Chapter 11

SOLAR RADIO EMISSION

W. R. Barron
E. W. Cliver
J. P. Cronin
D. A. Guidice

Since the first detection of solar radio noise in 1942, radio observations of the sun have contributed significantly to our evolving understanding of solar structure and processes. The now classic texts of Zheleznyakov [1964] and Kundu [1965] summarized the first two decades of solar radio observations. Recent monographs have been presented by Kruger [1979] and Kundu and Gergely [1980].

In Chapter 1 the basic phenomenological aspects of the sun, its active regions, and solar flares are presented. This chapter will focus on the three components of solar radio emission: the basic (or minimum) component, the slowly varying component from active regions, and the transient component from flare bursts.

Different regions of the sun are observed at different wavelengths. At millimeter wavelengths, the radiation is from the photosphere. Centimeter wavelength radiation originates in the chromosphere and low corona. Decimeter and meter wavelengths have their origin at increasing heights in the corona; at meter wavelengths the observed radiation comes from heights ranging from 100 000 to 700 000 km above the photosphere. For receiving equipment on the earth, the low-frequency limit for observation is the frequency at which radio waves are reflected by the ionosphere (for practical purposes, around 20 MHz). The high-frequency limit is set by absorption of radiation by atmospheric oxygen and water vapor. Recently, radio experiments on satellites have observed hectometric wavelength ($\leq$2 MHz) emission that originate at heights $\gtrsim$10 solar radii ($R_\odot$). This leaves only the frequency range form 2 to 20 MHz, corresponding to emission heights of 2–10 $R_\odot$, unexplored by radio methods.

11.1 BASIC DEFINITIONS

If the sun radiated only as a thermal source, the emitted energy density would vary with frequency and temperature according to Planck's radiation law. In the radio region, the Rayleigh-Jeans approximation for blackbody radiation is valid; the brightness, radiance per unit bandwidth, is

$$B_f = 2kTf^2c^{-2} = 2kT\lambda^{-2}. \qquad (11.1)$$

If the frequency f is in cycles per second, the wavelength λ in meters, the temperature T in degrees Kelvin, the velocity of light c in meters per second, and Boltzmann's constant k in joules per degree Kelvin, then B_f is in W $m^{-2}Hz^{-1}sr^{-1}$. Values of temperatures T_b calculated from Equation (11.1) are referred to as *equivalent blackbody temperature* or as *brightness temperature* defined as the temperature of a blackbody that would produce the observed radiance at the specified frequency.

The radiant power received per unit area in a given frequency band is called the power flux density (irradiance per bandwidth) and is strictly defined as the integral of $B_f d\Omega_s$ between the limits f and f + Δf, where Ω_s is the solid angle subtended by the source. In solar radio astronomy the relationship used is

$$F_s = B_f\Omega_s = 2kT_d\Omega_s\lambda^{-2}, \qquad (11.2)$$

where the apparent or disk temperature T_d is that temperature which a uniform source of the same angular size as the solar optical disk must have in order to produce the power flux density F_s received from the sun. Values of power flux density are usually given in solar flux units (1 solar flux unit, sfu = 10^{-22} W m^{-2} Hz^{-1}).

The power P_s received at the antenna due to solar radiation is given by:

$$P_s = F_sA_e, \qquad (11.3)$$

where A_e is the effective area of the antenna. P_s is also conveniently expressed in terms of the effective antenna temperature T_A corrected for any RF losses. T_A is defined by

$$P_s = kT_A\Delta f. \qquad (11.4)$$

T_A is readily measured with suitably calibrated instruments. The equation for calculating the solar power flux density

from a given antenna temperature measured at a given installation is

$$F_s = 2kT_A\frac{L}{A_e}, \qquad (11.5)$$

where A_e is the effective area of the antenna in square meters, and L is a dimensionless correction factor related to the antenna response shape and to the diameter and temperature distribution across the source. The value of L is unity only if the antenna half-power beamwidth is large compared to the source. L exceeds unity when the ratio of the antenna half-power beamwidth to the solar angular diameter drops below about five; thus, it is desirable to use a parabola small enough so the half-power beamwidth is more than five times the solar angular diameter. Once the solar flux density is known, the apparent temperature and the brightness of the solar disk may be calculated from Equation (11.2).

11.2 THE MINIMUM (ZERO-SUNSPOT) COMPONENT

The standard method for obtaining the basic radio flux density of the unspotted sun is to make a scatter plot of solar temperature at a given frequency against the projected sunspot area; the extrapolation of the curve that best fits these data to zero sunspot area determines the minimum or basic flux density at that frequency. By doing this for all frequencies, one determines the spectrum of the basic component of solar radiation. Figure 11-1 shows the distributions of power flux density for the sun and for black bodies at various temperatures. It is only at millimeter and shorter wavelengths that solar radio emission approximates a 6000 K blackbody. At wavelengths longer than 1 cm, the equivalent blackbody temperature ranges between 10^4 to 10^6 K for the spotless sun and from 10^4 to 10^{10} K for the disturbed sun depending on the condition of the sun and the time in relation to the 11-year sunspot cycle. Meter wavelengths are characterized by much burst activity; thus, the basic (or minimum) sun temperatures at these wavelengths are determined by making observations over a period of weeks or months. The low temperature to which the sun periodically returns, but never goes below, during this period is taken to be the zero-sunspot value; it is of the order of 10^6 K.

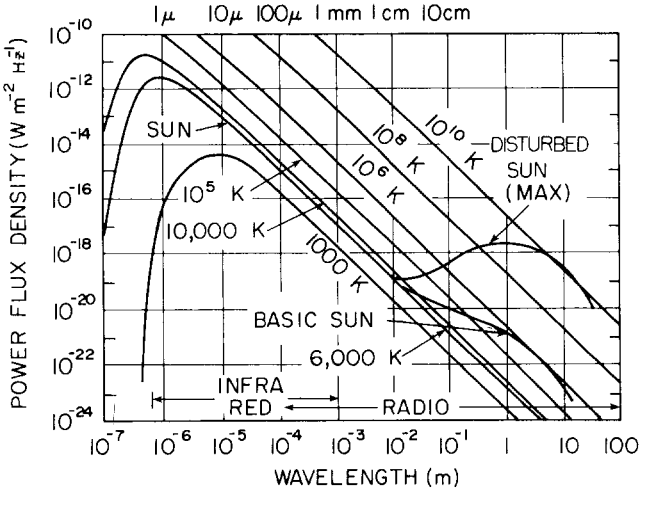

Figure 11-1. Solar spectrum and spectra of blackbody radiation at various temperatures. The solar power-flux density (power per unit area per unit bandwidth) is plotted against wavelength.

11.3 THE SLOWLY VARYING COMPONENT

The slowly varying component (SVC) exhibits a well defined 11-year cycle variation and a 27-day solar-rotation variation, since this emission originates principally in coronal condensations overlying active regions, and is well-correlated with sunspot number. The routine daily measurement of the combination of the basic (or minimum) component and the SVC of solar radio emission is referred to as the *quiet-sun flux density*. The SVC of the sun as a whole is obtained by subtracting the basic component from the quiet-sun flux density. The SVC of individual active regions can be obtained by either eclipse observations or interferometric measurements.

11.4 THE BURST COMPONENT

During solar flares (Chapter 1) there may be large increases (bursts) in radio emission lasting anywhere from a few seconds to several hours. These bursts originate by bremsstrahlung, gyrosynchrotron, and plasma radiations. Characteristics of the bursts vary with wavelength. Bursts in the meter-wave range (12 m to about 50 cm) are classified by spectral type. No spectral classification exists for the decimeter or centimeter wave regions.

11.4.1 Meter-Wave Range (25 – 500 MHz).

Most information on solar bursts in the range from 12 m to about 50 cm is obtained from swept-frequency observations. Dynamic spectra are displayed on a cathode-ray tube and recorded photographically as a series of intensity-modulated traces that give intensity as a brightening in the frequency-time plane. Figure 11-2 is an illustration of idealized dynamic spectra of various types of bursts. These spectral types are discussed below in the order of their occurrence in the flare event.

Type III bursts are the most common type of solar radio

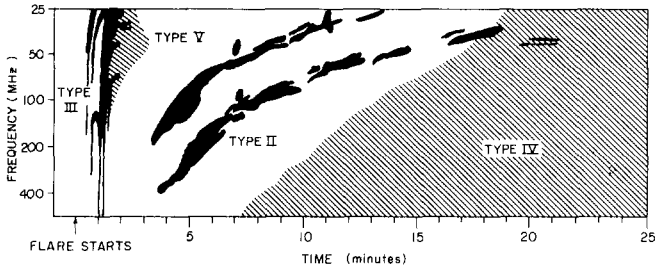

Figure 11-2. Idealized illustration of the record of a complete solar radio outburst as recorded by a dynamic spectrograph at meter wavelengths.

activity. They can occur either singly (duration ~5 s) or in groups. Only about one-third of Type III bursts are associated with flares. When associated with flares, however, the timing agreement with flare impulsive hard x-ray and microwave emission is often quite good (within seconds). Type III bursts are caused by streams of ~100 keV electrons propagating outward through the solar atmosphere and exciting plasma waves. Because of their relatively high drift rates (20 MHz/s) to lower frequencies, they are referred to as fast drift bursts.

Type V bursts consist of a broad band continuum of short duration (~1 min) that is preceded by a Type III burst and accompanied by centimeter-wave and hard x-ray bursts. The Type V burst may indicate the presence of a particularly rich stream of electrons, part of which is trapped in the corona and becomes visible either through gyrosynchrotron radiation or plasma waves.

The Type II burst, or slow-drift (~0.2 MHz/s) burst is presumed due to the presence of a shock wave propagating outward through the solar corona with a characteristic velocity of 1000 km/s. The disturbance excites plasma waves at the local plasma frequency. In the spectrograph record, these bursts appear as a narrow band of intense radiation that drifts gradually and often irregularly from high to low frequency. About 60% of all Type II bursts show emission at the second harmonic. Type II bursts are closely associated with solar flares.

Type IV emission has at least three distinct components; these components can not be separated on the spectrograph record and can only be distinguished by interferometers. *Flare continuum* is the broad band emission occurring at meter and decameter wavelengths during the flare impulsive phase. *Moving Type IV* bursts involve a variety of forms, although three basic types have been recognized. These are the magnetic arch, the advancing front, and the isolated source (ejected plasma "blob"). Both the flare continuum and moving Type IV emissions have durations ≤10–60 min. While the moving Type IV burst travels outward through the corona and can reach heights of ~10^6 km above the photosphere, the final stage of Type IV emission, the *storm continuum*, originates low in the corona near the corresponding plasma level and directly above the site of the optical flare. The storm continuum can last for several hours and often degenerates into the Type I noise storms whose durations range from hours to days. In contrast to the flare continuum and moving Type IV emissions that are only weakly polarized, storm continuum is strongly polarized in the ordinary mode. This suggests plasma radiation as the source of the storm continuum, while gyrosynchrotron radiation from energetic electrons spiraling in weak coronal magnetic fields are generally cited as the source of the flare continuum and moving Type IV emissions.

Type I events are distinguished from the relatively smooth broad-band Type IV emission by the presence of a great number of short (~1 s) intense bursts superimposed on the background continuum. These short intense bursts are distributed more or less randomly over the frequency range of the underlying continuum. Both the background continuum and the superimposed bursts are strongly circularly polarized, usually in the ordinary mode. Type I radiation appears to be more closely associated with certain active regions than with flares, although they can be flare-initiated. At present, the mechanism and origin of Type I emission are not well understood.

11.4.2 Decimeter-Wave Range (500 – 2000 MHz).

At decimeter wavelengths the emission is highly variable and complex. Rapid time structures (several peaks per minute) are often observed in the time profiles of decimetric radio bursts observed at discrete frequencies, and the relationship of these fast structures to the source of the smoother emission observed at centimeter wavelengths is not clear. Individual peaks in complex events are often strongly circularly polarized in the ordinary mode.

11.4.3 Centimeter-Wave Range (2000 – 35000 MHz).

Solar emission in the 15–1 cm range does not show as rapid fluctuations as emission in the meter and decimeter ranges. There appear to be at least two basic morphological types of centimeter-wave bursts. The first of these is the *simple impulsive event* that reaches a maximum peak-flux density ranging from 10^1 to $>10^4$ sfu in a few minutes. Impulsive bursts are interpreted in terms of gyrosynchrotron emission. Complex bursts may consist of several impulsive events in sequence, although the appearance of a relatively smooth broad band microwave Type IV component in the later stages of many complex events may indicate an additional or prolonged acceleration process. The second of these, the *gradual rise and fall* microwave burst, may occur by itself or may follow an impulsive event (monotonic decay only), in which case it is referred to as a *post-burst* event.

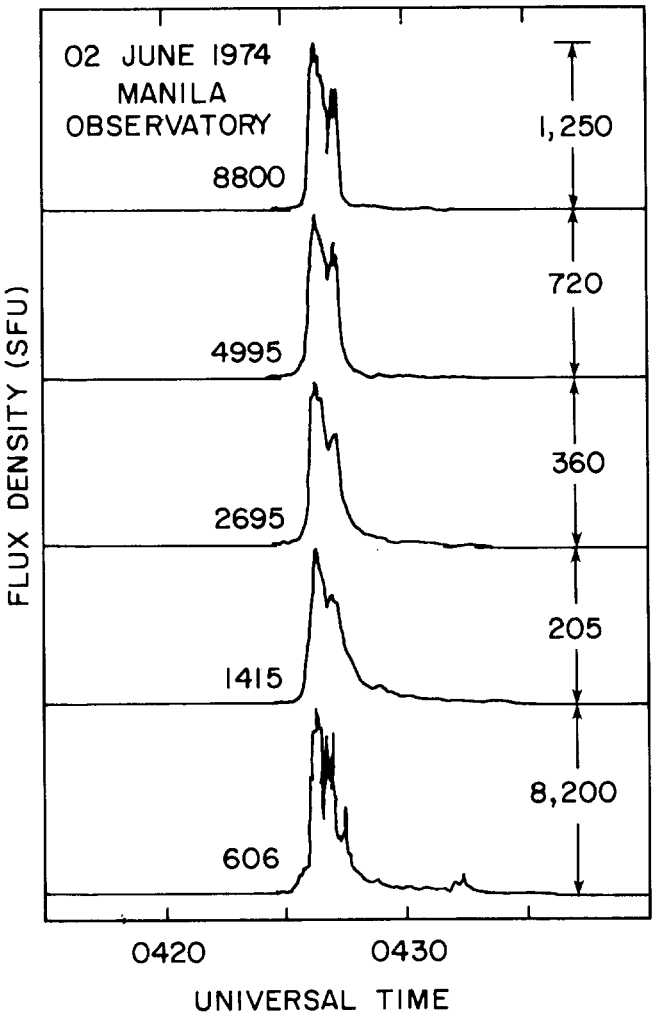

Figure 11-3. The time-intensity profile of an impulsive microwave burst.

Peak flux densities of these gradual events seldom exceed 50 sfu; these events are generally explained in terms of bremsstrahlung from a Maxwellian distribution of electrons. Examples of the time profiles of microwave bursts observed at Sagamore Hill Solar Radio Observatory are contained in the burst atlas compiled by Barron et al. [1980]. A typical impulsive event is presented in Figure 11-3.

Instantaneous spectra of events in the centimeter frequency range are relatively smooth and tend not to have narrow-band emission features. For moderate sized events ($\gtrsim$100 sfu), the peak-flux-density spectral maximum of the emission generally occurs at frequencies $\gtrsim$9 GHz. For the largest events with centimeter wave peak flux densities $\gtrsim$1000 sfu, the emission usually extends to the meter-wave range where it often exhibits a second spectral maximum with a minimum occurring at the intermediate wavelengths. This U-shaped spectral signature (Figure 11-4) is thought to reflect the fact that there are two different sources of burst radiation (one at centimeter waves and one at lower frequencies) with different electron energy distributions and different magnetic fields [Kundu and Vlahos, 1982].

11.5 CORRECTIONS TO QUIET-SUN AND BURST-FLUX DENSITIES

In the final two sections of this chapter, charts and tables of burst and quiet-sun flux densities from Sagamore Hill Solar Radio Observatory are presented. It is appropriate to discuss errors of absolute calibrations in these measurements. In 1973, a report [Tanaka et al., 1973] by an absolute calibration working group formed by Commission V of URSI was published. It contained corrections for Sagamore Hill for the years 1966–1971. For the years 1972–1976, correction factors were taken from the IAU's *Quarterly Bulletin of Solar Activity*. For 1977–1979, correction factors were derived by extrapolation from previous years and comparison of the Sagamore Hill quiet-sun flux densities with those of other solar-patrol observatories. For 245 MHz, a substantial correction factor (1.55) was applied to all the data as a result of an absolute calibrations measurement (using the radio source Cassiopeia A) carried out at Sagamore Hill in 1980. The multiplicative flux-density correction factors for the five frequencies for which data are presented are listed in Table 11-1. Before processing the data presented below, these correction factors were applied to the Sagamore Hill burst and quiet-sun data.

11.6 QUIET-SUN FLUX-DENSITY MEASUREMENTS

Solar microwave emission correlates well with solar EUV flux [Forbes and Straka, 1973], a fact which makes it useful as an input to ionospheric models in lieu of the more difficult to obtain sunspot number and EUV flux. For this reason, the 1965 edition of the *Handbook of Geophysics* included a table of the daily quiet-sun (non-bursting) flux densities observed at 2800 MHz (10.7 cm wavelength) by the National Research Council in Ottawa, Canada from 1947 to mid-1963. We continue the table in this handbook using Ottawa data through 1965 and Sagamore Hill data thereafter. In addition, the 8800 MHz quiet-sun flux-density values from Sagamore Hill are included.

In Table 11-2 we present the observed daily solar flux density value measured at 2800 MHz at Ottawa for the years 1963–1965 and the 2695 and 8800 MHz flux density values measured at the Sagamore Hill Radio Observatory from January 1966 through December 1979. It should be noted that these are observed values and not values adjusted to 1 AU. The values are taken at local noon at the Sagamore Hill meridian. This is done so that the radiation will have passed through the shortest path in the earth's atmosphere

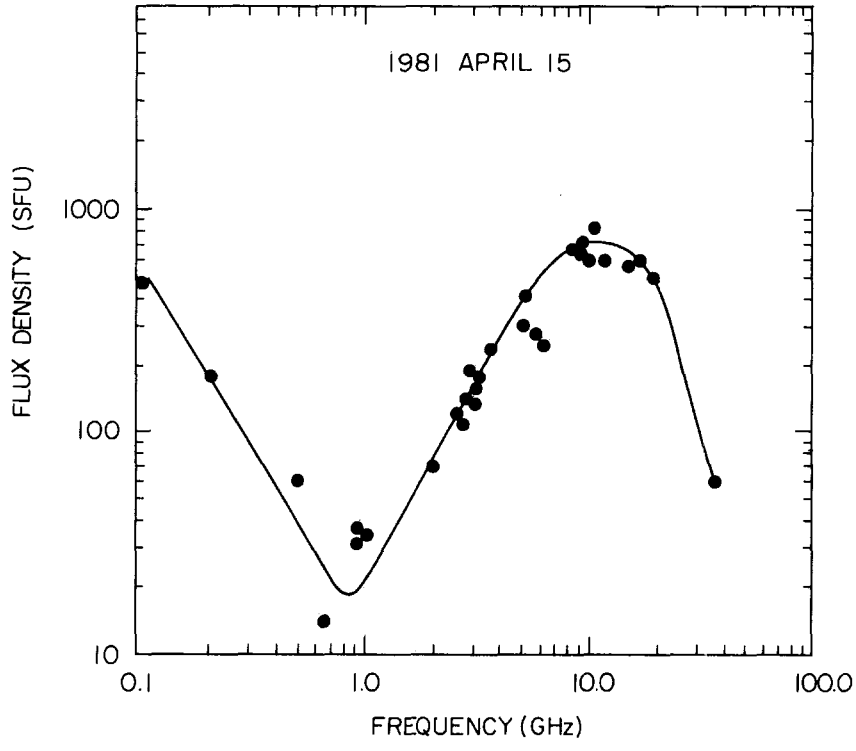

Figure 11-4. The peak flux-density spectrum of a large microwave burst. The U-shape is characteristic for large microwave bursts with peak flux density > 1000 sfu.

and be subject to the minimum atmospheric attenuation. In some instances this meridian-transit observation is not possible because a solar radio burst is in progress at that time. When this happens, the observation is taken as soon as it has been determined that the radio burst has ended. In virtually all cases this was within an hour of the time of meridian transit so that the added attenuation due to the increased atmospheric path length was negligible.

Note the asterisk (*) between the 2695 MHz flux-density value and the 8800 MHz flux-density value on some days. This indicates that there were adverse weather conditions, usually rain or snow, present when the observations were being made. These conditions will cause the signals received to be further attenuated. The asterisk indicates that some adjustment has been made to the observed value to compensate for this problem.

Table 11-1. Calibration correction factors, Sagamore Hill, 1966–1979.

Year	245 MHz	610 MHz	1415 MHz	2695 MHz	8800 MHz
1966	—	0.91	1.16	0.90	0.91
1967	—	0.91	1.16	0.90	0.91
1968	—	0.91	1.16	0.90	0.95
1969	1.55	0.91	1.16	0.94	1.00
1970	1.55	0.91	1.16	0.94	1.00(2)
1971	1.55	0.91	1.16	0.94	1.00(2)
1972	1.55	0.91	1.08	0.93	0.95
1973	1.55	0.91	1.03	0.91	0.90
1974	1.55	0.91	1.05	0.90	0.90
1975	1.55	0.91	1.05	0.90	0.87
1976	1.55	0.92	1.08	0.90	0.85
1977	1.55	1.00	1.06	0.88	0.88
1978	1.55	1.00	1.06	0.85	0.87
1979	1.55	1.00	1.06	0.85	0.84

Notes: (1) For the period 9 June to 31 August 1967, all 2695 MHz burst and daily flux-density values should be multiplied by 1.13.
(2) For the period 1 November 1970 to 31 August 1971, all 8800 MHz burst and daily flux-density values should be multiplied by 1.14.

CHAPTER 11

11.7 SOLAR RADIO-BURST CLIMATOLOGY BASED ON 1966-1978 SAGAMORE HILL OBSERVATIONS

In addition to its role in maintaining the ionosphere, the sun is the most powerful natural source of radio interference to ground-based or near-earth (aircraft or satellite) radio receivers. Therefore, it is of interest to designers and operators of radio receiving equipment to have information on what sort of interference one might expect from the sun at different frequency ranges in the radio spectrum and over what percentage of time the interference might occur (above a certain intensity level). Since radio burst emission from the sun varies unpredictably over a wide range of frequencies, one can only give the statistical likelihood of certain levels being exceeded at various frequencies (or frequency ranges) of interest. We call this body of statistics on solar radio-burst occurrence "climatology." Burst climatology is provided by Sagamore Hill observations at 245, 610, 1415, 2695, and 8800 MHz [Castelli et al., 1973]. Observations at 245 MHz began in March 1969; observations for the other listed frequencies began in January 1966.

To produce a useful solar-burst "climatology", one must first determine what intensity (flux-density) level a burst must reach to interfere with operational systems. Since radio-burst emission occurs over only a very small fraction of the time that any system is exposed to the sun's steady-state (quiet-sun) radio emission, the "disruptive" level of burst emission must be significantly greater than the quiet-sun flux-density levels which vary over the 11-year solar-activity cycle (Figure 11-5).

Since the quiet-sun flux densities are different at different frequencies, one could choose a burst level greatly exceeding the quiet-sun level at any frequency covered in the climatology study (1000 sfu, for example). One could also choose a burst level at each frequency that is a fixed multiple of the mean monthly quiet-sun emission (for ex-

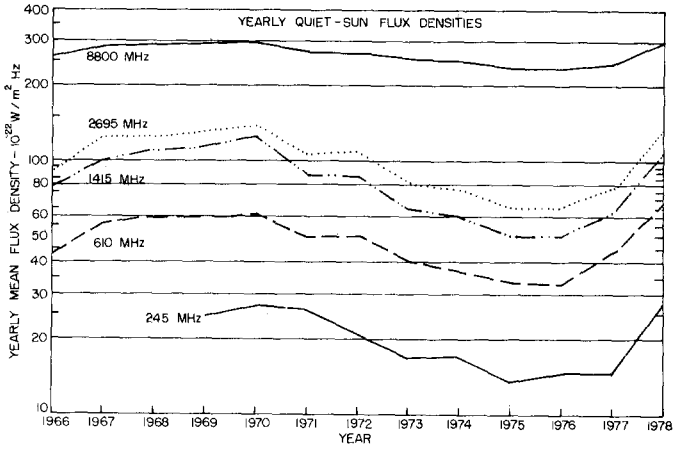

Figure 11-5. Yearly quiet-sun flux densities for several frequencies measured at Sagamore Hill.

Table 11-2a. Daily values of observed solar flux density at 2800 MHz recorded at the Algonquin Radio Observatory (ARO) of the National Research Council, Ottawa, Canada.

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
						1963						
01		87	74	73	82	84	76	87	74	68	87	79
02		86	75	74	82	81	77	87	73	69	85	80
03	77	85	78	74	81	81	78	87	74	70	83	79
04	79	88	80	70	82	79	78	88	75	71	83	77
05	77	87	82	72	84	78	78	86	74	73	80	76
06	77	85	85	78	87	77	77	88	74	77	78	76
07	77	83	84	80	88	84	77	85	78	79	76	77
08	76	82	83	81	86	90	77	81	75	85	75	77
09	78	79	82	82	88	93	77	80	77	86	76	78
10	80	79	80	82	87	99	86	77	76	87	75	79
11	81	76	78	88	84	103	75	72	72	87	76	80
12	78	74	77	93	87	109	74	73	77	84	77	82
13	79	74	74	89	89	107	76	74	89	84	77	81
14	86	75	80	87	95	100	77	71	98	86	78	79
15	85	76	80	88	98	96	76	72	99	88	81	81
16	82	77	79	88	100	89	76	76	105	87	81	78
17	82	79	79	87	100	86	74	82	99	84	80	78
18	80	81	80	88	98	82	74	80	97	83	82	79
19	78	79	77	84	99	79	74	79	102	88	86	78
20	78	77	77	78	91	75	77	81	109	89	84	79
21	76	74	76	74	88	73	75	84	90	94	86	79
22	75	76	76	72	89	72	73	86	105	96	86	77
23	74	75	75	71	93	72	72	90	99	94	84	76
24	73	76	75	73	89	72	72	87	95	94	83	76
25	74	78	75	72	83	74	74	85	86	96	82	
26	73	77	73	72	76	74	73	82	84	96	82	74
27	81	75	74	75	80	72	74	80	78	88	81	74
28	80	74	73	78	79	74	73	77	74	84	79	73
29	79		75	78	80	75	77	77	71	85	79	72
30	78		74	80	83	76	84	77	69	85	79	71
31	82		71		89		85	77		82		71
MEAN	78	79	78	79	86	83	76	81	85	84	81	77
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
						1964						
01		73	78	77	69	68	67	67	70	72	75	76
02	71	72	75	75	68	68	67	68	69	72	74	76
03	73	71	74	77	70	68	67	68	70	72	74	77
04	73	71	75	77	70	68	68	68	70	71	73	78
05	74	72	72	76	72	68	68	69	70	72	73	78
06	75	73	74	76	71	68	68	68	70	73	74	77
07	75	72	73	76	71	70	67	68	71	74	73	76
08	73	73	74	74	72	70	68	68	71	77	72	77
09	73	72	72	75	71	69	67	68	71	73	72	77
10	73	73	73	73	70	70	67	69	72	73	72	78
11	75	72	75	74	70	70	68	68	72	72	72	80
12	76	73	77	73	79	69	67	70	72	70	72	77
13	76	75	78	73	68	70	66	74	72	72	72	78
14	76	73	79	72	68	70	69	76	72	71	73	78
15	75	73	79	71	68	72	70	75	71	71	72	78
16	74	73	77	71	70	71	69	73	70	71	72	80
17	72	74	78	72	70	71	69	72	68	71	76	80
18	74	76	75	72	70	72	68	70	68	72	75	80
19	75	76	74	71	69	70	67	71	69	73	75	81
20	76	76	74	71	68	70	67	70	69	73	76	80
21	75	78	74	72	68	70	66	69	69	71	74	78
22	75	80	78	71	67	70	66	69	69	72	73	78
23	75	84	77	70	67	67	66	69	68	73	72	76
24	74	85	77	72	68	68	66	68	68	74	71	75
25	73	84	74	71	68	68	66	68	68	76	71	75
26	74	86	74	70	68	68	65	68	69	76	70	74
27	73	85	75	70	68	67	65	68	70	76	72	76
28	77	84	76	70	70	67	65	67	70	74	71	77
29	78	81	75	69	69	67	66	67	71	74	73	78
30	75		78	69	68	67	66	69	71	74	74	77
31	74		77		68		66	69		75		78
MEAN	74	76	76	72	69	69	67	69	70	73	73	78
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
						1965						
01	86	78	76	71	71	71	76	72	75	92	79	75
02	84	79	75	72	71	74	76	73	76	93	80	75
03	82	79	75	71	71	75	76	77	77	96	81	75
04	81	77	75	71	70	78	76	78	77	98	80	74
05	80	76	76	71	69	78	75	76	79	92	78	75
06	80	76	77	71	70	78	78	79	77	85	81	76
07	78	77	77	71	71	77	82	80	78	84	85	75
08	78	75	74	70	72	78	81	77	79	83	80	77
09	77	75	73	72	72	79	81	78	76	83	82	75
10	76	76	73	73	72	78	80	76	76	80	84	75
11	75	74	72	74	71	76	80	77	76	76	84	76
12	75	73	74	73	72	76	78	76	75	75	81	76
13	75	72	76	74	74	77	76	75	75	76	77	74
14	74	72	75	75	75	76	75	74	75	75	76	75
15	75	73	73	75	80	77	74	72	75	74	76	77
16	74	73	71	75	86	76	72	74	74	72	74	78
17	74	73	72	73	91	76	72	72	74	72	74	78
18	74	72	75	73	90	78	72	73	73	72	75	78
19	74	72	77	74	92	75	72	74	73	72	73	77
20	76	71	74	72	95	76	73	74	72	73	73	74
21	77	72	74	73	93	76	73	74	72	73	72	74
22	77	72	73	73	92	78	72	73	71	76	72	72
23	76	73	73	73	86	80	71	73	72	79	71	73
24	76	74	72	71	85	78	70	73	76	76	71	71
25	76	74	74	70	81	79	70	72	76	78	71	72
26	76	74	73	69	78	79	69	72	77	78	72	77
27	79	76	72	69	76	78	70	74	78	78	74	84
28	77	76	72	70	74	77	71	73	80	77	77	84
29	79		72	70	74	76	71	74	87	77	74	85
30	81		71	70	74	77	71	75	89	76	75	82
31	80		72		72		71	75		78		81
MEAN	78	75	74	72	78	77	74	75	76	80	77	76

Table 11-2b. Daily values of observed solar power flux densities at 2695 and 8800 MHz. Recorded at the AFCRL/AFGL Sagamore Hill Radio Observatory (SGMR); Hamilton, Massachusetts.

DAY	JANUARY 2695 MHZ	JANUARY 8800 MHZ	FEBRUARY 2695 MHZ	FEBRUARY 8800 MHZ	MARCH 2695 MHZ	MARCH 8800 MHZ	APRIL 2695 MHZ	APRIL 8800 MHZ	MAY 2695 MHZ	MAY 8800 MHZ	JUNE 2695 MHZ	JUNE 8800 MHZ	JULY 2695 MHZ	JULY 8800 MHZ	AUGUST 2695 MHZ	AUGUST 8800 MHZ	SEPTEMBER 2695 MHZ	SEPTEMBER 8800 MHZ	OCTOBER 2695 MHZ	OCTOBER 8800 MHZ	NOVEMBER 2695 MHZ	NOVEMBER 8800 MHZ	DECEMBER 2695 MHZ	DECEMBER 8800 MHZ
1966																								
1	74	253			72	262	97	278	79	250	93	257	86	247	103	261	96	270			86	259	87	247
2	77	253			69	252	92	273	81	253	90	249	84	247	103	260	90	267	92		88*	259	90	253
3	57				68	252	86	269	82	253	87	250	85	245	105	261	90	269	91		86*	258	92	256
4	72	258			68	251	85	265	82	256	86	250	87	255	101	258			93		86	260	102	260
5	73	250					85	263	80	250	85	250	86	266	93	256		263	92		87	264	115	274
6	75	243			66	252	94	263	77	250	85	253	98	288	89	251	82	256	96		95*		114	273
7	74	255			67	249	93	268	80	252	83	251	94	281	85	249	84	255	94		103	288	117	273
8					67	250	92	270	76*	236	86	251	94	272		252	84	256	89		107	285	119	271
9	74				68	252	88	266	74*	238	85	250	88	257	81	248	83	253	93		109	279	128	283
10	73	249			68	252	84	262	76	250	84*		91	255	79	248	84	253	95		112	278	146*	277
11	75	255			69	253	82	265	77	254	82	249	88	256	78	248	87	255			116	278	151	290
12	78	256			71	254	80	262	77	253	80	249	84	247	79	251	91	263			122*	277	148	275
13	83	261			73*	244	77	251	79*	240	84*	236	82	246	82	252					117	280	155	276
14	85	267			71	254	79	254	79	254	81	248	83	248	79	248			103		119	285	149	277
15	93	265	76	253	78	258	82	253	81	260	81	244	84	249	85	248			107		117	283	142	271
16	103	265	75	257	80	259	81	251	83	260	81	250	86	248	85	253	109		107*		114	280	136	267
17	96	267	73	262	87	271	83	252	82	254	86	248	84	248	83	250	114		109		109	278	119	263
18	101	268	75	260	93	271	79	251	81	257	80	249	83	249	83	256	120		108		106	273	105	261
19	101	268	76	262	93	270	75	248	89*	250	79	248	85	249	84	256	128		107*		106	260	110	266
20	94	263	75	264	94	270	81	253	93	264	80	245	89	253	87	257	125		108		104	257	106	259
21	88	264	75	268	99	278	79	250	94	271	81	244	86	252	88	258	120		109		104	257	101	260
22		264	77	268	89	263	82	251	96	276	82	248	91	254	90*	258	114		108		107	259	101	262
23	84	249	72	258	84	260	88	259	91	264	84	248	96	261	102*	262	115		95		107	258	102	265
24			76	258		260	90*	259	90	262	84	249	100	270	109	271	111		92		103	255	104	259
25	83	249			75	251	90	259	89	258	96	258	106	268	110	277	104		90		103	252		
26	82	235	74	268	74	253	91	259	92	263	95	256	110	271	112	278	100		87		104	254	108	257
27	78	232	73	260	74	252	86	254	89	257	82	248	107	268	115	287	103		82		108*	264	105	254
28	76	229	74	263	78	262	85*	254	87*		82	249			119	286	86		84	261	100	254	108	256
29	72	241			88	272	84	256	88*	249	84	248	112	274	108	280	88		89	267	92	258	103	256
30					88	277	79	250	85	252	85	249	108	268	107	280	84		92	267	92	254	112	263
31					95	291			92	253			106	268	102	278			90	258			116	262
MN	82	254	75	262	78	260	85	259	84	255	85	249	92	259	94	261	100	260	96	263	104	267	116	266
1967																								
1	120*	273	148	295	184	344	134	288	113	269	143	280	104	255	147	288	133	294	114	285	118	285	128	296
2	139	288	140*	292	188	347	117	280	114	269	128	282	103	255	135	281	130	291	108	273	120*	287	120	286
3	154	297	132	290	183	335	112	273	109	280	119	278	109	257	132	277	122	281	107	274	118	285	106*	279
4	157*	299	134	287	189	342	111	268	106	262	124	275	107	251	126	284	118	278	104	270	113	285	109	283
5	164	301	136	296	174	324	105	267	106	260	111	263	104	248	127	285	108	278	103	273	107	279	106	277
6	157	291	150	298	165*	313	108*	265	107	260	101	258	100	248	127*	280	107	268	107*	273	104	275	111	280
7	152	292	163*	300	150*	297	115*	268	105	260	93	251	97	246	115	274	105	266	104	271	99	274	115	281
8	134*	287	146	283	141	288	117	274	100*	248	87*	248	89	240	119	270	107	275	101	270	98	271	116*	278
9	136	289	140	288	140	282	116	264	96*	253	88	242	93	244	112	268	106	275	99	273	95*	275	116	283
10	142	283	137*	283	128	277	109	265	91*	244	79*	237	92	243	112	262	104*	277	104*	288	101	280	115	280
11	132	280	125*	283	120	270	115	269	88	249	79	240	92	240	112	266	105	278	116	288	110	291	125*	288
12	130	280	132	285	117	269	112	268	88	253	82	232	90	240	118	268	105	278	115	283	112	288	125*	290
13	130	274	127	280	114	275	107	266	85	249	85	249	93	248	118	265	103	276	109	275	117	289	128	294
14	128	272	120	282	111	271	106	275	89	255	88	248	104	259	106	263	101	275	107	278	121	288	136	303
15	116	264	112	279	119	278	110*	268	93*	251	91	251	109*	257	99	257	104	278	100	275	126*	289	147	315
16	116	262	106*	279	118	278	112*	269	94	255	92	253	106	259	103	261	97	269	98	274	134	299	173*	329
17	108	259	114	280	122	282	109	265	96	257	94	253	105	258	115	264	98	271	96	273	140	304	177	332
18	111	262	116	282	122	282	111*	262	103	260	108	253	111	262	123	279	102	268	96	272	140	307	198	355
19	120	266	111	281	121	280	113*	278	115	269	104	257	105	262	137	291	103	267	99	273	148	315	186	349
20	127	267	116*	283	123	279	107	268	120	275	104*	260	113	267	134	287	106	267	107	276	149	312	182	339
21	132	272	118*	285	129	288	111	270	142	297	108*		113	271	145	293	104	264	105*	271	142	306	175	337
22	135	276	132	299	137*	298	117	280	161	329	111	264	121	285	141	287	101	264	115	283	139*	305	159	322
23	139	281	136*	295	144*	296	110	265	176	348	119*	262	128	293	148	291	100	267	114	282	140*	298	144*	294
24	135	278	139	323	140	293	113*	264	177	337	107	244	141	307	140	295	108	274	113	279	134	298	129	290
25	138	282	152	329	142	287	113	270	184*	343	105	249	154	330	135	294	110	274	118	287	132*	285	145	299
26	139	289	158	337	152	294	106	264	201*	343	103	245	151	332	136	294	112	275	124	295	142	305	149	315
27	145	298	155	331	148	291	110	264	187	306	107	247	160	330	136	296	114	285	131	312	142	302	156	315
28	146	298	153	344	158	299	115	268	174	303	112	257	179	325			110	278	145	319	139	308	164*	326
29	151	302			162	316	115	269	161	294	112	257	179	308	141	303	107*	272	137	314	135	297	157*	313
30	155	298			155	308	112	268	151	289	114	255	162	301	130	295	109	272	136	306	128	298	144	302
31	147	296			143	296			153	290			149	291	132	295			128	298			142	309
MN	137	283	134	295	143	296	112	269	125	279	103	255	118	271	127	280	108	275	112	283	125	293	141	304
1968																								
1	152	337	205	405	137*	294	123	281	115	279	125	275	104	260	107	269	106	268	114	278	137	303	123	294
2	151	332	200*	391	138	295	120	280	122	285	121*	275	96	259	109	267	111	270	113	280	135	302	131	298
3	155*	337	194	370	132	292	114	279	128	282	121	275	95	257	113	280	117	276	120	286	126	292	127	295
4	164*	354	179	348	120	284	110*	275	129	286	121*	269	94*	256	110	278	119	278	125	283	121	280	126*	276
5	174	357	161	333	119	286	108*	275	127	281	115	269	96	265	109	280	116	277	125	281	115	276	135	293
6	181	362	144	307	119	286	104	264	122	281	121	279	98	269	117	286	113	279	125	285	109	275	126	275
7	192	370	143	302	111	275	104	269	117	280	129	280	106	276	112	288	115	278	123*	268	114	280	123	276
8	212*	364	134	294	100	273	111	274	117	281	126	282	112	293	118	293	124	285	121	282	118	284	122	277
9	209	353	134	298	103	276	116*	284	115	282	122	281	120	286	115*	280	124	283	115	273	120	289	128	282
10	191	351	137*	305	102	274	116	288	113*	283	124*	279	127	285	118	281	128	287	114	276	116*	273	131	287
11	190	348	138	302	113	279	115	284	107	275	124*	283	132	282	120	292	127	275	113	279	117	285	127	283
12	186	343	137	297	111	284	117	287	105*	272	114*	275	135	290	130	295	130	281	117	282	116*	286	122	276
13	182	340	129	289	110*	282	119	297	104	268	118	271	125	284	140	303	126	280	110	275	115*	284	113	272
14	174	337	126	284	110*	281	115	288	111	281	116	275	125	286	152	319	123	277	110	269	111	275	116	275
15	161	332	124	287	105	276	116*	283	113	284	113	278	122	275	148	311	112	273	117	277	116	287	119	276
16	153	321	122	285	107	274	116	284	122	287	114	286	123	281	146	305	108	269	117	281	112	289	112	267
17	150	313	118*	280	114	277	109	281	137	295	115*	276	115	278	139	292	108	270	123	290	124	294	119	276
18	144	313	117	281	110		106	288	145*	299	120	280	107	269	135	288	109	270	121	290	127*	289	119	273
19	135	305	118	285	112	277	107	278	152	305	119	285	108	269	131	282	105	268	131*	294	122	279	126	278
20	127	297	119	293	110	271	101	268	157*	305	124	289	109	266	134	282	105	266	134*	299	121	281	131*	275
21	122	297	126	296	120	276	102*	270	156	306	128	289	107	265	132	286	111	274	139	297	118	278	132	279
22	119	300	129	294	122*	277	97	262	151	312	124	289	112	270	133	285	104	267	143	299	115	278	133	284
23	120	303	131	294	127*	282	95	260	148	305	132	302	117	265	112	267	103	267	144	293	115	279	131*	275
24	131	314	141	300	136	285	100*	261	149	305	129	292	123	273	106	267	117	275	150	295	.17	281	139	280
25	134	323	154	309	142	291	100	265	143	302	128	292	129	279	102	266	135	294	151*	296	119	288	143	288
26	144	339	155	309	137	283	94	259	142*	298	120*	277	124	275	98	265	134	286	152	303	118	290	141	286
27	154	354	148	304	141	285	97	265	138	289	123*	281	118	271	95	257	130	279	156	310	120	285	149	294
28	164*	386	149	307	135	286	102	266	128	287	119*	272	118	275	98	256	132	286	151*	310	115	279	138*	294
29	187*	386	143	301	134	286	105	275	126*	279	114	268	121	287	100	266	130	292	166	341	110	278	127	288
30	203	415			136*	290	107	272	128	278	107	264	112	274	104	267	119	292	140	313	115	284	128	291
31	204	417			134	286			126	277			109	267	101	266			139	306			124	284
MN	163	342	143	309	121	282	108	275	129	288	121	280	114	274	119	281	118	277	130	290	118	284	128	282

Table 11-2b. (Continued)

DAY	JANUARY 2695 MHZ	JANUARY 8800 MHZ	FEBRUARY 2695 MHZ	FEBRUARY 8800 MHZ	MARCH 2695 MHZ	MARCH 8800 MHZ	APRIL 2695 MHZ	APRIL 8800 MHZ	MAY 2695 MHZ	MAY 8800 MHZ	JUNE 2695 MHZ	JUNE 8800 MHZ	JULY 2695 MHZ	JULY 8800 MHZ	AUGUST 2695 MHZ	AUGUST 8800 MHZ	SEPTEMBER 2695 MHZ	SEPTEMBER 8800 MHZ	OCTOBER 2695 MHZ	OCTOBER 8800 MHZ	NOVEMBER 2695 MHZ	NOVEMBER 8800 MHZ	DECEMBER 2695 MHZ	DECEMBER 8800 MHZ
1969																								
1	130*	294	120*	290	148	309	160	335	106	265	94	258	123*	277	149	293	136	273	114	270	126	289	118	270
2	130	294	126	293	138	290	163*	332	108	278	100	262	134	287	160	302	130	273	121	276	121	285	122	276
3	135	301	128	287	132*	293	167	325	113	274	110	270	144	301	155	293	128	272	115*	273	113*	278	127	275
4	144	302	127	275	131	298	154	308	114	271	126	289	139	298	161*	299	127	283	111	267	113*	271	129	279
5	152	304	131	286	130	297	148	306	131	282	161	317	138	291	154	295	116	268	120	276	112*	267	128	293
6	164	316	129	289	127	292	141	297	116	272	165	331	137	290	144	283	114	271	123	278	116*	272	122	281
7	175	328	131	291	123	289	133	290	112	271	178	329	136	285	135	279	107	268	126	286	116*	264	111	271
8	169	323	124	285	126	290	128	283	118*	273	200	342	137	288	128	274	104	259	124*	278	115	270	100*	257
9	172	340	122*	287	127	291	125	287	115*	271	195	351	136	282	123	272	100*	244	120	280	113	265	104	261
10	160	326			123	285	126*	289	117	274	200	369	134	280	116	264	98	257	116	283	107	262	103	265
11	156	321	119	284	123	285	128	288	129	278	200	369	131	276	112	267	99	258	110	276	106	271	104*	269
12	151	311	112	282	125	286	136	289	137	288	188	353	122	272	107	266	101	261	111	276	105	267	113	279
13	148	309	115*	278	120	284	151	304	128	279	186	353	121*	267	104	255	112	269	107	272	111	265	119	285
14	145	306	114	279	124	289	153	302	137	282	182	337	111	259	97	257	109	265	105	267	121*	270	121	282
15	141	305	116	274	143	318	155	315	136	283	164	314	106	257	97	252	115	272	100	263	123	278	128	285
16	140	302	117	279	155	320	142	287	132	290	144	298	105	256	92	248	115	264	96	263	125	296	127	285
17	141	299	123	283	181	337	134	282	136	289	132	280	103	255	89	247	113	267	106	273	143	318	132	288
18	135	290	127	282	182	332	132	281	140	292	128	275	99	255	88	246	117	269	111	276	161	358	134	296
19	121	287	135*	292	186*	340	130*	279	134	296	119	273	98	253	85	244	112	265	125	293	160	360	135	287
20	119	280	146	296	194	356	133	286	136*	297	117	271	96	250	91	250	117	273	141	306	165	344	142	295
21	122	279	154	294	207*	356	133	289	145	298	115	267	97	253	96	253	119	278	151	321	176	361	150	297
22	121	280	168	302	197	356	130	290	154	293	111	266	94	244	101	260	118	273	160*	328	186	362	149*	288
23	119	281	187	322	186	341	121	279	149	287	109	262	96	252	110	269	125	277	172	329	186	336	147	300
24	120*	284	183*	333	174	335	124*	281	150	285	107	264	95	254	121	282	134	282	178	326	176	339	145	296
25	124	289	181*	335	162*	342	122	280	146	293	99	255	98	254	131	281	145	292	184	328	176	348	143	256
26	135	297			174	350	121	277	140	291	97	259	99	257	131	287	141*	282	180	330	158	325	143*	289
27	122	288	176	332	155	338	117	268	130	288	94	252	105	258	140	289	130	277	180	325	159	319	135*	285
28	122	286	161	324	151	341	113	267	121	276	98	257	116	263	147	289	122	274	166	320	144	308	138	287
29	122	286			159	351	108	261	102	264	102	264	116*	265	151	289	118	277	155	312	128	285	140	289
30	116*	278			164	339	109	267	97	262	115	271	120	271	144	280	120	277	144	305	124	277	147	290
31	115	287			162	336			93	260			139	285	139	278			136	293			144*	283
MN	138	299	137	294	153	318	135	291	127	281	138	295	117	269	122	272	118	271	133	292	136	300	129	284
1970																								
1	141	295	122	295	161	328	145	302	135	291	125	274	149	301	114	264	130	289	110	265	146	334	140	279
2	135	282	124	292	159*	318	149*	298	141	297	121	274	158	307	109	265	132	288	105	262	143	329	144	284
3	127	278	113*	285	151	305	145	305	138*	287	114	269	166	315	110	260	137	290	104	267	140	313	141	284
4	126	275	111	278	153	309	149	308	139	298	111	267	165	313	107	266	144*	302	118	280	133	307	154*	291
5	117	271	115	281	155*	277	164	324	142	297	113	269	160	303	107	264	148	302	113	264	132*	290	155	300
6	110	272	122	289	156	304	174	336	139	298	104*	255	156	304	107	262	134	288	111	268	138	296	158	303
7	102	271	128	287	156	295	195	365	140	299	117	275	141	294	107	261	139	286	114	270	137	297	153	302
8	107	267	141	307	159	306	181	339	135	292	114	269	138	285	110	265	132	279	121	277	128	291	153	305
9	115	272	142	312	149	300	188	343	133	285	117	268	125	276	117	267	134	283	128	277	130	297	157	324
10	130	284	160	347	142	299	197	365	136	290	124	274	120	268	115	262	122	274	126*	277	136	305	148	297
11	152	305	174	350	144	296	177	332	148	303	144	297	115	268	105*	252	115	269	122	273	144	312	160	301
12	164	303	184	338	151	299	174	331	154	305	143	301	110	265	120	279	106	263	115	270	152	316	168	310
13	164	298	189	334	140*	302	164	320	165	317	169	330	109	264	130	297	103	260	113	265	160	333	148*	300
14	167	313	187	333	135	289	153	310	169	322	177	338	107	260	155	326	102*	233	114	270	177	372	141	301
15	175	321	185*	327	131	286	141	301	170	324	176	330	102	257	143	287	100*	239	120	265	179*	367	136	293
16	166	305	181	334	126	287	131	293	175	322	163	312	101	260	140	298	100	252	117*	269	189	426	132	296
17	171	300	188	344	120	283	128	292	165*	302	162	307	103	262	131	281	98	258	113	271				
18	175*	305	179	333	119	288	122	292	164*	286	151	297	109	269	124	282	102*	259	120	275			142	301
19	168	309	185	334	116	281	117	279	166	301	149	293	113	277	123	281	114	271	120	275	181	353	143	298
20	165	309	182	327	127	283	114*	274	156	294	137	287	116	287	123	276	123	274		275	163	324	143	301
21	172	320	192	336	135	284	111	270	148	290	134	286	136	298	119	270	127	272	120	279	168*	332	135	304
22	157	304	173	326	138	289	111	273	144	288	128	278	134	292	118	270	132	277	124	285	146	287	127	297
23	143	298	178*	331	148	285	112	274	139	287	122	270	142	292	124*	269	139	279	129*	285	134	291	121*	254
24	133	289	175	332	151	287	110*	274	139	292	121	269	139	284	117	270	135	284	140	299	126	282	112*	281
25	142	285	168	336	150	293	115	280	137	292	126	273	143	285	115	268	132	278	135	312	121	276	113	280
26	154	305	171	327	150	291	114	278	140	290	123	279	150	290	116	268	133	282	169	319	122	278	111	284
27	153	301	162	311	139	289	118	278	133	282	131*	286	162	293	115	274	127*	277	168	310	132	290	107	279
28	151	303	160*	312	137	282	128	283	132	282	133	284	153	293	119	279	126	283	166	303	140	287	107	276
29	152*	308			140*	291	133	291	136	286	145	291	134	279	124	282	118	272	167	301	143	291	113	279
30	151	304			133	286	130	286	139	290	146*	289	132	276	126	287	114	267	156	294	147	291	120	289
31	151	291			131*	277			140	287			121	269	131	291			150	287			119	280
MN	146	295	160	319	142	293	143	303	146	296	135	286	133	283	120	275	123	274	128	280	146	313	137	292
1971																								
1	118*	286	153	304	117	285	83	264	84	243	94	261	124	271	94	254	79	247	100	264	99	273	110	277
2	121	288	149	315	107	279	95	269	87	254	94	251	118	273	93	254	79	248	101	264	99*	273	107	273
3	124	294	138	308	104	281	94*	261	93*	256	93*	255	110	260	91	254	80	246	107	269	102*	274	104	277
4	127*	302	139	301	100*	273	96	268	99	258	94	256	115	276	90	252	82	248	97	269	104*	272	99	280
5	132*	301	137*	301	96	278	97	269	104	271	94	256	114	278	91	255	81	246	96		108	273	107	279
6	134	305	132	309	97	276	97	269	111	280	92	258	109	270	91	252	90*	248	93	263	101	269	106	284
7	138	306	124	294	90*	272	101	268	114	281	89	258	102	270	89	255	93	253	89	260	96*	268	107	281
8	136	305	114	285	89	274	98	268	115	275	88	253	99	269	97	257	90	254	91	259	95	264	109	286
9	141	305	105	273	85	273	97	268	118*	274	88	252	92	258	96	262	85	250	91	265	93	264	112	293
10	139	314	102	273	90	274	98	267	122	271	84	253	92	262	93	254	80	246	84*	264	97	269	115	290
11	137	306	104	273	92*	246	110	276	122	276	82	247	94	261	91	255	79	246	84	258	97	268	115	293
12	139	308	105	274	99	278	117	276	114	271	81	252	94	265	88	252	79*	241	85	261	96	267	117	291
13	134	302	108	276	98	271	126	282	111*	265	81	250	96	262	88	254	86	244	84	255	94	269	118	287
14	141*	312	108	275	96	272	127*	280	107	266	82	251	98	267	86	253	96	252	81	254	93	271	113	287
15	140	318	110	277	92*	265	127	283	104	261	79	249	106	276	85	251	102	259	78	249	96	270	112*	288
16	148	317	121	286	96	272	126	281	102*	256	78	250	106	275	85	254	99	254	79	249	95	272	110	289
17	141	319	125	293	96	277	127	280	102	257	80	250	103	268	90	255	101	257	84	251	98	276	123	296
18	144	319	120	297	95	273	127	280	98	255	82	247	104	271	97	268	104	255	89	260	97	278	124*	293
19	150	325	132	295	91	271	123	280	98	257	82	252	111*	267	109	284	99	260	97	273	100	281	124	294
20	159	314	124*	277	91	274	123	279	94	252	81	252	101	265	123	289	98	257	110	285	103	279	126*	292
21	164	327	126*		92	270	114	269	90	243	82	247	95	268	129	293	99	252	108	282	106	284	129	290
22	165	321	134	296	93	273	108	268	76*	243	84	247	99	270	130	277	97	250	110	286	113	287	131	295
23	155*	321	132*	288	89	266	109	279	76	247	82	244	104	279	129	282	97	259	109	280	113	286	129	290
24	163	320	133	293	90	270	98	275	75	246	89	246	114	281	138	289	96	259	116	291	116	290	123	290
25	154	319	130	297	91	272	92	258	79	246	95	253	105	269	124	273	97	264	114*	286	116*	289	122	284
26	151*	310	121	287	90	264	92	260	84	249	100	255	104	271	118	271	97	268	108	275	120	284	115	281
27	152	314	118*	275	90	268	89	258	91	257	105	262	101*	267	119*	264	103	275	105	274	120	282	115*	279
28	152	314	117	295	87	265	87	251	94	256	113	273	98	262	109*	257	103	274	99	266	124	284	107	278
29	146	303			85	262	83*	248	94	259	123	274	97	260	97	259	101	270	96	265	114	278	104	279
30	149	312			81	262	83	243	94*	259	126	279	100*	260	89	254	101	267	98	269	109	275	106	282
31	159	310			85	269			95	259			96	256	83	249			98	272			101	296
MN	144	310	124	290	93	271	105	269	98	259	91	254	103	268	101	262	92	255	96	267	104	276	114	286

Table 11-2b. (Continued)

DAY	JANUARY 2695 MHZ	JANUARY 8800 MHZ	FEBRUARY 2695 MHZ	FEBRUARY 8800 MHZ	MARCH 2695 MHZ	MARCH 8800 MHZ	APRIL 2695 MHZ	APRIL 8800 MHZ	MAY 2695 MHZ	MAY 8800 MHZ	JUNE 2695 MHZ	JUNE 8800 MHZ	JULY 2695 MHZ	JULY 8800 MHZ	AUGUST 2695 MHZ	AUGUST 8800 MHZ	SEPTEMBER 2695 MHZ	SEPTEMBER 8800 MHZ	OCTOBER 2695 MHZ	OCTOBER 8800 MHZ	NOVEMBER 2695 MHZ	NOVEMBER 8800 MHZ	DECEMBER 2695 MHZ	DECEMBER 8800 MHZ
											1972													
1	96	263	101	257	116	276	84	246	83	244	107	259	115	243	136	310	126	272	101	267	117	300	84	271
2	93*	264	101	260	118*	277	86	250	82	238	114	265	118	247	132	312	124	270	97	262	112*	287	81	269
3	94	252	96*	256	118*	276	87	255	84*	237	122	271	121	244	128	305	110*	269	93	261	102	274	77	264
4	92*	258	95*	257	123	280	88	257	87*	251	132	277	131	254	128	304	107	257	90	258	95	275	75	262
5	94*	256	94	255	127*	281	94	256	94	250	143	279	130*	254	128	307	108	266	88	255	90*	270	71*	265
6	95	252	94	256	131	281	105	266	103	256	136	277	127	255	121	294	104	263	88	256	84	262	71*	262
7	95	255	95	261	128	281	107	267	103	252	131*	276	125	253	136*	302	96	257	83*	256	77	254	80	268
8	94	256	100	263	126*	285	107	266	115*	258	129	286	117	246	108	274	101	264	86	257	75*	251	86	273
9	91	255	99	260	123	275	116	266	113*	259	130	287	111	245	106	278	100	265	89	264	75	253	88	274
10	85	251	106	267	123	275	115	264	121	262	120	278	105	238	102	271	93	263	84	260	75	253	90*	268
11	88*	253	112	264	122	274	116*	261	124	275	129	277	109	247	96	264	89	259	84	256	80	259	99	268
12	93	253	114	271	116	273	115	260	129	277	129	276	104	245	92	253	87	254	84	256	80	260	102	273
13	95	256	118	275	114	270	113*	255	140	288	121	257	104	240	89	247	84	252	83	261	80	261	105	283
14	104	258	126	281	117	275	111	256	146	293	119	252	104	244	86	240	86*	254	85	261	75*	259	109	282
15	111	264	134	286	122*	273	111	252	146	288	139	270	100	245	85	243	90	256	90*	270	77	263	108	285
16	115	265	147	293	119	281	109	256	145	284	121	258	96	239	86	249	89	256	94	270	81	265	103*	289
17	107	260	161	309	118*	281	107	261	147	284	126	257	99	237	93	245	88	253	101	276	82	260	104*	285
18	104	257	181	324	118	273	104	255	142	280	131	258	95	237	94	255	89	254	99	277	86	261	105	287
19	111	265	190*	325	116	273	100	256	134*	274	126	255	95	234	100	259	92*	262	106	287	92	263	105	286
20	114	263	189*	319	122	275	96*	256	129*	270	120	251	96	234	101	258	98	266	108	290	99	269	102*	279
21	121	266	184	306	121	276	93	244	127	268	123	256	96	231	102	262	104	272	118	303	100	275	107*	277
22	118	270	167	307	120*	276	97	248	125	263	118*	256	95	234	112	264	104	272	125*	304	103*	282	99*	271
23	127	276	164	298	127	278	97	247	118	269	114	249	96	243	111	265	110	273	133	325	107	286	98	264
24	128	277	153	293	111	267	98	251	117	275	110*	249	96	246	108	265	112	275	137	337	110	288	93	263
25	122*	272	141	287	103	261	98	255	109	277	107	248	97	248	112	263	112	274	155	364	102	285	97	263
26	119	266	141*	287	99	260	98	255	100	268	103	244	106	255	124	273	113	272	153	357	99*	280	91	264
27	114	265	126	276	93	259	96	262	98	256	107	244	109	262	126*	269	107	270	150	360	94	273	90	265
28	113*	265	118	273	89	259	90	257	100	269	112	247	117	275	133	277	104	269	150*	359	89	271	86	266
29	109	264	118	277	85	249	86	252	100	262	114	247	121	281	148	291	104	267	136*	335	84	267	88	270
30	110	270			86*	252	83	250	103	256	114*	247	125	293	146	287	104	264	133	325	88	271	86*	278
31	107	259			85	249			105	260			128	306	133	276			128	302			88*	271
MN	105	262	130	281	114	272	100	256	115	266	122	262	109	250	113	273	101	264	108	290	90	269	92	273
											1973													
1	86	245	79	263	88	264	97	266	98	274	72	239	74	242	73*	238	98	265	97	265	79	256	81	261
2	89	252	79*	261	89	263	105*	269	101	275	71	247	77	247	73*	235	111	275	94	260	77	257	81	266
3	98	260	84	262	87	265	113	279	101	270	69	243	77	247	72	231	116	271	92*	259	74	252	76	257
4	100*	260	84	262	85*	265	106	271	104	274	69	243	78	243	73	236	119	277	85	252	71	251	74	252
5	103	259	85	263	84	263	102	269	99	265	71	248	80*	244	72	240	120	269	80	248	67	252	70*	248
6	106	270	88	269	87	267	99	263	94	254	71	245	83	247	74	239	114*	263	78	252	67	250	66	248
7	102	265	89	272	81*	254	95	265	89	257	72	242	84	249	76	246	109	256	75	250	66	251	66	249
8	96	261	91*	270	87*	255	106	280	83	251	73	247	84	250	74	242	101	252	71	251	65	251	67	250
9	95	264	92	273	92	264	109	277	81*	247	74	247	86	257	73	239	100	248	70	251	64	252	63*	247
10	94	259	93*	274	97	270	102*	266	79	247	76	249	84	249	70	243	96	249	70	247	64	252	68	245
11	93	263	89*	274	102	271	99	269	73*	243	78	247	78	238	67	238	84	239	67	246	65	252	67*	250
12	93	268	94	275	101	261	90	261	73	241	78	250	71	241	65	233	79	240	64	242	66	249	69	249
13	93	269	93	273	105	268	87	265	71	243	81*	249	67	235	63	233	74	244	63	242	67	248	69	249
14	87	258	96	275	106	274	81	260	76	245	82	249	66	236	64	233	74	244	65	245	68	245	69*	251
15	86	258	96*	273	96	268	76	259	75*	244	83	250	68*	236	60*	236	73	242	67	247	70	247	72	251
16	83	253	89	268	94	265	73	254	77	243	80	248	68	240	62	239	73	241	67	248	70*	249	75	260
17	85	255	83	266	88*	260	71	249	78	242	76	246	68	240	63	238	72	247	72	251	69	253	77*	264
18	88	255	81	265	85	263	69	249	81*	247	77	244	70	241	64	238	72*	247	70	250	70	254	81	265
19	85	256	77	265	90	271	72	246	85	256	83	253	68	242	64	239	76	247	68	247	70	253	80	261
20	87	254	80	260	80	262	77	250	88	251	89	251	66	238	65	237	79	247	69	252	72	256	83	265
21	88	258	79	257	77	259	83	254	87	249	92	247	66*	238	70	243	84	255	72	252	76	256	89*	272
22	89	261	79	262	80*	259	90	256	88	250	91	253	65	238	70	243	87	256	76	258	78*	251	92	269
23	88	257	81*	262	77	258	94	262	81	246	90	250	65	237	71	243	92	256	79	257	81	256	92	274
24	87	259	86	264	78	257	96	264	87	252	88	248	68	242	73	247	98*	257	90	266	80	255	93	273
25	87	262	86	262	78	255	95	264	86	255	84	247	69	243	77	248	100	262	93	268			91	271
26	85	257	86	265	74*	256	94	265	84	254	83*	245	71	243	78	250	102	263	93*	268	85	258	84*	263
27	83	260	87	270	80	263	98*	274	84	255	78*	244	72*	242	81	251	102	267	96	278	85	253	80	264
28	82*	257	90	265	83	264	97*	279	80*	250	79	244	70	241	84*	253	104	267	92	270	84*	256	75	256
29	80*	261			86	264	96*	277	78	240	78	244	69*	245	87	256	104	266	91	263	89	256	71	251
30	81	258			90	263	94	275	76	241	81	247	71	242	87	256	103	267	93	264	93	260	67	249
31	79	262			97	265			73	242			73	240	95	265			84	260			66*	248
MN	90	259	86	267	88	263	92	265	84	252	79	247	73	242	72	242	94	256	79	255	73	253	76	257
											1974													
1	65*	249	65	249	69	243	64	244	84	252	80*	246	89	264	71	240	67		82	252	80	255	73	259
2	67	251	69*	256	69	246	63*	238	100	264	84	245	95	275	71	241	68*		83	254	84	261	68*	256
3	66	252	68	252	71	248	62	234	100	261	82	242	99	274	70	238	65*		83	255	87	264	69	254
4	66	256	66	252	69	240	66	237	102	256	80	245			72	241	69*		89	263	88*	256	68	252
5	66	249	70	250	71	242	67	236	102	257	79	239	107	287	71	241	69	236	93	274	86*	256	67	252
6	69	253	71	251	69	243	70	244	106	261	78	245	102	269	74	243	70	232	99	262	85	257	67	249
7	69	255	72*	252	68	243	70	244	103	256	77	242	95	261	72	243	73	232	100	263	78*	253	64	250
8	74	259	74	257	69	249	71	242	100	257	91	256	86	256	75	247			112	274	75*	248	64*	245
9	76*	265	75	256	72	251	78*	251	96	255	77	241	78	248	74	243	82	250	113	274	70	251	63	243
10	81*	266	75	256	76*	251	82*	256	89*	253	78	247	73	242	75	245	86	255	116*	272	70	256	65	254
11	84*	265	73	252	77	254	88	256	90	251	80	244	70	242	79	251	90	264	127	297	69	253	69	257
12	86	265	70	247	78	255	93	262	83*	250	74	245	70	238	83	256	90	267	121	291	72*	254	71	260
13	87	256	70	247	75	254	91*	267	79	244	73	243	69	237	80	251	98	275	113	280	68	251	74	256
14	88	256	70	250	75	250	99	277	73	245	72	241	69	243	77	247	90	265	100	268	71	252	76*	261
15	87	249	76	259	73	252	107	295	66	239	69	238	71	246	76	250	88	261	93	256	71	259	77	262
16	84*	253	77	256	75	254	99	284	67	237	71	239	77*	250	81	256	93	274	79*	254	73	261	82*	261
17	83	259	77	254	74	251	88	267	63	232	71	236	76	251	84	254	86	250	74	248	77	265	81	263
18	81	255	78	256	73	251	83	262	62	233	70	233	71	245	80	249	90	251	71	250	80	265	83	267
19	80	249	74	253	70	247	77	255	61	236	66	234	73*	245	74	250	80	245	67	249	87	270	84	271
20	78	254	73	245	70	247	71	247	59	236	68	232	73	243	70	246	74	243	67	247	87*	267	81	260
21	74	247	76	252	67*	247	67	241	60	238	67	228	75	252	70	237	72*	233	66	248	89*	272	79	262
22	78	247	75*	248	71	248	63	238	59	237	68	229	80	251	67	240	69		65	245	94	280	82*	267
23	76	244			71	248	62	235	60*	236	68	236	82	253	69	238	65		64	245	88	274	77	256
24	72	246	73	248	67*	246	63*	240	60	235	66	235	78	248	65	233	64	234	66	248	88	266	73*	256
25	67	241	73	249	66	245	65	242	62*	232	67	236	75	243	64	239	64	235	69*	245	85	265	71*	255
26	64	238	68	247	63	240	64	239	68*	239	67	237	78	245	62	235	65	237	72	253	83	272	69	255
27	65	236	70	244	65	244	64	242	73	246	69	235	74	242	62	233	67	237	71	254	83	265	67	257
28	64	236	70	246	62	245	65	238	74	245	70	238	71	235	61*	230	69	235	72	255	80	261	68	252
29	65	242			62	245	68	241	74*	246	76*	241	70	238	57*	229	77	249	72	252	76	259	69	251
30	66	245			63	239	76	250	75	246	79	244	71	238	61	226	79	249	73	248	76	261	68	250
31	63	243			64	238			79	247			73	244	64	236			81	257			70	253
MN	74	251	72	251	70	247	75	250	78	246	74	240	79	250	71	242	77	248	86	259	80	261	72	256

CHAPTER 11

Table 11-2b. (Continued)

DAY	JANUARY 2695 MHZ	JANUARY 8800 MHZ	FEBRUARY 2695 MHZ	FEBRUARY 8800 MHZ	MARCH 2695 MHZ	MARCH 8800 MHZ	APRIL 2695 MHZ	APRIL 8800 MHZ	MAY 2695 MHZ	MAY 8800 MHZ	JUNE 2695 MHZ	JUNE 8800 MHZ	JULY 2695 MHZ	JULY 8800 MHZ	AUGUST 2695 MHZ	AUGUST 8800 MHZ	SEPTEMBER 2695 MHZ	SEPTEMBER 8800 MHZ	OCTOBER 2695 MHZ	OCTOBER 8800 MHZ	NOVEMBER 2695 MHZ	NOVEMBER 8800 MHZ	DECEMBER 2695 MHZ	DECEMBER 8800 MHZ
1975																								
1	72	245	65	253	64*	229	64	229	66	238	65*	214	65	231	75	240	74	239	66	235	63	243	66*	247
2	70	245	67	251	66*	226	63	227	68*	243	59	218	63	228	77	242	74*	240	67*	236	64	239	68	245
3	71	251	68	250	67	226			68	235	61*	222	63	229	82	250	75*	241	67	240	64	240	67	244
4	68	244	70	248	68	234	63*	226	69*	232	61*	224	63	231	88	250	78	241	67	238	67	242	68	247
5	69*	245	72*	244	64	234	66*	228	68	235	60	224	62	231	89	251	79	242	66	239	70	249	70	246
6	67	243	72*	242	65	233	66*	224	65	231	57*		64	228	102	262	79*	242	64	237	72	250	68	242
7	70*	243	74	243	65	231	66	224	63	231	57*	220	61	227	98*	255	77	244	64	240	72	247	68	244
8	71	243	74	244	66*	231	65	227	61	228	58	224	61	228	96*	249	75	243	64	239	71*	242	68*	248
9	72*	244	72*	243	67	232	65	230	60	227	58	223	60	224	96	242	71	241	66	244	68	238	68*	246
10	73*	247	71	245	67*	231	64	230	60	227	58	218	60	224	96	246	69	238	64	245	72*	239	67*	245
11	75	244	70*	245	66*	229	63	225	59	224	57	220	63*	227	90	228	69	235	65*	244	71	246	67	244
12	76	243	69*	241	68	231	61	224	58	224	58*	218	68*	228	88	240	68*	235	67*	244	72	244	67	247
13	73*	242	69	239	69*	229	62	224	59*	224	57*	216	72*	231	81	239	64	237	68	244	73*	248	66	243
14	73*	240	66	248	66	231	61	223	58*	223	58	221	73	236	75	238	64	235	69	246	74	251	65*	241
15	71	238	65	244	65*	227	61	224	58	222	57*	221	71	232	71	238	63	235	71	242	76	248	65	240
16	70	237	67*	241	67	232	61	225	58*	221	58	221	68	230	69	237	63*	231	69	241	80	258	65	244
17	69*	240	63	239	67	230	61	221	58	220	58	221	66*	230	66	235	64	235	69	244	80	255	64	245
18	69*	241	64*	241	66	228	59	221	58	223	57	219	68	228	63	236	65	235	69*	243	84	256	64	245
19	68*	239	63	237	65	228	59*	220	58	223	58	222	67	227	64	235	65*	235	68*	241	84	256	64	246
20	68	238	64	242	66*	226			58	223	59	224	67*	231	64	235	65	234	68*	239	80	250	65	251
21	68*	238	63	244	64	230	59*	221	58	218	56	222	69*	235	67	235	65	234	67	237	78*	250		
22	69	236	63	243	63*	228	59	220	59*	215	57	220	68	233	66*	228	64	230	65	238	74	247	64*	246
23	67	238	62*	240	60	228	60	218	60	213	59	222	68	234	64	231	65*	230	64	238	70	244	63	243
24	66	235	62*	242	60	227	60	219	60	218	61	226	65	229	64*	231	65*	230	64	239	68*	241	66	249
25	65*	239	64*	238	60	228	62	223	60	223	63	231	66*	229	67	236	66*	230	64*	233	66	243	66*	248
26			64*	238	63*	230	63	221	60	219	65	235	66	229	69*	233	66*	233	63	231	65	244	66*	247
27	65*	243	63	238	62	231	64	221	59	220	67	233	66	232	69	234	64	232	64	237	64*	243	66	247
28	64	241	63	242	62	231	65	219	59	220	66	234	63	234	69	239	64	232	63	238	64	241	66	245
29	64*	239			62	230	64	224	59	217	63*	233	62	234	71	243	65	234	61	237	64	243	67	246
30	65	238			60*	229	63	222	60	215	66	238	64	234	72*	241	65	235	62*	238	65*	249	67	243
31	64	238			62	228			62*	211			68	235	73	239			62	242			66	244
MN	69	241	67	243	65	230	62	224	61	224	60	224	65	230	77	240	68	236	66	240	71	246	66	245
1976																								
1	66	239	63	237	60*	235	71*	257	67	232	58	224	58*	216	64*	226	65	230	66*	224	66	237	63	237
2	66*	241	63*	237	60*	235	68	250	64	223	58	224	58	217	66	227	64*	230	65*	226	63	237	65	241
3	67*	240	63	236	61*	236	67*	246	63*	230	57	222	59	219	70	232	64	229	65	230	63	237	66	241
4	67	240	63	234	61*	235	67	245	64	233	57	223	58*	222	70	232	65	227	64	229	62	235	66*	246
5	67	243	62	235	60	233	65	241	62	226	58	222	58	218	71	230	64*	225	66	228	63*	231	65	237
6	66	239	63*	238	60	231	63	235	61	224			58	218	71*	232	63	224	66*	225	59*	233	65	241
7	66	237	63	241	61*	231	63	230	63*	230	58	218	58	218	69*	232	62	228	65	227	62	232	64*	236
8	65*	239	62	241	61	232	65	231	62*	232	59	221	58*	219	70*	231	63	230	65	227	63	236	65	237
9	65	240	62	241	60	231	67	232	61	230	60	225	58	220	69*	234	63	227	66*	228	65	237	68*	236
10	65	241	62	240	63	233	67	237	61	228	58	221	58	224	70*	232	64	224	66	228	65*	238	70	242
11	66*	242	62	239	63	231	72*	238	62	230	59	221	58	222	68	230	65	223	65	233	65	240		
12	71*	246	61	239	64	232	71*	239	62*	219	61	226	58*	220	68	227	66	228	65	230	65	237	72*	236
13	74	249	62*	239	64*	230	71	237	63	229	61	228	58*	219	66	218	64	228	64	228	63	235		
14			62	238	64	230	71	238	63	224	62*	224	58*	218	61	216	65	230	67*	231	64	235	73		
15	74	247	63	239	66*	235	70	236	65	229	62	225	59	218	61	216	64	226	67	233	64	235	74	242
16	72*	247	63	238	68*	240	70	230	67	228	64	227	58	218	62	221	66	230	69	233	66	239	72	239
17	71	245	63*	237	72*	243	70	231	65	229	64	225	58	218	66	232	67*	227	70*	237	67	240	71*	241
18	71	247	63*	235	74	244	70	234	65	228	66	219	58	220	66	232	64	226	70	241	69	241	67*	245
19	69	250	64	235	76*	244	69	232	63*	219	65	223	58	219	66	237	63	224	68	239	69	244	67	245
20	69*	246	64	239	75	243	69	231	63*	221	66	221	58	218	63	234	61	225	68*	236	66	242	64*	238
21	66	241	64	239	80*	241	69	235	64*	226	65	222	58*	219	60	220	62	226	67*	235	64	242	66*	236
22			63*	239	79	243	69	236	62	225	66	224	59	220	61	222	61	227	68	237	66	241	67	240
23	65	243	63	240	79	245	66	227	61	229	63	224	58	217	60	222	63	226	73	239	66	241	68	237
24	65*	241	62	235	78	242	67	234	60	227	62	225	57*	218	59	225	63	225	73	241	66	239	68	235
25	64	241	61	235	77	245	68*	236	60	226	62*	220	58	223	59	227	64	226	77*	239	65	239	68	237
26	62*	240	62	233	79	253	67*	230	60	224	62	224	56	220	59	222	64	225	74*	237	64	240	70*	238
27	61*	238	61	230	76	252	67*	230	60	225	60	222	57	218	60	223	63	225	71	236	66	238	70	240
28	61*	235	60	228	80	256	66	232	58	218	60	219	58	223	61*	225	65	229	70	239	66	238	69	239
29	62	234	61	234	75	267	69	233	57	223	60*	219	58	225	62*	228	63	225	66	235	64*	240	69*	239
30	63	239			74	263	71	235	58	223	58	218	59*	226	62	230	63	224	66	235	64	241	70	238
31	64	239			74	264			58	223			60*	226	64	230			66*	235			70	239
MN	67	242	62	237	69	241	68	236	62	226	61	223	58	220	65	227	64	227	68	233	65	238	68	239
1977																								
1	68	248	75	263	67	242	66	241	65	238	77	238	86	241	69	233	72	237	81	251	87	250	80*	250
2	71	249	77	259	69	245	67*	238	65*		77*	242	85	243	69	237	70	238	83*	244	86	248	87	253
3	70	246	76*	248	70	245	66*	237	72	242	82	246	82	240	68	230	78	241	89*	245	83	246	88	252
4	71	245	73	258	70*	241	67	246	72	240	80	234	81	237	71	236	72	239	88	254	82		92	262
5	69	248	73	248	71	237	65*	243	68	235	77*	231	76	238	73	238	73	237	99	262	81*	246	96*	265
6	66	246	70	251	70	246	68	242	66	231	78*	241	76	243	74	233	73	237	94*	255	84	245	98*	271
7	66*		69	252	70*	241	69	243	67	235	81*	237	73	235	73	231	77	245	93	253	85	240	103	276
8	62		73	247	75		65	237	67	240	82*	239	65*	232	71	230	83	246	95	260	82*	242	101	276
9	64		78	257	73	246	68	243			75*	237	65	230	73	232			93*	255	83*	242	105*	282
10	65		77	246	72	243	67	244			76*	234	65	228	74	243	84*	258	87	250	85	246	112	290
11	66	246	78	252	70	241	70	239	70	233	73*	231	63	230	74	238	92	268	86	249	88	257	107	282
12	70	246	78	244	68	236	69	241	67	234	71	230	64*	230	74*	236	96	265	91*	251	89	259	109	284
13	71	244	77*	241	69*	238	71	241	69	235	71	231	64*	231	77	238	100*	263	90*	252	87*	263	98*	264
14	68*	259	76	244	70*	239	73	244	73	242	69	236	65	230	75	233	104	262	88*	246	92	266	89*	262
15	69	259	75*	250	67*	236	76	243	71	246	68	229	63	231	73	236	108	263	85*	240	94	267	85	258
16	73	260	79	256	66*	231	74	241	73	241	68	234	63	230	75	240	110*	263	88	243	92	258	86	260
17	72	259	84	260	66*	234	72	245	70	237	69	234	64	228	73*	236	109*	257	85*	238	94*	257	88	266
18	69	251	79	255	67*	235	69	236	70	244	71*	238			74	236	105	254	86	248	94	258	89*	253
19	72	253	76	246	66	241	71	249	70	239	76	233	65	226	74	243	91	256	95*	254	94	263	83*	260
20	70	259	74*	244	67	238	71	240	68	241	76	232	67	231	76	246	92*	253	93*	249	92	261	82*	254
21	66	254	73*	244	65	232	69	238	68		78	234	69	229	78	244	93*	249	91	255	87*	257	77*	255
22	70	256	71	244	68	240	68	234	66		87	242	74	235	77*	240	94	253	85	251	85	253	83*	264
23	72	256	70	245			66*	229	69	236	84	245	72	243	73	234	91	246	79	253	85	255	85	259
24	72	259	68*	238	68	240	66*	235	66	238	90	253	72	240	73	235	92*	246	81	251	80*	253	88	260
25	68*	250	66	235	66	238	68*	241	65	236	98	266	73*	239	75	246	92*	246	80	251	81	254	90*	264
26	71	254	67	237	68	239	66	234	64	240	101	262	73	238	76	240	92*	247	81*	251	78*	256	95	271
27	70	247	67	242	67	238	65	235	67	236	99	258	73	237	72	240	87	251	83	248	80	258	93	268
28	71	254	67	246	66	241	64	231	67	235	95	253	74	237	71	236	88	253	82	251	81	258	97	270
29	71	249			65	237	65	235	70	238	93	243	74	235	76	238	88	250	83	250	81	253	105	275
30	71	245			65	238	64	235	76	242	89	246	71	231	74	238	86	249	88	260	80	252	105	268
31	75	257			64*	231			76	239			69	238	74	239			90	260			117	275
MN	69	252	74	248	68	239	68	239	69	238	80	240	71	234	73	237	89	251	87	251	86	254	94	266

11-2b. (Continued)

JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ	2695 MHZ	8800 MHZ
1978																							
122*	277	133	293	133	300	118*	282	163*	318	122	278	119	283	84*	250	143	294	121	280	139	303	153	316
127*	276	148	305	135	312	117*	287	166	324	122	276	104	267	84*	247	144	318	119	276	145	302	156	314
122	286	159	321	138	309	122	290	156	321	106	264	96	259	84*	250	149	319	119	283	152	316	154	317
111	287	148	305	138	318	133	297	149	322	99	266	94*	261	92*	260	158	328	117*	279	164*	318	152*	314
113	278	153	311	144	317	134	292	159	316	96*	258	99	263	97	257	152	328	122*	276	168*	311	153	311
112	280	151*	315	154	317	137	288	154	311	89	251	99	265	102*	255	159	303	135*	281	157	306	159	316
106*	272			157	319	134	283	146	322			103	264	108	259	155	313	127	290	156*	304	165	325
96*	265			161	326	136	284	125	286	88*	253	110	279	114	255	149	296	133	299	156*	304	170*	337
		148	315	170	331	142	298	121*	279	89*	256	121	299	116	264	140	293	142	305	155	306	176*	347
		141	306	171	322	140	296	117	272	89	258	129	319	107	257	130	289	142	304	153	316	183	358
87	262	146	309	165	322	156	307	118	277	92	257	136	321	101	258	123*	284	157	312	148	313	195	383
85	261	153	324	156	310	138	286	122	275	95	256	144	336	101*	260	118*	285	158	307	141	310	200	388
83*	265	137	317	147	303	126	278	122	274	101	261	133	317	111	263	121	284	156	302	135	303	196	377
		139	323	145*	298	125	287	129	278	114	270	134	311	107	266	127	286	164*	308	122	290	185	376
81	253	126	310	144	291	127	290	127*	276	110	278	137*	307	109	271	132*	298	172	314	123	299	180	357
79	255	122	300	134	285	123	284	126*	273	117	278	136*	302	100	261	139	296	158	309	118	289	166	347
78*	253	118	285	124	288	117	277	126	271	122	274	127*	298	98	252	146	314	159	310	117*	288	161	339
75*	251	117	281	121	286	116	281	120	264	131	282	128	299	94		151	313	153	307	113	285		
78	254	112	279	115	278	133	290	113	253	137	298	120	290	91		146	310	155	307	119	292	144	321
		115	284	119	280	130*	281	114	269	149	295	116	284	87		148	298	153	306	121	303	123	306
84	258	114	285	107	268	125	277	114	267	164	298	110	281	87		146	293	158	313	116*	291	127	305
88	256	119	286	106	271	130	285	119	283	165*	302	102	264	85		155*	302	141*	311	116*	290	121	309
91	264	125	288	105	268	147	300	126	285	167	305	98	262	85		149	305	142*	307	113*	288	120*	299
93	269	126	289	108	272	139	307			170	304	95	257	89*	240	136	293	144	305	113*	291	126*	304
92*	271	133	290	107	273	149	305	124*	284	150	292	92	256	86	242	139	291	143	300	115	291	126*	301
		130	288	101*	269	146	308	126	286	158	291	88	261	84	253	133	289	140*	294	124	301	134	298
110	278	130	290	100*	266	156	319	127	278	151	278	88	253	91	259	137	298	138	291	133*	309	143	318
121	280	128	298	100	264	181	364	129	294	146	282	87	260	92*	258	131*	295	135	295	143*	316	148	319
122	278			98	264	164	331	122	274	141	282	87		94	258	129	289	137	300	146	313	150	321
126	285			107	272	184	355	125	278	133	284	89	252	106	268	124	284	133	302	154	318	164	336
128	291			109				122	274			88	257	117*	280			131	295			178*	341
100	270	134	300	130	293	137	297	130	286	125	277	110	281	97	258	140	300	142	299	136	302	157	330
1979																							
187*	331	173	324	146	305	175*	314	160	297	160	343	156	324	118	282	144	321	174	334	186	366	149	328
185*	333	169	323	148	296	178*	322	152	299	171	354	181	335	115	278	148	307	178	339	186	336	159	339
198	336	172	318	147	303	171	308	143	295	180	344	179	328	116	291	153*	311	177*	349	186*	344	190	365
178	333	170	318	155	307	163	314	152	297	192	333	184	339	112	279	149	324	176	357	186	354	201	369
186	342	185	316	173	317	158	307	144	287	194	344	166	333	113	276	149	303	163	334	220	391	208	371
182*	335	193	325	161	304	159	306	149	303	199	339	174	342	117	279	150*	310	163	330	239	438	196	352
178*	328	193	321	155	303	144	308	157	297	197	338	169	327	119	297	151	316	173	329	255	435	196	360
176*	328	199	331	150	302	151	302	154	303	202	339	169	329	126	313	152	302	179*	341	273	462	219	372
175	327	178	336	150	307	151*	306	151	307	199	344	162	329	129	307	158	314	168	339	285	445	210	370
173	323	181	361	162	308	152	308	145	302	197	349	151	319	123*	301	152	315	169*	337	319	479	206	370
167	324	189	370	156*	317	151	304	148	311	188	338	143	307	125*	299	154	332	186	335	295	459	208	364
159	332	180	350	174	326	157	306	150	310	181	336	134	297	117*	301	153	312	193*	347	252*	423	201	379
177*	330	186	345	158	323	154	310	156*	307	157		130	299	127	303	155	322	205	345	221*	396	217	365
178*	330	202	373	164	318	148*	303	153*	304	157	329	126	291	141	311	160	318	207	372	217	370	218	378
176	330	199	348	154*	314	151*	297	152*	303	144	306	119	284	136	307	166	340	208	376	225	380	218	373
182	324	205	365	162	325	155*	293	153*	303	137	314	113	281	134	306	166	351	200	385	209	371	201	371
154*	318	200	364	163	318	144	304	164	318	131	302	112	282	131	312	170	351	203	386	209	371		
168	339	223	386	175	325	144	296	144*	304	129	296	112	278	143	327	181	353	203	373	211	380	173	346
180	339	217	382	164	321	142	285	132*	291	119	298	115	289	151*	344	193	374	212	386	196	366	166	359
179	344	202	363	158	318	135	291	131	289	129	300	118	286	166	357	191	360	207	369	183*	358	173	369
188*	339	203	355	157	312	127	292	130	285	121	299	120	282	170	344	186	340	191	349	162	349	168	349
199	333	185	361	152	318	143	294	133	294	118	286	122	297	179	360	185*	344	188	349	166	340	152	327
207	349	169*	331	160	318	137	302	134*	282	115	286	132	291	180	352	190	347	185	345	160	335	148	315
190	325	155*	315	167	333	134	300	130*	277	120	291	135	308	179	340	199	343	200	354	155	321	144	307
182*	323	144	297	163*	328	140	286	127*	276	124	299	131	301	190	360	195	338	188	357	146	307	142*	307
175*	321	134*	281	179	335	156	295	133*	276	123	307	133	312	183	351	193	329	179	353	143*	318	140	307
178*	324	135	274	165	333			127	277	127	307	129	289	176	340	187	346	186	344	138	313	140	318
181	328	147	301	163	328	161	312	123*	274	135	302	129	288	172	334	189	355	189*	345	134	311	142	323
187	339			173	318	158	299	127	275	137	312	126	292	159*	316	180	341	188	350	138	297	158	342
186*	336			160*	323	162	308	135*	283	141	315	129	294	154	302	177*	318	193*	353	139	320	166	324
188*	336			179*	328			143	291			121	291	147	312			192	352			173	353
181	332	182	337	161	317	152	303	143	294	154	319	139	305	143	315	169	331	188	352	201	371	179	349

ample, five times the quiet-sun level). This climatology presents results using both approaches.

With regard to the statistics of burst levels over a certain threshold (flux-density level), one might want to know how many level-exceeding bursts occur in a given period (in a 24-hr day, for example). One might also like to know for what fraction of time (min per 24-hr day, for example) do bursts remain above a certain threshold. Again, both kinds of statistics are presented in this climatology.

The radio-burst climatology presented here is based on routine, daily, whole-sun patrol observations made at the Sagamore Hill Radio Observatory over the years 1966 to 1978. This period covers the decline from the maximum of the 20th solar cycle (a relatively low-amplitude cycle) through the minimum (around 1976) to the rising portion of the new (and higher-amplitude) 21st solar cycle. Data from the 1966–1978 period should provide a reasonable measure of the intensity/duration parameters of solar-burst radio emission during the least and most disturbed portions of the solar cycle.

The Sagamore Hill data on radio bursts, published routinely in *Solar Geophysical Data*(SGD) are given in terms of the following parameters: the peak flux density S_p (sfu), the mean flux density S_{mc} (sfu) and the duration (min) T_d from start to end. These parameters are illustrated for the idealized burst in Figure 11-6. The area under the curve is

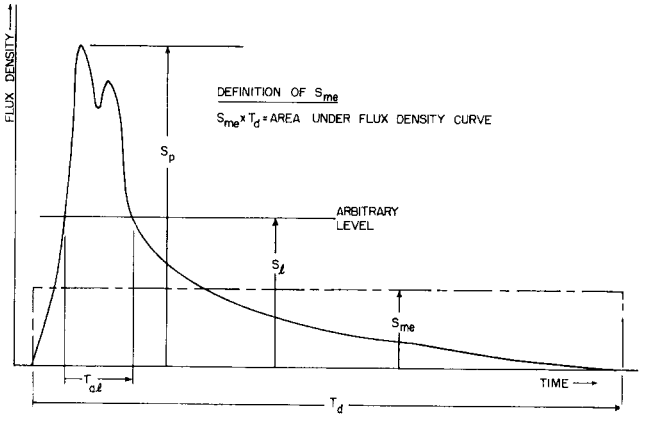

Figure 11-6. Burst parameters depicted for a typical microwave event. The symbols are explained in the text.

the time-integrated flux density. The mean flux density S_{mc} is defined as the amplitude (flux density) of a rectangle with area equal to the time-integrated flux density and duration equal to the burst duration T_d.

In Figure 11-6, we have also shown an arbitrary flux density level, S_ℓ. In the climatology study, we eventually want to derive (from the SGD-listed data alone) the time that bursts exceed a certain level. To illustrate the discussion that follows, we have shown the level S_ℓ between S_p and S_{mc} (if $S_\ell > S_p$, the burst would never exceed the arbitrary level). We have also shown the "above-the-level" time, $T_{a\ell}$.

For $S_{mc} < S_\ell$, the longest possible length of time that a burst with mean flux density S_{mc} could exceed the S_ℓ threshold is $S_{mc}/S_\ell \times T_d$. This is the worst case; it comes nowhere near representing the results for actual bursts.

In similar fashion if $S_{mc} > S_\ell$, the longest possible length of level-exceeding time would be T_d. Obviously, this maximum result is not representative of $T_{a\ell}$. A burst with an extremely large very-steep peak and long low-level tail could have its mean S_{mc} greater than S_ℓ, yet its flux density could lie below S_ℓ for the overwhelming majority of the burst duration time T_d.

For each burst there is a factor by which $(S_{mc}/S_\ell)T_d$ [for $S_{mc} < S_\ell$] or T_d [for $S_{mc} > S_l$] exceeds the actual "above-the-level" time T_ℓ. We do not have the resources to go over the time profiles of every burst at each frequency. Therefore we had to look at a representative sample of bursts and derive an overall factor to multiply the $(S_{mc}/S_\ell)T_d$ or T_d obtained from the SGD data.

Analysis of a limited number of relatively large events from a Burst Atlas compiled by Barron et al. [1980] shows that the factor by which $(S_{mc}/S_\ell)T_d$ or T_d overstates $T_{a\ell}$ varies between 1.5 and 10, independent of frequency, with a mean of about 3. Therefore, we have used the following relationships to derive the "above the level" times of bursts from the flux-density and whole-burst duration data listed in *Solar Geophysical Data*:

$$T_{a\ell} = \frac{1}{3}(S_{mc}/S_\ell)\, T_d \quad \text{for } S_{mc} < S_\ell$$
$$T_{al} = \frac{1}{3} T_d \qquad \text{for } S_{mc} > S_\ell. \tag{11.6}$$

Having discussed the data limitations and the approximating adjustments, we now present the results of the burst climatology study. In Figure 11-7, we show the number of bursts (statistically) per 24-hr day exceeding 500% of the quiet-sun (flux-density) level. The numbers are given for five frequencies (245 MHz, 610 MHz, 1415 MHz, 2695 MHz and 8800 MHz) over the years 1966 to 1978. In Figure 11-8 we show the number of bursts (statistically) per 24-hr day exceeding a flux-density level of 10^{-19} W/m^{2}Hz (1000 sfu).

In Figure 11-9, we show the time duration (min per 24-hr day) that bursts exceed (statistically) 500% of the quiet-sun flux density level. These durations are given, as in the previous graphs, for the five patrol frequencies over the years 1966 to 1978. In Figure 11-10 we show the duration (min per 24-hr day) that bursts exceed (statistically) the 10^{-19} W m^2 Hz^{-1} flux-density level.

The burst number and duration statistics (in Figures 11-7 through 11-10) are given on a "per 24-hr day" basis. Obviously, the sun is not in view (available to provide

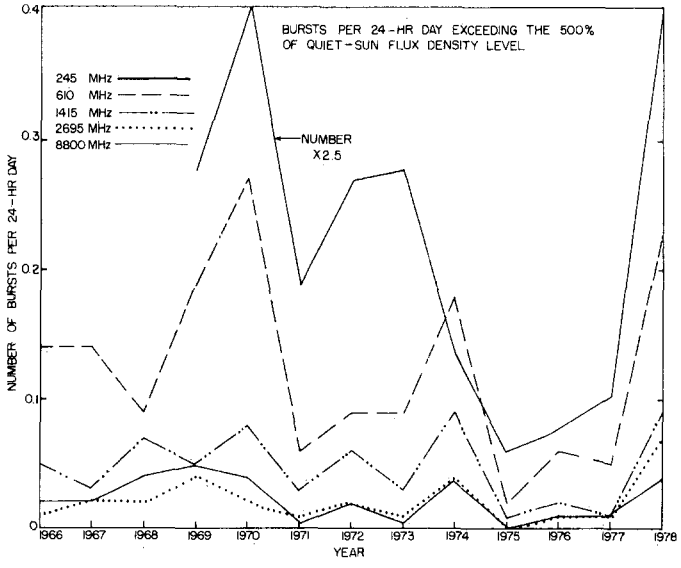

Figure 11-7. The number of bursts per day that exceeded 500% of the quiet-sun flux-density level for the years 1966–1978.

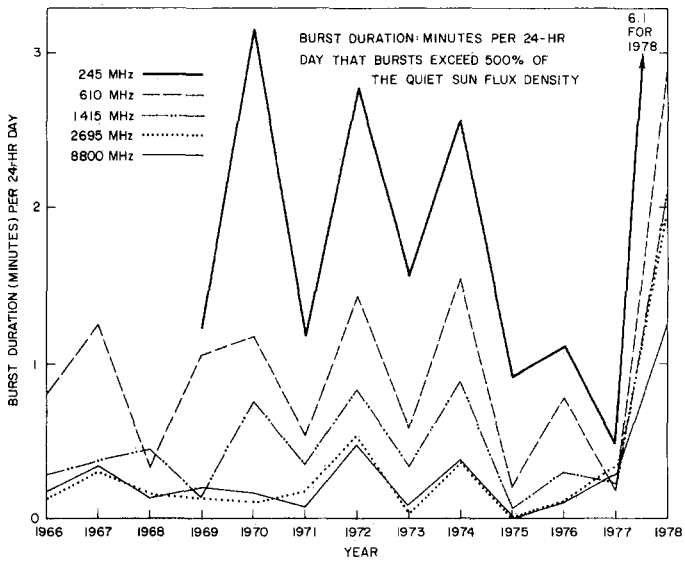

Figure 11-9. The number of minutes per day that solar burst radiation, at various frequencies, exceeded 500% of the quiet-sun flux density.

interference) 24 hours a day from any ground-based operating location. On sites far from the equator (high latitudes), sun-in-view hours per day vary widely with season. Also, the system susceptible to solar radio interference may be in operation only during certain hours of the day (or night). Hence, the best method of presentation is to give the statistics on a "per 24-hr day" basis and let the user determine what fraction of his operating time the sun is actually above the horizon to provide interference to his system. Finally, it is important to point out that the relatively low average "outage" times obtained (~ 1 min/day) result from sporadic events during which the burst radiation from the sun may exceed the indicated threshholds for durations ranging from ~10 min tb 2 hours.

At the higher radio frequencies (above 500 MHz), strong solar radio interference (above the quiet-sun level) occurs as distinct, individually-identifiable radio bursts. The bursts have different spectral (frequency) characteristics, but at a given frequency the burst has a start time, a peak (or several peaks), and a time of decay. At lower frequencies (245

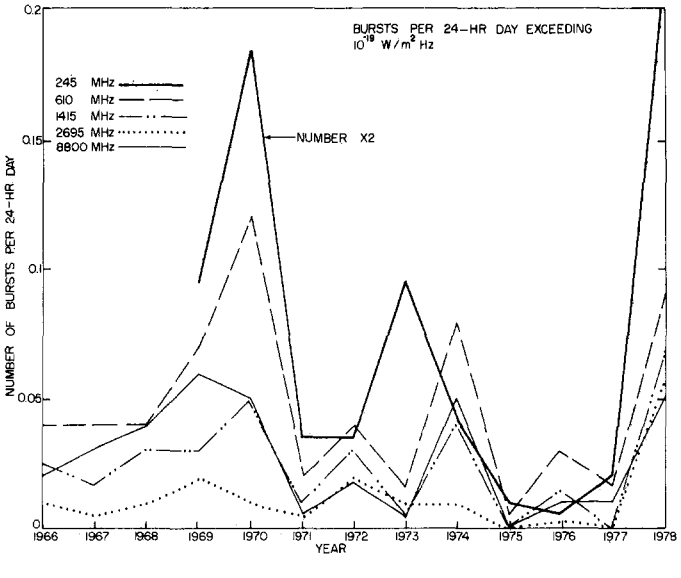

Figure 11-8. The number of bursts during a 24-hr day that exceeded, at various frequencies, 1000 sfu.

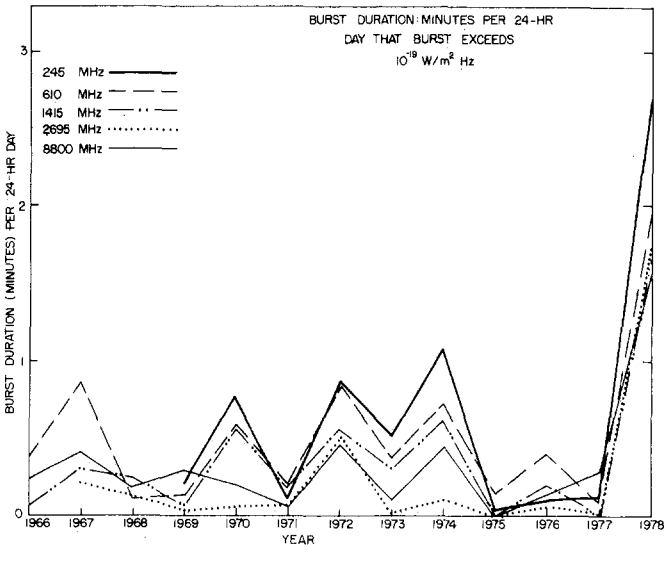

Figure 11-10. The number of minutes per day that solar-burst radiation, at various frequencies, exceeded 1000 sfu.

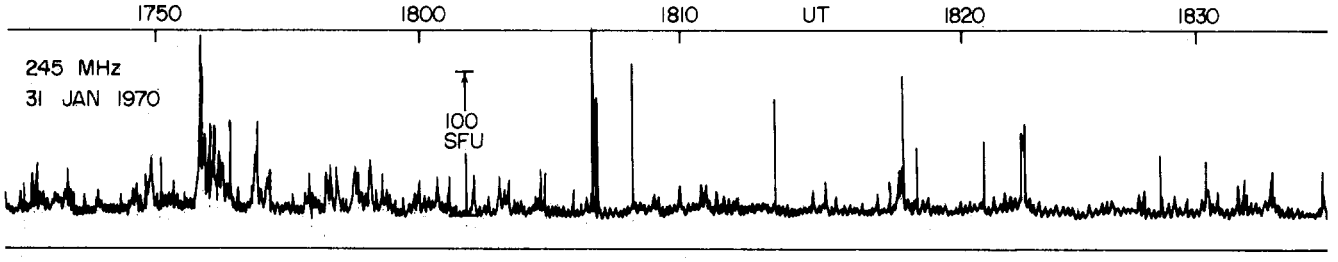

Figure 11-11. The time-intensity profile of a typical 245 MHz noise storm observed at Sagamore Hill.

MHz, for example) there is, in addition to distinct radio bursts, another phenomenon known as solar noise storms. These storms, more prevalent during the sunspot-maximum portion of the 11-year cycle, often last for many hours and sometimes last for a period of days. The noise storms consist of very irregular low-to-moderate increases in solar flux density above the quiet-sun level. For only a very small portion of the noise storm's duration does the added flux density exceed the moderate level (for example, 100 sfu). Figure 11-11 shows a typical example of such a noise storm observed at 245 MHz.

Since these noise storms constitute another significant type of solar radio interference for systems with operating frequencies below 500 MHz, we have also included a statistical graph on noise storm duration, based on our 245 MHz data. See Figure 11-12. The statistical duration is given in terms of minutes of noise storm occurrence per 24-hr day. The shortened period plotted (only 1970 to 1978) gives some indication of the sunspot-cycle variation.

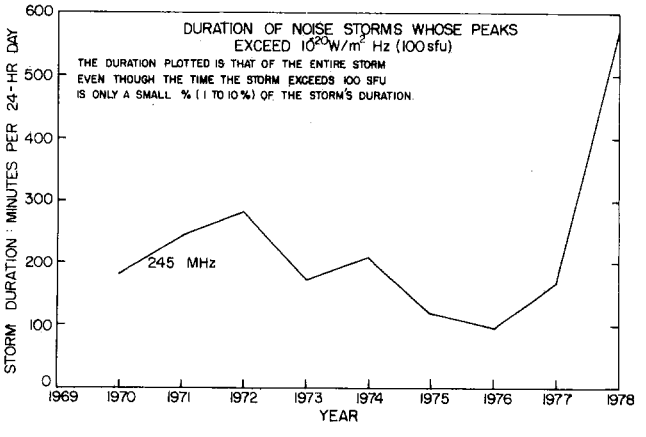

Figure 11-12. The average number of minutes per 24-hr day that a noise storm was reported by Sagamore Hill observatory for the years 1970–1978. The large peak in 1978 may be due (at least partially) to a change in reporting procedures.

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