Analysis of natural lightning phenomena and method for laboratory study

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Abstract: On Earth, the lightning frequency is approximately 44 times per second, or nearly 1.4 billion flashes per year. The average lightning duration is a few hundred milliseconds made up from a number of shorter strokes. Lightning is a transient process producing very high frequency pulses mostly in MHZ range. The analysis of lightnings using the BSM-SG models indicates that theoretically predicted and experimentally proved "Heterodyne Resonance Mechanism" (HRM) is involved in the transient process of lightning. The physics of HRM effect permits a new understanding on the energy of lightning. This article is focused mainly on lightnings between clouds and ground in which an avalanche process takes place. The enormous energy released during this process could not be only from the potential energy accumulated in clouds. A new technical method for a laboratory study of the lightning is proposed.

Keywords: *VHF spectrum of lightning, HRM effect and Rydberg matter, time evolution of lightning*

1. Observations and study of lightning phenomenon

The curiosity of lightning fascinated many scientists and researchers from the past until the present time. Many of them noticed that the lightnings especially between the clouds and ground release enormous energy that could not be explained only by the accumulated static charge. Today in the era of space research lightnings are observed not only between clouds and ground in the troposphere. The observations from satellites show lightnings and flashes in the ionosphere. Amongst them are sprites and ELVES and they are different from the lightning in the troposphere. They occur in the ionosphere and plasmosphere. Lightnings are also observed in Venus, Jupiter and Saturn where the atmosphere is quite different. Despite all efforts of many scientists the physics of lightning was not properly understood. From the other hand an enourmose data base of observations is accumulated. In many places on the earth an expensive research facilities collect data from lightning storms. Additionally artificial lightning are triggered by rockets. Despite the enormous number of publications the models are usually empirical and do not provide a satisfactory answer on the physics behind the enormous energy of the lightning between clouds and ground.

2. A new theoretical approach for study of lightning based on the HRM effect.

The Heterodyne Resonance Mechanism (HRM) is predicted in the BSM-SG unified theory. [1,2,3,4,5]. What is the HRM effect? In ionised neutral plasma a fraction of ions with one positive charge and electrons combines into ion-electron pairs. The electron circles around the heavier ion while simultaneously moves in a helical trajectory with high speed corresponding to velocities of electron energies: 13.6 eV, 3.41 eV, 1.51 eV etc. However, the electron trajectory is different from its trajectory in a normal atom, where it changes the rotational direction during the single orbital cycle. For this reason the ion-electron pair exhibits a strong magnetic field. The BSM-SG model of the ion-electron pair exhibits much richer properties that the properties of the Rydberg atom based on the quantum mechanical model of atom. The magnetic field of the ion-electron pairs causes them to form clusters and superclusters having own specific magnetic field. I found experimentally that their specific magnetic field opposes the applied external magnetic field. When the superclusters are synchronised they emits a specific spectra of discrete frequencies in the MHz range. Their spectra are distinctive from the atomic and molecular spectra. I firstly observed the spectra of predicted HRM effect in 2005. I arrived to the physical explanation much later, wandering why such spectra have not been reported before. The analysis presented in [6] is based on the measured spectra that I published in [7]. It leads to the conclusion that the discrete frequency spectra is a result of synchronized electron-spin flips of electrons involved in the ion-electron pairs. The high resolution discrete spectrum could be measured only in a small volume glow discharge, where the superclusters are synchronized. Probably, this is the reason that the discrete spectrum has not been observed and reported before.

3. Polarity of the lightning hitting the ground and phases. Signature of the

In a large volume, the groups of synchronised superclusters may emit discrete frequencies but the emission from a larger number of non-synchronized groups leads to a forest of frequencies. For example, the spectrum emitted from a Wimshirst machine and measured by a sensitive radiometer - spectrum analyser appears as a forest of discrete frequencies [7]. It comes from a large volume around the discs of the macine.

The observed spectrum of discrete frequencies from lightnings in MHz range also looks like a forest of frequencies. Below the MHz range the spectrum from the lightning is smoother, while in the MHz range a forest of sharp separated frequencies are observed. They are wrongly contributed to collisions. Collisions from such large volume could not appear as sharp descrete separated frequencies.

Negative and Positive lightnings

Cloud-to-ground lightning is either negative or positive, according to the direction of the electric current. Most lightings are negative, meaning that a negative charge is transferred to ground and electrons travel downward along the lightning channel. In a positive lightning the electrons travel upward along the lightning channel and a positive charge is transferred to the ground. Positive lightning is less common than negative lightning, and on average makes up less than 5% of all lightning strikes [8]. Table 1. shows the main averaged characteristics of positive and negative cloud-to-ground lightning

Table 1. Average characteristics of positive and negative lightnings, Uman, 1987 [22].

Characteristic	Negative	Positive
% occurrence	90	10
Average peak current (kA)	30	35
Average current half life (usec)	30	230
Average number of strokes	3 – 4	1
% containing long continuing current		

For positive and negative lightning I would like to make analogy with the HRM effect in the glow discharge experiments described in [6]. It does not matter which of the electrodes will be grounded - the anode or the cathode. The first one will corresponds to the negative lightning and the second one to the positive. However, this analogy could be applied only for the first phase of the lightning as discussed below.

The polarity reversal is experimentally confirmed by the rocket triggered lightning experiment described by J. Jerauld et al. [20]. Fig. 1. shows the current of a primary negative and a return positive strike.

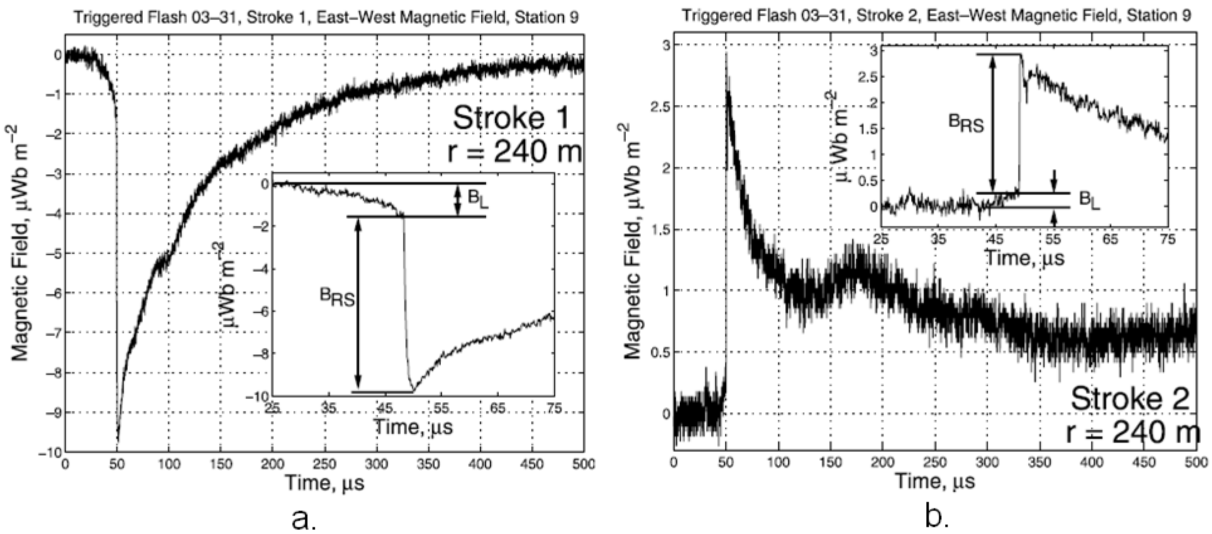


Fig. 1. a. – first (negative) and b. – second (positive) return stroke current waveforme. Courtesy of J. Jerauld et al. [20].

The first stroke waveform shown in Fig. 1 is obtained from the high-bandwidth (5 Mhz) record while the second stroke waveform was obtained from the low-bandwidth (50 KHz) record [20]. One should notice the analogy to the waveforms shown in Figure 12 of [6]. The burst rate is in the KHz range while the HRM frequencies are in MHz range. The conclusions **a.** and **b.** in §4 of [6] are in accordance with the lightning experiments. It was noticed that the active resistance plays a role in the continuing current and therefore on the time between the consecutive strokes.

4. Time evolution of the lightning hitting the ground

Let us focus on one of the most studied case of lightning between the cloud and the ground. Now there are many slow motion video-records of lightning that are useful for analysis of the lightning evolution [9,10]. The links to two of them are given in [11,12]. Initially we see how the lightning streams propagate within or between the clouds before reaching the ground. This is the first phase of lightning. It is similar to artificial sparks created by Tesla coil between the top of the coil and some conductive object. Once the lightning streamers reach the ground (or conductive object on the ground) an enormously intensive flash with much greater intensity and larger thickness is observed. Its optical emission is many thousand times stronger. This is the second phase of the lightning striking the ground.

Here I would like to mention one rear case I personally observed at my younger age. It was a time of approaching thunderstorm but the cloud were away like a wall and I was able to observe lightning near the cloud surface. I noticed that after the lightning is over some bright spots remain visible. They stayed for one to two seconds like stars while dimming slowly. They were at the zigzag kinks of the lightning. This was a repeatable event that took my attention. Now many years later I arrived to a reasonable explanation about these residual bright spots. They could be spots where intensive HRM may occur. They might be very active at the beginning of the lightning influencing the directions of the lightning streamers. Now such bright spots are visible in some slow motion videoclips, such as the video shown in [11] (spots are observable after 22 sec of the video)

First phase:

During this phase we observe the main lightning steamer and some adjacent streamers. Let us consider the negative lightning. The tendency of the main streamer is towards the ground object but it make zigzag due to adjacent streamers. Why the tendency is to the ground? The explanation is that the HRM effect involved in this phase generates scalar (longitudinal waves). They are compress-like waves in the ether, so they affect the electrical potential, guiding the main streamer to the ground. This conclusion can be verified by a simple experiment with a Tesla coil that also emits scalar (longitudinal) waves. For this reason we need to prepare two metal objects with one and a same external shape, but one - hollow, while the other – solid. It is better the solid one to be also from a heavier metal. The Tesla coil should operate in stable mode (stable repetition rate and stabilized supply voltage). Holding the hollow object by a long non-metal clip one must approach it slowly to the top terminal of the Tesla coil and marking the distance at which the streamers start. Then the same test must be repeated with the solid heavier object. One will observe that at the second case the streamers start at longer distance and they are more stable. It is better to observe in a dimmed light. The capacitance of both metal objects are the same (they are defined by external shape), however the streamers for the heavier metal object start from a longer distance. **The conclusion is:**

- **The scalar (longitudinal) waves have the ability to guide the discharge direction.**

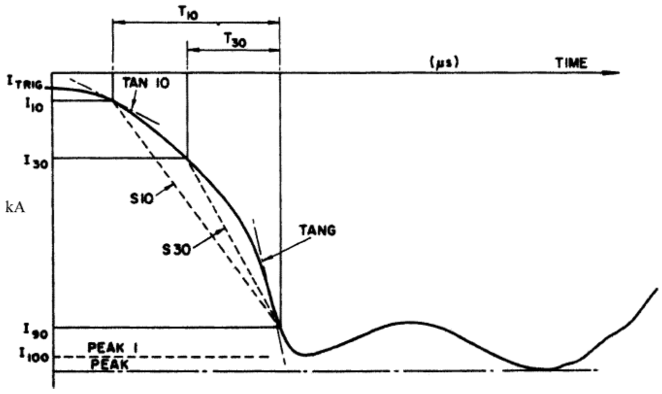
The above conclusion should be valid in the first phase of the lightning. It is reinforced also from the observations that lightning streamers can start simultaneously from the cloud and from the ground object, especially – in the case of a grounded lightning rod. During this process the HRM takes effect but the main energy is contained within the streamers. In the case of positive lightning the process is similar with some strength difference.

Second phase.

When the main streamer reaches the ground its thickness expands and the observed optical emission usually becomes thousand times stronger. Its duration is about hundreds of milliseconds. The initial stroke is followed by another second or third stroke. There is also a polarity reversal. The number of return strokes in the flash could be up to 10 and even more. This phase of the lightning in fact generates very strong EM emission in RF spectral range and the loud sound of the thunder. There is an extensive research on the lightning during the past few decades. [13,18]. The peak current of the first stroke could reach up to a few hundred kiloamps (250 kA are observed). The second return stroke is with a lower peak current but longer tail.

Figure 2 (adopted from Parameters of Lightning strokes, a review IEEE transactions [13]) shows the waveshape of a typical return stroke current [14] and some parameters in the table [15]. From the table we see that the current in the return stroke is in order of tens kiloamperes.

In lightning research a method of artificially triggered lightning is successfully used [16,17]. To induce a lightning strike, researchers fire a rocket dragging a wire into an approaching electrical storm. In a successful attempt, current flow from the cloud, through the wire, to the ground, and vaporize the wire. If scientists witness a second lightning strike, it typically follows the path of the vaporized wire...but not always. (Read the full story on the AGU GeoSpace blog: http://wp.me/p1t6VA-Ef).



STATISTICAL PARAMETERS OF LIGHTNING STROKES IN JAPAN

Parameter	Sample Size	Median	σ
I_p, kA	36	39.2	0.76
t_f, μs	36	4.5	0.37
S_{30}, kA/μs	36	13.6	0.71
S_m, kA/μs	36	28.4	0.70

Fig. 2. Waveshape and parameters of a typical return stroke current [14,15]

Figure 3. shows three consecutive picture frames of the transition from phase one to phase two of the rocket triggered lightning [19].

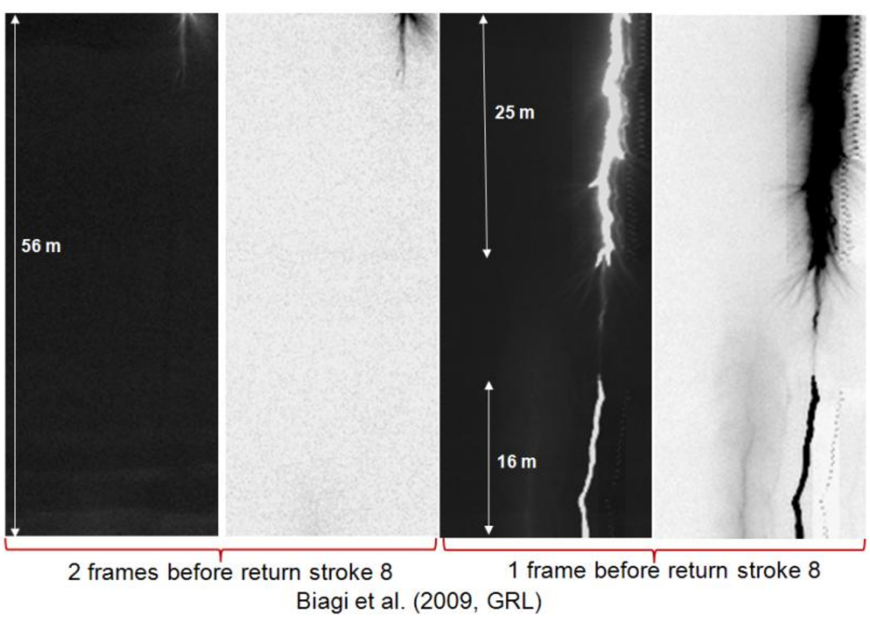


Fig. 3. Three consecutive frames shown as a positive and negative image for a better grey scale imaging. Courtesy of Biagi et al. (2009, GRL) [19].

There are few particularly important features during the second phase of lightning.

- The flash may contain multiple strokes with diminishing amplitudes and polarity reversal
- The current in strokes is huge in order of tens kA. Even return peak current could be in a range of 10-15 kA.
- The average duration of this phase is about hundreds of milliseconds.

There are cases when the lightning destroys a building. This is enormous energy. Despite the extensive research on lightnings it is acknowledge that the physics of the phenomenon is not understood. Empirical models usually are developed based on observations. The question: from where this enormous energy comes is avoided in the publications. We need to answer this question.

Fig. 4. shows the time-resolving spectra from lightning in a few spectral windows [21]. According to the author David M. Le Vine, the records from 3, 30 and 300 MHz are from TRIP-76; Pierce 1976 project obtained by several AM radio receivers with bandwidth of 300 kHz. The records at 30 and 300 kHz are based on literature reports (e. g. , Horner and Bradley, 1964; Malan, 1958). The author of [21] emphasizes that the radiation consists of a sequence of discrete impulses.

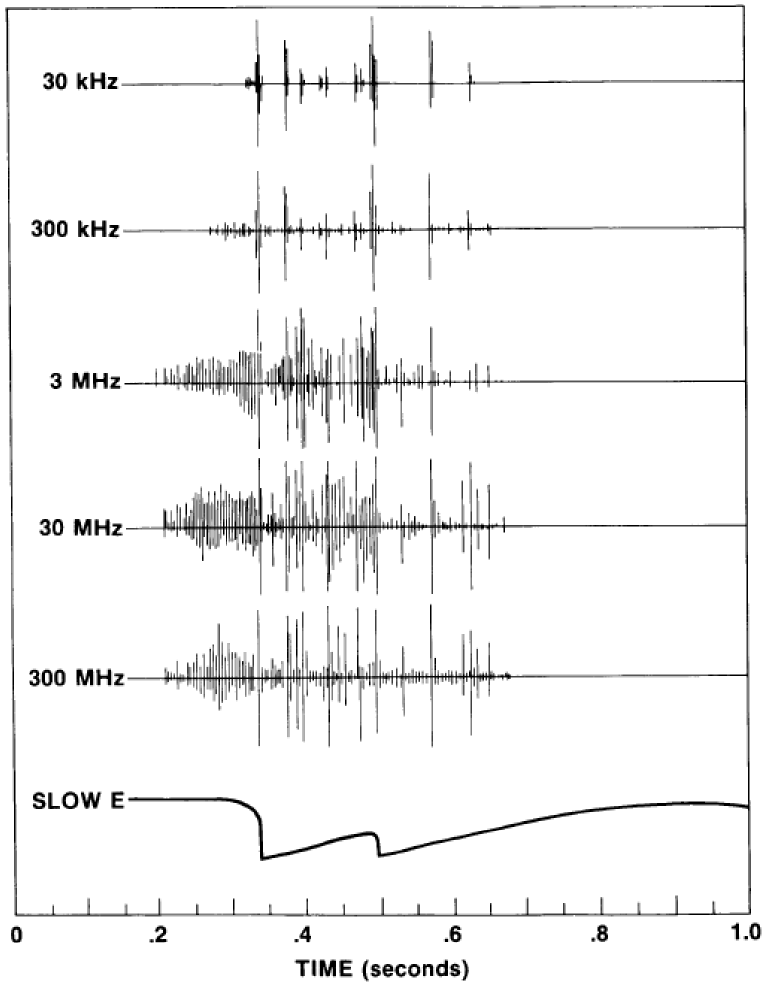


Fig. 4. Time-resolving spectrum from lightning in a few spectral windows. Courtesy of David M. Le Vine [21].

5. The Heterodyne Resonance Mechanism (HRM) in lightnings

Let us consider the physics of the HRM effect during the first and second phase. The accumulated charge in the clouds means that the condition for ionization is fulfilled and formation of oscillating ion-electron pairs takes place during the first phase. However, the sinchronization of ion-electron pairs is only within individual or nearby superclusters but not between all of them because the volume is quite large. Most of the accessed zeropoint energy is in the synchronised superclusters [6] and only a small amount is released. When the streamers reach the ground the scalar wave are able to synchronise a much larger number of superclusters and the conflict between synchronised and non-synchronised superclusters causes destruction of some of them, so their stored energy is released. This causes an additional ionization and development of avalanche process that involves formation of new superclusters of ion-electron pairs. Simultaneously the amount of free charges also increases. This leads to increased current between clouds and ground that exceeds some critical level. The current passes through the ionized path of the lightning and its magnetic field interacts with the magnetic field of the supeclusters. This also causes a destruction of superclusters of ion-electrical pairs and release of the stored energy. The avalanche process leads to fast expansion of the flash thickness that is observed in the second phase. The last frame in Fig. 2. is in full agreement with the suggested transition process involving the HRM effect.

During the second phase the emission of the radiofrequency EM waves is much stronger than during the first phase. One may ask questions why we cannot measure a well-defined spectrum of frequencies separated in bands like the spectra shown in the articles [6,7]. There are two reasons:

a. the spectra shown in [6,7] are obtained from a small volume glow discharge where the superclusters are synchronised;

b. It was noticed that there is a frequency jittering in the consecutive measured spectra that could be from the change of the magnetic field from the current (another probable cause – a Doppler shift is not excluded but must be verified).

From considerations a. and b. it follows that a time resolving spectral measurement are needed. There are not enough such data from lightnings. One useful time resolved spectrum was illustrated in illustrated in Fig. 4 [21].

From considerations **a.** and b. it is evident that the discrete frequency spectra must be measured not only in a small volume of glow discharge but also by using a fast and sensitive spectrum analyser – radiometer. A fast frequency sweep must also be used. The spectrum analyser-radiometer model HP 8590L was suitable for this purpose.

Another supportive argument comes from the observed RF spectrum of Wimshurst machine by sensitive spectrum radiometer, shown in Fig. 5. The spectrum is comprised of a huge number of frequencies in RF range because the supeclusters are distributed in a large volume around the discs, and therefore they are not synchronised.

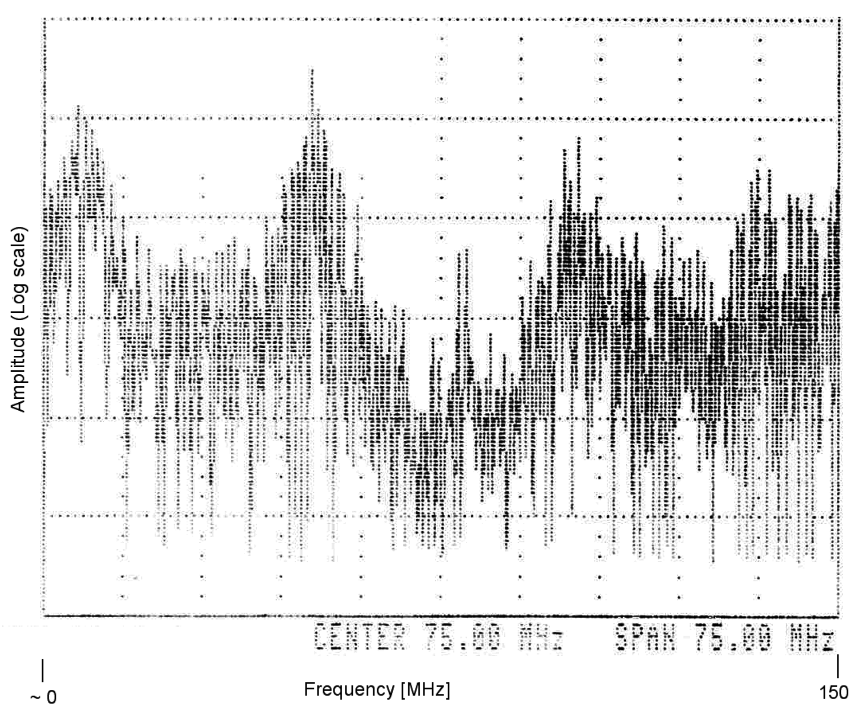


Fig. 5. RF spectrum of Wimshurst machine measured by HP spectrum analyser – radiometer HP8590L

Somebody may argue that the energy comes from the dissociated and recombined hydrogen atoms from the water molecules. The answer is that this could be the case only in the first phase of the lightning where we may have a long time dissociation process and a short time recombination during the lightning. The fast energy release in the second phase, however, could not be from such process. However, the dissociated hydrogen could be ionised and this is the ideal substance for creation of ion-electron pairs. In this sense the hydrogen ions from dissociated water molecules will be also a significant contributor to the released energy from the physical vacuum.

One additional supportive argument for our analysis is the fact that lightnings are observed also in Jupiter, Saturn and Venus. The researchers noticed that lightnings on Venus are unique because they are not associated with water clouds [22]. Instead, they are associated with clouds of sulfuric acid (H_2SO_4). My opinion is that some sulfur acid molecules could be dissociated and the released hydrogen ions could be involved in the formation of ion-electron pairs.

Jupiter atmosphere consists of 90% hydrogen, 10% helium and very small fraction of other compounds. These are ideal conditions for HRM effect and therefore – lightning.

Saturn also has enormous lightning activity. The outer atmosphere of Saturn contains 96.3% molecular hydrogen and 3.25% helium by volume. Evidently these are ideal conditions for HRM effect in lightning. When NASA's Cassini spacecraft approached Saturn, it found that lightnings on Saturn is roughly one million times stronger than lightnings on Earth. The emissions of RF frequency in MHz range were estimated as one million times stronger than from Earth's lightnings.

6. A method for a laboratory study of lightning

The lightning could be studies in a laboratory by the following technical approach.

a. **Providing ionization in air between two electrodes that creates clusters of ion-electron pairs**
b. **Passing a strong current by discharging a capacitor.**
c. **Both processes must be provided as a single short-time event.**

The ionization can be provided by a HV spark discharge from a Tesla coil. Spark voltage could be easily created up to 40 – 50 kV. It could be AC or rectified DC spark. Almost simultaneously a low voltage high current should be passed through the ionization path created by the HV spark. It is preferable to be from a capacitor discharge. A bright explosion will be observed the strength of which depends on the distance between the electrodes and the stored energy in the capacitor. Since the test is at normal atmospheric pressure the adjusting parameter for the spark is only the high voltage and distance between electrodes. For the critical time delay between the HV spark and capacitor discharge (that is in order of tens microseconds in HRM in low pressure) adjustable time delay must be provided. Experiments could be provided also at closed volume under pressure and also with different gazes. In case of closed volume a measure of pressure increase from the explosion should be considered. From the theory of HRM effect, hydrogen and inert gases are the most suitable. The author himself and with collaborators did some experimental tests. More details on the technical approach for laboratory study will be presented in a separate article or book.

7. A laboratory equipment for study of lightning phenomenon.

The predicted HRM effect in the natural lightnings permitted to build a laboratory equipment for creating a small scale lightning. The equipment is comprised by a mini-lightning device containing an electrical and mechanical part, a vacuum system for gas filling and a mechanical system for measurement of the output energy. The equipment permits measurement of important parameters like the input and output energy of the created mini-lightning. Apart of this it permits identification and of some important parameters of the process involving the HRM effect. The optimization of these parameters is expected to be useful in the goal for achieving of overunity, in other words – a derivation of energy from the physical vacuum, as predicted in the analysis of the natural lightnings. This is a new way for study of the lightning phenomenon in a laboratory environment.

I was invited keynote speaker in the 3rd International Conference on Nano Technology and Materials Science, July 22-24, 2019, Rome, Italy where I presented a talk; "Study of a transient plasma process in lightning using the BSM-SG models of atoms and elementary particles". The videorecords of the talk are available in [24,25] and the slides are available in slideshare.net [26]. At the conference I showed a demonstration of a mini-lightning by a device that I built. Only the electrical part of the device was demonstrated, while the electrical and mechanical parts were explained in the talk. The electrical part of the mini-lightning device is shown in Fig. 6, while the block-circuit diagram is given in Fig. 7. In device shown in Fig. 6 two 12 VDC battery sources are used instead of one. Further technical details will be given in another publication.

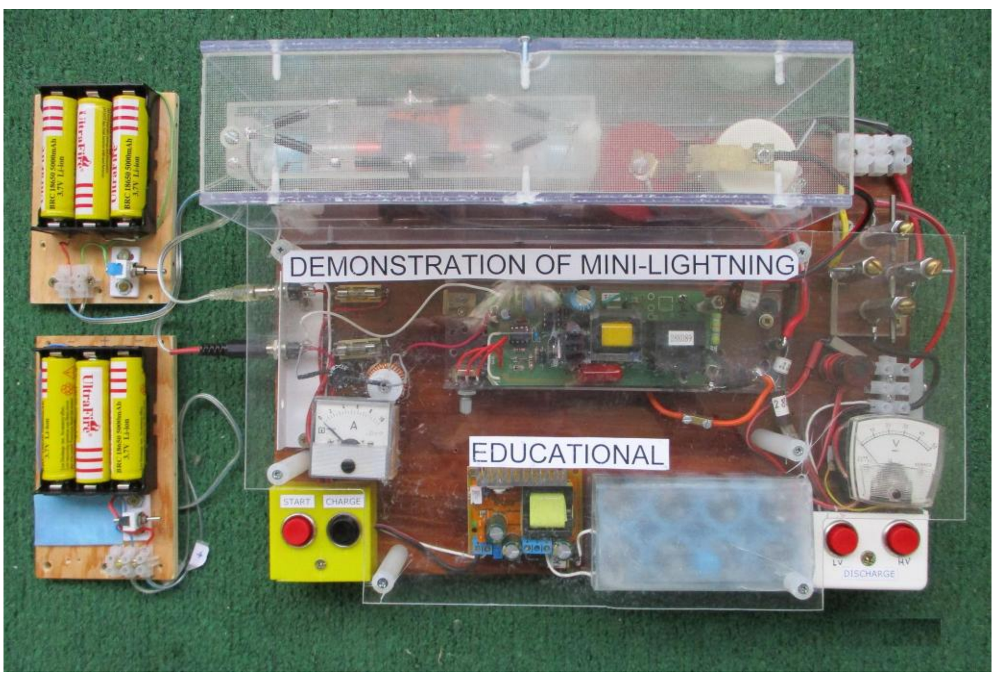


Fig. 6. Electrical part of the mini-lightning device

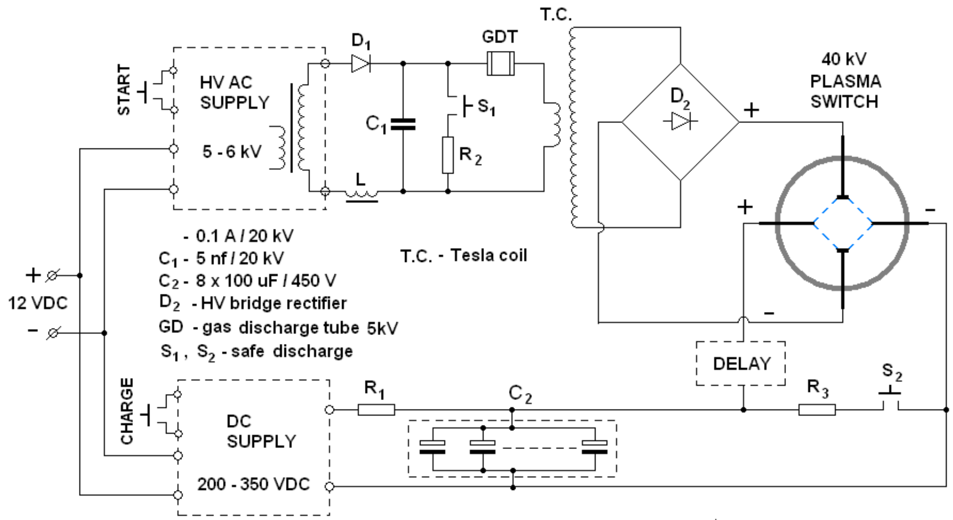


Fig. 7. Block-circuit diagram of the mini-lightning device

8. Conclusions:

1. The lack of water clouds is not critical for lightning, free positive ions and electrons are needed for HRM effect.
2. Free positive ions and electrons could be obtained by ionising radiation. Hydrogen and inert gas are the most suitable.
3. In the first phase of lightning there is a continuous process of creation and destruction of ion-electron pairs and release of free electrons and ions. However the free charges do not exceed some critical level.
4. The avalanche process in the lightning usually begins during the second phase when the generated scalar waves synchronise a greater number of superclusters. Then the current of free charges exceeds some threshold level. This causes a higher rate of destruction of superclusters, formation of new superclusters, and increase of the free charges that contribute to the larger observable current in order of tens of kiloampers.
5. The accessed zeropoint energy due to a large number of synchronised spin flipping of the electrons is transferred to the current of lightning. The transient process of lightning hitting the ground contains a few repetitive strokes and could last for a hundred of milliseconds or even more. The peak current of the first one in some cases could reach up to 250 kA, followed by a current tail. The current tail of the second stroke is longer. This is because the obtained free charges move with a finite velocity.
6. The emitted discrete spectrum in the MHz range is a signature of the involved HRM effect.
7. The observed negative and positive strokes in a single flash indicate that the motion direction of synchronised ion-electron superclusters could be reversed during a single lightning event.

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