SEA AND HISS ASSOCIATED WITH GREAT BURSTS OF SOLAR RADIO EMISSION IN NOVEMBER 1960

I. Solar Radio Emission, by Haruo TANAKA.
II. Mode IV Sudden Enhancement of Atmospherics, by Tetsuo KAMADA.
III. Hiss, by Jinsuke OUTSU and Akira IWAI.

Abstract—On 11th, 12th, 14th and 15th November 1960, very intense outbursts of Solar radio emission occurred successively. Three of these, except the one on 12th, were observed at Toyokawa on a frequency region from 9.4 Gc/s to 1000 Mc/s. Each of these is a composed burst composed of 1st and 2nd phase of cm wave burst and dm wave burst. It was found that the source of polarized component at 9.4 Gc/s moved appreciably during the 2nd phase of cm wave burst, though the center of brightness was left unmoved. This phenomenon suggests the existence of two different kinds of emission mechanisms on cm wavelength region.

Mode IV SEA was clearly observed at three frequencies of 10, 21 and 27 Kc/s on 11th, 14th and 15th November. It seems quite probable that SEA is closely correlated with the flare or the 1st phase of cm wave burst and not with the other parts of the burst at microwave frequencies. The type of SEA seems to be largely connected with the shape of intensity variation of cm wave burst. The duration of SEA seems to be proportional to the intensity of the flare. The lower the frequency, the later the time of maximum, which can be explained by the difference of time necessary to reach the state of saturation of reflection coefficient in D region. The turn-over frequency of positive and negative enhancement seems to be indefinite and to lie within 14–18 Kc/s.

Associated with these solar radio bursts, a generation of several series of hiss was confirmed at Wakkanai for the first time. The first series commenced at 1120 on 13th, lagging about 56 hours after the first burst. The second series, though uncertain, occurred intermittently from 1220 to 2350 on 15th. These observations indicate that the hiss is detectable at latitudes as low as about 35 degrees during a period of high sunspot activity.

I. Solar Radio Emission by Haruo TANAKA

On 11th, 14th and 15th November 1960, very intense outbursts were observed at Toyokawa station on a frequency range from 1000 Mc/s to 9.4 Gc/s. Fig. I–1's are the spectral diagrams of the bursts combining single-frequency observations available in Japan; observations at 800, 408, (200), 160, 100 and 67 Mc/s are by courtesy of Dr. Takakura of Tokyo Astronomical Observatory and observations at 200 Mc/s are by courtesy of Dr. Hakura of Hiraiso Radio Observatory. Fig. I–2's show the degree of polarization during the bursts at four frequencies and Figs. I–3's and I–4 show the results of interferometric observations at 9.4 Gc/s (16 elements) and 4 Gc/s (8 elements).

According to our classification (page 39), each of these bursts seems to have the following feature on microwave frequency range.

Date	Time (U. T.)	Type
11	0315-0410	1st phase of cm wave burst
	0410-0540	2nd phase 〃
	0340-	dm wave burst
14	0250-0423	1st phase of cm wave burst
	0423 0620	2nd phase 〃
	0258-0430	dm wave burst
15	0210-0320	1st phase of cm wave burst
	0320-0420	2nd phase 〃
	0300-	dm wave burst (The frequency of maximum intensity comes down to as low as 200 Mc/s)

The 1st phase of cm wave burst is characterized by an increasing intensity towards high frequency and is well associated with the flare.

Dm wave burst is characterized by a large degree of polarization and a comparatively large variability. The polarization has an opposite sense to that of the cm wave bursts.

The 2nd phase of cm burst has its peak intensity near 3000 Mc/s and its spectrum is similar to that of the S component. It is separated here from the 1st phase because it does not seem to be well associated with the flare. Furthermore, it has been found that the source of polarized component at 9.4 Gc/s moved appreciably during this phase of cm wave burst, as may be seen in Fig. I-3's. The position of the source of polarization at the 2nd phase seems to coincide with that of the S component from the drift curve on the 8th, when bipolar nature of this radio spot was clearly visible. These data suggest that this phase of cm wave burst may correspond to an emission mechanism similar to that of the S component, though it is still uncertain from these few examples. The brightness temperature at this phase is calculated to be 4.7, 7.0 and 5.1 x 10^7 °K for the bursts on 11th, 14th and 15th respectively.

Fig. I-1-a

Spectral diagrams of the bursts combinig single frequency observations at three stations in Japan.

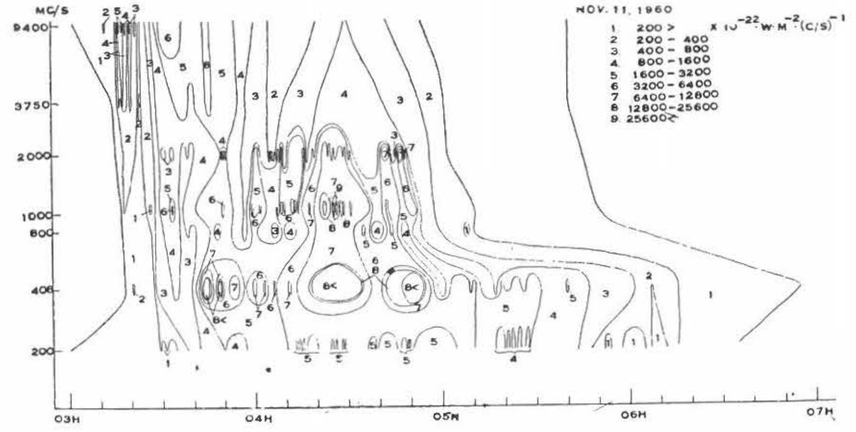


Fig. I-2-a

Variation of polarization during the bursts in percent.

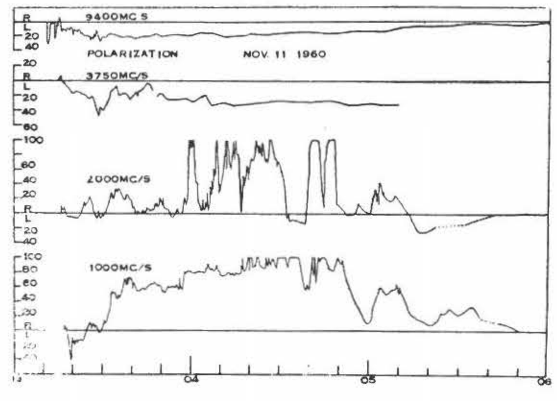


Fig. I-3-a

Position and effective size (uniform square disk) of the sources of bursts including the position of the sources of left-hand polarization at 9.4 Gc/s. Right-hand components were not observed on drift curves.

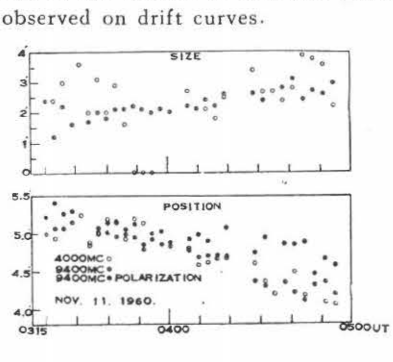


Fig. I-1-b

Spectral diagrams of the bursts combining single frequency observations at three stations in Japan.

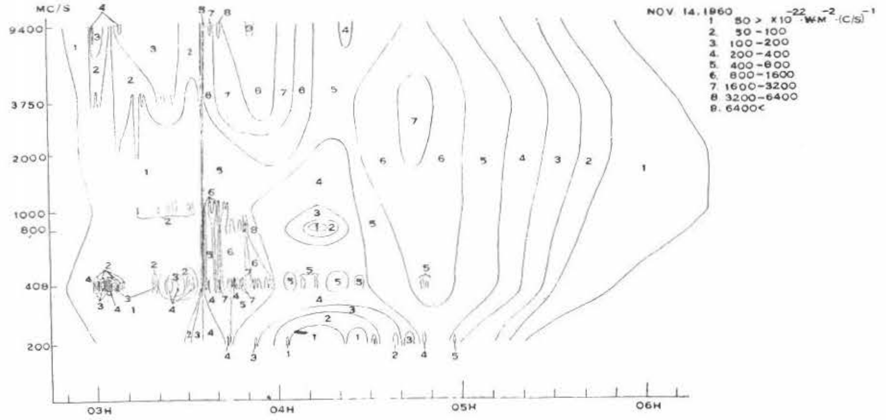


Fig. I-2-b

Variation of polarization during the bursts in percent.

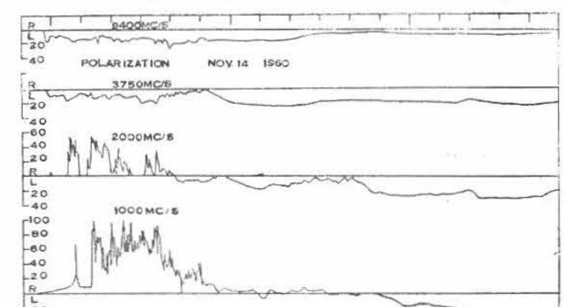


Fig. I-3-b

Position and effective size (uniform square disk) of the sources of bursts including the position of the sources of left-hand polarization at 9.4 Gc/s. Right-hand components were not observed on drift curves.

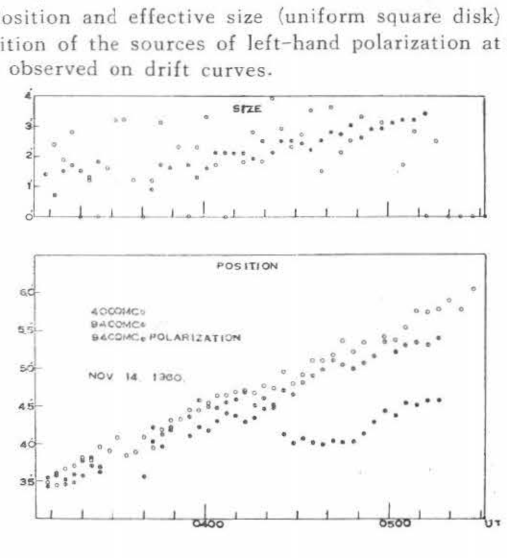


Fig. I-1-c

Spectral diagrams of the bursts combining single frequency observations at three stations in Japan.

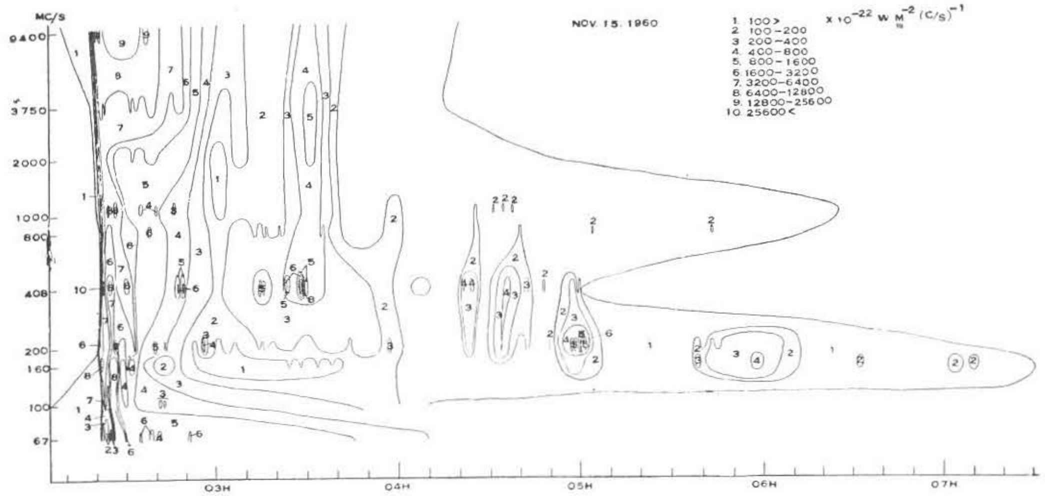


Fig. I-2-c

Variation of polarization during the bursts in percent.

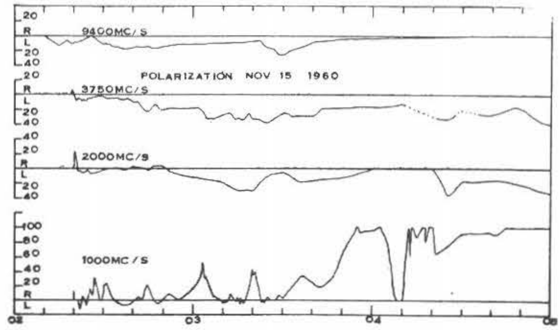


Fig. I-3-c

Position and effective size (uniform square disk) of the sources of bursts including the position of the sources of left-hand polarization at 9.4 Gc/s. Right-hand components were not observed on drift curves.

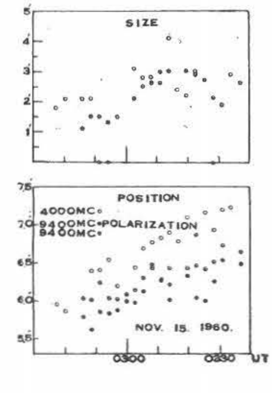
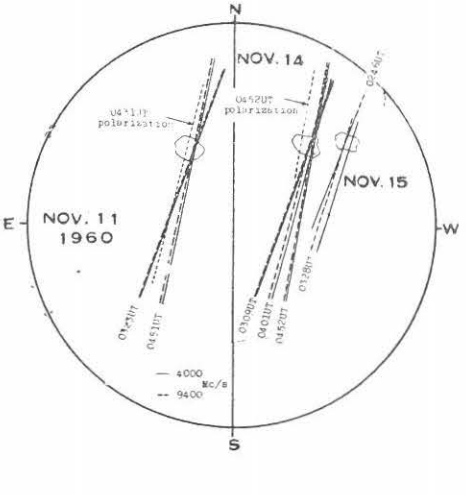


Fig. I-4

Position lines of the bursts.



II. Mode IV[1] Sudden Enhancement of Atmospherics

by Tetsuo KAMADA

1. Introduction

Solar flares generate various ionospheric phenomena known as sudden ionospheric disturbances (SID). These include sudden enhancement of atmospherics (SEA), sudden phase anomalies (SPA) and partial or complete fade-out of radio-reflections on medium and short waves. According to Friedman and Chubb (1955)[3], and Nicolet and Aikin (1960)[2], and others, the enhancement of ionization responsible for SID occurs in D region and is produced by short-wavelength X-ray originating in the flare. This X-ray radiation of wavelengths 1-2A is able to ionize the atmosphere near the base of D region without affecting the higher ionosphere.

This report describes some evidences to corroborate these theory mentioned above, which are obtained from Mode IV SEA data on 11th, 14th and 15th, Nov., 1960.

Mode IV SEA is a mode of SEA named by the author for the change of intensity where both 27 and 21 Kc components increase (positive SEA) and 10 Kc component decreases (negative SEA) suddenly.

On the assumption that the 1st phase of cm wave burst is closely correlated with solar flare, the correlation between SEA and SRO is examined in detail and some phenomenal evidences are obtained to indicate the condition in the disturbed D region.

2. Observational Results.

2-1. 11th, Nov., 1960

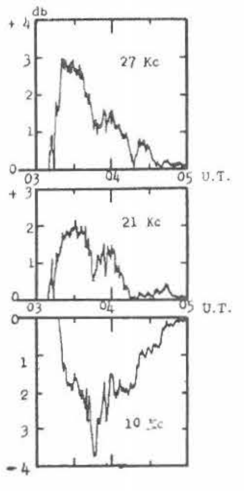
The Mode IV SEA was observed about 03.00 U. T.. The sketch of intensity variation during SEA observed at three frequecies is shown in Fig. 1.

Abnormal radiation of SRO is divided roughly into two group-bursts which are reported in this Proceeding (See the solar noise section) as cm wave burst and dm wave burst.

The occurring time of some corresponding points between SRO and SEA are tabulated in Table 1.

Fig. II—1 Mode IV SEA in 11st, Nov., 1960

Table. II—1 Corresponding points between SRO and SEA



Nov· 11 1960

Freq	A (U.T.)	B (U.T.)	C (U.T.)
MC 9400	0314	0316	0317.2
3750	0314.5	0316	0317.3
2000	0315	0316	0318
1000	0317	0317	0317.5
(KC) 27	0315	0317	0320
21	0315	0317	0320
10	—	0318	0322

From Table 1., the starting time of SEA averages about 0.5–1 minutes later than that of SRO. But as this difference is within the error of the chronometry of SEA records, the starting time of both SRO and SEA may be considered as the same. The time of the first maximum on SEA averages about 3–5 minutes later than that of SRO. This time difference is so significant to indicate that it seems to be proportional to the time needed for the increase of the reflextion coefficient to these three frequency components observed during disturbances. A detail discussion is described in a later section.

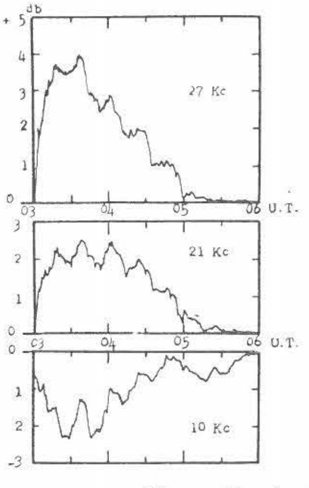
Looking over the data carefully, it is found out both positive and negative SEA's occur at the time corresponding to the initial stage of SRO and are determined by their general situation by this stage. At the next stage of cm wave burst, in spite of the powerful burst continued, 27 and 21 Kc components begin to start towards the normal level, while 10 Kc component keeps decreasing more and more in the first half of this stage and then begin to start towards the normal level.

These facts may be considered to indicate that the increase of reflextion coefficient to these three frequency components in the D region reaches near the state of being saturated at the initial stage of cm wave burst and tends towards recovery in spite of succesive agitations. The discussion of this point is explained later.

No clear corresponding points can be found between SRO and SEA for the stage of dm wave burst.

2–2. 14th, Nov., 1960

Fig. 2 shows the pattern of the Mode IV SEA occurred on this day. Abnormal radiation of SRO is also divided roughly into two-groups such as seen on 11th, Nov., (See the report of solar noise section). The occurring time of some corresponding points between SRO and SEA is tabulated in Table 2.



Nov. 14 1960

Freq	A (U.T.)	B (U.T.)	C (U.T.)	D (U.T.)
(MC) 9400	0258	0259.5	0336	0351
3750	0258	0259.4	0335.2	0354.7
2000	0257	0259.4	0336	0358.5
1000	0259	0301.8	0336	—
(KC) 27	0300	0303	0337	0400
21	0300	0303	0338	0401
10	0300	0303	0337	0402

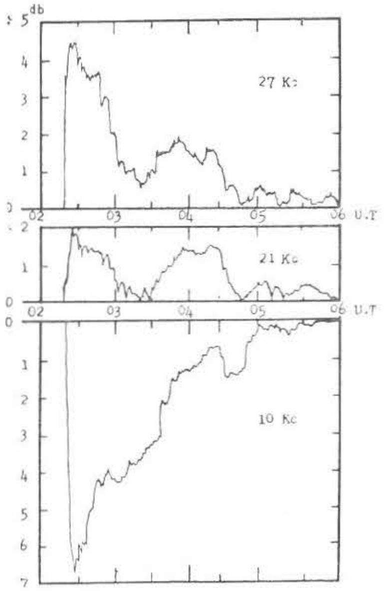
Fig. II—2 Mode IV SEA in 14th, Nov., 1960
Table. II—2 Corresponding points between SRO and SEA

A similar tendency to differ, as in the case of 11th SEA, is seen both in the starting time and the time of maximum between SRO and SEA. The ways of variation of SEA connected with both cm and dm wave bursts are also similar to that of the case of 11th, Nov..

2–3. 15th, Nov., 1960

Typical Mode IV SEA is observed about 02. 00 U. T. on this day. The intensity of SRO is the greatest in its order and such a great SRO is a rare occurrence.

A sketch of a pattern of Mode IV SEA is shown in Fig. 3. Abnormal radiation of SRO is also divided roughly into two groups. The occurring time of some corresponding points between SRO and SEA is tabulated in Table 3.



Nov. 15 1960

Freq	A (U.T.)	B (U.T.)	C (U.T.)	D (U.T.)	E (U.T.)
(MC) 9400	0218	0220	—	0246	0247,6
3750	0219	0222	0225.2	0245.6	0247.5
2000	0220	0222.5	0226.5	0245.7	0248
1000	0220	0224	0231.5	0246	0247.6
(KC) 27	0218	0224	0232	0249	0254
21	0219	0224	0233	0249	0254
10	0220	0227	0232	0249	0254

Fig. II—3 Mode IV SEA in 15th, Nov., 1960

Table. II—3 Corresponding points between SRO and SEA

The differences of both the starting time and the time of maximum in SRO and SEA are similar to the case of 11th and 14th. The ways of variation of SEA to cm wave burst are similar to those in the case of 11th and 14th, except that some enhancements are observed on three frequency components of atmospherics simalteneously at the time of dm wave burst. Two factors may be considered responsible for these enhancements ; one is the solar flare and the other is the reception of active sources of atmospherics at a distant place which reception is made possible by the reflextion coefficient rendered good by the enhancement of ionization in D region. According to our latest statistical studies', correlation with SRO is as poor as about 15% for SEA, and also, in this case, the way of enhancement is not the same as in SRO. Then, it may be normal to consider that the cause of enhancement at this time of dm wave burst belongs to the latter, and so the ways of variation of SEA to dm wave burst have the same tendency as that on 11th and 14th.

3. Results obtained and Its Discussions

To make some evidences obtained clear, spectral diagrams are drawn as shown in Fig. II-4.

Compared with the spectral diagrams of SRO shown in the solar radio emission, it is known that;

(1) It is clearly seen that the general situation of SEA is distinguished at the initial stage of the 1st phase of cm wave burst. The cm wave burst is a type of burst which has a greater intensity at high frequency components than at low ones and supposed to

be well associated with solar flare. In other words, SEA has a good correlation with the cm wave burst or with the abnormal X-ray radiations during solar flare.

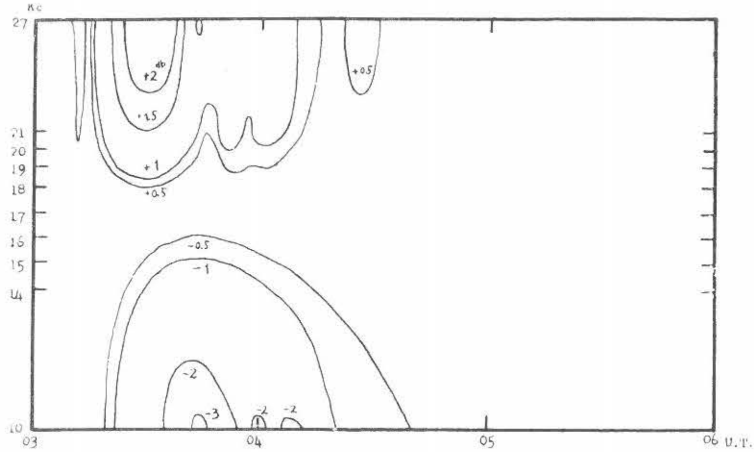


Fig. Ⅱ—4 a—1 Spectrical Diagram of SEA on 11th, Nov., 1960

(2) SEA on 11th and 15th indicated the V Type[1] in all frequency components, but SEA on 14th indicated the U Type at 27 and 21 Kc components and W Type at 10 Kc component. The types of SEA have been classified by the author in former reports[1]. As it is known from the spectral diagrams of SRO that the spectral pattern of the first phase of cm wave burst is differnt in the case of 11th and 15th, and of 14th, the progress of the time distribution of the 1st phase of cm wave burst seems to be a factor in the generation of the types of SEA.

(3) The duration of SEA has a tendency of being controlled by the intensity at the initial stage of flare and cm wave burst, and its length is proportional to the intensity of flare and cm wave burst.

(4) There is a tendency for an earlier starting time in a higher frequency components of atmospherics than in a lower one.

(5) The time of reaching the maximum intensity is different in the three frequency components of 27, 21 and 10 Kc. Taking 27 Kc component as a standard, 21 Kc is 10 minutes later and 10 Kc is 25 minutes later on 11th; 21 Kc is synchronous and 10 Kc is 6 minutes later on 14th, and 21 Kc is synchronous and 10 Kc is 3 minutes later on 15th. These differences of time become shorter from 11th to 15th.

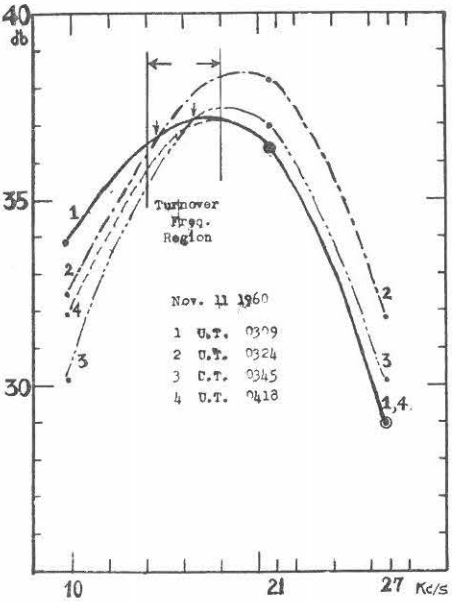


Fig. Ⅱ—4 a—2

Intensity vs Frequency Characteristic at various time of Mode IV SEA.

(6) Seeing the spectral diagrams of SEA on these three days, a movement may be seen for a turnover frequency at which the intensity of atmospherics is unaffected. From Fig. 4., it is supposed that the upper limit of the turnover frequency is about 18 Kc and the lower limit is about 14 Kc.

For discussing the obtained results mentioned above, it is necessary to examine the ionization process in the D region during the solar flare. According to the theoretical

Fig. II — 4 b — 1 Spectrical Diagram of SEA on 14th, Nov., 1960

studies of Friedman and Chubb (1955)[3], and Nicolet and Aikin (1960)[2], the ionization process in the D region during flare is dependent upon X-ray having the wavelength below 10 A. The activity of X-ray becomes readily apparent when energies are between 10^{-6} and 10^{-3} erg cm^{-2} sec^{-1} for the wavelength range 2 to 6 A. A strong flare leads to a very large increase of ionization. There is a general lowering of the layer caused by the increase of the X-ray intensity. When there is a flare activity, the lowering can easily be as much as 5 Km, and during the largest flares, the same electron concentrations are found 10 Km below the quieter sun level. It would require X-ray at 2 A to ionize at 65 Km; at 4 A to ionize at 75 Km and at 6 A to ionize at 85 Km. These wavelegths of X-ray are only observed during strong flares and produce a large increase on the ionization near the respective corresponding altitude.

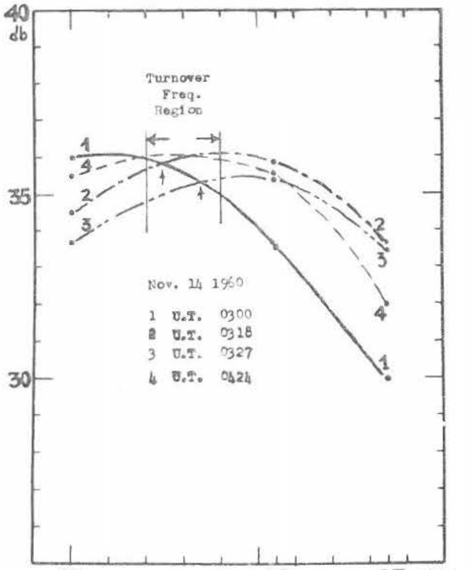


Fig. II — 4 b — 2
Intensity vs Frequency Characteristic at various time of Mode IV SEA.

Then, according to the theoretical results by Wait (1957)[4] for the attenuation vs frequency characteristics of VLF radio waves, the increase of the electron density and the lowering of the layer during solar flares can induce a increase or decrease of the attenuation factor for the frequency components in the range 10 to 30 Kc. Therefore, various modes in SEA may due to the differences in the rate both of the increasing of electron density and of the lowering of the layer, which differences appeared by the volume of radiation and the spectrum of wavelength in solar X-ray radiation. The facts that the time differences appear both in the starting time of each frequency components of 27, 21 and 10 Kc and in the time of reaching maximum intensity are proportional to the intensity of cm wave burst or of flare, seem to indicate some adequate observational evidence for the theoretical analysis mentioned above of the D region.

According to the theoretical calculation by Wait (1957)[4], the turnover frequency appear between 15 and 30 Kc on the VLF ionospheric propagation if either the reflextion

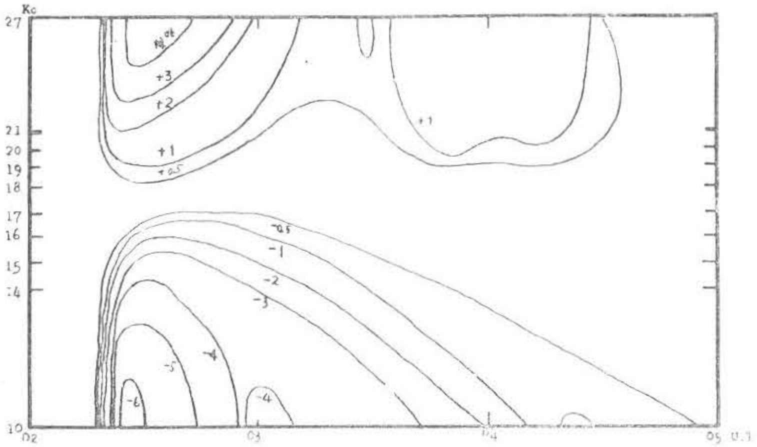


Fig. II — 4 c — 1 Spectrical Diagram of SEA on 15th, Nov., 1960

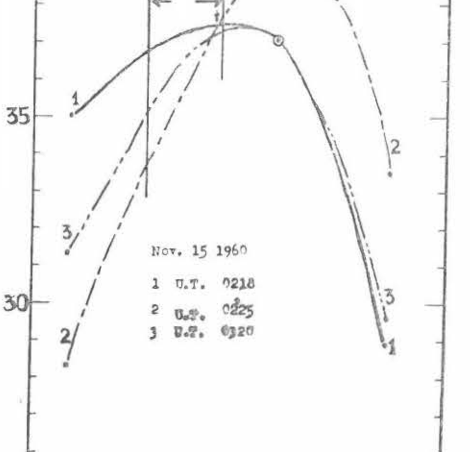


Fig II — 4 c — 2

Intensity vs Frequency Characteristic at various time of Mode IV SEA.

height or the electron density is changed in great degree. However, it is known by the theory of Nicolet that, at the time of great flare, a great change such as a order of 10 times occurs in both electron density and the altitude of reflexion. Then, it may be said that the turnover frequency is determined by the penetrating depth of the X-ray radiation caused by the flare. And as it may be supposed that an X-ray radiation by flare has various wavelengths, the depth of penetration in the D region is various, and so the lowering of layer is also various, and then the movement of turnover frequency may be considered to occur.

4. Conclusions

The investigation of Mode IV SEA appear at the same season shows that the general situation of SEA may be determined by the initial stage of the solar flare, and the modes of SEA correspond to the increasing rate of electron density and to the lowering of the layer caused by X-ray radiation during solar flare. It becomes clear that the observation of SEA is useful to obtained some observational evidences about the abnormal D region.

Acknowledgements

The author is grateful to Dr. Kimpara, director, Dr. Tanaka, chief of the Radio Astronomy Section, and Mr. Otsu for many useful discussions during the preparation of this report. The author wishes also to thank Mr. Nakazima for engaging in the observation and Miss Takeuchi for arranging the observational data.

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4. J. R. Wait : I. R. E. vol. 45. No. 6. p. 768 1957

III. Hiss

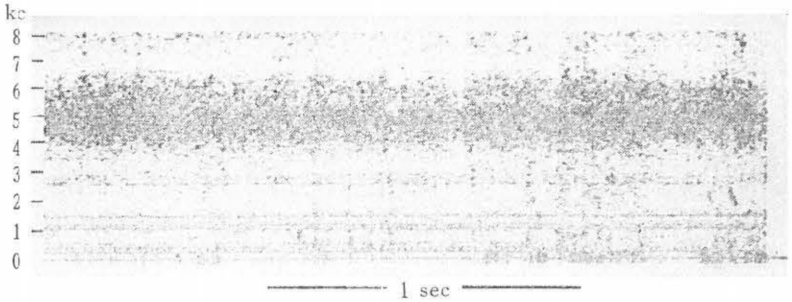
by Jinsuke OUTSU and Akira IWAI

1. Hiss

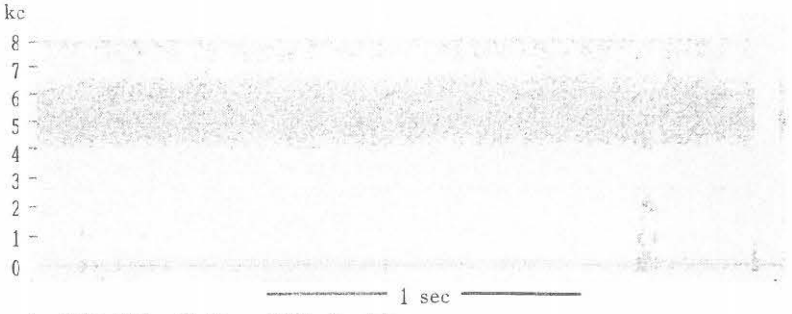
"Hiss"[1,2] is a relatively steady ionospheric radio noise and it has been frequently observed at high latitudes. And during magnetic storms the locations of hiss activity has shifted towards lower latitudes. But so far no hiss has been reported to have been observed at anywhere lower than about forty degrees of geomagnetic latitudes.

As a hiss has frequency components usually at the audio-frequency band, it can be observed with an observing apparatus for whistlers. Though we have continued a two-minute observation of whistlers every half an hour at Wakkanai (geomag. lat. 34°.3) since the commencement of IGY, we have been able to confirm hiss generations only for the first time during the present solar radio noise outbursts.

The hiss occurred two times. The first one was heard at every observation time during 1120 to 2350, 13th Nov., and it reached a maximum activity at 1620, when the intensity was so strong that it could be heard clearly amid interfering noises. Fig. III-1-a shows the result of frequency analysis of the hiss at the maximum activity. The dark parts continuous with time, seen at a frequency range between about 3 kc and 7 kc, are caused by the hiss energy. As the degree of darkness roughly corresponds to the hiss

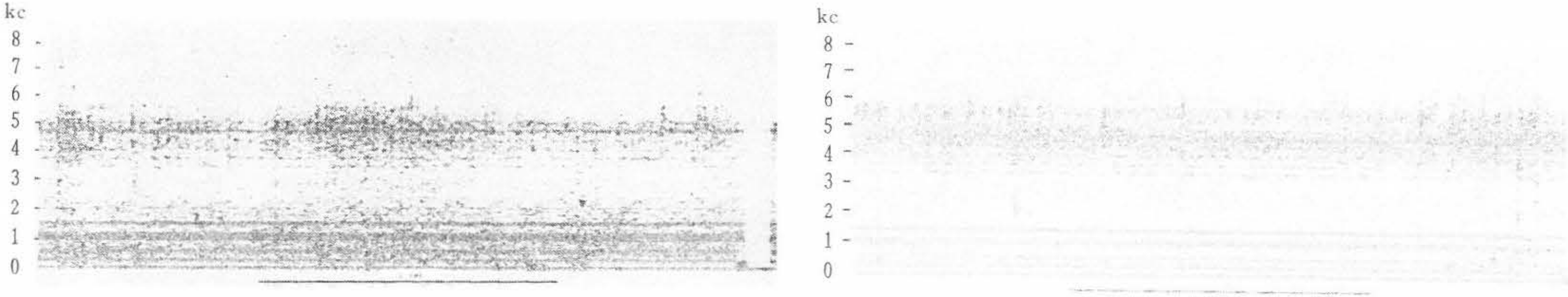


a. 1620 UT., 13 Nov. 1960, Wakkanai



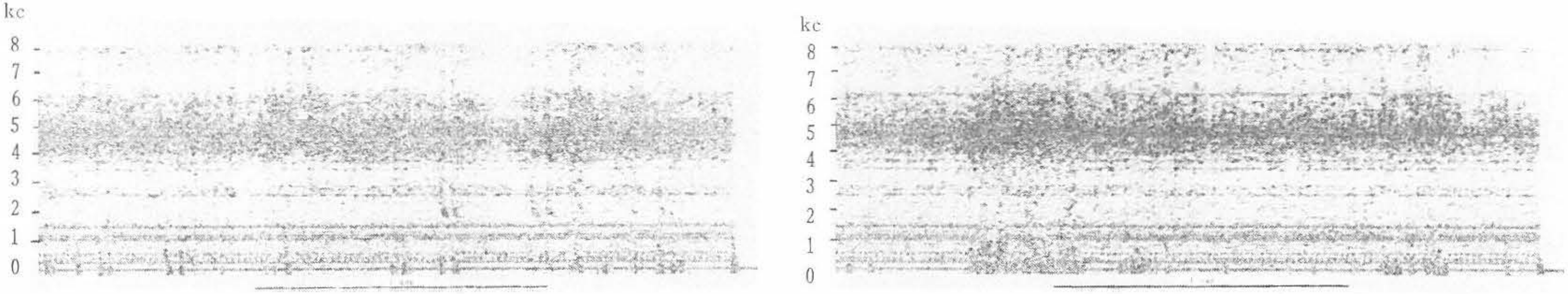
b. 0235 UT., 12 Nov. 1957, Boulder

Fig. III—1 Comparison of frequency spectrum of hiss at Wakkanai with one at Boulder
This is shown in order to indicate that the hisses observed at Wakkanai are undoubtedly real ones.



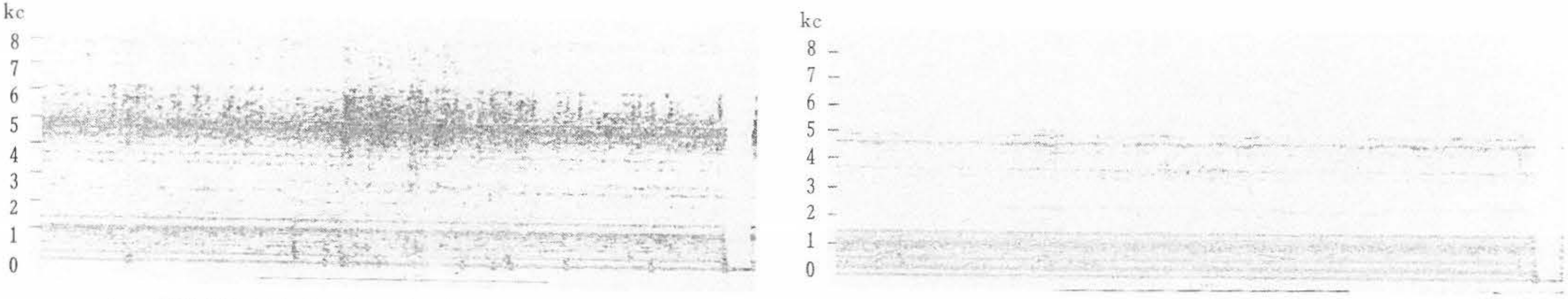
a. 1120 13th Relative intensity 1

b. 1550 13th Relative intensity 3



c. 1650 13th Relative intensity 5

d. 1720 13th Relative intensity 4



e. 2320 13th Relative intensity 2

f. 0020 14th Relative intensity 0

Fig. Ⅲ—2 Some examples of variations in the frequency and intensity of hisses observed at Wakkanai during 1120 13th to 0020 14th, Nov., 1960 intensity, the maximum intensity seems to exist between about 4 kc and 5 kc. Fig. III-1-b also shows a result of frequency analysis of a hiss observed at Boulder (geomag. lat. 49°) at 0230, 12th Nov., 1957. Considering the possible varieties in the nature of the hisses, it is surprising to find that the center frequency, band width and the steady situation with time are very similar in them. And this will be a good evidence that the hisses observed at Wakkanai are undoubtedly real ones. Figs. III-2-a to h show the frequency and intensity variations with time. These figures indicate that when the hisses were weak the remaining frequencies lay between 4 kc and 5 kc. If we assign a relative intensity with a number 0 to 5 as written below the figures, then the intensities at each observation time are as shown in TableIII-1.

TableⅢ—1

U. T.

time min.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0
20	0	1	1	3	3	3	5	4	4	3	3	3	3	2	0
50	0	1	2	3	3	3	5	4	3	3	3	3	2	2	0

Several steady narrow bands seen in these figures were due to man-made noises and they interfered with the detection of hisses by aural means, and especially the noises in the frequency band of the hiss influenced most over weak hisses.

The second hiss generated intermittently during 1220 to 2350, 15th, but as its intensities were generally very weak and even when at the peak they did not exceed 2 in the above intensity index, detections were difficult and doubtful cases might be involved.

Judging from the fact that a hiss was detected only during the nighttime and about 2 hours after sunrise, a hiss is likely to attenuate in the day time just as whistlers do.

We will examine the time differences between the hisses and their causal bursts at 3,750 mc observed at Toyokawa. If we take the burst begun at 1503, 11th (the first burst) for the first hiss generation, the time difference is about 56 hours, while if we take a burst at 2,980 mc commenced at 1332, 12th (the second burst) observed at Holland during the nighttime in our country it becomes about 22 hours. Though we can not conclusively decide which of the two should be taken, the first burst seems rather probable, because it has been reported that a hiss generally occurs during the recovery phase of a magnetic storm. For the second hiss if we take the burst begun at 0219, 15th (the fourth burst) the time difference is ten hours and this is clearly too short to regard the burst as the cause of the second hiss. The lag times of the second hiss after the 2nd burst and 3rd burst commencing at 0253, 14th are about 71 and 33 hours, respectively. As these two values of the time difference look equally probable, we can not come to a definite conclusion.

We do not know the true reason why the hiss generated only two times though the burst occurred four times, and why no corresponding hiss was heard for the fourth burst, the greatest burst of all, but we imagine that a corresponding hiss might have generated during the daytime in Wakkanai, but owing to its high attenuation it could not have been detected, or that the hiss generation depends not only on the intensity but also on the type of bursts, or the location of sunspots responsible for bursts affecting hiss generations. In connection with the third case, it has been found that a great sunspot regarded as the source of the present bursts traversed the solar central meridian during 11th to 12th. Decisive answers to these questions will be got only from statistical investigations after sufficient data have been obtained in the future.

The following are concluded from the present hiss observation at Wakkanai:

a. A hiss will be detectable at geomagnetic latitudes as low as about 34.5 degrees.

b. Intensity of a hiss is sufficient for aural detection at its maximum activity.

c. The observed hiss looks like a hiss at middle latitudes.

d. A hiss generates from about twenty or thirty to seventy hours later than the beginning of a solar burst, but it does not necessarily follow every burst.

e. In the daytime a hiss attenuates just as whistlers do.

Judging from the strong intensity of the present hiss, it seems likely that a hiss might generate in association with several past bursts, but as we had not heard the tone of a hiss, we might have missed it. However, with our present experience, we may expect to have more chances of hiss detection from now on.

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