

Radio Mobile

Radio Propagation and Radio Coverage Computer Simulation Program

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Program Operating Guide

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Radio Mobile Computer Program

The Basics and Program Operation

1 Copyright and Author – Radio Mobile

The Radio Mobile computer program is written and maintained by Roger Coudé, VE2DBE. The program is copyright by Roger Coudé. It is available from the Radio Mobile website, <http://www.cplus.org/rmw/english1.html>, hosted by Communications Plus and the [mirror site](#) by [Link Technologies](#)

2 Copyright and Author – Radio Mobile User Guide

This User Guide paper is written and maintained by Brian Henderson, P. Eng., VE6ZS as an assistance guide to using the program. The user guide is Copyright 2013, Brian Henderson.

There are other descriptions of Radio Mobile installation and program use on Roger's website. They are very good and well worth reading. This paper is simply another alternative description to assist with understanding and using the Radio Mobile program.

3 Contributors and Internet Links – Radio Mobile

Two of the major contributors to the website and radio mobile user information and guides are Ian Brown, G3TVU and Remko, PE1MEW. Both have excellent operating guides and links to their own websites from Roger's Radio Mobile site.

Both operating guides and others are:

- Ian's (G3TVU) website is http://www.g3tvu.co.uk/Radio_Mobile.htm
- Remko's (PE1MEW) website is <http://radiomobile.pe1mew.nl>
- Greg A. Bur also has written a user guide. It is found at <http://www.pizon.org/radio-mobile-tutorial/index.html>
- Noel – G8GTZ has written an operating guide. It is located at http://www.ve2dbe.com/getting_started.html

There is also a Radio Mobile Yahoo group. The group is a discussion centre for questions, answers, suggestions and solutions. The Yahoo Group is located at http://groups.yahoo.com/group/Radio_Mobile_Deluxe/

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Ian Brown also has written an excellent Radio Mobile setup program. It is referred to in this document. Installation of Radio Mobile on your computer is easily accomplished using Ian's Radio Mobile setup program at http://www.g3tvu.co.uk/Quick_Start.htm

Ian has also recently released an operating guide "Radio Mobile, An Illustrated Handbook" (Ian D. Brown, G3 TVU). The handbook can be ordered from <http://www.antennex.com/Sshack/radmob/radmob.htm> at a nominal cost.

Considering the Radio Mobile program itself is free, Ian's handbook is an excellent companion at a very nominal cost.

Ian has also provided many comments and suggestions to this Operating Guide throughout its evolution. Many thanks for your help and many suggestions, Ian!

4 Radio Mobile Program – Introduction

Radio Mobile is a computer simulation program used for predicting radio coverage of a base station, repeater or other radio network. Ground elevation and various radio parameters are taken into account to predict radio coverage around a single or multiple radio sites.

After coverage is calculated for a geographic area, a map can be overlaid on the coverage plot to show various locations and resulting coverage along roads and in areas of cities, towns, etc.

The program is extensive and has many options, parameters and settings. Only a few are covered here. The user is encouraged to experiment once becoming familiar with the basics of program operation.

The paper consists of 2 parts.

1. The first part describes radio propagation in general, including the mathematics of propagation calculation.
2. The second part describes the Radio Mobile program and some of the basics and input parameters required to use it.

5 Radio Mobile Program – Description

Radio Mobile uses the following input parameters to predict and provide a coverage map showing radio coverage:

- Transmitter location

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- Transmitter power output
- Frequency
- Antenna Type
- Antenna Pattern
- Antenna Gain
- Transmission line losses, including filters and multicouplers
- Receiver location
- Receiver antenna type
- Terrain and elevation data for the area

The program uses terrain elevation data from either the SRTM (Shuttle Radar Topography Mission) or the DTED (Digital Terrain Elevation Data) databases that are both available free on the Internet. Other formats for elevation are available; however, these two are the most common.

The program will produce a coloured plot of radio coverage from 1 or multiple base stations showing expected receive signal levels. Levels are displayed using any of the following units specified by the user:

- S-units
- μV
- dBm
- $\mu\text{V/m}$

Coverage contours can be displayed as either a pass/fail (above/below a user specified signal level). Coverage can also be displayed using a “rainbow” of coverage, using various colours to show various signal levels.

The program has the ability to combine this coverage prediction map together with a road or other geographic map. The plot can be quickly used to determine if communication from a specific location is possible.

6 Radio Propagation and Coverage Basics

This section discusses some of the concepts used for radio propagation simulation and how computers analyze radio propagation and coverage. These sections are presented as background information for the reader.

Radio propagation is the study of how radio waves travel from a transmitter site to a receiver site through the atmosphere. Radio signals are affected by terrain elevation between the sites, and obstructions, including trees, buildings, etc. that may be in between the two sites. Radio signals are also affected by atmospheric and other weather related conditions.

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Radio propagation and coverage has its own language, like any other specialty.

6.1 Radio Receiver Operation

The intent of any radio receiver is to receive and decode a specific signal from the many signals in the air and separate it from noise and other unwanted signals. Receiver threshold is the minimum amount of signal required for a receiver to decode and the user or listen to an intended message.

Example, most mobile radios have a receiver sensitivity of $0.5 \mu\text{V}$. A signal at this level has noise along with it. If the radio is moving (mobile or handheld radio), the signal level will change up and down, increasing and decreasing the background noise. Increase the signal level to $1 \mu\text{V}$, the noise is substantially reduced and the signal is much easier for the ear to decode. Decrease the signal below $0.25 \mu\text{V}$ and it may disappear into the noise and not be understood.

Changing from $0.5 \mu\text{V}$ to $1 \mu\text{V}$ as a reference and calculation level is a 6 dB increase in power level and makes the signal much easier to understand. The signal will continue to vary up and down; however, these changes are less noticeable to the ear when listening.

Additional fade margin improves the usability of a radio system. It is not recommended to design a radio system to the complete maximum of radio performance. The result of a system designed to the maximum is that it shows very good coverage on a map, however, it is not useable at the extremities of predicted radio coverage.

6.2 The deciBel (dB)

The deciBel (abbreviated dB) is a logarithmic value commonly used for radio propagation calculations. Radio propagation actually works using logarithmic numbers.

Why? Radio propagation involves complicated multiplication at varying points along a radio path. A directional antenna multiplies the signal by its gain. Feed line cable divides the signal by its loss. The equations become very complex.

Taking logarithms of all gain and loss values allows them to be simply added and subtracted. When all gains and losses are identified, they can simply be added up to determine the final receive signal level. Overall mathematics is simplified by using the deciBel, abbreviated to dB.

To keep the mathematics simpler, antennas, feed line losses and insertion loss of duplexers etc. are all specified as dB values.

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The Radio Mobile program works mostly in deciBels. Where input is required from a normally linear device, such as transmitter power output or receiver sensitivity, the program provides the ability to enter number in either Watts or μV (linear) or dBm (logarithmic). The program will convert these numbers to a dB value for program use.

6.3 Decibel Mathematics

The deciBel is logarithmic number that is a ratio, in this case, between 2 power levels.

The decibel is defined by the following equation:

$$\text{dB} = 10 * \log_{10} \frac{(\text{Power level 1})}{(\text{Power level 2})}$$

Note that the units in the above equation must cancel out, meaning that if the top is specified in Watts, the bottom must also be specified in Watts.

For example, linear amplifier gain may be specified in deciBels.

If input power = 75 Watts and output power = 300 Watts, the gain of this amplifier is:

$$10 * \log_{10} \frac{300 \text{ Watts}}{75 \text{ Watts}} = 6.02 \text{ dB.}$$

Note also that if voltages are used in the equation, the mathematics changes. Since power is proportional to V^2 , the equation becomes:

$$\text{dB} = 20 * \log_{10} \frac{(\text{Voltage level 1})}{(\text{Voltage level 2})}$$

Comparing 2 voltage levels,

If voltages of 1 μV and 0.5 μV are compared,

$$20 * \log_{10} \frac{1 \mu\text{V}}{0.5 \mu\text{V}} = 6.02 \text{ dB.}$$

6.4 deciBel and Radio Standards

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It is also worth noting that several standards have been established within the radio industry using the deciBel.

dBW is deciBels above a 1-Watt reference.

- A 1-Watt transmitter has an output of 0 dBW.
- A 10-Watt transmitter has an output of +10 dBW.
- A 25-Watt transmitter has an output of +14 dBW.

dBm is deciBel above a 1-milliWatt (mW) reference and a 50 Ω input impedance.

- A 1-Watt transmitter has an output of +30 dBm.
- A 10-Watt transmitter has an output of +40 dBm.
- A 25-Watt transmitter has an output of +44 dBm.

As can be seen, changing from dBW to dBm is simply a matter of adding or subtracting 30 dB.

dBm can and is commonly used to specify receiver sensitivity at a 50 Ω input impedance.

- 0.5 μ V is equivalent to -113 dBm
- 1.0 μ V is equivalent to -107 dBm
- 10 μ V is equivalent to -87 dBm

Note that dBm for receiver sensitivity is based on a voltage level in μ V, not a power level in Watts. Mathematically, this is taken into account and does make a difference to the deciBel calculations.

6.5 Propagation Modes

Line of sight is simply that – if the distant site is optically visible (using your eye) from the transmitter antenna location on the tower, it is considered within the coverage area. This is referred to as “optical line of sight coverage”. The optical line of sight method does not take into account reflections, Fresnel Zones or the slight bending of radio waves along the surface of the earth.

Radio path loss between 2 sites that are within line of sight uses “free space loss” only. No other loss parameters are considered.

We all know that radio waves travel in straight lines. The early mathematics of radio propagation considered that radio and light were essentially the same and travelled in the same manner. If a distant site could be seen optically, radio communication was possible. Therefore, there is an option to show optical line of sight coverage.

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Radio Mobile uses a computer algorithm called the Longley Rice model to determine signal loss for non Line of Sight radio paths.

Line of sight paths use a calculation called the “two ray” method. This method takes into account Free Space Loss only.

6.6 ‘K’ factor

It was discovered by the British during early radar research (at really high frequencies, around 300 MHz in the late 1930s) and later by AT&T at Bell Laboratories, that radio waves travel a little further and actually bend with the surface of the earth. The bending is proportional to frequency. The higher the frequency, the less the bending.

VHF radio systems have better coverage than UHF systems due to the better bending of VHF frequencies.

After some extensive analysis of propagation, it was determined that if the diameter of the earth is increased by approximately 1.33 or $4/3$, radio waves do travel in straight lines over this “larger” earth. The $4/3$ earth radius is called the ‘K’ factor and continually shows up in radio path design and propagation theory. The earth’s curvature, as it begins to protrude into a radio path as distance between sites increases, is commonly called the earth “bulge”.

The ‘K’ factor is the difference between performing radio propagation studies as line of sight paths and actual radio paths.

It is also worth noting that ‘K’ is another of the variables that changes with atmospheric conditions. The typical value of K is $4/3$. However, it can range anywhere from about $2/3$ to up as high as 10. These ranges do not occur often; however, they can and have occurred on microwave test ranges.

‘K’ usually has a tendency to increase, producing less earth bulge, and less loss between radio sites. K can range up to 10, depending on atmospheric conditions.

‘K’ can also decrease. Sometimes, ‘K’ can decrease to as low as $2/3$ or 0.66. Again, this does not happen often, however, can occur. Effect is an increase in signal loss and lower signal level at the receiver.

7 Propagation and Signal Loss

There are 2 signal losses that add together as distance loss and atmospheric loss between a transmitter and receiver site. Both can be calculated between the transmitter and receiver sites.

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Calculations can use a number of computer algorithms for path loss. Radio Mobile uses the Longley-Rice model for propagation calculation.

7.1 Free Space loss

Free Space loss is the loss due to the distance between sites. It does not take into account obstructions. It assumes that the sites are completely in the clear, hence the term “Free Space”. It may also be called “Line Of Sight loss”.

One accepted equation for calculating Free Space Loss is:

$$\text{FSL (dB)} = 36.57 + 20 \cdot \log_{10} (\text{Distance in miles}) + 20 \cdot \log_{10} (\text{Frequency in MHz})$$

7.2 Diffraction Loss

Diffraction loss is the additional loss that occurs due to an obstructed path. The path may be obstructed by trees, hills, buildings or other objects. Diffraction loss also results as the distance between sites increases and the curvature of the earth obstructs the path. The earth obstruction is commonly referred to as the “earth bulge”.

It can be calculated based on the location of the obstruction along the path and its height. There are a number of computer algorithms that will calculate diffraction loss. The Radio Mobile program uses the Longley-Rice algorithm.

Diffraction loss is calculated and added to Free Space Loss to determine overall propagation loss between transmit and receive antennas.

Actual calculation of diffraction loss is very complicated and beyond the scope of this paper.

7.3 Total Loss Between Sites

Total path loss between 2 sites is calculated by adding together all the dB values including Free Space Loss and Diffraction Loss. The remaining parameters that must be added to arrive at a receive signal level are summarized here.

Provide all numbers are in deciBels as described above.

This table can be filled in and the numbers added to determine receive signal level.

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Transmit Power Output		dBm
Connector loss		dB
Multicoupler or filter loss		dB
Duplexer loss		dB
Feed line loss		dB
Transmit Antenna Gain		dB
Free Space Loss		dB
Diffraction Loss		dB
Receiver Antenna Gain		dB
Feed line loss		dB
Duplexer loss		dB
Multicoupler or filter loss		dB
Connector loss		dB
Calculated receive signal level		dBm
Receiver sensitivity		dBm
Fade Margin		dB

Many of these loss parameters, such as duplexer and antenna losses and gains, are available from manufacturer's specification sheets.

Connector loss is a parameter commonly overlooked in many calculations. Depending on connector type, it can be from 0.2 to 1.0 dB per connector. Some connector types have more loss than others. It also depends on the quality of a specific connector and experience of the connector installer.

Frequency is a factor in connector loss. The higher the frequency, the more critical the connections and possibly, the higher the loss.

When purchasing connectors, "you get what you pay for". Yes, 'N' connectors cost more. However, their loss can be significantly lower at higher frequencies. However, if improperly installed, there can be a significant increase in loss. Follow the installation guide and cable cutting chart when installing any connector.

The higher the frequency, the more critical the connector and the more loss through the connector. Use the wrong or a poor connector and loss increases substantially.

As an example, the standard type "UHF" connector is only rated to a maximum frequency of 150 MHz.

A type "BNC" connector is rated to a maximum frequency of 1,000 MHz or 1 GHz.

A type "TNC" connector is rated to a maximum frequency of 12 GHz.

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A type “N” connector is rated to a maximum frequency of 20 GHz.
A type “SMA” connector is rated to a maximum frequency of 40 GHz.

8 Radio Wave Propagation

For this discussion, it is worth noting that radio waves are sine waves. They oscillate between high and low at the carrier frequency of the transmitter. Radio waves travel through the air at close to the speed of light. Since they are sine waves, they have a frequency and phase component. Phase is a specific point on the sine wave curve. All sine waves repeat themselves after 360° of arc, similar to a circle.

One cycle as shown also defines the wavelength of the sine wave.

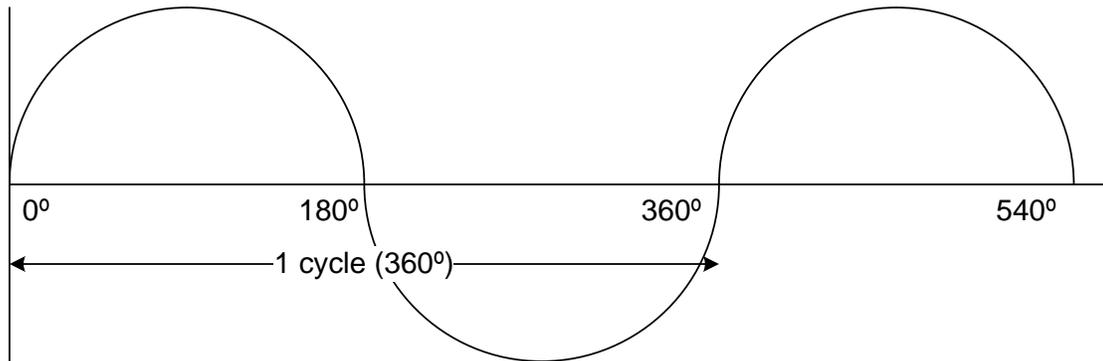


Figure 1. The Sine Wave

8.1 Fresnel Zones

Fresnel zones are used in propagation theory to calculate reflections and other losses between a transmitter and receiver. Fresnel zones are sequentially numbered and are called ‘F1’, ‘F2’, ‘F3’ etc.

There are an infinite number of Fresnel zones, however, only the first 3 have any real effect on radio propagation.

8.1.1 What is a Fresnel zone and why is it important?

First, what is it? A Fresnel zone is a three dimensional ellipse drawn between transmitter and receiver. The size and diameter of the ellipse at a specific location is determined by the frequency of operation and the distance between the two sites.

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The Fresnel Zone radius is important when calculating signal loss between 2 sites. If the main signal is clear of any objects along the path (trees, hills, mountains, etc.) the path is unobstructed. More detail follows in section “Fresnel Zone Radius and Earth Clearance.”

When a radio signal travels between transmitter and receiver, it can travel in several ways. It can go directly between transmitter and receiver (main signal). Signal can reflect off the ground or other object, such as a mountain wall face or cloud, then carry on to the distant receiver (reflected signal). It can go left or right and be reflected back by a hill to the side of the radio path (another reflected signal).

This is where wavelength of the signal is important. Wavelength is the inverse of frequency. Wavelength difference and arrival time and phase difference between the main and reflected sine wave signal paths is the purpose of knowing the Fresnel zone number.

$$\lambda \text{ (wavelength)} \propto \frac{1}{\text{frequency}}$$

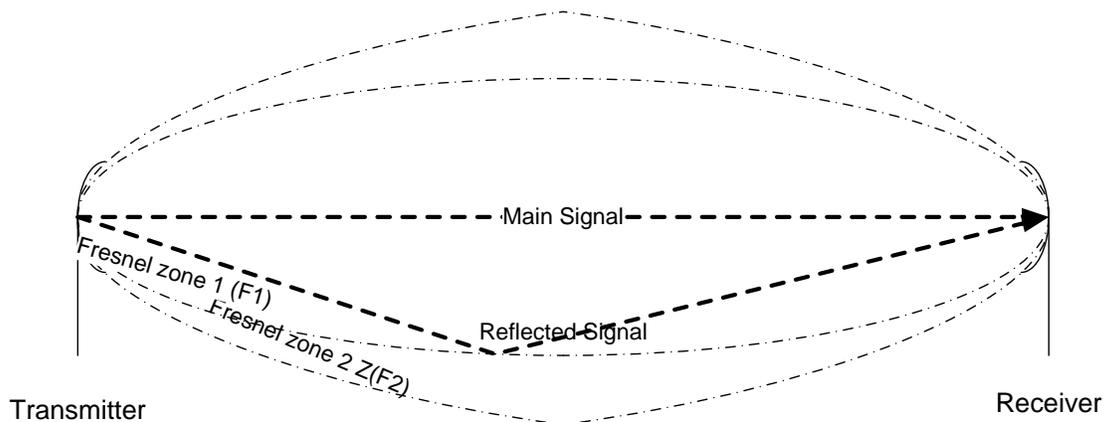


Figure 2. – First and Second Fresnel Zones

8.1.2 How big is it?

Fresnel zone radius describes this reflection in relation to overall radio path length. Figure 2 above shows main and reflected signals and F1 (first Fresnel zone) and F2 (second Fresnel zone). The reflection can happen at any location between the transmitter and receiver. The figure shows the reflection happening at a random location, not the centre of the path.

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When a signal is reflected two things happen.

- the phase of the signal reverses and the signal changes phase by 180° .
- Since the signal is being reflected and not going in a direct line, it travels slightly further to the reflection point and then on to the receiver. Therefore, the signal is shifted further in phase, by the difference in path length. Over a long path, this can amount to 180° or more.

8.1.3 Why is this important?

The receive antenna cannot differentiate between a main and reflected signal. They are both on the same frequency. It receives both main and reflected signals. It also receives any other signals within its designed frequency range. All of these signals are carried along the transmission line to the receiver.

When an antenna receives a main signal and a reflected signal on the same frequency, the 2 signals will combine and add together at the antenna. If they are 360° shifted (in phase), they will add together and there is no issue. However, if the signals are 180° apart (opposite phase), they will cancel and the receiver will receive nothing.

The cancelled signal is the one to be avoided.

8.2 Fresnel Zone Radius and Earth Clearance

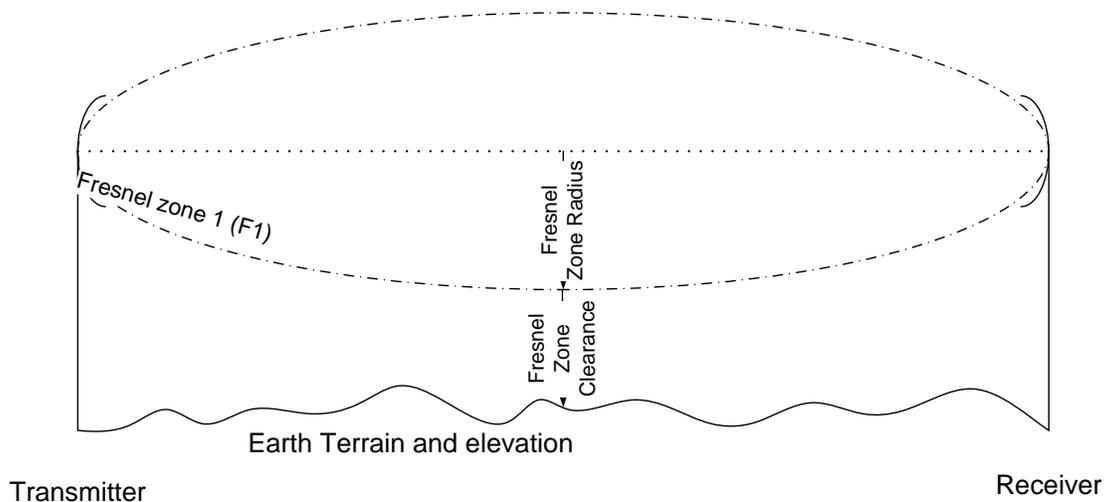


Figure 3. Fresnel Zone Radius and Earth Clearance

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The diameter of the Fresnel Zone (half the diameter is the radius) of the elliptical cylinder can be calculated, based on frequency of the signal and distance between the 2 endpoint radio sites. The distance between the ground and the actual main signal path is known as Fresnel Zone clearance.

The important component of the Fresnel Zone is the clearance between the Fresnel zone ellipse and the surface of the earth. Figure 3 shows the Fresnel zone radius and Fresnel zone earth clearance along a radio path.

If the ratio of

$$\frac{\text{Fresnel zone earth clearance}}{\text{Fresnel zone radius}}$$

is greater than 60%, the radio path is considered “clear, line of sight” and incurs no diffraction loss. This is also referred to as Free Space Loss.

The 60% clearance (and not 100% clearance) is due to the bending of radio waves over the surface of the earth.

This understanding of Fresnel zones and their effect helps know the how and why that radio coverage can be predicted using mathematics and computers.

8.2.1 Clear Line-of-Sight

If the signal path exceeds 60% clearance of F1 (First Fresnel zone), the radio signal is considered “clear line-of-sight” and will incur no diffraction loss.

As terrain obstructions or the earth bulge reduces Fresnel clearance below the 60% value, diffraction loss increases.

Clear line of sight is also referred to as optical line of sight or LOS. Radio signal levels are calculated as Free Space Loss only, no other loss is incurred along the radio path.

8.2.2 Obstructed Path

If the signal is not a line of sight path and the Fresnel clearance is not 60%, obstructions add loss called “diffraction loss” or “building and tree loss”. These obstructions reduce signal received at the far end of the path.

There are a number of algorithms used to calculate diffraction loss. The Radio Mobile program uses the Longley-Rice calculation.

8.3 Fresnel Zone Numbering

The specific numbered Fresnel zone describes the difference in path length between a direct signal, traveling in a straight line between 2 antennas, and a reflected signal from the calculated boundary of the specific Fresnel Zone.

Each Fresnel Zone number sequentially increases the phase reversal and adds a 180° phase shift.

The table shows the effective phase shift by reflected signals from different Fresnel Zones. It includes the 180° phase reversal from the reflected signal from the ground or other object. Adding the reflection phase reversal to the difference in path length gives the total phase shift from transmitter to receiver.

Fresnel Zone	Phase Shift caused by reflection	Path Length Phase Shift	Total Effective Total Phase Shift
Fresnel Zone 1 (F1)	180°	1*180° = 180°	360°
Fresnel Zone 2 (F2)	180°	2*180° = 360°	540° (same as 180°)
Fresnel Zone 3 (F3)	180°	3*180° = 540°	720° (same as 360°)
Fresnel Zone 4 (F4)	180°	4*180° = 720°	900° (same as 180°)

8.4 Fresnel Zone 1 (F1)

The first Fresnel zone radius is calculated so that the difference in path length between the main signal and a reflected signal from the F1 radius distance is 180°. A reflected signal shifted by 180° of path distance plus 180° from the actual reflection point totals 360° of phase shift. The 2 signals, main and reflected, arrive at the antenna 360° apart or in phase. They will add together and actually improve receiver performance as there is up to a 6 dB signal gain.

This reflection phase shift can happen anywhere from the calculated Fresnel zone “tube”, properly known as an ellipse.

8.5 Fresnel Zone 2 (F2)

The second Fresnel zone radius is calculated so that the path length difference between the main and reflected signals from the second Fresnel zone “tube” is 360°.

This is critical, since a reflected signal has an automatic 180° phase shift plus the path length difference of 360° equals a phase shift of 540°. 540° and 180° are the

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same phase shift in mathematics and the 2 signals will cancel, leaving no signal at the receiver.

The second Fresnel Zone, F2, is the zone of reflection that is not wanted when designing a radio path.

8.6 Fresnel Zone 3 (F3)

The third Fresnel zone has a path length difference of 540° . Add this to the 180° reflection shift; the total is 720° , and the 2 signals are in phase.

8.7 Fresnel Zone Effect

Two important effects rely on Fresnel zone calculations.

For reflection and multipath analysis, even numbered Fresnel zones (F2, F4, F6) incur a net 180° signal reflection. These are detrimental to radio propagation. Odd numbered Fresnel zones (F1, F3, F5) incur a net 360° phase shift and have little effect. Odd numbered Fresnel zones are the “good guys”.

The effect of these reflections in mobile operation can be experienced near the coverage limit of a repeater for example.

What is heard in the receiver is a rapid increase/decrease of signal, often called “picket fencing.” The rapid increase and decrease of signal from a moving radio or vehicle is called Rayleigh fading. It is a direct result of Fresnel zone reflections coming and going in and out of phase as the vehicle moves down the highway.

Point to point paths also make use of Fresnel zone calculations. For point-to-point paths, antenna locations are fixed and there is no rapid signal fade due to an antenna moving. There are long-term effects (over several hours) that are taken into account when performing Fresnel Zone calculations.

8.8 Specular Reflection

If a reflection occurs along the path, the reflected signal is not perfectly reflected. The theory assumes a perfect mirror on the path, reflecting the entire signal along the reflected path. In practice, this does not happen. Signals are reflected by snow, small lakes etc.

The reflection point is somewhat like a dirty mirror, or one smeared with Vaseline. The reflected signal is lower in level than the main signal.

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Reflection location changes location and phase constantly. Net result is that a reflected signal is constantly changing with respect to the main signal. A change in weather, clouds, humidity in the air and a host of other things will change the reflections.

Since they cannot be predicted, reflections are to be avoided. Careful selection of antenna heights is the key to reducing reflections.

8.8.1 Effect of Specular Reflection

A reflected signal will have additional loss by this non-perfect or “dirty mirror”. Therefore, the reflected signal received will be lower than the main signal received at an antenna.

When the 2 signals (main and reflected) mix together at the distant antenna, the main signal will be mixed with an out of phase signal from the reflected path.

What happens? The signals will mix together. Signals that are 180° out of phase will mix with the main signal and reduce the overall signal. They will not cancel out entirely; however, the signal seen by the receiver will be lower than expected.

8.8.2 How to reduce reflections

It is worth noting a common design trick for point-to-point links.

Since the F2 zone is detrimental to receive signal level, antenna heights are selected so that F1 is an unobstructed path and F2 is obstructed by a hill or the earth bulge along the path.

Any 180° reflected signals along the F2 zone are attenuated by the hill or the earth and do not reach the receive antenna to interfere and reduce the main receive signal.

Another method of reducing reflections is called a “high low”. It works when one antenna can be made significantly lower in elevation than the other. This works very well when a communication path is from a coast at sea level to a coastal mountain range at a higher elevation.

8.9 Inter Symbol Interference

Another effect of signal reflection is called Inter Symbol Interference. It usually affects digital radio systems, although analogue voice systems can experience the same effect.

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Digital radio systems transmit 1s and 0s from transmitter to receiver. These 1s and 0s must be received and decoded by the receiver. Each 1 or 0 is referred to as a “Symbol”. Symbols are transmitted as a bit stream along the radio path.

Depending on modulation used, a symbol can represent more than 1 useable throughput data bit.

BPSK	Binary Phase Shift Keying	1 useable bit per symbol
QPSK	Quadrature Phase Shift Keying	2 useable bits per symbol
QAM, 16 QAM, 32 QAM, 64 QAM etc.	Quadrature Amplitude Modulation	16, 32, 64 useable bits per symbol
TCM	Trellis Code modulation	128 or more useable bits per symbol

The above table shows some types of modulation where bits transmitted over a radio link represent more bits from the original data transmission bit stream.

A received symbol can represent 64 or more bits of actual payload data.

As symbols are received at the antenna and passed on to the receiver, they are decoded from the RF signal to the 1s and 0s of the original transmission.

Symbols received along the main path are received at a specific data rate set by the radio transmit clock. This may be anywhere from 9.6 kbps to 50 Mbps or more. Clocks at each end of a radio link must be synchronized so that data is interpreted within the correct timing and format.

The clocks set a specific Symbol window time where a 1 or a 0 is valid and can be decoded within that window.

If a reflected signal is received, it is delayed by the difference in path length. If this delay is outside the Symbol window, data bits received from the main path signal will become confused with delayed data bits from the reflected path.

This confusion between received data bits is called “Inter Symbol Interference”.

The higher the data rate, the smaller the symbol decode window and the more critical that a reflected signal does not interrupt data transmission along the main path.

9 Path Reliability – Point to Point Radio

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Radio path reliability and fade margin are discussed in “Radio Path Fade Margin”.

Point to point radio links have extensive analysis performed to determine radio path reliability. Mobile coverage is calculated in the same manner. It is simply many, many point-to-point radio links calculated to predict radio signal level at many points. These points are then assembled together to form a coverage map.

The “clear line-of-sight” path was discussed in section “Fresnel Zone Effect”. A radio path must be more than 60% clear of the First Fresnel zone (F1) to incur no (0 dB) diffraction loss. Here is where some of the “free” calculation tools may give overly optimistic radio link calculations.

These propagation tools usually specify that the radio path must be “clear line-of-sight” paths. They do not take into account the earth bulge, diffraction loss or Fresnel Zone clearance.

9.1 Radio Path Fade Margin

Reliability and availability of any radio path is always given as a probability. No radio path is perfect; they are simply very high availability numbers.

The following is an approximate list of common fade margins and signal probability/availability numbers. Other factors do influence fade margin, including path distance and frequency, however, these numbers give a reasonable appreciation of the fade margins required for high availability paths.

Percentages refer to time period, as in “50% of the time, signal will be at or greater than the calculated value”.

50%	6 dB
90%	10 dB
99%	20 dB
99.9%	30 dB
99.99%	40 dB

Obviously, the higher the fade margin, the higher the probability that a usable communication signal will be received, and the smaller the coverage area displayed to maintain this fade margin.

For most mobile systems, a fade margin of 6 to 10 dB is acceptable. Critical systems such as police, fire and ambulance may require higher reliabilities and require higher fade margins during system design.

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Coverage for mobile radios will always be greater than for a handheld radio. The difference is due to the smaller and lower gain antennas and smaller capture area of the handheld antenna and the lower transmit power of a handheld compared to a mobile radio.

It is worth noting that cellular radio systems and to a limited extent, public trunked radio systems use fade margins of the order of 10 to 20 dB.

To keep cellular and trunked telephones small, antennas are small and inefficient. They are also often close to the human body that reduces antenna efficiency. Therefore, more signal level is required to maintain a reliable communication path from a cell site to a cellular telephone.

9.2 Point to Point Reliability

Point to point reliability is a calculation that involves signal fade margin, distance between the sites, channel bandwidth and a myriad of other factors.

There are 2 important input parameters that involve 'K' and Fresnel zone clearance. These parameters will allow calculation of the required antenna height to achieve the Fresnel zone clearance required.

Telephone networks have long used $K=4/3$ or 1.33 and a Fresnel clearance of 60% for microwave path design. Space diversity (2 receive antenna) systems commonly use a 100% Fresnel clearance for the higher antenna and 60% clearance for the lower antenna.

Military networks have long used $K=2/3$ or 0.66 and a Fresnel clearance of either 60% or 100%. This does give higher antennas and shorter paths and usually higher path reliability.

Care must be taken, as antennas higher up on a tower can run into reflection problems and the F2 clearance and reflected signals can become a problem when using the military design criteria.

It is always worth checking for signal reflections along a radio path. Radio mobile cannot perform reflection analysis. One program that does provide reflection calculation is [Pathloss](#), from Contract Telecommunication Engineering (CTE).

9.3 Radio Coverage Probability

All radio coverage is based on probability theory. Radio coverage at a specific location relative to a distant transmitter can be specified for a 50%, 90% or higher

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probability of successful communication. Radio coverage cannot be guaranteed 100% of the time.

Radio coverage is affected by weather and atmospheric conditions on a continual basis. Rain or snow can affect higher frequency satellite and microwave communication. Temperature inversions can affect VHF and UHF and cause reflections that either increase or decrease signal level at a distant site.

Because of these variables, radio networks rely on a parameter called “Fade Margin”. Fade margin is the safety factor used to determine the level of probability of successful radio communication. Fade margin is the additional signal, above a receiver threshold, that is not necessary for communication, however, is necessary for reliability prediction.

10 Geographic Coordinate Systems

Radio Mobile has the ability to operate using 4 different coordinate systems. All of these locate a radio or user at a unique location on the earth’s surface.

Better descriptions of these coordinate systems are available from Wikipedia on the Internet and other sources. Simple descriptions of the coordinate systems are presented here.

Radio Mobile input makes use of the following coordinate systems:

- Latitude and Longitude (Lat and Long), default and always used
- Maidenhead Locator System (Maidenhead) or QRA
- Military Grid Reference System (MGRS)
- UTM Universal Transverse Mercator
- WGS 84 Geosys input

MGRS Military Grid Reference System is based on and is similar to UTM coordinates.

Radio Mobile initially defaults to using Latitude and Longitude and the QRA (Maidenhead Locator System).

The alternate coordinate system can be changed under “options”. Select “Options”, “Coordinates” and any of the above 4 coordinate systems can be set as the alternate. Latitude and Longitude remain always available.

Note also that the status bar at the bottom right of the page will show up to 3 coordinate systems of where the cursor, as displayed on the map, is located. Simply check off the boxes of the coordinate systems desired.

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When moving the cursor around on the map, the display continually shows cursor location and elevation in metres at the cursor point. Note that the X-Y reference, if selected, shows the cursor location in pixels, selected when the size of the map (in pixels) is chosen for map display during map extraction. Pixels and map resolution are defined under “Map Properties” when extracting a map.

The X-Y reference 0, 0 point is at the top left corner of the map.

10.1 Earth Reference Points – Map Datums

Also, note that in order to represent the round earth on a flat map, there are a number of reference survey points selected on the earth for various coordinate systems. These reference points are called Map Datums.

The earth is not a perfect sphere. The technical term is “oblate spheroid”. In mathematical terms, the earth is an ellipse. There are a number of ellipsoids used to represent actual points on the earth using the survey reference points.

Because of the different mathematical models used to represent the earth, there are slight differences in survey points. It is necessary to know the reference point and geoid used in order to locate a point on the earth. Differences are usually small, of the order of only a few hundred metres or less.

- The most common ellipsoid used to represent the non-round earth (until about 1984) was Clarke, 1866 (of Lewis and Clarke). This ellipsoid has been replaced substantially by WG84 and other ellipsoids. Many of Canada’s topographic maps are still in Clarke 1866.
- Numerous geographic reference datums are used as survey reference points.
- Canada uses two North American Datums, 1927 (NAD27), located west of Kansas City. This datum is more or less the geographic centre of the 48 States.
- Canada is in the process of upgrading to North American Datum 1983 (NAD83). This reference datum uses a different ellipsoid to represent the shape of the earth and is based on satellite imagery. The reference point is virtual (not a real point) and derived by mathematics.
- The UTM coordinate system and other locations use an ellipsoid and reference point defined by the World Geographical Standard, 1984 (WGS84). WGS84 is the reference ellipsoid used by the GPS navigation system.
- The Global Positioning System (GPS) uses the WGS84 standard.
- The SRTM elevation database, discussed later, uses the WGS84 ellipsoid.

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These locations cause slight shifts in reference points of a map and shift in location of a specific point on the surface. The shifts are small and for the most part have limited effect on calculation or display of radio coverage.

Surveyors are concerned about the 200 m to 300 m differences between the various reference points; however, radio coverage is not significantly affected.

10.2 Latitude and Longitude

Latitude and Longitude is probably the most widely known and universally used method of locating a point on earth.

The world is divided into horizontal “slices”. These are lines of Latitude. The equator is at 0° , the north pole is at 90° North and the South Pole is at 90° South.

Points are measured north and south of the 0° equator and are referred to as North and South Latitude. Each degree is divided into 60 minutes ($'$), each minute is divided into 60 seconds ($''$), just like a clock.

The world is divided into vertical “segments” (like an orange). These are lines of Longitude. The 0° “meridian” passes through Greenwich, England (now a suburb of London, England). The 180° meridian lies in the Pacific Ocean, east of Asia.

Points are measured east and west of the 0° meridian and are referred to as East and West Longitude. Each degree is divided into 60 minutes ($'$), each minute is divided into 60 seconds ($''$), just like a clock.

The intersection of lines of Latitude and Longitude defines a specific unique location on the earth.

A location on the earth appears as

$51^{\circ} 2' 43.63''$ N, $114^{\circ} 3' 26.14''$ W.

One minute of Longitude at the equator is defined as 1 Nautical mile. One degree of Longitude at the equator is 60 Nautical miles.

However, the actual distance between lines of Longitude decreases with distance, as the earth tapers north or south of the equator, requiring the map scale to continually change as the lines of longitude merge at the North and South poles.

The disadvantage to Latitude and Longitude is that distances and map scales change, depending on the latitude of the location. Further north or south, the

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lines of Latitude represent different horizontal distances on a map, because of the taper of the lines of longitude.

10.2.1 Decimal Degrees

Sometimes Latitude and Longitude are specified in “Decimal Degrees” and do not show minutes or seconds of arc. A location may be specified as 51.1234 N and 114.0456 W.

Most computer programs, including Radio Mobile, will accept latitude and longitude entered as decimal degrees. It will convert these numbers into the required format used for calculation.

Note also that Radio Mobile latitude and longitude defaults are specified as:

Latitude	Positive numbers are North Latitude, north of the equator, Negative numbers are South Latitude, south of the equator.
Longitude	Positive numbers are east of 0°, east longitude Negative numbers are west of 0°, west longitude

10.3 Maidenhead Locator System (QRA – Amateur Radio)

The Maidenhead Locator system locates amateur radio stations into grid squares on earth using a minimum number of characters. The intent is that these characters can be easily sent and exchanged using short transmissions of voice or Morse code.

The format of the Maidenhead system is XY45xy. Alternating characters X, 4, x combine to represent Longitude and Y, 5, y combine to represent Latitude.

The Maidenhead system divides the earth into 10° (north south or latitude) by 20° (east west or Longitude) grid squares. Latitude begins counting at the South Pole; Longitude begins counting at 180° West. There are no negative numbers using the Maidenhead system.

Longitude is presented first, beginning at 180° W, with letter ‘A’. Letters increment sequentially to letter ‘R’ that completes the zone circle around the earth.

Latitude is the next character and begins counting at the south Pole with the letter ‘A’. Zones are lettered south to north (south to north pole) using letters ‘A’ through ‘R’.

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Single digit numbers appear next. First digit is again Longitude and divides the 20° zone into 2° squares. Second digit is Latitude and divides the 10° zone into 1° squares. Each grid square is 1° by 2°.

Another pair of lowercase letters (usually) further divides a grid square into sub squares. Each grid square is divided by 24 into 2.5' by 5' sub squares. Letters 'a' through 'x' show these sub squares. The same convention is used, first letter is longitude; second letter is latitude.

A location using the Maidenhead locator system appears as

DO21xb

10.4 Universal Transverse Mercator (UTM)

UTM coordinates are metric coordinates and define a location on earth by Easting and Northing (E and N). Coordinates are based on latitude and longitude, however, the distance scale is fixed does not change.

The earth is divided into 60 vertical Zones around the equator. Each zone has a longitude width of 6°. Zones are sequentially numbered from west to east, beginning at the 180° meridian of longitude in the Pacific Ocean. A UTM coordinate will always quote the zone number.

Eastings are measured in metres east of a numbered zone boundary. Northings are measured in metres north or south of the equator. Note also that the zone will be followed by a letter. Letters are assigned every 8° moving north from 80° South Latitude, beginning with letter "C" (Letters I and O are omitted). The equator is at "N", Canadian locations may be at "T", "U" or "V".

Letters indicate the approximate north-south location and are used to indicate if a location is north or south of the equator. A negative UTM coordinate does not appear. The equator is defined as 0 North.

A UTM coordinate appears as

706,277 E, 5,658,780.9 N, Zone 11U.

Most topographic maps show UTM coordinates on the map, making a location easy to find. Canadian National Topographic System (NTS) maps show Eastings and Northings in blue and include 1-kilometre grid lines to locate a specific point on the map.

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Note that there are exceptions to this description. Within the north and south polar areas, a slightly different system is used, also defined in the UTM standard. These exceptions are described in other references, including Wikipedia.

10.5 Military Grid Reference System (MGRS)

The Military Grid Reference System is based on the UTM system. It is the system used by NATO to specify a location on the earth. Radio Mobile can accept location input using the MGRS coordinate.

The MGRS locator system relies on grid squares defining a 100,000 m or 10 km square on the earth's surface. It is similar to and based on UTM coordinates, however, letters are used to indicate the location of these squares on the earth.

UTM zones are divided into 100,000 m slices and lettered from west to east using letters A through Z, omitting 'I' and 'O'. At the equator, each UTM zone requires 8 letters. Lettering is repeated when the end of the alphabet is reached. As distance from the equator increases north or south, letters are dropped from the end of the alphabet (since the lines of longitude get closer together).

North or south of the equator, squares are lettered 'A' through 'V' (omitting 'I' and 'O') in odd numbered zones. In even numbered zones, lettering begins at 'F'. After the letter 'V' the letters repeat. Letters begin at the bottom of the square and sequentially increase moving north.

The offsets allow unique lettering of each 100,000 m grid square.

Following the grid square letters are a series of numbers: 2, 4, 6, 8 or 10 digits. These numbers are the metric UTM coordinates and are the Easting and Northing numbers.

The number of digits specifies how accurate a location is. The series of numbers is split equally (even number of digits) for Easting and Northing respectively and specifies a location to the following accuracy:

- 1+1 digits specify distances to 10,000 m (10 km)
- 2+2 digits specify distances to 1,000 m (1 km)
- 3+3 digits specify distances to 100 m
- 4+4 digits specify distances to 10 m
- 5+5 digits specify distances to 1 m

A typical Military Grid Reference System location appears as:

11U QS 06277 58781

10.6 Geosys

Geosys input data is similar to UTM, however, a difference reference point is used. Geosys is a Geospatial mapping company that provides very localized elevation data. This data uses a variation of UTM coordinates.

11 Elevation Data and Elevation Maps

Elevation data is available in many printed and paper forms (printed maps), however, has only been recently available in electronic form for use by computers. First, a little history of paper maps.

In Canada, elevation data continues to be available on topographic contour maps, either in 1:50,000 or 1:250,000 scales, produced by the Geological Survey of Canada. These maps show elevation contour lines at 25 or 50 feet intervals (older maps, not yet converted to metric) and 10 or 20m intervals (newer maps). Other countries have similar topographic maps in similar scales.

Most of the Canadian contour maps were made from aerial photography pictures taken in the late 1940s and early 1950s. Over time, these maps have been updated to show city growth and other changes. However, it is not uncommon to see dates from the 1970s or earlier on current contour maps. Since elevation contours have not changed much in 50 years, this is not considered a problem.

Contour maps are available publicly for some countries; the USA uses a 1:24,000 scale standard. Some countries do not have contour maps, or do not release them to the general public.

Last resort are Aeronautical "WAC" charts (World Aeronautical Charts) that show all land areas of the world. Contour intervals are either 100 or 500 feet only. Scale of WAC Charts is usually 1:500,000, which gives very low resolution for calculating radio coverage or a point to point microwave path.

11.1 Digital Terrain Elevation Data (DTED)

During the late 1980s Canada began leading the way with electronic maps that could be interpreted and used by computer. They developed the Digital Terrain Elevation Data or "DTED" series of maps for north-eastern Alberta, near Cold Lake. These were expanded and now cover most of Canada.

The original maps took "spot" elevations every 500 m horizontally using a symmetric grid from a 1:250,000 scale map (1 cm = 2.5 km, or 1 inch = 6.3 miles).

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The second generation of maps averaged the elevation over that same 500 m square and provided the single elevation number for each 500 m square.

It was reasonably well known among geography and radio people that within a 500 m horizontal distance along the ground, larger hills were often missed (particularly in mountainous areas) and the original DTED maps were not accurate. They were not trusted for radio path design, specifically microwave point-to-point links. They were used, however, for early coverage plots of radio systems.

Canada has now completed digitizing all of their topographic maps at both scales of 1:250,000 and 1:50,000. The digital elevation data is now considered quite accurate. This work was overseen by the Canadian Council on Geomatics. Natural Resources Canada, Provinces, Territories and Municipalities all contributed to digitizing terrain elevation data.

DTED maps are available from www.geobase.ca. It is required to register to download DTED maps. Registration is at no charge. Maps are easily downloaded once registered. Select "Digital Elevation Data" from the main Geobase menu.

The data is downloaded by selecting the scale of map and the various maps required from a map of Canada.

Files are "zipped" files and must be unzipped for use. PKZip, 7-Zip or other programs may be used to decompress the files.

11.2 Shuttle Radar Topography Mission (SRTM)

In 2001, NASA took the initiative to map the elevation of the earth. They took radar images of the earth every 3 seconds of arc around the earth from the Space Shuttle during mission STS-99. This works out to an average of 90 m intervals. In the USA, they went to both 1 second of arc, about 30 m on the ground and 1/3 second of arc, about 10m on the ground.

The space shuttle was placed in a highly inclined orbit of 55° in order to observe more of the earth. Normal space shuttle orbit is at an inclination of 28° and would miss a lot of the earth's surface.

The NASA data is accurate from 56° S to 60° N latitude.

Note that there was noise introduced along with elevation data. Some of this noise resulted from the radar receiver. Some of it was due to land cover at that specific area of survey.

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There are “holes” in SRTM data. Much of the SRTM data has been processed to fill in the holes. Holes are also slowly being filled in with known elevation data.

Availability of data for northern and southern latitudes, north of 60° N and south of 56° S is becoming more and more available. Allow the program to check the Internet for additional files if required, by setting the Internet options to check for available files.

Latitudes in the far south may or may not be available. However, the following website may be used to download data for most of the world. USA and Canada data are available in 1 arc second resolution; the rest of the world is available in 3 arc second resolution.

The US and some other parts of the world are available in 1/3 arc second resolution, about every 10m on the ground. The US has developed SRTM format data from topographic maps, which are more accurate ground elevation than the SRTM surveys.

Roger has set up an SRTM database location and has filled in holes to provide an alternate data source. These files are specifically used by Radio Mobile.

SRTM data is provided in 1° by 1° squares on the earth's surface. Radio Mobile will automatically check for elevation data for the area of coverage provided a connection to the Internet is available.

11.3 Google Earth

Google Earth also has capability of displaying elevation data along a linear path.

Create a path in Google Earth. Save and name the path within the Google Earth sidebar directory.

Right click on the path, 'Show Elevation Profile'. The lower portion of the screen will show terrain elevation between the 2 endpoints. Click 'Properties;' the ends of the path can be moved and relocated while watching the effect on the elevation profile. Very convenient when searching for a link radio site.

Although Google Earth is being constantly updated with new pictures and images around the world, there can be significant differences between the surveyed map elevation data and the pictures from space displayed by Google Earth.

I use Google Earth as an approximation, then use more accurate terrain elevation data when calculating the final path.

11.4 Using downloaded Elevation Data

If data is downloaded, it must be stored in a specific file on your computer. Radio mobile must be programmed to look in this file to obtain elevation data.

Radio mobile will automatically search Roger's SRTM database files for required elevation and land cover files. It will download the file it needs to calculate the path or coverage required. Disadvantage of this is an Internet connection is required when performing radio calculations. "Stand alone" path calculations cannot be performed unless the data has been previously downloaded.

Note that, as data is downloaded from Roger's site, there is an option to store the data locally in your computer. It is then available for use the next time it is required for that location. Over time, a database of elevation data and Land cover data will be stored in your computer.

The location of elevation data files is defined in the Map Properties window when extracting a map. See section "Maps and Map Properties" for a description of setting the digital elevation map file locations.

Also, note that files are downloaded in compressed file format, or "zipped" file format. More modern versions of the Windows operating systems, Windows Vista and Windows 7, will automatically decompress these files for use by a program.

Files can be left on a hard drive as compressed files. The operating system will decompress for use in the program as required. This reduces file size on the hard drive.

Using compressed files is actually faster than manually uncompressing files after downloading. The time required for hard disk access is relatively long compared to the amount of CPU time required to decompress the files. A saving of disk space and increase in processing time results by continuing to use compressed files.

12 Radio Mobile Program Installation

There are already several available descriptions on how to install the Radio Mobile program and where to obtain elevation data from the Internet. This document outlines how to use the program and how to make it produce useable coverage maps.

If you click on "Downloads" on Roger's website, you will enter an installation page called <http://www.cplus.org/rmw/download/download.php?S=2>

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A number of steps are used to describe installation of Radio Mobile on a computer. Installation of the program requires following the instructions described.

My particular favourite is from Ian Brown, G3TVU. He has created a Radio Mobile installation program. Ian's installation program and Quick Start Guide can be found at http://www.g3tvu.co.uk/Radio_Mobile.htm Ian's program makes installation of Radio Mobile a one-step process. Many thanks to Ian for his program; it certainly made installation of Radio Mobile easier for me.

Ian's installation program will generate a working network in the United Kingdom. It can easily be located to any other part of the world to get you started using Radio Mobile.

13 First Time Program Start up Options

When Radio Mobile is used for the first time, a number of settings and options must be set for your own operating environment.

The following Option parameters may or may not be required for your operating environment. Select "Options" from the toolbar.

13.1 GPS

Radio Mobile has the ability to accept GPS data from a GPS receiver. GPS data must be in standard GPS NEMA data format.

Data can be saved in a text file for later use comparing a GPS location to a coverage plot. The various input parameters, com port, etc. are set in this window.

13.2 APRS

Automatic Packet Reporting System (APRS) is primarily an Amateur Radio application where interactive packet data (transmit and receive) is stored to indicate location of a receiver along a route or map. Map location data is shared with all other operators who may be monitoring an APRS network.

Active units can be displayed on a map and shared with other users.

13.3 Internet

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A number of Internet options must be checked and/or set under “Internet Options.”

13.3.1 Proxy

Proxy settings are used if Internet access available uses a Proxy server. Set the proxy name and port, if assigned.

13.3.2 Web Update

Web update can automatically check if there are any program updates to Radio Mobile. Check the box “Check every time when the program starts” for a verification of the latest Radio Mobile Version.

Alternatively, for a manual update, click “Help” and “Check for program update.” A dialogue box will be returned stating the version of program is either “up to date” or that a new version is available.

If a new version is available, the option is presented to download the new version. Note that downloading a new version does not change any of the program settings previously defined by the user.

There are 2 Internet locations that may be visited to check for program updates, one at cplus.org; the second at ve2dbe as shown. It is best to check both of these locations, in case one is not available at the time of checking the program version currently installed.

13.3.3 SRTM

SRTM specifies type and how SRTM files will be obtained.

- First, files may be obtained from the Internet as required.
- Second, files may be obtained from the Internet and locally stored on the computer hard drive for later use.
- Third, files may be obtained from the local hard drive only. The option is convenient when Internet access is not available.

The local file location must be specified where files will be stored when downloaded. These files will then be available for future use.

It is suggested that SRTM files, once downloaded, be stored in a common location on your computer. Within the Radio Mobile directory are folders “SRTM0.3”, “SRTM1” and “SRTM3”.

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Alternatively, the user may specify a separate directory for storage of elevation data. This directory must be identified in SRTM options so Radio Mobile knows where to obtain elevation data.

- SRTM data at 1/3 arc second (10 m elevation resolution) is available for USA and is referred to as SRTM0.3 data.
- SRTM data at 1 arc second (30 m elevation resolution) is available for Canada and other countries.
- SRTM data at 3 arc second (90 m elevation resolution) is available for most of the world.

Specifying the type of SRTM data will automatically identify the FTP (File Transfer Protocol) server.

There are 3 sites available (Site 2 is Roger's website) where SRTM data can be located when required. Roger has spent time filling in known "holes" in SRTM data, particularly along the Canada/US border.

13.3.4 Land Cover

Land cover is data of trees and other cover on the earth's surface. Options for land cover are similar to those of SRTM data.

Specify the file storage location and select the Internet FTP location.

13.3.5 Geographic Map files

Map files identify various geographic maps that may be used to merge with a coverage map. These maps will show roads and other significant points to provide a local reference for the coverage plot.

A file in the Radio Mobile program, Map_Link.txt file in the Radio Mobile directory, must be edited as described during program installation. Until this file is edited, some of the maps will be grayed out and not be available for merging with a Radio Mobile coverage plot.

Note that, after editing the Map_Link.txt file, the program must be restarted for the changes to take effect.

The following Internet map services may be available:

- Open Street Map
- TerraServer

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- Toporama
- Virtual Earth
- Google Map
- YahooMap
- MapQuest

13.4 Elevation Data

Elevation data has several parameters, “use elevation data generated by Map Properties”, meaning the program will either:

- Data extracted when Map Properties creates a map of an area, or
- Extract data directly from the stored database.

If data is extracted directly from the stored database, the file window is brought up to specify the various databases, similar to that specified in the Map Properties window. File locations must be the same as in the Map Properties window.

A very important parameter under “Elevation data” is “profile extraction”, located at the bottom of the window. Default number is 158, meaning that only 158 records will be used for any profile created. It is best to set this to 2,000, the maximum number of records currently permitted by Radio Mobile. Otherwise, coverage will not use the maximum number of elevation points and may give erroneous output when calculating coverage plots.

13.4.1 Land Cover

13 different land cover items are identified in this list. An overall average type, height and density of trees are shown, along with other types of ground obstructions.

These ground obstructions can be modified for a particular geographic area if required.

13.5 S-Unit

S-Units are a signal level method used by Amateur Radio operators. Radio Mobile uses its own standard, the standard traditionally used in North America (IARU Region 2).

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There is also an International Amateur Radio Union (IARU) Region 1 S-Unit standard that is available. IARU Region 1 represents member countries in Africa, Europe, the Middle East and Northern Asia.

Alternatively, a custom standard can be created by the user and used by the program.

S-Units are used mostly in Amateur Radio and are rarely used for commercial coverage.

13.6 Toolbar

Use this option to add or remove icons from the Radio Mobile toolbar, always displayed at the top of the screen.

A number of default icons are placed on the toolbar initially. Users may customize their own toolbar for their own functions. The toolbar can be modified at any time. Add or remove check marks on each icon box to add or remove that icon from the toolbar.

Toolbar icons can also be accessed by right clicking on gray space in the toolbar itself. The toolbar selection window will be presented.

13.7 Coordinates

Coordinates sets the input type available as coordinate data. Latitude and Longitude are always available as defaults. Other input parameters are:

- QRA, the Maidenhead Locator system, also known as Amateur Radio grid squares,
- UTM (Universal Transverse Mercator)
- MGRS, the Military Grid Reference System,
- Geosys, the coordinate reference system based on World Geographic Survey 1984 “WGS84”)

For more information, see “Geographic Coordinate Systems” for a description of the various location grids used for location of a point on the earth.

14 Program Use and Operation

14.1 Data Entry and Format

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Radio Mobile data input is strictly in metric units. Elevations are in metres, distances are in kilometres, cable lengths and tower heights are in metres. Program input parameters cannot be changed to accept or display British units.

If feet and miles are the preferred working units, there is a metric conversion section available in the program. Under the tools menu, there is a menu called "metric conversion". It is also available by typing Ctrl 'm'. Convert your British units to metric, and then enter them as program parameters.

The metric conversion icon can be added to your toolbar, very handy if metric conversion is used frequently.

Either click on "Tools", or use Ctrl 'M' to get to metric conversion. Clicking on the "units" box scrolls through a number of metric conversions, including feet to metres, miles to kilometres, dB/foot to dB/metre.

14.1.1 Metric Input Data

1. Highlight any input box used for any data entry.
2. Either click the "M" metric conversion tool on the toolbar or use Ctrl 'M' to access and use the metric conversion tool.
3. Select the correct conversion (metres, kilometres etc.), using the 'Units' button.
4. Enter your British unit (feet, miles etc.)
5. Click and the converted data will be entered into that data entry box.

14.2 File Structure

When Radio Mobile is installed (Windows operating system), the default file location is a directory called "Radio Mobile" at the top level of the "C:" drive (default file location).

Within the "Radio Mobile" directory is a folder called "Networks". Initially, there will be 3 Network folders created when the program is installed within the "parent" Networks folder:

- Base network
- Network 2
- Network 3

Base Network is a first example and has default input parameters used when the program is opened for the very first time.

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When the program is closed, the program will ask to save 3 files in the current default directory. The 3 files are:

- *.net
- *.map
- *.jpg

These 3 files are used the next time the program is opened to set the operating parameters for the Radio Mobile program. The files are always opened from the last active network directory.

It is suggested that each time a new project is started for a new geographic area, that a new network folder be created to store the data and coverage information for a site or group of sites.

When the save files dialogue box comes up, right click on each of the 3 files. The file selected can be renamed and saved in a network folder specified by the user. Perform this task for each of the 3 files. The next time the program is opened, that directory will be the previous active file directory, therefore files will be opened from and stored in that directory.

Alternative – when a new network and coverage map is created, manually use the “file” command to “Save Network As” and define a folder, the name of the network and file location. The option is then given as to where files for that network are stored. Manually using the newly created directory, all files for that coverage plot will be saved in this new location. This becomes the new default file storage location for that specific network.

This assists with your own file management to keep all files relating to that particular network in their own folder.

When exiting the program, the program will ask to save the 3 files in the new default directory. The program always asks before saving files. Manually defining a network folder first ensures the file location is defined and files can be found and reloaded as a project progresses or changes.

The last directory used always becomes the default file location when the Radio Mobile program is restarted.

If it is required to work on a different network, from the File menu, “Open Networks” and navigate to the correct folder holding the Network files required. This will become the new default file storage location, until changed again to a new or different network.

15 Program Start and check for Program Updates

Either start the program using the desktop icon or from the Start menu, Programs, "Radio Mobile".

Once the program is running, click on "Help" and "Check for Web Update". The program does get updates, changes and revisions regularly; ensure the latest version is running.

As an option, open the "Options" tab at the main menu. Select "Internet". Check the box "Check every time the program starts". Each time the program starts, it will automatically check to ensure it is up to date with the latest version.

When starting Radio Mobile, the last Network used will open in the display window. If that network is not today's task, either Open another network or create a new network as directed in this User Guide.

16 Radio Mobile Input Parameters

Before a coverage plot can be produced, 3 radio input parameters must be defined for the Radio Mobile program. In addition, a map of the area of coverage must be defined, including centre of map, map size and display resolution.

The map is then extracted from the elevation database and used as a background for the coverage plot. See Section "Maps and Map Properties"

Radio mobile radio parameters can be defined in any order; however, all must be defined before a coverage plot can be produced.

The 3 parameter names default to:

- Net 1, Net 2, Net 3
- System 1, System 2, System 3
- Unit 1, Unit 2, Unit 3

As the various input parameters for the program are defined and have specific data entered, the default names can be changed to better describe the network and various radios, units, systems and the operating parameters for the overall network.

Label names can be changed for any of the following input parameters:

- Network
- System

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- Unit

Make use of the label fields; it makes it so much easier to look at the program next week or next month and remember the setup and input parameters used for a specific network and coverage plot.

It is much easier to look at a coverage plot that has labels such as:

- Network UHF coverage
- System Base radio, mobile radio, handheld radio
- Unit Base, mobile, handheld, repeater

The 3 parameters are defined:

Net or Network defines an overall radio group and set of operating parameters. It defines the frequency band for the network. The relationships between the various units and systems are specified as Network properties.

System Defines the specific operating parameters of any radio Unit. This includes transmitter power, receiver sensitivity, line loss and antenna height, type, pattern and gain.

Unit Each radio is a Unit. This includes base stations, repeaters, mobiles and handhelds. Unit parameters define the geographic location and elevation of a radio.

Note that the 3 inputs, Network, System and Unit are related. A unit has a specific location. A Unit can be assigned to a single "System" of operating parameters to produce a coverage plot. Many Units can use the same System.

Multiple Units can be placed at the same location if multiple systems are required at a single Unit location.

See the section "Membership" explaining the allocation and relationship between Units and Systems.

Program users must ensure input parameters are correct. The program does not check for input data errors; it either will not draw a coverage plot, or the coverage plot will be in error.

For example, a VHF network may have VHF mobile, handheld or base station Units. Systems may be defined for each of the units within a network. If incorrect system parameters are programmed, such as incorrect antenna gain for a 430 MHz system instead of a VHF system, the program cannot recognize this error.

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Systems for mobile, handheld and base station or repeater units will be different and must all include realistic radio operating parameters for the frequency in use.

A common mistake is to define antenna cable loss the same for VHF or UHF systems. Cable loss increases at higher frequencies. Enter the correct System operating parameters. Specify the correct System for each Unit.

17 Maps and Map Properties

Maps in Radio Mobile refer to elevation, terrain and land cover data. Maps are specified by size in kilometres. Maps can be square or rectangular. Resolution of the map (level of detail) is specified by size in pixels.

17.1 Map Resolution

The lower right corner of the Map Properties window specifies the map resolution in metres per pixel of display area, based on map height and width in pixels and the height specified in km.

Map resolution should align with the elevation database used. If the SRTM 1 database is used, resolution should be 30m/pixel or greater. 60m/pixel is acceptable, however, 10m/pixel is not realistic as it exceeds the elevation database resolution available.

Some experimentation may be required to obtain a reasonable resolution.

17.2 Rainbow Colour Elevation

When a map is extracted, the map default is a “rainbow” colour scale map (unless “force gray scale” is checked). The rainbow of colours represents elevations across the map. This rainbow can be turned “on” or “off” and a gray scale of elevations can be selected.

At the top left of the map (use sliders along the side and bottom to get to the top left or ‘ctrl’ left click to drag the map) is a legend showing ground elevation in metres and corresponding elevation colour.

The area of map in view on the computer screen can be moved by holding ‘ctrl’ and dragging the map with the left mouse button.

17.3 Changing Elevation Colours

Default elevation colours can be changed. In “Picture Properties”, select “Rainbow”, then the “Colours” block. There are 12 ranges of elevation that can be changed from default colours to a choice of colours.

17.4 Gray Scale

Select “File” and “Picture Properties” to change the map display from rainbow to gray scale. The gray scale can also be turned “on” in Map Properties, when extracting a map file, by checking the box “Force gray scale” at the lower left of the window.

From the main menu, “Edit”, “Force Gray Scale” will also change the map to a Gray scale representation of elevation.

Generally, when plotting radio coverage, a gray scale map is preferred. Radio signal levels may be displayed using the same rainbow colour scale as the elevation display. Therefore, to avoid confusing elevation colours with signal level colours, leave the map as a Gray contrast map.

Rivers and waterways along with high hills and/or mountains can be easily seen and identified on the elevation map. Rivers show as a trench or valley, mountains show as peaks and up slopes.

Geographic maps and combining with road and other maps are discussed later; see Section “Combining with Geographic and/or Roadmap”.

17.5 “White” Picture

Another option that can be used is to draw the map with a white background, by selecting “White” in Picture Properties. It will appear as a blank picture, although it will contain the required elevation data for Radio Mobile calculation. It does not show the grey or coloured background elevation.

The picture can then be easily merged/multiplied with a road map or other map for a geographic representation of radio coverage. Coverage is displayed directly on the map without the elevation data.

Select this from the “File” menu, under “Picture Properties”. There are a number of options that can be set here, including grey elevation scale, rainbow elevation scale. Parameters for displaying grey scale, brightness, contrast and light source direction can be set using this window.

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It is also possible to check off and display various contour intervals on a map.

Larger maps can display the city database as a reference on any map. Cities are usually shown a transparent, although this image can be turned on or off by selecting the check box.

18 Status Bar Display

After a map is extracted, a status bar appears at the bottom of the map. The status bar is split into left and right sides, each displaying different information about program operation, the map, cursor and mouse position.

The left block identifies current operation. If no calculations are proceeding, the area will state "ready". If a coverage plot is in process, the current site name in calculation will be displayed.

If intersecting red dotted lines are displayed (the Cursor), the status bar displays information about cursor position.

18.1 Status Bar – Left Side

Click anywhere on the map and a set of intersecting red lines are displayed. The intersection is referred to as the cursor. The left block of the status bar displays the location of the cursor. The following information is displayed:

- Cursor position in Latitude and Longitude
- Cursor position in selected alternate display units, Maidenhead, UTM, Military Grid Reference or Geosys
- Rectangular X – Y coordinate on the map selected. 0, 0 is the lower left corner of the map.
- Elevation of the cursor point in metres.
- Type and description of land cover encountered

18.2 Mouse Pointer Location – right side

The right side of the status bar displays the location of the mouse pointer as it is moved around the map. The following information is displayed:

- Mouse position in Latitude and Longitude
- Mouse position in selected alternate display units, Maidenhead, UTM, Military Grid Reference or Geosys

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- Rectangular X – Y coordinate on the map selected. 0, 0 is the lower left corner of the map.
- Elevation of the mouse pointer in metres.

As the mouse is moved over the map, the mouse position and elevation is continually updated in the status bar.

19 Cursor Block

When the left mouse button is clicked, red dotted cross hairs will appear, along with the Elevation Grid data block.

The Elevation Grid data block is a 5 X 5 square showing the elevation of the cursor at the centre of the map grid. Surrounding squares show elevation of surrounding pixels around the cursor position. This display feature is useful when searching for the top of a hill in a small area.

20 Step by Step Operating Guide

The following is a step-by-step method of producing a coverage map using Radio Mobile.

20.1 *Extracting a Map*

Step 1 Extract an elevation map for the area of interest, where the coverage map will be produced. Click on “File”, “Map Properties”. A window will open showing the map parameters of the map. Values must be set to define the geographic area of interest.

Step 1a Select the centre of the map. This can be selected a number of ways.

Use Cursor position – cursor location is not yet defined, will give a default value based on size of the map. If a map is open, the current cursor position can be used as map centre.

World map – brings up a world map. Position cursor over the area of interest, and then click once. This location is set as the centre of the map.

Select City Name – database of cities around the world is contained within Radio Mobile. Select a city as the centre of the map. If other locations have been previously added to the city database, they will

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continue to be available as a city for setting as the centre of the map. Selecting a known city, close to the area of interest, is a good start to begin a coverage profile.

Enter Lat and Long or other coordinate (QRA, Military Grid Reference or UTM) – enter Latitude and Longitude directly. Alternatively, enter the 6 character Maidenhead Locator System square (also called the ARRL grid square), Military Grid Reference System (MGRS) or UTM coordinate.

Select a unit – If Unit locations are defined within the coverage being developed, any unit can be selected and set as the centre of the map.

Step 1b Merge pictures allows merging a geographic map along with elevation data at this step. Although the merge can happen at this point, the map picture does become very cluttered and difficult to read. It is preferable to extract the map showing elevation only, place the coverage on it and then merge in the geography and/or roadmap later. More is described later under “Antenna Patterns”

Step 1c Force Gray scale – The map extracted defaults to a rainbow colour scale showing elevations on the map. Check this box to show elevations as a Gray scale for elevation data. When a coverage plot is produced, it can show the same rainbow of colours defining signal levels.

The choice can be made here – extract the map as a gray scale format and leave the colours for radio signal levels. Contrast and brightness of the gray scale may be adjusted later to better show signal coverage on top of the gray scale map. There are also other places to make the change to gray scale if needed.

Alternatively, coverage can be defined using the Pass/Fail criteria above or below a specified signal level. See the section on “Style” for further description. Colours can then be left showing terrain elevation. Coverage is plotted on the map using a single colour.

Coverage plot colours can be selected to not obscure the terrain and geography shown on the produced map.

Step 1d Set the size of the map. Map size is calculated based on size in km and number of pixels and resulting map resolution. Map size will remain in perspective chosen for map size in km.

Step 1e Width and height (pixels) define the resolution of the map. The larger the number of horizontal or vertical pixels, the higher the resolution of the map. However, more pixels mean more processing time and longer wait for a coverage calculation.

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Size in pixels will define the shape of the map, square or rectangular.

Maximum size and resolution of the map can be up to 8,000 X 8,000 pixels, depending on the display and video card of your computer. See section on map resolution below.

Another option for map size is to define all the unit locations, then “Edit/Fit map to Units.” This will size the map so that all units fit onto the map displayed, plus a small additional area.

Step 1f Set size of the map in kilometres. Only one of the dimensions can be specified, the other will be calculated to maintain correct map aspect ratio and geographic perspective. The dimension refers to the overall width or height shown by the map when extracted.

Map resolution in m/pixel is stated in the Map Extraction window, along with the geographic corners of the map.

When extracting a map observe the pixel resolution in the lower right of the map extraction window. The map resolution should more or less match the available elevation data.

- For 1/3 arc second data, resolution should be approximately 10m / pixel.
- For 1 arc second data, resolution should be approximately 30m / pixel.
- For 3 arc second data, resolution should be approximately 90m / pixel.

The map should have a pixel resolution that meets the resolution of the elevation map data available. Either adjust the pixel size of the map or the size in kilometres to balance the resolution of the map with the resolution of the elevation map available.

Step 1g Set file locations of the elevation database(s) source. First set the format of the database, SRTM, DTED, BIL, etc. Using the Browse button, set the correct file location in the computer where your database map files are stored.

There are 5 locations defined where map information may be stored. Hierarchy of map lookup is from the bottom up.

The bottom line is the first location where the program will look for elevation data. The top line is the last location option. One way of operating uses GTOPO 30 (30 arc second data) as the first option and

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SRTM as the final option. More than 3 different elevation databases is probably overkill, unless specific maps are available for an area of interest.

As data is extracted, improved data will overwrite less accurate data. For example, if GTOPO is the first alternative (bottom line), SRTM set as the top line, SRTM will overwrite GTOPO data as it is extracted, creating a more detailed map.

Obviously, the map location on the earth may govern what computer mapping data is available for elevation data. SRTM is probably the most universal.

Step 1h If “ignore missing files” is not checked, map extraction will stop and an error message will be displayed if data cannot be found either locally on the computer or on the Internet.

Missing areas on a map, due to holes in map data or simply a missing map will show as a blue area on the extracted display.

Step 1i Extract the elevation map. An elevation map will be displayed based on the input parameters and location supplied. Either it will use a rainbow of colours showing elevation or it will be in a gray scale, depending on options set. Radio coverage will be overlaid on top of this map.

20.2 Find Peak and Low Elevation

A convenient feature offered on any map is to find the highest elevation point. Under “View,” “Find peak elevation” or “ctrl f”. The cursor will be set to the highest elevation value on the map. This may be useful for radio site selection.

A similar feature allows finding the lowest elevation on the displayed map. Under “View”, “Find lowest elevation”.

20.3 Expanding a Map to provide more detail

If you left click and hold the mouse button, and drag it across the map, a line will be drawn. If the line is dragged diagonally across a map, a small rectangle will be created along the map.

Right click within this rectangle, and the option will be presented to “Create a Zoom Picture from this selection”. Choose “yes” and a smaller, expanded, lower resolution map area is created.

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To recover the resolution, merge with the data source and a higher resolution of the smaller map area can be created. The higher resolution image can be saved as a new picture.

Another option is to edit “Fit map to picture”. This will extract a new map of the smaller area with a higher resolution of elevation data.

This is a convenient method of locating a unit on a hill (repeater location) by manually placing a unit at the cursor position.

- a. Expand the view area, left click, draw a line and expand the view.
- b. Manually select the hill from the elevation colours.
- c. Place unit at cursor position,
- d. Go back to the previous map and re extract to view the original larger geographic area, with the repositioned units.

21 Radio Stations

A radio station, either a handheld, mobile, base station or repeater is assembled using 3 major parts of the program.

1. A Unit that defines the location of the radio
2. A System that defines the operating parameters, transmit power, receive sensitivity, antenna type and height and feed line loss.
3. A Network that governs operating frequency, a Unit’s operating parameters by association with the correct system and which Units are part of a particular Network.

22 Units

A “Unit” is a radio at a defined site location. All base stations, repeaters, mobile or handheld radios are referred to as a “Unit” by the program.

Unit labels default to Unit 1, Unit 2, etc. When defining the various units for a specific application, change the name to a site name or description, “base station”, “mobile”, “handheld”, etc.

Radio Mobile calculates using latitude and longitude as positive and negative numbers. Anytime latitude and longitude locations are entered, there is a box to allow changing to the correct hemisphere of the world. The default box in the Latitude column that says “N”. Click on the box, it will be changed to “S”.

Longitude works similarly. Default box displays “E”. Click on the box; it will change to “W”.

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Defaults for Latitude and Longitude are North Latitude (+ number) and East Longitude (+ number).

Latitudes and Longitudes continue to be displayed as plus (+) and minus (-) numbers. Ensure the correct hemisphere is selected.

Radio mobile uses the convention:

North Latitude is positive (+)
East Longitude is positive (+)
South Latitude is negative (-)
West Longitude is negative (-)

Step 2 Open “File”, Unit Properties Menu.

Step 2a Change the label of the various units, Unit 1, Unit 2, Unit 3, etc. to identify the various radio units that are in the radio network. Names can be as simple as “base station”, mobile, etc., or they can be site names of repeaters. Names should be unique and define the function of each radio unit.

Elevation of the radio unit will be automatically filled from the terrain maps once the location of the unit is set and the map is defined.

Step 2b Position of any radio unit can be copied and pasted to a new radio unit. Use the “copy” and “paste” icons to do this.

Step 2c Specify the location of each unit. There are 3 ways to define the location of a unit.

- Enter Latitude and Longitude directly – if the Latitude and Longitude of the unit is known, they can be directly entered. Ensure that latitude and longitude is entered as the correct north or south latitude and east or west longitude.
- Place unit at cursor position – when a map is extracted from the database, the cursor may click on the map and identify a position anywhere on that map. Any unit can be defined at the location of this cursor position. This is handy if a mobile or handheld unit is simply represented somewhere on the map.
- Place cursor at unit position – if the unit already has a defined location, the cursor can be moved to that unit location.

Step 2d Style refers to the label and icon identifying the specific unit.

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- **Enabled** specifies whether the radio unit will be displayed on the map.
- **Transparent** makes the text label transparent so that other details can be read through the printing. Careful selection of colours will allow the label to continue to be displayed in readable format. Default text colour is white on a black background.
- **No Label** turns off the label text entirely. It is useful when using coloured icons that already define what the specific unit is.
- **Left, Centre and Right** move the text label in relation to the icon. Useful when multiple units are displayed, cluttering the viewing window.
- **Back colour** is the background colour for the text label. Default colour is black.
- **Fore colour** is the print colour for the text label.
- The slider at the bottom is a method for selecting the icon to display that particular unit. An example of the unit is always shown in the lower right of the Unit display window.
- The small + symbol to the right of the slider is another method of selecting the icon to be changed to a different icon or picture. The icon can be changed to be a car (mobile), handheld radio or numerous other icons. Using these different icons makes it much easier to identify the various units and understand the coverage plot when complete.
- “Small fonts” being checked makes the print size of each label small. If the label is to be larger as displayed on the map, leave this box unchecked.

The more labels and more units, the more cluttered the map will be. If there are many units, it is best to leave the unit labels displayed as small.

Small font is the default setting for Unit labels.

Step 2e Buttons to the right control the display and order of radio units, sort the list, etc.

Note that once units are shown on a map, double clicking on any displayed unit will bring up the Unit Properties menu and changes can be made to each unit as required.

Any radio unit can be displayed on a map or coverage area by clicking on “View” and “Show Networks”. Three options are presented,

- “All” displays all units and the links between them.
- “Units” shows only the units.
- “Lines” shows the lines linking units together.

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Step 2f When unit properties have been defined, click “OK” to close the Unit Properties window.

23 Systems

A “System” defines the specific operating parameters for a radio unit. Operating parameters include:

- Transmitter power output,
- Receiver sensitivity and threshold level
- Antenna type
- Antenna gain
- Antenna pattern
- Feed line, duplexer, filter and other losses

The default system name should be changed to a name representing each unique radio unit.

Different Systems are required as radios may have the same power output; however, antenna height, gain, cable loss, multicoupler, duplexer and filter loss may be different for various radio units. Therefore, a specific system or multiple system sets of parameters should be defined for each radio unit.

Mobile and handheld radio units have different operating parameters. Handhelds have a lower antenna gain and no feed line loss. Mobile radios may have a $\frac{1}{4}$ wave antenna, a $\frac{5}{8}$ or a higher gain collinear antenna.

Cable loss for all systems will vary with frequency of operation.

Step 3 The system variables define the operating parameters for different types of radio units in the network. This includes base stations, repeaters, mobiles, handhelds, etc.

Step 3a Change the System name to correspond with the associated radio unit.

Step 3b Enter transmit power output in Watts or dBm. The corresponding value will be automatically calculated.

Step 3c Enter receiver threshold sensitivity in either μV or dBm (not both). The corresponding value will be automatically calculated.

Step 3d Enter total feed line loss between transmitter and antenna. Remember to include:

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- Coaxial cable loss – varies with frequency and length of cable
- Duplexer used
- Multicoupler if used
- Any additional filters used that may be in line between transmitter or receiver and antenna
- Connectors – for type 'N' connectors, 0.5 dB loss is typical per connector. UHF connectors have higher loss; include 1.0 dB each for these connectors.

Step 3e Antenna type – enter the type of antenna used. Several types are available from the library in Radio Mobile.

- Omni antennas have a perfectly circular pattern.
- Cardioid antennas represent a typical offset pattern using multiple dipole antenna.
- Ellipse antennas represent a bi directional offset multiple dipole antenna.
- Dipole antennas represent a slightly shifted omni pattern, characteristic of a dipole, side mounted to a pipe mast. It is very close to an omni pattern.
- Yagi antennas are directional antennas, having a main directional forward lobe and typical Yagi side lobes.
- Corner Reflectors are also directional, with significantly reduced side lobes.

Note the “View” Option. It can be used to observe the antenna pattern used. The pattern represents the antenna pattern, plus antenna gain as dictated by the selected antenna pattern. It also includes the direction of the antenna as specified by antenna azimuth.

Step 3f Antenna gain is available from the manufacturer. VHF and UHF systems usually specify antenna gain in dBd (gain relative to a dipole). Microwave and spread spectrum systems usually specify gain as dBi (gain relative to an isotropic radiator). Ensure the correct field and value are entered; the corresponding gain value (for either dBi or dBd) will be automatically calculated.

As an additional note, handheld antennas are usually a negative gain. First, they are usually shorter than a quarter-wave length. Second, they are next to the human body that reduces their efficiency.

Step 3g Enter antenna height in metres. Note that this antenna height is then defined for this system. Antenna height can be temporarily changed in several modules, when performing a coverage plot, etc.

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Step 3h Typical cable loss is entered in dB per metre for the cable and frequency in use. If the antenna is changed in height manually, for a specific unit or site in either the coverage or other section of the program, this additional cable loss will be added to or subtracted from the originally specified cable loss for default antenna height. e.g. if the original antenna height was defined at 30m and it is raised to 40m to test a different antenna height, the difference of $40\text{m} - 30\text{m} = 10\text{m} \times \text{cable loss per metre}$, will be added to cable loss.

This is convenient if antenna heights are manually set for individual sites.

Step 3i System data can be added to or removed from the Radio Mobile system database. If multiple systems are calculated, with similar system parameters, the system file can be stored in the program library for later use and lookup for other networks.

24 Antenna Patterns

Antenna patterns are stored in the “antenna” directory, under the Radio Mobile directory. Antenna patterns are stored as an “.ant” file. It is possible to create other antenna patterns for use by the program, if another antenna pattern is required.

Data format is a single column of numbers specifying gain of the antenna (relative to 0 dB as maximum gain) at 1° increments around the antenna. The first number is the 0° maximum gain of the antenna. The gain is set as the 0 dB reference point. All other gain parameters are generally negative, representing lower gain than the front main lobe of the antenna.

The first 360 data points represent 1° increments clockwise, horizontally, the “E-Plane”, from a vertically polarized antenna (first 360 data points).

The second, beginning at line 361 is the H-Plane pattern (vertical gain beginning at +90° above the antenna, ending at -90° below the antenna). This covers the remaining 180 data entry points.

Format of data is extrapolated to a 3 dimensional antenna pattern by Radio Mobile.

Ian Brown, G3TVU has created an antenna utility to create different antenna patterns if required. The utility is located at <http://www.g3tvu.co.uk/AntDiag.xls> and is an Excel spreadsheet. Antenna pattern data can be entered at 10° points for both the E-plane and H-plane of an antenna. Intermediate 1° angles are extrapolated by the spreadsheet.

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24.1 Use of Antennas

Antenna patterns are a relative pattern, based on adding the gain of an antenna, as specified by the user, along with the defined antenna pattern, based on 0° Azimuth (True North).

Changing the azimuth of the antenna pattern from 0° will move the antenna pattern to display the correct azimuth.

Any of the directional antennas can be used as part of a system. Alternatively, a user antenna pattern can be used, provided it is in the directory along with other antenna patterns. Two things to keep in mind.

When Radio Mobile calculates coverage, the specific direction between base station and mobile station is calculated. Path calculation takes into account the gain of the antenna in the direction specified.

Ensure that in the Network / Membership window, both the base station/repeater antenna and the mobile antennas are pointing in the correct direction. A coverage plot may be incorrect if an antenna were pointing in the wrong direction and the gain in that direction was incorrectly taken as it may be lower than maximum expected.

This may be the case when an omnidirectional antenna is used at a repeater station and Yagi antennas are used at base stations that are to communicate with the repeater. Each individual Yagi antenna at a base station must be pointed at the repeater to give correct coverage plot.

Also, ensure that the polarization of all antennas is set correctly. Incorrect polarization between antennas will lead to incorrect coverage plots.

24.2 Omni Antenna use

An alternative to this is to use an Omni Directional antenna and set the gain parameter to equal the gain of the directional antenna in use. The mathematics of the path calculation remain the same and it is not necessary to ensure that the antennas are pointing in the correct direction.

25 Network

A Network is the overall collection point for the base stations, mobiles, handhelds, etc. within a radio group. It also defines the relationship between Units, Systems and Networks. For each single or combined site coverage plot, all

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pieces of the puzzle are collected together in a “Network”. The network defines the relationship between components, which radio uses which system, etc.

Each network can be thought of as a coverage “Project”, possibly in a different geographic area or for a different client or customer.

If, for example, coverage of 5 repeaters in a city will be plotted, all must be defined and be members of the same common “Network”.

The Network defines the frequency band for radio coverage. If a coverage plot is required for both a VHF and UHF system, they must be defined as different Networks; each network defined as a different frequency band.

Note that the same “units”, base stations, mobiles and handhels may be used in different networks. It is quite possible to name Net 1 as “VHF” and Net 2 as “UHF”. These can be used to provide coverage maps for different frequency bands for the same area and using the same mobile or base station units to show coverage.

A mobile radio unit, for example, may have the same power output and receiver sensitivity at VHF and UHF frequencies, however, the antenna and feed line loss will be different. The Units can be common; however, units will have a different “System” for each Network.

Step 4 Create a New Network – defines the database sizes and quantities available for the completely New Network. Defaults are:

Nets	25
Units	50
Systems	25

These sizes are defined when a Network is created. Default numbers are large enough for most applications; however, there are always exceptions. If more components, base stations, mobiles etc. are required, it must be defined at this stage.

Size of a network, allowing more Units, Systems or Networks can be changed later; however, all previous coverage plots and pictures will no longer be valid for the modified network.

Step 4a Open an Existing Network – If a Network has already been created, it may be reopened using “Open Network”. If changing coverage areas or moving to another coverage project, opening a new network will change the default files and directory to the next project.

25.1 Changing and Viewing Networks

Open 'Tools' and click on 'Network Manager'. Networks, Systems and Units can all be viewed in this window. The relationship between the Network, System(s) and Unit(s) can be viewed, i.e. the members of a given network are shown in a table.

Example, for a defined VHF network, specific Systems and Units are associated with that specific Network.

Other Networks may have other Systems and other Units associated with them.

This is useful to check for errors. It is easy to determine from the Network Manager that a Unit, defined as a VHF Mobile radio, is actually associated with a System called a UHF base station, leading to an error in coverage.

At the top of the Network Manager screen is the maximum number of Networks, Systems and Units defined in the current Network File.

If more Networks, Systems or Units are required, the maximum numbers can be redefined. Enter a corrected or revised number in the appropriate box and click on "Apply".

Note that if any of the Network quantities are changed, all existing coverage plots will become invalid and must be redrawn.

25.2 Network Properties

Step 5 Open Network Properties and begin defining and entering data to the one or more Nets. Click on "Parameters" to access the nets.

Step 5a Input parameters for each net. Change the name of the net to the specifics of that particular coverage plot e.g. "VHF" or the overall name of the group of repeaters, customer or user.

Step 5b Enter the frequency range in MegaHertz. Note that 2.4 or 5.8 GHz systems should be entered as "2400" or "5800" respectively. The program mathematics operates using MHz.

Step 5c Enter polarization – polarization does affect coverage slightly and must be entered as the correct value.

Step 5d Mode of Variability – This refers to probability and fade margin. The Radio Mobile program defaults to "Spot", 70% reliability of coverage. Spot coverage is a good starting point. Depending on the service or client that

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uses this radio system, reliability can be specified as a higher number, with correspondingly small coverage areas.

Other coverage options are available, as “accidental”, “mobile” or “broadcast”. These represent different reliability parameters and will provide slightly different coverage results.

Step 5e Select “Mobile” and change parameters for % of time and % of situations accordingly. Both parameters should be set to the same percentage. The percentage refers to fade margins described earlier.

E.g. Standard Commercial Radio Service is acceptable at 50%. Ambulance or Fire Service should increase this number to 90% and possibly higher. Numbers below 50% may give a coverage plot that is overly optimistic and may require a handheld user to “pick a site” for consistent communication.

Step 5f Additional Loss – Can be added if operating inside a dense city or dense forest. This is partly open to judgement of operating parameters. Dense cities include large cities (in Canada, Toronto, Montreal, Vancouver or Calgary). Density of the city is related to the number of tall buildings around a transmitter site. A smaller centre will have less building density and correspondingly smaller effect. The city parameter adds loss for buildings that are not on topographic maps, however, will reduce coverage in the downtown city core, as would be expected.

Forest increases humidity (deciduous trees) and/or becomes an obstruction (coniferous trees). A high density of trees around a radio site will reduce coverage if radio waves must travel through trees between transmitter and receiver. If the antenna is installed on a tower that is taller than the surrounding trees, effect will be minimal.

However, as radio waves travel and get closer to the ground as the earth bends, they begin to go through trees and are attenuated. If trees are known to exist, it is best to include them when performing a coverage calculation.

Note that deciduous trees only affect coverage when there are leaves on the trees. In winter, coverage will improve in a deciduous forest. Remember that leaves reappear in the spring, again reducing coverage.

Specific example, pine tree needles are about the same wavelength as 850 MHz cellular signal frequencies. There is a significant decrease in expected cellular coverage in a pine forest that was discovered in the early days of cellular telephones.

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These parameters may also be adjusted in the Land Cover parameters window.

Step 5g Surface Conductivity, Ground conductivity and Relative Ground Permittivity are defaults and are applicable to most of Canada. Exceptions are coastal regions, complete over water paths or in the Arctic. The Geological Survey of Canada website is a good source for these numbers, for use around the world, if producing coverage maps for other areas.

Step 5h Climate – Most of Canada is “Continental Temperate”. If coverage is in a maritime area, desert, Arctic or high humidity equatorial region, select the correct option.

25.3 Topology

Topology refers to the overall system layout and communication methods and architecture of a radio network.

Voice networks are expected to transmit messages so that others can hear them the first time. Repeat transmissions are used in the real world, simply because a user requests a repeat voice transmission. It is normally expected that a voice message is transmitted only once.

Voice communication is similar to being in a very noisy room, trying to carry on a conversation. If a person constantly has to repeat a statement because it cannot be heard above the noise in the room, communication is not reliable.

Computers, on the other hand, do not care about repeat message transmission. Until a message is received with no errors, a computer can ask for a message re transmission as many time as required to “get the message through”.

There are 2 other topology methods available within Radio Mobile.

Data Net, Star Topology has 1 master station communicating with several distant outstations. Outstations are “slaves” and only respond when information is requested from them. They cannot initiate a message on their own. Some data transmission protocols have available a Report By Exception (RBE) mode, that allows a slave station to originate a message. Communication is usually polled by the master station.

The biggest thing to keep in mind is that there is no collision detection or “traffic cop” maintaining order among message traffic. If a collision occurs, a message will be corrupted and the Master station has to poll all the outstations to find out any missed message traffic.

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Data Net, Cluster (Node/Terminal) is similar to an Ethernet network with routers. Essentially, any radio unit is assumed capable of communicating with any other radio unit. A node in the system can act as a repeater when necessary. Messages are addressed and rely on a network to get a message through using any available nodes.

Radio Mobile will calculate paths, using as much iteration as necessary, to find the shortest successful path between units. If no path is found after the maximum number of iterations is reached, a link will be shown in red.

Step 6 Select the radio network technology being used.

- Voice Net
- Data Net, Star topology
- Data Net, Cluster

Two other options are presented that may be used.

Step 6a Check the box “If a unit is set to Master, set all others as Slave”.

Depending on the network topology, a slave can only communicate with a master.

Step 6b Check the box “Slave unit must have a directional antenna pointing toward a master”. This will correctly point an antenna at its master unit.

These check boxes do not have to be used; they are there for convenience and assistance setting up the program.

25.4 Membership

Membership defines 3 parameters.

First, it defines all the active units that are part of a specific network. Select a specific network and place a check mark in the active units for this particular calculation. This is useful if a coverage plot is required plus or minus one or more specific sites. It allows the difference in coverage area to be displayed plus or minus 1 or more sites simply by checking or not checking the sites within a network.

Note that Units can be common between several networks. A unit represents a location. The parameters for that unit can be defined within several active networks.

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Each network defines a frequency band. If two different networks are defined, for example, one for VHF, the second for UHF multiple coverage maps can be created, one for each band or network. Units can be shared between networks.

Ensure that the correct Units are selected as members of the correct Network and that the correct System is defined for each unit in each Network.

Second, membership identifies the System associated with each unit. A system contains the specific operating parameters for a unit. A system specifies transmit power, receiver sensitivity, transmission line loss, antenna type, gain and height.

Each unit must have an associated System, defining the complete operating parameters for that unit.

As an example, VHF and UHF radios have different operating parameters, antenna gains, cable losses etc. and therefore must be defined as different Systems.

Third, it defines the antenna direction for each unit, if a directional antenna is being used. Antennas may be fixed in a specific direction, or they may be “aimed” at a unit, for example, a point-to-point station.

Step 7 Define the membership of various units within each network. Select a network and check off the units that are members of that network. It is best to work on 1 network at a time.

Step 7a Define the communication relationship for each radio unit. The section allows for activating various radios and sites within a network, depending on the coverage plot and calculation required. Each active “unit” must have a checkmark to make it a member of that network.

Note that it is often wanted to have a coverage plot of mobile coverage and handheld coverage. If a mobile and handheld unit and systems are defined for each, coverage can be plotted by checking the mobile unit as “active” and producing a mobile coverage plot. Then uncheck the mobile unit, check a handheld unit as “active” and a coverage plot for a handheld can be calculated and displayed.

Similar parameters can also be used in the coverage module.

Coverage may be shown as originating from a base station or repeater transmitter site and a mobile or handheld radio as the receiver. A reverse calculation can also be performed using the base station as the receiver and the mobile or handheld radio as the transmitter site.

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This is useful when balancing “talk out” with “talk in” capability.

Step 7b Define repeater radio units as “Command”.

Step 7c Define mobiles, handhelds and fixed base stations that communicate with repeaters as “Subordinate”

Step 7d Define data repeaters in a mesh data network as “rebroadcast”.

Step 7e Place check marks in the active units that are being used for coverage calculations. Any unit not checked as being “active” in this screen will not be calculated as an active site. Note that a unit may appear on the map as a reference location point, however, it may not be used for calculations.

Step 7f Define the system to be used for each radio unit. Systems can be named to represent the system function so that it is easier to relate systems and units.

Step 7g Define the antenna height, if it is different than specified by the system parameter. Antenna height is usually defined as part of system parameters; however, an override is available here, if required. It is sometimes desired to plot the coverage from a site using several antenna heights. The override feature can easily be used for each of these heights.

Step 7h Define the antenna direction. Antennas can be “fixed” and point in a specific direction relative to True North. They can also point at a specific site.

To see a proper coverage plot, when using directional antennas, ensure the antenna is pointing in the correct direction.

25.5 Style

Style defines one of the ways a coverage plot can be presented. Coverage can be shown using 3 methods.

- Coverage can be shown using a pass/fail criteria, and single colour on the map, based on receiver threshold setting (sensitivity).
- Coverage can be shown using multiple colours (referred to as “rainbow” in the program) showing the variation of calculated signal levels around the map. A legend of 12 colours shows how the colours relate to calculated signal level.
- Style uses 3 colours, typically Green for good coverage, Yellow for marginal (within +/- 3 dB of receiver threshold) and red for no coverage.

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The receiver threshold refers to receiver threshold defined in the selected System.

- Another method for “Style” is to set the > (greater than) and < (less than) values equal to 0. The yellow area will not be plotted. The map will show red as “fail” and green as “pass” over the entire map area.

Actual method is selected in the program as part of the input parameters before calculating radio coverage.

Step 8 If style coverage is used, select method of showing “Line of Sight” coverage.

Step 8a Select the criteria for coverage display.

As an example, if receiver threshold is specified for the System as -90 dBm, then,

- Signals greater than -87 dBm (-90 +3 dB) are shown in green (good coverage)
- Signals between -87 dBm (-90 +3 dB) and -93 dBm (-90 –3 dB) are shown in yellow (marginal)
- Signals less than -93 dBm are shown in red (no coverage)

Step 8b The 3 dB criteria can be modified to any value required. Set the difference in signal level from the receiver threshold. It can be set to any number from the 3 dB default.

Step 8c When finished entering all these parameters, click on “OK” to close the Network Properties window.

25.6 Showing Units and Links

After the Network, Systems and Units are defined and the map extracted, they should be displayed on the map to verify that the map is the correct size for the units within the coverage area.

Click “View”, “Show Networks”. Three options are offered.

All – Shows both the units and links connecting all enabled units together.

Units – Shows the units as they are positioned on the portion of the map shown. Note that if the map area was originally defined as too small for the defined units, units that are “off the map” will not be displayed. Be aware that you may have to use horizontal and vertical scroll bars (or drag the map using ‘ctrl’ left mouse) to see the entire map and all of the units.

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Note that under Unit Properties, it is possible to “enable” a unit. Removing the checkmark disables that unit for calculations and coverage.

Again, this is useful, if different units have been defined, for VHF and UHF systems. Different mobile radios (Units) may be defined, each having the correct antenna gain, cable loss and radio parameters for the respective systems.

Lines – Shows point to point links only between all enabled units.

26 Producing a Coverage Map

The map displayed is the previously extracted elevation terrain map. Next step is to overlay radio coverage on top of that map.

Elevation maps show elevation using a rainbow colour scale. When coverage is plotted, the 2 colour scales will be mixed up and colours showing elevation and coverage cannot be differentiated.

26.1 Three Choices for Coverage display

The program has the ability to change the map to a “gray scale” and will automatically request this change before calculating radio coverage. It is best to show the map as a gray scale if rainbow coverage is requested. Coverage signal levels can then use the rainbow of colours to show signal levels, rather than elevation.

If coverage can be plotted using pass/fail criteria and a specific defined signal level. This level can be displayed on the map as a single colour. Elevation and coverage colours will not be “mixed up”, as coverage will be shown as a single colour only.

Coverage can be shown using parameters defined under “Style”. Style uses 3 colours,

- Green, for good coverage,
- Yellow for marginal (within +/- 3 dB, or as specified, of receiver threshold),
- Red for no coverage.

26.2 Gray Scale

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When the program requests a change to the gray scale, it may or may not produce a useable result. The gray may hide some details and not display others in a manner that is visible and useable.

The gray scale can be changed and modified by changing the contrast, brightness and illumination source. This may take some experimentation, however, will eventually produce a better result.

Step 9 modify the gray scale parameters as required to see the map. Under the File menu, click Picture Properties. The 3 main parameters that can be changed are contrast, brightness and light azimuth.

Contrast and brightness are similar to setting parameters on a black and white picture.

Light azimuth is the direction of illumination by a virtual sun. Shadows on the black and white image can be moved to suit the overall map display by changing the azimuth of the virtual light source.

All of these may take some experimentation, depending on terrain and parameters of the specific map.

The picture defaults to a gray scale so that coverage may use the colour rainbow to display coverage. Elevation can be displayed as a colour rainbow if coverage is displayed as a solid colour overlaid on the map.

26.3 Other Display Options

Numerous other display options may be changed using this screen. Experiment with the program and its display to produce what is wanted.

- Cities can be displayed.
- Elevation can be changed back to the rainbow display.
- Elevation contour lines can be added to the map at various intervals; 1m, 2m, 4m, 10 m or 20 m contours can be shown.
- Stereo display is more for cartographers examining a printed map with stereo glasses to show a 3D image.

26.4 Add Radio Coverage

Step 10 Select Tools, Radio Coverage and select either “Single Polar” or “Combined Cartesian”. First, check if the “Draw” option is available as an operating button. If it is grayed out, one of the input parameters is missing, a

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unit is not “enabled” or membership is not correctly defined. Coverage cannot be calculated until the error is found and corrected.

Step 10a Select a mobile unit. Coverage is calculated for a specific defined mobile or handheld unit or base station.

Step 10b Select a Network. Coverage is calculated for the selected network; VHF, UHF or other defined frequency band coverage must be selected.

These 2 steps effectively define the transmitting station (Network) and receiving station (Mobile Unit). These specify input parameters for performing the radio coverage calculation.

26.5 Polar Coverage

Step 11 Two options are available to produce a coverage calculation. Note that coverage will be sequentially calculated for each base station unit selected, defined as “Command” and “enabled” or “checked/selected” in the Membership menu. This is often a reason why the “Draw” option may be grayed out; the correct base station is not selected under “Membership”. For coverage to be calculated, each unit in the calculation must be defined as “enabled” under “Unit Properties”.

Step 11a Single polar coverage calculates coverage using radial lines centred on each selected base station. As the distance from the base station increases, distance between radial lines increases and coverage resolution is reduced. This coverage calculation is faster to perform; however, resolution can be reduced at the extremities of the coverage plot. Correct selection of radial angle can be used to minimize this error.

Combined Cartesian coverage calculates signal levels using an X-Y coordinate system. Resolution is the same all over the map; however, the calculation process takes significantly longer.

Polar coverage can be used for a “quick and dirty” plot; Combined Cartesian can be used for the detailed and final map.

Step 11b Select the link direction. Either plot coverage from base station transmitter to mobile receiver or from mobile transmitter back to the base station receiver.

A “worst case” of either direction can be selected in Polar coverage or route coverage. See description under “Other notes about Coverage Plots”. This option is not available in Combined Cartesian coverage.

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Step 11c Select the type of plot. The default is a range of signal levels represented by a rainbow colour scheme.

Several colour schemes are available. Select any of 7 “colors.dat” file from the Plot coverage section in Polar Coverage.

Check the rainbow box for a rainbow colour display; colours representing various signal levels. Colours can be manually changed by clicking on “Rainbow” and selecting the “Color” box.

A signal level legend can be displayed on the coverage plot showing the range of signal levels between the lower and upper defined signal levels.

Along with the signal level colour menu, the legend display can be turned on and turned off and positioned in any of the 4 corners of the map plot.

Polar Coverage also allows selection of an “Auto set” box that will evenly distribute signal levels across a rainbow of colours from lowest to highest signal level calculated.

“Fill” fills in the successful coverage area based on the defined signal level in the “From” box with a solid colour. Acceptable coverage is shown in yellow (default colour) Colour can be changed from the default yellow by clicking on the “Colour” button.

The “From” and “To” boxes will plot signal levels in a single colour between the lower and upper levels specified. Note that signal levels above the “To” maximum and signals below the “From” minimum will not be displayed.

Click on the Network Style box and coverage will be displayed as 3 colours as defined in “Style” under Network Properties. Colours used are red, yellow and green (default).

Display colours for Network Style coverage use the reference signal level defined as receiver threshold for that particular System.

Green – ≥ 3 dB more than specified receiver threshold.

Yellow – within the 3 dB “window” between these signal levels.

Red – ≤ 3 dB less than specified receiver threshold.

All colours can be changed before producing a coverage plot to change a coverage display.

Step 11d Select threshold display type. Four reference options are offered:

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- **S-Unit** – may use the Radio Mobile default values or IARU Region 1 standard values. Specific S-Unit criteria set can be programmed to calibrate your own “S-meter”.
- **dBm, μ V** are conventional radio coverage parameters used in industry. Use the boxes to the right to set the range of values displayed by the coverage plot.
Note that receivers for spread spectrum and microwave radios are usually specified in dBm, while mobile and handheld radios are usually specified in μ V. Select a coverage sensitivity parameter that relates to the coverage plot required.
- **dB μ V/m** is typically used to specify broadcast contours from either a Broadcast Radio or a television station. dB μ V/m plots use mobile antenna height to define the receiver elevation Above Ground Level.

Step 11e Select the length of radials used for polar coverage calculation. The program will calculate coverage along the length of each of these radial lines. They may be selected to be the same length as can be displayed on the map, or they may be shorter, allowing display of several repeaters and overlap areas on the same map.

Step 11f select the azimuth for radials. 360° will give a complete circle. Use either 0.1° or 0.5° spacing for radial angular calculation. The more radials and smaller the angle between them, the higher the resolution, however, the longer the plot will take.

Step 11g Antenna height at the central station can be changed, or the antenna programmed in the System associated with each radio unit may be used. Note that changing it here will change the antennas for all sites. Changing and selecting antennas as part of a System for each radio unit allows different antennas to be used at each site. Useful only when all antennas at all sites are the same.

Step 11h Check “Draw” and the antenna pattern will be drawn in its own window. This is simply to check what is being used for antenna pattern. Close the antenna pattern window before proceeding.

26.6 Combined Cartesian

Coverage using “Combined Cartesian” uses an X-Y rectangular method of calculating coverage. Combined Cartesian coverage has many more features than Polar coverage.

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Advantage of this is that resolution of coverage plots does not change across the entire coverage plot. Disadvantage is that it takes longer to produce the coverage plot.

Similar input parameters must be used as with Single Polar Coverage.

Step 12 Select the Fixed radio units that will be used to provide the combined radio coverage. One or more sites can be selected to give coverage from one site or coverage from several sites combined. Coverage will be sequentially calculated for each of the unit sites specified as “Command” and checked off as “active” units.

Antenna patterns for each base station site are set to their default values from the system parameters; they can be changed here if desired for each individual base station.

The antenna pattern can be viewed in a separate window, to see what pattern is being used.

Step 12a Check the antenna height. It may differ from what was set for the system. This is useful if various repeater sites have various antenna or tower heights. Other parameters can also be adjusted here.

Step 12b Set the background colour of the unit label. This is useful if selecting a specific site among a number of sites. Changing the background colour makes it easier to identify.

Step 12c Select mobile unit. This could be a previously defined mobile radio handheld radio or base station unit. Consider this the “receiving station”.

Step 12d Select the network. This can be a previously defined VHF, UHF or other defined network.

Step 12e uncheck the “use network antenna” if antenna settings are to be modified, otherwise the program uses antenna pattern from previously programmed system parameters.

Step 12f select link direction, either from base to mobile (mobile receive) or from mobile to base (mobile transmit).

Step 12g Select signal levels to plot. As before, signal levels can use 4 different reference options.

- S-Unit – may use the IARU Region 1 standard values or Radio Mobile defined values, or specific criteria “Custom” can be programmed to calibrate your own “S-meter”.

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- dBm, μV are conventional radio coverage parameters used by industry. Use the boxes to the right to set the range of values displayed by the coverage plot.
- dB $\mu\text{V}/\text{m}$ is typically used to specify broadcast contours from either a radio or television station. Sometimes linear values of $\mu\text{V}/\text{m}$ are used.

Step 12h specify the range of signal levels for units selected. Either a minimum level can be specified, or a range of values can be specified in the units chosen. If a range is wanted, check the box that allows a high range level to be specified. Enter this higher level in the units specified.

Step 12i specify the type of display required, either a pass/fail criteria (default) using a solid colour, or rainbow that presents signal levels as a rainbow of colours. Pass/Fail criteria uses the minimum level specified in the “From” box.

Alternatively, Network Style can be used, providing 3 colours, Red, Yellow and Green described previously.

Step 12j specify the resolution for the plot. The default is 5 pixels that gives a somewhat poor quality image, particularly in rainbow mode. Reduce this number to 1, 2 or 3 pixels to give a better quality image. Note that computer processing of the plot will take correspondingly longer to obtain a more detailed image.

How long? Depending on computer processing power and resolution defined, it can be up to an hour to obtain the plot output.

26.7 Zoom to a smaller area

When performing a coverage plot using the Cartesian method, if a small area of the plot is used to zoom in; a coverage plot can be performed on that small area to give a better view of a small area.

27 Other notes about Coverage Plots

1. Check the “Complete.wav” box for any coverage plot. A warning sound will be played when the coverage calculation is finished. This is useful for large coverage plots that take a long time to plot.
2. Often, the map display is larger than the computer screen. Hold down “control”, left click and the map view can be dragged to show a different area of the map.

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3. When a coverage plot is complete, the tower sites that were used for the coverage calculation are displayed in Bold Font.
4. Although coverage plots can be printed directly from Radio Mobile, for editing, changing the size of coverage plots, etc. it is best to copy the plot file as a .jpeg or .png format file into a picture editing program.
5. When printing a coverage plot, the signal level defined as the range (for a rainbow plot) is defined in the coverage window. Various colours default to various signal levels. Signal levels, of the range originally specified are evenly distributed across the 12 colours available.

Colours representing 12 signal levels can be changed in the polar coverage module.

- a. Open a polar coverage plot.
 - b. Set the threshold signal method, S-units, μV , dBm or dB $\mu\text{V}/\text{m}$.
 - c. In the Plot area, Select "Rainbow Colour".
 - d. In the Plot area, select "Colour".
 - e. The default colours for 12 different signal levels (in units selected) are shown. Colours can be changed and modified by selecting any of the 12 levels and defining them as various signal levels.
 - f. There are several (7) predefined colour palettes that can be used for plots. They are labeled "color.dat", "color0.dat", "color1.dat", etc. and can be selected from the polar plot window. They are simply a different list order of rainbow colours.
6. A graphical screen shows placement corner location of the rainbow signal level legend. The legend can be placed in any corner of the coverage plot. Ensure that it is not in the same corner as the elevation legend. The elevation legend defaults to the upper left corner of the plot.
 7. **A distance scale** can be placed on the map to assist with determining relative distance and map scale. Click 'Edit', 'Distance Scale' and select the position to place this scale using the graphical corner representation. The distance scale can be placed on any of the 4 corners of the map.

The distance scale can display a number of distance scales, metres, kilometres, Nautical miles, feet or statute miles.

8. **Map Corner Lat and Long** can be displayed on the picture. Select "Edit" and "Corner Coordinates". Each corner of the map will have the Lat and Long displayed, both in Degrees/Minutes/Seconds and Decimal Degrees.

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9. **Link direction** – in several calculations, it is possible to specify “link direction”. Coverage can be plotted from a repeater to a mobile or handheld or the reverse can be plotted, from mobile or handheld back to the repeater.

This direction calculation is used to balance “talk out” and “talk in” of a repeater station.

This is important and a useful comparison. If a radio system is designed so that mobiles and handhelds can receive a base or repeater, it is also important to ensure that the same mobiles and handhelds can “talk back” to the base receiver. Proper radio design includes analysis of the “talk back” path to more or less match signal received at a mobile or handheld from a repeater with signal received at the repeater from the same mobile or handheld radio.

There is little point to designing a system with good repeater coverage, if distant radio units cannot “talk back” to the repeater for communication with others within the repeater coverage area.

10. To show set coverage parameters, such as a contour at 5 μV and 1 μV , run the coverage calculation more than once, each with a different colour and threshold criteria, using the same map. Specify a different colour for each signal level plot and the coverage parameters will be overlaid on top of each other.

This may also be used to show handheld versus mobile coverage from the same transmitter site. Simply run the coverage plot using different radio units and systems for the same map. Select a different colour to show the different signal contour levels.

28 Combining with Geographic and/or Roadmap

Once the coverage map is developed, a geographic map can be combined or overlaid to better show the coverage area and location.

Internet connected to the computer is required for this step. The program obtains map data from the Internet and must have the network available to obtain geographic data.

The various units and base stations can be displayed on the map at any time. Click on “View”, “Show Networks” and select units or lines/links to be displayed.

If what is displayed is not what is wanted, 3 steps can be taken to start over and recalculate coverage.

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1. File – Map Properties, extract a new elevation data map.
2. Tools – Radio coverage and replot the radio coverage.
3. Edit – Merge Pictures to add the geography to the coverage map.

Step 13 Select “Edit”, “Merge Pictures”.

The intent of this is to merge the coverage plot with a number of different map options from the Internet. Several commonly available maps are available and can be selected.

Step 13a choose the method of combining the coverage map with the geographic map. There are 4 options. The options refer to how the computer combines the maps mathematically.

The map_link.txt file must be edited to allow use of the various Internet map files.

- Copy – replaces and overwrites data from the coverage map with data from the geographic map
- Add
- Multiply – multiplies values from the elevation map and geographic map.
- Bitwise

This will take some experimentation. There are differences in display; however, they are dependent on location and geographic maps selected. Experiment with several to obtain the desired output. Copy, for example, will overlay a roadmap over top of the coverage map.

Step 13b Save the coverage plot including the map, to a named .jpeg file. The coverage plot merged with a map is not automatically saved when the program is closed.

29 Top of Screen Toolbar

There are numerous icons along the top “toolbar” of the working screen. These can be added, subtracted and customized by the user.

1. Select “Options”, “Toolbar”.
2. Add or remove checkmarks from any of the function icons. They will be added or removed from the toolbar at the top of the screen.
3. Changing, adding or subtracting icons and functions from the tool bar can also be selected by right clicking on the gray area of the tool bar itself.

30 Hot Keys

A number of “Hot keys” are defined within Radio Mobile. Menus may continue to be used; however, the Hot Keys will access various locations in the program more quickly. A list of these hot keys follows.

- F2 opens Radio Link.
- F3 opens Polar coverage.
- F4 opens Cartesian coverage.
- F5 opens Find Best site.
- F6 opens Route coverage.
- F7 opens Merge pictures.
- F9 opens Adjust map to picture/selection.
- F11 opens Visual coverage.
- F12 opens Visual horizon.

31 Point to Point Radio links

Another aspect of radio path propagation is a point-to-point link. These are used when linking repeaters together, for example. Usually different antennas and frequency band are used. Radio Mobile provides the ability to predict receive signal level of these point-to-point links.

Many of the sites will be common and can be used; however, frequency band and systems (gains and losses) will probably be different. If another network is specified and used, frequencies can be changed and additional systems can be defined for the point-to-point links, using the same Radio Unit locations.

Step 14 Input is virtually identical. A few changes should be made to separate these links from radio coverage.

Step 14a Identify a different ‘Net’ within the same Network. Set the correct frequency band for the point-to-point links.

Step 14b Radio Units may be the same.

Step 14c Define additional systems as antennas will probably be directional (different gain parameters and patterns) and therefore different for the point-to-point link.

Step 14d Select “File”, “Network Properties.” Click “Membership” and select the specific units at each end of the point-to-point link. Close Network Properties.

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Step 14e Select “Tools”, “Radio link”. A point-to-point radio link screen is displayed.

The point-to-point link file can be reversed by clicking on “swap”. It is recommended to look at any point to point link from both directions to determine if there are any obstructions that become significant in one direction and not the other.

Reading information across the top of the point to point link are several important parameters. They are identified and explained further here.

Azimuth	Calculated antenna azimuth from transmitter to receiver. Calculation is based on Latitude and Longitude of the 2 sites, specified under Unit Properties. Angle is calculated relative to True North.
Path loss	Total path loss between sites, in dB.
Elevation Angle	Angle that the signal leaves the transmit antenna. This number is useful for interference calculations later.
E-field	Calculated signal level in dB μ V/m. These E-field numbers are usually used for broadcast radio calculations and coverage plots.
Obstruction	Identifies the first obstruction the signal encounters. The first obstruction usually has the highest effect, reducing signal level on a point to point radio link.
Receive Level (dBm)	Receive signal calculated in dBm
Worst Fresnel	Lowest Fresnel Zone clearance calculated along with the Fresnel Zone number.
Receive Level (μ V)	Receive signal calculated in μ V.
Distance	Distance between transmitter and receiver site in kilometres.
Rx (relative)	Calculated signal level above receiver threshold. This number is essentially the fade margin of the path.

Radio links are displayed using line colours in the “Style” section.

Green line between radio sites – Calculated signal is greater than 3 dB above defined receiver threshold signal level.

Yellow line between radio sites – Calculated signal level is with ± 3 dB of defined receiver threshold signal level.

Red line between radio sites – Calculated signal level is less than 3 dB below defined receiver threshold signal level.

Note that the 3 dB variation can be changed to any value under “Network” and “Style” if required. 3 dB is simply the default unless changed to another value.

32 Printing a Coverage Map

Printing a coverage map from Radio Mobile is available, however, it is suggested that the map be copied into a graphics program for printing. Many more options are available from graphics programs that allow printing a better coverage plot.

33 Google Earth Interface

Radio Mobile can accept place marks from Google Earth. A single place mark can be copied and pasted as a Unit. Several locations can be saved from Google Earth as a “.kml” file and imported as a number of units into Radio Mobile.

Similarly, Radio mobile can save a coverage plot as a file that can be over layed onto Google Earth.

Create a coverage plot that can be over layed on Google Earth,

1. Extract a map file in the normal manner. The map should be sized to correspond with the coverage area that will be plotted.
2. Modify “Picture Properties, File, picture properties. Change contrast to ‘0’ and brightness to ‘100’.
3. Create the coverage plot using rainbow, solid or other colours in the normal manner.
4. When coverage plot is complete, File, ‘save picture as’ and define the name and storage location of the coverage plot. The default format Radio Mobile saves the picture in is ‘.png’. The program will also ask ‘Save picture options’ – White is transparent. Opacity must be set to 255.
5. The file will be saved as a transparent coverage plot. Format becomes a .kml file compatible with Google Earth.
6. Open Google Earth.
7. File, Open and look for the coverage file previously named.
8. The coverage plot will be opened as an over lay on Google Earth. The display can be rotated, viewed from above, viewed from an angle as all the options of Google Earth allow.
9. Further, an image can be saved using Edit, ‘Copy Image’.
10. Image can be pasted to any photo editor program to adjust and insert into a document as a picture showing coverage.

Some experimentation with coverage colours may be required in order to see the coverage plot on Google Earth.

Earth image on Google earth is often dark and some of the rainbow colours can be obscured using the over lay technique.

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Note that although Google Earth is being constantly updated with new pictures, its elevation contours are not considered as accurate as Canadian DTED data or the SRTM mapping completed by the space shuttle.

34 Exiting the Program

Each picture created showing a coverage plot can be saved in a number of formats. Select “File” and “Save Picture as”. Several formats are available for saving the picture file, including bitmap, JPG and TIFF. Others are also available.

When the initial network is created, Radio Mobile creates a directory on the computer for storage of coverage information relating to that network. It is best to continue saving files related to that user or geographic area in the same directory. They can be reused later or backed up to a storage device if required.

When exiting the program, there are 3 files that should be saved for next time. The program should request they be saved; however, the 3 files are identified here.

Step 15 The program will automatically ask to save 3 files, if they have not been saved previously. Manually saving allows creation of a new or separate directory for the particular coverage plot.

When the 3 files are displayed in the save window, right click on the files individually. They can then be placed in a directory defined and specified by the user, rather than the default location selected by Radio Mobile.

Step 15a Network file – ‘Save Networks’ or ‘Save Networks as’. File is *.net’

Step 15b Map file – ‘Save Map as’ – saves map data. File is *.map’

Step 15c Picture file – ‘Save Picture as’ – the combined output of coverage and geographic maps that were created using Radio Mobile. This picture may or may not have been calculated, depending on whether coverage calculations were completed. File can now be selected as several formats, including *.bmp or *.jpg.

Note that there may be several picture files open.

Before closing the program, click on “Window” to view any intermediate picture files that Radio Mobile may have open. Some you may want that can be saved; others may not be required.

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Different coverage plots can be saved as different pictures in the same coverage directory. It is possible to plot VHF coverage, followed by a UHF coverage plot, provided the picture names are different.

Coverage plots are saved as pictures. They can be opened or viewed by any program that can read the image format of the coverage plot picture.

35 Summary

The Radio Mobile program is an extensive program for predicting radio coverage. This paper is meant to provide background information on radio coverage and describe how to “get started” with the program. There are many options within the program not covered by this article.

Once getting started with the program, the user is encouraged to experiment, use and learn more of these options and parameters.

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Thank you, Roger.

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