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Maxxwave Introduction

Maxxwave currently operates the largest Band I (55-66mhz) narrowband system in the UK, perhaps worldwide, and has recently invested around 3000 man-hours into research and development into this band along with millions of results from automated data collectors. These attentions have been focused upon propagation characteristics and overcoming such obstacles. This is the most in-depth research into this frequency band conducted anywhere in the world for the past 20 years.

Furthermore Maxxwave has spent a considerable amount of time researching and developing data protocols which are suited for these low frequency bands, and currently uses these primarily for GPS polling of mobile vehicle based terminals, which is similar to several other proposed IoT uses. We believe we are the only people within the UK using Band I for mobile applications in this manner today.

We have a number of major issues with the Ofcom Internet of Things spectrum consultation as published. Our number one issue is that, in the context of a predictable commercial grade of service (as is required for the proposed uses towards the end of the consultation), **Band I and the other closely related low frequency bands are inferior in every technical respect to other available business radio bands.** In the course of our several years worth of use of this frequency band, with over 3000 mobile terminals deployed and used on a daily basis all around the UK, and around 40 fixed links of various different path lengths, we have found absolutely no evidence to suggest that these frequency bands have any "range advantage" over other available radio frequency bands, nor do they in any way permit lower transmit power to be used.

Looking on the internet at the plethora of press releases surrounding this consultation, there appears to be one fundamental misunderstanding, encouraged by the wording in this consultation. The basic premise of this consultation fails to recognise that VHF-Low (~30mhz-80mhz) does not propagate at all in the same manner as VHF-Mid/High (~130mhz-200mhz). This fact has not been made clear in the preamble of the consultation and there is a clear misunderstanding within the IoT industry.

Due to this fact, we therefore feel that the entire Ofcom consultation is fundamentally flawed, and having seen the many press releases that quote the Ofcom preamble to this consultation, which clearly states that this frequency band offers range benefits compared to other frequency bands, we feel it therefore is necessary to respond to this consultation by means of technical evidence and detailed description of why we know this frequency band to be technically inferior, and therefore why this consultation is probably invalid.

Our uses of this band are both base to mobile, base to base and "Fixed Link" type applications. We share some of our findings of this band as a response to this consultation with the hope that some of the misunderstandings regarding this frequency range are corrected.

Due to the nature of our findings and the relevance to this consultation (and indeed anyone planning to deploy systems within this frequency range), the first part of this document details

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our findings of this band in a non-technical manner, the second part is a set of detailed "technical noted" and then we address the specific Ofcom questions at the end.

Some of our findings we are treating as "commercially confidential", since they lead on to commercial inventions which give us a competitive advantage (such as the considerable advances we have made in virtually eliminating atmospheric interferences), and as such we cannot disclose all findings within this report.

It must be noted that our technical improvements in this frequency band have not yielded any improvement in range, they simply address the problematic availability issues.

Form of response of this consultation
This consultation response is divided into three parts:-

1: A non-technical response with an "overview" of how the lower frequency bands work
2: A series of technical "notes" relating to propagation of this band
3: Our response to the actual consultation

We are happy to meet with any interested party to discuss our findings in more depth.

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Part 1

A non-technical overview of the propagation characteristics of Band I

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Subsection 1: VHF-Low (~30mhz-80mhz) is NOT VHF-High (~130mhz-200mhz)
We feel it is necessary to begin our response to this consultation with a few words regarding VHF-Low and VHF-High.

The term "VHF" can be a little misleading, and it can imply that the entire VHF frequency range (30mhz-300mhz in most definitions) behaves in the same manner. This is not true and there are distinct sub-bands within this range that share common propagation characteristics.

We have approximately grouped VHF-low as 30mhz to 80mhz, since this frequency range shares similar propagation characteristics (with the "undesirable" characteristics in terms of a reliable commercial service being exaggerated below 50mhz in particular), and 130mhz-200mhz as VHF-high, since this entire frequency block behaves in more or less the same manner.

80mhz to 130mhz is a "transition zone" with these frequencies not clearly falling into either category.

VHF-low (~30mhz-80mhz)	VHF-High (~130mhz-200mhz)
• Prone to electrical noise • Long antennas • Antennas need to be clear of buildings/obstructions • Signals will not reflect • High ambient noise • Comms over 15 miles very difficult • Availability is difficult to achieve over 95% without complex systems	• Relatively immune to electrical noise • Shorter antennas • Antennas will operate within the "clutter" of buildings • Signals will reflect around corners • Low ambient noise • Long range (>40 miles) comms possible • Systems can be planned for "high availability" (>99%)

There is very little use in "VHF-Low", and has been for a number of years, predominantly due to the low availability, high noise floor (resulting in poor range) and antenna difficulties. Therefore most of the VHF use has been in the higher frequency ranges.

The traditional use of VHF-Low has been as an "overspill" band in urban areas where the better performing frequency bands have not been available and also in some rural areas where the higher frequencies available within the band (86mhz) previously showed some range advantages over other frequency bands before the noise floor rose around 2000-2005. Since 2005-2008 the band has been very stagnant with very few new deployments.

There are no commonly used VHF-Low licence exempt bands that the IoT community will be familiar with, with their experience of VHF mainly limited to 169mhz licence exempt spectrum.

Therefore we insist that Ofcom, when considering other responses to this consultation, consider the experience of the respondents with these particular frequency bands.

In the 1990's there were trials of the Band I spectrum by the PAMR (Public Access Mobile Radio – Trunked radio operators) community, with the licences being "given" away for £50 per duplex channel on a "lifetime" basis. Many operators installed systems around the UK (we have had detailed conversations with at least 10 of these) but were very disappointed by the problems (which we detail in this response) so ultimately closed the systems down, despite the high investment in equipment and low costs of the licences.

Maxxwave can only make this frequency band workable due to our development of innovative custom antenna systems and heavy reliance upon weak signal digital processing within the radio units, coupled with owning many radio sites around the UK (we are the UK's largest independent communications site owner and operator).

Subsection 2: Key points for normal low frequency propagation characteristics

This section deals with the propagation characteristics under normal conditions. It is not concerned with the abnormal propagation conditions that exist for circa 5% of the time on the lower frequency ranges. We will cover this later in subsection 3.

With radio signal propagation, there are three propagation modes of interest for "normal" propagation, LOS (line of sight), reflected (semi-line of sight) and ground-wave type propagation (non line of sight).

Line of sight propagation

"Line of Sight" in radio terms does not necessarily mean that you can physically "see" from one end of a link to another. What it means is that you have an unobstructed path from one end to another, free of interactions from nearby structures along the link (buildings, trees, windfarms and even the ground itself).

In order to get true LOS propagation, you require approximately at least third-order Fresnel zone clearance.

Fresnel zones are a complicated topic all by themselves, but Wikipedia does have a good article which explains the concept in detail. For this paper, we are only concerned with the effect of them, not exactly what they are and how they are formed.

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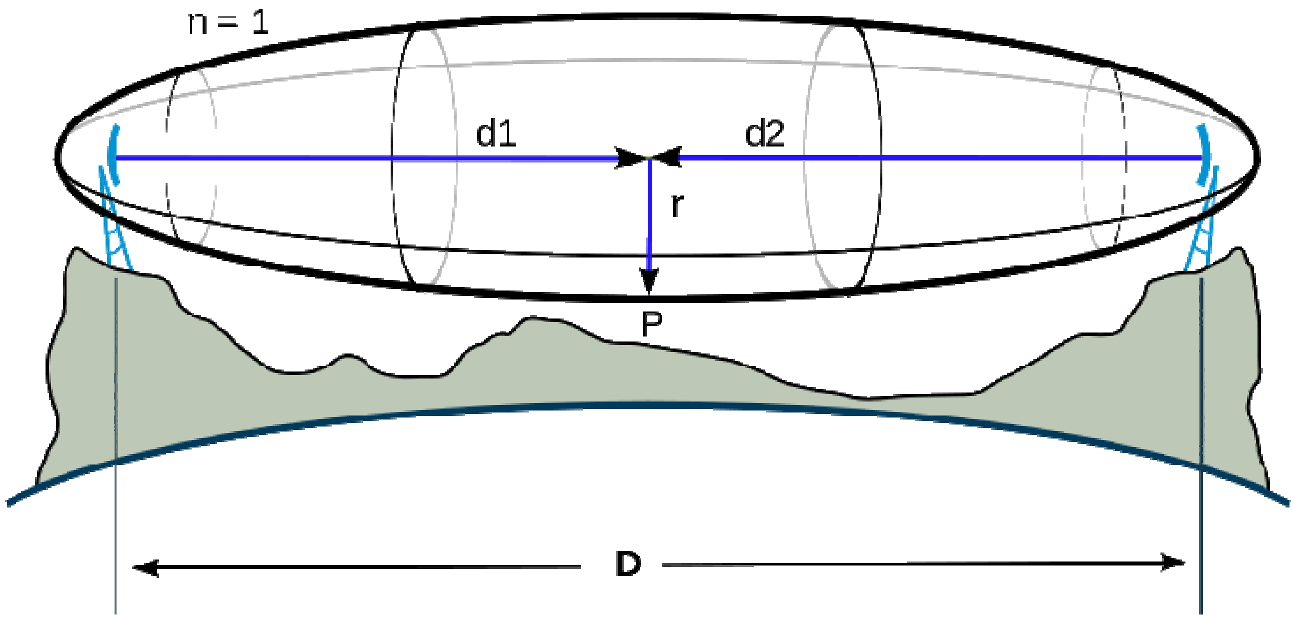

Fig 1.1 – Fresnel zones.

Frequency	r (Fresnel size) for 10 miles	r (Fresnel size) for 1 mile
8ghz (8000mhz)	12 metres	4 metres
450mhz	52 metres	16 metres
65mhz	136 metres	43 metres

This means that for 65mhz, you would need to have a clearance of 136 metres above terrain to start to achieve LOS type propagation. This is nearly impossible to achieve on most transmission links.

LOS transmission links are characterised by very low path loss ("free space loss") between transmitter and receiver, allowing very low transmit powers to be used.

It is in this LOS mode of propagation that virtually all fixed point to point microwave links operate. Having a very low path loss means that the wanted signal is received a considerable level above any ambient noise or co-channel interference. This gives a considerable "fade margin" which allows the signal to be considerably degraded by interference, fog, rain, atmospheric disturbance, etc before any effect is noticed on the actual link, potentially giving an availability of 99.99995% or higher

Since the LOS propagation mode is unavailable on these low frequency bands, they cannot achieve this "ultra low power" long-range linking mode, and so any links on these lower frequency bands will not be able to enjoy these high fade margins and low transmit powers that are so common on the higher frequency bands, meaning point to point links will normally be around 95% availability (see subsection 3 for more details)

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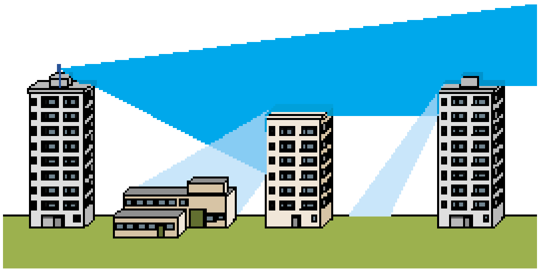
LOS propagation also can account for much of the longer-distance propagation that is possible on the higher frequency bands, particularly from prime sites. For example when driving down a motorway, the signal strength can be seen to increase when driving on top of hills, and “hilltop reception” is possible for many miles (40-50 miles) from the transmitter site. This does not happen with the lower frequency bands for the same reasons.

Conclusion – LOS type propagation is VIRTUALLY IMPOSSIBLE on low frequencies at any distance above 2 miles, unless using very high prime transmitter sites at both ends (120m antenna height or similar, or extremely prominent sites, excluding the effects of ground reflection from having a low antenna giving a high take-off angle).

Reflected propagation

Reflected propagation is whereby a line-of-sight signal hits a large reflective structure, such as a building, and then gives coverage in an otherwise shielded area.



This mode of propagation is prevalent at higher frequency bands (450mhz +), and serves to give coverage to street-level in urban environments.

It is naturally a very lossy propagation mode, with the reflected signal being generally weak and of a poorer quality due to multi-path effects. However it does give reasonable street-level coverage on a non-line of sight path.

Reflected propagation does not typically occur on lower frequency bands, due to the lack of true LOS propagation hitting the reflecting surface (so a far lower signal strength to reflect in the first place) - and because the reflecting surfaces tend to be physically small relative to the size of the radio wavelength.

Therefore signal strengths in dense urban areas tend to be lower than rural areas due to building attenuation, and coupled with higher ambient noise floors, this can make urban environments a challenging area for low frequencies.

“Ground wave” type NLOS propagation

Ground-wave propagation is typically extremely lossy when compared with LOS propagation, with initial signal strength dropping rapidly within the first 1000 wavelengths from the transmitter site (~4.5km in the case of 65mhz). Within this initial area, the signal strength is relatively high, but then quickly drops to a consistently low signal level.

This lower signal level then stays fairly constant, dropping in a similar manner to "free space loss", with around 6dB extra loss every time the distance is doubled, until the radio signal reaches the "radio horizon".

The "radio horizon" is defined as approximately 4/3 the normal "optical" horizon, which is around 25km for a radio site with 50m HAAT (height above average terrain), thereby giving a radio horizon of 33km (21 miles).

Once you reach the "radio horizon", the signal begins to drop rapidly.

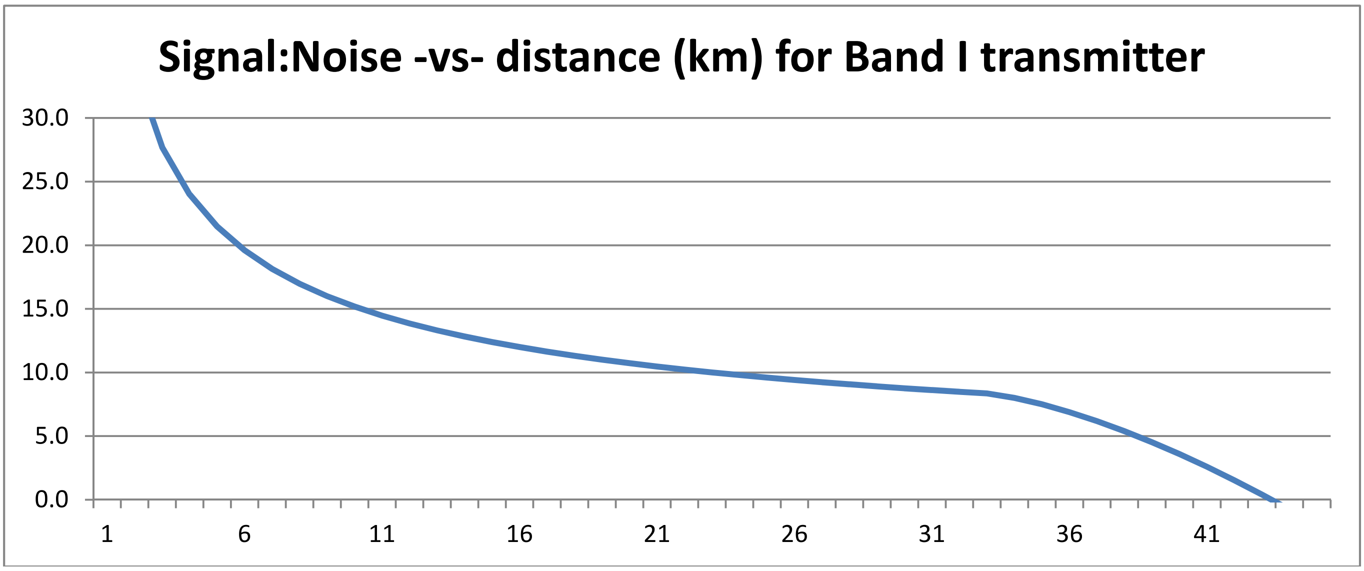


Figure 1.2 – "Best fit line" graph showing Signal:Noise ratio compared to distance for transmitter station with approx 50m HAAT, 50W ERP. This data was taken from normalised readings on around 27 million GPS polls. Some extrapolation below 9dB S:N has been used.

However in order to be able to actually use this "ground wave" type signal, it is necessary for the transmitter power to be sufficiently high that the received signal strength is high enough above the noise floor. With 12.5khz channel spacing this therefore requires approximately 25W ERP in order to give any form of usable signal strength at 10km on 65mhz, as can be seen from the graph above (15dB C:N @ 10km @ 50W ERP = 12dB C:N @ 10km @ 25W ERP).

Higher ERP levels therefore serve to give increased margin against noise and also marginally increase the transmitter range. 50W ERP gives around 16km (10 miles) usable range and 200W ERP gives around 25km (15 miles) usable range. In terms of actual transmitter sterilisation area however, there is very little difference between the two transmit powers since the sterilisation area typically plans for 0dB C:N, which is in the point where the graph is falling off rapidly.

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Therefore increasing the transmit power from 25W ERP to 200W ERP (as we have done with a T&D licence we were granted by Ofcom) does NOT significantly increase range, it simply improves the field strength within the service area, thereby giving greater resilience to noise.

This means therefore that low frequency bands are either good for NFC (Nearfield communication) (<10wl, <45m range), or medium-range, higher power systems (10-15 miles).

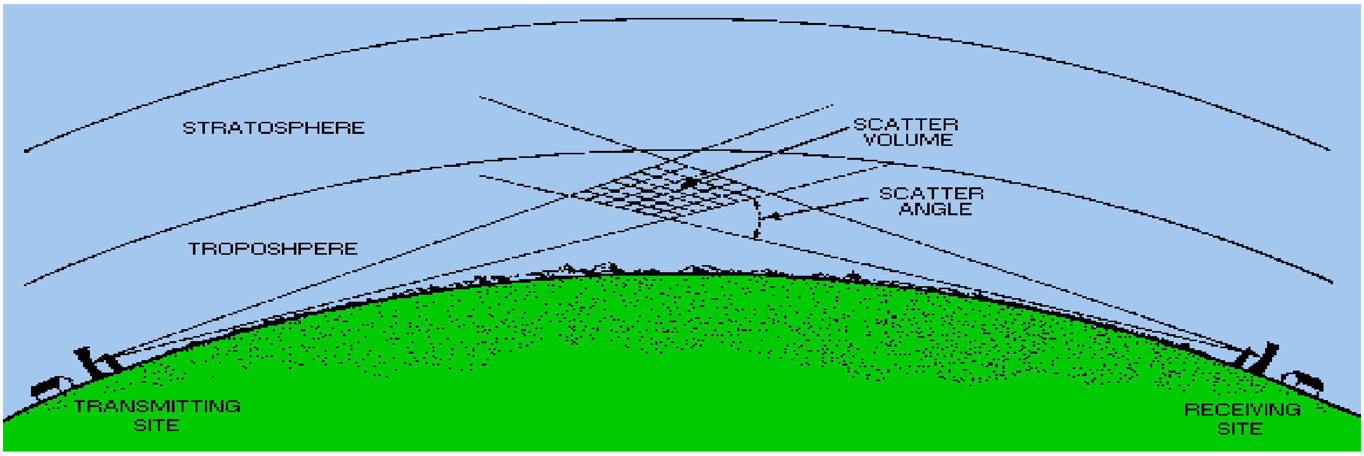
It must be noted that Maxxwave sees no advantage in using low frequencies for short-range NFC type communications, especially considering the number of relatively uncongested internationally harmonised short-range frequency bands already available today.

It must also be noted that if a wider bandwidth than 12.5khz were used, the transmit powers would need to be scaled upwards accordingly otherwise the power density would be insufficient to get above the noise floor.

Troposcatter

It is not possible to achieve troposcatter propagation at the power levels available in the Business Radio environment, simply due to the low transmit powers, ICNIRP limits and lower aerial gains available.

We cover Troposcatter however since it is highly relevant and is a commonly used propagation mode by amateur radio enthusiasts. It is this misunderstood mode of propagation that perhaps leads to the greatest misconceptions regarding the range of Band I and the other low frequency bands.



Troposcatter propagation is whereby the radio signal is reflected from particles within the troposphere and near atmosphere to distant (200km+) stations. This mode of propagation however has extremely high path loss, necessitating high transmit powers coupled with high antenna gains (typically 200W+ transmit power coupled with 10dB+ antenna gain giving 2kW+ ERP).

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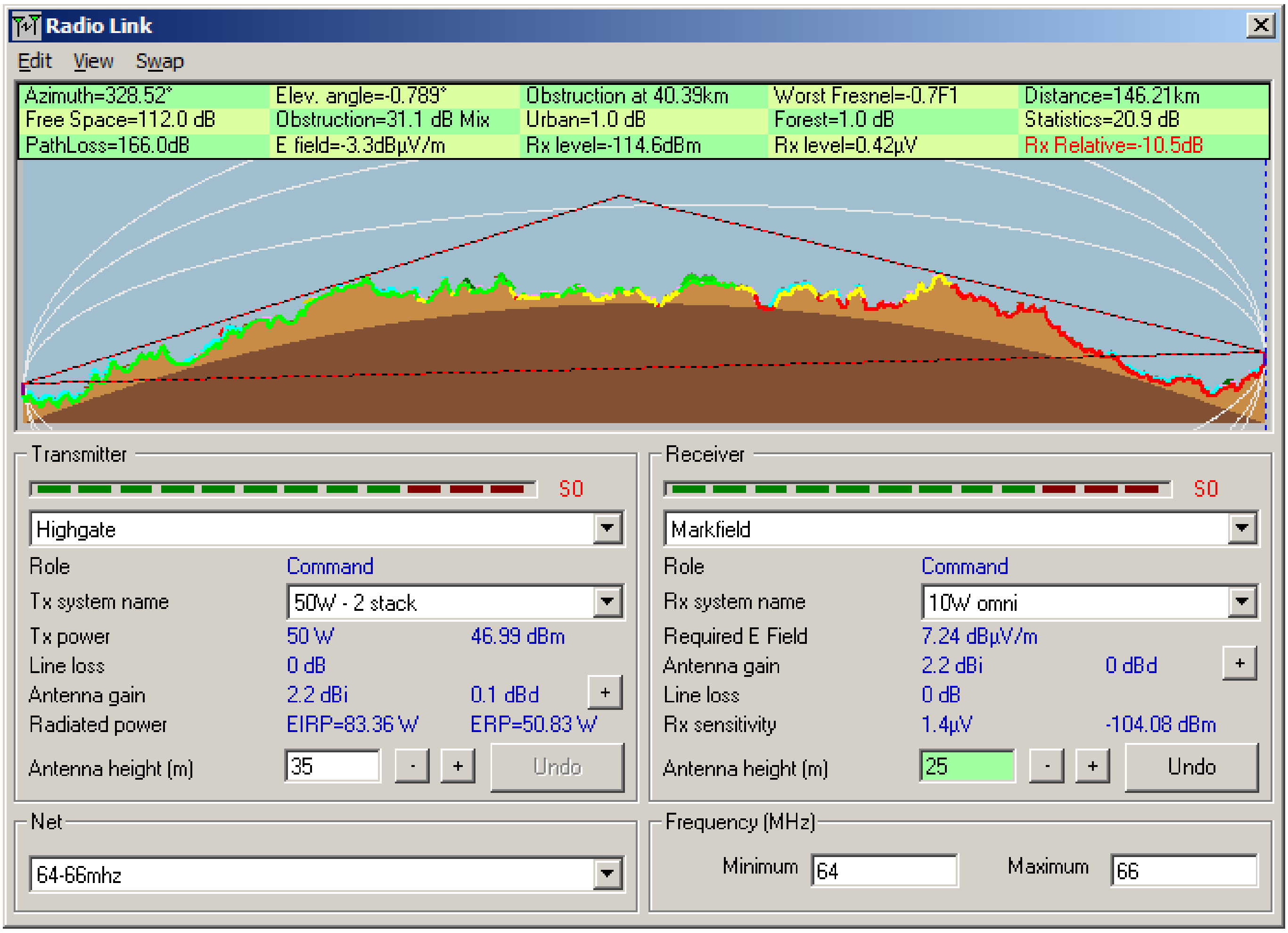
By running such large transmit powers it is possible to achieve reliable communications across a wide communications area, and it is this propagation mode that is commonly employed by amateur radio operators using high transmit powers into high gain antennas mounted high above the ground, with extremely sensitive narrowband (typically Single Sideband) modulation schemes.

"True" troposcatter is normally accepted as running in excess of 50kW ERP, and hundreds of these systems were employed commercially before the 1990's when they were replaced by satellite technologies. However the troposcatter effect is easily noticeable before this type of power, when sacrificing availability and using narrow bandwidth modulation modes (as with amateur radio).

We cover troposcatter only as a curiosity to explain why amateur radio operators are capable of achieving such great distances with these frequency bands when we are not.



A simulated radio link between Markfield (Leicester) and Highgate (London), a distance of 146km. The link is not viable with typical ERP and antenna gains (50W ERP and dipole receive antenna), since it is 10dB below the required threshold.

If the ERP were increased to 500W and the antenna gain increased to 10dB, then the signal would be received 10dB above the noise floor, starting to make a viable link.

Subsection 3: Normal noise floor of lower frequency bands (65mhz)

This section deals with the electrical noise floor under normal propagation conditions. It is not concerned with the abnormal propagation conditions that exist for circa 5% of the time on the lower frequency ranges.

The lower frequency ranges are characterised by a significantly higher electrical noise floor than higher VHF bands (110mhz +). This is due to the difficulty in screening lower frequency bands (due to electromagnetic induction into the actual screening itself, making the screening a re-radiator of the interference), the poor efficiencies of electrical interference suppression devices (such as capacitors/inductors) at lower frequency bands, the low usage of these frequency band (no pressure from any user groups to lobby against the gradual rise in noise floor over the past 20 years) and the rising clocking rates of computers and wide-area telecommunications networks (such as VDSL, PLT, G.Fast and Ethernet).

In a nutshell, the low frequency bands can be summed up as having high noise floor in rural areas and even higher in urban areas. Furthermore due to the “ground wave” type propagation, this interference can readily travel several miles from the interference source, with buildings, underground ducting and internal cable trays doing very little to stop this interference from travelling, as happens at the higher frequencies. Even internal electronics within most vehicles are noisy enough to cause a noticeable rise in the noise floor.

Furthermore the power-sum of all of these noisy electrics devices creates a noise “cloud” around towns and cities, similar to “skyglow” light pollution caused by street lamps at night. This radiates a considerable distance from towns, cities and even villages. In one test a ferry crossing the North Sea was equipped with noise measurement equipment, and it was not until the vessel was more than 40km from land that the radio noise floor measurably began to decrease.

The current EMC regulations are simply not adequate to ensure the same communications-grade noise floor that is enjoyed on the higher frequency bands. This is because the pressures to allow a high noise floor (by equipment manufacturers of offending devices) have outweighed the opposition (mainly radio amateurs), and historic use of this band (broadcasting) is far more tolerant of high noise floors than narrowband long-range communications.

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Therefore the noise floor (as measured with a ¼ wave antenna on a vehicle) is around -104dBm in rural areas (such as Cornwall, East Anglia and central Wales) and can readily rise to -92dBm in urban areas, without even getting close to EMC thresholds.

When you add a typical “wanted” C:N ratio of 12dB (as is required with most FM/digital systems today), this means that an extremely high field strength is required to successfully receive the signal.

We see that with the advent of higher speed broadband, such as G.Fast, PLT and other similar technologies, it is very likely that this noise floor will substantially increase in the coming years, so that any system deployed today may be unable to operate in just five years time due to the extreme high noise floors.

It must also be noted that noise can be readily generated from faulty electrical installations, such as a poor connection on overhead power lines and railway lines. Furthermore any lightning within a 100 mile range will seriously interfere with communications.

A “noise glow” can be readily seen for around 300 metres around any high voltage substation installation (main grid switching substations, not your typical 11kV urban substation), making communications very difficult and unreliable in these locations.

Due to the difficulty of accessing these overhead power lines and their nature as “critical national infrastructure”, interference can take weeks or months to resolve. Maxxwave has been waiting for over 5 months for Network Rail to resolve a faulty insulator on the West Coast Mainline, causing interference across a 2 mile area, and Ofcom has been unable to use any powers to force Network Rail to comply. This would prove disastrous to any critical communications network. It is estimated that there are tens of thousands of such faulty electrical connections all across the UK today, all being an interference source.

The high noise floor is perhaps the most misunderstood characteristic of these low frequency bands, yet is the biggest single factor in the poor performance of the lower VHF bands when compared to higher VHF bands (150mhz) and the UHF bands.

Subsection 4: Adverse propagation conditions and availability

Perhaps the most defining characteristic of Band I as opposed to higher frequency bands is the very high prevalence of adverse propagation characteristics. After the high noise floor (which exists for 100% of the time), this is the second biggest obstacle to achieving the theoretically possible long range.

This is defined primarily as three types of interference:-

1: Ducting (to the detriment of the wanted signal)

2: Ducting (to introduce unwanted signals from other transmitters nationally)
3: International interference (such as Sporadic E).

We do not wish within this section of this document to detail adverse propagation characteristics, and should you need to gain more information this subject there are plentiful documents available online.

It is worth noting that the amateur radio fraternity, as cited within the original Ofcom document, regularly use the unpredictable abnormal propagation conditions to achieve great distances. This is one of the key reasons for the misunderstandings of the potential range available from these frequency bands, that it is relatively easy to carry out tests during abnormal propagation conditions and get favourable results.

Generally these disturbances take the effect of ducting, occurring around 15% of the time, which increases the range of your transmitters (and also the range of other unwanted co-channel transmitters, causing you interference). Providing that good channel planning has been used, with liberal transmitter<>transmitter spacings and a reasonable fade margin, this type of interference should not cause serious issues.

It must be noted that due to the ducting type of interference which occurs for around 15% of the time, the normal Ofcom MASTS allocation criteria will result in quite a poor quality of assignments, which are likely to suffer significant degradation.

The more severe interference types occur around 5% of the time, and are caused by more extreme ducting or from “international interference”.

At present (2015), worldwide use of Band I is low, due to the problematic nature of its propagation. Therefore interference from foreign transmitters has been significantly reduced to that experienced in the period 1950-1985 when the band was used for domestic television, and during the PAMR experiments in the UK around 1995. However if the UK does proceed with actively deploying Band I, other countries are sure to follow and so the noise floor will rise significantly.

Interference from 1000km range is not uncommon on these frequency bands, and when it does occur the path loss is minimal. Therefore it is normal that the interfering signal will be of a far higher signal strength than the wanted signal (which is naturally low on these frequencies, as discussed earlier).

Maxxwave has had some success with developing active interference mitigation techniques which improve our availability considerably. However these come with a not inconsiderable cost burden and also a greatly increased technical complexity. This is only offset by the low licence fees and high availability of spectrum.

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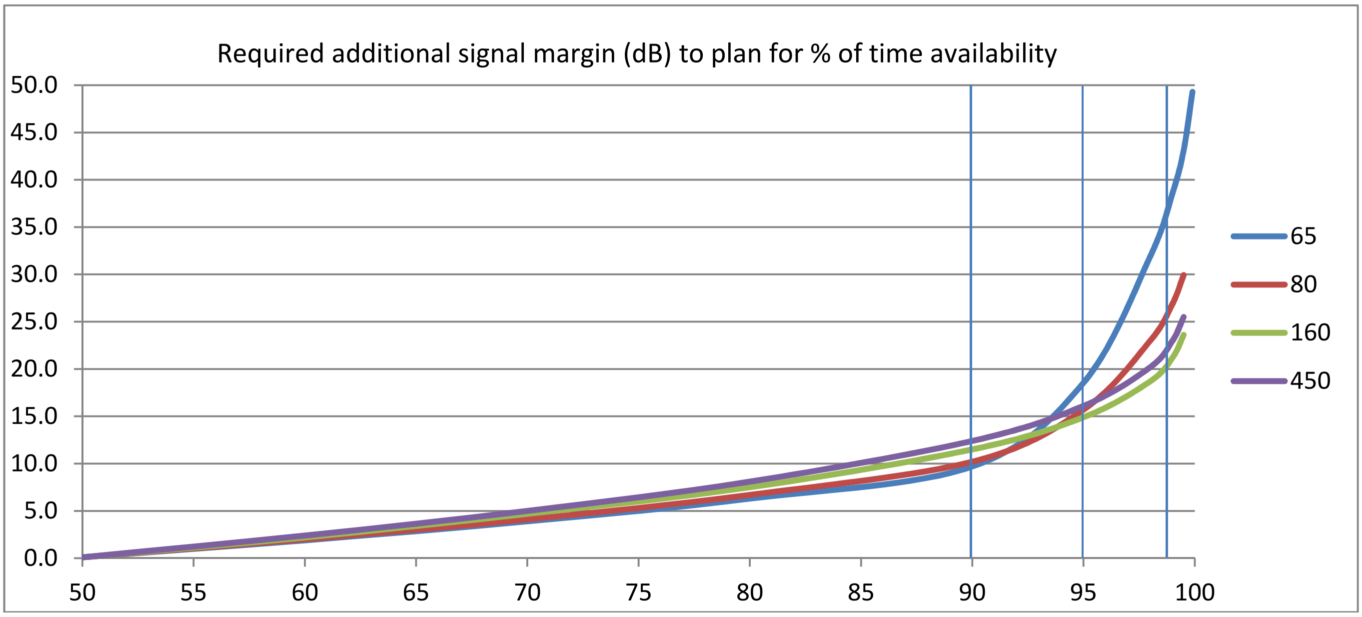

Many commonly used propagation algorithms, when considering percentage of time availability, simply do not take into account the effects of Sporadic E and other atmospheric effects that take place only at the lower frequencies. Therefore they do not calculate the effects that these will have upon avaliability.

The graph above is generated using the commonly used CCIR report 238 (used to calculate additional signal margin required to cope with ducting and other VHF/UHF effects) combined with data from P.1240 (used to calculate additional signal margin required to cope with Sporadic E and other HF/low VHF effects). At the higher percentages for lower frequencies, the P.1240 data is dominant, which creates the noticable uplift in required fade margin on 65mhz above approximately 90% required availability. At the higher frequencies P.1240 gives no input whatsoever but CCIR 238 is dominant. On 80mhz the two algorithms give very similar results.

Subsection 5: Antennas – physical size and mounting heights

Perhaps one of the most important subjects regarding Band I is that of antennas. However this would be multiple pages in itself, and is covered in detail in the technical notes part of this response (section 2). Therefore the most pertinent points are presented here.

There has been much interest in higher frequency bands in shortened antenna designs, which have had a great deal of success. However, shortening any antenna will reduce the gain.

In Band I, for far-field propagation (>45m), the maximum ERP possible must be transmitted to ensure that the signal strength at the receiving end is sufficiently high to give an adequate margin over the noise floor and so give a reasonably high availability. Furthermore in a base/mobile type scenario it would be typical that the base station would be located in a lower noise environment than the mobile station, and thereby even greater ERP must be used to “balance” the path, otherwise it is very easy for the mobile to be unable to receive the base, although the base can easily receive the mobile.

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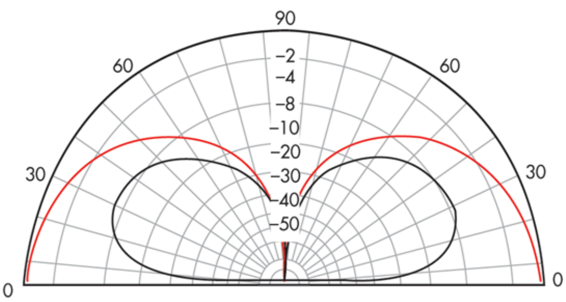
The requirement for high ERP is therefore distinctly at odds with reducing the antenna size, and therefore in order to “break through” the ~4.5km barrier (discussed earlier in subsection 1) and actually achieve proper ground wave propagation, at least 25W ERP must be used. This therefore requires an antenna gain of at least 0dBd (a dipole) if reasonable transmit powers are to be used.

A 0dBd gain antenna will measure around 2.5m long at 65mhz, and this must be taken into consideration when looking to deploy any system in this band – mechanical mounting, visual intrusion and the suchlike must all be carefully considered. Furthermore there are height issues as discussed later.

For a mobile installation, it is very difficult to get an antenna to resonate adequately for transmission below 65mhz simply due to the size of the roof (normally used as a ground plane) on most vehicles. Therefore vehicle based radios cannot make use of the lower frequencies for transmission. There also is a size issue – the only practical antenna that works on a vehicle is a ¼ wave ground plane, which is around 1m long, therefore having several mechanical and visual issues.

A small “telemetry type” antenna would only give a range of a 500m or less, due to the inability to get a sufficiently high ERP to achieve longer-range ground wave type propagation. It must therefore be carefully considered the suitability of this frequency band for many monitoring type applications, where large antennas would simply not be possible to mount.

Also of note is the requirement for the antenna - at least at one end of the link - to be located high and prominently. This is partly due to the Fresnel zone clearance issues presented at the beginning of this section, but is also due to ground reflections and the effect on the resultant elevation angle.



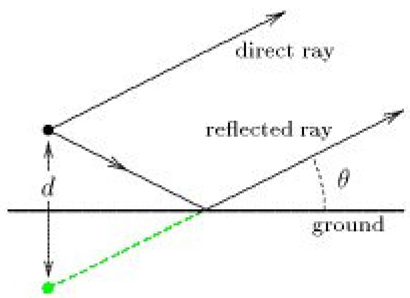


Figure 3a (left) and 3b (right). Figure 3a (left) shows the radiation pattern from a theoretical dipole antenna (red) and a real dipole antenna (black) mounted one wavelength (4.5m @ 65mhz) above ground. Figure 3b shows the reason for this up-lifted radiation pattern due to the ground reflection effect.

The effect of the ground (or even the roof of a building, if mounted on a building) upon the elevation angle from an antenna is perhaps one of the most misunderstood aspects of radio communications. At higher frequencies this is perhaps not so important since the measurements are in number of wavelengths, which are relatively short at high frequencies, but at low frequencies are rather long and so distances involved become rather large.

What can be summarised from the above diagram however and in general is that it is essential to get the antenna as high as possible above the ground, otherwise the signal received/transmitted to/from “local” (<50 miles) stations is considerably reduced, and the signal received/transmitted to/from distant interfering stations is dramatically increased, meaning that availability will considerably drop, since the antenna will favour “distant” signals (reflected via the ionosphere and arriving at a high elevation angle) over “local” signals (arriving from the horizon).

It is sufficient to say that as a “rule of thumb”, an antenna height of five wavelengths above ground is the bare minimum (22.5m at 65mhz), and ten wavelengths above ground is the minimum target height to remove the effects of ground reflections. At 65mhz this therefore requires an antenna height of around 45m at one end of the link (the higher end).

Where the base site is located on a high hill and the mobile stations are local at lower heights, it appears that the ground reflection on the mobile station is a lesser concern, perhaps due to the fact that the signal needs to travel 5-10 degrees up into the air anyway.

It is also of importance to note that the base antenna where located on the roof of a tall building must be a number of wavelengths above the roof such that the roof does not present a similar effect. Measurements have been taken from dipole antennas located close to the roof of large building, and the signal was considerably lower than expected due to this effect. Once the antenna was raised around 15 metres, the effect became marginal.

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Part 2

Technical notes relating to the propagation of Band I and Lowband

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Subsection 1: Frequency range and bandplans
Currently Band I is split into a simplex band at the lower frequency range, and a duplex band with a large duplex split at the upper frequency range.

We believe this is in general the correct configuration, but have the following comments:-

Duplex split
This currently is too wide. Antenna bandwidth on this band is narrow and as such accommodating such a wide split (7mhz currently) is not generally possible. We have finally decided that a 2.5mhz duplex split is optimal, requiring a 2.5mhz “prime” antenna bandwidth for transmit and an extended 5mhz bandwidth for receive only. This is possible with many common antenna designs.

Base transmit high
Currently the band is configured such that the base transmits on the upper frequency range. We propose that this should be reversed. The reason is that the mobile station generally uses the vehicle roof as a “ground plane”. Due to the physical width of roads, there is a limit on the size of the vehicle roof which the antenna can be tuned against. This therefore limits the lower frequency range of a ¼ wave antenna groundplane (with the vehicle roof being the groundplane) to around 65mhz.

Proposed bandplan
We therefore propose the following bandplan should be adopted:-

55-62mhz	62-63mhz	63-65.5mhz	65.5-66.5mhz	66.5-68mhz
Simplex	Duplex fixed links	Base transmit	Duplex fixed links	Mobile transmit

Some allowance also should be made for licence-free operation, ideally in the centre of the band, perhaps in the 61-62mhz range. This will encourage equipment manufacturers to make a licence-free version of their product, which will have greater appeal, but which also could easily be reprogrammed onto licensed frequencies, thereby increasing the availability of equipment.

We would like to see any licence free requirement come with a duty cycle limit and a mandated spectral efficiency.

Subsection 2: Antennas
Band I is characterised by being relatively low in frequency and high in noise.

Being low in frequency, it means that antenna bandwidths also are low. Thereby wide duplex splits cause problems due to greatly differing propagation characteristics (giving asymmetrical links) and difficulties with resolving antenna bandwidths.

Antennas are generally large due to the low frequency, with a dipole being around 2.5m long.

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It is necessary to mount the antenna at least 20m above the ground to give a reasonable elevation angle on the transmitted signal. Low antennas give high antenna radiation angles due to ground reflection which give poor local range and high atmospheric interference during summer months.

An antenna such as a 2-stack gives significant reduction in interference (we have made some developments in this sector), but requires around 25ft (7.6m) of mast space, with the bottom of the antenna being at least 20m AGL (above ground level).

Due to a high noise floor, shortened antennas work well for receive, dropping both the signal and noise equally, such that antennas on receive can be shortened to around 20cm without any degradation in received signal quality, but they have significantly reduced transmit range due to the lower ERP. This makes the band interesting for short range paging applications.

Subsection 3: Noise floor (under normal conditions)

Under normal conditions the noise floor (using a dipole antenna) is around -104dBm in rural areas, -90dBm in urban areas. This must be modelled within the coverage software to get a realistic expectation of coverage.

However, noise is very changeable. For example, faulty HV isolators on mains pylons / overhead railway electrical cables can radiate extremely high signal strengths over several miles.

We reported to Ofcom interference caused by a Network Rail faulty isolator in June 2015. As of October 2015, the issue has still not been resolved due to the very slow speed at which Network Rail works. This is giving us an unusable noise floor over a radius of around 1 mile from the interference source.

We reported to Central Networks one of their faulty medium-voltage 11kV pylons which was giving us interference across a 3 mile radius. It took 7 weeks to get this resolved due to their legal statutory obligations to notify businesses of planned maintenance work.

Any deployment in these low frequency bands therefore should have extreme care taken due to the interference aspect, and Ofcom MUST expect to spend considerable time and resources to resolving these types of interference cases if they are to have widespread deployments in these low frequency ranges. 72mhz appears less affected and 82mhz is only marginally affected by this type of interference.

G.Fast DSL and PLT are also large threats to low frequency operation in the future. Tests carried out by BT on G.Fast can effectively obliterate large areas, raising the noise floor to around -65dBm (as measured near a BT G.Fast test site). With the push for faster internet speeds, PLT and G.Fast are only going to cause more troubles.

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A PLT installation around 1 mile from one of our base transmitter sites raises the noise floor by around 10dB.

Subsection 4: Noise floor/adverse propagation characteristics

Band I is characterised by a highly changeable propagation characteristic, which makes the 50mhz and 70mhz frequency band of great interest to radio amateurs.

Currently the Band I frequency range is seldom used around the world for Broadcast. However during Summer months we have seen (prior to our interference cancelling antenna system that we have developed) the noise floor raise to -40dBm on a transmitter site from a Band I broadcast system in Greenland.

FM broadcast stations in OIRT countries (Poland, etc), commonly are received at around -75dBm using dipole antennas in modest locations).

Within the UK, stations located 200 miles apart regularly cause interference to each other. We have measured only 94% availability on a pair of 10km long fixed links which are both located 200 miles apart, all stations using directional antennas and typically being received at around -80dBm. Interference from your own network is high.

Generally availability therefore is only 95%. This can be extended to around 98.5% using interference-cancelling antennas, but cannot be raised beyond this without resorting to other techniques.

It is worth noting that interference is centred around the afternoon, typically 2pm-4pm, which is generally a “prime time” for radio networks. This is in stark contrast to higher frequency bands which generally experience their “atmospheric downtime” during early hours of the morning, such as 1am-3am, when it is rarely even noticed.

Subsection 5: Availability

On a single frequency, non-adaptive antenna network (such as our fixed-link deployments), availability is typically only around 94-95%, which will decrease further as more deployments are made around the country.

On a frequency-agile network, which can actively avoid interference, an additional 2% of availability is gained.

With an active receiving antenna, which can actively null interference (as we have developed), an additional 2% of availability is further gained.

Therefore with a large active receiving antenna, in a high location, with frequency-agile base stations, and a liberal spacing between transmitters and generous “planned service levels”, it is possible to achieve around 99.5% availability. However this is ONLY achieved with these considerable technical inventions.

Subsection 6: Comparison to VHF (fixed links)

We have transitioned around 30 fixed links from Band III (177-196mhz) to Band I (primarily 64 and 66mhz). Typical ERP in both cases was around 15W, receive antenna on Band III was typically 5 element yagi, on Band I is typically 3 element yagi (2.5m x 4m large). All links were "viable" beforehand, having good fade margin.

In 90% of cases, the received signal was around 6dB stronger. However the received Carrier:Noise ratio was always around 20dB worse.

10% of links which were previously usable are no longer workable and have had to be decommissioned or had a "halfway" repeater station installed.

90% of the links are noticeably worse in terms of availability, with the customer regularly complaining of outages due to atmospherics and suchlike.

No links were better for having been moved from Band III to Band I, including non-line of sight links (although the RSSI was better, the C:N and availability were considerably worse).

The higher frequency bands are *definitely* better for fixed links, of any distance. However it must be noted in this experiment all links were previously viable on Band III. The customer is unhappy with the results of the move to Band I, and would have preferred to remain on Band III.

Lower frequency bands have very large Fresnel zone sizes so therefore it is very difficult (nearly impossible, even with large high radio sites) to get Fresnel zone clearance, so the radio signal does not behave in the traditional "low loss" line of sight mode. Therefore even high prime sites linked together are not really any better than mobile stations, so fixed point to point links have very little fade margin.

When planning point-to-point links in higher frequency bands, 30dB fade margin is not unusual to give high availability. Because of the propagation characteristics of Band I, it would be impossible to achieve such a fade margin across most paths.

For example, across a 22.6km path, transmit power on 67mhz was 12.2W. On 167mhz, 8mW was required and on 5850mhz, 0.4mW transmit power was required. The higher frequency bands (167mhz/5850mhz) were behaving in a line of sight mode whereas the low frequency band (67mhz) was behaving more as expected for an obstructed NLOS path.

Subsection 7: Comparison to VHF (Mobile)

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With Band I, the "ultimate range" is less. However the coverage within the "planned service area" is more consistent, with fewer "black holes" caused by multipath effects. High transmit power (100W ERP +) is essential. When using low powers (5W ERP, for example), coverage is considerably worse since it just doesn't have enough power to get over the noise floor.

The best way to describe the coverage for a 50W ERP transmitter on both bands is as follows:- "If you draw a 10 mile circle on a map around a transmitter site, you get good coverage within this area, between buildings, behind hills, in the open, with relatively little flutter. With Band I, if you drive down a motorway away from a transmitter site, when the signal has gone, it has gone and doesn't reappear. With Band III, the signal reappears on top of every hill for the next 100 miles".

Large antennas are essential, with a good DC connection to the ground plane. "Mag mount" antennas, which use a capacitive connection to the ground plane, perform poorly due to a poor ground plane connection.

Antennas offset to one side of the vehicle become noticeably directional. This effect is not so noticeable at higher VHF/UHF.

Subsection 8: Comparison with UHF (450mhz)
Providing that you compare antenna type with antenna type (¼ wave with ¼ wave), we find the two frequency bands to be fairly similar in terms of range, but UHF450 considerably better in terms of availability. It must also be noted that atmospheric disturbances occur on UHF in the early hours of the morning (1am-5am), and on Band I they occur in the middle of the afternoon (2pm – 4pm)

We feel that the achievable range of Band I is very similar to the 1250mhz frequency band, except that the coverage is more consistent within the "planned service area". UHF450 range will typically exceed that of Band I since you can easily use a 3dB collinear type antenna on a vehicle with UHF and it will still be shorter than with Band I.

If shortened antennas are used, the results are considerably worse than UHF450, perhaps even on par with 2.4ghz licence-free or similar.

For point to point links, UHF has a significant advantage, in that it offers the "line of sight" propagation mode (extremely low path loss, allowing very low transmit powers). This is not possible on the lower frequencies due to the Fresnel zone obstruction, which means all links will need relatively high transmit powers.

Subsection 9: Propagation overall
PAMR has tried this band in the past (mid-1990's) and it was not successful due to the limited range and high noise. This was typically at lower ERPs (10-25W ERP).

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It is often believed that as you reduce in frequency, range improves. If this were solely the case then there would not have been a historic shift from low frequencies to higher frequencies. The fact is that whilst the "50% of time" range may increase, the "99% of time" range significantly decreases, due to the lower availability. If you look at the microwave linking bands, for example, excluding the effects of rain/fog (which are unique characteristics to those bands and are not relevant to this example), the lower frequencies have more range, but consequently have poorer availability due to wider antenna beamwidths, higher atmospheric disturbances and are more prone to electrical interference/jamming, which is particularly true at 1.4ghz compared to something like 6ghz, which is one reason as to the decline in popularity of this band.

The fact is that lower frequencies are generally less congested because they are less attractive, so are more readily available. But they are troublesome and offer poor frequency reuse, so are more suited to the less common uses of spectrum, or for people who are prepared to invest the time and resources in developing bespoke solutions to the interference present on these bands.

At higher ERP (100W +), this is sufficient to overcome noise, and at 200W ERP exhibits good coverage. Due to no high power licences within UK at 200W ERP, it is not possible to realise this coverage, so is generally run at lower ERP which gives 8-10 miles coverage from a transmitter.

Lower frequencies are only usable at the moment we suspect because foreign countries are not using it at present. If they begin high power DVB-T type broadcasts in this range, it would be very difficult to use during the summer months without serious mitigation techniques at our end (see previously).

A receiving-only antenna can be small, since it reduces both signal and noise, and noise is typically 20dB over a "good" receiver noise floor anyway, so -20dB gain can be used.

"Non line of sight" two-way propagation advantages compared to microwave bands come with some drawbacks, namely large antennas and reasonable antenna height at both ends required. This only works in the short-ranges anyway (<10 miles), with higher transmit powers. Low powers do not give the "non-LOS" advantages.

Poor coverage unless at least one site high (>25m height). This is due to the elevation angle.

Fast path loss in first few miles, then sits at low signal for next 10 miles. Therefore most signals are being received at or near to the noise floor. We use considerable digital signal processing to enhance audio in fringe signal areas, since this is where the radio signals are most of the time.

Beyond 10 miles range the signal starts to drop rapidly, with very little "over horizon" type propagation.

"Line of sight" does not exist at these low frequencies and is not really a valid term. In radio terms, "line of sight" is generally >3 fresnel zone clearances. At these frequencies this is not

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possible due to the huge Fresnel zones, so ALL Band I propagation is actually behaving in a non-line of sight manner.

The higher band proposed in this consultation (81mhz) should have close attention paid to it, due to the higher availability and lower noise floor present. We believe that a wider band than just 1mhz should be allocated to IoT requirements.

We note that the HO released spectrum in 80.0-81.5mhz and 83.5mhz-84.0mhz, but only part of this has been the subject of this consultation. We believe that this is prime spectrum, of great interest for this IoT consultation because it is far lower noise and higher performance than Band I, and therefore this full block should be included within consideration for IoT.

However we believe that the spectrum that should really be considered for IoT use is the upper part of VHF (130mhz +) or Band III (177-208mhz)

As previously mentioned, this band shares much in common with the 2.4ghz Licence free band – poor predictability, short range unless using large antennas, etc.

Subsection 10: Low power operation

Wide-area low-power operation is simply not possible due to the nature of the band. A 7 mile “line of sight” link at just 20W ERP is only received a few dB above the noise floor.

Lower power (50mW ERP) will give around 50 yards range. Therefore low powers would be suitable for short-range purposes, such as car keyfobs, etc.

We have often thought that due to the low loss of Ethernet cable at these frequencies and the ubiquitous nature of Ethernet within buildings that it would be easy to implement a “distributed antenna system” within a building using the existing Ethernet cabling, with loop antennas hidden behind face plates and integral loop antennas within handsets.

Subsection 11: Coverage algorithms

P.1546 and P.1812 absolutely useless at this low frequency range. The results are extrapolated from 100mhz, and the frequency bands do not behave in the same manner as normal VHF/UHF.

Longley-Rice is our preferred algorithm, since it was designed for this frequency band, although it is clearly not very up to date and sacrifices data quality in favour of processing power (or lack of it in the 1970’s!).

We feel a lot more work would need to be done in this area, but the current Ofcom assignment tools and criteria are unsuitable for high-quality assignments in this frequency band.

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Part 3

The Ofcom Consultation Itself

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Subsection 1: Comments on individual points within the consultation document

3.30 – "No international co-ordination required"
Maxxwave has applied in the past for a number of licences in the 68-88mhz frequency band (lowband) and has had these rejected due to international co-ordination issues. This is actually a superior frequency band to the Band I range in which we have found ourselves, and have had to go due to international co-ordination issues.

The reason is that most of our UK lowband band is used in France for military purposes, and so under the HCM agreement they are allowed to reject our requests. It must be noted however that the HCM agreement uses what we feel to be a flawed threshold since it assumes a noise floor of -116dBm, not the actual -104dBm.

4.8 – *Senaptic are happy to operate at "low frequencies"*
In the context of the response to the IoT consultation it is clear that Senaptic are discussing the multi-gigahertz and 868mhz spectrum that most IoT deployments to date have been focused upon. Indeed they actually say "we welcome further extension of licence exempt spectrum in the 400mhz to 1ghz range". In the context of their consultation this would classify as "low frequencies".

Nowhere in their consultation do they specifically state they would be "happy to operate down to low frequencies" and having discussed with several people at Senaptic they feel that even 200mhz would be too low for their uses, let alone 65mhz or even 80mhz. We therefore feel this point is fundamentally flawed.

4.13 – 160km range quoted
This is not stated anywhere in the reference document as "flat band" range, and amateur radio kit uses 5 element yagi antennas (as shown in photo), base to base at high locations, high power, SSB comms (see our comments on Troposcatter). The document is also referring to anything from 50mhz to 500mhz, it does not even mention 70mhz, the nearest amateur radio frequency band to this consultation. We have never been able to achieve 160km range under normal propagation conditions and believe this to be pure fantasy.

4.17 – Being able to use lower power than 800mhz
Again we believe this to be pure fantasy in most circumstances. This would only, in our opinion, apply on ultra short-range scenarios (<50m) when considering ERP (not transmit power), where it will propagate through walls and buildings better than 800mhz. It would also apply to heavily obstructed paths where >100W ERP would be required for 800mhz, and the low frequencies may make the path more viable. In normal "day to day" scenarios, 800mhz, especially due to the efficient aerials and comparatively very low noise floor, 800mhz is an excellent low power band.

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It is worth noting that we believe that if you used an equivalently sized antenna on 800mhz to low frequencies, with the corresponding increase in gain on 800mhz, then it would be possible to use low powers on 800mhz also.

A5.10 – Claims that this band will give longer ranges than currently available at higher frequency bands
Note our comments earlier in this document reference 180mhz links transitioning to the lower frequencies. It is our opinion that 130-180mhz represents something of the "sweet spot" with respect to radio propagation with respect to noise, non-LOS situations, etc, and thereby this frequency range would give the maximum range. We have found that 99% of situations below 100mhz decrease in range because of the dramatically rising noise floor.

However, we are comparing the typical PMR 160mhz / 450mhz, not the high frequency gigahertz bands, and perhaps this is what this particular comment was referencing.

Subsection 2: Ideal uses for the low frequency bands
This frequency band does have some merit for short range nearfield type devices (<45m) where licensed spectrum is required, simply due to the sheer amount of spectrum available. These low frequencies were once a very popular SRD band, but lack of assigned spectrum made them congested and prone to self-generated interference, so people transitioned away from them.

Furthermore a "distributed antenna system" could easily be installed into a building at these frequencies using the existing Ethernet cabling, and this could relieve pressures on UHF in congested areas, although very little suitable terminal (handportable) equipment exists today.

With higher transmit powers (prominently located high power base with large (25ft/7m long) high gain antenna, 25W mobiles with ¼ wave antennas measuring 1 metre), 10 miles range can be achieved relatively easily to devices. This gives a good "metro" coverage radio frequency band, comparable in coverage to UHF, and can relieve spectrum pressures on other frequency bands. Expensive bespoke mitigation techniques are required however to increase the availability to a level which would be considered commercially acceptable.

It is in this higher power "metro" coverage mode that Maxxwave makes use of this band, and we generally find that the low licence fees and security of knowing there is ample spectrum offset the expense and complication of needing more transmitter sites and specialist antenna systems.

Subsection 3: Maxxwave response conclusion
The lower frequency bands (particularly Band I) are considerably below what we consider the "sweet spot" of radio spectrum. It is very prone to noise, atmospheric disturbance and electrical interference across wide areas, which can take Ofcom months to resolve, since the noise

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source is often the UK's "Critical National Infrastructure" (Railways Power lines and Electricity Pylons).

The 81mhz band is somewhat better in respect of interference, and the sub-60mhz band is very poor in this respect.

Maxxwave has had some success with 63-68mhz due to our adaptive antenna arrays, frequency agile equipment and generous link margins during network planning, but the reduced cost of spectrum is most certainly offset by the increase in cost of running the network, in terms of additional complexity of equipment and additional number of sites required).

The band shows limited promise in very short range devices (<50m), and the 81mhz band could be used as a "poor man's VHF", which is really how Maxxwave treats it.

We encourage any innovation in this band, since we feel that our experience would be beneficial to anyone looking to deploy networks in this band, and we would be happy to offer consultancy services. Therefore it is not our intention in any way to attempt to make the band less attractive for incumbent users to safeguard our interests, especially considering there is more than enough spectrum for what we require, and we have already acquired sufficient spectrum for our needs.

Our response is therefore intended to give people a realistic expectation of what can be achieved with these frequency ranges and correct the common misunderstandings about this frequency spectrum from people who have clearly never actually used it before.

Subsection 4: Comments on potential IoT uses (from the Ofcom website)
The Ofcom website lists several potential IoT uses, which we comment on the suitability of these lower frequency bands for.

Smart Farming – not suitable. Devices would be low on ground so therefore short range. Large areas required, propagation not suitable. Noise could be high with overhead power cables running across fields. We suggest 900mhz or similar

Smart Grids – Limited usage. Noise is **very** high in an electrical environment, so reception would be problematic. High power paging transmitters (200W or more) would give good penetration and range, like a broadcast transmitter, so it could be used for one-way paging of data to devices, perhaps using the actual electricity cables as carriers and having a WT Act licence because of the huge amount of leakage.

Telehealth and Healthcare –Wearable pill boxes, Sensors, etc. This spectrum offers absolutely no advantages over the other existing harmonised spectrum for this application.

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Intelligent Transport Systems – Provided the range is kept low may be a good use because of the sheer amount of spectrum available. High power "paging" transmitters covering wide areas could also be used to advertise traffic info. However wide-area talkback would require large antenna (1m) and high power (25W TX) so may be less suitable.

This spectrum may be good for short-range communication between driverless cars and the roadside controllers due to the amount of licensed spectrum available, but would need protocols that are suited to the characteristics of this particular frequency band.

Finally: Maxxwave responses to questions

Q1. Do you agree that the spectrum we have identified (in figures 4.2 and 4.3 above) is suitable for M2M applications for remote and rural locations?

Please provide as much information as possible on likely applications.

We do not believe this spectrum is suitable since it offers no advantage over other frequency bands that will be available in rural and remote locations.

The only advantage that this spectrum has over any other available spectrum is that it is available on a national basis (since nobody wants it due to the problems associated with it) and therefore is normally available in urban areas. However this consultation is not interested in urban scenarios and other (better) frequency bands are generally available in rural locations. High-VHF (such as Band III) is a far superior frequency range and is available on a national basis, although is considerably more expensive in an urban environment due to the popularity of the band.

We feel that the spectrum identified may be of use for short-range devices (<50m), but we also believe it offers no technical advantage over other harmonised spectrum currently available. It would therefore only offer an advantage where fully licensed spectrum is essential.

There is more spectrum available in the 80mhz range from the HO spectrum release than you have proposed, and this is of greater interest because of the better suitability for longer range purposes. We believe that you should have included all of the 80mhz spectrum in your proposal from the Home Office spectrum release, since this is of greatest use to your proposed IoT applications.

We suggest that closer attention should be paid to higher VHF bands (130mhz +), such as Band III since these offer considerably more favourable propagation characteristics in every respect, and would be far more suitable for M2M applications in all locations. In "remote and rural locations" (as specified within the question), there is a lot of spectrum available in most other business radio bands so therefore spectrum congestion would not be an issue.

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We feel that there is a clear lack of understanding (within Ofcom itself apparently) on the propagation characteristics of these frequency bands, which will significantly hamper deployment with unrealistic expectations on coverage. We feel this consultation therefore has been conducted in an improper manner since the facts presented within the introduction to this consultation are fundamentally flawed, and this incorrect information has been seized upon by the press and accepted as fact since it comes from the regulator, someone who should know what they are talking about.

We therefore would insist that when Ofcom considers the responses made by other parties it takes into account the level of first-hand experience these people actually have (and demonstrate within their response) with the lower frequency bands.

Close attention should be paid to 80mhz as opposed to the 55-66mhz frequency range since it is far lower in noise and far less variable and not as affected by atmospherics as the lower ranges. Therefore this is the preferred IoT spectrum within the context of this consultation and the lower frequencies proposed are significantly “sub-prime”. The lower frequencies may be of some merit for higher power communications as per the proposed bandplans for Band I.

We do question however as to what advantage Band I spectrum would have over the currently available higher frequency bands for short range data, since there are already many chipsets available today for those other frequency bands.

Our other concerns (as detailed within this response) are the high noise floor, large antennas and high variability of these frequencies making deployment of any critical system extremely complicated and risky.

We also feel that commonly available data protocols would not be best suited to the characteristics of these frequency bands so customisation of equipment would be needed, but that is probably a matter outside of the scope of this consultation.

Q2. Do you agree with our analysis that encouraging new IoT uses in the bands 55.75625-60 MHz, 62.75625-64.8 MHz and 64.8875-66.2 MHz, 70.5-71.5 MHz and 80.0-81.5 MHz should still leave sufficient spectrum to meet demands for Business Radio in the VHF range?

We feel that you should change the Bandplan of Band I to that proposed by us in this document. If you do this then yes, there should be sufficient spectrum and the two services could happily co-exist, providing it is not taken en-masse by people who believe it will do things that it won’t, and then don’t return it when they don’t any longer use it (as has happened with many other frequency bands).

We are about the only Business Radio actively deploying systems in these lower frequency bands, and we are reasonably happy that we have sufficient spectrum for our needs. We only anticipate that we would ever need 32 x 25khz duplex channels, which is only an extremely low percentage of the available spectrum.

We think once more people realise how poorly these bands work (particularly the lower ones) then they may quite disappointed and simply hand the spectrum back anyway, as happened in the late 1990's PAMR trials of this frequency spectrum.

Q3. Do you think the conditions associated with the current range of BR licences available now should change to facilitate new IoT services uses? If you do, what should these changes be?

We believe that due to these lower frequency bands not behaving as most people appear to expect that there should be a minimum channel loading requirement, so that people who do not use their spectrum must hand it back.

Business radio does not currently allow products approved to ETSI EN 300 220 to be utilised. This is a common standard for short range devices, and we suspect that many of the IoT devices would be approved to this more relaxed standard. ETSI EN 300 086 is rather cumbersome, and would probably significantly increase the cost of IoT devices, making this a far less preferred band for short-range use.

It must be noted that Maxxwave would be opposed to allowing equipment approved to ETSI EN 300 200 be used in any deployment other than small integrated antennas for short range communications, as it is designed to be used.

We believe this point is so important we have made it twice: Perhaps these people should demonstrate clear understanding of how these frequencies work and what they will do to overcome the obstacles BEFORE they are issued with a licence. This will save a "gold rush" for the spectrum that then lays dormant for years, a worse situation than currently because at least it is currently unassigned.

The main two changes to conditions that we would like to see for these lower frequency bands, as we have discussed with Ofcom previously is increase of maximum base ERP to 200W ERP/12.5khz channel (as is used by German Police on their new TETRAPOL network on these frequencies, South African Police and many others around the world) and also change to the "standard" bandplan to that proposed by us.

We are opposed however to the separation of IoT products from BR products and would like to see these two proposals integrated into the BR product also.

Q4. Do you think we should create a new licence product specifically for IoT services?
No, we think the current BR system is suitable. However please note our comments to Question 3, that most people don't understand how poor these lower frequencies actually are so we would like to see some mechanism in place that stops people simply getting all of the available frequencies "en masse" and then doing nothing with them.

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We are STRONGLY opposed to any changes in the application method for these frequency ranges, such as a spectrum auction or similar. We believe the current annual licence application process is more than adequate for both IoT and BR licensees.

Perhaps these people should demonstrate clear understanding of how these frequencies work and what they will do to overcome the obstacles BEFORE they are issued with a licence. This will save a “gold rush” for the spectrum that then lays dormant for years, a worse situation than currently because at least it is currently unassigned.