Waimakariri District Council
215 High Street
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Rangiora 7440, New Zealand
Phone 0800 965 468

DISTRICT PLAN REVIEW

Proposed Waimakariri District Plan - Submission

Clause 6 of Schedule 1, Resource Management Act 1991

Submitter details

*(Our preferred methods of corresponding with you are by **email** and **phone**).*

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(if different from above)

Please select one of the two options below:

☑ I **could not** gain an advantage in trade competition through this submission *(go to Submission details, you do not need to complete the rest of this section)*

☐ I **could** gain an advantage in trade competition through this submission *(please complete the rest of this section before continuing to Submission details)*

Please select one of the two options below:

☐ I **am** directly affected by an effect of the subject matter of the submission that:

A) Adversely affects the environment; and

B) Does not relate to trade competition or the effect of trade competition.

☑ I **am not** directly affected by an effect of the subject matter of the submission that:

A) Adversely affects the environment; and

B) Does not relate to trade competition or the effect of trade competition.

Submission details

The specific provisions of the proposal that my submission relates to are as follows: *(please give details)*

My submission is for EI-R29 "New amateur radio configurations."
The limitation provided for in the new rule.

My submission is that: *(state in summary the Proposed Plan chapter subject and provision of your submission. Clearly indicate whether you support or oppose the specific provisions or wish to have amendments made, giving reasons) (please include additional pages as necessary)*

I partially support EI-R29 and would wish to have amendments
1. Instead of using the term "pole" use Amateur Radio Configurations (per definitions)
2. Removal of para 2. or alternatively amend (see attachments)
3. Provide an additional rule for secondary structures.
4. Provide for an additional dish antenna.
5. Recognition of boundary poles (structures)
6. Support the rule providing for 5 m dish antenna.
7. Retain "Restricted Discretion" assessment categories for cases where an individual amateur seeks a configuration which exceeds the permitted limits
8. Note Height in Relation to Boundary exceptions for amateur structures.

I/we have included: 28 ________ additional pages

I/we seek the following decision from the Waimakariri District Council: *(give precise details, use additional pages if required)*

Please see additional pages.
The Council Decision Sought.
1 Change the Definition of Amateur Radio Configurations, to "means antenna, aerials and associated support structures which are owned and operated by licensed amateur radio operators."
Rationale: The current definition refers only to "Poles", but amateurs may use other structures, including towers on some occasions. Therefore the term "Support Structures" is more appropriate.

2 The Rules of EI-R29 are unreasonably restrictive. It is understood that Council is keen on controlling the visual effect by limiting structures to a single pole per site. This visual amenity (which is, at best, merely a subjective amenity) has been applied without any consideration of balancing it against the objective amenity values given on Page 3 of this submission.
AMEND RULE: (paragraph 2. of Draft District Plan) The restriction to having a maximum of one pole per site should therefore be removed.
This would bring the Waimakariri District Plan in line with our neighbouring Christchurch and other District Plans.
ALTERNATIVE RULE: There may be only one main supporting structure per site, and its maximum height in relation to infrastructure will be 20m."

Submission at the Hearing

☑ I/we wish to speak in support of my/our submission

☐ I/we do not wish to speak in support of my/our submission

☑ If others make a similar further submission, I/we will consider presenting a joint case with them at the hearing

Signature

Of submitters or person authorised to sign on behalf of submitter(s)

Signature ______________________ Date 24 November 2021

(If you are making your submission electronically, a signature is not required)

Important Information

1. The Council must receive this submission before the closing date and time for submissions.
2. Please note that submissions are public. Your name and submission will be included in papers that are available to the media and public. Your submission will only be used for the purpose of the District Plan review process.
3. Only those submitters who indicate they wish to speak at the hearing will be emailed a copy of the planning officers report (please ensure you include an email address on this submission form).

If you are a person who could gain an advantage in trade competition through the submission, your right to make a submission may be limited by clause 6(4) of Part 1 of Schedule 1 of the Resource Management Act 1991.

Please note that your submission (or part of your submission) may be struck out if the authority is satisfied that at least 1 of the following applies to the submission (or part of the submission):

- It is frivolous or vexatious
- It discloses no reasonable or relevant case
- It would be an abuse of the hearing process to allow the submission (or the part) to be taken further
- It contains offensive language
- It is supported only by material that purports to be independent expert evidence, but has been prepared by a person who is not independent or who does not have sufficient specialised knowledge or skill to give expert advice on the matter.

Send your submission to: Proposed District Plan Submission
Waimakariri District Council
Private Bag 1005, Rangiora 7440

Email to: developmentplanning@wmk.govt.nz

Phone: 0800 965 468 (0800WMKGOV)

You can also deliver this submission form to one our service centres:

Rangiora Service Centre: 215 High Street, Rangiora

Kaiapoi Service Centre: Ruataniwha Kaiapoi Civic Centre, 176 Williams Street, Kaiapoi

Oxford Service Centre: 34 Main Street, Oxford

Submissions close 5pm, Friday 26 November 2021
Please refer to the Council website waimakariri.govt.nz for further updates

Submission to the
Waimakariri Proposed District Plan EI-R29

Joint Submission of

- New Zealand Association of Radio Transmitters, Inc. (NZART).
- North Canterbury Amateur Radio Club (Inc) (Branch 68 of NZART)

Submitter Details, Organisation Name, and Addresses for Service.

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We wish to appear in person at any hearing to present our case.

Orientation

The New Zealand Association of Radio Transmitters Incorporated (NZART) is a voluntary association. We rely entirely on amateurs who live in the area to advise the parent organisation (NZART) of District Plan Reviews. NZART therefore works closely with the assistance of locals who live in the locale of the District Council producing the proposed plan.

The recently issued Proposed District Plan for Waimakariri does provide for Amateur Radio Configurations in Rule EI-R29. However, there are several aspects of these rules which are very restrictive, and in this submission we seek that these restriction to be reviewed.

Context.

Radio waves do not recognise national boundaries, so they have to be managed internationally. The International Telecommunications Union (ITU), an operational subsidiary of the United Nations, every four years holds a world administrative radio conference (WRC) in which every government, every military, all the significant telecommunications authorities, significant tertiary establishments, satellite operating companies, and other significant users of radio spectrum, come together to regulate/allocate spectrum. Commercial operators can make billions of dollars through the radio-based services they can offer, and the military has multiple complex needs in order to maintain security, so there is real pressure on the ITU for spectrum allocation. However, there is one thing that all parties agree on – there must be an allocation for experimental development, and this has to be free of commercial and/or security bias, so right up the spectrum, from the lowest frequencies to the super high frequencies there are blocks of bandwidth set aside for this experimentation. Each bandwidth block has its own characteristic performance issues, and needs different treatment. These are the blocks which are allocated to unpaid professionals (called amateurs) for experimentation.

No amateur has the ability or inclination to experiment with everything, as a result each amateur has his/her own preferences, so in allocating District Plan rules two fundamental factors emerge:

1. Council has some sort of obligation NOT to put in place rules (or lack of rules) which frustrate the objectives of the United Nations and the International Community in general.
2. There cannot be "one size fits all". Councils cannot satisfy everyone. In seeking permitted Amateur Radio Configurations in District Plans, we therefore aspire to achieving a compromise – a "Basic Set" of rules which will satisfy a wide range of preferences.

Broadening our Perspectives.

- If the concept of "Serious Leisure Perspective" is researched (for example, on the WEB) it will become evident that at one end of the "Leisure Spectrum" there are "Hobbies" and at the other end there are "Volunteers" and "Amateurs".
- Amateur Radio is an Experimental Science, licenced under International and Domestic law. There are international treaties associated with this law.
- Hobbies include pastimes such as making collections, and some things that come to mind are a garden full of 47 different gnomes, or a collection of 367 salt cellars from all over the world, and extensive model railway sets. These are impressive activities for the Hobbyist, but they provide no tangible benefit to society.
- Amateur Activities, on the other hand, include Theatre, Geology, Astronomy, Archaeology, Sport, and several examples of Experimental Science. Amateur Radio is an experimental technology which has provided, and is still providing, many innovative developments in the field of radio technology which the general population, by and large, now takes for granted. Unlike Hobbies, Experimental Science does provide tangible benefits to society, and should not be dismissed lightly, as one might dismiss many "hobbies".

In some other districts, NZART has not in-frequently encountered very prejudiced views on this issue. Amateur radio is not just a toy for rich people to dabble with, it is an essential experimental science.

Amenity Values of Amateur Radio.

The decisions that Councils make on the permitted status of anything in the Plan inevitably results from a judgement of the amenity effects of different groups within the community. It is acknowledged that to some people the existence of amateur aerials adversely affects their "Visual Amenity". The planner's task is to balance the loss or gain of amenity of one group against the loss or gain of amenity of another group. Visual Amenity is very much a ***subjective*** quantity, and depends very much on the perspective of the viewer. On the other hand, the amenities of amateur radio are generally ***objective***, and must be seriously weighed up in any decision about any "permitted" status.

Amateur Radio provides to the Community:-

- Telecommunications and information technology expertise.
- A reliable system of communication during civil or environmental emergencies.
- Competent communications for Search and Rescue.
- A widely dispersed source of experimental researchers.
- Keeping New Zealand a significant player in international technology development.
- Space technology. Radio amateurs are the only group outside Governments, the Military, and large corporates that have operated satellite technology continuously since the 1970s.

Amateur Radio provides to the Individual:-

- Guidance and education towards qualifying for an amateur radio licence
- Self Education in technology.
- An interest that can be pursued throughout life.
- A network of friendships linked by radio communications.

The Amateur Radio Licence allows operators to design and build their own equipment, because it is specifically set up as an experimental and/or technology development service. It is ***the only*** radio service in which it is the licensed operator, and not the equipment, that is licenced. In ALL other types of radio service it is a requirement that "type approved" equipment which has been rigorously tested to meet tight technical specifications must be used, and that equipment must not be modified.

In the book "Radio Science for the Radio Amateur" the author Eric P. Nichols makes the point:

> *"A big difference between Big Science and Amateur Science is that most of the "official" participants in the former do it as a full time job. Radio Amateurs who do Radio Science, for the most part, do it in their free time. That is why it is called **amateur**, which means that the work is done without pay, **not** that it is done without expertise."*

Restrictive controls applied to Amateur Radio Configurations could put at risk the amenity of attracting future electronic technologists from being spread widely through the community. Several highly qualified people have been known to check out how "amateur friendly" a particular district is before relocating.

It should be recognised that not every amateur wants to use large ARCs as his/her experimental preferences. Many use aerials that are of a similar scale to standard TV aerials. The aerial dimensions depend entirely on the frequency bands they are interested in.

Some Aerial Fundamentals.

Aerials are the means by which radio signals are launched into space, (transmitted) and by which signals in space can be captured (received). An aerial is far more effective if it is "resonant" on a desired frequency, and generally an aerial resonant on one frequency could be virtually useless on other frequencies. Every frequency has a corresponding "wavelength" - for instance, a 3.5MHz frequency has a wavelength of about 80 metres, and a 144MHz frequency has a wavelength of 2 metres. The base-line for an aerial to be "resonant" is that its length needs to be half a wavelength long, so a 3.5MHz aerial needs to be 40m long, and a 144MHz aerial needs to be one metre long.

• The dipole. Technically, the least complex place to attach a feedline to an aerial is in the centre of the aerial, so in this configuration, the aerial is termed to be a dipole. A 3.5MHz dipole will therefore be a wire aerial (optimally supported between two poles) fed by a cable coming from its centre, and a 144MHz dipole might be constructed of a rigid aluminium tube, extending half a metre either side of a central support.

• The Yagi. In 1926, two Japanese men, named Uda and Yagi, discovered that if another (resonant) element was positioned near to a dipole, the radiation pattern of the dipole was skewed in a particular direction. This developed into the Yagi-Uda array (commonly known as a "Yagi" antenna). TV antennas between 1960 and 2013 were typical Yagi arrays – but to enable TV to receive both VHF and UHF channels, later aerials had a mixture of longer and shorter elements (remembering that they optimally work at their "resonant" frequencies – so two or more different element lengths were required). Such combination antennas are a compromise and can work OK for receive antennas, but can be very problematic as transmit aerials.

• Loop Antennas. "Loops" are just another way of achieving resonance. A fundamental loop for 3.5MHz would be a full 80m length of wire, supported by four poles in a square formation round the perimeter of the rear of a typical residential section. These aerials are extremely effective, both on the fundamental frequency they are designed for, and also on harmonically related higher frequencies. One characteristic is that they are omni-directional, meaning that the power transmitted is spread out in all directions. The advantage of a Yagi antenna is that it directs its power into one predominant direction enabling a much stronger signal being received at the far end of the transmission path.

• Magnetic Loop antennas. Loops can be reduced in size by having multiple turns of the wire with a reduced diameter. They are becoming popular as an experimental antenna, but I cannot see them as having more than little interest with respect to District Plans.

• The "Dish" aerials.

a Parabolic dishes are used as "reflectors" to aim a signal in a beam exactly the same way that torches have a reflector to beam light. Commercial operators (Telecommunication companies) used dishes of 2m to 3m diameter to beam high capacity microwave signal between two specific (unmovable) points. Amateurs rarely if ever use these types of dishes (or Panel Antennas) – except, perhaps, to receive Sky TV.

b It is a very great technical challenge, however, to beam a microwave signal to the moon, where it bounces back to earth at some distant point, enabling communications between continents. Currently there are a number of 5 metre diameter dishes available at very low cost, so some amateurs (not many) like to take the challenge. The desired objective is to permit dishes up to 5m diameter, and that they be mounted at their exact centre with a swivel so that they can be pointed in any direction. That swivel is attached to the top of a pedestal which is no more than 4 metres high. (This is called the pivot point). If the dish is pointed at the horizon, mounted 4m above the ground, then the highest point of the rim would be 6.5m above the ground. If pointed upwards towards the moon, then the maximum height would be considerably less than 6.5 metres.

Aerial Heights.

The effectiveness of any aerial is fundamentally affected by its height above ground. If for a moment, we turn our attention to the Yagi (as defined above) we have an aerial which in free space. (that is, well above the atmosphere of the earth) is highly directional. It behaves like a torch beam – sending out all its "light" in the direction it is pointed.

• But close to the ground, its performance changes dramatically. If, for instance, it is just half a metre above the ground a) a large component of its signal will be absorbed by the ground, and b) that part which is not absorbed will go vertically upwards.

• Mounted about 5m above ground, the signal splits into two parts – a component which comes out of the aerial itself, and another component which is reflected by the earth. The resulting ray from this "low" aerial may travel upwards at about 45^0 to the horizontal.

• If it is mounted, say, 20m above the earth, the main beam will travel only slightly upwards – at around 6^0 to 10^0 above horizontal. This is the sort of angle that is required to get a signal to travel around the world.

Height is therefore a very essential feature of an effective aerial, and it is the first thing that Council Plans seek to control. When faced with this issue during the 2012 Environment Court case in Tauranga City, the presiding Judge is reported in the local newspaper as saying: (see attached =>)

What Judge Jeff Smith said:

"In our view, 20m represents a reasonable provision for the radio community, while balancing that against the potential impact.

"Permitted activity status has the advantage of the council not becoming involved in extensive and expensive applications for consent from an almost minute sample of the population of Tauranga.

"There are potentially some amenity impacts. In our view, those are on adjoining neighbours. Others we disregard in the end as being minimal. Those [impacts] on adjoining neighbours must be balanced against the national and international need to encourage the amateur radio transmission community.

"Radio amateurs constitute an important part of our community, particularly in times of emergency.

"The issue in this case should not turn upon whether or not people agree [with an aerial next door] but whether it is appropriate to provide for radio amateurs or not."

Recognition of amateur radio aerial diversity.

The geographic location of New Zealand means that long distances exist between amateurs here and those overseas. Radio signals are correspondingly weak, and efficient aerials/antennas are required to send and receive such signals.

Radio waves travel through the ionosphere in the upper parts of the atmosphere and may return to earth depending on the frequency of operation. For reliable communication during day or night, summer or winter, the desirable frequencies for long distance communication are found typically between the 7 MHz band (the 40 metres wavelength) and the 28 MHz band (10 metre wavelength). With variation in the sun's activity the highest usable frequency may be reduced to the 14 MHz band (20 metres) or even lower. The propagation of radio waves is variable but never-the-less antennas for this range of frequencies are used by many amateurs for long distance communications.

Scientists and amateurs have studied, simulated, constructed and measured the performance of antennas to find the most suitable configurations at every frequency that the Licence permits an amateur to use. The performance of an antenna depends on the radiation pattern where its best efficiency occurs. Based on the frequencies required for long distance communication and how the pattern of an antenna changes with height, an academic paper by K Siwiak PhD, MSEE, PE, SMIEEE is included as Attachment B8. In summary it says: -

> *"Optimum height is 1.5 to 1.6 wavelengths for any one band, or a compromise height can be found for a multiband antenna operating over several bands by using the optimum for the highest frequency."*

And also

> *"If operation anywhere within the 10 – 40 metre bands are of equal interest, the "best" height works out to be 19.9 metres."*

When the sun limits the upper frequency to the 20 metre band (or lower), it is desirable that the antenna height should be raised. A height of 20m is desired for the primary supporting structure for amateur radio configurations

New problems have emerged over the last 50 years. The number of devices using radio frequencies has increased exponentially, and many of them unintentionally produce noise and interference to radio communication networks. This has resulted in man-made background noise level rising every year. Whereas 50 years ago, an army surplus radio outputting six watts of RF energy was able to communicate anywhere in New Zealand, radios are now outputting more than fifty times the power and they still cannot always be heard above the background noise level.

This has resulted in radio amateurs experimenting with many different aerial systems to try to improve the wanted signal response, and to reject at least some of the unwanted noise. Aerial experimentation might result in several different configurations being tried out in any one year on any one site.

In addition, due to the sun changing the electrical properties of the upper atmosphere it may be necessary for an amateur radio operator to change his/her frequency up to four different bands during the course of the day to maintain communication to a specific part of the world. Each change will require a change in the transmitting aerial.

In his book "Radio Science for the Radio Amateur" the author Eric P. Nichols provides some very interesting perspectives concerning science. After following a professional career, in the preface he writes:-

> *"Even monster installations like HAARP or EISCAT (European Incoherent SCATter) facility in Tromso, Norway, can only be in one place at once. Hams are everywhere, and a lot of ionospheric research can only be done with widely scattered sensors, which Hams are uniquely equipped to provide……… Much of the research can be performed by the Amateur Radio community ……. And that we can contribute significantly, towards completing some long unfinished business regarding understanding radio propagation."*

To a greater or lesser degree, every active amateur is continuously contributing to science, because it is only through communicating with other parts of the world or country that practical data on when and how radio waves propagate is able to be collected and analysed. This is not possible with commercial networks which are invariably point to point services, engineered very conservatively. Usually it is only when communication links are operated at the limits of their capabilities that useful scientific knowledge is obtained.

Defining the need for neighbourly approval.

Immediate neighbours have been known to lodge objections. Neighbours move house from time to time, and unless ARCs are defined clearly in the Plan, amateur radio operators can now be faced with expensive proceedings. While good neighbourly relations are sought, there are some people who delight in creating difficulty, which is why the Plan should state clearly a comprehensive ARC definition. A vexatious resource consent hearing could cost the amateur radio operator far more than the ARC equipment - and could even result in causing affected Amateurs to give up on their self-education and technological passion, for which a nationally recognised and regulated Licence had been granted.

Once again, Judge Smith has provided some very relevant thoughts on this issue in his Oral Decision at the Tauranga Environment Court hearing.

Rules need to be incorporated in the Plan.

A range of ARCs should be provided in the Waimakariri Plan for the following reasons:

a The ARCs for which permitted activity status is sought will not generate adverse effects on adjacent properties or otherwise, and accordingly need not be the subject of any additional consenting process.

b The permitted activity status sought for ARCs is consistent with the approach taken in other city and district plan provisions throughout New Zealand

c Licenced amateur radio operators provide an essential service to the community and to civil defence agencies, particularly during civil defence emergencies, and it is appropriate and desirable that the District Plan should enable those activities to occur in at least some places in Waimakariri District.

How are aerials used?

a) **The 80m band** is useful for communication over the length and breadth of New Zealand, and probably one third of active radio amateurs might want to operate on that band. In its basic form it would require two poles, preferable 12 to 15 metres high, 40 metres apart, with a thin wire between them. This is noted in the Waimakariri Draft Plan as the "*simple wire dipole*". Most commonly, the configuration has 3 poles, a centre, slightly higher pole, and lower elevated poles each end. End elevation is important to keep antenna voltages away from being touched by members of the public, and additionally, to minimise trip hazards etc.

b) VHF and UHF bands are used for local line-of-sight transmissions, and for very local contacts short vertical "whip" antennas work well. For transmission over longer distances they require multi-element Yagi arrays, most of which would be commensurate in size and style to older TV antennas. Being line-of-sight bands, the possible communication distance becomes greater if the antennas are higher. Generally these would be at 10m to 12m height on a simple pole, with a rotator at the top.

c) High Frequency Bands (for example, the 20m to 10m bands) are most useful for international communications. Because distances from an island in the middle of the South Pacific to the bulk of other population centres in Europe and North America are very long, it is desirable to direct the signal in a beam towards the desired country. Complex wire antennas can be used, but generally they are limited to one specific direction, so the preferred style of antenna is a Yagi, which can be pointed in the desired direction by a "rotator".

Unfortunately these HF Yagis can be very large. A full sized three element Yagi for the 20m band would have three elements each approximately 10m long, on a boom which is 7 metres long. It is possible to use "coils" to reduce the physical length of elements to about 7m (on a 7m boom). By very clever design, these coils can be designed to enable other bands to also work on the same antenna, so a Yagi with 14m elements on a 7m boom with strategically place "enlargements" in the elements could work equally well on all six bands from 40m to 10m band. Such an aerial would be called a "Multi-band Yagi".

This option has a far less visual impact than the option of having individual Yagis for each of the most commonly used bands.

Please note, however, that more useful HF Yagis can get quite large in size, and the dimensions given in the proposed rules allow for that.

The Council Decision Sought.

1 Change the Definition of Amateur Radio Configurations, to "means antenna, aerials and associated support structures which are owned and operated by licensed amateur radio operators."

Rationale: The current definition refers only to "Poles", but amateurs may use other structures, including towers on some occasions. Therefore the term "Support Structures" is more appropriate.

2 The Rules of EI-R29 are unreasonably restrictive. It is understood that Council is keen on controlling the visual effect by limiting structures to a single pole per site. This visual amenity (which is, at best, merely a subjective amenity) has been applied without any consideration of balancing it against the objective amenity values given on Page 3 of this submission.

AMEND RULE: (paragraph 2. of Draft District Plan) The restriction to having a maximum of one pole per site should therefore be removed.

This would bring the Waimakariri District Plan in line with our neighbouring Christchurch and other District Plans.

ALTERNATIVE RULE: There may be only one main supporting structure per site, and its maximum height in relation to infrastructure will be 20m."

3 There are 36 wave-bands that are assigned for amateur experimentation and communications. Council's proposed rules seem to be failing to recognise this and they seem to be assuming that all radio amateurs must be herded into a single waveband. See Attachment 2 – RSM Band-plan for New Zealand Amateur Operators.

NEW RULE: There may be secondary supporting structures which have a maximum height of 14 metres. The elements of any VHF antenna on secondary structures must not exceed 3m in length (i.e. similar in size to traditional TV antennas).

4 Parabolic "dish antennas" are used primarily by commercial operators for transmitting high-capacity links between major installations. Very occasionally amateurs do wish to experiment, or to set distance records, on microwave frequencies, and may wish to use dish antennas for this.

NEW RULE: Up to two Dish antennas with a diameter of 2m or less, may be mounted on the Primary or Secondary structures, at a height of 14m or less.

5 The mainstay of communications around NZ uses the 80m band. This classically uses a horizontal wire antenna, which is 40m in length, and is noted in para 3. of the Waimakariri Draft Plan as the "*simple wire dipole*". It is a physical impossibility for both ends of such an antenna to be mounted on a single structure. It is also virtually impossible to fit such a long length of wire onto a standard section if large building offsets have to be observed.

NEW RULE: There may be a maximum of four additional poles, used for holding the ends of wire antennas and which may be placed on the boundary of the section, provided they are

- a. Less than ten meters high
- b. Any part of the pole above 5m height shall have a diameter of 50mm or less.

6 Traditionally international communications have used High Frequency wave bands. In more recent times, because of poor solar flux conditions, and because of high noise interference on the HF bands, amateurs have launched their own communications satellites to partially solve this problem. But amateurs are also experimenting with bouncing signals off the moon to reach overseas shores. Because the moon is so far away, very large dish antennas need to be used. These are not high structures – they are usually mounted very close to the ground, and are always within the setback and recession plane standards.

WE SUPPORT THE PROPOSED RULE: Large dish antennas shall

- a. be less than 5m in diameter/width
- b. be pivoted less than 4m above the ground
- c. will meet the setback and recession plane standards

7 Retain "Restricted Discretion" assessment categories for cases where an individual amateur seeks a configuration which exceeds the permitted limits. Restricted discretion should be limited to the degradation of perspective of the immediate neighbours. That is, *"what is the degree that the requested condition is significantly worse than what would otherwise be "permitted" under the existing rules?"*

This test should be assessed from the main living areas of an adjoining residence, (i.e. bedrooms and utility areas are excluded.) The test will, as always, be *"is the effect less than minor?"*

8 ***Height in Relation to Boundary.*** In a previous era, this was known as "Daylight Profiles" and was predicated on a neighbour's right not to suffer significant deprivation of sunlight or daylight from neighbouring properties. Because aerial poles are usually very slender (generally 114mm or less) they do not cast a shadow beyond about 10m away. For that reason, we seek exemption that ARCs not be subject to *Height in Relation to Boundary* rules. They would, of course, still be subject to setbacks.

Attachments

Attachment A1: Graphical Performance of Height in relation to Antenna Performance.

Attachment A2: RSM Amateur Radio Licence.

Attachment A3: Definitions in draft District Plan

Attachment B8: Paper by K Siwiak PhD, MSEE, PE, SMIEEE on the optimum Height of antennas.

Attachment A1: Graphical Performance of Height on Antenna Performance.

In the article published in QEX May/June 2011 magazine, the author Dr Siwiak KE4PT postulated the best height for an antenna on a single band to be 1.5 to 1.6 Wavelengths, but the best compromise height for an HF antenna installation covering the 10 m to 40 m bands was 19.9 m.

NZART seeks this compromise height of 20m in all its Local Government submissions, but I am often asked by hams why we seek such heights in NZ? We look like we are being greedy; it seems to be such an overwhelming height to expect to be permitted in a residential environment.

I came to realise that the argument about how the launch angle of a transmitting aerial becomes more vertical as an aerial gets lower was not well understood, not even by amateurs, so how were we going to get Councils to see the issue? Perhaps a change of approach is needed – how does height affect incoming signals from distant places?

In a recent article in the Auckland VHF Group magazine "Spectrum" Peter Loveridge ZL1UKG provided some useful antenna modelling on how Yagi performance changes with height, and with his permission I carried out an analysis of received signal performance for the 20 metre HF Band.

See The first Graph, which shows Yagi gain for various heights above ground.

If we consider the most commonly used "High Frequency" band, being the 20m band, a height of 32 metres represents approximately 1.6 wavelengths; 20 metres is approximately 1 wavelength; 15 metres (a figure in the previous North Shore part of the Auckland Plan, and several other District Plans) is approximately equivalent to 0.75 wavelengths; and 10.66 metres, (proposed in the Auckland Independent Hearings Panel report) is approx. 0.5 wavelengths.

The second Graph shows the angle of an incoming distant wave that is "favoured" by a three element Yagi at different heights, together with the angles at which the performance of the Yagi drops to half (i.e. 3 dB down) either side of the optimum angle.
The results are:

- A 32m high Yagi has 13.5dB gain, an optimum angle 9° with a 3db bandwidth from 4° to 13°
- A 20m high Yagi has 13.1dB gain, an optimum angle of 14°, with 3db bandwidth from 6° to 24°
- A 15m high Yagi has 12.8dB gain, an optimum angle of 17°, with 3db bandwidth from 8° to 28°
- A 10m high Yagi has 11.5dB gain, an optimum angle of 28°, with 3db bandwidth from 12° to 50°

Angles of arrival of incoming signals.

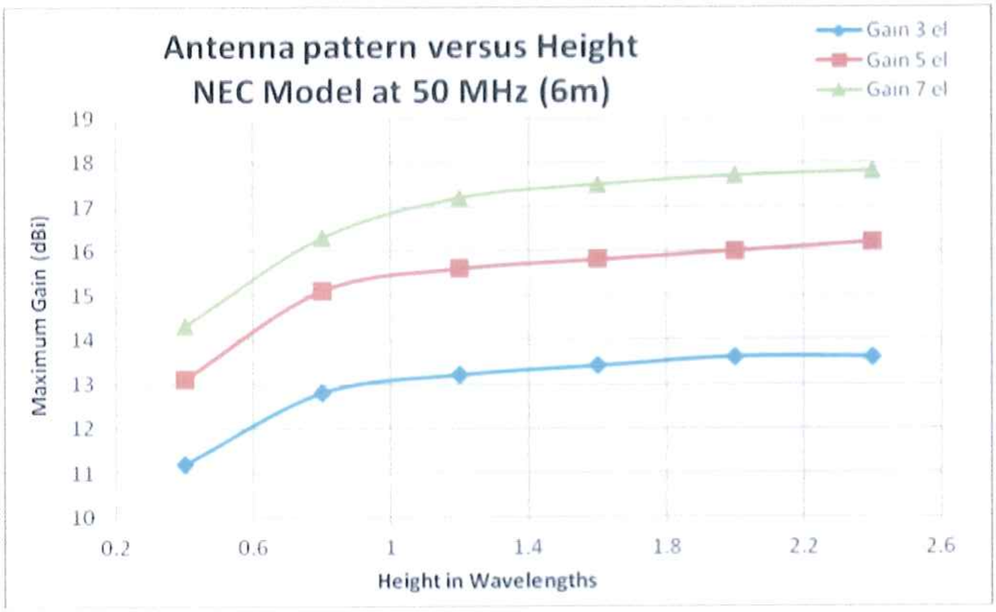
The Table of measured incoming signals is extracted from the ARRL Antenna Handbook, and shows the incoming wave angles measured over a long period of time for the route Boston (USA) to Europe. Regrettably, we don't have readily available data for the NZ to Europe route, but the Boston data is an example of a long path, and it is indicative of the type of distribution of incoming wave angles that are experienced. The second column shows the percentage of time that an incoming wave can be expected for each degree of elevation in the first column, from 1 degree to 50 degrees.

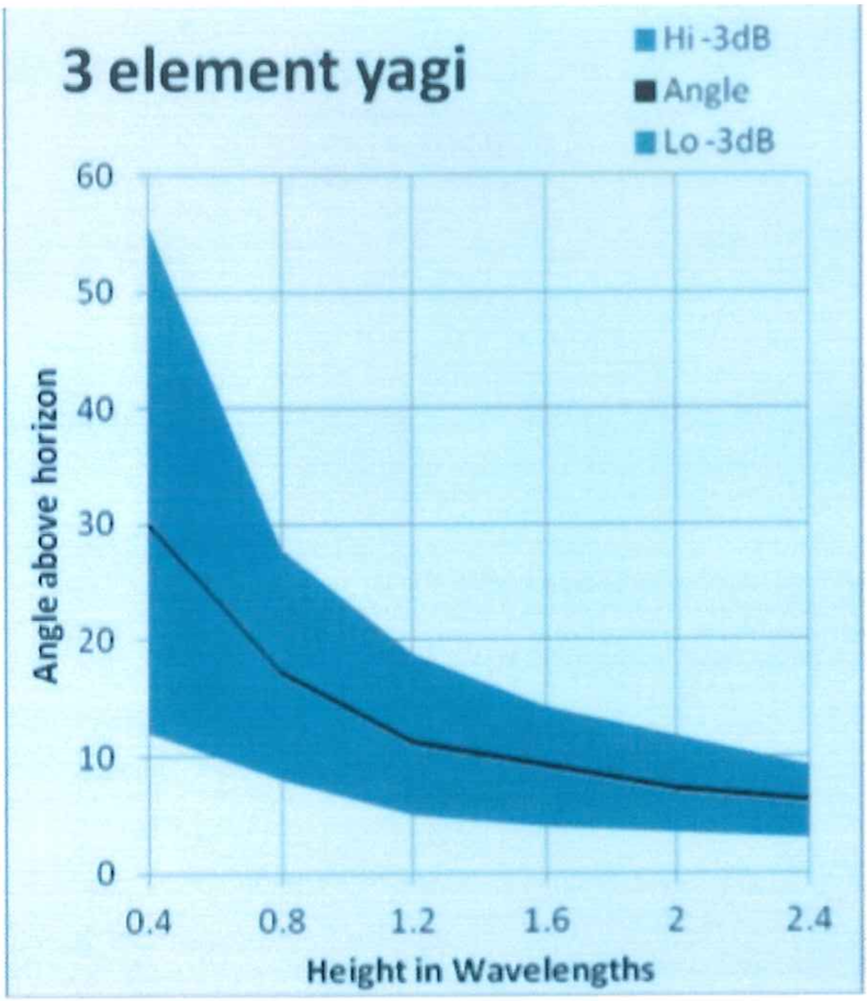
Because distances to Europe from NZ are even longer, a similar chart showing incoming signals from Europe to NZ would be weighted even more towards the lower elevation angles.

Conclusion.

The Independent Hearing Panel for the Auckland Unitary Plan recommended for Auckland a primary support structure height of "Zone Height" plus 30%, which amounts to 10.66 m in most residential areas, with the result that a 3 element Yagi at that height would have a gain of 11.5dB and would provide usable reception for only 25.8% of the time. That simply isn't good enough.

An aerial at 20m height would provide approx. 1.5dB more gain than a 10m high one, and has useful reception for 61.7% of the time, which is still a compromise, but is reasonable.


Antenna pattern versus Height
NEC Model at 50 MHz (6m)
Gain 3 el
Gain 5 el
Gain 7 el
Maximum Gain (dBi)
19
18
17
16
15
14
13
12
11
10
0.2
0.6
1
1.4
1.8
2.2
2.6
Height in Wavelengths


3 element yagi
Hi -3dB
Angle
Lo -3dB
Angle above horizon
60
50
40
30
20
10
0
0.4
0.8
1.2
1.6
2
2.4
Height in Wavelengths

Measured incoming signals to Boston, Massachusetts, from All of Europe

Source" the ARRL Antenna Book, 21st edition, page 23.30

Elevation of Incoming Sig	% of time	Antenna Height 32 m	Antenna Height 20m	Antenna Height 15m	Antenna Height 10.66m
1	1.7				
2	1.4				
3	3.1				
4	11.6				
5	12.7				
6	9.2				
7	4.6	32 m high			
8	3.2	Useful for			
9	3.1	74% of			
10	6.3	the time			
11	10.2		20m high.		
12	8.5		Useful for		
13	4.1		61.7% of		
14	2.7		the time		
15	1.5				
16	2.9				
17	3.1				
18	3.1			15m High	10.6m high
19	2.3			Useful for	Useful for
20	1.8			48.6% of	25.8% of
21	0.8			the time.	the time
22	1.1				
23	0.3				
24	0.5				
25	0.1				
26	0.2				
27	0.2				
28	0.2				
29	0				
30	0				
•	0				
•	0				
50	0				

KEY: Aerials at 32m high (blue) receive incoming signals at angles 4^0 to 13^0
Aerials at 20m high (yellow) receive incoming signals at angles 6^0 to 24^0
Aerials at 15m high (green) receive incoming signals at angles 8^0 to 28^0
Aerials at 10.66m ht (beige) receive incoming signals from 12^0 to 50°

Attachment A2

RADIO SPECTRUM MANAGEMENT

TELEPHONE 0508 776 463
RSM.GOVT.NZ

RADIOCOMMUNICATIONS REGULATIONS 2001, REGULATION 8 - RECORD OF RADIO LICENCE

1. **Licence details—**
   1. **Licence Type:** General User Licence (Radio) (ZZ)

      General User Radio Licence for Amateur Radio Operators for the transmission of radio waves by amateur radio operators in New Zealand, for the purpose of communications in the amateur radio service in accordance with the applicable terms, conditions and restrictions of this licence
   2. **Licence Status:** Current
   3. **Licence Holder:** Every Person
New Zealand
   4. **Client Number:** 137373
   5. **Commencement Date:** 18 May 2017
   6. **Granting Date:** 18 May 2017

2. **Spectrum Details—**

Low (MHz)	High (MHz)	Reference Frequency (MHz)	Maximum Power dBW	Remarks
0.1300	0.1900	0.1600	7	Special Conditions 1, 3 and 8
0.4720	0.4790	0.4755	14	Special Condition 1 and 8
1.8000	1.9500	1.8750	30	Special Condition 1
3.5000	3.9000	3.7000	30	Special Condition 1
7.0000	7.1000	7.0500	30	Special Conditions 5 and 6
7.0000	7.1000	7.0500	30	
7.1000	7.2000	7.1500	30	Special Condition 1
7.2000	7.3000	7.2500	30	Special Condition 1
10.1000	10.1500	10.1250	30	Special Condition 1
14.0000	14.2500	14.1250	30	Special Conditions 5 and 6
14.0000	14.3500	14.1750	30	
18.0680	18.1680	18.1180	30	Special Conditions 5 and 6
21.0000	21.4500	21.2250	30	Special Conditions 5 and 6
24.8900	24.9900	24.9400	30	Special Conditions 5 and 6
26.9500	27.3000	27.1250	7	Special Conditions 1, 2, 4 and 8
28.0000	29.7000	28.8500	30	Special Conditions 5 and 6
50.0000	51.0000	50.5000	30	
51.0000	54.0000	52.5000	30	Special Condition 1
144.0000	146.0000	145.0000	30	Special Conditions 5 and 6
146.0000	148.0000	147.0000	30	Special Condition 1
430.0000	440.0000	435.0000	30	Special Condition 1
433.0500	434.7900	433.9200	30	Special Condition 2
435.0000	438.0000	436.5000	30	Special Conditions 5 and 6
915.0000	928.0000	921.5000	14	Special Conditions 2, 7 and 8
1240.0000	1300.0000	1270.0000	30	Special Condition 1
1260.0000	1270.0000	1265.0000	30	Special Condition 5
2396.0000	2450.0000	2423.0000	30	Special Condition 2
2400.0000	2450.0000	2425.0000	30	Special Conditions 5 and 6

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

New Zealand Government

Low (MHz)	High (MHz)	Reference Frequency (MHz)	Maximum Power dBW	Remarks
3300.0000	3410.0000	3355.0000	30	Special Condition 1
3400.0000	3410.0000	3405.0000	30	Special Conditions 5 and 6
5650.0000	5670.0000	5660.0000	30	Special Condition 5
5650.0000	5850.0000	5750.0000	30	Special Condition 2
5830.0000	5850.0000	5840.0000	30	Special Condition 6
10000.0000	10500.0000	10250.0000	30	Special Condition 1
10450.0000	10500.0000	10475.0000	30	Special Conditions 5 and 6
24000.0000	24050.0000	24025.0000	30	Special Conditions 2, 5 and 6
24050.0000	24250.0000	24150.0000	30	Special Conditions 1 and 2
47000.0000	47200.0000	47100.0000	30	Special Conditions 5 and 6
76000.0000	81000.0000	78500.0000	30	Special Conditions 1, 5 and 6
122250.0000	123000.0000	122625.0000	30	Special Conditions 1 and 2
134000.0000	136000.0000	135000.0000	30	
134000.0000	141000.0000	137500.0000	30	Special Conditions 5 and 6
136000.0000	141000.0000	138500.0000	30	Special Condition 1
241000.0000	248000.0000	244500.0000	30	Special Condition 1
241000.0000	250000.0000	245500.0000	30	Special Conditions 5 and 6
244000.0000	246000.0000	245000.0000	30	Special Condition 2
248000.0000	250000.0000	249000.0000	30	
275000.0000	1000000.0000	637500.0000	30	Special Conditions 1 and 3

3. Site Details—

(1) Transmit Location: All New Zealand.

(2) Receive Location: All New Zealand.

4. Special conditions—

1. These frequencies are, or may be, allocated for use by other services. Amateur operators must accept interference from, and must not cause interference to, such other services.
2. These frequencies are designated for industrial, scientific and medical (ISM) purposes. These frequencies may also be allocated to Short Range Device (SRD) services. Amateur operators must accept interference from ISM and SRD services within these frequency ranges.
3. Allocated to the amateur service on a temporary basis until further notice.
4. Use is limited to telemetry or telecommand.
5. These frequencies may also be used for amateur satellite communications in the earth-to-space direction.
6. These frequencies may also be used for amateur satellite communications in the space-to-earth direction.
7. Amateur operators must ensure that unwanted emissions from 800-915 MHz must not exceed -79 dBW (-49 dBm e.i.r.p.). The reference bandwidth for emissions is 100 kHz.
8. The maximum power is the radiated power in dBW e.i.r.p.

5. General conditions applying to all transmissions under this licence—

1. The use of callsigns, including temporary and club callsigns, must be in accordance with publication PIB 46 "Radio Operator Certificate and Callsign Rules" published at www.rsm.govt.nz.
2. Callsigns must be transmitted at least once every 15 minutes during communications.
3. National and international communication is permitted only between amateur stations, and is limited to matters of a personal nature, or for the purpose of self-training, intercommunication and radio technology investigation, solely with a personal aim and without pecuniary interest. The passing of brief messages of a personal nature on behalf of other persons is also permitted, provided no fees or other consideration is requested or accepted.
4. Communications must not be encoded for the purpose of obscuring their meaning, except for control signals by the operators of remotely controlled amateur stations.
5. Amateur stations must, as far as is compatible with practical considerations, comply with the latest ITU-R recommendations to the extent applicable to the amateur service.
6. In accordance with Article 25 of the International Radio Regulations, amateur operators are encouraged to prepare for, and meet, communication needs in support of disaster relief.
7. Amateur beacons, repeaters and fixed links may not be established pursuant to this licence.
8. Unwanted emissions outside the frequency bands specified in this Schedule must comply with the requirements of technical standard ETSI ETS 300 684 published by the European Telecommunications Standards Institute (ETSI).

9. The frequency ranges, maximum power of transmissions within those frequencies ranges, and designated uses of frequencies are those prescribed in this licence. All transmissions in a given frequency range must comply with any special conditions relating to that frequency range.
10. Should interference occur to services licensed pursuant to a radio licence or a spectrum licence, the chief executive reserves the right to require and ensure that any transmission pursuant to this licence changes frequency, reduces power, or ceases operation.
11. Except as provided to the contrary in this licence, maximum power in dBW is the peak envelope power (PX) of the radio transmitter, as defined in the International Radio Regulations Article 1, No. 1.157.

6. Terms, conditions and restrictions applying to New Zealand amateur operators

1. Persons who hold a General Amateur Operator's Certificate of Competency and a callsign issued pursuant to the Regulations may operate an amateur radio station in New Zealand.
2. The callsign prefix of "ZL" may be substituted with the prefix "ZM" by the callsign holder for the period of, and participation in, a recognised contest, or as the control station for special event communications.
3. Operation on amateur bands between 5 MHz and 25 MHz is not permitted unless a person has held a General Amateur Operators Certificate of Competency for three months and logged 50 contacts during this period. The person must keep the logbook record for at least one year and, during this period, produce it at the request of the chief executive.

7. Terms, conditions and restrictions applying to visiting amateur operators

1. Persons visiting New Zealand who hold a current amateur certificate of competency, authorisation or licence issued by another administration, may operate an amateur station in New Zealand for a period not exceeding 90 days, provided the certificate, authorisation or licence meets the requirements of Recommendation ITU-R M.1544 or CEPT T/R 61-01 or CEPT T/R 61-02 and is produced at the request of the chief executive.
2. The visiting overseas operator must use the national callsign allocated by the other administration to the operator, in conjunction with the prefix or suffix "ZL", except where subsection (3) applies, which is to be separated from the national callsign by the character "/" (telegraphy), or the word "stroke" (telephony).
3. The visiting overseas operator may use the prefix or suffix:
   a. ZL7 when visiting the Chatham Islands
   b. ZL8 when visiting the Kermadec Islands
   c. ZL9 when visiting the Sub-Antarctic Islands

RADIO LICENCE GENERAL CONDITIONS

TERMS, CONDITIONS, AND RESTRICTIONS APPLYING TO EVERY RADIO LICENCE UNDER THE FIRST SCHEDULE TO THE RADIOCOMMUNICATIONS ACT 1989 ('the Act')

1. **Compliance with International Radio Regulations**
   Every person transmitting radio waves must comply with the International Radio Regulations.

2. **False or misleading communication**
   No person may—
   (a) cause or permit the transmission, under any radio licence, of any radiocommunications of a false, fictitious, or misleading character; or
   (b) cause or permit to be transmitted any false or deceptive distress signal or distress call.

3. **Breach of other enactment**
   No person may transmit radio waves under a radio licence in breach of any other enactment.

TERMS, CONDITIONS, AND RESTRICTIONS APPLYING TO EVERY RADIO LICENCE UNDER THE SCHEDULE 1 TO THE RADIOCOMMUNICATIONS REGULATIONS 2001 ('the regulations')

1. **Technical compliance**

Any radio transmitter operating under a radio licence must comply with the requirements of the International Radio Regulations (to the extent that they reasonably apply to the category of service specified on the radio licence), and with any technical specifications or standards that may be notified from time to time by the chief executive by notice in the *Gazette*.

2. **Operational Compliance**

The operation of any radio transmitter operating under a radio licence must comply with the requirements of the International Radio Regulations to the extent that they reasonably apply to the category of radiocommunication service specified on the radio licence.

3. **Responsibility for observance of provisions**

Observance of all terms, conditions, and restrictions relating to a radio licence by any person authorised to operate a radio transmitter under a radio licence remains the personal responsibility of the holder of the radio licence, as the case may be.

4. **Notification of change of address**

If a radio licence applies specifically to a radio transmitter at a particular address, the licensee must, within 7 days of removing the radio transmitter from the address, notify the chief executive of the removal.

5. **Compliance with directions**

The holder of a radio licence must comply with any directions given by the chief executive, or any person authorised by the chief executive to give directions on the chief executive's behalf, for the use of the radio transmitter operating under the radio licence.

6. **No monopoly conferred**

No radio licence confers upon the holder of the radio licence a monopoly on the use of any frequency or frequencies or frequency band or frequency bands specified on the radio licence.

7. **Operator of radio transmitter to hold valid operator certificate**

If a radio licence specifies that the operator of any radio transmitter operating under the radio licence must be the holder of a certificate of competency of the class specified on the radio licence, the radio transmitter must not be operated by any person who is not the holder of a certificate of competency of the required class, or of a certificate recognised by the chief executive.

8. **Callsigns**

If a radio licence requires the use of a callsign, the callsign of the radio transmitter to which the radio licence relates must be the callsign shown on the radio licence.

9. **Dismantling of radio transmitter when contravention has taken place**

If an authorised officer is of the opinion that a contravention of the Act or the regulations has taken place and requires that a radio transmitter cease operating, the licensee under the relevant radio licence must comply with the requirement.

FURTHER CONDITIONS

GENERAL TERMS, CONDITIONS, AND RESTRICTIONS APPLYING TO THIS RADIO LICENCE

1. Radio transmitters to which this radio licence relates must operate only on or at the frequency(ies), emission(s), power(s) and location(s) prescribed on this licence, or on any schedule annexed to this licence.

2. Nothing in this radio licence, the Act, the regulations, or the International Radio Regulations prohibits any person in distress from using any means at the person's disposal to attract attention, indicate the person's position, and obtain assistance.

3. While all reasonable care has been taken in the engineering of this radio licence, the nature of radio propagation is such that no guarantee can be given that harmful interference will not occur. In the event that harmful interference does occur, the licensee must comply with any direction given by the chief executive, including cessation of transmissions, until the cause of the harmful interference is identified and remedied.

4. The chief executive does not accept liability under any circumstances for any loss or damage of any kind as a consequence of action taken by the chief executive pursuant to these conditions.

5. The engineering of a radio licence does not imply reservation in perpetuity of the frequency shown on the radio licence.

6. The chief executive may, by notice in writing to the licensee, or by notice in the Gazette, modify, transfer, suspend, or revoke this radio licence.

7. This radio licence remains valid until revoked by the chief executive, or until the expiry date (where specified on the licence), whichever occurs first. If this radio licence is revoked at the request of the licensee, the date of revocation cannot precede the date of notification by the licensee.

8. For the period for which a licence is valid, a fee is payable in proportion to that period, rounded up to the nearest month.

9. Fees are prescribed in **Schedule 6** to The Radiocommunications Regulations 2001 and are inclusive of Goods and Services Tax.

10. Any fees payable that are not paid constitute a debt to the Crown until paid in full, and may be recovered from the person liable at the suit of the chief executive or the Registrar in any court of competent jurisdiction.

11. The chief executive or any inspector duly authorised by him shall be granted by the licence holder at all reasonable times entry to any place, premises or building for the purposes of ensuring compliance with this licence.

12. Should a management right be recorded by the chief executive under S9 of the Radiocommunications Act 1989 ('the Act') in respect of any frequency to which a radio licence relates, Part XIII of the Act shall cease to apply to that frequency and the radio licence shall cease to be in force.

13. All digital fixed service systems must adhere to latest Recommendation ITU-R F-1191, in regards to the necessary and occupied bandwidths of transmissions, by the emissions permitted under this licence.

Radio Licence Certificate for General User Radio Licence for Amateur Radio Operators

Certificate Issued Pursuant to Regulation 12(b) of the Radiocommunications Regulations 2001

I, SIEGMUND WIESER, Approved Radio Engineer, having regard to –

a. the International Radio Regulations; and

b. the ITU-R reports and recommendations; and

c. Annex 10 to the Convention on International Civil Aviation; and

d. the International Convention for the Safety of Life at sea; and

e. the nature of the service proposed to be operated under the radio licence; and

f. publication PIB 38 issued by the Chief Executive

but not having regard to the reception of radio waves by inappropriate receivers

hereby certify that in my opinion the authority to transmit radio waves conferred by the radio licence to which this certificate relates, being the radio licence identified as the General User Radio Licence for Amateur Radio Operators

a. will not endanger the functioning of any radionavigation service; and

b. will not endanger the functioning of any radio service essential to the protection of life or property; and

c. will not cause harmful interference to rights conferred by registered spectrum or radio licences; and

d. is technically compatible with services authorised to be operated under existing spectrum licences and radio licences; and

e. will sufficiently define the nature and characteristics of the proposed transmissions to enable subsequent spectrum licences and radio licences to be co-ordinated for the purpose of avoiding harmful interference.

Approved Radio Engineer Number: ARE43

Dated: 11-May -2017

Attachment A3

AMATEUR RADIO CONFIGURATIONS	means the antennas, aerials, and associated poles which are owned and used by licenced amateur radio operators.
ANTENNA	has the same meaning as in the NESTF and is a device that receives or transmits radiocommunication or telecommunication signals but is not a small cell unit.
BUILDING	means a temporary or permanent movable or immovable physical construction that is: a partially or fully roofed; and b is fixed or located on or in land; but excludes any motorised vehicle or other mode of transport that could be moved under its own power. (National Planning Standard definition)
COMMUNITY FACILITY	means land and buildings used by members of the community for recreational, sporting, cultural, safety, health, welfare, or worship purposes. It includes provision for any ancillary activity that assists with the operation of the community facility. (National Planning Standard definition)
DISASTER MANAGEMENT ACCOMMODATION	means the erection and use of tents or buildings in response to a disaster event, such as an earthquake, for the purpose of providing shelter or accommodation for people displaced or impacted by the event. The requirement for such facility will be determined by the Waimakariri District Council, Civil Defence or emergency organisations, or lawfully established organisation for the purpose of post disaster management. This definition includes: a temporary accommodation for people required to work as part of the immediate disaster relief efforts or post disaster development team; b temporary accommodation for people displaced by the disaster event; and c temporary facilities for disaster event management d temporary educational facility.
EMERGENCY SERVICE	means an authority or service that is responsible for the safety and welfare of people and property in the community during times of emergency that include, but are not necessarily limited to, fire service, ambulance, police and emergency co-ordination authorities or services.
HEIGHT	means the vertical distance between a specified reference point and the highest part of any feature, structure or building above that point. **(National Planning Standard definition)**
HEIGHT CALCULATIONS	means for the purpose of calculating building height, the following shall be excluded: a lines and wires; b radio and television aerials, provided that the maximum height is not exceeded by more than 2.5m; C finials, parapets and similar architectural features on buildings, provided that the maximum height is

not exceeded by more than 1.5m;

d lift and stair shafts, plant rooms, water tanks, air conditioning units, ventilation ducts, flagpoles;

e chimneys (not exceeding 1.1m in any direction); and

f the spires, steeples or towers of spiritual activities that exceed the maximum height by no more than 3m or 20% of the building height (whichever is greater).

See also the definition for "height in relation to infrastructure".

HEIGHT IN RELATION TO BOUNDARY	means the height of a structure, building or feature, relative to its distance from either the boundary of: a a site; or b another specified reference point. **(National Planning Standard definition)**
HEIGHT IN RELATION TO INFRASTRUCTURE	means height measured vertically from either ground level or the top of a plinth or foundation at the centre of a structure to the highest point of the structure, including conductors, but excluding ancillary infrastructure equipment, antennas, lightning rods, earth peaks and GPS units.
NETWORK UTILITY OPERATOR	has the same meaning as in s166 of the RMA (as set out in the box below)
POLE	means a non-lattice structure that supports conductors, lines, cables, antennas, lights or cameras, but is not a tower, and includes foundations and hardware associated with the structure such as insulators, cross arms and guy-wires.
RADIOCOMMUNICATION	means any transmission or reception of signs, signals, writing, images, sounds or intelligence of any nature by radio waves.
RECREATION ACTIVITIES	means the active or passive enjoyment of sports, recreation or leisure, whether competitive or non-competitive, casual or organised, and whether a charge is made for admission or participation or not.
TELECOMMUNICATION	means the conveyance by electromagnetic means from one device to another of any encrypted or non-encrypted sign, signal, impulse, writing, image, sound, instruction, information, or intelligence of any nature, whether for the information of any person using the device or not, but it excludes any conveyance that constitutes broadcasting.
TOWER	means a lattice steel structure (or a tubular steel structure where this replaces a lattice steel structure) that supports conductors, lines, cables or antennas, and includes foundations and hardware associated with the structure such as insulators and cross arms.

Attachment B8 (QEX pages 32 to 38)

Kazimierz "Kai" Siwiak, KE4PT

10988 NW 14th St, Coral Springs, FL 33071; ke4pt@amsat.org

An Optimum Height for an Elevated HF Antenna

What is the best height for your antenna? The author considers factors that can help you decide.

There are two ways to think about antenna and propagation problems in linear media: in transmit mode and in receive mode. By the reciprocity theorem both methods will predict the same performance. We will view the problem of finding an optimum height for HF antennas in receive mode rather than in transmit mode, because this reveals very interesting insights. For example, the field-strength at the receiving location is the result of an interference pattern between waves that arrive by a direct path added to the wave reflected from the earth's surface. The addition of these two waves results in a standing wave versus height for the field strength at the receiving location. Because this vertical standing wave has peaks and can have deep nulls, there is an optimum placement for an antenna. In the equivalent transmit mode point of view, far-field transmit patterns are calculated as an interference pattern between the direct wave and a ground reflected wave, but as *The ARRL Antenna Book* explains, that point of view obscures the physical meaning of "take-off" angle, so we can't directly appreciate what happens when an antenna is elevated.[1] By viewing the problem in receive mode, however, we see, among other things, that waves arriving from the lowest arrival angle do not always result in the best link margin to a DX station. We can also see that low antennas can work surprisingly well for DX, and that the best height for vertically polarized antennas is not the same as for horizontally polarized antennas.

With this analysis it is easy show that the optimum antenna height depends on frequency, polarization, properties of the earth at the reflection point, and on the arrival angle from the wave source in the ionosphere. While surface roughness is considered, there is also a terrain dependence, which for simplicity will not be considered here; see Dean Straw's terrain analysis program HFTA in the 21st edition of *The ARRL Antenna Book*. Furthermore, since the apparent wave earth reflection point is usually distant from the antenna, it is not important what the earth looks like directly under an elevated antenna. What is important is the earth's properties at the reflection point — typically hundreds to thousands of meters distant from the tower. This is an idealized problem where we allow for surface roughness, but we assume an earth that is smooth enough so that we can apply spherical earth geometry.

We begin by laying a foundation based on a spherical earth geometry for the propagation of waves to the receiving location. The reflection properties of ground and sea water are shown to affect how the reflected wave combines in constructive and destructive interference with the direct wave. Optimum heights are found for desired ranges of arrival angles and for multiple bands. Finally, path link margins are estimated for multi-hop propagation. We discover that a range of "take-off" angles must be accommodated for optimum performance.

[1]Notes appear on page 38.

Spherical Earth Geometry

Because we are dealing with distances that approach the earth's horizon, we calculate the direct and earth-reflected paths using spherical-earth reflection geometry. The solution to the spherical earth geometry given in Chapter 2 of M. I. Skolnik's *Radar Handbook* involves a cubic equation to find the arc distance G_b to the reflection point.[2]

$$2G_b^3 - 3GG_b^2 + \left[G^2 - 2a_e\left(h_{ant} + h_i\right)\right]G_b + 2a_e h_{ant} G = 0 \quad \text{[Eq 1]}$$

where:
h_{ant} is the height at the receiving antenna,
a_e is the earth's radius,

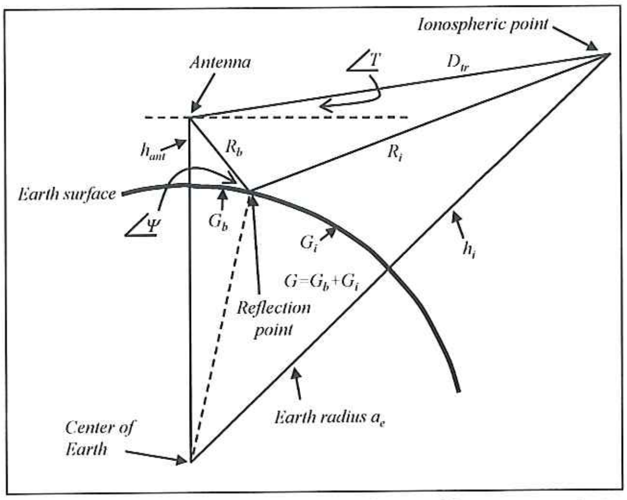


Figure 1 — Spherical earth geometry, shown with an exaggerated height dimension. Source: based on information from *Radar Handbook* (see Note 2).

and the distances G and G_b are functions of the angle T between the local horizon and the direction to the wave source point at height h_i in the ionosphere. Figure 1 shows the spherical earth reflection geometry and identifies all of the parameters.

The angle T is also called the "take off angle" and the "local elevation angle." See the ARRL website files update to *The ARRL Antenna Book*.[3] The direct wave arrives along path D_{ir}, and the reflected path includes distance R_i from the ionosphere to the earth reflection point and R_b from the reflection point to the receiving location. The reflection occurs at the arc distance G_b from the base of the antenna tower, and as the direct wave arrival angle T deceases, then the arc distance to the reflection point increases. Our chief concern is with the difference in the path lengths,

$$\Delta R = (R_b + R_i - D_{ir}) \qquad \text{[Eq 2]}$$

and with the surface reflection coefficient at the reflection point because these determine the nature of the field variation versus height, h_{ant}.

Reflection Coefficients and Combined Waves

The plane wave reflection coefficients Γ_H for horizontal and Γ_V for vertical polarization are used to find the reflection from land or sea on a spherical earth. (See Chapter 6 of *Radiowave Propagation and Antennas for Personal Communications*.[4]) The reflection coefficient is modified by the divergence factor D and surface roughness S_r factor. The wave divergence factor is:

$$D = \left[1 + \frac{2G_b G_i}{a_e G \sin\psi} \right]^{-1/2} \qquad \text{[Eq 3]}$$

where ψ is the angle of incidence on the earth's surface. The surface roughness factor is:

$$S_r = \exp(-r) I_0(r); \quad r = 2\left(kh_{sd}\sin(\psi)\right)^2 \qquad \text{[Eq 4]}$$

where:
I_0 is the modified Bessel function
$k = 2\pi f / c$ is the wave number
f is the signal frequency in Hz
c is the speed of light in m/s.

The roughness factor for the reflected wave is based on a roughness factor originally derived for a ratio of rough-sea to smooth-sea reflection, and is applied here generally to an earth reflection. The surface roughness parameter h_{sd} is the standard deviation of the surface height distribution in the reflection region. The complete reflection coefficients are thus $\Gamma_H S_r D$ and $\Gamma_V S_r D$ for a rough spherical earth. The reflected term fields are also multiplied by $d = D_{ir} / (R_b + R_i)$ to account for the difference in free space loss due to the differential distance between the direct and reflected waves.

For this study we will assume that horizontally polarized power is added to vertically polarized power in a ratio, P_{HV}. For substantially horizontally polarized waves, P_{HV} is chosen here to be between 10 and 20, and for substantially vertically polarized waves, P_{HV} is between 0.005 and 0.01. The polarization impurity primarily results in a slight reduction of the depths of nulls in the vertical standing wave patterns. The two polarization components are added as power because the polarization is decomposed by the ionosphere into elliptical polarization, (see *Ionospheric Radio Propagation*[5]) and reflections from a rough surface are generally random and time-variable. The expression for the signal power, P normalized to the free space value, of the combined waves at the receiving height, h_{ant} is:

$$P = \frac{P_{HV}\left[1 + \exp(-jk\Delta R)\Gamma_H S_r Dd\right]^2 + \left[1 + \exp(-jk\Delta R)\Gamma_V S_r Dd\right]^2}{1 + P_{HV}} \qquad \text{[Eq 5]}$$

The unity terms in each of the brackets represent the direct wave amplitude, and the remaining terms are the reflected wave, each in ratio to the free space value. The phase difference, $k\Delta R$, along with the phase of the reflection coefficients conspire to produce the vertical standing wave pattern of the field strength at the receiving location. *This is before any antenna is placed at the receiving location.* Since the earth's radius is large compared with the height of the ionosphere, angles T and ψ are nearly the same value, despite the exaggerated view in Figure 1. Since antenna free space elevation patterns for a level antenna are essentially symmetrical in elevation about the local horizontal plane, the direct wave entering the antenna from angle T above the horizontal plane is weighted by the same antenna pattern gain value as the reflected wave entering the antenna from angle ψ below the horizontal plane. Note also that the earth's horizon is *slightly below* the elevated antenna horizontal plane.

Expected Angles of Arrival

We will be optimizing our solution over a desired range of arrival angles. Expected arrival angles T for waves from the ionosphere for HF Propagation are available in *The ARRL Antenna Book* product notes files on the ARRL website for HF (see Note 3). For example, the combined 80 m to 10 m arrival angle statistics between Florida (FL) or Massachusetts (MA) and all regions of the World are shown in Figure 2.

Those statistics show that half the arrival angles are less than 6°, and that 90% of the arrival angles are smaller than 16°. So for HF cases, we will confine our interest to arrival angles between 2 to 16°. Viewed in transmit mode, this is the *range* of "take-off" angles that must be accommodated. Similar curves may be derived for 6 m band sporadic-*E* propagation. Notably, in the July and August 2009 "World Above 50 MHz" *QST* column, Gene Zimmerman, W3ZZ, comments on the work of Joe Kraft, CT1HZE, suggesting that arrival angle probabilities for 6 m band sporadic-*E* are bimodal, with one peak at ~5° and another at ~10° with very little below 3° or 4° or above ~13° or 14°.[6,7] Thus, arrival angles of 3° to 14° emerge as a range of interest for 6 m sporadic-E operations. Also see my article, "Optimum Height for an Elevated Communications Antenna," in *DUBUS* magazine.[8] While different from HF in the specifics, the angle ranges of interest are similar, and justify the range between 2° and 16°.

Location of the Reflection Point

The distance G_b to the reflection point on the earth's surface is solved by Equation 1 as a function of receiving point height. There is only a very

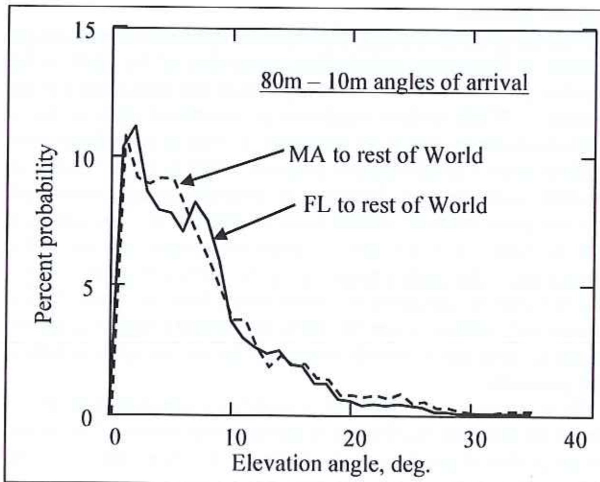


Figure 2 — Composite probability of arrival angles.

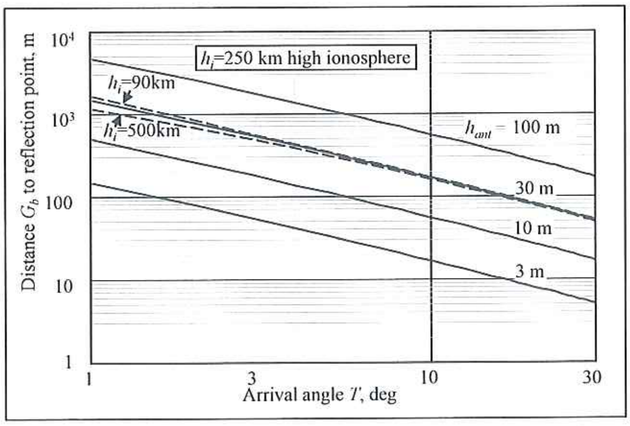


Figure 3 — Distance to the reflection point is tens to thousands of meters.

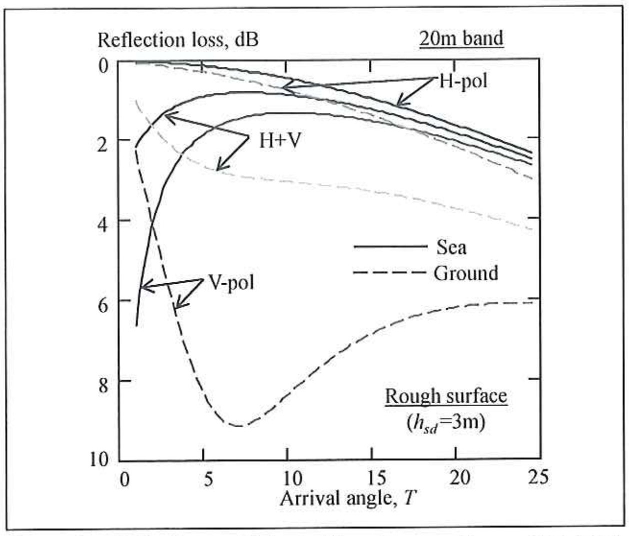


Figure 4 — Reflection coefficient with surface roughness, 20 m band.

weak dependency on the height of the ionosphere; heights from 90 km to as much as 500 km, the range of heights for the E, E_S, and F layers of the ionosphere, give very nearly the same geometrical result. There is, however, a strong dependency on the receiving height location. Figure 3 shows the distance to the reflection point versus the arrival angle for several receiving heights between 3 and 100 m with a 250 km high ionosphere. The 30 m high antenna distances are also shown (dashed lines) for 90 km and 500 km high ionosphere. *Since the reflection point is typically from a few kilometers to tens of meters away the ground immediately below the antenna does not affect elevated antenna performance*. A very good approximation to the reflection point distance is:

$$G_b = \frac{55h_{ant}}{T} \qquad \text{[Eq 6]}$$

where:

h_{ant} is the antenna height in meters

T is the arrival angle in degrees.

The reflection point given by Equation 6 is the same as for the transmit case; please see "The Effect of Ground in the Far Field" in Chapter 3 of *The ARRL Antenna Book* (see Note 1). It should be noted that transmit patterns computed in the presence of the ground often quoting a "take off angle," *implicitly assume that, the ground is flat to beyond the distance given by Equation 6*. Here, in contrast, recall that we have allowed for a ground roughness factor.

Earth Reflection Loss

The ground or sea reflection loss, L_{earth} in dB for *multiple hop paths* can be found by setting the direct wave "1" terms to zero in Equation 5 and expressing the result in decibels. Figure 4 shows the loss in the 20 m band for horizontal, vertical and a 50% mix of the polarization, for reflection from the sea and from a medium earth (ε = 12) versus the angle T. The reflection includes a surface roughness factor of 3 m. For $2 \le T \le 16°$ this reflection loss can amount to more than 1 dB for horizontal polarization, but as much as 9 dB for vertical polarization reflected from earth ground.

Optimum Antenna Height

We can now solve Equation 5 at various frequencies, polarizations, ground constants and as a function of the height of an antenna. The specific antenna pattern — that is, the free space pattern — is not important as long as the elevation plane beamwidth is sufficient

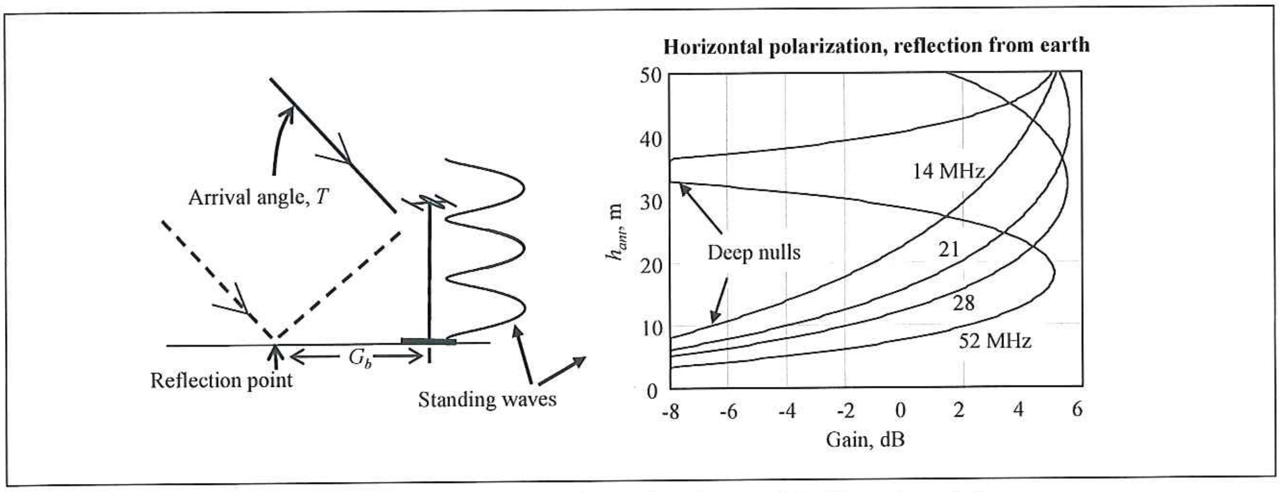


Figure 5 — Horizontal polarization (P_{HV} = 20), earth ground, T = 5°, roughness is 3 m.

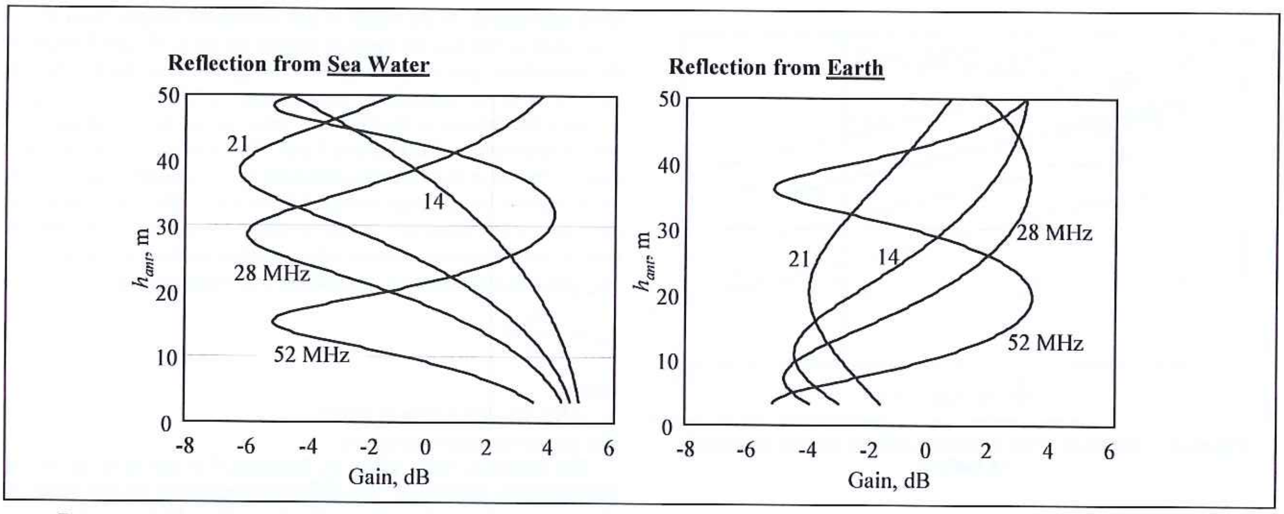


Figure 6 — Vertical polarization (P_{HV} = 0.05), T = 5°, roughness is 3 m, reflections from (left) sea water and from (right) earth ground.

to include the important angles of arrival, both above and below the local horizontal plane. We do note, however, that as the angle T increases, the waves arrive in pairs above and below the main beam peak, so that the full antenna gain for directive antennas cannot be always be realized — especially for very high gain (narrow elevation plane beamwidth) antennas.

Figure 5 shows the geometry and the calculated vertical standing wave patterns produced by the interaction of the direct and earth reflected waves for earth ground parameters $\varepsilon = 5$ and $\sigma = 0.005$ S/m. The standing wave peaks and nulls depend on frequency and on arrival angle, here 5°. This suggests placing the antenna at the signal peak, which is one definition of the optimum antenna height.

Results for horizontally polarized waves reflected from the sea differ primarily in the depth of nulls compared with earth ground reflected results of Figure 5. There are transmitter mode equivalents to the receive mode standing wave patterns shown in Figure 5. The transmit mode patterns are computed in the presence of a ground, and usually a peak "take-off angle" is identified; see for example Figure 3 in the companion article in the June 2011 issue of *QST*.[9] Clearly the transmit mode patterns do not make it easy to identify the best height for the antenna.

Figure 6 shows the vertical polarization performance for reflection from sea water $\varepsilon = 70.6$ and $\sigma = 4.54$ S/m, on the left and from ground with $\varepsilon = 5$ and $\sigma = 0.005$ S/m on the right. The saline water model is from *Radiowave Propagation and Antennas for Personal Communications* (see Note 4). The sea-reflected, vertically polarized case has an optimum at sea level. This is why vertically polarized antennas on the beach are so effective on some DXpeditions such as during the VP6DX operation. Note that the optimum heights per frequency for vertically polarized antennas with the reflection from earth ground are not the same as for horizontal polarization. Ground mounted vertical antennas with a reflection from earth ground will have negative height gains of −1 to −5 dB. The gains shown in Figures 5, 6 and 7 are in addition to any free space directive gain provided by the antenna system. Results in Figures 5 and 6 are exactly analogous to the results that have been predicted and measured to within a decibel at open air test sites in the 30 to 932 MHz range. See Section 6.3 in *Radiowave Propagation and Antennas for Personal Communications* (see Note 4).

Concentrating now on the 20 m band, Figure 7 shows field-strength signal levels relative to the free space value for reflections from the ground. *These are not antenna patterns but rather signal field strength levels that are then sampled by an antenna*. The axes have been flipped compared with the previous figures. The upper dashed asymptote is the *maximum constructive interference* for the continuum of all arrival angles between 2 and 16°. Specific results for 2°, 5°, 10° and 15° are shown by the embedded curves. The lower dashed asymptote is defined by the *destructive interference* for the continuum of arrival angles. The lower asymptote intersects the 2° arrival angle curve at a cusp, which defines an optimum antenna height for that frequency. At that elevation, the height gain, g_w has the smallest variation versus the range of arrival angles, and its minimum gain value is the highest. When an antenna is placed there, the actual free space antenna gain, at the pattern elevation angle, T, adds to this field strength height gain. Antennas that are higher than the optimum height will encounter degraded performance at the higher angles of arrival because the nulls defining the lower asymptote to the right of the cusp are likely to be a factor. This is why in some cases a lower antenna can significantly outperform a higher antenna. If we had chosen a higher minimum required arrival angle, the optimum height would decrease. Similar curves can be drawn for other HF bands or combinations of bands, and optimum heights can be found.

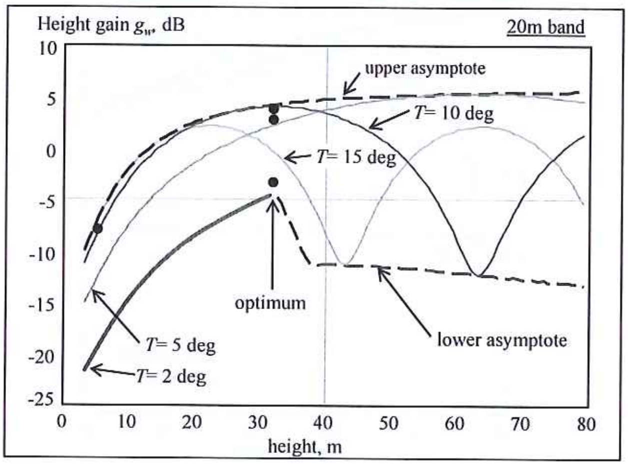


Figure 7 — Height gain for horizontal polarization in the 20 m band.

Multiband Considerations

Since the geometry of the reflection point, including divergence and surface roughness, are fixed in physical dimensions, the vertical interference patterns don't quite scale with wavelength. Thus, the optimum height does not scale exactly with frequency. Some multiband Yagi beams can cover the 40 m to 6 m bands in a single structure. Raising and lowering such an antenna is not usually desirable, so knowing an overall optimum height could be very useful. A family of curves like the 20 m band curves in Figure 7 can be calculated for any frequency band or any combination of frequency bands.

One effective strategy for finding an overall optimum over multiple bands is to choose the best height for the highest frequency band of interest. That somewhat sacrifices the performance for the lowest arrival angles at the lower frequency bands, but more gently than the destructive interference loss of height gain for higher arrival angles if a higher antenna were chosen.

The optimum heights for various frequency bands between 7 and 54 MHz are shown in Figure 8. The three curves are for three different minimum angles, the upper curve shows optima for a 1° to 16° arrival angle range, the middle curve for 2° to 16°, and the lower curve for 3° to 16°. The middle curve slopes from about 1.5 to 1.6 wavelengths between 7 and 29 MHz.

If operation anywhere in the 10 m to 40 m bands is of equal interest, the "best" height works out to about 19.9 m. That height is suitable for arrival angles as low as 1° in the 10 m band, and is also suitable for angles above about 4° in the 20 m band. In the 40 m and 30 m bands the results are "best effort," but as will be shown in the next section, paths at higher arrival angles may exist, but with an increased number of earth-ionosphere hops. If the 20 m band is to be optimized, then the best height is about 32 m. If 6 m band operation is important then the optimum height is about 15.3 m. The heights between about 15 m and 32 m (50 to 105 ft) emerge as a good range of compromise choices for multiband HF and 6 m band operations.

This analysis also provides some insight into the physical basis for the operation of phased Yagi antennas mounted at different heights on a tower. By combining the signals from the two or more Yagis using phase shifters, it is possible to enhance gain in the direct-wave path while minimizing the destructive interference from the earth reflection. Possibly significant performance improvement might be realized.

Path Link Considerations

Many details are important in calculating a path link at HF, but for illustration here we examine a simplified path where both ends of the link are located on relatively flat (but not smooth) terrain, and the ionosphere and earth are suitable for the needed reflections along the path. Path link margin depends on the height of the ionosphere, h_i as well as on the arrival angle, T. Figure 9 shows the hop distances for several ionospheric heights as a function of the arrival angle over a spherical earth. For our example we will assume that the ionospheric refraction and reflection occurs at an effective height of 250 km. So a 10,000 km path might be traversed with 3, 4 or 5 hops, each 3,333 km or 2,500 km or 2,000 km respectively. Other paths are possible as well, as Davies described in *Ionospheric Radio Propagation* (see Note 5). The three different hops are marked by the shaded circle in Figure 9, with corresponding marks in Figure 7. Different hop distances mean different arrival angles, which affects the total path loss.

The wave interference gain, or height gain, g_w in dB shown in Figure 7 applies to each end of the link. Ionospheric reflection/refraction loss is L_{ion} in dB and can be as little as 2 to 5 dB.[10] In this simplified example, we will use 3 dB to account for polarization decomposition, as described by Davies (see Note 5). The free space loss is $27.6 + 20\log(2\,D_{tr} \times f)$ dB for one hop, where the frequency,

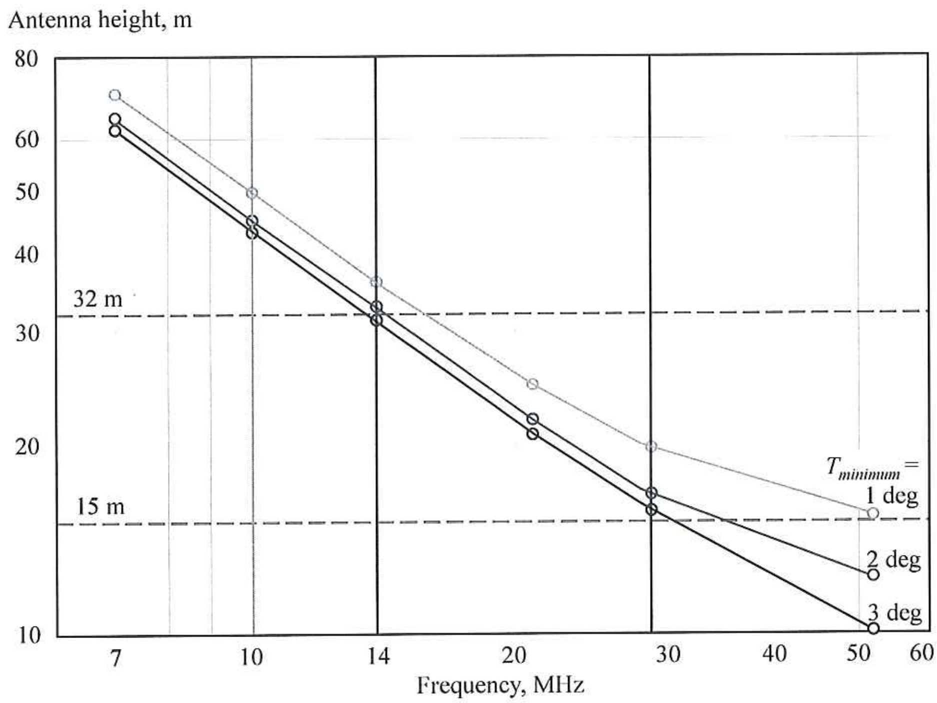


Figure 8 — Optimum antenna heights over even terrain for various frequencies.

Table 1
Path Losses in a 10,000 km Path for Different Numbers of Hops.

Hops	*T (deg)*	*First hop loss (dB)*	*Height gain (dB)*	*Rest of hops loss (dB)*	*PL (dB)*	*S-units*
3	2.8	[126.1 + 3]	–[–4 – 4]	{ 9.6 + 7.1}	153.8	3.6
4	6.9	[123.7 + 3]	–[+3 + 3]	{10.6 + 8.1 + 7.1}	146.4	4.8
5	10.4	[121.8 + 3]	–[+4 + 4]	{11.7 + 9.2 + 8.2 + 7.6}	157.8	2.9

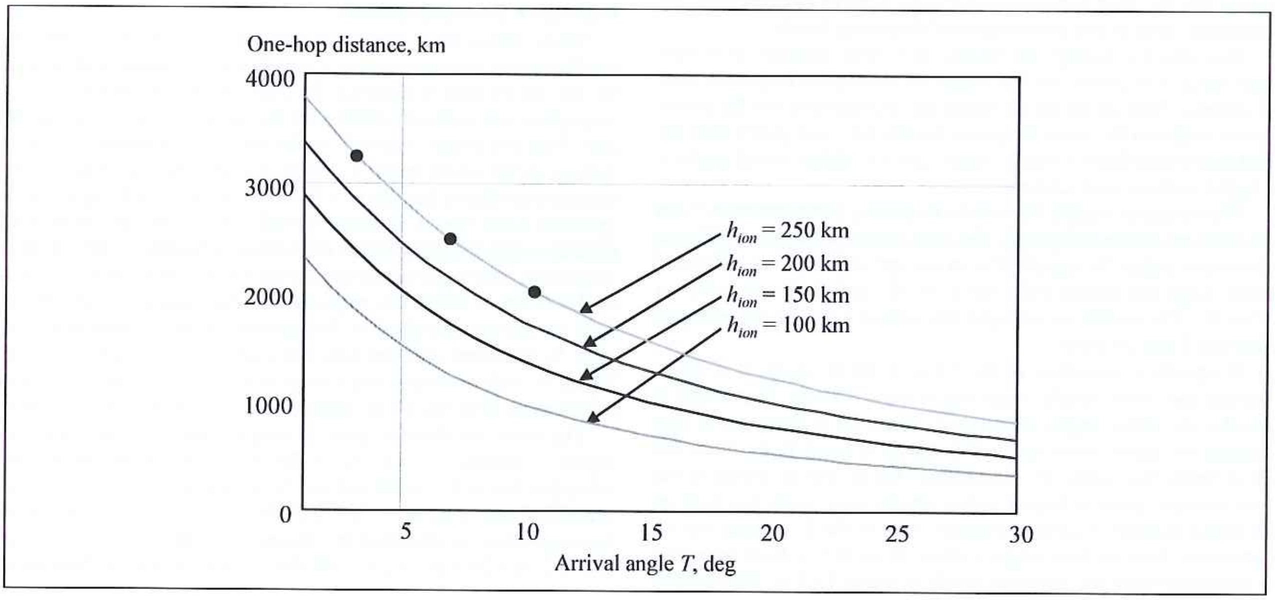


Figure 9 — Hop distances, with the 3, 4, and 5 hop points marked for a 10,000 km path.

f, is in MHz and the distance, D_{tr} is in meters. Each additional j^{th} hop adds an incremental free space loss, an earth reflection loss, $L_{earth,j}$ (from Figure 4), and another ionospheric reflection loss, $L_{ion,j}$. The path loss for n hops is written in Equation 7 so that the bracketed terms are for a single hop or first hop, including wave interference at the link ends A and B. The braces contain additional losses for hops 2 through n if present.

$$L_{path} = \left[27.6 + 20\log(2D_{tr}f_{MHz}) + L_{ion} - g_{w,A} - g_{w,B}\right] + \cdots$$
$$+\left\{\sum_{j=2}^{n}\left(20\log\left(\frac{j}{j-1}\right) + L_{ion,\ j} + L_{earth,\ j}\right)\right\}$$

[Eq 7]

Our example path in the 20 m band with a 250 km effective ionospheric height might require 3 to 5 or more hops to traverse a 10,000 km path. The various gains and losses for this idealized example are listed in Table 1. In general, several of these as well as other possible paths will exist, causing fading and signal variations as the ionosphere changes. Table 1 shows the path losses and estimated received S-units for 50 W transmitted power (approximately 100 W PEP for CW or processed SSB) and with 32 m high dipoles at each end. Gain antennas will improve signals in proportion to the antenna gains. The bracketed and braced terms in Table 1 correspond to the same terms in Equation 7.

Notice that the four-hop path has a stronger signal by over an S-unit more than the example three-hop path because the increased height gains g_w of a combined 8 dB at the higher arrival angle (the difference between the top and bottom solid circles at the optimum height in Figure 7) at both ends of the link more than compensate for the additional reflection losses of an additional hop. The height gain is the intersection of the arrival angle, T, with the antenna height in Figure 7. The four-hop 6.9° arrival angle results in less destructive interference by 7 dB at each end of the link than the three-hop 2.8° arrival angle. *The lowest arrival angle path is not always the best!* Agonizing over a lower "take-off angle" is futile. This effect justifies a compromise lower limit for the angle of arrival at lower frequencies when choosing a compromise height for a multiband antenna. The five-hop path suffers additional earth and ionospheric reflection losses, but still results in a respectable S = 2.9 signal.

Suppose that the antenna at one end of the link is lowered to 5m. The height gain, g_w becomes –17 dB for the 2.8° three-hop path, so that path is not viable. The gain is –8 dB for the four-hop path, however, which is 12 dB lower than at the optimum height, resulting in an S = 1 reading. That is still a –115 dBm signal, which is suitable for CW as well as SSB. This result helps to explain the occasional spectacular DX results possible from low and indoor attic antennas.[11] If the arrival angle is, say >5°, the low antenna captures signals that are not dramatically worse than from a high antenna. Indeed, KE4PT has earned WAS-TPA and DXCC, now with 200 confirmed entities as well as a 6 meter VUCC from southern Florida, using just an indoor antenna.

Uncertainties in the ionospheric reflection/refraction loss increase as the number of hops increases, and Equation 7 represents a best case value. Link reliability can be estimated by attaching variances to the several propagation loss components and by using the method of Hagn described in Section 8.4 of *Radiowave Propagation and Antennas for Personal Communications* (see Note 4).

Summary and Conclusions

Constructive and destructive wave interference from a direct path and an earth reflected path causes a vertical standing wave at the antenna location. The standing wave pattern details depend on the wave angle of arrival, polarization, on whether the reflection point was ground or sea water, and on the terrain profile (not considered here). Optimum antenna heights are largely governed by the lowest arrival angle deemed important at the highest desired frequency. Antennas that are placed too high can suffer from significant wave destructive interference at desired higher arrival angles. The earth reflection point is typically several kilometers away for low arrival angles, but can be tens of meters for very high arrival angles, so the condition of the ground immediately below an elevated antenna is of little importance. Because height gain can be significantly greater for higher arrival angles, the lowest arrival angle path (fewest hops) does not always result in the best link margin for paths that can be closed with different numbers of earth-ionosphere hops. Optimum height is 1.5 to 1.6 wavelengths for any one band, or a compromise height can be found for a multiband antenna operating over several bands by using the optimum for the highest frequency. Keeping in mind that this analysis was limited to rough, but not locally mountainous earth, nor a dense urban region, antenna heights in the range of 15 m to 32 m (50 to 105 ft) are found to be reasonable compromise choices for multiband antennas operating from a fixed height.

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Notes

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[7]Eugene Zimmerman, W3ZZ, "Long Distance E_s Propagation on 50 MHz at Solar Cycle Minimum — Part 2," The World Above 50 MHz, *QST*, August 2009, p 86.

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[10]Recommendation ITU-R P.534-4.

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