Memoirs of Fukui University of Technology,Vol. 36, Part1, 2006

Discovery of Decimeter Radio Wave Pulses from Super Massive Black Holes in the Center Region of Our Galaxy — First Preliminary Results

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Pulses of decimeter wavelength radio waves, in the frequency bands of 1.4GHz and 1.6GHz, arriving from the center part of our Galaxy have been discovered by observations made from July 25 to August 26, 2005 at Awara Space and Cosmic Radio wave Observatory of Space Communication Science and Technology in Fukui University of Technology,. The identified pulse periods are 129.99, 104.55 and 52.003 sec which correspond, respectively to Gaa, Gab, and Gac that had been already detected in decameter wavelength range. Because the decameter wave pulses have been considered to be from the rotating super massive black holes, the origins of decimeter radio pulses detected in the present study can also be considered to be radiated from the same black holes in the center part of our Galaxy.

1. Introduction

In 1999, the discovery(1) of 24 kinds radio pulses with periods ranging from 130sec to 0.3sec have been made in the decameter radio wave frequency range. Considering the characteristic of pulses which show i) high stability with periods given by more than 6 decimal digits, ii) high radiation power more than 7000Jy in the direction of sources located at center part of our Galaxy, iii) the period change, in a special case of the Gac pulse, which can be attributed to the orbital motion around the super massive black hole with mass larger than 10^5 solar mass, it has been concluded that radio pulses discovered in the center part of our Galaxy are radiated from rotating super massive black holes(1). The mass of black holes which linearly depends on the rotation period is estimated to be 5000 solar mass versus 1 sec of the period. Based on the Kerr metric, we can find a sphere where entire plasma in that region rotates with same angular velocity, surrounding the regions extremely close to the event horizon. Therefore, we can observe a given rotation period when there are some azimuth in-homogeneities in the plasma states which give radio wave emissions intensities with azimuth dependence. In the discussing special region located very close to the event horizon, time passage becomes extremely slow due to red shift predicted from the Kerr metrics(2). For this reasoning, the pulsating components of radiated radio waves can be considered to be confined in low frequency range such as the case of decameter radio waves. In this context, it is important to observe the spectra

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indices of radiated pulse waves; i.e., how fast the radiation power decreases as the function of the radiation frequency. For this purpose we start with the observations of the decimeter waves using the decimeter radio wave observation facility at Awara campus of Fukui University of Technology from July 25, 2005. Though it is still preliminary stage to give complete quantitative results for pulse levels, we report the first outcome because it is thought to be significant for future study in this field.

2. Instrumentation

The decimeter radio waves in frequency bands of 1.4GHz and 1.6GHz have been detected with cross dipole antenna equipped with parabola reflector of 10m diameter that gives antenna gain of 41dB in these frequency bands with beam width of 2.5deg. As given in Figure 1, a low noise amplifier with gain of 50dB is facilitated at feeding point

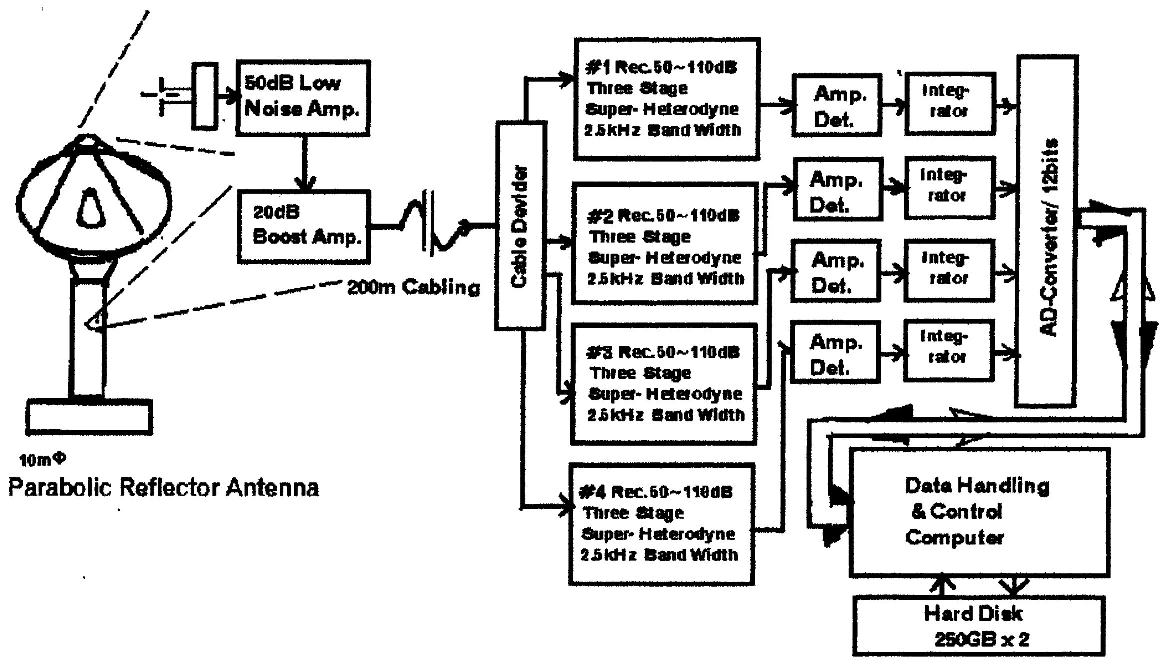

Figure 1. Block diagram of observation system at Awara Radio Wave Obsevation Point

of this parabola antenna being followed by 20dB boost amplifier to cover the attenuation due to 200m coaxial cable which feeds the signal to 4 back-end receivers; these receivers are running in parallel each other with adjustable gain from 50 to 110dB by applying 3 stages super heterodyne system. The final output signals in frequency range from 30Hz to 2.5kHz are integrated with time constant of 0.25sec after diode shaping to detect the amplitude. After transformation to 12bits codes, the signals are sent to a computer.

3. Observations

Observations for the center[3] of our Galaxy at RA of 17h42m29.33s and Dec of -28° 59'18.6" have been made since July 25, 2005, with 1.4GHz band where the frequency is selected at 1435.000MHz, 1400.000MHz, 1425.000MHz and 1409.705MHz, and the observation frequency have been switched to 1.6GHz band where the center frequency is selected at 1610.090MHz, 1625.000MHz, 1634.995MHz and 1641.000MHz since August 16, 2005. The data have been sampled with a rate of 2Hz during these periods of observations. For all of these periods , 3.6×10^6 data points corresponding to 125 hours observation are obtained by tracking in the direction of the center of our Galaxy.

Observations of general sky have been made during September to November in 2005, mostly to check the fluctuating noise characteristics related to the observation system. In this mode of observations, the dish antenna has been fixed in the direction of the zenith where no identical radio source which continues more than 8 minutes when a celestial objects are passing by the antenna beam with cone angle of 2.5deg.

4. Data analyses

4.1 Analyses by Modified FFT method

Because the objects of analyses are pulse signals of extremely low S/N ratio which are buried in intense back-ground emissions of our Galaxy, the data handling should be done with critical care not to be contaminated by noises from all kinds of artificialy pulsating sources. The base to avoid this type of contamination is to take long time average of analyzing results of FFT ;in addition to this treatment, the system characteristics which may have nature to generate periodic variation should be disclosed not to be mixed with the actual radio pulse signal.

In the present study, the Fourier transformation have been made applying modified FFT analyses method(called M.FFT hereafter) where we have employed " octonary code brake down" to treat the product of frequency and time steps of 512×512, instead of employing the orthodox FFT where "the binary code brake down" is applied.

In Figure 2, results of M.FFT analyses for the data of three days,(on November 7, 14, and 21, 2005) observations in the direction fixed to the zenith are given both in Panels (a) and (b). In panel (a), two components of spectra characteristics are indicated ; one is white noise, from sky being modified by characteristics of integration circuits, which merges smoothly to inherent white noise level in the high frequency range. The other are spectra of low frequency fluctuations mostly related to the stability of amplifiers of the system in the range lower than 0.00245 Hz

Our interest of the data analyses for the present study is to identify meaningful pulses which have levels higher than calculation error caused by background noise. The error rate of Fourier analyses, in general, is estimated to be $1/\sqrt{N}$ for the average of N times trial of the Fourier analyses. In panel (b) in Figure 2 where fine structures of the analyzed spectra corresponding to the data given in panel (a) are displayed being

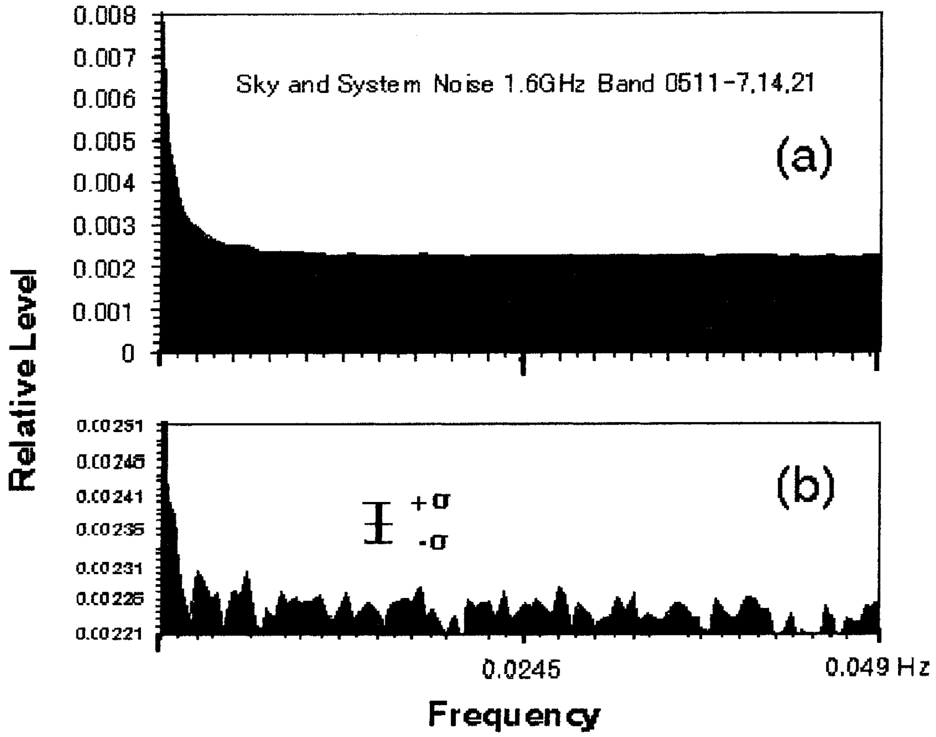

Figure 2. **Results of FFT analyses for sky noise together with characteristics of the system: (a) raw results (b) expanded display for the fluctuation level (see main text for details of error bar)**

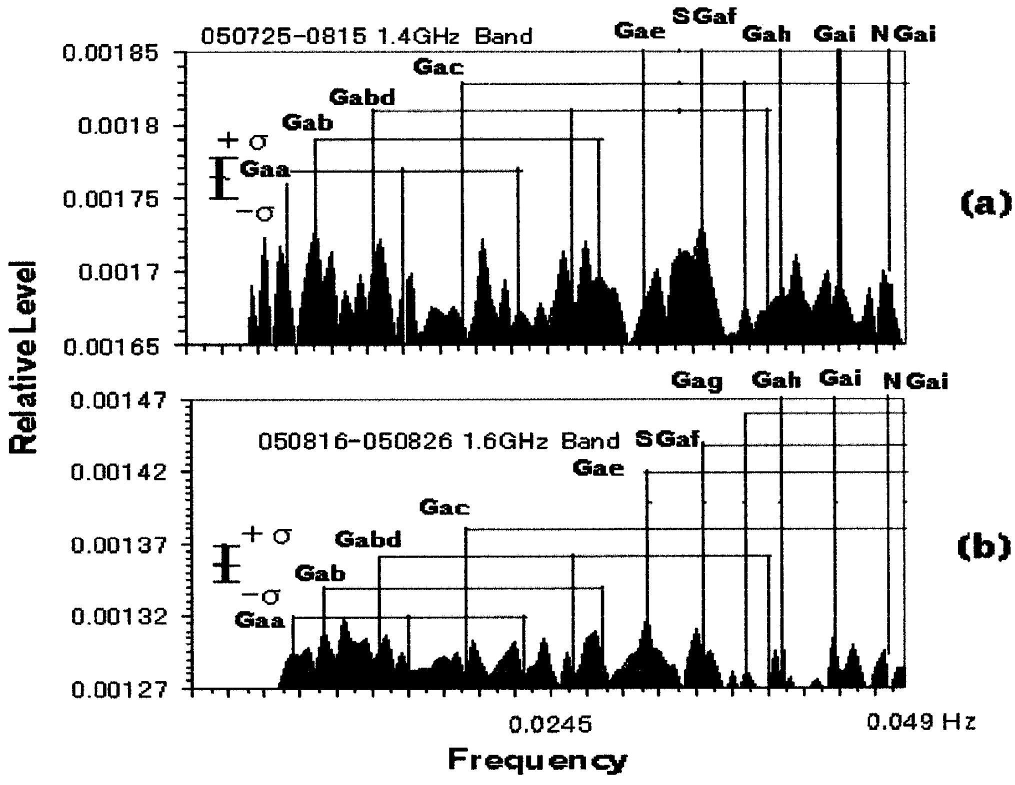

Figure 3. Results of M.FFT analyses for observation of the center of our Galaxy in the frequency range of 1.4GHz band in Panel (a) and 1.6GHz band in Panel (b) (see Main Text for details)

expanded with respect to level range of remarkable variation of the spectra, the error bar is given by the statistic estimation based on trial times of M.FFT. It is apparent from this result that the detected M.FFT levels show no selective peak exceeding the estimated error level, except for the long period fluctuation in the periods range longer than 400 sec.

In Figure 3, results of M. FFT analyses are indicated for the Galaxy center data for observations from July 25 to August 15,in 2005 in the frequency range from 1400MHz to 1435MHz, in Panel (a) and for the period from August 16 to August 26, in 2005 in the frequency range from 1600MHz to 1635MHz, in Panel (b). The data sampling rate in these periods of observations is 2Hz in 3 (or 4 in some cases) channels providing time series data points of 2.5×10^6 and 1.1×10^6 respectively for 1.4GHz band and 1.6GHz band. The error bars are estimated based on the same statistic criteria given for the evaluation of total system noise characteristics (see Figure 2).

For the resulted spectra in Figure 3, harmonic relations reflecting the existence of underlying pulses labeled as Gaa, Gab and Gac etc.. are pointed out with straight line indicators with combination of three lines tied by the horizontal lines. These indications coincide with spectra peaks, for majority of the cases, though there are some exception. The coincidence ,therefore, means that the present spectra show potential existence of radiation sources that are the same with sources of the pulses in the decameter wave length range. Though 9 pulses from Gaa to NGai are indicated in Figure 3, we, here , confine the attention to pulses Gaa, Gab and Gac that show the period, respectively, around 130, 104 and 52. sec. In this stage, we meet important finding, even from the selected three limited examples, that there are two categories of feature in comparison with the indicators of decameter pulses; one is the category of complete coincidence as the cases of Gaa and Gab ,the other is category where simple coincidence cannot be found, as the case of Gac, suggesting that some sort of variation takes place between the decimeter and decameter radio wave pulses.

4.2 Boxcar analyses

Being based on the starting information of periods indicated by FFT results given in Figure 3, , the box-car accumulation method has been applied to measure more accurate pulse periods to confirm the existence of pulses from the Galaxy center. The results have been given for the cases of Gaa, Gab and Gac in Figures 4 and 5 where top panels show raw results analyzed for a box-car period which consists of two pulse cycles, while the second panels show the average of wave forms of raw two cycles data, and bottom panels show the deviation values of raw data from the obtained average. The error bars are estimated from the statistics considering the accumulation times in the box-car analyses; the accumulation times are 5×10^{4} for observations of 1.4GHz band and

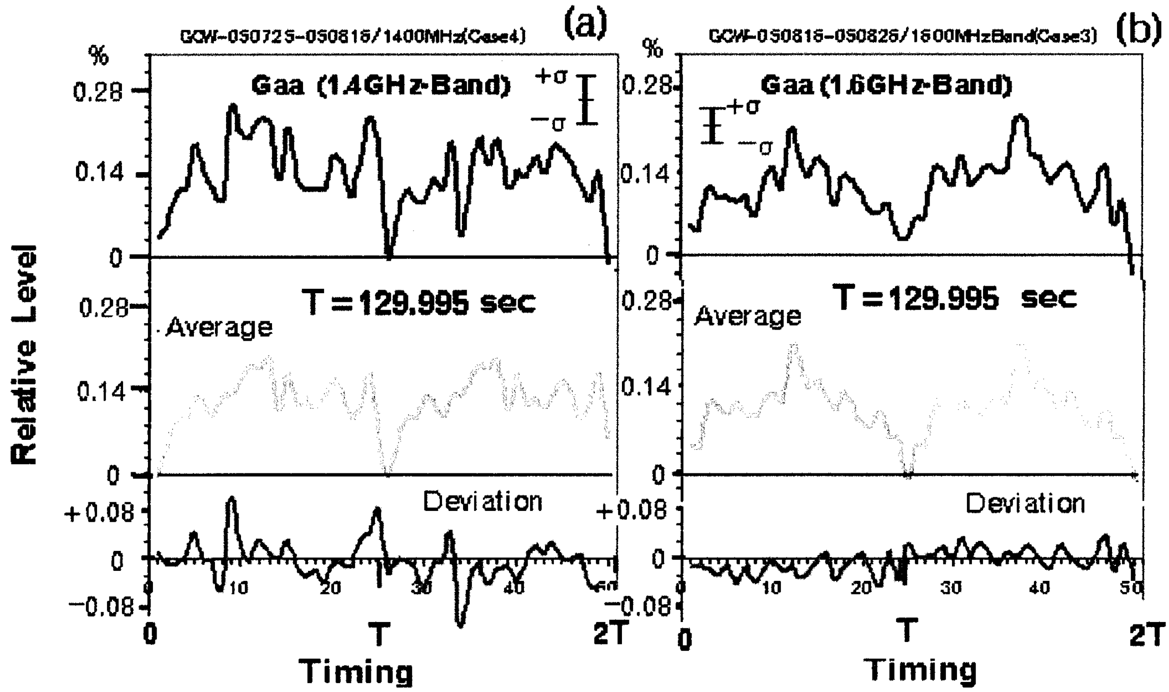

Figure 4. Two cycle display of box-car analyses of decimeter pulse at the period of 129.995 sec for the radiation from the center of our Galaxy ,in the frequency range 1.4GHz band (a) and 1.6GHz band (b): The period of Gaa coincides with the case of decameter wave observations.

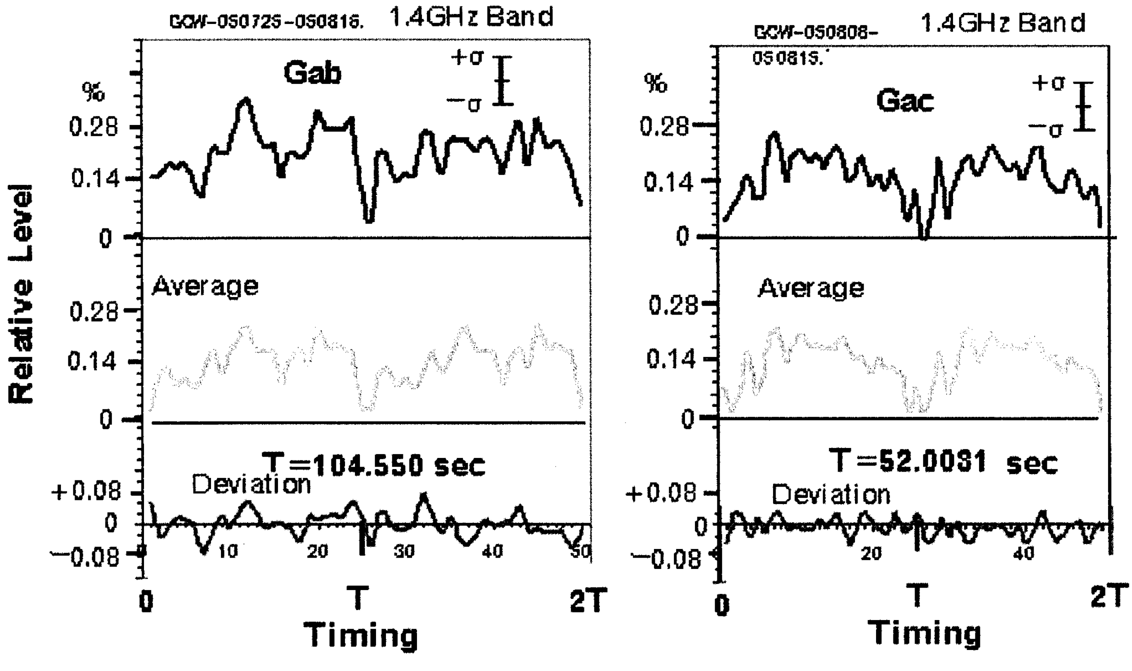

Figure 5. Same with Figure 4. except for the cases Gab and Gac for the periods respectively 104.550 52.0031 sec observed in 1.4GHz band

2.2×10^{4} for 1.6GHz band. The pulse levels in these results are indicated by percentage with respect to the back ground level of radiation from the direction of the center of our Galaxy. From all of these basic resultant data, it can be concluded that there are apparent existence of the pulses in the decimeter frequency range radiated from the same pulse sources that have already been confirmed in the decameter wave frequency range.

5. Discussion

5.1 Comparison with Decameter pulses from the center of our Galaxy

It has already been confirmed that there are 24 kinds of pulses with spectra associated with almost three higher harmonics(1). From these in the group of decameter pulses, three cases of Gaa, Gab and Gac can be compared with the decameter wave results in the present works; the result of comparison of pulse levels is given in Table 1.

Table 1. Comparison of the pulse level relative to the back ground radiation level

Frequency Range	Gaa	Gab	Gac
Decameter(22MHz)	0.4 %	0.5 %	0.7 %
Decimeter(1.4GHz)	0.2 % *	0.25 % *	0.2 % *

Considering the spectra index , the rate of back ground level of the radiations from the center region of our Galaxy is estimated to be about 0.036 between the radiations at 22MHz and that at 1400MHz, the radiation powers in the decimeter wavelength range show, therefore, the spectra indices , - 0.96 for Gaa and Gab and -1.10 for Gac. The results show faster decrease of power spectra versus frequency than the power spectra ,of the back ground radiation, that show the index of -0.8.

5.2 Relation to Kerr Black Holes

Because of the identical characteristic of pulse observed in the direction of the center of our Galaxy, we can conclude that the presently studying spectra of decimeter wave pulses are also radiated from rotating black holes that have been concluded from the observations of decameter wave radiations(1). The faster decrease of radiation spectra of pulses compared with the background emissions is taken as a manifestation of the red shift effects in the region close to the event horizon of the rotating black holes; i.e. radiations originally to be extended in wider wavelength range even to that of X-ray or shorter could be compressed within a longer wavelength range where the spectra index should be steeper for decreasing than the decreasing rate in original spectra.

Investigations of possible rotation period in the Kerr time-space, it becomes apparent that there is a region of sphere extremely close to the event horizon where all sphere in terms of latitude and longitude of the region rotates with a synchronized period. This region is highly possible to be origin of the observed pulses with given periods. The rotation periods are however widely distributed in the region outside of a limited region apart from the event horizon. When we make observation in a higher frequency range than some limit frequency, therefore, pulses may not be observed. In

* Complete decision of values is defered to future observations.

1.4GHz band, so far, such the case is not apparent, however, there are some peculiar phenomena suggesting splitting of periods from Gac which shows large decrease of levels compared with the case in the decameter wavelength range.

6. Conclusion

As the results of observations made from July 25 to August 26 in 2005 in decimeter wavelength range at 1.4GHz and 1.6GHz bands, the pulses with periods of 129.995, 104.550, and 52.003 sec have been identified by analyzing time series data which consist of total 3.6×10^{6} points obtained in 4 channels during 125 hours of tracking of our Galaxy center by using a radio telescope with 10m diameter at Awara space observation facility in Fukui University of Technology. The results have been carefully investigated not to be mixed with system fluctuation or noise by measuring radiations from average sky in the zenith direction together with noise of observation system.

Considering the coincidences of source direction in our Galaxy center and pulse periods also with similarity of pulse shapes between decimeter and decameter radio waves pulses, the decimeter wave pulses detected by present study are concluded being radiated from the pulse sources, Gaa,Gab and Gac that are detected in the decameter wavelength range. As a consequence, the pulses discovered in the decimeter wavelength range are considered to be from rotating super massive black holes in the center region of our Galaxy. The detected pulse levels show that the spectra indices of Gaa,and Gab are negatively larger than the case of background emissions of our Galaxy . The faster decrease of power spectra of radio pulses, in higher frequency, supports the hypothesis of pulse sources at the region close to the event horizon of Kerr black holes where remarkable red shifts are taking place. As for the peculiar phenomena in periods of Gac, detailed investigations are deferred to future studies.

Acknowledgements

The present work has been supported by Special Research Grant in Aids of Fukui University of Technology, the author is grateful for the support which leads the research activities to significant results.

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(Received December 2, 2005)