Phase-Referencing Cycle Times
VLBA Scientific Memo No. 20

Jim Ulvestad

April 9, 1999

Abstract

This memo gives phase-referencing switching times to be used by the VLBA, as calculated from equations given by Beasley and Conway. Estimates are given as a function of elevation angle for 8 wavelengths ranging from 7 mm to 21 cm, and for good, bad, and typical tropospheric conditions, always assuming a speed of 10 m s^{-1} for the turbulence.

1 Description

Switching times are a critical component of scheduling a phase-referencing observation with the VLBA. Beasley and Conway (1995) give two equations for the longest allowable switching time $\tau_s(\max)$, depending on whether the time scale is less than or greater than that for fluctuations to cross a distance equal to the scale height of the troposphere:

$$\tau_s(\max) = 25\lambda^{6/5}\cos^{3/5}(z){C_n}^{-6/5}v^{-1} \quad , \qquad [\tau_s < L/v] \qquad (1)$$

$$\tau_s(\max) = 100\lambda^{3}\cos^{3}(z){C_n}^{-3}v^{-1} \quad , \qquad [\tau_s > L/v] \; . \qquad (2)$$

Here, $\tau_s(\max)$ is in minutes, λ is the wavelength in centimeters, z is the zenith angle, C_n is the strength of the tropospheric turbulence (${C_n}^2$ is the amplitude of the structure function), and is in units of 10^{-7} m$^{-1/3}$, v is the velocity of the turbulence in meters per second, and L is the scale height of the troposphere. See Beasley and Conway (1995) for more detailed discussion.

Below, we provide tables and plots that can be used to estimate the phase-referencing switching time (or "cycle time") as a function of observing wavelength, elevation, and tropospheric conditions. Here, the switching time is defined as the time between the midpoints of the two calibrator observations before and after the target observation. A "typical" value of $C_n = 2 \times 10^{-7}$ m$^{-1/3}$ is assumed, while a "good" troposphere (similar to some winter nights) is assumed to have $C_n = 1 \times 10^{-7}$ m$^{-1/3}$, and a "bad" troposphere (similar to some summer days) has $C_n = 4 \times 10^{-7}$ m$^{-1/3}$. For all cases, the maximum switching time is assumed to saturate at a value of 10 minutes. At the longest wavelengths, ionospheric effects will become dominant, while at intermediate wavelengths, model errors (e.g., source position errors) may limit the integrations to about this value. Note that (1) the difference between 10-minute and 20-minute cycle times is only about 6% in total on-source integration time, or 3% in signal-to-noise; and (2) elevation angles greater than 60° will be uncommon except for the shortest baselines.

References

[1] Beasley, A. J., & Conway, J. E. 1995, "VLBI Phase-Referencing," in ASP Conf. Series 82, Very Long Baseline Interferometry and the VLBA, ed. J. A. Zensus, P. J. Diamond, & P. J. Napier (San Francisco: ASP), 327–343

Table 1. Phase-Referencing Cycle Times (min)
Typical Weather, $C_n = 2 \times 10^{-7}$ m$^{-1/3}$

	Wavelength (cm)							
Elevation	21	18	13	6	3.6	2	1.3	0.7
5°	9.7	8.1	5.5	2.2	1.2	0.6	0.3	0.2
10°	10.0	10.0	10.0	3.3	1.8	0.9	0.5	0.3
15°	10.0	10.0	10.0	4.7	2.3	1.1	0.7	0.3
20°	10.0	10.0	10.0	10.0	2.7	1.3	0.8	0.4
25°	10.0	10.0	10.0	10.0	4.4	1.5	0.9	0.4
30°	10.0	10.0	10.0	10.0	7.3	1.7	1.0	0.5
40°	10.0	10.0	10.0	10.0	10.0	2.7	1.1	0.5
50°	10.0	10.0	10.0	10.0	10.0	4.5	1.3	0.6
60°	10.0	10.0	10.0	10.0	10.0	6.5	1.8	0.7
70°	10.0	10.0	10.0	10.0	10.0	8.3	2.3	0.7
80°	10.0	10.0	10.0	10.0	10.0	9.6	2.6	0.7

Table 2. Phase-Referencing Cycle Times (min)
Bad Weather, $C_n = 4 \times 10^{-7}$ m$^{-1/3}$

	Wavelength (cm)							
Elevation	21	18	13	6	3.6	2	1.3	0.7
5°	4.2	3.5	2.4	0.9	0.5	0.3	0.2	0.1
10°	7.6	5.3	3.6	1.4	0.8	0.4	0.2	0.1
15°	10.0	10.0	6.0	1.8	1.0	0.5	0.3	0.1
20°	10.0	10.0	10.0	2.1	1.2	0.6	0.3	0.2
25°	10.0	10.0	10.0	2.6	1.3	0.7	0.4	0.2
30°	10.0	10.0	10.0	4.2	1.5	0.8	0.4	0.2
40°	10.0	10.0	10.0	9.0	1.9	0.8	0.5	0.2
50°	10.0	10.0	10.0	10.0	3.3	0.9	0.6	0.3
60°	10.0	10.0	10.0	10.0	4.7	1.0	0.6	0.3
70°	10.0	10.0	10.0	10.0	6.1	1.1	0.6	0.3
80°	10.0	10.0	10.0	10.0	7.0	1.2	0.6	0.3

	Table 3. Phase-Referencing Cycle Times (min) **Good** Weather, $C_n = 1 \times 10^{-7}$ m$^{-1/3}$							
	Wavelength (cm)							
Elevation	21	18	13	6	3.6	2	1.3	0.7
5°	10.0	10.0	10.0	5.0	2.7	1.3	0.8	0.4
10°	10.0	10.0	10.0	10.0	4.1	2.0	0.8	0.6
15°	10.0	10.0	10.0	10.0	8.1	2.6	1.5	0.7
20°	10.0	10.0	10.0	10.0	10.0	3.2	1.8	0.9
25°	10.0	10.0	10.0	10.0	10.0	6.0	2.0	1.0
30°	10.0	10.0	10.0	10.0	10.0	10.0	2.8	1.1
40°	10.0	10.0	10.0	10.0	10.0	10.0	5.8	1.3
50°	10.0	10.0	10.0	10.0	10.0	10.0	9.9	1.5
60°	10.0	10.0	10.0	10.0	10.0	10.0	10.0	2.2
70°	10.0	10.0	10.0	10.0	10.0	10.0	10.0	2.9
80°	10.0	10.0	10.0	10.0	10.0	10.0	10.0	3.3

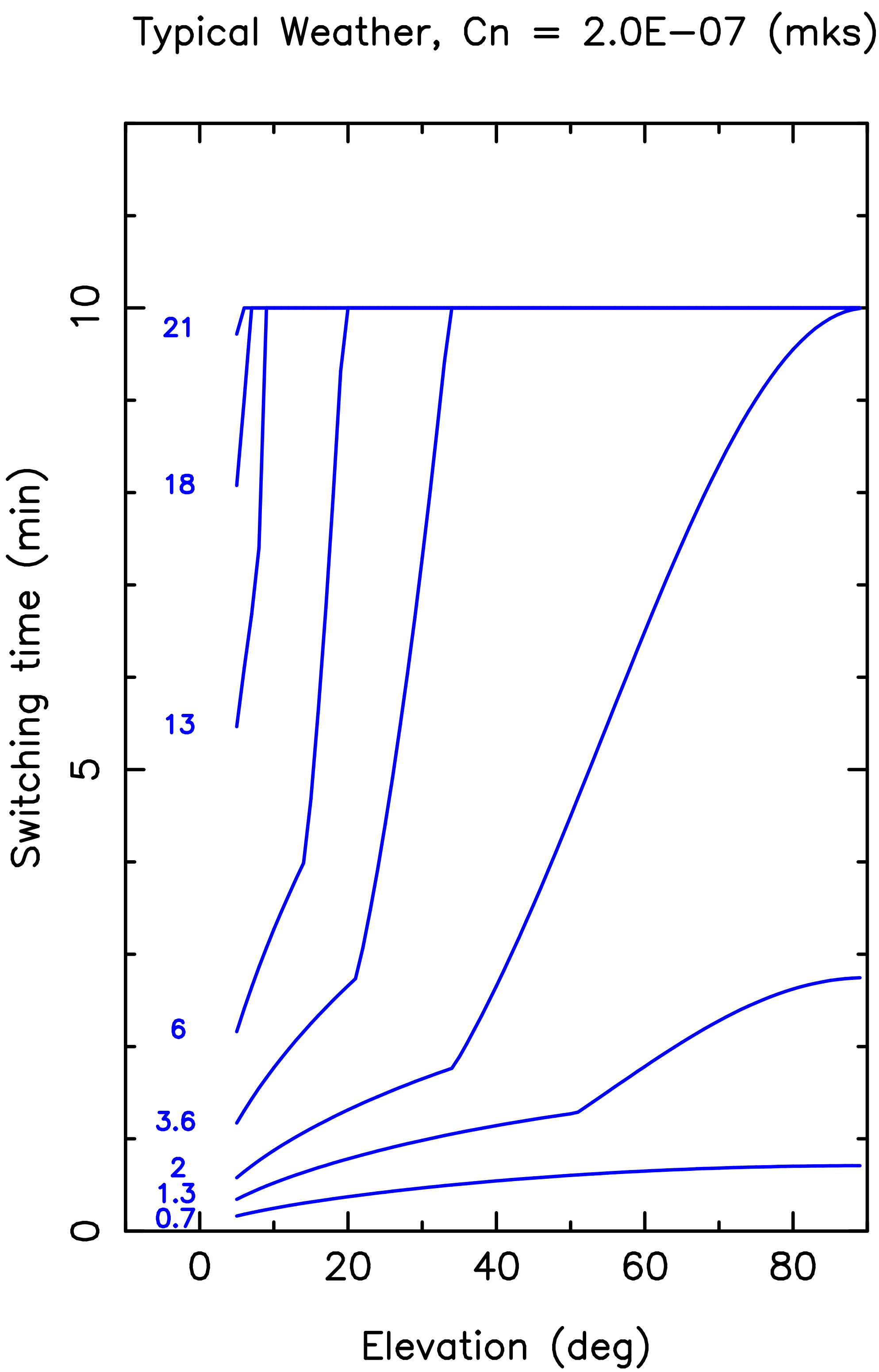

Figure 1: Maximum phase-referencing switching times for typical weather. Plots are given for eight different wavelengths ranging from 0.7 cm (7 mm) to 21 cm.

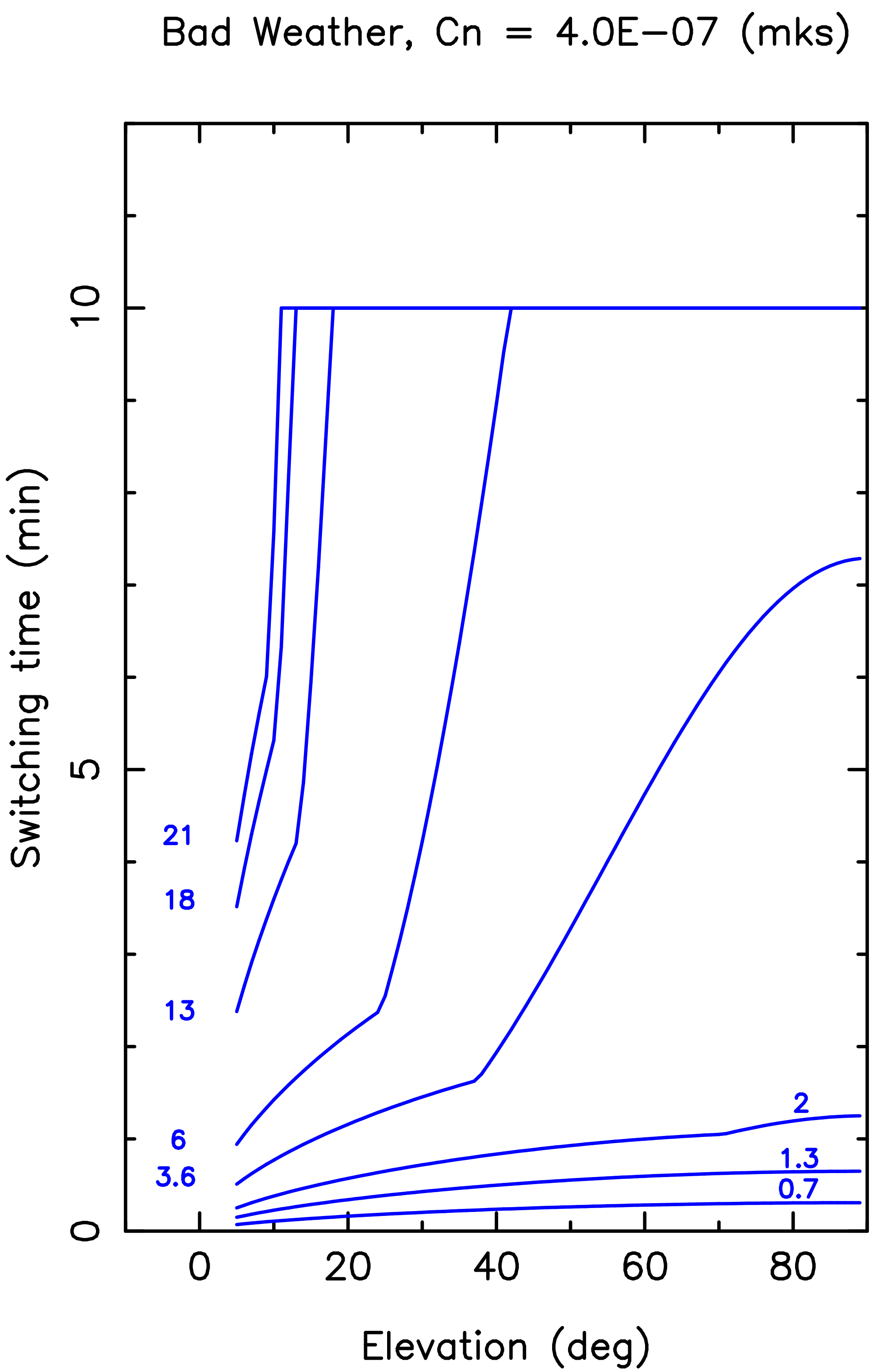

Figure 2: Maximum phase-referencing switching times for bad weather. Plots are given for eight different wavelengths ranging from 0.7 cm (7 mm) to 21 cm.

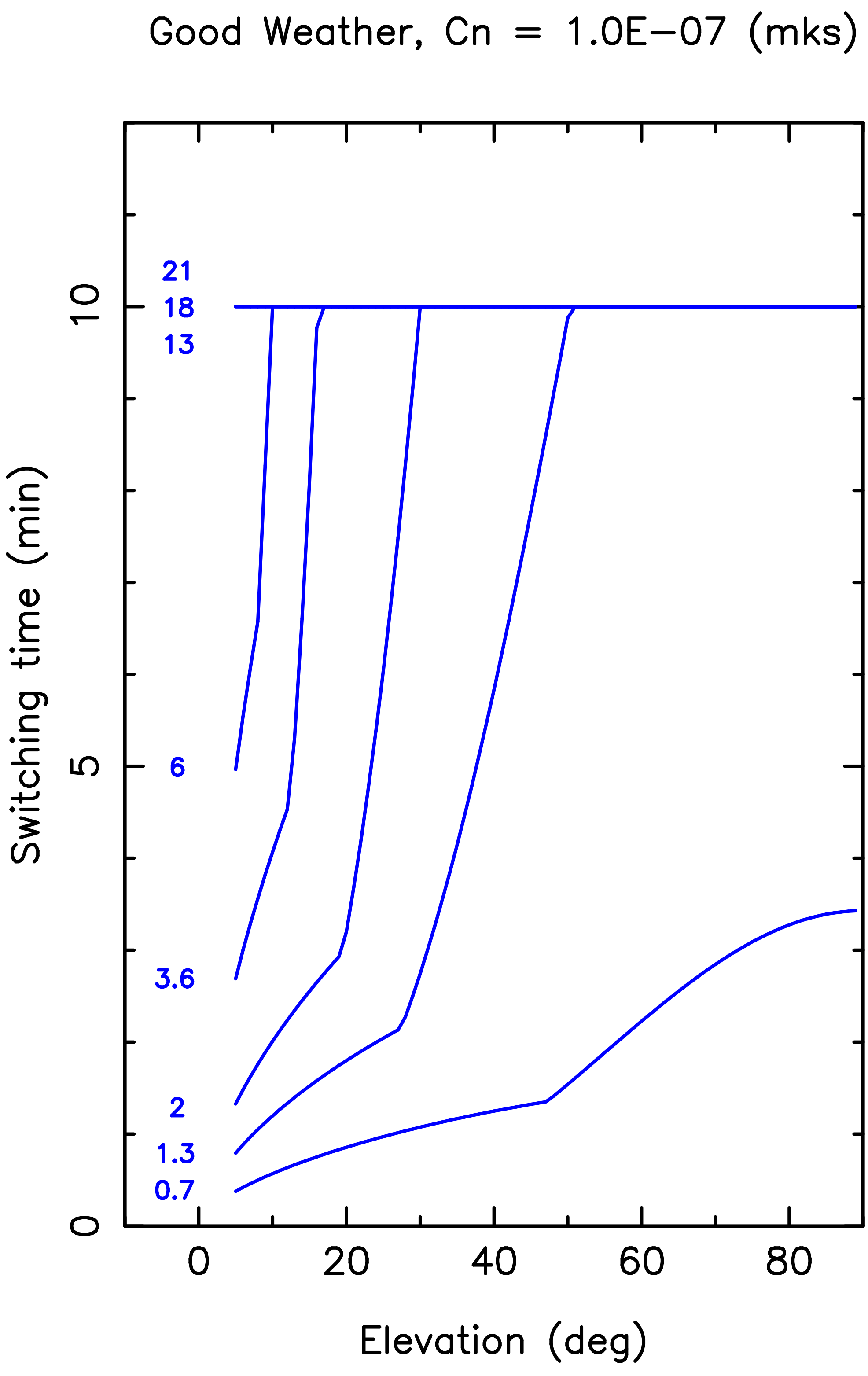

Figure 3: Maximum phase-referencing switching times for good weather. Plots are given for eight different wavelengths ranging from 0.7 cm (7 mm) to 21 cm.

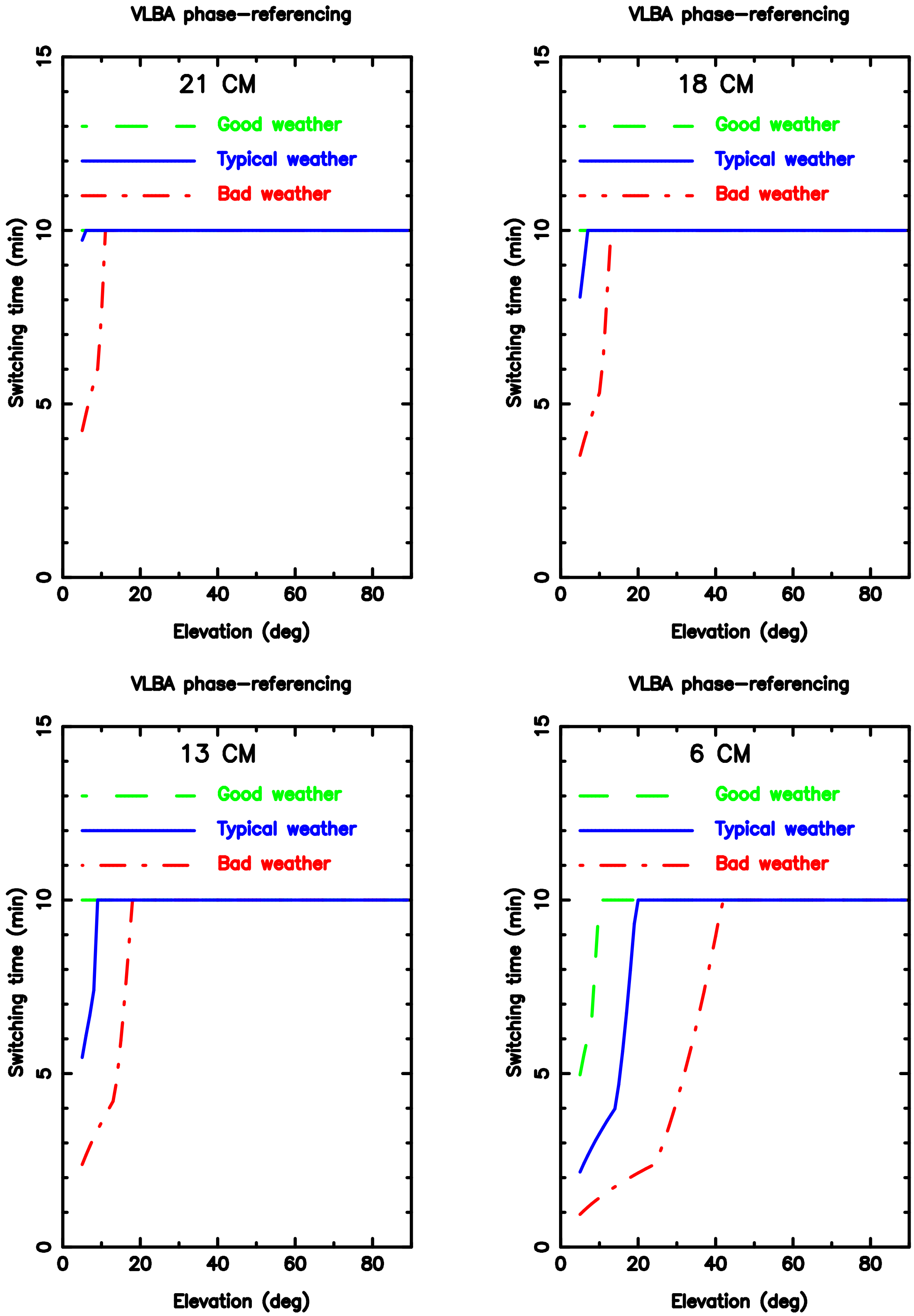

Figure 4: Maximum phase-referencing switching times for good, typical, and bad weather, for wavelengths ranging from 6 cm to 21 cm.

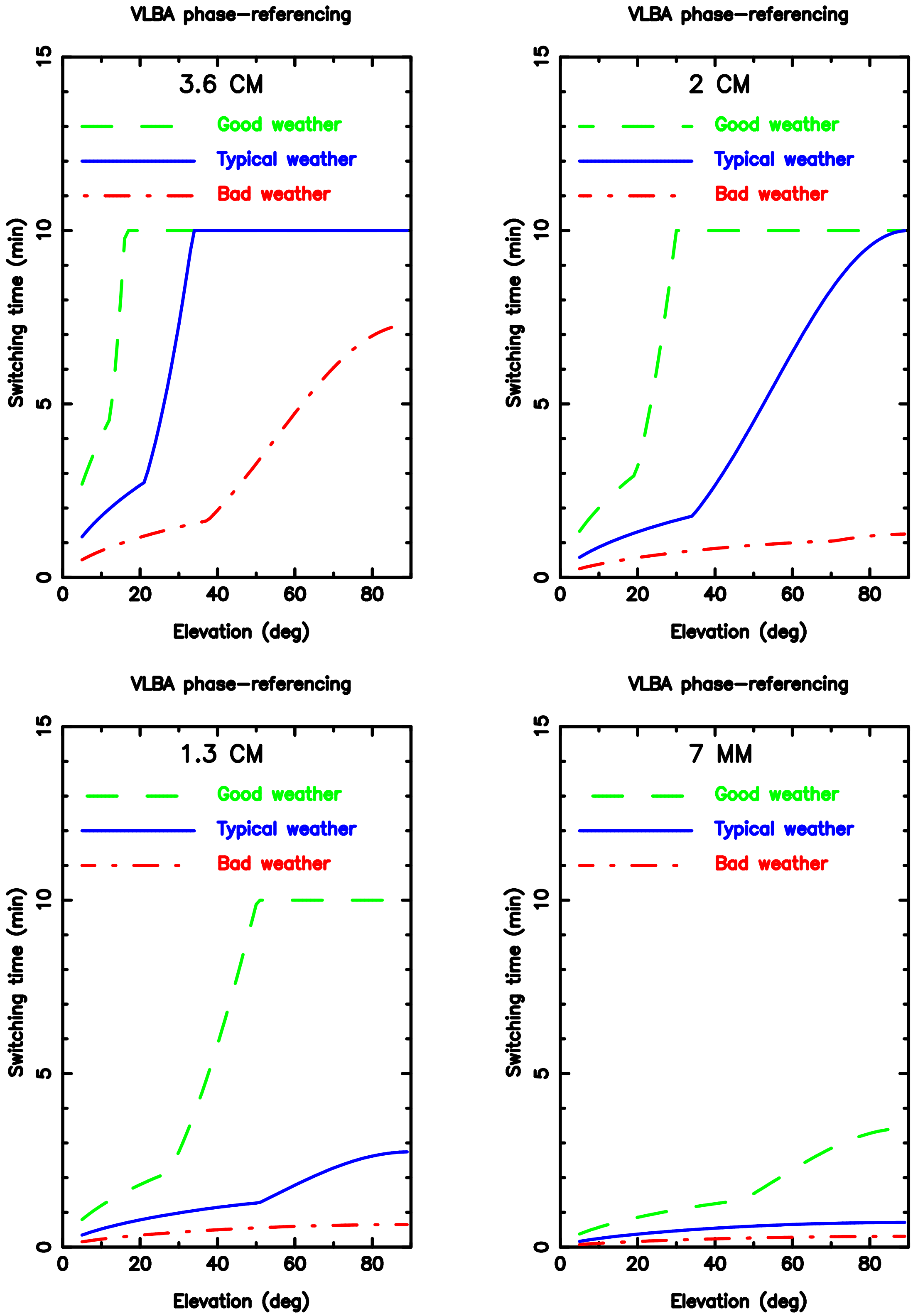

Figure 5: Maximum phase-referencing switching times for good, typical, and bad weather, for wavelengths ranging from 7 mm (0.7 cm) to 3.6 cm.