

## VI. Signal Propagation Effects

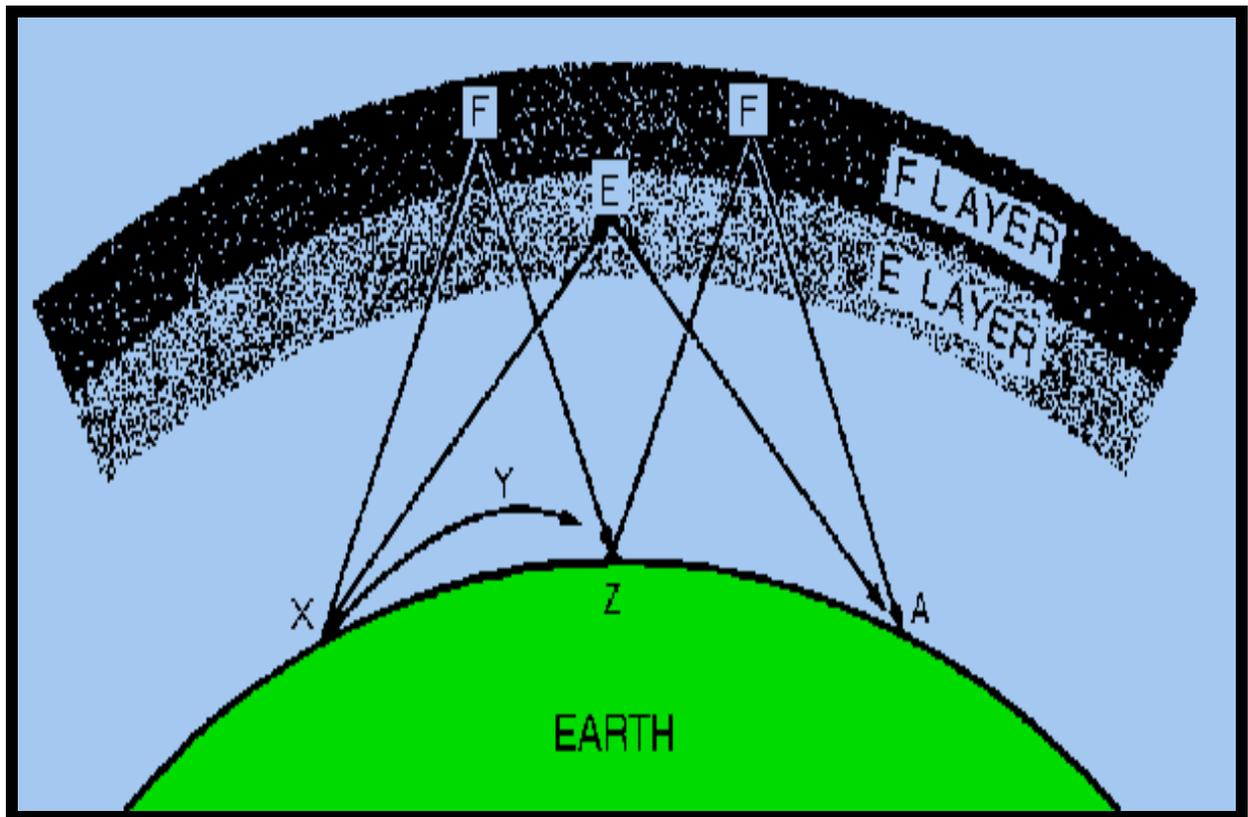


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## VI. Signal Propagation Effects

Name \_\_\_\_\_ Date \_\_\_\_\_ Class \_\_\_\_\_

### At Home Assignment

Tune to the most remote AM station you can find. You should attempt to find to other stations of comparable distances. Fill in the data below and bring to class tomorrow. Use the Internet to find the location of your remote AM station.

Station Name	Location and distance	Time of Reception

You are no doubt surprised that your AM radio stations aren't coming in clearly if at all. Don't worry. We believe you really did hear those remote AM stations. There is some very interesting physics at work here.

If you stand outside and look all around you, you can see about 2.5 – 3.0 miles at eye level before the horizon, where the land meets the sky. If you were a radio station and your transmission antenna were placed at eye level, you could transmit signals for a distance of 2.5 – 3.0 miles before the land features prevented anyone from hearing your signal. Why does this happen? We found out a long time ago that the Earth is round. If you travel directly outward in a straight line, as radio waves do, the Earth curves beneath you. Two people at eye level sending and receiving radio signals cannot communicate with each other beyond a certain distance because the transmitted signal will go right over their head. Again, the Earth is curved. Your friend might want to receive your signal but can't because your friend has descended approximately 1m in altitude relative to your line of sight just by being far away.

Going to higher altitude can enlarge the horizon. At the top of a mountain, you can see for miles and miles. In a jet plane you can actually see the curve of the Earth's horizon if you look closely. AM radio towers are large and have a transmission height at around 500 feet. At this height, the horizon is approximately 100 miles away. If the land is smooth and devoid of any unusual features, the station can transmit a clear signal within 100 miles. Beyond 100 miles, the Earth's curvature drops any receiver below the AM stations line of transmission (line of sight).

But wait you say, how can I still receive stations that are more than 100 miles away? We'll come back to that question in just a moment. To answer the question, let's first examine how FM radio waves behave. FM radio waves can't be heard beyond the

horizon of the transmitter. Above the FM transmitter, the radio waves propagate through the atmosphere, through the ionosphere and into deep space. Perhaps someone on Alpha Centauri has already heard our FM radio transmissions. It takes 4.22 years for radio waves to go from Earth to our nearest star, Alpha Centauri. Let's just hope that if there are intelligent beings in the Alpha Centauri system listening to our FM stations, they won't be turned off and ignore us assuming there's no intelligent life here!

So FM radio waves pass effortlessly into the icy blackness of deep space. You suppose we're going to tell you AM radio waves are different. Well, yes, we are. The ionosphere reflects radio waves with a frequency less than 10 MHz. FM radio station waves occupy the 88 – 107 MHz bandwidth and thus pass right through the ionosphere. AM radio stations transmit at 535 – 1605 kHz. AM radio waves are very reflective against the ionosphere. The result being that AM stations get to have their signals retransmitted from the height of the ionosphere! A significant improvement of 500 feet! Depending on how much power these signals are transmitted with, an AM signal can reflect from the ionosphere and ground several times, and be received over most of the Earth. Long distance radio communication was based on this phenomenon. Ship-to-shore communications, aircraft links and some military communications depend on the ionosphere to reflect their signals.

The shape of the ionosphere changes during the day. The ionosphere is made up of several distinct layers. The D and E layers absorb AM radio signals during the day. Since the D and E layers are made up of ions from the Sun and lay closer (100 km) to the thicker layers of Earth's atmosphere, these ions recombine with the atmosphere during the nighttime and the D and E layers disappear almost entirely at night. While the D and E layers are facing the Sun in the daytime, these ions are constantly replenished as the lower atmospheric layers siphon the ions away. The D and E layers are strongest at high noon. With the absorbing D and E layers gone at nighttime, the reflective F layer is exposed making long distance communication at AM frequencies.

**Note to teachers:**

Students will find the most remote AM station they can locate using their radios at home. They will make a record of the time that they received these AM signals. Students should be encouraged to make these measurements after sunset when it is dark. Upon returning to class the next day, collect their results. Place some results on the board and ask students to tune to the stations they found from the previous night. Few, if any of the signals these stations transmit should be heard during day.

At this point, introduce students to how the ionosphere affects the propagation of radio signals and why they were able to hear their distant AM radio stations and night but not during the day.

Encourage students to monitor space weather for a week. The Internet is an excellent resource. Have students go to [www.spaceweather.com](http://www.spaceweather.com). A brief discussion at the start of class might be appropriate particularly if we are in an active time in the 11-year solar cycle.

Students will monitor a tiny bandwidth of a distant AM radio station overnight using the AR3000-A communications receiver and SEARFE software. They will see firsthand how signal strength varies with time of day. If there was any special solar event, e.g. a flare, from the spaceweather.com website, we might be able to see its effects during a scan.

This is an opportune time to introduce students to more features of the AR3000-A radio communications receiver and how it interfaces with the SEARFE software. A quick scan over a weather station or FM station band might be helpful in illustrating its use.

## Questions and Further Investigations

1. Radio emissions from lightning from thunderstorms are fairly noisy. Their frequency distributions resemble a blow from a hammer, a chaotic distribution of overtones, instead of the organized frequencies and overtones of Itzhak Perlman playing a single note on the violin. How is it possible to detect a thunderstorm from half way around the world using a radio? Are all frequencies from the lightning carried? Why or why not? Most of all, what does lightning sound like on the radio? How can we know for sure that we are hearing lightning?
2. Investigate the layers of the ionosphere. The ionosphere is not so simple as it seems. There are layers within layers, for example, the F layer splits into F1 and F2 at night. Each layer has its own unique set of effects. So far we have concerned ourselves only with the D, E and F layers. What other effects are there? Make a poster of your findings and share it with the class.
3. FM radio waves pass unaffected through the ionosphere but they have trouble passing through water. Why is it so? Investigate the transmission of FM radio waves through fog and rain. Do AM radio waves have the same problem? FM radio sounds best in the morning. Why? FM radio has trouble on hot summer days? Why? Share your findings.
4. Investigate the optical window and the radio window. Prepare a poster and a couple of lecture notes and share your findings with your peers. Which atmospheric features are responsible for the attenuation of certain frequency bandwidths?
5. Molecules and atoms absorb light of certain frequencies but not others. This happens because certain transitions or quantum jumps inside the atom or molecule involve a specific amount of energy. Only this amount of energy is allowed to affect the transition. According to Planck's formula  $E = h * f$ , energy corresponds to frequency thus only certain frequencies are allowed to affect transitions. Prepare a poster explaining why molecules are responsive to only certain frequencies (not every detail has been explained here, you'll need to investigate)

and give the frequencies of some common molecules like oxygen, nitrogen, water, and ammonia. What phenomena are associated with these transitions of Earth and in space?

6. The ionosphere has its own weather just like the troposphere, which closely blankets the Earth's surface. The Sun follows an 11-year cycle. At the bottom of the cycle, the Sun is rather quiet. At the height of its cycle the Sun is active with sunspots and flares that bombard Earth's magnetic field with a stream of ions from the solar wind. What effects can space weather have on communications? What events have happened in the past where solar weather produced a significant disturbance here on Earth? Resource: [www.spaceweather.com](http://www.spaceweather.com)

## Activity: Monitoring Remote AM Radio Stations

### Equipment

- AR3000-A Communications Receiver
- SEARFE Software
- AM radio station 100 km or more away
- Stopwatch

### Procedure

1. Load up the SEARFE Spectrum Scanning Software.
2. The *Spectrum Scanning Wizard* should appear.
3. Choose new scan
4. The *Spectrum Scan Conditions* window should appear. Change antenna to the appropriate type either whip or disconn. Click next.
5. The *Receiver Setup* window should appear. Set the baud rate to 4800 and the receiver type to AR3000-A. Click next.
6. The *Scan Settings* windows should appear. Set the start frequency to 5 kHz below and the stop frequency 5 kHz above the remote AM station under investigation. Set the frequency increment to 0.01 kHz. Note: the SEARFE software uses MHz as its frequency unit. Converting kHz to MHz is necessary. Set the dwell time to 100 milliseconds. Set the scan number to one.
7. Using a stop watch figure out the time for one complete scan to occur. Press start to begin scanning.

Time for one scan \_\_\_\_\_

8. Calculate the number of scans attainable during a 24-hour period.

Number of scans during 24-hour period \_\_\_\_\_

Scans per hour \_\_\_\_\_

9. Go back and change the number of scans so that the scanner will survey the background for a 24-hour period. Calculate the number of scans per hour.

## Data Table and Graph

From the SEARFE scanning data, construct a data table and graph of maximum signal strength vs. time for you data over the entire 24-hour period. You should have one data point per hour. Examine the SEARFE data for a one-hour period and estimate the average maximum signal strength for that time interval. Ignore sudden spikes in the signal when performing your average. The spikes are due to spurious signals or disturbances in the ionosphere. Note any significant spikes and when they occurred on a separate sheet of paper.

## Questions and Interpretation

1. At what time did the D and E layers of the ionosphere diminish?
2. During what times was the AM signal strongest?
3. Did the time of strongest transmission coincide with 12 O'clock midnight? Does it necessarily need to do be strongest at midnight? Explain.
4. What happened to the signal during the daytime?
5. Identify any irregularities on your graph during the 24-hour scan.
6. Go to [www.spaceweather.com](http://www.spaceweather.com). Investigate the space weather for the previous day. Were there any events that might have produced fluctuations in the ionosphere thus affecting your transmission?

7. Sound cannot travel in a vacuum. Yet if space is a vacuum, how can scientists actually hear sound waves from the Sun? Investigate. What is the sound in space traveling through?