ABSTRACT

In this advanced physics and astronomy lesson, students measure sporadic meteor activity (SMA) with a laptop computer. Students construct dipole antennae, and build, test and wire a full-wave diode rectifier between the dipole antenna and the laptop. A voltage program measures voltage across the rectifier output to detect radio waves scattered off meteor trails. Students use a histograph to verify that they are measuring SMA. SMA is applied to mobile communications equipment, and the "meteor channel" is explained in terms of an ellipsoid. Students use their SMA data to calculate how many words per minute the meteor channel can support as a function of keying speed.

TIES TO CURRICULUM

Meteor Monitor has ties to both math and science curricula. Students use a mathematical model to explain a physical phenomenon, apply formulae in metric to antenna construction, and use field data for graphical verification. Students use principles of science when they describe wave phenomena (particularly electromagnetic [EM] waves); use gravity and celestial motion to explain meteor trails; and classify meteors as "under-dense" or "over-dense." *Meteor Monitor* addresses the *National Science Education Standards* call to integrate technology in scientific study.

LEARNING OBJECTIVES

In *Meteor Monitor*, students

- evaluate throughput in words-per-minute (wpm) from SMA data as a function of keying speeds;
- use EM wave propagation and forward scatter to explain the "meteor channel";
- analyze forward scatter in terms of an ellipsoid;
- use the EM radiation wavelength vs. frequency relationship to build a dipole antenna.
- build a full wave diode rectifier to measure DC from an AC signal;
- construct histographs to verify SMA data; and
- determine meteors per hour, average path duration, and under-dense vs. over-dense meteors.

NUMBER OF LAPTOPS AND GROUP SIZE

Use one laptop per group of two students.

TIME REQUIREMENT

Conduct *Meteor Monitor* over a two-day period.

Task	Time	Location
Introduction	3 hours	Classroom
Field activity	3 hours	Field
Report	3 hours	Home

LESSON DESCRIPTION

MATERIALS

- Laptop computers
- TI Universal Lab Interface (ULI) or Serial Box Interface
- Vernier voltage probes
- Logger Pro software
- 4X 1N4007 rectifier diodes
- 1X 100 microfarad capacitor
- Radio Shack TV Pre-amp
- American Meteor Society histographs of SMA vs. time of day
- 2.5 m 12-gauge copper wire
- Wire cutters
- Rubber hose
- Two 2 m pieces of PVC
- 40 cm piece of PVC
- PVC T-Connector
- 80 cm lead wire
- Soldering iron

Teacher Preparation

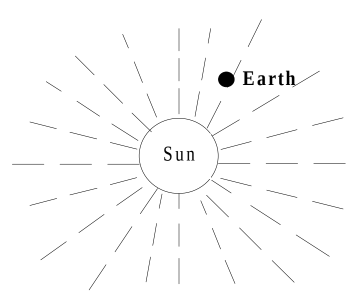
Before beginning the activity, select a field location with low radio interference (RI). The site should be far from roads, houses, transformers, overhead wires, metal fences, etc. To measure sporadic meteor activity (SMA), the students will build dipole antennae tuned to offset television frequencies of TV channels 2, 3 and 4. It is not possible to measure at that frequency if there is a 2,3 or 4 transmitter within the line of sight.

Introduction

Introduce the phenomenon of SMA, explaining that it is caused by the Earth's motion through solar dust left by eons of asteroids and comets orbiting the Sun. The solar dust, which causes sporadic meteor activity, is distributed evenly over concentric shells about the sun. Gravity draws the dust radially in toward the Sun. As it orbits the Sun, the Earth sweeps up dust at an average daily rate. Dust forms meteors in the atmosphere and creates an ionized trail 50–75 miles up in the sky.

Another type of solar dust causes predictable *seasonal meteor activity*. As comets approach the sun, they give off jets of particles, creating a path of dust around the sun. The Earth passes through the comets' dust path at the same time each year. At these times, there are predictable meteor streams and enhanced meteor activity, although meteor activity varies from day to day.

Figure 1: The Earth sweeps up solar dust



For periods ranging from a fraction of a second to three seconds, meteor trails can scatter radio frequency EM radiation large distances over the horizon in an effect called *forward meteor scatter*. In forward meteor scatter, two stations located over the horizon from each other can use an ionized meteor trail as a communications satellite.

Forward meteor scatter is an interference effect. When the meteor has created an ionized trail such that the path length difference between

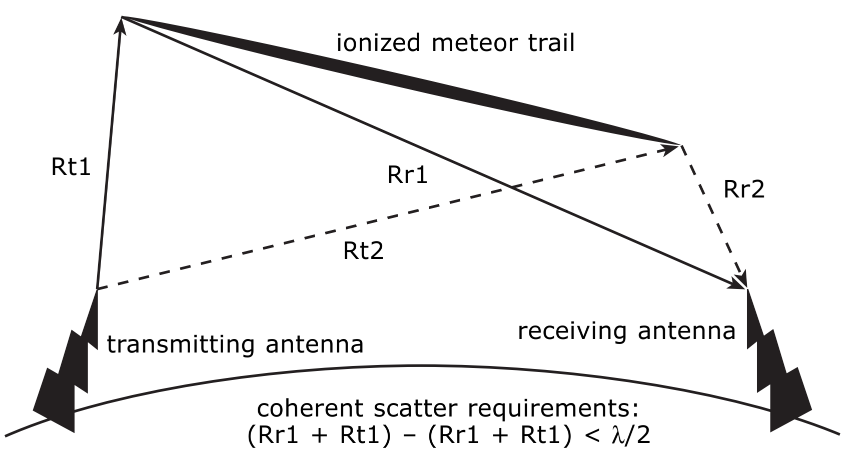
$$(R_{t1} + R_{r1}) - (R_{t2} + R_{r2}) = (m + ½)\lambda$$

all the signals scattered from the meteor trail arrive at the receiver in phase and add constructively (See Figure 2). The received signal level (RSL) will rise 3 to 4 dB above background noise. For example, when the meteor creates a path such that

$$(R_{t1} + R_{r1}) - (R_{t2} + R_{r2}) = \lambda/2$$

there will be an observable spike in voltage. The number of voltage spikes detected is proportional to SMA.

Figure 2: Forward meteor scatter



Constructing the antennae

Dipole antennae detect forward-scattered TV signals from distant transmitters. Demonstrate the construction of a ¼-wave dipole antenna tuned to a suitable frequency, 67.25 MHz (λ = 4.44m)

1. Straighten and cut two pieces of 12-gauge wire 1.11 m long.

SUGGESTIONS

- It is critical to use a low RI site, where noise level is less than S3.
- This lesson plan is easily replicated in the classroom (high noise) but a receiver with rear-panel access to Automatic Gain Control voltage is required. Such a setup will provide better results and a stronger diurnal variation. The dipole should be 1–2 m above ground, on flat and unobstructed terrain.
- The best time to start measuring is 15 minutes before dawn, when sporadic meteor activity is at a maximum.
- Use Logger Pro in Real Time Collect with 10–50 pts/sec sampling rate and 10 minute runs. At the end of each run, save data to a floppy disk for analysis later.

2. Insulate the 2 pieces of wire with a 5 cm length of rubber hose. The wire ends inside the hose should be 1 cm apart (see Figure 3).
3. Cut a wedge of hose to create a feed point (see Figure 4).
4. Place a PVC T-connector centered on the 5 cm length of hose (see Figure 5).
5. Place ½ m pieces of PVC tube into the opposite ends of the T-connector, and screw them in firmly (see Figure 6).
6. Mount the antenna on two rods as high as possible with the wire length facing the transmitter. Attach Vernier voltage probes across the feedpoint.

Have students build dipoles tuned to suitable offsets of TV channels 2,3 and 4. Review wavelength, frequency and period. Explain that the signals detected by the dipole are EM waves from electrons oscillating in distant TV transmitters and reflecting off a meteor trail.

Demonstrate the construction of a full wave diode rectifier and a 50–60 MHz bandpass filter, and explain the operation of each. Test each with a function generator and oscilloscope. Introduce the concept of

Figure 3: Building a dipole antenna (steps 1-2)

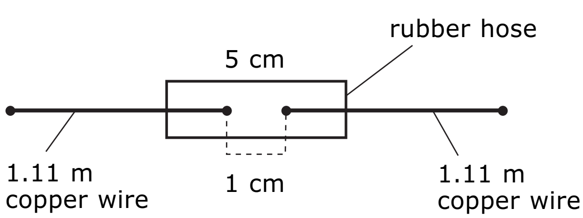


Figure 5: Building a dipole antenna (step 4)

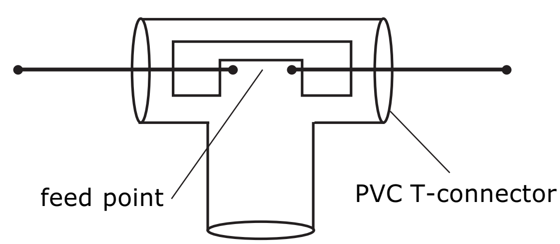


Figure 4: Building a dipole antenna (step 3)

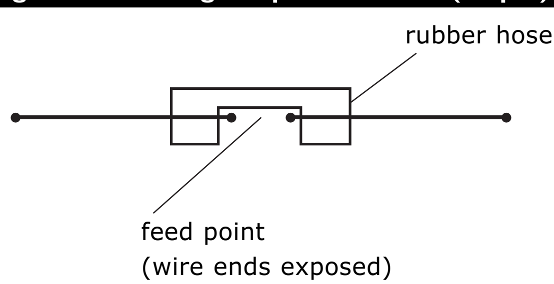
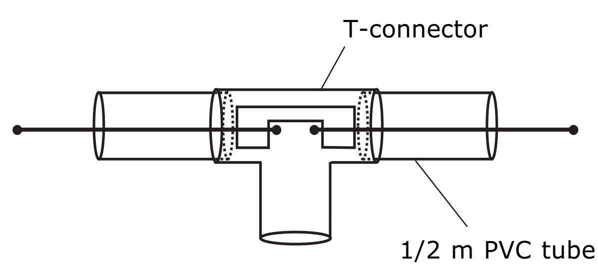


Figure 6: Building a dipole antenna (step 5)



Signal-to-Noise (S/N) and explain that a pre-amp can be used to improve the S/N ratio.

Putting it all together

Connect in order: dipole—bandpass—preamp—rectifier—voltage probes—ULI—laptop. Mount the antenna on two rods, as high as possible, with the wire length facing the transmitter. Attach Vernier voltage probes across the feed point.

Run Logger Pro: voltage in real time to collect different sampling rates. Note the noise level and record any spikes 3–4 dB above noise. Expand the time axis for any spikes to find the spike duration. Have students build rectifiers, suitable bandpass filters, setup their receiver systems and run Logger Pro for five minutes as practice.

Students count as meteors any 3–4 dB spikes lasting .15 sec or longer. Explain that reception occurs for as long as the meteor trail is dense enough to reflect EM waves at a particular frequency. This depends on meteor parameters such as mass, velocity, and density. Define *underdense* meteors as causing spikes of 1 second or less and *overdense* meteors as causing spikes for over 1 second. Ask students to analyze their data as total number of meteors and in subcategories listing underdense and overdense meteors. Due to Earth's orbit, the dawn side of the planet is forever rushing into solar dust and the dusk side is forever rushing away. We expect a diurnal variation in meteors—a higher dawn meteor count than dusk meteor count. Diurnal variation verifies that our SMA measurements are valid. Distribute American Meteor Society meteor count histographs to illustrate diurnal variation.

Introduce data keying and have students calculate how many words per minute could be transmitted on the "Meteor Channel" if there were 100 trails per hour of .5 second duration and a 3500-wpm keying rate. Detail the mechanics of forward scatter using an ellipsoid with foci at the transmitter and receiver; forward scatter is only possible for meteor trails tangent to such an ellipsoid.

Activity

Students use their dipole devices at a rural site to measure voltage spikes for one hour at dawn and one hour at dusk. Have some students use a horizontal dipole polarization and some a vertical polarization.

Students analyze their data on histographs, state total meteor counts, average signal duration and estimate how many words-per-minute can be transmitted at dawn and at dusk as a function of keying speed.

ASSESSMENT

To assess student performance, require a summary report of SMA data that will include an evaluation of security, information throughput and sources of error. To evaluate security, the students will need to apply an understanding of the forward scatter phenomenon to an appropriate ellipsoid and look at the reception "footprint" due to meteor burst communications. This will require some independent research into meteor scatter. In order to calculate data transmission rates on the meteor channel, students will need to apply their understanding of keying rates to their SMA data. To identify sources of error, students should address sources of radio interference and detail what steps they took to eliminate RI. In their discussions of error, students should also refer to their histographs as verification of their results, assuming they have a strong diurnal variation.

Assess students' understanding of EM waves according to how effectively they applied the frequency-wavelength relationship when designing and constructing a ¼-wave dipole for a given frequency. Assess students' understanding of basic radio electronics sincluding preamp, bandpass and rectifier function, as well as their ability to design and construct a bandpass filter and a full wave diode rectifier.

REFERENCES

Books

National Research Council. *National Science Education Standards*. Washington DC: National Academy Press, 1996.

Schilling, D.L., ed. *Meteor Burst Communications: Theory and Practice*. New York: Wiley, 1993.

Web sites

American Meteor Society: http://www.amsmeteors.org/

International Meteor Organization: http://www.imo.net/