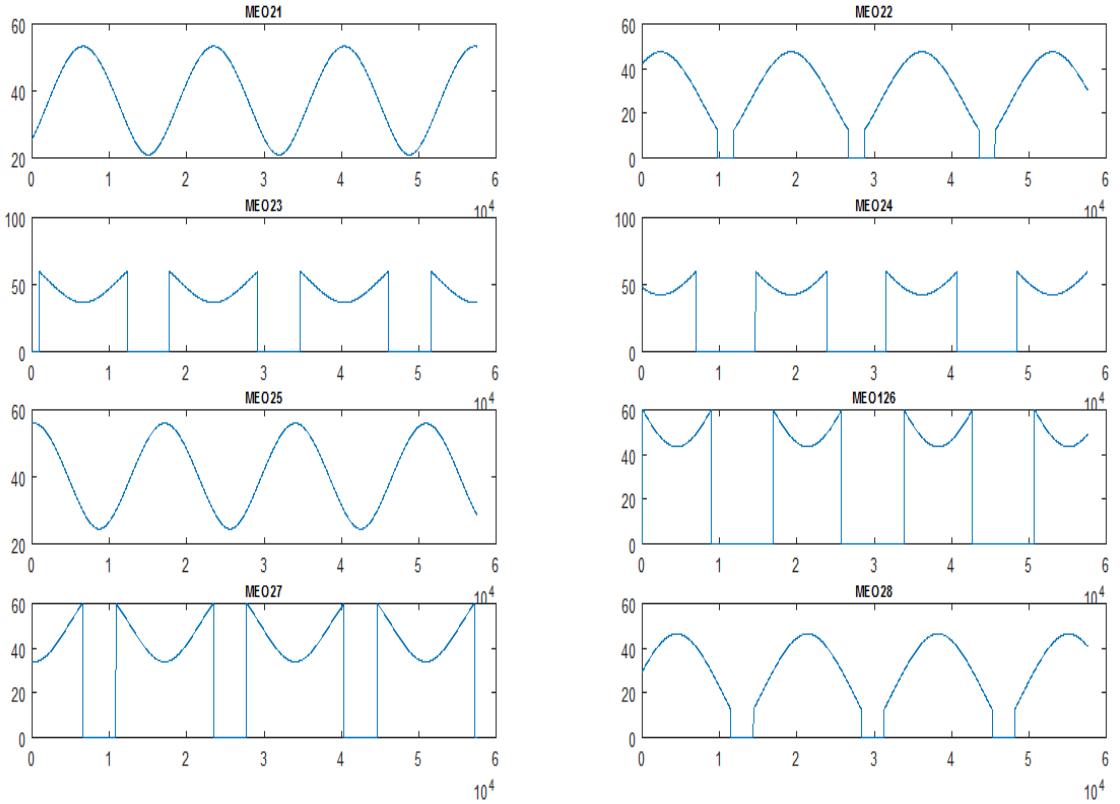
- This slide shows the out-of-plane satellite visibility w.r.t. MEO11.
- 4 out-of-plane satellites are continuously visible.
- The coverage angle variation is from 12.5 deg to 80 deg (approx).
- Range variation is from 29500 to 57800 km.
- The minimum beam coverage required is ± 60deg for continuous visibility of 2 satellites.
- Antenna steering required with rapid movement for continuous tracking.

2. Antenna configuration selection: Summary of visibility analysis

A single antenna with electronic beam steering mechanism with a minimum beamwidth of ±60deg to track both in-plane and out-of-plane satellites continuously is required.

	24 MEO	
Parameter	In-plane satellites	Out-of-plane satellites
Off-boresight angle (deg)	22.45 to 22.54	12.5 to 60.0
	44.0 to 45.0	
Azimuth angle (deg)	180 or 360	0 to 360
Slant range (km)	41800 to 54700	29500 to 57800
Number of satellites continuously visible	4	4 (2 from each plane)
Continuous non-visible satellites	3	0 (non-continuous visibility)
Total number of satellites visible	15 to 18 satellites	

Out-of-plane satellite visibility w.r.t. MEO11 for off-boresight angle of 60deg



3. PRN code rate selection- Effect of Doppler Frequency

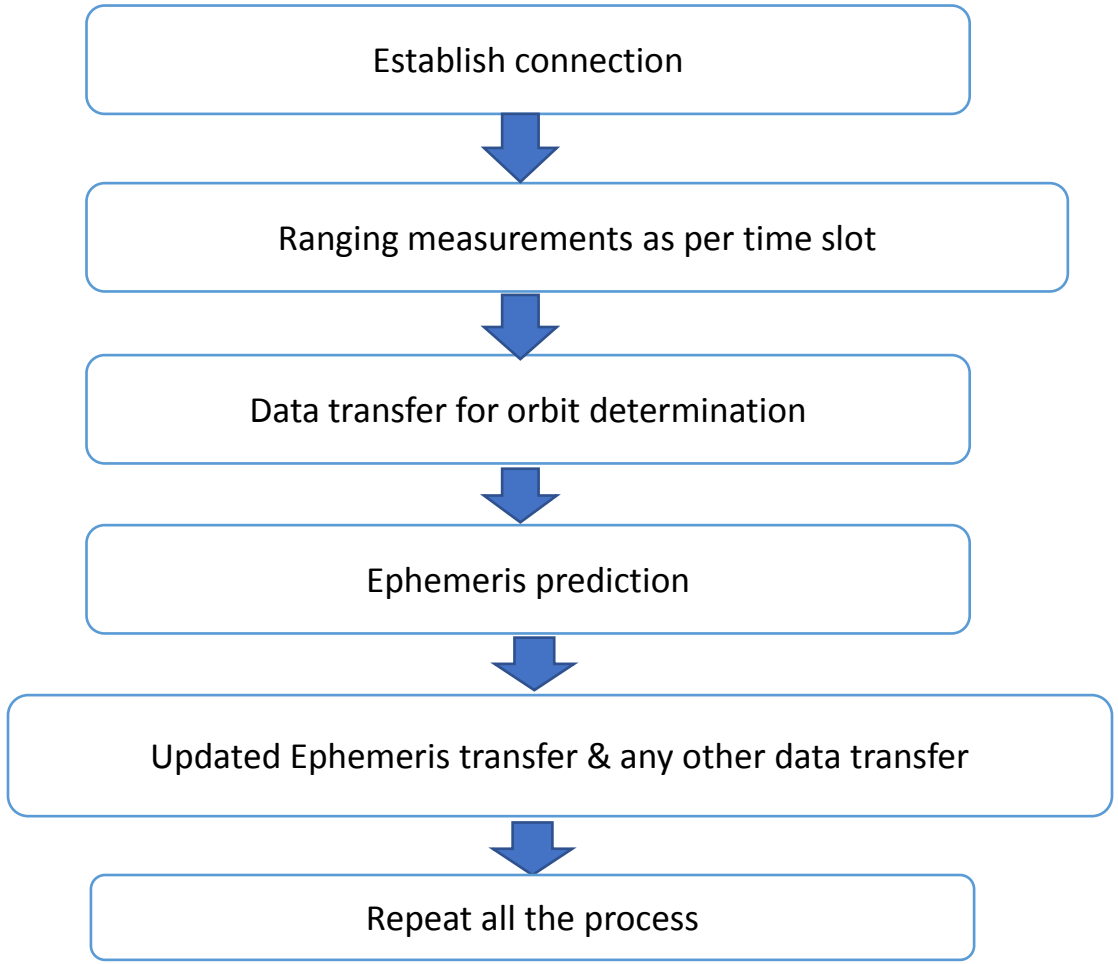
- The ISL communication (ranging and data transfer) between the satellites will be carried out using PRN code.
- The table shows the offset of 1 code chip depending on the incoming doppler frequency.
- The code doppler limits the total integration time which makes it difficult to acquire during weak signal acquisition.
- From the above table, it is clearly seen that with the increase in the code rate, the code doppler is increasing and hence offset of 1 chip occurs in very less time which in turn limits the code period.

Doppler frequency	250 kHz	
Code rate	Code Doppler (Hz)	Offset of 1 chip (msec)
1 Mcps	10.23	97.8
2 Mcps	20.46	48.9
5 Mcps	51.15	19.6
10 Mcps	102.3	9.8
20 Mcps	204.6	4.9

The optimum code rate is upto 5 Mcps.

4. Data Rate Selection for ranging between satellites

Flowchart of Orbit determination using Inter-satellite Ranging



- Data rate depends upon the time slot duration, amount of data to be transferred, time taken for establishing connection and time taken for range measurements.

Assumption is a 3 sec time slot.	
Time for ranging measurements (sec)	Data rate (kbps)
0.5	4
1	2
2	1

The optimum data rate for ranging is 2 kbps.

ISL Payload Configuration for MEO-MEO satellite configuration

Parameter	Requirements
Frequency	➢ Ka band from 23.38 GHz to 23.55 GHz
Antenna	➢ Antenna with minimum ±60^0 beam coverage for: azimuth 0 to 360^0 and elevation 12.5^0 to 60^0 (out-of-plane).
Data Rate	Ranging: 2 kbps
Receiver system onboard	➢ Dynamic range of 6dB for distance variation from 29000 km to 58000 km. ➢ A receiver capable of handling high Doppler frequency of around 250 kHz.
Ranging code properties	Code rate upto 5 Mcps.
Power requirements	For maximum distance of 58000km, the antenna gain required is around 32dBi (for transmission and reception) with 2 Watt power amplifier.

Summary:

- The constraints on the antenna, data rate, code rate, power requirements and receiver system onboard have been analyzed and derived one possible configuration of ISL payload for the defined frequency.
- The payload configuration can be further refined depending on the actual hardware availability (for power requirements), orbit accuracy requirements etc.

Thank You