Saving Endangered Species: the Application of Computer-based Radio Coverage Modelling to Wildlife Telemetry Systems

David Wilson
Massey University

Follow this and additional works at: http://aisel.aisnet.org/acis2005

Recommended Citation
http://aisel.aisnet.org/acis2005/78
Abstract
The research described in this paper is aimed at improving wildlife telemetry systems by means of improving radio frequency (RF) visualization and planning, and improving RF coverage by adoption of improved techniques and tactics. The use of a computer-based modelling application has proved to be of benefit in the area of visualisation and planning. Use of this tool and other work in this area has led to the identification of opportunities to improve field practice, e.g. staff training in RF techniques and tactics, selection of optimum receiver sites, improved receive antenna systems, and improved planning for airborne monitoring and tracking.

Keywords
Information systems, information systems applications, wildlife telemetry

INTRODUCTION
Kiwi – a New Zealand national icon – is one of several endangered species subject to national conservation and recovery programmes. This paper describes research conducted for the kiwi recovery program of the NZ Department of Conservation (DOC) (for details see Bank of NZ, 2005). During 2004, the author spent some time working as a volunteer with DOC staff at the Moehau kiwi sanctuary, mainly assisting in the location of kiwi to enable the annual change of telemetry transmitter, undertaken because of limited battery life. This process is normally undertaken in the May-early June period each year.

While engaged in this work, two issues became apparent. Firstly, the terrain of the Moehau area is very rugged: the northern part of the Coromandel Peninsula is only about 10 km wide, and the main mountain range rises to a height of nearly 1000m. Most of the area is clad with dense primary bush or secondary-growth scrub. The terrain means that vehicle movement is mainly restricted to one road around the coast, foot movement is difficult and radio coverage, which is in the very high frequency (VHF) band (30-300 Mhz) and limited to radio line-of-sight, is also problematical.

Secondly, the majority of work involving monitoring and tracking of birds utilizing telemetry involves long periods of time in the field for relatively few detections. (For example, in one day that the author was out with a DOC team, only one bird was located, and that was found by a trained kiwi dog, rather than using the telemetry system.) Although monitoring and tracking by aircraft is possible (and actually undertaken once or twice a year) the cost makes regular use prohibitive, and the rugged nature of the terrain creates problems even for this mode, as will be outlined later in the paper.

As a result of these experiences, an informal research question was formulated: can improvements (that are cost-effective and practicable to implement) be made to the telemetry system, to enhance the effectiveness of endangered species management and research?

The approach taken to the problem was one of incremental and piecemeal improvement: that is, visualizing the problem, formulating ideas for improvement and then evaluating these ideas from the points of view of functionality improvement potential, economic feasibility and practicality. Lack of resources within the Department meant that a “big bang” approach to upgrade or replace the current system is just not feasible. Some of the initial results were presented at the national kiwi recovery conference held in Thames in March 2005.
2005 and were regarded as promising by most attendees. This paper summarizes work to date - albeit still at an early stage. The results are applicable to any wildlife telemetry scenario that uses RF techniques, not just the kiwi recovery program.

**RADIO COVERAGE MODELING**

Wildlife telemetry has gained increasing prominence in NZ conservation management and research efforts over the past decade or two (e.g. Thomas, 1982, Taborsky and Taborsky, 1995, Gibbs and Clout, 2003, Seddon and Maloney, 2004). There is good general coverage of wildlife telemetry systems in the literature (e.g. Mech, 1983, Kenward, 1987, Priede, 1992, Geers et al., 1997, Government of British Columbia, 1998, Mech and Barber, 2002). Most of these references give a high-level overview of RF technology (e.g. frequency bands and their propagation characteristics, and antenna types and characteristics) but there is no in-depth coverage of RF techniques or tactics. Tactics, in this context, are considered to be decisions or actions derived from in-depth knowledge of RF propagation characteristics that allow, for example, selecting the best receiver site(s) to cover a particular area. Nor do the main references on wildlife telemetry make mention of the use of RF coverage modeling (either manual or computer-based) to assist in improving RF reception in the field, an approach which could also lead to savings of time and resources.

On the basis that, often, a good start point for solving a complex problem is being able to visualize the problem, the initial step was to carry out some radio coverage modelling over the Moehau Sanctuary area. The first intention was to use an orthodox geographic information system (GIS) application such as ESRI ArcInfo or ArcView. However, these applications support only optical line-of-sight coverage modeling and the incorporation of RF coverage capabilities would have required significant programming effort. Therefore, attempts were made to locate an off-the-shelf RF coverage planning tool. Eventually, one was located – the Radio Mapper application developed for military tactical radio planning by the Australian Defence Force Academy (ADFA); part of the University of NSW. Agreement was reached for use by the author in support of DOC endangered species work and the necessary software and documentation was dispatched to NZ.

Radio Mapper requires Digital Terrain Elevation Data (DTED) to provide the terrain model base for radio coverage modelling. DTED is a well-known topographic data standard that essentially represents terrain as a set of (x,y,z) coordinates. There are three levels, representing different coverage granularities: level 0 has horizontal cell widths of 1 km, level 1 has cells of 90m and level 2 has cells of 25m. An approach was made to the NZ Defence Force Joint Geospatial Support Facility at Devonport Naval Base, who agreed to supply DTED level 2 coverage of the Coromandel area. After assembling the necessary application software, data and hardware, modeling activities commenced in early March 2005.

The initial intention for the use of Radio Mapper was to assist in problem visualisation. That is consistent with the use of computer models or simulations in orthodox decision support applications (e.g. Turban and Aronson, 1998). However, the tool proved to be far more effective and useful than originally envisaged, and probably offers the following lessons for IS designers (and educationalists):

- A decision support application can sometimes be utilised successfully in a problem domain significantly different from that for which it was originally intended.
- The use of Radio Mapper, in this instance, has contributed far more to the problem domain than could possibly have been imagined at the outset. In that regard, the tool can be thought of as a key element in a learning process and can be equated to what Papert terms *objects to think with* (Papert, 1993).

**Initial Results and Observations**

Radio Mapper is a radio communications path-planning tool that assists planners in predicting performance using both point-to-point and area coverage calculations. Parameters which can be varied include transmitted frequency and power, antenna and antenna feeder gains or losses, receiver sensitivity, ground type (e.g. wet, dry, urban) and transmit and receive antenna heights above ground level (AGL). Modelling can be conducted for any area for which a DTED data set is available.

Initial work with Radio Mapper concentrated on learning to use the tool. For this purpose, default military tactical radio equipment parameters were used, using a worst-case approach (e.g. selecting lowest possible transmitter output power, lowest gain antennas). When details of DOC-owned telemetry systems were available, these were substituted into the tool. (In fact, it was discovered that there was only about 2-3 dB difference in the maximum allowable path loss from the default parameters used initially.)

Examples of outputs from Radio Mapper are shown at Figures 1 and 2 below.
As Radio Mapper displays only include terrain-related information (i.e. horizontal coordinates and height), it was discovered that toggling between Radio Mapper and another digital mapping application (in this case TUMONZ\(^2\) was used) allowed selection of likely sites taking into account natural and artificial features such as streams, roads, tracks, built up areas etc not shown on Radio Mapper. The ability to specify locations using

\(^2\) The Ultimate Map of NZ: see URL http://www.tumonz.co.nz/ for details
latitude-longitude coordinates in degrees, minutes and seconds in both systems allowed manual transposition of locations between them.

By varying the site locations and other non-constant parameters such as receive antenna height, a “profile” of the sanctuary area was compiled. It was notable that raising the receive antenna height to around 100m had a large effect on coverage - of the order of 7-8 times that obtained at 1.5m, the typical height of a hand-held antenna. This is shown in Figure 3 below. This result has a bearing on techniques and tactics which could be adopted to improve coverage – some of these are discussed in following sections.

![Figure 3: 1.5m receive antenna height (on left) compared with 100m receive antenna height](image)

Another interesting result is that Radio Mapper predicts that the whole of the sanctuary area could be covered by five carefully sited receivers, provided the antennas were 100m AGL.

To date, practical validation of the RF coverage modeling results has only been undertaken to a limited extent; for example:

- The tool predicts that receivers active on the high points of the main Moehau Range should be able to pick up transmitters operating on Great Barrier Island (some 25 km to the north east of Moehau) and from the Hunua Ranges (some 50 km south west of Moehau). Moehau sanctuary staff has confirmed that that is the case.  

- The selection of a migration monitoring site, described in the next section, also confirmed the predictions of Radio Mapper.

Although only limited in-field validation has been conducted, results are sufficient to give a reasonable degree of confidence in the coverage predictions. Validation will be extended as time permits.

**SOME PRACTICAL APPLICATIONS OF RADIO COVERAGE MODELING**

Following presentation of initial results of this work at the national kiwi recovery conference in March 2005, Moehau sanctuary and Hauraki Conservancy staff met with the author and requested three tasks in the short term:

- Selection of a radio receiver site at the southern end of the sanctuary area where a receiver/data logger could be installed to monitor transmitter-equipped kiwi entering or leaving the sanctuary area.
- Predictions for the best altitude and track to fly while undertaking airborne monitoring.
- Analysis of the telemetry monitoring sites currently used by staff in the sanctuary area, to identify gaps in coverage and possible identification of better sites.

This work was carried out during April - June 2005 and the results are reported in this section.

---

3 The transmitter power output is considerably less that 1 milliwatt, and the theoretical maximum range of the particular telemetry system in use is of the order of 50 km.
Selection of a Migration Monitoring Site

The aim of this task was to determine if there are suitable site(s) where a receiver/data logger system could be installed to monitor, on a long-term basis, transmitter-equipped birds entering or leaving the sanctuary area. Experimentation with Radio Mapper identified four possible sites – one to the north of, and three to the south of, the Colville-Port Charles road. Figure 4 below shows predicted coverage from one of these sites. On 27th April, the author and a small group of DOC staff and volunteers undertook a site survey of the three southern sites, to assess their suitability, in terms of access, security, space to erect antennas etc. All three sites proved to be suitable from a practical point of view.

A communications test was also performed from one of the sites. Two people were equipped with telemetry transmitters tied to their bootlaces and they walked from the selected site down to the sea on each side (about 5 km each way). On the hill, staff were able to receive the signals continuously, down to the sea on each side. This demonstrates that the location is viable as a migration monitoring site, and also reinforces confidence in the Radio Mapper tool.

![Figure 4: Predicted coverage from selected migration monitoring site](image)

The use of Radio Mapper in the selection of this site and the subsequent communications test indicate that there should not be a significant issue of “false negative” results. That is, transmitter-equipped birds should not be able to move through the monitoring zone undetected, unless there is a failure of the receiver/data logger equipment, which is a separate (design and management) issue.

A significant issue, however, is likely to be “false positives” – that is, detection of birds at high points on the main range that are within the coverage of the selected site, who are not actually emigrating from the area. It is considered that this risk can be managed – over a period of time, such birds will be detected within the sanctuary area during normal monitoring operations, indicating they have not emigrated. Similarly, any birds that immigrate would be transmitting on channels not allocated within the Moehau area, so should be able to be located and identified once in the sanctuary area.

Airborne Monitoring

There is good coverage of this topic in the literature (e.g. Kenward, 1987, Mech, 1983, Seddon and Maloney, 2004). The paper by Seddon and Maloney (2004) is considered to be particularly valuable. Predictions made as a result of plotting coverage of the Moehau area using Radio Mapper include the following:

- Minimum viable flying height is 300m AGL.
- Optimum flying height is around 600m AGL.
• There is no coverage improvement over about 800m AGL.

• Depending on the size of the area to be covered, and the configuration of the antennas on the aircraft, it may be necessary to conduct a “sweep”-type search that divides the area into strips that correspond with the coverage width of the antennas’ radiation patterns (Seddon and Maloney, 2004). At the optimum height, the best track in the Moehau sanctuary area (which is relatively narrow) would be to follow the coastline – this allows “look in” to valleys.

The first two observations above (minimum and optimum heights) show remarkable agreement with Kenward (1987), who recommends a height range of 300-1000m AGL. However, Seddon and Maloney’s (2004 p. 16) statement that: “… a researcher should consider gaining altitude to 2000-2500m AGL to increase range during searches for missing transmitters …” is not borne out by results from Radio Mapper, which indicate that no appreciable coverage advantages accrue above approximately 800m AGL.

A major problem with aircraft monitoring seems to be the slowness of scanning channels. The modulation method used (pulsed CW with a pulse repetition frequency of 40 pulses per minute) means that it is necessary to dwell on each channel for a minimum of 2-3 seconds (Seddon and Maloney, 2004, recommend 3-5 seconds). This may mean that not all channels may be scanned in a single pass of the aircraft over a particular area of interest, e.g. a valley. The Telonics TR5 scanning receiver available at Moehau for the task may not be suitable, and staff, in fact, prefer to manually scan channels using two non-scanning TR4 receivers. A better solution may be a wideband receiver that monitors all channels of interest simultaneously. The investigation into the issues associated with airborne monitoring will continue.

Analysis of Current Telemetry Monitoring Sites

At the time of writing this paper, modelling of coverage from current sites in one area only (in the vicinity of Kennedy Bay) had been completed. Coverage is shown in Figure 5 below.

Figure 5: Coverage from monitoring sites in the vicinity of Kennedy Bay

As a result of this modelling, three new sites were identified which should allow coverage of the gaps.

APPLICATION OF RF ENGINEERING TECHNIQUES AND TACTICS TO IMPROVE TELEMETRY COVERAGE

The author is of the view that there is potential for significantly improving telemetry systems by introduction of relatively simple, and cheap, RF techniques and tactics (the term tactics, in this context, was defined earlier in

4 The author was unaware of Kenward’s recommendations when initial Radio Mapper modelling was carried out for this task
the paper). Some of these will be briefly outlined below. These short term initiatives are all considered to be relatively cheap and easy to implement. The longer term initiatives are rather more complex and likely to be much more costly, but should at least be considered in due course, even if they are discarded.

**Short term Initiatives**

A few examples of initiatives which could be implemented relatively quickly and inexpensively are as follows.

**Staff Training**

Observations made from working with staff in the field indicate there would be considerable advantages in providing training in RF techniques and tactics. It is estimated that a half-day session, possibly provided in conjunction with a national conference, would pay dividends. Techniques include such things as using directional antennas or varying the antenna polarization. An example of a tactic which would increase success in detecting transmitter-equipped birds is as follows: when on top of a high feature and trying to detect birds deep in a valley, it is advisable to get off the top of the feature, a short way down the slope towards the likely contact. This allows the full gain of the Yagi antenna to be brought into play without being “crested” by the terrain at the top of the hill. Figure 6 below portrays this graphically (“tx” = transmitter, “rx” = receiver).

![Figure 6: Effect of cresting on receive antenna](image)

Figure 6: Effect of cresting on receive antenna

Figure 7 below demonstrates the cresting effect by means of the Radio Mapper tool (and also demonstrates another useful feature of the tool – the ability to produce point-to-point path profiles). Figure 7a is based on a receive antenna situated on the main ridge (880m) of the Moehau range, with a transmitter located deep in a valley to the west. The receiver cannot detect the transmitter (the path loss is 3 dB higher than that allowable). In Figure 7b, the receive antenna has been moved 100-200m west, off the top of the hill. The receiver is now able to detect the transmitter - the radio path has improved by 25dB.

![Figure 7: Effect of cresting demonstrated by Radio Mapper point-to-point path profiles](image)
Selection of Key Reception sites

Another relatively quick and low cost improvement to the telemetry system is the use of Radio Mapper to analyze the coverage from sites currently used by staff, and to predict new sites that are not currently used. This activity could be supplemented by outputs from an elevated antenna design and construction program, as described in the next sub-section.

Elevated Antenna Systems

Also in the area of improved techniques, as previously mentioned, Radio Mapper graphically demonstrates the effect of increasing the height of the receive antenna. (Obviously, increasing the height of the transmit antenna would have the same effect, but is not feasible in a wildlife telemetry scenario.) For example, Figure 3 above demonstrates that a receive antenna at 100m AGL would have a coverage roughly 7-8 times that of an antenna at 1.5m AGL. This effect could be exploited by a number of initiatives, for example:

- Investigate the feasibility of mounting a receive antenna under a tethered balloon or in an unattended airborne vehicle (UAV). Limited by payload, the most likely antenna configuration is something simple such as a half-wave dipole or quarter-wave monopole. (At the frequencies in use for VHF telemetry this is feasible as the wavelengths are less than 2m.) These antenna types, being omni-directional, would not allow any direction-finding capability. However, Bosak (1992 p. 93) provides a design for a lightweight, improvised Yagi that could be mounted on the side of a balloon – the ability to roughly “steer” the balloon by tether ropes at either end could allow a rudimentary direction-finding capability. It is estimated that this would be no more accurate than, say 15-20°, but this would still produce an estimated location around the size of a 1000m square at a range of around 5km, which may be useful.

- Investigate the feasibility of a quick-erect (e.g. by pneumatic means) antenna mast mounted in the back of a truck or utility vehicle. This would allow utilization of good reception sites accessible by vehicle. This concept is widely used in military tactical communications.

- Design and develop a range of cheap, lightweight, antennas that could be hoisted into tall trees at key reception sites and left there, so that staff could move to them and connect to their receiver on arrival. This concept is also widely used in military tactical communications, particularly for jungle operations. The improvised Yagi design by Bosak (1992) may be viable, and therefore provide a direction-finding capability.

Longer-term Initiatives

While the ideas and possible innovations expressed above will assist in improving wildlife telemetry systems, they are still all relevant to a manual system which will continue to require a large amount of staff time in the field for limited detection or contacts. A major improvement will only be realized if telemetry systems are able to be partially or (desirably) fully automated. This should be adopted as a long-term goal, although the economic feasibility has yet to be demonstrated. This section contains a brief description of automated monitoring and tracking systems that could be contemplated at some stage in the future. There are potential limitations to the use of such automated systems, and the economic feasibility has not been addressed in this paper.

Automated Land-based Monitoring and Tracking

An example of an automated land-based system for wildlife monitoring and tracking is the Auto Track AT 350 developed by Sirtrack, a commercial subsidiary of Landcare Research (a NZ Government Crown Research Institute). Details are available from (Landcare Research, 2005). The manufacturer claims that field tests by wildlife researchers on brush-tail possums have proven its viability, and some examples are provided.

The directional accuracy claimed is of the order of 1-2°, which is comparable with military electronic warfare direction-finding capability. However, as the carrier frequency remains in the VHF band, reception will still be limited to radio-line-of-sight. In the case of a rugged area such as Moehau, continuous coverage of the whole area would not be feasible, and would be limited to small areas (e.g. a particular valley). Wider coverage would require extensive movement of the direction-finding stations and control station.

A variant of this type of system is one in which the animal transmitter units have built-in GPS receiver capability, which allows the transmitters to send data messages that contain location information, thus eliminating the need for direction-finding by the base stations (Tomkiewicz, 1997, Hulbert and French, 2001). However, a potential problem with this is that GPS coverage is generally poor under a heavy forest canopy, particularly in the types of forest floor conditions favoured by kiwi.
Space-based Monitoring and Tracking

The obvious (and, apparently, only) current option in this category is the Argos system. Details of this system are widely available in the literature (e.g. Argos Inc, 1998, Argos Inc, 2004, Taillade, 1992).

Although this system has been available for over a decade, there have been issues associated with the weight of transmitters, or “PTTs” (platform transmitter terminals) in Argos terminology, which can be attached to small animals and birds. The satellite transponder requires a transmitted power of the order of 500mW to be able to detect and retransmit a data “message” from the animal. This issue, essentially, becomes a tradeoff between PTT transmitted power, weight and battery life. Modern PTT technology allows units that would be of a weight suitable for adult or juvenile kiwi, or similar sized birds, with battery life of the order of a year or more. According to (Telonics Inc, 2005), PTTs weighing as little as 16.6g are now available.

The system can provide data on the location of PTTs anywhere in the world using Doppler Effect (based on the motion of the satellite). There are various classes of service, providing locations with accuracies ranging from 150m to 1km. Other options include the transmission of other telemetry data collected from the animal, e.g. temperature, heart rate. Also, PTTs can be used in conjunction with GPS, and GPS positions transmitted to the satellite. As there is a regional earth station in Wellington NZ, users could obtain real-time positional information on PTTs operational within NZ (Argos Inc, 2004).

As mentioned in the preceding section, RF attenuation is significant under a heavy forest canopy, particularly in the types of forest floor conditions favoured by kiwi, and this will limit the use of GPS techniques and space-based monitoring systems. Under such conditions, the transmitter power would have to be significantly increased to ensure detection from a satellite, and this will have implications for both PTT weight and power consumption.

SUMMARY AND CONCLUSIONS

The research described in this paper is aimed at improving wildlife telemetry systems by means of improving RF visualization and planning, and improving RF coverage by adoption of improved techniques and tactics. The use of a computerized modeling application – Radio Mapper – has proved to be of benefit in the area of RF visualisation and planning. It has been recommended that DOC consider acquiring a licence to operate Radio Mapper, or identify and procure a similar RF coverage modeling tool.

Use of Radio Mapper and other work in this area has led to the identification of opportunities to improve field practice: staff training in RF techniques and tactics, selection of optimum receiver sites, improved receive antenna systems, and improved planning for airborne monitoring and tracking. It has been recommended that all DOC staff involved in field telemetry work undergo training (of the order of half a day is considered sufficient) in RF propagation techniques and tactics. In the kiwi recovery program, this could be run in conjunction with the annual national conference.

In the long term, however, automated land-based or space-based monitoring and tracking systems appear to have the best potential for maximizing effectiveness in this domain. Given that NZ has mostly rugged terrain and that the main RF bands used require line-of-sight propagation, space-based systems would appear to be the preferable long-term option. However, the feasibility (including economic) of both of these options still needs to be evaluated.

REFERENCES


\[5\] GPS Standard Positioning Service, giving accuracies of the order of tens of metres


ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of the following:

- Dr Mike Ryan and Associate Professor Michael Frater, ADFA, UNSW, for supplying, assisting and advising on the Radio Mapper tool.
- The NZ Defence Force Joint Geospatial Support Facility, Devonport, for supplying the DTED data set for the Coromandel Peninsula area.
- DOC staff and volunteers of the Moehau kiwi sanctuary for their patience, advice and support.

COPYRIGHT

David Wilton © 2005. The author assigns to ACIS and educational and non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The author also grants a non-exclusive licence to ACIS to publish this document in full in the Conference Papers and Proceedings. Those documents may be published on the World Wide Web, CD-ROM, in printed form, and on mirror sites on the World Wide Web. Any other usage is prohibited without the express permission of the author.