Nat. Hazards Earth Syst. Sci. Discuss., 2, C1192–C1208, 2014
www.nat-hazards-earth-syst-sci-discuss.net/2/C1192/2014/

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Spatiotemporal multifractal characteristics of electromagnetic radiation in response to deep coal rock bursts" *by* H. Shaobin et al.

H. Shaobin et al.

weytopcumt@163.com

Received and published: 25 June 2014

Response to referee #2 Manuscript Number: nhess-2014-3 Title: Spatiotemporal Multifractal Characteristics of Electromagnetic Radiation in Response to Deep Coal Rock Bursts Submitted to Natural Hazards and Earth System Sciences

On behalf of my co-authors, I thank you for your comments on our manuscript entitled 'Spatiotemporal Multifractal Characteristics of Electromagnetic Radiation in Response to Deep Coal Rock Bursts'(Manuscript Number:nhess-2014-3). These comments are all valuable and very helpful for revising and improving our paper, as well as the impor-

tant guiding significance to our researches. We have studied the comments carefully and have made corrections, which we hope meet with approval. Revised portions are marked in red in the paper. The main corrections in the paper and the responses to the comments are as follows.

We hope with these revision, our manuscript can be accepted to publish in the Natural Hazards and Earth System Sciences. Sincerely yours, WANG Enyuan

[1] Ambiguity concerning the names/surnames. To be in accordance with references...

Response: As suggested, we have rewritten it: Shaobin Hu, Enyuan Wang, Xiaofei Liu

[2] P 2308 Line 6:Coal rock in the burst-prone zone often exchanges materials and energy with its environment and gradually transits from its original stable equilibrium structure to a non-equilibrium dissipative structure with im-plicit spatiotemporal complexity or multifractal structures, resulting in temporal variation in multifractal EMR. What materials are exchanged? Response: We are very sorry, that is not given in detail. In fact, underground coal mine is a complex system which contains roof and floor, coal, gas and water. Gas and water flow in underground. Affected by the mining stress, the coal and rock would also occur damage and deformation. And in this process, the material and energy will transfer between coal and rock.

[3] P2308 Line 10-15: Correct English: Results show that the time-varying multifractal characteristics of EMR are determined by damage evolutions process, the dissipated energy caused by damage evolutions such as crack propagation, fractal slid-ing and shearing can be regarded as the fingerprint of various EMR micro-mechanics. Response: This statement does exist error, it has been revised to: Results show that the time-varying multifractal characteristics of EMR are determined by damage evolutions process. And the dissipated energy caused by the damage evolutions, such as crack propagation, fractal sliding and shearing, can be regarded as the fingerprint of various EMR micro-mechanics.

[4] P 2309 Line 2,6,9: Wrong/Missing Reference, What the term (dynamic disasters) means? correct english: as well as fractal structure. Response: We are sorry for our carelessness. There are problems of lacking of some references. We have already added some references in the revised manuscript. The term of dynamic disaster is a mainly used in mining engineering, it consists of rock burst, coal and gas outburst, strong phenomenon of underground pressure and roof and floor collapsed and so on.

[5] P 2309 Line 20-24: Correct English: Moreover, EMR emitted before seismic or in the process of rock failure not only has critical characteristics, experimental and in-situ observation data also show that the EMR time series exist characteristics of the time-varying fractal dimension, change inentropy, and multifractal. Response: This statement does exist error, it has been revised to: Moreover, EMR emitted before seismicevents or rock failure process. EMR has critical characteristics, and experimental and in-situ observation data also show that the EMR time series exist characteristics of the time-varying fractal dimension, change in entropy, and multifractal.

[6] P 2310 Line 1: Correct English: before global ruptures of various scales occurred from rock failure to crust collapse, EMR underwent a very complex, intensity-increasing process. Response: This statement does exist error, it has been revised to: while before global ruptures, EMR underwent a very complex, intensity-increasing process.

[7] P 2311 Line 4-5:Increasing evidences have shown that it is difficult to quantitatively describe seismic electromagnetic (SEM) phenomena by “linear” models using “averaged” parameters. But also the fractal parameters, $\Delta\alpha$, Δf, are also interpreted by you in an average manner concerning their temporal evolution. Just keep the non-linearity or comment on that... Response: As the experts said, this sentence may cause readers ambiguity. In this paper, the nonlinear theory (multi-fractal theory) is used to analyze data. And fractal parameters $\Delta\alpha$, Δf change over time. Here, we want to emphasize that a non-linear method (time-varying multi-fractal theory) is applied to analyze the signal that the nonlinear system (rock burst is a nonlinear mechanical behavior) generated with the time changing. Compared to use the critical value to forecast coal-rock

dynamic disaster, the method has been improved. We have made a corresponding adjustment in the relevant parts of the revision. Following: More and more evidence shows that it is difficult to describe the evolution of nonlinear systems by linear theories and models. Nonlinear theory provides a new approach for describing the behavior of nonlinear dynamics.

[8] P 2311 Line 20-25. Actually is more spatial because as excavation proceeds monitoring refers to different coal blocks. Response: As the experts said, the electromagnetic radiation signal indeed changes with spatially dynamic tunneling processes. We make the following adjustmentïijŽ This article is actually to show monitoring the time and space electromagnetic fieldãĂĆBecause the tests are carried on in the underground space which is a natural shielded room, electromagnetic signals that we set is mainly from coal-rock rupture process. For stable tunneling process(no shock hazard), although the mining space is changing, the electromagnetic radiation signal is substantially in a steady state. Only in shock hazard area (stress concentration area), coal and rock deformation and failure become serious and Electromagnetic signal appear abnormal. Electromagnetic signal is actually changing over time, and it is a space-time evolution of the process. Generally, for the stable system, even if the space is changed, the electromagnetic radiation is in the "steady state". For hazardous areas, even if space is not changed, there will be abnormal electromagnetic radiation. Therefore, time and space are synchronized in the underground space. We analyze the time series of electromagnetic radiation anomalies to determine the status of coal and rock system.

[9] P 2312 Line 14. Provide key-specifications of the antenna. Response: Since wide band of electromagnetic radiation in underground mining space, we chose a high-sensitivity wideband directional magnet receiver antenna. Frequency bandwidth: WidebandïijĹ1kHz$\sim$500kHzïijL’. Test mode: Non-contact orientation test. Predict the distance: 7$\sim$22m, up to 50m. Antenna size: diameter 70 * 300mm. Passive, not requiring external power supply. The monitoring signal is amplified by the additional

preamplifier.

[10] P 2312 Line 20. No need of numbers. Response: We have already cancelled the number

[11] P 2313 Line 10-15. Improve English of underlined text. Response: We have revised the English sentences. According to electromagnetic theory, the frequency of the maximum power point of EMR changes over distance from radiation source, frequency varies inversely as the square of the distance. The frequency of the max power radiation is determined by spectrum analysis. And then we could effectively predict the distance of EMR radiation source. The specific derivation was given out in literature (Wang Enyuan et al., 2009). All of the above factors would affect the EMR antenna layout

[12] P 2313 Line 15-20. Justify fully the different observation limits. 5m, 20m ... Why?. Response: We are sorry fou our carelessness. We have already recised this part and procided basis of the above installation conditions in detail The EMR signals attenuation can be influenced by electrical parameters of coal and rock (resistivity/conductivity), coal mechanical parameters, composition, the stress state of the coal seam, gas and moisture content. Therefore, the signals attenuate sharply when the signals propagate outward through the surrounding coal and rock. The monitoring areas of EMR are limited due to the high signal attenuation. EMR signals generated by coal and rock deformation and fracture mainly belongs to low frequency signal. According to electromagnetic theory, the frequency of the maximum power point of EMR changes over distance of radiation source, frequency varies inversely as the square of the distance. Make spectrum analysis for the recorded EMR signal, determine the frequency of the max power radiation, then we could effectively predict the distance of EMR radiation source. The specific derivation was given out in literature (Wang Enyuan et al, 2009). All of the above factors would affect the EMR antenna layout. According to the literature (Wang Enyuan et al,2009), the most suitable distance between the antenna and the measured area is equal to or less than 5 m, depending upon the size of

the mornitoring area, which has to locate in the opening direction of the antenna. The monitoring distance or range of each antenna is about 20 m, thereforem the measuring points are set every 10 m to 20 m in the working face. For those zones of greater rock burst risk, the measuring points should be arranged as more as possible (see in Fig.3).

Wang Enyuan, He Xueqiu, Liu Xiaofei, Zhao Enlai., 2009. Technology and application of coal and rock electromagnetic radiation. Science press, BeiJing, China.

[13] P 2313 Line 27. $\sim$.06Hz sampling rate. Why? Response: We are very sorry for the improper expression. This expression is not clear, we have revised it in the . The sampling frequency of our antenna is 25 KHZ/s, which is close to the frequency of the coal rock EMR. In fact, the system can collect data every second, but only record and store data every 15 seconds.

[14] P 2314 Line 1-5. Crucial! Provide more info. Explain! See also my comment on page 2311. Response: First of all, the electromagnetic radiation data we collected are in deep underground space, it is a very good electromagnetic shielding room. But, it is also easily affected by underground space operations. So we have to conduct a filter processing to the EMR signal. Our specific filtering algorithm mainly adopt an average of five point, and conduct a big wave filter to high value intense fluctuation signals over a certain period of time. Therefore, we are actually do a further statistical analysis and calculation to the electromagnetic radiation data from the field, as shown in the following figure:

Usually, we regard it as a symbol of system evolution based on the changes of the basic value of the background EMR signal. But it is easy to ignore the local abnormal signal in this way. They are real signals, as shown in figure. 5 to 7, by compressing the timeline, we can see the change trend of reference signal. In the back of the section, we analyzed the local abnormal signals and all internal information based on nonlinear theory.

[15] P 2314 Line 6. Provide some info concerning both mines. Magnitude, age, com-

plexity (in terms of tunnels and shafts) of the mine, depth of excavation under study, types of coal rocks. Add a geographical map with their locations and distance between and if possible a couple of photos. Response: We are very sorry, due to confidentiality reasons, some information about the two coal mine disasters and accidents could not be open, but we try to provide detailed information about the two disasters. In addition, we focus on the analysis of the data detected in the evolution process of the accident. The specific information of two mines are as follow, which has been revised in paper: Coal mine A: The first field investigation on rock burst was conducted at Coal Mine A located in Yi Ma city, Henan Province, China. Coal mine was founded in 1958, now the mine production capacity is 1.48 million tons per year. It occurred during excavation at No. 23150 mining face of the bolted roadway before dawn on March 12, 2013 causing great damages to the roadway long up to 50 m, slight roof sinking, upheaval of 0.8 m floor, 0.8 m displacement of roadway's both sides, and deformation of the supports at different degrees. Ground elevation is + 532 $\sim$ + 560.2 m, an average elevation of roadway is about - 330m, the buried depth is about 880 m. Coal seam roof is mudstone, 20 m thick or so, bottom for fine grained sandstone, 0 $\sim$ 25 m thick. The compressive strength of coal is as high as 40 mpa. Average thickness of coal seam is about 6.6 m, having a strong bump proneness.

Fig. 4. Schematic of EMR monitoring in the mining roadway coal mine B is located in HeiLongJiang province, China. It is in deep mining currently, the strata behaviors are serious, Sevral rock burst accidents happened. The coal seam is thick, which is about 8.21-12.94 m, immediate roof is fine sandstone for 4 to 7 m, directly low is siltstone for 4 to 7 m.

[16] P 2314 Line 15-20. This discussion is actually on the "dc like" average (over time) EMR intensity or equivalently on the background level of EMR and their change through time. You must justify this statistical approach of non-linear phenomena. Response: As expert said, the discussion is indeed equivalently on the background level of EMR and their change through time. Due to the limited underground space scale,

the collected data influenced by cable, drilling operations. which make the electromagnetic radiation data contains a lot of interference signals. According to our field EMR monitoring experience, we analyzed the characteristics of all kinds of EMR interference signal, and developed the corresponding methed to filter interference signals. Such as the response to comments 16, We first make a 5 point average, then conduct big wave filtering. Accordingly, we preliminary analyze the overall trend of electromagnetic radiation. Because of the shortcomings of the above analysis method (although the critical value and the dynamic trend method can filter out the interfereence signal, yet it is easy to lose the true and useful signal). That is why that, in this paper, the time-varying multifractal theory is used to deal with and analyze the original EMR data. The nonlinear characteristic of electromagnetic radiation is more obvious due to the anisotropy of coal or rock, the mining stress and interference on-site. We can not simplily put a electromagnetic radiation mutation point as a danger signal (It has the possibility, but at the same time, it is possible that it is interference signal, or tightly the "stable" nonlinear change of EMR signal caused by mining activities). Therefore, we need to reveal the implicit information of EMR signals during the process of coal deformation and failure.

[17] P 2314 Line 15-20. From 6 March to 10, EMR intensity increased about three-fold from its basal level of 18 mV to the peak of 60 mV, and the measured EMR varied fiercely. What about the amplitude of the spikes (?) Actually they seem like spikes due to compressed time-axis (?) See comment in Fig. 5. Response: We are sorry that we do not describe the related content clearly, Which leads to some ambiguity. Usually, due to the big interference on site, so in dealing with field data, generally the method of average statistical analysis was carried out on the electromagnetic radiation. Therefore, the amplitude of the spikes we refers here, in fact, is the maximum basic value (the background EMR signals). This kind of processing method can avoid the interference signal, but also it is easy to lose the true and useful signal. Therefore, in this paper, We studies the time-varying multifractal of electromagnetic radiation, the original electromagnetic radiation signals were used. This method can analyze the partial abnormal signals and the overall trends. In this paper, there are indeed problems

that figure 5 and figure 10 are not clear. Because of the great amount of our acquisition of data, if not compressed timeline, data is difficult to show in one figure. As a result, we compress the time axis, resulting in a number of key nodes electromagnetic signal is "hidden". Therefore, according to the opinions of the experts, we have carried on the correction.

[18] P 2314 Line 15-20. EMR intensity is affected by different stope backgrounds.Very important statement to my opinion that demands thorough elaboration and discussion. Response: As the reviewer said, we have added the related content. The underground space electromagnetic radiation signals, under the condition of undisturbed, have their own independent background signal, and the signal is very stable. The production of coal and rock electromagnetic radiation signals is mainly affected by the development and slipping of internal cracks of coal or rock. EME from loaded coal is determined by its mechanical properties, stress level, and loading rate. In general, the higher the coal intensity is, or the greater the stress level, or the greater the energy inflow rate, the greater the EMR signals are. Even if in the same coal mines, the background electromagnetic radiation signal is also different in different working face. Based on our years of experience in electromagnetic radiation monitoring and warning, we usually adopt the critical value method and the dynamic trend method for dynamic disasters monitoring and early warning. Before EMR monitoring and early warning on an area, generally we need monitor the EMR signals of the area for a period of time, determine the background EMR signal strength. According to the phenomenon of underground pressure situation, determine the critical value of electromagnetic radiation (we have our own algorithms and software, it is not convenient to provide detailed information), Detailed information you can get in the reference (Wang et al., 1997; 2011; 2012; He et al., 2012).

[19] P 2315 Line 1. On what ground the critical value is defined (in both cases)? Response: Based on our years of experience in electromagnetic radiation monitoring and warning, we usually adopt the critical value method and the dynamic trend

method for dynamic disasters monitoring and early warning. Before EMR monitoring and early warning on an area, generally we need monitor the EMR signals of the area for a period of time, determine the background EMR signal strength. According to the phenomenon of underground pressure situation, determine the critical value of electromagnetic radiation (we have our own algorithms and software, it is not convenient to provide detailed information), Detailed information you can get in the reference (Wang et al., 1997; 2011; 2012; He et al., 2012).

[20] P 2315 Line 1. The overall EMR background level is almost one order of magnitude greater on Coal Mine B compared to A. You should comment on that. Response: According to the expert's advice, we have added the corresponding comments. As previously we replyed, due to the difference of mechanical properties of coal, water content, extractive speed, ground stress and roof and floor rocks, on-site methods, resulting in the background electromagnetic radiation signals different. Even the same coal mines, different coal face roadway, the electromagnetic radiation also have obvious difference.

[21] P 2315 Line 6-9. The above two typical examples indicated that when abnormal EMR signal is an indicator of rock burst regardless its location, either the mining face or the heading face and affected by the coal rock mechanical properties, coal seam geological structure, working environment, etc. Lacks clarity. Rephrase. Response: We carefully analyzed the words, we think that translation is not accurate, expression is not clear, now do the following adjustments: It can be seen from the above two examples that the electromagnetic radiation will be abnormal before rock burst. The generation of electromagnetic radiation of coal or rock is mainly produced by the development of internal cracks of coal or rock and the slip, the higher the coal and rock stress, the greater the intensity of electromagnetic radiation. Literature (S.B Hu, et al.,2013) shows that the electromagnetic radiation is affected by the mechanical properties of coal, stress level and loading rate. Different mining face, the mechanics properties of coal, coal face stress state and geological structure, the background electromagnetic radiation

signal has obvious differences. In the process of rock burst evolution, the electromagnetic radiation reference signal will be increased, at the same time, the electromagnetic radiation will be intense changes. Wang et al (2011) have proved that rock burst could occur when EMR intensity changes, either increase or decrease, making it very difficult to monitor and early warn rock burst. For example, the rock burst in mine A occured in the process of the electromagnetic radiation reducing, but for mine B, the rock burst occurred in the process of electromagnetic radiation increasing. In the process of the rise or fall of electromagnetic radiation, imply much potential information, such as, at a certain moment, the fierce change of electromagnetic radiation (On March 6 and 7 in figure 5). We can not ignore the "abnormal" signal (it can be regarded as interfering signal easily). So it is necessary to further analyze the nature and inherent laws of the nonlinear dynamic characteristics of EMR during the spatiotemporal evolution of rock burst.

Shaobin Hu, Enyuan Wang, Zhonghui Li, Rongxi Shen, Jie Liu.,2013. Time-Varying Multifractal Characteristics and Formation Mechanism of Loaded Coal Electromagnetic Radiation. Rock Mech Rock Eng, DOI 10.1007/s00603-013-0501-9

[22] P 2315 Line 17. So it is a matter of the EMR background level? Why? What is the cause? Explain its nature and physical mechanism. Response: As the reviewer said, it is indeed the electromagnetic radiation signal in the background where no rock burst danger and no mining. As is known to all, the generation of electromagnetic radiation of coal or rock is mainly produced by the development of internal cracks of coal or rock and the slip, the higher the coal and rock stress, the greater the intensity of electromagnetic radiation. The electromagnetic radiation antenna monitoring scope is limited, At the same time by underground natural shielding effect, for no danger zone, the stress is low, coal and rock is in the stable state (slow development of fracture), which leads to the electromagnetic radiation is relatively stable, and low level. As reviewer said, it is indeed the electromagnetic radiation signal in the background where no rock burst danger and no mining. As is known to all, the generation of electromagnetic radiation

of coal or rock is mainly produced by the development of internal cracks of coal or rock and the slip, the higher the coal and rock stress, the greater the intensity of electromagnetic radiation. The electromagnetic radiation antenna monitoring scope is limited, At the same time by underground natural shielding effect, for no danger zone, the stress is low, coal and rock is in the stable state (slow development of fracture), which leads to the electromagnetic radiation is relatively stable, and low level.

[23] P 2316 Line 1. You should clarify what the index i is indexing. Response: We have made comments in the paper. Xi refers to the collected electromagnetic radiation time series, i is a sign of the electromagnetic radiation data changing over time, which reflect the amount of electromagnetic radiation data, but also corresponds to the corresponding time (Because the time interval for each data record is certain). Therefore, i refer to the electromagnetic radiation data quantity, through the conversion, it also can reflect the collection time.

[24]P 2317 Line 17-20. The difference of e.g. α(max) and α(fmax)? ResponseïijŽWe are sorry, that is a mistake. In the paper, only the α(max) exist. α(fmax) is spelled wrong, we have correct it.

[25] P 2318 Line 17. Happening in different time and place...? Response: During the process of coal and rock deformation and failure, the monitor area change over time during excavation. The electromagnetic radiation signal is mainly produced by coal and rock crack propagation slip. Therefore, no matter how change monitoring area, for the same kind of coal, the strength of the electromagnetic radiation and change law can reflect the state of stress concentration and cracking of coal or rock. Here, the time and space can be synchronous actually, the space and time are changing.

[26] P 2319 Line 19. Throughout Figures 5 to 10 the time axis should be expanded to depict clearly the time evolution. Include major and minor time units (ticks) to facilitate the reader. Actually I see a step-increase between 7 and 8 March 2013. The increase of Δf foreruns. Furthermore, for Δf follows a step decrease and then a gradual in-

crease...

Response: In this paper, there are in fact problems that figure 5 and figure 10 are not clear. Because of the great amount of our acquisition of data, if not compressed timeline, data is difficult to show in one figure. As a result, we compress the time axis, resulting in a number of key nodes electromagnetic signal is "hidden". Therefore, according to the opinions of the experts, we have carried on the correction. In figure 8, the experts see a step-increase between 7 and 8 March 2013. The increase of Δf foreruns. Furthermore, for Δf follows a step decrease and then a gradual increase.... First of all, it is normal that Δ f rise/fall periodically. In this thesis, we do not explain the details. As is known to all, in the process of underground mining, the mining stress is periodic change, we call it 'Periodic weighting. And the intensity of coal or rock electromagnetic radiation is proportional to the stress state. Caused by the periodical change of stress state, the electromagnetic radiation signals contain these internal implicit information. For the spatial variation of the electromagnetic radiation during underground mining, $\Delta\alpha$m and ΔÆŠm have clear physical meanings. The EMR released from coal or rock is a result of the combined action of different micro radiation mechanisms (Gokhberg et al. 1982; Nagahama and Teisseyre 1998; Freund 2004; Triantis et al. 2006; Miura, T and Nakayama, K. 2001; Muto, J et al. 2006; Akito Tsutsumi et al. 2008). Generation of EM signals is related to the dislocation and sliding of coal joints, cracks, and lattices, as well as crack development and could lead to dynamic nonlinear changes hang of EMR. The greater the $\Delta\alpha$m is, the more obvious the multi-fractal characteristics of EMR, which suggests increased difference of EM mechanisms and implies coal and rock system from stable state into nonlinear acceleration deformation stage, reduced stability and increased outburst risk. ΔÆŠm reflects the difference in proportion of micro mechanisms of EMR. EMR is associated with coal or rock dissipation energy (Yao et al 2010; Song et al. 2012). The greater the dissipated energy rate is (the greater the damage rate is), the greater the EMR intensity. Thus, compared to the strong plastic flow (shear failure), brittle fracture (crack propagation) is a strong microcosmic mechanism of radiation. ΔÆŠm > 0 indicates that the weak radiation mechanism is dominant

and suggests that the coal and rock system is prone to plastic flow failure (sliding failure). ΔÆŠm < 0 indicates that strong micro radiation mechanism is dominant and that the coal rock system is at the stage of crack propagation. In figure 8ïijŇon March 7 to 8, $\Delta\alpha$m jumped and maintained at a high level, Δ ÆŠ m also began to rise gradually. This indicates that the coal and rock has begun to enter the stress concentration area (the closer the orbit up the mountain, the more concentrated the stress), the deformation and fracture of coal or rock gradually increased, at this point, the coal rock system is at the stage of crack propagation.

[27] P 2320. Although Δf<0 which means strong radiation mechanism is dominant (according to authors) this is not the case of EMR intensity (Fig. 5). This is also the case for Mine B? Then why we observe strong EMR (in amplitude and level) at the time of rock burst?On the other hand, one can notice that in both cases the rock burst in comparable values: $\Delta\alpha\sim$0.2, Δf$\sim$-0.2 to -0.4??? Actually I notice in Fig. 9 step-increase for $\Delta\alpha$ and Δf in the "development phase". Again, as in case A, the increase of Δf foreruns (31-10-2011).

Response: In this section, there are many questions. Now we will explain one by one. Although Δf<0 which means strong radiation mechanism is dominant (according to authors) this is not the case of EMR intensity (Fig. 5). Electromagnetic radiation is closely related to the strength and stress state of coal, at the beginning of the loaded coal and rock, micro cracks developing, but due to the low stress level, while the electromagnetic radiation intensity is dominated by micro crack propagation mechanism (radiation), but the intensity of electromagnetic radiation may still be not high. In addition, the change of two parameters $\Delta\alpha$, Δf need to be considered at the same time, Than we can determine the state of coal rock system. As expert said, two rock bursts occurred in $\Delta\alpha\sim$0.2, Δf$\sim$-0.2 to -0.4. The results of this study are also our attention. EMR signals from these two rock burst evolution processes are obviously different. In Coal Mine A, basal EMR intensity in the advancing roadway was around 20 mV and rock burst occurred at the process of EMR intensity declining. By contrast, in Coal

Mine B, basal EMR intensity in the combined mining face was 150 mV and rock burst occurred in the process of EMR intensity increasing. According to our on-site observation and experience, Thus, the rock burst event may occur in the process of both EMR increasing and declining. We must reveal the nature of dynamic nonlinear characteristics of EMR and seek its internal unity. Site conditions are very complicated, the electromagnetic radiation is influenced by many factors. Because of the complexity of the problem, we conducted experiments and adopt the method of nonlinear processing to find the rule underlying EMR. We believe that our findings are of great significance for the electromagnetic radiation monitoring and early warning. In fact, we have carried out a lot of laboratory experiments. A series of uniaxial compression and multi-stage loading experiments with coal samples of different mechanical properties were carried out. The EMR signals during their damage evolution were real-time monitored, the inherent law of EMR time series were analyzed by using fractal theory. We found the same rule. Literature (S.B Hu, et al.,2013) gives the details. That is also the reason that we conducted field test. This result that “Actually I notice in Fig. 9 step-increase for $\Delta\alpha$ and Δf in the "development phase". Again, as in case A, the increase of Δf foreruns (31-10-2011) ” is not conflict. Due to the mining process of mine A, the monitoring area changes constantly, coal or rock fracture and damage periodically. However, in Coal B, the driving speed is slow and stops for a long time, therefore there is no phenomenon of periodic weighting. Two mine electromagnetic radiations have the obvious difference. But the time-varying multifractal characteristics of EMR are the same and has the inherent unity..

Shaobin Hu, Enyuan Wang, Zhonghui Li, Rongxi Shen, Jie Liu.,2013. Time-Varying Multifractal Characteristics and Formation Mechanism of Loaded Coal Electromagnetic Radiation. Rock Mech Rock Eng, DOI 10.1007/s00603-013-0501-9

[28] P 2322 Line 5-25. Copy from Kawada et al (Nat. Hazards Earth Syst. Sci., 7, 599–606, 2007). Not necessary I think. Response: We have modified the part, and added new contents (our previous research). please refer to the revised paper for specific

changes.

[29] P 2323 Line 10-15. It is important to provide more theoretical and modeling information here. Response: In fact, we have carried out a lot of laboratory experiments. A series of uniaxial compression and multi-stage loading experiments with coal samples of different mechanical properties were carried out. The EMR signals during their damage evolution were real-time monitored, the inherent law of EMR time series was analyzed by using fractal theory. Results show that the time-varying multifractal characteristics of EMR are determined by damage evolutions process, the dissipated energy caused by damage evolutions such as crack propagation, fractal sliding and shearing can be regarded as the fingerprint of various EMR micro-mechanics. Based on irreversible thermodynamics and damage mechanics, we introduced the damage internal variable, constructed thedissipation potential function and established the coupled model of the EMR and the dissipated energy, which revealed the nature of dynamic nonlinear characteristics of EMR. Dynamic multi-fractal spectrum is the objective response of EMR signals, thus it can be used to evaluate the coal deformation and fracture process. Literature (S.B Hu, et al.,2013) gives the details of the modeling process. Now, we have added some corresponding content. Details see section 5.1 Shaobin Hu, Enyuan Wang, Zhonghui Li, Rongxi Shen, Jie Liu.,2013. Time-Varying Multifractal Characteristics and Formation Mechanism of Loaded Coal Electromagnetic Radiation. Rock Mech Rock Eng, DOI 10.1007/s00603-013-0501-9

[30] P 2326 Line 1-10. Authors repeat arguments and information already discussed in section 5.1 and before. Response: Indeed, we summarized the front content again. According to the expert’s advice, we have deleted the related content.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C1192/2014/nhessd-2-C1192-2014-supplement.pdf