Microwave QSOs with the aid of airplane reflection

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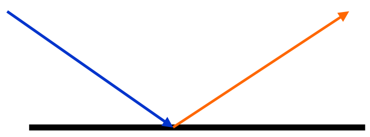
Content

- Some theory
- Observations on beacons
- Experience from QSOs
- Airplane tracking with ADS-B
- A propagation test
- Conclusion

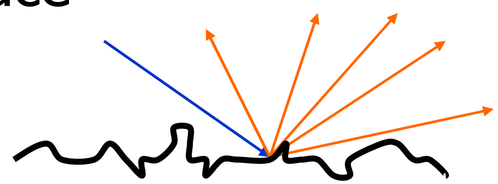
Reflection or scatter?

- Reflection:
  - like a mirror: angle of incidence = angle of reflection
  - reflective area must be:
    large - smooth - plane

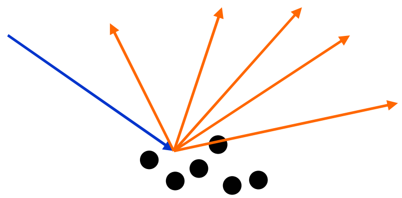


e. g. dish reflector

- Scatter:
  - mostly omnidirectional (with varying power density)
  - from either a rough surface
    or from a large number
    of small particles

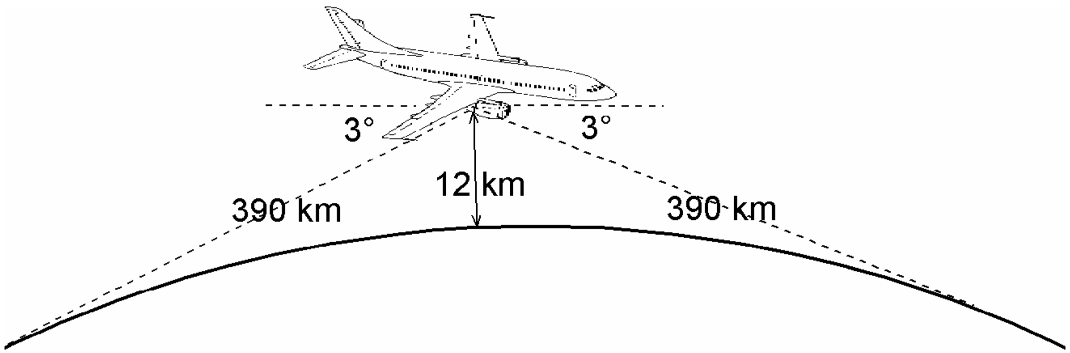


e. g. moon (EME)



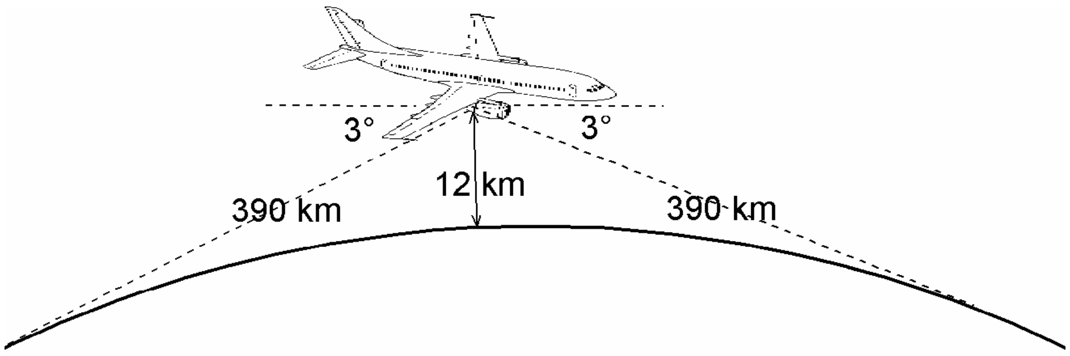
e. g. rain (RS)

Geometry of DX via airplane



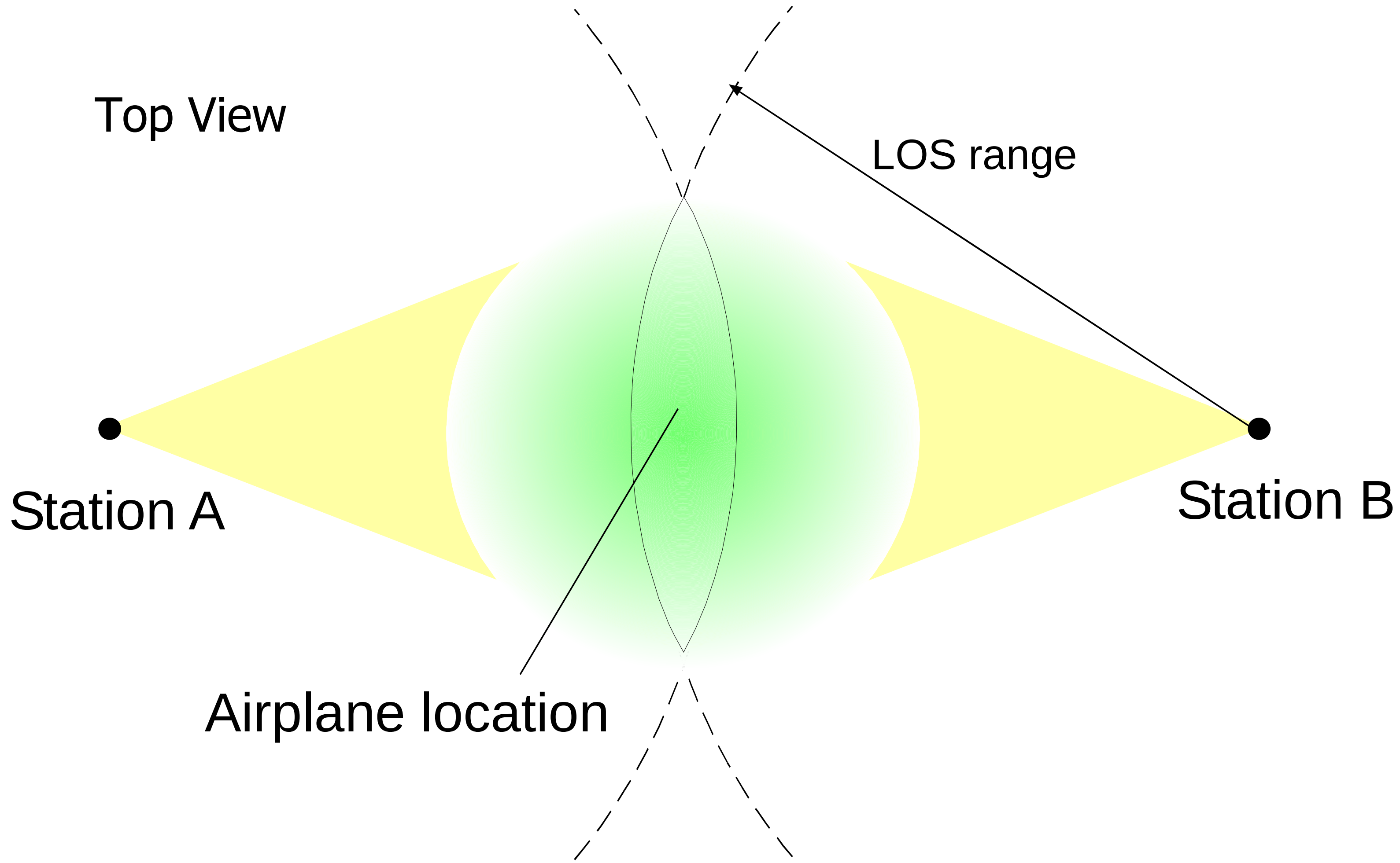
- Large passenger and freight airplanes use a height of FL300 - FL400 (30.000 - 40.000 ft)
- the airplane is close to the horizon for maximum range (very low elevation 0...1°)
- then the angle of incidence of the wave on the aircraft is around 3°

Maximum range via airplane



- Maximum range by airplane at FL400 at the right position and radio LOS path including refraction in the atmosphere is 1040 km
- Experimental limit on 1296 and 2320 is 800 km for good probability and duration (from DF9IC SK7MW 777 km easy, SM7ECM 809 km difficult)

Geometry of DX via airplane



Path attenuation

- Reflection:

$$\frac{a}{\mathrm{dB}} = 10 \cdot \lg \frac{(4\pi)^2 \cdot d_1^{\,2} \cdot d_2^{\,2}}{A^2} - \frac{g_{TX}}{\mathrm{dB}} - \frac{g_{RX}}{\mathrm{dB}}$$

- Scatter:

$$\frac{a}{\mathrm{dB}} = 10 \cdot \lg \frac{(4\pi)^3 \cdot d_1^{\,2} \cdot d_2^{\,2}}{\lambda^2 \cdot \sigma} - \frac{g_{TX}}{\mathrm{dB}} - \frac{g_{RX}}{\mathrm{dB}}$$

with A : effective reflective area
σ : radar cross section

- Example: $d_1 = d_2 = 390$ km, $f = 1296$ MHz, $g_{TX} = 32$ dBi, $P_{TX} = 51$ dBm, $g_{RX} = 24$ dBi, $P_{RX} = -130$ dBm

results in $A = 2.7\ \mathrm{m}^2$ $\sigma = 5000\ \mathrm{m}^2$

Duration and Doppler shift

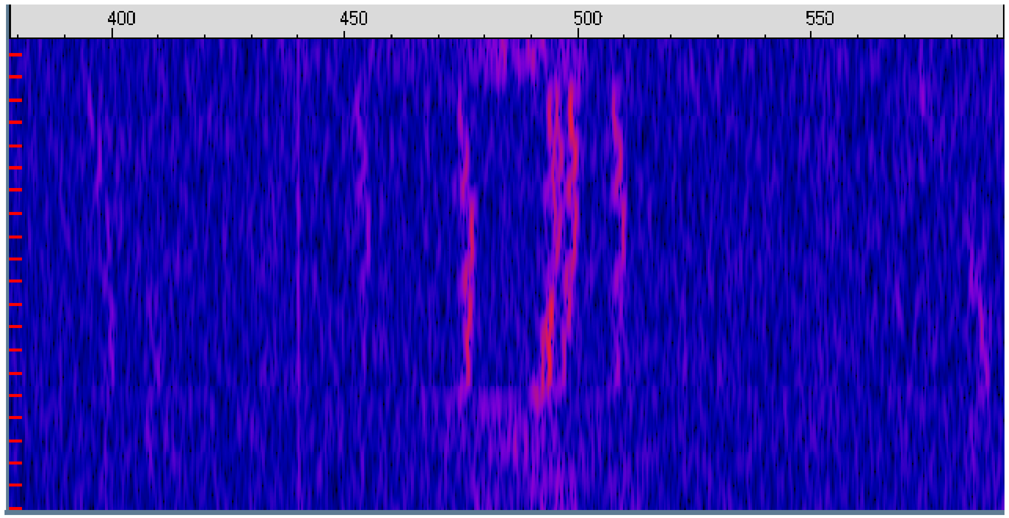
- Airplane speed = 900 km/h = 15 km/min
- typical duration of one reflection is between few seconds to few minutes
- Doppler shift occurs because of difference in aircraft speed perpendicular to both stations
- Different Doppler shifts from various airplanes allow to differentiate between them (only CW)

Which is the best frequency?

- Path attenuation is frequency independent
- Pro lower frequencies:
  - wide beamwidth of antennas
  - curvature of reflecting planes is less harmful
  - angle condition (incident = reflected) is less stringent
  - we use more TX power (but microwave will QRO in future)
- Pro higher frequencies:
  - more antenna gain
- Conclusion: we should try more on microwave!

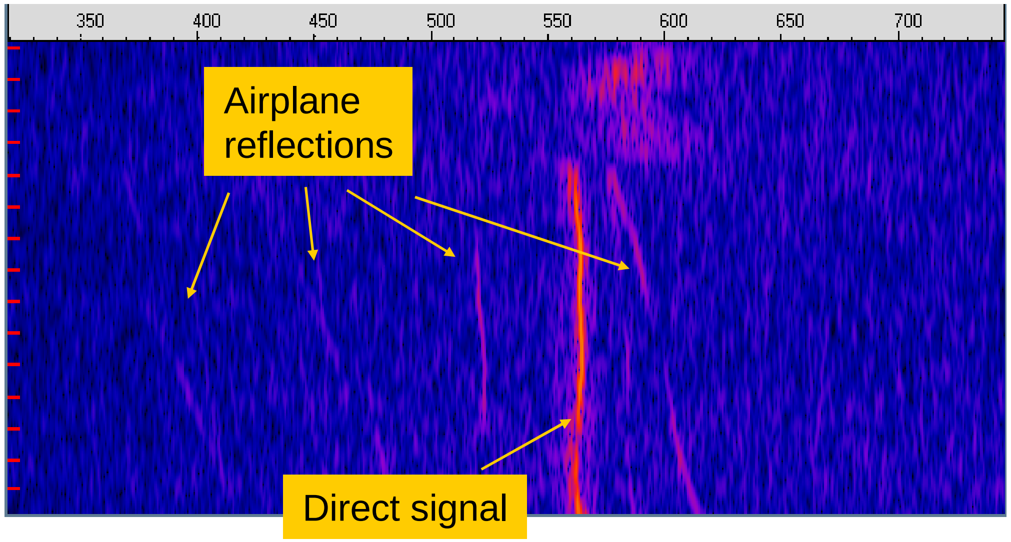
Observations on beacons

- Use of SPECTRAN or similar programs for audio analysis (spectrogram, waterfall display)
- Airplane reflection is Doppler-shifted; frequency depends on its speed relative to both stations
- Example:
  GB3MHL
  1296.830
  at DF9IC
  d = 630 km

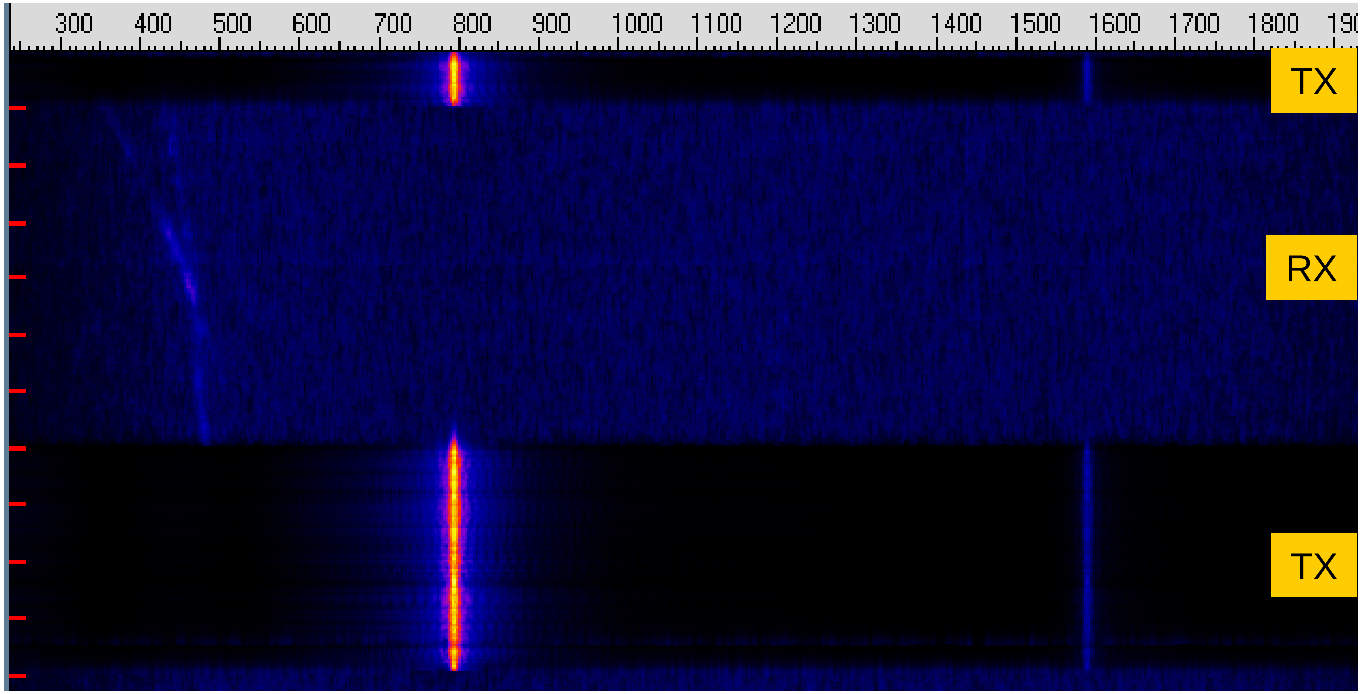


Observations on beacons

- Even on local signals you can often see airplane reflected spurs below the main signal
- Doppler shift changes fast when airplane is close to one of the stations
- Example:
  DB0KI
  1296.840
  at DF9IC
  d = 263 km

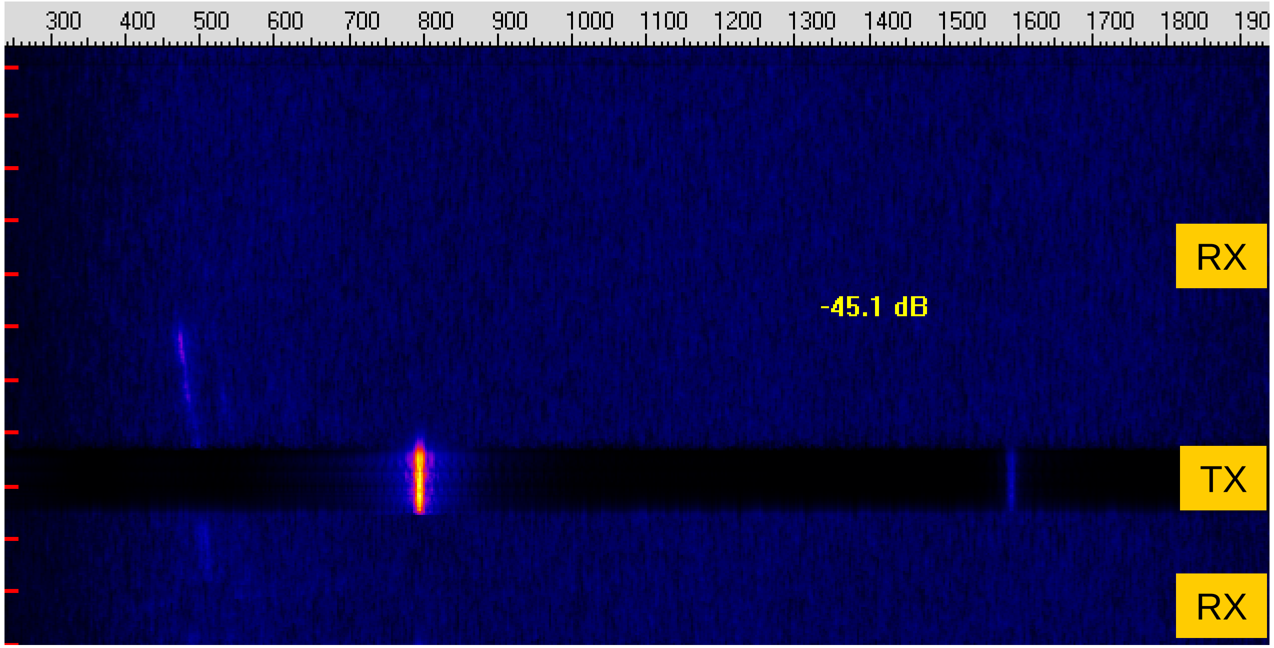


Experience from QSOs



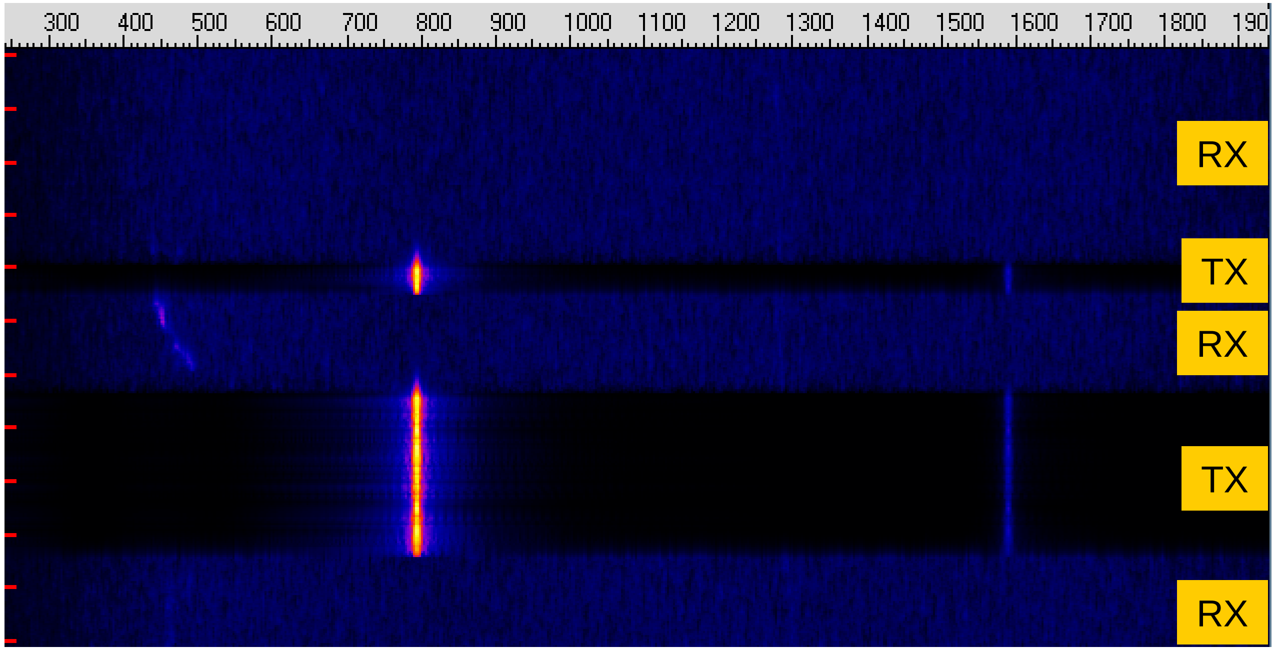
ON4IY 1296 MHz 750 mW 360 km recorded in NAC May 2006
(each red tick is 10 seconds): just readable in CW in the peak

Experience from QSOs



OZ2LD 1296 MHz 688 km recorded in NAC May 2006
(each red tick is 10 seconds): end of QSO

Experience from QSOs



DL7VTX 1296 MHz 528 km recorded in NAC May 2006
(each red tick is 10 seconds): end of QSO

Experience from QSOs

- Example: 23 cm NAC May 2006 DF9IC in JN48iw

17:41	DL1SUZ	559	579	JO53UN	555 km	Airplane
17:51	PA5DD	55	56	JO22IC	452 km	
17:54	PA3CEG	53	54	JO33FB	485 km	
18:00	OZ1FF	529	519	JO45BO	743 km	Airplane
18:05	SK7MW	53	55	JO65MJ	777 km	Airplane (?)
18:15	OZ9KY	519	519	JO45VX	787 km	Airplane
18:20	OZ2LD	529	559	JO54TU	688 km	Airplane
18:29	SM7ECM	519	519	JO65NQ	809 km	Airplane
18:32	DJ8MS	52	52	JO64AD	624 km	Airplane
18:39	DK3WG	549	569	JO72GI	560 km	Airplane
18:45	DK9TF	56	57	JO31NF	279 km	
18:46	DJ6JJ/p	549	539	JO31LG	288 km	
18:48	DL3YEE	54	57	JO42GE	362 km	
18:49	DL5YEE	54	57	JO42GF	366 km	
18:56	DB6NT	59	59	JO50TI	263 km	
19:07	G4EAT	529	529	JO01HR	653 km	Airplane
19:16	ON4IY	519	559	JO20IV	360 km	Airplane
20:18	G4HUP	55	55	JP02PC	632 km	Airplane
20:19	DG1KJG	57	57	JO30NT	237 km	
20:23	DB5KN	54	59	JO31NB	262 km	
20:30	G4BEL	54	54	JO02BI	715 km	Airplane (?)
20:59	DL7VTX	519	539	JO62TM	528 km	Airplane

Airplane tracking with ADS-B

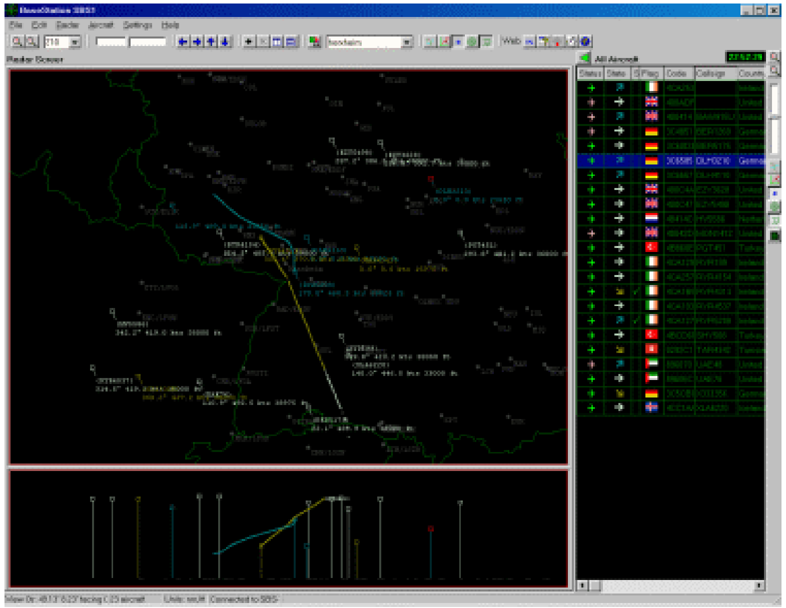
- Questions:
  - where are the airplanes now? (interesting)
  - when will an airplane be there where I need it? (even more interesting :-))))
- Solutions:
  - experience from former tests
  - flight plans, departure lists in the internet
  - real-time tracking of airplane positions

Airplane tracking with ADS-B

- ADS-B (automatic dependence surveillance - broadcast mode) is a data protocoll for the transmission of information about the status of airplanes
- ADS-B datagrams are transmitted by a growing number of airplanes on the transponder output frequency 1090 MHz with 1 Mbit/s in ASK
- information is not encrypted (!!), frame structure is known

Airplane tracking with ADS-B

- Since 2005 a non-professional ADS-B-RX is available from Kinetic Avionics (UK)

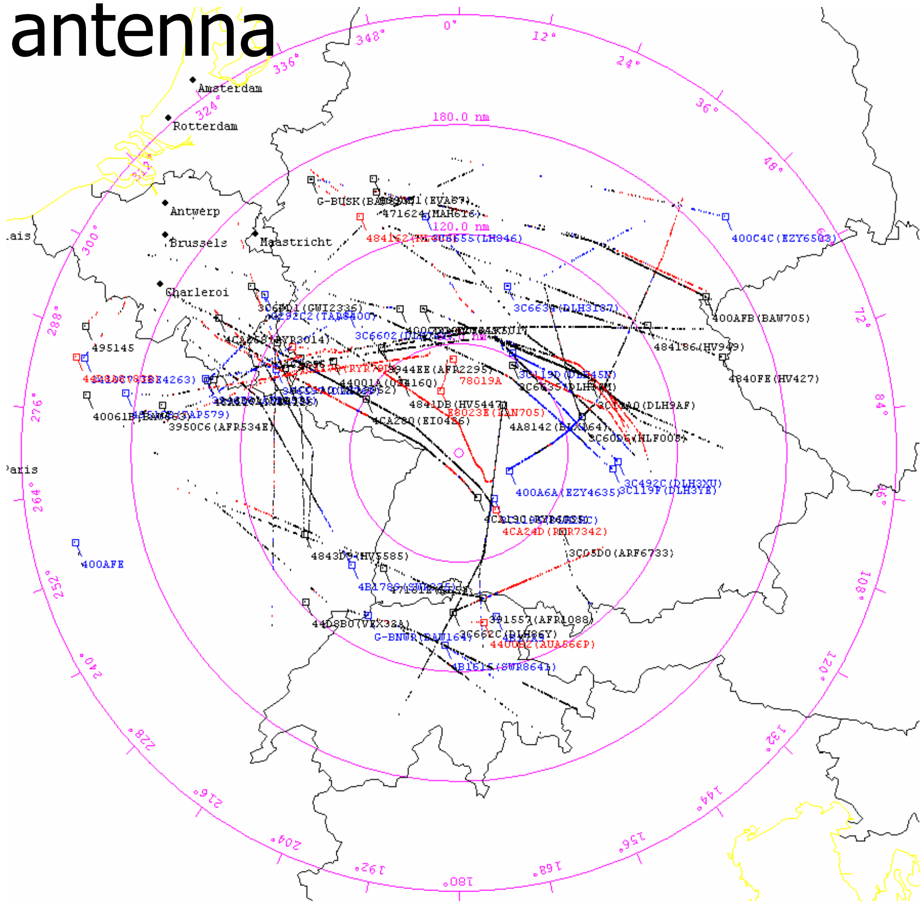


Airplane tracking with ADS-B

- The SBS-1 with base station software allows real-time tracking of ADS-B equipped airplanes (GPS position, speed, heading, etc.)
- About 50% of the big airplanes are equipped (2006)
- Data is visualized on a map
- Reception is limited to LOS
- But the 1090 channel is overloaded so distant airplanes are received only sparsly

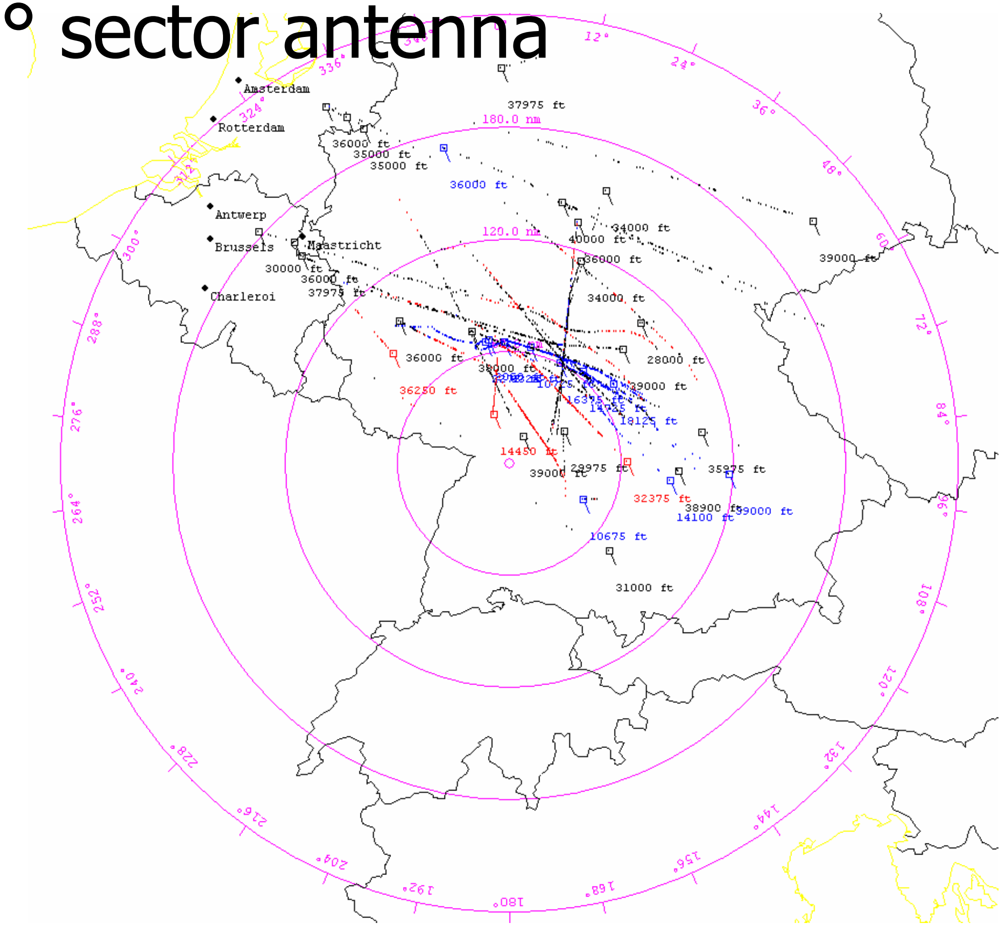
Airplane tracking with ADS-B

⌘Reception with omni antenna



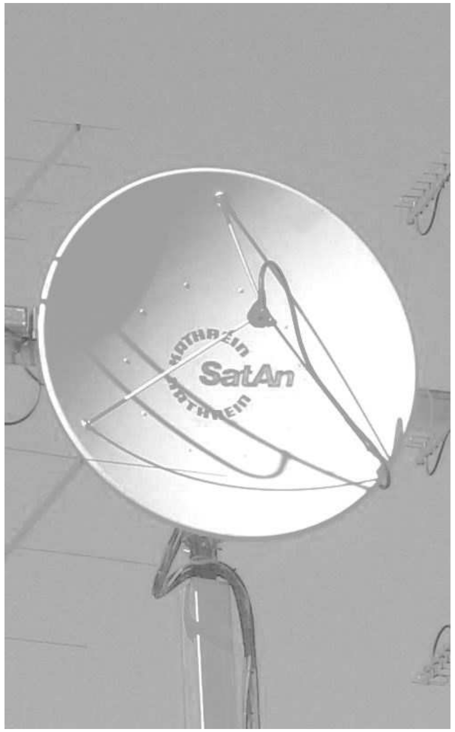
Airplane tracking with ADS-B

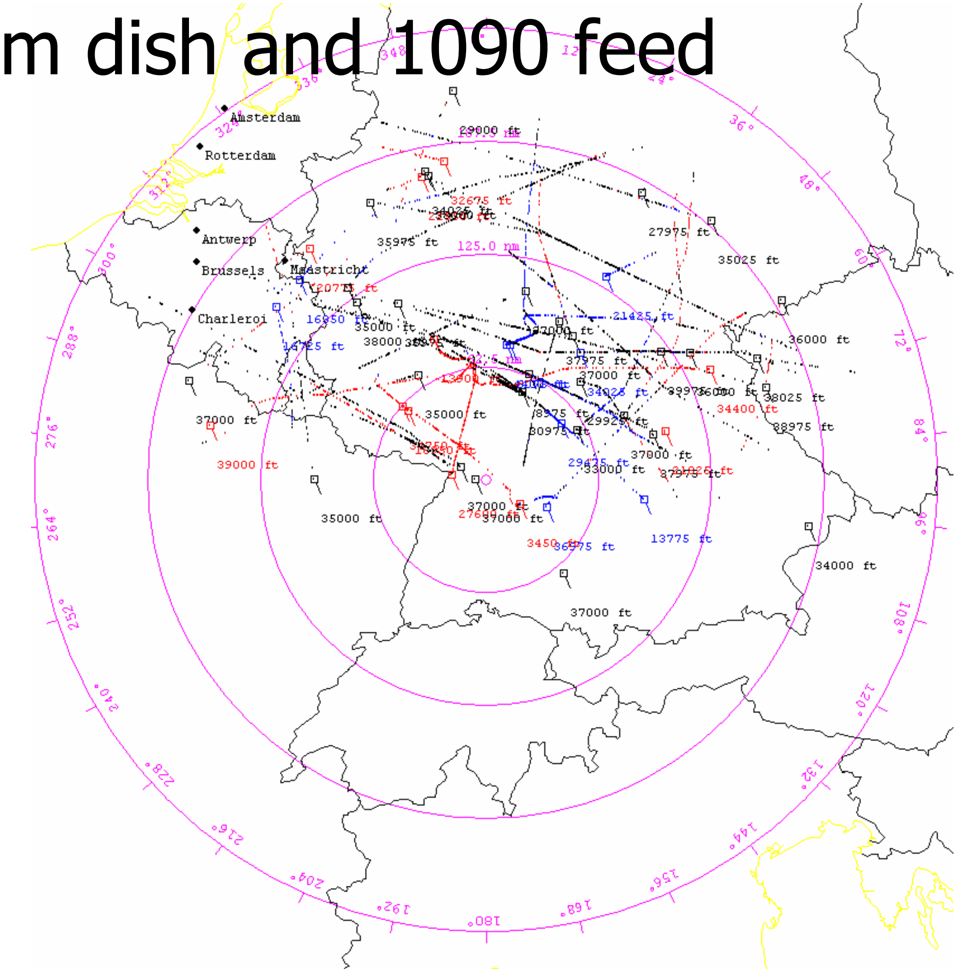
⌘ Reception with 120° sector antenna



Airplane tracking with ADS-B

- Reception with 1.2 m dish and 1090 feed





A propagation test on 1296 MHz

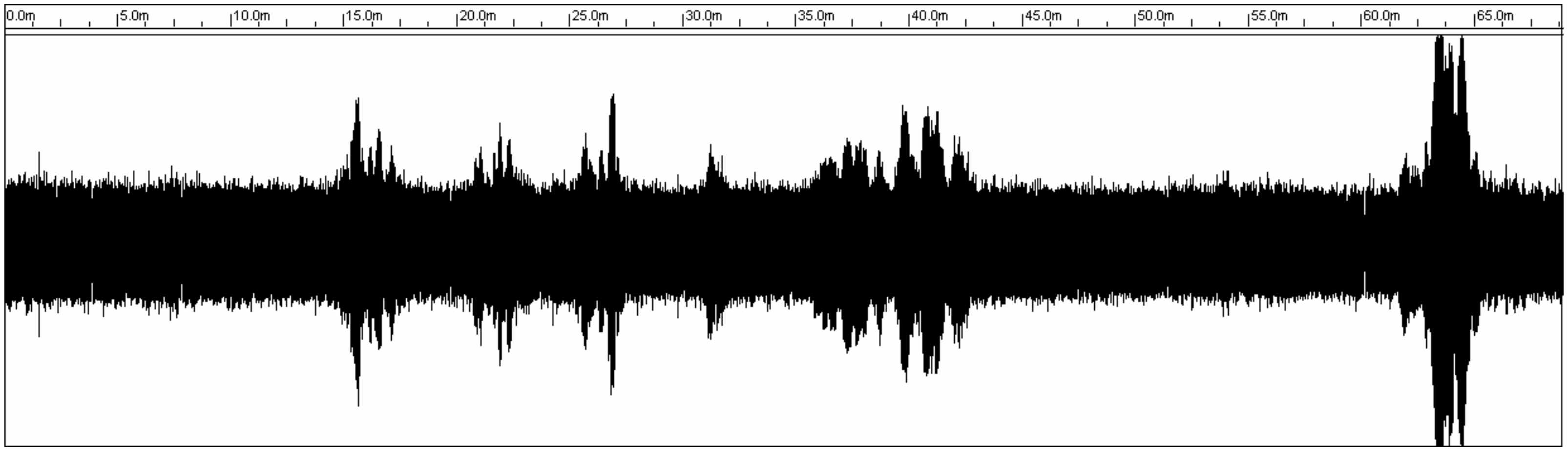
- On 23rd Oct. 2005 we did a test >1h between SK7MW and DF9IC on 1296 MHz (777 km)
- SK7MW transmits dots with 2x2C39 and 4.5 m dish

A propagation test on 1296 MHz

- DF9IC receives with 4x35 Ele Yagi and RX AGC off
- Airplanes were tracked at DF9IC on 1090 MHz with ADS-B RX on a 1.2 m dish

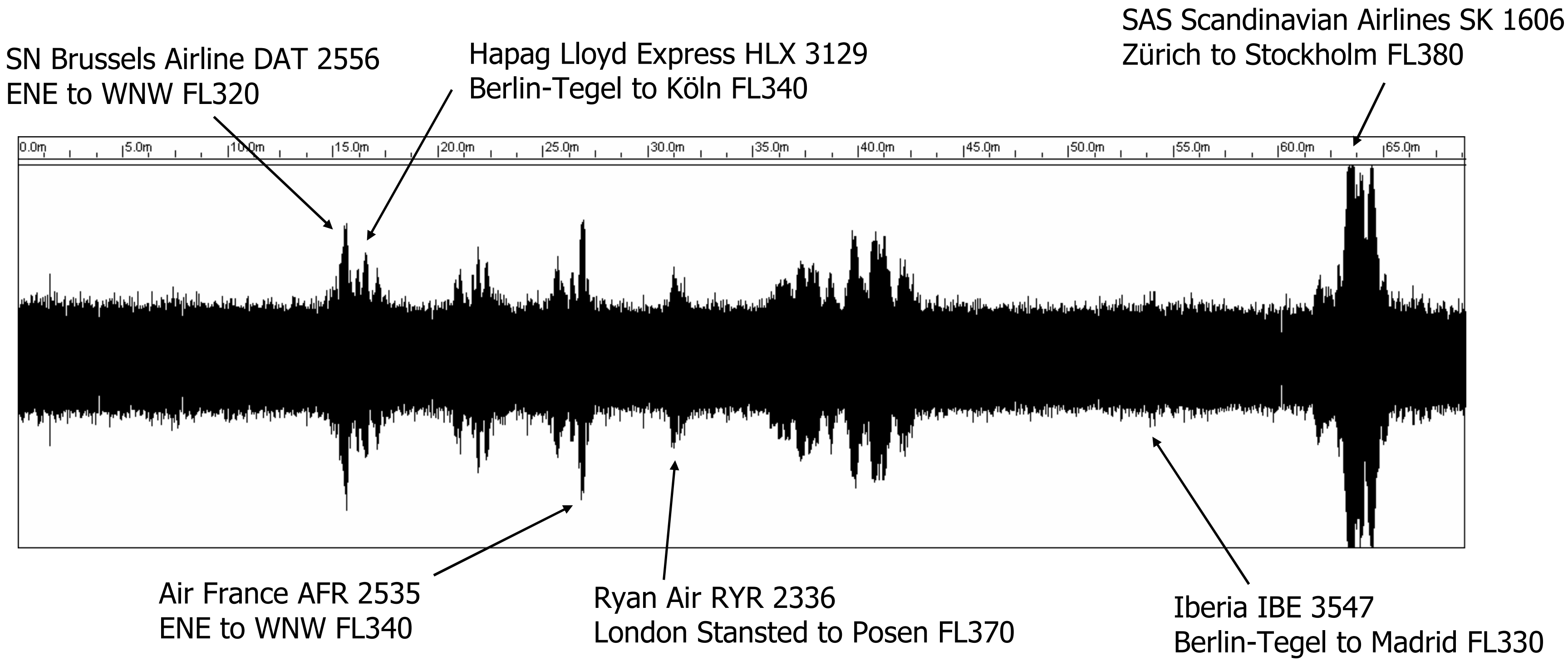
A propagation test on 1296 MHz

- During this time about 7 major airplane reflections could be observed
- Audio voltage from the RX with AGC off:

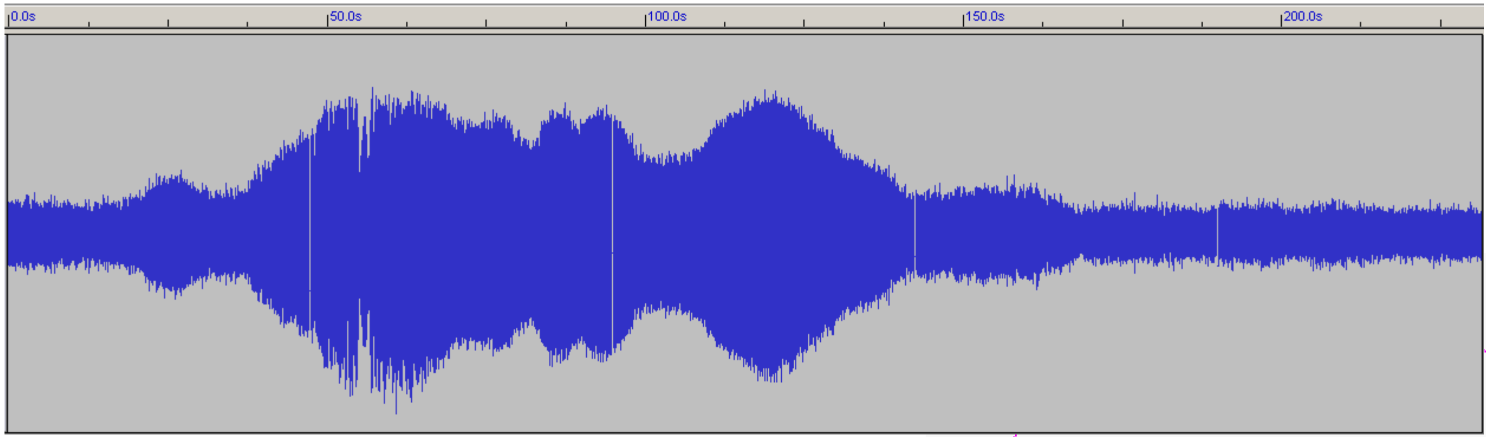


A propagation test on 1296 MHz

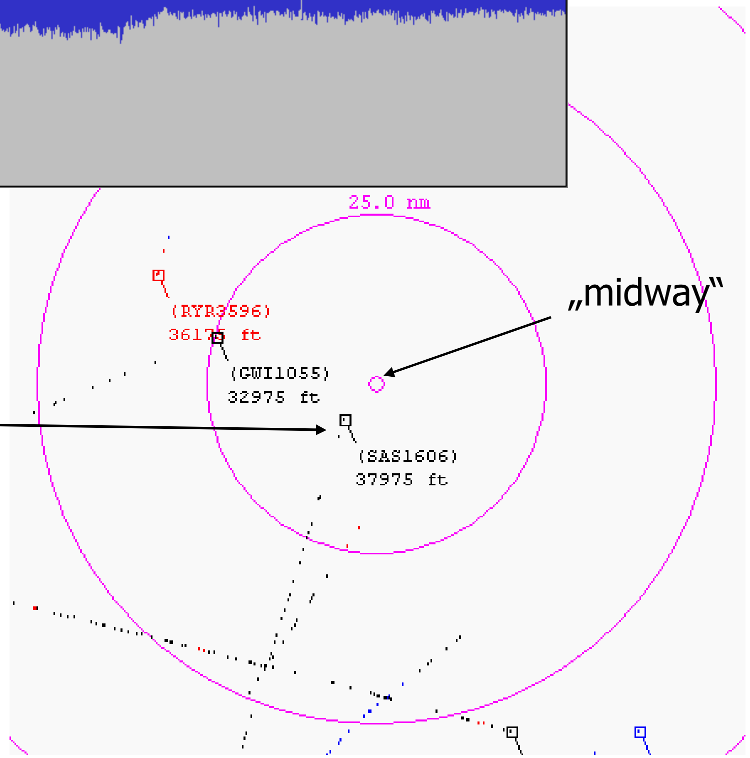
- Some reflections could be correlated with airplanes passing the „midway" area



A propagation test on 1296 MHz



- Best reflection from SAS SK 1606
- it was flying exactly along the radio path



2320 and 3400 MHz

- 2320 MHz:
  - multiple QSOs on this same path
  - DF9IC: 1.2 m dish -4 dB cable loss and 250 W
  - SK7MW: 1.8 m dish -1 dB cable loss and 250 W
- 3400 MHz:
  - only one test in the evening of May 3rd 2006
  - DF9IC: 1.2 m dish and 35 W
  - SK7MW: 1.8 m dish and 50 W
  - two good reflections of 1 min duration in a 40 min test, up to SSB signal strength

Conclusion

- QSOs by airplane need directive reflection, not scatter
- on 1296 MHz, 2320 MHz and 3400 MHz a range of 800 km is possible with good equipment
- we have to use short CQ and make QSO quickly
- airplanes along the radio path seem to be best
- ADS-B reception may allow an airplane forecast but needs a network of receiving stations
- How about 5.7 and 10 GHz with high power?