ANALYSIS OF DESIGN CRITERIA FOR A RADIO FREQUENCY PROTON EVENT WARNING SYSTEM OPERATING IN THE FREQUENCY RANGE 1000-3750 MEGACYCLES PER SECOND

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ABSTRACT

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A statistical analysis has been made on solar radio emission associated with large proton events and solar radio outbursts associated with no proton events and small proton events for the frequency range 1000-3750 mc/s. Specific criteria have been established for this frequency range. Furthermore, investigations have been made into false alarms and frequency combinations.

The results of this analysis can serve as the basic design criteria for an electronic system that may provide a warning for large solar proton events. This criteria will hold for any frequency in the range 1000-3750 mc/s. Such a warning system would reduce the corpuscular radiation hazard to future space flights.

Author

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INTRODUCTION

Large solar cosmic ray increases are a danger to space flight. The total radiation dose from one of these events definitely presents a hazard to future space travelers. The radiation effects on materials, electronic components, and other instruments used in space missions also present a problem. Consequently, a solution to this problem must be found before further penetration of space is attempted.

One of the areas where a possible solution to the space radiation problem may be found is the field of warning. A "warning" is the indication of a large solar proton event, which has already occurred, before the arrival of the corpuscular radiation. In the case of an interplanetary mission, once a warning is given that a stream of particles from a solar radiation event is headed toward the space craft, various precautionary measures may be taken. To protect the space travelers and sensitive instruments, spot shielding, near body shielding, shadow shielding, artifically generated magnetic fields around the space craft, and a variety of other techniques can be used.

There are many indications that a warning of solar proton events may be provided by means of a scientific system which uses selective criteria on the characteristics of solar radio emission outbursts associated with these events. The results presented in this report can serve as the basic criteria for an electronic system that may provide such a warning. Specific signal characteristics of solar RF emission which are indicative of large proton events, can be built into an electronic proton event warning system. Since the RF signal characteristics specified in this study precede the start of the PCA event in every case, such a warning system would give an alarm before the arrival of the actual proton hazard. A system of this type would not be overly complex and can possibly be operated in the future both from the ground and on a manned space craft.

The purpose of this report is:

A. To present a set of warning criteria for RF systems operating between the frequencies 1000 and 3750 mc/s.

B. To discuss the method of arriving at this criteria.

C. To discuss the importance and significance of these results.

A previous report from Schellenger Research Laboratories[1] has established various relations between solar radio emission and solar proton events. This report is a supplement to that initial analysis. In this present study, fixed frequency records have been studied for a frequency range to include 1000, 1420, 1500, 2000, 2800, 2980, 3000, and 3750 mc/s. However, 1420 mc/s has been deleted from this range because of a small sample size in comparison to the other frequencies within the assigned range. The small sample size may be attributed to the observation of the 21 cm spectral line of Hydrogen by the 1420 mc/s observatory[2] thereby decreasing the contribution of that station in recording solar RF emission. Consequently, when discussing the frequency range 1000-3750 mc/s, it is understood that 1420 mc/s is not being considered. The frequencies 1000, 1500, 2000, 2800, 2980, 3000, 3750 are then the included frequencies.

A set of criteria, pertaining only to the frequencies within the range 1000-3750 mc/s have been established for solar radio emission to be indicative of large solar proton events. These criteria have been thoroughly investigated to insure the most reliable indications of large proton events.

PROCEDURE

The source of solar RF emission has been the International Astronomical Union (IAU) Quarterly Bulletins of Solar Activity from 1956 to 1961. The data published in the IAU Quarterlies are compiled from data submitted by radio observatory locations all over the world. For a list of the stations observing within the frequency range 1000-3750 mc/s, as of December, 1961, see Table 1.

To insure maximum consistency in this analysis, a Schellenger Research Laboratories Proton Event List for the period 1956-1961 has been compiled (Table 2). The data for this list has been obtained from various sources. These sources and contributing information are:

1. Proton event data, PCA start time and duration, H,H. Malitson.[3]
2. The Event size at E > 30 Mev, was determined using W.R. Webber's proton event list[4] as first importance.
3. The remaining event sizes, at E > 20 Mev, were further completed using the list developed by D.K. Bailey[5] as second importance.
4. The E.L. Chupp and R.W. Williams list[6] at E > 100 Mev assumed third importance in determining the proton event size.
5. Least importance was assigned to the W.R. Webber - H.H. Malitson list[4] which was used to determine event sizes for the remainder of the proton events.

Therefore the Schellenger Research Laboratories Proton Event

List has been constructed by first listing the PCA event, the date and start time. The PCA dates have been assigned a proton event size using W.R. Webber's list, then Bailey's, then the Chupp and Williams list, and then the Webber-Malitson list. The only discrepancy arose in conjunction with the August 29, 1957 proton event. W.R. Webber treated this event as occurring on August 29, 1957 through August 31, 1957 and stated, in his proton event list, that there were possibly two events during this period. From all available information, it is believed that there were two events, one on August 29, 1957 and one on August 31, 1957. Therefore, the August 29 event was accepted as having been considered by W.R. Webber while the August 31 event was listed as a Bailey consideration. It is firmly believed that the compilation of this new proton event list has been necessary to insure maximum consistency and accuracy in the analysis.

In the analysis, possible errors in the data have been taken into consideration before establishing the optimum criteria. All time recordings have been assumed correct to plus or minus one minute. A maximum of 10% error on the RF emission flux density readings has been considered.[7,8] All proton event sizes are taken to be correct to a factor of two.

Some specific terms have been defined and are expressed in their abbreviated form. A_i (an alarm) is a case where the signal, received at a solar radio observatory at a particular frequency, is associated with a prescribed proton event and meets the signal characteristics specified. $(FA)_i$ (a false alarm) is a case where a characteristic signal is received and no proton event (NPE), or a proton event of size less than a specified event size (N) is observed. Characteristic signals received during a PCA (DPCA) are considered false alarms. F_i (an RF failure) is a case where a signal associated with a prescribed proton event does not meet the specified signal characteristics. In this analysis there are no F_i since the criteria has been established to maintain a P(A/N) of 100%. P(A/N) is the probability of an alarm being given, provided a proton event of size greater than or equal to N has occurred. P(N/A) is the probability of a proton event of size equal to or greater than N occurring, provided an alarm has been given. These conditional probabilities are defined mathematically as follows:

$$P(A/N) = \frac{\Sigma A_i}{\Sigma A_i + \Sigma F_i}$$

$$P(N/A) = 1 - \frac{\Sigma(FA)_i}{\Sigma(FA)_i + \Sigma A_i} = \frac{\Sigma A_i}{\Sigma(FA)_i + \Sigma A_i}$$

where $\Sigma(FA)_i = \Sigma[FA(NPE)] + \Sigma[FA(P.E.<N)] + \Sigma[FA(DPCA)]$.

If a particular case is taken, the P(A/N) basically establishes the following proposition: if a large proton event occurs, then certain characteristics will be met on the RF signal. Therefore, in the analysis a P(A/N) of 100% indicates that when a large proton event occurs the associated RF signal will meet the established criteria in all cases. The P(N/A) establishes the converse proposition to the P(A/N), namely: if certain characteristics are met on the RF signal, then a large proton event will occur.

This analysis has been approached using the non-restrictive outlook. In the previous SRL report[1] it was stated that the study on the relationship between solar RF emission and solar proton events encompasses both the restrictive (pessimistic) and non-restrictive (optimistic) approaches. The P(A/N) is generally higher using the non-restrictive approach. In this analysis the goal has been to maintain a P(A/N) of 100% which means that the criteria must be established to insure that there are no RF failures (F_i). This can best be accomplished using the non-restrictive approach.

To determine a reliable criteria for this frequency range, a number of tables have been compiled. Among these tables is the standardized proton event list. This table has been used in the determination of the solar RF emission which occurred before the onset of the PCA. This solar RF emission has been taken from the IAU Quarterly Bulletins, 1956-1961. It has been necessary to determine which proton events were $\geq 10^7$ protons/cm^2 and which were $<10^7$ protons/cm^2 at E > 30 Mev. The W.R. Webber events at energies greater than 30 Mev and sizes $\geq 10^7$ protons/cm^2 were named the large proton events. Those events considered by Bailey at E > 20 Mev, Chupp and Williams at E > 100 Mev, and Webber-Malitson at E > 30 Mev were considered as small proton events.

Solar radio emission associated with large proton events for the frequency range 1000-3750 mc/s (non-restrictive) (Table 3) was completed after careful consideration of the information in the

IAU Quarterly Bulletins. It should be noted that for each date there is one entry. This entry was chosen because it was the solar RF outburst which best characterized the proton event that followed.

This data (Table 3) has been carefully analyzed to establish criteria, mindful that a P(A/N) of 100% must be maintained, to be used throughout the analysis. The criteria are, duration ≥ 25 minutes, and Maximum flux density of 260 x 10^{-22} $wm^{-2}(c/s)^{-1}$. Taking into account the duration and maximum flux density correction factors, these criteria were lowered to D ≥ 24 minutes and MFD ≥ 230 x 10^{-22} wm^{-2} $(c/s)^{-1}$ for proton event sizes $\geq 10^7$ protons/cm^2 at E > 30 Mev. Proton event sizes $\geq 10^8$ protons/cm^2 are best indicated by D ≥ 24 minutes, MFD ≥ 250 x 10^{-22} wm^{-2} $(c/s)^{-1}$, while $\geq 10^9$ protons/cm^2 events are characterized by D $\geq$ 49 minutes, MFD ≥ 690 x 10^{-22} wm^{-2} $(c/s)^{-1}$.

Using the established criteria, "Solar Radio Emission Associated with Small Proton Events" (Table 4), False Alarms (NPE) (Table 5), and False Alarms (DPCA) (Table 6) have been compiled from a general false alarm table which contained information extracted from the IAU Quarterly Bulletins. The general false alarms have been carefully analyzed to separate the false alarms into the categories NPE and DPCA. The resulting information has been used to mathematically determine the P(N/A) of this frequency range.

Another type of false alarm must also be considered in the mathematical calculation of the P(N/A). This false alarm occurs when the solar RF emission characteristic of a very large proton event occurs and is followed by a large proton event. For example, if a signal meets the $\geq 10^9$ protons/cm^2 criteria but is followed by a 10^7 protons/cm^2 or 10^8 protons/cm^2 event, it is considered a false alarm for it was indicative of a $\geq 10^9$ protons/cm^2 event but was not followed by an event of that size.

Efforts have not been made to alter the criteria to increase the P(N/A) because initially the objective has been to maintain a P(A/N) of 100%. Any alteration in these established criteria will decrease the P(A/N). Consequently, all calculations have been made using consistent criteria.

STATIONS RECEIVING SOLAR RADIO EMISSION

TABLE 1

Freq. Mc/s	Station	Normal Observing Period Dec. 1961 (Hours U.T.)
9500	Tokyo Astronomical Observatory, Mitaka, Tokyo	00-07
9400	Research Inst. of Atmos. Nagoya Univ., Toyokawa, Japan	23-06
9400	Heinrich Hertz Inst., Berlin-Adlershof	08-14
9100	Netherlands PTT Obser. Station Nera	08-15
3750	Research Inst. of Atmos. Nagoya Univ., Toyokawa, Japan	23-06
3000	Tokyo Astronomical Observatory, Mitaka, Tokyo	00-06
3000	Heinrich Hertz Inst. Berlin-Adlershof	08-14
2980	Netherlands PTT Obser. Station Nera	08-15
2800	National Research Council, Ottawa, Canada	12-21
2000	Research Inst. of Atmos. Nagoya Univ., Toyokawa, Japan	23-06
1500	Heinrich Hertz Inst., Berlin-Adlershof	08-14
1000	Research Inst. of Atmos. Nagoya Univ., Toyokawa, Japan	23-06
808	Astro. Inst. of the Czechoslovak Academy of Sciences, Ondrejov near Prague	08-14
600	Obser. Royal de Belgique, Uccle, Belgium	08-16
545	Netherlands PTT Obser. Station Nera	08-15
545	Surinam Department of Public Works & Traffic & Netherlands PTT Obser. Station Paramaribo	11-21
545	Netherlands PTT Obser. Station Hollandia	21-08
545	Research Inst. of Terrestrial Magnetism, Ionosphere & Radio Propagation, Krasnaia, Pahra, Moscow,	07-12
234	Astroph. Obser. Potsdam, Tremsdorf, Germany	09-14
208	Crimean Astroph. Obser. Crimea, USSR	09-12
208	Ussurijak Radio-Astron. Obser., USSR	21-01
208	Research Inst. of Terrestrial Magnetism Ionosphere & Radio Propagation, Krasnaia, Pahra, Moscow	07-12
200	Hiraiso Radio Wave Obser., Japan	23-08
200	Tokyo Astronomical Observatory, Mitaka, Japan	00-06
200	Netherlands PTT Obser. Station Nera	08-15
200	Surinam Department of Public Works & Traffic & Netherlands PTT Obser. Station Paramaribo	11-21
200	Netherlands PTT Obser. Station Hollandia	21-08
178	Kislovodsk Radio-Astronomical Obser., USSR	07-12
169	Obser. de Paris, Meudon, Nancay Station	11-13
127	Astronomical Obser. of the New Copernicus Univ., Poland	09-15
111	Astroph. Obser. Potsdam, Tremsdorf, Germany	09-14
108	National Bureau of Standards, Central Radio Propagation Lab. Boulder, USA	14-23
100	Tokyo Astronomical Observatory, Mitaka, Tokyo	00-06
23	Astroph. Obser. Potsdam, Tremsdorf, Germany	09-14
18	National Bureau of Standards, Central Radio Propagation Lab. Boulder, USA	14-23

SRL PROTON EVENT LIST

TABLE 2

NO.	DATE	PCA START TIME	DUR. (DAYS)	EVENT SIZE	ENERGY (MEV)	SOURCE
1.	2-23-56	0430	3	$2x10^9$	>30	Webber (G)
2.	8-31-56	1500	2.5	$\sim 3x10^7$	>30	Webber (G)
3.	11-13-56	2100	2	$2x10^8$	>20	Bailey
4.	1-20-57	1500	2.5	$\sim 3x10^8$	>30	Webber (G)
5.	4-3-57	1500	2.5	$1x10^8$	>20	Bailey
6.	5-19-57	0200	0.5	$1.1x10^3$	>100	Chupp-Williams
7.	6-22-57	0530	3	$3x10^8$	>20	Bailey
8.	7-3-57	0845	2	$\sim 1x10^7$	>30	Webber (G)
9.	7-24-57	2015	0.5	$1.5x10^7$	>20	Bailey
10.	8-9-57	2245	1	$2.6x10^4$	>100	Chupp-Williams
11.	8-29-57	1300	2	$5x10^7$	>30	Webber (G)
12.	8-31-57	1530	2	$1.6x10^8$	>20	Bailey
13.	9-2-57	1730	1.5	$1x10^8$	>20	Bailey
14.	9-12-57	b1200	1.5	$1.2x10^7$	>20	Bailey
15.	9-21-57	1630	2	$2.3x10^8$	>20	Bailey
16.	9-26-57	2315	1	$2x10^4$	>100	Chupp-Williams
17.	10-21-57	0630	1	$1x10^7$	>30	Webber (G)
18.	2-10-58	b0700	1	$\sim 5x10^6$	>30	Webber (G)
19.	3-23-58	1830	1.5	$4x10^8$	>30	Webber (G)
20.	3-25-58	1300	4.5	$1.2x10^9$	>20	Bailey
21.	4-10-58	1000	2	$1x10^8$	>20	Bailey
22.	6-6-58	1345		10^6	>30	Webber-Malitson
23.	7-7-58	0130	4	$5x10^8$	>30	Webber (G)
24.	7-29-58	0405	1	$1.7x10^7$	>20	Bailey
25.	8-16-58	0600	2.5	$2x10^7$	>30	Webber (G)
26.	8-22-58	1530	3.5	$5x10^7$	>30	Webber (G)
27.	8-26-58	0100	3	$5.3x10^7$	>30	Webber (G)
28.	9-22-58	1400	3.5	$1.7x10^8$	>20	Bailey
29.	5-10-59	2300	7	$1.2x10^9$	>30	Webber (G)
30.	6-13-59	1330	>2	$7.6x10^3$	>100	Chupp-Williams

SRL PROTON EVENT LIST

(continued)

TABLE 2

NO.	DATE	PCA START TIME	DUR. (DAYS)	EVENT SIZE	ENERGY (MEV)	SOURCE
31.	7-10-59	0400	4	$8x10^8$	>30	Webber (G)
32.	7-14-59	b0700	3	$2x10^9$	>30	Webber (G)
33.	7-17-59	a0200	7	$3x10^9$	>30	Webber (G)
34.	9-2-59	0400	2	$2.3x10^7$	>20	Bailey
35.	3-31-60	0300	1	$1.2x10^7$	>20	Bailey
36.	4-1-60	0930	2	$2.7x10^6$	>30	Webber (G)
37.	4-5-60	b0800	2	$2x10^6$	>30	Webber (G)
38.	4-28-60	0200	1	$2.5x10^7$	>30	Webber (G)
39.	4-29-60	b0600	5	$3.5x10^8$	>20	Bailey
40.	5-4-60	1044	2	$7x10^6$	>30	Webber (G)
41.	5-6-60	b1830	4	$\sim 5x10^6$	>30	Webber (G)
42.	5-13-60	0620	3	$1x10^8$	>20	Bailey
43.	9-3-60	b0800	3	$4x10^7$	>30	Webber (G)
44.	11-12-60	1445	3	$2.7x10^9$	>30	Webber (G)
45.	11-15-60	0505	3.5	$2x10^9$	>30	Webber (G)
46.	11-21-60	0500	1	$6x10^7$	>30	Webber (G)
47.	7-12-61	0000	1	$2x10^6$	>30	Webber (G)
48.	7-13-61	b0700	2.5	$1x10^7$	>30	Webber (G)
49.	7-15-61	1545	3	$2.5x10^7$	>20	Bailey
50.	7-18-61	1135	2.5	$2.5x10^8$	>30	Webber (G)
51.	7-21-61	0300	1	$9x10^6$	>30	Webber (G)
52.	9-10-61	2300		$7.5x10^7$	>20	Bailey
53.	9-28-61	2335		$1.6x10^8$	>30	Webber-Malitson
54.	11-10-61			$1.6x10^7$	>20	Bailey

SOLAR RADIO EMISSION ASSOCIATED WITH LARGE PROTON EVENTS
(1000-3750 mc/s)

TABLE 3

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH	EVENT SIZE E > 30 MEV
7-3-57	1000	NAG	0723	0809.7	60		7570	~$1x10^7$
8-16-58		NAG	0435	0442	85		4800	$2x10^7$
8-23-58		NAG	0017	0022	59	1900	1600	$5.3x10^7$
4-28-60		NAG	0117	0139.2	25	265		$2.5x10^7$
9-3-60		NAG	0216	0231.2	270	$4.72x10^4$		$4x10^7$
7-7-58	1000	NAG	0101x	0112	60		800	$5x10^8$
7-10-59		NAG	0209	0223	100	6000	4750	$8x10^8$
5-10-59	1000	NAG	2200	2222	>100		1550	$1.2x10^9$
7-14-59		NAG	0331	0422	125	20600	4900	$2x10^9$
7-17-59		NAG	2204	2226	>65		6500	$3x10^9$
11-15-60		NAG	0220	0227.1	235	8600		$2x10^9$
8-31-56	1500	HHI	1230		85		4920	~$3x10^7$
8-28-57		HHI	0900	1001	280		692	$5x10^7$
8-22-58		HHI	1427	1509	128	443		$5x10^7$
7-13-61		HHI	1010	1042.5	240	~1700		$1x10^7$
7-18-61	1500	HHI	0938.5	0958	231.5	1180		$2.5x10^8$
11-12-60	1500	HHI	1323	1328.7	>90	770		$2.7x10^9$
7-3-57	2000	NAG	0726	0809.5	50		1690	~$1x10^7$
8-16-58		NAG	0434	0440	60		2900	$2x10^7$
8-26-58		NAG	0005	0042	57		2100	$5.3x10^7$
4-28-60		NAG	0115	0129.7	30	285		$2.5x10^7$
9-3-60		NAG	0035	0105.2	90	7100		$4x10^7$
7-7-58	2000	NAG	0055	0111.5	38		1300	$5x10^8$
7-10-59		NAG	<0211	0224	>90		3000	$8x10^8$
5-10-59	2000	NAG	2200	2213	>100		1300	$1.2x10^9$
7-14-59		NAG	0331	0420	125		8450	$2x10^9$
7-17-59		NAG	2201	2210	>65		2350	$3x10^9$
11-15-60		NAG	0220	0222.6	75	4950		$2x10^9$

SOLAR RADIO EMISSION ASSOCIATED WITH LARGE PROTON EVENTS
(1000-3750 mc/s)

TABLE 3

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH	EVENT SIZE E > 30 MEV
8-31-56	2800	OTT	1231		39		340	$\sim 3\times10^{7}$
10-20-57		OTT	1644	1651	51		4000	1×10^{7}
8-22-58		OTT	1430	1506	120		1500	5×10^{7}
11-21-60		OTT	2023	2026.5	>47	400		6×10^{7}
3-23-58	2800	OTT	1115	1134	>247		300	4×10^{8}
7-10-59		OTT	2112	2129	56		490	8×10^{8}
5-10-59	2800	OTT	2100	2149	>160		2500	1.2×10^{9}
7-17-59		OTT	2118	2154	>180		6500	3×10^{9}
11-12-60		OTT	1320	1345.5	340	5500		2.7×10^{9}
7-3-57	2980	NED	0726.5		31	585	152	$\sim 1\times10^{7}$
8-29-57		NED	0943		40	1192	333	5×10^{7}
7-13-61		NED	1018		87	4100	1100	1×10^{7}
3-23-58	2980	NED	0953		~110	>1340	536	4×10^{8}
7-18-61		NED	0938		65	2400	800	2.5×10^{8}
7-3-57	3000	GOR	0733		30	285		$\sim 1\times10^{7}$
8-16-58		TOK	0434	0440	70	5030	4794	2×10^{7}
9-3-60		TOK	0059		50	5600		4×10^{7}
3-23-58	3000	JOD	1105	1115	25	555	50	4×10^{8}
7-7-58		TOK	0050.2	0111.3	100	3770	3432	5×10^{8}
2-23-56	3000	TOK	0333		50	>4700	4410	8×10^{9}
7-3-57	3750	NAG	0727	0742	45		337	$\sim 1\times10^{7}$
8-16-58		NAG	0434	0439	60	5800		2×10^{7}
8-26-58		NAG	0005	0041	50		5050	5.3×10^{7}
4-28-60		NAG	0116	0129.5	40	260		2.5×10^{7}
9-3-60		NAG	0039	0104.6	85	1.2×10^{4}		4×10^{7}
7-7-58	3750	NAG	0102.5x	0111.4	30		1700	5×10^{8}
7-10-59		NAG	0209	0224	>38		6300	8×10^{8}

SOLAR RADIO EMISSION ASSOCIATED WITH LARGE PROTON EVENTS
(1000-3750 mc/s)

TABLE 3

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH	EVENT SIZE E > 30 MEV
2-23-56	3750	NAG	0334		~50		18000	$8x10^9$
7-14-59		NAG	0330	0356	100		6000	$2x10^9$
7-17-59		NAG	<2201	2201	>60		1500	$3x10^9$
11-15-60		NAG	0219	0222	80	11600		$2x10^9$

SOLAR RADIO EMISSION ASSOCIATED WITH SMALL PROTON EVENTS

(1000-3750 mc/s) $(N < 10^7)$

TABLE 4

CHARACTERISTICS: D $\geq$ 24 MIN MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
8-31-57	1000	NAG	0548x	0549	100		285
6-6-58		NAG	0433	0446.1	40		263
3-31-60		NAG	0656	0812.8	120	2.47×10^4	
4-5-60		NAG	0136	0302.8	135	18000	
4-29-60		NAG	0139	0207.3	82	3.03×10^4	
		NAG	0348	0442.2	75	340	
5-13-60		NAG	0517.5	0556.8	122	2200	
4-3-57	1500	HHI	0829		38		383
9-2-57		HHI	1246	1329	142		304
9-21-57		HHI	1330	1336	31		432
4-1-60		HHI	0816	0928/32	~224	>950	
5-4-60		HHI	1011.4	1042.4	107.6	370	
5-6-60		HHI	1408	1435.4	213	520	
7-15-61		HHI	<1435	1600.7	>240	296	
7-21-61		HHI	1552	1621.5	>170	412	
6-6-58	2000	NAG	0433	0447.2	26	420	
3-31-60		NAG	0655	0733.4	120	4.9×10^4	
4-5-60		NAG	0140	0206.1	125	1230	
4-29-60		NAG	0356	0427.4	50	370	
5-13-60		NAG	0417	0557.8	122	1440	
9-28-61		NAG	2211	2220.2	40	1000	
7-24-57	2800	OTT	1628	1838.5	290		1080
8-31-57		OTT	1301	1315.5	65		3900
3-31-60		OTT	1518	1556	220	1750	
5-6-60		OTT	1406.5	1434.5	90	695	
7-12-61		OTT	1650	1745	115	1500	360
7-21-61		OTT	1552	1621.3	42	1800	500
		OTT	1634	1725.5	222	250	55
9-10-61		OTT	1930	2001	61	880	300

SOLAR RADIO EMISSION ASSOCIATED WITH SMALL PROTON EVENTS
(1000-3750 mc/s) ($N < 10^7$)

TABLE 4

CHARACTERISTICS: D $\geq$ 24 MIN MFD $\geq 230 \times 10^{-22}$ wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	MAX FLUX DENSITY SMOOTH
7-24-57	2980	NED	1801.5		>85	1275	255
9-2-57		NED	1257		45	429	
9-22-58		NED	0739		31	336	37
5-4-60		NED	1015		62	2650	1400
9-26-57	3000	TOK	0523x	0541	>39	361	23
9-22-58		HHI	0733	0745	31.3	314	
4-1-60		HHI	0848		>250	1000	
8-31-57	3750	NAG	0548x	0548	60		261
6-6-58		NAG	0433	0450.2	28		360
3-31-60		NAG	0655	0733.5	52	8250	
4-5-60		NAG	0140	0202.3	90	6000	
4-29-60		NAG	0356	0359.7	55	365	
5-13-60		NAG	0517	0532	105	3750	
9-28-61		NAG	2212	2217.3	40	1690	

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN; MFD $\geq 230 \times 10^{-22}$ wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
9-11-57	1000	NAG	0235	0320	70		8200
11-16-57		NAG	0318	0328	70		290
3-11-58		NAG	0022	0026.9	37		293
3-12-58		NAG	0058	0121	31		400
7-11-58		NAG	0759	0811.7	>30		260
10-21-58		NAG	2321	2356	55		530
11-25-58		NAG	0216	0308	60		300
12-11-58		NAG	2352	2400	25		1100
12-12-58		NAG	0633	0634	>30		295
2-12-59		NAG	2304	2333	40		325
5-8-59		NAG	2255	2257	25		1100
6-9-59		NAG	0455	0630	150	3100	1000
8-14-59		NAG	0130	0220	90		435
4-3-60		NAG	2145	2146.6	50	910	
4-4-60		NAG	0216	0218	40	250	
4-4-60		NAG	0305	0310.5	75	320	
6-27-60		NAG		2209.6	>50	2000	
8-14-60		NAG	0515	0518.2	24	630	
10-11-60		NAG	0519.5	0524.7	40	310	
11-11-60		NAG	0317	0422.8	120	47500	
11-19-56	1500	HHI	0906		125		733
11-20-56		HHI	1010		215		>1500
11-22-56		HHI	1328		>45		419
4-18-57		HHI	1305		25		451
9-7-57		HHI	0811	0812	43		571
11-24-57		HHI	0857	0904	61		251
12-14-57		HHI	1230	1240	53		397
12-17-57		HHI	1020	1100	43		319
4-1-58		HHI	1052	1055.5	69	838	
4-7-58		HHI	1013	1016.5	36	564	

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION ≥ 24 MIN; MFD ≥ $230x10^{-22}$ wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
5-4-58	1500	HHI	0737	0744.3	25	337	
6-5-58		HHI	0833	0841.5	37	451	
6-5-58		HHI	1616	1723.4	84	635	
8-30-58		HHI	1420	1500	66	312	
9-14-58		HHI	0834	0904	85	460	
10-24-58		HHI	1439	1445	>56	291	
12-11-58		HHI	1111	1129	24	683	
12-12-58		HHI	1258	1302	55	884	
2-9-59		HHI	1312	1318	28.3	342	
3-6-59		HHI	1223	1233	29.2	230	
3-24-59		HHI	1005	1013	30	812	
4-7-59		HHI	1522	1524	27.7	822	
6-9-59		HHI	1644	~1656	103.5	>1130	
6-12-59		HHI	0904	0906	28	346	
7-5-59		HHI	1141	1149	40.2	242	
7-14-59		HHI	1433	1447	32	340	
7-27-59		HHI	1225	1229	45	570	
8-18-59		HHI	1025	1030	63.5	745	
1-15-60		HHI	1335	1410	>85	440	
2-22-60		HHI	1351.4	1355.4	50	319	
6-25-60		HHI	1148.5	1207	241	610	
6-30-60		HHI	1019.5	1037.1	52.5	541	
8-7-60		HHI	0723.5	0730.5	50.5	284	
10-29-60		HHI	1026.5	1055.2	273.5	583	
9-11-57	2000	NAG	0243	0304	70		564
7-11-58		NAG	0757	0811.4	>48	265	30
10-21-58		NAG	2323	2355	55		520
12-23-58		NAG	0534	0605	65		370
2-12-59		NAG	2250	2314	55		335
8-28-59		NAG	0029	0043	25		250

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION ≥ 24 MIN; MFD ≥ $230 x 10^{-22}$ $(c/s)^{-1}$ wm^{-2}

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	MAX FLUX DENSITY SMOOTH
8-28-59	2000	NAG	0111	0123	30		2250
8-11-60		NAG	0223	0253	35		375
10-11-60		NAG	0523	0527	26		630
7-28-61		NAG	0226	0235.6	35		260
2-10-56	2800	OTT	2113		28.5		>346
2-16-56		OTT	1756		51		623
2-19-56		OTT	1425		29		643
2-29-56		OTT	2217		>23		525
11-20-56		OTT	1209		>66		350
11-22-56		OTT	1526		120		250
12-2-56		OTT	1354		24		360
12-26-56		OTT	1403		165		800
1-6-57		OTT	1758		92		585
4-2-57		OTT	1914		38		247
4-16-57		OTT	1040		54		1650
4-17-57		OTT	2006		79		6000
7-15-57		OTT	2019	2043	78		300
7-16-57		OTT	1739	1757.3	32		350
9-18-57		OTT	1821	1825	40		275
1-15-58		OTT	1640	1643	28		1350
6-4-58		OTT	2138	2156	47		570
6-5-58		OTT	1655	1710	47		330
8-2-58		OTT	1840	1842	25		2050
11-24-58		OTT	1613	1620	25		285
1-21-59		OTT	1702	1708	26.5	600	600
3-25-59		OTT	2013	2017	25		475
5-8-59		OTT	2254	2257	>48		2200
6-9-59		OTT	1635	1652	412		2000
6-9-59		OTT	1728	1740	70		1800
6 9-59		OTT	1139	1140	180		1225

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION ≥ 24 MIN; MFD ≥ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
7-27-59	2800	OTT	1225	1229	76		1025
7-29-59		OTT	1158	1209	290		325
7-29-59		OTT	2118	2119	65		790
8-17-59		OTT	1219	1221	67		335
12-2-59		OTT	1245	1248	182		875
2-22-60		OTT	1353.5	1359	28		340
3-28-60		OTT	2047.7		70		>885
5-12-60		OTT	1340	1426	80		250
6-25-60		OTT	1148		88		425
6-25-60		OTT	2037	2046	40	700	
8-11-60		OTT	1923.5	1928	37	1100	
9-16-60		OTT	1702	1756	97	2000	
10-23-60		OTT	2100.7	2122.5	37	325	
12-5-60		OTT	1828	1837.5	27	330	
6-11-61		OTT	1500	1507	27	365	77
7-11-61		OTT	1952	2002.3	36	230	90
4-16-57	2980	NED	1037		50	~1670	
11-24-57		NED	0859		40	>998	285
12-16-57		NED	1135		35	366	38
1-25-58		NED	0932		40	278	
3-3-58		NED	1005		28	1338	446
8-13-58		NED	0921		37	366	33
9-14-58		NED	0847.5		43	>870	290
12-20-58		NED	1044		42	251	24
1-26-59		NED	1032		34	1099	236
3-24-59		NED	0734		25	371	47
3-24-59		NED	1003		25	>1729	494
6-9-59		NED	1640		27	>759	
6-9-59		NED	1735		45	>759	446
5-6-60		NED	1428		28	>620	

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN: MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
5-26-60		NED	0909		27	>1350	~475
6-1-60		NED	0831	0848	60	3100	1300
10-29-60		NED	1036	1049	50	1000	350
11-10-60		NED	1119		33	>600	
9-16-61		NED	1101	1104.6	34	532	106
2-14-56	3000	TOK	0541		80	1080	890
3-10-56		TOK	0443		80	850	670
8-13-56		TOK	0052		24.2	238	14
10-10-56		TOK	0100		25.5	280	16
11-8-56		TOK	0312		25	382	25
11-17-56		TOK	0412		83	492	190
11-23-56		TOK	0439		25	259	13
11-25-56		TOK	0211		30	290	17
11-29-56		TOK	0006		25	296	16
12-1-56		TOK	0247		>60	266	30
12-6-56		TOK	0030		>40	369	19
12-6-56		TOK	0318		>60	312	9
12-7-56		TOK	0417		39	300	10
12-8-56		TOK	0024		26	332	12
12-9-56		TOK	0111		>60	332	21
12-15-56		TOK	0311		25	285	16
12-17-56		TOK	0151		>30	362	62
12-20-56		TOK	0018		30	355	35
12-20-56		TOK	0203		>30	375	64
12-20-56		TOK	0444		24	530	229
12-29-56		TOK	0043		90	1150	870
1-2-57		TOK	0216		24.8	390	32
1-3-57		TOK	0128		52	421	112
1-4-57		TOK	0103		60	472	106

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN; MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
1-4-57	3000	TOK	0450		27	331	15
1-5-57		TOK	0050		58	501	193
1-6-57		TOK	0038		25.8	334	13
1-6-57		TOK	0526		34	342	31
1-7-57		TOK	0339		90	349	63
1-8-57		TOK	0326		150	283	17
1-9-57		TOK	0424		37.5	371	11
1-13-57		TOK	0232		28	230	10
1-15-57		TOK	0214		49	231	11
1-27-57		TOK	0122		47	328	12
1-31-57		TOK	0400		120	234	34
2-27-57		TOK	0133		>40	239	36
3-16-57		TOK	0146		47	230	13
3-17-57		TOK	0357		38.5	238	11
3-27-57		TOK	0416		>33	332	120
4-1-57		TOK	0348		>75	234	17
4-2-57		TOK	0301		60	800	567
4-20-57		TOK	0246		>31	231	11
5-9-57		TOK	0310		42.5	253	15
5-10-57		TOK	0100		27	265	13
5-16-57		TOK	0054		72.2	286	23
5-17-57		TOK	0047		77	270	26
5-22-57		TOK	0035		37.8	254	19
5-25-57		TOK	0039		43	265	14
6-3-57		TOK	0436		>84	268	36
6-15-57		TOK	0054		25.5	365	24
6-15-57		TOK	0349		39.7	350	21
6-21-57		TOK	0150		39	400	17
6-28-57		TOK	0008		250	504	188
7-2-57		TOK	0137	0210.2	79	353	46

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN; MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
7-6-57	3000	TOK	0126.2	0134.2	24.8	334	15
7-6-57		TOK	0223.5	0238.5	27.2	332	21
7-30-57		TOK	0229.3	0300	32	250	12
8-8-57		TOK	0124	0158	>34	255	21
8-13-57		GOR	0925	0959	45	299	
8-16-57		TOK	0258	0319	31	247	10
8-18-57		TOK	0136	0150	69.2	288	16
8-21-57		TOK	0351	0418	63	250	16
8-28-57		TOK	0242.7	0314.5	37.3	310	10
9-6-57		TOK	0117	0126	>30	350	15
9-9-57		TOK	0137	0137	>30	335	13
9-10-57		TOK	0223	0228	35	349	31
9-11-57		GOR	0629	0630	24	284	54
9-20-57		TOK	0340	0350	30	433	49
9-21-57		TOK	0403	0406	25	420	29
9-29-57		TOK	0135	0142	53	394	83
9-30-57		NAG	0210	0220	32	439	124
10-16-57		TOK	0142	0142	39	523	167
10-17-57		TOK	0525	0540	>38	392	27
10-18-57		TOK	0050	0103	70	407	24
10-19-57		TOK	0120	0126	>28	437	66
10-20-57		TOK	0129	0154	59	440	36
10-20-57		TOK	0239	0254	40	1100	700
10-21-57		TOK	0154	0156	40	360	11
11-2-57		TOK	0321	0330	30	401	15
11-6-57		TOK	0510	0534	47	327	16
11-12-57		TOK	0119	0131	65	346	22
11-15-57		TOK	0046	0129	>50	395	36
11-15-57		TOK	0522	0542	>38	537	187
11-16-57		TOK	0333	0420	90	369	28

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN: MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
11-22-57	3000	TOK	0406	0409	30	870	509
11-24-57		TOK	0226	0229	60	390	13
11-28-57		TOK	0155	0217	60	348	22
11-30-57		TOK	0450	0541	>70	392	29
12-2-57		TOK	0454	0459	50	366	12
12-4-57		TOK	0201	0244	60	380	22
12-11-57		TOK	0217	0220	35	303	22
12-13-57		TOK	0153	0232	70	1130	824
12-14-57		TOK	0258	0306	45	302	13
12-14-57		TOK	0457	0507	31	366	72
12-17-57		TOK	0040	0124	63	355	27
12-17-57		TOK	0401	0520	105	392	28
12-18-57		TOK	0442	0456	40	409	24
12-23-57		TOK	0513	0558	>50	493	40
12-25-57		TOK	0158	0200	24	485	26
1-7-58		TOK	0338	0339	70	371	21
1-23-58		TOK	0502	0503	42	318	10
1-25-58		TOK	0036	0039	27	331	34
1-25-58		HHI	0949	1015	83	358	
1-25-58		HHI	1202	1205	25	276	
2-3-58		TOK	0404	0424	>30	310	21
2-5-58		TOK	0052	0122	60	292	21
3-1-58		TOK	0352	0400.3	34	424	199
3-8-58		TOK	0127	0148	31	326	26
3-8-58		TOK	2356	0015	25	372	19
3-11-58		TOK	0021	0024.8	38	406	8
3-14-58		HHI	1458	1501	34	375	
3-17-58		HHI	1013	1026	42	252	
5-2-58		HHI	0719	0729.5	34	309	

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN; MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST	SMOOTH
5-2-58	3000	HHI	0947		98	293	
5-5-58		HHI	0909	0922	79	307	
6-5-58		HHI	0839.5	0843.4	25.5	868	
6-23-58		HHI	0841	0842.5	49	241	
7-23-58		HHI	1125	1138	45	249	
7-31-58		HHI	1103.5	1125	26.5	294	
8-12-58		TOK	0413	0426	30	314	79
8-13-58		HHI	0905	0933	41	373	
9-14-58		HHI	0830	0904	69	1259	
10-18-58		TOK	0103	0114	57	371	59
10-21-58		TOK	<2345	<2345	>35	>1900	>1600
10-24-58		HHI	1442	1445	>35	381	
12-12-58		HHI	1254		30.5	1270	
12-23-58		TOK	0536	0605	>50	1750	1509
1-8-59		TOK	0331	0407	56	313	59
1-26-59		HHI	0852	1036	189	964	
2-9-59		HHI	1310	1318	29.7	430	
8-18-59		HHI	1026	1030	106.2	621	
1-15-60		HHI	1334	1357.6	87	750	
2-3-60		HHI	1227	1231	37	327	
9-26-60		TOK	0532	0545	28	1120	210
10-29-60		HHI	1026	~1045	>235	>800	
2-14-56	3750	NAG	0541		75		2720
3-8-56		NAG	0320		29.5		421
9-11-57		NAG	0243	0304	90		373
12-13-57		NAG	0155	0232	46		650
3-1-58		NAG	0337	0344	50		351
3-20-58		NAG	0636	0647.1	55		460
10-21-58		NAG	2323	2327	55		1150

FALSE ALARMS

1000-3750 mc/s (NPE)

TABLE 5

CHARACTERISTICS: DURATION $\geq$ 24 MIN; MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME	TIME OF MAX.	DUR.	MAX FLUX DENSITY INST.	SMOOTH
12-23-58	3750	NAG	0534	0605	50		1020
2-12-59		NAG	2250	2313	70		440
8-28-59		NAG	0024	0041	30		540
6-27-60		NAG	0451	0501.6	27	290	
8-11-60		NAG	0222	0252.9	35	610	
10-11-60		NAG	0520	0532.8	40	1580	
11-11-60		NAG	0315	0345	115	3450	
7-28-61		NAG	0226	0235.2	55	400	
9-15-61		NAG	0030	0040	40	280	

FALSE ALARMS

1000-3750 mc/s (DPCA)

TABLE 6

CHARACTERISTICS D ≥ 24; MFD ≥ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME U.T.	TIME OF MAX. U.T.	DUR. MIN.	MAX. FLUX DENSITY 10^{-22} watts $m^{-2}(c/s)^{-1}$ INST.	SMOOTH	PCA NO.
8-30-57	1000	NAG	2211	2213	30		433	11
8-31-57		NAG	0249	0314	26	244		12
9-2-59		NAG	0725	0740	26		1170	34
11-14-60		NAG	0259	0336.1	140	1400		44
11-14-56	1500	HHI	1032		73		820	3
9-3-57		HHI	1022	1026	28		274	13
9-3-57		HHI	1420	1425	80		509	13
9-12-57		HHI	1515	1516	28.5		627	14
9-13-57		HHI	1415	1420	40		266	14
8-18-58		HHI	0811	0933	150	243		25
5-17-59		HHI	0706	0707	29.5	922		29
11-14-60	2000	NAG	0258	0443.7	140	1800		44
9-3-57	2800	OTT	1417	1425	25		1350	13
3-28-58		OTT	2043	2045.1	33		520	20
5-11-59		OTT	2010	2022	>200		900	29
7-15-59		OTT	1925	1926	>37		290	32
7-20-61		OTT	1552	1621.3	42	1800	500	50
7-20-61		OTT	1634	1725.5	222	250	55	50
1-22-57	3000	TOK	0243		32.5	262	21	4
1-22-57		TOK	0440		60	276	31	4
7-4-57		TOK	0052.5	0116.7	>56	335	28	8
9-23-57		TOK	0131	0152	>39	425	18	15
7-29-58		HHI	1139	1201.3	56	342		24
7-29-58		HHI	1405	1421.5	32.3	382		24
8-18-58		HHI	0748	0814	103	338		25
8-25-58		HHI	0952	1005	74	334		26
8-28-58		HHI	1019	1039	36	573		27

FALSE ALARMS

1000-3750 mc/s (DPCA)

TABLE 6

CHARACTERISTICS D $\geq$ 24; MFD $\geq$ 230×10^{-22} wm^{-2} $(c/s)^{-1}$

DATE	FREQ.	STA.	START TIME U.T.	TIME OF MAX. U.T.	DUR. MIN.	MAX. FLUX DENSITY 10^{-22} watts $m^{-2}(c/s)^{-1}$ INST.	SMOOTH	PCA
9-4-60	3750	NAG	0010	0028	25	280		43
11-14-60		NAG	0258	0354.6	140	4300		44
3-30-58	2980	NED	0910		~100	437		20
7-11-58		NED	0755		50	264		

RESULTS

The P(N/A) for the frequencies in the range 1000-3750 mc/s may be found in Table 7A. The P(N/A) has been calculated with respect to the proton event size and the signal characteristics specified in this table.

As a prelude to a more thorough false alarms analysis, the P(N/A) for the frequencies between 1000-3750 mc/s have also been computed excluding the FA(DPCA). The results, contained in table 7B, although encouraging, do not warrant any profound statement at this time. See Figure 1 for a comparison of the calculations of the P(N/A) including and not including the FA(DPCA).

The results obtained from the frequency range may be found in Table 8A. Again, so that some comparison might be made, Table 8B contains the results of the same analysis excluding the FA(DPCA). However, these results (Table 8B) are not offered as conclusive evidence. To provide further insight as to the contribution of an individual frequency to the range, Tables 8C and 8D were computed. Table 8C contains the results of the entire range excluding one frequency, 2980 mc/s. Table 8D also was computed excluding one frequency, 3000 mc/s.

It is apparent that 3000 mc/s does contribute greatly to the lower P(N/A). This deficiency evolves from the large number of false alarms at this frequency. An explanation of the greater false alarms might be found by a close analysis of the IAU Quarterly Bulletins. However, all statements projected in this manner would be assumptions. Formal acceptance of any such theories might possibly lie in further investigation of false alarms and investigation of station handling at the 3000 mc/s observatory.

The consideration of mixed frequency combinations (Table 9) show that by using selective frequency combinations, the P(N/A) may be further increased without altering the criteria for the frequency range. Table 9A presents the non-selective results. Table 9B is simply a reproduction of Table 9A eliminating the FA(DPCA).

INDIVIDUAL FREQUENCIES
1000-3750 mc/s
(Non-Restrictive)
TABLE 7A

PROTON EVENT SIZE (N) IN PROTONS/CM^2 with E > 30 MEV	FREQ (MC/S)	DUR. (MIN)	MFD $[10^{-22} wm^{-2} (c/s)^{-1}]$	ΣFA (NPE)	ΣFA $(P.E.<10^7)$	ΣFA $10^7 \leq P.E.<10^8$	ΣFA $10^8 \leq P.E.<10^9$	ΣFA (DPCA)	$\Sigma(FA)_i$	ΣA_i	P(A/N) %	P(N/A) %
$\geq 10^7$	1000	≥ 24	≥ 230	20	7			4	31	11	100	26.2
$\geq 10^8$	1000	≥ 24	≥ 250	20	7	5		3	35	6	100	14.6
$\geq 10^9$	1000	≥ 49	≥ 690	5	4	4	2	1	16	4	100	20.0
$\geq 10^7$	1500	≥ 24	≥ 230	34	8			7	49	6	100	10.9
$\geq 10^8$	1500	≥ 24	≥ 250	32	8	4		6	50	2	100	3.8
$\geq 10^9$	1500	≥ 49	≥ 690	6	1	3	1	1	12	1	100	7.7
$\geq 10^7$	2000	≥ 24	≥ 230	10	6			1	17	11	100	39.3
$\geq 10^8$	2000	≥ 24	≥ 250	10	6	5		1	22	6	100	21.4
$\geq 10^9$	2000	≥ 49	≥ 690	0	3	4	1	1	9	4	100	30.8
$\geq 10^7$	2800	≥ 24	≥ 230	42	8			6	56	9	100	13.8
$\geq 10^8$	2800	≥ 24	≥ 250	40	8	4		6	58	5	100	7.9
$\geq 10^9$	2800	≥ 49	≥ 690	10	6	2	0	1	19	3	100	13.6
$\geq 10^7$	2980	≥ 24	≥ 230	19	4			2	25	5	100	16.7
$\geq 10^8$	2980	≥ 24	≥ 250	19	4	3		2	28	2	100	6.7
$\geq 10^9$	2980	≥ 49	≥ 690	3	2	1	2	0	9	0	---	----
$\geq 10^7$	3000	≥ 24	≥ 230	135	3			9	147	6	100	3.9
$\geq 10^8$	3000	≥ 24	≥ 250	123	3	3		9	138	3	100	2.1
$\geq 10^9$	3000	≥ 49	≥ 690	10	1	2	1	0	14	1	100	6.7

INDIVIDUAL FREQUENCIES

1000-3750 mc/s

(Non-Restrictive)

TABLE 7A

PROTON EVENT SIZE (N) IN PROTONS/CM^2 with E > 30 MEV	FREQ (MC/S)	DUR. (MIN)	MFD $[10^{-22} wm^{-2} (c/s)^{-1}]$	ΣFA (NPE)	ΣFA ($P.E. < 10^7$)	ΣFA $10^7 \leq P.E. < 10^8$	ΣFA $10^8 \leq P.E. < 10^9$	ΣFA (DPCA)	$\Sigma(FA)_i$	ΣA_i	P(A/N) %	P(N/A) %
$\geq 10^7$	3750	≥ 24	≥ 230	16	7			2	25	11	100	30.6
$\geq 10^8$	3750	≥ 24	≥ 250	16	7	5		2	30	6	100	16.7
$\geq 10^9$	3750	≥ 49	≥ 690	4	3	3	0	1	11	4	100	26.7

INDIVIDUAL FREQUENCIES
1000-3750 mc/s
(Non-Restrictive)
TABLE 7B

PROTON EVENT SIZE (N) IN PROTONS/CM2 with E > 30 MEV	FREQ (MC/S)	DUR. (MIN)	MFD $[10^{-22} wm^{-2} (c/s)^{-1}]$	ΣFA (NPE)	ΣFA $(P.E.<10^7)$	ΣFA $10^7 \leq P.E.<10^8$	ΣFA $10^8 \leq P.E.<10^9$	ΣFA_i	ΣA_i	P(A/N) %	P(N/A) %
$\geq 10^7$	1000	≥24	≥230	20	7			27	11	100	28.9
$\geq 10^8$	1000	≥24	≥250	20	7	5		32	6	100	15.8
$\geq 10^9$	1000	≥49	≥690	5	4	4	2	15	4	100	21.1
$\geq 10^7$	1500	≥24	≥230	34	8			42	6	100	12.5
$\geq 10^8$	1500	≥24	≥250	32	8	4		44	2	100	4.3
$\geq 10^9$	1500	≥49	≥690	6	1	3	1	11	1	100	8.3
$\geq 10^7$	2000	≥24	≥230	10	6			16	11	100	40.7
$\geq 10^8$	2000	≥24	≥250	10	6	5		21	6	100	22.2
$\geq 10^9$	2000	≥49	≥690	0	3	4	1	8	4	100	33.3
$\geq 10^7$	2800	≥24	≥230	42	8			50	9	100	15.3
$\geq 10^8$	2800	≥24	≥250	40	8	4		52	5	100	8.8
$\geq 10^9$	2800	≥49	≥690	10	6	2	0	18	3	100	14.3
$\geq 10^7$	2980	≥24	≥230	19	4			23	5	100	17.9
$\geq 10^8$	2980	≥24	≥250	19	4	3		26	2	100	7.1
$\geq 10^9$	2980	≥49	≥690	3	2	1	2	9	0	---	----
$\geq 10^7$	3000	≥24	≥230	135	3			138	6	100	4.2
$\geq 10^8$	3000	≥24	≥250	123	3	3		129	3	100	2.3
$\geq 10^9$	3000	≥49	≥690	10	1	2	1	14	1	100	6.7

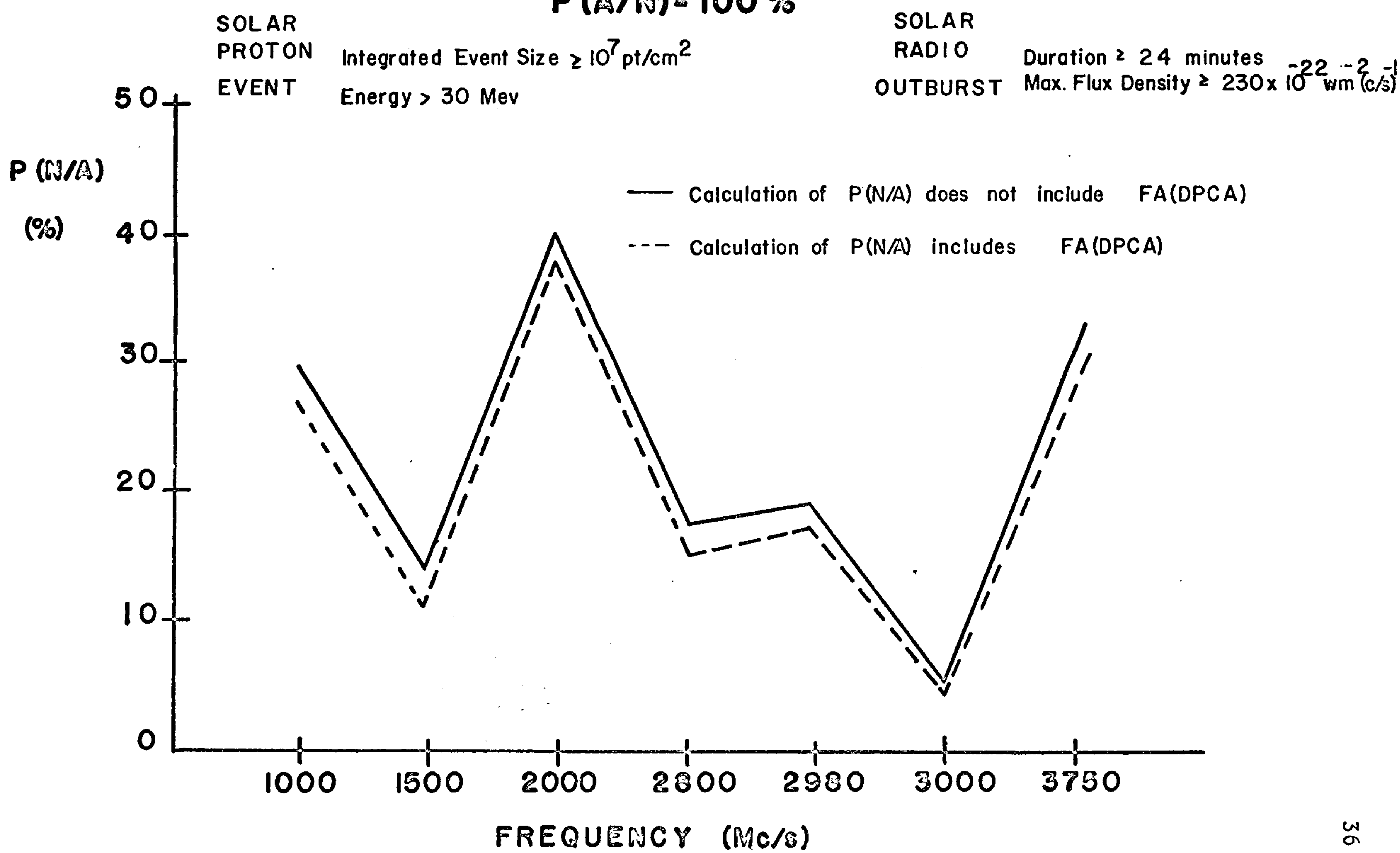
INDIVIDUAL FREQUENCIES
1000-3750 mc/s
(Non-Restrictive)
TABLE 7B

PROTON EVENT SIZE (N) IN PROTONS/CM^2 with E > 30 MEV	FREQ (MC/S)	DUR. (MIN)	MFD $[10^{-22} wm^{-2} (c/s)^{-1}]$	ΣFA (NPE)	ΣFA P.E.$<10^7$)	ΣFA $10^7 \leq$ P.E.$<10^8$	ΣFA $10^8 \leq$ P.E.$<10^9$	ΣFA_i	ΣA_i	P(A/N) %	P(N/A) %
$\geq 10^7$	3750	$\geq$24	$\geq$230	16	7			23	11	100	32.3
$\geq 10^8$	3750	$\geq$24	$\geq$250	16	7	5		28	6	100	17.6
$\geq 10^9$	3750	$\geq$49	$\geq$690	4	3	3	0	10	4	100	28.6

FIGURE I

INDIVIDUAL FREQUENCIES, 1000-3750 mc/s

P(A/N) = 100 %



FREQUENCY RANGE
1000-3750 mc/s

TABLE 8

PROTON EVENT SIZE (N) IN PROTONS/CM^2 with E > 30 MEV	FREQ (MC/S)	DUR (MIN)	MFD $[10^{-22} wm^{-2} (c/s)^{-1}]$	$\Sigma(FA)_i$	ΣA_i	P(A/N)	P(N/A)
			8A				
$\geq 10^7$	RANGE	≥ 24	≥ 230	350	59	100	14.4
$\geq 10^8$	RANGE	≥ 24	≥ 250	361	30	100	7.7
$\geq 10^9$	RANGE	≥ 49	≥ 690	90	17	100	15.9
			8B				
$\geq 10^7$	RANGE	≥ 24	≥ 230	319	59	100	15.6
$\geq 10^8$	[Exclude F.A. (DPCA)]	≥ 24	≥ 250	332	30	100	8.3
$\geq 10^9$		≥ 49	≥ 690	85	17	100	16.7
			8C				
$\geq 10^7$	RANGE	≥ 24	≥ 230	325	54	100	14.2
$\geq 10^8$	[Exclude	≥ 24	≥ 250	331	28	100	7.8
$\geq 10^9$	2980 MC/S]	≥ 49	≥ 690	81	17	100	17.3
			8D				
$\geq 10^7$	RANGE	≥ 24	≥ 230	203	53	100	20.7
$\geq 10^8$	[Exclude	≥ 24	≥ 250	223	27	100	18.0
$\geq 10^9$	3000 MC/S]	≥ 49	≥ 690	76	16	100	17.4

MIXED FREQUENCIES
(1000, 2000, 3750 MC/S)
TABLE 9

9A

PROTON EVENT SIZE (N) IN PROTONS/CM^2 with E > 30 MEV	DUR. (MIN)	MFD [10^{-22}wm^{-2} (c/s)$^{-1}$]	$\Sigma(FA)_i$	ΣA_i	P(A/N) %	P(N/A) %
$\geq 10^7$	$\geq$24	$\geq$230	73	33	100	31.1
$\geq 10^8$	$\geq$24	$\geq$250	87	18	100	17.1
$\geq 10^9$	$\geq$49	$\geq$690	36	12	100	25.0

9B
[Exclude F.A.(DPCA)]

$\geq 10^7$	$\geq$24	$\geq$230	66	33	100	33.3
$\geq 10^8$	$\geq$24	$\geq$250	81	18	100	18.2
$\geq 10^9$	$\geq$49	$\geq$690	33	12	100	26.7

CONCLUSIONS

The results presented in this report have certain limitations. First of all, it is not completely certain that the Proton Event List used is the most accurate list available. Consequently, any error in this solar proton emission data would produce errors in the analysis of the related phenomena. Also there is no absolute assurance that criteria established for large proton events from solar cycle 19 will apply to large proton events occurring in future solar cycles.

It should also be noted that the frequencies considered in the assigned range have not provided a complete 24 hour RF monitor of solar emission. Furthermore, from the 3000 mc/s analysis alone, it is evident that station inconsistency and/or error will affect the results.

This analysis of the frequency range 1000-3750 mc/s has indicated the following:

1. A set criteria can be used for a frequency range. (However, the optimum criteria cannot be obtained in this manner.)
2. The optimum criteria for the 1000-3750 mc/s frequency range, the frequencies 1000, 1500, 2000, 2800, 2980, 3000 and 3750 mc/s in particular, are for $\geq 10^7$ protons/cm^2, Duration $\geq$24 minutes, Maximum Flux Density $\geq 230 \times 10^{-22}$ wm^{-2} (c/s)$^{-1}$, $\geq 10^8$ protons/cm^2, Duration $\geq$25 minutes, Maximum Flux Density $\geq 250 \times 10^{-22}$ wm^{-2} (c/s)$^{-1}$, $\geq 10^9$ protons/cm^2, Duration $\geq$49 minutes, Maximum Flux Density $\geq 690 \times 10^{-22}$ wm^{-2} (c/s)$^{-1}$.

3. The optimum situation, with respect to the P(A/N) and P(N/A), is obtained when signal characteristics are specified on a combination of frequencies rather than on only one frequency.
4. A study of the methods and operation of individual solar radio observatories is necessary.
5. In setting up a P.E. Warning network, the frequencies must be chosen to insure complete monitoring of Solar RF emission throughout each day.
6. A false alarm analysis may serve to reduce the false alarms, thereby increasing the P(N/A) for the frequency range.
7. The results of this analysis can serve as the basic criteria for an electronic warning system.

LIST OF REFERENCES

1. Shlanta, A., An Analysis of the Relation Between Solar Radio Emission and Large Cosmic Ray Increases, (Schellenger Research Laboratories, Texas Western College, El Paso, Texas, 1965.)

2. Roberts, Morton S., Hydrogen in Galaxies, (Scientific American, Volume 208, No. 6, June 1963.)

3. McDonald, Frank B. (ed.), Solar Proton Manual, (Goddard Space Flight Center, X-611-62-122, Greenbelt, Md., 1963), p. 107-115.

4. Ibid, pp. 1-15

5. Gill, W.L. Analysis of Solar Proton Events to Determine the Radiation Flux Exposure for Manned Space Flight, (NASA TN, 1962.)

6. Chupp, E.L., and Williams, R.W., Intensity of Solar Proton Emissions, (Journal the Physical Society of Japan, Vol. 17, Sup. A-II, 1962.)

7. Tanaka, Dr. Haruo, Chief of the Radio Astronomy Section, The Research Institute of Atmospherics, Nagoya University, Toyokawa, Aichi, Japan, May 10, 1963, Personal Letter.

8. Covington, Arthur E., Chief of the Radio Astronomy Section, Radio and Electrical Engineering Division, National Research Council, Ottawa, Canada, May 22, 1963, Telephone Conversation.