

# The GPS Block IIR/IIR-M Antenna Panel Pattern



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# Topics

- GPS Block IIR and IIR-M Panel Types
- Panel Coordinates and Orientation
- Directivity and Gain
- The GPS IIR/IIR-M Terrestrial and Space Service Requirements
- IIR Legacy and Improved Antenna Pattern – L1
- IIR Legacy and Improved Antenna Pattern – L2
- IIR Antenna Power Measurements
- Conclusion
- Appendix A – SV-specific Directivity Plots
- Appendix B – SV-specific Directivity Data
- Appendix C – SV-specific Relative Phase Data

# GPS Block IIR and IIR-M Panel Types

## GPS Block IIR Antenna Panel Types

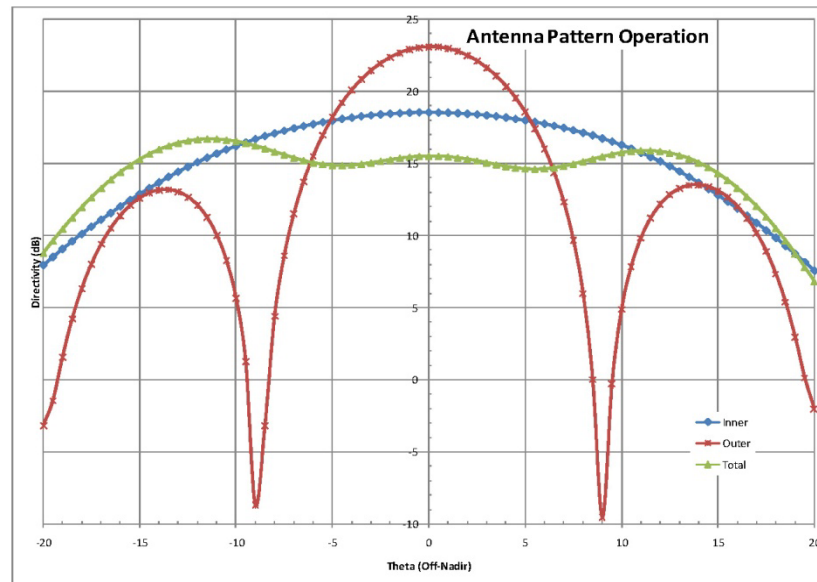
- GPS IIR 'Legacy' (original) antenna panel used on first 8 of 12 IIR SVs
- GPS IIR 'Improved' antenna panel used on final 4 of 12 IIR SVs, and all 8 IIR-M SVs
- Chart on following slide shows which panel type on which SV

## IIR/IIR-M Flavors

SVN (Launch Order)	SV Type		Antenna Panel Type	
43	Classic IIR SV		Legacy Antenna Panel	
46	Classic IIR SV		Legacy Antenna Panel	
51	Classic IIR SV		Legacy Antenna Panel	
44	Classic IIR SV		Legacy Antenna Panel	
41	Classic IIR SV		Legacy Antenna Panel	
54	Classic IIR SV		Legacy Antenna Panel	
56	Classic IIR SV		Legacy Antenna Panel	
45	Classic IIR SV		Legacy Antenna Panel	
47	Classic IIR SV			Improved Antenna Panel
59	Classic IIR SV			Improved Antenna Panel
60	Classic IIR SV			Improved Antenna Panel
61	Classic IIR SV			Improved Antenna Panel
53		IIR-M SV		Improved Antenna Panel
52		IIR-M SV		Improved Antenna Panel
58		IIR-M SV		Improved Antenna Panel
55		IIR-M SV		Improved Antenna Panel
57		IIR-M SV		Improved Antenna Panel
48		IIR-M SV		Improved Antenna Panel
49		IIR-M SV		Improved Antenna Panel
50		IIR-M SV		Improved Antenna Panel

## GPS Block IIR 'Legacy' Antenna

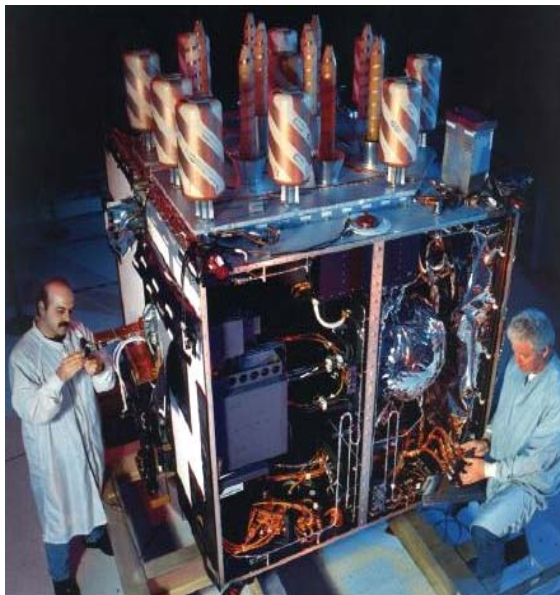
- Used on first 8 of 12 IIR SVs
  - 8 helix elements in circle with 4 elements in the center (Pictured on next slide)
  - 12-way power divider and beam forming network distributes the signal power with a phase offset between the rings to provide balanced power over the horizon-to-nadir earth coverage range (13.8 deg)



Nominal Antenna Panel Pattern from Inner (Blue) and Outer (Red) Rings

## GPS Block IIR 'Improved' Antenna

- Used on final 4 of 12 IIR SVs, and all 8 IIR-M SVs
  - New element designs and configurations on the panel
  - At Edge of Earth, 1-2 dBW added to L1 and L2 for IIR
  - IIR-M SVs provide additional power due to higher power transmitters; power envelope further increased on IIR-M with new modernized signals: L2C, L1M, L2M



Legacy Antenna Panel



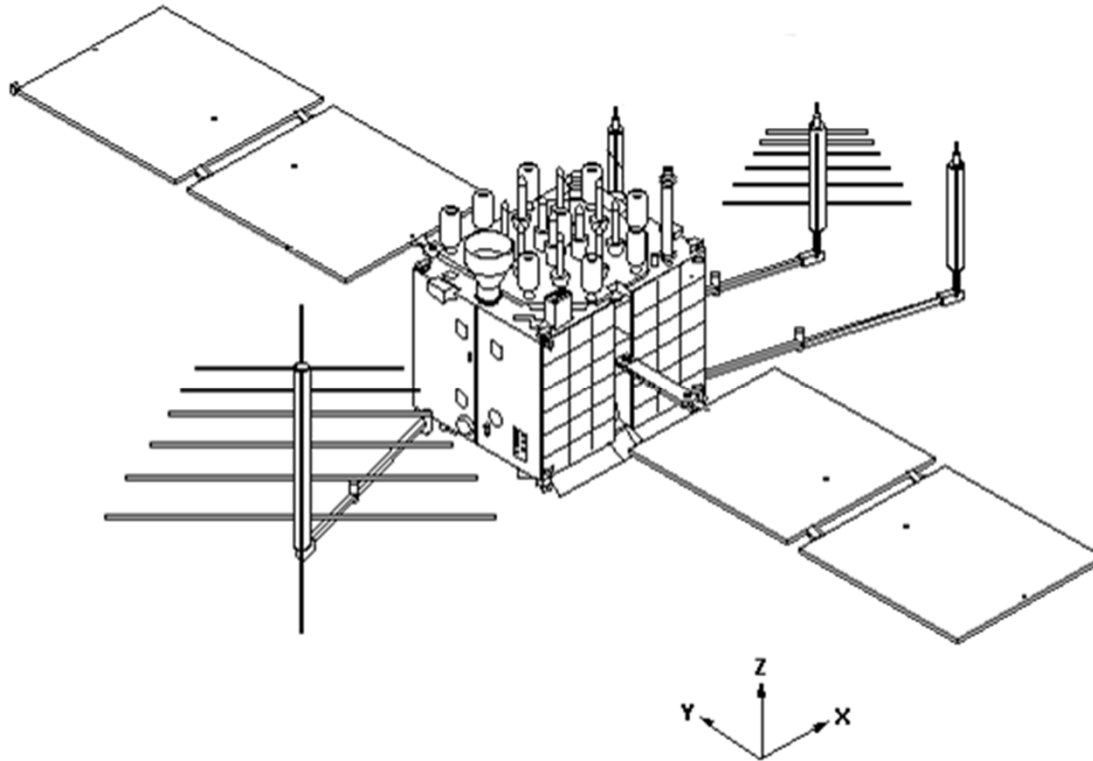
Improved Antenna Panel

# Panel Coordinates and Orientation



# SV Body Axis Definition

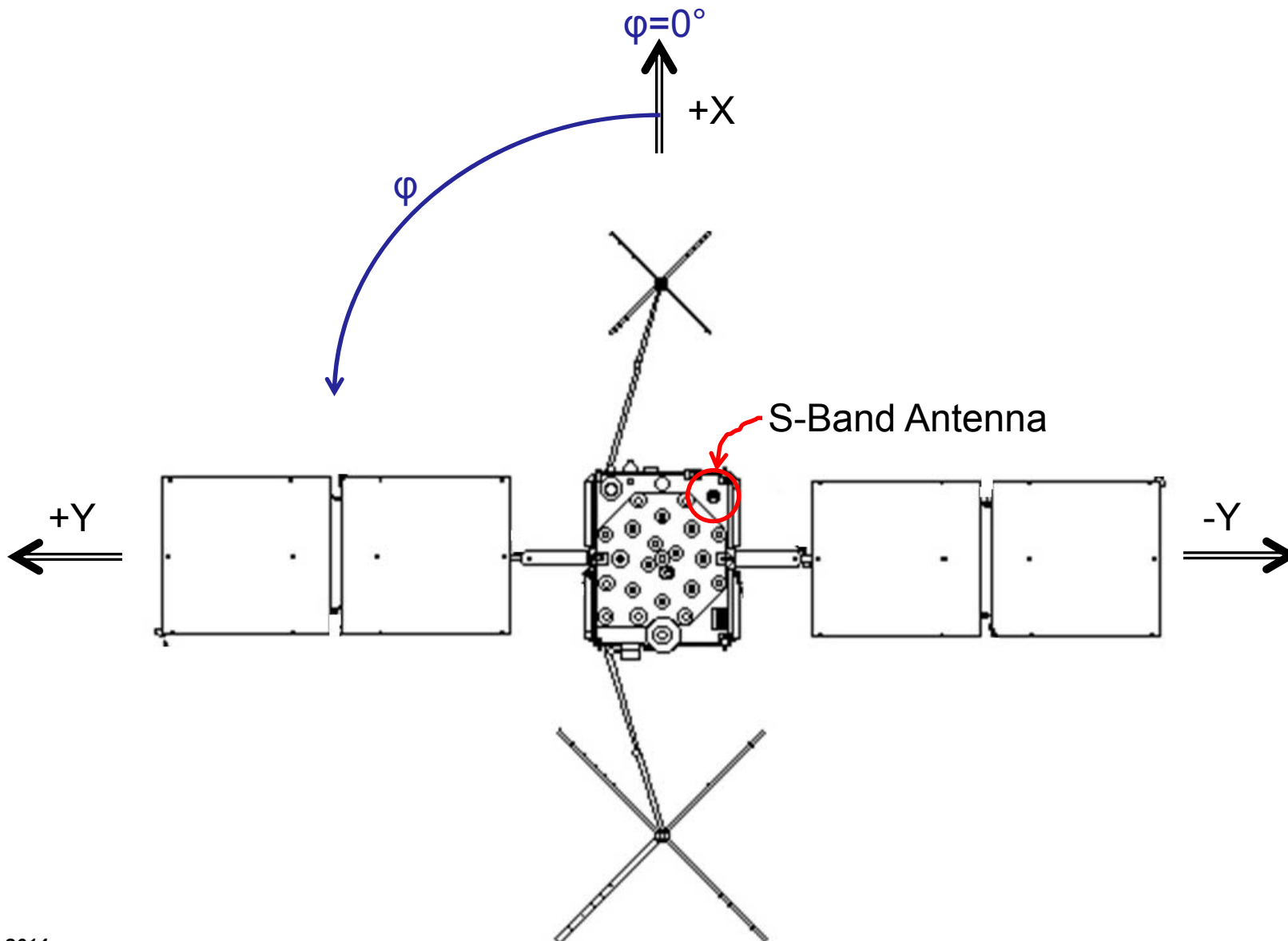
- IIR SV body axes
  - +Z axis directed toward Earth (nadir)
  - +Y axis along 'positive' solar array axis
  - +X completes right-handed system



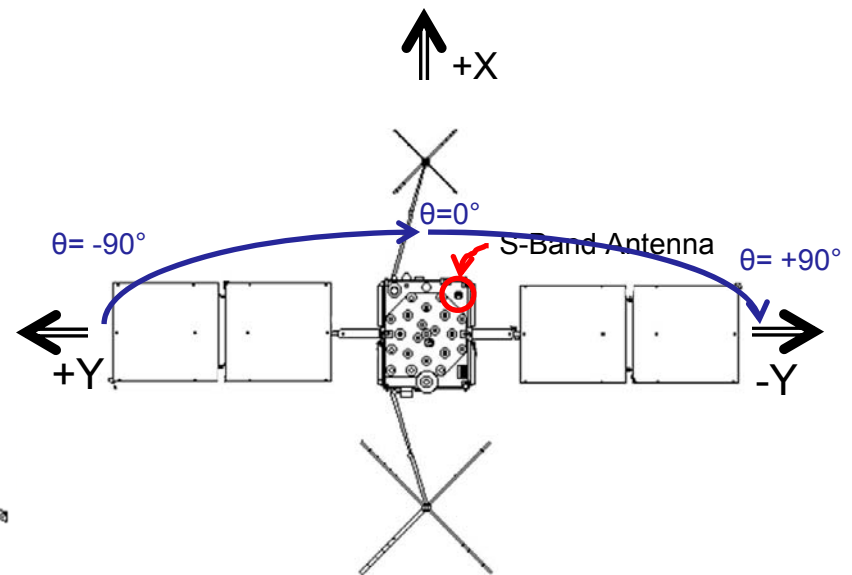
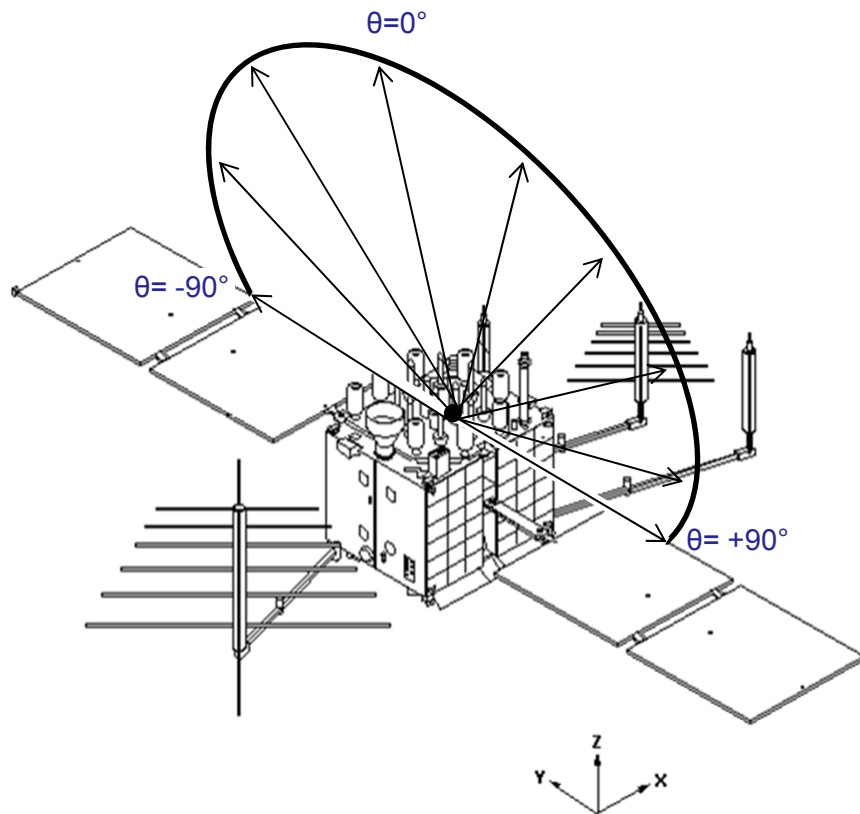
# Antenna Panel Coordinates and Orientation

- Antenna Panel Measurement Coordinates
  - Refer to diagrams on following 2 slides:
    - $\varphi$  = angle that is counter-clockwise around antenna panel boresight (in nadir direction) axis (0 – 360 degrees)
    - $\theta$  = angle across face of antenna panel:
      - from +Y solar array ( $\theta = -90$  degrees)
      - through nadir ( $\theta = 0$  degrees)
      - to -Y solar array ( $\theta = +90$  degrees)
  - Edge of Earth (EoE) boresight angle:  $\theta = \pm 13.8$  degrees
- Antenna Panel Mounting Orientation
  - Antenna panel orientation on the earth face of the SV:
    - Panel reference line,  $\varphi = -90$  degrees, is aligned along the -Y SV body axis (SV s-band antenna boom in “upper right” corner)

# Antenna Orientation – Around Boresight



# Antenna Orientation – Off-Boresight



# Directivity and Gain

## Antenna Panel Directivity

- Antenna pattern plots in this presentation provide the directivity of the signal from the antenna panel
  - Directivity measurement uncertainty typically +/-0.25 dB
- The plot of the far field pattern data consists of a series of azimuthal variation (theta,  $\theta$ ) cuts from -90 degrees to +90 degrees as the roll (phi,  $\phi$ ) axis is stepped every 10 degrees (in phi,  $\phi$ )

## Antenna Panel Gain

- Antenna gain is computed by applying the gain correction factor (GCF) values (the L1 and L2 loss in dB; values found on the next chart) for each SV:

$$\text{Gain(dB)} = \text{Directivity(dB)} - \text{GCF(dB)}$$

- GCF is computed from the measurement of a standard gain horn and the measurement of the panel and the directivities for each frequency

# IIR/IIR-M Gain Correction Values

SVN (Launch Order)	L1 GCF (dB)	L2 GCF (dB)
43	0.9	1.1
46	1.0	1.2
51	0.7	1.2
44	1.1	1.0
41	0.9	1.1
54	0.8	1.0
56	0.7	1.1
45	1.1	1.2
47	1.3	0.8
59	1.3	0.8
60	1.3	0.7
61	1.2	0.8
53	1.4	0.8
52	1.2	0.7
58	1.3	0.9
55	1.3	0.8
57	1.3	0.8
48	1.4	0.9
49	1.3	0.8
50	1.3	0.8

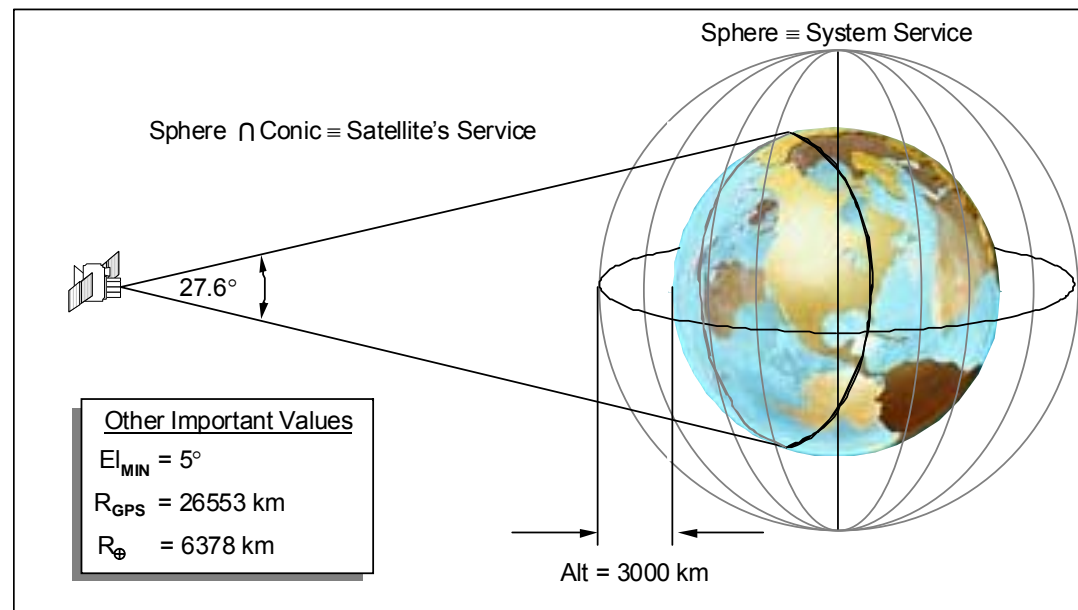
GCF = Gain Correction Factor



# The GPS IIR/IIR-M Terrestrial and Space Service Requirements

# The GPS Terrestrial Service

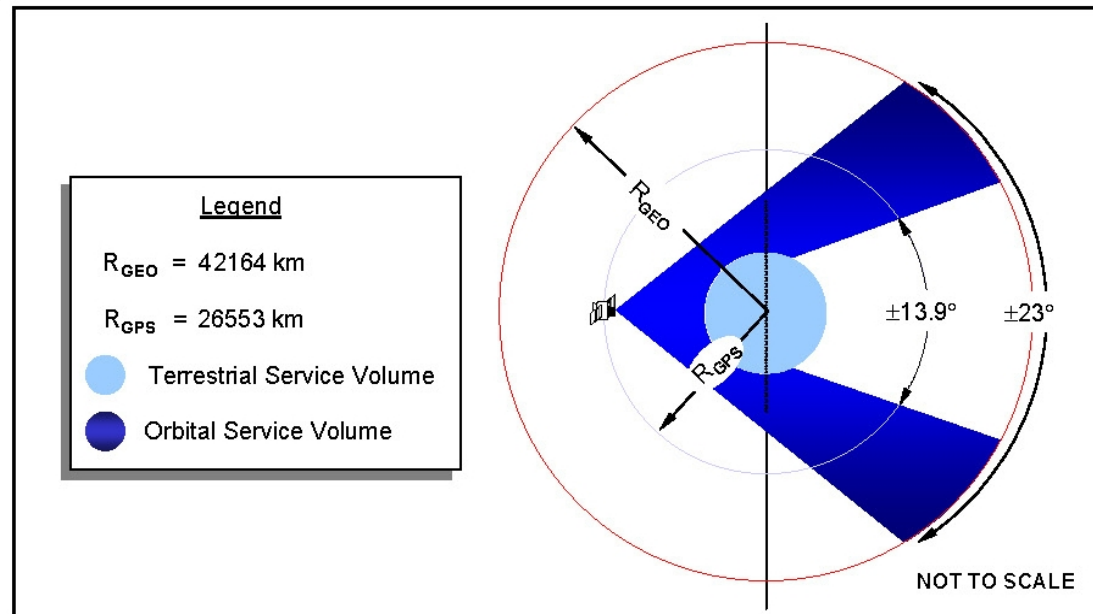
- Definition of the Earth Terrestrial Service Volume:  
The near-Earth region up to 3,000 km altitude



Source: ICD-GPS-700

# The GPS Space Service Volume

- Definition of the Space Service Volume (SSV):  
The spherical shell up to 36,000 km altitude (approximately the geosynchronous orbit altitude)
- Not a requirement for IIR/IIR-M, but some service is available

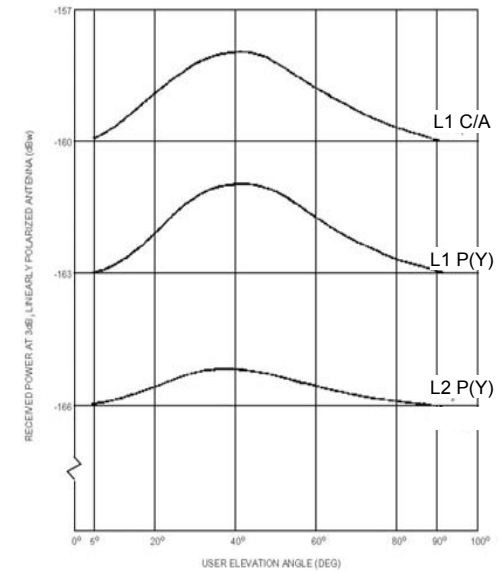


Source: ICD-GPS-700

# GPS Block IIR/IIR-M Signal Power Requirements

	GPS Block IIR	GPS Block IIR-M
L1 C/A (dBW)	-158.5	-158.5
L1 P(Y) (dBW)	-161.5	-161.5
L2 P(Y) (dBW)	-164.5	-161.5
L2C (dBW)	N/A	-160.0 (-161.4 on IIR-M contract)
Terrestrial Req	Measured at 5 deg elevation == Edge of Earth (EOE)	
Space Service Volume Req	None for IIR/IIR-M*	

\*GPS IIF and GPS III SSV requirements shown on following slide for comparison purposes only



Notional Terrestrial Service,  
EOE-to-Nadir  
Source: IS-GPS-200

## For Comparison: GPS Block IIF and GPS III Space Service Volume Requirements

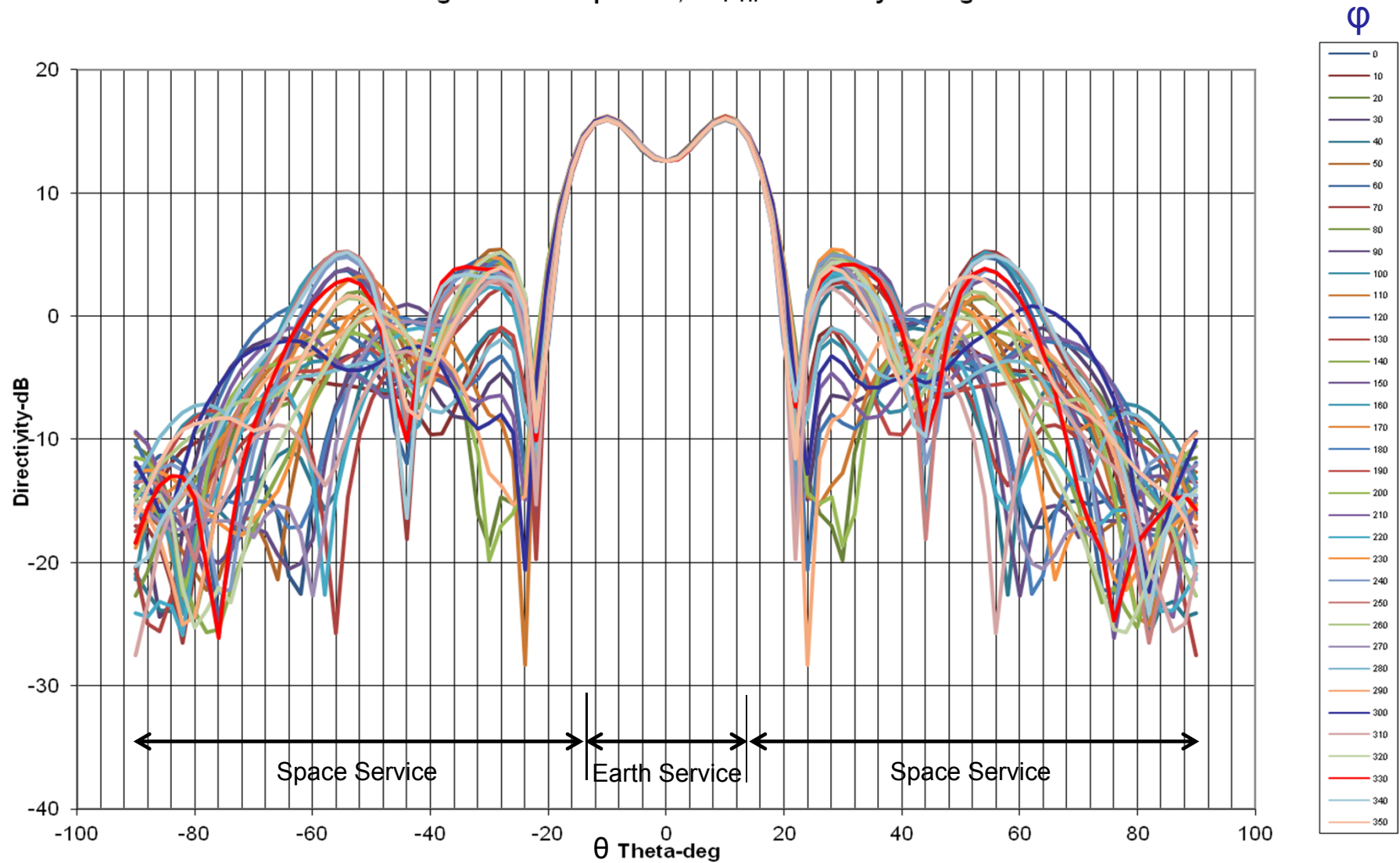
	GPS Block IIF*		GPS III*	
	from EOE out to 20 deg off-nadir	from EOE out to 23 deg off-nadir, decrease monotonically down to --	from EOE out to 23.5 deg off-nadir	from EOE out to 26 deg off-nadir, decrease monotonically down to --
L1 C/A (dBW)	< 10 dB decrease	< 18 dB decrease	-184.0	N/A
L1 P(Y) (dBW)			-187.0	
L2 P(Y) (dBW)	N/A	< 10 dB decrease	N/A	-186.0
L2C (dBW)				-183.0

\*Ref. IS-GPS-200

# IIR Legacy and Improved Antenna Pattern L1

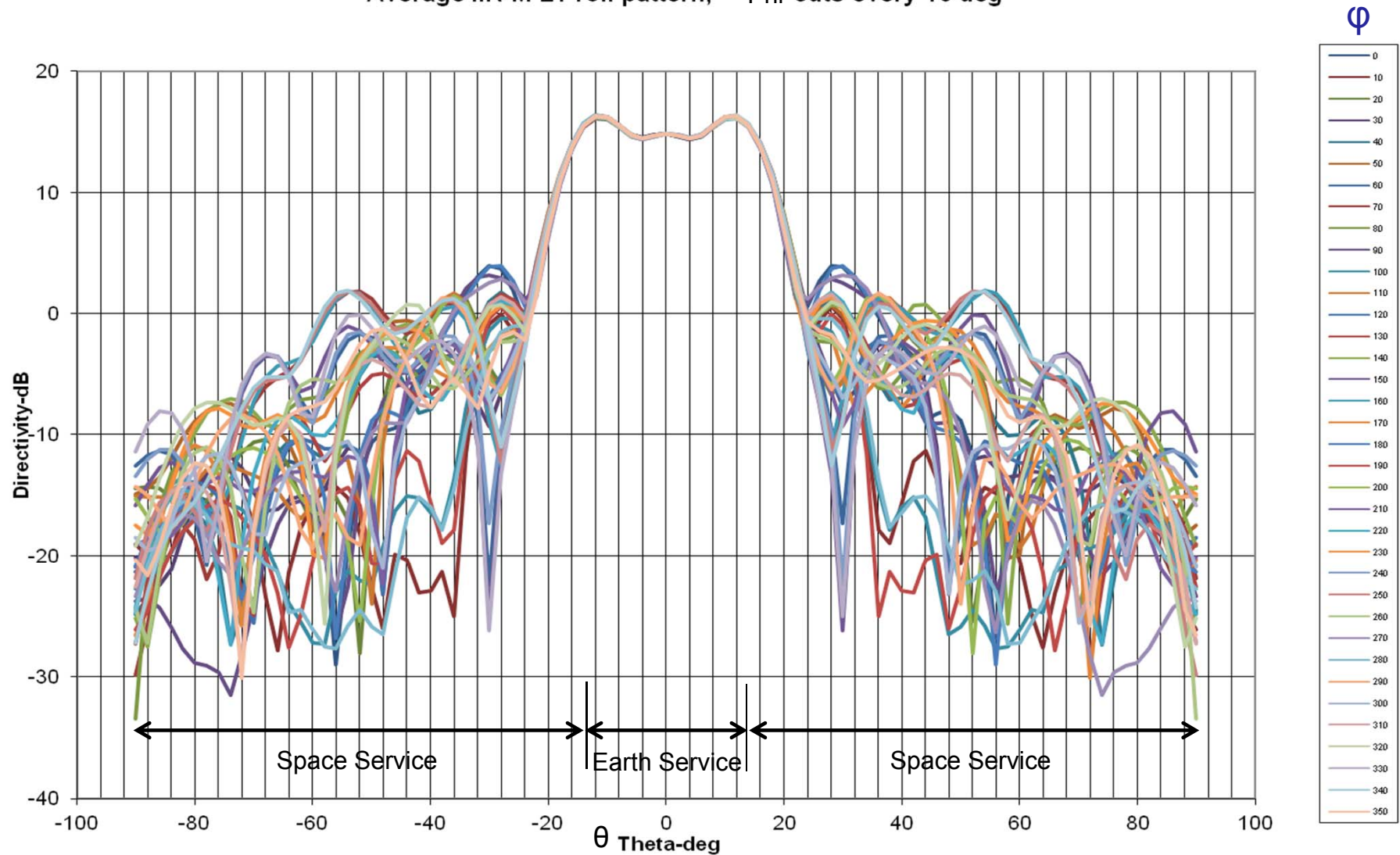
# Legacy Antenna Pattern – L1

Average IIR L1 roll pattern,  $\Phi$  cuts every 10 deg



# Improved Antenna Pattern – L1

Average IIR-M L1 roll pattern, Phi cuts every 10 deg





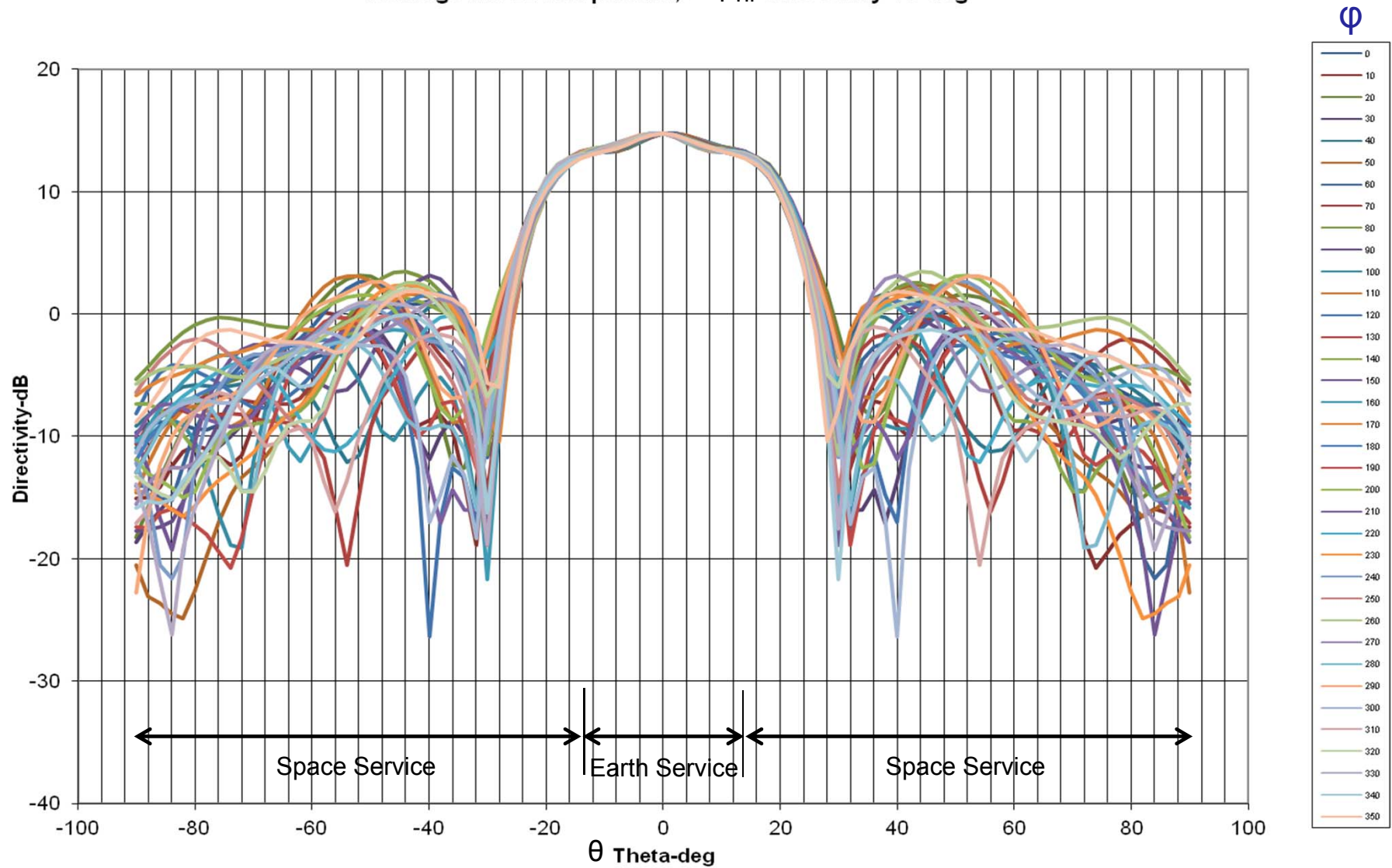
## Legacy vs. Improved Panel – L1

	Edge of Earth (EOE) (dB)	EOE out to 20 deg		EOE out to 23 deg	
		Magnitude (dB)	Reduction (dB)	Magnitude (dB)	Reduction (dB)
Legacy Panel	+15	+4 to -5	-11 to -20	-2 to -19	-17 to -34
Improved Panel	+16	+9 to +5	-7 to -11	+2 to -4	-14 to -20
Change from Legacy to Improved		+5 to +10		+4 to +15	

# IIR Legacy and Improved Antenna Pattern L2

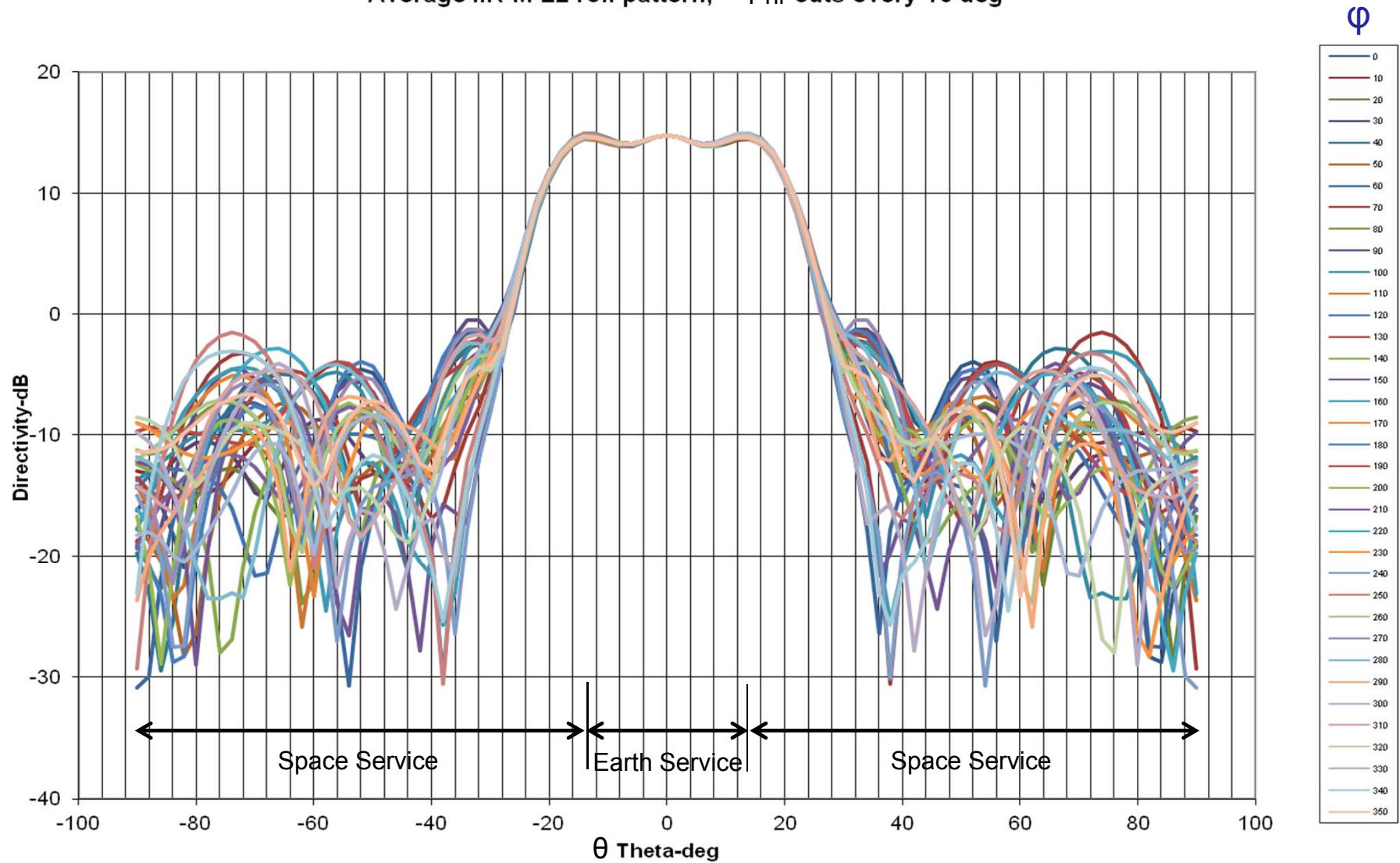
# Legacy Antenna Pattern – L2

Average IIR L2 roll pattern,  $\Phi$  cuts every 10 deg



# Improved Antenna Pattern – L2

Average IIR-M L2 roll pattern, Phi cuts every 10 deg



## Legacy vs. Improved Panel – L2

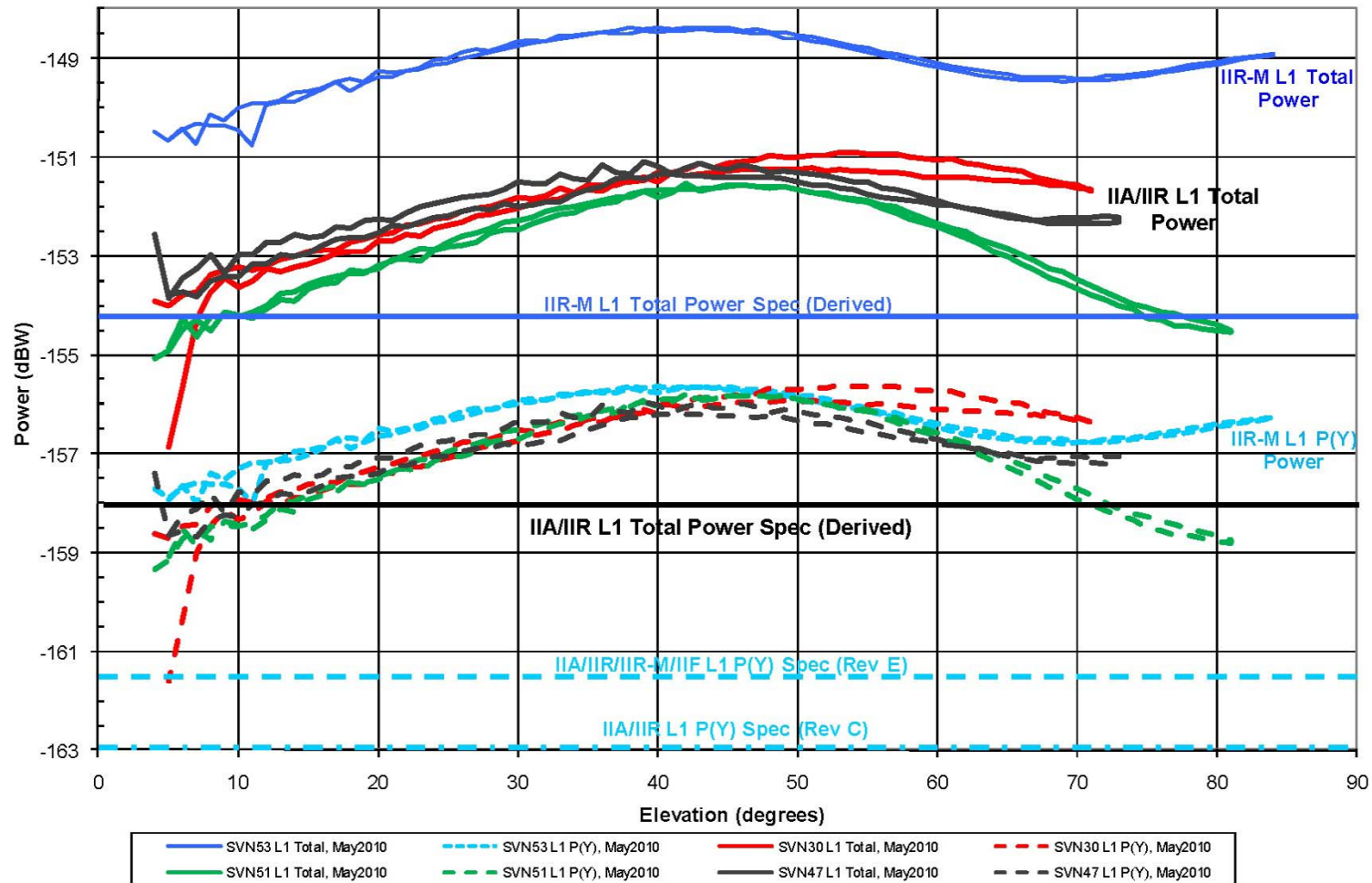
	Edge of Earth (EOE) (dB)	EOE out to 23 deg		EOE out to 26 deg	
		Magnitude (dB)	Reduction (dB)	Magnitude (dB)	Reduction (dB)
Legacy Panel	+14	+9 to +5	-5 to -9	+5 to -3	-9 to -17
Improved Panel	+15	+9 to +6	-6 to -9	+5 to 0	-10 to -15
Change from Legacy to Improved		0 to +1		0 to +3	

# IIR Antenna Power Measurements

## Antenna Power Measurements

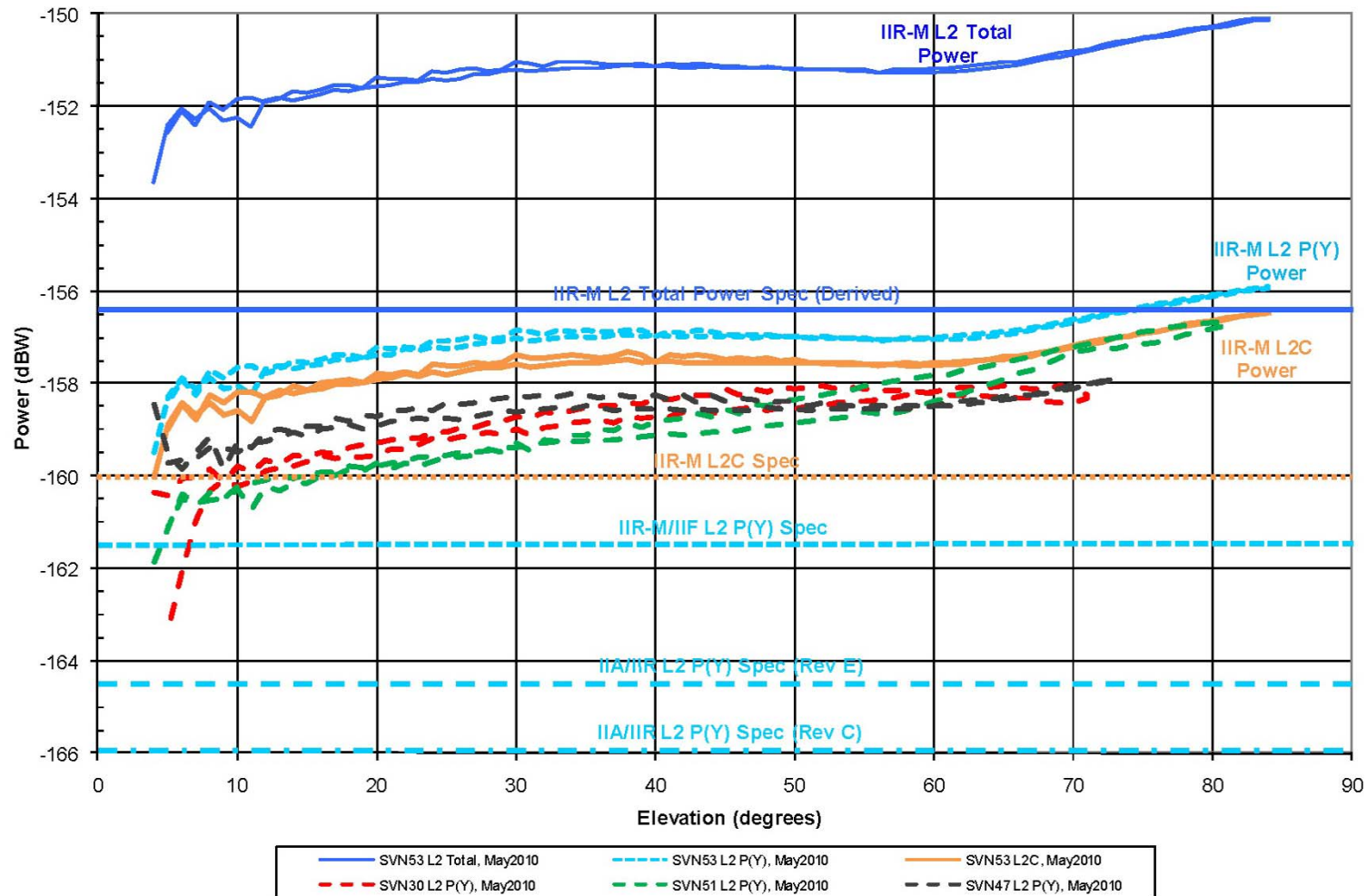
- Regular GPS earth coverage antenna power measurements provided by SRI, Inc. (Palo Alto and Menlo Park, CA).
- Typical measurement curves (horizon to zenith) from May, 2010 are provided in the next 2 slides for L1 and L2
- Other measured results may be found in “On-Orbit Performance of the Improved GPS Block IIR Antenna Panel”, Marquis & Reigh, ION-GNSS-2005

# SRI Measurements – L1





# SRI Measurements – L2



# Conclusion

## IIR Terrestrial Service Results

- The IIR legacy panel
  - Exceeds spec for L1
  - Exceeds spec for L2
- The IIR improved panel
  - Exceeds spec for L1
  - Exceeds spec for L2
- The IIR improved panel provides stronger terrestrial service

## IIR Space Service Volume Results

	Though not a IIR requirement, the following service is provided at the levels presented in IS-GPS-200:			
	L1, at 20 deg	L1, at 23 deg	L2, at 23 deg	L2, at 26 deg
IIR Legacy Panel	At some yaw angles	At some yaw angles	Yes	At some yaw angles
IIR Improved Panel	At some yaw angles	Yes	Yes	Yes

- The IIR improved panel provides stronger Space Service, though SSV not a requirement for IIR/IIR-M

## Conclusion

- GPS Block IIR and IIR-M SVs exceeds terrestrial service requirements
- GPS Block IIR and IIR-M SVs provide the desired space service volume levels in many cases, though they are not applicable requirements
- GPS IIR improved antenna panel (used on all IIR-M SVs) provides stronger terrestrial and space service