Rosetta Interference Analysis

March 23, 2003

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Rosetta Interference Analysis Background

- Purpose of this study is to determine potential interference scenarios with the new Rosetta trajectory
- Rosetta launch date: March 2, 2004
- Rosetta mission end date: May 14, 2014
- Rosetta trajectory used for analysis has launch date of Feb 26, 2004
- Rosetta mission has already been assigned Channel 19 both in S-band and X-band for uplink and downlink operations
- Rosetta has three Earth Fly-By's -- potential interference with Rosetta uplink and the downlinks of missions using nearby channels
- Rosetta has a Mars Fly-By -- potential interference with Mars missions in nearby channels

Rosetta Interference Analysis
Rosetta Telecom Parameters (X-Band)

		General Info	Rosetta				
Mission		Rosetta					
Mission ID		-226					
Mission Start Date		2004 FEB 26 09:44:44.725					
Mission End Date		2014 MAY 24 01:43:30.119					
Trajectory File Name		Rosetta					
Trajectory Start Date		2004 FEB 26 09:44:44.725					
Trajectory End Date		2014 MAY 24 01:43:30.119					
Uplink			Uplink Phases				
Frequency Band		X-Up					
Phase No			0	1	2	3	4
Phase Name			Nominal	All			
Start Date			2004 FEB 26	2004 FEB 26			
End Date			2014 MAY 24	2014 MAY 24			
Channel Number		19	19	19			
Earth Station Power	dBm	73	73	73			
Earth Station Transmit Antenna Gain	dB	67.1, Perth(64)	67.1	67.1			
Subcarrier Frequency	kHz	16	16	16			
Subcarrier Type		sine	sine	sine			
Mod Index	Degree	CMD(57.3, 80.2), RNG(22.9, 80.2)	80	80			
Uncoded Data Rate	bps	7.8125-2000	2000	2000			
Symbols Per Bit		1=NRZ, 2=Biphase	1	1			
Modulation Scheme		PCM/PSK/PM	PCM/PSK/PM	PCM/PSK/PM			
Spacecraft Receive Antenna Gain	dB	-2, 13.5, 40	40	40			
Spacecraft Receive Noise Bandwidth	Hz	20-200	200	200			
Spacecraft Receive Threshold	dBm	-146	-146	-146			
Downlink			Downlink Phases				
Frequency Band		X-Down					
Phase No			0	1	2	3	4
Phase Name			Nominal	All			
Start Date			2004 FEB 26	2004 FEB 26			
End Date			2014 MAY 24	2014 MAY 24			
Channel Number		19	19	19			
Spacecraft Power	dBm	43.2 (HGA), 42.8 (HGA)	42.8	42.8			
Spacecraft Transmit Antenna Gain	dB	25.5,43	43	43			
Subcarrier Frequency	kHz	0, 8.192-262.14	262.14	262.14			
Subcarrier Type		sqrw	sqrw	sqrw			
Mod Index	Degree	TLM(68.8, 72.2), RNG(40.1)	68.8	68.8			
Coding Method		RS, 7-1/2	RS+7-1/2	RS+7-1/2			
Uncoded Data Rate	kbps	0.01-26	26	26			
Symbols Per Bit		1=NRZ, 2=Biphase	1	1			
Modulation Scheme		BPSK, PCM/PM, PCM/PSK/PM	PCM/PSK/PM	PCM/PSK/PM			
DOR Tones	MHz						
DOR Tone Mod Index	Degree						
Earth Station Receive Antenna Gain	dB	DSN(68, 74), Perth(68)	67.1	67.1			

HGA is used throughout the analysis. LGA can be used to reduce interference during Earth fly-by's.

Rosetta Interference Analysis
Rosetta Telecom Parameters (S-Band)

		General Info	Rosetta				
Mission		Rosetta					
Mission ID		-226					
Mission Start Date		2004 FEB 26 09:45:00.000					
Mission End Date		2014 MAY 24 01:40:00.000					
Trajectory File Name		Rosetta					
Trajectory Start Date		2004 FEB 26 09:45:00.000					
Trajectory End Date		2014 MAY 24 01:40:00.000					
Uplink			Uplink Phases				
Frequency Band		S-Up					
Phase No			0	1	2	3	4
Phase Name			Nominal	All			
Start Date			2004 FEB 26	2004 FEB 26			
End Date			2014 MAY 24	2014 MAY 24			
Channel Number		19	19	19			
Earth Station Power	dBm	73 (34m); 64.7 (70m); 72.4 (35m)	73	73			
Earth Station Transmit Antenna Gain	dB	55 (34m); 48.5 (15m); 62 (70m)	55	55			
Subcarrier Frequency	kHz	16	16	16			
Subcarrier Type		sine	sine	sine			
Mod Index	Degree	.2 (TC); 80.2 (RNG); (57.3, 22.9) (TC +RN	80.2	80.2			
Uncoded Data Rate	bps	8 - 2000	2000	2000			
Symbols Per Bit		1=NRZ, 2=Biphase	1	1			
Modulation Scheme		PCM/PSK/PM	PCM/PSK/PM	PCM/PSK/PM			
Spacecraft Receive Antenna Gain	dB	31 (HGA); 13.5 (MGA); -2.0 (LGA)	31	31			
Spacecraft Receive Noise Bandwidth	Hz	20-200	200	200			
Spacecraft Receive Threshold	dBm	-146	-146	-146			
Downlink			Downlink Phases				
Frequency Band		S-Down					
Phase No			0	1	2	3	4
Phase Name			Nominal	All			
Start Date			2004 FEB 26	2004 FEB 26			
End Date			2014 MAY 24	2014 MAY 24			
Channel Number		19	19	19			
Spacecraft Power	dBm	31.7 (HGA), 33.1 (MGA), 32.7 (LGA)	31.7	31.7			
Spacecraft Transmit Antenna Gain	dB	31 (HGA); 14.1 (MGA); -2 (LGA)	31	31			
Subcarrier Frequency	kHz	262.14	262.14	262.14			
Subcarrier Type		sqrw	sqrw	sqrw			
Mod Index	Degree	.2 (TLM); 40.1 (RNG); (68.8, 40.1) (TLM+R	72.2	72.2			
Coding Method		RS, 7-1/2	RS+7-1/2	RS+7-1/2			
Uncoded Data Rate	kbps	0.01-26	26	26			
Symbols Per Bit		1=NRZ, 2=Biphase	1	1			
Modulation Scheme		BPSK, PCM/PM, PCM/PSK/PM	PCM/PSK/PM	PCM/PSK/PM			
DOR Tones	MHz						
DOR Tone Mod Index	Degree						
Earth Station Receive Antenna Gain	dB	56 (34m); 56 (Perth, 35m); 49.2 (15m)	56	56			

HGA is used throughout the analysis. LGA can be used to reduce interference during Earth fly-by's.

Rosetta Interference Analysis
Missions in Nearby Channels

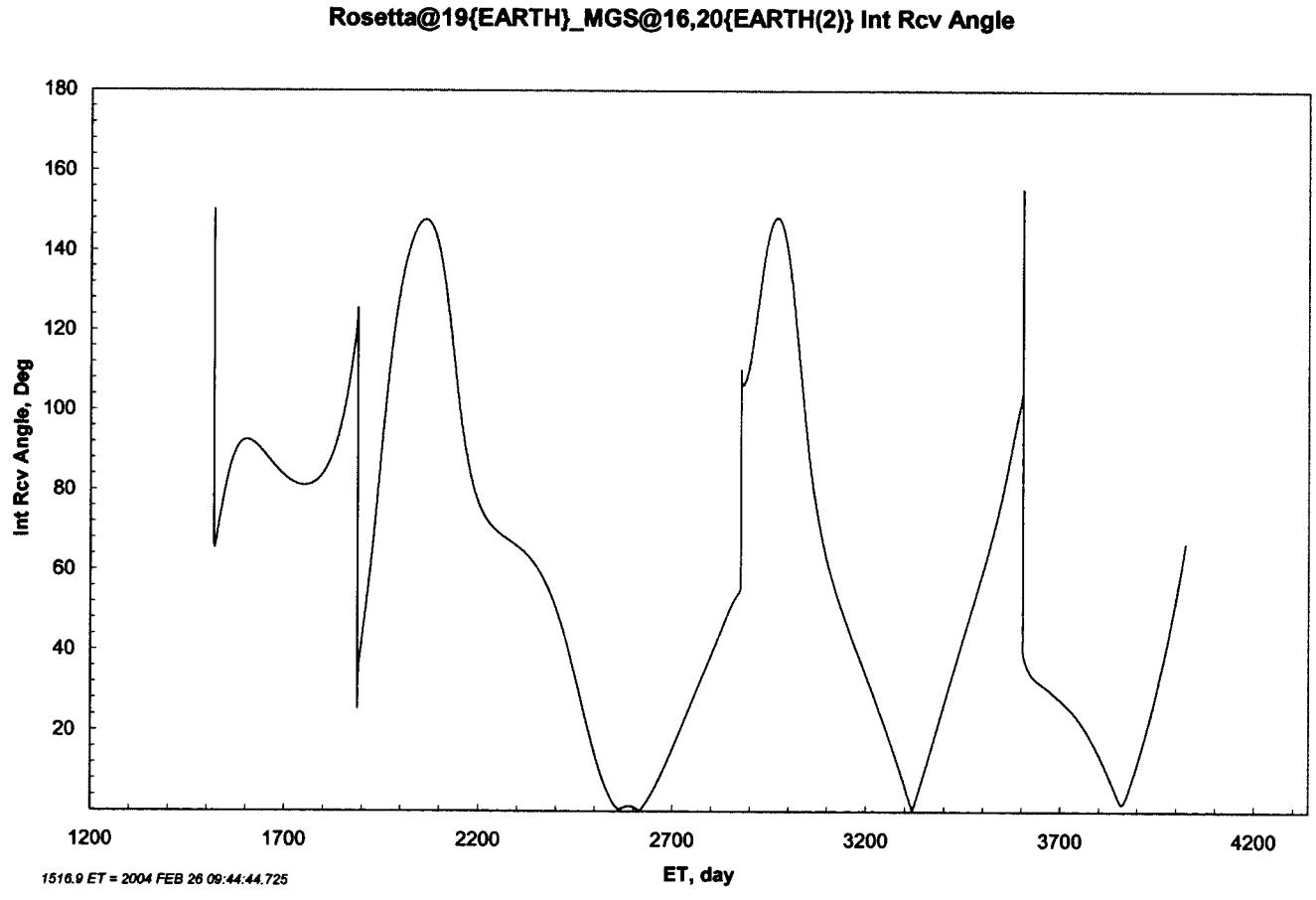
- Nearby X-band Missions
  - Mars Global Surveyor (16), MGS, uplink and downlink, mission expected to end on Jan 3, 2008
  - VenusExpress (17), VEX, uplink and downlink, mission expected to end on Aug 19, 2007
  - MarsExpress (18), MEX, uplink and downlink, mission expected to end on Aug 3, 2008
  - Voyager-1 (18), VGR-1, downlink only, mission expected to end on Sep 30, 2007
  - MGS (20) downlink only, mission expected to end on Jan 3, 2008
  - Kepler (21), KEP, uplink and downlink, mission expected to end on Sep 26, 2011

- Nearby S-band Missions
  - VenusExpress (17) uplink and downlink,mission expected to end on Aug 19, 2007
  - MarsExpress (18) uplink and downlink, mission expected to end on Aug 3, 2008
  - Voyager-1 (18) uplink only, mission expected to end on Sep 30, 2007

Rosetta Interference Analysis
Analysis Assumptions

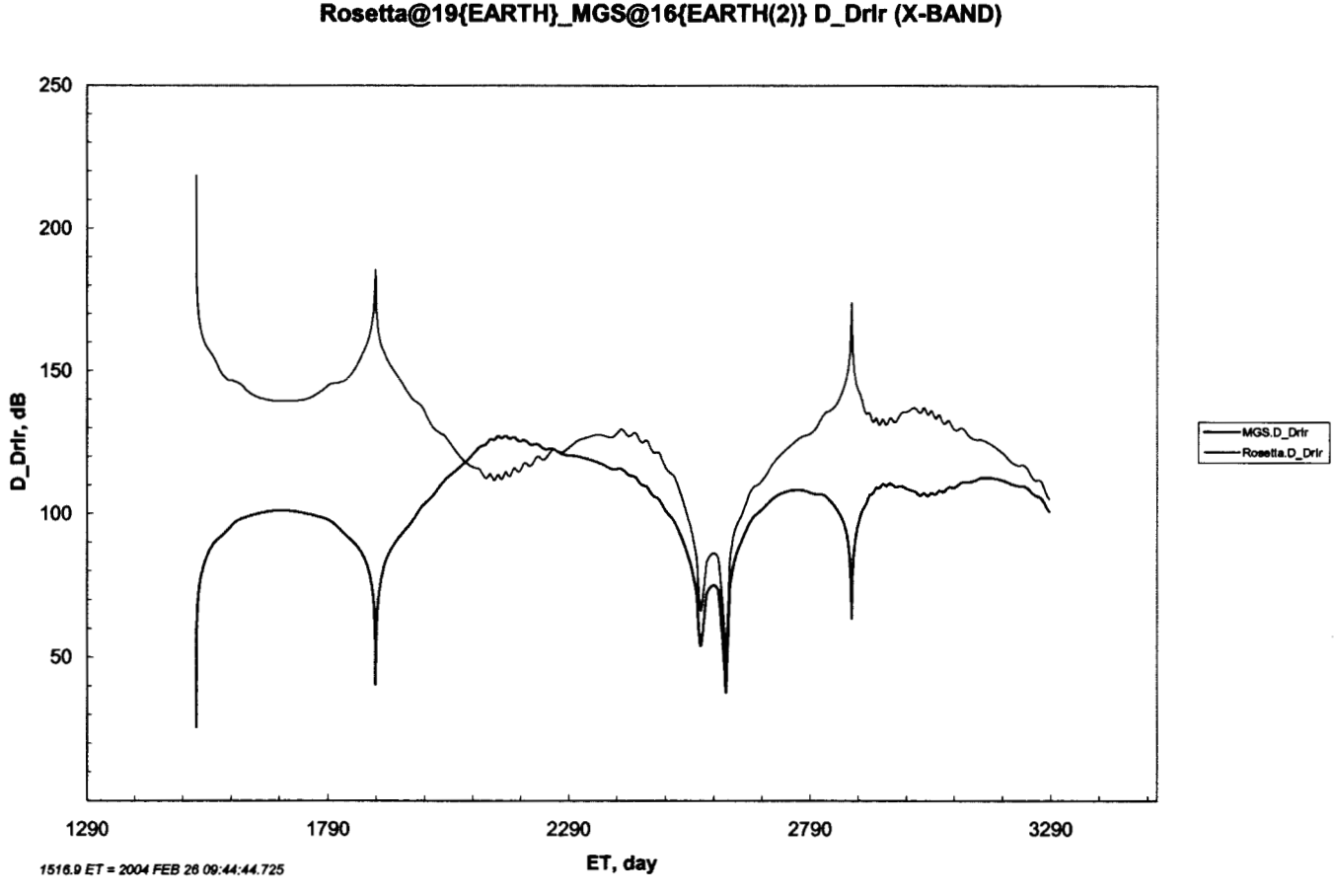
- If the uplink interference power is above -158 dBm around the center frequency of the receiver, we consider this a potential uplink interference scenario.
- If the downlink telemetry signal-to-interference ratio (SIR) is below 20 dB, we consider this a potential downlink interference scenario.
- One uplink/downlink sample per day is used for interference analysis, assuming Earth is a point source/destination. (using the center of Earth instead of ground stations on the surface for analysis)
- The Rosetta initial near-Earth (right after launch) interference analysis has already been performed

Rosetta X-Band Interference Analysis
Angular separation between Rosetta and MGS (Channels16, 20)



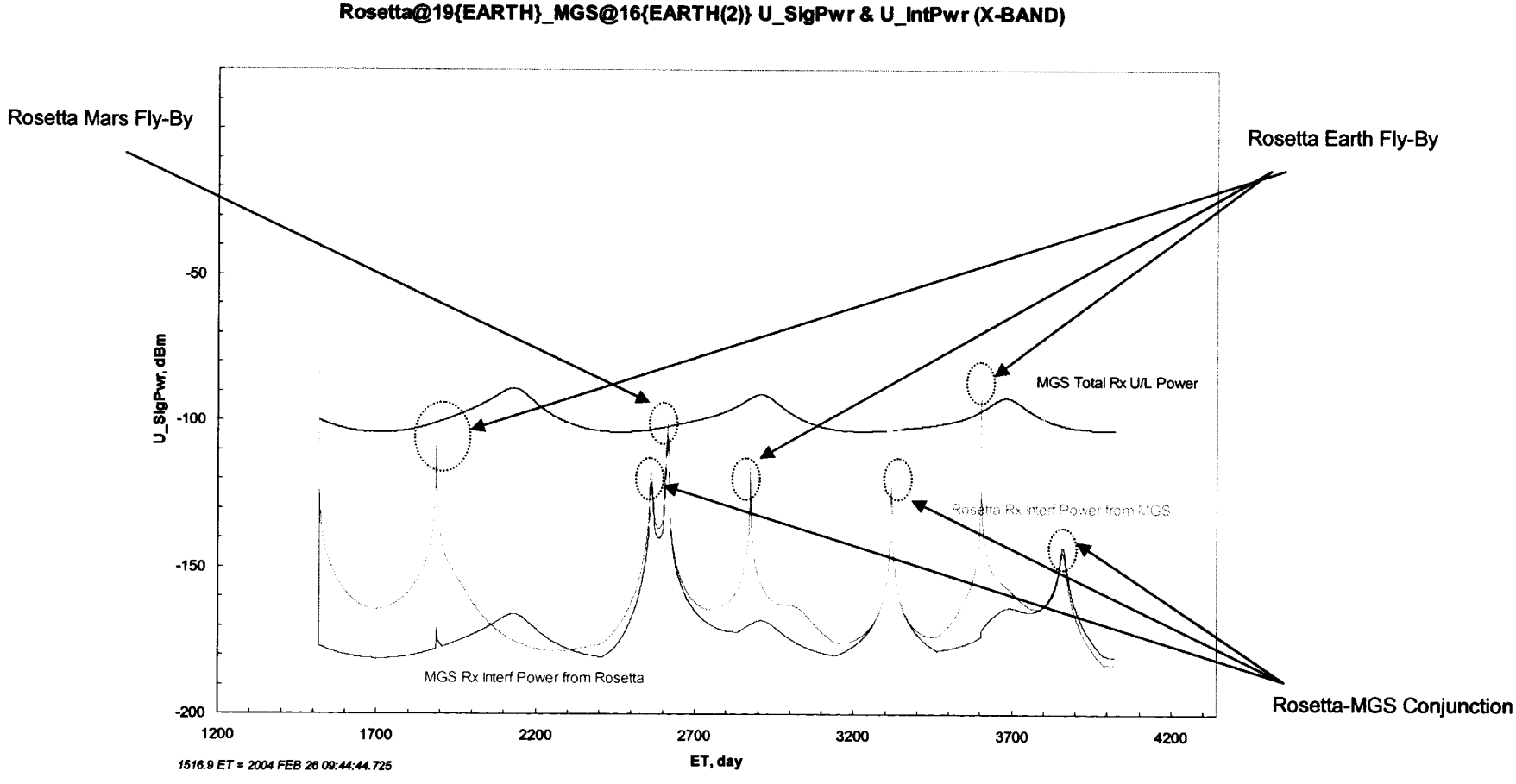
Assuming the MGS mission is extended to the Jan 6, 2011.

Rosetta X-Band Interference Analysis
Downlink (Telemetry) SIR (Signal-to-Interference Ratio) between Rosetta and MGS (Channel 16)



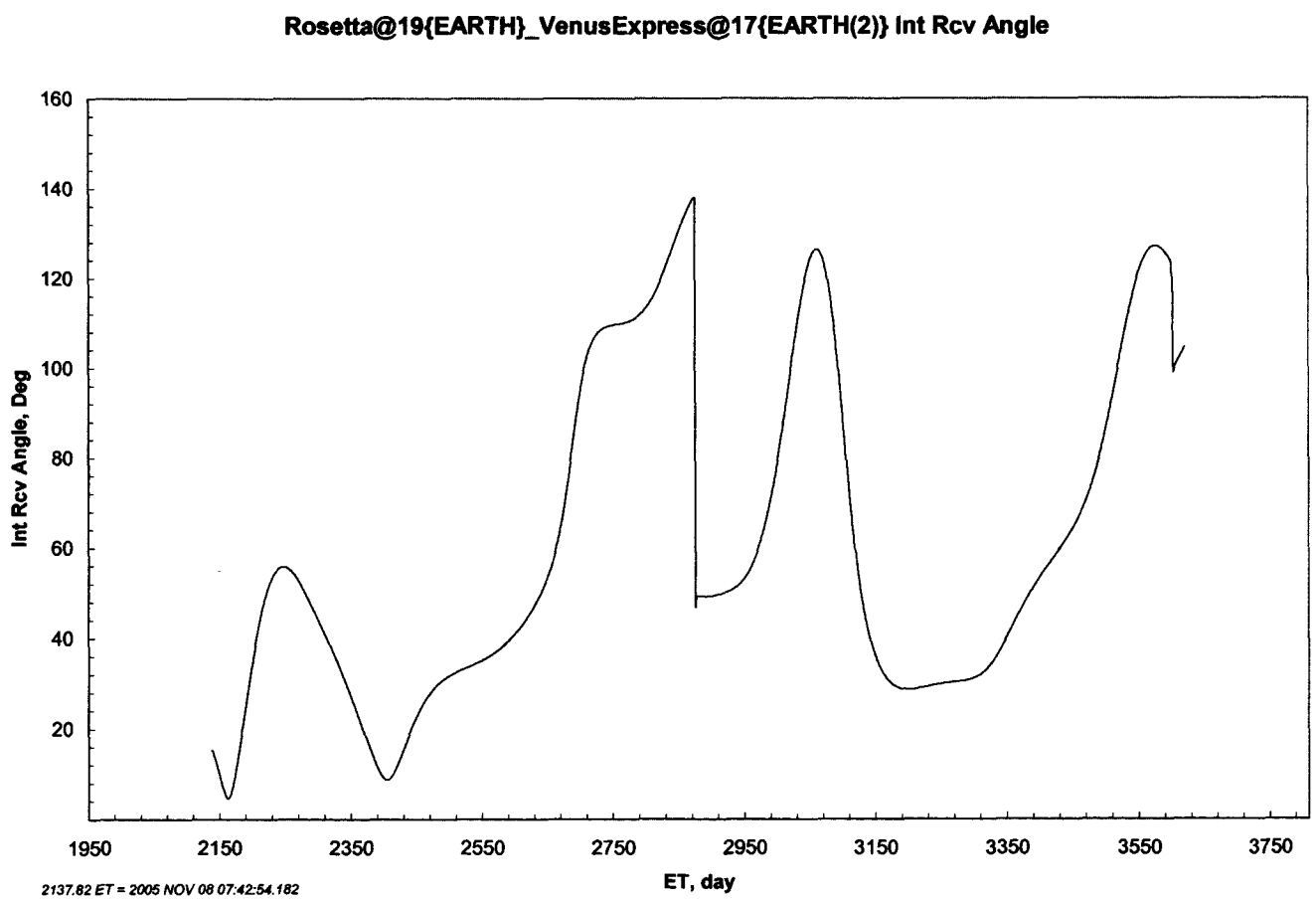
D_Drlr = Downlink telemetry signal-to-interference ratio (SIR)

Rosetta X-Band Interference Analysis
Total Uplink Power for Rosetta and MGS (Channel 16)



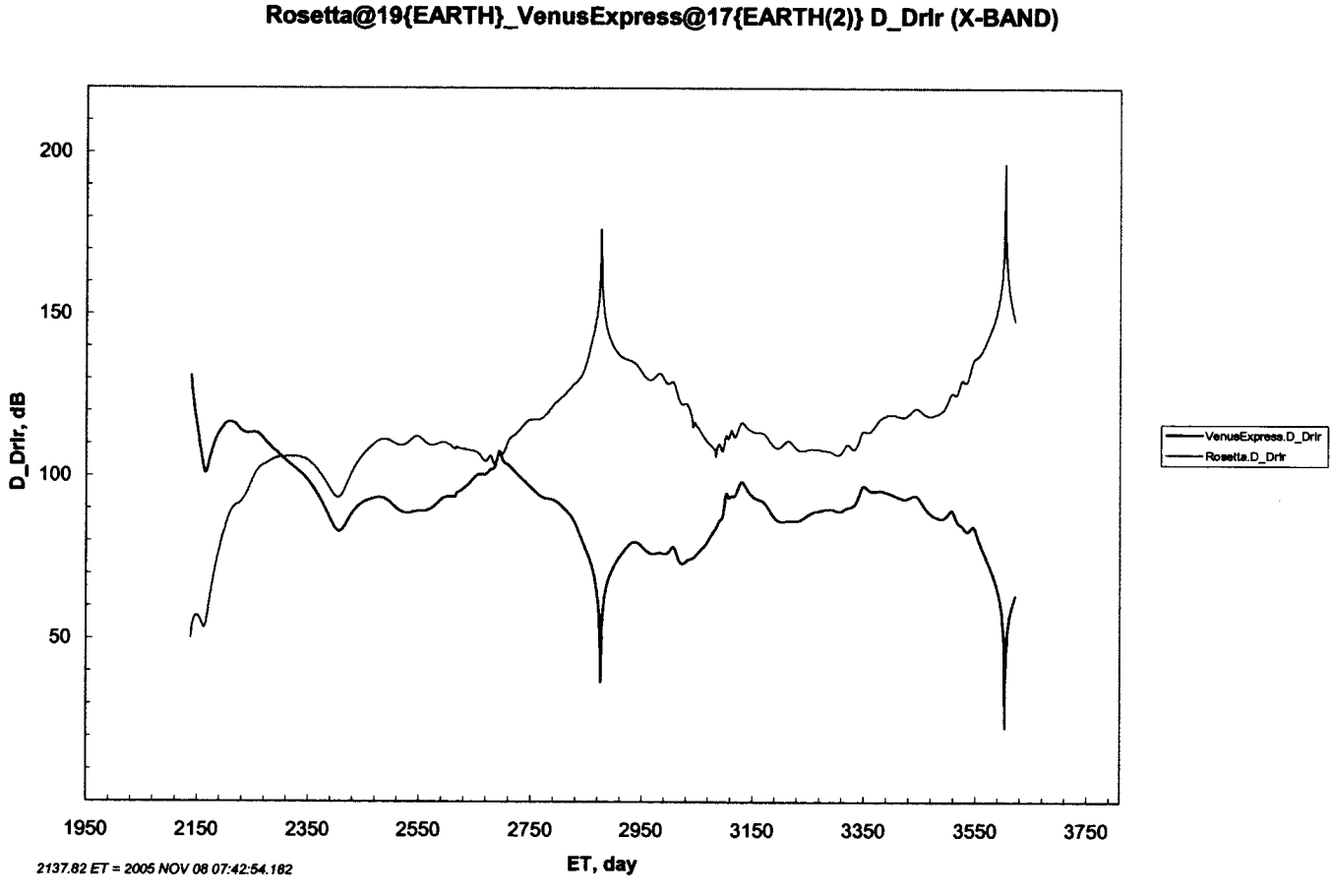
Assuming the MGS mission is extended to the Jan 6, 2011.
Min uplink frequency separation of 2.8 MHz corresponds to -23 dB of range tone suppression, assuming 3 dB carrier suppression

Rosetta X-Band Interference Analysis
Angular separation between Rosetta and VenusExpress (Channel 17)



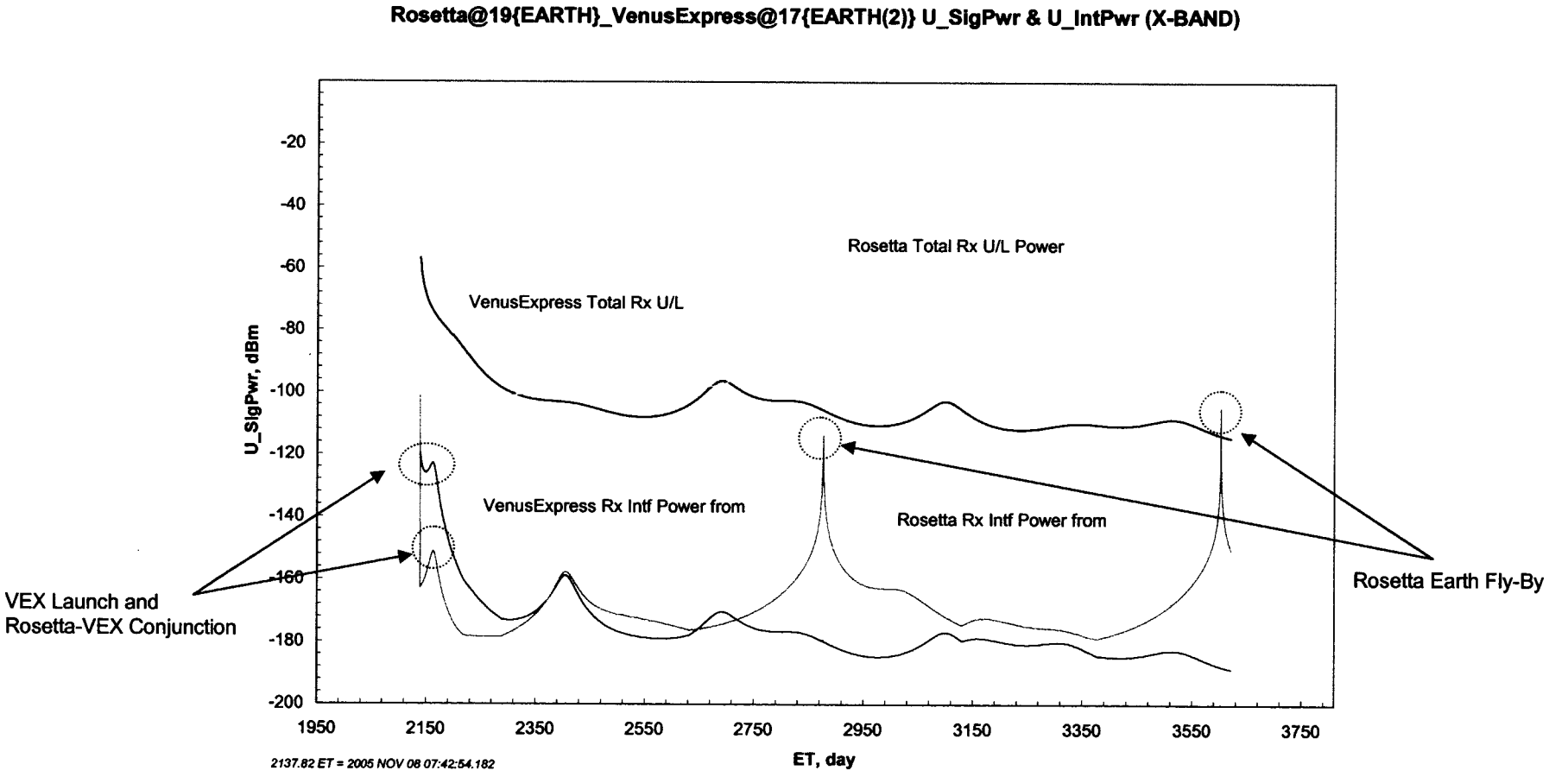
Assuming the VenusExpress mission is extended to Nov 30, 2009.

Rosetta X-Band Interference Analysis
Downlink SIR between Rosetta and VenusExpress (Channel 17)



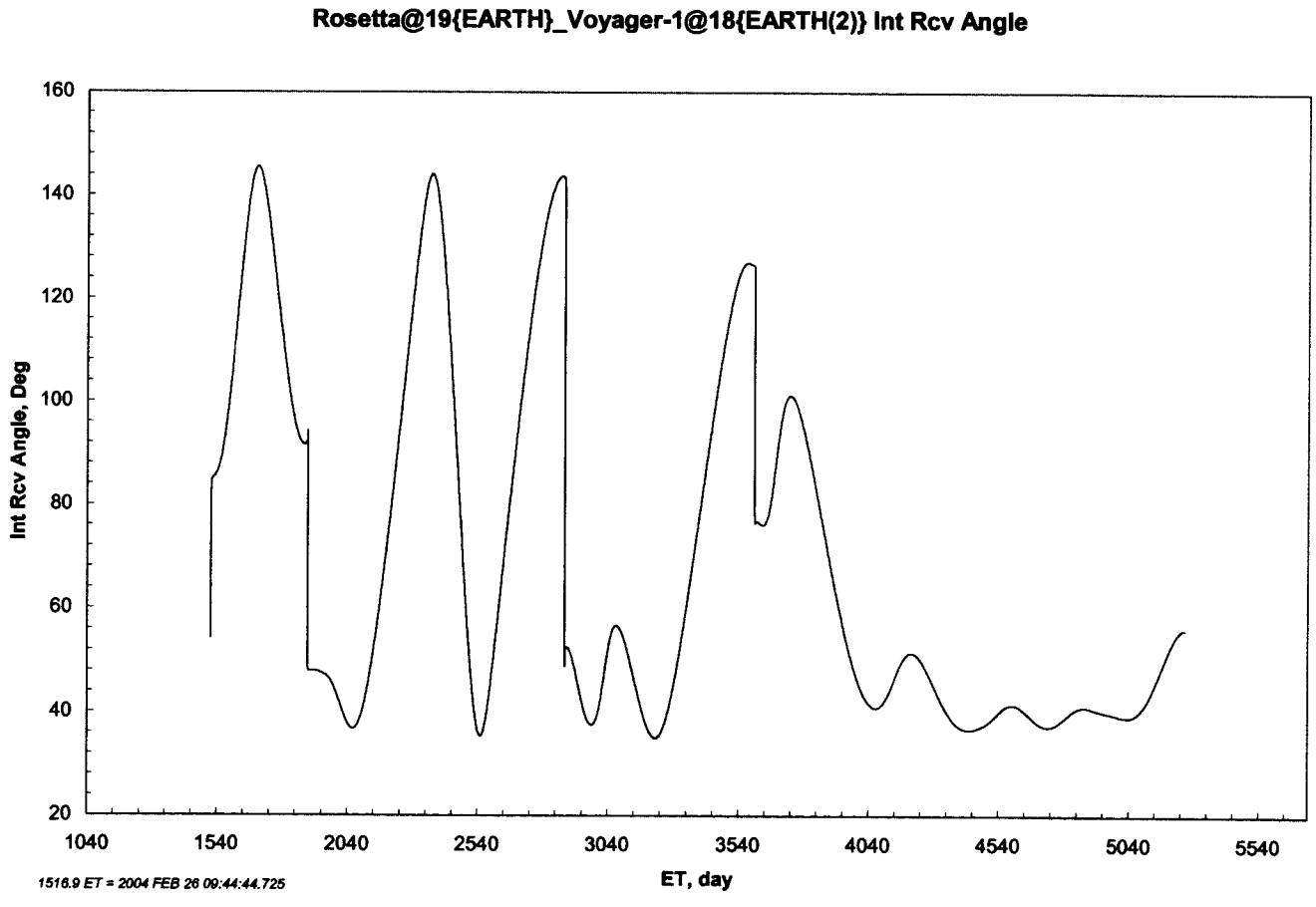
Assuming the VenusExpress mission is extended to Nov 30, 2009.

Rosetta X-Band Interference Analysis
Total Uplink Power for Rosetta and VenusExpress (Channel 17)



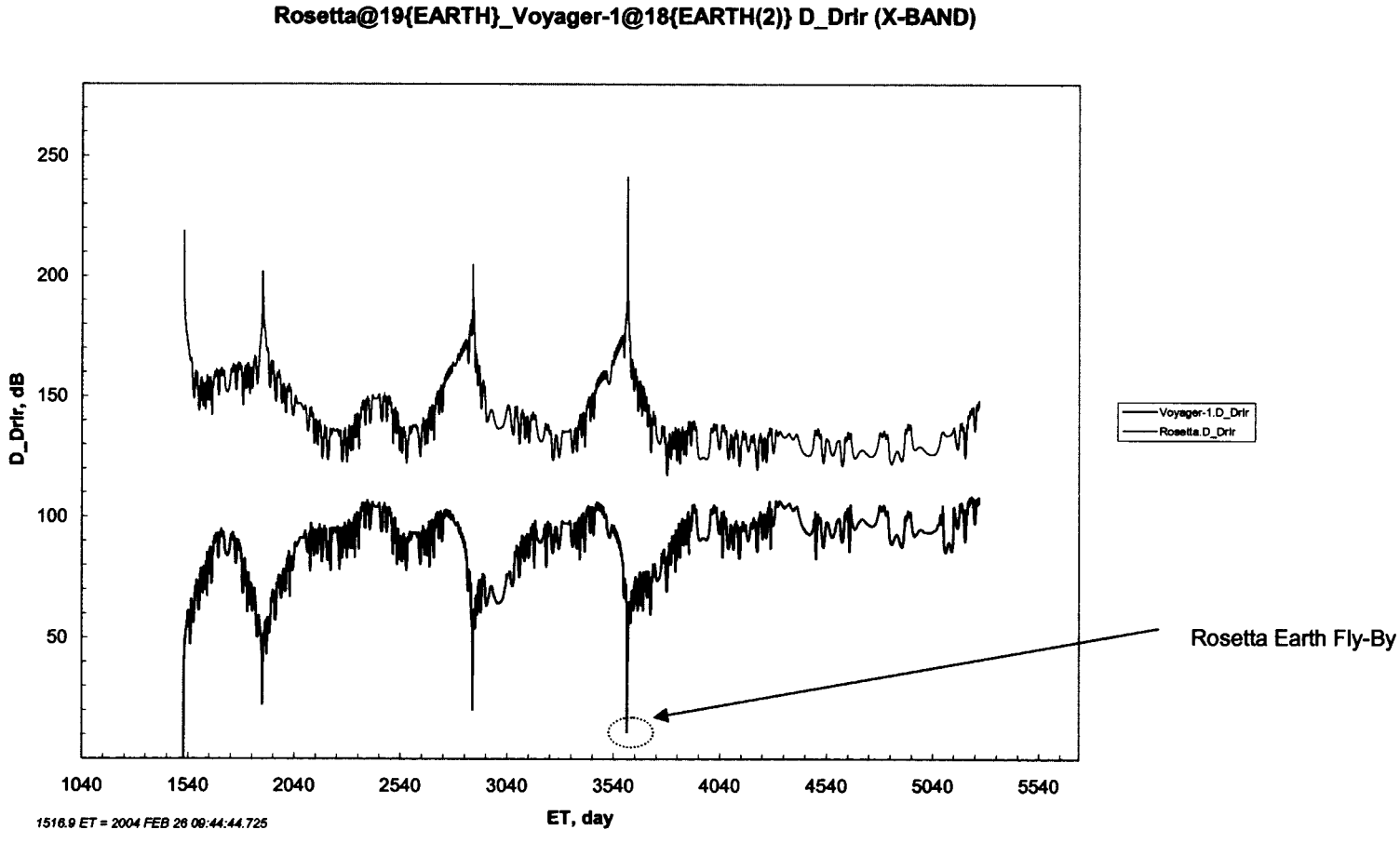
Assuming the VenusExpress mission is extended to Nov 30, 2009.
Min frequency separation of 0.9 MHz corresponds to 10 dB ranging tone suppression, assuming 3 dB carrier suppression

Rosetta X-Band Interference Analysis
Angular separation between Rosetta and Voyager-1 (Channel 18)



Assuming the Voyager-1 mission is extended to the end of Rosetta mission.

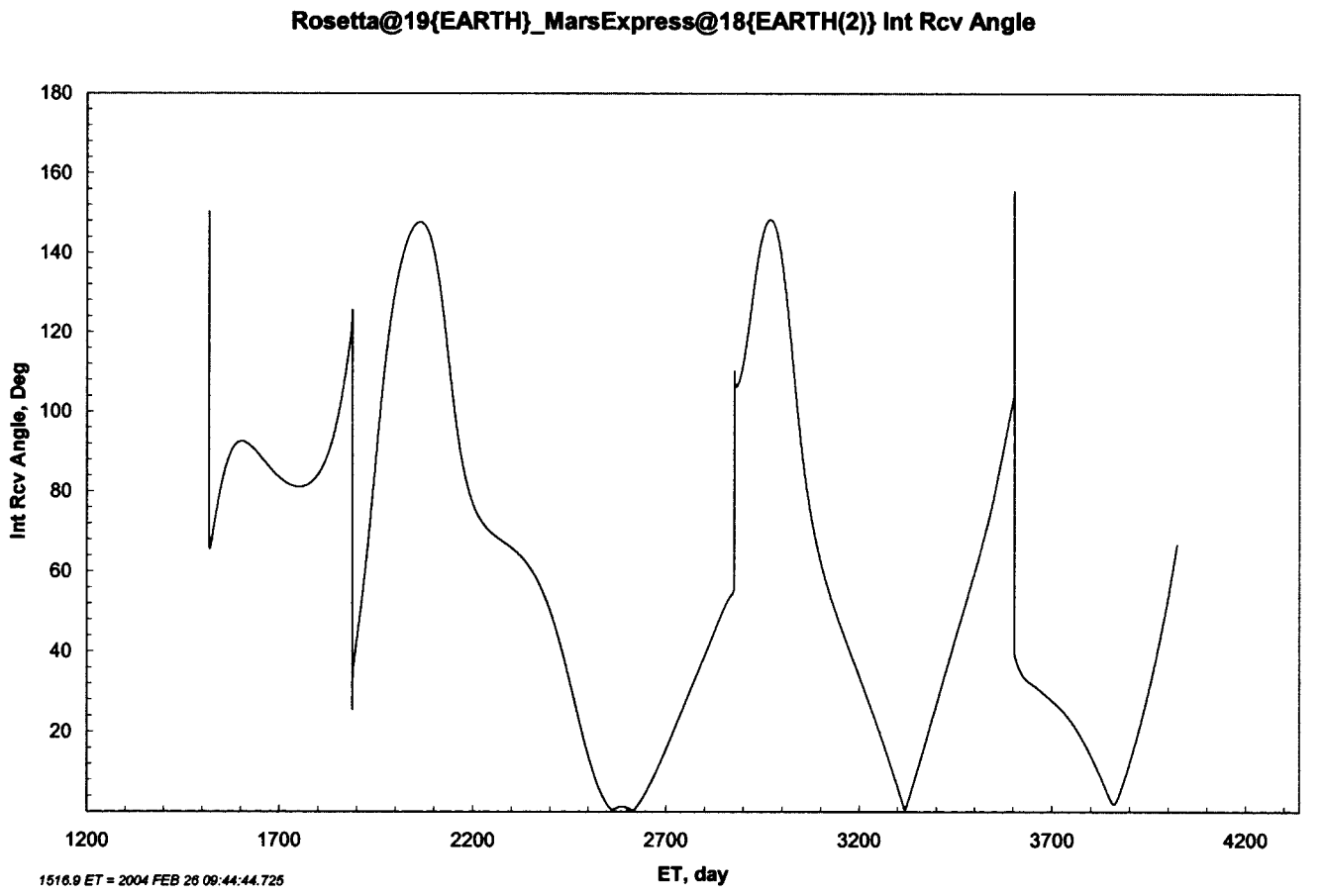
Rosetta X-Band Interference Analysis
Downlink SIR between Rosetta and Voyager-1 (Channel 18)



Assuming the Voyager-1 mission is extended to the end of Rosetta mission.

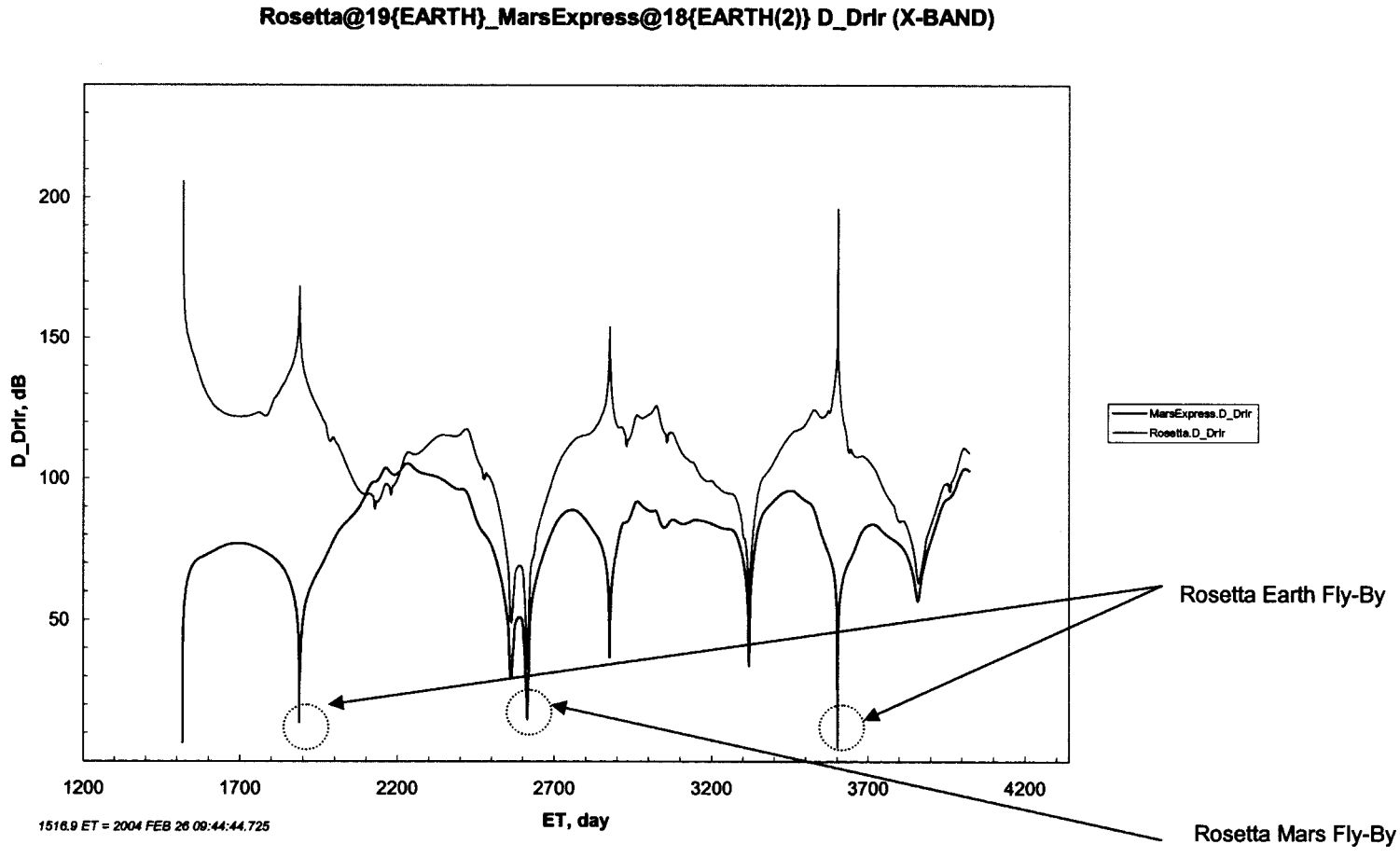
Rosetta X-Band Interference Analysis

Angular separation between Rosetta and MarsExpress (Channel 18)



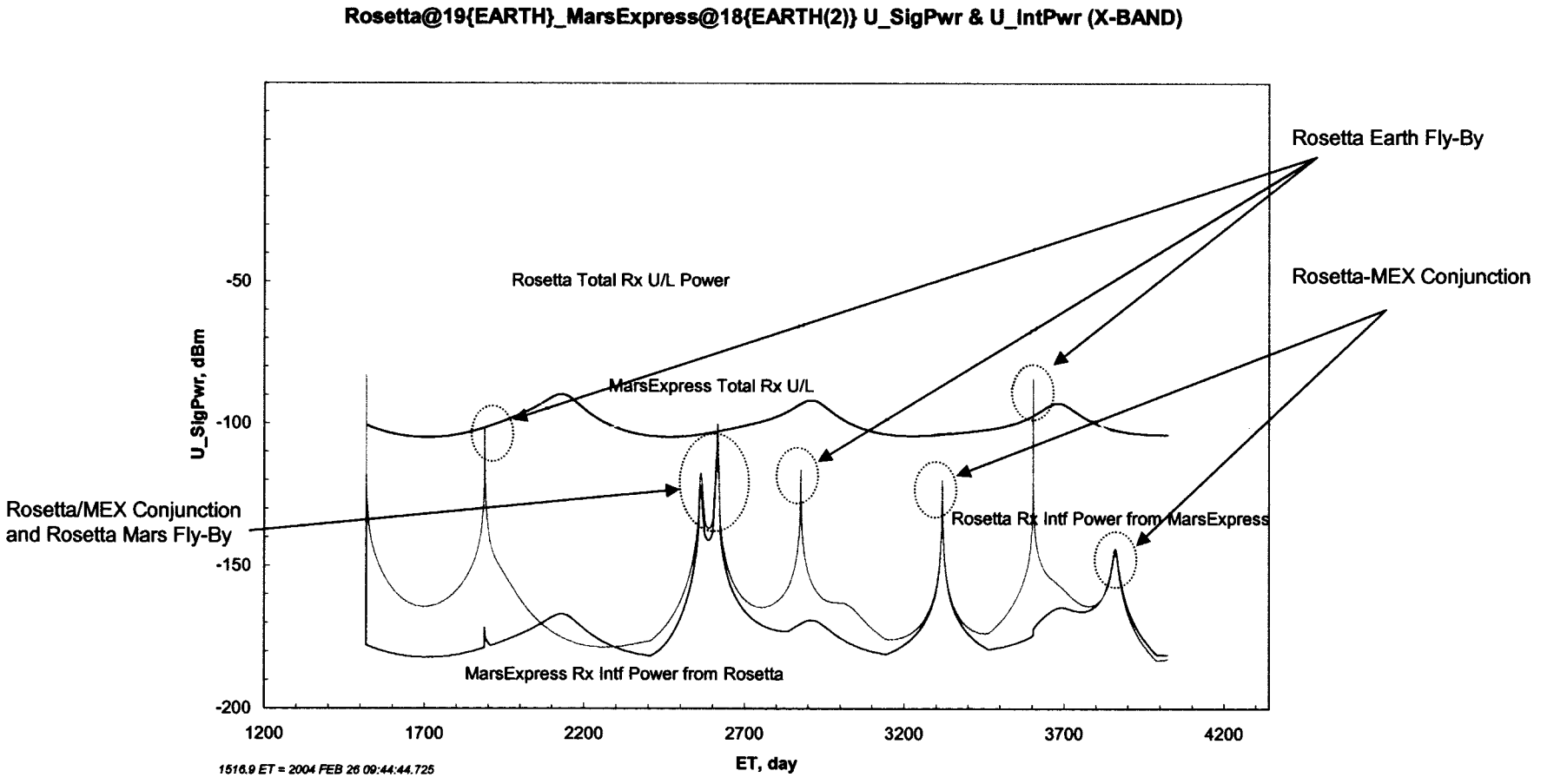
Assuming the MarsExpress mission is extended to Jan 6, 2011

Rosetta X-Band Interference Analysis
Downlink SIR between Rosetta and MarsExpress (Channel 18)



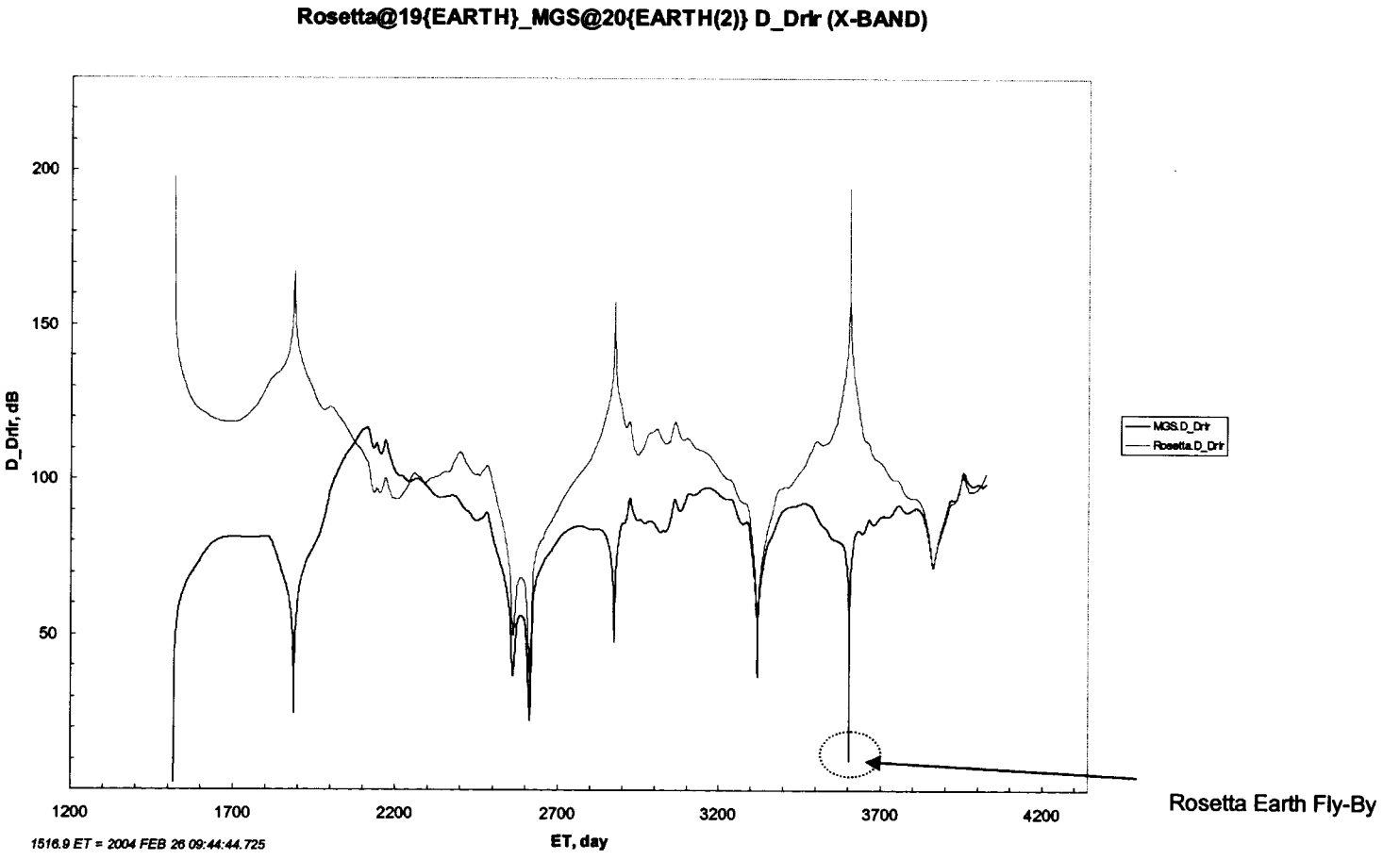
Assuming the MarsExpress mission is extended to Jan 6, 2011

Rosetta X-Band Interference Analysis
Total Uplink Power for Rosetta and MarsExpress (Channel18)



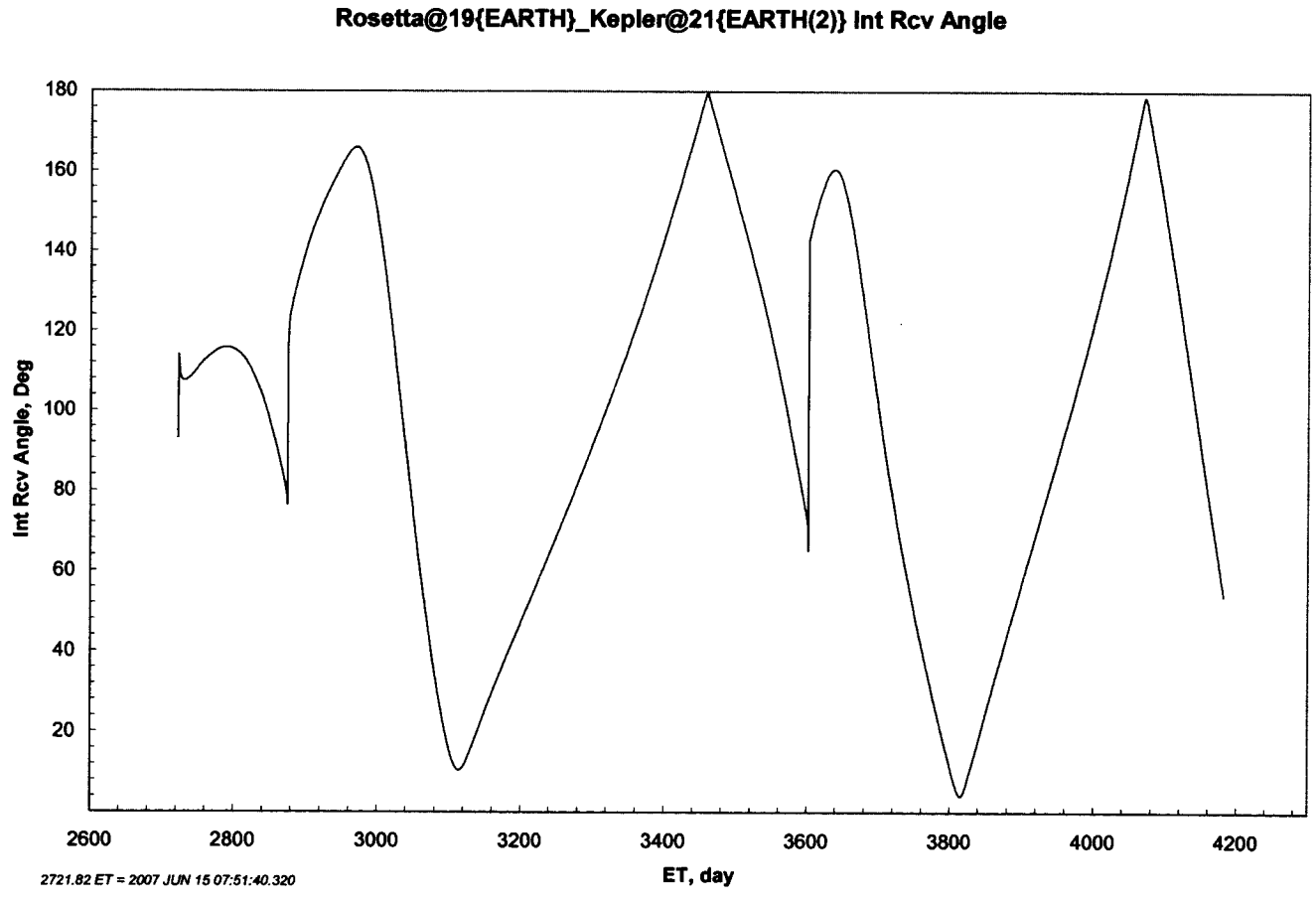
Assuming the MarsExpress mission is extended to Jan 6, 2011

Rosetta X-Band Interference Analysis
Downlink SIR between Rosetta and MGS (Channel 20)

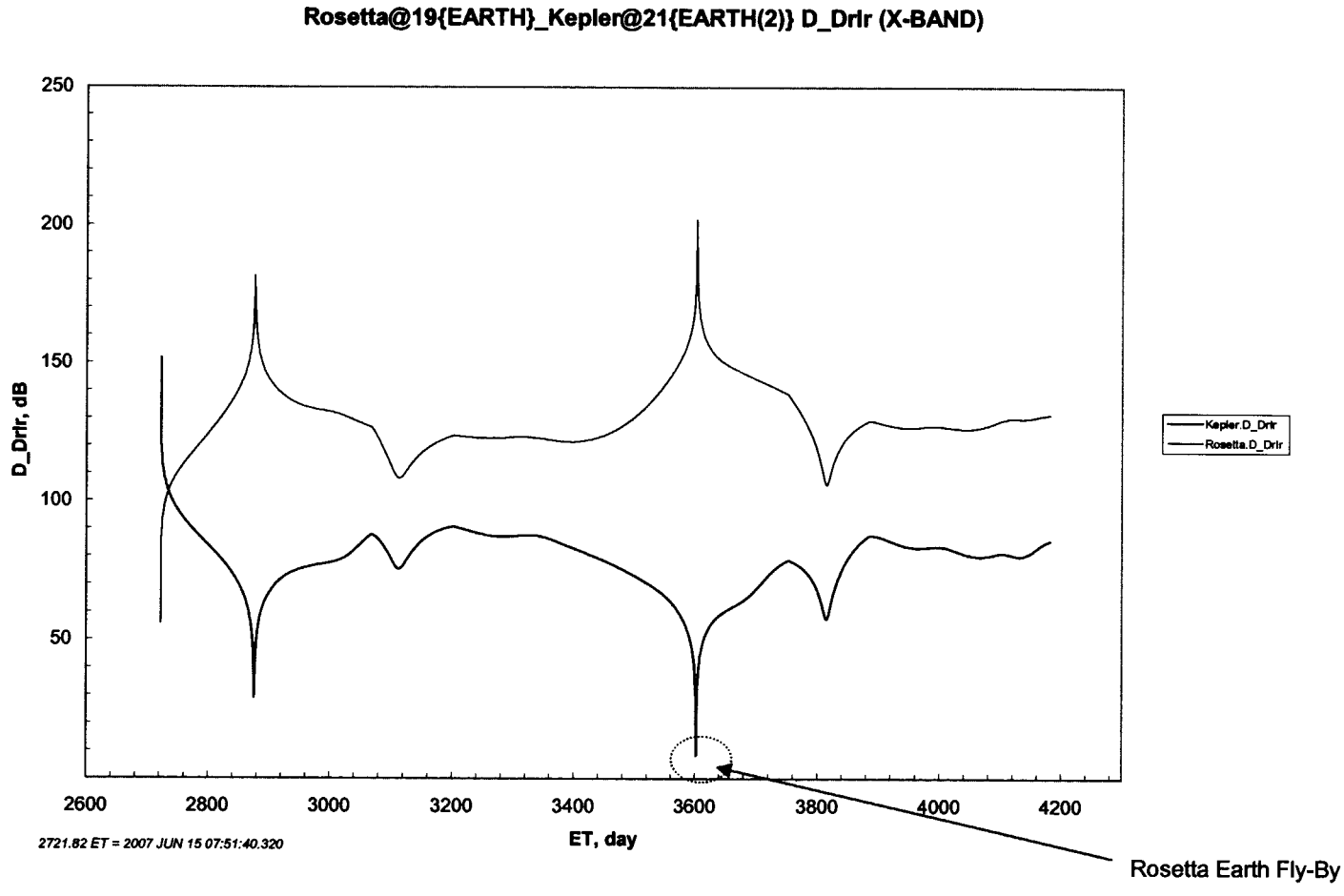


Assuming the MGS mission is extended to the Jan 6, 2011.

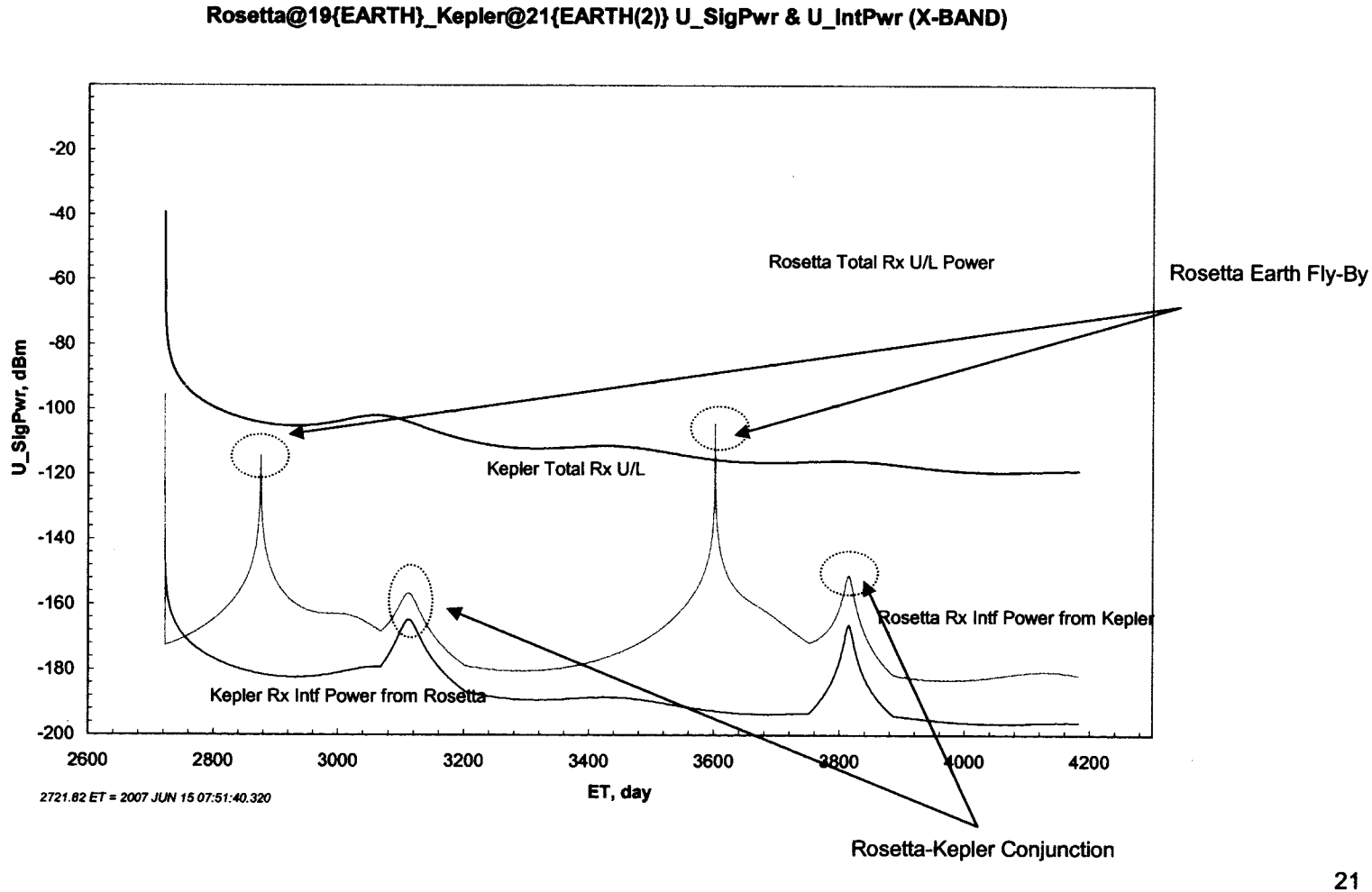
Rosetta X-Band Interference Analysis
Angular separation between Rosetta and Kepler (Channel 21)



Rosetta X-Band Interference Analysis
Downlink SIR between Rosetta and Kepler (Channel 21)



Rosetta X-Band Interference Analysis
Total Uplink Power for Rosetta and Kepler (Channel 21)

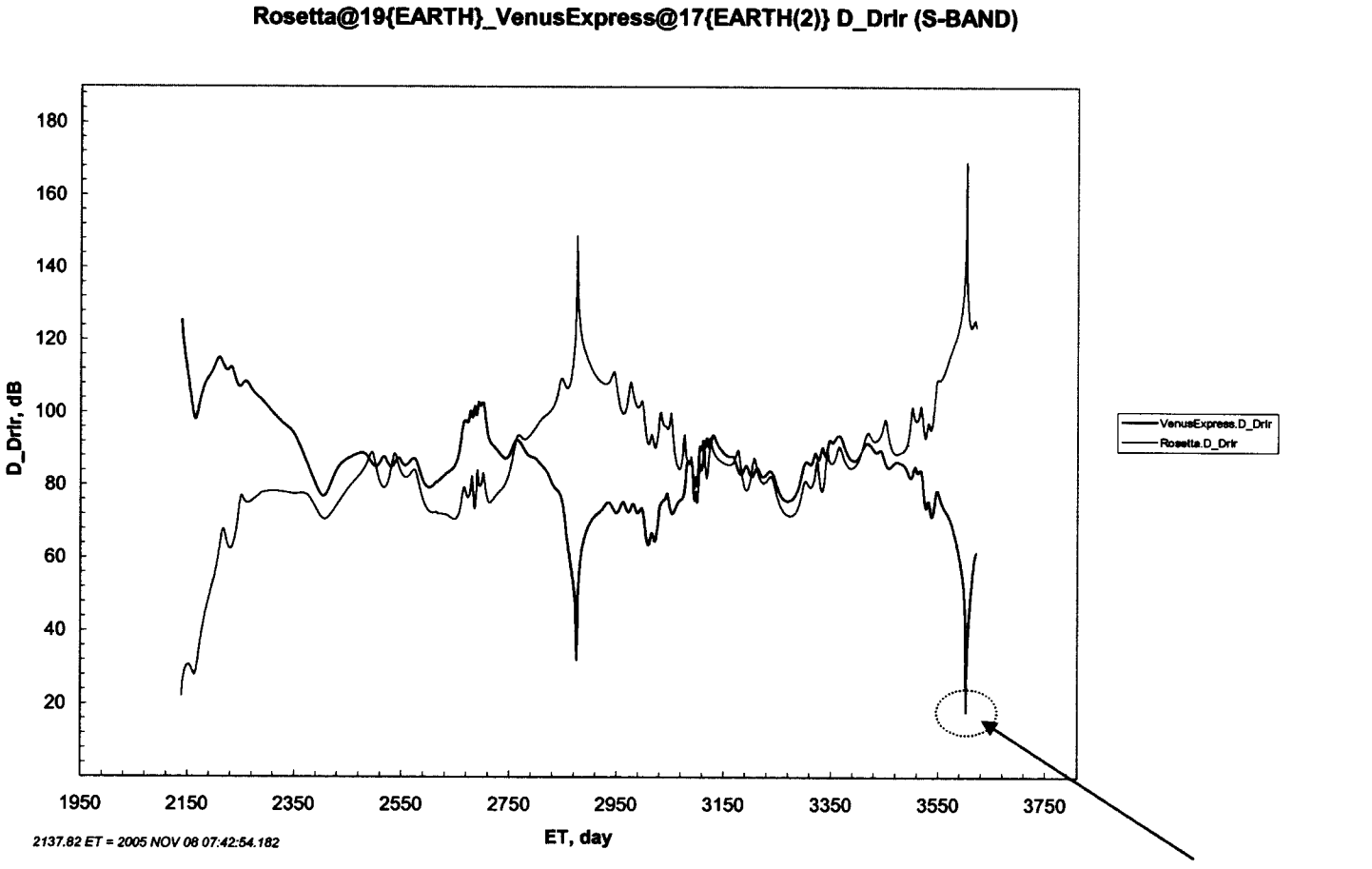


Rosetta Interference Analysis
Potential X-Band Interference Scenarios

- Many potential interference scenarios. Most cases are for uplinks. Except with MEX during the Rosetta Mars Fly-by, the remaining downlink interference scenarios occur during Rosetta Earth Fly-By's.
- Analysis performed assuming Rosetta uses HGA the whole time. If LGA is used during Earth fly-by's, potential interference periods are either reduced or in some cases eliminated.
- If HGA is used by Rosetta during the whole mission, the potential interference periods are shown below:

Potential Interference Around	Cause	X-Band Links Affected
March 3, 2005	Rosetta Earth Fly-By	Rosetta (U/L), MEX (D/L)
November 8, 2005	Venus Launch	VEX (U/L)
January 6, 2007	Rosetta-Mars Conjunction	MGS (U/L), Rosetta (U/L), MEX (U/L)
February 28, 2007	Rosetta Mars Fly-By	MGS (U/L), Rosetta (U/L), MEX (U/L), MEX (D/L)
November 17, 2007	Rosetta Earth Fly-By	Rosetta (U/L)
February 1, 2009	Rosetta-Mars Conjunction	MGS (U/L), Rosetta (U/L), MEX (U/L),
November 11, 2009	Rosetta Earth Fly-By	Rosetta (U/L), MGS (D/L), VGR-1 (D/L), MEX (D/L), KEP (U/L)
July 26, 2010	Rosetta-Mars Conjunction	Rosetta (U/L), MEX (U/L)

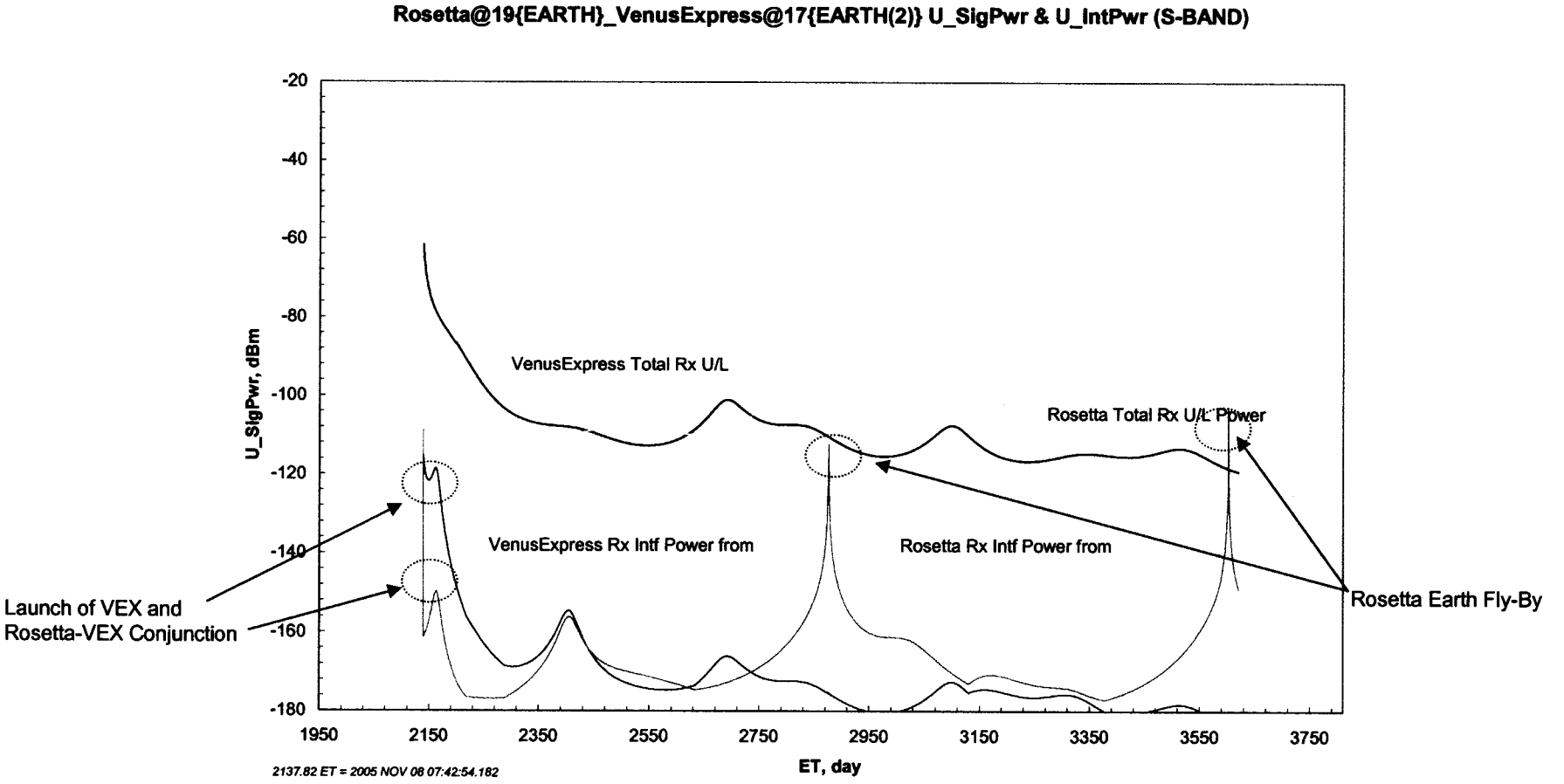
Rosetta S-Band Interference Analysis
Downlink SIR between Rosetta and VenusExpress (Channel 17)



Rosetta Earth Fly-By

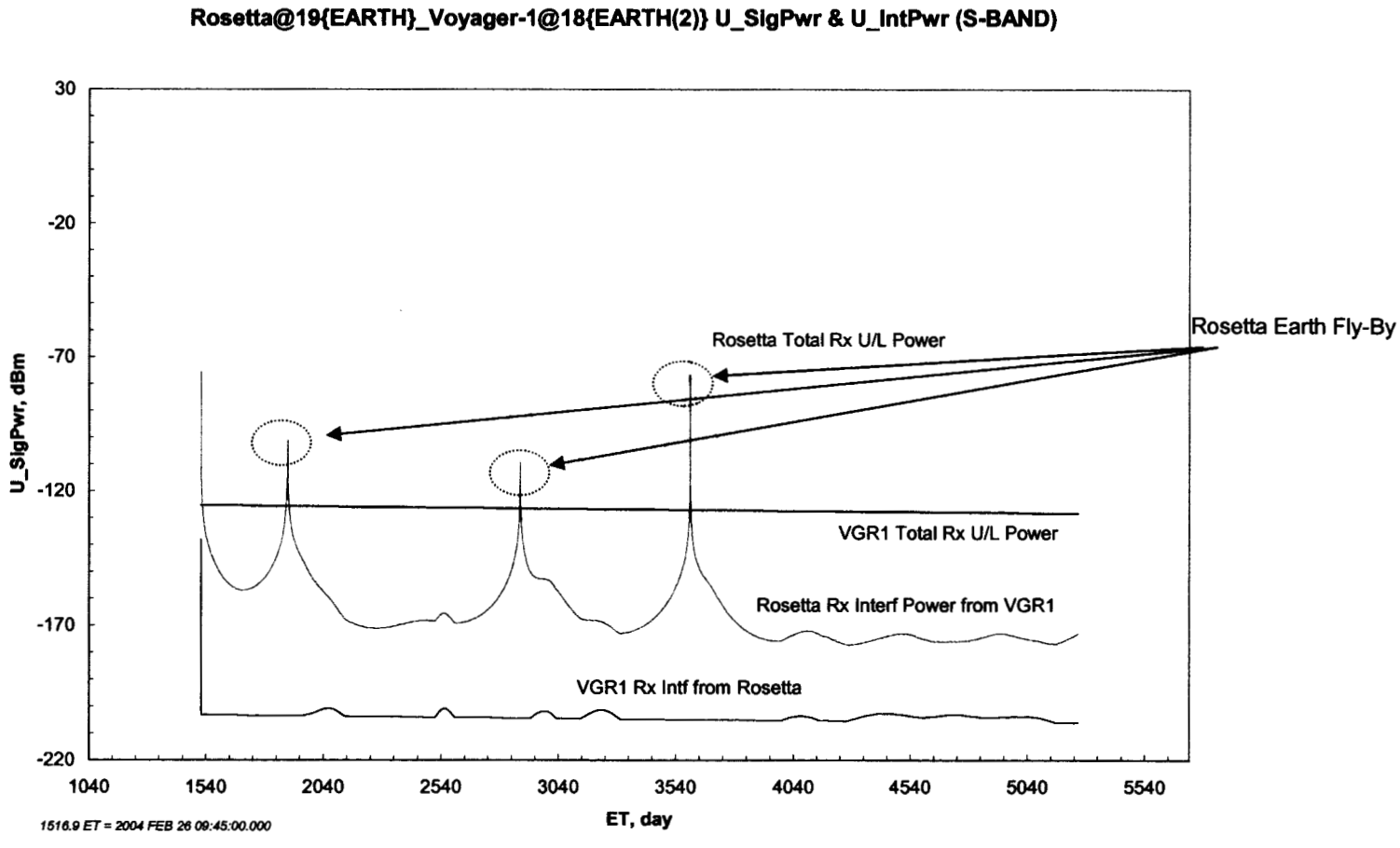
Assuming the VenusExpress mission is extended to Nov 30, 2009.

Rosetta S-Band Interference Analysis
Total Uplink Power for Rosetta and VenusExpress (Channel 17)



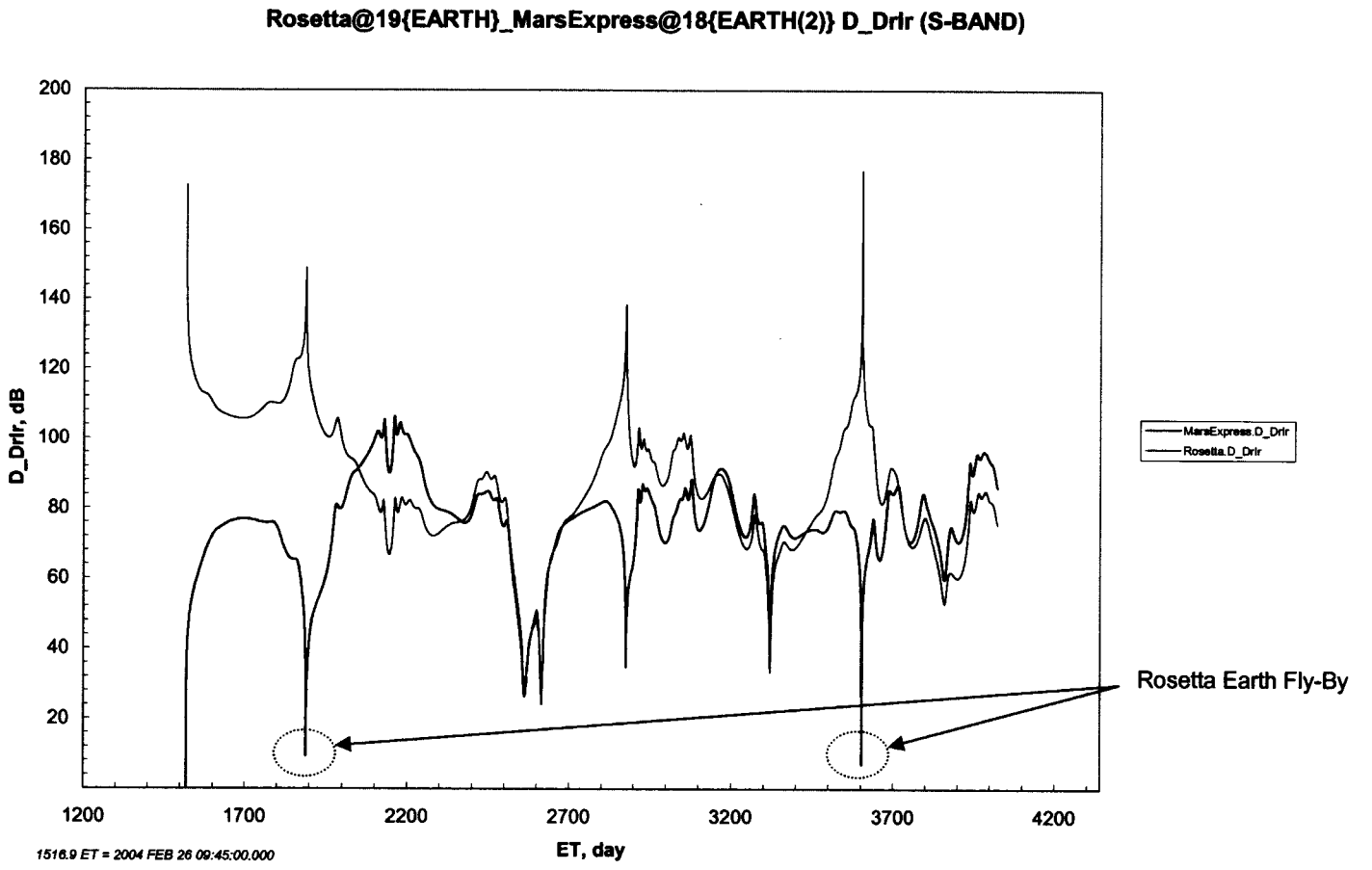
Assuming the VenusExpress mission is extended to Nov 30, 2009

Rosetta S-Band Interference Analysis
Total Uplink Power for Rosetta and Voyager-1 (Channel 18)



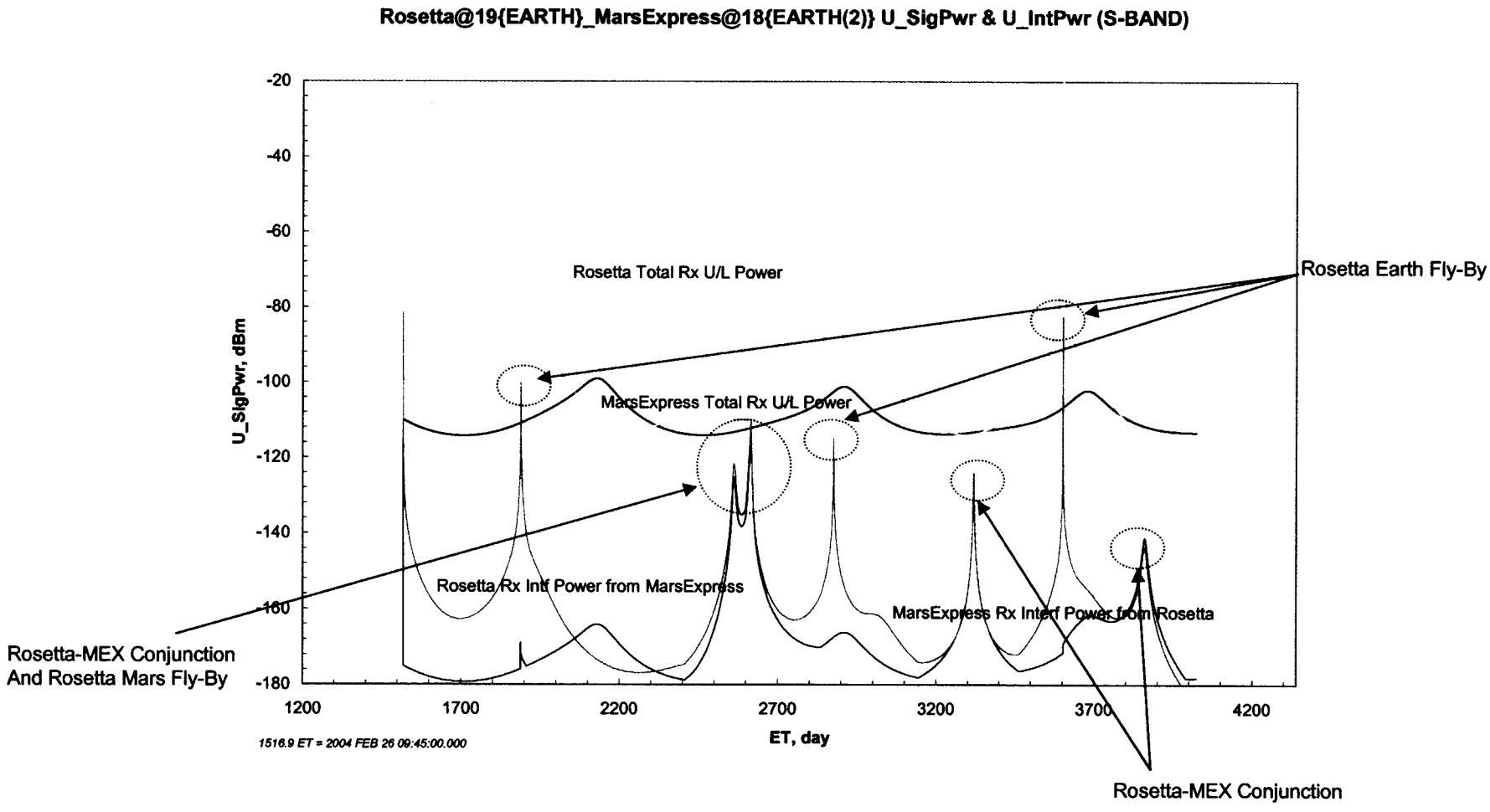
Assuming the Voyager-1 mission is extended to the end of Rosetta mission.

Rosetta S-Band Interference Analysis
Downlink SIR between Rosetta and MarsExpress (Channel 18)



Assuming the MarsExpress mission is extended to Jan 6, 2011

Rosetta S-Band Interference Analysis
Total Uplink Power for Rosetta and MarsExpress (Channel18)



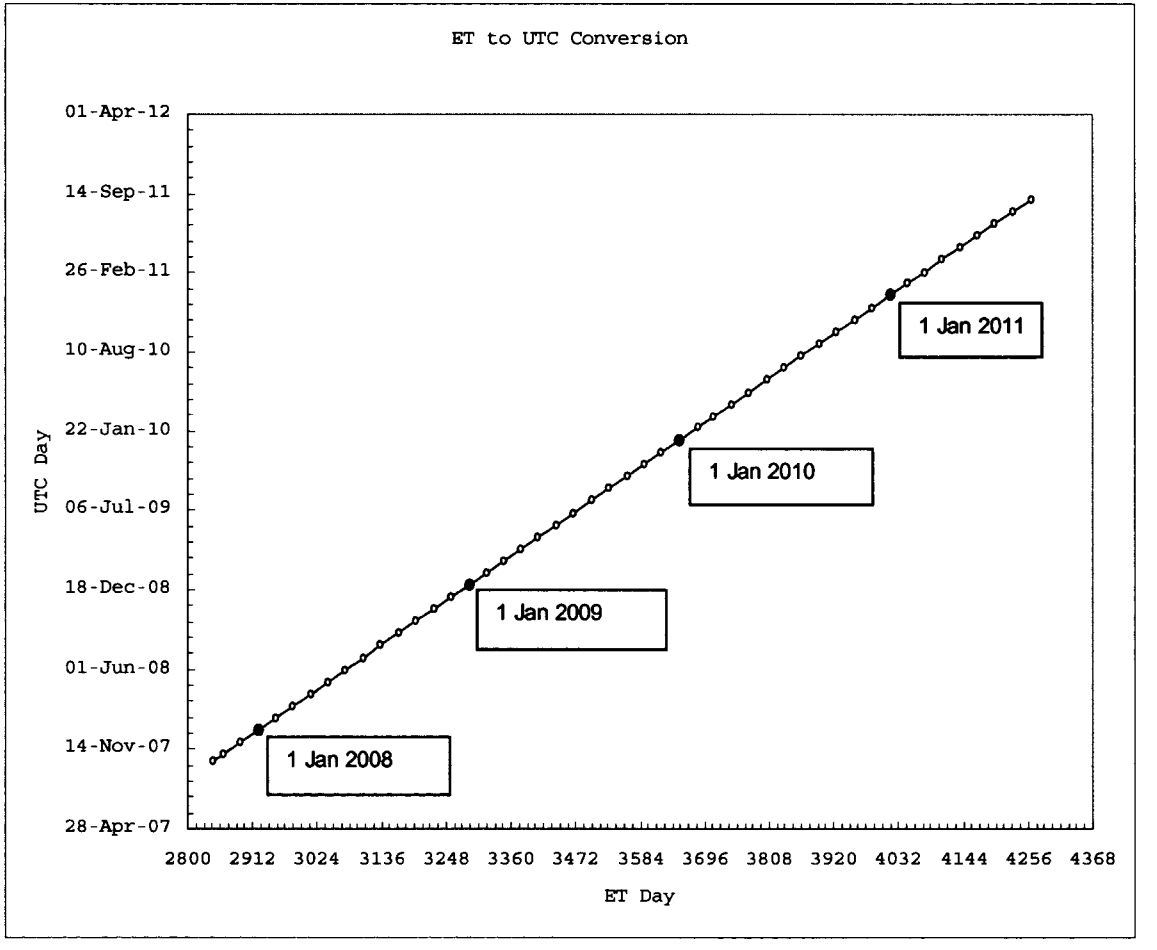
Assuming the MarsExpress mission is extended to Jan 6, 2011

Rosetta Interference Analysis
Potential S-Band Interference Scenarios

- Similar results as X-Band. Many potential interference scenarios. Most cases are for uplinks. All downlink interference scenarios occur during Rosetta Earth Fly-By's.
- Analysis performed assuming Rosetta uses HGA the whole time. If LGA is used during Earth fly-by's, potential interference periods are either reduced or in some cases eliminated.
- If HGA is used by Rosetta during the whole mission, the potential interference periods are shown below:

Potential Interference Around	Causes	X-Band Links Affected
March 3, 2005	Rosetta Earth Fly-By	Rosetta (U/L), MEX (D/L)
November 8, 2005	Venus Launch	VEX (U/L)
December 3, 2005	Rosetta-VEX Conjunction	VEX (U/L), Rosetta (U/L)
January 6, 2007	Rosetta-Mars Conjunction	Rosetta (U/L), MEX (U/L)
Feburary 28, 2007	Rosetta Mars Fly-By	Rosetta (U/L), MEX (U/L)
November 17, 2007	Rosetta Earth Fly-By	Rosetta (U/L)
Feburary 1, 2009	Rosetta-Mars Conjunction	Rosetta (U/L), MEX (U/L),
November 11,2009	Rosetta Earth Fly-By	Rosetta (U/L), VEX (D/L), VGR-1 (U/L), MEX (D/L)
July 26, 2010	Rosetta-Mars Conjunction	Rosetta (U/L), MEX (U/L)

Rosetta Interference Analysis -- Conclusion

- Many interference scenarios because of the Earth and Mars fly-by's and many Mars-Rosetta conjunctions
- One potential solution: since most missions in nearby channels use X-band channels, Rosetta can use S-Band during Earth and Mars fly-by's and during other conjunctions to avoid mutual interference, but will need to coordinate with Voyager-1 for uplinks sessions to avoid interference to Rosetta during Rosetta Earth fly-by's, even if Rosetta uses LGA during the fly-by's.

Rosetta Interference Analysis
Appendix: ET Conversion