Starting the work on microwaves (2022)

Matěj Petržílka, OK1TEH
www.ok2kkw.com

Why and how to successfully (long-term) work on frequencies above 1 GHz (except EME)?

What are microwaves?

- We consider of microwaves as electromagnetic waves with wavelengths from about 30cm to 1 mm, corresponding to frequencies ranging from 1 to 300 GHz

Electromagnetic spectrum			
Name	**Wavelength**	**Frequency (Hz)**	**Photon energy (eV)**
Gamma ray	< 0.01 nm	> 30 EHz	> 124 keV
X-ray	0.01 nm – 10 nm	30 EHz – 30 PHz	124 keV – 124 eV
Ultraviolet	10 nm – 400 nm	30 PHz – 750 THz	124 eV – 3 eV
Visible light	400 nm – 750 nm	750 THz – 400 THz	3 eV – 1.7 eV
Infrared	750 nm – 1 mm	400 THz – 300 GHz	1.7 eV – 1.24 meV
Microwave	1 mm – 30cm	300 GHz – 1000 MHz	1.24 meV – 1.24 µeV
Radio	≥ 30cm	≤ 1000 MHz	≤ 1.24 µeV

- **Radio amateurs have assigned 11 amateur radio bands – 1,3GHz, 2,3 GHz, 3,4 GHz, 5,7 GHz, 10 GHz, 24 GHz, 47 GHz, 76 GHz, 122 GHz, 134 GHz, 242 GHz**

- **Each of these GHz bands has its own unique characteristics!**

- **The bandwidth of the allocated hamradio bands allows sufficient room for experiments**

Why pursue microwaves?

- Not only because we have a rich frequency allocation on them as radio amateurs, but also because:
- getting good results is not easy - it is a challenge!
- it's an opportunity to try something new and there is hardly any automatic FT8 RTTY's like traffic because of narrow antenna beams ;-)
- It's an area where new discoveries and insights are constantly being made,
- working on microwaves brings radio amateurs back to their roots, i.e. mainly to "experimentation" and engineering !
- The effect of proportionality of results - i.e. if we put enough effort into building a good station and use a suitable QTH, the effort expended will in the vast majority of cases be proportional to the effort invested (see the contrast e.g. 2m Es ;-). However, this rule of course does not always and absolutely apply.
- Microwaves are a completely different world from, for example, HF. This is not to denigrate HF in any way, it is just not possible to compare apples and pears. E.g. the meaning of what is the term "DX" or "QRP" on 14 MHz vs. e.g. 76 GHz. In the 122 GHz band, QRO is e.g. even a mere 1mW (!).
- And by the way - there aren't so many "crazy" individuals here who would intentionally making QRM as is e.g. common practice on 2m, because most of the equipment (especially from 13cm upwards) cannot be bought commercially as a ready-made unit.. While microwave community isn't so large, it's very friendly and ready to help anybody!

Frequent mistakes made by newcomers from the lower bands

- **Microwaves only propagate over a line of sign (LOS)** - although ionospheric propagation is no longer used here, a variety of reflections, scattering and refractions can be used. These are not only EME, but also, for example, tropospheric waveguides or reflections from aircraft, which can cover considerable distances of several hundred km.

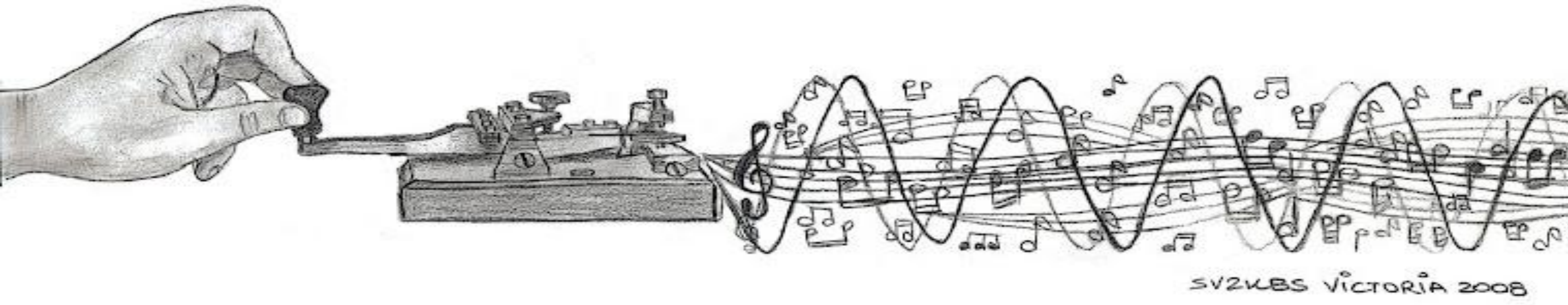
- **There is no one on the MW band (there is no one to do it)** - although the total number of stations operating on these frequencies is certainly lower than e.g. on 2m, it is necessary to remember that thanks to directional antennas, even during contests, we can usually hear only the one who turns the antenna precisely at us. This fact makes it very important here to use microwave chats or lower VHF/UHF bands to arrange the SKED to set frequency or turn antenna in good direction. This, however, does not completely exclude Random operation, i.e. without SKEDs, see for example RainScatter in the 10 GHz band.

- **Cheating on chats** - you don’t have to worry about cheating such as RST forwarding due to the use of chats, microwave radio amateurs have great operational discipline and communication on ON4KST chat is traceable. By the way, unlike the lower bands with “5NN like”, it is quite common to get a real report here, e.g. 419 or 56.

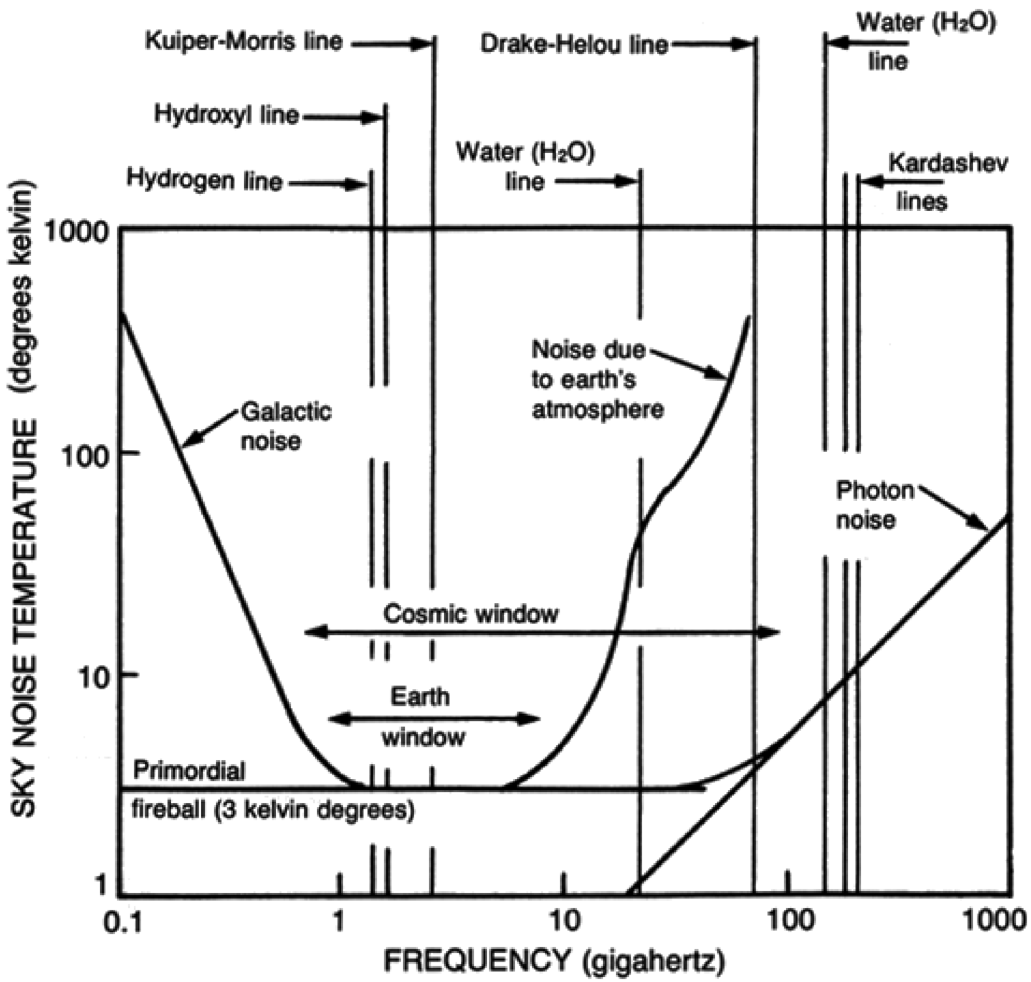
- **It makes no sense to invest money in buying equipment that will cost a disproportionate amount of money and on which only a few QSOs will be made** - in bands above 1 GHz you can't convert money into QSOs. It is necessary to adopt a different philosophy here, namely that <u>the goal is the journey to making contact itself and the resulting QSO is just the icing on the cake</u>. After all, it should be remembered that a larger amount of money is only a tax for the lack of time, knowledge or expensive measuring equipment.

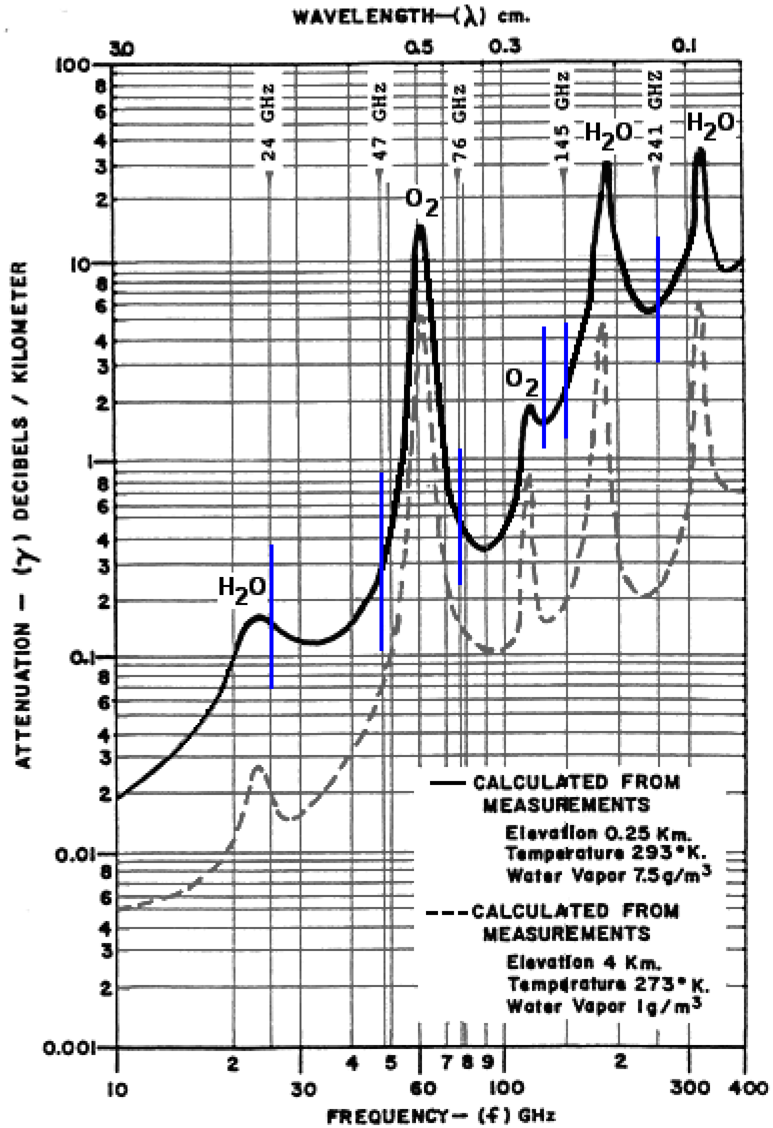
Essential things that influence the success of work on microwaves

- Mastering propagation conditions and their specifics - tropo, RS/SS, AP, EME, ...
- Availability of usable QTH and knowledge of its capabilities - height, position, QRM, …
- Different importance of beacons against lower VHF or HF bands
- Equipment requirements - LIFE IS TOO SHORT FOR QRP!
- Knowledge of contest dates and rules, test equipment before going to /P QTH
- Knowledge of the telegraph and knowledge of working with microwave chat and the Internet in general (Airscout, weather & propagation predictions, DX clusters, …)
- And above all, GREAT PATIENCE !!!

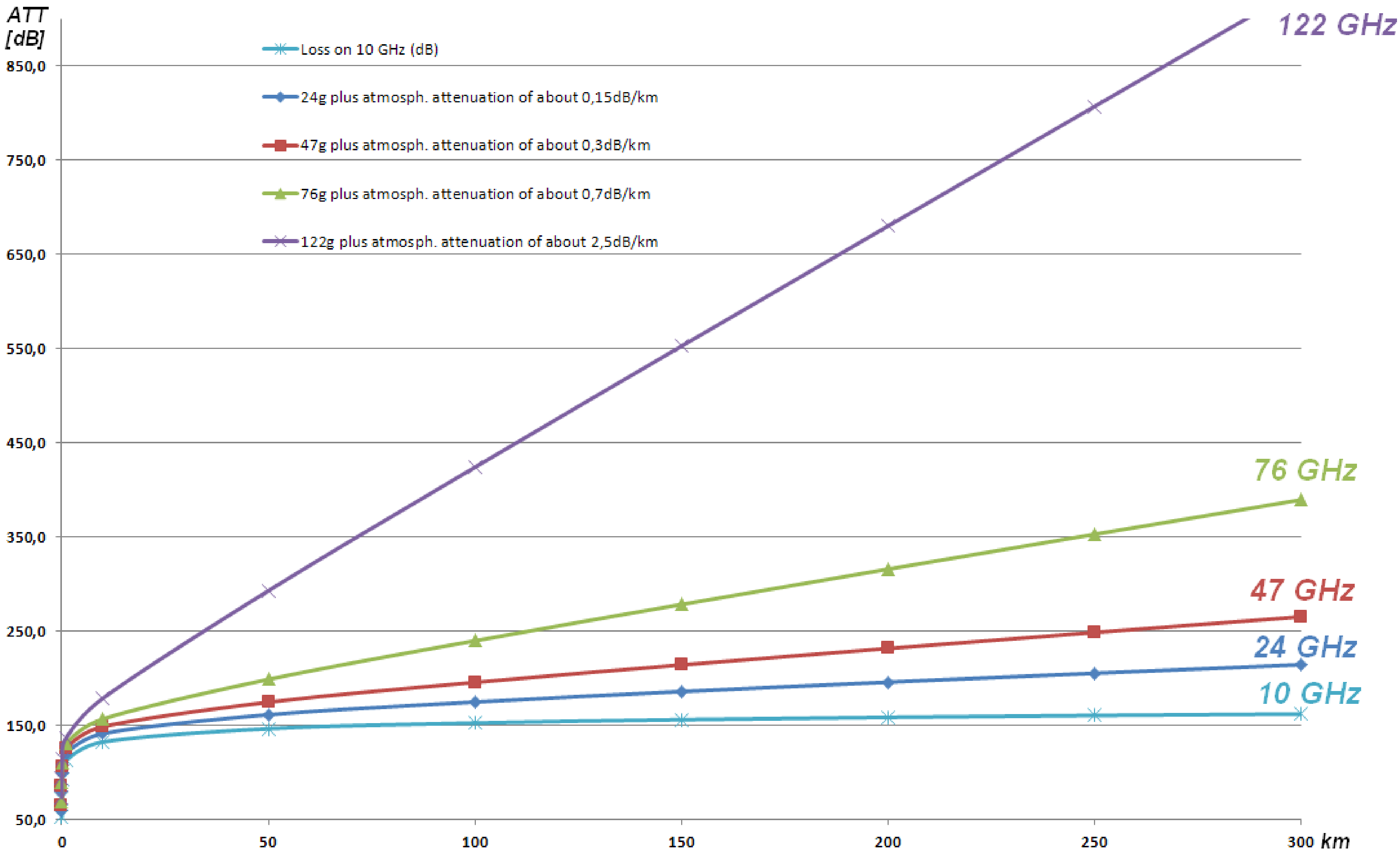


Propagation conditions on microwave bands - role of atmosphere





Propagation conditions on EHF and SHF atmosphere + free space



Propagation conditions atmosphere + free space = what does this mean in practice e.g. on 122 GHz?

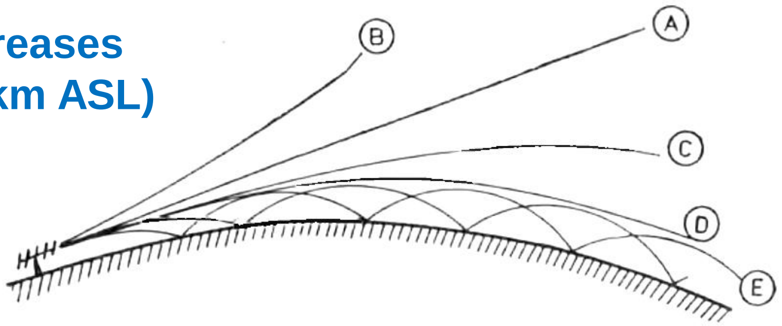
Path:	Power:	Antenna 1:	Antenna 2:	RX Limit:	S/N
150 m	1 mW	opened WG	opened WG	-107 dBm	5 dB
13 km	1 mW	opened WG	40 cm	-107 dBm	5 dB
100 km	1 mW	40 cm	40 cm	-107 dBm	5 dB
132 km	1 mW	121 cm	47 cm	-107 dBm	5 dB
150 km	1 mW	121 cm	121 cm	-107 dBm	5 dB
200 km	25 mW	121 cm	121 cm	-107 dBm	5 dB
220 km	100 mW	121 cm	121 cm	-107 dBm	5 dB
250 km	1 W	121 cm	121 cm	-107 dBm	5 dB
250 km	100 W	40 cm	40 cm	-107 dBm	5 dB

Propagation conditions – tropospheric ducts (superrefraction)

- the basic element determining the electrical properties of the medium is the dielectric constant (permittivity of the medium = ε), with which the value of the refractive index $N = \varepsilon^{1/2}$ is directly proportional

- the vertical gradient of the refractive index (g) characterizes the change in the refractive index as a function of the change in altitude, which is affected by humidity and temp.

- in the normal troposphere, the refractive index decreases continuously with increasing altitude (-6,5° C per 1km ASL)



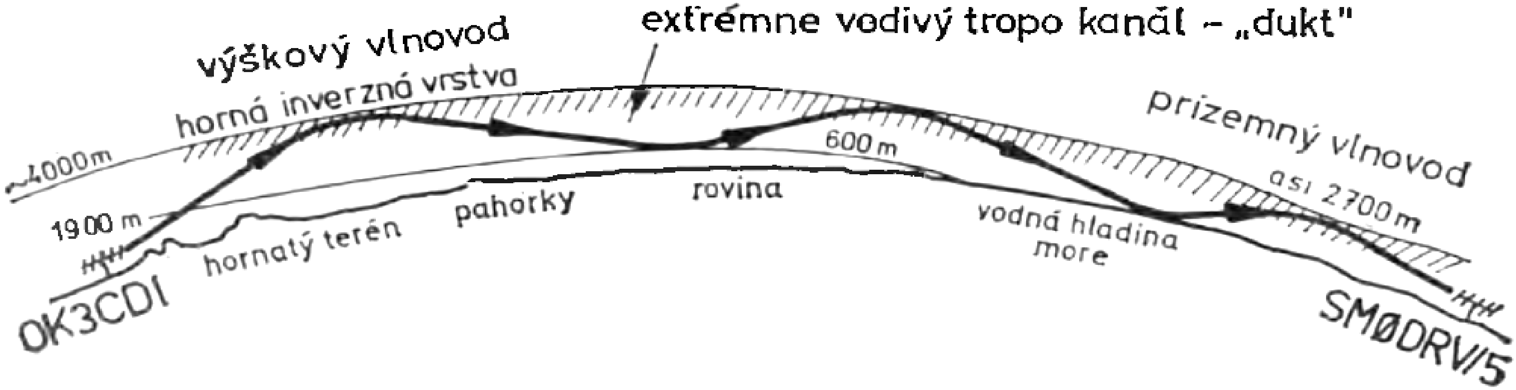
- Positive refraction (situation where $g<0$):

- **1) standard** - propagation slightly beyond the optical range (Earth's radio-radius)

- **2) critical** - refractive index decreases faster with height. At the value of the vertical gradient of the refractive index $g= -1.57 *10^{-7}$ m^{-1} conditions occur at which the equivalent radius of curvature of the VHF/UHF/SHF path is the same as the Earth's radius

- **3) supercritical refraction - superrefraction** - formation of a waveguide duct. In this case, the radius of curvature of the VHF/UHF/SHF changes than the Earth's radius - the waves return to the Earth's surface. Contacts over a distance of over 1000km can be established in the 70 MHz to 10 GHz bands..

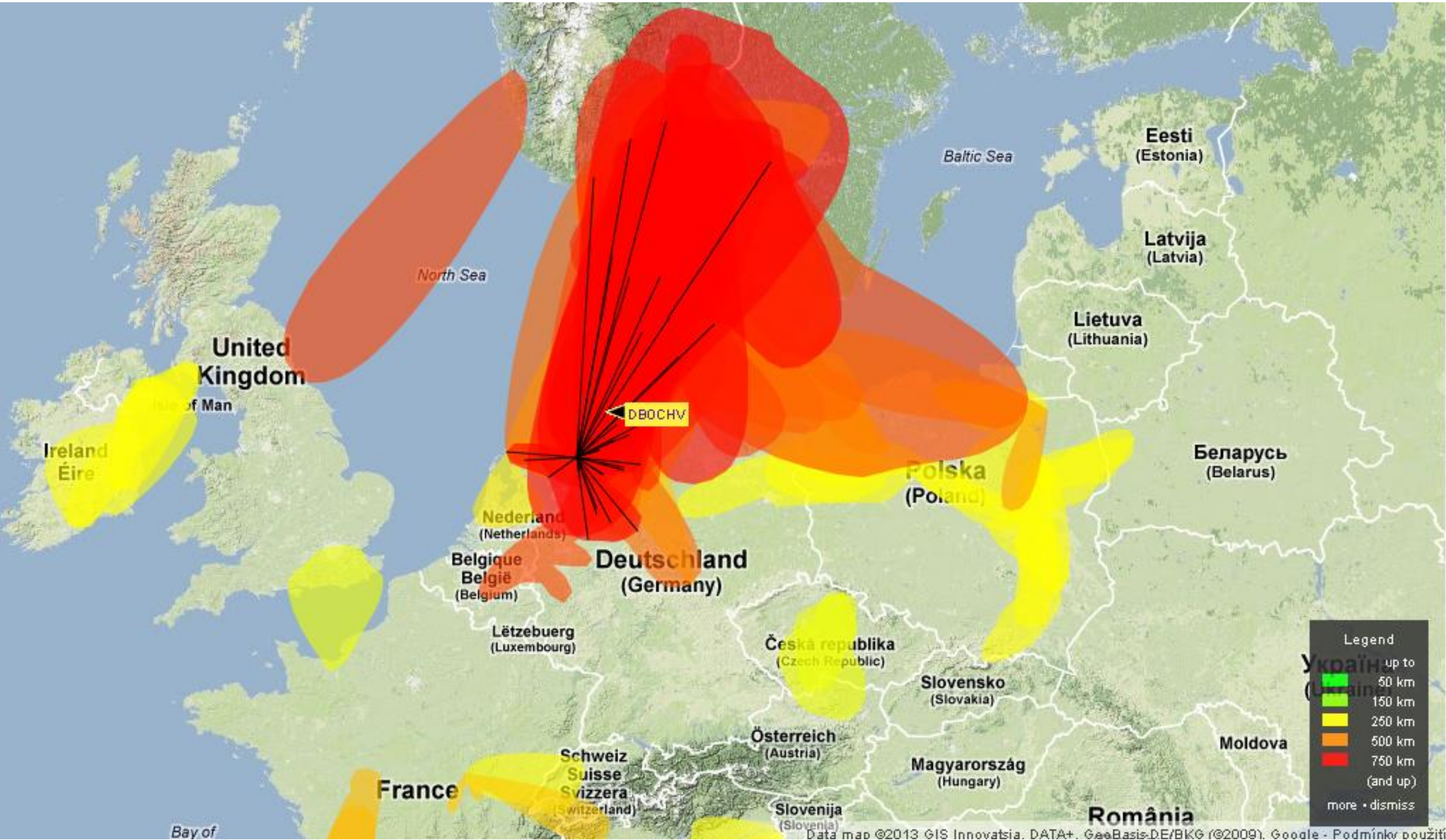
Propagation conditions – tropospheric ducts (superrefraction)



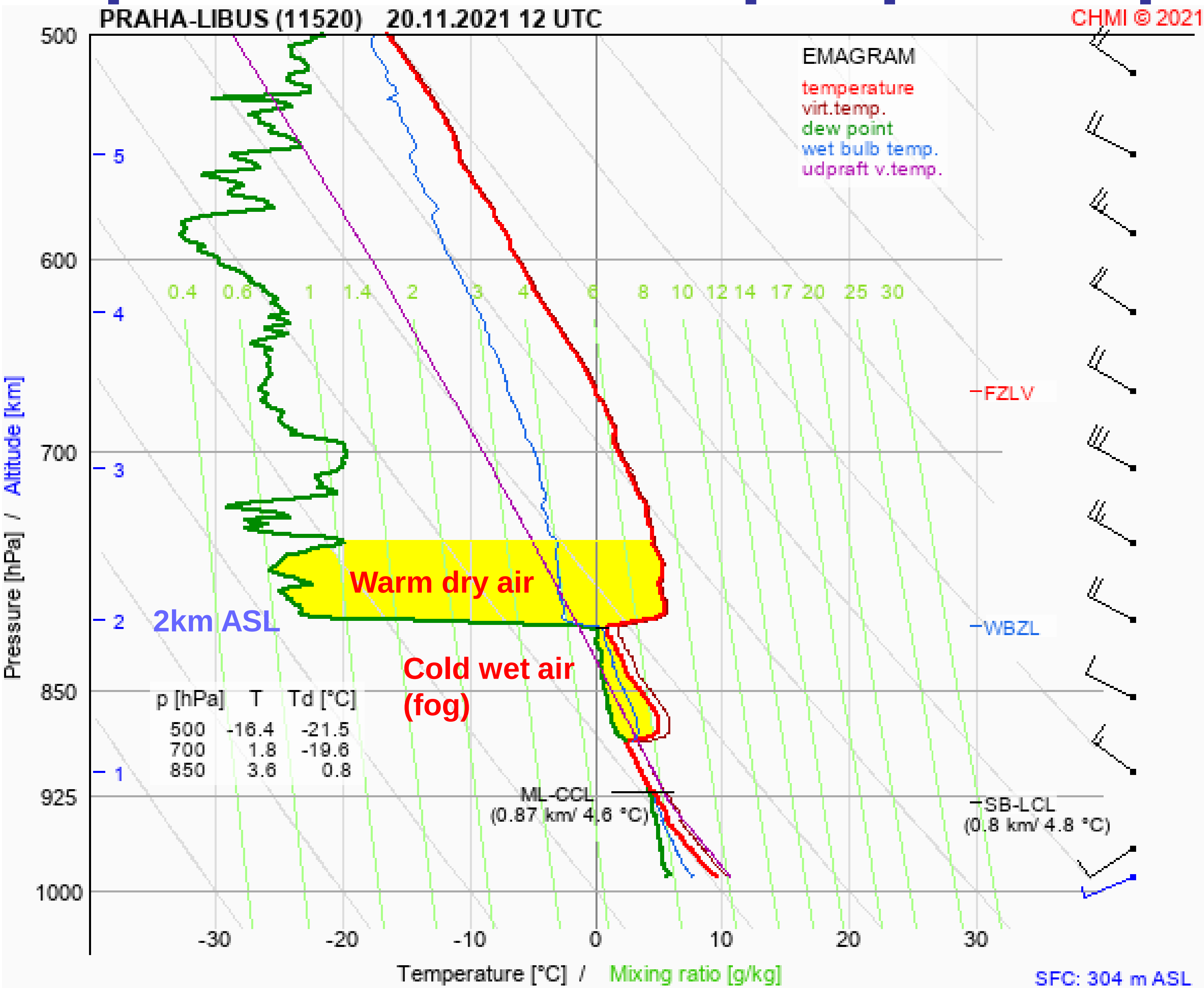
- The thickness of the waveguide affects the usable frequency, it can easily happen that for example a duct works at 23cm and not at 2m. Extremely narrow waveguides usable above the 13cm band are very rare with the special exception of 3cm propagation near the sea surface.
- Disadvantageous location of the Czech Republic surrounded by high border mountains, more frequent propagation over lakes and lowlands e.g. from SP to G, OH, SM
- In OK availability of usable QTH over approx. 700m ASL (better 1km ASL) is essential !
- Monitoring the drop of duct entry levels - more chance for lower QTH in the evening!
- Usability of inversion weather for DX on bands above 24 GHz > dry air = low attenuation!
- Prediction of propagation conditions - Hepburn, F5LEN, synoptic charts, regular monitoring of beacons, DX cluster, FT8 frequencies and APRS nets - less false detections

Propagation conditions – tropospheric ducts - APRS

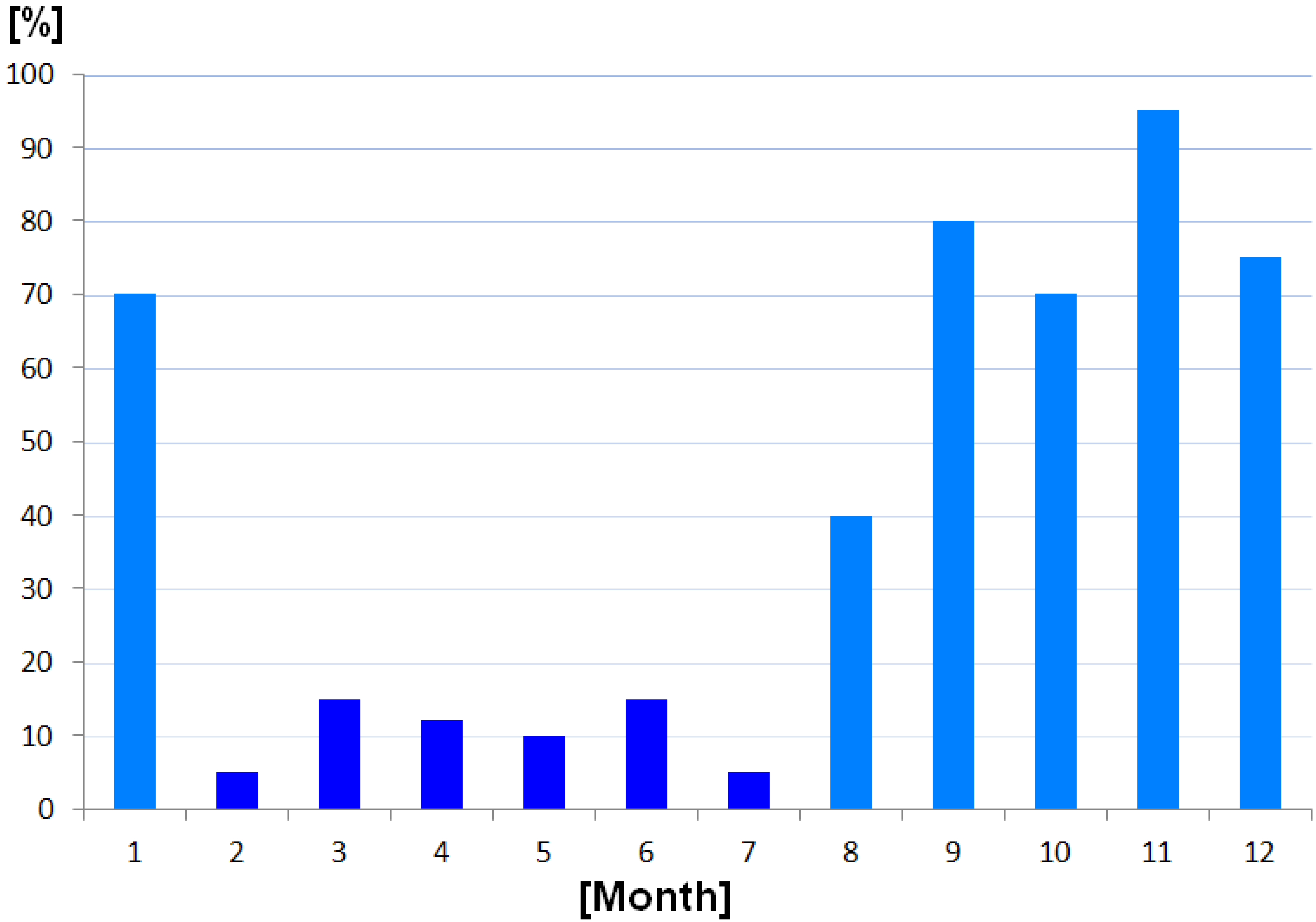
http://aprs.mennolink.org



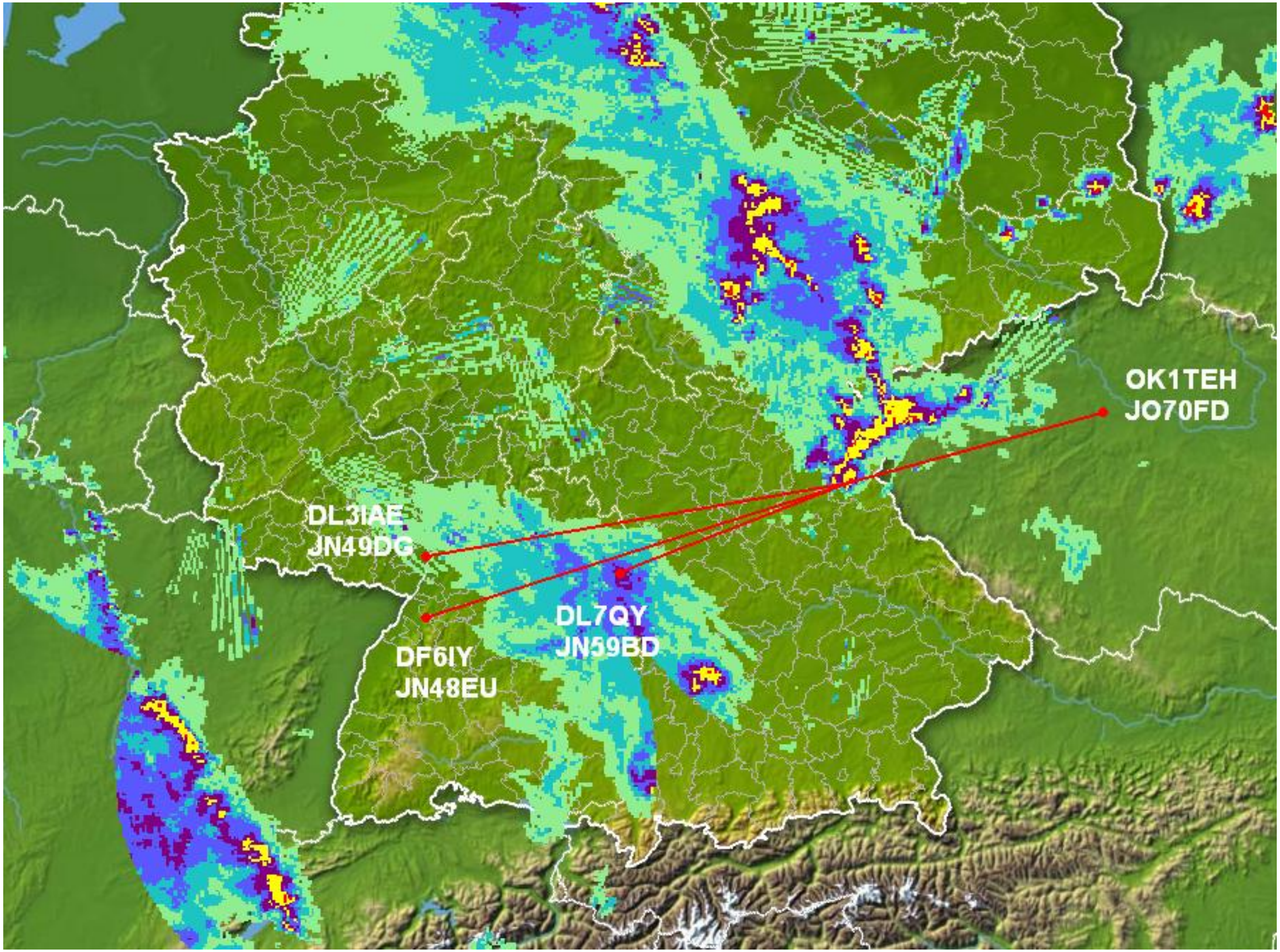
Propagation conditions – tropospheric ducts - tropospheric profile



Propagation conditions – tropospheric ducts - probability



Propagation conditions in microwave bands - RS, SS



Propagation conditions in microwave bands - RS, SS

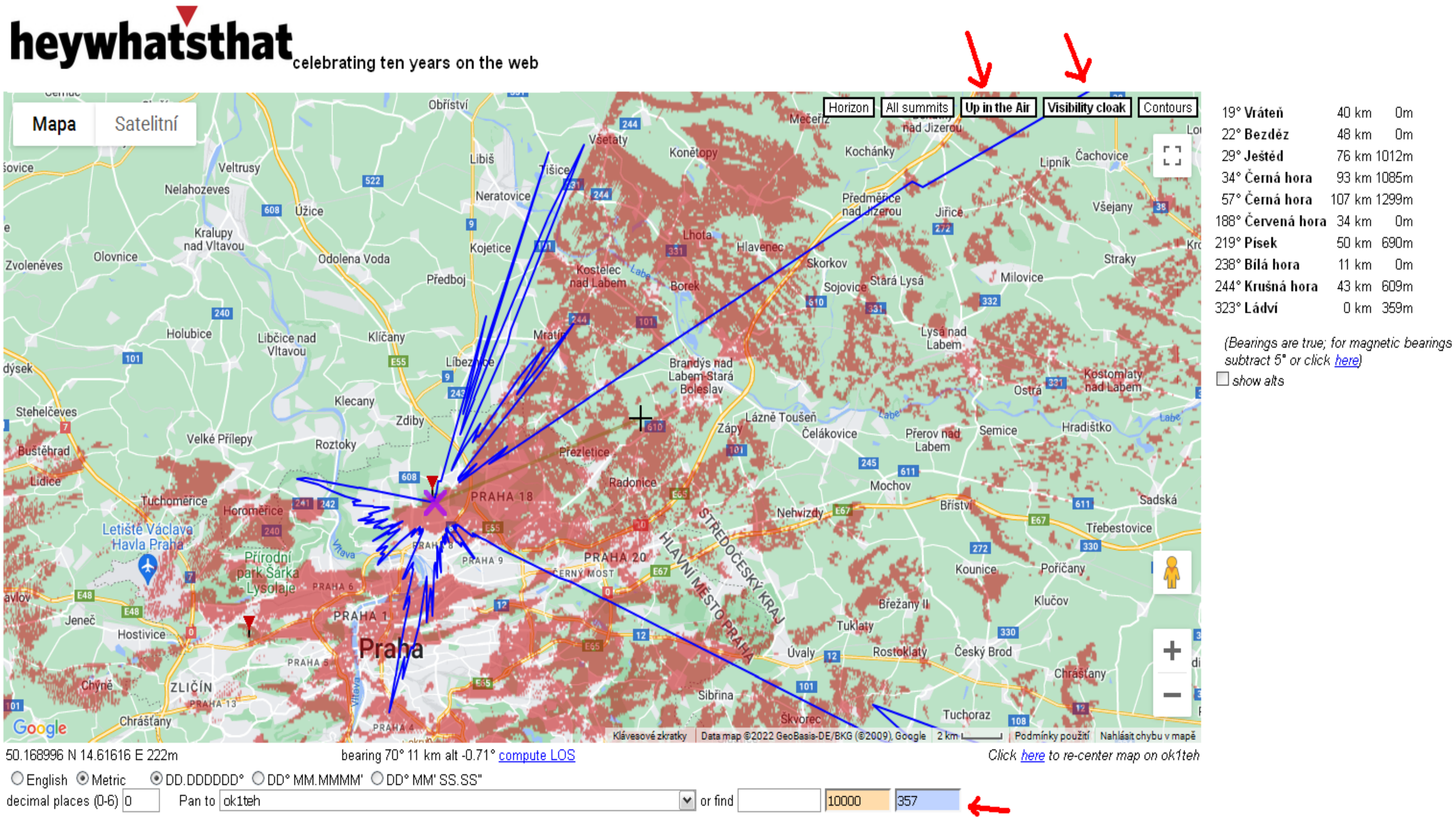
- RS - RainScatter - scattering on water droplets works very well in the 2.3 GHz to 24 GHz bands and in exceptional cases in the 23cm, 47 and 76 GHz bands. The most suitable band is the 10 368 MHz band.
- SS - SnowScatter - snowflake scattering - advantageous for 24 GHz and above, its use is hampered in higher GHz bands by so far difficult to generate powers of a few watts

- There are 2 basic divisions of storm formation:

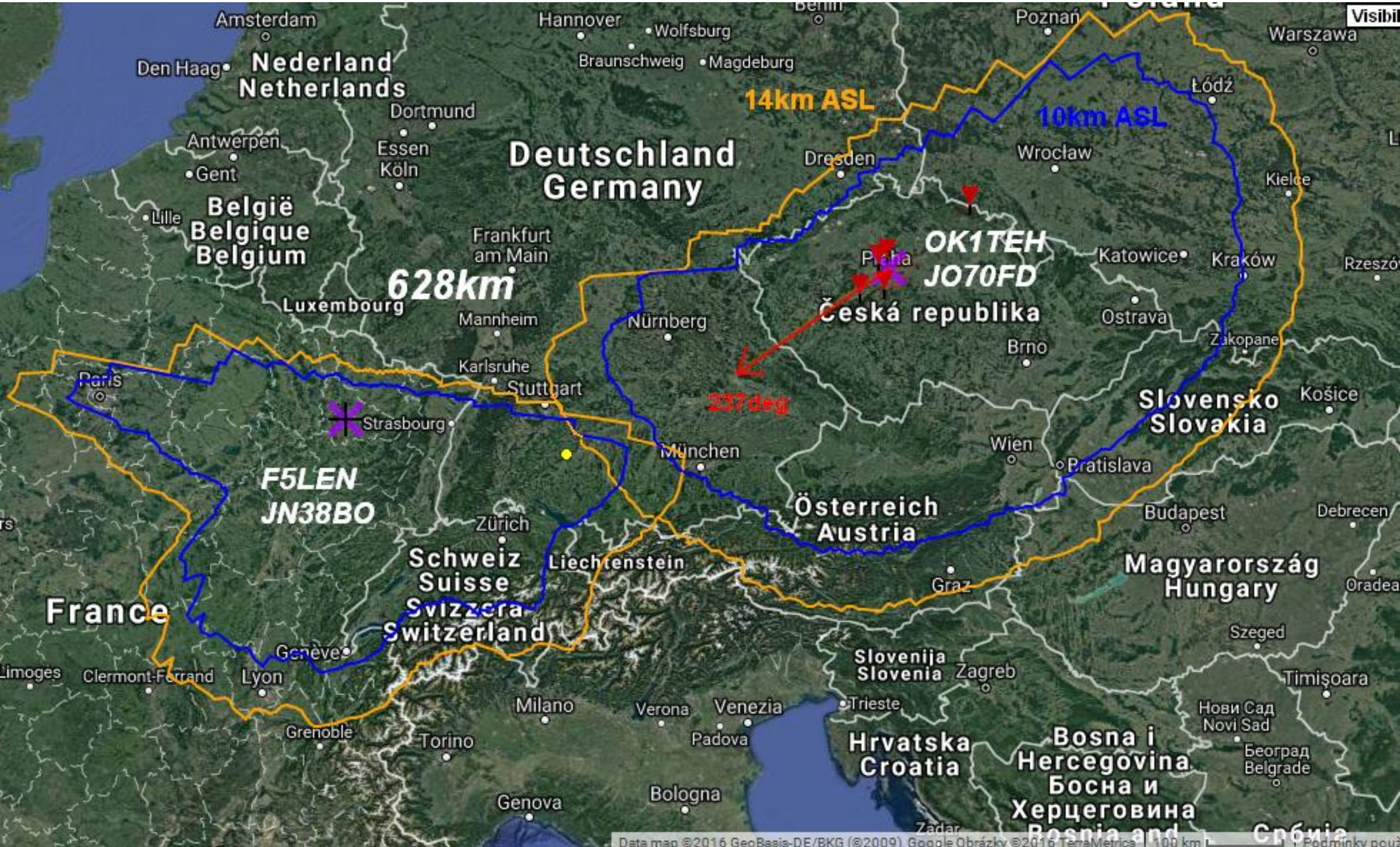
1. Frontal storm formation - the storm system advances at the head of a cold front and its occurrence can be predicted several days in advance. If the weather forecast issues a thunderstorm warning for a particular day, for long RS contacts it is most advantageous to try activity from OK a day earlier when storms are still in the western DL.

2. Convective storm formation - "storm formation from heat" - Cumulonimbus clouds - these are often the strongest storms reaching high into the stratosphere, allowing for maximum distance connections. Storms of this type form mainly over or near the high mountain ranges of the Alps and Carpathians during the midday and afternoon hours. In terms of RS, it is often a locally confined reflectivity scatter point (SCP) and has the advantage of the absence of other associated cloud fronts causing attenuation along the path. The disadvantage is the difficulty in predicting the exact occurrence location. This type of storm occurs primarily between late May and mid-August.

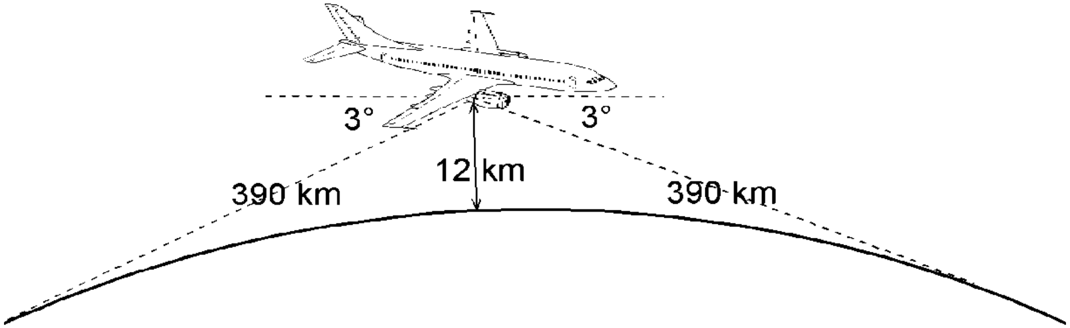
Availability of usable QTH & knowledge of its capabilities



Availability of usable QTH & knowledge of its capabilities for RS/AP

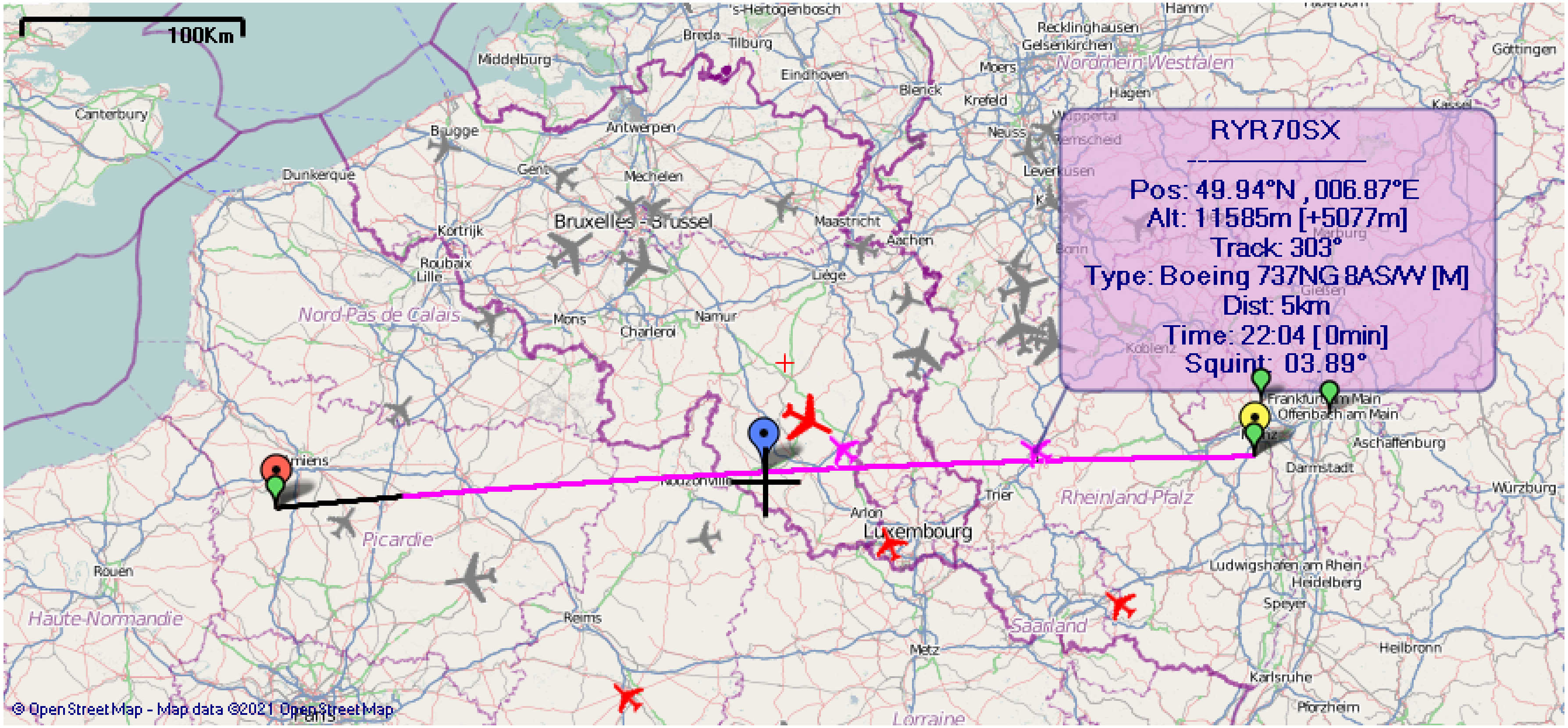


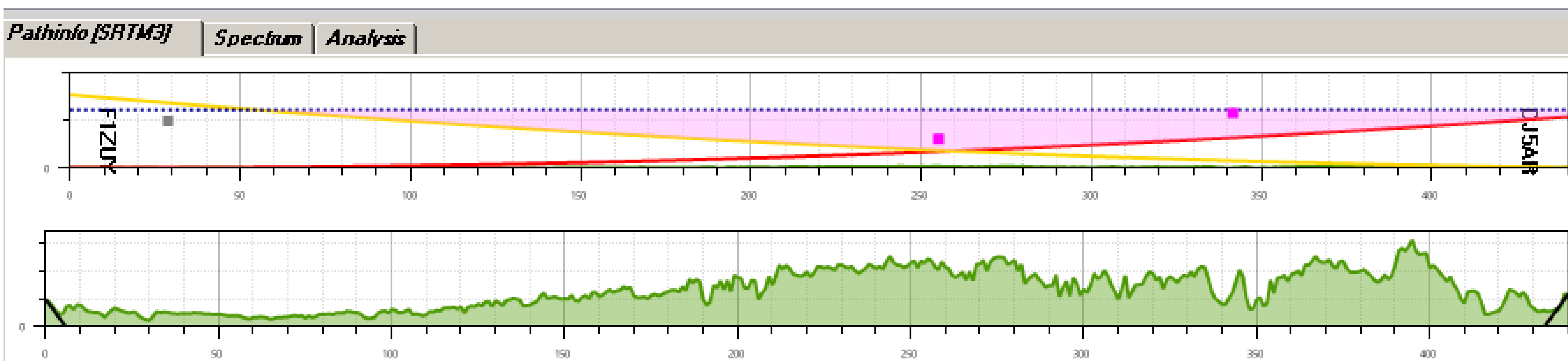
AP = Contact by reflection from aircraft



- AP – Aircraft Propagation - Airplane Scatter – in fact this isn't a scatter, but a reflection
- maximum distance is determined by the maximum cruising altitude of transport aircraft at altitudes around 10-13km ASL in the center of the path, then it is possible to establish a connection up to a distance of about 900km, the big advantage is the high QTH allowing high visibility. The height of the reflection point is similar to the occurrence of storms > RS, therefore the maximal range is similar.
- reflections work very well from about 50 MHz up to high GHz frequencies, the longest reflections of tens of seconds occur when the aircraft flies along the path of the contact
- the best reflections are given by large aircraft with the largest possible RCS ("Radar Cross-Section" = reflecting surface), i.e. e.g. A-380, B-747, MD11, A330, B-777, on the contrary, relatively weak reflections are given by aircraft with a large proportion of composite materials like B-787
- the key is to use the DL2ALF AirScout software http://www.airscout.eu to calculate the appropriate time for SKED. Due to the very short duration of the bounce, high operational discipline and minimum CW keying errors are required. It is advisable to practice the QSO in advance, for example during a small NAC type contests.

AP = Contact by reflection from aircraft





Different meaning of beacons against lower bands

- On HF beacons are only used to monitor conditions (usually MUF) and over time they are being replaced by automatic monitoring systems (PSK reporter, …)
- On the UHF and microwave bands, apart from monitoring conditions, they are mainly used to rectify antenna rotators and to rectify the exact frequency
- A proper beacon must have sufficient power, i.e. it must be audible and operate stably to be relied upon
- The importance of monitoring DX-clusters
- Warning not to underestimate the logarithmic scale of the TRX S-meter, it is recommended to use an attenuator to rectify the antenna's rotator's controller
- Updated beacon list: https://www.ok2kkw.com/okombeacons.htm

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OE5LJM     10368810.0 DB0ANU/B     JN77DX(RS)JN59GG 53s              1730 18 Aug
OE5LJM     10368910.0 SR6XHC/B     JN77DX(RS)JO80JG 51s              1729 18 Aug
OE5LJM     10368060.0 S55ZRS/B     JN77DX(RS)JN76MC 53s              1728 18 Aug
OE5LJM     10368870.0 OK0EK/B      JN77DX(RS)JN89VJ 53s              1727 18 Aug
OE5LJM     10368880.0 OE1XGA/B     JN77DX(RS)JN88EG 55s              1725 18 Aug
OE5LJM     10368930.0 OE3XAC/B     JN77DX(RS)JN78SB 51s              1724 18 Aug
OE5LJM     10368980.0 HG1BSB/B     JN77DX(RS)JN87FI 55s              1722 18 Aug
IK6CAK     10368040.0 I3CLZ/B      JN72DJ(TR)JN55OQ 599              0857 18 Aug
IK6CAK     10368960.0 I3ZNI/B      JN72DJ(TR)JN55UU 579              0849 18 Aug
IK6CAK     10368950.0 IR3UFD/B     JN72DJ(TR)JN65AW 599              0752 18 Aug
IK6CAK     10368930.0 IK3TCH/B     JN72DJ(TR)JN55NO 589              0714 18 Aug
IK6CAK     10368840.0 IQ6AN/B      Reflection on Oil platforms       0647 18 Aug
IK6CAK     10368800.0 IQ3UD/B      JN72DJ(TR)IQ3UD 599               0643 18 Aug
IK6CAK     10368860.0 I3EME/B      JN72DJ(TR)JN55WT 599              0639 18 Aug
IK7UXW     10368862.0 I3EME/B      579                               0515 17 Aug
IK7UXW     10368930.0 IK3TCH/B     539 QSB                           0512 17 Aug
IK7UXW     10368930.0 IK3CTH/B     539                               0509 17 Aug
G4RGK      10368960.0 GB3LEX/B     IO91NQ(RS)IO92IQ 57s              1839 16 Aug
IK7UXW     10368952.0 IR3UFD/B     599                               1617 16 Aug
G0API      10368750.0 GB3CAM/B     IO80XS(RS)IO92WI 53s              1614 16 Aug
IK7UXW     10368863.0 I3EME/B      559                               1613 16 Aug
G0API      10368960.0 GB3LEX/B     IO80XS(RS)IO92IQ 53s              1608 16 Aug
G0API      10368870.0 GB3KBQ/B     IO80XS(RS)IO80LX 59s              1314 16 Aug
G3LTF      10368910.0 GB3SCX/B     IO91GG(RS)IO80UU 53S              1314 16 Aug
G4RGK      10368940.0 GB3GCT/B     IO91NQ(RS)IO91IJ 59s              1142 16 Aug
G0API      10368450.0 GB3PKT/B     IO80XS(RS)JO01MT 53s              0936 16 Aug
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Dish - main lobe° width for -3dB (1/2 PWR)

m	432	1296	8400	10368	24048	47048	76032	122000
3,4	14,30	4,77	0,74	0,60	0,26	0,13	0,08	0,05
3	16,20	5,40	0,83	0,68	0,29	0,15	0,09	0,06
2,4	20,25	6,75	1,04	0,84	0,36	0,19	0,12	0,07
1,9	25,58	8,53	1,32	1,07	0,46	0,23	0,15	0,09
1,2	40,51	13,50	2,08	1,69	0,73	0,37	0,23	0,14
1	48,61	16,20	2,50	2,03	0,87	0,45	0,28	0,17
0,9	54,01	18,00	2,78	2,25	0,97	0,50	0,31	0,19
0,6	81,02	27,01	4,17	3,38	1,46	0,74	0,46	0,29
0,48		33,76	5,21	4,22	1,82	0,93	0,58	0,36
0,3		54,01	8,33	6,75	2,91	1,49	0,92	0,57

Methodology for working on microwaves with respect to equipment and antennas

- The bigger the antenna the better, but it is necessary to remember about precise beaming, especially in windy weather, i.e. use sufficiently massive tripods, precise indication of azimuth and elevation. Sometimes it’s helpful to use lower gain HORN type antennas, especially at frequencies above 76 GHz, because they eliminate the problem of extremely accurate antenna pointing, dish surface accuracy and good surface irradiation. A great advantage in beaming is to use multiple dishes on one tripod.

- For a successful contact it’s necessary to solve as many variables as possible in the contact’s equation, these are for both stations: precise frequency (advantage of GPSDO or beacons), precise antenna beaming in AZ and EL, reliance on well working RX and TX. As a general rule, if one of the stations hears the signal of the opposite station, it is usually a “won game”, because then you just need to adjust the right antenna beaming.

- Special features of the operation in the bands 24 GHz and above: the FM channel in DL/OK1 = 145.525 and in OK2 = 145.400 MHz are used for the intercom. If we are working with a QRPP station so that uses only a mixer, it is practice to send back the signal on 2m so that we can then aim the dish for maximum signal.

- It is advisable to test the equipment before each portable trip to see if the receiver or transmitter is working properly. If beacons aren’t available, it’s possible to try connecting e.g. a Shottky diode to the generator and listen to its harmonics. The change in frequency of the IF generator will be proportional to the change in frequency on the desired band.

Possibility to use multiple GHz bands with one antenna

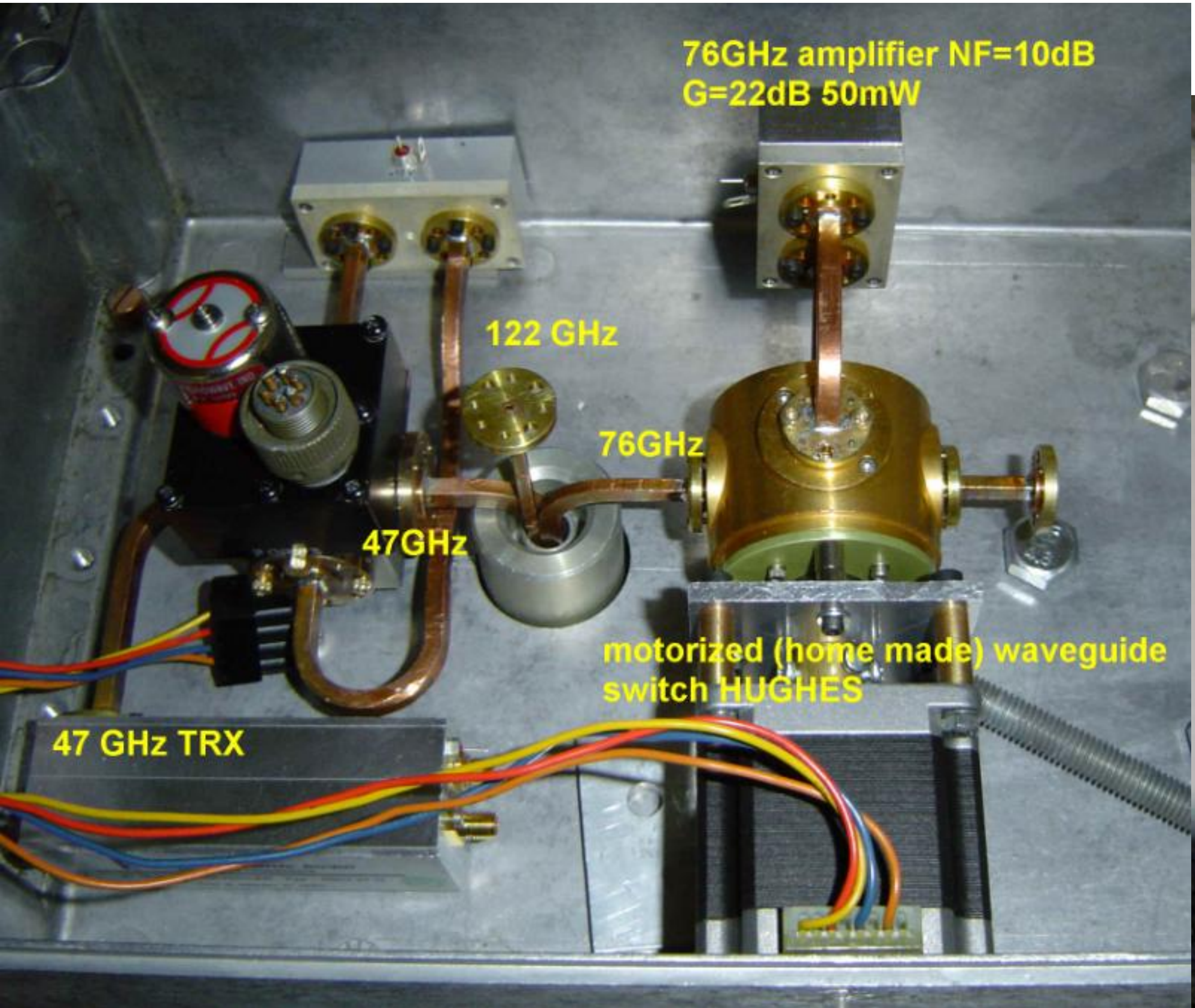
- When working in the 24 GHz bands and above, it is sometimes disadvantageous to use multiple heavy equipment and dishes on multiple tripods, which can be a problem when working on a portable. There are several ways to ride multiple bands with a single dish, some are compromises and others are not suitable for dishes with different F/D ratios. Elsewhere again, there is a risk of displacement of the dish in AZ/EL when changing bands (WG = waveguide). Some options:

- 1) lever system e.g. OE5VRL / OK1AIY - tilting individual feeds on one hand(lever) to the center of the focus
- 2) e.g. DL7QY's system – it's possible to irradiate a pseudo-cassegrain mirror from multiple waveguides simultaneously. Another trick is taking advantage of the fact that some waveguides e.g. WR15 can be used for both 47 and 76 GHz bands together. The disadvantage is the necessity of more expensive WG relays.
- 3) Multi-feed system e.g. OM6AA /OK1JHM /RA3WDK - use a combined ring-feed containing another feed in the focus - e.g. for 23-13-9cm , or place a feedhorn in the middle for higher bands, or also a multi-irradiator system with a logarithmic-periodic antenna
- 4) different variations of real Cassegrain systems e.g. W1GHZ / VK5ZD - a secondary hyperbolic mirror is placed in the focus, which is irradiated through the bottom of the dish by feedhorn, which can be moved or inserted into the bottom hole in the backside of dish.
- 5) RW3BP's system - shifting RX or TX units into the focus of the offset dish, where no WG relay is required.
- 6) OE5VRL/ OE2JOM/ OE3WOG's system - massive feed holder with counterweight for easy replacement of transverter box directly in focus

Possibility to use multiple GHz bands with one antenna - 1st OE5VRL system

Moving of individual feeds into the center of the focus

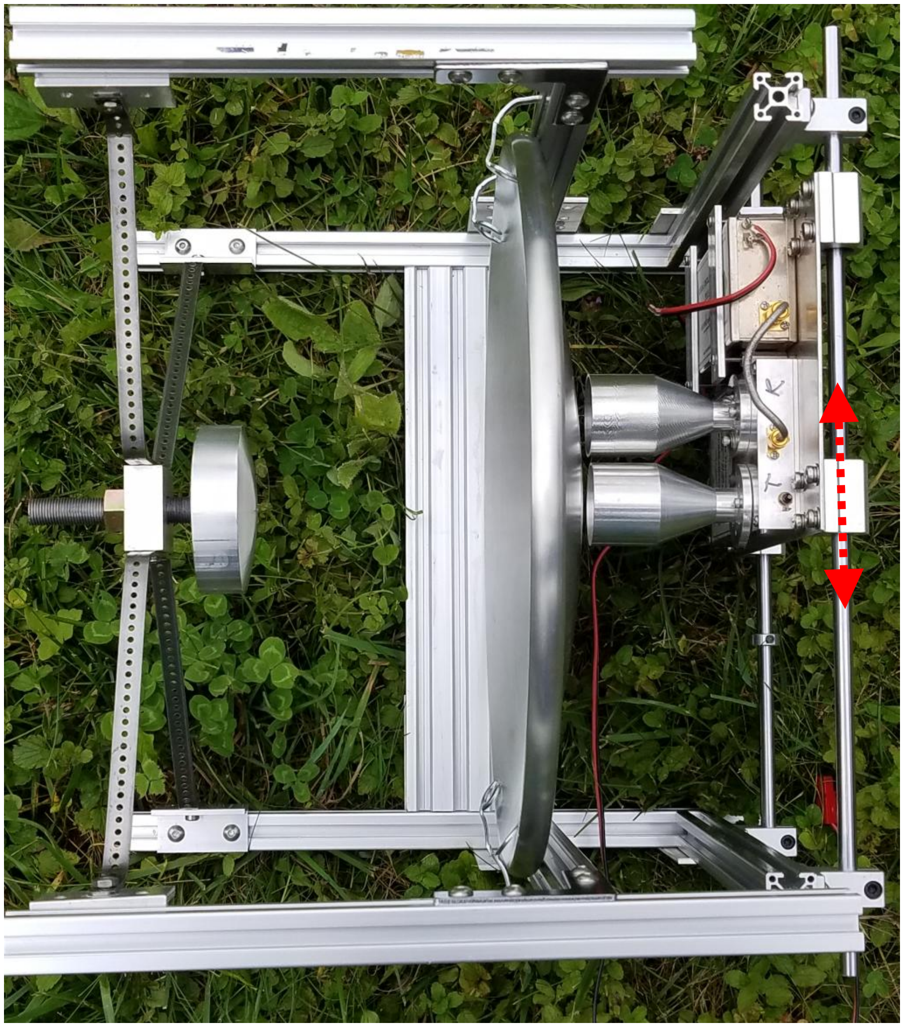
Possibility to use multiple GHz bands with one antenna - 2nd DL7QY system



Possibility to use multiple GHz bands with one antenna - 3rd system OK1JHM

RING FEED – multi-feed

Possibility to use multiple GHz bands with one antenna - 4th system W1GHZ, ..

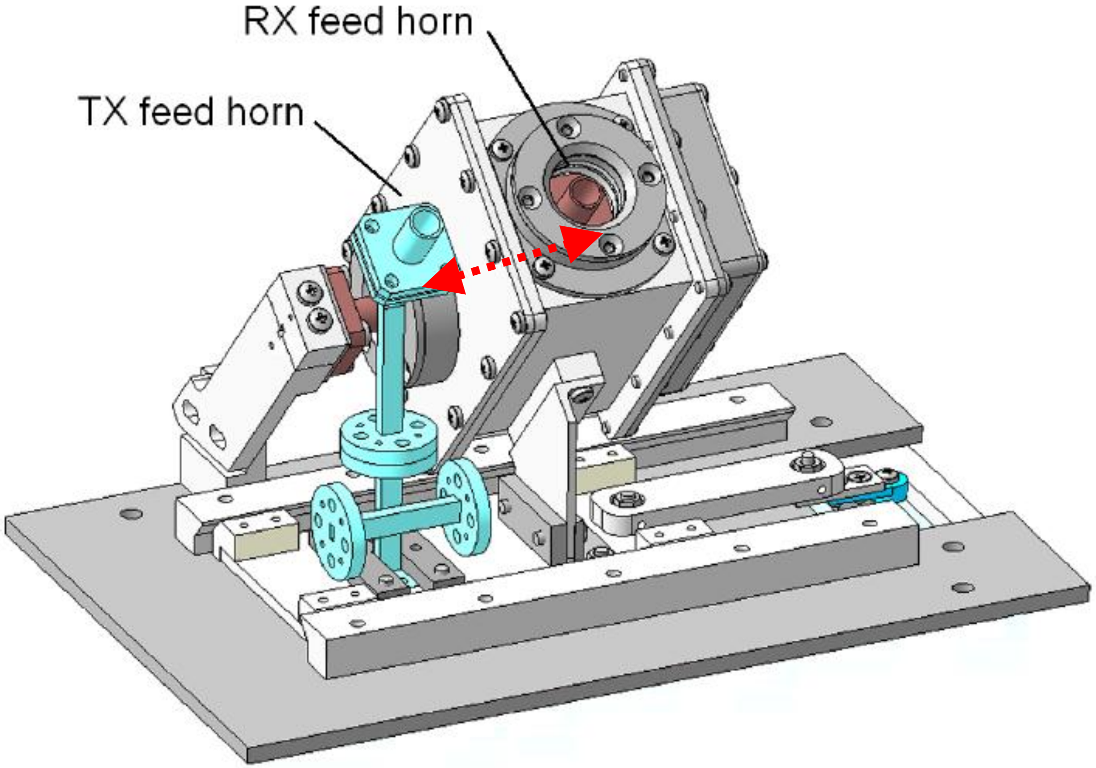


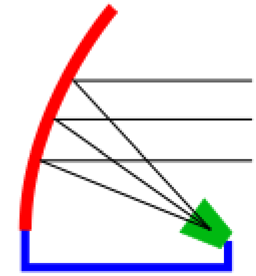
47 GHz Cassegrain system made by Paul, W1GHZ for simple RX/TX feed switching

VK5ZD's system for easy band swapping by simply inserting the desired transverter

Possibility to use multiple GHz bands with one antenna - 5th system RW3BP

RX feed horn in focus point of Antenna





In an offset dish, it is possible to shift at the focus the desired RX or TX feed without need of a waveguide relay. This is particularly useful in the case of 47/ 76 GHz EME where the 0,4dB of attenuation of the WG relay already plays a significant role. The same system can be used for simple switch between more bands!

With an offset dish, there is no danger of the flip-flop mechanism in the focus interfering with the radiation characteristics of the antenna and therefore reducing gain.

RW3BP system for 76 GHz EME from the
RW3BP's presentation at the Swedish EME Meeting Orebro 2017.

Possibility to use multiple GHz bands with one antenna - 6th OE2JOM's system

It's easy to change transverter at the dish focus - disadvantage is required counterweight and massive feed mount

Minimum power ratings and antennas recommended for serious DX microwave work (except EME)

Band	PWR at feed	dish Ø	note
1296 MHz	100 W	140cm	limit due to AP QSO
2320 MHz	50 W	120cm	limit due to AP QSO
3400 MHz	10 W	90cm	limit due to AP and RS QSO
5760 MHz	10 W	90cm	limit due to AP and RS QSO
10 GHz	5 W (better 10W+)	60cm	limit due to AP and RS QSO
24 GHz	1 W	48cm	limit due to attenuation of H_2O
47 GHz	10 mW	30cm	limit due to att of atmosphere
76 GHz	1 mW	30cm	limit due to att of atmosphere
122-134-241 GHz	0,5mW (?)	20cm or horn(!)	limit due to att of atmosphere, QSO for few km..

Recommended G4LDR's presentation: https://rsgb.org/main/blog/tonight-at-eight-archive/2021/02/01/1-february-starting-out-on-the-microwaves-bands-by-neil-underwood-g4ldr/

Work on microwaves during the year

- **Every 3rd Tuesday of the month NAC/IAC on 23cm and every 4th Tuesday on 13cm-up**
- **OK/OM Activity contests & DUR every 3rd Sunday of the month 8-11 UTC**
- **(CW/SSB) QSO opportunities in 24h Eu contests (not /R): 23cm >200 QSOs, 13cm >50 QSOs, 9cm >20 QSOs, 6cm >20 QSOs, 3cm >50 QSOs TR & >80 QSOs with RS, 24 GHz >10 QSOs, 47 & 76 GHz >10 QSOs, 122/134/241 GHz 1-5 QSOs**
- **Large contests during the year:**
  1st sub-regional in March - work mostly from the fireplace
  2nd sub-regional in May - high DL station activity
  Microwave Contest in June - high activity, frequent occurrence of RS
  RS ALPE ADRIA UHF Contest in June - frequent occurrence of RS
  Field Day - RS probability & stations around Balkan & fewer DL stations
  IARU UHF Contest in October - highest activity, higher chances for TR ducts
- **For frequencies 47 GHz and above, the best time of year is March and April when the air tends to be the driest. RS season starts in late April and ends in late August.**
- **The best time for long tropo condx with TR ducts is from September to the end of January.**

Questions?

Thank you for your attention