Improving Your Mobile Phone and Internet Reception in Regional Australia

Summary

This article applies to any vehicle or building in a regional area with weak mobile phone signals. My personal experience is with a 'blue tick' phone that receives a weak ground-level outdoor signal of about −120 dBm (RSRP) on the Telstra wholesale network (luckily across several towers and frequency bands). Installation of a basic repeater system (CEL-FI R41 with roof-top LPDA ‘donor’ and indoor dome ‘server’ antenna) increased my indoor signal strength to about −90dBm, and indoor download data speed increased from zero to >10 Mb/s. The instructions with the system and on-line from suppliers are clear, so it was a DIY job in which the biggest challenges were setting the donor antenna, choosing a location with power for the repeater unit, and running the cables. No harder overall than installing an outdoor TV antenna. If desired, the same repeater unit can be moved to a vehicle, with different antennas, for use on the move. There are a few tricks to get the best data speeds at home, as explained below.

The Problem

If you live or travel outside of a major ‘population centre’(city) you have probably experienced poor mobile phone reception and data (internet) speeds. Phone network companies (carriers, providers or telcos) boast that they serve a high percentage of the population, but this is a much smaller percentage of the land area in Australia. Reception sometimes got worse as companies turned off older transmission technologies such as 3G that phones still used in many regional areas, and as barriers such as trees continued to grow. Reception gets worse inside a house or vehicle. So what can you do? Unfortunately all of the potential solutions cost money.

Potential Solutions

One thing that can help is to use a new phone with improved reception capability for newer (4G and 5G) transmission technologies. Prefer phone models that have been found better in regional areas (eg Telstra ‘Blue Tick’ designated models) and be sure that the phone can use all of the bands (frequencies) used for phone signal transmission in Australia. Sleek modern phones rarely have an external antenna port. Though mobile phones vary in internal antenna strength, all use small omni-directional antennas, which inevitably have much lower gain than the best outdoor antennas used with home repeater systems (see below).

Check which telco provides best service in your area. The full Telstra network provides the widest cover, but others such as Optus may be better in specific areas depending on transmitter locations. Ask your neighbors. MVNO Boost uses the full Telstra network but others (such as Belong) access the lesser ‘Telstra wholesale network’ or the networks of other telcos.

If you have a land-line (NBN) connection that drives a Wi-Fi modem, be sure that both your phone and your phone service subscription (plan) include Wi-Fi calling. Then you should be able to use your mobile phone within the limited range of your Wi-Fi modem. But what if you have no hard-wired NBN? One option is to explore NBN fixed wireless or satellite services / plans.

Alternatively, if you receive a fair outdoor phone signal and want simultaneous use of multiple Wi-Fi devices inside, your best option may be a 4/5G modem/router with high-gain outdoor antenna/s (all MIMO if such signals reach you). Some are designed for use in vehicles. Setting of the outdoor antenna/s can be critical for data speed. You would need a SIM card and data plan for the modem, as well as the phone. You would still need Wi-Fi calling. I have not tried this.

If you get poor phone reception outside as well as inside buildings (or vehicles) you will probably have to install (and subscribe to) a satellite phone service such as Starlink.

Installing and Adjusting a Repeater

If you get a low but reliable phone signal outside, and little or nothing inside, you are likely to benefit from installation of a repeater (often mistakenly called a signal booster, which technically uses a wired connection to a single phone, illegal in Australia). An outside antenna and inductive phone cradle (without repeater) may be enough in a small vehicle such as a car. A repeater can provide more gain. It does not need a separate SIM card or data plan, but there are a few pitfalls.

If you use a search engine to look for mobile phone repeaters the top hits are probably devices that are illegal to install in Australia. Poorly designed repeaters are likely to interfere with the phone network, causing problems for all users, so you can be fined and/or forced to cease use of devices that are illegal. The cheaper units typically work on only one or a few frequencies, which may not match the phone signal at your location. Be sure to use a device that is legal in Australia and approved by the owner of the phone network that you intend to use. At present this means Nextivity CEL-FI devices. They may be more expensive than some of the illegal devices, but they work better as they are designed and tested for compatibility with Australian phone networks.

At present there is a model (R41) designed for vehicles that works well (with a suitable 12V power supply) for some smaller houses (with direct line of sight and no more than 7 m from the service antenna to phone use areas). Given a strong enough input signal, the G41 model gives more output for larger homes, two-band amplification, and the option of band 28U. Be careful that the repeater matches your phone company in band 28 coverage. Some overseas countries split this band between TV and phone use, whereas in Australia it is split between companies (with Telstra and Optus using 28A≡L whereas Vodaphone and TPG use 28B≡U). IF your phone and Telco support LTE inter-band aggregation (one type of confusingly-named 'carrier aggregation', CA) two-band amplification may be a real benefit for data speed. One way to check is to look for 4G+, LTE+ or LTE-A at the top of your mobile phone screen, during data transfer. Or look in "service mode" in your phone (*#0011# in Samsung) to see bands used by the serving tower to support CA. Aggregation may also work in 5G (NR) with some (typically more expensive) phones and plans.

You will also need to install a 'donor' antenna (probably outside, *eg* on the mast for your roof-top TV antenna) and an inside 'server' (='service', ='broadcast') antenna (or several of these in a large or multi-story home); along with appropriate connecting cables. If you do not want to do the research to choose between omni-directional vs Yagi vs open or enclosed (radome) LPDA donor antennas (or even a dish, or multiple donor antennas, in special cases), and (one or more) dome vs panel server antennas, and then site and aim the donor antenna, it may be best to get help from a professional installer who should make the decisions based on your specific circumstances. For DIY types, the entire (basic) system can be purchased for about $1,200 (including R41) when some components are on special. Use a reputable supplier (such as Powertec, RFI, Redfleet or The Antenna Company), who can also give helpful advice about antennas and cables.

If you want to know which phone tower your device is using (to help aim your directional donor antenna), the best website I have found is *Cellmapper*. It uses algorithms on crowd-sourced input, so it may not have data in your area. Cell boundaries and unconfirmed tower locations are not precise, and some other data (like cell 'direction') seem wrong. But it gives TAC codes for regions, eNB codes for phone towers and ECI codes for cells; which are lacking from the next-choice *ACMA* map. You can compare these with the codes in an app like *Network Cell Info Lite* (or *Net Monster* or *G-NetTrack Lite*) to determine which tower(s) and cells your phone is selecting for strongest reception. Do this (with phone wi-fi off) before installation of the repeater. In areas with signal blockages due to topography, vegetation or buildings, your rooftop antenna may receive a reflected signal from a direction other than the phone tower. Some receivers reconstitute multipath signals that others treat as noise, and the best direction for uplink vs downlink can differ. This can be unpredictable, and personal priorities also differ, so you may need to experiment. A change of 5° in LPDA donor antenna direction can make a speed difference. If you are in an area served by multiple towers (or on the move), your phone or repeater may switch between towers over time.

An advantage of the CEL-FI repeaters is that they will lock onto a single network (which you can alter if needed) and amplify a signal from any 4G band (or 2 bands for the G41) in that network. Signal strength, quality and stability are important for voice calls. But if speed of data download and/or upload is important to you, antenna position score (in the CEL-FI *Wave* app) and signal strength (bars on your phone, or dBm in your phone status or an app) can be misleading.

Depending on factors including user load and wavelength, data speeds can be unrelated to apparent signal strength. This can be a problem for mobile phone data users, as the phone (and the repeater) seem to select the strongest signal; perhaps taking account of signal quality but without testing data speed. You can test speed in an app like *Network Cell Info Lite*. Speed tests consume data, and results vary between tests (like most other measures). In general, distance covered for reliable voice calls increases at low frequency, but data speed at the same signal strength decreases (table below). Commonly, because Band 28 covers the largest area with best indoor penetration, it has many users and can suffer congestion that slows speed even further. Congestion depends on bandwidth available at the phone tower, and the problem varies with user load (time of day etc).

A repeater can amplify the signal from a phone tower. While selecting a band to boost, it may take interference from other towers into account. How noise and interference are weighted against signal strength, whether both uplink and downlink are considered, and test duration are all unclear. They probably vary between models. Noise lowers signal quality and thus data speed. With a high-gain directional antenna, there may be an increase in signal quality. But neither repeater nor donor antenna can relieve congestion in any particular band at the tower. An important advantage of the CEL-FI repeaters over a mobile phone, if you receive multiple bands at the donor antenna, is that you can disable any band that is slow, so that the device uses a faster band (even if it is not the strongest signal). Once it has chosen a band to boost, my repeater seems far less aggressive than a phone in switching bands to chase a stronger signal. Indoors, the phone then stays locked onto the signal boosted by the repeater. Network congestion effects, and compromise between data speed and area covered using different frequency bands, apply even indoors with a boosted signal.

Telcos can give data speed priority to selected customers (who typically pay more). New technology like 5G can increase data speeds (and use more battery power), but when 5G is implemented in the frequency range used for 4G (as in most of Australia: low-band and lower mid-band, DSS / NSA 5G), I find it no faster. The CEL-FI repeaters mentioned above boost DSS 5G (though they do not say so). Different repeaters (and different antennas) will be needed for higher-frequency 5G bands, if these are ever implemented in Australian areas of low population density. MIMO (from slant polarized transmissions) is mostly used at high signal strength, so it is less relevant where repeaters are needed. Any advantage requires multiple donor antenna inputs, but repeaters that are legal in Australia currently have only one (so multiple repeaters would be needed). Get advice from a trusted mobile phone professional experienced in your region before going down this expensive path. A single repeater with a vertical donor antenna is usually fine.

Reliability takes longer to discern. It is affected by signal strength and quality, which can vary over time. If you experience drop-outs or upload problems with a fast but weak band, you may be able to improve this by adjusting the donor antenna. Alternatively, enable a band with a stronger signal (or higher uplink quality), even if download is slower. You will have to experiment. The good news is that data speeds above 5 Mb/s are fine for most users (even 1.5 Mb/s is sufficient to avoid frustration in most tasks). Multi-user households and 4K HD streamers may want more.

Each user site will differ in factors affecting signal propagation, and user priorities also vary. I got the best result for phone reliability, area covered, and consistent data speed from a Band (26) never received without the repeater, with roof-top LPDA directed ~30º away from the serving tower, and a compromise between downlink and uplink speeds (each >10 Mb/s, despite low and fluctuating CQI in the phone). The signals probably reflect off nearby landforms, as the direct path (2.9 km) to this tower is blocked at several places by tall and dense vegetation. The best choice may change if Telstra alters settings, or if more people use that cell. For a more distant cell tower (4.1 km) with direct line of sight to trees neighboring my property, the best orientation of the LPDA was direct.

Appendices

1. Australian Mobile Phone Bands: 4G (and DSS 5G)

Band	(Telco)*	Nominal (Telstra DL) Frequency in MHz	Area Covered	Data Speed‡
28	(T,O,V)	700 (778)	++++	+
5 / 26	(T, V)	850 (864)	+++	++
8	(O)	900	+++	++
3	(T,O,V)	1800 (18-10, 12.5, 15, 17.5, 32.1, 34.8, 40)	++	+++
1	(T,O,V)	2100 (21-20, 27.5, 55, 60, 62.5)	+	++++
40	(O)	2300	+	++++
7	(T,O)	2600 (26-40, 59.8)	+	++++

* Telcos Telstra, Optus, Vodaphone. ‡ At equivalent signal strength and quality, without network congestion. 5G may also be provided in some areas on higher frequency bands *eg* n78 (3500MHz), n258 (26GHz).

2. Readouts in the Nextivity *Wave* app (v 2.1.5)

Most of the readouts in the Nextivity *Wave* app are self-explanatory. On the Home page, the system reports on signal **Quality** (as **SINR** in dB). In poor reception areas, quality is more often limiting than strength. You may be able to improve quality by adjusting the position, direction or gain of the (outdoor) donor antenna, and you may need to compromise between uplink and downlink. Donor SINR given under Activity>Channels is **Downlink SINR** (Booster Receive Quality). It should normally be above 0 dB for reliable reception. But you may still experience call dropouts and poor upload data speeds if **Uplink SINR** (estimated Tower Receive Quality) is poor. Measures for Settings>**Antenna positioning** are not specified.

Under Activity>Channels: **RSSI** (Received Signal Strength Indication) and **RSRP** (Reference Signal Received Power) are ways of considering signal **Strength**. **RSSI** includes noise and varies with bandwidth. **RSRP** is a better indicator of signal above noise, used (+/- RSSQ) for cell selection. For reliable reception it should be > −125 dBm (*ie* closer to zero). **RSRQ** as a measure of LTE signal quality (ideally > −10 dB) is defined in 3GPP. Other quality indicators (SNR, **SINR**, RSSNR) vary between equipment makers. SINR in *Wave* may be useful in antenna setting. But data speed depends on SINR measured by the phone, then used to calculate Channel Quality Index (**CQI** in Service Mode or *NetMonster*) and reported to the network for control of block allocation and modulation. SINR may fluctuate more when reception is marginal. These measures are normally specified on a logarithmic (dB) scale, but many websites give linear (mW) formulae. Repeaters amplify both signal and noise (and they add a little noise): they increase signal strength, not quality.

A directional donor antenna can reduce noise. If **Antenna Separation** (shown on the Home page) is not sufficient, you should reposition or shield the server antenna; and/or reposition or use a more directional donor antenna. If it is Excellent (your goal), the Repeater does not have to work hard with gain adjustment for **Echo cancellation**. Under Activity>Channels, **Echo Gain** numbers ideally will be low (below 0 dB).

Tx power is **specified** for the repeater model (**uplink** 22 to 24 dBm, and **downlink** 0 dBm for R41 or 20 dBm for G41). **System Gain** (100 dB) and power refer to RSSI, not RSRP. The unit normally delivers up to specified gain to achieve specified Tx power to the relevant antenna. With no echo, signal strength sent to the server antenna is limited by gain when RSSI is < −100 dBm (max gain), then by Tx power. Thus, model G41 has an advantage over R41 in downlink at RSSI > −100 dBm. Because the phone is close, the server antenna normally receives > (22−100) dBm from it. Then uplink signal strength is limited by repeater Tx power. If uplink signal strength could interfere with the phone network (eg close to a phone tower), the unit will not exceed an **Uplink Safe Mode Gain**. In poor reception areas, this should not reduce uplink strength.

PCI (Physical Cell ID) is based on synchronization codes that are transmitted in each cell every 1 to 10 ms. Values are 0 to 503 in 4G and 0 to 1007 in 5G. PCI helps User Equipment (**UE**) to separate signals from different cells. PCI optimization aims to assign different PCI codes to overlapping cells, thereby improving RF performance. PCI is sometimes wrongly said to be unique across a network, or confused with CI / ECI.

3. Other LTE Codes and Abbreviations

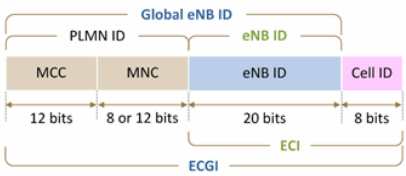
Several systems identify **4G / LTE** (Long-Term Evolution) towers, cells, antennas and channels. Some are carried over from previous phone network standards (2G = GSM/EDGE, 3G = CDMA/UMTS/HSPA). Some (notably ECI *vs* other Cell IDs) differ markedly, causing confusion even on seemingly reputable websites. 5G (NR) can differ again. Some codes are broadcast, and interpreted by UE and apps. Sadly, different websites and apps use different systems, usually without explanation or cross-reference.

In an LTE phone, ***Network Cell Info Lite*** Gauge tab specifies **TAC-ECI** (Tracking Area Code - Evolved UMTS Terrestrial Radio Access Network Cell Identifier) and **eNB-LCID** (evolved NodeB - Local Cell IDentifier). The last digit in (decimal) LCID≡CELLID can roughly indicate orientation, but not all Telcos follow this convention. More codes are under the Raw tab. Unfortunately, it seems unpredictable which codes any phone model will correctly report to any app, including its own **Service Mode (**which may reveal extra information like carrier aggregation, modulation and **EARFCN –** a finer indicator of frequency).

To help locate the transmitter of any phone signal, Telcos could easily make eNB locations public, but they resist doing so. There are work-arounds. For known towers, ***CellMapper*** gives eNB, MCC, MNC, TAC (as 'Region'), local cell ID, ECI (as 'Cell Identifier'), PCI (with SSS, PSS), Band & bandwidth, EARFCN, Spectrum Sharing *etc*, but it may not be up to date. *ACMA* (Australian government) hides a (slow) web-map that gives up-to-date information about licensed transmitters, including antenna polarity, orientation, radiation pattern and height (if you drill down). *RFNSA* (industry) maps active sites. But ACMA and RFNSA use different codes, and may indicate different locations for the same base station. One RFNSA site may comprise several ACMA sites. One site may be used by several Telcos. Each Telco may assign several eNBs per site. Neither RFNSA nor ACMA provides anything to match the codes in your phone (like ECI or eNB ID), so they do not allow sure confirmation of the relevant transmitter site. *Aus Phone Towers* (app version) uses ACMA data and tries to triangulate by TA, but this does not work in all phones.

An LTE network comprises **eNBs**, base stations that communicate with mobile devices (UE). Each eNB has multiple cells, each with an **ECI**. The eNB sends each UE a **TA** (timing advance) that varies with signal distance (sometimes used to estimate location).

A (local**) eNB ID** is used within a Telco's network. A **global eNB ID** is a combination of a **PLMN ID** (Public Land Mobile Network ID) and the (local) eNB ID. It is used outside the local network. Decimal values of the constituent parts are not obvious after hex conversions.



LCID in 4G may be used for Local Cell IDentifier (≡CELLID, 0 to 255 to identify a cell in a specified eNB, sometimes confusingly called "cell-/cell/sector" ID - *cf* ECI & PCI); Logical Channel ID (0 to 10 in Tx and Rx to identify a logical channel within a radio frame); Long Cell ID; or even LoCale ID. This code is not needed for cell location if ECI is given, because ECI can be decoded to reveal eNB ID and CELLID.

TAC (like LAC in 3G) designates a geographic group of cell towers. It is assigned by the LTE network operator (different networks may use the same TAC for different regions). Because eNB ID (and thus ECI) is unique within a PLMN, TAC/LAC is not required in ECGI (in contrast with CGI in 3G). This is still confused in some online sites.

ECGI (Extended Cell Global Identity) is a globally unique identifier for a cell from a base transceiver station in LTE mobile phone networks. ECGI consists of three parts: Mobile Country Code (**MCC**, 505 = Australia), Mobile Network Code (**MNC**, 01 = Telstra) and ECI (comprising local eNB ID and CELLID). **NID** (Network ID), which is most useful for private and CB networks, sits below MCC & MNC.

4. More on Cells, Sectors, Antennas and Channels affecting mobile phone calls and data

In practice, a **cell** is generally considered to be the area covered at one radio carrier **frequency** by one **antenna** system (directed at that area) on one base transceiver station (eNB, mobile phone tower). Under this definition, the cell boundaries vary with UE sensitivity, and with elevation.

The idea of a **sector** arose as network operators moved away from omni-directional antennas (they moved from a 360º antenna at the centre of a cell to multiple directional antennas that resulted in multiple cells in corresponding directions out from the cell tower). For example, if the antennas covered ca. 120º each, this became a 3-sector tower. Because the edges of transmission patterns are not perfectly sharp, the carrier **frequencies** and **PCIs** used in each sector and cell are managed to reduce interference.

Several **frequencies** can operate through one antenna, and travel for various distances, so we can think of several **cells/antenna**. However, in some technologies several antennas are used to get the best signals in each area, so there may be several **antennas/cell**. Thus the relationship between **cell**, **sector**, and **antenna** varies across sites, and **cell** remains the most useful of these from the perspective of the common user.

Through communication between a user's phone and the serving antenna (or network equipment behind the antennas), a **mobile phone call** in progress may be transferred to an antenna (and cell) with a stronger signal (a 'handover'), especially if the user is moving. This is done so rapidly that it is not normally noticed by the user. Some apps show how your phone monitors **neighbor cells**.

Each **cell** can handle multiple users. Conceptually, each user is assigned a **channel** in the available bandwidth. When user numbers increase, assigned channel **bandwidths** (and thus data speeds) per user will decrease. Multiplexing is more complex, but congestion still reduces data speed per user.