Proceedings of the Research Institute of Atmospherics,
Nagoya University, vol. 30(1983) －Technical Note－

AN OBSEVATION SYSTEM OF COSMIC RADIO NOISE ABSORPTION BY RIOMETERS USING CORNER-REFLECTOR ANTENNAS

Masanori NISHINO, Yoshihito TANAKA, Yasuo KATOH
and Akira IWAI

Abstract

This report describes the observation system of cosmic radio noise absorption in the ionosphere by Riometers using corner-reflector antennas. Two sets of the corner-reflector antenna for the observing frequencies of 30 and 60MHz were installed at Moshiri Observatory. One antenna set is directed towards the Pole-star and the other in parallel to the earth's magnetic field. An example of preliminary obsrvation results is shown.

1. Introduction

Observations of CNA(Cosmic Radio Noise Absorption) in the ionosphere using a Riometer(Relative Ionospheric Opacity Meter) have been carried out at many ground stations from low to high latitudes for the purpose of detecting absorption events such as PCA, SID and Auroral Absorption. In the auroral region, a sudden enhancement of CNA strong correlates with the occurrence of auroral VLF emissions(Harang,1968). We have installed a VLF observation system with high sensitivity at Moshiri Observatory(lat.44°22'N, long.142°16'E) in 1980 in order to study the generation and propagation of low latitude VLF emissions. Simultaneous observations of VLF emissions with CNA are required for the investigation of the relation between low latitude VLF emissions and CNA. This report describes the observation system of CNA by Riometers using corner-reflector antennas for the observing frequencies of 30 and 60MHz installed at Moshiri Observatory. One antenna set is directed towards the Pole-star of elevation angle of about 44° for the detection of CNA due to the particle precipitation in the geomagnetic storm. The other set is directed in parallel to the earth's magnetic field intersecting Moshiri with elevation angle of about 58° for the detection of CNA due to the energetic particle precipitating along the field line through the wave-particle interaction and also the associated wave excitation in a future active experiment which has a strong LF wave injection from Moshiri into the magnetosphere.

2. Antenna system

2-1. Corner-reflector antenna

Yagi antenna and the two half-wavelength elements separated horizontally by half-wavelength have been generally used for the measurement of CNA in VHF range. Since these antennas are usually directed to the zenith, CNA records have the sidereal time variation. So, at least one year observation of CNA is necessary for obtaining the variation of cosmic background noise. H.Schwentek and E.H.Gruschwitz (1970) used a corner-reflector antenna with a circular polar diagram directing towards the Pole-star in order to avoid the sidereal variations. We also adopted the corner-reflector antenna for CNA observation.

The reflecting sheets of the corner-reflector antenna usually require the dimension of more than one wavelength (λ=10m at 30MHz, λ=5m at 60MHz). It is economically designed to use the vertical sheet of the reflector in common for the two directions, in other words, the antenna system is composed of a bi-directional corner-reflector with three sheets, as shown in Fig.1. Therefore, the corner angles of the corner-reflector antennas are about 90° for the north direction and about 60° for the south direction.

At Moshiri, snow amounts to about 3m deep in winter, so the horizontal sheets must be placed at an altitude higher than 3m above the ground. The height of the vertical sheet is limited below 15m high by the construction cost. Then, the actual length of the three sheets was given by 12m for the frequency of 30MHz.

The antenna-to-corner spacing was given by 0.35λ, though the antenna gain becomes maximum at about 0.4λ for the corner angle of 90°. The gain-pattern of the corner-reflector antenna in the vertical plane perpendicular to half-wavelength element is deduced from the image analyses of the half-wavelength element to the reflecting sheets(Kraus, 1950). In the case of the spacing of 0.35λ and the corner angle of 90°, the calculated gain-pattern of the field intensity is shown in Fig.2a, which gives the half power width of about 44° in the vertical plane. On the other hand, the gain-pattern of the horizontal plane including the element and the corner is supposed to become wider for a single element, so colinear array of two elements separated by half-wavelength in the horizontal plane was adopted. As shown in Fig.2b, the calculated gain-pattern in the horizontal plane is 44°, which is equal to that in the vertical one. So, the directivity of the corner-reflector antenna gives nearly circular polar diagram toward the Pole-star. Hence, the daily variation of the cosmic noise record is expected to be independent of sidereal time.

In the case of the corner-reflector antenna directed to the south at the corner angle of 60°, the antenna-to-corner spacing was given by 0.35λ as well as that of the north directed antenna, though the antenna gain becomes maximum at 0.7λ. The calculated gain-patterns in the vertical and horizontal planes are shown in Fig.3a and b, respectively. The half power width is 32° in the vertical plane and 54% in the horizontal one. So, the directivity of the south directed antenna shows elliptically polar diagram to the direction along the earth's magnetic field.

The length of the reflecting conductor shown by Fig.1 should be equal to or greater than 0.6λ for a single element(Kraus, 1950). The actual length of the reflecting conductor was taken as 25m for the colinear array of the two elements. The reflecting sheet is formed by a grid of parallel wires of 0.4mmϕ stainless steel stretched in the spacing of 25cm between two arms which are placed 25m apart. The spacing of 25cm (0.025λ) is sufficiently less than the allowed length of 0.1λ. Each of the wires is pulled by a spring to reduce the sag. Surface accuracy of the sheet is about 13mm which is about 0.0013λ.

For the corner-reflector antenna at 60MHz, the dimensions of the reflecting sheet and conductor, and the antenna-to-corner spacing were given by one half of that at 30MHz. Fig.4 shows the configuration of

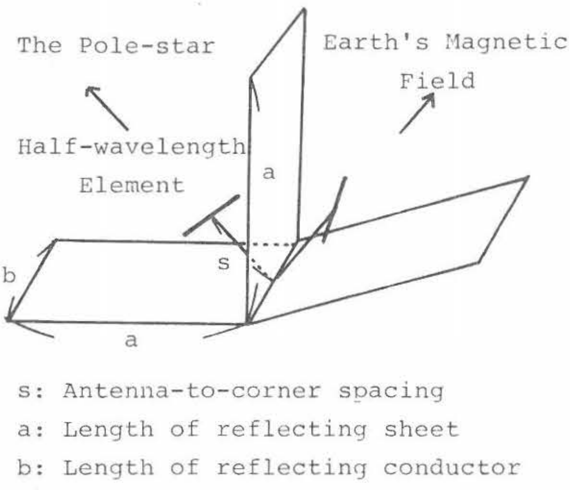

Fig. 1. A bi-directional corner-reflector antenna with three sheets.

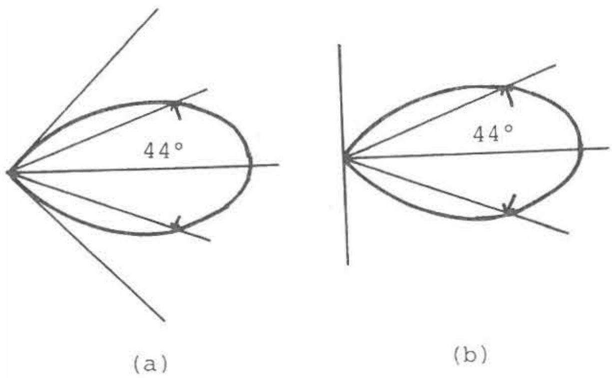

Fig. 2.
Gain-patterns of field intensity in the vertical (a) and the horizontal (b) planes (corner angle, 90°, spacing, 0.35λ).

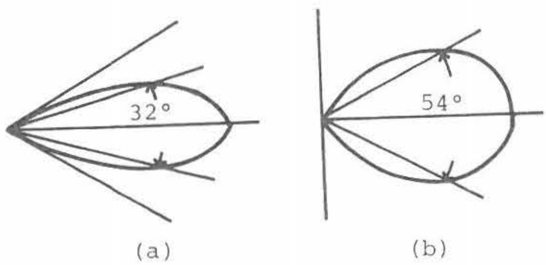

Fig. 3.
Gain-patterns of field intensity in the vertical (a) and the horizontal (b) planes (corner angle, 60°, spacing, 0.35λ).

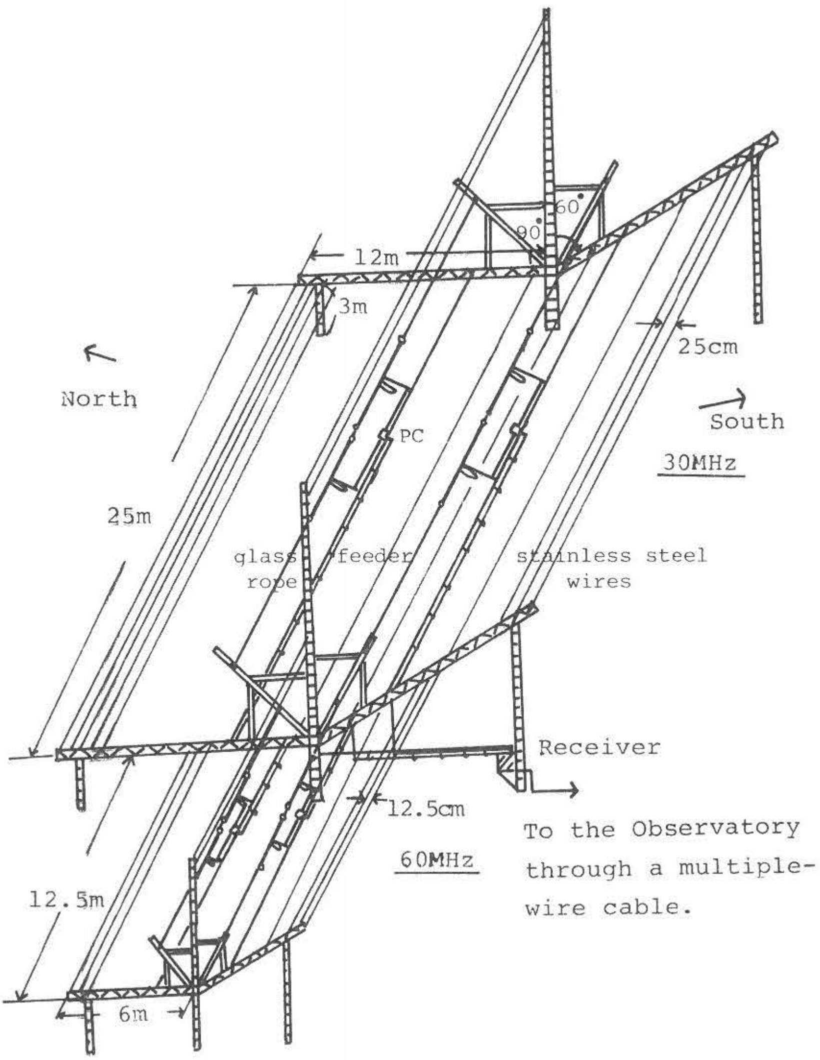

Fig. 4. Configuration of the corner-reflector antennas.

the corner-reflector antennas for 30MHz and 60MHz directed towards the Pole-star and along the earth's magnetic field.

2-2. Feeder

Fig.5 shows the antenna feeder system. The half-wavelength elements are made from light aluminum pipe with a diameter of 12mmϕ, and are stretched by the glass rope of 7mmϕ diameter. These elements are supported by glass rods to compensate the sag.

The terminal radiation resistance of half-wavelength antenna depends on the corner angle and the corner-to-antenna spacing. In the case of the spacing of 0.35λ, the radiation resistance is 70Ω at the corner angle of 90°, and 15Ω at 60° (Kraus,1950). The received signal from each element is conducted to an U balun, and matched with a parallel short-stub, and thereafter fed to a power combiner through the coaxial cable(3D-2V). The signal combined by the power combiner is led to the receiver through the coaxial cable(5D-2V). Fig.6 shows the corner-reflector antennas installed on the gentle slope being about 1.5km apart from the Observatory to avoid the artificial interference noises.

3. Receiver system

3-1. Receiver

Observed intensities of cosmic noises, on the average, $1.1\times10^{-19}W/m^2Hz$ at 40MHz, and $8.4\times10^{-20}W/m^2Hz$ at 64MHz(Pawsey and Bracewell, 1955). The input voltage at the receiver(bandwidth,15kHz) is estimated to be a few μV from the power gain(~8dB) of the antenna(corner angle,90°), power losses (~3dB) by impedance matching and feeder, and power gain (~2dB) by the colinear array.

Fig.7 shows a block diagram of the receiver system. The receiver in VHF range is put beside the antenna. Cosmic noise signals received by the north and south directed antennas are switched alternately in every 1 minute by a switch circuit to use one receiver in common. The cosmic noise signals from the antenna and the servo noise from the servo noise generator are switched by an electronic switch driven by a timing oscillator (f=140Hz). The output of the RF switch is fed to a superheterodyne receiver which is tuned to 30MHz or 60MHz with the IF

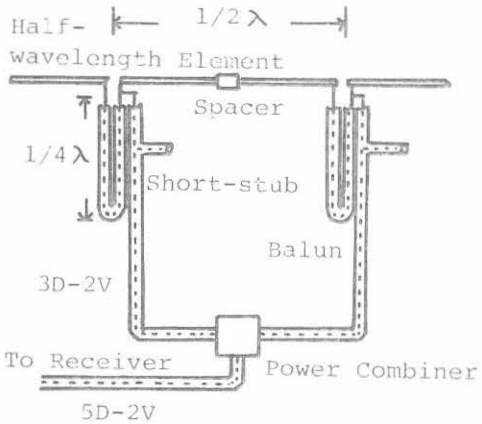

Fig. 5.
Colinear array of two half-wavelength elements and the feeder lines.

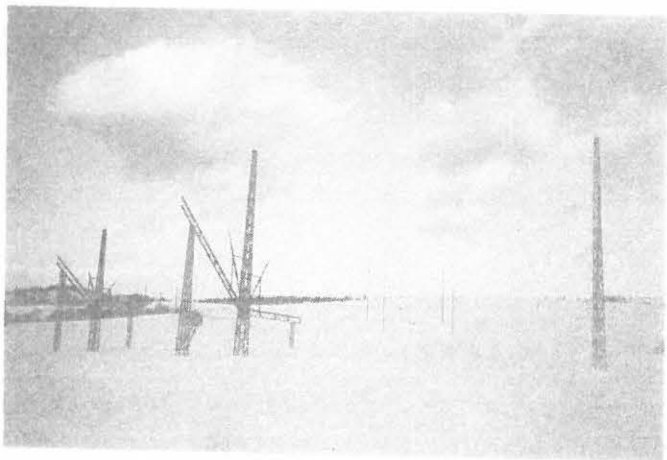

Fig. 6.
The corner-reflector antennas installed at Moshiri.

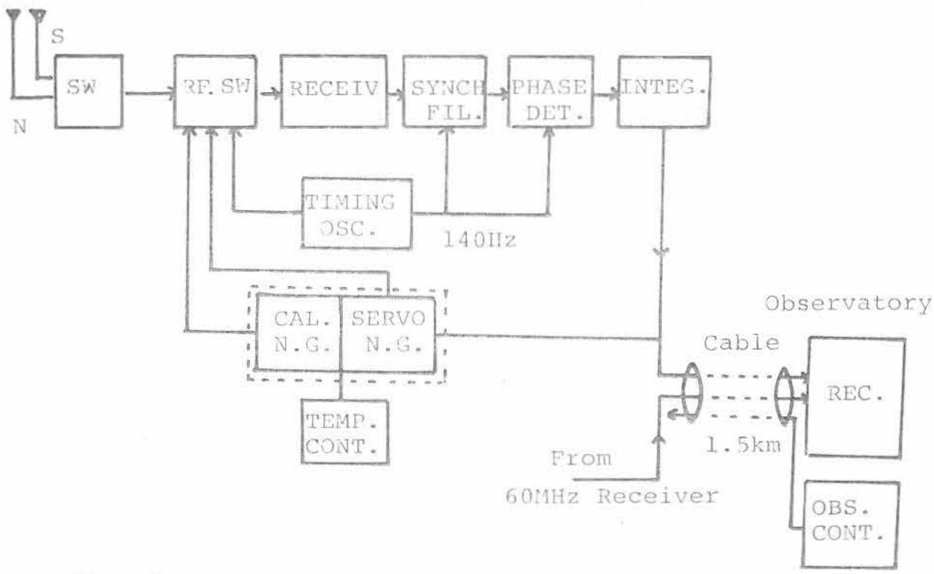

Fig. 7. Block diagram of the receiver system.

of 10.7MHz. The IF output passing through the three stage amplifiers is led to a synchronous filter to remove noises without degrading the 140Hz signal component. The 140Hz signal is then fed to a phase detector whose output voltage is either above or below a certain reference level, depending on the sense. This output voltage of the phase detector is applied to the integrator, whose output drives the servo noise generator in the correct sense. The time constant of the integrator is about 0.25sec.

The servo and calibration noise generators utilize the shot noise characteristics of planar silicon transistors. Fig.8 shows the circuit diagram of the servo noise generator for the 30MHz receiver. Fig.9 shows the output noise level versus the servo noise current. Fig.10 shows the output noise level of the servo noise generator versus ambient temperature. The output level is affected by ambient temperature, so the servo and calibration noise generators are put in a constant-temperature oven for the temperature control range of 40±2.5°C. Hence, the variation of the output noise level is less than 0.1dB.

3-2. Observation control and recording

An observation control unit in the Observatory controls the four-step calibration levels once a day. The time of the calibration noise generation and its duration are controlled by an elctronic clock. The temperature of the noise generators in the outdoor receivers is watched by a meter of the control panel.

The output signals which drive the servo noise generator are led through the multiple-wire cable of about 1.5km length, and are recorded on 4 channels of the 6ch pen recorder; North and South signals at 30 and 60MHz. The other two channels will be used for the record of VLF emissions in order to elucidate the correlation between the VLF emissions and CNA.

An example of CNA observation results on the south and the north directions at Moshiri is shown in Fig.11. Some of impulsive enhancements of CNA record during the daytime received by the south antenna are VHF components of solar radio emissions. A gradual decrease of 30MHz North started about 8h30m JST is the effect of SID(Sudden Ionospheric Disturbance) which is confirmed by SPA(Sudden Phase Anomaly) of NWC signal. It is clear that the daily variation of cosmic noise of 30MHz North is independent of sidereal time, while the

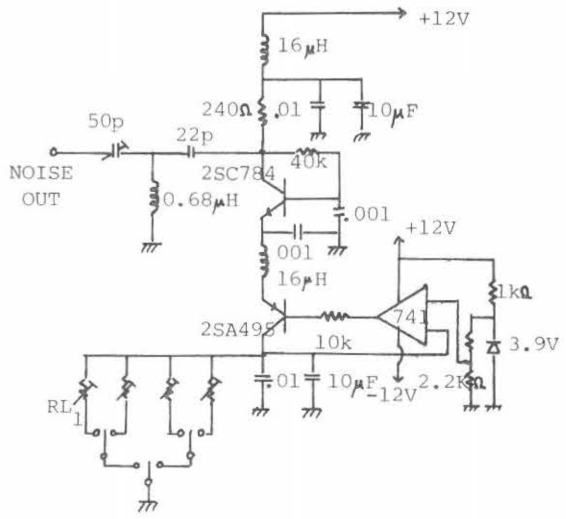

Fig. 8.
Circuit diagram of the servo noise generator for the 30MHz receiver.

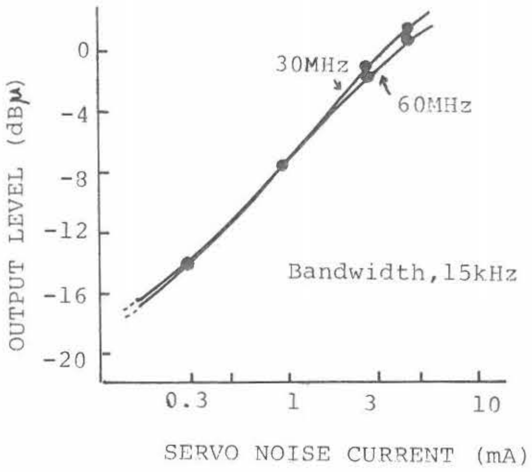

Fig. 9.
Output noise level versus servo noise current.

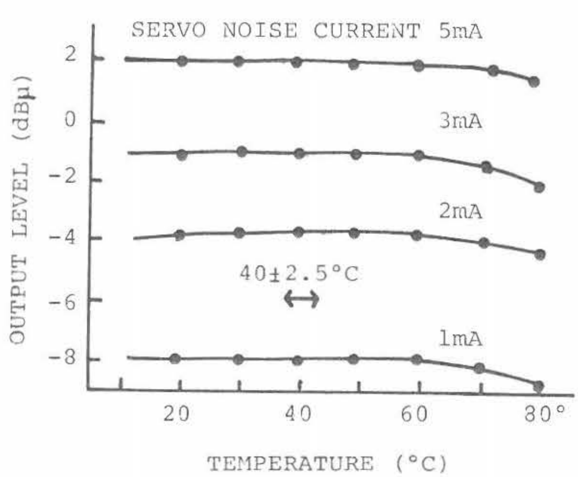

Fig. 10.
Output noise level versus ambient temperature.

daily variation of the 30MHz South which has a maximum at around 16h and a minimum at around 6h, shows the amplitude variation of several dB. The daily variation of 60MHz South is not clear because of the low sensitivity of the receiver.

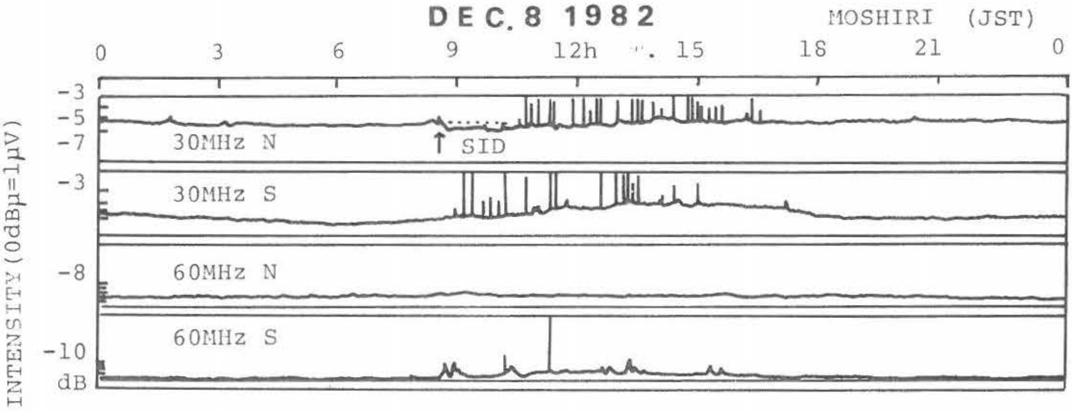

Fig. 11. An example of CNA observation results at Moshiri.

4. Concluding remarks

Test observations of CNA have been carried out since December 1982. It is necessary in near future to check the operation of the receiver in the winter circumstances of low temperature and to increase the receiver sensitivity. It is also necessary to identify origins of artificial interference noises during the daytime.

Acknowledgements

We wish to express our thanks to Prof. J.Ohtsu and Dr. M.Hayakawa for helpful suggestions. We appreciate very much Messrs. T.Katoh, T.Yamaguchi, M.Sera and Y.Ikegami for constructing and operating this system. This research project is supported by a Grant-in-Aid for Scientific Research from the Ministry of Education of Japan.

References

Harang, L: Emissions of VLF during the great disturbance of 25-26 May 1967, Planet. Space Sci., 16, 1081-1094 (1968).

Kraus, J.D. : Antennas, McGrow-Hill Book Company, 324-336 (1950).

Pawsey, J.L. and R.N.Bracewell : Radio astronomy, Oxford Clarendon Press, p 159, (1955).

Schwentek, H. and E.H.Gruschwitz : Measurement of absorption in the ionosphere on 27.6MHz at 52° N by means of a riometer and a corner reflector antenna directed to the Pole star, J. Atmos. Terr. Phys., 32, 1385-1402, (1970).