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Concerns with Sharing Studies for HF Oceanographic Radar Frequency Allocation Request (WRC-12 Agenda Item 1.15, Document 5B/417)

SERAFIN P. RODRIGUEZ

*Advanced Radar Systems Branch
Radar Division*

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14. ABSTRACT The International Telecommunication Union (ITU) is seeking a frequency allocation in the High Frequency (3–30 MHz) and VHF band of the spectrum for oceanographic surface wave radar. However, the 'Sharing Studies' undertaken for this issue use some inappropriate assumptions, do not sufficiently address what will likely be the most significant interference path, and thus reach incorrect conclusions. These concerns are addressed along with two data collections and an experiment by the Naval Research Laboratory which support these concerns.					
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Executive Summary

Currently, the International Telecommunications Union (ITU) is considering an allocation for High Frequency (HF) Oceanographic Radars in the 3-50 MHz band. This issue is WRC-12 Agenda Item 1.15.

As part of the allocation process, several studies were undertaken to determine if sharing spectrum with existing services is possible. This document raises concerns about the sharing studies including the use of inappropriate assumptions and not sufficiently considering the most likely interference path, thus reaching incorrect conclusions. In order to make an informed decision on the allocation, these concerns need to be addressed.

This document specifically looks at U.S. Draft New Report ITU-R M.[RLS 3-50 MHz Sharing] –On the feasibility of sharing sub-bands between oceanographic radars and fixed and mobile services within the 3-50 MHz Band,” (document 5B/417) and the underlying studies the document is based on. The concerns are:

1. The interference by a 24/7 HF oceanographic radar, particularly via skywave propagation, is greater than the studies indicate because inappropriate assumptions/considerations (more relevant to communications systems) were applied to the radar. In particular, two assumptions appear inappropriate. First, assuming the radar is not interfering when swept through the victim receiver's passband, even though it will sweep back through in less than half a second. Second, decreasing the interference power by the ratio of the radar swept bandwidth to the victim receiver bandwidth, even though the radar is instantaneously narrowband. It is unclear how effective a service will be if a radar signal sweeps through every 0.5 seconds.
2. The studies did not adequately consider the shorter-range, single-hop propagation mode and the fact that HF oceanographic radars will be located on the coast where most of the world's population resides. Single-hop, high-elevation-angle skywave propagation will likely be the dominant interference path.
3. The fact that 10 oceanographic radars can be seen simultaneously via skywave propagation around 5 and 13.5 MHz in a very noisy urban environment (Washington, D.C.) for hours at a time means they have power well above the external noise and could be interfering for hours at a time. These radars were observed occupying about 125 kHz around 5 MHz and 200 kHz around 13.5 MHz. While other documents indicate methods for the radars to share frequencies, it is unclear if these would be implemented or if the radars would spread across the full range of allocated frequencies to avoid interference between radars.
4. The fact that 25 HF oceanographic radars could be observed for hours via skywave propagation around 5, 8, and 13 MHz in Gakona, Alaska, located 150 km from the coast. These radars utilized approximately 825 kHz of bandwidth.

5. Experimental data for a similar radar waveform of known power and geometry showed multiple high-angle skywave propagation paths can be observed at a ground range of 230 km.

The impact of this new allocation on the US Navy's use of the HF band is uncertain at this time but could be significant and requires further study. The overall conclusions that interference will be similar to that of other low-power HF users, occur only a small percentage of time, and that spectrum can be shared during the periods the radar sweeps out of a victim receiver's passband appear incorrect.

In addition to the sharing studies, several other documents relating to this allocation request were produced. While many are still in draft form, there are concerns with respect to some of the statements. Some of these will be indicated in the main body of this document.

Introduction

Currently, the International Telecommunications Union (ITU) is considering an allocation for High Frequency (HF) Oceanographic Radars in the 3-50 MHz band. This issue is WRC-12 Agenda Item 1.15.

Several documents were produced relating to this allocation request including:

1. Draft NEW RECOMMENDATION ITU-R M.[OCEANOGRAPHIC-RADAR] –Technical and operational characteristics of oceanographic radars operating in sub-bands within the frequency range 3-50 MHz” (document 5/171-E)
2. U.S. Draft New Report ITU-R M.[RLS 3-50 MHz Sharing] –On the feasibility of sharing sub-bands between oceanographic radars and fixed and mobile services within the 3-50 MHz Band,” (document 5B/417)

As part of the allocation process, several studies were undertaken to determine if sharing spectrum with existing services is possible. These are reported in document 2, U.S. Draft New Report ITU-R M.[RLS 3-50 MHz Sharing] –On the feasibility of sharing sub-bands between oceanographic radars and fixed and mobile services within the 3-50 MHz Band,” (document 5B/417).

The purpose of this paper is to raise concerns with Document 2 and the underlying studies that Document 2 is based on, including the use of inappropriate assumptions and not sufficiently considering the most likely interference path, thus reaching incorrect conclusions. In order to make an informed decision on the allocation, these concerns need to be addressed. The concerns are:

1. The interference by a 24/7 HF oceanographic radar, particularly via skywave propagation, is greater than the studies indicate because inappropriate assumptions/considerations (more relevant to communications systems) were applied to the radar. In particular, two assumptions appear inappropriate. First, assuming the radar is ‘not interfering’ when swept through the victim receiver’s passband, even though it will sweep back through in less than half a second. Second, decreasing the interference power by the ratio of the radar swept bandwidth to the victim receiver bandwidth, even though the radar is instantaneously narrowband. It is unclear how effective a service will be if a radar signal sweeps through every 0.5 seconds.
2. The studies did not adequately consider the shorter-range, single-hop propagation mode and the fact that HF oceanographic radars will be located on the coast where most of the world’s population resides. Single-hop, high elevation angle skywave propagation will likely be the dominant interference path.
3. The fact that 10 oceanographic radars can be seen simultaneously via skywave propagation around 5 and 13.5 MHz in a very noisy urban environment (Washington, D.C.) for hours at a time means they have power well above the external noise and could be interfering for hours at a time. These radars were observed occupying about 125 kHz around 5 MHz and 200 kHz around 13.5 MHz. While other documents indicate methods

for the radars to share frequencies, it is unclear if these would be implemented or if the radars would spread across the full allocated frequencies to avoid interference between radars.

4. The fact that 25 HF oceanographic radars could be observed for hours via skywave propagation around 5, 8, and 13 MHz in Gakona, Alaska, located 150 km from the coast. These radars utilized approximately 825 kHz of bandwidth.

5. Experimental data for a similar radar waveform (linear FM) showed multiple high-angle skywave propagation paths can be observed at a ground range of 230 km. In this instance, the transmit power (300 Watts), geometry and antennas were known. The path was over ground, thus similar to the landward propagation paths considered in some of the sharing studies. No ground wave path was observed. However, the multiple skywave paths indicate that a ring of ranges around an HF oceanographic radar can be illuminated.

The impact of this new allocation on the US Navy's use of the HF band is uncertain at this time, but could be significant and requires further study. The overall conclusions that interference will be similar to that of other low-power HF users, occur only a small percentage of time, and that spectrum can be shared during the periods the radar sweeps through a victim receiver's passband appear incorrect.

In addition to the sharing studies, several other documents relating to this allocation request were produced. While many are still in draft form, there are concerns with respect to some of the statements and implications. Some of these will be discussed in the section "Related Documents".

Discussion of Sharing Studies

The U.S. draft document has been significantly edited from the original ITU version of document 5B/417-E, dated 11 December 2009. It now combines information from four separate studies. In consolidating the information, some of the critical assumptions used in the analysis were not cited. Several of these assumptions appear inappropriate and lead to incorrect conclusions.

While the studies (particularly Study 3) were quite extensive, this document delineates some of the concerns with the individual studies and the conclusions reached. In addition, some anecdotal information is provided that supports an assertion of incorrect assumptions which led to incorrect conclusions.

Using the ITU version of document 5B/417-E dated 11 December 2009 numbering scheme for the studies, the following discussion expresses some of the concerns.

Study 1 – Annex 1

Study 1 finds minimal interference, particularly in the skywave propagation path. This is because all of the grid points are so far away that the propagation is double-hop or more, and just the $1/r^2$ spreading losses at these ranges drop the power sufficiently that there will seldom be interference. However, with high-frequency surface wave radars located all along the coast, single-hop skywave propagation will often occur that yields powers above external noise levels which will cause interference to other users of the band. In addition, most of the world population lives along the coastal regions.

More specifically, in Figure 3, the closest victim receiver is approximately 5000 km from the transmitter. Thus, all the victim receivers are multi-hop propagation paths. At 5000 km, just the spreading loss is 145 dB. There would be additional losses for each ground bounce and, during the daytime, D-layer absorption for each pass through the ionosphere. It would be more appropriate to have the ‘cross’ of victim receiver geographic positions go through the radar location to capture the shorter-range, single-hop skywave propagation paths.

For the shorter-range, single-hop propagation paths, lower and mid frequencies will support higher elevation angle skywave refraction. Later in this document, data is presented of 10 HF surface wave oceanographic radars, (likely CODAR systems), which were all simultaneously seen at the Naval Research Laboratory in Washington, DC. These radars were seen by skywave propagation, persisted for hours and were clearly well above the external noise levels. Thus, even this single case would yield an effective interference percentage of time much greater than the percentages indicated in Table 8.

Study 2 – Annex 2

Study 2 limits the interference to the time the radar is actually sweeping through the band of a victim receiver. Thus, for a 15 kHz swept bandwidth, the interference to a victim receiver with a 3 kHz passband is assumed to be at most 20% of the time. This assumption, in conjunction with the propagation variations, leads to interference for a maximum of 18.4% of the time.

This assumption is not valid for a radar signal that operates continuously 24/7 in one frequency band with a typical sweep rate of 2 Hz. Thus, every 0.5 seconds the radar will sweep through the victim receiver’s passband, interfering with the victim receiver. The victim receiver will be clear for about 0.4 seconds before the full radar power sweeps through its passband again. Depending on the receive system, periodic interference on the order of two times per second may severely impact performance.

In addition, the study gives a benefit to the radar of the ratio of the radar swept bandwidth to the victim receiver bandwidth. This is inappropriate for this situation. The radar signal is instantaneously a narrowband signal at full power. If one considers the narrowest 25 kHz swept bandwidth, this yields an inappropriate benefit to the radar of 9 dB and at 150 kHz of 17 dB.

Study 3 – Annex 3

Sharing Study 3 is very complete and merits an in-depth read. However, the summary of Sharing Study 3 in the main body of Document 417 concludes that the nature of the interference is no different than what exists today between fixed, mobile, and other HF services. It is of note that this is not the conclusion stated at the end of the full Sharing Study 3 included as an Annex.

This conclusion does not take into account the 24/7 operations of oceanographic radars. When the radars are seen either by ground wave (which, if that occurs, will be 24/7) or skywave (which could be half the day or more depending on frequency and distance from the radar) the signal will interfere every 0.5 seconds. Other high-frequency band users, for example voice communications, do not tend to operate continuously at the same frequency 24/7.

In fact, when Sharing Study 3 looked at potential interference to the radar by 150 Watt comms systems, the potential interference for many frequencies and site locations was 100% of the time. If a comms system can interfere with the radar, then it would generally be the case that a 50 Watt radar (-5 dB from 150 W) would interfere with the comms system.

Study 4 – Annex 4

This study looks at spectrum utilization at one location for several 30 minute periods over 3 days and notes lower utilization above 20 MHz. However, it is currently the extreme minimum of the solar cycle. As the solar cycle continues, users will more often use higher frequencies.

In addition, the antennas used were short active antenna. While designed to be externally noise-limited, such antennas generally seem to perform worse than resonant monopoles and in practice can often be internally noise-limited, thus missing weaker signals. The HE309 antenna used for some of the measurements has a noise figure of 22 dB at 20 MHz. Thus, it could be limiting the measurement system sensitivity, since the noise tends to decrease at the higher frequencies.

Recorded HF Oceanographic Radar Signals in Washington D.C.

The following section provides some data collected at the Naval Research Laboratory in Washington, D.C., at a very electrically noisy site (office buildings). The data (Figures 1-3) shows that multiple HF oceanographic radars can simultaneously be observed via skywave propagation. Some of these radars were observed many hours at a time above the local noise floor that was very high due to the antenna location on the rooftop of a laboratory building. At an electromagnetically quieter site, the oceanographic radar signals would have been more pronounced. Thus, if a user tried to share the frequency band, the oceanographic radar would be continually sweeping through the victim receiver's passband at full power every half second for hours at a time.

To further elaborate, Figures 1-3 are spectral plots of a portion of the HF band. Figure 1 displays 0.4 MHz over a 2.5 second period for 11:45AM DST. Clearly evident are four Linear FM continuous wave (LFMCW) ‘chirp’ signals with a nominal 2 Hz pulse repetition rate and bandwidths of approximately 25 to 100 kHz. At this resolution, one cannot definitively determine if the signals are interrupted (i.e. less than 100% duty cycle). However, these parameters are typical of oceanographic radars and CODAR systems in particular. The signals were known to be via a skywave propagation path by their fading characteristics over both short (minutes) and long (hours) time scales.

While the spectrograms were only checked intermittently for two days, it was clear that some of the signals could be observed for a minimum of hours. Clearly, if a user were to attempt to share the frequency band with this radar, then the radar signal would sweep through the victim receiver’s passband every half second.

In addition, it is evident that for a LFMCW signal, the power is instantaneously narrowband. That is, the full power is concentrated at one frequency at a time. Thus it is inappropriate to give the radar the benefit of the ratio of the radar swept bandwidth to the victim receiver passband bandwidth. In addition, any automatic gain control and filters may be negatively impacted by the periodic effect of the radar energy sweeping in and out of the victim receiver’s passband every half second.

Figure 2 is similar to Figure 1 but taken about a minute earlier. One can see that the power levels of the oceanographic radars have changed as is typical for skywave propagation. In addition, the arrow marks a ROTHF skywave HF radar signal. This system constantly monitors the HF spectrum and only dwells on clear channels (as measured at the radar site with a high-dynamic-range, low-noise radar receiver). One can observe that the signal came up between users. In addition, the ROTHF signal only existed in this range of frequencies for approximately 2.5 seconds. Thus the ROTHF’s use of the HF band can be shared with other users.

Figure 3 is a spectrogram showing 1.5 MHz of bandwidth from 4.115 MHz to 5.585 MHz for 9 seconds at 6:30 PM DST. In this instance, six oceanographic (probably CODAR) radar signals can be seen, each using approximately 25 kHz of bandwidth. At this time of day, most skywave users are operating at higher frequencies and the other apparent signals are local noise sources from the building and other electrical infrastructure. However, as it moves into nighttime, other HF users will be moving down to these frequencies.

It is also of note that hardly any of the oceanographic radars are sharing frequency. Only the three signals at 13.45 MHz are overlapped in frequency. In this case, the fact that three different sweep rates are utilized offers the radars some orthogonality. It is unclear that if more than 100 kHz was allocated at some portion of the spectrum, that oceanographic radar users would not spread out to fill the allocation rather than implement techniques as described in other documents to share the spectrum between multiple radars.

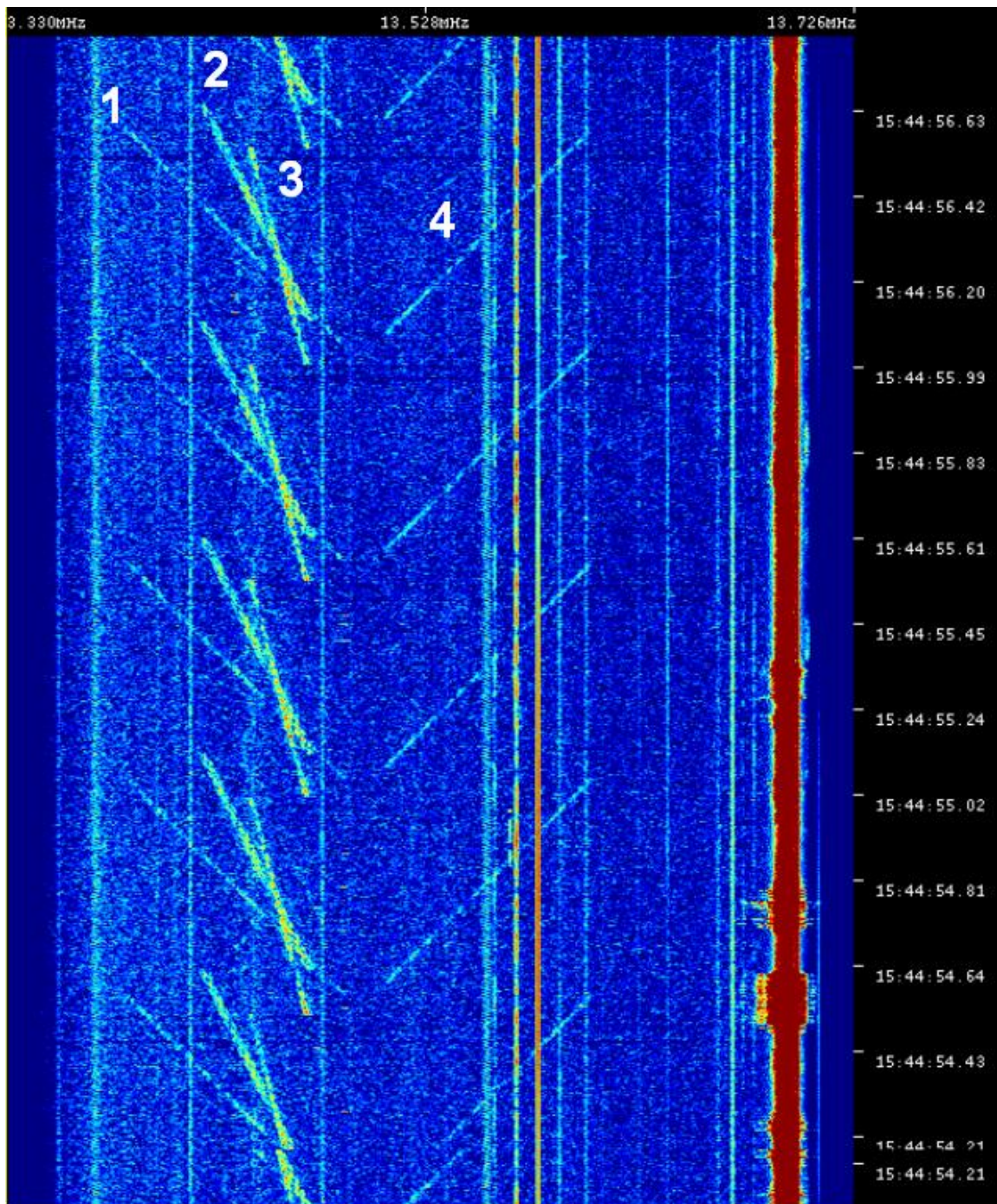


Figure 1 - Spectrogram of 0.4 MHz of bandwidth from 13.330 to 13.726 MHz (x-axis) over 2.5 seconds (y-axis). Marked by the numbers 1-4 are four oceanographic (probably CODAR) radar signals received via a skywave path. The waveform repetition rate is 2 Hz with bandwidths typical of CODAR systems. The time of day was 11:45 AM local DST. Clearly evident are other HF users at the same frequencies.

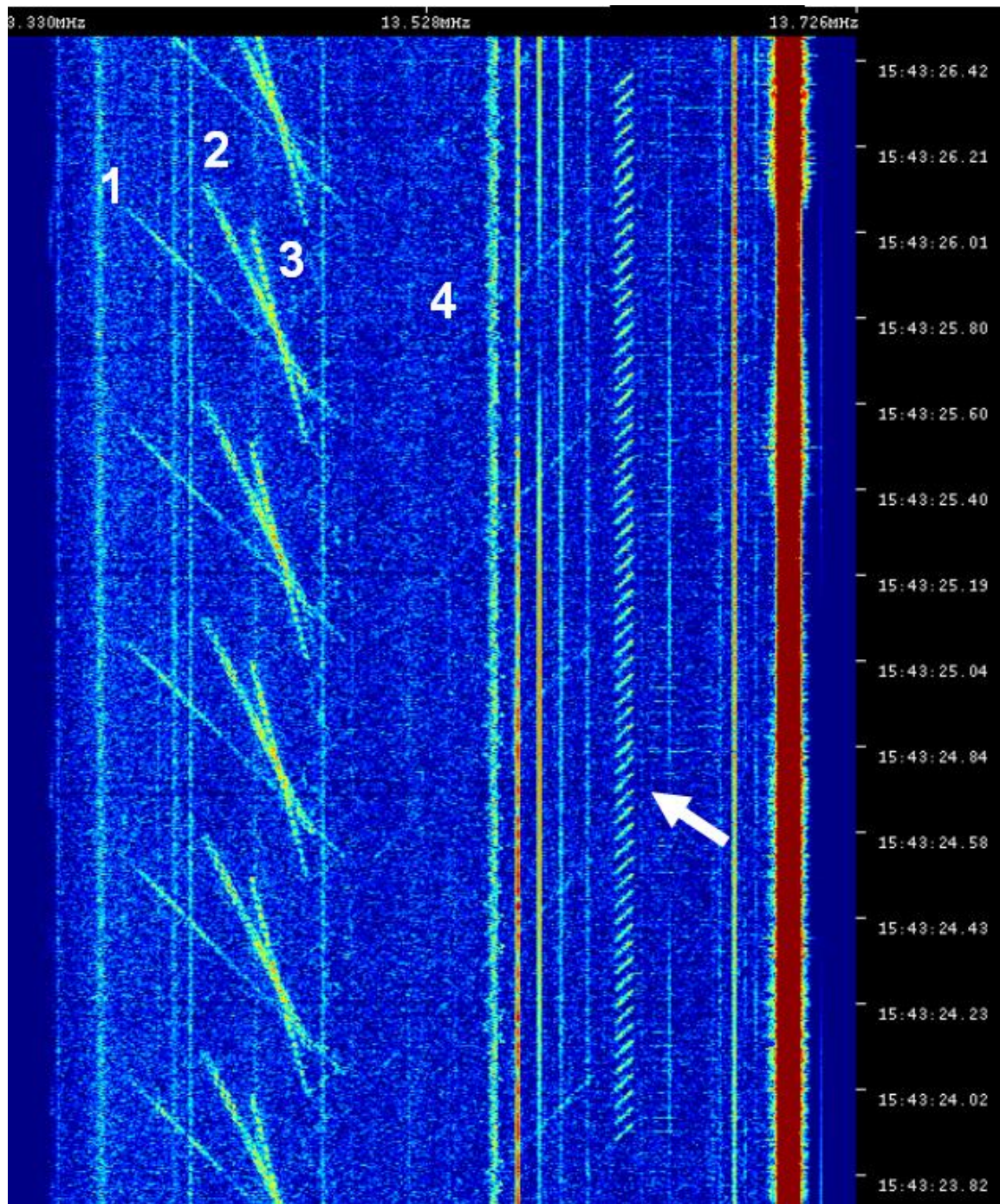


Figure 2 - Spectrogram of 0.4 MHz of bandwidth from 13.330 to 13.726 MHz (x-axis) over 2.5 seconds (y-axis). Marked by the numbers 1-4 are four oceanographic radar signals received via a skywave path. The waveform repetition rate is 2 Hz with bandwidths typical of CODAR systems. The time of day was 11:43 AM local DST. The arrow indicates a ROTHF skywave radar signal that came up between users. (ROTHF monitors the spectrum before radiating and was gone after the nominal 2 second integration time.)

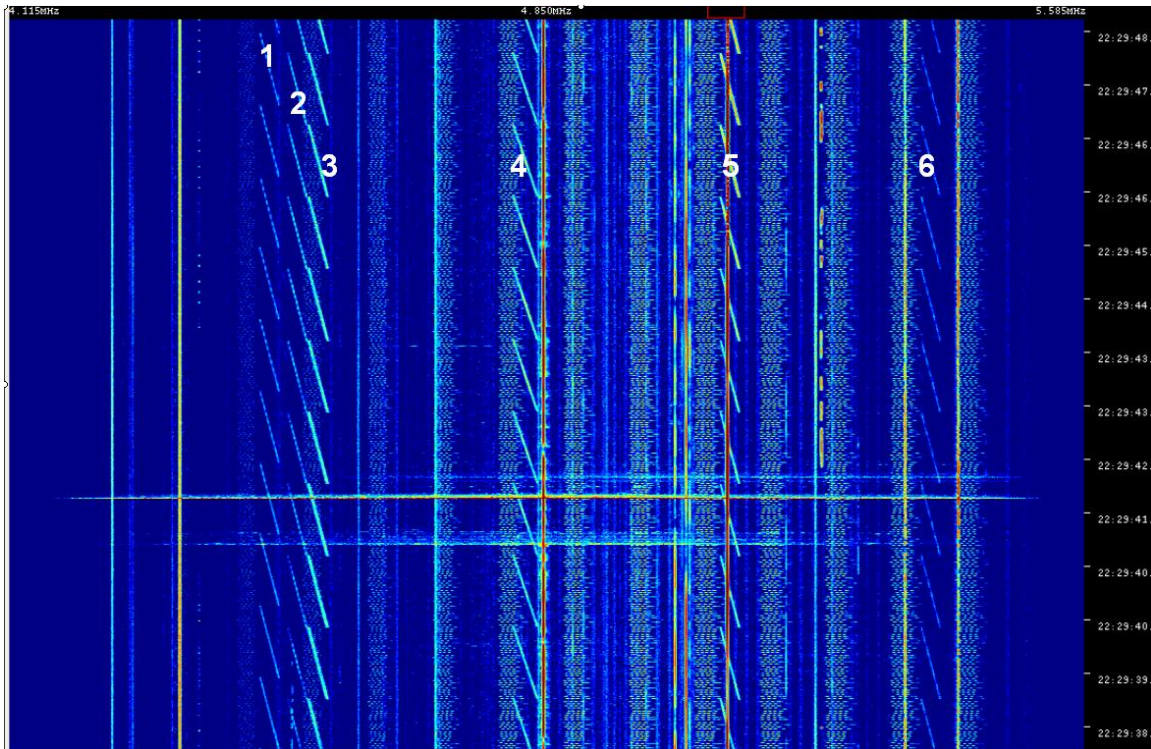


Figure 3 – Spectrogram of 1.5 MHz of bandwidth from 4.115 to 5.585 MHz (x-axis) over 9 seconds (y-axis). Marked by the numbers 1-6 are six oceanographic radar signals received via a skywave path. At this time of day (6:30 PM local DST), most skywave users are operating at higher frequencies. The other apparent ‘signals’ are local noise sources from the building and other electrical infrastructure.

Recorded HF Oceanographic Radar Signals Inland Alaska

A second set of spectral measurements was taken in July, 2010, at Gakona, Alaska, approximately 150 km from the coast. Twenty-five (25) HF oceanographic radars were observed via skywave propagation around 5, 8, and 13 MHz. These signals were observed continuously for hours. Some were observed apparently stepping on other users. Some were observed sharing frequencies, while others spread out utilizing additional HF spectrum. The total utilized bandwidth was approximately 825 kHz (150 kHz at 5 MHz, 225 kHz at 8 MHz, 450 kHz at 13 MHz).

The antenna utilized was optimized for the low end of the HF band. At the current low point of the sun spot cycle, the higher end of the HF band may not propagate via skywave. Thus, no conclusion can be drawn from this data with regard to HF oceanographic radars at the higher end of the HF band.

Figure 4 shows a spectrogram (spectral waterfall) plot for the frequency span of 4 to 6 MHz at 0620 UTC (10:20 PM DST local,) with 10 seconds of data displayed down the vertical axis. Clearly evident are ten Linear Frequency Modulated (LFM) waveforms typical of HF oceanographic radars. These signals are operating with a 1 Hz repetition

frequency. The total bandwidth occupied is approximately 150 kHz. It can be seen that signals 1-3 partially overlap in frequency and signals 6-8 overlap in frequency.

Figure 5 is a similar spectrogram for the frequency span of 7 to 9 MHz at 1450 UTC (6:50 AM DST local), with 10 seconds of data displayed down the vertical axis. Six HF oceanographic radars are evident. The waveforms have either a 1.5 or 3 Hz waveform repetition frequency. A total of approximately 225 kHz of bandwidth is utilized with minimal overlap in frequency.

Figure 6 is a spectrogram for the frequency span of 12 to 14 MHz at 0621 UTC (10:21 PM DST local) with 10 seconds of data displayed down the vertical axis. Nine HF oceanographic radars are evident. They are grouped in two bands around 12.1 and 13.5 MHz. A total of approximately 450 kHz of bandwidth is being utilized.

The HF oceanographic radar signals at 13.5 MHz are similar to those shown in Figure 2 that were recorded in Washington, D.C. However, the relative start frequencies of signals 1-3 in Figure 2 compared with 6-8 in Figure 6 are different and the sites (Alaska and Washington, D.C.) are well separated, so it is likely the sources are different radars.

Figure 7 is similar to Figure 6 but taken at 1452 UTC (6:52 AM DST local), which is 8.5 hours later. Clearly evident are the same nine HF oceanographic radar signals.

Evident from these snapshots is the persistent nature of HF oceanographic radars via skywave propagation. In addition, it appears many of the oceanographic radars appear to be stepping on other users. The level of interference cannot be assessed from these measurements as the recording location (Gakona, Alaska) is not the same as the receive sites for the communications signals.

Finally, in Figure 6, a skywave radar signal is evident. The signal is utilizing approximately 50 kHz (though 10 kHz is a more typical bandwidth). Western skywave radars will listen before radiating and hop around in frequency from coherent dwell to coherent dwell, thus operating on a not-to-interfere basis.

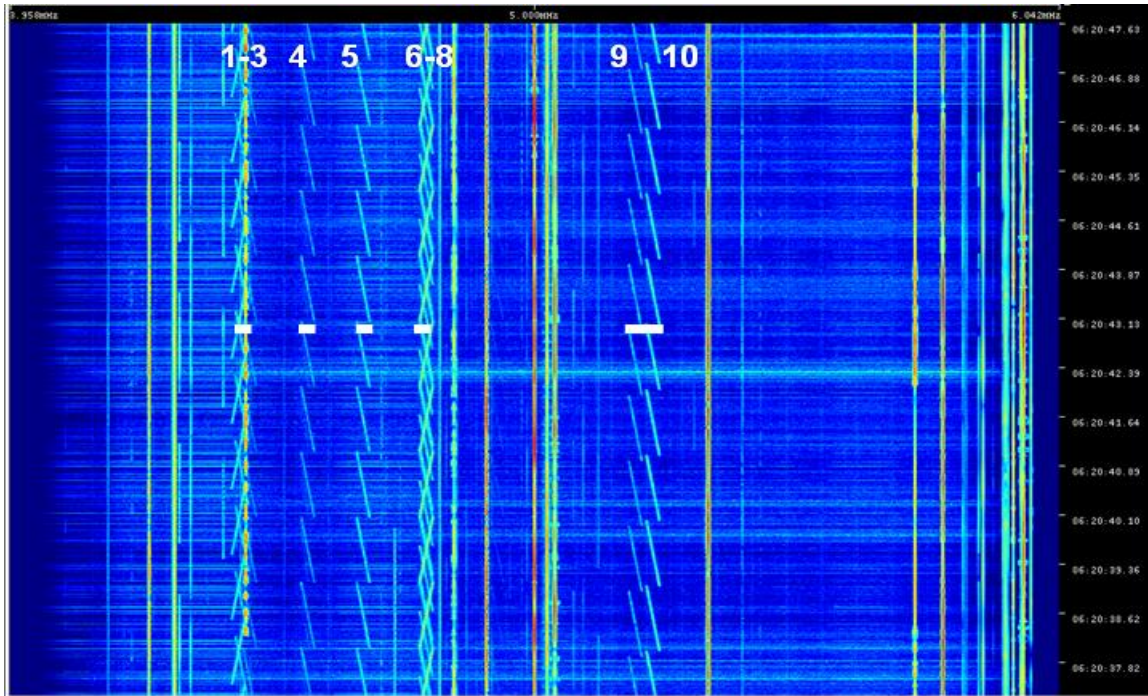


Figure 4 – Spectrogram of 2 MHz of bandwidth from 4-6 MHz (x-axis) over 10 seconds (y-axis) taken in Gakona, Alaska, at 0620 UTC (10:20 PM DST local). Marked are ten HF oceanographic radars with a 1 Hz waveform repetition rate. A total of approximately 150 kHz of bandwidth is being utilized for signals of approximately 25 kHz.

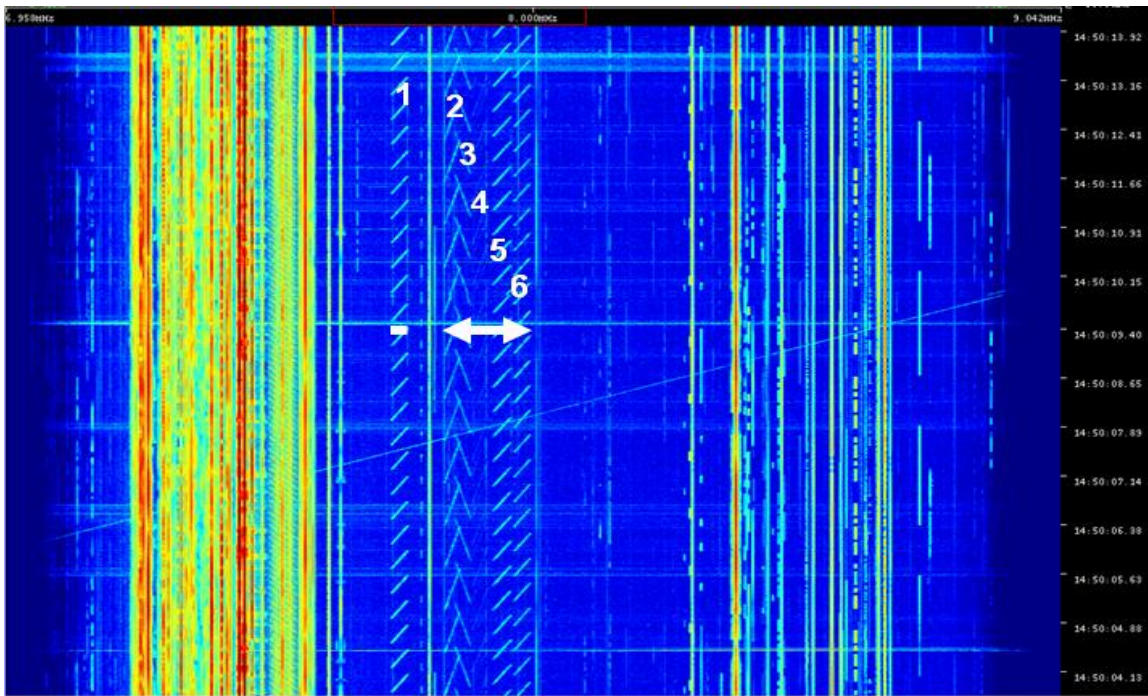


Figure 5 – Spectrogram of 2 MHz of bandwidth from 7-9 MHz (x-axis) over 10 seconds (y-axis) taken in Gakona, Alaska, at 1450 UTC (6:50 AM DST local). Marked are six HF oceanographic radars with either 1.5 or 3 Hz waveform repetition rates. A total of approximately 225 kHz of bandwidth is being utilized.

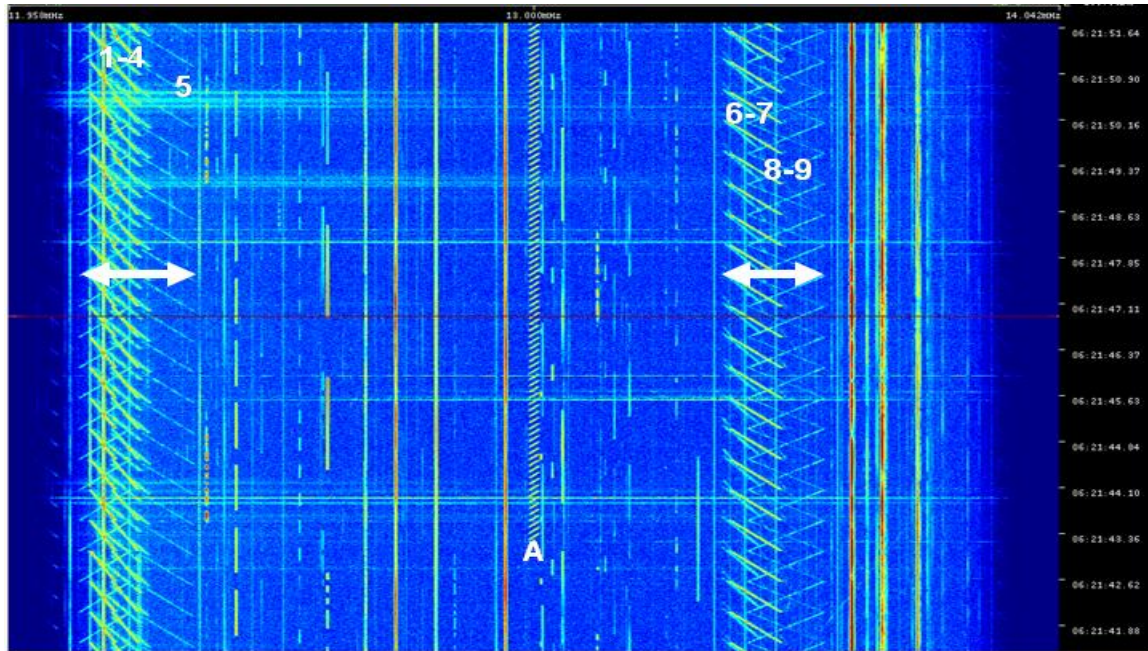


Figure 6 – Spectrogram of 2 MHz of bandwidth from 12-14 MHz (x-axis) over 10 seconds (y-axis) taken in Gakona, Alaska, at 0621 UTC (10:21 PM DST local). Marked are nine HF oceanographic radars with a 2 Hz waveform repetition rate. A total of approximately 450 kHz of bandwidth is being utilized. The signal ‘A’ is a skywave radar operating with approximately 50 KHz of bandwidth (typical bandwidths are generally on the order of 10 kHz). Western skywave radars will monitor the frequency before radiating and will ‘jump’ in frequency to operate on a not-to-interfere basis.

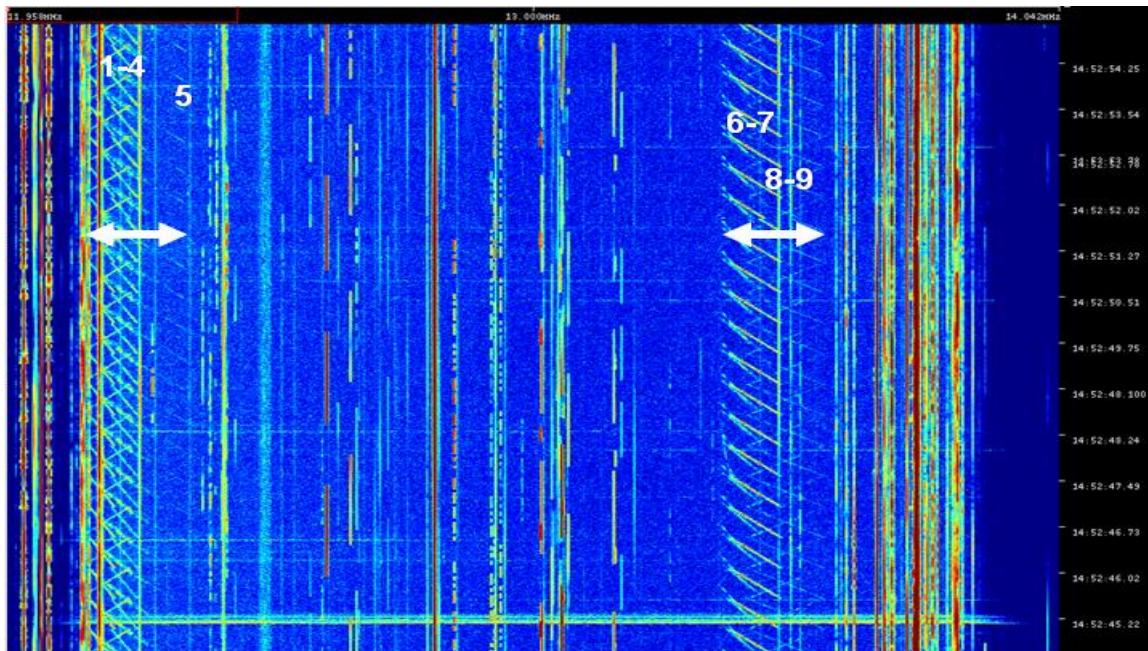


Figure 7 – Spectrogram of 2 MHz of bandwidth from 12-14 MHz (x-axis) over 10 seconds (y-axis) taken in Gakona, Alaska, at 1452 UTC (6:52 AM DST local). Marked are nine HF oceanographic radars with a 2 Hz waveform repetition rate. A total of approximately 450 kHz of bandwidth is being utilized.

Experimental Data Point (High Angle Short Range Skywave Propagation)

A third data point with respect to high-angle, short-range (several hundred km) propagation paths indicates the potential for interference by HF oceanographic radars. Tests were performed that propagated a 300 Watt Linear FM signal at high elevation angles in the 5 MHz band. At a distance of approximately 230 km, the signal could be observed via a single, double, triple and occasionally quadruple-hop path up to the ionosphere and back down. No ground wave was observed at this range. Thus potential interference can occur for a ring of ranges encompassed by the high-elevation propagation paths.

Figure 8 shows a range (y-axis) Doppler (x-axis) plot of the range-compressed LFM signal. This signal is similar to that typically utilized by HF oceanographic radars. The data was recorded at a ground range of 230 km from the transmitter. Each of the points indicated by E_s , F_2 , $2F_2$, $3F_2$ correspond to the signal propagating up to the ionosphere at a high elevation angle and coming back down to the receiver. The E_s is a signal that refracted in the Sporadic E layer at approximately 100 km height. The F_2 is a signal that refracted in the F_2 layer at approximately 250 km height. The $2F_2$ is a double hop and $3F_2$ is a triple hop up to the F_2 layer and back down to the ground.

Figure 9 is simply a diagram delineating the propagation paths for the data recorded in Figure 8. Marked are the sporadic E and F_2 layers as dashed lines. The multiple propagation paths E_s , F_2 , $2F_2$, $3F_2$ are indicated. Of significance is the fact that this same diagram will hold for a range of ground ranges. That is, the diagram can be compressed and stretched along the ground range (within some limit), and the ionosphere will still support propagation. Thus, there is a ring of ranges around an HF oceanographic radar that will be illuminated via high-angle propagation paths.

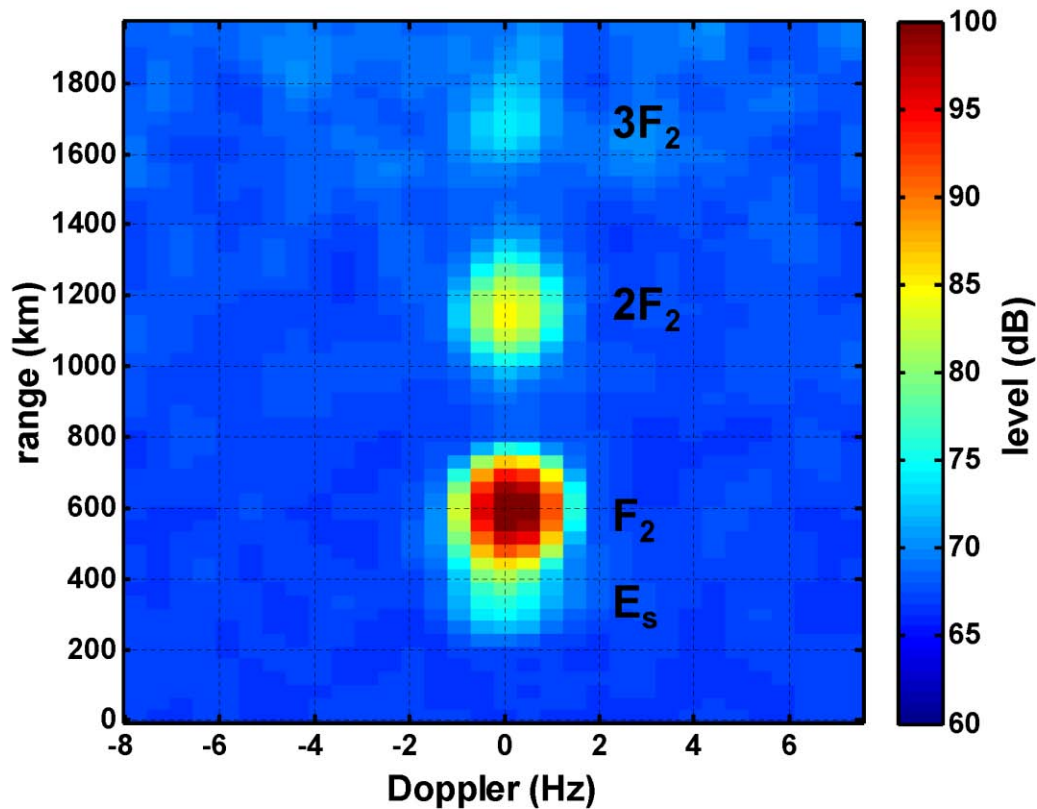


Figure 8 – Range-Doppler plot showing the range-compressed Linear FM signal received at a ground range of 230 km via multiple high-angle propagation paths.

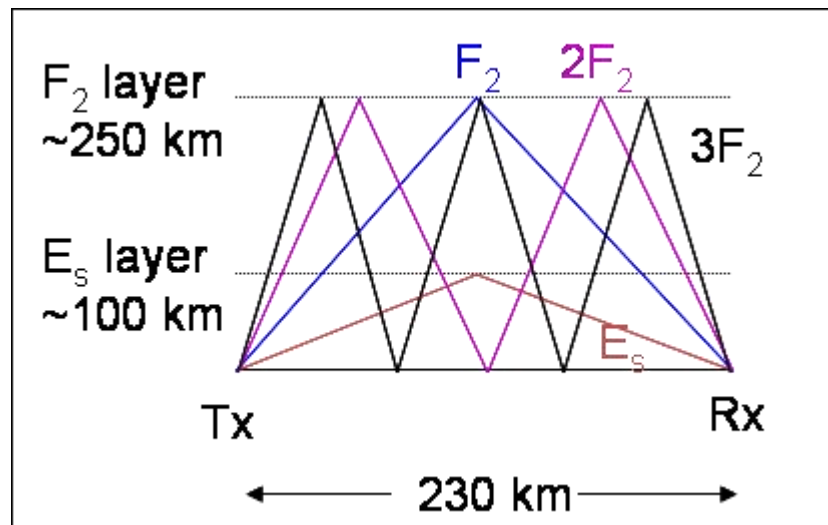


Figure 9 – Simple diagram indicating the multiple high-angle propagation paths observed for transmit/receive locations separated by 230 km ground range. The ionosphere will support propagation for a range of ground ranges, resulting in a ring of ranges around an HF oceanographic radar that will be illuminated via high-angle propagation paths

While this data indicates potential interference at 5 MHz via high-angle skywave propagation, it is not complete. This data was taken during the daytime when most users move to higher frequencies and the noise levels drop. At night, as users move down to 5 MHz, the noise levels will rise and could potentially be stronger than the radar signal. At higher frequencies, particularly at night, the radar energy can penetrate the ionosphere and will not come back down to the ground.

Interference can also occur for lower-elevation propagation paths. However, some different considerations must be made. The lower elevation paths (particularly landward) will have transmit antenna attenuation due to the typical cutback in the elevation pattern as indicated in the studies. In addition, the low elevation angles will have longer propagation paths and thus some additional $1/r^2$ spreading loss. But lower elevation angle paths will be in the ionosphere for a longer time/distance and are more likely to refract back down to the earth (than the higher elevation angle paths).

Related Documents

In addition to the sharing studies, several other documents relating to this allocation were produced. Several of these documents also have items of note.

For example, the Document 5B/TEMP/243-E 19 May 2010 Preliminary Draft New Report –“Oceanographic radar interference mitigation techniques and spectrum efficiency improvements –Technical and operational considerations” claims few interference issues over 40 years. This is an anecdotal claim, and an alternative explanation is the 24/7 nature of the HF oceanographic radar operations leads other HF users to operate around the radars. A complaint would likely cause the radar to move slightly in frequency, but again start dwelling 24/7. Also, it has been observed that when HF radars operate in certain bands, primary users will key transmitters until the radar moves. This has been written about when the Soviet Union Woodpecker radar operated in Ham bands. However, the surface wave oceanographic radars do not monitor the spectrum and will simply continue to operate. It is likely that an allocation will lead to many more radars in operation, thus making it more difficult for other HF users to operate around the HF oceanographic radars.

The primary method the paper proposes to help mitigate the amount of spectrum utilized by HF oceanographic radars is time/spectrum sharing using GPS timing with other HF oceanographic radars. This is a patented (but allowing licensing) method of time/spectrum sharing. However, there are several HF oceanographic radar manufacturers, so it is unclear how such a system would be implemented.

Finally, the paper states that the high-angle skywave path will be attenuated. However, the data in this document shows that skywave (likely high-angle) paths are producing multiple received oceanographic radar signals in Washington, D.C. and Gakona, Alaska and controlled experiments indicated propagation via high-angle skywave paths for 5 MHz.

Conclusion

The interference by a 24/7 HF oceanographic radar, particularly via skywave propagation, has been underestimated because inappropriate assumptions (more relevant to communications systems) were made regarding the effect of the oceanographic radars. First, assuming the radar is ‘not interfering’ when swept through the victim receiver’s passband, even though it will sweep back through in less than half a second. Second, decreasing the interference power by the ratio of the radar swept bandwidth to the victim receiver bandwidth, even though the radar is instantaneously narrowband.

In addition, some of the studies did not consider the shorter-range, single-hop skywave propagation mode and the fact that HF oceanographic radars will be located on the coast where most of the world’s population resides.

The fact that ten oceanographic radars can be seen simultaneously via skywave propagation around 5 and 13.5 MHz in a very noisy urban environment (Washington, D.C.) for hours at a time means they have power above the external noise and could be interfering with other users of the HF band for hours at a time. These radars were occupying about 125 kHz around 5 MHz and 200 kHz around 13.5 MHz.

In addition, twenty-five HF oceanographic radars could be observed for hours via skywave propagation around 5, 8, and 13 MHz in July 2010 at Gakona, Alaska, located 150 km from the coast. These radars utilized approximately 825 kHz of bandwidth.

While other documents indicate methods for these radars to share frequencies, it is unclear if these would be implemented or if the radar would spread across the allocated frequencies to avoid interference between radars.

Finally, experiments at 5 MHz via high-angle propagation paths for short ranges (several hundred km) indicated that radar signals could be observed on multiple hops (propagation up to the ionosphere and back down). This indicated that a ring of ranges around an HF oceanographic radar could potentially experience interference, even in the landward direction where the ground wave signal is attenuated.

The overall conclusions that interference will be similar to that of other low-power HF users, for only a small percentage of time, and that spectrum can be shared during the periods the radar sweeps through a victim receiver’s passband appear incorrect.

It is important that the sharing studies and related documentation accurately and adequately capture the likely impact of HF oceanographic radars on other HF users in order to make an informed decision concerning a possible allocation.