AN AMATEUR RADIO APPROACH TO SPECTRUM SHARING STUDIES

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I am sometimes asked how the Amateur Radio community goes about acquiring new frequency space and why it seems to take as long as it does. In the following article I hope to give a partial answer to at least the first part of that question.

I feel I should say at the outset that the principal reason RAC participates as it does in the affairs of Industry Canada and the International Telecommunications Union is to help ensure continued unimpeded access to our existing bands. Our new allocations at 138 kHz and 472 kHz, and the seeking of a new allocation at 60 metres are undertakings which, while exciting, are not our main *raison-d'être*.

That said, let me try to explain, by example, how we might try to make a case – as we are doing now in the preparations for the 2015 World Radiocommunication Conference – for a secondary allocation at 60 metres.

First of all, like seafront property, there are no unallocated frequencies in the parts of the radio spectrum of interest to Radio Amateurs. Any allocation involves sharing the spectrum with existing users who have primary allocations there.

After a demanding exercise justifying why the Amateur Radio service needs more spectrum (saying we need more space to ragchew or contest garners no sympathy), we are usually called upon to document our case in a sharing – or compatibility – study.

At its simplest, this involves demonstrating that Amateur use of the spectrum will not disturb the operations of the primary users. A simple assertion that this will be the case won't be sufficient. Nor does resorting to our good record of "listen-before-transmit" help enough. In the end generally a full-blown compatibility study is called for.

While there are a number of different and creative ways to do this, the most-accepted method and the one with the greatest likelihood of success is to follow a process based upon the ITU's own Recommendations.

First, the primary user or users are asked to provide their "protection ratios" which, simply put, quantify how much interference they could tolerate before their uses of the frequencies are impeded. There are a number of technical formulations this might take; however, a primary service might indicate that they require a 29 dB ratio of signal to noise plus interference for their use of SSB voice in 3 kHz channels. Here "noise" would be understood to be the normal atmospheric plus man-made noise, and the "interference" would be as might be caused by the proposed Amateur operations. Of course, where the primary users use the spectrum for something else, e.g., data, they might express the protection requirement in very different technical parameters.

For our part, we Amateurs would have to specify what would be the minimum criteria for us to use the spectrum space for our purposes. Again, there might be several ways to express this depending on what we are seeking. A simple example, however, might be that we require a minimum of, say, a 19 dB margin of received signal to noise for a useable Amateur 3 kHz SSB link.

There are a number of scenarios that might be prepared to quantify to what extent these conditions might prevail. Some of these can be quite creative and – indeed – fanciful depending upon whether you are trying to argue that the Amateur operation can coexist or whether you are arguing the opposite.

Here's a simple scenario which is representative of one approach. We imagine a primary user – for example, a government or military communications link, who operates a 5 kW link over a path of about 1500 kilometres at around 5 MHz – and an Amateur path of about the same distance both of which terminate in the same general vicinity. While contrary to our reputation for good operating practice, we will consider what might happen if both signals are on the same frequency.

To better visualize this, imagine the primary user link on about 5.3 MHz is between Churchill, Manitoba and Sault Ste-Marie, Ontario – a path length of about 1,510 kilometres. The Amateur path might be from Regina, Saskatchewan to Sault Ste-Marie over a 1,550 kilometre length as shown in the map at the top right.

Note: *The locations in this example have been chosen to be familiar to Canadian Amateurs. They are different from those used in the Canadian contribution to the current WRC-2015 agenda item. Those were chosen to show higher latitudes so as to be more comparable with other similar studies. The current studies are in the public domain and can be accessed at the link referenced in the footnote) – see note 1 at the end of this article. The primary user is assumed to be using reference log-periodic antennas which are pointed at each other and which are assumed to exhibit considerable gain. The Amateur antennas are assumed to be half-wave dipoles broadside to each other with zero gain.*

Since the receiver geographical locations are in the same general area for both the primary user link and the Amateur link, the "noise" for the purposes of our study will be assumed to be of the same magnitude at both receiving sites. The noise here is understood to be the natural cosmic and terrestrial noise plus the ambient man-made noise at Sault Ste-Marie. The forecast program used in the study would input the noise parameter in a standard format, e.g., noise power in dBW for a 1 Hz bandwidth.

Now, estimating the signal strength for a given ionospheric path can be done using a variety of tools. The best known tool is probably the Voice of America Coverage Analysis Program (VOACAP) for which there is a well-known interactive Amateur online calculator by Jari Perkiömäki, OH6BG (see note 2), which will calculate signal strength and noise (both in dBW) for any path on any Amateur HF band.

For an ITU study, however, it is more convenient – and likely more accurate – to use the ITU's own Recommendation for the calculation. Recommendation ITU-R P.533 (see note 3) and, in particular, REC533 software implementing the

Table 1: Primary-User SNR @ Sault Ste-Marie

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	30	32	32	31	31	32	24	10	9	13	23	23	25	33	30	30	32	34	37	37	42	40	29	30
February	32	33	31	30	29	25	22	10	9	10	21	14	19	28	25	25	27	30	33	34	38	40	30	30
March	26	20	21	22	20	17	18	15	19	23	7	12	10	21	20	20	25	26	29	30	34	37	35	30
April	27	18	21	16	20	19	22	22	22	16	13	10	9	21	21	21	24	25	27	28	30	33	31	31
May	28	22	18	17	24	23	25	20	20	21	11	9	8	19	18	17	21	22	23	24	27	29	27	28
June	29	29	28	28	25	22	25	31	29	28	24	23	21	21	20	20	21	22	23	23	25	28	27	28
July	30	29	29	23	22	21	24	25	26	27	23	22	21	22	21	21	22	23	24	24	26	28	28	29
August	32	32	25	24	26	25	26	28	26	27	25	22	21	22	22	22	23	24	25	26	28	30	30	32
September	25	18	20	22	25	22	19	14	19	16	11	9	9	20	19	18	22	23	25	26	29	30	28	31
October	24	19	20	22	30	23	19	13	18	23	16	18	15	25	23	23	27	29	31	32	35	37	33	28
November	25	21	21	21	29	25	20	13	13	20	14	20	19	29	27	26	30	32	34	36	39	38	26	25
December	31	33	29	33	32	28	22	10	9	9	26	22	26	34	31	30	32	34	37	38	41	32	30	31

Table 2: Amateur SNR @ Sault Ste-Marie

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	12	12	16	16	16	16	16	8	-5	-5	8	4	5	-1	5	3	3	8	12	18	18	23	18	10
February	11	13	10	9	10	10	8	5	-6	-6	5	2	4	-1	4	3	4	8	12	17	17	21	21	11
March	9	7	5	5	-4	0	1	2	-1	4	7	1	-3	-7	-2	-2	-2	2	5	9	11	16	20	18
April	15	5	4	-4	-7	-1	-1	2	3	7	5	-2	-5	-7	-1	-2	-2	0	2	5	7	11	15	16
May	13	11	3	1	3	12	15	12	7	5	5	-3	-6	-8	-2	-3	-4	-1	1	3	4	8	11	11
June	13	14	14	13	5	7	9	11	12	13	11	3	0	-3	-2	-3	-3	-1	1	4	3	6	9	11
July	14	15	14	6	5	8	10	11	11	5	10	2	0	-3	-1	-2	-1	1	3	5	3	7	10	12
August	17	15	8	8	8	6	5	6	15	11	12	4	1	0	1	1	0	2	4	7	6	9	12	15
September	14	6	5	-2	-7	0	-2	-4	-8	5	3	-1	-4	-8	-2	-3	-3	0	2	4	6	9	13	15
October	8	8	5	5	3	5	1	-1	-5	5	10	8	3	-2	2	0	1	4	6	9	11	15	19	15
November	9	9	0	5	5	14	7	4	-3	-1	11	9	7	2	5	3	2	6	9	13	15	19	15	9
December	13	4	5	6	9	11	12	11	-3	-6	1	6	7	1	6	3	3	7	11	17	17	21	13	11

recommendation (see note 4), is used to estimate signal strength on a given path given a set of parameters.

Similarly for noise, ITU Recommendation ITU-R P.372 (see note 5) is used to estimate the level of noise at a given receiver location again for a given set of parameters.

Now, with a forecast of signal-strength values and another of noise values, it is possible to construct a table such as Table 1 – which estimates signal-to-noise ratios at Sault Ste-Marie from the Churchill transmitter. Table 2 shows similar data for the Amateur signals from Regina as observed at the Amateur site in Sault Ste-Marie.

Note: *These tables show the received signal-to-noise (SNR) ratios and, in this example, are for an assumed smoothed sunspot number of 10.*

In addition to the parameters already mentioned – frequency, output power, antenna type and gain, and the geographical coordinates of the transmitting and receiving locations – other input parameters would include, for example, the transmission mode being employed, an estimated Smoothed Sunspot Number (SSN), desired format of the output data, e.g., periods per day, months per year, etc. Finally, there is also the desired degree of probability of the resulting data – for example, in what follows, a 50% availability probability has been specified.

In Table 1, the time periods when the signal is estimated to meet or exceed the user's useability criterion (29 dB SNR) are shown on a white background while those which do not meet this criterion are shown on a greyed background (and in italics). Similarly, in Table 2, for the Amateur link those time periods meeting or exceeding 19 dB are shown in white and those which do not are shown in grey.

Now, all of the Amateur signals shown in Table 2 might be counted as interference to the primary-user's received signal – shown in the "clear" in Table 1 – were we to assume the Amateur was transmitting on the same frequency and had not "listened before transmitting".

There are, however, two other considerations:

1) The Amateur should not be considered to be transmitting during those time periods when the path for him is not useable as previously defined (19 dB SNR)

2) The Amateur signal is being received off the side of the primary user's directional antenna and will accordingly exhibit a different – typically lower – SNR there.

Taking account of all these factors we can calculate Table 3 showing the SNR values of the interfering Amateur signal at the primary-user's site assuming the Amateur will only transmit when there is a "useable" path and that the primary user's antenna is not pointed at the Amateur transmitter.

Table 4 then calculates the impact on the primary user's signal of both the signal being received from Churchill, and the interference on the side lobe from the Amateur transmitter in Regina in those time periods when the Amateur might be transmitting. This can be shown as a "signal plus interference to noise" ratio.

Since the noise is common to both signals, the resulting "useability" criterion can be expressed as S/I – sometimes shown as C/I (where C represents "carrier").

For the primary user the channel would be useable for him at a ratio of 29 dB.

Table 3: SNR from an Amateur transmitter at Regina received on side of FL antenna at SSM when Amateur is transmitting

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	18	na	na
February	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	16	16	na
March	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	15	na
April	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
May	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
June	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
July	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
August	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
September	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
October	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	14	na
November	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	14	na	na
December	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	16	na	na

Table 4: S/I Ratio at Primary-User in Sault Ste-Marie

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	30	32	32	31	31	32	24	10	9	13	23	23	25	33	30	30	32	34	37	37	29	22	16	30
February	32	33	31	30	29	25	22	10	9	10	21	14	19	28	25	25	27	30	33	34	38	24	14	30
March	26	20	21	22	20	17	18	15	19	23	7	12	10	21	20	20	25	26	29	30	34	37	20	17
April	27	18	21	16	20	19	22	22	22	16	13	10	9	21	21	21	24	25	27	28	30	33	31	31
May	28	22	18	17	24	23	25	20	20	21	11	9	8	19	18	17	21	22	23	24	27	29	27	28
June	29	29	28	28	25	22	25	31	29	28	24	23	21	21	20	20	21	22	23	23	25	28	27	28
July	30	29	29	23	22	21	24	25	26	27	23	22	21	22	21	21	22	23	24	24	26	28	28	29
August	32	32	25	24	26	25	26	28	17	27	25	22	21	22	22	22	23	24	25	26	28	30	30	32
September	25	18	20	22	25	22	19	14	19	16	11	9	9	20	19	18	22	23	25	26	29	30	28	31
October	24	19	20	22	30	23	19	13	18	23	16	18	15	25	23	23	27	29	31	32	35	37	19	28
November	25	21	21	21	29	25	20	13	13	20	14	20	19	29	27	26	30	32	34	36	39	24	26	25
December	31	33	29	33	32	28	22	10	9	9	26	22	26	34	31	30	32	34	37	38	41	16	22	31

Now, let's look at Table 1 which is the primary user's expectation of signal useability without interference. Of the 288 time slots shown, the primary user's criterion of 29 dB would be met in 87 time slots. In Table 4, with the Amateur station operating as described, the useability criterion would be met in 80 time slots. Is this manageable?

Factor in a couple of other considerations. For starters, we have ignored for the sake of the foregoing the Amateur practice of "listen before transmitting" and indeed the obligations which would be on the Amateur station as a secondary user. In addition, the data in Tables 1 and Table 2 are calculated at an assumed 50% level of availability. The calculations generating Table 1 and Table 2 are uncorrelated so the probability of the two independent transmission events coinciding and resulting in the interference shown in Table 4 is theoretically 25%. So, while some interference situations may arise, they are likely to be quite infrequent.

Canada also submitted a spectrum occupancy survey for a period of one year to show that for North America there is unused spectrum for this band, notwithstanding a large number of primary-user licenses – many of them inactive – in the proposed Amateur allocation frequency range.

The foregoing (much-abbreviated summary) makes a case for Amateurs to share spectrum at 60 metres. As an argument it is not unassailable. Whether Radio Amateurs can gain an international allocation at 60 metres will depend on factors and agendas which are not evident in any of the foregoing – factors which are not deduced from mathematics. Leaving aside the very real role politics beyond our control play in these decisions, there are factors whose perception play in the margins of these decisions. How good is our reputation for not putting signals on frequencies which are in use? How responsible are Amateur Radio operators perceived to be by the delegates making the decisions at ITU Conferences? How well have we presented our most responsible and technically-savvy image in the ongoing meetings at the ITU and in Regional groupings over the years leading up to a Conference?

While detailed studies and years of meetings by ITU Working Groups precede decisions taken during a World Radiocommunication Conference, it is worth remembering that the delegates who cast their votes during the Conference are often not the individuals who have participated in these meetings and – in many cases – may not always have carefully read the preparatory material. Ultimately, 198 administrations have to agree to allocating spectrum space to the Amateur Radio service. So, we do the best we can and then hold our breath.

I hope, however, that this gives you some insight into how the Amateur Radio service has argued its case in this and in many preceding instances and will, hopefully, inspire us to continue this effort so as to preserve our hard-fought-for frequencies into the future.

In conclusion, I would be remiss if I didn't point out the debt I owe to those who have coached and guided me in these arcane processes: the late Ken Pulfer VE3PU, Jim Dean, VE3IQ, and above all in the present instance, Dr. Nur Serinken (ex-TA1RF) recently retired from the Communications Research Centre in Canada.

Also, my colleagues in the Amateur Radio working group at ITU-R and its chairman Dale Hughes, VK1DSH.

To these gentlemen goes all the credit for any insights and knowledge the reader may glean from this article.

Any errors, however, are entirely my fault.

Notes

1) http://www.itu.int/md/R12-WP5A-C-0543/en (Annex 10)

2) http://www.voacap.com/prediction.html

3) http://www.itu.int/rec/R-REC-P.533/en

4) http://www.greg-hand.com/hfwin32.html

5) http://www.itu.int/rec/R-REC-P.372/en