Mission 9
Separating a Radio Signal from “Noise”

Static, Static, Everywhere!

Notes

Radio technology, although only a few generations old, permeates our society–every thing from garage door openers to radar to cellular phones use the same radio-based technology. In Mission 8, students gained firsthand knowledge and experience with radio technology. They discovered that radio waves are all around us, and that they can be detected with a radio receiver.

Overview

In Mission 9.1, students confront the problem of separating a signal from noise to gain an appreciation of the difficulty of detecting a faint signal from far away amid the static from the gas and stars in the galaxy as well as the static from Earth radio and television signals. This is accomplished by using two radios, one tuned in–between radio stations to the static that comes from the universe (and from the radio itself), the other tuned to a “signal” (radio station). Students discover the point at which the signal can be heard and understood amid the static. They also practice signal detection with simulated radio data as a prelude to Mission 10.

Mission 9.1
Materials

For a Class of 30

- 2 radios, preferably the same type
- Overhead projector
- “Spectrum Analysis Display # 1” transparency or PowerPoint slide 9.2
- “Spectrum Analysis Display # 2” transparency or PowerPoint slide 9.3
- “Signal in Background Noise # 1” transparency or PowerPoint slide 9.4
- “Signal in Background Noise # 2” transparency or PowerPoint slide 9.5
- Transparency markers or grease pens

For Each Team

- Envelope
- 1 set of data strips (page xxx)
- (optional) 2 rulers

For Each Student

- "Finding a Signal on the Radio" worksheet (pages xxx)
- "Finding a Signal in Noise" worksheet (page xxx)
- Pencil

Getting Ready

1. Copy the worksheets "Finding a Signal on the Radio" and "Finding a Signal in Noise" for each student.

2. Make one copy of the "Data Strips" (page xxx) for each team. Cut out the strips so that there are no white margins, but be sure to leave the numbers (88 and 108) on the ends. Put each set into an envelope. These strips can be reused many times, especially if they are laminated.

3. Locate two similar AM radios. Set up the two radios side by side in the classroom. Set up the chairs or desks so that all students are about the same distance from the two radios. Tune one radio to static and the other radio to a station broadcasting someone talking.

4. Set up the data projector.

Classroom Action

1. **Lecture.** Divide the class into teams of two to four students each. Tell the class that central to the whole concept of what SETI is trying to accomplish is separating an intelligible signal from the noise of cosmic static that comes from all objects in space and from the detectors/receivers themselves.

2. **Demonstration.** Hand out the "Finding a Signal on the Radio" worksheet to each student. Show the class the two radios which have been set up side by side. Tell students that one will be tuned to static and the other to a radio station, a signal. Ask students if it helps to turn up the volume when you get a very weak radio signal, such as a radio station accompanied by lots of static. *(Of course not, because the static gets louder, too.)* Demonstrate this, on one of the radios. Ask students to name sources of static. *(Static comes from electric motors, electrical storms, and virtually anything that is electromechanical in nature. It can also come from cosmic sources, like our Sun and stars in our galaxy. At high frequencies, a lot of it is caused by synchrotron emission from electrons whizzing around magnetic field lines in the galaxy. However, the bulk of the noise is caused by the electronics of the radio itself.)*

   Tell students that to appreciate how static, or noise, can interfere with reception, you are using two radios so that you can separately adjust either the signal or the noise. Turn up the static volume as loud as the class can tolerate. Try to set the volume dial at a whole number if you want to simplify the math. Make sure all students are roughly the same distance from both radios. Slowly turn up the volume of the other radio. At what point can the class hear the signal against the background static? Students should record that volume on their worksheets. At what point can the class understand what the person on the radio is saying? Record that volume.

Usually the ratio of static noise to the volume when they can understand what the person is saying is 1:1. SETI scientists are attempting to do the same thing; pick a signal out of the background static or noise. Tell them that SETI scientists need a much better ratio than 1:1. They need anywhere from 5:1 to 10:1 to be certain that they are getting a signal amid the background noise. Demonstrate this by turning the static volume level to “1,” and the volume of the person talking to “5” (5 times as loud) or more.

3. **Activity.** Pass out the envelopes with the “Where Are the Radio Stations?” data strips inside. Ask students to proceed with their worksheets. When they are finished, make sure students realize that they have simulated how the SETI scientists sort natural static from the broadcast of some distant transmitter by repeated scans.

4. **Transparency or PowerPoint Slide 9.2** Put the “Spectrum Analysis Display # 1” transparency on the overhead or data projector and tell students that this is what radio noise looks like when it is put on a television monitor. This transparency is a scan of radio frequencies coming from space. It was done by a computer exactly the way students sorted their data strips. The computer tuned across the dial of a radio telescope, starting at a low frequency (left) and going to a high frequency (right). It put a dot of light on the screen at each frequency where it detected a signal. The dot is large for a strong signal and small for a weak signal. That was SCAN 1, just like STRIP 1 for the data strips. SCAN 1 is labeled at the lower left.

   Then the computer started over (SCAN 2, lower left) and again tuned across the dial from low to high frequency, putting a large or a small dot at each frequency where a signal was detected. The screen shows what it found after 300 scans, each one taking about a second. This is exactly like the 10 strips lined up next to each other, except that in this image the edges of the strips (or scans) cannot be seen. This is how SETI scientists search for a signal, by looking for a frequency that is always “on” (a transmitter) amid frequencies that go “on” and “off’ randomly (static), and by looking for a strong signal amid weak background signals.

   Now ask students what an extraterrestrial transmitter would look like on this screen. *(An extraterrestrial transmitter would look exactly like the line of dots on the 10 data strips- always “on” amid the background of static.)* Is there a signal in this screen? Remember, a signal would be a pattern of dots. Is there any visible pattern? The pattern to look for is a straight line of dots. This line may be hard to see because the eye becomes distracted by all of the random dots (the background static). Using a ruler or other straightedge may help. Give students a few minutes to find a pattern. They should find there is no pattern in the first screen.

5. **Transparency or PowerPoint Slide 9.2.** Put the “Spectrum Analysis Display #2” transparency on the overhead or data projector. Tell the class that this is an actual radio signal coming from beyond our solar system, from the *Pioneer 10* spacecraft. Does the

signal stand out over the noise? *(Yes. Blatantly!)* What kind of pattern does it make? *(A straight sloped line.)* This is a strong signal, deliberately generated. Would it be hard to detect if it were weaker than most of the noise? Make sure they see the analogy to the two radios. The signal picture needs to be louder or stronger than the background's random dots; the stronger it is, the easier it will be to detect. Or, the signal needs to be always "on." Or both.

Ask students to name a difference between paper detection of radio stations and computer detection of a distant transmitter. *(First, Earth AM radios operate between 0.8 and 1.6 MHz; the SETI detector searched frequencies of 1 to* 3 *GHz, or 1,000 to 3,000 MHz. These frequencies cross space with less interference than AM radio frequencies and could be the ones to use to broadcast toward another star.)*

(Second, the detected Pioneer *transmitter frequency changed between scans, unlike Earth radio stations, causing the line of dots to angle upward across the screen rather than go straight up. The* Pioneer *transmitter didn't really change frequency; the shift was caused by the Doppler Effect as the rotating Earth moves the radio telescope toward* Pioneer, *then away. The speed with which we riders on a turning Earth go directly toward* Pioneer *changes every second,* so *every second the Doppler shift is slightly less. This causes an angle across the screen, rather than a straight vertical line, that is somewhat shifted from* Pioneer's *true frequency. If students want to pursue this, have them imagine riders on a merry-go-round: Earth… turning past a buzzer ...* Pioneer.)

6. **Transparencies 3 and 4 or PowerPoint slide 9.2 Figures 9.4 and 9.5.** Tell students that you're going to put on a spectrum-analysis screen and you want them to find a signal. Put the "Signal in Background Noise #1" transparency on the overhead. Give the class a minute or two to study and search. Is there a signal? *(Yes. There is a weak signal.)* Many of your students will probably find it. If there were a stronger signal, how would the screen look different?

   Put the "Signal in Background Noise #2" transparency on the overhead for a brief moment, then align transparency #1 with #2. The signal in this transparency is the same signal as in the first transparency, but it is strong and obvious. Allow students time to "see" the weak signal in #1.

   Here is a method of finding the straight line signal that you may wish to share with your students at some point: You can see the straight line of dots more easily if you hold the sheet of paper level with your eyes, parallel to the ground, and rotate the sheet until you see a signal. This happens when your eyes are lined up and looking straight along the signal path. SETI scientists do the numerical equivalent of this; they add up the signals along all possible straight line paths and find the ones (if any) with very large sums.

7. **Activity.** Hand out the "Finding a Signal in Noise" worksheet to each student. Ask students to complete the worksheet in class or as homework. Ask teams that find signals to keep quiet about it until everyone has had time to find them. The first ones are easier than the last ones. Students may ask you for rulers to help them find the straight-line data on this worksheet.

Going Further

Activity: Red and Green Pictures

Instruct students to make line drawings in a single color (red, green, or blue) and then use the other two colors to fill up their pages with similar but random shapes and lines until the original line drawing is sufficiently obscured and cannot be readily identified. Ask students to look at each other's pictures through red, blue, and green filters. Can they make out the line drawings? Try combining filters and using diverse colors. Colors are various frequencies of the electromagnetic spectrum that are carried to the eye by light. Filters allow only specific wavelengths to reach the eye; they filter out the "noise"–the random shapes and lines drawn with other colors (wavelengths). So, with the right filter, the original line drawing (the wavelength that has the "signal") can be seen clearly.

Mission 9
Separating a Radio Signal from "Noise"

Finding a Signal on the Radio–Teacher's Key

1. Most of the static on a radio is produced within the radio itself at the higher frequencies. Static on a radio or television set can also be caused by any interfering electromagnetic wave produced by other electric devices, power plants, or any discharge such as lightning, or from poor connections.

2. Answers will vary.

3. For a SETI scientist to detect a signal, it must stand out above the noise, and/or the signal must always be "on." SETI scientists construct radio telescopes and instrumentation to optimize their signal detection capabilities, to minimize noise, and to observe long enough to distinguish a signal that is always "on." It is also possible to find a signal that flashes on and off at regular intervals. Such a signal might be sent by a transmitter rotating like a lighthouse beacon, or would be "seen" by us as "on" every time the rotation of the extraterrestrial planet turned the transmitter in our direction.

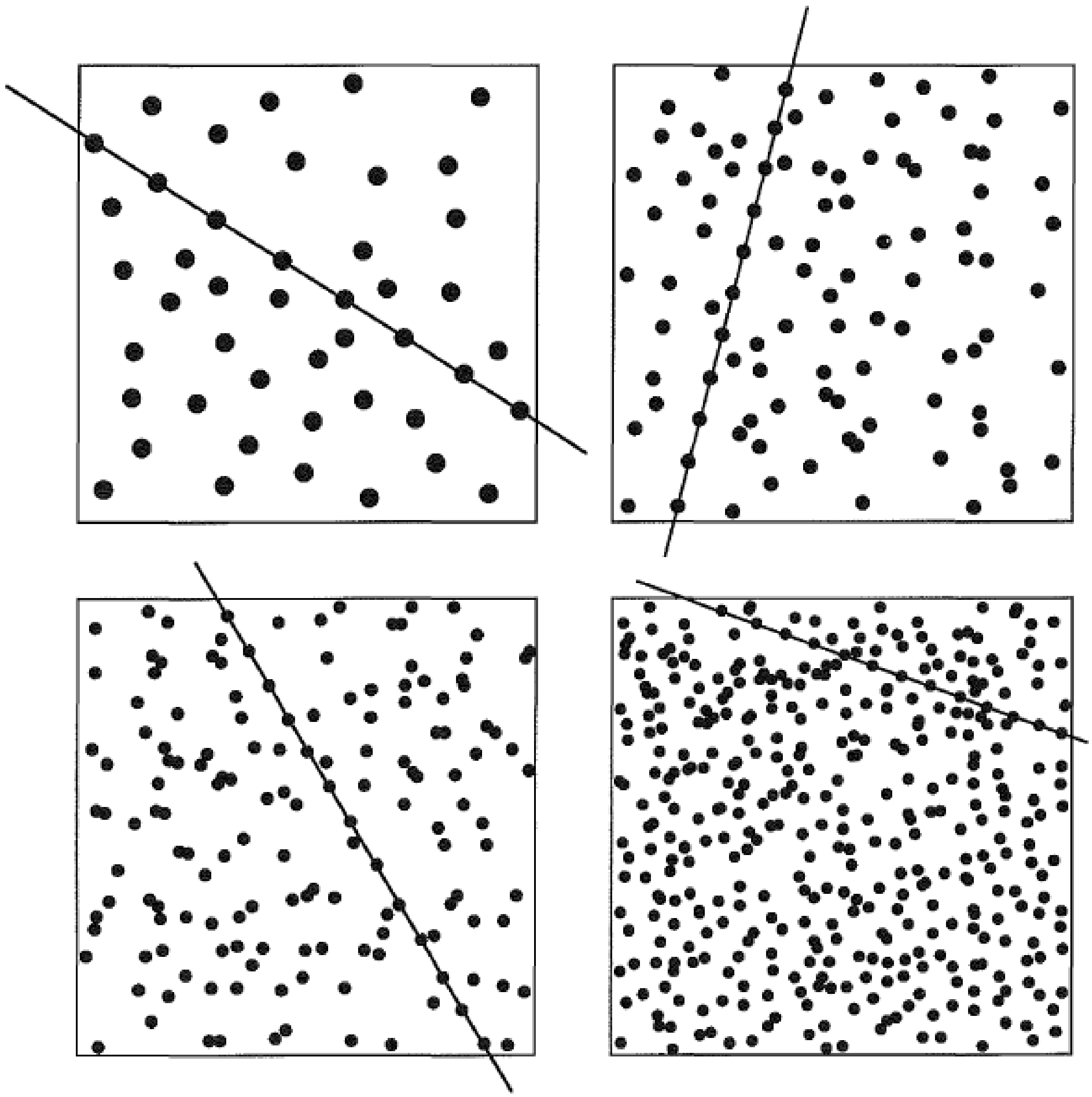
4. 90.7, 92.0, 93.3, 100.5, 104.2, 106.8

5. As SETI scientists look at the sky, they receive data from over 28 million channels at a time. Among those 28 million channels there is a great deal of noise produced by matter in space (some of the radio noise is from interstellar gas) and sometimes by Earth-based sources (television, radio, microwave communication, satellites, *etc*.), and of course, unavoidable noise from the radio receiver itself. All 28 million channels are looked at about once a second. If you lined up strips of 28 million channels and looked at them once a second you can get an idea of what SETI scientists are doing. SETI scientists have built super computers to help them analyze these 28 million channels for signals among the noise.

Mission 9
Separating a Radio Signal from "Noise"

Finding a Signal in Noise–Teacher's Key

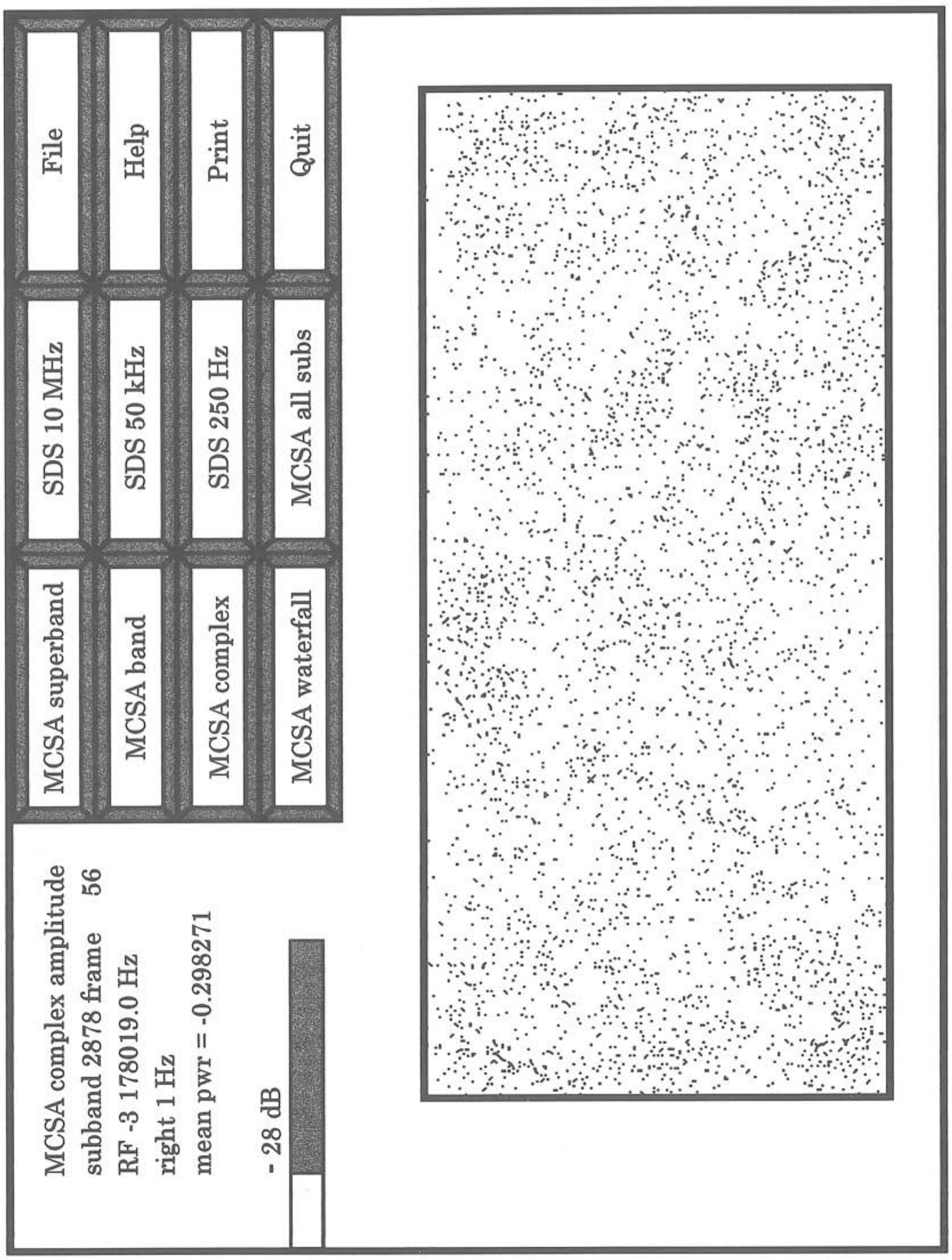
Figure 9.1.



Mission 9
Separating a Radio Signal from “Noise”

Spectrum Analysis Display #1–Transparency or PowerPoint slide

Figure 9.2.

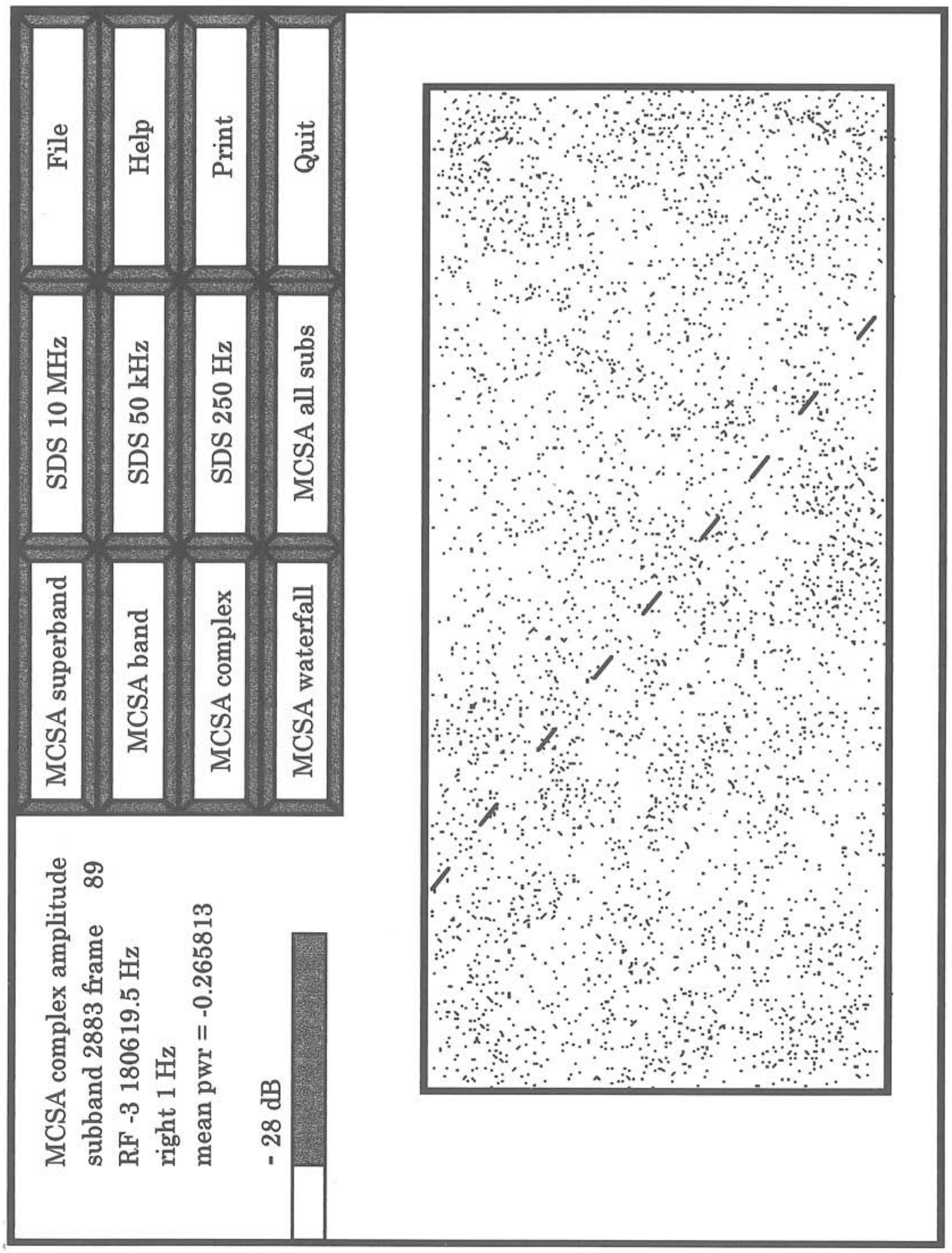


SETI INSTITUTE

Mission 9
Separating a Radio Signal from “Noise”

Spectrum Analysis Display #2–Transparency or PowerPoint slide

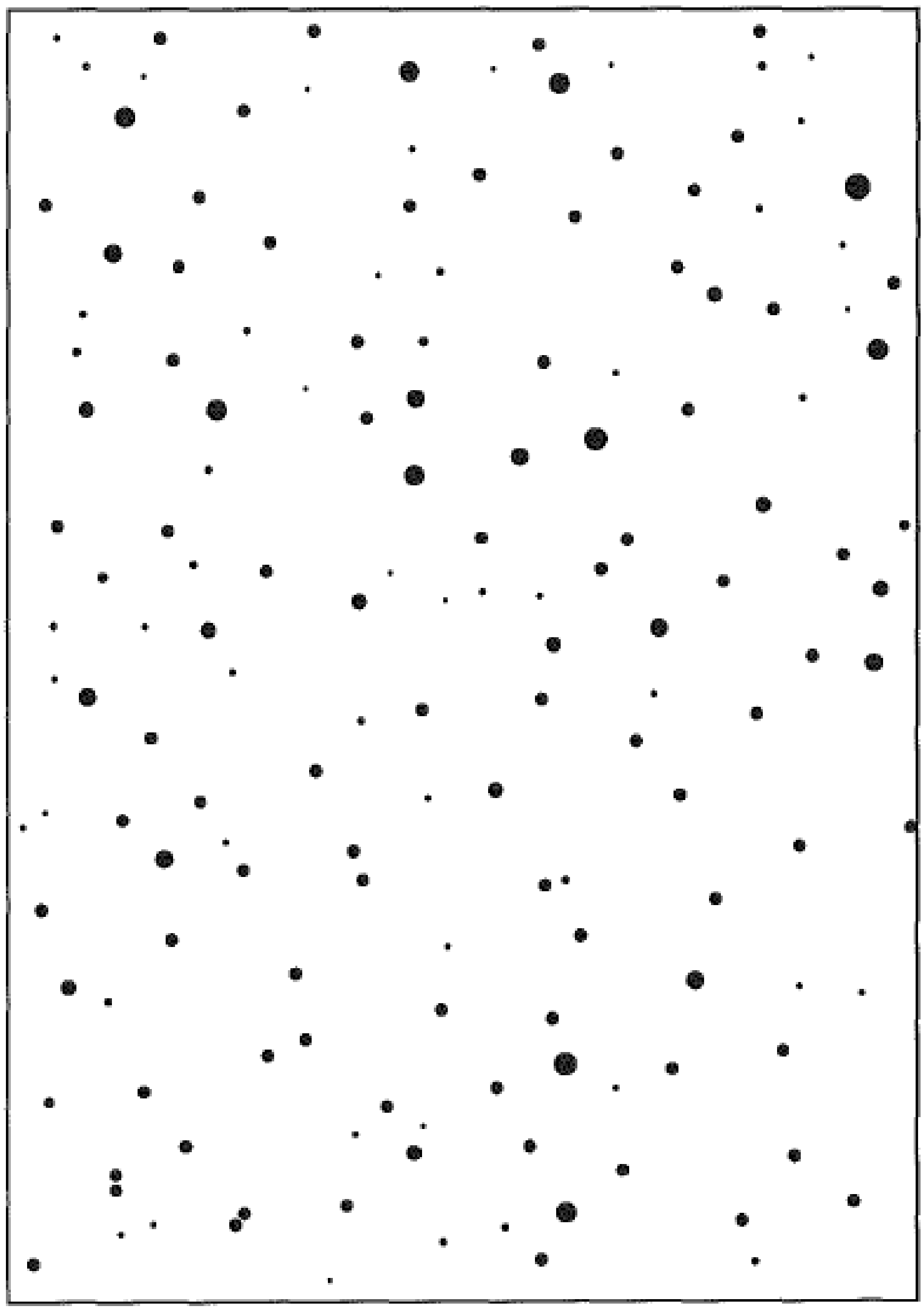
Figure 9.3.



Mission 9
Separating a Radio Signal from "Noise"

Signal in Background Noise # 1–Transparency or PowerPoint slide

Figure 9.4.

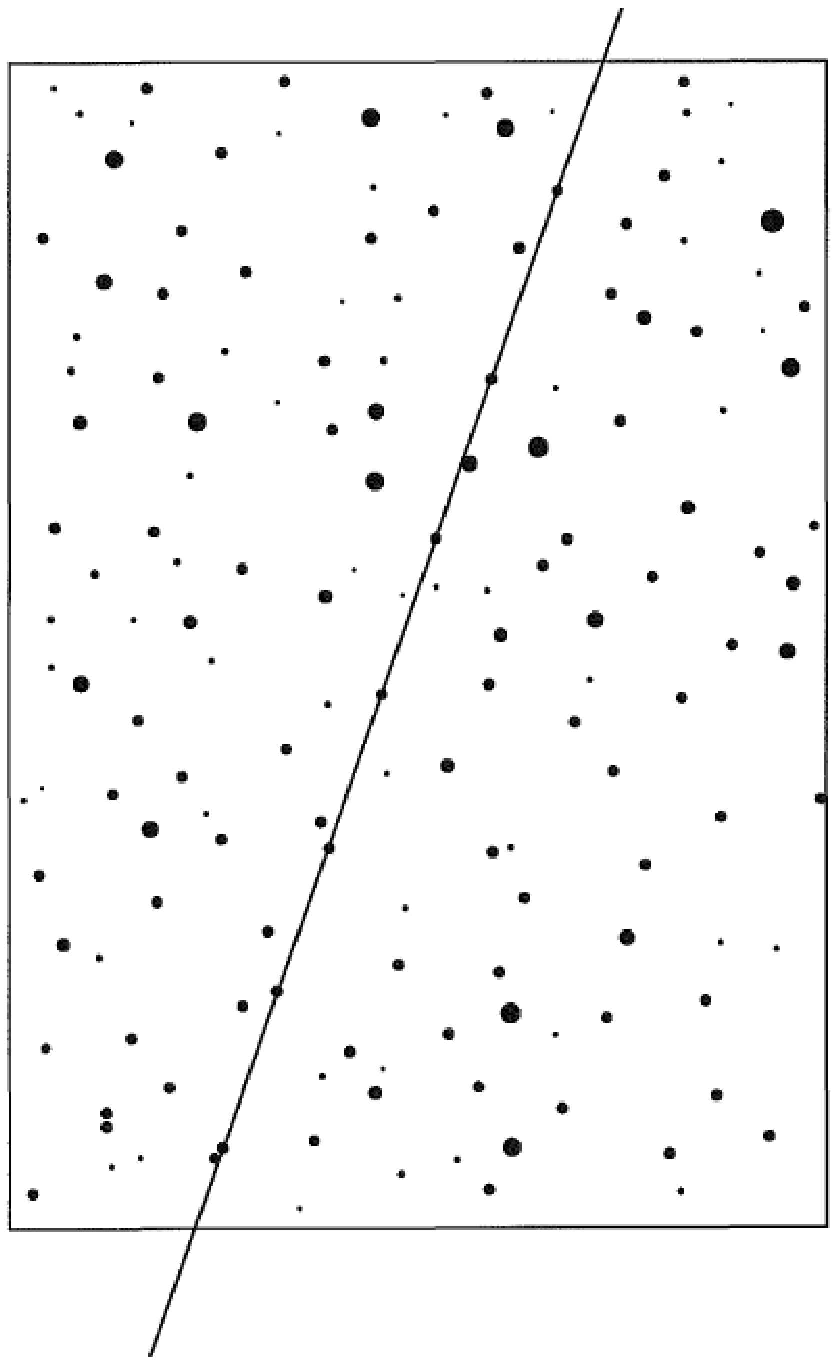


SETI INSTITUTE

Mission 9
Separating a Radio Signal from "Noise"

Signal in Background Noise # 2–Transparency

Figure 9.5.



This page left deliberately blank.