Analyses of the Decimeter Radio Wave Pulses from the Center of Our Galaxy Based on Data Observed at Awara Radio Wave Station of Fukui University of Technology

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Abstract

Analyses of the decimeter radio wave pulses in the frequency range of 1.4GHz have been made for the data observed at Awara radio wave station of Fukui University of technology from April to July, in 2008. Results show that there are pulses in wide period range from 0.3sec to 1600sec in the data from our Galaxy center. Basically the appearance of pulses in the decimeter range corresponds to that of decameter radio wave pulses . Based on the hypothesis that these radio wave pulses are generated in the region extremely close to the event horizon of Kerr black hole, we have expected a wider spreading of the pulse period for the case of decimeter radio wave pulses compared with the spreading of the decameter radio wave pulses. In several cases of the pulse periods results support this difference of the pulse periods spreading between decameter and decimeter radio wave pulses

Keywords: Kerr black hole, decimeter radio wave pulses, decameter radio wave pulses, FFT analyses, box car (coherent accumulation) analyses

1.Introduction

Discovery[(1)] of the radio wave pulses in the decimeter wavelength range in 1.4GHz band had been reported being based on the observation which were made, in 2006, using cosmic radio wave observation facility at Awara station of Fukui University of technology. In that report it was claimed that the decimeter radio wave pulses were coming from the same origin of the decameter radio wave pulses which were inferred to be arriving from the rotating super massive black holes, in the center region of our Galaxy, whose rotation periods coincide with detected pulse periods[(2)]. To arrive at this conclusion for decameter radio wave pulses, several critical points of evidence had been investigated. These are 1) distances which were measured by dispersion of the pulse form as function of the observation frequency, 2) direction of the arriving radio wave pulses using long base line interferometer and 3) the pulse periods that theoretically give super massive objects ranging from several thousand to a few million solar mass corresponding to the period range from 0.4sec to 130 sec.

Further studies on the pulses in the decameter wavelength range, however, disclosed new evidences that the conclusions made in early stage of the studies[(2)] in 1999 should be improved, though these new evidences are still on the process of the analyses. Significant point of the revision is to put

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more emphasis on the existence of the binary black holes though it had been already pointed out in 1999 paper(2) that there are several cases of black hole binary . By further advanced analyses, signatures of existence of these binary black hole systems that are strictly affecting on the detected pulse form are clarified; that is, a large number of associated pulses are detected centered around the intrinsic period. These multiple periods of pulses are understood as results of Doppler shift effects due to the orbital motion of binary black holes. There should, therefore, be also inevitable improvement on the decimeter radio wave pulses discovered in 2006.

A conclusion that the decameter radio wave pulses and the decimeter radio wave pulses are emitted from the same black holes leads to significant points which are strictly reflecting the environments of the source regions. It was proposed by Oya(3) that the source regions of both the decameter and decimeter radio wave pulses may be located extremely close to the event horizon of the Kerr black holes where the rotation periods of plasma environment almost coincide with those of event horizon. When we investigate the rotation periods accurately depending on study of time-space of the Kerr black holes in the regions close to the event horizon, there are slight shifts of rotation periods of space depending on the distance away from the exact position of the event horizon. Further more, it is proposed (3) that lowness of frequencies of the decameter and decimeter radio wave emissions is principally due to slowness of the time passage in the source regions due to the extremely large red shift as effects of the general relativity in the strong gravity fields of the black holes. Because decimeter radio wave frequencies are higher by about 100 times than decameter frequencies, the sources of the decameter radio waves could be located much closer position to the event horizon than the source regions of the decimeter radio wave sources. It can, then, be expected that there would be difference between characteristics of decimeter radio wave pulses and decameter radio wave pulses reflecting characteristics of rotation periods of source regions. That is, the rotation periods may spread wider than the case of the decameter, even within a range of a few percent of the given periods.

In this paper we report then results of new analyses of the decimeter radio wave pulses from the center of our Galaxy based on data which were observed in 2008, again at Awara Radio Wave Observation Station of Fukui University of Technology. Significant issue which basically gives improvement on the 2006 results is to present evidences to manifest the existence of black hole binary. To search for the source positions that may manifest the differences of the spreading characteristics of pulse periods between the decimeter radio wave pulses and the decameter radio pulses is also significant purpose of present study. For confirmation of these evidences, comparison with the results of decameter radio wave pulses observed in 2002 and 2004 by long base line interferometer of Tohoku University whose characteristic points were already reported in 1999 paper(2) have also been made.

2. Observations

The decimeter radio wave observation system consists of a dish antenna of 10m diameter with 1degree resolution angle of the direction for 1.4GHz band as the front end (see Figure1). The signals detected by dipoles at the focal-point of the dish antenna are amplified by 50 dB through the low noise amplifier. Being further amplified by 20 dB through the preamplifier, to compensate the loss due to cable of 200m length between antenna sight and main station, the signals are sent to the main station where the signals are amplified by main amp th bandwidth of 2.5kHz: the amplification is made up to 110dB through three stage heterodyne system in the main receiver (see Figure 2).

Figure 1 **10m diameter dish antenna at Awara Radio Wave Observation Station**

In the backend the signals in the frequency range from 30 Hz to 2.5 kHz are integrated with time constant of 2.5msec after shaping to detect the amplitudes of signal. Final stage analog signals are converted into digital signals of 12bits with sampling rate of 100 data per second (see A/D in Figure 2).

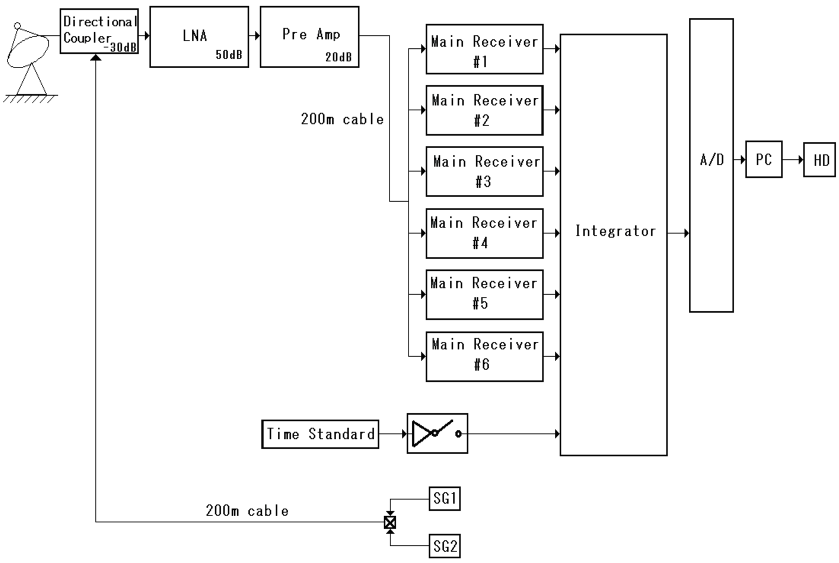

Figure 2. **Block diagram of observation system**

Observations ,for the center of our Galaxy, which provided the data for the present studies were carried out from April 25 to July 31, in 2008. During these periods the effective data have been acquired for 69 hour when 24,840,000 data have been provided for each channel .In each observation day, observation start times and end times are accurately recorded ; these records are significant to obtain coherent accumulation of the pulse form for long time periods to cover the entire observation periods.

3. Data Analyses

The special approach to detect the pulse signals buried within large fraction of cosmic radio noises which are 100 to 1000 times larger than the signal level had already been described in previous papers (1) (2) i.e., the methods are characterized by a large number of average times for FFT, and the box-car analyses to overcome the stochastic fluctuation resulted by random noises. In addition to methods for this kind of special analyses ,we have applied, in this work, the analyses of random noises to make strict confirmations for separation of stochastic fluctuation resulted by random noises. That is, we analyzed time series of pseudo random number with completely same algorism that are applied to the analyses of the observed data for the Galaxy center, in parallel to the main purpose analyses.

In Figure 3, an example of analyzed data both for observation data and Gaussian form random signals are given versus data sampling number; sampling had been made with a rate of 100 times per a second for the observations. As we can see in this example case, range of the variation or fluctuation of the amplitude of the observed signals and that of random noise are set to the same level which are normalized by the average level of the unity. That is, the deviation around the average is adjusted to be same ,for Gaussian noise level, with the observed signals from the stand point of the signal level and fluctuations to form the same samples.

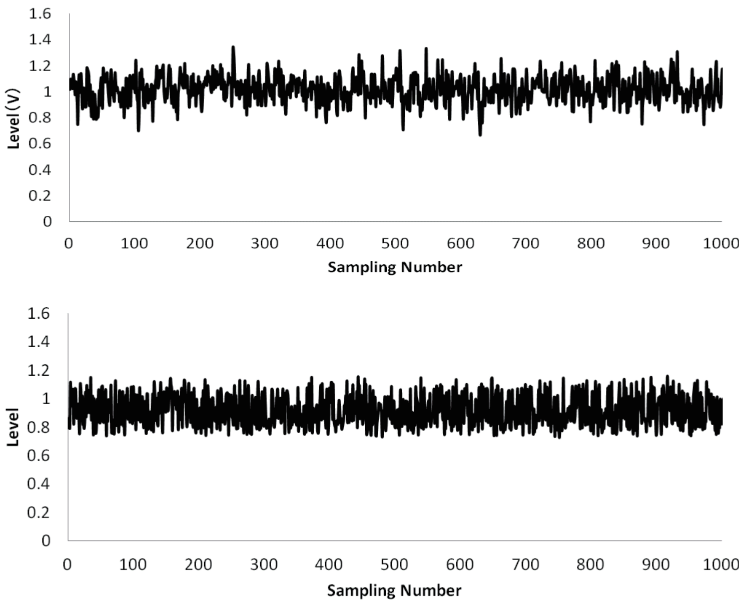

Figure 3. Time series of observed data and pseudo random noise converted to Gaussian levels for corresponding time scale (100sample / 1sec)

In Figure 4, the results of FFT analyses that are averaged over 61,952 cases are given both for observation signals and for random noise. In this display we cut the lowest portions of the fluctuation frequency that are resulted from the DC components both of signals and Gaussian formed random noise. From this result, it is quite remarkable that the signals from the Galactic center show completely different feature from that of the random noise; i.e., we can find meaningful peaks only in the results of signals.

4. Pulse Periods and Pulse Forms

Analyses of box-car (coherent accumulation of the pulse form) for a searching period of pulses and pulse forms have been applied to both random noise and the observation signals for the periods from April 25 to July 31 with data duration time of about 248,4000sec in total.

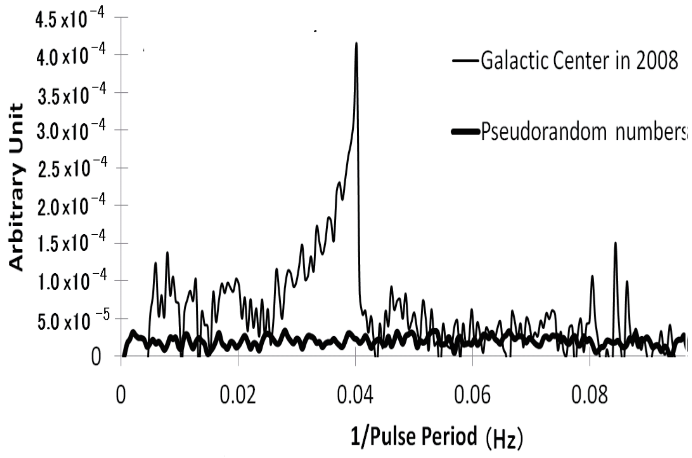

Figure 4. Results of FFT analyses for observed data from our Galaxy center and for pseudo random numbers. Analyses have been made for pulse period range from 2000sec to 10 sec.

In Figure 5, an example result for the pulse period of 75.8517sec is given ; original pulse form for two succeeding time periods are given in the top panel while averaged pulse form for the two cycle data is given in the middle panel. In the bottom panel deviation of the original wave form from the average form is indicated. We can see the rate of deviation to the average becomes good quanti- tative indicator to pick up the pulse signals that are buried within large noise levels which are almost 1000 times larger than the level of the pulse signal, in this case. In a series of studies relating to the pulses from our Galaxy center, the timing of pulse is expressed with 25 bins for each cycle; that is, total data for pulse form analyses are given by 50 bins correspond- ing to two cycles. The deviation D, is then defined by

$$D = \sqrt{\left(\sum_{i=1}^{50} \left(ObsData(i) - Average(i) \right)^2 \Big/ 50 \right)} \qquad \text{..................................} .(1)$$

where ObsData(i) shows coherently accumulated two cycle observation data at the corresponding bin number i. We here also define the pulse height P as

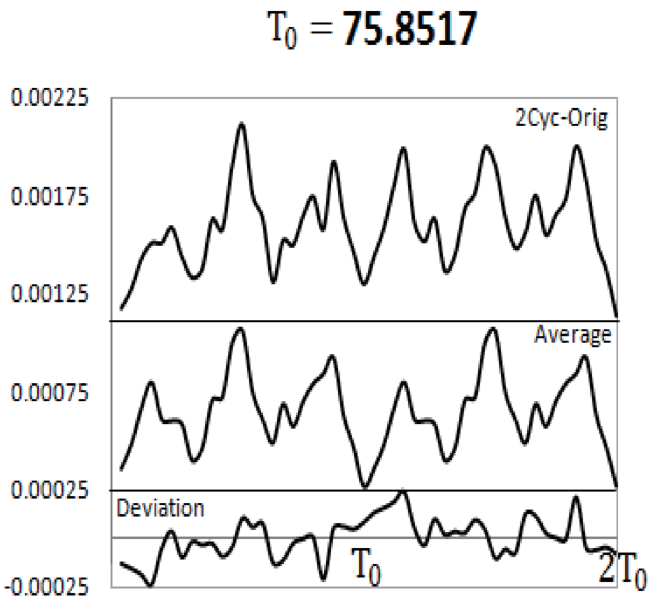

Figure 5. Example of pulse form detected by box-car analyses. Top, second and bottom panels show, respectively original 2 cycle results, average of these two cycle, and deviations of original form from the average form. The ordinate indicates rate of levels relative to back ground noise level.

$$P = \sum_{i=1}^{50} Average(i) \Big/ 50. \quad \cdots\cdots (2)$$

To express the symmetry of the two cycle data, then, P/D becomes effective indicator. When we investigate the wave form, existence of sharp peak levels have significance independently to average height of the pulses, then a parameter P_{max} is also defined as

$$P_{max} = (Maximum\ Level\ of\ pulse\ among\ the\ averaged\ pulse) - (Minimum\ Level\ of\ pulse\ among\ the\ averaged\ pulse) \cdots\cdots (3)$$

Then in addition to P/D parameter we have employed the index, Total-Eval that is defined:

$$Total \cdot Eval = (P/D) \cdot P_{max}^2 . \quad \cdots\cdots (4)$$

In Figure 6, an example of the results of box-car analyses is given to compare between the observation and generated random noise; results are given in term of P_{max}/D. It is apparent that random noise gives a sought of pulse form with P_{max}/D value around unity flatly in all periods of analyses but there is no remarkable pulse form as cases of observation signals where a large P_{max}/D values are indicated with several selected peaks.

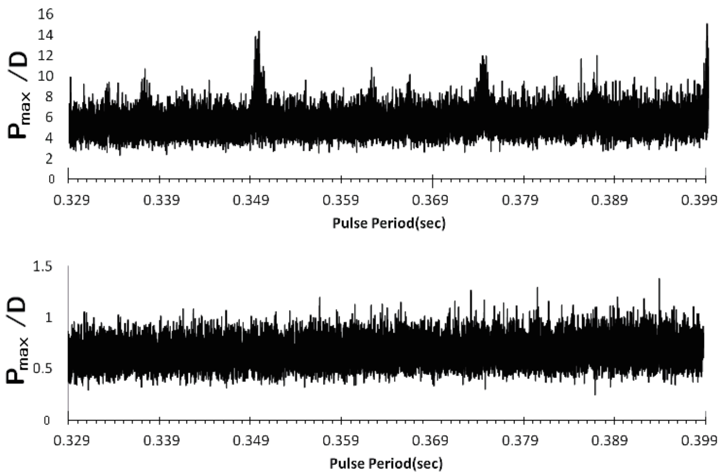

Figure 6. Results of box-car analyses expressed by P_{max}/D both for observation data and generated random noise.

In Figure7, results of the pulse form analyses carried out by the box-car method are given in a wide period range from 0.3 sec to 3000 sec where ordinates are indicated in term of Total-Eval; the evaluation is, therefore, much more weighted to the pulse level though importance of the symmetry of the detected two cycle pulse form is also considered. In the box-car analyses 1,987,200 times accumulation has been made; this accumulation allows to have pulse form with error rate of 7×10^{-4} with respect to normalized level of unity. This means that the error level of the Total- Eval is 3×10^{-9} for the case where Total- Eval is 1.0×10^{-6}. Four significant subjects at least can be pointed out from the results given in Figure 7, as 1) short periods pulses are clearly detected in period range from

0.3 sec to 0.5 sec, 2) especially enhanced pulses around the period of 24.9 sec and effects appear in longer periods range selectively at each integer multiple, 3) except for effects of multiple periods of 29.4 sec there are apparently dominant components of pulses in the period range from 100sec to 300 sec , and 4) high level pulses appear in large period range longer than 800sec.

4.1) Cases of short periods

In Figure 8, an expanded version of Total-Eval in the period range from 0.399sec to 0.489 sec are given with example pulse forms at the periods 0.400164 sec and 0.44952 sec. The existence of such short periods pulses are consistent with the case of decameter radio wave pulses; one of the most dominated pulse period was 0.421578 sec at 21.86 MHz though the pulse level had been gradually decayed; and it becomes difficult to detect after 2010.

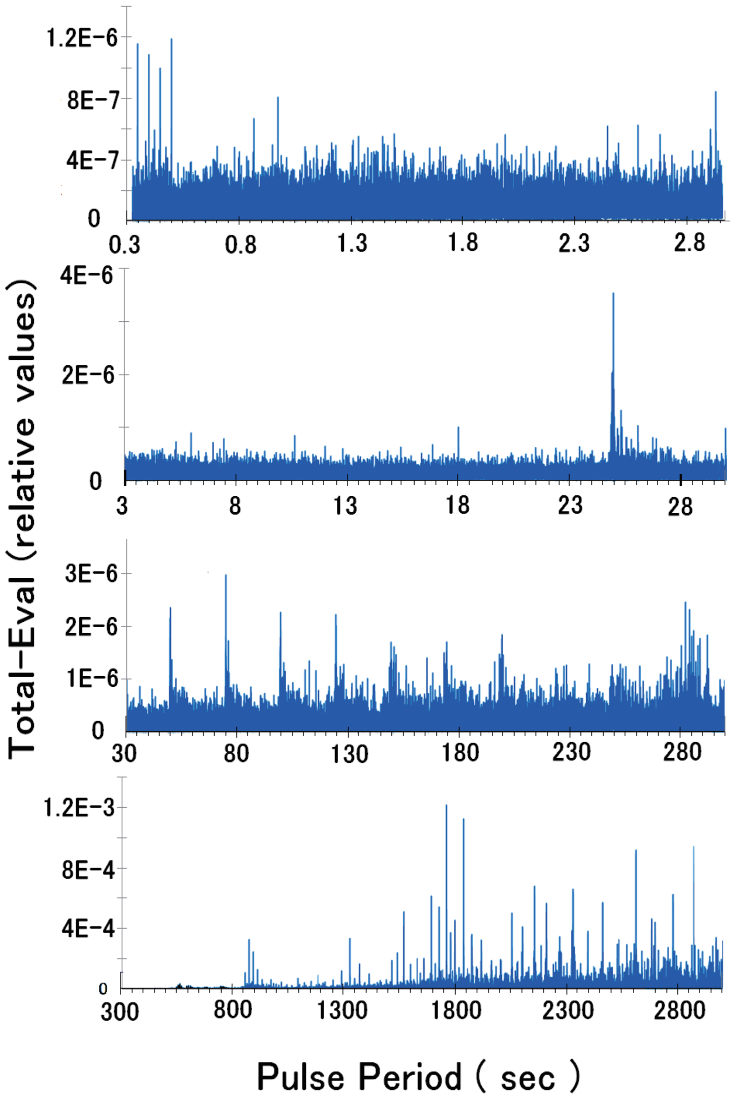

Figure 7. Results of box-car analyses in the period range from0.3 sec to 300sec with period resolution of 4E-4. Ordinate in each panel indicates Total-Eval whose unit is caused by rates of pulse level with respect to normalized back ground noise level.

4.2) Dominated pulses around 24.9 4sec

In Figure 9, a group of the enhanced pulses around the period 29.4 sec are displayed with examples of pulse form. The pulses in this period range appear at selected periods with period gaps of about 0.007 sec being characterized by single peak for each period. Possible cause of detection of group of pulses can be understood as coming from the same origin. An original pulse with a given intrinsic period might be observed being modified to variety of periods due to the Doppler shift caused by orbital motion. We can estimate the orbital motion with period of 24 hour 36.21 min. applying the frequency modulation mechanism due to an assumed orbital motion.

4.3) Pulses in the period range from 100 sec to 300 sec

As that has been given in Figure 7, there are remarkable effects of the integer multiple of the pulse periods such as from 24.94x2, to 24.94x12 sec, sequentially as natural consequence of the box-car method where we can not avoid repetition of the detection of the fundamental pulse form at the periods of integer multiple of the fundamental period. We therefore discriminate these multiple pulses as pseudo pulse forms by referring the results of FFT analyses

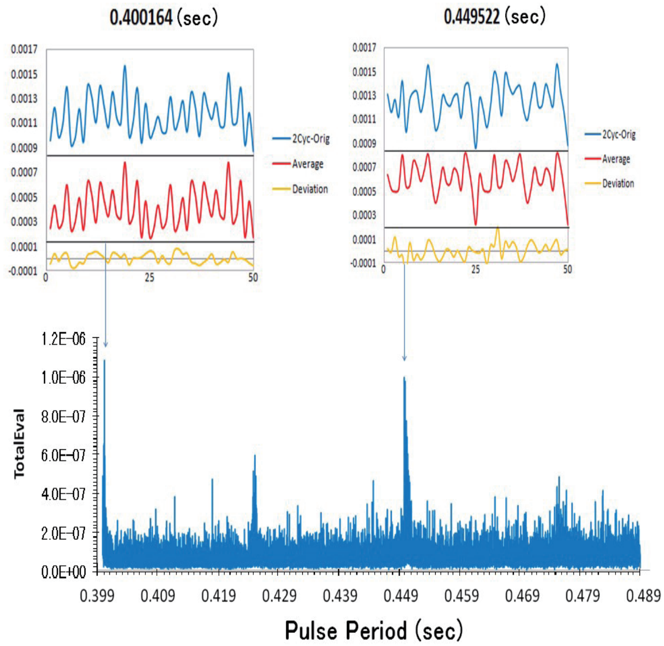

Figure 8. Total-Eval for the box car analyses in the short period range from 0.399 sec to 0.489 sec with examples of pulse form. The pulse forms at the period 0.400164 sec and 0.449522 sec are given with the format given in Figure 5.

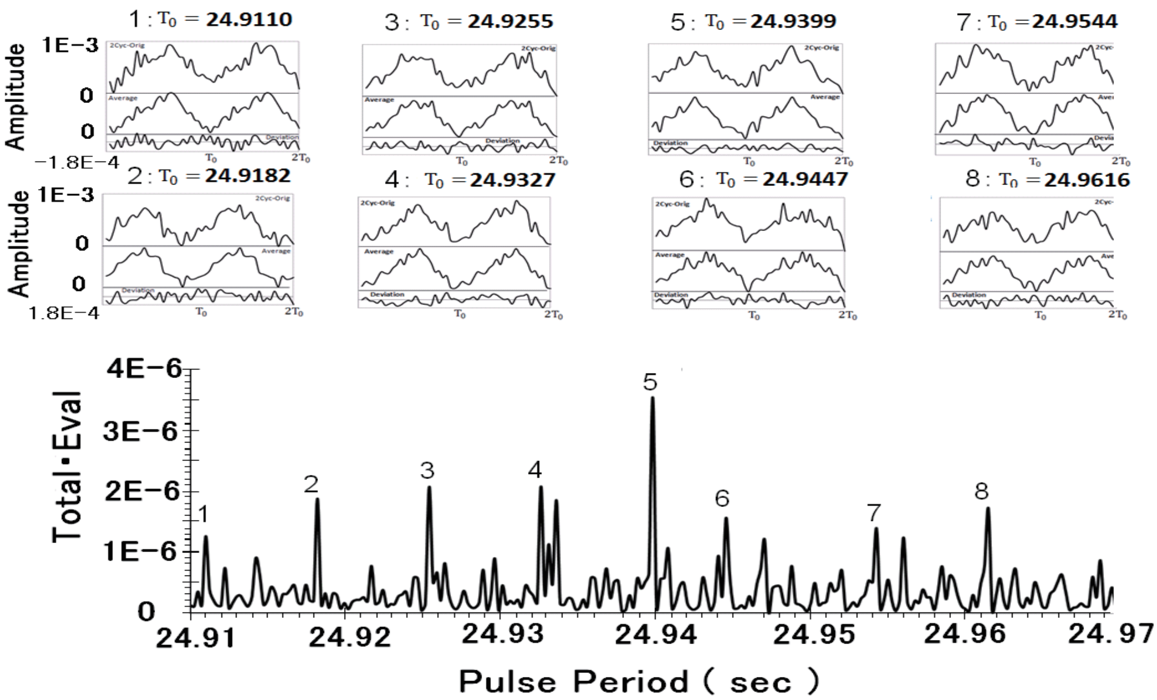

Figure 9. Total-Eval index for the results of box-car analyses in periods range around 24.94 sec with example pulse forms. Amplitude is given relative to back ground noise level. Wave forms are given with the same format of Figure 5.

where we can find fundamental period though there appears higher harmonics contrary. By discriminating these integer multiple of the periods, we can find existence of clear pulses in the period range from 100sec to 300sec. Especially the pulses with periods of 110 sec to 135sec have significance that manifest possibility of the two major black holes which forming a binary system. To clarify this binary, analyses are progressing in the decameter wavelength range.

4.4) High level pulses appear in the period range longer than 800sec.

The pulses are detected with high Total-Eval that is approximately two order of the magnitude lager than cases of period range from 100 sec to 300 sec ; i.e. about 10 times larger in terms of the pulse height. The pulse form rather sinusoidal in these cases. Though the detailed studies are deferred for future works, the most possible origin of these long periods pulses are considered as manifestations of orbital motions of black holes binary; we estimate that there, at least ,more than 10 binary system are possibly existing.

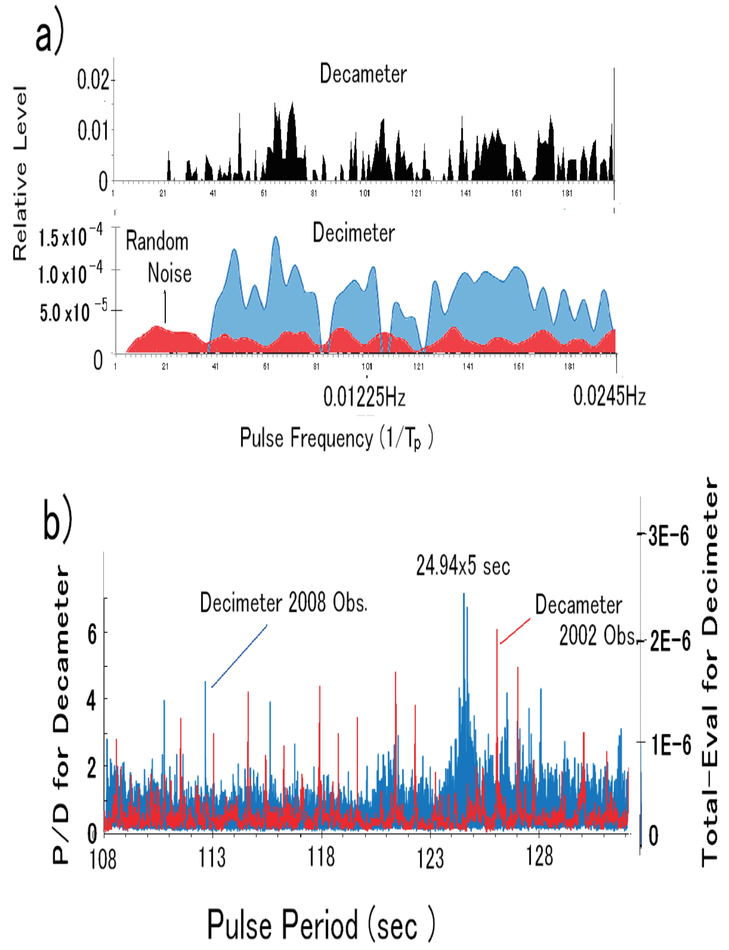

Figure 10.
Comparison of pulse characteristic in decimeter and decameter radio wavelength range. a) FFT results of decameter observed at Iitate in 2010 and results of present study for range smaller than 0.0245Hz: b) results of box-car analyses for decameter cases observed in 2002 by long baseline interferometer and results of present study for period range from 108 sec to 130sec.

5. Discussions

5.1 Comparison between the results of decimeter and decameter cases

In Figure 10. examples for results of FFT and box-car analyses compared between the cases of decameter and decimeter are displayed . The comparison shows that there is no discrepancy to understand the origins of the decimeter radio wave pulses and the decameter radio wave pulses ,from the center region of our Galaxy, to be at the same rotating black holes. One of characteristic point is existence of a large number of associated pulses centered around the intrinsic period as we can see both in the decameter pulses and in present results of decimeter case. Occurrence of these group of pulses are due to the frequency modulation caused by Doppler shift effects resulted by orbital motions of origins i.e., rotating black holes which are forming binary black holes.

The spreading of the pulse periods is another important subjects of comparison between the decameter pulses and decimeter pulses because we can discuss the source positions of the observed pulses. as has been mention-ed in the introduction of the present paper. The rotation periods of the plasma that becomes source agency of the radio wave pulses varies as functions of the source position[3] that is expressed by the distance from the event horizon, as is the case of the gravitational red shift effects (see Figure 11[3] and Figure caption there). That is, the decimeter radio wave pulses emitted in outer region than the decameter radio wave sources where less red shift effects compared to the case of the decimeter radio waves are expected , may reveal the wide spreading of the pulse period. From this stand point of evaluation we may state that the spreading of the detected pulse periods given in Figure 10 where signature of

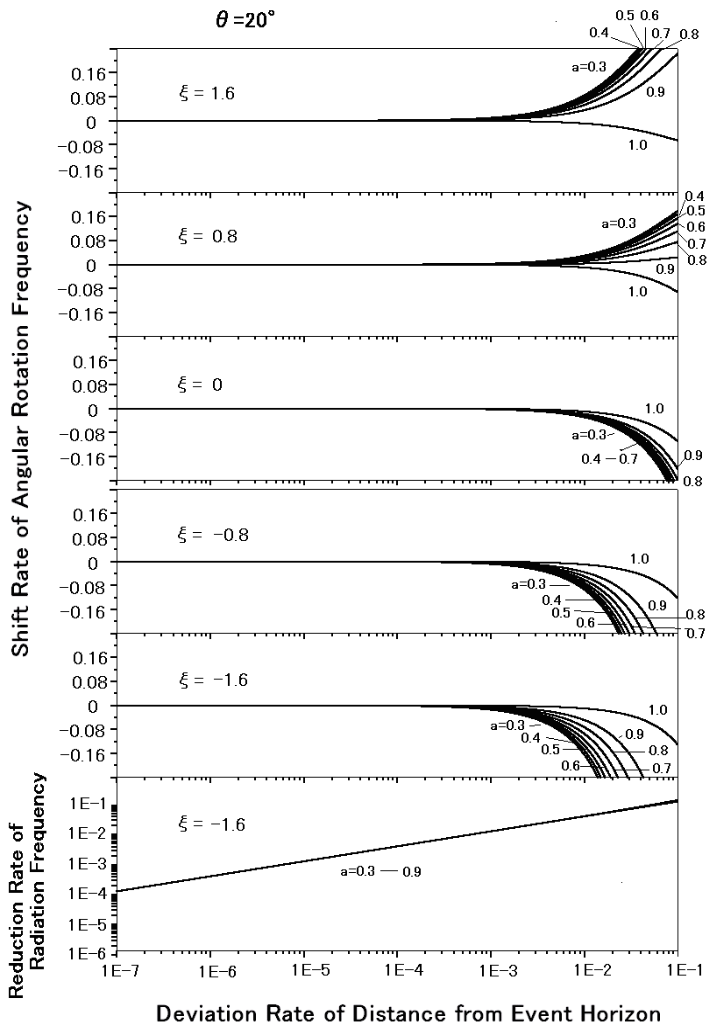

Figure 11.
Shift of rotation periods of Kerr BH space time close to the event horizon. Shift of rotation deviating from that of event horizon are calculated versus relative distance apart from the event horizon with rotation parameter a as parameter. In corresponding panel, ξ indicates the rate of rotation velocity of plasma with respect to the rotation velocity of space. Red shift rate at corresponding space is given in the bottom panel.

wider spreading of the periods can recognize for decimeter case cannot deny the possibility that decameter and decimeter radio wave sources are located in the region close to the event horizon of Kerr black holes; and the source positions of the decameter radio pulses are located in the region much more close to the event horizon than that of the decimeter radio wave sources

. 5.2 Enhanced pulses around the period 24.94 sec

In the results of FFT and box-car analyses, respectively given in Figures 4 and 7, the enhanced pulse signals which are remarkably larger than the pulses in another period can be identified. Though the progress of the study is in the stage of investigation, these enhancements are attributed to short term bursts of radiation, from the identified black hole binary, that may continue for a few years as are similar cases that had occurred in the case of decameter pulses at the periods of 0.425 sec and 51.8sec.

6. Conclusion

Analyses of the decimeter radio wave pulses from the center part of our Galaxy have been carried out for observations at Awara radio wave station of Fukui University of Technology, from April 25 to July 31, in 2008. The results show basically consistent characteristics with decimeter wave pulses that are discovered in the 2006 observations. In the present analyses, however, multiple of pulses are detected at periods associated with intrinsic periods as analog of the case of decameter radio wave pulses that are understood as manifestation of Doppler effects originated by orbital motions of black hole binary, though details of parameters of black hole binary system for each case are deferred for future study.

A unique evidence for the case of the decimeter pulse is the existence of pulse with enhanced level at the period of 24.94sec and associate group of pulses, within the periods from 24.91 to 24. 97 sec , that take place at the selected periods indicating 0.007sec gap of the periods each other. Though search for the counter part black hole is needed at the present, we can estimate the orbital motion of black hole binary with period of 24 hour 36.21 min. considering the frequency modulation mechanism as origin of this multiple occurrence of the pulses at selected periods. In the period range from 100 sec to 300sec the detected pulses show similar tendency with the case of the occurrence of the decameter pulses which are investigated as major black hole binary whose total mass exceeds one million solar mass.

The present study also provides significant data for the spreading range of the detected pulses. Though more detailed studies are required, we may state that there is difference between spreading ranges of decameter radio wave pulses and decimeter radio wave pulses. In the case of the decimeter pulse periods, the spreading is wider than the case of decameter pulses as expected from the theory of the rotation periods of the source agency in Kerr space time assuming the source position to be extremely close to the event horizon.

Acknowledgement

This work is based on the observation data acquired in 2008, at Awara space radio observation facility, we thank to all related staffs of Fukui University of Technology who had supported the present work for running facility and observation system. Data analyses had been carried out in Graduate School for Science, Tohoku University, we are grateful to Profs T.Ono ,N.Terada and Y. Kato for their efforts to accommodate the facility for data analyses and their worthwhile discussions.

References

1)

Oya, H. Discovery of decimeter radio wave pulses from super massive black holes in the center region of our Galaxy-First preliminary results, Memoirs of Fukui University of Technology, **36 Part 1,** 221-228, 2006

2)

Oya,H. and M.Iizima, Cluster of super massive black holes in the central region of our Galaxy observed by decameter radio wave pulses:-Discovery of 24 super massive black holes and their motions, Tohoku Geophysical Journal, Science Rep. Tohoku Univ., Ser 5, **35** No.2,1-78, 1999

3) Oya,H., On the detection of rotation periods of Kerr black holes, Submitted to ApJ, for evaluation, 2011.

（平成 24 年 3 月 31 日受理）