Investigating Acoustic Waves as a Solution for hail in farms (reveiw)

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Abstract
all countries suffering of hail, from early spring to late autumn. And at global climate change many countries that are not currently affected by hail may be face to face with this problem soon, like Saudi Arabia in 2018 (Sharif 2018). The existing difference between the growth rates of the world population and food production, the uninterrupted increase in the pollution of nature and the deterioration of the ecology of the environment require solving the problem of lossless preservation of the crop in order to partially overcome the inevitable famine on the Planet. Currently, in agricultural regions, new antihail guns are being used quite efficiently to protect fruit crops from hailstorms. The operating principle of an antihail gun is to generate a vertically directed high-power shock wave by burning acetylene–air mixture in thecombustion chamber located in the basement of the hail gun..
In this research, scientists' research on how to break hailstones by this technology has been investigated

Keywords: acoustic waves ,hail,farm

1. INTRODUCTİON

All countries suffering of hail, from early spring to late autumn. And at global climate change many countries that are not currently affected by hail may be face to face with this problem soon, like Saudi Arabia in 2018 (Sharif 2018).
Though hailstorm can occur in any part of the world, temperate zones are the most vulnerable. Among the countries, hail related losses are most prevalent in USA (Hughes and Wood, 1993). The damage with hails is determined by the size ranges and the number of hailstones that fall per unit area during a hail fall, wind force during the event and the property of the target. The extent of crop-hail damages also varies depending on the stage of occurrence of hail during the crop growing season. Even a short episode of hail can cause severe injury to crops, fruit trees, both downgrading the quality and causing subsequent losses due to diseases like blight, mould, canker and fruit rots. The hailstorms in a region often follow a definite pattern. However, the recent events in the country have surprised farmers and fruit growers when hail moved in from unexpected directions. Widespread unseasonal rainy spells accompanied by hail occurred in several states during February- March, 2014.
Hail being a very short term and localized phenomena, its prediction well in advance to inform all stakeholders for adequate preventive measures is a major challenge for even themost technologically advanced and hail affected countries like as US. India, being situated in the tropical and subtropical region, the frequency of hail eventsis less than midlatitude and temperate countries.However,with climate change, the instances of severe weather aberrations are increasing the demand for strong institutional arrangements to combat such challenges.
While occurrence, losses and post disaster management have been discussed extensively for the other climatic hazards such as excess rainfall, drought and flood, little attention has been given to hailstorm. The following sections elaborate on various aspects of hails for better hail preparedness and posthail management measures.(Figure1)

Hailstorm

Thunderstorm is a meso-scale system with space scale of few kilometers to a couple of 100 kilometers and time scale of less than an hour to several hours. It produces heavy rain showers, lightning, thunder, hail-storms, duststorms, surface wind squalls, down-bursts and tornadoes. Hail is often associated with thunderstorm activity and changing weather fronts. This is formed in huge cumulonimbus clouds, commonly known as thunderheads.

Hailstorms are the result of four atmospheric factorswhich are characterised as:

i. Strong convective instability creating strong updrafts
ii. Abundant moisture at low levels feding into the updrafts
iii. Strong wind shear aloft, usually veering with height, enhancing updrafts
iv. Some dynamical mechanisms that can assist the release of instability such as air flow over mountain ridges

Figure1-Anvil shaped thunderstorm cloud (cumulonimbus) formed over south-central Kansas, USA during June, 2004.

The typicalmechanismof hail formation in a thunderstorm is described in Fig. 2.2. When the ground is heated during the day by the sun, the air close to it gets heated as well. Hot air, being less dense and lighter than cold air, rises and cools. As it cools, its capacity for holding moisture decreases. When the rising, warm air has cooled somuch that it cannot retain all of its moisture, water vapour condenses, forming puffy-looking clouds. The condensing moisture releases heat of its own into the surrounding air, causing the air to rise faster and give up even more moisture.

Cumulonimbus clouds contain vast amounts of energy in the form of updrafts and downdrafts. These vertical winds can reach speeds over 175 km/hr. Hail grows in the storm cloud's main updraft, where most of the cloud is in the form of "super-cooled" water. This is water that remains liquid although its temperature is at or below 0°C (32°F). A supercooled water droplet needs something on which to freeze, or it remains liquid. Ice crystals, frozen raindrops, dust, and salt fromthe ocean are also present in the cloud. On collision, super-cooled water will freeze onto any of these hosts, creating new hailstones or enlarging those that already exist. The faster the updraft on these balls of ice, the bigger they can grow.Cross sections of hailstones often reveal layers,much like those of an onion. These layers are caused by the different rates of accumulation and freezing of super-cooled water, as the hailstone forms. When there is a very high amount of super-cooled liquid in the air through which the hailstone falls, water accumulates faster than it can freeze, so a coat of liquid forms. This becomes a layer of clear ice when it does freeze. When a hailstone falls through air with
less amount of liquid, the liquid freezes on contact with the hailstone forming small air bubbles in the opaque layers. The more supercooledwater a hailstonemakes contact with, the
larger and heavier the stone is likely to become.The growth of hailstones sufficiently large to reach the ground requires very strong updrafts, forces creating taller than usual thunderstorms (Brandes et al., 1997).As a thunderstorm moves along, it may deposit its hail in a long narrow band (oftenseveral kilometers wide and about 10 kilometers long) known as a hail-streak or hail-swath. If the storm

should remain almost stationary for a period of time, substantial accumulation of hail is possible. Its size and shape depend on how fast the storm is moving and how strong the updrafts are inside the storm. A typical hailstreak is about 1.5 km wide and 8 km in length.However, these may vary from a few acres to large belts, about 16 km wide and 160 km long. Most storms that produce hail generate one or two hail-streaks during their lifetime. Some organized lines of thunderstorms producemany hail-streaks with hail covering hundreds of square kms as the storms move across the terrain. Infrequently a thunderstorm becomes a well-organized giant and lasts for three or more hours. These “supercell storms” generate very large hail-streaks.

Hail characteristics and damage potential

The damages accrued with hails are determined by its characteristics that include the size and number of hailstones that fall per unit area and the strength of winds during a hail fall. The association between intensity and the damage depends greatly on the target such as crop, livestock or property. Some delicate-leaf crops such as tea and tobacco suffer damage fromsmall hailstones, whereas other crops such as maize may not be damaged unless hailstones are of size more than 2 cm. The extent of crophail damages also varies with stage of a given crop. A specific type of hailstormmay not cause much damage during vegetable phase growing season but the same storm can be very destructive during flowering and seed/fruit development.

Hailstones range in size from pellets to golf balls or even larger. These are seld perfectly circular, mostly of oblate shape and some have knobs of ice radiating outwards and usually have layered structure inside .

Unusual shapes such as pyramids and discs (Fig2) and size variations arise out of the different atmospheric conditions in which theywere formed.

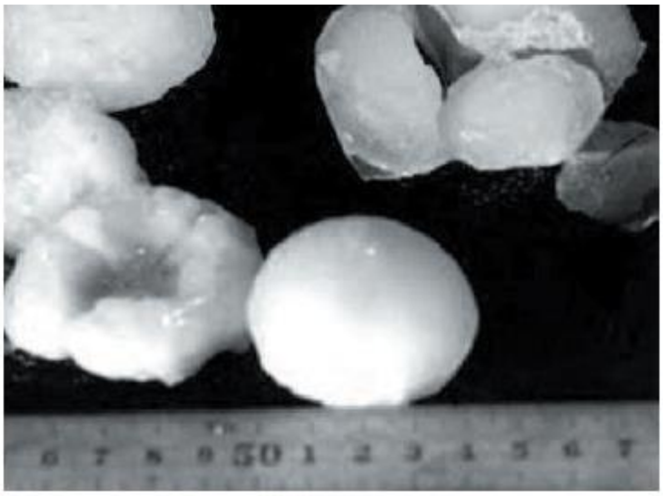

Figure2 .Hailstones of different shapes (Source: Illinois State Water Survey, USA)

Hail control mechanisms

Artificial hail control is an important measure in disaster prevention and mitigation. With the development of atmospheric science and related science and techniques, the ability of hail cloud identification and subsequent hail suppression technique has been improving continuously.The existing difference between the growth rates of the world population and food production, the uninterrupted increase in the pollution of nature and the deterioration of the ecology of the environment require solving the problem of lossless preservation of the crop in order to partially overcome the inevitable famine on the Planet. However, one of the main obstacles to solving the problem of lossless crop preservation is hail and heavy rain which every year cause great and severe damage to agriculture and human properties, as well as injure people, livestock and wild animals (World of Facts, 2015; Harland, 2018). In (Steiner, 1988) (m.fojlaley 2012)the details of some hail events that took place in the last quarter of the last century are presented. Some non-professional, but realistic pictures, footages and videos mostly shot by eyewitnesses and victims during sever hail events of last decade and their comments are shared on social media, for instance (Euronews, 2018; TreerootCO, 2017; Bowie, 2017; The Canadian Arcade, 2016; Jeff, 2012; Romero, 2015; Bezants, 2014: Unwetter, 2013; Dottyriver, 2013; Athanaiadis 2012, and others). Mentioned references show that the size of the damage may consist billions and billions USD all over the World. Therefore, to minimize material damage in size or to prevent economic disruption and downturn in agriculture it is necessary to develop and to use new approaches inanti-hail protection.

At present the anti-hail protection is implemented by the following three methods: hail prevention method, which hinders in advance hail formation or interrupts the further growth of small ice particles in clouds, hail suppression method, which hinders the growth of already formed small and moderate hailstones into large ones, and plants overlapping method, which complete hinders or reduces the physical-mechanical impact of hail on the plant. The overlapping method of plants by the anti-hail net of course is an efficient technique for protection. However, this technique is widely employed to protect some important farms only, and never for wheat and corn fields, for forage and herbaceous vegetation fields, since, the expenses of the anti-hail net's installation and handling are high enough and in a case of large-area farms the overlapping will cost very expensive. Really, in various countries (in Armenia, for Instance) the cost is about 18,000-20,000 USD per hectare for installation and is about 1,200-1,500 USD/hectare/year for both mandatory required handling operations (unroll nets in springtime and roll up in winter). In addition, its use is limited, and after a few years the net must be fully renovated and repaired. And therefore, to use the net throughout the warranty period, and not replace the net with a new one before that period, in some countries with a continental climate, when winter temperature is -200 ÷ -250C, and the summer temperature under the sun can reach 500 ÷ 600C, it is necessary to collect and store the net in warehouses in winter. It should also be borne in mind that the likelihood that the same garden, orchard or vineyard will be damaged by hail every year is very small. Most likely, hail cadamage the crop of the same area only once every 3 or 4 years. Unfortunately, in spite of its high cost the anti hail net is not efficient in the event of severe hail storms. Consequences are potentially even worse than for a completely unprotected farm, because if the net’s structure collapses on the crops the grower will often be forced to replant the entire afflicted areas (Anti-Hail News). Really, in a case of the severe hail with a thickness of 10cm the weight of the ice on each square meter of the net’s areawill be about 80-90 Kg. Therefore, it is more reasonable to protect such areas as well additionally by cheaper cost methods and means of hail suppression and to prevent initially the severe hail using supersonic cannons (gasgenerators), for instance, which may operate autonomous and automatically.Two other techniques for hail prevention and suppression is widely employed in the world: seeding of clouds with silver iodide or other substances, which induce freezing to occur warmer temperatures than otherwise, and the use of sonic cannons or other kinds of explosivedevices.There are two ways in which seeding is postulated to reduce hail severity. Seeding is intended to cause a vast increase in hail embryos, none of which grows to large hail because of competition for the available liquid water. Another approach, premature rainout, involves seeding of cloud elements at an early stage, so that particles which might otherwise become hail embryos fall out of the cloud as rain from lower levels rather than ascend to the higher levels where hail formation takes place. Seeding of clouds, which is implemented by shells or rockets, is an expensive and ecologically harmful one, since each shell or rocket (Alazan-5, for instance) contains 12.6g silver iodide (Antigrad) and costs 20-30USD at least, and for seeding of appeared hail or hail generative cloud a volley of 12-24 rockets is needed. It means that all quantity of silver of launched rockets and their debris (~4.7kg each (Antigrad)) will fall to the ground. Besides, as mentioned in (Steiner, 1988), carefully designed scientific experiments have not demonstrated any reduction of hail resulting from cloud seeding, however there is evidence that many hail suppression operations in various parts of the world appear to have reduced hail damage. There is another problem with rockets and shells application for anti-hail protection of near boundary areas, since the flight range of shells and rockets is about 2-6 km, and at the slightest mistake a Shell or rocket can cross the border of a neighboring state and thereby cause undesirable conflicts or tensions in interstate relations. The use of supersonic cannons, which are cheap and ecologically harmless in application, involves supersonic and significant shock waves generation by sequential detonating an explosive mixture of combustible gas (fuel) and air in a combustion chamber of the gas-generator and their direction upwardly to the sky. It is believed that the succession of shock waves transports positive ions from ground level to cloud level which disrupt formation of hail nuclei. It is assumed as well that due to the shockwaves which emanate from the gas generators, the super cooling water situated on the external layer of hailstone is transformed from liquid state to solid state. Therefore the hail nuclei do not melt anymore and remain at small sizes which thus prevent them from inflicting damage when they hit the ground. By selecting material and quantity of the combustible fuel, number and duration of detonations it is possible to provide significant shock waves and to effect on the hail clouds up to 10km of altitude (Ollivier, 1995),changing hail cloud structure, preventing further development of hail and transforming hail into rain or wet snow or small ice drops.Both described techniques of hail prevention and suppression are not efficient against already formed hailstones and severe hail, so the most important requirement in their application remains their timely startup.

Shells or rockets must be fired or launched at least in cumulonimbus before large hailstones forming.Of course,it is more reasonable to fire shells or to launch rockets innimbus (hail generative cloud), in order to prevent theformation of hail at once, but it will become very expensive way for anti-hail protection and will require the development of new types of devices for hail generative clouds' detection with high probability. The hail preventing supersonic cannon's (gas-generator's) operation must be approximately initiated 15-20 minutes before hail storm forming or storm arrival. The efficiency of both techniques decreases in proportion to startup delay. If the anti-hail device is activated when the storm is directly above, its efficiency will be very low. Therefore, for both techniques of protection it is strongly recommended to use them inconjunction with hail and hail generative clouds detectors Despite the fact that in some countries anti-hail launchers are manually controlled and their positioning along both azimuth and elevation directions are regulated on the basis of commands coming from human operators, in most countries for hail detection and clouds accurate and timely seeding usually powerful Weather Doppler radar is used, operating at short centimeter band of waves.The control of separately operating cannon or a small group of cannons is carried out by the staff operator, manually or remotely by means of cellular or radio communications, in accordance with their visual observations, which is not acceptable for effective prevention or suppression of the hail, since include human factor. Usually, the anti-hail protection network, including a plurality of spatially distributed supersonic gas-generators and coordinating by the State, also controlled by the radar.

Flaws of Radar in Hail Prediction

Although these radars cost several hundred thousand (Weather Radar) or millions (Antigrad) USD, in dependence of the power and service facilities, however, they have serious disadvantages and cannot solve the problem totally. The Weather radar can detect and classify with high probability already formed hail clouds, but cannot classify hail generative (hail bearing) clouds which may be transformed in hailstorms. In addition, the meteorological radar consumes relatively high power 0.2kW (Weather Radar) and 14kW+14kW (Antigrad) and requires certain installation and operating conditions, which should provide the necessary condition for direct observation.Solid spheres made of nonconductive materials will generally have an RCS of approximately zero. Rain drops and spherical hail stones have small RCS. However, rain clouds and hail clouds may have enough RCS to be detected by weather radar if water quantity in clouds isenough for that. Water droplets in clouds in rare case can grow in size upto 10mm in diameter. Opposite, hail pellets can grow their size up to 10cm and more in diameter (Jeff, 2012; World of Facts, 2015; Bowie, 2016) and mostly with a ruffle non spherical shape RCS of which is higher than RCS of spherical pellets of the same diameter. To show flaws of weather radar for the task of hail generative clouds detection and recognizing (classification) let's assume that a cloud (a cumulonimbus) appears on the horizon with a mixed composition of water droplets and hail pellets of small size. Moreover, let's suppose that water droplets and hailstones have the same sizes and spherically shaped. Then RCS of cumulonimbus will be less than RCS of pure rain cloud (a nimbus) with the same quantity and sizes of droplets, since hail pellets in cumulonimbus will absorb part of the radar signal energy (power) and will decrease the power of the backscattered radar signal. And, since, detection and classification of hail or hail generative clouds is performed on the background of cloudy sky for high probable detection of hail generative clouds it will be necessary to set detection threshold of thecumulonimbus below the detection threshold of nimbus.But then there will be a high level for false alarm, which willlead to huge expenses in anti-hail protection and inundesirable pollution of agricultural lands, since it will be necessary to fire shells or to launch rockets in any nimbusis appearing in the horizon. And probably, thereat, in alladvertisements of weather radars and in their technicalcirculars there is not any information about probabilities ofdetection and false alarm which are very significantparameters for radars and their application.With a further increase of hail pellets' sizes anddistortions of their shapes RCS of the cloud will grow and itwill be possible then to clearly argue the appearance of hailon the screen of the monitor of radar. But then it will be too late, because the moment to prevent or to suppress hailwill be missed, and the only thing that can be done in thiscase it is to try to interrupt further growth of hail pellets andto force the hail to fall down in that state in which it wasdetected. However, this is not always possible, and it is notthe best solution to ensure the effective protection of ruraland urban areas from hail.

4. Application of Microwave Radiometry for Hail Early Detection and Prediction

It is known that all objects greater absolute zero radiate a little microwave energy as well as visible and infrared because of thermal radiation. This radiation is called thermal radiation because it mainly depends on temperature and emissivity. Thermal radiation can be expressed in terms of black body theory.A black body is matter which absorbs all electromagnetic energy incident upon it and does not reflect nor transmit any energy. According to Kirchhoff's law the ratio of the radiated energy from an object in thermal static equilibrium, to the absorbed energy is constant and only dependent on the wavelength and the physical temperature o T . A black body shows the maximum radiation as compared with other matter. Therefore a black body is called a perfect radiator. Real objects, the so called gray bodies are not identical to a black body but have constant emissivity which is less than a blackbody. Therefore, for real objects a correction for emissivity should be made because normal observed objects are not black bodies.

5. **A Method of a Restricted Areas' Anti-Hail Protection and Hail Trapping**

The idea to use micro wave radiometers for hail and hail generative clouds early detection, which is very significant for hail prevention and suppression by timely starting-up of sonicgenerators has been initially patented in Armenia as an invention (Arakelyan, 2013). After that the invention was patented in China (Arakelyan, 2016a), in the USA (Arakelyan, 2016b), in Canada (Arakelyan, 2017a), in the EU (Arakelyan, 2017b), in the Russian Federation (Arakelyan, 2017c). On the basis of the obtained European Patent the invention is patented in France, in Germany, in Spain, in Italy, in Switzerland, in the UK and in Turkey. The invention is patenting also in India (Arakelyan, 2014).

The application of two microwave radiometers allows implement fully autonomous and automatically functioning anti-hail protection of an area of a minimum size of 50-70 hectare (circle space of a radius of ~500m) which is a maximum size of protecting area by one sonic cannon (gas-generator) (Ollivier, 1995).In Figure 1 an outline of a version of implementation of a local network of autonomous and automatically functioning anti-hail protection of the protected area (1) of a limited size is presented. The far-range detector-alerter (2) set on the scanner (4) is used to observe sky of the adjacent land all around the protected area and to warn the anti-hail protection system (3) by alert signals about the impending hail danger when it detects hail generative clouds or cumulonimbus at distant approaches to the protected area, usually 4-6km far to the protected area.Detailed descriptions of operational peculiarities of alocal network of anti hail protection of Figure 3 and blockdiagrams of the far-range detector-alerter (2) and the hail prevention system (3) are presented in any of abovementioned patents (Arakelyan, 2013; Arakelyan, 2016a;Arakelyan, 2016b; Arakelyan, 2016c; Arakelyan, 2017a; Arakelyan, 2017b; Arakelyan, 2017c) and in (Arakelyan,2017d). The scanned far-range detector-alerter (2), set onthe scanner (4), permanently observes and measurescontinuously the adjacent land's sky intrinsic microwaveemission under specified elevation angle of observation (tilted observation). Approximately up-directed localdetector-alerter (5) simultaneously measures the protectedarea's sky intrinsic microwave emission and comparesmeasured values with the “minimum” threshold level andstarts-up the supersonic cannon (gas-generator) (6) if the sky intrinsic microwave emission exceeds the “minimum”threshold level. The local detector-alerter uninterruptedlylistens as well radio ether to receive warning signals aboutimpending hail danger transmitted on the air by the farrangedetector-alerter when the danger is appeared. If thelocal detector-alerter receives warning signals then itbegins to compare sky intrinsic emission with the “alert”threshold level, which is 3-15K lower of the “minimum”threshold level, and if measured values of the intrinsic emission of the edge of the looming cloud exceed the “alert” threshold level, then the local detector-alerter startsup the sonic cannon (gas-generator).

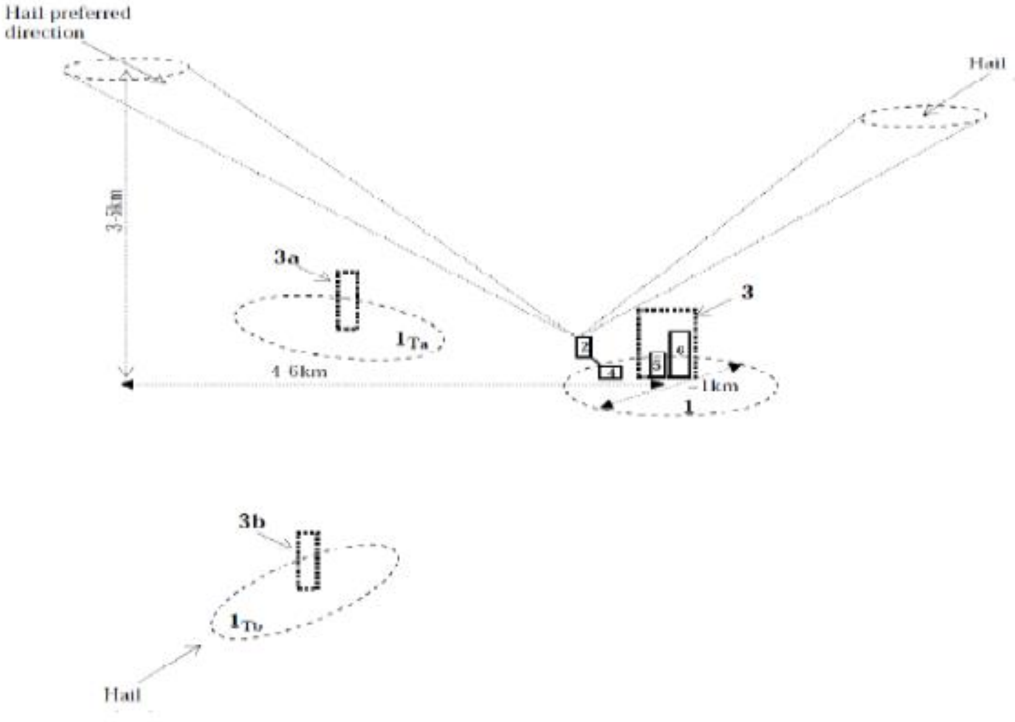

Figure 3An outline of a version of a local area anti-hail protection and hail trapping 1 – a protected area of a limited size, 1Ta and 1Tb – hail trapping areas, 2 – a far-range detector-alerter, 3, 3a and 3b – hail prevention systems, 4 – a scanner, 5 – a local detector-alerter, 6 – a supersonic cannon (gasgenerator)

For some regions, hail or cumulonimbus has a preferred direction and usually comes approximately from the same direction, and sometimes near of the protected area one can find places where hail is allowed. These facts can be used to capture hail, to force hail to fall out on the territory where its damage can be relatively small. The method of hail early detection and prediction by microwave radiometers described above makes it possible to implement a completely autonomous and automatically functioning network of hail traps. Such a network of hail traps first described in (Arakelyan, 2017d) can be completely implemented separately or in combination with an implemented network of anti-hail protection, if there are places near or far of the protected area where hail may be allowed fall out.6. Wide-Ranging Anti-Hail Protection of a Vast Area As shown above and in (Arakelyan, 2017d) by two radiometers it is possible to implement fully autonomous and automatically functioning of the anti-hail protecting device, like a supersonic cannon, for instance, and to provide anti-hail protection of the area (circle space) of 50- 70 hectare of a size. In accordance with (Artashes K. Arakelyan, 2017) by application hundreds, thousands radiometers it will be possible to perform a global anti-hail protection of a vast area functioned fully autonomous and automatically. But, if the cost of hundreds or thousands of radiometers can reach the cost of the meteorological radarthen, where is it the benefit to use radiometers? The benefit is obvious from the following.

In addition to the flaws of the radars in detecting and classifying hail and hail generative clouds, let us assume as well that the meteorological radar and thousands of radiometers protect the area of the same size. Then, in the event of an accidental failure of the radar, the whole protected area remains unprotected for a long time, since, it is not always possible to repair the failed radar on site, and its replacement will require large financial and labor costs and the time whichis the main decisive factor for successful implementation of the protected area's anti-hail protection.

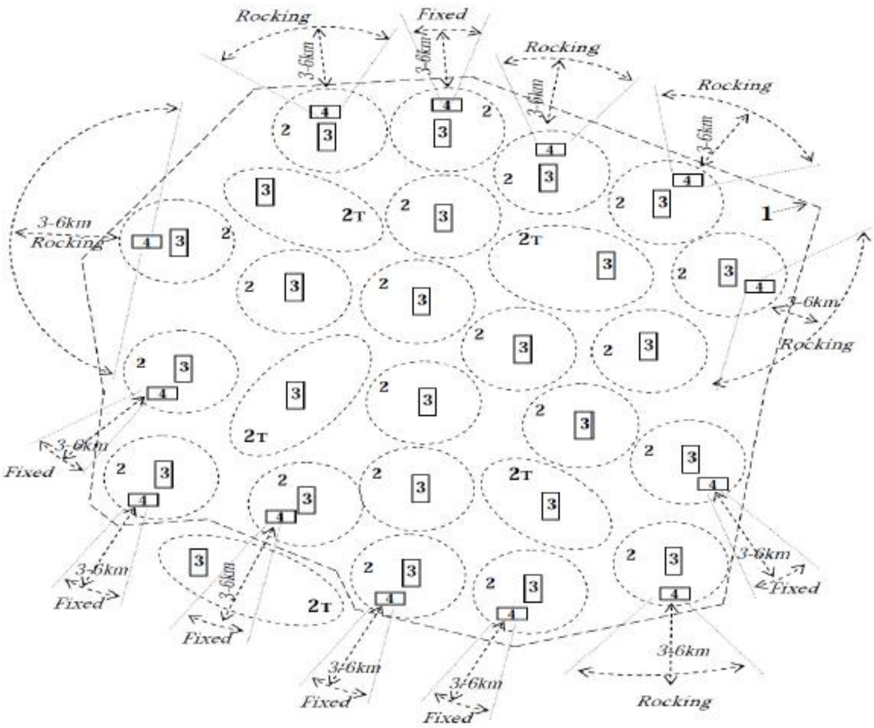

Figure 4An outline of a version of large-scale anti-hail protection network 1 – a protected area, 2 – a protected site, 2T – a trapping area, 3 – an antihail protection system comprising a local detector alerter and a supersonic cannon (gas-generator), 4 – a far-range detector-alerter with a scanner if necessary

Acoustic Waves Generated by the Shock Wave of an Antihail Gun

The creation of shock waves can prevent the formation and growth of hail by melting altogether. Shockwaves are produced using hail guns/cannons . The super-cooled water situated on the external layer of hailstone is transformed from liquid state to solid state.

Currently, in agricultural regions, new antihail guns are being used quite efficiently to protect fruit crops from hailstorms. The operating principle of an antihail gun is to generate a vertically directed high-power shock wave by burning acetylene–air mixture in the combustion chamber located in the basement of the hail gun. After the instant of spark breakdown in the combustion chamber, the gun generates a high-power shock wave with output excess pressure P = 3.8 kPa, which corresponds to the intensity J = 166 dB. The Mach number for the shock wave is M = 4.46. The impulse time is about 20 ms. The average impulse energy is about 600 kJ under total transformation of fuel energy into shock-wave energy. The aperture angle of the hail gun is a=8 The length of the conical part of the horn of an antihail gun is 4 m; the exit iameter is 0.8 m. During an impulse about 15– 20 grams of gaseous fuel are burned. An antihail gun operates in the impulse-periodic mode with a repetition rate of 6 s. Figure5 presents a schematic drawing of an antihail gun.

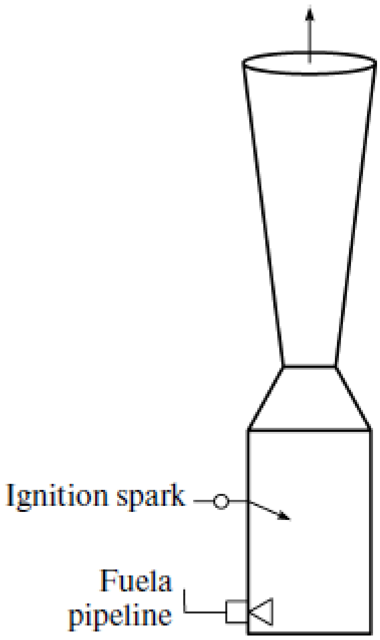

Fig. 5. A schematic drawing of an antihail gun

The first experimental research on this problem was done at the beginning of the 20th century
This problem is part of the general problem of the effect of acoustic waves on atmospheric processes, including fog dispersion, precipitation enhancement, protection from hailstorms,
and others. Precipitation enhancement is one of the most important potential ways of managing drought. For the first time, artificial precipitation was produced in Holland in 1931 by seeding overcooled clouds with solid carbon dioxide. Later, electric, acoustic, and laser methods were used for artificial precipitation enhancement (L. G. Kachurin, 1991)
E. L. Aleksandrov and Yu. S. Sedunov analyzes the effects of temperature pulsations generated by periodic air compression and air extension due to the effect of acoustic waves on evaporation processes of drops. It is shown that water dropsof a definite critical radius can be evaporated due to an increase in temperature. Larger drops preserve their core temperature and become larger in the high power acoustic field.In order to describe the coalescence
process of water drops, the change in the microstructure of the distribution of size of drops in homogenous fog being affected by acoustic waves was calculated on the basis of numerical simulation of stochastic processes.(M. P. Foster and J. C. Paflam1988).
It is known fromA. L. Lazarev, V. V. Kovalenok, and S. V. Avakyanwork in , 1987 that strong gradients of gas temperature and electron concentration are noted in the ionosphere at an altitude of 100 km. When the acoustic wave reaches a specified altitude and begins interacting with the medium mentioned (a plasma layer with the corresponding gradients) in the ionosphere vortex motions of plasma electrons and ions are induced. As a result, electromagnetic waves are generated and measured by a surface radiometer. Thus, we deal with the process of the transformation of acoustic waves into electromagnetic waves in the ionosphere owing to vortex motion of plasma, resulting from the interaction of acoustic waves with the gradients of electron concentration and gas temperature in the ionospheric plasma.

Thus, it was found that a vertically propagating shock wave generated by an antihail gun reached an altitude of 100 km; that is, on the way, an acoustic wave can affect on clouds. In the course of propagation of shock waves, a microphone detects acoustic waves. Studying these acoustic waves is of fundamental interest and practical value. This is due to the fact that
research related to the stimulation of atmospheric precipitation by acoustic waves has been conducted for a long time.(B. E. Nemtsov and V. Ya. Eidman, Akust. Zh. 35, 882(1989)

2. Conclution

Based on the articles studied in this research and the review of the mentioned results, we conclude that the Acoustic Waves method is an effective method to prevent hail in fields and is a low-cost method. Even the s acoustic wavessystem can be used together with the microwave method to have a higher effect.

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