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Radio meteor detection in Malaysia

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ABSTRACT

T Meteor is a luminous effect, light is created as the rocky body is frictionally heated to incandescence when entering Earth's atmosphere. The ionized trails of the meteor are also capable of reflecting radio signals from terrestrial stations, which include those broadcasted by commercial FM and TV stations. For this research, 3 sites are identified as candidates but only the best will ultimately be utilized to do the research. The selection criterion depends on the radio frequency interference (RFI) level and whether they have any free FM frequency from local radio stations. The 3 sites are Jelebu in Negeri Sembilan, Behrang in Perak and Merang in Terengganu. The best site is Behrang and the average floor noise level at this site within the FM frequencies of 88 MHz to 108 MHz is -97.111 dBm. The average number of meteor detections in the span of three days is 48 meteors per day. A number of 50 underdense and 38 overdense meteor trails are detected for the first day.

Key words: Astronomy and Astrophysics; Radio Astronomy, Radio Frequency Interference and Meteor.

INTRODUCTION

Meteors usually leave a bright short-lived trail behind. It is commonly called "shooting" star or "falling" star. The size of meteors ranges from a sand-like size to a rock with diameter of up to 10 meter. Their brightness varies from apparent magnitude +6.5 to -4.5. Their velocities can be quite high when they initially strike the atmosphere; about 25-150 thousand miles per hour. Meteors originate from a meteoroid coming from outside the Earth's atmosphere and are traditionally observed with the naked eyes. However, due to the fact that their ionized trails are able to deflect low frequency radio waves (coming from FM and UHF radio telecommunication frequencies), there is a special technique which can be utilized to detect and count the meteors besides by just looking at it. This is the technique used in this project. There are a few things to consider before this technique can be implemented. Firstly, the site where the observation is done must be low in radio frequency interference (RFI) level within the FM radio frequencies, i.e. 88 MHz to 108MHz. Secondly, the reflected radio signal has to come from a non-local radio telecommunication station. The transmitter station has to also have significant power of transmission in order for the deflection to reach the receiver. The signature of the received signal is also crucial in identifying whether the signal is indeed representing a deflection off a meteor trail. All these conditions will be discussed in more detail in subsequent sections. This project also ideally aims to identify whether the group of detected trail deflections are coming from sporadic or meteor showers. Most of the meteors that are observed are usually sporadic, which means they do not belong to any recognizable shower. Sporadic meteors can come from any direction. Meteor showers appear to initially radiate from a small area on the celestial sphere. This centre is called the radiant. The rates also vary throughout the year and more importantly, in our case, it differs between the northern and southern Earth's hemisphere. Estimation of sporadic meteors rate is about 5 to 10 meteors per hour and meteor showers rate is about 80 to 100 meteors per hour. Meteor showers have been observed using the naked eye by many people throughout the human history. Sporadic meteors are harder to observe due to its randomness, as opposed to the meteor shower events which can be predicted. Another problem with looking for meteors is they cannot be seen in the daytime. Even at night time, a bright moon will also not help attempts to see meteors. This is not the case for detection by radio wave. However, some count losses can still exist due to the Sun's strong radio emission especially when it is on its high solar activity period. This is still a huge improvement in meteor count detection from using the naked eye. The radio method can also detect meteors in cloudy and rainy weather. The moon also does not affect radio meteor counting. Radio meteor detection rates are also higher due to the fact that particles down to 10^{-5} kg can be detected with the naked eye, while even smaller particles (down to 10^{-10} kg) can be detected by radio. An international group of radio meteor scatter observers is currently active in this type of observations and our project aims to provide a platform for researchers in Malaysia to eventually join the group. Monitoring and understanding the detailed nature of meteor showers are one of their main science goals.

MATERIALS AND METHODS

As a meteor streaks through Earth's atmosphere, about 10% of its energy is released as light, with the remainder is dispersed in a trail of ionized air or ionization train and this electrified air will reflect the radio waves. This completely ionized meteor trail at altitude about 120 km to 800 km can reflect radio signals coming from commercial FM and TV stations. Because of this, we can then use a commercial radio as a receiver. In our case, we initially use radio receiver from vehicle as early test.

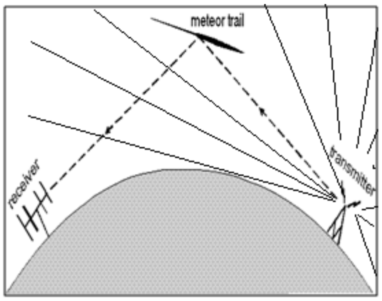

Figure 1. An Illustration of the radio meteor counting method using a transmitter 500km to 2000km away.

The first part of the observation involves finding a commercial radio frequency that is free from transmissions of local radio stations. Receiving signals from a local radio station will completely rule out deflection off a meteor trail. When the 'empty' frequency is found, the next step is to find whether there is a transmitter at this frequency some 500km to 2000km away. This will make sure that the Earth can be used as a shield from our receiver getting the radio signal at this 'empty' frequency directly without deflection off the meteors (see Figure 1). The power of the transmitter should ideally be as high as 30 kilowatts. The receiver must also be a directional antenna capable of receiving signals in the commercial FM radio frequencies and it must be pointed to the transmitter's latitude and longitude. An 'empty' frequency will only gives out continuous static (random noise) sound. When a meteor passes and if its trail deflects the transmitter's radio waves towards the receiver, we should be able to tune in to that non-local radio station. A more clearer and prolonged sound from the transmitter represents longer meteor trail it has been reflected through. This might even be up to a few minutes long. A very sudden 'ping' are not considered a detection of meteor trail as that usually means an existence of non-meteor matter such as airplanes. The signals reflected from a meteor are usually slightly prolonged, mostly quite clear and end gradually. The methods that have been used are referred to Sky Scan Science Awareness Project. The equipments used include a receiving FM antenna, an electronic radio signal receiver and a laptop with the Radio Sky Pipe software (see Figure 2).

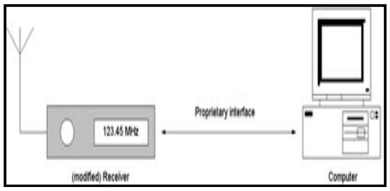

Figure 2. The experimental setup.

The antenna that is used a 5-element Yagi antenna. The most common method is to point the antenna horizontally towards the distant transmitter but it is better to apply a 45^{o} upward angle to it. A vehicle radio is the best receiver to do the radio meteor observation because it is cheap and easy to obtain, and relatively easy to modify for this project's purpose. The modification includes nullifying its automatic gain control (AGC). The laptop should also have an analogue-to-digital interface.

RESULTS AND DISCUSSION

For this research, we identified three candidate sites for observation. They are are Jelebu in Negeri Sembilan (location: 03°05.226'N, 102°02.261'E), Behrang in Perak (03°45.916'N, 101°31.030'E) and Merang in Terengganu (05°32.136'N, 102°56.837'E). As for any radio astronomy survey or experiment, RFI at the site should initially be measured and identified. Hence, we must measure the RFI at the chosen frequency. Figure 3 shows the RFI profile at 88 MHz-108 MHz for the three sites. The average noise level is -97.111 dBm. In our case, the RFI is actually our source of interest. However, we needed to be sure that there are not much interfere from strong neighboring signals which can come from machines and vehicles. Generally, this interference is low.

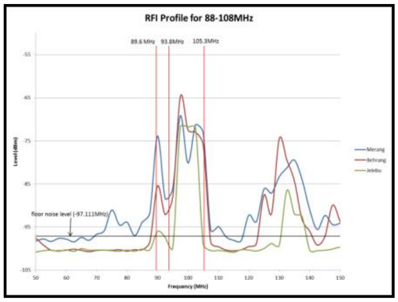

Figure 3. The RFI Profile at 88-108MHz at the three chosen sites during the observation.

Table 1 shows the candidate sites with their ‘empty’ frequencies and possible transmitters. The ‘empty’ frequency in Merang is eventually ruled out since there are not completely empty as thought initially. Jelebu and Behrang are chosen as good sites for our observation. Ultimately, we chose Behrang due to the availability of basic infrastructure such as electricity and covered observation area. The actual experiment, after many testing, is done for 3 consecutive days. The final results are shown in Table 2 using frequency 89.6 MHz. According to most other observers, the most counts come from times between midnight and 7 a.m. mainly because at this time there is a low level of interference from intense human activity.

Table 1 The site candidates and expectation transmitter locations at targeted frequencies.

Receiver Site	‘Empty’ Frequency	Possible Transmitter
Jelebu	105.3MHz	Sing Buri, Thailand (~1315 km away)
Behrang	89.6 MHz	HauGiang, Vietnam (~794.7 km away)
Merang	93.8MHz	Andulau, Brunei (~1284 km away)

Table 2 Data collection and comparison data collected by other radio meteor observer.

Day	1		2		3	
Time/Place	A	B	A	B	A	B
0000-0300	21	42	2	36	2	43
0300-0600	20	57	2	52	0	64
0600-0900	21	67	4	66	1	76
0900-1200	1	78	0	67	0	96
1200-1500	13	98	2	88	1	107
1500-1800	11	112	19	84	0	107
1800-2100	1	103	18	100	1	110
2100-2400	0	62	0	62	3	103
TOTAL	88	619	47	555	8	706

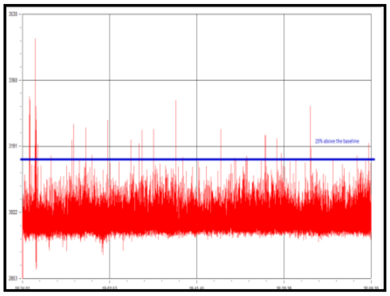

Figure 4. A part of the whole strip chart used to show an example of the detection limit (blue line).

The Radio Sky Pipe software plots time-ordered variation of the radio signals at the chosen frequency, i.e. 89.6 MHz in our case. This software does give considerable advantage as it can be used to automatically store the detected signals, instead of listening carefully for echos from the meteor trails. A 25% of the fluctuation noise level is set as the limit of detection.

The strip chart enables us to identify whether the detected meteors are overdense or underdense. Underdense meteors are faint and most of the time is not visible. A signal from an underdense meteors last less than a second, while overdense can be measured for seconds. For the first day, there are approximately 50 underdense meteor trails and 38 overdense meteor trails. Examples of overdense and underdense meteor trail echos from our observations are given in Figure 5 below.

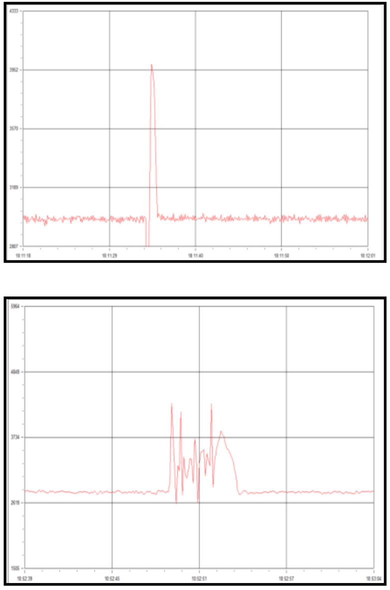

Figure 5. The two types of meteor trails detected during experiment, underdense (above) and overdense (below).

The final detection count is simplified in Figure 6. A comparison is made with a more advanced radio meteor scatter observer (also in Figure 6). His higher sensitivity radio receiver is located in Los Negrales in Madrid. Their data is chosen as comparison due to the direction of his receiver is in Azimuth and Elevation, 40 and 40 while our receiver is pointed 45 and 45. His observation is made in the northern hemisphere, hence the big difference as well. There is quite a big difference between the two sets of data. The average detections in Behrang is 48, compared to 627 in Los Negrales.

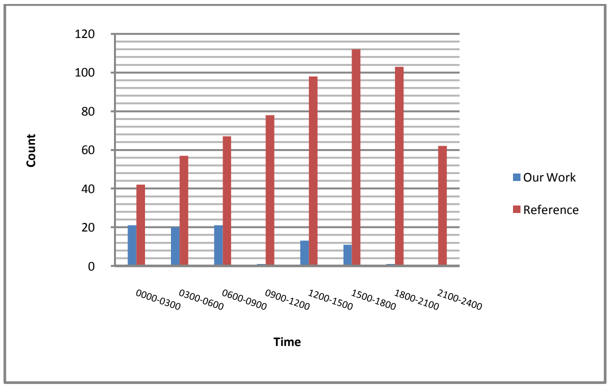

Figure 6. The histogram of the detection count for this project and for the observer in Madrid for the first day.

CONCLUSION

The project successfully detected meteor echos from the sky and significant numbers of detection counts are made. The drop in count after the first day coincides with the start of consistent light rain. The system setup might not have been ideal for rainy condition. However, there is a significant number of detection of the two different densities of meteor trails. The main difference between our system and the system used by the Madrid observer most probably is the type of radio receivers used. He uses a wider band radio scanner Yaesu VR5000, while we used a simple modified vehicle radio. He uses an international standard radio count software (Colorgramme) while we improvises on a software which is initially written for measurement and detection of radio burst from Jupiter. Other RFI for this type of observation include interference from cross transmitters that are randomly deflected into the antenna's main beam, man-made broadband interference from spark in electrical devices (including engines of vehicles and trains), natural broadband interference from lightning and interference from oscillators (clock) in microprocessors such as in laptops. We have not detected any of these RFI but further investigation is needed in the future. Collaboration with international organizations which involved in meteor observing such as RMOB & IMO should be done in the future so that we can exchange data and information and hence improve our skills in conducting observation such this. Some scientific research can also be done with such collaborations. An example of such research is the effort to find the relationship between the size of meteors' speed and altitude.

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