IRCA Technical Column

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Signal Strength Recording as an Aid to Propagation Studies

by Nick Hall-Patch

Introduction

For the past few years I've been monitoring radio signals using the Dymek DR-333, a 10 kHz to 30 MHz communications receiver which is controlled using the serial port of an IBM compatible personal computer. A detailed description and review of this receiver was published in the 1991 Proceedings from Fine Tuning Publications; the article is now available as a reprint from ODXA, Box 161, Station A, Willowdale, Ontario, Canada M2N 5S8. (http://www.durhamradio.ca/odxa/mailordr.html for the Web aficionado)

After obtaining source code for the DR-333's control program from the manufacturer, I found that the receiver is capable of tuning in a signal and registering its signal strength in about 100 milliseconds, so it is possible to tune 10 channels in one second and record the signal strength from each one. For some years, I've been intrigued by signal propagation at medium frequencies; now I had an instrument to record evidence of that propagation. I wrote a program in "C" which makes the IBM PC act as a signal strength data logger on up to 120 channels at a time. This was described in an article in DX Monitor October 12/96 and in following issues (the article is also available on the Web; follow the link from http://espresso.ts.uvic.ca/radio.htm to the "synth" button). Essentially, it records hour long text files containing time-stamped signal strengths which are updated every 10 to 60 seconds for each desired frequency. The format is such that the data can easily be imported into Microsoft's Excel spreadsheet program for further processing and be displayed as charts of signal strength versus time.

In mid-1997, on the Washington coast, I used this program to record some impressive sunrise signal enhancement of Australian medium wave broadcasters. After viewing these, Bob Brown, NM7M, suggested that I initiate ongoing recording of a few stations to provide data for propagation studies. Until now, the 160 meter radio amateur and the medium wave DXer have relied on years of anecdotal evidence to guide them to the best time for finding DX. In general, we in the Pacific Northwest "knew" that Australian signals tended to be better between March and September, that East Asian signals had better signal strengths the rest of the year, that local sunrise sometimes brought enhancement of these signals, and that some days there was no DX to be heard or worked. But there was little solid data to back up these perceptions or to allow us to speculate as to why a certain opening was better than another opening.

Setting up an ongoing monitoring program

With a modification to allow it to run 24 hours a day and to record at predetermined times, my program was able to automatically provide signal strength magnitude on a daily basis. Recording signal strengths from certain AM broadcasters since September 1997, it has started generating the historical database which could help us explain medium frequency propagation with greater confidence.

AM broadcast stations can be useful beacons for those interested in propagation, as they are fixed frequency, and much of their transmitted energy is a constant carrier wave, often for 24 hours a day. I chose to monitor two stations in the upper part of the medium wave broadcast band which had been heard frequently on the North American west coast by MW DXers, 4QD-1548 kHz in Emerald, Australia, and HLAZ-1566 kHz on Cheju Island, South Korea. Both stations broadcast continuously when there is a darkness path across the Pacific, are high powered, and are pretty well alone on their respective channels. In addition, I am recording signal strengths from two similar stations in comparable geographical locations, but below the electron gyrofrequency, JOAK-594 kHz from Tokyo, Japan and 4QR-612 kHz in Brisbane, Australia. I also discovered that even with my resonant antennas described below, I was able to record attenuated signals from on 1314 kHz, so I recorded that channel as well in case the big Norwegian broadcaster should make an appearance.

The monitoring setup (see **Figure 1**) is at my home near downtown Victoria, B.C., close to three powerful AM transmitters capable of overloading the DR-333, so a tuned antenna was a necessity. Therefore, my antenna system is a pair of 5 foot square unamplified loops in my attic, both oriented east-west, with one tuned to about 1557 kHz, and the other to 603kHz. Using link coupling and matching transformers, each loop's output is run through a hybrid combiner to a single coax downlead to the 50 ohm antenna input of the receiver in the basement. This separation of the antenna system from the receiver/PC helps minimize interference from the PC.

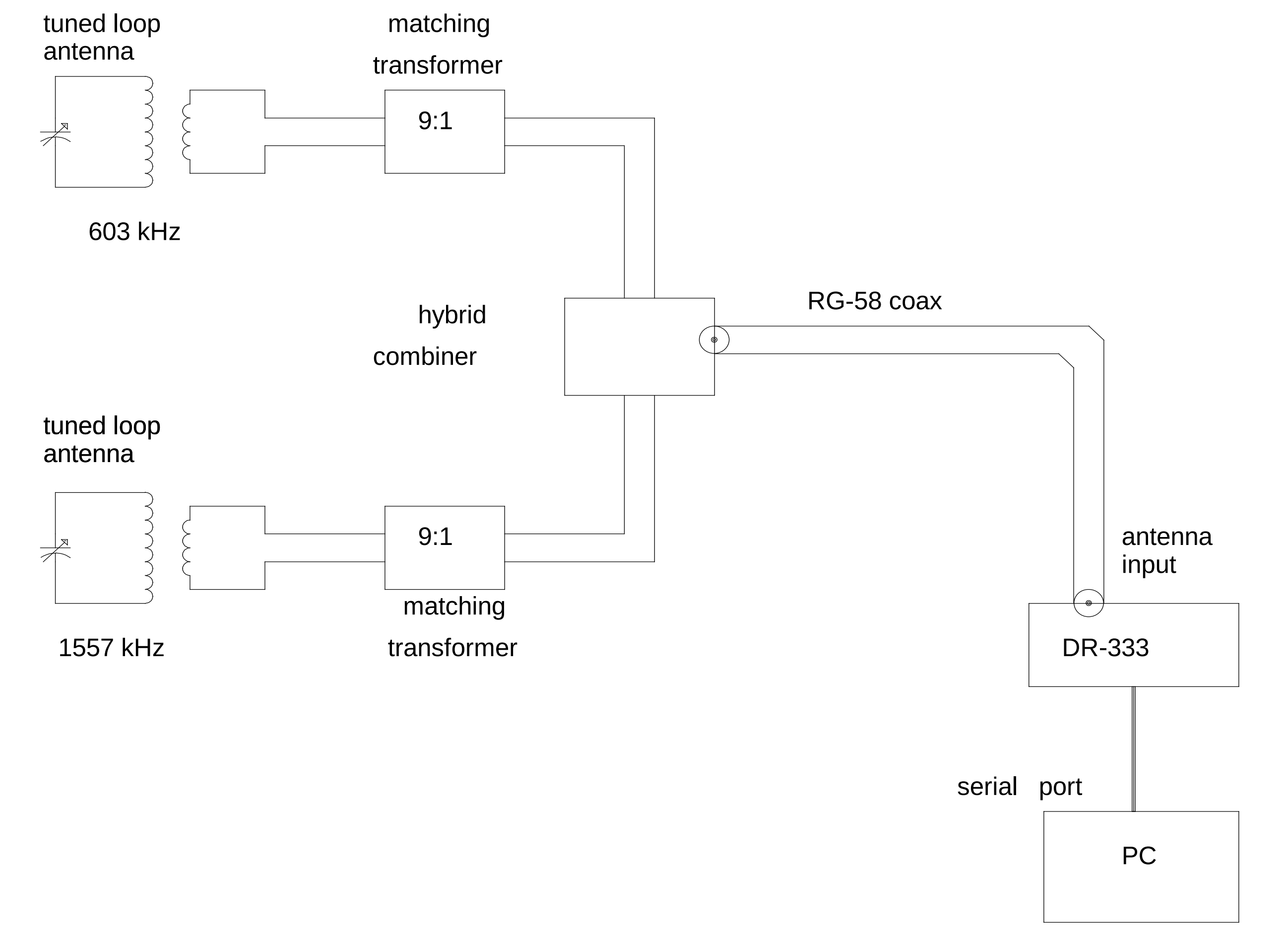


Figure 1 -- The DR-333 Monitoring System

One problem with monitoring overseas AM broadcast band stations is eliminating the large amount of interference to the desired signal, primarily from the sidebands of domestic broadcasters, but also from atmospheric and local electrical noise. The 400 Hz intermediate frequency (IF) passband of the receiver reduced interference to some extent, but I needed to reduce the interference further.

Although each frequency is monitored in turn approximately every 100 milliseconds, the program logs an average of 10 such points for each frequency, which, besides reducing the data file size, also reduces the effects of impulse noise on the signals. In addition, signals one kilohertz above and below the desired frequency are monitored. The interference levels are similar on these nearby frequencies, but the narrow IF filter removes any trace of the target station's carrier wave. When I import the data files into Excel, I subtract a weighted average of these two extra signal strengths from the desired signal frequency's strength to deliver a closer estimate of the target station's signal intensity. Finally, I perform a running average of 20 of the resulting points to further smooth the data set. At this point, I'm not sure whether I'm smoothing out short term signal strength fluctuations or whether I'm removing more interference, but when the data set is converted to graphical form, the result of the smoothing is a clear illustration of medium term signal strength variations. Note that the original data are retained, and more elegant forms of post-processing could be performed on them in the future.

Results

Each day for the past two years, barring hardware and software glitches, the computer controlling the radio has recorded averaged signal strengths from these stations every 20 seconds, and parked the results in hourly files. What do the preliminary results show? **Figures 1** and **2** display the percentage of days per month when any signal was heard from each station throughout the two seasons. It seems the data generally support the received wisdom that signals from East Asia are heard in the Pacific Northwest between September and April, with better signals around the equinoxes, but generally with a lull between November and February, and that signals from Australia, at least in the upper portion of the band, are better heard here after April. The low band Australian, 4QR, however, seems to have more in common with the East Asians than with the higher band 4QD. Interestingly, in the season of '98-'99, the fall was not as good for trans-Pacific DXing as the spring was, and the Aussies seemed to be making more overall appearances, perhaps due to the approach of the sunspot maximum.

Figure 2 -- '97 - '98 season

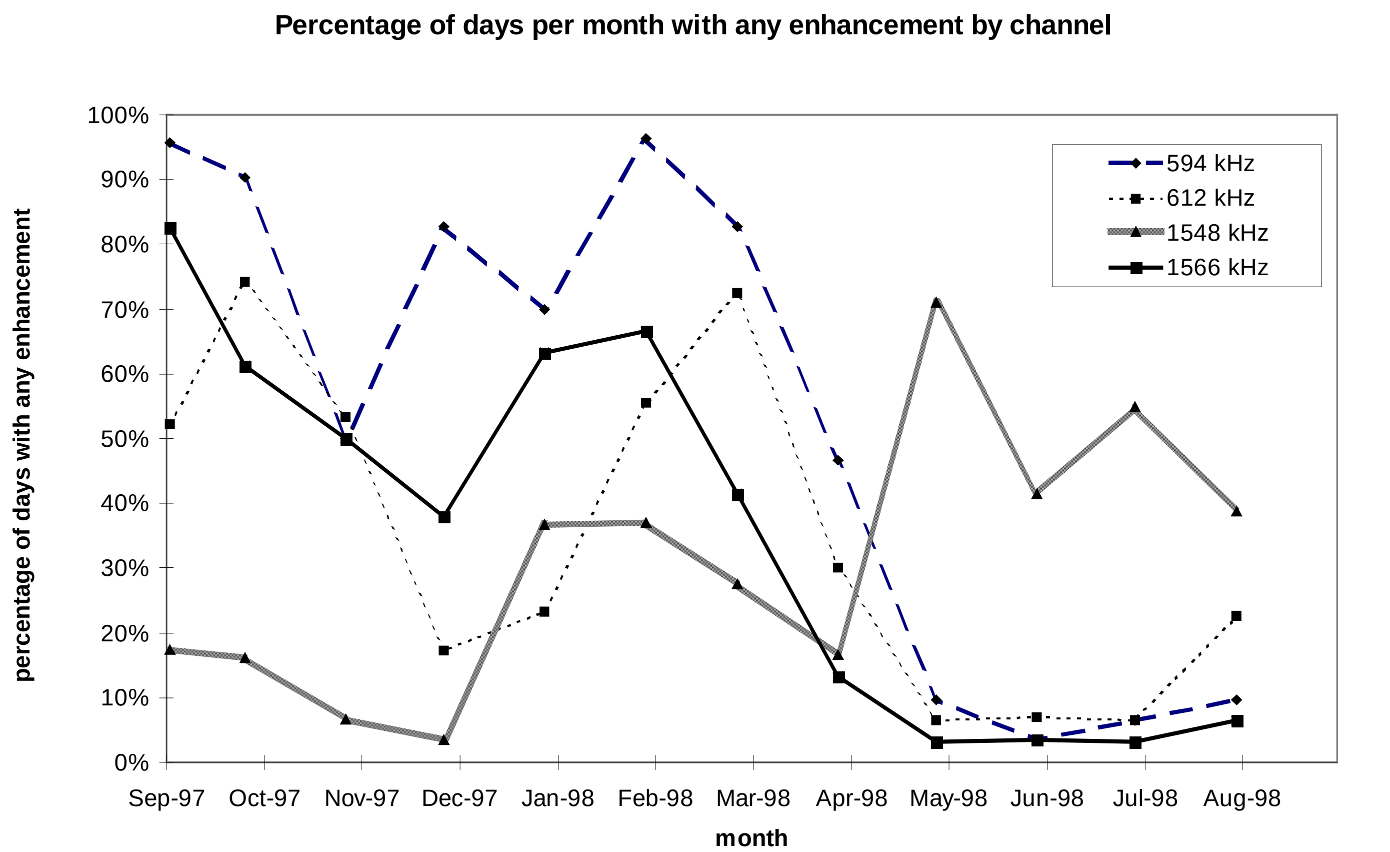
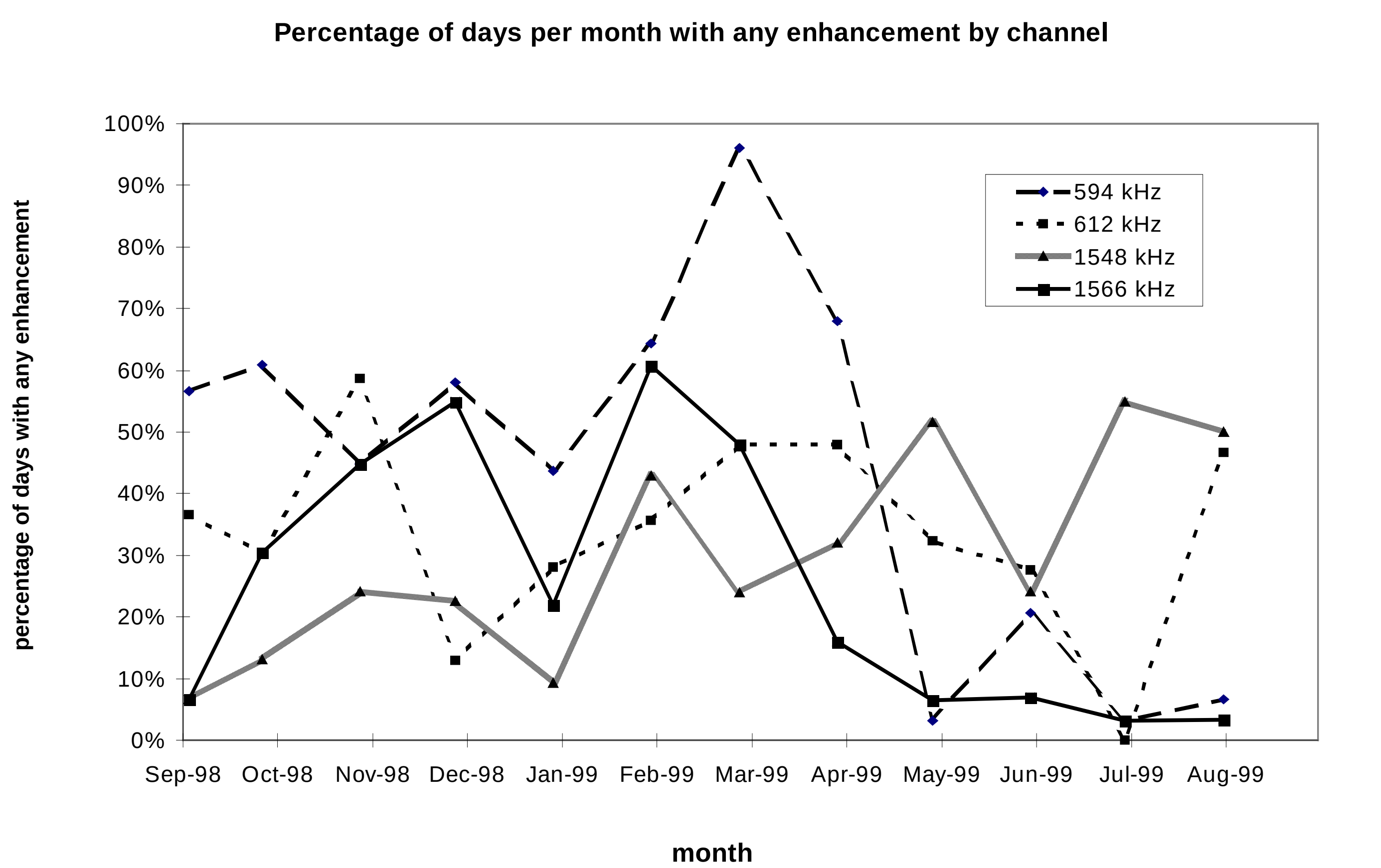
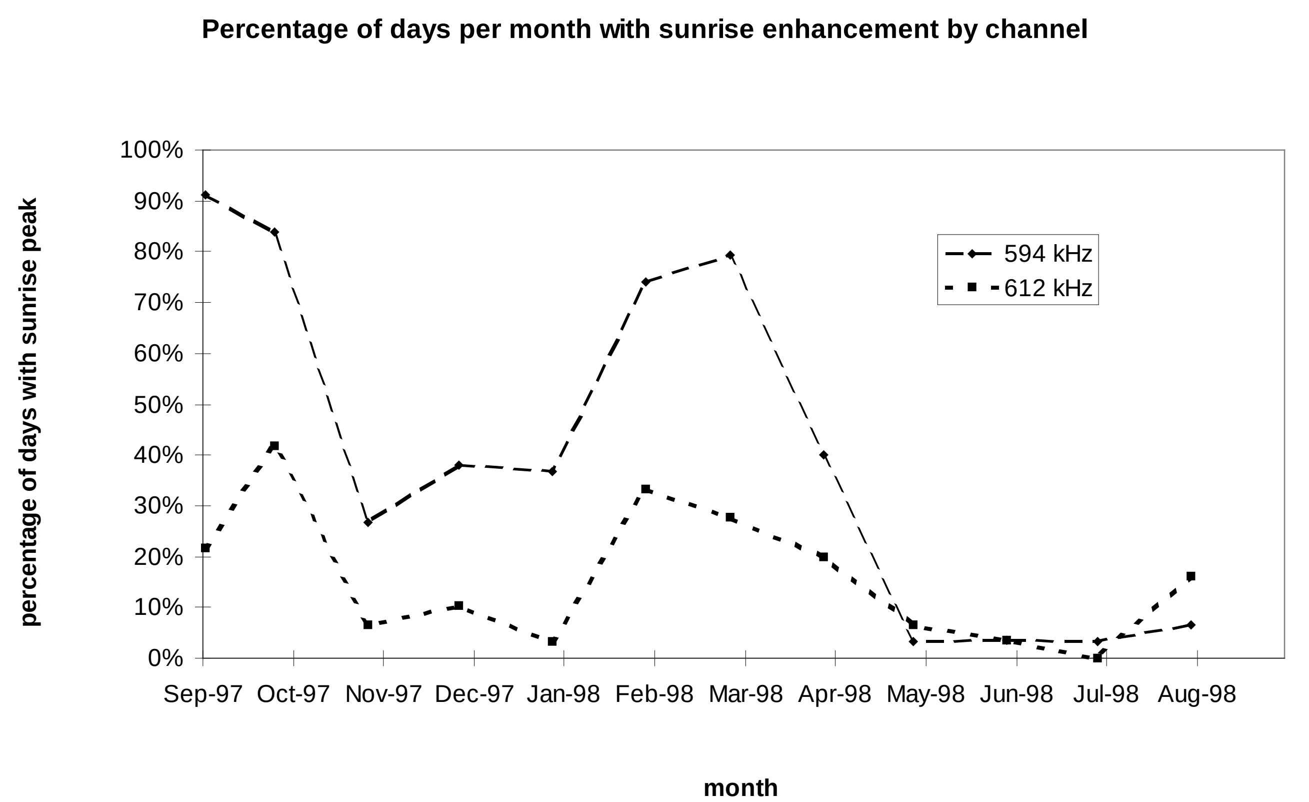


Figure 3 – '98 -'99 season



Although receptions of these trans-Pacific stations could occur at any time during the darkness path between transmitter and receiver, a greater likelihood of reasonable reception occurred near local sunrise at the receiver, and there was often a marked enhancement (sometimes more than 12 dB) of signal strength at this time. In fact, on many days, the only reception of HLAZ or of 4QD occurred during the hour previous to sunrise, with the signal rising out of the noise to a greater or lesser peak, then fading away again, often in less than 15 minutes, as local sunrise approached. Interestingly, however, with JOAK and 4QR, this sunrise peak was more common during the fall and the spring, and to a much lesser extent in the summer. **Figures 4** and **5** chart the days per month when sunrise (rather than any) enhancement was observed on 594 and 612 kHz. If you compare these figures with **Figures 2** and **3**, you will see that there is a decided dip in receptions in the winter months if only sunrise enhancements are counted. In the winter months, even though there might be a sunrise peak (and there often wasn't one), it was usually dwarfed by a slowly building peak starting after transmitter sunset, followed by a slow fade out well before local sunrise. This was most obvious on the signals for JOAK, but was also noticeable on 4QR as well. In comparison, almost all receptions of HLAZ and 4QD were close to local sunrise. See **Figures 6, 7** and **8** for illustrations of these enhancements.

Figure 4 -- '97 -'98 season



The first example of a strong sunrise enhancement is shown in **Figure 6**, and seems typical of 1548 kHz traces observed particularly in the spring and summer of 1998, in that no signal was observed until near receiver sunrise when a relatively sudden increase occurred (receiver sunrise was at 1235 UTC). This channel very occasionally showed enhancements around transmitter sunset as well. Note that for the present, I regard any signal trace below about -120dB as noise, though there may well be useful information there.

On previous days on 1548 kHz, sunrise enhancements of just a few dB had been observed from May 7th through the 11th, with no enhancement at all on the 12th, followed by large enhancements on the 13th and 14th, followed once again on the 15th by no enhancement at all. So there can be some large day to day variations, and while the enhancements on the 13th and 14th did occur on days that were geomagnetically quiet compared with previous days, the 12th had similar geomagnetic activity to the 7th through the 11th, yet showed no enhancement. A sudden impulse to the geomagnetic field was observed at 1435 UTC on the 15th, but one would not have expected that impulse to have wiped out a potential sunrise enhancement at the receiver two hours earlier. From these and other observations, there appears to be no easy correlation between geomagnetic activity and good radio conditions at local dawn. (The geomagnetic conditions noted are from the Space Environment Center via Cary Oler's Solar Terrestrial Dispatch at http://solar.uleth.ca/)

Figure 7 illustrates a late fall enhancement on 1566 KHz, when receiver sunrise was at 1512 UTC. On this channel, one sometimes sees significant signals outside the sunrise period, though some of them are due to the use of a directional antenna at the transmitter; see below for details. A geomagnetic storm had occurred on November 7, and there had been no signal enhancements on the 7th or 8th. However, although the geomagnetic field remained relatively quiet after November 9, there were no further signal increases at dawn on the following several days, so it appears that something other than geomagnetic activity is influencing these enhancements also.

Figure 5 – '98 -'99 season

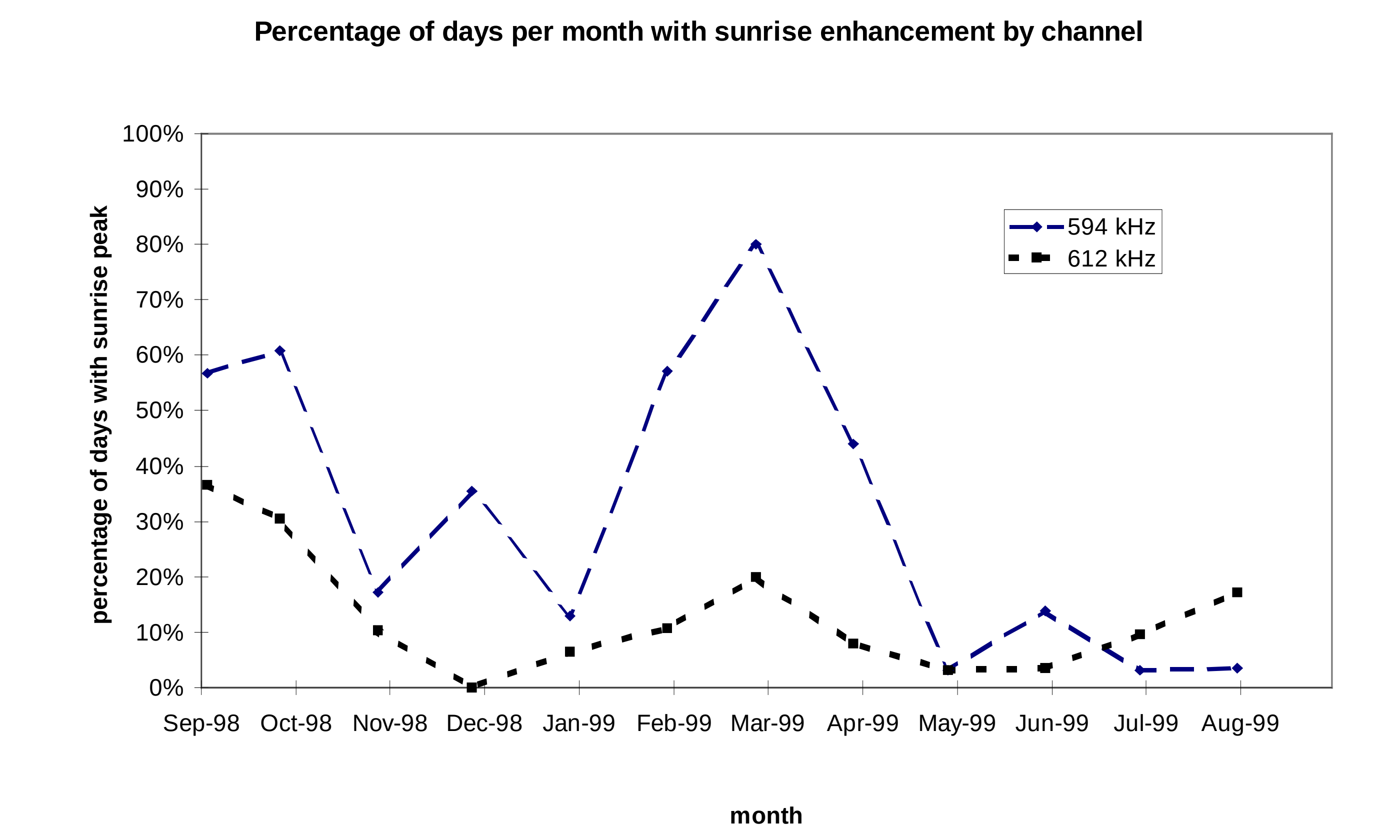
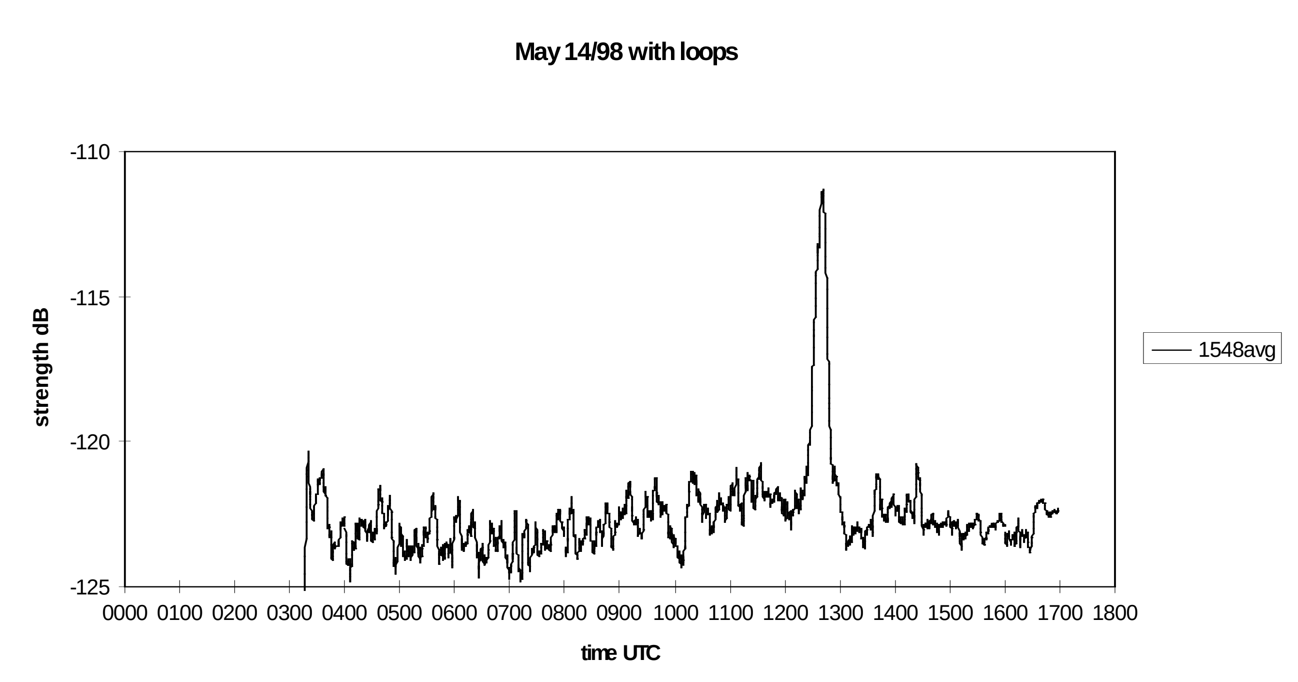
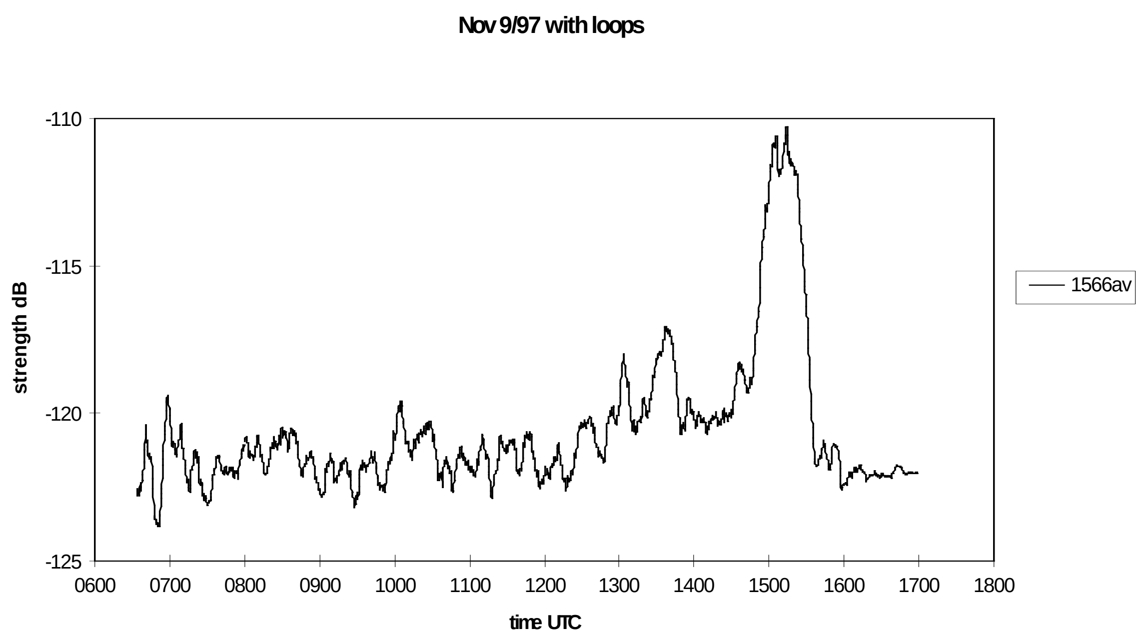


Figure 6 -- 1548 kHz



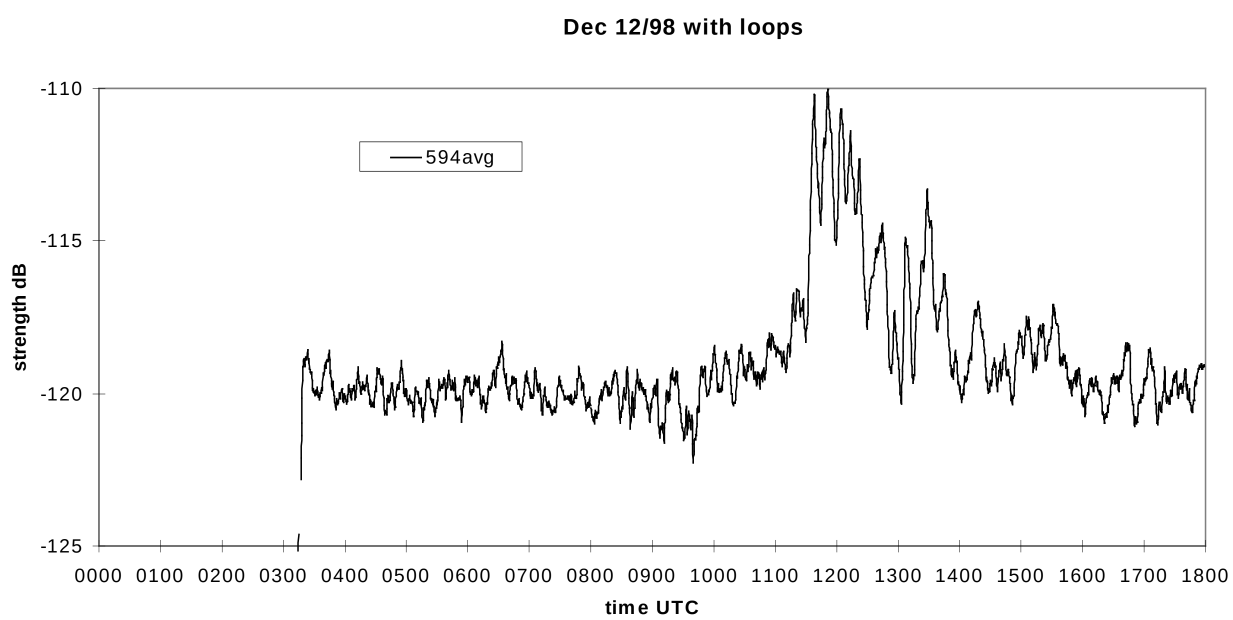
As mentioned earlier in this article, signal enhancements at local sunrise are not always the norm. In fact, at
the lower frequencies recorded, such as on the 594 kHz trace shown in **Figure 8**, they seemed to be the exception during the winter months. Though such enhancements were quite common during the spring and fall the time that the strongest signal occurred seemed to move away from local sunrise closer to the winter solstice. There could be smaller enhancements close to sunrise as well in the winter. For example, there is a smaller boost in **Figure 8** not long before local sunrise at 1557 UTC. Similar changes in the enhancement patterns during the winter months were observed on 612 kHz also, though sunrise enhancements were less frequent during those months. (a further note: because the DR333 is less sensitive at lower frequencies, the signal traces recorded on 612 kHz and 594 kHz should be regarded as noise below about -118 dB).

Figure 7 -- 1566 kHz



These data should lead to some worthwhile hypothesizing. Why are the local sunrise enhancements so variable in magnitude, and what is causing them? And why were the excellent mid-winter high latitude openings to Europe in December 1997 not always paralleled by good high latitude signals on Asiatic

Figure 8 -- 594 kHz



signals?

For example, **Figure 9** illustrates a signal trace from Norway on 1314 kHz during that period, yet **Figure 10** shows relatively little activity from the Korean on 1566 kHz a few hours later, in spite of a continuing quiet geomagnetic field.

Incidentally, if one looks closely at **Figure 10**, there is evidence of a small boost in signal strength between 1630 and 1730 UTC (local sunrise was at 1604 UTC, so this is a post sunrise reception) as well as a boost between 1230 and 1345 UTC. In fact, there were many mornings throughout the year with signal increases between 1230 and 1345 UTC, no matter what time local sunrise occurred. These times corresponded with the times given in the World Radio TV Handbook for Japanese language broadcasts, and it took me longer than I would have liked to conclude that, with Japan directly on the path from Cheju Island to Victoria, the station was likely to be using a directional antenna at that time. Indeed it did; HLAZ posts a rough coverage map on the internet (http://www.febc.org/images/mail94cj.gif) showing a big lobe towards Japan (and Victoria)
presumably for Japanese broadcasts. A quick posting on Hardcore DX, and within a few days I had a faxed field strength map from the engineering staff at HLAZ (ain't the Internet wonderful?). For the interest

of west coast DXers, HLAZ's effective radiated power towards here is only about 3 kilowatts between 1000 and 1230 UTC and also between 1345 and 1630 UTC, but increases to about 19 kilowatts between 1630 and 1730 UTC, and delivers nearly a megawatt between 1230 and 1345 UTC.

Figure 9 -- 1314 kHz

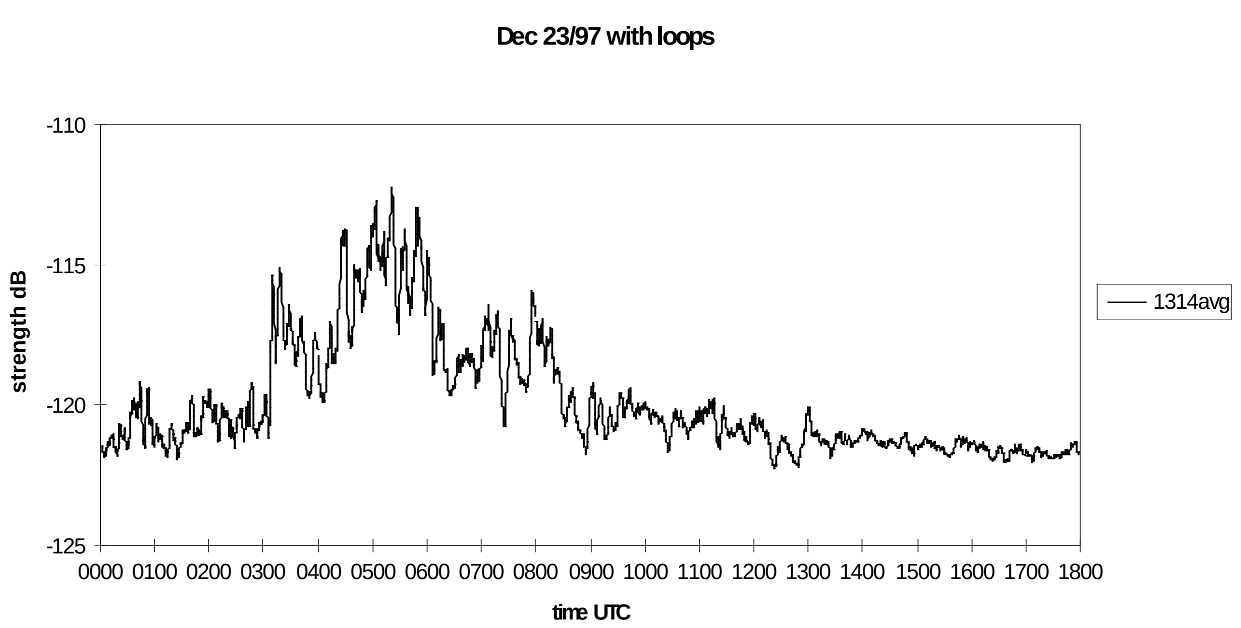
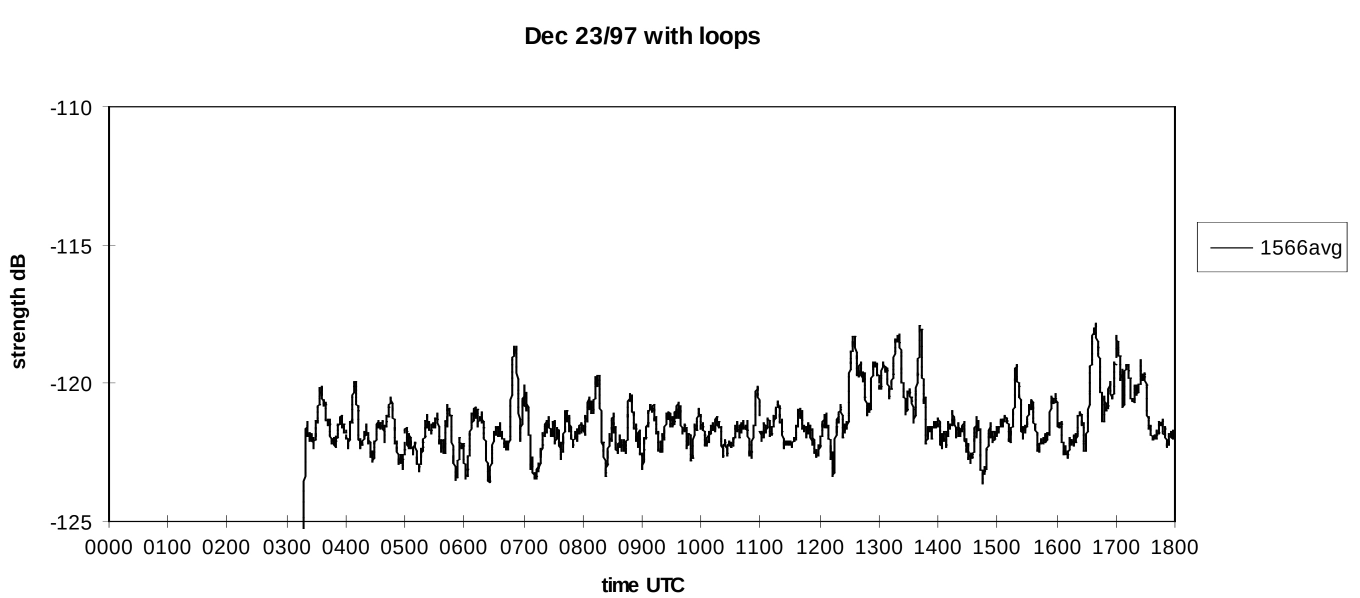


Figure 10



As a further aside, you will note that the y-axis title of all the above charts is described as signal strength in decibels. As the DR-333 outputs its signal strength in an 8-bit code (0 to 255), it is necessary to convert the data to something more meaningful. When I first started using the radio, I connected a lab-grade signal generator to it and using various medium frequencies, varied the generator output over eight points from -110 to -40 dBm (dB referenced to a one milliwatt signal at the antenna terminal), and logged the signal strengths indicated by the 333 versus the generator output settings. A linear relationship between the 333's output and the generator output in dBm was derived, which I apply to the data in the spreadsheet. Strictly speaking, the signal strength should be in dBm, but after applying my empirical corrections for interference and noise, I hesitate to claim that sort of accuracy. However, I feel that the relationship in dB is roughly valid, even if the point of reference is a bit undefined.

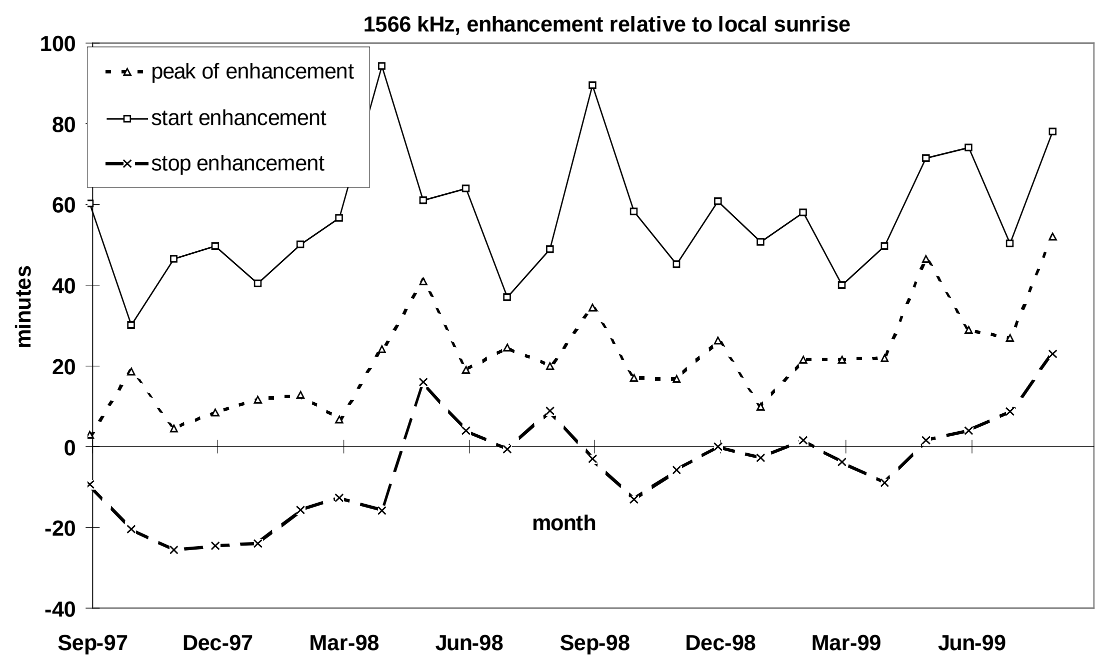
A trend in sunrise enhancements on 1566 kHz

In an attempt to characterize the likely times of sunrise enhancement, I looked at the data for HLAZ over the two years, and charted the start, stop and peak times of these enhancements relative to ground sunrise at my listening post in Victoria, B.C. **Figure 11** shows monthly averages of observed times offset from local sunrise, but note that there are some months with very few receptions from this station, which may call into question the usefulness of the monthly average.

Three points should be made here. The first is that receptions of the signal are not really influenced by sunrise at the surface of the earth at the receiver. However, the time of local sunrise is one easily available to the DXer, and it is related to the time of sunrise at various ionized layers along the signal path from the transmitter. Those sunrises do influence the quality of our receptions.

The second and third points can be seen by looking at **Figure 11**: The time of sunrise enhancement seems to be within 5 and 40 minutes of local sunrise all year round, and not particularly influenced by the time of year (well, perhaps a few minutes earlier in the winter months). The enhancement also seems to have moved slightly earlier relative to local sunrise over the two years, as we approach the sunspot maximum. For this part of the world in the coming season, it seems one should start listening for a sunrise enhancement on high band East Asians about 60 minutes before local sunrise, and expect a peak in signal strength to occur about 30 minutes beforehand on average. Note that this is for one channel only; I have not completed this exercise on the other three trans-Pacific stations.

Figure 11



Conclusions

This data set verifies some things we already know, such as winter being a better season for East Asian DX than summer, and that sunrise enhancements of long range signals are a reasonably frequent occurrence.

The information gathered over the last two years may have further potential to help us to understand how and why sunrise enhancements occur. It seems possible that ionospheric tilts at local sunrise could be directing signals to the receiver at local sunrise, perhaps from a duct between the E and F regions. If we knew the arrival angle of the received signal during the enhancement, we could visualize more exactly the path out of the ionosphere to the receiver, but that would involve exotic antenna arrays at the very least. A string of recording receivers laid out on the path, preferably far away from domestic sources of interference, would also be helpful in understanding how DX signals arrive at our antennas.

It would be useful to discover why sunrise enhancement does not occur on a daily basis. I have looked at the A-indices for the two years, and aside from the obvious effects of geomagnetic storms, sunrise enhancement does not seem particularly dependent on geomagnetic activity, so what are the influences that determine whether a signal is heard just before sunrise? And, it does appear at first glance, that the mechanisms for propagation in the lower part of the medium wave band are not entirely the same as those for the upper part of the band, so what is happening there to deliver enhanced signals long before sunrise in the winter months? Unfortunately, I am not really a propagation expert, so it is to be hoped that others with more knowledge can make use of the data or suggest better ways to record it.

Finally, as a DXer, the first thing I should do is modify my program to set off an alarm during major enhancement periods to alert me to worthwhile openings!

(These articles are based on ones which have appeared in the Western Washington DX Club's Top Band Anthology)