# Square Kilometre Array

# Level 7

## Science

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**www.anzska.govt.nz**

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# Introduction

**This resource has several student science activities reinforcing aspects of the 'big idea' in astronomy: that everything we know about the universe is from "messages" in the electromagnetic radiation we receive from beyond planet Earth.**

**The activities at this level are part of a series for Years 7–13 (up to Level 8). If your students had not experienced the earlier activities a selection of them would be a useful introduction to the 'big idea'.**

**The previous activities in this series included how common devices encode messages in light, exploring wavelengths of light, the properties and behaviour of waves, using radiation to measure temperature, colour temperature, etc.**

The activities support some Achievement Standards:

| | Activity | | | | | | |
|---|---|---|---|---|---|---|---|
| **NZQA standards** | *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| 90254 | × | × | × | | × | × | × |
| 90520 | | × | × | | × | × | × |
| 90257 | × | | × | | | × | |
| 90258 | | | | | × | × | × |
| 90259 | | | | | | × | |
| 91038 | | | | × | | | |

## The Level 7 student activities

These activities introduce several 'big ideas'.

1. Detecting electromagnetic radiation.
2. Using interference to measure wavelength of a signal.
3. Using directional aerials.
4. Random signals 2.
5. Noise cancellation using phase differences.
6. Effect of aerial length on radio transmission.
7. Aerials for different signals.

Each of the activities varies in the time required, from about 45 minutes if equipment is ready to use, with students in groups of 3–4, to two or three times that.

## Starting with the familiar

The intention is to use everyday examples to show some of the concepts of electromagnetic radiation that astronomers utilise to gain information about the universe. The strength of the linkage between these common examples and astronomy will depend on the particular objectives you may have in this area. While the concepts are not difficult, their practical realisation in astronomy can be complex and beyond the level of understanding required at this level.

An additional aspect is that activities are designed as much as possible to use simple, easily obtained and often cheap materials*, so they could be carried out by students as individual or group projects. *[*see Activity Six for a cheap walkie-talkie recommendation.]*

As your time is limited, the teacher guide section for each activity attempts to provide essential information. The 'extensions' section suggests topics for student project work, or for alternative group activities. References are given as URLs, mostly to Wikipedia as they are likely to remain available, to be updated, with diagrams often under the Wikimedia Commons licence so may be freely used.

## Assessment

Assessment examples have not been included.

## Radio telescopes

This resource is part of the **Square Kilometre Array (SKA) Project**, the largest international science project so far attempted. It would consist of an extensive array of radio telescopes providing a total collecting area of about one square kilometre, hence the project name. Australia has been short-listed as a location and it would also involve New Zealand to give a 5,500 km baseline – the longer the baseline the higher the resolution. The sensitivity and resolution of this array would enable it to see further into the universe, almost as far back in time as when it was formed.

From an educational perspective, the SKA project provides a context for several curriculum areas at different levels. It may also be where some of your students could work in the future.

**For details of the whole SKA project see:**
http://www.skatelescope.org/

**For the Australian and NZ part of it:**
http://www.ska.gov.au/Pages/default.aspx

**For the NZ part of the project see:**
http://www.ska.ac.nz/news

**For an overview:**
http://en.wikipedia.org/wiki/Square_Kilometre_Array

# Teacher Guide to Activity One

## Detecting Electromagnetic Radiation

The big idea here is how aerials and other detectors of electromagnetic radiation work. Aerials detect electromagnetic signals because the signal induces small currents in the wire of the aerial and voltages across the ends of it. This fact can be used to detect signals and measure how strong they are by the size of the voltages induced. In modern times digital multimeters have sensitive enough scales to perform this task.

Light is an electromagnetic wave and when it falls on particular surfaces it will induce currents to flow. The wavelength of light is very much shorter than radio waves. The idea of an aerial is not useful for light and higher frequency electromagnetic radiation. For light the aerial would be only a few atoms long. Light is energy and does cause a current to flow in some surfaces it hits. For example, a common light detector is an LDR which changes its resistance value with the intensity of the light. Photodiodes begin to conduct when light lands on them. The human eye contains sensors on the retina that cause tiny electrical impulses which our brain interprets as sight. Modern digital cameras work on the same general principle.

Activity Three of Level Six in this series just looked at the fact that electric signals can transmit energy from one place to another and that the signal can be detected by using some of the signal's energy and converting it to current in the wire and voltage across the diode.

In all of the above examples the signal can be affected by being absorbed or reflected. In this exercise more investigation is done on how absorption and reflection affect transmission and detection of a radio signal.

### Equipment

1. A piece of insulated wire about the same length as the wavelength as the radio signal.
2. A digital multimeter (DMM) with clip leads.
3. A low forward voltage (small signal) germanium diode (OA91 or similar).
4. A source of radio signals, the most convenient being a cheap hand-held PRS 'walkie-talkie', utilising the 476.425 – 477.400 MHz band; $\lambda \approx 0.63$ m. Note: do **not** transmit on channels: 1–8, 22, 23, 35.
5. A selection of shielding materials, e.g.: metal plate or mesh of different metals, plastic, expanded polystyrene foam or fibreglass panels, buckets of water, soil, wood-chips, wet and dry towels, concrete or paving slabs, even the operator's body!

*To make a signal detection meter:* Take a loop of wire and connect one end to a diode, the other end to a DMM. The diode will rectify the signal and enable a DC reading on the meter. It does not matter which way round the diode is as DMMs will read either way around, they just put a minus sign at the front if the voltage is the 'wrong way around'.

For high sensitivity the length of the wire (including DMM leads) should be about one wavelength ($\approx$0.63 m for PRS walkie-talkies). This is important if you are trying to get a reading of relative strength of a signal at a distance away where the signal has become very weak. However, field testing with a common CB handset transmitting and a diode directly connected to a DMM gave a useful reading (in mV) at classroom-sized distances, which would be ideal for many school situations. The only concern would be to ensure that only one transmitter was being used within range of the detector at any one time, as it would not discriminate between signals.

Many groups could work using the one transmitter and have their own detection apparatus (loop, diode and meter) and test materials. It would require a degree of cooperation and organisation, but it could be done.

### Reference

http://en.wikipedia.org/wiki/Radio_waves

### Outcomes

Able to recognise that signal energy is absorbed differently by different media.

### Background information

A PRS (Personal Radio Service, UHF CB) walkie-talkie has 40 channels utilising frequencies from 476.425 MHz to 477.400 MHz ($\lambda \approx 0.63$ m).

When using a PRS walkie-talkie for the radio signal do **not** use these channels:

- 1–8 (these are repeater channels and you do not need to take up repeater space, with channel 5 for emergency use only).
- 22, 23 (these are telemetry channels only).
- 35 (this is for emergency use only).

It is advisable to first listen on the channel selected for use to find if there is anyone already using it.

### Extensions

Microwave ovens (which use radiation at 2.45 GHz). This is only one application of RF heating; see: http://www.pscrfheat.com/rfbasics.htm

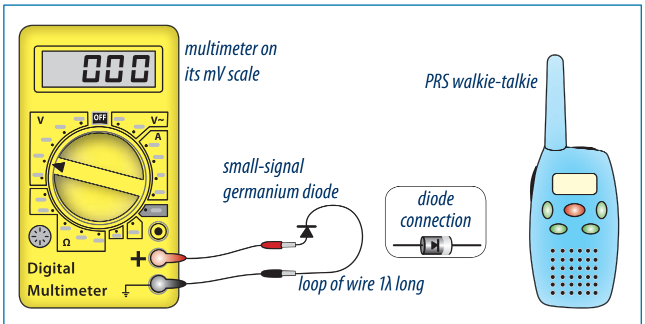
# Student Activity One

## Detecting Electromagnetic Radiation

Electromagnetic radiation can be detected when the energy in it is absorbed by an aerial, inducing a voltage which indicates the strength of the signal. A piece of wire plus the leads of a digital multimeter are used as an aerial to collect radio signals, and a diode and multimeter to measure the strength of the signal. The aerial is most effective where its length is about the same as the wavelength of the signal. When an electromagnetic wave meets a material, it may be absorbed, reflected, refracted or transmitted. This activity investigates the effect of various materials on the reception (detection) of a radio signal. A microwave oven is an example of where most of the radio wavelengths used will be absorbed by materials in food, water especially. A radio telescope is an example of where the metal used will reflect most radio waves. Many building materials, e.g. wood, readily transmit radio waves; others don't.

### What to do

1. Set the digital multimeter to the mV (millivolt) scale and clip the leads to the wire and diode provided.




2. Take a background reading of any ambient electromagnetic radio energy and then get your partner to press the transmit button on the CB handset (but do **not** transmit on channels: 1–8, 22, 23, 35).
3. Note the reading on the multimeter and the orientation of the diode.
4. Note the signal strength at the start and before or after each trial.
5. Place each of the test shielding materials in the path between the radio transmitter and the detector circuit and close to the detector to minimise the effect of any possible diffraction around the test material.
6. Note the reading on the detector and complete the table for each different shielding material. Note down your observations and results and draw a conclusion.
7. The human body is 70% water. Investigate whether your body absorbs radio signals. Should you be concerned if you have a domestic radio clock on your bedside table?
8. State what you did in the investigation to ensure it was a fair trial.

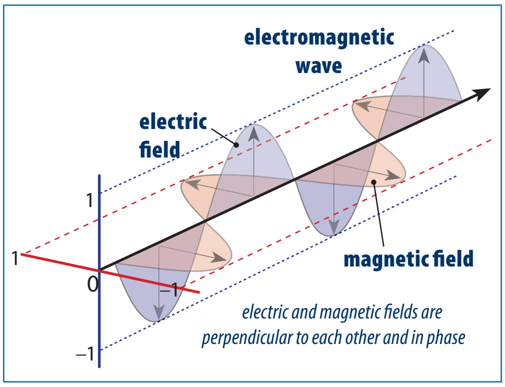
| Shielding material | Unshielded signal reading ($S_U$) | Shielded signal reading ($S_S$) | Signal loss reading $S$: $S = S_U - S_S$ | Comment |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

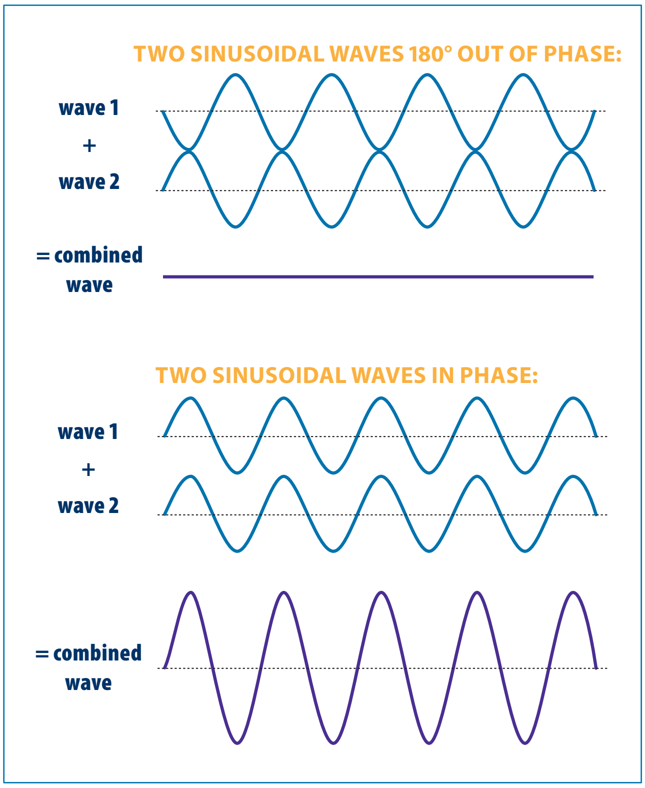
# Using Interference to Measure Wavelength of a Signal

The 'big idea' is the effect of changing path length on the interference pattern.

Microwaves and radio are forms of electromagnetic radiation, as is light. Microwaves occupy a part of the electromagnetic spectrum just below infrared, with wavelengths of about 0.01 m. Radio waves have much longer wavelengths (and lower energy) while light has much shorter wavelengths (about 0.000000500 m or 500 nm).

Like all other waves, electromagnetic waves will interfere with each other and form nodal points (nodes) when they meet completely out of phase. This is called destructive interference and happens because the positive amplitude of one wave meets the opposite negative amplitude of a second wave, cancelling it out. The opposite happens at points where waves meet in phase. This is called constructive interference and forms antinodal points (antinodes).




At antinodes positive amplitudes of the waves meet and add together making a greater amplitude. This phenomenon of interference is easily observable for sound waves and water waves. It is less easy to observe for radio waves and light, but can still be done with some simple equipment.

## Equipment

1. At least three PRS (Personal Radio Service, UHF CB) walkie-talkies. (These have 40 channels utilising frequencies from 476.425 MHz to 477.400 MHz; $\lambda \approx 0.63$ m.) Do **not** use these channels:
   - 1–8 (these are repeater channels and you do not need to take up repeater space, with channel 5 for emergency use only).
   - 22, 23 (these are telemetry channels only).
   - 35 (this is for emergency use only).
2. Tape measure or ruler.

## Rationale

Utilising the interference pattern to measure the wavelength of radiation is an important technique in astronomy.

## References

http://www.physicsclassroom.com/calcpad/light/problems.cfm (see problems 23–25)

http://en.wikipedia.org/wiki/Interference_(wave_propagation)

http://en.wikipedia.org/wiki/Node_(physics)

## Outcomes

- Understanding of how differences in path length introduce phase differences.
- Recognition that path differences can cause constructive or destructive interference.

## Background information

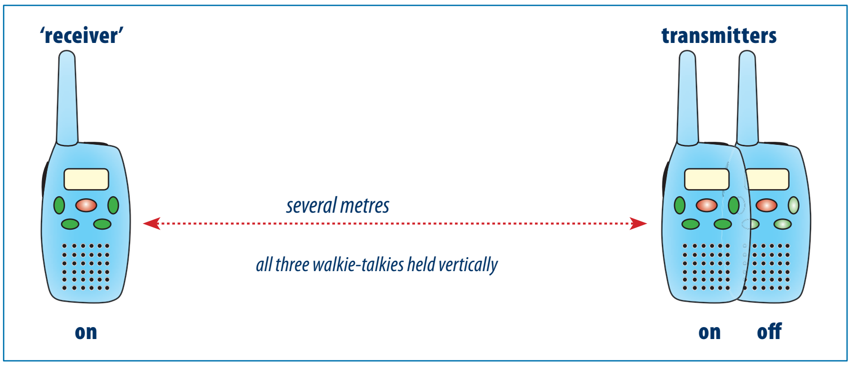
In the SKA the extra path travelled to the widely separated radio telescope dishes needs to be allowed for.

## Extensions

Investigate how the signal strength could be enhanced by having three PRS walkie-talkies transmitting when one wavelength apart from each other.

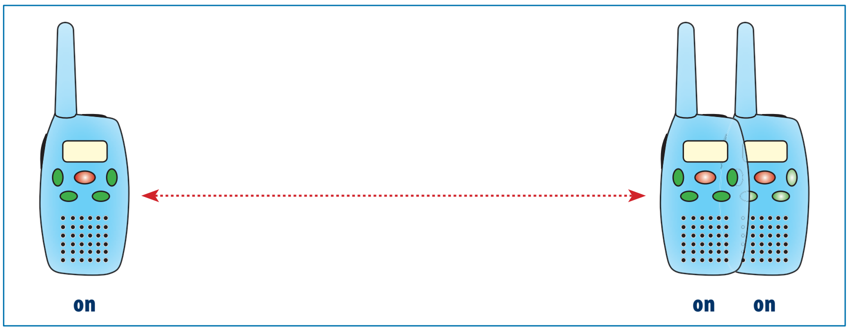
# Using Interference to Measure Wavelength of a Signal

1. Set all three walkie-talkie handsets to the same channel (but **not** any of 1–8, 22, 23, 35) and then place one (in the receive mode) at some distance away. This one will be called the 'receiver'.

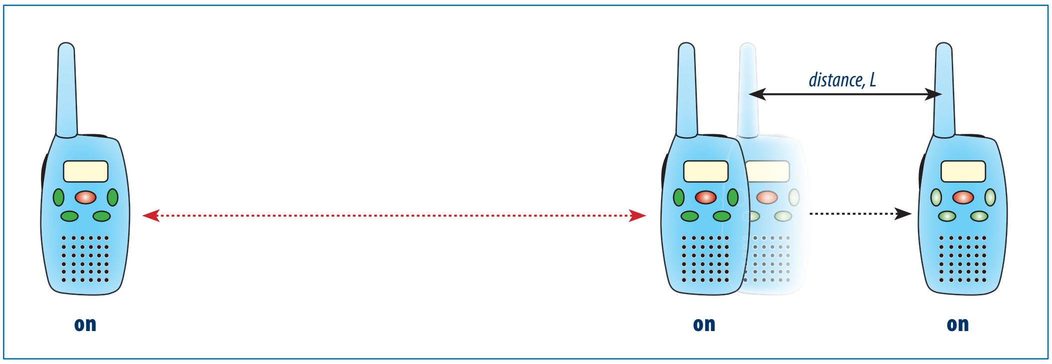



2. Press the transmit button on one of the two remaining handsets and note that its signal is being received. Repeat for the remaining handset.

3. Now hold the two handsets close together with their antennae lined up with the 'receiver' and hold down the transmit button on each.




4. Gradually move the rearmost transmitter further away from the receiver, noting how the volume of the received signal varies. Estimate the wavelength of the transmitted wave by measuring the distance, L. This is the change in separation of the transmitters as the received sound goes from high to low or vice versa. This change in separation (L) is half a wavelength ($\lambda$/2).




5. Record the length, **L:** ____________________________________________

   Calculate the wavelength, **λ:** ______________________________________

# Using Directional Aerials

The 'big idea' is that aerials are a way of transferring electromagnetic signals to and from the surrounding environment.

## Background information

Single wire or 'monopole' aerials and dipole aerials are omnidirectional, which means the energy carried by the radio signal is emitted in all directions around the aerial. There are advantages and disadvantages to this. The advantage is that all receivers can obtain signals of equal strength anywhere on a circle surrounding the transmitter with it at the centre. The big disadvantage is that radiated energy is wasted in transmitting signals to regions where there are no receivers.

Transmission of radio wave energy is most efficient if it is directed in a narrow beam using a directional aerial. Aerials having a narrow receiving angle are more discriminating.

Monopole aerials are used on receivers that cannot be oriented towards a particular transmission aerial. Car aerials are the most obvious example of this as cars move in any direction over long distances.

Fixed receivers benefit from using a directional aerial because this design enhances a signal coming from a particular direction. This is why TV aerials, for example, are highly directional and aimed at the signal source. Much effort goes into aerial design to improve the reception of particular signal frequencies from the transmitter direction. If the aerial is moved away from that direction the signal weakens markedly.

There are many different designs of directional aerials, with some being more suited to particular wavelengths than others. Yagi-Uda aerial designs (commonly called just 'yagi') are common for VHF and UHF frequencies. Radio telescope dishes are directional and adjust the direction they are receiving from by moving the dish. The radio dish can also adjust the direction of the received beam by moving the pick-up along the focal plane of the dish reflector in much the same way that the dip filament of a headlight is slightly above the focus point of the headlight reflector in a car (although the energy in the headlight is being transmitted, not received).

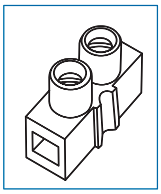
The directional nature of aerials means they can be used for direction finding. The aerial can provide a 'fix' on the direction the signal is coming from. If two 'fixes' can be obtained from different positions then the source can be located (see Activity 7, Level 6). Yagi aerials were used in the early days of radio astronomy, replaced by dish reflectors which had more signal collecting area.

A yagi aerial is being used in this activity. It is recommended that this aerial be prebuilt for this exercise as the directional nature of the aerial is the purpose of this activity, rather than the detail of the aerial itself. Designing and building a yagi aerial and some of the principles of design and operation of it are an activity undertaken at Level 8 in this series. The dimensions for a yagi aerial suitable for a PRS walkie-talkie as an identifiable signal source are given below.

During the development of this exercise it was found that the multimeter leads also act as an aerial, but that this is minimised if the leads are as horizontal as possible when leading back from the yagi (i.e. parallel to the boom). Use RG6 coaxial cable (it has a single wire core) from the aerial as it is more suited to the frequencies received. Two diodes were used to rectify the signal, which for this activity worked better than the single diode used in other activities in this series. The added complexity is justified for better performance.

## *Construction details*

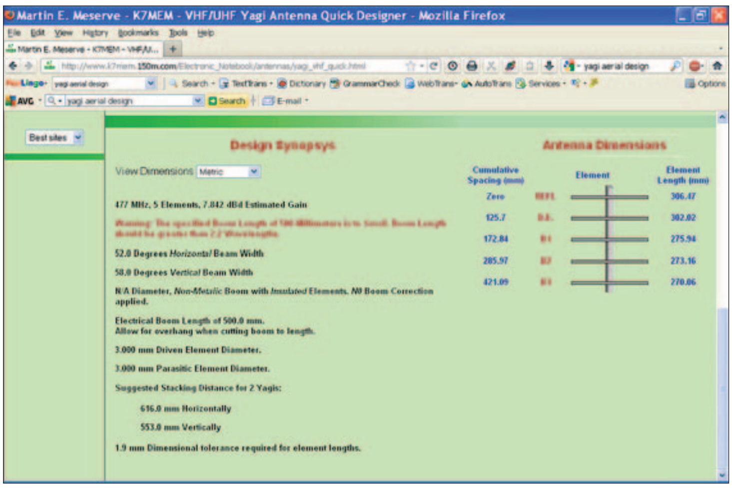
A wooden boom was used and all of the elements connected onto the boom using 'chocolate block' connectors. The wooden boom insulates the elements from each other. All of the elements except the driven element are each one piece. The driven element is in two pieces (it is a dipole) with a combined length as given on the diagram. The centre wire of the coax is connected to one piece and the shield to the other piece.



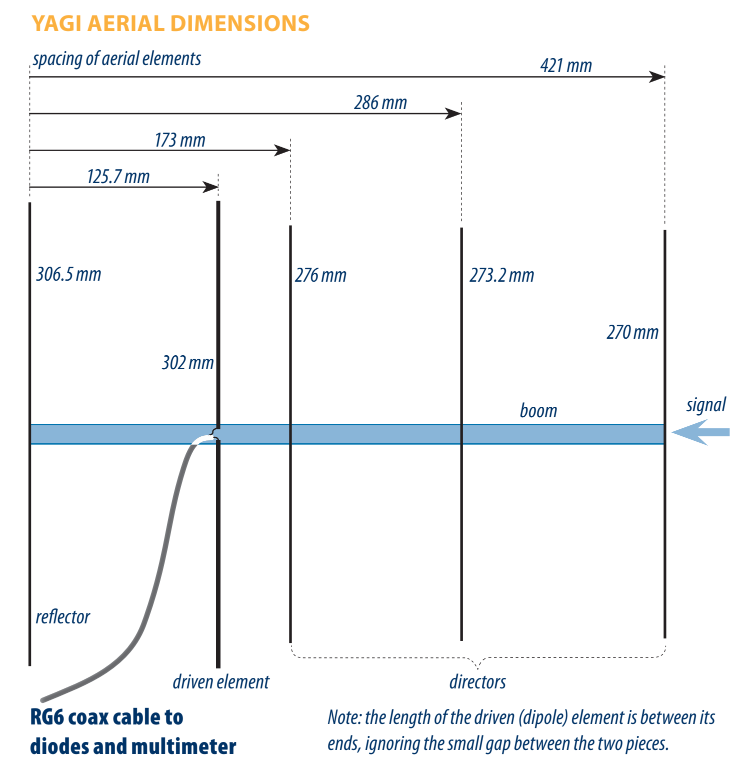
The length of the boom determines the gain of the aerial. The length and spacing of the reflector, driven element and the directors depends on the frequency being detected. In the design used in evaluating this activity the elements were all made of wire from coat-hangers, assumed to be 3 mm thick.

Below is a screen capture of the design program used for the yagi aerial that needs to be built. See:
http://www.k7mem.150m.com/Electronic_Notebook/antennas/yagi_vhf_quick.html

*Layout and dimensions of a yagi from this screen:*



## Equipment




1. PRS (Personal Radio Service, UHF CB) walkie-talkies. These have 40 channels utilising frequencies from 476.425 MHz to 477.400 MHz ($\lambda \approx 0.63$ m.) These do not require a licence but transmission power must not be increased.
   Do not use these channels:
   - 1–8 (these are repeater channels and you do not need to take up repeater space, with channel 5 for emergency use only).
   - 22, 23 (these are telemetry channels only).
   - 35 (this is for emergency use only).
2. Yagi aerial, as above.
3. Multimeter and two small-signal germanium diodes.
4. Protractor and stiff card.

## References

http://en.wikipedia.org/wiki/Yagi-Uda_antenna

http://www.skyscan.ca/Antennas.htm

## Outcomes

- Increased understanding of the way constructive interference, through path differences enhance reception.
- Awareness of the resonant nature of an aerial and how length of the aerial is critical to performance.

## Extensions

Modify a PRS walkie-talkie to take a yagi aerial and compare the signal strength of the modified and unmodified sets (see Activity Six).

# Using Directional Aerials

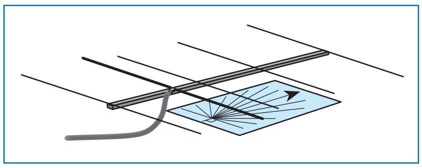
Aerials perform best if they are able to enhance the signal received from a particular direction. This obviously means the signal source has to be in a fixed position.

The yagi type of aerial (shown in the photograph, right) that you will use has existed in various forms for over 80 years. It is commonly used to receive television broadcasts.

The principles behind aerial design are very complex and beyond the scope of this exercise. However, the result is that the aerial is highly directional, which means it will produce a strong received signal when directed towards the source and a weak signal from all other directions. You will build or be given a pre-built yagi aerial and the purpose of the activity is to investigate how good it is at receiving a signal in one direction.

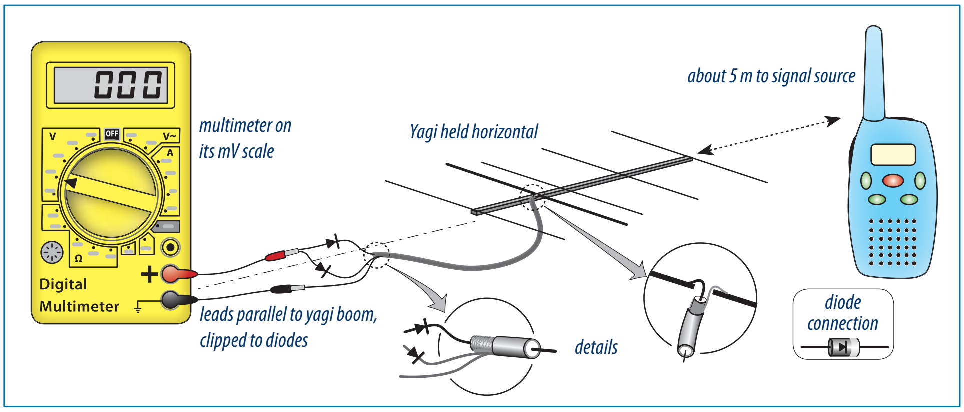
In addition, you will have a signal detector (a digital multimeter and diodes, connected as below), and you will need a protractor and some stiff card.

## Procedure

1. Make the aerial or use the prebuilt one supplied by your teacher.
2. Connect the terminals of the yagi to the meter and the diode so that all are in a series circuit, as shown below.
3. On a long stiff piece of card draw a long line along the length of the card, mark it as being 0° and then mark and label other shorter lines at 10° intervals until 90° is reached.
4. The aerial will pick up all sorts of signals. To minimise the effect of other signals on the aerial, a reasonably strong transmitter is needed. Walkie-talkie radios are ideal, if reasonably close to the aerial and signal strength meter. A suitable distance is about 5 m away. Longer distances may be possible if the yagi has been well designed and built.
   Have a partner press the transmit button while the aerial is pointed towards it and establish that the signal meter is responding to the walkie-talkie signal and not spurious signals from other sources. Note: do not use channels 1–8, 22, 23 or 35.
   The aerial effect of the signal meter leads is minimised if they are in line with the yagi boom and are as short as possible.
5. Have your partner hold the CB set with its aerial vertical and the transmit button pressed.
6. Line up your aerial with the boom along the line towards the transmitter and the 0° line on the card.
   
   The elements of the yagi aerial should be horizontal. Fix this direction using some definite reference point. Remember that the card must maintain the same alignment throughout the investigation (e.g. rest it on a desk, with the 0° line always pointing at the walkie-talkie). Record the signal strength reading from your meter and note it on the table below.
   It may fluctuate a little, making an accurate reading difficult, but it is sufficient for this exercise to record the strongest signal reading at each angle.
7. Rotate the aerial horizontally through 10° at a time, using the marks on the card to align the aerial. Record the signal strength reading from your meter and note it as before.

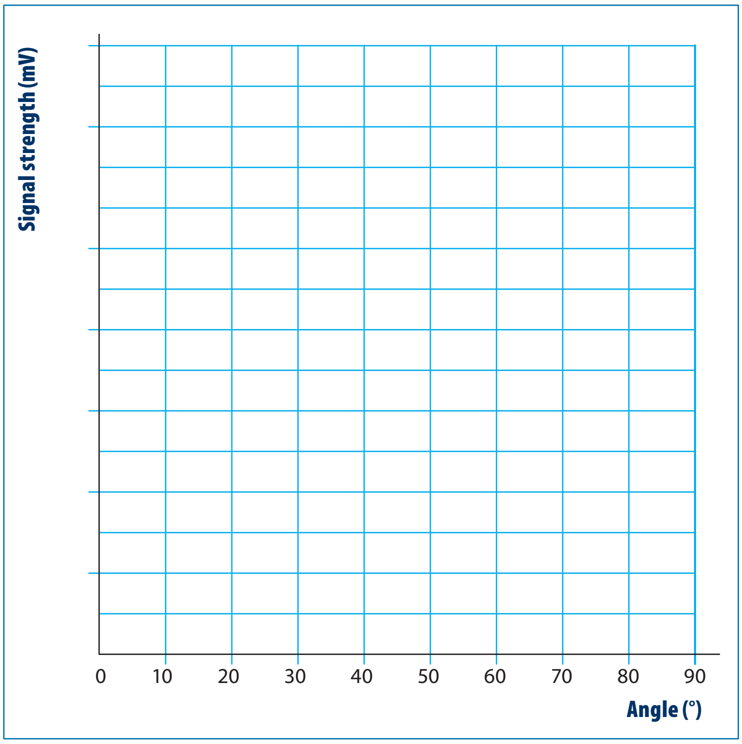
**Results**

| Angle (°) | Signal strength (mV) |
|---|---|
| 0 | |
| 10 | |
| 20 | |
| 30 | |
| 40 | |
| 50 | |
| 60 | |
| 70 | |
| 80 | |
| 90 | |



8. Repeat the previous steps for all the other directions up to 90° if you can. There may be reflections and other factors that affect collecting signals at wider angles.
9. Draw a graph of the signal strength against the directional angle of the aerial and answer the questions following.

## Graph:




## Questions:

1. Do you think this aerial works well as a directional aerial? Give reasons for your answer.

2. From your graph, how far around did the aerial have to rotate before the signal strength was halved?

3. Describe how an aerial like this could be used to locate a transmitter? Assume the aerial was well designed and sufficiently sensitive to detect the signal from a weak distant source.

4. Look at the aerial you used. It is designed to resonate at 477 MHz. Which dimensions of the aerial would need to change if a lower frequency signal was to be detected?

# Random Signals 2

This is again a great simplification, but illustrates that radio signals of interest can be isolated from random signals. The first part of this exercise is in the SKA Level 6 Science resource.

The student scenario is that radio emissions from a point in the sky are received and analysed. There will always be background random unwanted signal ('noise') recorded from extra terrestrial sources, man-made electrical noise, and the noise generated in the receiver/ amplifier of each radio telescope. The big idea here is that random noise will average out to zero. The analysis here is greatly simplified, but does illustrate how techniques can be developed to bring out a signal from background hash.

## Rationale

Random signals, or 'noise', is a problem in many contexts, from trying to hold a conversation in a noisy environment, to identifying and extracting significant information from faint radio signals received by a radio telescope.

## Information provided to students

Below is the table of information, with the student activity presenting it in graph form:

**Result table of information downloaded from 10 receiver stations**

| Receiver | Frequencies (kHz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| 1 | –1 | 1 | 2 | 0 | 2 | 1 | –2 | 2 |
| 2 | 2 | 1 | 3 | –2 | –1 | 2 | –2 | 1 |
| 3 | –3 | 3 | 2 | 1 | –3 | 2 | 3 | –2 |
| 4 | 4 | -2 | 4 | –1 | 1 | 2 | 0 | –2 |
| 5 | 1 | 0 | 3 | –2 | 2 | 3 | 1 | 2 |
| 6 | –2 | –1 | 2 | 1 | –1 | 2 | 3 | –1 |
| 7 | 1 | 1 | 3 | 2 | 0 | 2 | –2 | 1 |
| 8 | –4 | 0 | 3 | 1 | –3 | 3 | 1 | –2 |
| 9 | 2 | –2 | 3 | –1 | 4 | 3 | –2 | 1 |
| 10 | -1 | –1 | 2 | 1 | –2 | 3 | 0 | 1 |
| **Totals** | –0.1 | 0 | 2.7 | 0 | –0.1 | 2.3 | 0 | 0.1 |

## References

http://en.wikipedia.org/wiki/Noise_reduction
*(also see the 'External Links' in this reference)*

## Outcomes

Able to describe a method of removing 'noise' from signals to reveal the significant information.

## Background information

Random signals, or 'noise', are present in any signal, whether radio waves, music, speech, pictures, etc. We are familiar with the difficulties of carrying out a conversation in noisy environments, where random noise threatens to overcome the information signals. Engineers use sophisticated signal processing techniques to identify and separate noise from the information in a signal.

## Extensions

In the Level 6 version of this activity, these extensions were suggested:

1. Noise cancelling microphones; see:
   http://en.wikipedia.org/wiki/Noise-canceling_microphone
2. Noise cancelling headphones; see:
   http://en.wikipedia.org/wiki/Noise-cancelling_headphones

   ***Note:*** *Activity Five following is on using phase differences for noise cancellation, so Extensions 1 and 2 would be considered only if Activity Five was not going to be carried out and have been included there.*
3. Sensor noise subtraction from long exposures by digital cameras; see:
   http://www.astropix.com/HTML/I_ASTROP/SIGNAL.HTM
   http://qsimaging.com/ccd_noise.html
4. How digital cameras work; see:
   http://www.cambridgeincolour.com/tutorials/camera-sensors.htm
   http://electronics.howstuffworks.com/cameras-photography/digital/question362.htm
5. Another example is passive radar:
   http://en.wikipedia.org/wiki/Passive_radar
6. However, at this level it may be appropriate to introduce the concept of the signal-to-noise ratio and develop the idea in various contexts, e.g. the problem of designing a hearing aid to function in a noisy environment – obviously, it can't just amplify all sound, it needs some way of selecting speech from the random noise of people movement, other conversations, etc.
   An extension of #4 above in relation to signal-to-noise ratio is noise in digital images:
   http://www.cambridgeincolour.com/tutorials/image-noise.htm
7. 'White noise' is a common term for random signals, see:
   http://en.wikipedia.org/wiki/White_noise

# Student Activity Four

## Random Signals 2

The resource page shows 10 frequency analysis graphs of radio signals coming from a point in the sky. There is a lot of unwanted signal ('noise') from atmospheric sources and from the electrical circuits in the satellite dish detectors. This noise will hide any faint signal received from space.

The graphs on the following page show samples of radio signals coming from a point in the sky as recorded from ten receiver stations. Is there any "real" signal present?

To find out, take the information from the tables and transfer it to the blank table below.

Calculate the average signal over all 10 receivers at each frequency.

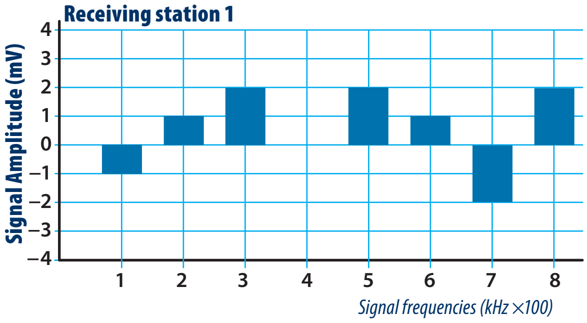
2. Explain how you know you have isolated a real signal from background random 'noise'?

| | Frequencies sampled from each signal (kHz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Receiver** | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| **Totals** | | | | | | | | |

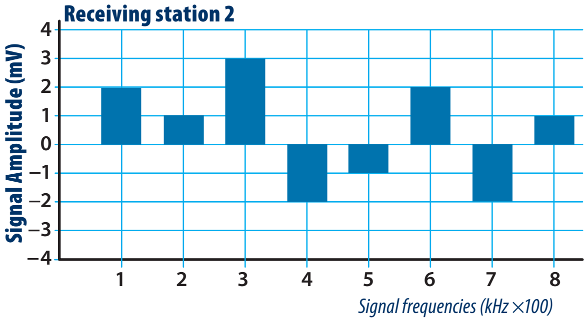
1. What is the frequency of the real signal you found?

## Graphs of the signals at different frequencies from each of ten receiving stations

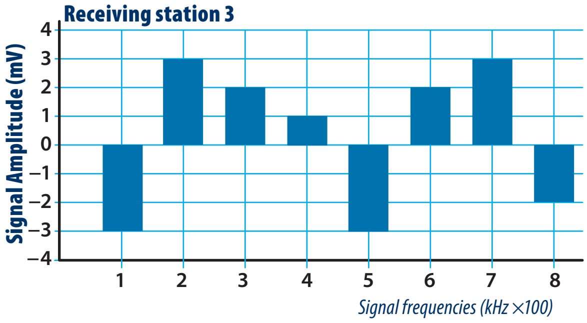
**Receiving station 1**



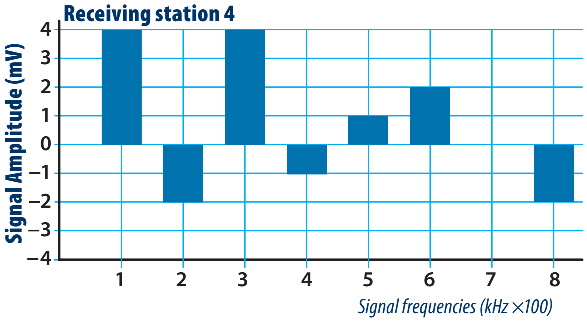

**Receiving station 2**



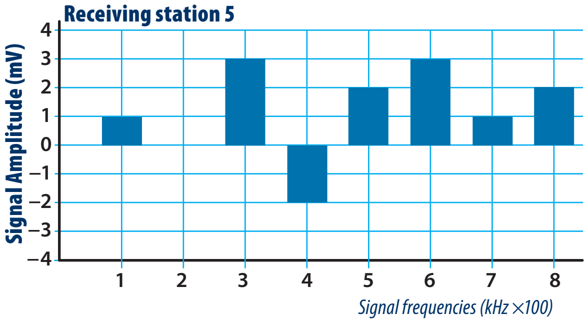

**Receiving station 3**



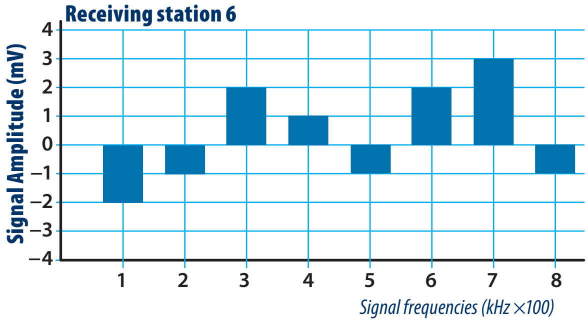

**Receiving station 4**



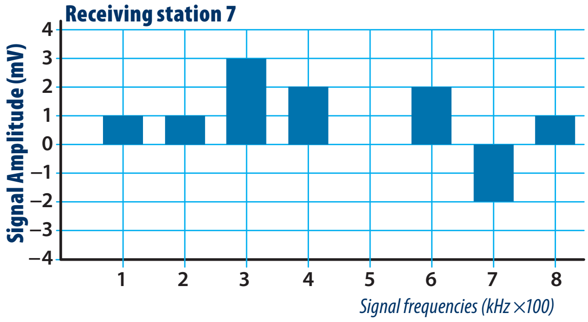

**Receiving station 5**



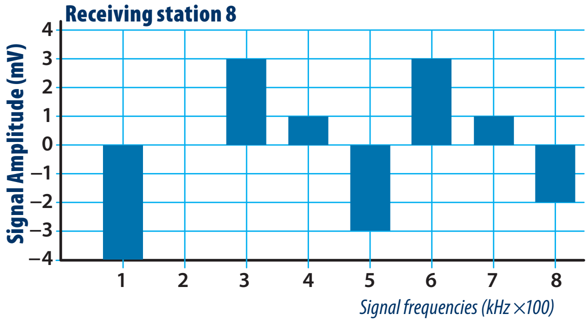

**Receiving station 6**



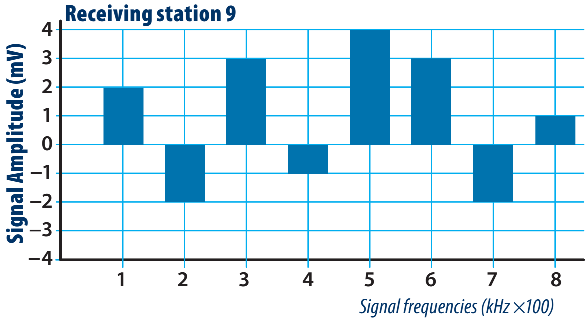

**Receiving station 7**



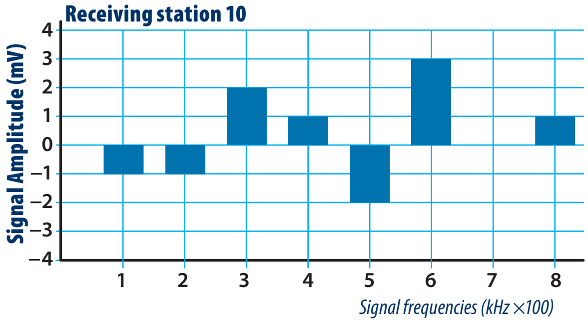

**Receiving station 8**




**Receiving station 9**




**Receiving station 10**



# Noise Cancellation Using Phase Differences

In radio interferometry, as in many other wave applications, noise is a problem. In electromagnetic waves noise is unwanted signal generated from such things as electric motor contacts and lightning. Radio telescopes receive very weak signals and must be located in areas where noise (interference) is least.

The 'big idea' in this investigation is that an unwanted signal can be removed or minimised by adding another but opposite phase signal to it.

## Background information

Destructive interference occurs in many situations. Nodal points on any wave pattern occur because opposite phase signals meet at those points. The development of very high speed signal processing has meant that opposite phase signals can be actively created electronically, rather than just passively occurring as a result of reflection or diffraction of the original signal. The actively created signals can respond quickly to a change in the environment, whereas passive signals may no longer have the required phase.

When signals are amplified, noise that is present is amplified as well. The 'hum' from an audio amplifier that is turned on but has no signal is the 50 Hz 'noise' caused by the AC supply inducing small currents and voltages in the amplifier circuits which are then amplified.

Noise is present in all electronic circuits and much effort is made to eliminate it using various noise cancelling techniques. To examine radio noise requires specialised and expensive equipment and is impracticable in a school laboratory. However, the audio equivalent is easily observed and uses the same general principles of destructive interference.

Audio noise cancellation is not new. Noise cancelling headphones have been available for several years, and some car manufacturers are now offering noise cancelling capability in the interiors of their more up-market models. In all these cases the noise is recorded, electronics reverse the phase and re-emit the out-of-phase noise to cancel the original. The process is done so quickly that the re-emitted signal is effectively simultaneous with the original noise signal and, being completely out of phase, cancels the original signal by destructive interference.

This audio demonstration of signal removal by interference exercise is able to be done in two ways:

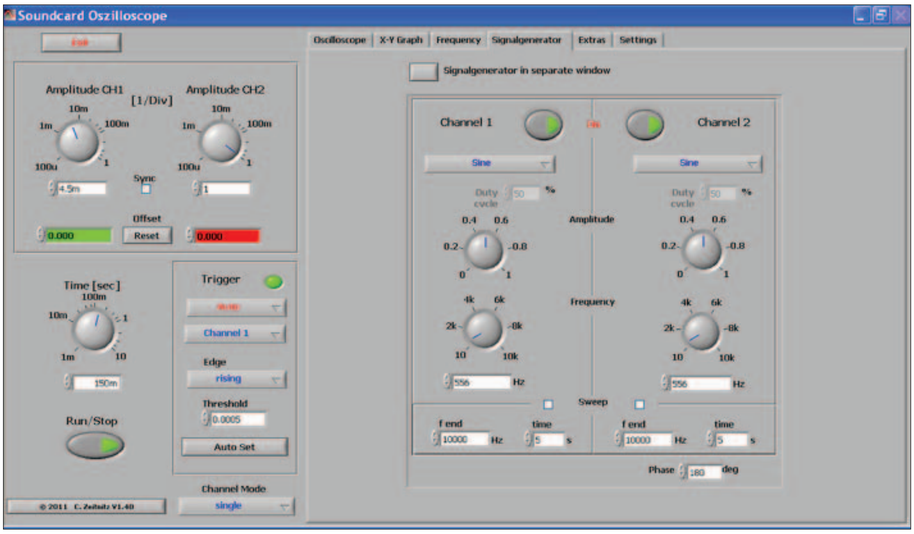
***METHOD 1:***

The first method uses the sound card of the computer and a shareware frequency generator program (Soundcard oscilloscope) to produce signals in each speaker.

The program used in testing this activity even provides a phase shift for the channel output to the second speaker. Once the program is accessible to the students, all that is needed is a computer with small separate moveable speakers that can be stacked on top of each other and are plugged into the computer's sound card output socket.

The following screen shots show how this was done. The first step is to press the signal generator tab on the screen using the cursor. This changes the screen to a signal generator window as seen below. The most difficult part of this exercise is arranging the two channels to have the same frequency and amplitude. These are controlled by clicking the cursor on the virtual knobs as shown on the display. It was difficult to make fine adjustments with these knobs but it was found that greater adjustment control was obtained by clicking on the knob to be adjusted and then dragging the cursor further away so that movements of the cursor translated to smaller adjustments of the relevant knob. At the bottom right hand side of the display is a phase control for small phase changes. The phase is adjusted by clicking the arrow or typing in the required phase. The result is quite startling if the two speakers start in phase and then the phase of the second one is reversed (phase change set to 180°).

*Below: Signal generator window:*




It is recommended that you are familiar with the relevant setting up and ensure that the computer is delivering output tones that respond to changes of frequency and amplitude before the activity is attempted.

This sound card oscilloscope shareware program (Windows only) may be downloaded from:
http://www.zeitnitz.de/Christian/scope_en

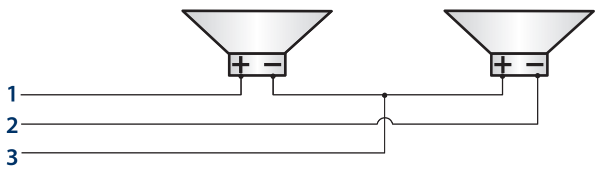
This same program is used in another activity at Level Eight. As with any shareware, it is recommended that a good virus checker be used. At the time of writing the program was free, had no virus infection, and downloading was a simple process. While there are other oscilloscope programs available for Windows, Mac and iPad, they may not output a phase shift on the second channel.

***METHOD 2:***
In the second method a signal generator and two small loudspeakers are needed.

The signal generator creates an audible tone that is sent to two small loudspeakers which are located as close together as possible. The connections to the speakers are arranged so that one speaker is working in the reverse manner to the other. This is simply achieved by connecting the second speaker's terminals the opposite way around.

Observers at some distance away will hear very quiet sound. It will not be silent, because of differences in the speakers, the fact that they are not exactly at the same spot, and that reflections from the walls will create their own effects. This does work best where the opportunities for reflection are minimised, as would happen in a carpeted room with fabric wall board and no furniture. The principle, however, is still quite well illustrated in an ordinary classroom or laboratory. The construction details for the speaker set up is given below. Very small speakers are readily available from various electronics suppliers. The ones used in this exercise were obtained from Electroflash Resourcing, who have quite a wide range of suitable small speakers.

This diagram shows how the speakers are wired:




Connections 1 and 2 are connected together. If the signal generator has two connection terminals, then 1 and 2 connect to the first, and 3 to the second.
If coaxial cable is needed (as in BNC and similar connectors) then the central wire connects to 1 and 2 and the shielding braid connects to 3.

## Equipment

***METHOD 1:***

1. A PC loaded with the required Soundcard Oscilloscope program.
2. A pair of small stackable computer speakers connected to the computer sound card.

***METHOD 2:***

1. Audio signal generator.
2. Two speakers connected out of phase with each other (as given in the diagram above). Note that there needs to be a reasonable length of connecting wire between them so the second speaker can be shifted some distance away.

## References

http://www.school-for-champions.com/science/noise_cancellation.htm

http://en.wikipedia.org/wiki/Active_noise_control

## Outcomes

Increased awareness and understanding of noise suppression by superposition of an inverted signal with the original signal.

## Extensions

1. Noise cancelling microphones; see: http://en.wikipedia.org/wiki/Noise-canceling_microphone
2. Noise cancelling headphones; see: http://en.wikipedia.org/wiki/Noise-cancelling_headphones

# Noise Cancellation Using Phase Differences

Radio interferometry uses change of phase to compensate for different distances of the signal path. Destructive interference between two similar signals that are completely out of phase is used in both electronic and audio noise cancelling.

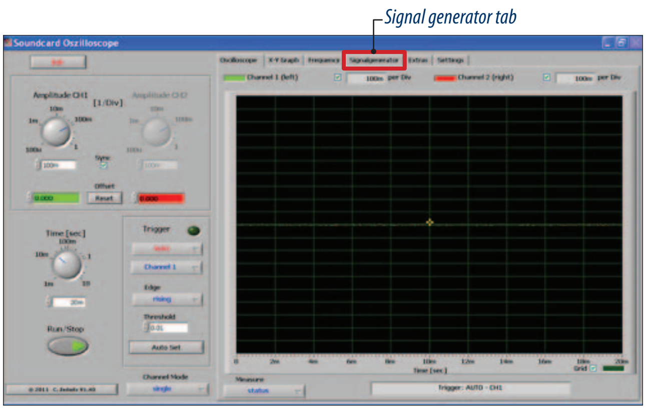
Noise cancelling headphones used by aircraft pilots have a small microphone located in the headset. This detects the general background noise of the plane while it is operating and then gives the signal the opposite phase. This opposite phase ambient noise signal is fed into the audio signal being received and cancels the ambient noise, leaving a clearer audio signal.

This investigation will look at this phenomena of destructive interference, which is exactly the same principle as that used in electronic noise suppression. There are two different methods depending on the resources available to you.

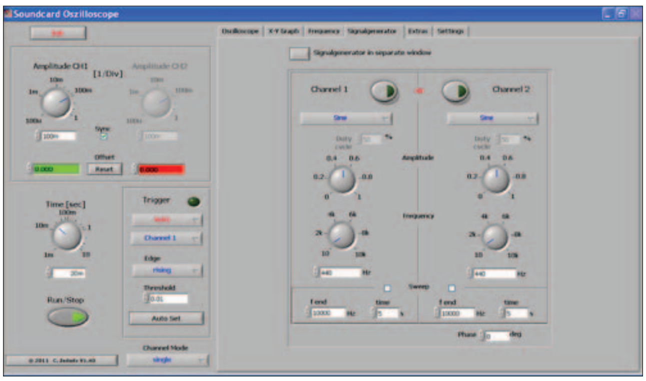
### *METHOD 1:*

***Signal suppression investigation using a computer sound card.***

1. Get the program display showing the signal generator. This is the third tab from the right at the top of the oscilloscope screen that shows up first, as shown below:




The signal generator window will then appear:

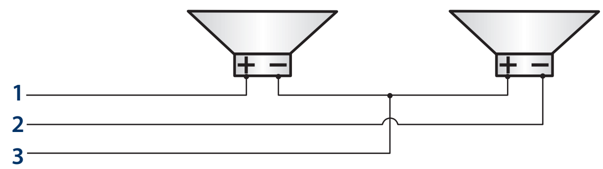



2. Set the two channels to the same frequency and amplitude. In the first instance set the frequency to 200 Hz. The adjustment of the knobs is accomplished by clicking on them and using the cursor to cause them to rotate on the screen. ***Hint:*** Once you click on the knob, drag the cursor a small distance away before you attempt the adjustment. This will make it easier to get the second channel to have the same settings as the first, as the knob adjustment is very sensitive and fiddly to accomplish otherwise.
3. Turn up the volume on the speakers. Often both channels on the speakers are adjusted simultaneously using the same knob.
4. Using the keyboard make the second channel out of phase by typing in 180 in the white window at the bottom right of the screen.
5. Note the effect on the audio volume when the second speaker is exactly out of phase. Pick up the second speaker and now move it away. Note any changes in audio volume before returning the speaker on top of the other. Enter your observations on the table below.
6. Change the frequency of the system to higher and lower values, keeping both channels the same amplitude and frequency, noting the effect each time of the signals being in phase and out of phase.
7. Answer the questions at the end of the investigation.

### *METHOD 2:*

***Signal suppression investigation using a signal generator.***

For this investigation you will be supplied with a signal generator and two small speakers, wired as shown below:




Connections 1 and 2 are connected together. If the signal generator has two connection terminals, then 1 and 2 connect to the first, and 3 to the second.
If coaxial cable is needed (as in BNC and similar connectors) then the central wire connects to 1 and 2 and the shielding braid connects to 3.

1. Set the signal generator to some audio frequency. In the first instance set this to 200 Hz.
2. By standing with your ear close to each speaker in turn, check that they are both emitting the same sound at the same volume. Fill in the relevant space in the table below.
3. Stand some distance away and note the audible volume. One of your group then separates the speakers; observe any differences in volume that occur before putting the speakers back in close proximity to each other. Record your observations on the table below.

4. Repeat the exercise at various other frequencies and complete the table.

## Results table

| Frequency | Speaker 1 | Speaker 2 | Speakers close together | Speakers far part |
|---|---|---|---|---|
| *200 Hz* | *200 Hz (loud)* | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

## Questions

1. What did you notice about the combined volume of the two speakers when close together? Explain your observation using standard physics terms and phenomena.

2. Did the combined volume change when the speakers were separated? Explain your observation.

3. Did different frequencies all have the same effect when close together and then separated (apart from the difference in pitch of the sound heard)?

4. Describe in general terms how a radio telescope interferometer could use this technique to reduce electric noise.

# Effect of Aerial Length on Radio Transmission

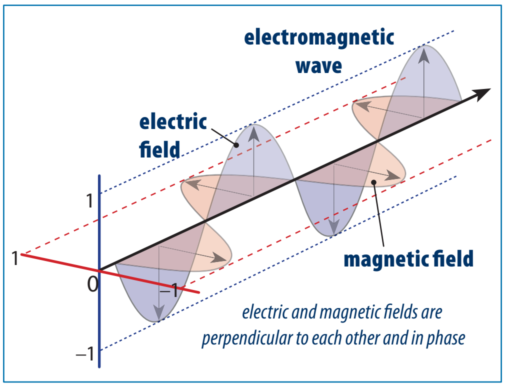
The 'big idea' in the following activities is to examine how electromagnetic signals can be transmitted and received. This requires looking at the function and design of aerials for transmitters and receivers.

## Background information

The word "aerial" includes all forms of "aerial" and "antennae". Antenna used to be a particular form of aerial, like the "rabbit's ears" on top of old TVs or long (usually monopole) wire aerials. Recent common usage has resulted in the word "antenna" being considered as a much broader term equivalent to the more correct term of "aerial".

To effectively send or receive radio signals requires an aerial. The theory of design of aerials is quite complicated and mainly beyond the scope of these activities. Some simple general statements and calculations can, however, be made.

Electromagnetic waves travel as a combination of electric and magnetic fields and can be detected or transmitted using either or both of these forms of energy. Wire aerials like monopole or dipole aerials and their variants, like Yagi aerials, use the electric field component of the signal. Small coil aerials are, in effect, inductors and use the changing magnetic component of the signal to induce small fluctuating currents in the wire loops of the coil, which can then be magnified. Large single-turn loops are in essence a folded dipole aerial and create electric field standing waves in the loop, rather than operating by detection of changing magnetic fields. Radio frequencies range from VLF (very low frequency) to EHF (extra high frequency) and higher. They all travel at the same speed (*c*). The lower the frequency (*f*) the longer the wavelength (λ), as given by the formula:




$$\lambda = c/f$$

All aerial designs take into account the wavelength of the signals to be transmitted or received. Different frequency bands lend themselves to different aerial designs. VLF and LF frequencies require aerials too long for meaningful practical exercises, but interesting investigations can be done with higher frequencies like the UHF PRS walkie-talkie band (476.425 MHz to 477.400 MHz).

Two aerial types are:

- Monopole (whip): A single wire connected to the receiver/transmitter and quarter-wavelength (¼λ) long. It is in effect half a dipole with the ground as the other half.
- Dipole: The total length between the two ends of the dipole is ½λ.

### *Monopole aerials:*

Car aerials are a form of aerial called a whip or monopole aerial. These are a single length of wire with one end connected to the radio transmitter/receiver. These aerials are typically ¼λ for best reception and transmission. At this length a standing wave is set up which results in more efficient transmission and reception. When the aerial is a lot shorter than desirable, the receiver will have a signal pre-amplifier and a capacitor to compensate for the less-than-ideal aerial length.

Monopole aerials are found in cellular phones and walkie-talkie radios, where they are built-in as part of the case. Aerials on CB radios on the 26.330 MHz to 26.770 MHz band are too long to fit in the casing of the radio and so the short aerial is compensated for with internal circuitry.

As the frequency rises the length of the aerial required for best efficiency (¼λ) becomes smaller. A pair of cheap low power PRS UHF walkie-talkie radios are very useful for these activities. They use the 476.425 MHz to 477.400 MHz band.

The model 'Uniden UH 036SX' (PRS UHF) can be bought as a cheap four-pack. These are readily available at electronics shops. This is a cost-effective way of getting walkie-talkie units that can be used for investigations and the loss is not great if there are any 'accidents' with modifying aerials, damage, etc. These use AAA batteries so it is advisable to remove the batteries when not using the units. Set the power to the lowest setting on whatever unit you use. Within a school setting the reception range could go outside the school grounds. It is a good idea to check out the reception first – see Activity One for details.

**The investigation** is to examine how the strength of the emitted signal varies with aerial length. To do this, the CB radio needs modification to replace the fixed aerial with a connector to attach variable lengths of aerial. In testing the validity of this experiment lengths varying from 26 cm to 92 cm were used to obtain the following results on a meter about a metre away. The distance from the walkie-talkie circuit board to the alligator clip is estimated to be 12.5 cm.

The results following are from trials of this activity.

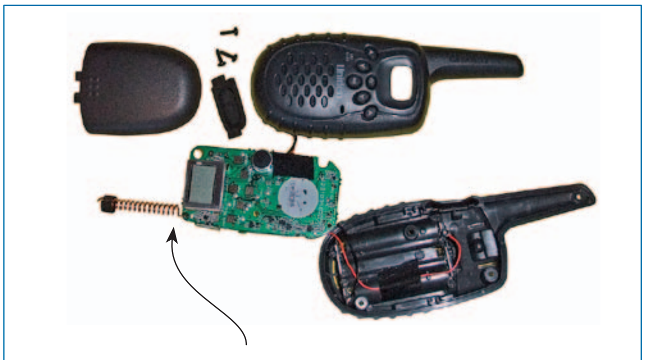
| Length w of aerial wire (cm) | Signal strength reading (mV) | Corrected aerial length $L$ $L = d + w$ | Fraction of emitted signal wave-length $L/\lambda$ |
|---|---|---|---|
| 26 | 44.5 | 38.5 | 0.63 |
| 35 | 27 | 47.5 | 0.75 |
| 53 | 38 | 65.5 | 1.03 |
| 74 | 12 | 86.5 | 1.37 |
| 92 | 87 | 104.5 | 1.65 |

These results tend to indicate that the length is underestimating the true aerial length by the order of 0.1λ or so, which would result in the first and last results being 0.75λ and 1.75λ respectively.

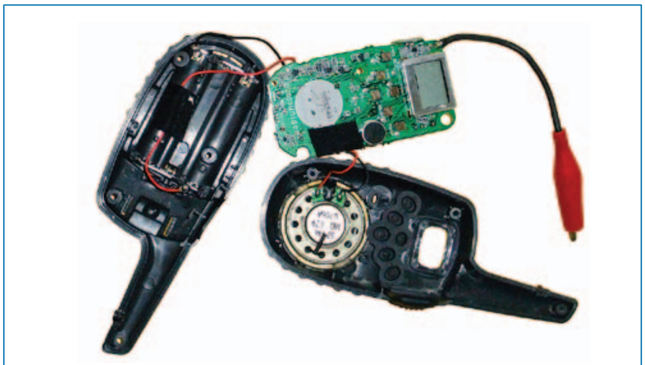
**MODIFICATION PROCEDURE FOR WALKIE-TALKIE HANDSET:**

Tools and materials: Screwdriver, wire stripper/cutter, soldering iron and solder wire; small alligator clip or similar connected to a short length of thin insulated wire, with the other end bared and tinned. Half of a commercially available crocodile clip connecting wire is ideal.

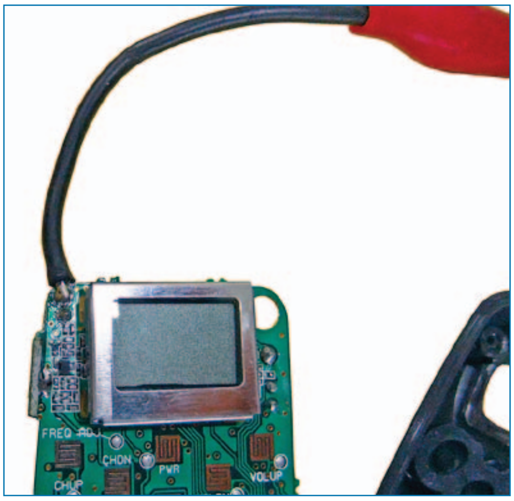
1. Open the case of one of the CB units, ensuring you note how to reassemble the case. Typically there will be 3 or 4 small screws to undo, which in some cases may be hidden behind labels.



2. Note where the aerial is connected to the circuit board and unsolder it, removing the coil and replacing with a short wire connected to a connector like a crocodile clip or similar.



3. Reassemble the unit with the aerial connector emerging from the case in the space left by the removal of the original aerial, or by making a very small hole in the side of the casing. A school technician should have no trouble doing this modification.



## Equipment

1. PRS (Personal Radio Service, UHF CB) walkie-talkies, one at least with a modified aerial having a crocodile clip on it. Check for other users first, and do **not** use channels 1–8, 22, 23, or 35.
2. Several lengths of wire, probably better if they are insulated, with lengths ranging from about the length of the original aerial to about four times that.

## References

http://www.iw5edi.com/ham-radio/?fabricating-cb-antennas,135

http://electronics.howstuffworks.com/question490.htm

## Outcomes

- Increased awareness that aerial length is an important factor in radio transmission and reception.
- Realisation that all odd multiples of ¼λ are suitable lengths for aerials.

## Extensions

Attach a directional aerial to the modified walkie-talkie handset and investigate whether the reception range is increased. It is important to remember to use the directional aerial on a receiver to avoid the possibility of exceeding legal transmission power output levels for these licence-free devices.

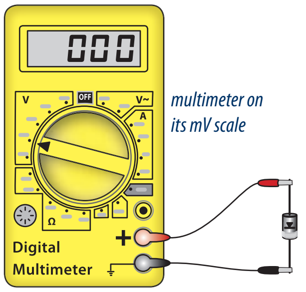
PRS walkie-talkie radios operates channels around the 477 MHz frequency range. The transmitters have short aerials which have been trimmed to give good performance and still fit into the case. This investigation is to see how the strength of the signal emitted would change if the length of the aerial changes.

# Effect of Aerial Length on Radio Transmission

Theory predicts that the biggest output signal voltages will occur if the radio aerial has a length of one-quarter of the wavelength (¼λ or 0.25 λ), or odd multiples of this (0.75 λ, 1.25 λ, 1.75 λ, etc.). You will have a low power PRS walkie-talkie radio, modified to have an aerial connection point, with several different lengths of wire for the aerial.

## Procedure

1. Connect the replacement aerial wire (ensure there is a good electrical connection to the clip!). Set the transmitter on a channel (but **not** channels 1–8, 22, 23 or 35) and first listen to find if anyone nearby is using that channel; change channels if it is in use. Clip the walkie-talkie to the longest piece of wire.
2. Test the signal strength using a diode connected to a digital multimeter set to its mV scale, as shown. The detection arrangement could be several metres away, but the orientation should be the same as the wire aerial. Hold down the transmitter button and note the reading on the multimeter millivolt (mV) scale.




3. Cut the aerial shorter, in 1 cm steps, or use already prepared shorter lengths, testing the reception each time the aerial length changes, until the aerial length gives the best reception. Measure the length of the aerial, recording your results in the table below, and then complete the analysis following.

## Results:

| Length of aerial wire, w (m) | Signal strength reading (mV) | Corrected aerial length (L) L = d + w | Fraction of emitted signal wavelength L/λ |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

1. Wavelength (λ) of PRS signal
   = *c/f*
   = 3.00 × 108/____________
   = ______________________
2. Ideal length of aerial ¼λ
   = ______________/4
   = ______________
3. Length of aerial for best reception from investigation
   = ____________________
4. Theory states that the aerial should be ¼λ or odd multiples of that value. How does your experimental value compare with the theoretical value of ¼λ and its odd multiples, allowing for uncertainties in the actual length of the aerial you have used?

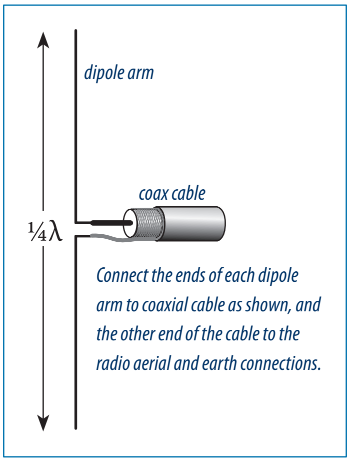
## Extension

If your connection to the radio has an easily identifiable ground connection near it on the CB unit's circuit board, you could build a dipole aerial and investigate whether using a dipole instead of a whip aerial would work better.

## *To make a dipole aerial:*

Use RG6 coaxial cable with the centre wire connected to one arm of the dipole and the other arm connected to the coaxial cable shielding sheath.

Connect the other end of the coaxial cable centre wire to the aerial connection on the CB unit's circuit board and the shielding sheath to the unit ground (or battery negative terminal). The length of the arms are each ¼λ and so will depend on the signal frequency under investigation. The gap between the arms of the dipole should be kept small.



# Aerials for Different Signals

Every household has several devices utilising aerials specific to the radio wavelengths they are to receive or transmit. These may include broadcast radio receivers, cellular and cordless phones, TV aerials (including a satellite TV dish), Wi-Fi, Bluetooth, garage door opener, car locking remotes, toys, etc. While significant in everyday life, aerial designs illustrate aspects of characteristics of electromagnetic radiation.

The type and style of aerials used depends mostly on the wavelength of the signal that is to be received or transmitted. Other factors are also considered, in particular whether the transmitter and receiver are fixed or mobile.

## *Omnidirectional aerials*

Dipole aerials are commonly seen as a part of other aerials. The ends of the dipole can be folded over to reduce the space needed for the aerial, so that the aerial now does not resemble the normally expected outline of a dipole aerial. The folding does reduce the efficiency of the aerial but less than shortening it would. VHF and UHF aerials for receiving TV signals incorporate a dipole aerial as part of more complicated aerials (like Yagi-Uda aerials described below). The lengths for monopole and dipole aerials are investigated in Activity 6 of SKA Level 7. This investigation will look at directional aerials.

Directional aerials have the advantage that they can transmit the electromagnetic energy in a directed beam, so that reception can be greatly enhanced in the target direction. Yagis work well enhancing the performance of the system for both transmission and reception. Parabolic dishes are good at collecting the signal energy over a big area (aperture) and focussing it on the receiver pick up located at the focus of the parabola.

## *Parabolic dish collectors and aerials*

Parabolic dish collectors are used in a wide variety of situations and for a great range of frequencies in the radio spectrum. These dishes are highly directional and reflect signals of any polarisation. Examples include microwave radio relay stations, satellite communication, and radio telescopes. They are limited in use only by the wavelength of the signal being received. For example, it would not be useful to try using a parabolic dish for long-wave radio with wavelengths of 300 m. The aerial pick-up may be connected to the receiver or transmitter by a coaxial cable.

Parabolic dishes work by reflecting electromagnetic radiation to the focus of the parabola. As all electromagnetic radiation reflects in the same way, the focus point is the same for visible light and all radio waves. The focal point of a shiny solid reflector can be found by using light and then a radio receiving aerial placed at that point. The disadvantage is that the focus point will get very hot if the sun is in the dish's aiming area. The solution is to not use a bright parabolic reflector, but to use a dark dull reflector, or even better, make the dish from metal mesh. Designing and building a metal mesh parabolic dish reflector is not part of this exercise, but would be a useful activity in itself. An everyday example of metal mesh allowing light to pass through but not radio waves is the mesh inside the door of a microwave oven.

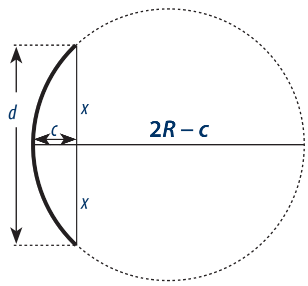
Note that a dish with a spherical surface will serve as an approximate parabola and in this exercise will provide useful improvement in transmission and reception over a simple monopole or dipole aerial. The spherical aberration inherent in such a reflector has little effect on the signal collection in this exercise as the dish shape will not be very accurate. The required measurements to find the focal length *f* of a suitable spherical dish reflector of diameter *D* and depth *c* is:

$$f = D^2/16c^2$$

It is useful to be able see where this formula comes from, especially as science at this level requires some mathematical knowledge. The relevant mathematics is obtained from the intersecting chord theorem for circles: "When two chords of a circle intersect, the product of the lengths from the ends of the chord to the intersection point is the same for both chords". In our case one chord is the line from the top to the bottom of the dish and the other chord is a diameter of the sphere for which the reflecting dish is a part of the surface. As the dish is symmetrical, any calculation we do in a two-dimensional plane would be valid in any other plane.

The focal length (*f*) of a spherical approximation to a parabolic mirror is at half the radius (*R*) of the circle as given by the formula: $2f = R$. This comes from the law of reflection at each point on the surface where incident angle = reflection angle.
For the diagram shown, $2x$ is the diameter *D* of the reflector dish and *c* is the depth to the centre of the dish as shown. The maths calculation is included.

Doing investigations using dishes is quite informative. They also reinforce the idea that radio waves behave like visible light.




**Intersecting chord theorem**

$x^2 = c(2R - c)$, now substitute $2f$ for $R$ and $D/2$ for $x$:

$D^2/4 = C(4f - c)$ expanding this gives:

$D^2/4 = 4cf - c^2$ but $c^2$ is very small for a shallow dish and can be ignored, leaving us with:

$d^2/4 = 4cf$ or $f = D^2/16c$

Parabolic dishes are best but would, in most cases, need to be specially made. Spherical dishes on the other hand are very common and found in many kitchen applications like woks or sieves. The reflecting dish need not be perfect, it just needs to be able to illustrate the principle.

The reflector should be insulated from the ground and the receiving/ transmitting aerial. For really short wavelength signals, like microwaves, a small-signal germanium diode could be used as the receiving antenna, and then fed back to a meter like a digital multimeter set on a sensitive current scale.

A cellular phone showing minimal or no reception could be placed at the centre of the parabolic dish and this will greatly improve the signal strength on the 5-bar signal strength display common on cellular phones.
WiFi USB "dongles" could be located at the focus and connected back to the computer via USB cable. Internet shareware programs like NetStumbler can be used to help optimise the set up for best reception.

Take a PRS walkie-talkie radio and use it with its aerial placed at the focus of a large (~ 20+ cm diameter) insulated reflecting dish and measure the increase in signal strength at a distance away using the diode and multimeter arrangement used before. The measurements should be taken along the principal axis of the mirror. This last is the investigation being done in this activity.

**WARNING:** Do not use the parabola and aerial set up as a transmitter unless you are sure it will not break the legal limit for transmitted power from such devices. A transmitter, set up like this with a parabolic reflector, is highly directional and will greatly increase the power output in the direction it is aimed. This could easily exceed the maximum allowable power output for such devices.

## Equipment

1. PRS (Personal Radio Service, UHF CB) walkie-talkies. These have 40 channels utilising frequencies from 476.425 MHz to 477.400 MHz ($\lambda \approx 0.63$ m.) These do not require a licence but transmission power must not be increased.
   Do **not** use these channels:
   - 1–8 (these are repeater channels and you do not need to take up repeater space, with channel 5 for emergency use only).
   - 22, 23 (these are telemetry channels only).
   - 35 (this is for emergency use only).
2. Parabolic dish of suitable size made from a wok, sieve, 'reshaped' gauze frying pan cover, or by using shaped 0.5 m square pieces of aluminium gauze (e.g. as used for insect screens).
3. Diode and digital multimeter detector (see Activity Two for the setup).

## References

http://en.wikipedia.org/wiki/Parabolic_reflector

http://mysite.du.edu/~jcalvert/math/parabola.htm

http://www.sciences.univ-nantes.fr/sites/genevieve_tulloue/conics/drawing/para_string.html
(shows the simple method of drawing a parabola with string)

http://www.youtube.com/watch?v=vYxTlQqw-PE&feature=related
(animation of a similar string method of drawing a parabola)

## Outcomes

Recognition that radio dishes work exactly the same way as curved mirrors do for light, and that the focus of the dish is a function of the curvature of the dish and is the same for all electromagnetic radiation.

## Extensions

A parabolic reflector, as commonly used for satellite TV reception, would also reflect sunlight to the focus. These dishes are about 65 cm in diameter and would gather sufficient sunlight to overheat the antenna and its circuitry at the focus of the dish. This obviously does not happen. What reasons, both in its design and its orientation, could explain this?

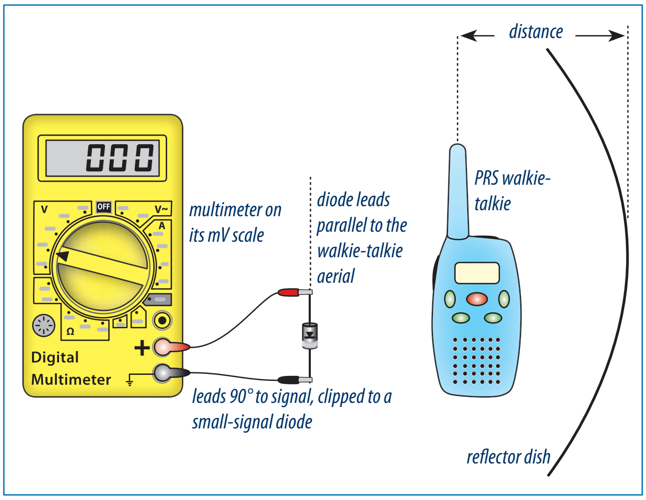
# Aerials for Different Signals

Every household has several devices utilising aerials specific to the radio wavelengths they are to receive or transmit. These may include broadcast radio receivers, cellular and cordless phones, TV aerials (including a satellite TV dish), Wi-Fi, Bluetooth, garage door opener, car-locking remotes, toys, etc.

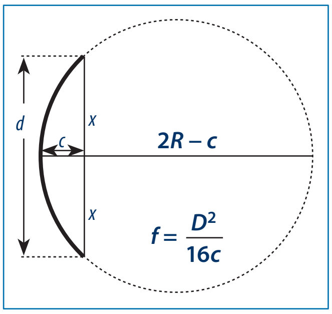
### INVESTIGATION 1

The aim is to investigate the effect on the signal strength of a PRS walkie-talkie radio using a parabolic reflector.

For this investigation you will use a PRS (Personal Radio Service) walkie-talkie radio, a multimeter and diode connected as shown below, and a dish to reflect the signals. Do **not** use PRS channels 1–8, 22, 23, or 35.




1. With your partner locate the focus (*f*) of the dish by measurement. This only needs to be approximately found, as the fine tuning will be done by moving the transmitter and noting the distance of the walkie-talkie from the dish when the maximum reading is obtained on the meter. Use this diagram to help you. It assumes the dish you are using is a spherical approximation to a parabolic dish. The location will need to be located more precisely once the calculation gives the approximate position.




2. To find the precise location of the focus take the diode and multimeter detector, the walkie-talkie radio and the dish reflector to an empty space outdoors. Turn on the radio and select a channel not being used (i.e. you can't hear anyone speaking).

3. One person will hold the detector (meter and signal diode) about 1–2 m away from the walkie-talkie. Measure the strength of the walkie-talkie radio signal at various distances from the aerial both closer and further away from the calculated focus point, moving the radio only a small distance each time. Make sure the aerial (not the body of the radio) is located in the centre of the dish. Note the results on the table below.

| Distance of aerial from centre of dish (mm) | Signal strength (mV)) |
|---|---|
| | |
| | |
| | |
| | |
| | |

4. Which reading indicates the location of the focus point? Explain.

5. Measure the signal from the walkie-talkie radio by itself without the dish and with the same distance from the radio to the detector. What was the effect of the dish?

   Signal strength (mV):

6. The radio transmits (and receives) in all directions. What would be the effect of the dish on transmission and on reception?

   *transmission:*

   *reception:*

## INVESTIGATION 2

The aim is to investigate the effect of a dish on mobile phone reception. For this you will need a mobile (cellular) phone and the reflecting dish you used above.

1. Find a place where cellular phone reception is about 2–3 bars on the signal strength display and note the name of the cell transceiver if your phone shows it.

2. Hold the cell phone at the focus of the dish (as located previously), ensuring that the cell phone will not be shielded by the hand or body of the person holding it. Get your partner to move the dish around gradually, so that the dish completes a full horizontal circle around the cell phone and observe the directions where the signal is weakest and strongest.

3. Explain why the dish increased the signal in one direction but decreased it in another direction.

4. Explain how this difference in signal strength in different directions would enable you to locate the direction of the cell tower your phone is locked into. Include the property of electromagnetic radiation that using this direction assumes.