Ka-band and X-band Observations of the Solar Corona Acquired during the Cassini 2001 Superior Conjunction

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Spacecraft Solar Conjunctions

- A superior solar conjunction occurs when the sun lies near the signal path of a source as observed from the Earth
- Interplanetary spacecraft sent to the planets typically encounter one or more solar conjunctions during their mission lifetimes
- During these periods, the signals sent to and from the spacecraft encounter degradation due to the intervening charged particles of the solar corona
  - Flight Projects typically downscale their operations
  - Radio Scientists use these opportunities to study the sun
  - Telecommunication engineers use these opportunities to study the effects of solar charged particles on signal propagation
- Charged particle effects depend upon the telecommunications link frequency
  - S-band (2.3 GHz) & X-band (8.4 GHz) are currently used telecom link frequencies
  - Ka-band (32 GHz) is currently used for telecom demonstrations and Radio Science

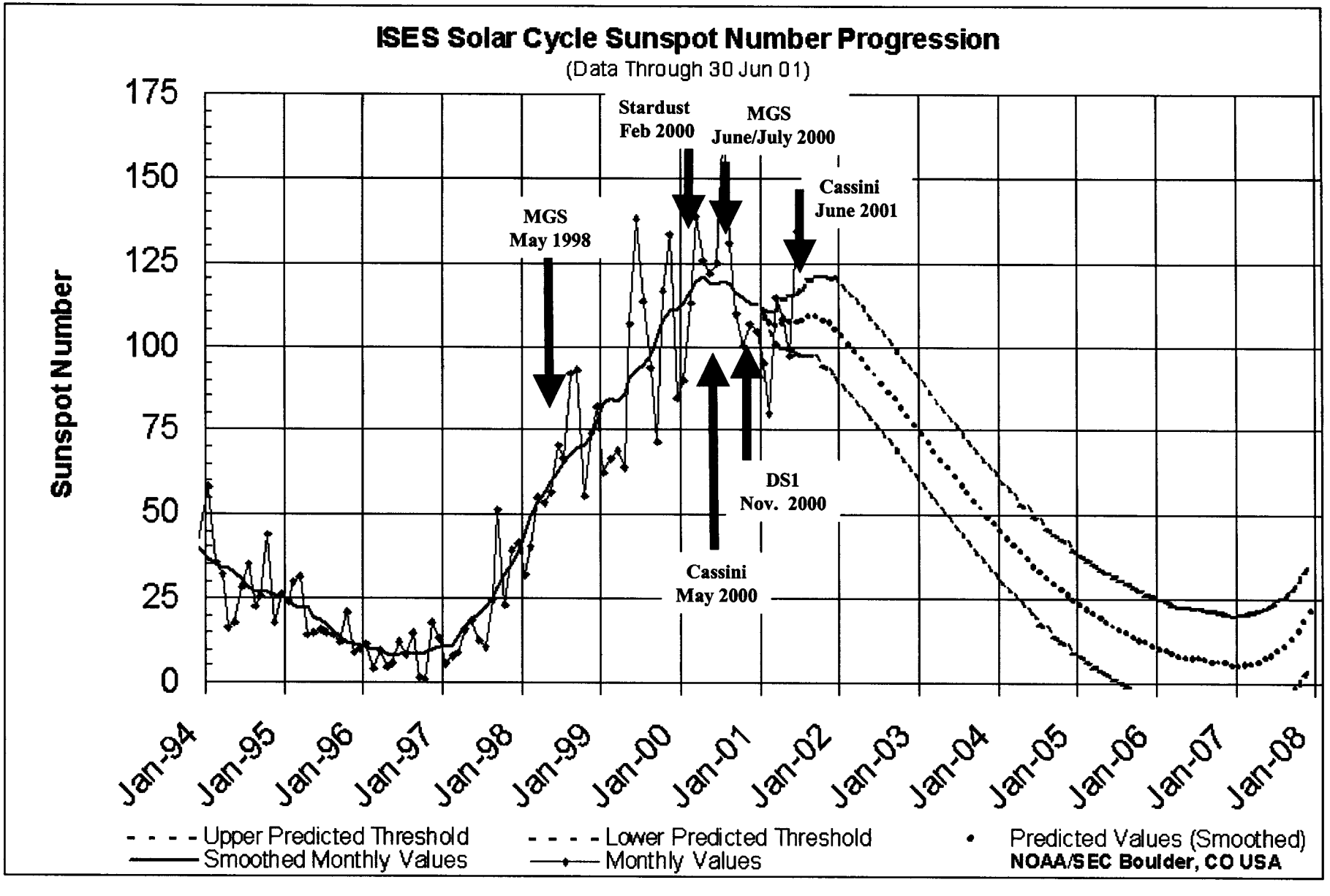
Ka-band vs X-band

- Theoretically Ka-band (32 GHz) provides an 11.6 dB (factor of 14) advantage over X-band (8.4 GHz) as a telecommunications link frequency
- In practice, this advantage is reduced to 6 to 8 dB due to increased atmospheric and amplifier noise at Ka-band and DSN antenna imperfections, which are less significant at X-band
- This link advantage can result in higher data rates or savings in spacecraft mass and power
- An analysis of simultaneous Ka-band and X-band Mars Global Surveyor (MGS) data acquired between 1996 and 1998 demonstrated the 6-8 dB link advantage using a 34-m beam waveguide (BWG) ground antenna outside of the May 1998 solar conjunction period
- For spacecraft passages behind the Sun's corona, the signals will encounter degradation due to charged particle density variations.
  - Ka-band will have less degradation than X-band and is less likely to drop lock
  - Ka-band is more resilient to fades
- Dual-frequency X/Ka data from several solar conjunctions of spacecraft have been acquired at solar elongation angles (SEP) below 5° and analyzed to evaluate relative performance

Cassini 2001 Solar Conjunction

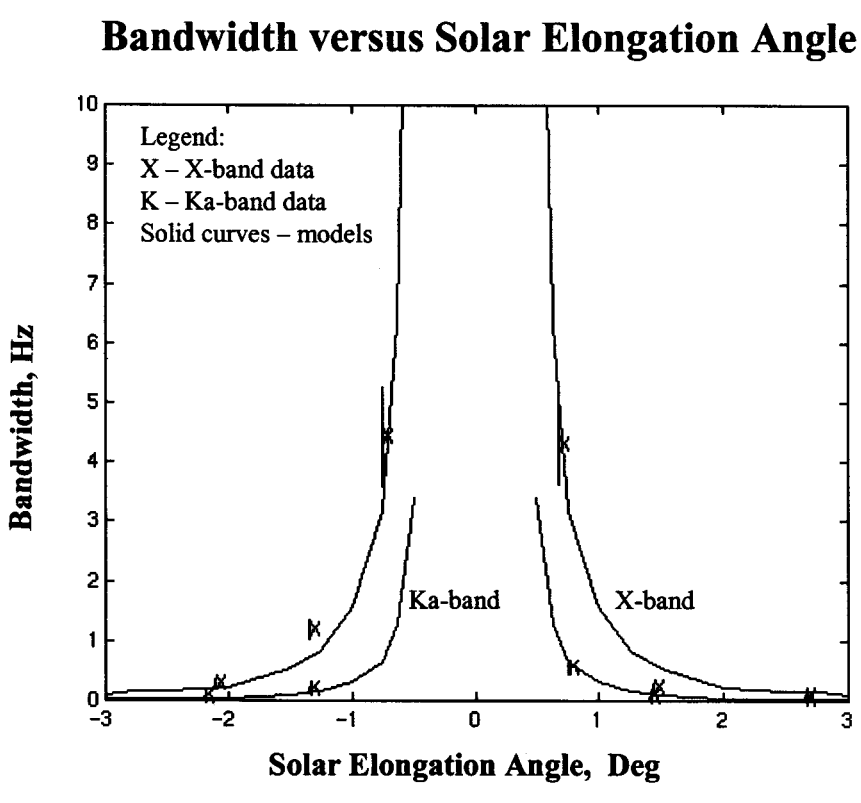
- Cassini spacecraft is currently en route to the planet Saturn
- Cassini uses X-band (8.4 GHz) as a telecommunications link frequency
- Cassini emits Ka-band (32 GHz) carrier signals used for Radio Science
- The first Cassini solar conjunction experiment occurred in May 2000, in which simultaneous X-band and Ka-band carrier signals were received for the purpose of characterizing solar coronal charged-particle effects
- The second Cassini solar conjunction occurred between June 2 and June 14 2001 in which the solar elongation angles of the observations ranged from 4° to 0.6°
- The observed charged particle effects on the signals include amplitude scintillation, phase scintillation and spectral broadening
- Both Cassini solar conjunctions occurred near the peak of the current 11-year solar cycle

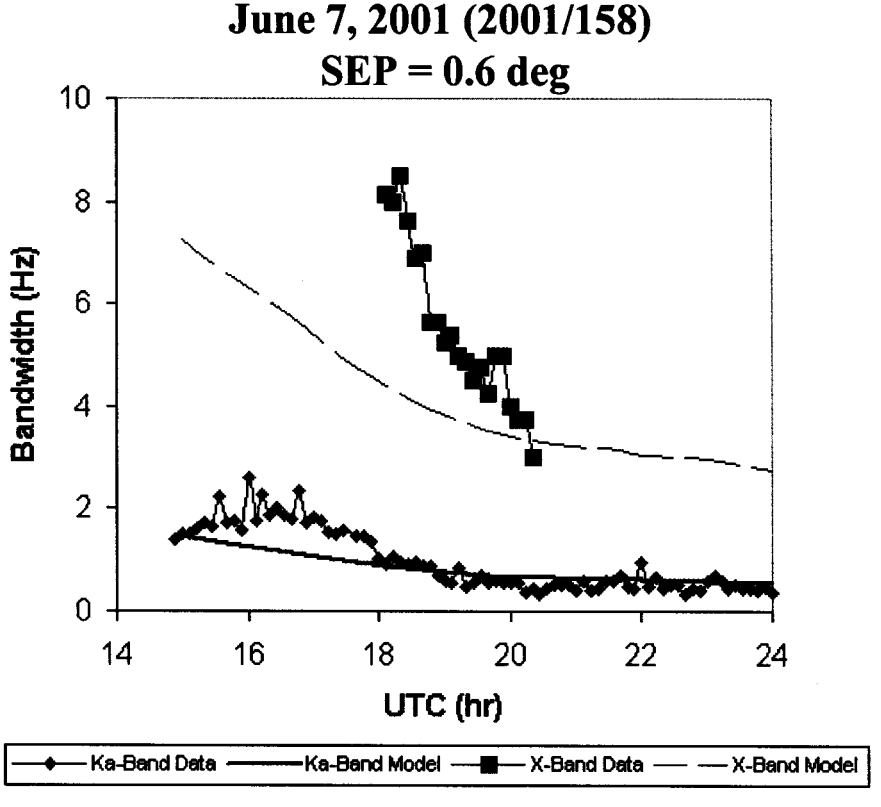
Current Solar Cycle



Plot created by U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Space Environmental Center (web site at http://sec.noaa.gov).

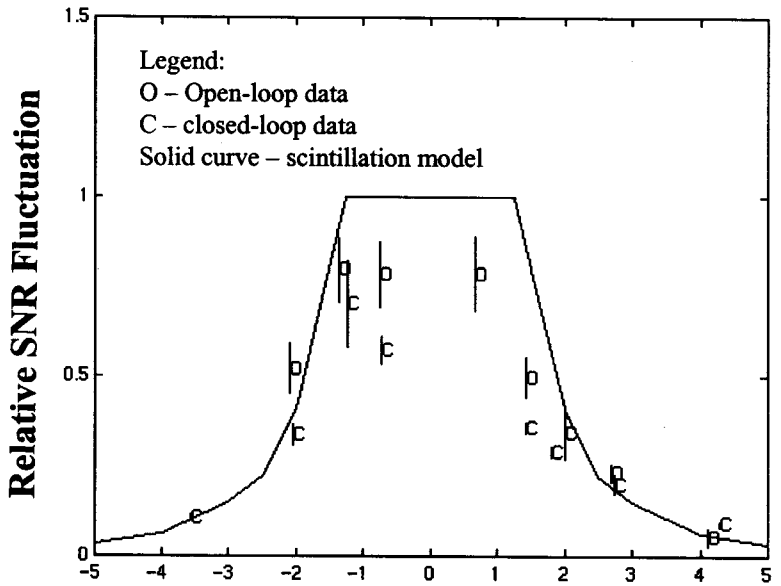
Cassini June 2001 Solar Conjunction Spectral Broadening



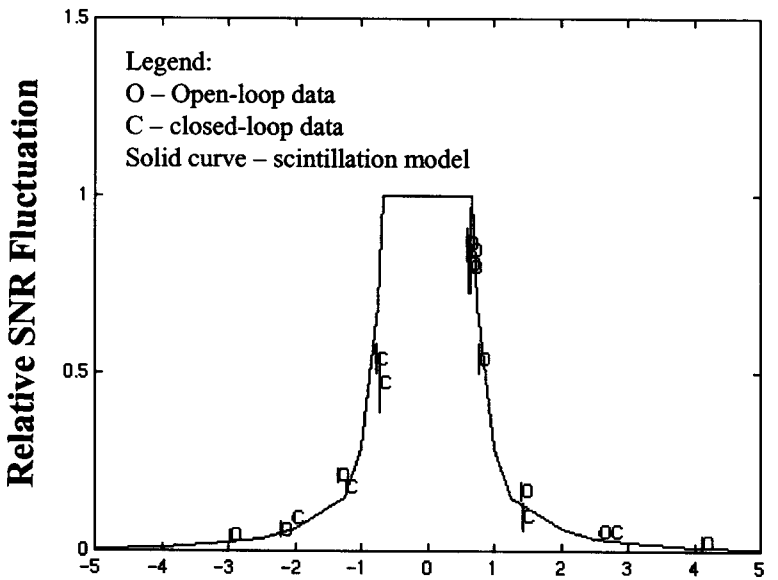


Cassini June 2001 Solar Conjunction X-band and Ka-band Carrier Relative Fluctuations vs Solar Elongation

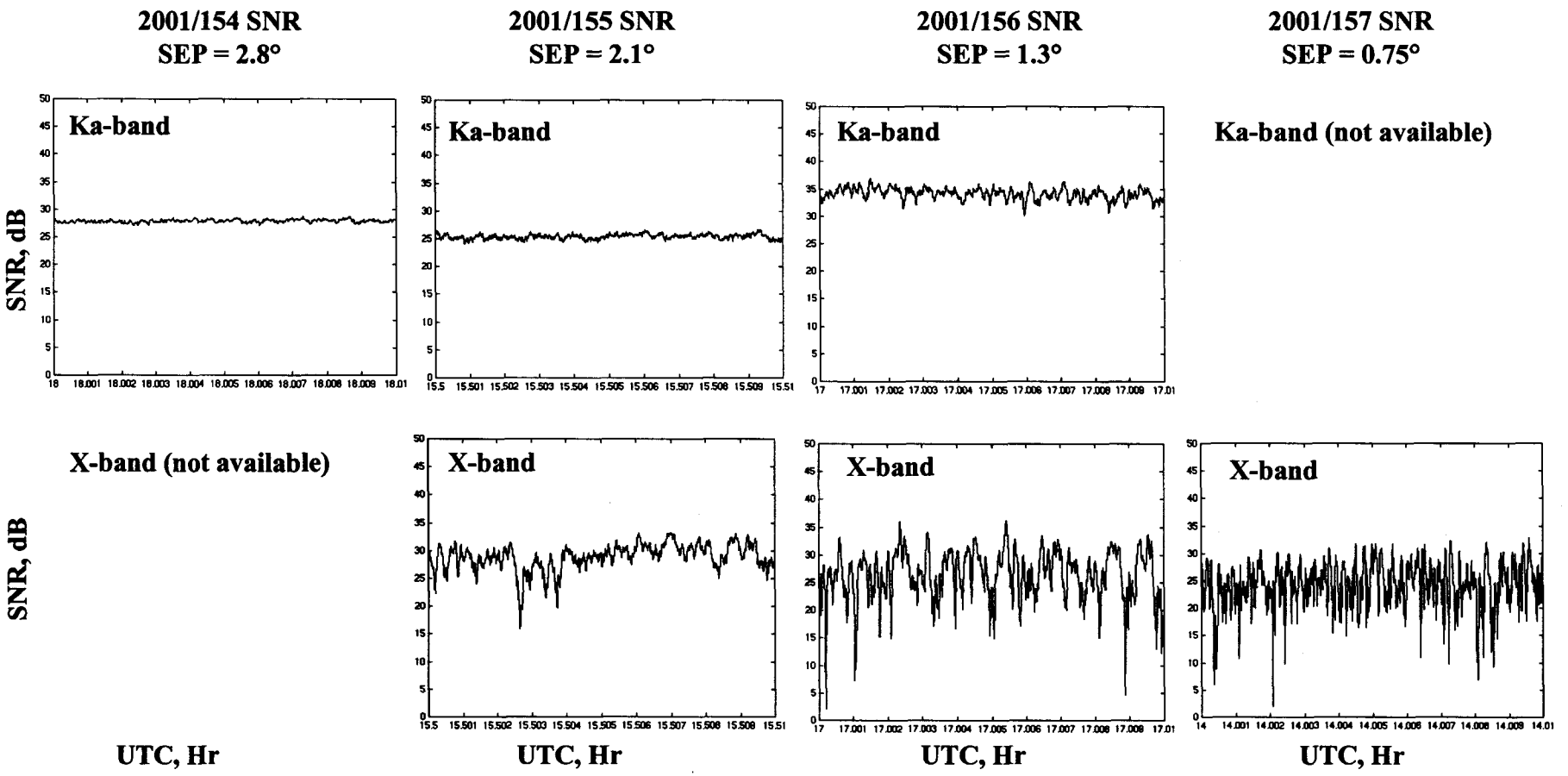
X-band



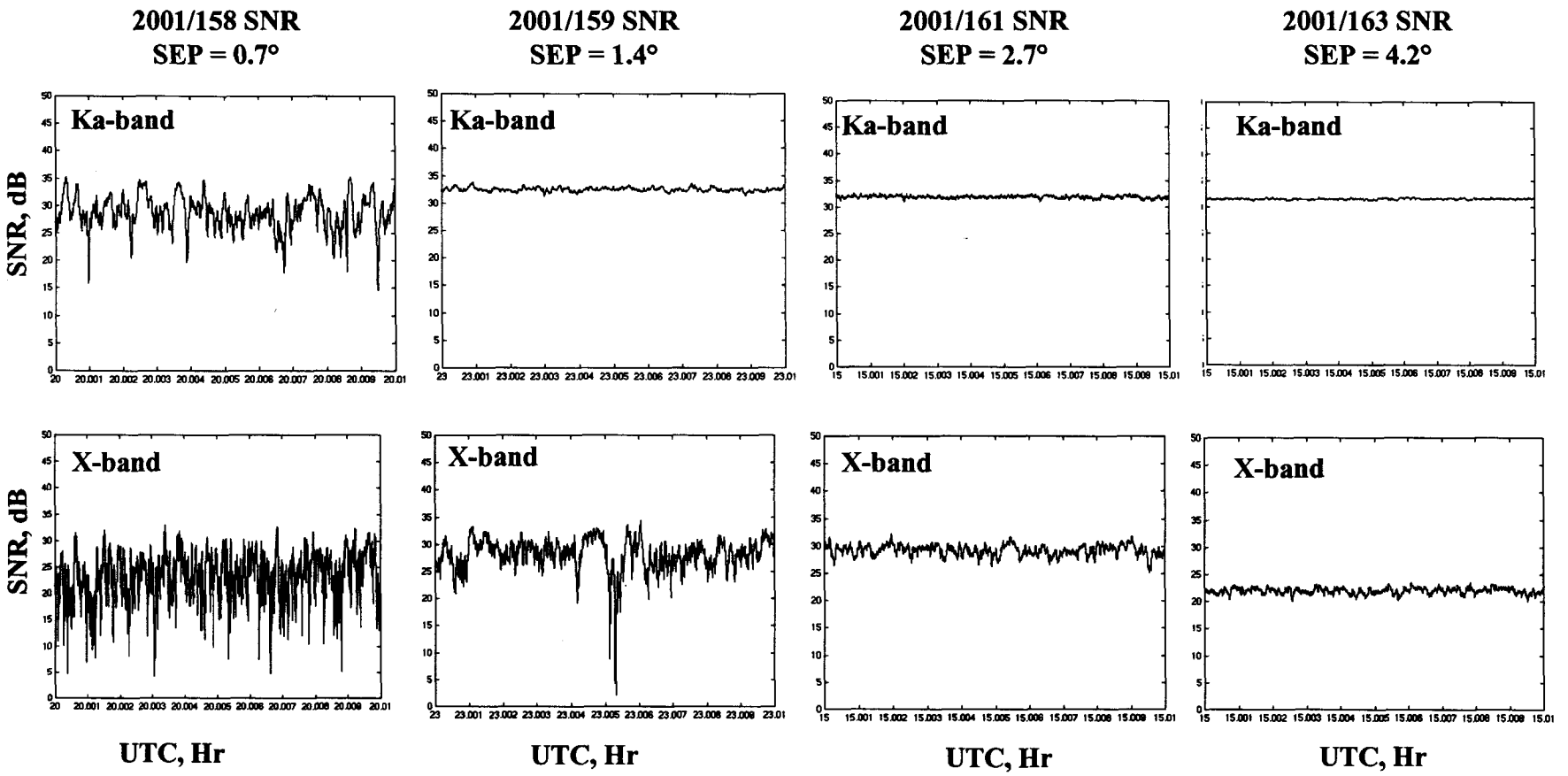
Ka-band



Examples of short time-scale fluctuations at Ka-band & X-band due to solar charged particles



Examples of short time-scale fluctuations at Ka-band & X-band due to solar charged particles (continued)



CONCLUSION

- Ka-band (32 GHz) and X-band (8.4 GHz) carrier data were acquired during the superior solar conjunction period of the Cassini spacecraft in June 2001
- Quiescent background measurements of scintillation and spectral broadening were generally consistent with model predictions
- Amplitude SNR fluctuations at Ka-band were significant for only the pass conducted at SEP = 0.7°
- Amplitude SNR fluctuations for X-band were significant for passes conducted below SEP = 2°
- Very strong (near saturation) and very rapid amplitude fluctuations (few milli-second time scales) were observed only at X-band for passes conducted with SEP < 1°