HFDL - some Ideas [Work in Progress]

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The new SDRs with multi-channel demodulators do offer new perspectives for DXing and monitoring. Here are some ideas, concerning the HFDL HF communications system of Rockwell (ARINC).

The HFDL communications system comprises 15 Ground Stations (GS), strategically scattered over the globe, see *Figure 1*. It uses >150 HF channels with GPS-clocked TDMA-slots, preceded by a carrier (prekey) which delivers a sharp trigger point, see *Figures 2* and *3*. The mode is highly efficient, and the transmissions do also carry their own time stamp (UTC) plus a table of all active frequencies/stations of the net. Highly efficient software decoders are available for free or at low costs (>50 $), as is some software to organize the up to 6.000+ monitored transmissions during 24 hours over just one GS on just one frequency. See here for a general description from a DXer's view, here and here you will find a more detailed system's manual.

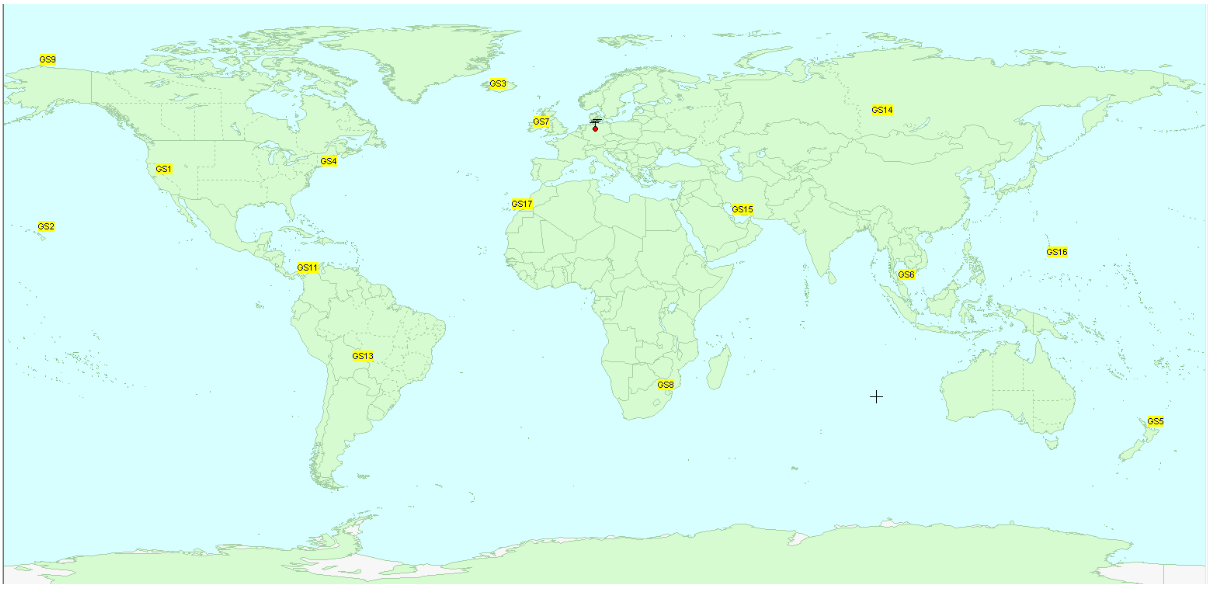


Figure 1: Map of all HF Ground Stations (GS), DX Atlas.

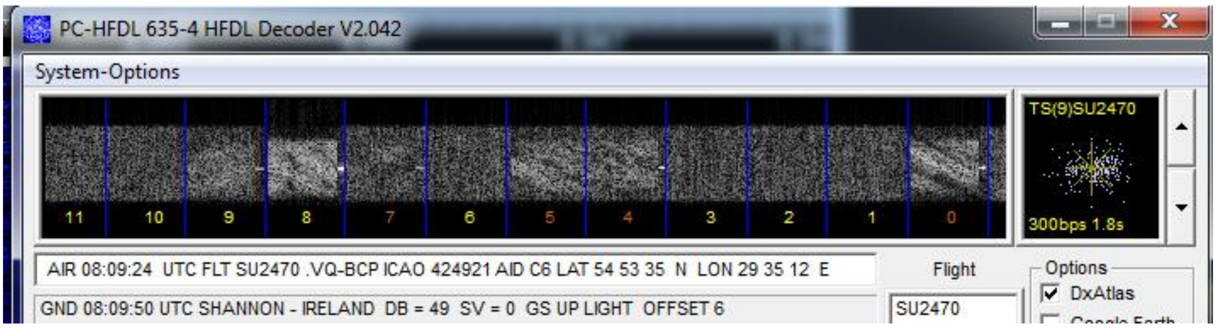


Figure 2: One "cycle" of 32 seconds duration consists of 13 TDMA time slots, starting with a "squitter" from the GS in slot "0". Software PC-HFDL automatically synchronizes to this squitter.

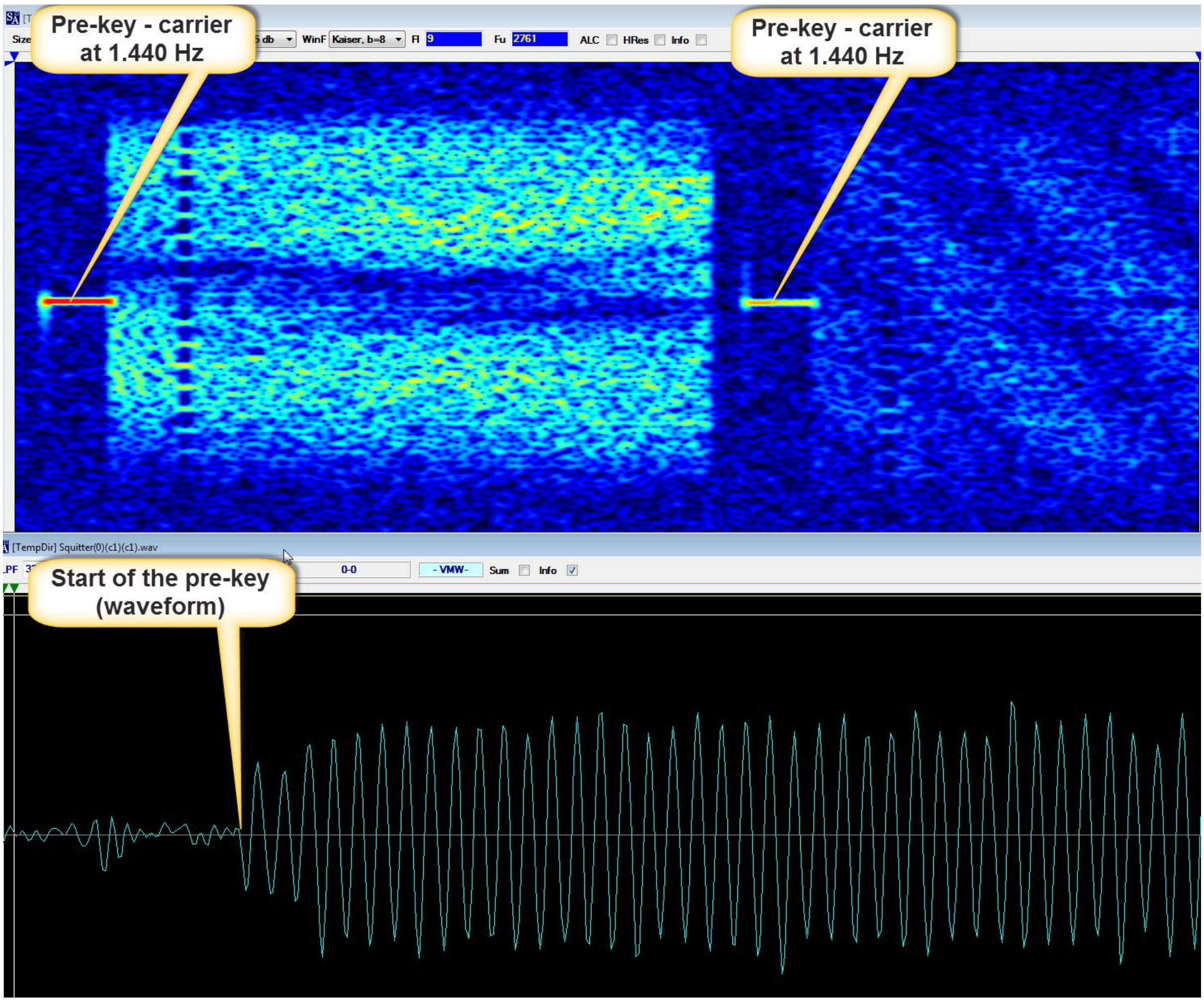


Figure 3: The prey-key of 249 ms length provides a signal of high energy even with weaker signals (the second one, top sonagram). For HF, it gives an unusually clear and GPS-precisely timed trigger point which potential for propagations studies still remains to be unlocked (largely zoomed waveform of the first signal, bottom oscillogram). Software: Signals Analyzer.

Multi-channel Monitoring

The view of this paper onto HFDL is from the perspective of a DXer: I want to understand this system a bit better to use it for e.g. propagation purposes and to optimize monitoring.

First, I did an observation over 24 hours on three channels of my nearest Ground Station Shannon on three of their four channels used on February 2nd/3rd, 2015: 6.532 kHz, 8.942 kHz and 10.081 kHz. Their lowest channel of 2.998 kHz hasn't been monitored for this time.

I used ELAD's FDM-S2 receiver at a bandwidth of 6 MHz. Hence, I could assign three out of four of its demodulated outputs to one instance of Charles' PC-HFDL each.

Mike's PC-HFDL-Display has been used to represent the content of all three frequencies via its Log 1, Log and Log 3.

This setup (see *Figures 4* & *5*) worked flawlessly for even many days in a row, collecting up to 15.000 entries in 24 hours from just these three channels, see *Figure 6*.

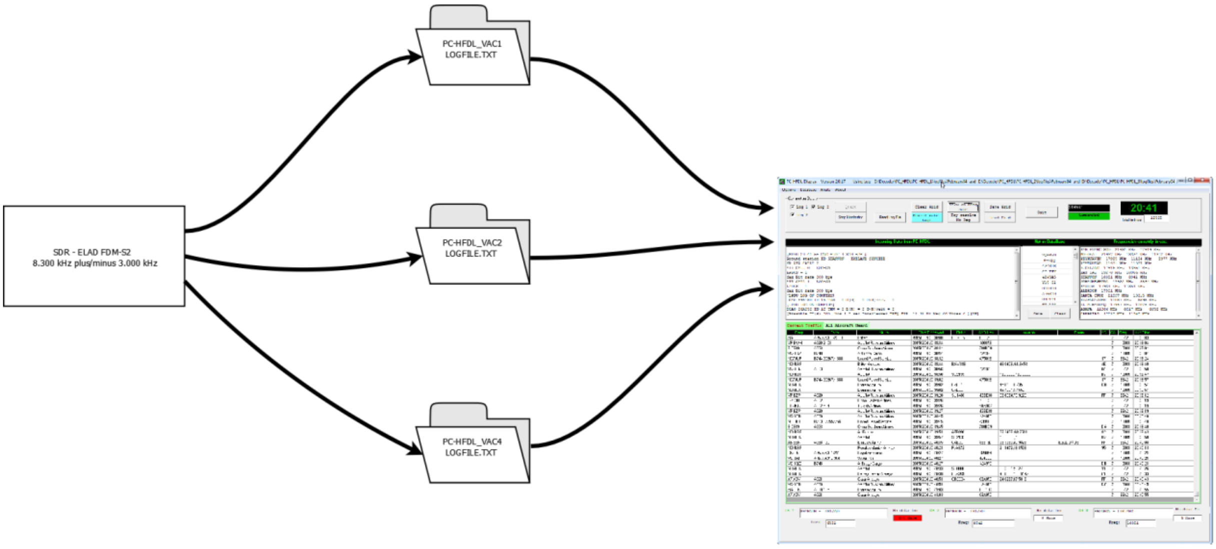


Figure 4: The SDR receives three different Shannon channels and transfers the demodulated audio via virtual audio cables 1 - 3 to separate instances of PC-HFDL which is hosted in three different folders each. Mike's PC-HFDL-Display software then is fed by each of these instances. This setup can be scaled up with more instances of PC-HFDL and PC-HFDL-Display. You just have to maintain a strict structure of instances, folder, sources (VACs) and sinks. Graphic with [DIA](DIA).

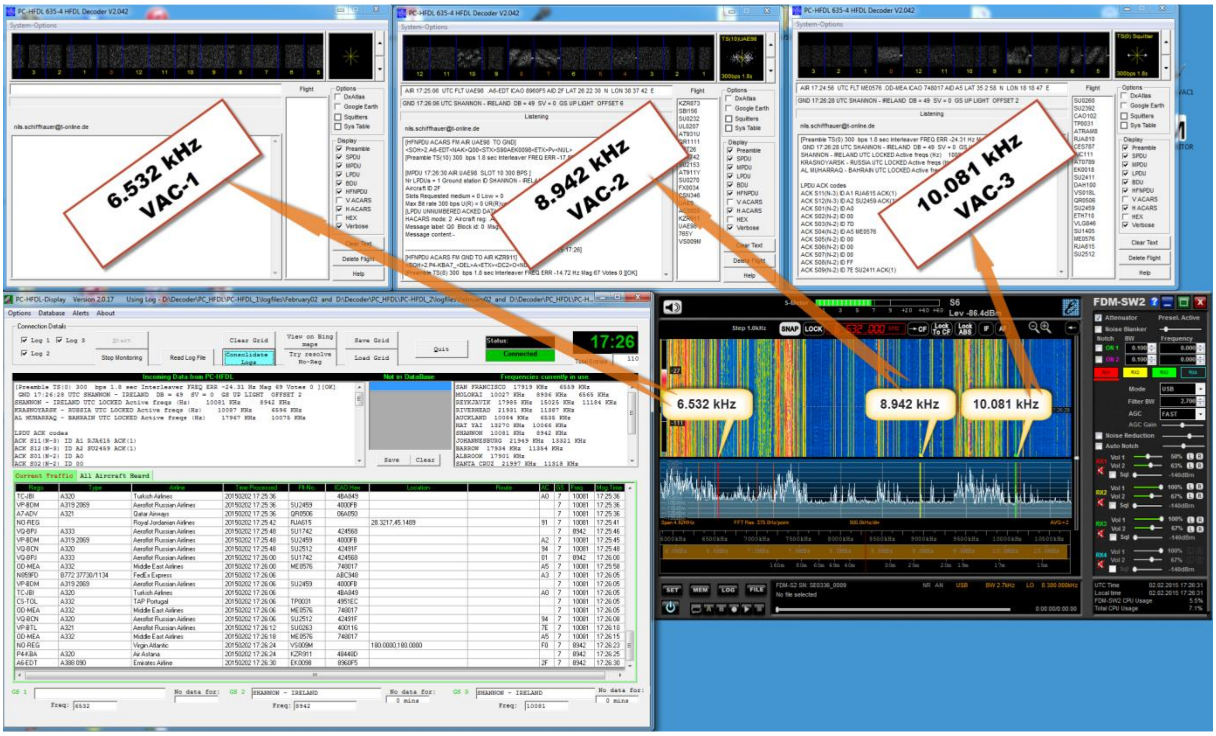


Figure 5: A look onto the screen with the setup as above: In the upper row, you have the three different GUIs of PC-HFDL. At the bottom left you see the PC-HF-Display collecting all the information. On the right you see the GUI of receiver FDM-S2 with a bandwidth of 6 MHz, where I placed the three Shannon channels.

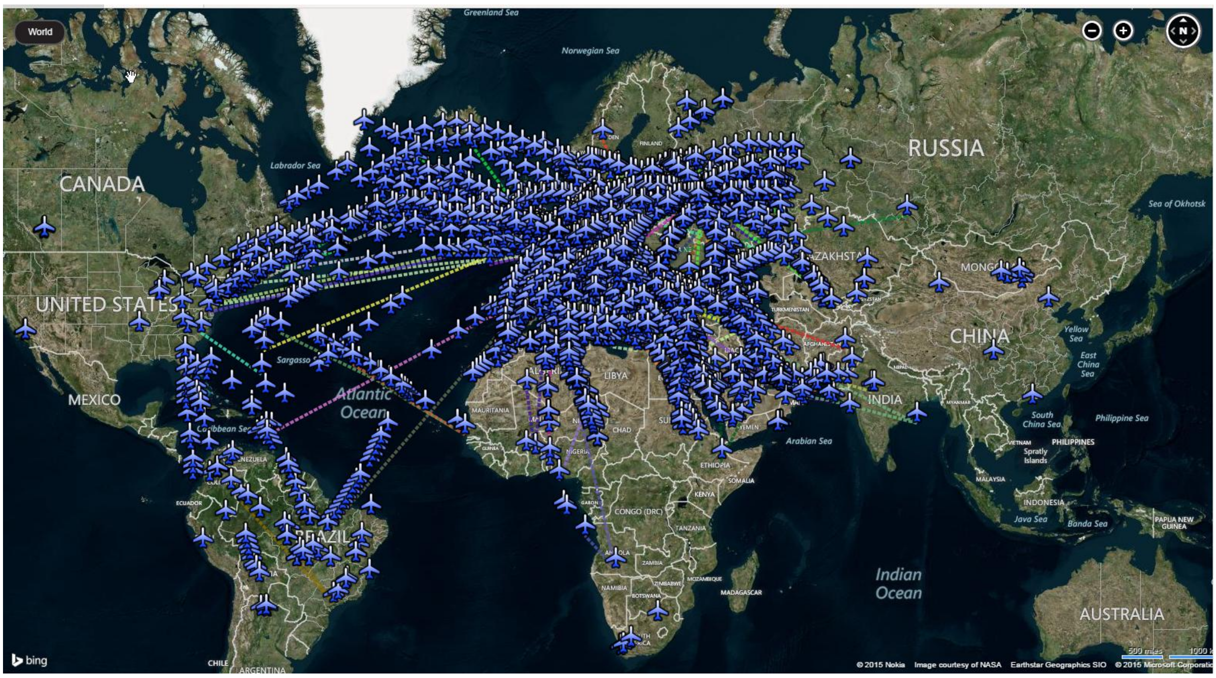


Figure 6: 21 hours of this setup resulted in 13.000+ "Total entries"out of three channels of GS Shannon at Mike's PC-HFDL-Display. It produced this bing-map which has to be further zoomed to follow the routes of each airplane.

To get a first overlook over the complete net, I imported the file "FreqInUse.csv" (Display Launcher → Reports) into a spreadsheet (Excel). The file "FreqInUse.csv" contains all received frequency information of all 15 Ground Stations in steps of one hour. I took these information for granted, knowing that there is a discussion about several aspects of these data.

In the next step, I looked a bit deeper into Frequency Table of the system, and how the used frequencies are distributed within the system so that the aircraft can access them.

The used frequencies are transmitted just as numbers. They have to be matched with the "Frequency Table" in used, early February it was #49. The used Frequency Table is automatically renewed after some time of monitoring a strong Ground Station. BTW, some elder software may refer to outdated look-up tables for stations (converting e.g. San Francisco to Annapolis) as well as outdated Frequency Tables.

Have a look at the most recent information at Yahoo's HFDL group. You will find the most recent Frequency Table in their files' section, file "pchfdl.dat" (for decoder PC-HFDL).

Stations “clustered”

First result: 15 Ground Stations used 71 channels for 769 hours. Only four of these channels were used by two stations - at different times, of course. The remaining vast majority of 67 channels were exclusively used by just one Ground Station, see *Figure 7*.

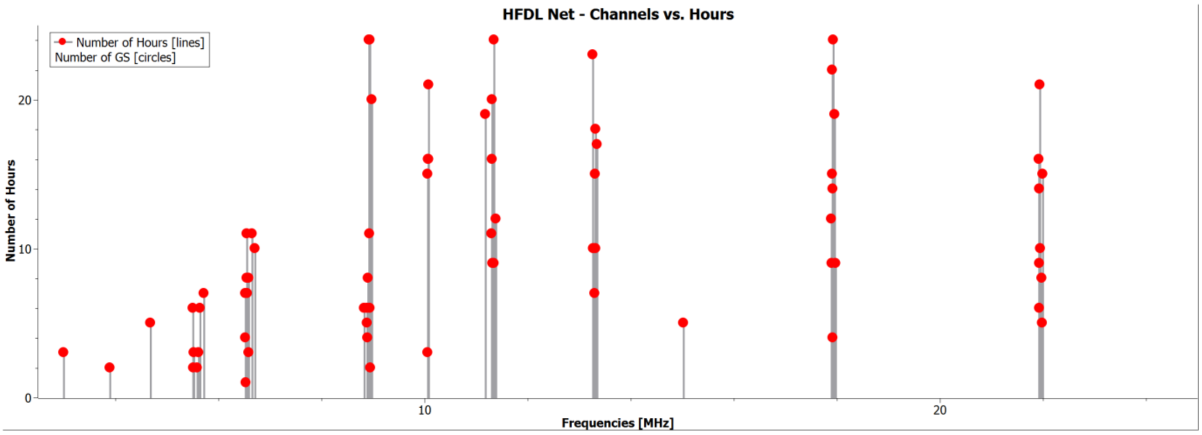


Figure 7: Diagram of the number of stations and frequencies versus the duration of use in hours. Software: SciDAvis.

Figure 7 (above) shows a representation of these results. It shows the hours of usage as vertical lines, and each Ground Station has been marked by a red circle. You will easily see a few rarely used channels e.g. below 5 MHz and at 15 MHz plus many clusters of activity.

Because within a given band, the HFDL channels are assigned to in near neighborhood, *Figure 8* (below) is a zoomed version of *Figure 7* to give better resolution in the 6-MHz-range.

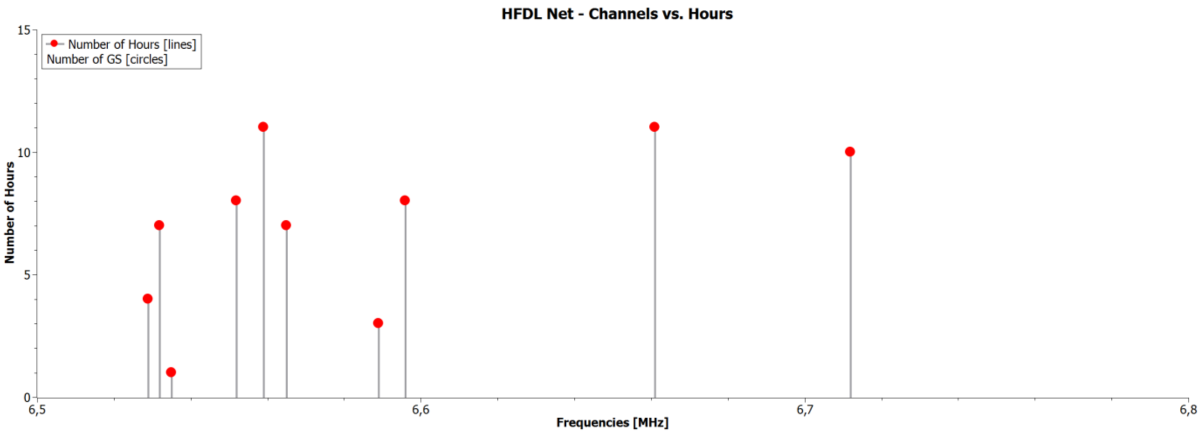


Figure 8: One cluster around 6,6 MHz zoomed.

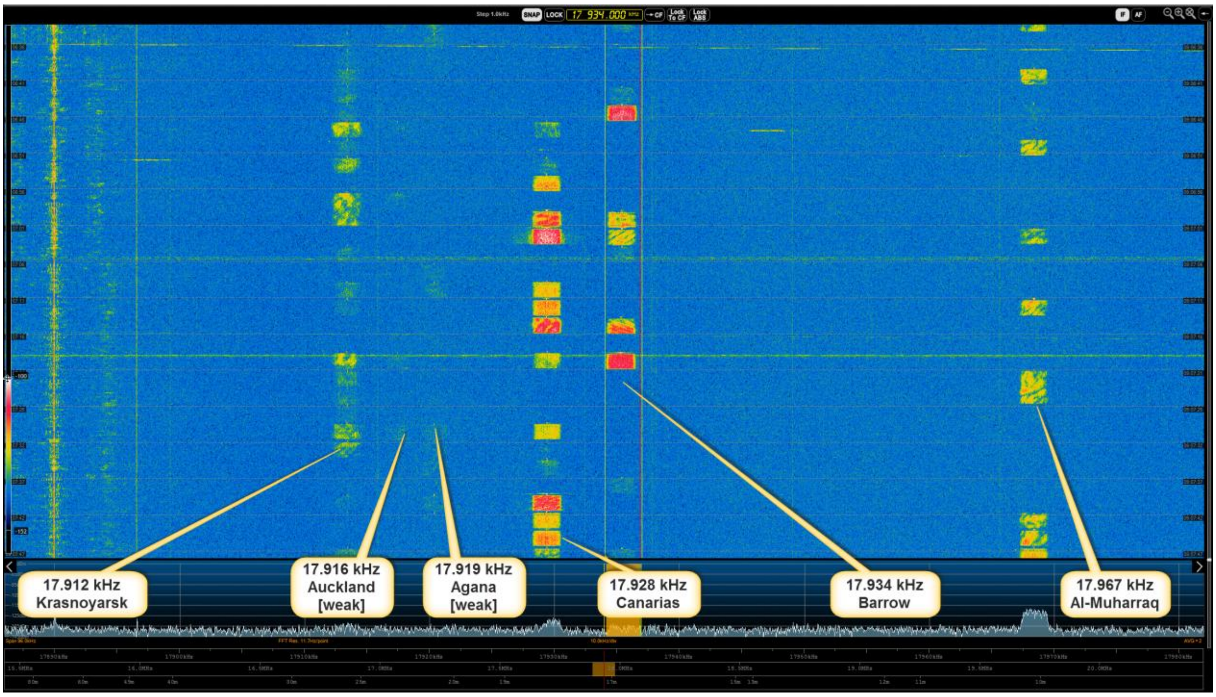


Figure 9: Cluster around 17,9 MHz on February, 7th, 2015 at 09:UTC as received at DK8OK's location. It shows six stations from Agana/Guam to Barrow/Alaska, received at the same time. Thanks to the robust mode and the excellent decoder, even many of the weak squitters from Auckland and Agana can be decoded.

Frequency Change of a Ground Station

It had been asked, what forces a Ground Station to change frequency? Is it following a strict schedule like broadcasters, or does it more follow analyzing the quality of decoded transmissions from airplanes?

The other question was: How fast does Ground Station B updates its frequency table, after Ground Station A has changed its channel?

To get a clue, I monitored two stations in parallel:

- GS Canarias, starting at 22:11:53 UTC on 11.348 kHz after a change from 13.303 kHz
- GS Riverhead, continuously transmitting on 11.387 kHz

GS Canarias starts with an 1-kHz-tone of 5 s length. After 19 s, the transmitter enters service with the first squitter at the normal timing, starting with:

GND 22:11:53 UTC CANARIAS - SPAIN *DB = 49 SV = 0 GS UP LIGHT OFFSET 4*

CANARIAS - SPAIN UTC LOCKED Active freqs (Hz) 17928 KHz 11348 KHz

REYKJAVIK - ICELAND UTC LOCKED Active freqs (Hz) 11184 KHz 8977 KHz 6712 KHz

RIVERHEAD - NEW YORK UTC LOCKED Active freqs (Hz) 21931 KHz 11387 KHz

The following four squitters inform about being locked to other stations, see below with time and GS:

GND 22:12:25 UTC CANARIAS - SPAIN *DB = 49 SV = 0 GS UP LIGHT OFFSET 4*

CANARIAS - SPAIN UTC LOCKED Active freqs (Hz) 17928 KHz 11348 KHz

AUCKLAND - NEW ZEALAND UTC LOCKED Active freqs (Hz) 17916 KHz 10084 KHz

HAT YAI - THAILAND UTC LOCKED Active freqs (Hz) 13270 KHz 10066 KHz

GND 22:12:57 UTC CANARIAS - SPAIN *DB = 49 SV = 0 GS UP LIGHT OFFSET 4*

CANARIAS - SPAIN UTC LOCKED Active freqs (Hz) 17928 KHz 11348 KHz

SHANNON - IRELAND UTC LOCKED Active freqs (Hz) 10081 KHz 8942 KHz

JOHANNESBURG - SOUTH AFRICA UTC LOCKED Active freqs (Hz) 13321 KHz 5529 KHz

GND 22:13:29 UTC CANARIAS - SPAIN *DB = 49 SV = 0 GS UP LIGHT OFFSET 4*

CANARIAS - SPAIN UTC LOCKED Active freqs (Hz) 17928 KHz 11348 KHz

BARROW - ALASKA UTC LOCKED Active freqs (Hz) 17934 KHz 11354 KHz

ALBROOK - PANAMA CITY UTC LOCKED Active freqs (Hz) 17901 KHz

GND 22:14:01 UTC CANARIAS *- SPAIN DB = 49 SV = 0 GS UP LIGHT OFFSET 4*

CANARIAS - SPAIN UTC LOCKED Active freqs (Hz) 17928 KHz 11348 KHz

SANTA CRUZ - BOLIVIA UTC LOCKED Active freqs (Hz) 21997 KHz 13315 KHz

KRASNOYARSK - RUSSIA UTC LOCKED Active freqs (Hz) 10087 KHz 6596 KHz

Then the first aircrafts jump in, and at 22:15:17 UTC, the first aircraft successfully logged in. From the start on this frequency it took just two minutes, eight seconds; one before had failed.

How fast now is the new frequency spread to Ground Station Riverhead and transmitted by them? Before 22:11:53 UTC, GS Canarias worked on 13.303 kHz instead of 11.348 kHz, and has been accordingly noted by GS Riverhead.

With its squitter at 22:13:22 UTC, Riverhead announces Canaria's frequency change to 11.348 kHz. And this is the nearest available quitter, where GS Canarias again is mentioned: A squitter each time announces the frequencies of two other stations. The last mentioning of GS Canaria by Riverhead had been at 22:09:38 UTC with the old, but then correct frequency of 13.303 kHz.

Figures 10 and *11* do illustrate this.

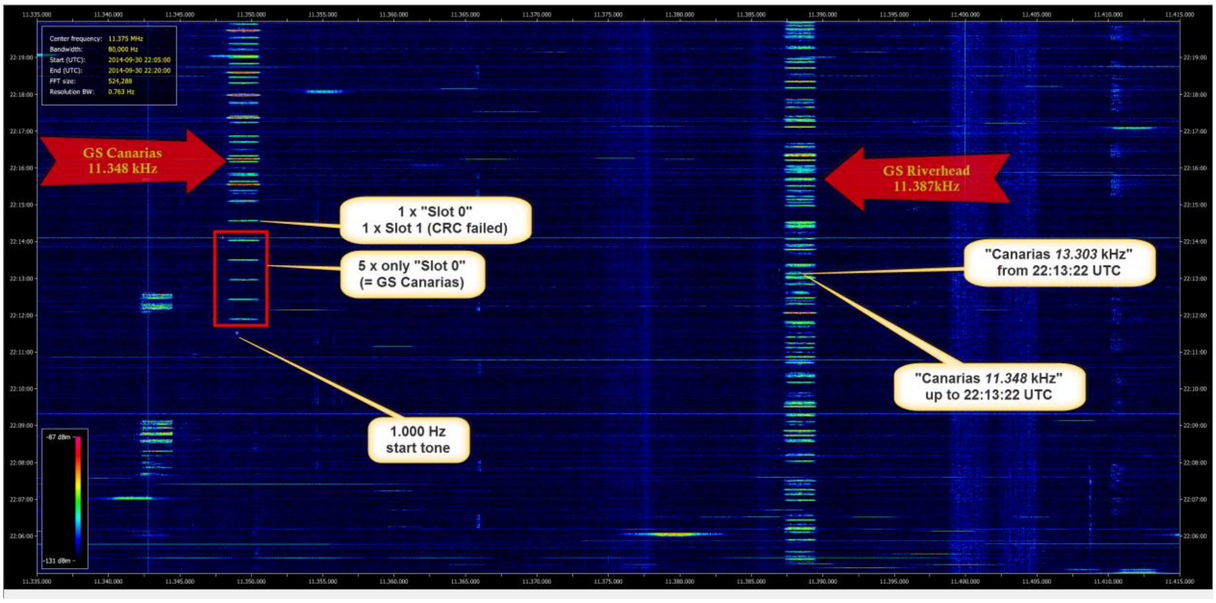


Figure 10: This sonagram (running from down to up) shows the start of GS Canarias/11.348 kHz at 22:11:53 UTC with 1-kHz tone and some lonely squitters. GS Riverhead on 11.387 kHz is working continuously at this time. They change their "Canarias" entry from 13.303 kHz to 11.348 kHz from their squitter at 22:13:22 UTC. Software for the sonagram: [*SDR-Radio.com*](SDR-Radio.com)*.*

22:11:53 UTC	+32 s	+32 s	+32 s	+32 s	+32 s	22:15:05 UTC	+32 s	+32 s	+32 s	+32 s	+32 s	+32 s	22:18:17 UTC
Canarias 17.928 **11.348 kHz**	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 **11.348 kHz**	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz	Canarias 17.928 kHz 11.348 kHz
Reykjavik 11.184 kHz 8.977 kHz 6.712 kHz	Auckland 17.916 kHz 10.0084 kHz	Shannon 10.081 kHz 8.942 kHz	Barrow 17.394 kHz 11.354 kHz	Santa Cruz 21.997 kHz 13.315 kHz	Al-Muharraq 17.967 kHz 8.885 kHz	San Francisco 21.934 kHz 13.276 kHz	Reykjavik 11.184 kHz 8.977 kHz 6.712 kHz	Auckland 17.916 kHz 10.0084 kHz	Shannon 10.081 kHz 8.942 kHz	Barrow 17.394 kHz 11.354 kHz	Santa Cruz 21.997 kHz 13.315 kHz	Al-Muharraq 17.967 kHz 8.885 kHz	San Francisco 21.934 kHz 13.276 kHz
Riverhead 21.931 kHz 11.387 kHz	Hat Yai 13.270 kHz 10.066 kHz	Johannesburg 13.321 kHz 5.529 kHz	Albrook 17.901 kHz	Krasnoyarsk 10.087 kHz 6.596 kHz	Agana 21.928 kHz 11.306 kHz	Molokai 21.937 kHz 13.324 kHz 13.312 kHz	Riverhead 21.931 kHz 11.387 kHz	Hat Yai 13.270 kHz 10.066 kHz	Johannesburg 13.321 kHz 5.529 kHz	Albrook 17.901 kHz	Krasnoyarsk 10.087 kHz 6.596 kHz	Agana 21.928 kHz 11.306 kHz	Molokai 21.937 kHz 13.324 kHz 13.312 kHz

22:09:38 UTC	+32 s	+32 s	+32 s	+32 s	+32 s	22:12:50 UTC	+32 s	+32 s	+32 s	+32 s	+32 s	+32 s	22:16:02 UTC
Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz	Riverhead 21.931 kHz 11.387 kHz
Agana 21.928 kHz 11.306 kHz	San Francisco 21.934 kHz 13.276 kHz	Reykjavik 11.184 kHz 8.977 kHz 6.712 kHz	Hat Yai 13.270 kHz 10.066 kHz	Johannesburg 13.321 kHz 5.529 kHz	Albrook 17.901 kHz	Krasnoyarsk 10.087 kHz 6.596 kHz	Agana 21.928 kHz 11.306 kHz	San Francisco 21.934 kHz 13.276 kHz	Reykjavik 11.184 kHz 8.977 kHz 6.712 kHz	Hat Yai 13.270 kHz 10.066 kHz	Johannesburg 13.321 kHz 5.529 kHz	Albrook 17.901 kHz	Krasnoyarsk 10.087 kHz 6.596 kHz
Canarias 21.931 kHz **13.303 kHz**	Molokai 21.937 kHz 13.324 kHz 13.312 kHz	Auckland 17.916 kHz 10.0084 kHz	Shannon 10.081 kHz 8.942 kHz	Barrow 17.394 kHz 11.354 kHz	Santa Cruz 21.997 kHz 13.315 kHz	Al-Muharraq 17.967 kHz 8.885 kHz	Canarias 21.931 kHz 13.303 kHz	Molokai 21.937 kHz 13.324 kHz 13.312 kHz	Auckland 17.916 kHz 10.0084 kHz	Shannon 10.081 kHz 8.942 kHz	Barrow 17.394 kHz 11.354 kHz	Santa Cruz 21.997 kHz 13.315 kHz	Al-Muharraq 17.967 kHz 8.885 kHz

Figure 11: Two rounds of squitters each for GS Canarias (top) and GS Riverhead (bottom). The first round of 13 squitters with 32 seconds distance each is marked gray, the second in blue in their first line. At GS Riverhead, the frequencies for GS Canarias are marked yellow. You see that GS Riverhead is taking over the new frequency of GS Canarias as soon as possible, i.e. in its next available "round" changing from 13.303 kHz (left yellow mark) to 11.348 kHz (right yellow mark). Observe the offset between the squitters of each Ground Station!

Propagation

Even with existing software, you may get a good impression of propagation between a Ground Station, exactly: the whole channel, and your location (*Figures 12* and *13*).

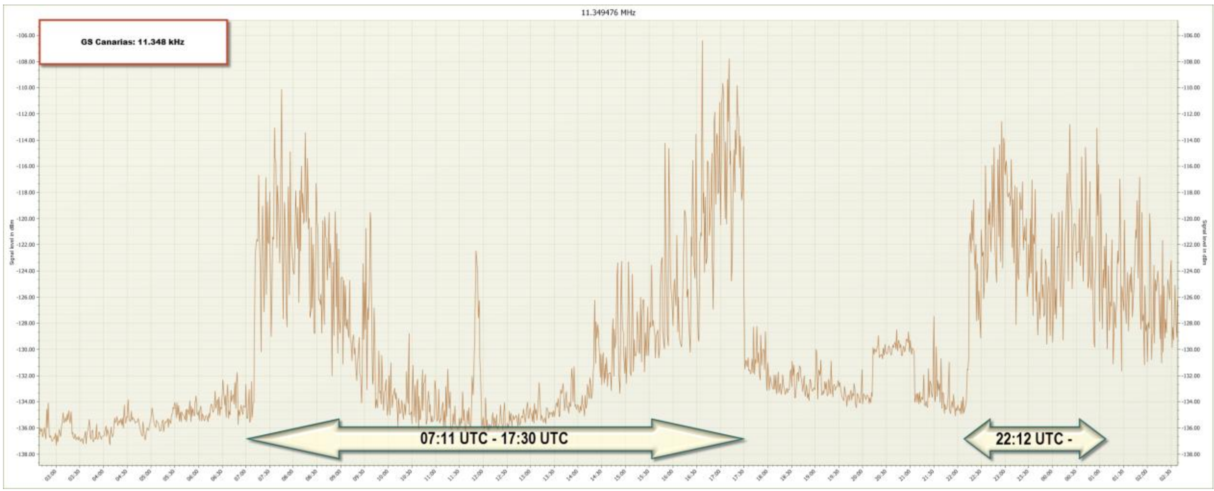


Figure 12: Here you see a graph of the observed signal strength on 11.348 kHz over 24 hours, early October, 2014. You see a big bathtub curve during the first session of activity, 07:11 UTC to 17:30 UTC. Its minimum occurs a little after noon UTC. The one spike just in between there had been noise/interference.

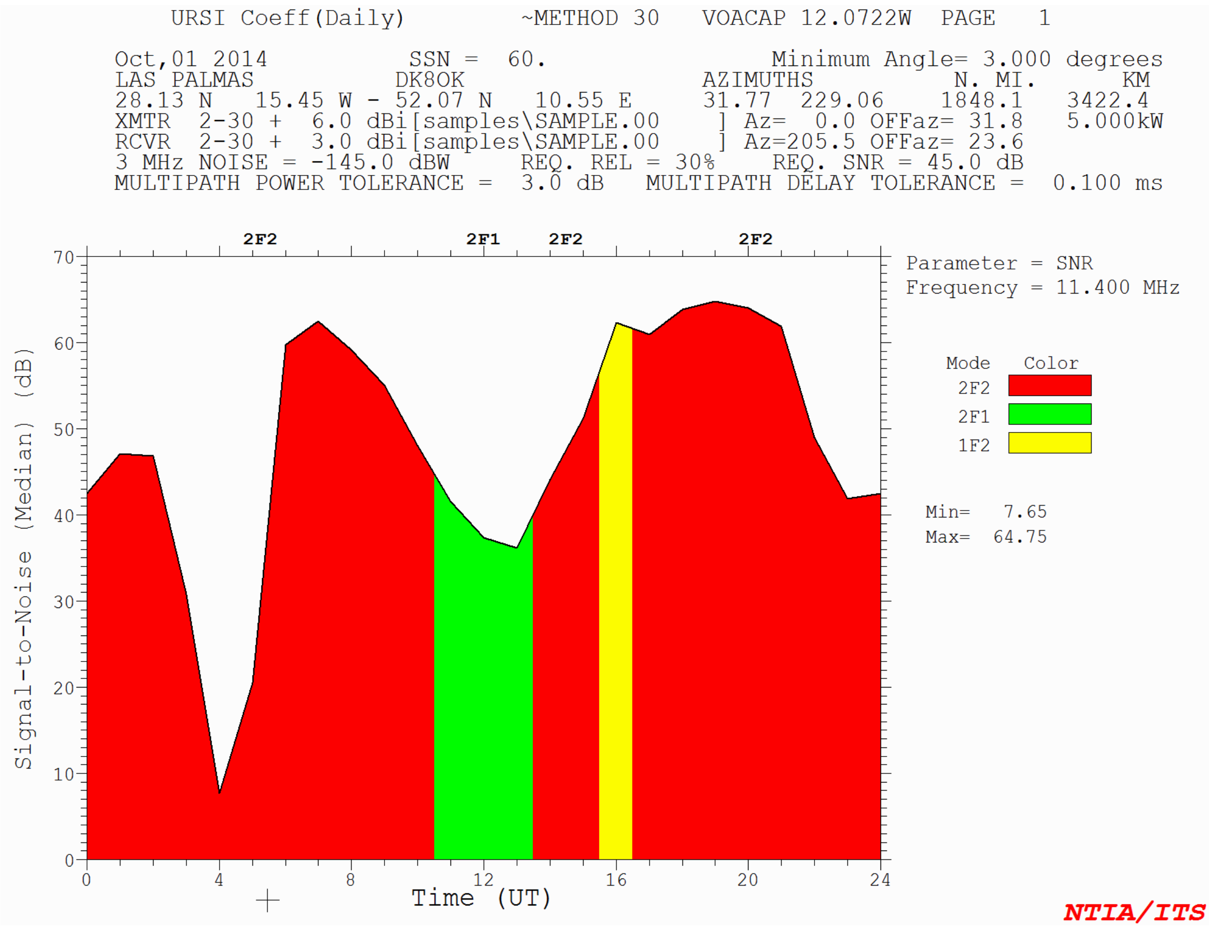


Figure 13: This observation perfectly matches the results from [VoACAP](#) *in each respect.*

To receive a Ground Station, the time must match propagation as well as the activity of the given station. This can be easily managed by some software propagation tool. Let's assume, I want to receive Al-Muharraq station from Bahrain in Germany in early February, 2015. I take the schedule (time/frequencies) of this station and put the frequencies into a software tool which will return these time/frequencies combination which will give best propagation between Bahrain an me - see *Figures 14* and *15*.

```
==============================================================================
ASAPS V6 FREQUENCY PLAN PREDICTIONS ---------------------------- 6 Feb 2015
==============================================================================
Circuit 1: DK8OK_Bahrain                 Distance: 4457km       Date: 6 Feb 2015
Tx: Bahrain              26 0.0   50 30.0  Bearings: 322  115     T-index: 90
Rx: DK8OK                52 16.2 10 0.6    Path: Short Path
Selected frequency set: Bahrain
  8.885 10.075 17.967 21.982
==============================================================================
      Mode: 2F          TakeOff Angle: 7- 9              | Mode: 2E  NONE
   Probability > 90%    |    Probability 50-90%          |
==============================================================================
  Time      Frequency   |    Time      Frequency         |    Time      Frequency
   UT          MHz      |     UT          MHz            |     UT          MHz
0000-0500    8.885      |  0000-0500    10.075           |
0500-0700   10.075      |  0500-0700      None
0700-0800   17.967      |  0700-0800    21.982
0800-1400   21.982      |  0800-1400      None
1400-1600   17.967      |  1400-1600    21.982
1600-2000   10.075      |  1600-1800    17.967
2000-2400    8.885      |  1800-2000      None
                        |  2000-2400    10.075
==============================================================================
      Mode: 3F          TakeOff Angle:15-18              | Mode: 3E  TakeOff Angle:3
   Probability > 90%    |    Probability 50-90%          |
==============================================================================
  Time      Frequency   |    Time      Frequency         |    Time      Frequency
   UT          MHz      |     UT          MHz            |     UT          MHz
0000-0600     None      |  0000-0600      None           |  0000-0700      None
0600-0700    8.885      |  0600-0700    10.075           |  0700-1400    10.075
0700-0900   10.075      |  0700-0800      None           |  1400-2400      None
0900-1200   17.967      |  0800-0900    17.967           |
1200-1900   10.075      |  0900-1200      None           |
1900-2400     None      |  1200-1600    17.967           |
                        |  1600-1900      None           |
                        |  1900-2000    10.075           |
                        |  2000-2100     8.885           |
                        |  2100-2400      None           |
==============================================================================
```

Figure 14: This plan of best frequencies between Germany and Bahrain has been done with propagation software ASAPS. Of course, you have to start at the set with the highest probability and lowest number of hops (here: 2F). If during these times the transmitter doesn't work on this frequency, change to an alternative, e.g. more hops, high probability or lowest number of hops, but lower probability.

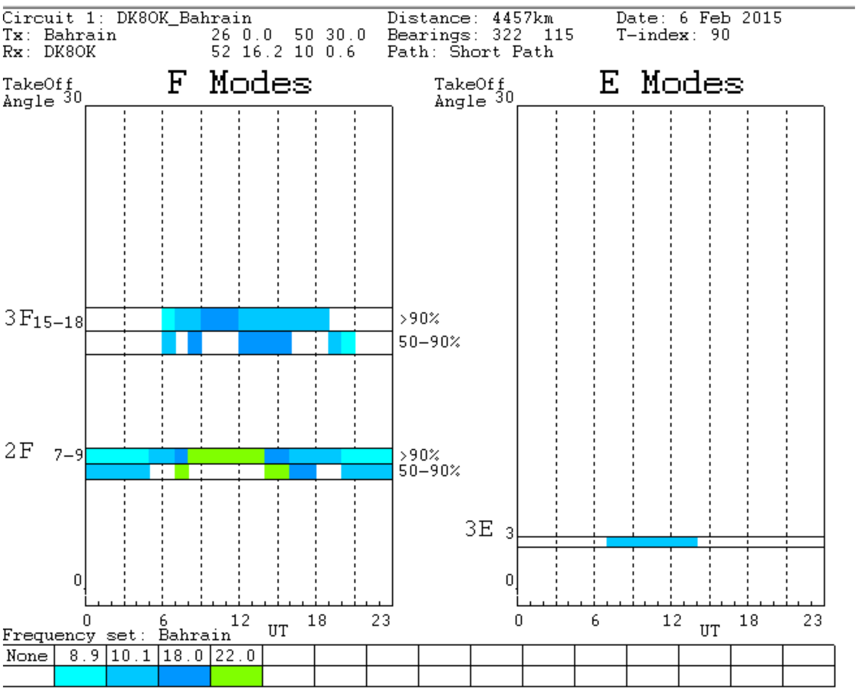


Figure 15: A graphical interpretation of Figure 14 often gives a more intuitive overview.

After matching propagation with schedule, you quickly come to the following time/frequency combination giving you the best reception:

00:00 - 04:00 UTC: 8.885 kHz
05:00 - 07:00 UTC: 10.075 kHz
07:00 - 08:00 UTC: 17.967 kHz
08:00 - 14:00 UTC: 21.982 kHz
14:00 - 16:00 UTC: 17.967 kHz
16:00 - 20:00 UTC: 10.075 kHz
20:00 - 24:00 UTC: 8.885 kHz

This is the perfect schedule for receiving; lazybones may prefer a lower probability to avoid at least some of the frequency changes.

In this case, best frequencies and station's activity do match closely. That's, because my location is also covered, see *Figures 16* and *17*.

Current Traffic | All Aircraft Heard

Rego.	Type	Airline	Time Processed	Flt-No.	ICAO Hex	Location	Route	AC	GS	Freq	Msg.Time
JA09MC	A320	Star Flyer	20150207 09:44:45		842292						01:58:00
JA820A	B788	All Nippon Airways	20150207 09:45:13		86D572						03:31:26
JA820A	B788	All Nippon Airways	20150207 09:45:13	ANA203	86D572	51.2125,11.7200	RJAA-LFPG	FF			03:30:33
JA820A	B788	All Nippon Airways	20150207 09:45:13	NH0203	86D572			E2			03:31:48
JA827A	B788	All Nippon Airways	20150207 09:44:20		86D660						00:46:35
JA828A	B788	All Nippon Airways	20150207 09:44:12		86D682						00:29:31
JA828A	B788	All Nippon Airways	20150207 09:44:13		86D682			06			00:30:38
JA828A	B788	All Nippon Airways	20150207 09:44:13		86D682			06			00:31:10
JY-AYF	A321	Royal Jordanian	20150207 09:44:36		740726						01:27:17

Figure 16: Part of monitoring on 10.075 kHz (GS Al-Muharraq), on February, 6th, 2015. JA820A has been received seven times, but only one time with their geographical coordinates, see the following Figure.

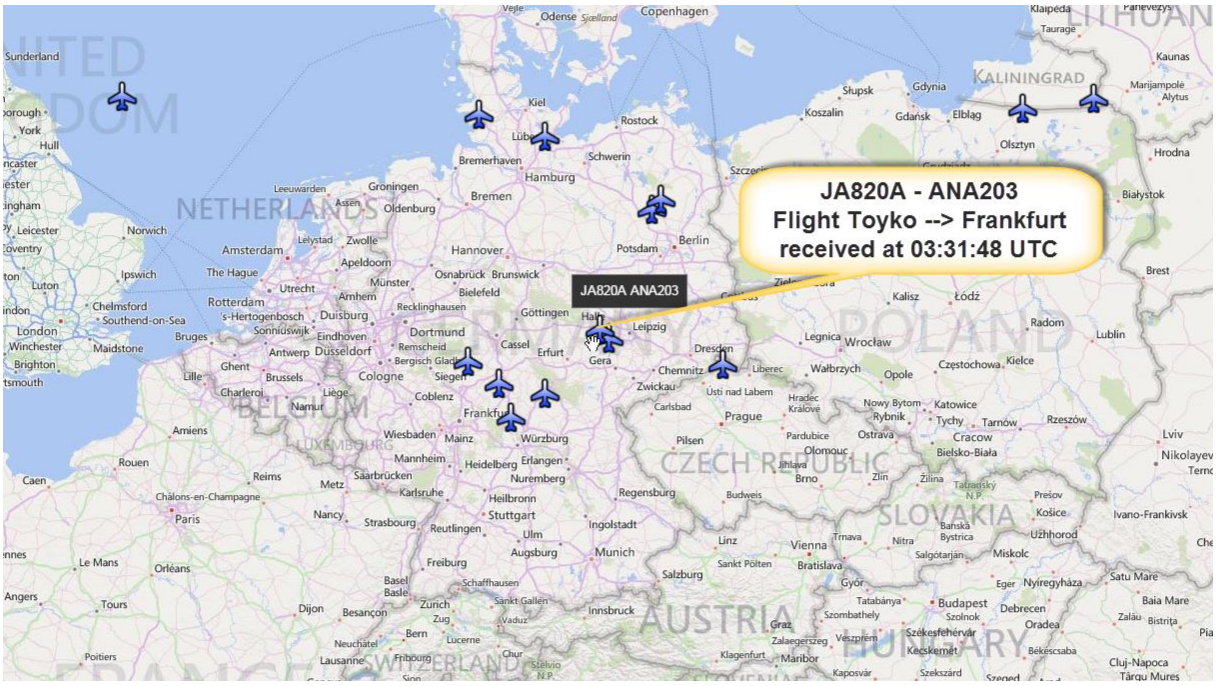


Figure 17: This shows a zoomed export of the data from PC-HFDL-Display software (see Figure above) onto bing map. When I heard the aircraft at 03:31:48 UTC in Hannover, it was just flying at a height of meters between Leipzig and Erfurt, approaching Frankfurt, see next Figure.

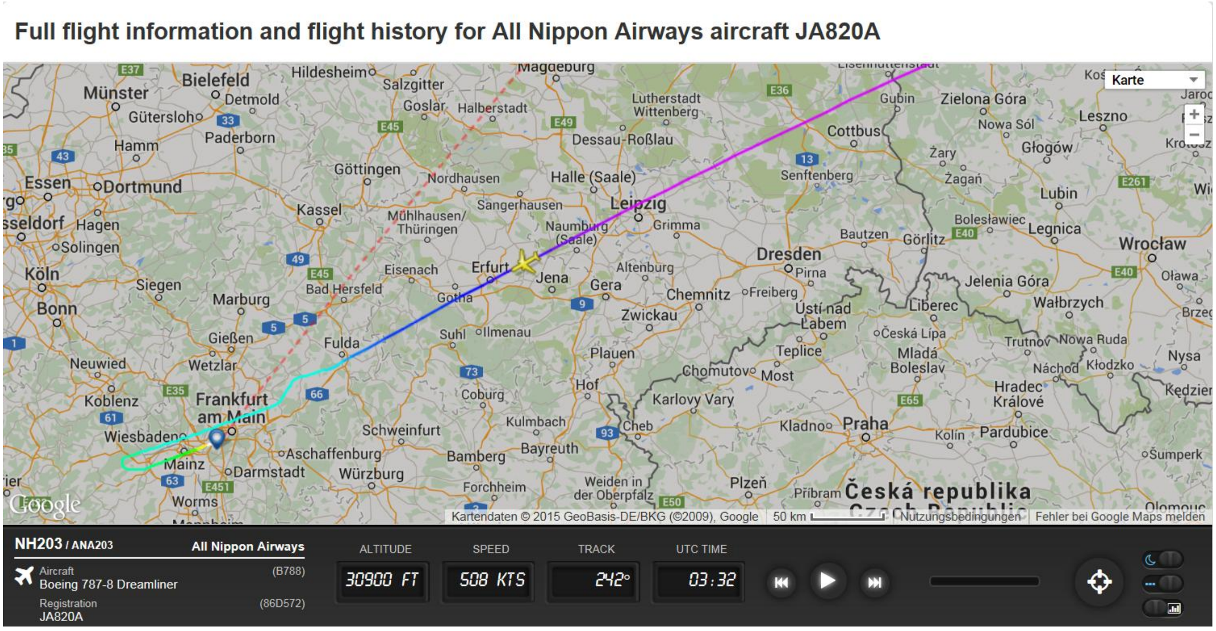


Figure 18: The situation as in Figure 17, but tracked with flightradar24.com. At a height of 30.900 feet, the radio horizon of this aircraft is a circle of 346 km. As the distance to my location is around 190 km, this had been a line-of-sight reception with a strong signal of this 400-watts-transmitter, resulting in a strong signal and a complete decoding. This has not been the case, when their transmission was first received around 00:30 UTC, see next Figure.

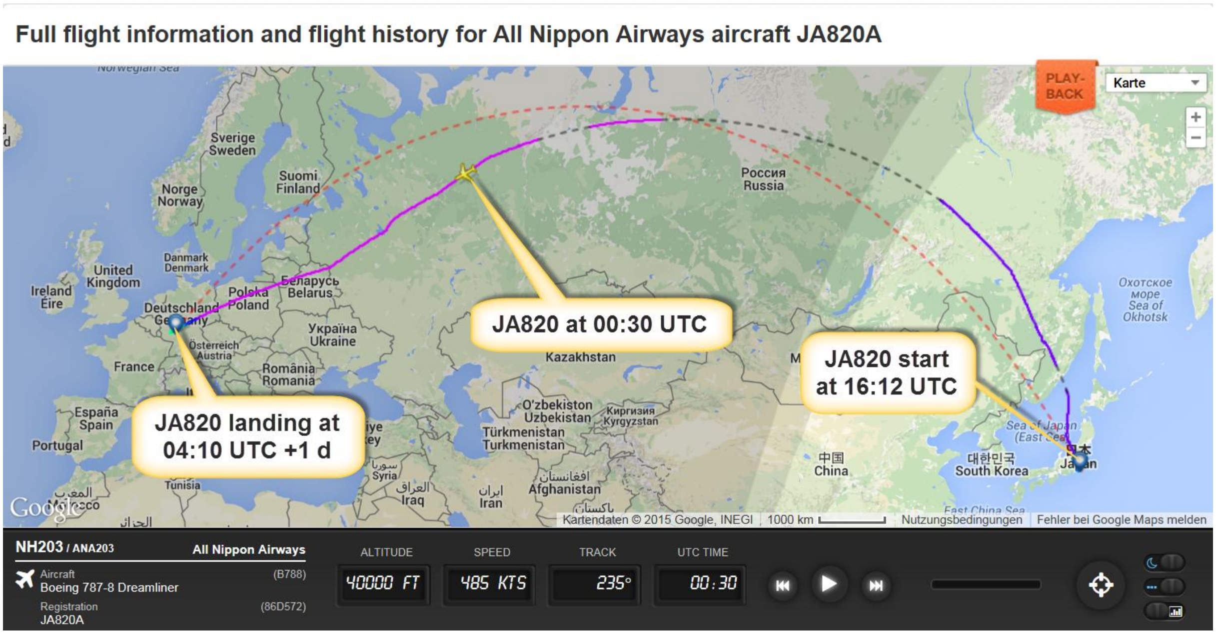


Figure 19: Replay of the complete flight, marked are start in Toyko, landing in Frankfurt plus reception of the first signal of this airplane at around 00:30 UTC, near Syktyvkar, north-west Russia. From there and at this time, propagation to my location on 10.075 kHz is bad.

Usually, the majority of the Ground Stations is serving aircraft in other regions as the one in where you live. This can reduce your reception of many Ground Stations to a (rather) limited time because you have to take into account the schedule of the Ground Station and match this propagation to you.

As much Information as possible …

As we now know, how:

- to get the up-to-date schedules by monitoring,
- to tune into the GS-channels/-clusters with the most traffic and
- to calculate the best propagating frequencies,

we now may be to develop a strategy to get as much information as possible via monitoring. This calls for a multi-channel receiver. They have to be separated into "multi-channel HF-wise" and "multi-channel AF -wise".

Up to now, the general technique is to provide more than just one demodulated audio output within one HF band. The FDM-S2 features up to four different demodulated audio output within an up to 6 MHz wide HF band. Each AF output must be assigned to a different VAC input which will feed a separate instance of PC-HFDL.

State-of-the-Art at a price tag of around 2.000 US-$ is TitanSDR with up to 40 demodulated audio channels in up to four HF bands, each of it placed within up to four HF bands of 312 kHz width.

My next step will be to define a strategy for TitanSDR to get as much decoded data as possible. This has to cope with the limitations of even this receiver.

Some first Ideas/Suggestions

There are seven main clusters of activity, namely around 5,5 MHz, 6,5 MHz, 8,9 MHz, 11,3 MHz, 13,3 MHz, 18 MHz and 22 MHz. A 312 kHz wide HF band easily covers all HFDL channels within this cluster. With respect to propagation, the four highest frequencies will work best only at *local* daylight.

After recording, each channel has to be processed off-line with PF-HFDL-Display to extract the important data.

Handle these data even better

On my wish list is a software, which can handle all these logfiles from PC-HFDL decoder, stamp each entry by Ground Station an frequency, merge them into one file and illustrate the information on Google Maps or bing maps - with to define several layers, e.g. specific Ground Stations, airlines, flights etc.

Receiver control of Frequencies - and up to the Internet

Another idea could be using the extracted tables of activities to control a receiver, on your desk or remotely over the internet. It would be most interesting to get a live impression of real HF propagation.

The output might be also added to a webpage as flighradar24.com (basing mainly on VHF data) to fill in the "missing links", see Figure 19, dashed part of the blue line.

This means "big data" in comparison to what we DXers dealt with in the past. One busy channel ma deliver >6.000 entries within 24 hours.

Propagation: Separate this TDMA Time Slots

For propagations studies, it would be interesting, to concentrate on just the the squitters of the Ground Stations - or just only their strong pre-key. CloudSDR will offer a feature called "triggering" with which you may "de-spread" the time slots. You must take only the signal squitters of a Ground Station which is transmitted each 32 seconds.

As the HFDL system is synchronized with <25 ms and bears time stamps, this feature may be also looked after.

It may be also possible by some software to use the "probe" parts of a transmission to visualize the number and each of its strength at multi-path propagation, similar to PSKSounder with STANAG4285.

See also the following pages with "schedules" of each station. These had been made manually, just to trigger someone writing a software doing this "Monkey Business" (Marx Brothers, 1931, as well as Chuck Berry, 1956) - as another idea to unlock some of the potential of one of the biggest global HF nets …

Appendix: Schedules of each Ground Station

The decoded data has been used to visualize the schedule of each Ground Station. As said before, at this stage these information has to be taken "as is".

The Ground Stations are listed in alphabetically order, and I added the time between sunset and sunrise ("Darkness"), also in 1-hour-steps.

The general ideas behind these schedules are threefold:

- Low frequencies at darkness, high frequencies in daylight
- Fast frequency changes over a wide range in the vicinity of sunrise/sunset
- At least two different frequencies per Ground Station, where resources allow for that (thus, not at Albrook, where the frequency changes are a bit delicate).

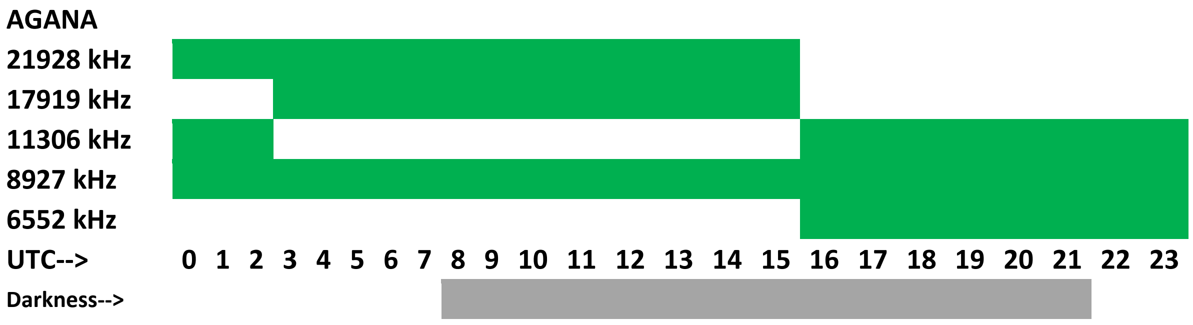
This all speaks for the very smart use of the VoACAP propagation software which additionally had been fine tuned by profound knowledge and experience of first-rate experts. If there is a role model for perfect worldwide communications over even difficult paths like these in the North Polar Region, than you find it here. It seems to pay also attention not only to the economics of frequencies in use but also to that of gas/electricity to feed the transmitters.

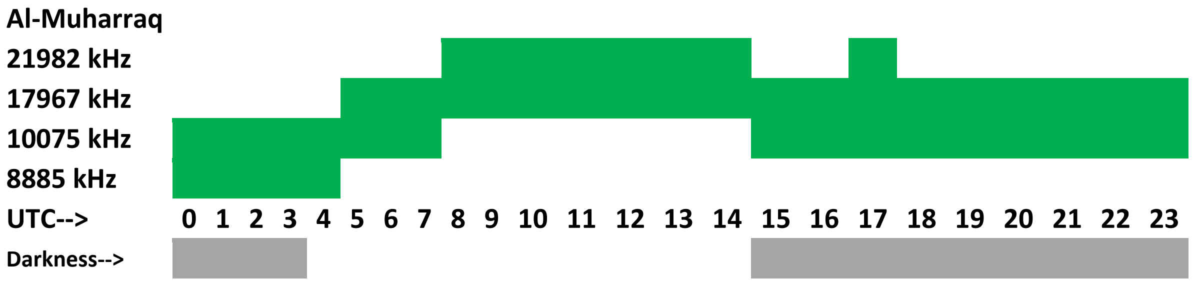
You should judge on these schedules with the eyes of a pilot who doesn't see just the next Ground Station. It's not mandatory that the "best" station is found only at a one-hop distance. It's a clever system with clever located Ground Stations: Applause!

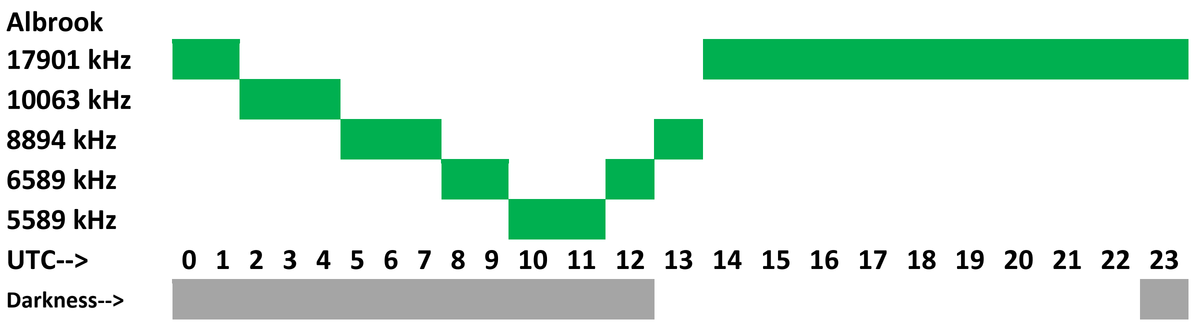
Said this, it's very likely that the transmitted tables will give quite a good picture of what is really happened.

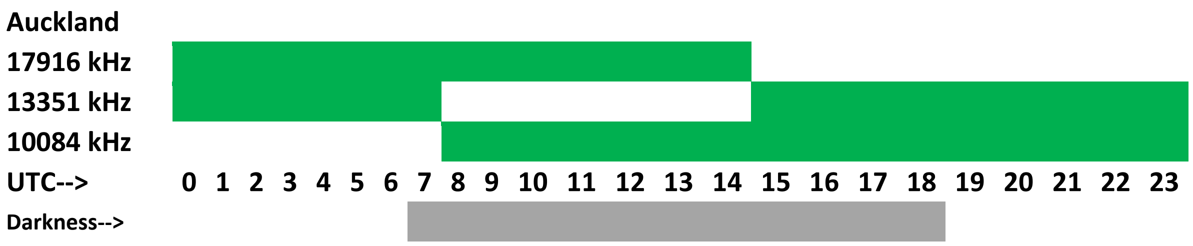
What leaves to be answered, is the question after how the airplane gets the best channel.

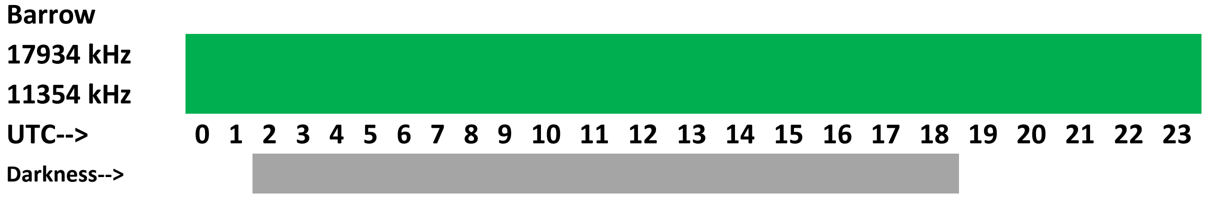
Please find each schedule of the 15 Ground Stations, as from the transmitted tables in early February, 2015, on the next pages.

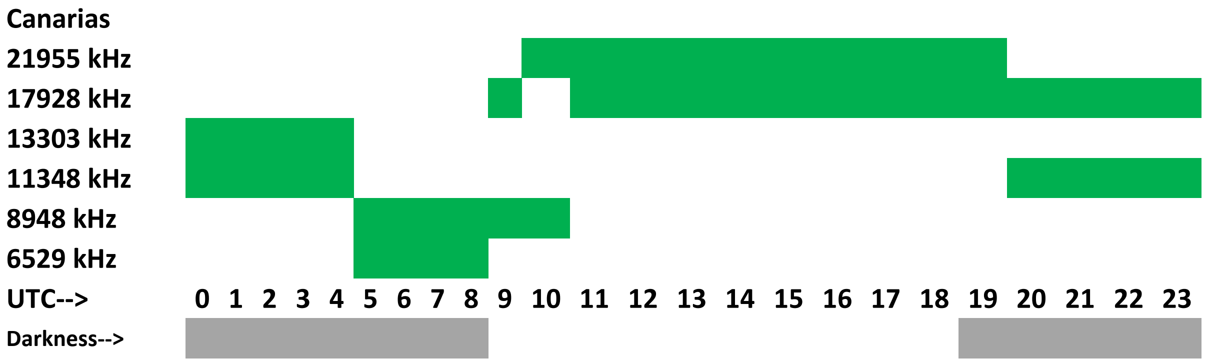

AGANA
21928 kHz
17919 kHz
11306 kHz
8927 kHz
6552 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

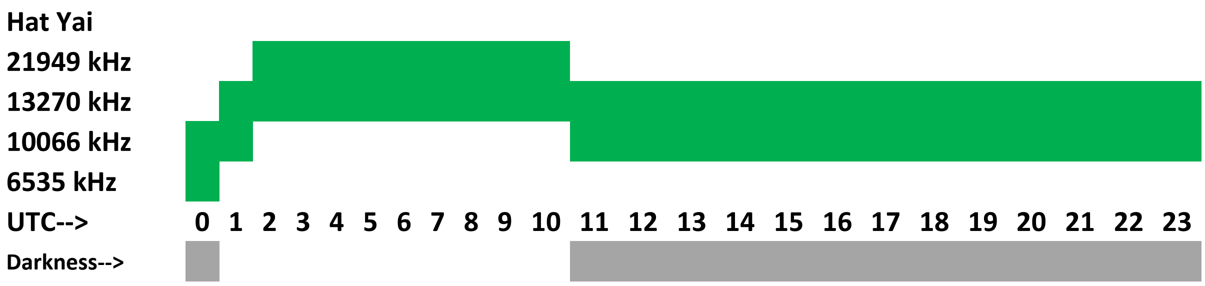

Al-Muharraq
21982 kHz
17967 kHz
10075 kHz
8885 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

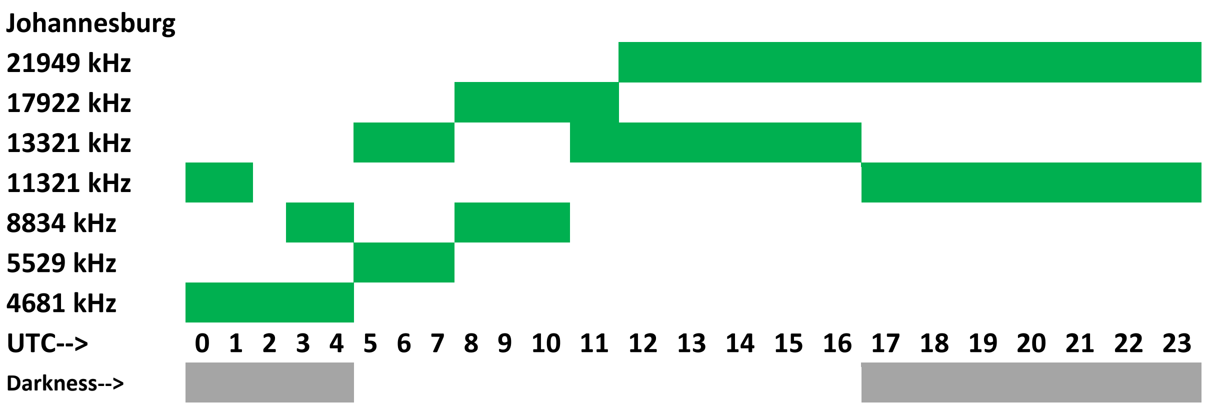

Albrook
17901 kHz
10063 kHz
8894 kHz
6589 kHz
5589 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

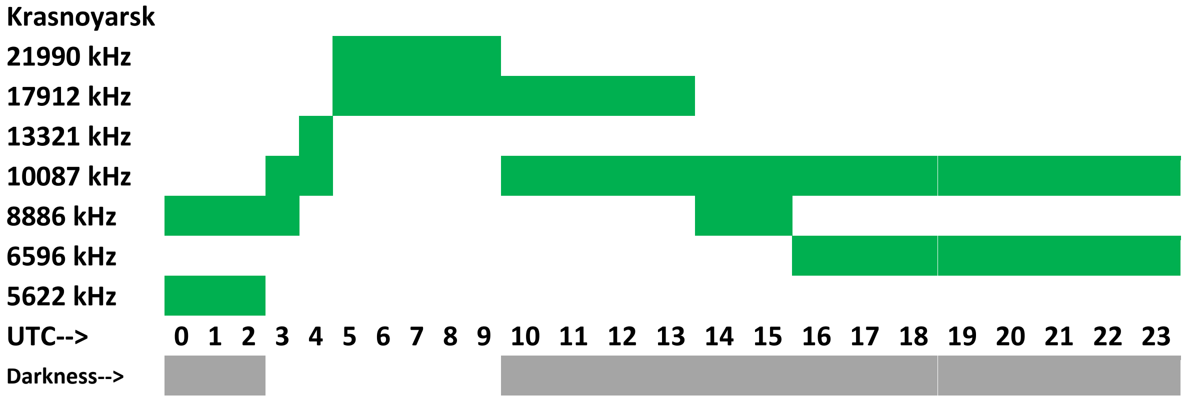

Auckland
17916 kHz
13351 kHz
10084 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

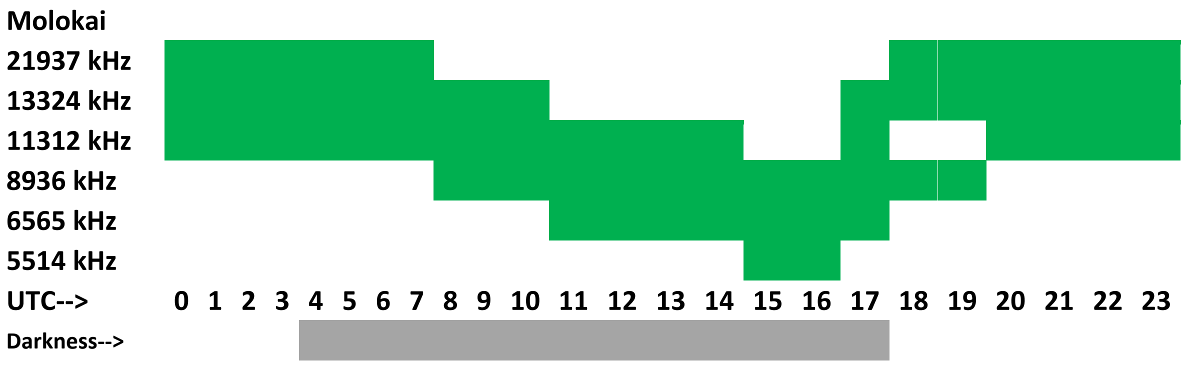

Barrow
17934 kHz
11354 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

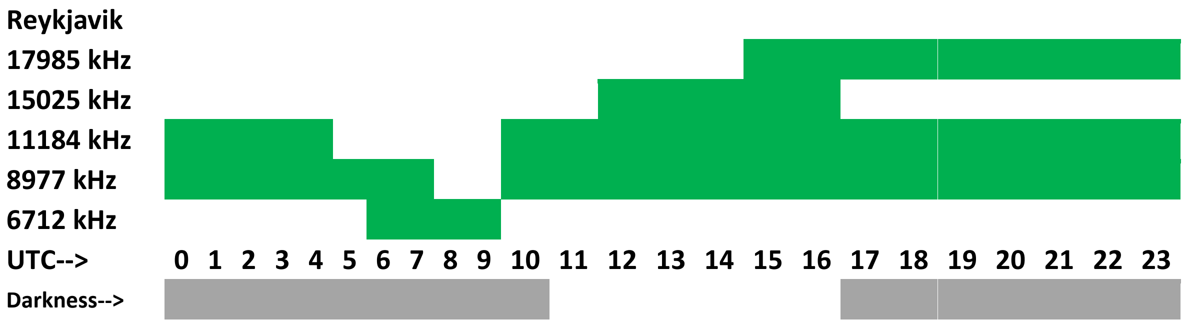

Canarias
21955 kHz
17928 kHz
13303 kHz
11348 kHz
8948 kHz
6529 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

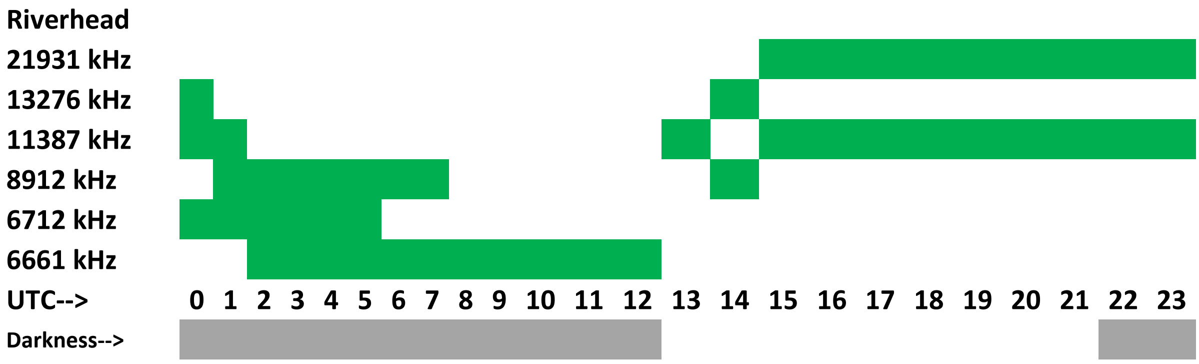

Hat Yai
21949 kHz
13270 kHz
10066 kHz
6535 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

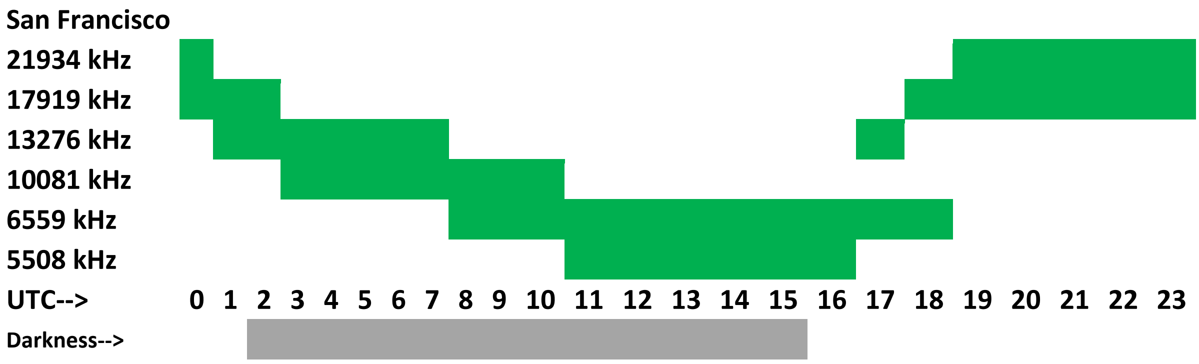

Johannesburg
21949 kHz
17922 kHz
13321 kHz
11321 kHz
8834 kHz
5529 kHz
4681 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

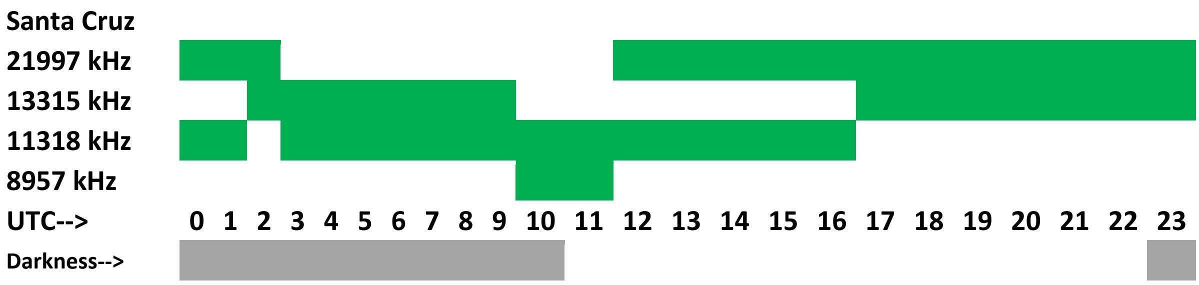

Krasnoyarsk
21990 kHz
17912 kHz
13321 kHz
10087 kHz
8886 kHz
6596 kHz
5622 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->

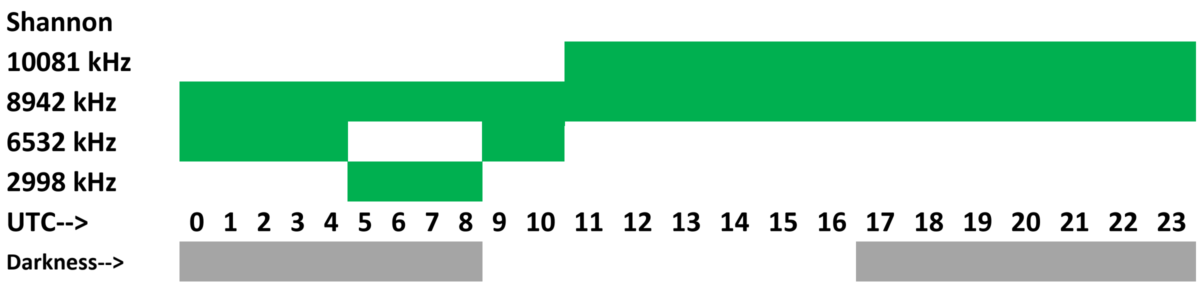

Molokai
21937 kHz
13324 kHz
11312 kHz
8936 kHz
6565 kHz
5514 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->


Reykjavik
17985 kHz
15025 kHz
11184 kHz
8977 kHz
6712 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->


Riverhead
21931 kHz
13276 kHz
11387 kHz
8912 kHz
6712 kHz
6661 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->


San Francisco
21934 kHz
17919 kHz
13276 kHz
10081 kHz
6559 kHz
5508 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->


Santa Cruz
21997 kHz
13315 kHz
11318 kHz
8957 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->


Shannon
10081 kHz
8942 kHz
6532 kHz
2998 kHz
UTC-->
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Darkness-->