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Telecommunications Reception in Residential and Low-Rise Buildings

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OVERVIEW

This Technical Note discusses some of the factors that lead to better or poorer telecommunications performance in homes and similarly constructed buildings. The transmission and reception of radio waves for voice and data communication, entertainment, navigation and security is an integral part of modern life. Radio wave use, particularly for mobile applications, is growing in all parts of the world including Australia. Inevitably this means that the radio signals that we rely on are required to pass through both natural features as well as objects in the built environment. How successfully the signals do this depends on many factors, some controllable and some not.

Radio transmission in urban environments can be quite complex with multiple effects due to the surrounding environment, transmission distances and building materials. Except in extreme cases such as a building fully shielded from radio waves, results may vary between apparently similar buildings.

Most of us seem to experience satisfactory telecommunications performance within residential buildings from most devices, most of the time. When we don't, there is likely to a combination of factors leading to the poor reception.

For signals that need to pass through the external envelope of a residential building, such as mobile phone and digital TV signals, significant signal reduction can occur with metal cladding, foil sarking and dense masonry construction. Performance will vary with distance from the transmission tower, location within the building and proximity to windows and doors that can provide entry points for radio waves. Weather conditions especially rain can also play a part.

For signals passing between the rooms of a dwelling, such as portable phones and home wireless networks, steel or timber framed walls cause very little signal reduction. Where many walls are passed through, or walls are constructed of concrete or masonry, signal reduction is likely to be much higher and greater transmission power may be needed.

GPS navigation signals are a special case. Although the devices are quite sensitive, the satellite network transmits very weak signals that generally cannot be satisfactorily detected inside most buildings, regardless of their construction.

CHANGING USAGE TRENDS

Until about 1990, the reception of radio waves within buildings was confined largely to analogue radio and television signals. These signals were transmitted from ground-based towers and received by devices that varied widely in sensitivity. Whilst reception in homes was generally acceptable in most cities, reception inside industrial and commercial buildings was frequently poor or non-existent. If signal reception was poor, the user accepted that the problem was with the location or the device and would arrange an external antenna or upgrade the device.

The last two decades have seen a rapid increase in the applications of radio transmission, and our increasing reliance in our everyday lives on these things like mobile and cordless phones, wireless data networks and GPS.

At the same time, the built environment has become more complex with higher density living combined with a greater range of materials. A significant technical change has occurred with higher frequency digital signals largely replacing lower frequency analogue signals for radio and television services. Analogue signals generally gave a smooth gradation in performance depending on signal strength at the device antenna, with the useable signal gradually replaced by static as the signal weakened. Digital reception does not smoothly improve or degrade as signal strength changes - you get "all or nothing" based on what your receiving device decides is an acceptable signal.

The consequences of these technical and social trends in telecommunications and construction are that many more factors now influence whether any particular wireless device will be able to function in a particular situation. This has led to some misunderstandings as to the possible causes of poor performance.

RESIDENTIAL FRAMED CONSTRUCTION

In residential and low-rise construction, roofs are typically steel or timber framed with tiles or steel sheeting. External walls generally consist of a steel or timber frame with brick, fibre-cement, steel or timber external cladding and plasterboard interior lining. Wall bracing panels, thermal insulation, vapour barriers and glazing may also be present.

Internal walls are typically constructed of steel or timber framing with plasterboard lining and acoustic insulation.

Of the materials used in framed construction, only the roof sheeting, wall cladding and aluminium foil sarking are significantly opaque to radio waves. The wall and roof frames are almost transparent to radio waves. Even in relatively opaque structures, transmission through windows and glazed doors is usually unaffected to any significant degree. However some specialty metallic glazing films can cause significant signal loss.

Flooring materials may affect transmission between rooms in multi-storey dwellings. Steel or timber framed floors with particleboard or strip flooring will be relatively transparent to signals while compressed fibre-cement or reinforced concrete will reduce signals to a greater extent.

The following sections explain in more detail the nature of radio waves and their transmission through various materials.

PROPERTIES OF RADIO WAVES

Radio waves are part of a continuous spectrum of electromagnetic radiation (EMR) that also includes visible light. All EMR travels at about 300 million metres per second. The EMR spectrum varies by the distance between "waves" (wavelength) and the number of waves per second (frequency). Visible light has a wavelength of about half a millionth of a metre and a frequency of about 600 terahertz or 600 million million waves per second.

All telecommunications frequencies of EMR taken together are referred to as the radio frequency spectrum, which is internationally regulated. The radio waves of interest in telecommunications have longer wavelengths and lower frequency than visible light. Table 1 summarises the parts of the radio frequency spectrum that are used for common everyday communication in Australia.

The other variable in EMR is transmission power, measured in watts. Two signals may have the same frequency and wavelength but quite different transmission power. Signals with stronger power will be received over longer distances by less sensitive devices.

TABLE 1: TYPICAL FREQUENCIES AND WAVELENGTHS

Use	Frequency Range (MHz)	Wavelength Range (mm)
Mobile (3G) phone	850 - 2100	140 - 350
Portable (DECT) phone	1900 - 5800	50 - 160
WiFi	2400 - 5000	60 - 120
GPS	1228 - 1575	200 - 250
Analogue radio - FM	88 - 108	2700 - 3400
Digital TV	175 - 800	400 - 1700
Digital radio	174 - 230	1300 - 1700

TRANSMISSION CHARACTERISTICS OF DIFFERENT MATERIALS

When telecommunication radio waves encounter a solid material, what happens depends on the frequency and power of the radio waves and the physical nature of the material – its density, atomic structure, geometry etc. The amount of reduction in signal strength through the material is referred to as attenuation. A material with high attenuation is said to be opaque and with low attenuation is transparent – the same terminology as used for visible light. The fact that different materials pass, absorb, scatter or reflect radio waves is a useful thing in fields such as medical imaging and non-destructive testing of materials.

Most solid building materials of typical thickness are relatively transparent to radio waves at the commonly used frequencies. That is, they are said to have low attenuation. The general attenuation properties of common solid building materials are:

LOW ATTENUATION:
Air, wood, glass, plastic, glasswool/fibreglass

MEDIUM ATTENUATION:
Bricks, plaster, fibre-cement

HIGH ATTENUATION:
Ceramics, concrete

VERY HIGH ATTENUATION:
Metals

Materials that are not solid but consist of bars or mesh are in general much more transparent to radio waves than solid materials.

In a metal mesh or grid, provided one of the opening dimensions is more than about 50% of the wavelength, the attenuation will be quite low. A metal wall frame, for example, would typically have a maximum opening of 900 to 1200 mm and therefore has low attenuation at the wavelengths listed in Table 1. The weather and in particular the moisture content of absorbent buildings materials may also affect attenuation.

Interference is another potential cause of poor reception. It is apparent from Table 1 that there is the possibility for some operating frequency bands to overlap, for example portable phones and WiFi may share the 2400 MHz band. When this occurs, interference may result and cause poor or irregular performance in some households, especially with wireless data transmission. Interference may also result when a transmitter or receiver is close to electrical equipment or electricity transmission lines.

While metal surfaces attenuate radio signals effectively, reflection from them can be of benefit in some situations, particularly once the radio signal is inside the structure. Surrounding objects such as trees, hills and other buildings can also contribute to signal loss.

IN SUMMARY

Numerous technical and social trends in telecommunications and construction affect whether any particular wireless device will be able to function in a specific situation. This Technical Note explains the different transmission and reception factors that produce better or poorer reception.

There is a lot of useful information on this subject available and we suggest the following resources as a starting point:

www.acma.gov.au

en.wikipedia.org/wiki/Electromagnetic_radiation

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