Ground-based radio tracking: a best practice protocol

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Abstract

Radio tracking is widely used in New Zealand to investigate the biology of both native and invasive animal species. However, a lack of understanding of the technique can result in an inefficient use of time and, even worse, the incorrect interpretation of findings. This protocol provides a basic overview of how the equipment works and how it should be operated, as well as troubleshooting tips and information about equipment maintenance. This should be considered an essential guide for anyone who is about to embark on a radio tracking study for the first time, as well as a useful reference for those who are more experienced with the technique. This protocol accompanies an online training module named 'Animal Radio Tracking'.

Keywords: radio tracking, receiver, Yagi antenna, species biology, breeding biology, gain, volume, angle of acceptance, direction finding, Telonics TR4, online training module.

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1. Introduction

Radio tracking is the practice of using receivers to gain information about animals that have had radio transmitters attached to them. It allows these animals to be monitored remotely, so that they experience minimal disturbance.

In the last four decades, radio tracking has enabled biologists to gain previously unavailable insights into animal biology and to manage many animal species for conservation outcomes. In particular, it has been vital for species management studies on location, habitat use and breeding patterns. It is used throughout New Zealand, not only to track threatened wildlife such as birds and wētā, but also to study the impacts of invasive species such as goats (*Capra hircus*) and pigs (*Sus scrofa*).

The technique is not without its critics, however, and research continues to investigate the impacts of attaching radio transmitters to animals. Therefore, although improvements are continually being made to the size and service life of transmitters, they should not be fitted as a matter of course in a study; instead, each case should be evaluated with regard to the overall benefit to the species.

Purpose of this protocol

This protocol provides guidance to field workers on the correct use of radio tracking equipment. It outlines the theory behind how radio frequency is used in wildlife tracking and provides practical information about the use of radio tracking equipment. It also explains the two tracking methods that are currently in use: remote direction finding and close approach direction finding. The final sections provide troubleshooting tips and advice on equipment maintenance.

This protocol supports the Field Skills online training module 'Animal Radio Tracking' (see section 9).

Terminology

The correct name of the wildlife tracking technique described in this protocol is 'radio direction finding'. However, several names or terms are in common usage for this technique and the equipment it uses, most of which are interchangeable. In this document, the more commonly used term 'radio tracking' is generally used; and 'antenna', 'aerial' or 'Yagi' are referred to with regard to the equipment used to detect radio signals.

'Telemetry' or 'radio telemetry' are also frequently used terms. However, they are technically incorrect in this situation, as 'telemetry' actually means to receive a signal that contains some form of data or information **within** it.

Equipment

Several types of radio tracking equipment are available, each with their own sets of advantages and disadvantages. The most common receiver used for radio tracking by the New Zealand Department of Conservation (DOC) is the TR4, which is made by the American company Telonics. Therefore, this protocol uses the Telonics TR4 as the equipment standard.

2. How the equipment works

A basic understanding of how your radio tracking equipment works is important, as this will make the time you spend monitoring more effective. Without such an understanding, errors can be made and the behaviour of the study animals incorrectly interpreted, which will, in turn, result in false data records.

2.1 The signal

Electromagnetic spectrum

The electromagnetic spectrum extends from radio frequencies at the bottom end of the spectrum to X-rays and gamma rays at the top; the visible light spectrum sits roughly halfway between these. The receiver that is used in radio tracking detects electrical impulses (signals) from the transmitter that are at the lower end of the electromagnetic spectrum (i.e. at frequencies that cannot be seen).

A radio receiver, in combination with an antenna, then converts photons in the radio frequency portion of the electromagnetic spectrum into a format that we can interpret, i.e. sound waves that we can hear (as occurs with a normal car radio).

Radio waves—reflect, refract, absorb

The average radio transmitter that is fitted to wildlife produces a very low-power radio pulse (measured in milliwatts) that is at, or close to, a frequency of 160 MHz. Each pulse is approximately 0.02 seconds in duration and the pulses are repeated continuously at a rate of 40 times per minute ('40 ppm'). DOC operates under a General User Licence for its use of radio transmitters, under which 47 separate transmitter 'channels' can be used for wildlife tracking. These channels are little slices of the allocated radio frequency between 160.1 and 160.6 MHz, and are assigned the numbers 00 to 47. Since these numbers do not directly correspond to their true radio frequencies, most transmitters are supplied with their precise radio frequency and the designated channel printed on them, e.g. 160.541 MHz, channel '42'.

The electromagnetic pulse radiates out from the transmitter in every direction and the further away from the transmitter you are, the weaker the signal becomes. However, environmental conditions can also influence signal strength. In the same way that light can refract, reflect or be absorbed, radio frequency transmissions in the 160-MHz band can be affected by the surroundings, depending on the frequency being transmitted. For example, thick and/or tall vegetation, rocks or topographical features can all reflect, refract and absorb the signal from the transmitter.

Gain and volume

A radio receiver is designed to pick up the signal from the radio transmitter with maximum sensitivity. '**Gain**' describes the sensitivity of your receiver to detect signals, whereas '**volume**' is how loud the signal appears to you; both of these can be adjusted. For people new to radio tracking, there appears to be no difference between the gain and the volume—increasing each has the effect of making a weak signal sound louder. However, a weak signal on full volume is still a weak signal. If the gain can be increased, the signal will become stronger, clearer and easier to find, even at low volume.

As a general rule, it is beneficial to have higher gain whilst initially locating a transmitter. However, too much gain will make it difficult to determine which direction the signal is coming from, as it overloads the receiver's sensitive circuitry.

Note: In the 'Telonics TR4' radio receiver, the gain and volume control are combined in one knob.

Angle of acceptance

The '**angle of acceptance**' of the antenna used in radio tracking is important, as this is what enables us to direction find. The angle of acceptance can be likened to looking through a pair of binoculars—the lenses of the binoculars will narrow your total field of view (and enlarge the image), and similarly, the antenna narrows your field of 'view' by reducing the field or angle at which it accepts signals from the transmitter (to around 30° in a hand-held antenna). This restricted field of view helps you to isolate the location of your radio-tagged animal (see section 3: Fig. 1).

The operator of the equipment is key

The most important part of the equation in radio tracking is the operator of the equipment. To be a successful operator, you need to understand how the radio waves from transmitters travel and what can affect them before they are detected by the receiver, as has been described in this section. Further explanation of the effects of reflection and refraction are presented in section 4.1.

2.2 The equipment

The antenna

The hand-held antenna used in wildlife tracking is often called the 'Yagi'[1]. This **three element antenna** has three pairs of two arms, which are pivoted on each side of a central beam. These arms form the three elements of the antenna and are positioned to resonate at the radio frequency of the transmitters. Each arm is held in position by a small spring and ball bearings, which stop the arm from falling out of position under its own weight, but allow it to fold back to avoid breakage should it strike an object. For the antenna to function properly, these arms must be folded out so that they are at 90° to the central support beam of the aerial. Failure to keep the arms positioned correctly will result in a loss of signal strength, a reduced ability to accurately determine the direction of the signal and/or a reduced ability to determine whether the signal is coming from behind or in front of the antenna. If the arms of the antenna are damaged or fail to 'snap' into position, the antenna should be fixed or replaced.

Once the arms of the antenna have been unfolded into their working position, the arms in the middle form an elongated loop called the **dipole**, while the arms at either end are single straight rods, one pair of which is slightly longer than the other. This longer 'back' element is called the **reflector**, while the front element is called the **director**.

The other significant features of the antenna are the **handle** and a **cable** that is connected to the receiver. The **handle** is fastened at the point of balance on the antenna's central beam and is the most comfortable way of holding the antenna during an extended period of radio tracking. The only other way in which the antenna should be held is by the central beam. However, this should be avoided unless absolutely necessary, as the placement of a hand or arm in between the elements of the antenna may obstruct the radio frequency signal, which can reduce the effectiveness of the antenna.

The cable is vital to the operation of the antenna, as it carries the very faint electrical impulses that are generated by the antenna to the receiver. If there are any signs of damage to this cable, be it along its length, where it connects to the dipole, or damage to the **BNC (Bayonet Neill-Concelman) connector** (which plugs into the receiver), the cable should be replaced (see section 7.1). On close inspection it can be seen that the antenna cable is thicker where it lies against the central beam. This thickening is called the balun and is a secondary piece of cable that has been cut to a specific length and which acts as a 'matching' transformer across the two

[1] The 'Yagi' antenna is named after one of its inventors, Hidetsugu Yagi. It was widely used for airborne radar sets in World War II.

terminals of the dipole. This transformer balances the incoming signal with the negative or ground side of the antenna. Without the balun in the cable, the signal would be mismatched and effectively cancel itself out, severely reducing the sensitivity of the antenna.

The radio frequencies that DOC is licensed to use determine the width and length of the antenna. Although other antenna designs have been used for radio tracking, the Yagi's performance makes it the best all-round aerial, despite the drawback in size.

The receiver

The **radio receiver** is a highly sensitive instrument that converts the weak electrical current that is generated by the antenna receiving the radio frequency into an audible tone. To hear a transmitter on any given channel the receiver needs to be connected to an antenna via the **BNC socket**, which is located on the front panel of the receiver.

Major controls on the receiver

A radio receiver that is used for tracking wildlife is a small box, whose main features are the front panel and the battery compartment. The front panel will typically have power/volume controls, channel selector switches, a BNC socket and a headphones socket.

As mentioned in section 2.1—'Gain and volume', the Telonics TR4 receiver has a simplified control panel on which the **gain** and **volume** controls are combined into one knob. This knob controls the gain and volume in a non-linear relationship—essentially, when the volume is high, the gain is high; and when the volume is reduced, the gain is low. However, although this generally works well, in some situations the combination of the gain/volume control can be frustrating, particularly when trying to find small, cryptic animals that hide in dense cover, and to which you are trying to get close enough to be able to catch.

Other types of receivers have separate controls for the gain and volume. This makes these receivers more versatile, but also more complicated to use, as both controls need to be constantly checked to ensure the optimum operation of the equipment. Thus, operators who are less familiar with the equipment may have difficulty locating a weak transmitter signal because the gain control has been accidentally turned down.

3. Using radio tracking equipment in the field

Note: Additional equipment that should be carried in the field is listed in Appendix 1.

How to receive a transmitter signal

1. Connect the antenna and turn on the receiver by rotating the volume knob clockwise.
2. Set the **channel selector switches** to the channel of the transmitter you are trying to locate and then raise the antenna above your head. The antenna should be held with the three elements in a horizontal plane and the **director** element pointing forwards.
3. Check the **fine-tuning** calibration and set it to the appropriate value, which will be between +4 and −4. This value may be supplied to you with the channel, but is more often noted when the transmitter is attached to the animal and first activated, e.g. 23 −2.5, where 23 is the channel and −2.5 is the fine-tuning setting.
4. To initially detect a transmitter signal, set the volume/gain control at a mid to high level, depending on the amount of background noise and radio frequency 'clutter' being generated by the receiver (see section 4.3—'Noise and clutter'). The transmitter signal will come from the internal speaker in the receiver, or can be heard through a set of headphones plugged into the appropriate socket on the front panel.

   Note: If using headphones, take care that the volume is not set too high or this may cause hearing damage (see section 4.3—'Enhancing your ability to hear the transmitter signal').
5. Most transmitters are set to pulse 40 times per minute (often notated as 40 ppm). Therefore, to ensure that you detect a weak signal, rotate the antenna through a complete 360° rotation taking around 60–90 seconds to do so—at this speed, you should detect at least one or two pulses from the transmitter before the **angle of acceptance** of the antenna passes by[2]. Note: On a slow rotation, it is easiest to rotate yourself with the antenna rather than trying to rotate the antenna in your hand.
6. The signal you are listening for is a series of short 'beeps', which is unmistakeable when correctly tuned. If you detect a beep or series of beeps, point the antenna towards their source and reduce the volume/gain to a point where you can **just** hear the signal. You will find that the signal volume will change with only subtle movements of the antenna—this is due to the inherent properties of the antenna and the higher gain that is associated with the central portion of the **angle of acceptance**. Therefore, to address this and to get certainty as to the direction of the target animal, follow the 'finding the null' procedure (see below), and then carry out the most appropriate direction finding method (see sections 4.1 and 4.2).
7. If you do not detect a signal on the first 360° rotation, check that the channel, fine-tuning and volume/gain are set correctly and conduct a second rotation. If you still do not detect a signal, select the next frequency to find or move to your next listening location and repeat the process.

[2] In practice, the Yagi has an angle of acceptance of around 30° either side of a line down the central beam.

Finding the null

Finding the null is a process by which you find the points on either side of the signal where the signal can no longer be heard. This seems slightly odd as, having just found a signal, you are then asked to deliberately lose it again. However, by bisecting the angle that the two nulls create, you will be pointing in the direction of the signal. This is more accurate than trying to detect the direction of the signal by pointing the antenna towards it. To find the null, follow these steps:

- To find the null on the left-hand side, hold the antenna out in front of you in your right hand at eye level. Point the antenna towards the strongest signal and stand with your body square on to the direction in which you are pointing, with your shoulders over your hips.
- Extend your left arm out in front and with both arms parallel to the ground slowly move your right arm in an arc towards your left arm. Keep going until the point where the 'beep' can no longer be heard. This is the **left null**.
- Mark this point by holding your left arm out in this position.
- Making sure that you do not move your left arm or your body, slowly move the antenna to the right, making an arc to the point where the beep becomes inaudible. This is the **right null**.
- In one fluid movement, bring your arms together so that both hands meet in the middle. You have now bisected the two nulls and the direction in which your hands are pointing is the direction of the signal.
- Read the bearing off the compass attached to the antenna (if fitted), or sight down your arms to a distant visual reference point and then use this when marking the bearing.

Figure 1 illustrates this process.

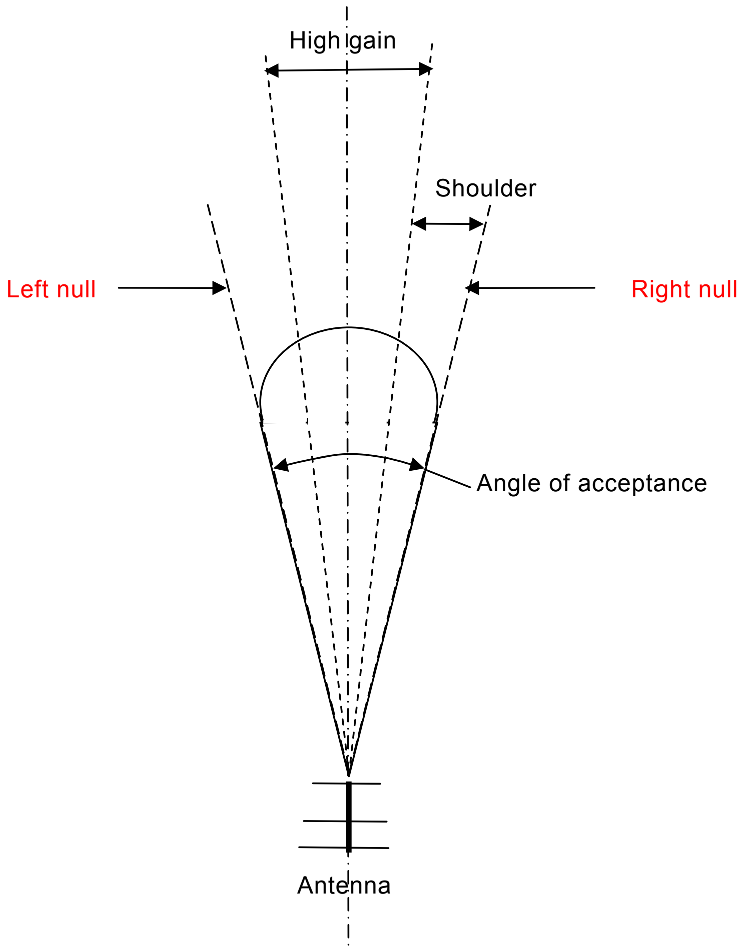

Figure 1. Illustration of the null and the 'angle of acceptance'.

4. Radio direction finding methods

Two radio tracking methods can be used to find a radio-tagged animal, the choice of which will depend on the monitoring objective:

- Remote direction finding method—This is used to find the approximate location of the animal.
- Close approach direction finding method—This allows the user to get very close to the animal and find a nest or the animal itself. It is especially successful with flightless or ground-dwelling animals.

This section describes these two tracking methods (sections 4.1 and 4.2), and then provides additional important information about both methods (sections 4.3 and 4.4).

4.1 Remote direction finding

Remote direction finding is used to determine the location of the radio transmitter at a distance to give the approximate location of the animal. This method is used to track mobile/flying or non-breeding birds, or animals such as pigs and goats. The target animal is found via a process called 'triangulation', which is carried out from a few different set locations[3]. Triangulation is a surveyor's technique that uses bearings and distances to form triangles.

Remote direction finding is carried out as follows:

1. Collect a series of compass bearings to the direction of the signal (using 'finding the null'; see above) at two or more known locations or 'listening' points.
2. Draw a line on a map (or Geographic Information System (GIS)) from where you are standing (at a known GPS point) to where the strongest signal is coming from (see Fig. 2).
3. Repeat step 2 at two or more points that are several hundred metres apart. This will provide a **point of intercept**.
4. This point of intercept will be near to the location of the animal. Generally, the more lines of intercept you have collected, the more triangles you can draw and the more accurate the location will be.
5. Ideally, each line of intercept should be at an angle of around 60–90° different from the last. Three to five bearings will provide a reasonable degree of confidence.

To further explain how the triangulation process works, see Table 1 (an example of a field notebook entry) and Fig. 2 (a map of the results).

From Fig. 2 it can be seen that the transmitter is located within the triangle that has been created by the compass bearings. However, it should also be noted that the bearing taken from location Rx 4 was well wide of the triangle created from listening at the other locations. This happens from time to time, due to reflection, refraction or absorption (see section 2.1—'Radio waves—reflect, refract, absorb')—and in this particular example can be explained by the main signal being shielded from Rx 4 by the rock outcrops below Rx 3, which have absorbed and/or scattered the signal, and reflected part of the signal back up to Rx 4.

As Table 1 shows, more than one transmitter may be tracked in the field during a single project. For example, five transmitters may be heard from three locations visited, all five of which will need to be checked from each location before moving on.

[3] Most radio tracking projects set up 'listening' points, which are used consistently over the course of the study. These points should be numbered and marked with a suitable tag, and the NZ Topo50/NZMS260 grid coordinates should then be accurately determined using a differential Global Positioning System (GPS).

Table 1. Example of a field notebook entry when carrying out remote direction finding. Note: The pale type indicates the project's daily recordings.

DATE: 17 September 2010		WEATHER: (wind, cloud, rain, temp) calm, 6/8, clear, mild			
TR4 channel	Bands	Time (h)	Listening point	Bearing (°)	Observer
31 (+1)	RYW/L33432	0945	Rx point 1	270	JR
31 (+1)	RYW/L33432	1030	Rx point 2	120	JR
31 (+1)	RYW/L33432	1045	Rx point 3	210	JR
31 (+1)	RYW/L33432	1120	Rx point 4	80	JR
33 (–2)	S81792/BGY	0945	Rx point 1	275	JR
33 (–2)	S81792/BGY	1030	Rx point 2	197	JR
33 (–2)	S81792/BGY	1045	Rx point 3	140	JR
33 (–2)	S81792/BGY	1120	Rx point 4	138	JR

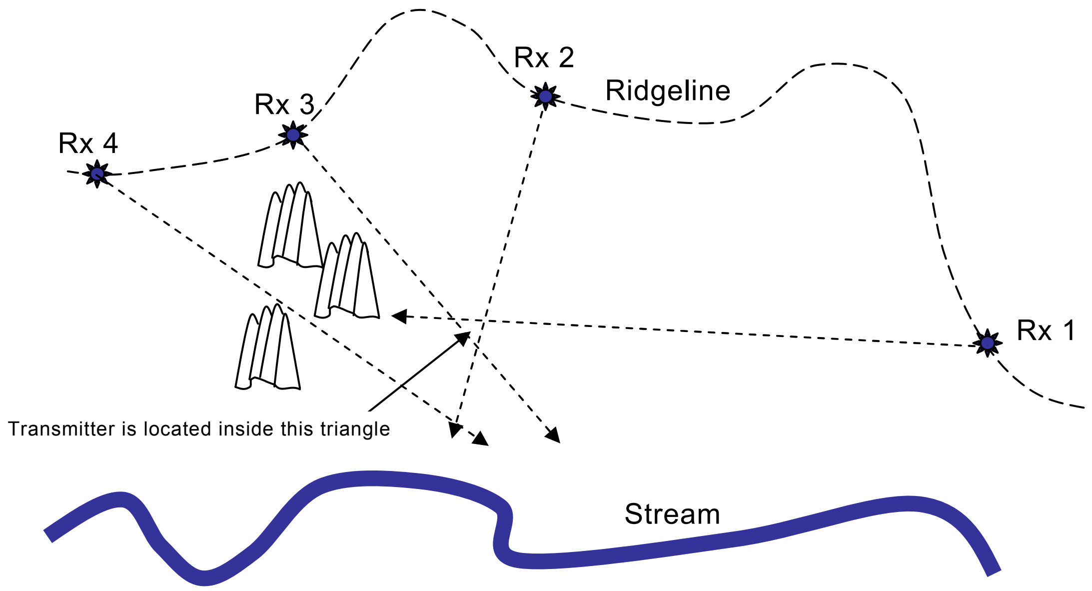

Figure 2. Diagram of the triangulation process—locating the target from a series of compass bearings.

4.2 Close approach direction finding

Close approach direction finding involves getting very close to the transmitter so that some procedure can be carried out on the animal that is wearing it, e.g. to find a nest or perhaps a body, or to retrieve the transmitter itself.

The initial part of the close approach direction finding method is very similar to that used for remote direction finding as, in the first instance, it is likely that you will need to employ some informal triangulation to efficiently locate the transmitter. However, it is generally not necessary to record and map the bearings as described in section 4.1, as ultimately the location of the transmitter will be recorded with a handheld GPS device once you have found it. There are some instances where triangulation as per the remote direction finding method should be carried out, however; for example, where there is the potential to disturb or injure the target animal, e.g. a ground-nesting species that has a cryptic nest in dense cover.

Close approach direction finding is carried out as follows:

1. Walk in the general direction of the strongest signal. Note: You need to be aware of the surrounding topography, and the location of tracks and informal routes so that you can move around quickly and assess where the signal is coming from, narrowing down the search area.
2. If the signal is weak (i.e. the volume/gain knob needs to be set high to hear the signal), the transmitter may be on a ridge a kilometre away on the other side of a deep river valley, or could be just 50 m in front of you but under an overhanging bank. Therefore, it is helpful to take an **offset bearing**. To do this, take a bearing to the strongest signal, and then shift your position 20 or 30 m to the left or right of where the signal is coming from and take a second bearing to the strongest signal. If the difference between the two bearings is greater than 20°, the transmitter is close by. By contrast, if the bearing hardly changes, the transmitter is far away. This technique should be repeated regularly as you close in on the signal.
3. As you get closer to the transmitter, the signal strength will ultimately increase and the beeps will become louder. To retain the ability to direction find, turn down the volume/gain knob so that the beeps can just be heard and retune the receiver using the fine-tuning knob to get the clearest toned beep. Eventually, the angle to the transmitter will change dramatically when checking the offset bearing, indicating that you are less than 100 m away from the animal.

What you do next will depend on the terrain and the amount and type of cover that is available for the target animal to hide in. It is best to plan the most effective way to use the terrain and ground cover to ensure that you will be able to catch the animal. However, you should also assess the risk to the animal with regard to disturbance or injury, and whether the animal has eggs or young.

The spiral—circling the transmitter

To ensure that you do not injure or disturb the animal before you find it, it is vital that you reduce the search area to approximately 1–2 m^2. This can be achieved by 'spiralling in' on the signal rather than walking directly towards it:

1. When you think you are around 50–100 m away from the transmitter, stop and do a complete rotation of the antenna with the volume/gain turned to the highest setting.
2. If you detect beeps constantly during a full rotation of the antenna, the signal is very strong and you are likely to be within 50 m of the transmitter. Check this position first by turning down the volume and gain to normal levels, and then by walking 20 m at right angles to this bearing and taking an offset bearing. If the bearing has changed by 20° or more, you are within 50 m of the target. If not, continue further along the same course and try again.
3. When the bearing changes by the required amount, set a course at approximately 45° to the strongest signal and walk in this direction whilst continuing to check the signal. When the signal is at right angles to the direction in which you are travelling (i.e. drops off your shoulder), make another 45° turn.
4. Continue to follow this procedure, trying to identify the most likely position of the transmitter at every turn and reducing the volume/gain on the receiver constantly so that the signal is just audible, maximising your ability to determine the direction of the transmitter. By doing this, you are slowly circling the transmitter, refining the search area and getting closer to it all the time, but never approaching the transmitter/bird directly (see Fig. 3).
5. It is also helpful to use the null technique (see section 3). This is best achieved by continually checking for the null on the right-hand side when undertaking a left-hand spiral. Not only does this reinforce where the strongest signal is, but it also ensures that

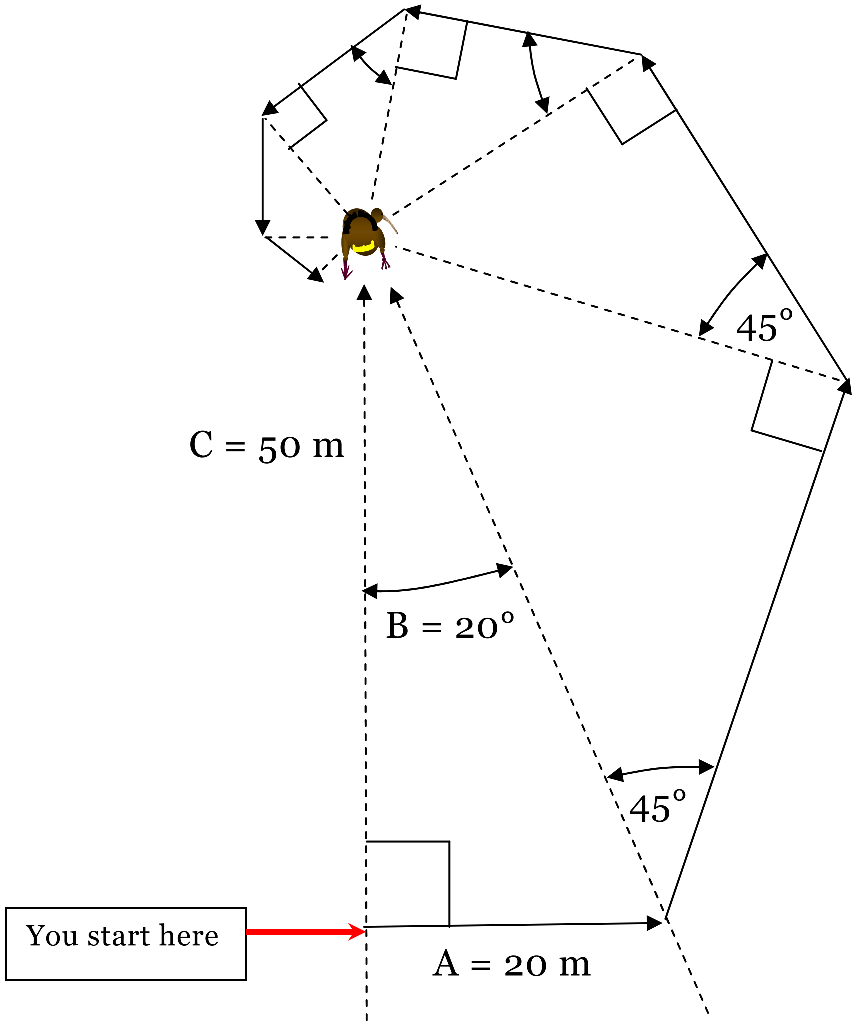

Figure 3. Diagram of 'the spiral'.

you are checking directly ahead of you, just in case you have wandered off course or misjudged the direction of the signal due to refraction or reflection of the signal, or the transmitter has moved.

6. Once you are confident that the transmitter is in the area of vegetation right beside you, look for field sign to find the commonly used paths of the animal, which will be the most likely route it will use if it tries to escape. Get down on your hands and knees and see if you can get a glimpse of feathers, feet, etc. to pinpoint the bird. It pays to carry a small torch for this purpose, as it can be very difficult to see cryptic species in thick cover.
7. If you cannot see anything, or the area of cover includes a hollow log or series of burrows, you will need to obtain the exact position of the animal by slowly bisecting 1–2 m^2 of the cover using the antenna. Slowly move the antenna in a straight line along 1–2 m of the cover and try changing the direction of the antenna by turning it 90°. The animal will be located in the area with the strongest signal.

   Note: Listening through headphones or with an attenuator will allow you to turn the volume/gain down to the absolute minimum as you perform this process, enabling you to detect very subtle changes in signal strength. This will also increase the chances of you capturing any wary, sensitive animals that have been captured several times previously and recognise the sound of the TR4 'beep'.

4.3 Additional notes on use of equipment

Front to back (FB) ratio of the antenna

The antenna is roughly symmetrical in shape, with the reflector and director only marginally different in their relationship to the dipole and in their length. This configuration means that radio signals can be collected not only from in front of the antenna, but also from behind (albeit at a reduced level). In most situations, the front to back (FB) ratio is clearly discernible, with a much weaker signal being detected when the antenna is turned 180° so that the rear element points towards the signal. However, when a weak signal is detected in the first instance—for example, if the transmitter is shielded by an overhanging bank—it is easy to 'walk over' the transmitter when moving between listening positions and to continue along the same bearing, receiving the signal through the rear of the antenna. This could mean that you move forward, expecting the signal to be ahead of you, when the transmitter was actually at the base of a bank only 50 m away from where you started. Therefore, it is important not only to check the back signal regularly by flipping the antenna around 180° to see whether the signal is stronger, but also to move off to the side from time to time to see whether the bearing to the transmitter changes significantly, indicating that it is closer than you think.

Enhancing your ability to hear the transmitter signal

Receiving radio signals is a balance between the functioning of the equipment and what the operator can hear. Ideally, when you are close to a transmitter, the volume/gain will be reduced so that the antenna is performing optimally in relation to its direction finding ability with the angle of acceptance and not swamping the receiver with an overly strong signal. However, the volume still needs to be loud enough for the operator to hear the signal. This can be an issue if the operator has some hearing loss, or if environmental conditions such as high wind, fast-flowing water or motor noise create a lot of background noise.

If these conditions are likely to be experienced, it is useful to either use a set of headphones or to fit an **in-line attenuator** between the receiver and the antenna, which reduces the power of the signal without distorting it. An attenuator is about 3–4 cm long and about 15 mm in diameter, and comes fitted with corresponding BNC connectors. Attenuators come in a range of different values that are measured in decibels (dB). You should experiment with different value attenuators for your application, but you may like to start with a 3-dB attenuator with 50-ohm impedance.

Extreme weather conditions

Do not use radio tracking equipment in an electrical storm, as there will be severe risk of injury or death from electrocution by lightning strike.

Looking for very weak signals

When looking for very weak signals, changing the **polarity** of the antenna by tipping it 90° on its side to a vertical position may increase the strength of the signal only by chance. However, this may also hinder your search, because signals radiate out from the transmitter mostly in one plane, so the received signal will be weaker when the antenna is tipped at right angles to this plane of transmission. Therefore, since we do not know which way the transmitter is orientated in relation to the antenna, the signal will fluctuate, making interpretation difficult. However, once the area has been narrowed down, the antenna can be rotated through 90° along its axis so that it receives a weaker signal, making hearing easier.

Signals from mobile animals

The signal you hear can also change in strength if your target animal is active while you are tracking it. The signal will fluctuate between loud and quiet (with no change in the volume/gain control) as the animal moves its body in relation to your antenna.

Noise and clutter

Noise and clutter are radio waves that are on the same frequency as the channel you have selected, but which are not part of the signal you are searching for. These radio waves often take the form of hiss, static, buzzing or hums, but in some instances can also be other 'beeps' and data streams from transmitters using the same frequency. The latter may include things such as tidal buoys used by NIWA and port authorities, or transmitters that are attached to other species that have turned up in your search area, including Judas goats, pig dogs or dispersing birds.

The majority of strong, continuous noise is generated from radio repeaters and centres of human habitation. However, this can also occur during electrical storms and solar sun spot activity. All of these additional noises are amplified by the antenna and the receiver, and make hearing the selected transmission difficult at times. However, most of these signals will be emanating from a particular direction, which means that you can position yourself and the direction in which the antenna points to keep the majority of this interference at right angles to you or behind you.

In some locations, certain transmitter channels should be avoided due to the amount of clutter at that location. Most existing research programmes will have these channels noted. However, when establishing a new project, it is worthwhile checking for noise and clutter from several high points in your study area across the channels you will be using—you will soon determine which channels should be avoided.

Note: If you regularly carry out radio tracking in noisy environments, or from vehicles or aircraft, the TR4 does not perform as well as equipment with greater control over gain and volume, and equipment that is electrically shielded from the high-energy radio frequency emissions that come from aircraft and vehicles. Therefore, seek advice on the most appropriate equipment to use.

Transporting the radio tracking equipment

When moving any distance, and particularly when moving 'off track', most operators disconnect the antenna from the receiver and fold in the **elements**. The antenna is then carried in one hand and the receiver is placed in the carry pouch and slung around the neck, fastened around the waist, or worn with the strap across the neck and one shoulder (satchel style). This leaves one hand free for moving vegetation aside and supporting yourself on steep or difficult terrain, and also helps to reduce the risk of damage to the equipment. Note: Subtle damage to the equipment such as a 'stretched' antenna cable can cause the delayed failure of an internal wire; therefore, it is advisable for spare cables to be carried.

With practice, the antenna can be disconnected from and reconnected to the receiver using only one hand. Therefore, most operators will do this over the first or last few steps as they depart or approach a 'listening' point.

4.4 Bad habits

Field practitioners have developed numerous techniques as 'workarounds' to problems they encounter, which have been passed on as 'lore' to successive generations of radio trackers. However, many of these problems are due to a poor understanding of the equipment and its operation, with most, if not all, being associated with the operator's ability/inability to accurately discern where the strongest radio signal is coming from when close to the radio transmitter.

Therefore, in most cases, these 'workarounds' are unnecessary if best practice is employed. While most of these bad habits are harmless, there are instances where they can be detrimental, particularly when locating nesting birds where, if signals are misinterpreted, there is potential for harm.

Poor technique falls into three broad classifications:

1. Antenna configuration

Changing the antenna configuration by collapsing some or all of the elements (arms) reduces the amount of signal that it collects. Whilst this may be helpful if the receiver is overloaded with a strong signal, with a three element Yagi there is little scope to do this without compromising its effectiveness in discerning the direction of the signal.

Some operators try to take advantage of the fact that the receiver emits beeps with the antenna disconnected when in very close range of the target. They use the varying signal strength when moving the receiver around the suspected location of the transmitter to locate it. However, while this is effective in attenuating signal strength, it eliminates the ability to direction find; and, furthermore, the strongest signal actually may not be created by holding the receiver over the transmitter.

Therefore, the best and safest technique for locating the radio-tagged animal is to use the Yagi antenna with all of its elements fully extended and with a set of headphones, so that the gain/volume control can be reduced to a level where the direction to the transmitter can be discerned accurately.

2. Holding the antenna

Some operators change the polarity of the antenna by holding it in a vertical position, to detect weak signals. However, this should only be carried out in certain circumstances and is generally not best practice (see section 4.3—'Looking for very weak signals').

3. Receiver configuration

Some operators 'detune' the receiver to attenuate the gain on the incoming signal. Secondary weaker signals are generated above and below the main carrier signal by the transmitter (see Fig. 4), and this technique tunes the receiver to one of those side bands. However, tuning to one or other of these side bands dramatically reduces the strength (gain) of the signal, so that the pulse is only heard as a click rather than a clear tone, meaning that another nearby transmitter could cause confusion.

While this is not best practice and is generally unnecessary, it does retain the complete function of the antenna, including the ability to discern direction. Thus, it has more merit than changing the antenna configuration, and can be a good 'workaround' when the use of headphones is impractical or you are in a high-noise environment.

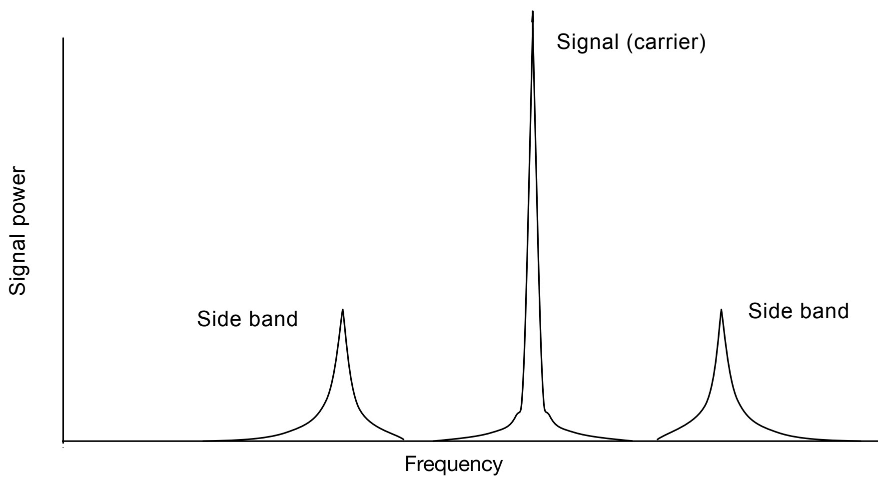

Figure 4. Radio transmitter signal output.

5. Troubleshooting

Table 2 outlines some troubleshooting tips, and can be printed and laminated to become part of your daily field kit.

Table 2. Troubleshooting tips.

PROBLEM	CAUSE	SOLUTION
Beep coming from all directions	Gain/volume too high	Turn gain/volume down
	Antenna elements folded	Set antenna elements correctly
Cannot hear beep	Channel or fine tuning incorrect	Set correct channel and fine tuning
	Transmitter out of range	Move yourself closer or higher
	Gain/volume too low	Turn gain/volume up to maximum
	Battery low or flat	Check battery light / replace battery
	Antenna not connected or cable broken	Replace cable
	Channel switches faulty	Use test transmitter to confirm—Unplug the antenna and tune the receiver to the test transmitter channel. If the transmitter is held next to the BNC socket, a clear tone should be heard. If not, send for service.
	Headphone socket faulty	Use headphones / clean socket by plugging and unplugging headphones repeatedly
	Loud ambient noise	Use headphones
	Duty cycle of transmitter in 'off' mode	Check records to determine when the transmitter will be 'on' / sending signals
Beep tone is 'off key'	Fine tuning incorrect	Adjust fine-tuning knob until the correct tone is achieved
	Faulty transmitter	Replace as soon as possible

6. Care of radio tracking equipment in the field

Avoid moisture/water

It is important that the receiver and exposed plugs and connectors are kept as dry as possible. Use a plastic bag to shield the receiver from the rain and keep it under your raincoat as much as possible. Note: One source of moisture that is generally overlooked in warm environments is sweat dripping off the operator and onto the front panel of the receiver; as sweat contains salts, this is particularly damaging to the receiver as it enters into the switches and connectors.

The most common fault with the TR4 is the ingress of moisture into the channel selecting switches and the headphone socket. This effectively makes the unit useless until it dries out and, even then, the fault will generally reoccur with increasing frequency as corrosion of the delicate contacts in these components increases. This results in the channel selector switches failing to change channel on one or both of the selector switches, **despite appearing to operate normally**. This is sometimes hard to detect in the field and is only realised when transmitters that could previously be found easily cannot be found. The only solution is to send the receiver in for repair and have the channel switches replaced.

Similarly, the internal switch on the headphone plug becomes corroded, switching out the speaker even when headphones are not plugged in. This may be resolved in the field by plugging and unplugging the headphone jack several times in quick succession, dislodging the built up corrosion. This will only be a temporary fix, however, and the receiver should be sent away to have the socket replaced. Generally, the receiver will continue to function through headphones if the loud speaker fails to function.

On return to base, it is best practice to remove the receiver and antenna from their carry bags, dry them off and place them in a warm, dry place. If the equipment has got very wet, the back cover of the receiver can be unscrewed, allowing air to circulate more effectively.

In particularly wet environments, the TR4 can be modified to increase its ability to cope with moisture. This modification involves replacing the front panel of the TR4 and changing the channel selector switches to rotary dials, like that of the volume/gain knob; the 12-V socket is also removed. This can be done by the supplier of your receiver. Alternatively, waterproof housing can be purchased for the TR4, although some feel that this is an impractical solution as it makes the equipment hard to use.

Avoid physical trauma to equipment

To avoid physical trauma to the equipment, keep the receiver in its padded carry pouch and keep this half-zipped up, to prevent the equipment from slipping out and hitting the ground when you bend forward. Disconnect and fold up the antenna when moving through thick vegetation or difficult terrain.

Physical trauma generally affects the antenna, the connecting cable and plug. Issues with the antenna can include bent or snapped elements and broken connecting cables. Bent elements can be straightened by hand in the field, but ultimately the aluminium will become brittle and snap. If an element snaps, it can be temporarily taped in place with electrical or duct tape using a stick as a splint. Try to maintain an electrical contact between the broken pieces by scraping the paint away and taping tin foil in place to make a connection across the break.

A broken connecting cable needs to be replaced. This can be done in the field with the aid of a multi-tool and some tape. Therefore, it is strongly recommended that a spare cable/balun complete with BNC plug is carried.

The BNC socket on the TR4 receiver can work itself loose and turn in the front panel. This generally results in the connecting wires inside the receiver snapping off the socket, which generally leads to an intermittent signal that comes and goes when the socket is wiggled. The receiver needs to be sent for service to repair this fault.

The best way of testing whether the antenna and receiver are functioning properly is by carrying a test transmitter with you. This simple, lightweight addition to your daily field kit will save many hours of wasted time, frustration and worry by simply turning it on and checking if you receive a normal signal.

7. DIY maintenance

7.1 Replacing the balun/antenna cable on a Yagi antenna

If a known signal, i.e. a test transmitter, cannot be detected when the antenna is connected to an appropriately tuned receiver, carry out the following procedure:

1. Undo the two machine screws that attach the cable to the antenna at the dipole. Note: Take care to retain any washers and nuts along with the screws to ensure that you can complete the reassembly process—if you are replacing the cable in the field, it is best to undertake your repair on your raincoat laid out on the ground so that you will not lose anything.
2. Using a knife or pair of side cutters, snip the electrical ties or tape that attaches the balun/cable to the central beam of the antenna.
3. Remove the old balun/cable and install the replacement by first reattaching the two terminals to the dipole using the screws, washers and nuts that held the faulty item in place. It does not matter which terminal is connected to which arm of the dipole as long as the cable lies flat against the central beam of the antenna. Check to see whether the cable is running to the back of the antenna from the dipole—this is easy to determine, as the rear element is slightly closer to the dipole and slightly longer than the front element. With the terminals secured tightly and the cable positioned down the central beam, attach the cable to the antenna using electrical ties or tape—if you do not have these, string or rubber bands will do as an interim fix. Do not use wire, i.e. twisty ties or similar, as this may affect the performance of the antenna.
4. Reconnect the antenna to the receiver via the BNC plug and test its operation with your test transmitter. If the receiver still does not detect a signal, check the connections at the dipole and reassure yourself that the cable assembly you have fitted is new or has been repaired and tested appropriately. If you are convinced that all is well with the cable and connections, the fault will lie with the receiver (see Table 2).

7.2 DIY Servicing

It is possible to service some faults with a minimal range of service equipment and a steady hand—you can even make your own replacement balun/cables by measuring the length of the cable used in the balun and soldering up the required connections and plug.

If you have an interest in electronics and have assembled any of the basic Dick Smith electronic kitsets using a soldering iron and a multimeter, it is well within your skills to swap out channel selectors, switches, headphone sockets and BNC sockets on the receiver, as well as to test antenna cables and baluns for continuity, repair broken cables and resolder the BNC connectors. This not only saves considerable time, but also significant money for your project, as the receiver will not need to be sent away to be serviced.

All of the components that are required to undertake this level of servicing are available through online electronic component providers, such as Radiospares (www.radiospares.co.nz) or Element14 (nz.element14.com). Furthermore, all of these components are ancillary to the main circuit board, so that even a botched fix-up job will not be catastrophic and will cost no more to rectify than it would have cost to send the equipment away for repair in the first instance. To fix most of the above issues is a five-minute job (with three of those waiting for the gas soldering iron to heat up!) and can easily be achieved in a backcountry hut.

8. Acknowledgements

The authors are grateful for the comments received on drafts of this protocol by Graeme Elliott, Pete Graham, Suzy Randall and Siobain Browning.

9. Related resources

This protocol accompanies an online training module 'Animal Radio Tracking', which is available in DOCLearn. DOC staff can log into www.doclearn.net.nz and search the catalogue for this module. Members of the public have access to the module via the DOC website at www.doc.nz/training

The following report provides useful background information about radio tracking:

Seddon, P.J.; Maloney, R.F. 2004: Tracking wildlife radio-tag signals by light fixed-wing aircraft. *Department of Conservation Technical Series 30*. Department of Conservation, Wellington. 23 p.

The Science and Capability Group also has several documents in preparation, regarding radio tracking projects, data-logging projects and attaching radio transmitters to birds.

Appendix 1

Field kit list

The following items should be carried when spending a day in the field carrying out radio tracking (in addition to required health and safety equipment):

- Up-to-date list of transmitters (channel, fine tuning and identifier/animal name)
- Compass
- GPS device
- Map
- Test transmitter, with magnet to turn it on/off
- Spare battery for receiver
- Pencil
- Headphones for TR4

For possible repair to equipment (see sections 6 and 7):

- Spare antenna cable assembly
- Multi-tool
- Strong adhesive tape
- Small amount of tin foil
- Multimeter
- Small torch