ELEVEN-YEAR VARIATION OF THE SPECTRUM OF SOLAR RADIO EMISSION ON THE MICROWAVE REGION

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Abstract

Daily values of flux density at four frequencies on microwave region observed at Toyokawa for more than the half of a complete solar cycle were reviewed and some corrections were made for 9400 and 2000 Mc/s. Basic components were estimated with the aid of interferometric observations as well as by statistics. It was found that the eleven-year change of the basic components amounts to 3.0, 1.56 and 1.13 times the quiet sun levels for 1000, 2000, 3750 and 9400 Mc/s respectively. The spectrum of the slowly varying component changes appreciably during the solar cycle. The slowly varying components at 3750 and 2800 Mc/s are remarkably parallel in spite of an appreciable difference in the variation of basic components. The slowly varying component at 9400 Mc/s is relatively strong at the slope of the solar cycle. The spectrum of slowly varying component seems to be connected with a great burst following proton events. The slowly varying component at 1000 Mc/s is relatively small at the solar maximum, the effect of the sunspot seeming to be masked by the increased electron density in the corona.

1. Introduction

It would be quite reasonable to regard the microwave solar radio emission as being composed of three components; basic component, slowly varying component and solar radio burst. Among these three components, we are going to discuss the first two components, i. e. basic and slowly varying components, on the microwave region ranging from 1000 to 9400 Mc/s.

Since a little before the International Geophysical Year 1957-8, the continuous observations of flux density and polarization have been conducted at four frequencies, 9400, 3750, 2000 and 1000 Mc/s at the Research Institute of Atmospherics, Nagoya University at Toyokawa placed about 60 kilometers away from Nagoya.[1] Among these observations, the observation of flux density at 3750 Mc/s is the oldest one which started in November 1951. After five years, the observation at 9400 Mc/s started in May 1956, which is followed by the observations at 2000 and 1000 Mc/s completed in March and June 1957 respectively. The observed data have been piled up for more than one solar cycle for 3750 Mc/s and for about the half of the solar cycle for the other frequencies.

The purpose of these observations was to study the variation of flux density with the time as well as with the frequency, so that the equipments were deliberately designed from the beginning to fit this purpose. Especially, paraboloidal antennas were made in a similar form to get a high relative accuracy of calibration.[2]

In 1958, we have already pointed out that the spectrum of slowly varying component has its maximum near 5000 Mc/s.[1] The spectrum of basic component was also studied at that time when the solar activity was near the maximum. It would be quite interesting and useful to know how the spectra of these components have changed during the half of this solar cycle.

Before making these statistics, we have reviewed the data and made some corrections of the monthly reports, where more probable values have been obtained.

2. Review of the data

2-1 3750 Mc/s

Among the observed daily values of solar radio emission published over a long period, it seems to be generally accepted that the data of both Ottawa at 2800 Mc/s and Toyokawa at 3750 Mc/s have the highest accuracy of observation because both series are quite in parallel wtth each other.[3][4][5] For the latter, however, we are not quite sure that the calibration is perfectly consistent throughout these twelve years. The ambiguity is still left owing to the fact that we had not used the sqare law detector until January 1953[6] and also had not used the isolator circuit between the antenna and the receiver until April 1956. But according to the calibration using the same horn antenna,[7] the systematic error is believed to be less than 2 or 3 percent even in those earlier days. It should be noted that the observed values at the Astronomical Institute of Tübingen University coincide with ours within 5 percent in absolute calibration.[8]

2-2 9400 Mc/s

At this frequency, we cannot neglect the tropospheric absorption. Sometimes the absorption was quite serious due to the heavy rain which made the observation almost impossible. But on most of the cloudy or rainy days, the absorption was less than 20 percent. On these days when the absorption did not change rapidly, the calibration of flux density was not so difficult, because the absorption does not affect the accuracy of calibration by more than 2 or 3 percent as far as we use two calibration points, the one being the room temperature and the other being the effective antenna temperature when the antenna is directed toward the zenith. The absorption is almost similar to the transmission line loss since the temperature of the rain or cloud is approximately the same as the room temperature.

When it was fine, there were no reasons of having lower accuracy than the one at 3750 Mc/s. An improvement of the data has been done, however, for a short period before June 26th 1957 by multiplying the factor of 1.04. This correction is based on the statistics compared between 3750 and 9400 Mc/s. The change of calibration would have been caused by the change of the antenna feed for making a continuous polarization measurements. The corrected values are presented in Table 1.

In 1960, we have tried to make the absolute calibration by using a standard horn. The result suggested that the values are still about 4 percent lower than the most probable values though we are not going to make further corrections to avoid confusion.

2−3 2000 Mc/s

We have also tried to keep the high accuracy for a long period for both 2000 and 1000 Mc/s. Sorry to say, however, that the accuracy for these frequencies is not so high as the one for 3750 Mc/s. The main cause of this inaccuracy seems to lie in the uncertainty of calibration point corresponding to the room temperature. This uncertainty is attributed to the lack of isolator circuit between the antenna and the receiver. This circuit will be inserted within several months, so that the high accuracy is to be expected in the next solar cycle on the whole frequency region.

For 2000 Mc/s, the correction of the data was partly possible. We found that the calibration changed a few times durings seven years when we changed the mixer crystals. This change of calibration was suggested by Drs. A. Krüger and A. Wiener of the Heinrich Hertz Institute in 1963.[9] Fortunately the level of room temperature has been recorded quite frequently by putting the antenna in a cabin, which was available for making further corrections. The corrected values are presented in Table 2. The accuracy of the data after the correction is believed to be much improved because the correlation with the values of 3750 Mc/s has been much improved as shown in Fig. 4. The values until August 1st 1957 will have less accuracy, since the correction was impossible.

2−4 1000 Mc/s

Unfortunately the accuracy of data at this frequency seems to be the lowest. There would have been some changes of calibration which cannot be found later. But probably the systematic error would not have exceeded several percent considering the similarity of the equipment between 2000 and 1000 Mc/s.

2−5 Presentation of monthly values

Fig. 1 shows the variation of monthly mean, maximum and minimum values for each frequency after the above corrections. We must mention here that the values presented in this figure have been corrected by placing the sun at one astronomical unit from the earth. Monthly mean values are plotted in closed circles and the maximum and minimum values are connected in bars.

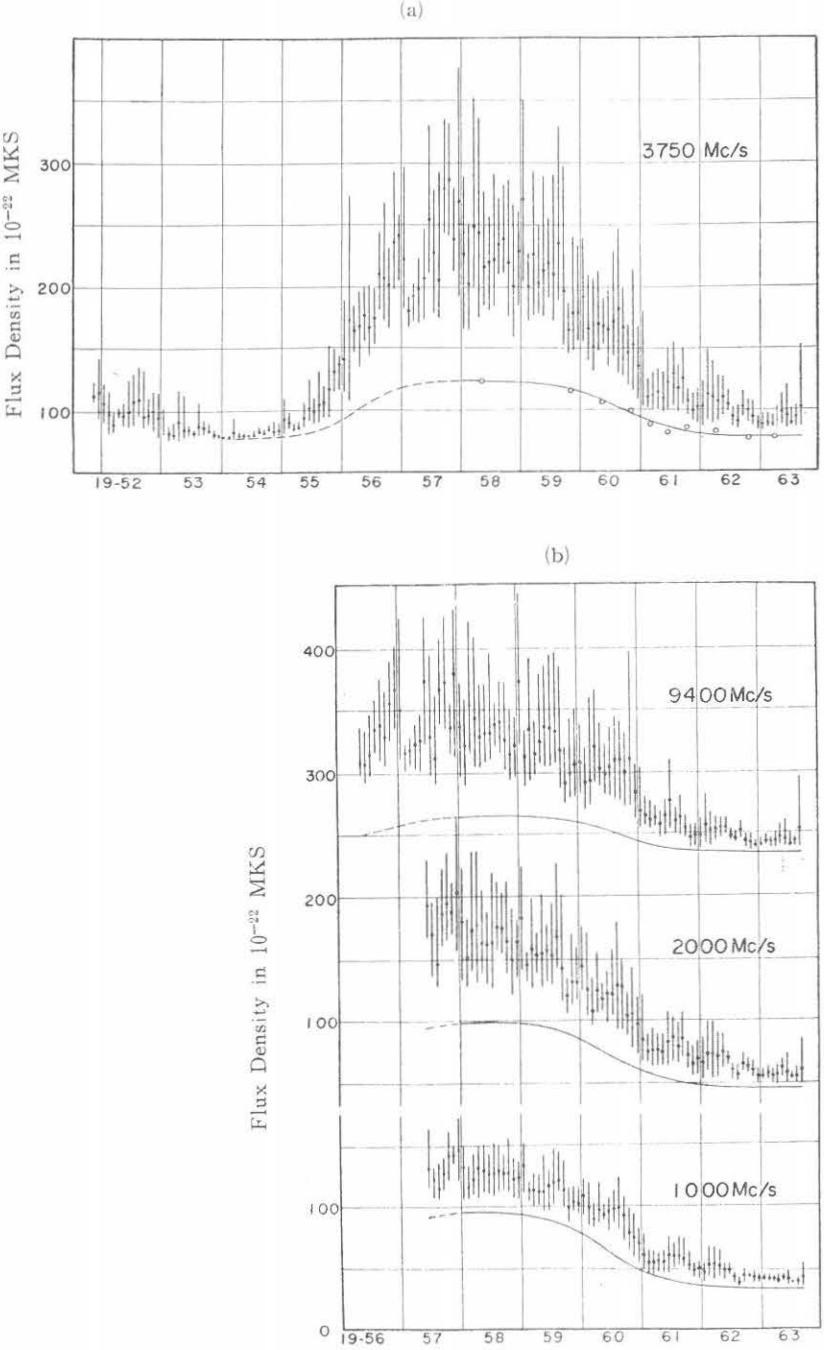

Fig. 1. Monthly mean, maximum and minimum values of flux density with the estimated levels of the basic component.

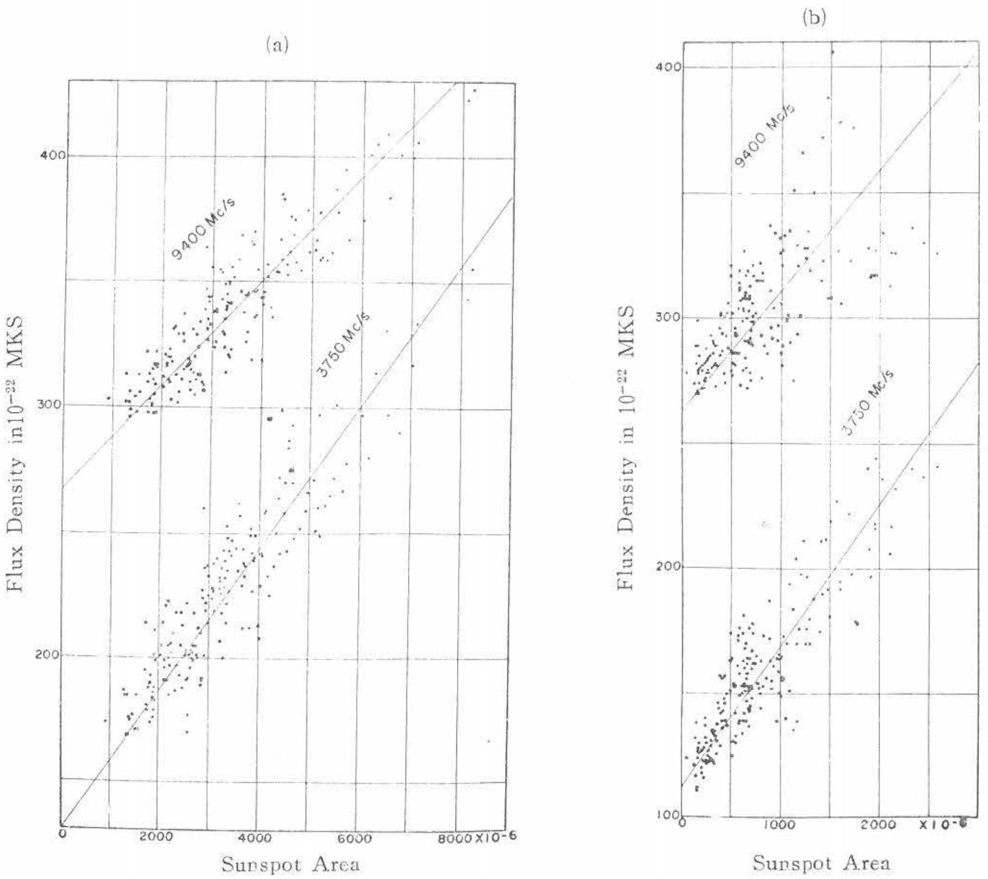

Fig. 2. Plot of daily values of flux density versus sunspot area (a) near the sunspot maximum, Jan.—Jun. 1958 and (b) at the slope of the solar cycle, Jul.—Dec. 1960.

3. Basic component

It is not an adequate expression to say that the daily values of flux density are composed of two components, quiet sun and slowly varying components. If the quiet sun component is defined as the flux density when the sun is at its minimum activity, the slowly varying component should be divided into two components; the one is the component corresponding to the radiation from active regions on the sun and the other is the component which changes gradually with a period of eleven years independently of the rotation of the sun. This concept, however, is not acceptable because it would be reasonable and convenient to define the slowly varying component as directly connected with active regions localized on the solar disk. This definition leads us to the concept that the component which changes gradually with a period of eleven years is included in the quiet sun component. Since it is confusing to express that the quiet sun level changes gradually, we are going to call it as the basic component. In conclusion, the daily values are considered to be composed of the slowly varying component or S component and the basic component or B component. The minimum level of B component should be called as the quiet sun level.

There are two methods of estimating B component. In the first place, B component can be estimated with the aid of optical observations. If we plot the correlation diagram between the flux density and the sunspot area or number for a period of several months, we can get the most probable correlation line be-

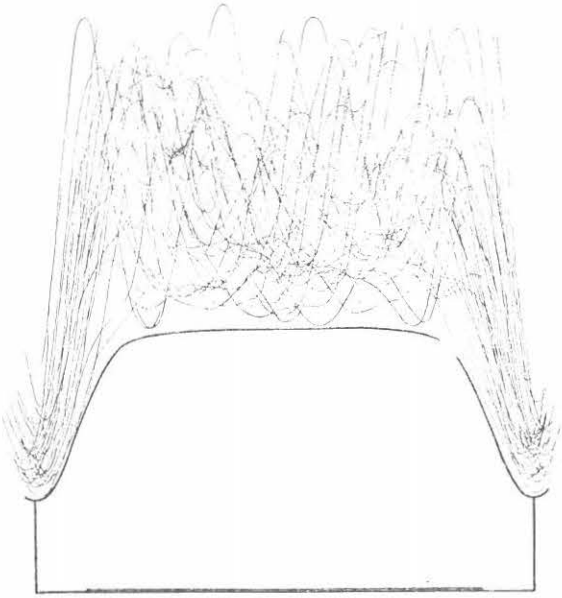

Fig. 3. Estimation of the basic component by the interferometric method. Selected drift curves taken on comparatively quiet days are superimposed during the period Jan.—Jun. 1958.

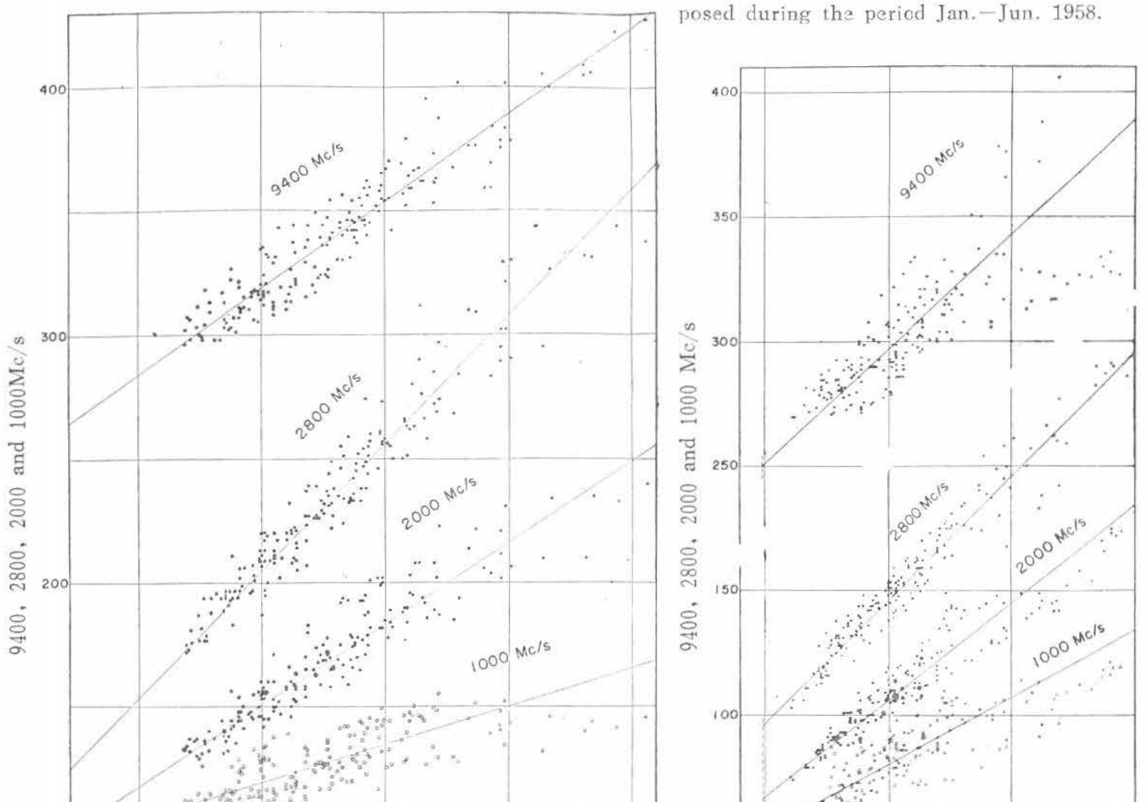

Fig. 4. Plot of daily values at 9400, 2800, 2000 and 1000 Mc/s versus those at 3750 Mc/s (a) near the sunspot maximum Jan.—Jun. 1958, (b) at the slope of the solar cycle Jul.—Dec. 1960 and (c) near the sunspot minimum Jan.—May 1963.

tween two quantities. The values of flux density corresponding to zero sunspot activity will give the B component at this period. Generally we can get a better correlation from the sunspot area than the sunspot number. Two examples of this method are shown in Fig. 2. The values of flux density at 3750 Mc/s is plotted against the values of sunspot area observed in U. S. S. R.[10] when the sun was at its maximum activity and on the decline.

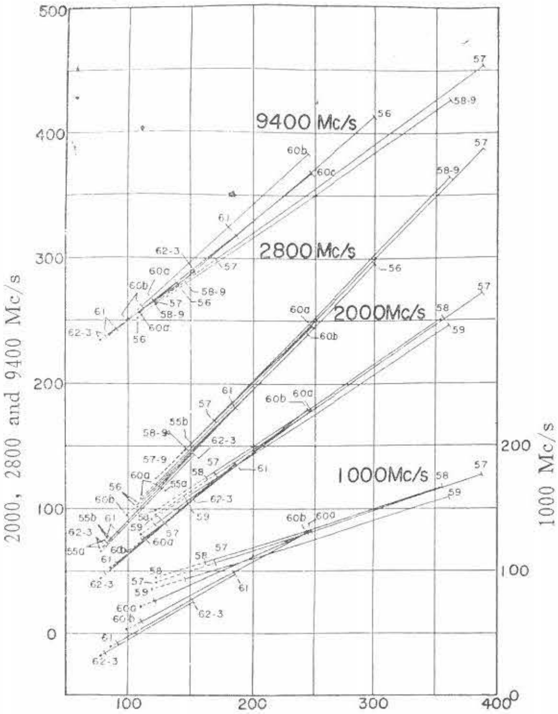

Fig. 5. Statistical correlation lines between 3750 Mc/s and the other frequencies. Estimated basic levels are plotted on the extension of each lines which are limited by the maximum and minimum values at 3750 Mc/s. 60a means, for example, the period Jan.—Jun. 1960 and b means the period of Jul.—Dec..

With the aid of interferometric observations, on the other hand, we can estimate the level of B component in a more direct way; the lower envelope of the superimposed daily drift curves will correspond to the B component. We must be careful, however, to keep the drift speed and the sensitivity constant as far as possible. An example is shown in Fig. 3, where the drift curves are used taken by an 8-element interferometer at 4000 Mc/s.

The values of B component obtained from these two methods coincide with each other within the accuracy of several percent. The values obtained from the interferometric method are plotted on the lower part of Fig. 1 (a), which are connected smoothly to give the variation of B comonent during the solar cycle. We must note here that the brightness distribution on the solar disk is assumed to be quite similar at 3750 and 4000 Mc/s.

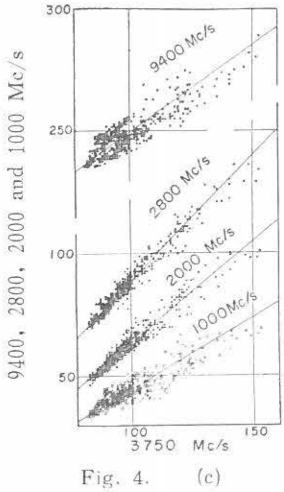

Fig. 4. (c)

To estimate the B component of the other frequencies, a correlation method is used. On a correlation line taken from a scatter diagram between a certain frequency and 3750 Mc/s, we can fix the level of B component of that frequency referring to that of 3750 Mc/s. The actual process is shown in Figs. 4 and 5 which will be explained later. For 9400 Mc/s, interferometric method is also available after 1959. We have confirmed, however, that the values obtained from these two methods coincide within the accuracy of 3 or 4 percent. The levels of B component thus obtained are shown as the smooth curves in Fig. 1 (b).

Spectra of the B component at three peculiar intervals, solar maximum, decline and minimum, are shown in Fig. 6 as three curves from the bottom. The lowest one corresponds to the quiet sun level. It was found that the eleven-year change of B components amounts to 3.0, 2.2, 1.56 and 1.13 times the quiet sun levels for 1000, 2000, 3750 and 9400 Mc/s respectively. It has also become clear that the eleven-year variation of the total flux density near 1000 Mc/s is largely due to the change of B component.

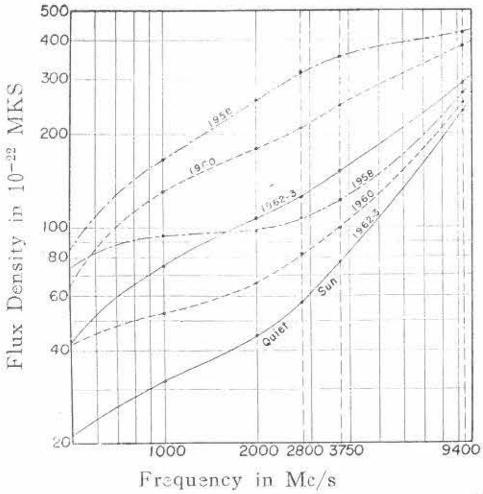

Fig. 6. Spectra of statistical maximum flux density and basic component at three peculiar intervals; Jan.—Jun. 1958, Jul.—Dec. 1960 and Jan. 1962—May 1963. The lowest curve corresponds to the quiet sun level.

4. Slowly varying component

Many works have been done for these several years on the S component by using the eclipse and interferometric observations. But most of the research were made using the data at a certain phase of the solar cycle, so that it would be useful to study the change of the spectrum of S component statistically in terms of the solar cycle.

To study the spectrum of S component, it would be necessary to draw correlation diagrams among the values of respective frequencies. In this procedure, it would be convenient to make the values of one frequency as a standard. We know that the values of 3750 Mc/s have good correlation with sunspot area and, what is more important, the slope of correlation changes little during the solar cycle as is shown in Fig. 2. This shows that if we take the values of 3750 Mc/s as a standard, it would have the similar meaning statistically as taking the values of sunspot area as a standard so far as the S component is concerned. The flux density of 170 units at 3750 Mc/s corresponds to the sunspot area of 6000×10^{-6} solar disk area.

Since it is too much trouble to show all of these correlation diagrams, we have selected only the three intervals representing sunspot maximum, decline and near the minimum. These are shown in Fig. 4. For all the periods available, only the correlation lines obtained from scatter diagrams are summarized in Fig. 5. In this figure the levels of B component are also plotted by a menthod mentioned in the previous section. The slope of these lines corresponds to the flux density against a certain value of 3750 Mc/s or the sunspot area. The variation of this slope during the solar cycle is given in Fig. 7. Fig. 8 is the spectral presentation of the S component at three phases of the solar cycle and Fig. 9 shows the spectra of S/B ratio normalized by taking S/B ratio at 3750 Mc/s as unity. Furthermore, the spectra of the statistical maximum flux density taken from Fig. 5 are shown in Fig. 6 for the same period.

In these figures, the values of 2800 Mc/s taken at the National Science Council, Ottawa are also used, but the factor of 0.87 is tentatively multiplied to make the quiet sun level consistent.

From these figures, following features have become clear.

(1) The correlation is best between 3750 and 2800 Mc/s. This is striking if we consider the difference of observation time as well as the different way of tabulation; the post burst increase is included in the S component at 3750 Mc/s while not at 2800 Mc/s. Indeed a slight difference of S components appears near the sunspot minimum between two frequencies as shown in Fig. 7, but they are remarkably parallel for a

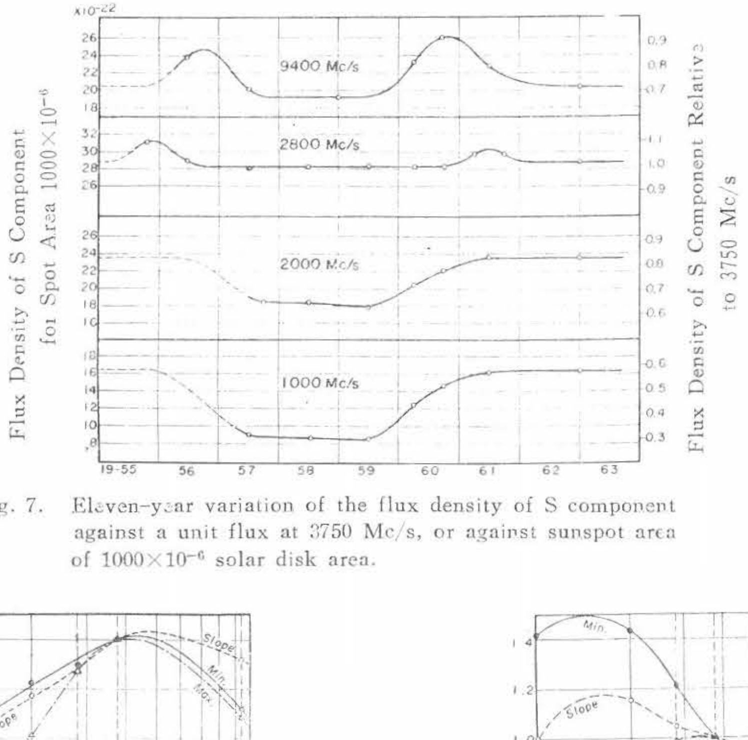

Fig. 7. Eleven-year variation of the flux density of S component against a unit flux at 3750 Mc/s, or against sunspot area of 1000×10^{-6} solar disk area.

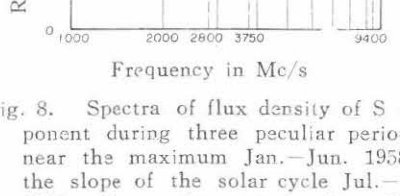

Fig. 8. Spectra of flux density of S component during three peculiar periods; near the maximum Jan.—Jun. 1958, at the slope of the solar cycle Jul.—Dec. 1960 and near the minimum Jan. 1962—May 1963. The values are normalized by taking 3750 Mc/s as a standard.

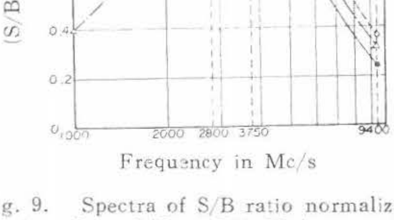

Fig. 9. Spectra of S/B ratio normalized by taking S/B at 3750 Mc/s as unity. Periods are the same as in Ftig. 8.

complete solar cycle. The gradual change of the ratio of daily values between two frequencies during the solar cycle[5][11] should be attributed to the change of the ratio of B components. This change, however, has an important meaning when taking the correlation with the temperature of upper atmosphere, which has been extensively studied by Nicolet.[11] The correlation between 3750 and 2000 Mc/s has become much better than was supposed from the data before the correction. The correlation between 3750 and 9400 Mc/s is not good even by taking into account the handicap of small percentage variation of flux density as shown in Fig. 9. The scatter is pronounced especially at the slope of the solar cycle.[12] This is connected with the fact that

(2) the values of flux density at 9400 Mc/s becomes relatively strong at the slope of the solar cycle. We cannot help recalling here the fact that the great bursts which produce the unusual increase of cosmic rays are concentrated also at the slope of the solar cycle. We can imagine that the spectrum of S component is connected with a certain activity of an active region which is liable to produce great bursts. Anyway, the possibility of forecasting a great burst is suggested and further study by interferometers is considered to be quite valuable.

(3) We have pointed out at the sunspot maximum that the maximum flux density of S component appears near 5000 Mc/s. This is true for almost all the period of solar cycle though the spectrum has the tendecy of becoming flat above 4000 Mc/s at the slope of the solar cycle as shown in Fig. 8.

(4) The S component at 1000 Mc/s is relatively small near the sunspot maximum as shown in Fig. 8 in contrast with a remarkable increase of the B component. This is the cause of a striking change of the spectrum of S/B ratio during the solar cycle as shown in Fig. 9. The influence of the sunspot will decrease at this frequency due to the increase of eleatron density in the corona.

5. Acknowledgement

This work is based on a patient and careful observation for a very long period by all the members of the Radio Astronomy Section so that thanks are due to all of them, but especially to Mr. Torii who has kept the equipment always in a good condition. The author must add his thanks to Dr. T. Kakimuma for his valuable discussions and to Mr. T. Takayanagi and to Misses M. Agata and K. Kondo for the preparation of this paper. Finally the author wishes to thank Director A. Kimpara for his unceasing encouragement.

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Table 1. Revised flux density at 9400 Mc/s for the period May 1956 – June 1957.

	1956								1957					
Date	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1	294	291	294	317	322	321	350	347	371	322	318	333	295	328
2	—	292	288	318	316	335	347	350	395	324	326	333	304	328
3	295	310	290	311	312	344	347	366	433	324	312	324	308	328
4	294	298	293	312	318	358	356	385	439	314	310	321	311	320
5	292	294	292	317	321	368	367	387	412	315	316	312	322	316
6	294	304	292	316	354	346	385	396	416	328	316	304	313	313
7	292	298	300	322	364	339	388	384	388	331	322	307	318	321
8	301	292	310	329	361	334	389	384	374	328	319	323	323	
9	300	286	311	331	349	338	—	383	350	331	322	331	336	
10	313	284	309	324	357	336	383	390	339	324	322	323	324	
11	307	283	307	317	364	333	372	395	331	331	328	318	326	
12	318	289	308	317	354	336	382	383	334	330	331	312	323	
13	330	290	—	313	372	333	370	369	334	328	329	311	335	
14	318	290	300	318	364	333	365	374	328	328	329	309	341	
15	—	298	300	316	350	321	365	373	329	321	322	318	340	
16	297	307	302	309	354	313	378	384	333	318	316	327	336	
17	296	298	297	310	344	309	398	415	321	314	320	333	336	
18	301	293	289	318	339	307	391	379	324	324	316	328	323	
19	301	300	292	322	333	313	380	374	342	317	323	330	321	
20	300	307	291	321	322	324	366	398	355	310	326	331	313	
21	307	324	296	345	322	318	374	368	354	310	330	321	324	
22	293	324	312	342	323	324	361	368	349	330	333	318	322	
23	290	313	336	344	327	316	342	390	381	329	324	326	320	
24	292	—	326	339	327	318	333	368	382	327	321	337	315	
25	295	311	326	339	314	321	337	374	391	324	318	323	316	
26	301	297	315	346	315	318	339	390	390	327	315	337	315	
27	—	287	310	350	309	329	341	381	400	324	319	321	304	
28	300	285	303	336	307	341	342	373	357	322	317	316	304	
29	315	293	308	345	306	346	345	379	338		314	305	302	
30	313	298	310	342	309	343	343	370	331		326	301	300	
31	293		326	327		346		366	333		328		324	
MEAN	301.5	297.9	304.4	326.4	334.3	331.1	363.4	378.9	363.0	323.4	321.6	321.1	319.2	

Table 2. Revised flux density at 2000 Mc/s for the period August 1957–December 1961.

	1957					1958								
Date	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	137	191	183	217	202	202	140	142	235	192	160	159	207	190
2	143	183	186	211	209	208	150	145	234	194	160	160	192	197
3	136	179	179	202	209	203	153	154	221	196	170	161	189	196
4	132	174	172	196	203	199	159	158	212	195	175	166	170	183
5	131	166	168	188	206	202	165	166	207	202	182	167	163	169
6	129	160	167	183	199	193	178	175	202	190	182	165	164	153
7	129	159	172	178	192	188	182	178	204	177	171	176	169	152
8	128	163	179	175	185	192	188	184	189	174	165	166	168	151
9	127	163	184	174	179	193	179	184	182	163	170	155	167	161
10	128	172	192	179	167	195	178	178	179	157	167	151	157	168
11	126	196	199	184	166	200	175	172	163	150	169	146	158	177
12	126	187	201	193	162	208	174	169	147	146	163	139	162	187
13	125	182	200	189	163	214	170	166	135	145	158	130	158	199
14	130	185	196	187	170	231	159	166	130	141	153	128	158	200
15	133	177	199	197	169	222	152	157	132	137	145	127	157	202
16	141	178	199	188	176	223	146	152	138	136	136	126	158	193
17	153	183	197	180	198	208	144	150	148	140	129	129	153	185
18	158	187	197	178	203	201	136	147	150	138	126	122	157	183
19	153	197	206	177	213	193	134	146	163	142	131	135	163	173
20	150	208	213	183	223	194	133	159	168	144	132	144	165	168
21	143	220	197	195	247	183	133	162	171	144	135	142	167	165
22	137	215	195	206	256	180	132	177	169	148	148	145	177	162
23	139	201	201	211	274	171	131	185	172	150	157	152	184	162
24	143	192	201	213	264	156	146	187	171	153	160	157	177	158
25	147	187	192	202	271	154	158	186	175	155	165	167	188	157
26	147	181	192	191	274	153	158	194	176	156	169	173	193	152
27	152	190	205	191	269	156	146	206	177	155	165	180	182	152
28	161	189	223	190	241	144	141	210	185	148	166	213	178	162
29	166	182	234	197	225	140		210	189	156	160	208	177	163
30	172	184	237	202	215	137		233	190	156	156	204	186	162
31	195		229		208	137		240		158		202	189	
MEAN	142.5	184.4	196.6	191.9	210.9	186.5	155.0	175.4	177.1	159.3	157.5	157.9	172.0	172.7

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
				1959										
1	166	162	185	168	148	134	170	150	127	142	150	200	111	123
2	165	172	183	172	149	129	168	139	133	132	157	198	109	123
3	167	165	172	183	151	127	155	136	135	130	162	180	107	121
4	161	162	172	192	149	132	150	134	135	132	164	171	109	116
5	147	160	174	200	144	129	141	129	136	130	154	160	115	114
6	143	155	177	208	147	134	139	132	140	132	157	145	124	117
7	141	150	177	202	146	134	143	142	140	134	154	141	123	118
8	139	142	182	192	135	138	148	160	141	135	149	140	117	125
9	140	134	186	194	134	142	156	176	156	146	144	141	112	135
10	148	133	187	188	134	146	160	188	160	170	144	143	106	138
11	152	126	187	181	137	143	160	198	163	139	146	141	106	141
12	159	124	186	172	149	139	161	185	157	157	141	138	106	140
13	166	125	183	165	141	145	155	184	153	178	144	132	109	138
14	170	131	179	157	146	150	152	175	154	189	146	138	106	141
15	168	127	173	150	149	159	143	164	173	175	138	132	114	137
16	179	133	167	146	149	169	139	156	160	188	140	126	121	132
17	201	133	151	149	157	174	138	156	160	185	150	125	127	124
18	214	133	144	163	159	179	137	154	163	169	158	128	130	122
19	207	138	141	185	158	189	138	146	166	168	149	129	127	115
20	200	138	139	201	157	197	142	144	161	151	152	137	132	114
21	197	145	144	217	158	201	148	141	159	139	156	140	130	115
22	187	151	148	220	160	197	145	145	156	132	164	141	134	125
23	177	157	153	230	154	183	157	145	159	129	172	142	135	133
24	166	165	158	232	152	178	163	143	163	130	178	138	132	146
25	152	174	170	227	152	178	164	142	163	125	180	134	132	156
26	—	181	175	219	153	174	165	143	160	128	181	131	132	158
27	152	189	170	213	149	172	164	146	160	134	191	122	130	155
28	151	195	169	206	141	174	160	134	162	140	209	122	130	161
29	153	186	169	195		176	155	127	154	142	215	115	122	167
30	153	193	166	171		175	155	123	143	145	222	114	122	174
31	155		171	157		173		125		148	213		120	
MEAN	165.9	152.6	169.0	188.9	148.5	160.3	152.4	150.4	153.1	147.6	163.9	141.5	120.3	134.1

Date	Dec.	1960 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	164	138	168	106	132	109	117	135	101	98	88	93	100
2	155	137	175	108	128	115	117	141	98	107	85	92	105
3	155	138	174	104	139	120	118	146	92	119	87	95	107
4	154	143	163	104	141	113	115	142	91	109	91	101	116
5	152	149	157	107	154	109	122	152	90	106	98	102	123
6	151	159	150	106	132	110	130	139	90	108	102	107	121
7	150	158	142	112	121	112	133	129	92	117	106	113	119
8	137	164	136	107	111	115	133	122	101	126	110	121	119
9	135	161	138	106	108	118	132	128	107	130	114	122	117
10	128	152	138	102	108	121	129	125	116	136	118	131	114
11	134	139	131	100	113	127	129	113	130	135	124	146	113
12	127	148	124	98	117	126	132	108	145	139	123	134	109
13	124	131	122	97	129	—	125	106	154	143	123	129	101
14	122	128	123	98	129	125	125	101	166	144	121	142	99
15	121	129	120	101	132	116	124	105	172	142	120	143	98
16	121	134	119	103	134	111	119	106	175	143	118	126	97
17	123	139	113	102	129	105	116	111	170	142	114	117	91
18	123	132	112	101	128	112	107	111	174	143	112	112	86
19	132	131	106	101	126	109	98	108	173	148	111	111	83
20	138	130	107	103	126	109	98	111	158	145	109	108	83
21	144	127	108	106	125	109	94	114	149	145	105	106	82
22	136	130	108	109	121	110	94	112	149	139	101	93	79
23	126	133	107	114	126	110	96	110	126	134	99	89	75
24	134	145	107	115	126	110	96	110	120	129	97	86	74
25	124	164	108	114	121	109	101	108	116	120	93	80	79
26	120	174	113	118	113	109	110	109	111	116	90	79	84
27	126	180	113	130	105	110	125	110	108	107	89	84	88
28	127	182	113	124	107	115	130	109	100	101	89	85	90
29	128	178	110	135	117	120	133	108	95	93	89	86	98
30	136	179		137	109	122	136	106	93	91	88	90	106
31	134	172		132		123		105	97		91		110
MEAN	134.9	148.5	127.8	108.6	123.6	114.3	117.8	117.4	124.5	125.2	103.4	107.4	98.9

1961

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	118	91	73	84	87	61	70	64	78	74	62	81
2	125	90	72	79	85	61	72	62	81	73	61	82
3	124	89	73	74	81	63	73	62	81	75	60	86
4	114	87	72	74	78	63	73	63	82	78	62	84
5	110	85	68	74	76	62	72	63	84	81	63	75
6	105	84	67	74	74	62	73	65	87	80	65	75
7	99	84	68	73	70	62	76	67	85	77	68	74
8	95	80	67	72	68	64	76	72	86	75	71	71
9	90	78	66	69	67	66	78	79	90	78	73	66
10	85	77	65	69	68	72	84	87	97	80	74	64
11	81	73	65	67	68	75	95	94	100	82	75	60
12	76	71	64	63	70	79	94	96	97	83	71	59
13	72	69	63	63	69	81	94	96	96	81	69	57
14	69	68	67	66	68	84	96	94	103	79	65	57
15	68	67	67	69	67	90	97	95	105	76	62	58
16	71	68	67	74	64	95	97	94	102	73	58	57
17	74	68	71	76	65	96	99	92	96	72	57	57
18	72	68	72	78	66	97	97	86	89	72	56	57
19	72	67	73	78	72	101	90	83	82	71	55	59
20	73	68	75	77	75	102	92	80	75	68	57	62
21	75	69	77	76	77	103	89	77	70	66	58	64
22	74	73	78	76	78	104	87	73	68	64	60	69
23	75	74	81	76	80	99	90	70	69	62	59	77
24	76	75	86	79	78	93	88	68	72	60	61	81
25	77	75	91	81	78	85	85	67	73	60	64	81
26	78	76	90	84	75	77	82	67	73	61	69	81
27	81	75	91	86	71	73	80	67	76	60	73	78
28	86	74	94	86	68	69	77	68	76	61	73	77
29	93		95	88	66	69	73	71	74	61	76	76
30	97		94	87	64	70	68	74	73	63	81	73
31	95		92		62		64	76		63		69
MEAN	87.1	75.8	75.6	75.7	72.1	79.3	83.3	76.5	84.0	71.3	65.3	69.9