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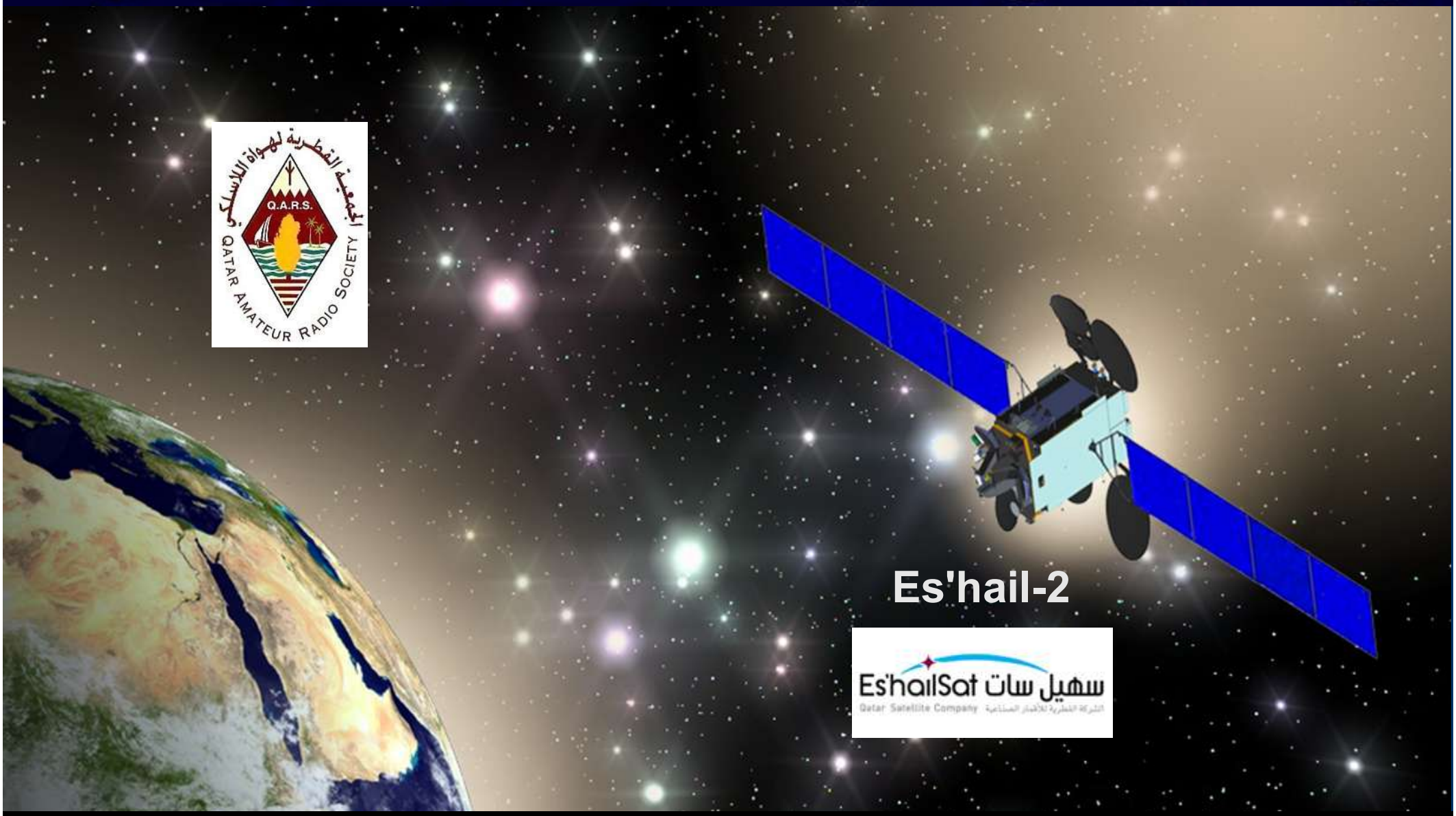
Satellites for Communication and Science
Satelliten für Kommunikation und Wissenschaft



Es'hail-2 (P4-A), the first geostationary OSCAR from Qatar

Peter Gülzow, DB2OS AMSAT-DL President with G3VZV updates!

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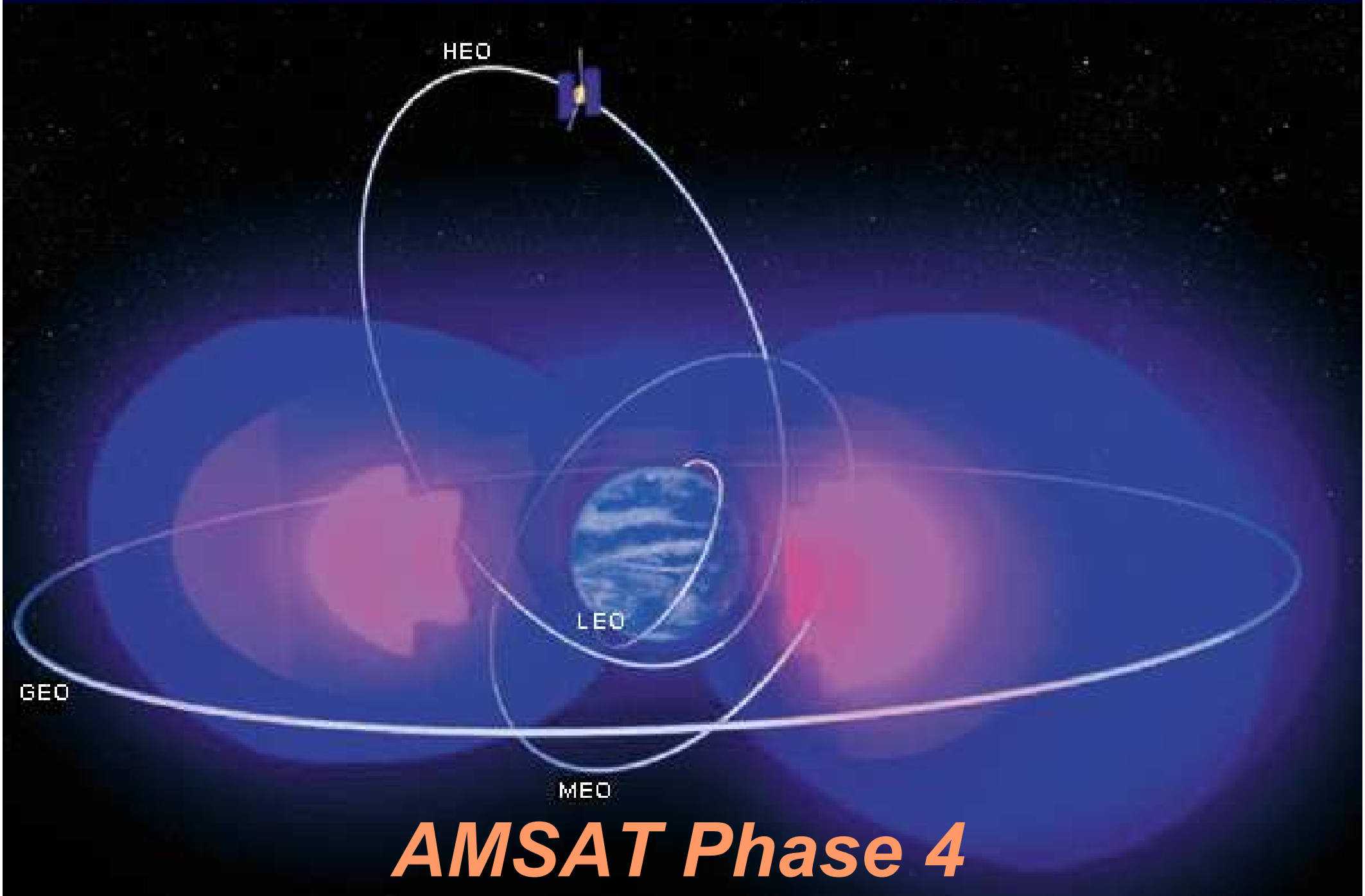

AMSAT Phase 4

AMSAT-DL

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Hosted Amateur Radio Payload (AMSAT P4-A):

- S-Band uplink / X-Band downlink
- TWO Linear transponder s(all modes)
- 15 years lifetime

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الجمعية القطرية لهواة اللاسلكي

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Timeline

- **Dec 2012:** Invitation of Peter Gülzow DB2OS to International Amateur Radio Festival in Qatar by QARS
- **February 2013:** QARS and Es'hailSat Qatar Satellite Company made agreement. AMSAT-DL to start technical discussions with Es'hailSat.
- **March 2013:** First teleconference DB2OS with Es'hailSat and start of discussions.. ***the idea to place an AMSAT payload on Es'hail-2 into GEO was born***.
- **June 2013:** first Meeting with Es'hailSat at Paris Airshow in Le Bourget to start discussion with potential Satellite Manufacturers.
- **August 2013**: final preparation of RFQ including AMSAT part
- **October 2013:** Meeting in Doha including AMSAT-DL, AMSAT-OH and AMSAT-UK experts. Ongoing to prepare and finalize specification and requirements.
- **March 2014:** RFP issued
- **September 2014:** MELCO was selected to build Es'hail-2 satellite
- **November 2014:** Technical Presentation and Discussion with MELCO in Japan.
- **May 2015:** CDR at MELCO in Japan
- **September 2015:** RFD for Test, Groundstation discussions etc.
- **June 2016:** Meeting in Doha, AMSAT-DL groundstation part.

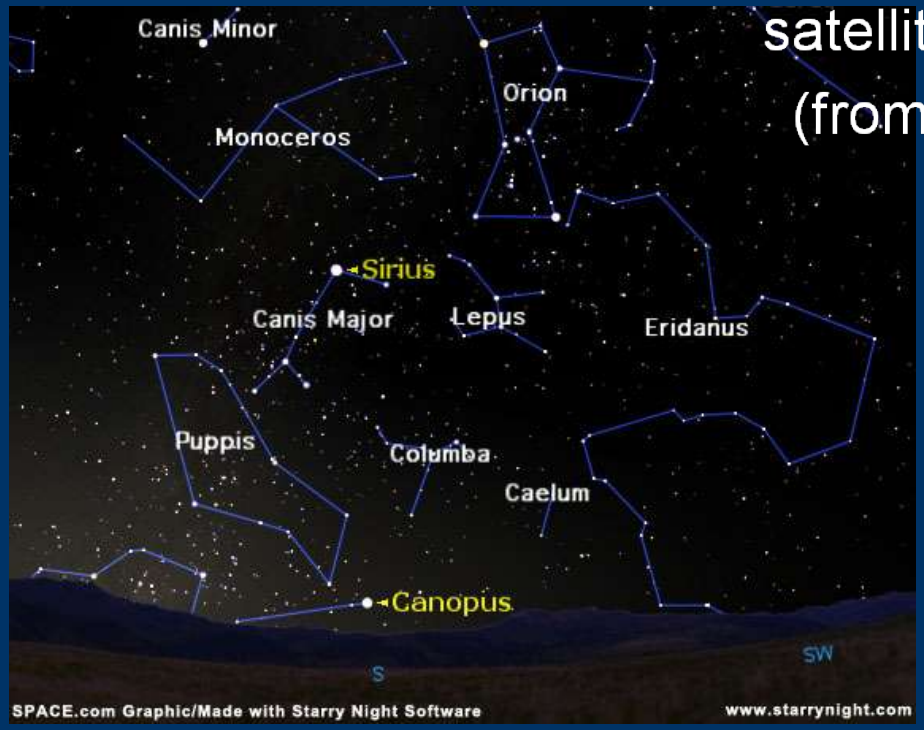
H E Abdullah bin Hamad Al Attiyah, Chairman of the Administrative Control and Transparency Authority, who is also the Chairman of the Qatar Amateur Radio Society (QARS) during the Qatar international amateur radio festival in December 2012.

SpaceX launch schedule

- 2016
  - JCSAT-16
  - FORMOSAT 5 & Sherpa
  - ECHOSTAR-23
  - AMOS-6
  - Iridium Next 1-10
  - SES 10
  - SES 11/EchoStar 105
  - CRS-10
  - Falcon Heavy Demo
  - Koreasat-5A
  - Iridium Next 11-20
- 2017
  - ??Q3?? : **Es'hail-2**

The meaning of "Es'hail"

"The story behind the name Es'hail (Canopus) is the name of a star which becomes visible in the night sky of the Middle East as summer turns to autumn. Traditionally, the sighting of Es'hail brings happiness as it means that winter is coming and that good weather will soon be with us.
We hope that the arrival of Es'hailSat will equally be beneficial for the satellite community."
(from Es'hailSat: *Follow the star*)



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Earth Coverage

Es'hail-2

Es'hailSat سهيل سات
Qatar Satellite Company الشركة القطرية للأقمار الصناعية

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Satellites for Communication and Science
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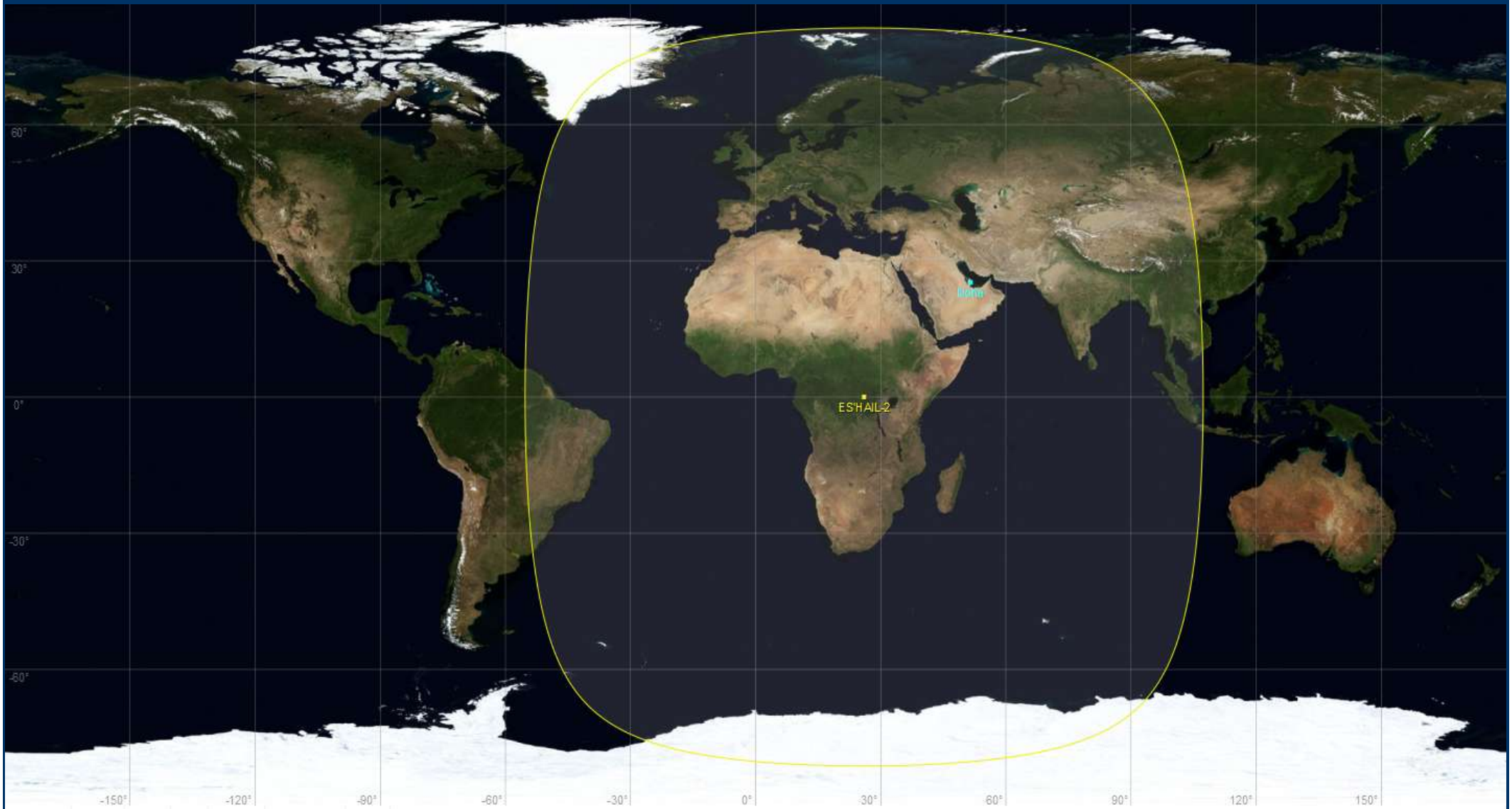
Earth Coverage Es'hail-2



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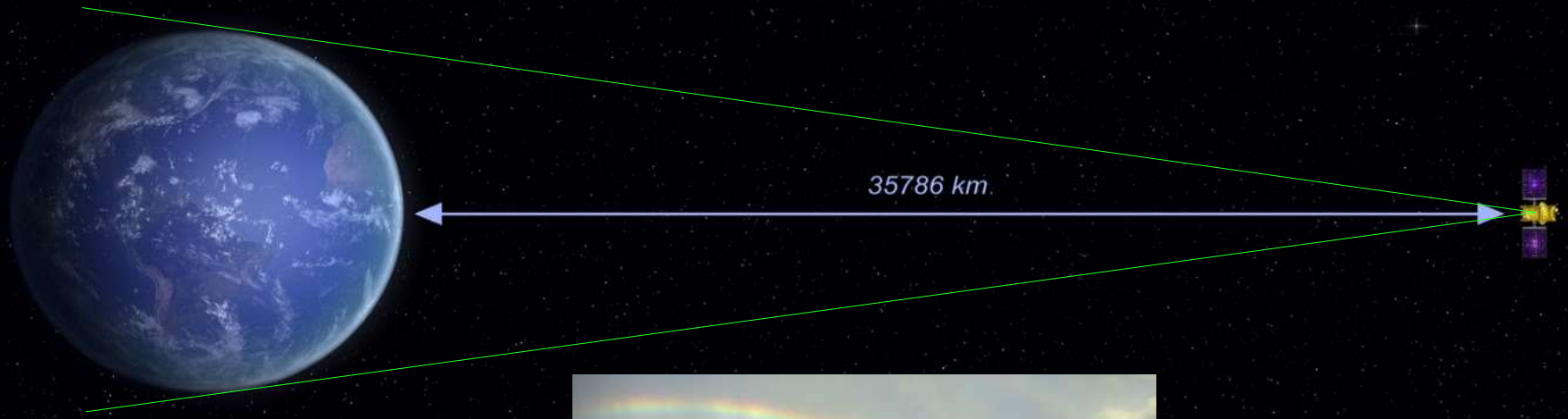
-3dB Beamwidth = 17.4° → ~20dB Antenna Gain !!



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Bochum

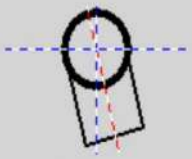
Your location:

Latitude:
51.48° N (51° 28' 47")

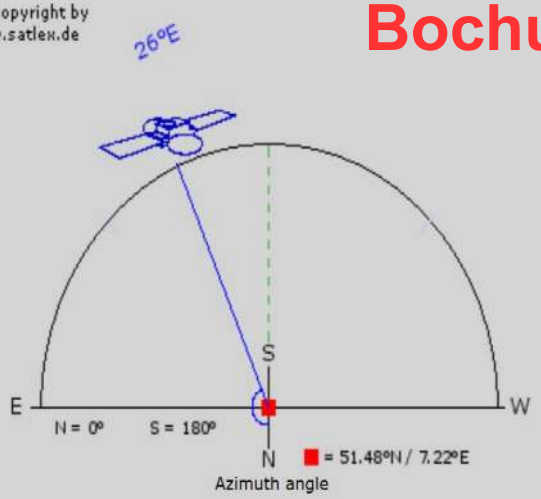
Longitude:
7.22° E (7° 13' 11")

City:
Bochum

Country:
Germany



LNB tilt (Skew)



Azimuth angle

Following values have been calculated for your location:

Azimuth angle:
156.51° *(True North)*

Elevation angle:
28.55°

LNB tilt (Skew):
-14.37°

Offset angle:
20.36°

Distance to satellite:
38747.37 Km

Signal delay:
258.32 ms *(Uplink + Downlink)*

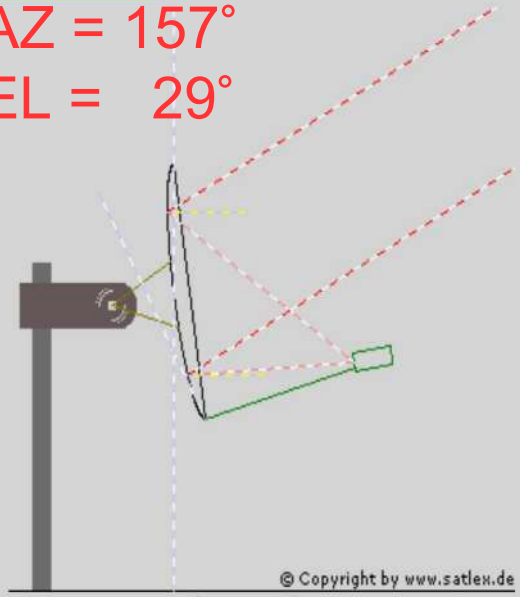
Declination angle:
-7.34°

Polarmount hour angle:
159.33°

Angle setting on motor:
20.67° East

Satellite:
Badr 4/5/6 (26° E = 334° W)

AZ = 157°
EL = 29°



Elevation angle

Doha

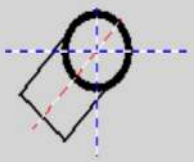
Your location:

Latitude:
25.25° N (25° 15' 0")

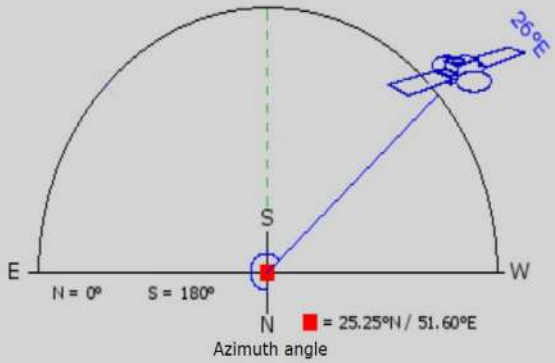
Longitude:
51.60° E (51° 36' 0")

City:
Doha

Country:
Qatar



LNB tilt (Skew)



Azimuth angle

Following values have been calculated for your location:

Azimuth angle:
228.32° *(True North)*

Elevation angle:
48.98°

LNB tilt (Skew):
42.49°

Offset angle:
20.36°

Distance to satellite:
37145.43 Km

Signal delay:
247.64 ms *(Uplink + Downlink)*

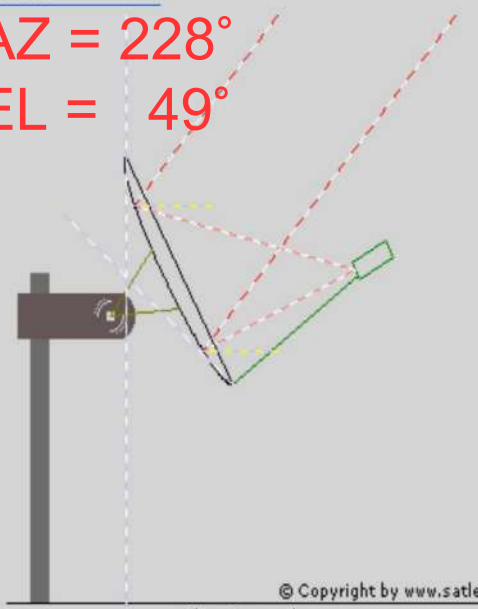
Declination angle:
-4.18°

Polarmount hour angle:
209.44°

Angle setting on motor:
29.44° West

Satellite:
Badr 4/5/6 (26° E = 334° W)

AZ = 228°
EL = 49°



Elevation angle

Rio de Janeiro

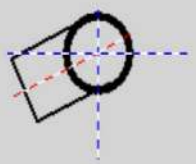
Your location:

Latitude:
-22.90° N (22° 53' 59")

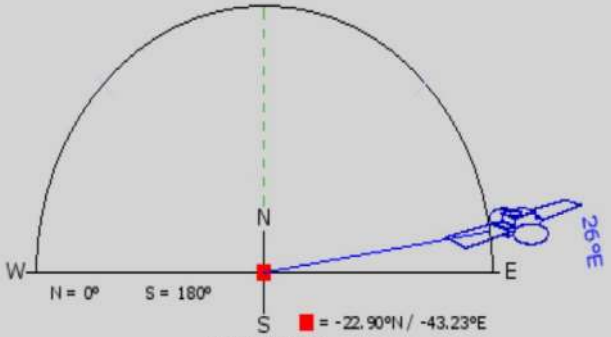
Longitude:
-43.23° E (43° 13' 47")

City:
Rio De Janeiro

Country:
Brazil



LNB tilt (Skew)



Azimuth angle

Following values have been calculated for your location:

Azimuth angle:
81.60° *(True North)*

AZ = 82°

Elevation angle:
10.61°

EL = 11°

LNB tilt (Skew):
65.69°

Offset angle:
20.36°

Distance to satellite:
40531.41 Km

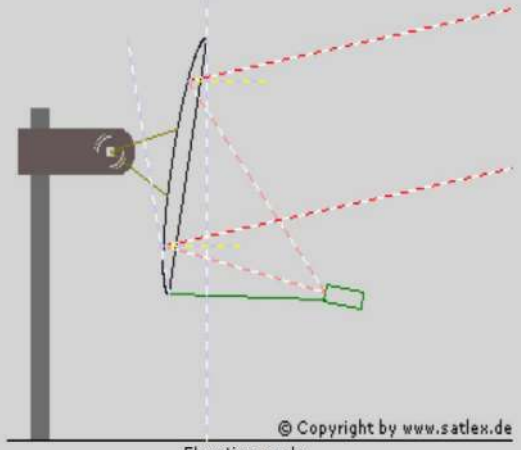
Signal delay:
270.21 ms *(Uplink + Downlink)*

Declination angle:
3.48°

Polarmount hour angle:
76.94°

Angle setting on motor:
103.06° East

Satellite:
Badr 4/5/6 (26° E = 334° W)



Elevation angle

Penang

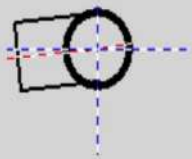
Your location:

Latitude:
5.50° N (5° 30' 0")

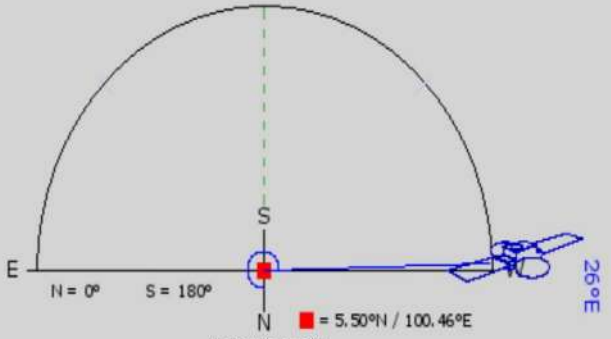
Longitude:
100.46° E (100° 27' 35")

City:
Pinang

Country:
Malaysia



LNB tilt (Skew)



Azimuth angle

Following values have been calculated for your location:

Azimuth angle:
268.47° *(True North)*

AZ = 268°

Elevation angle:
6.95°

EL = 7°

LNB tilt (Skew):
84.29°

Offset angle:
20.36°

Distance to satellite:
40927.52 Km

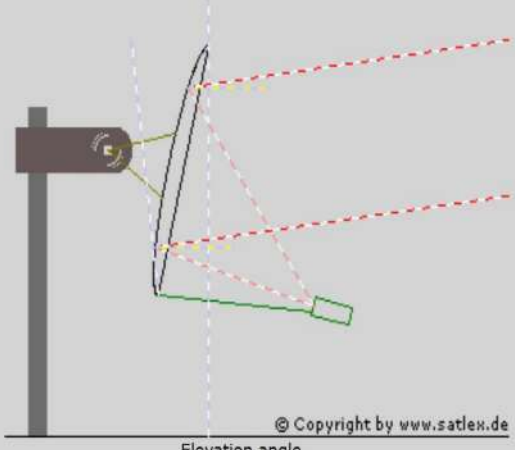
Signal delay:
272.85 ms *(Uplink + Downlink)*

Declination angle:
-0.85°

Polarmount hour angle:
262.93°

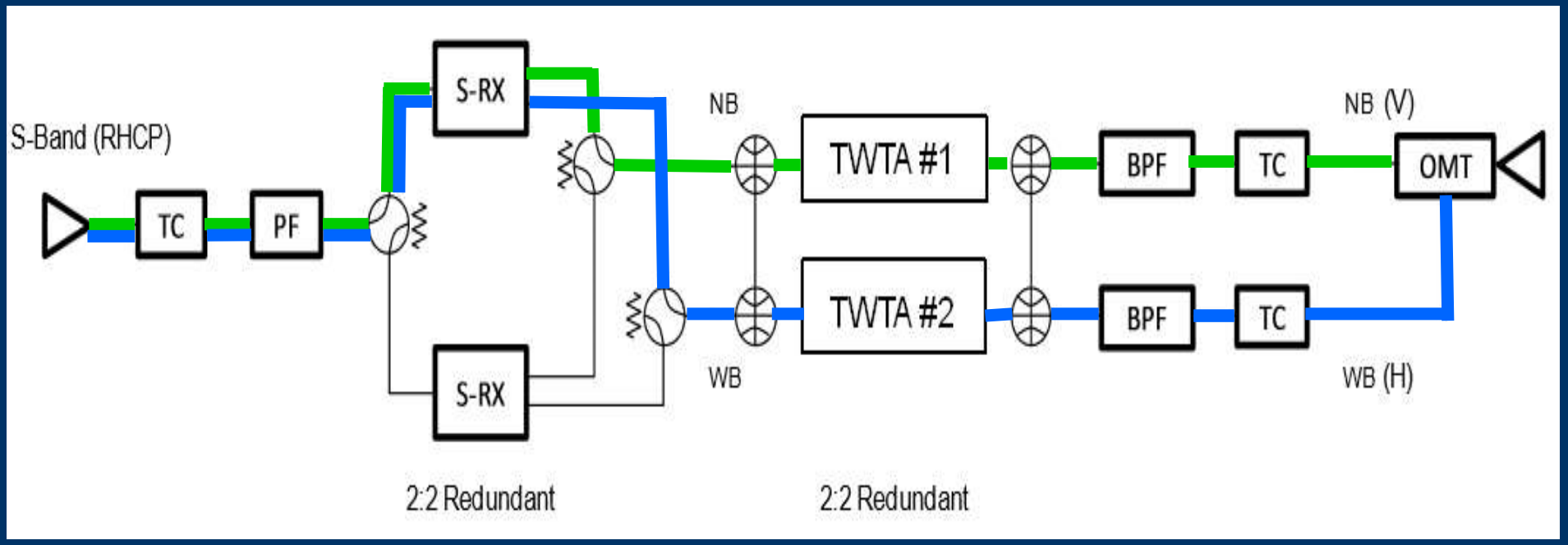
Angle setting on motor:
82.93° West

Satellite:
Badr 4/5/6 (26° E = 334° W)



Elevation angle

AMSAT Payload Block Diagram



"NB" Transponder (narrow band)

Linear Transponder for low power narrow bandwidth voice, morse and digital communication

- preferred modes: narrow band modes like SSB and CW, PSK

- 250 kHz allocated bandwidth

- non-inverting bent-pipe transponder

- Assumes 50 simultaneous 2-way carriers to serve 100 Users

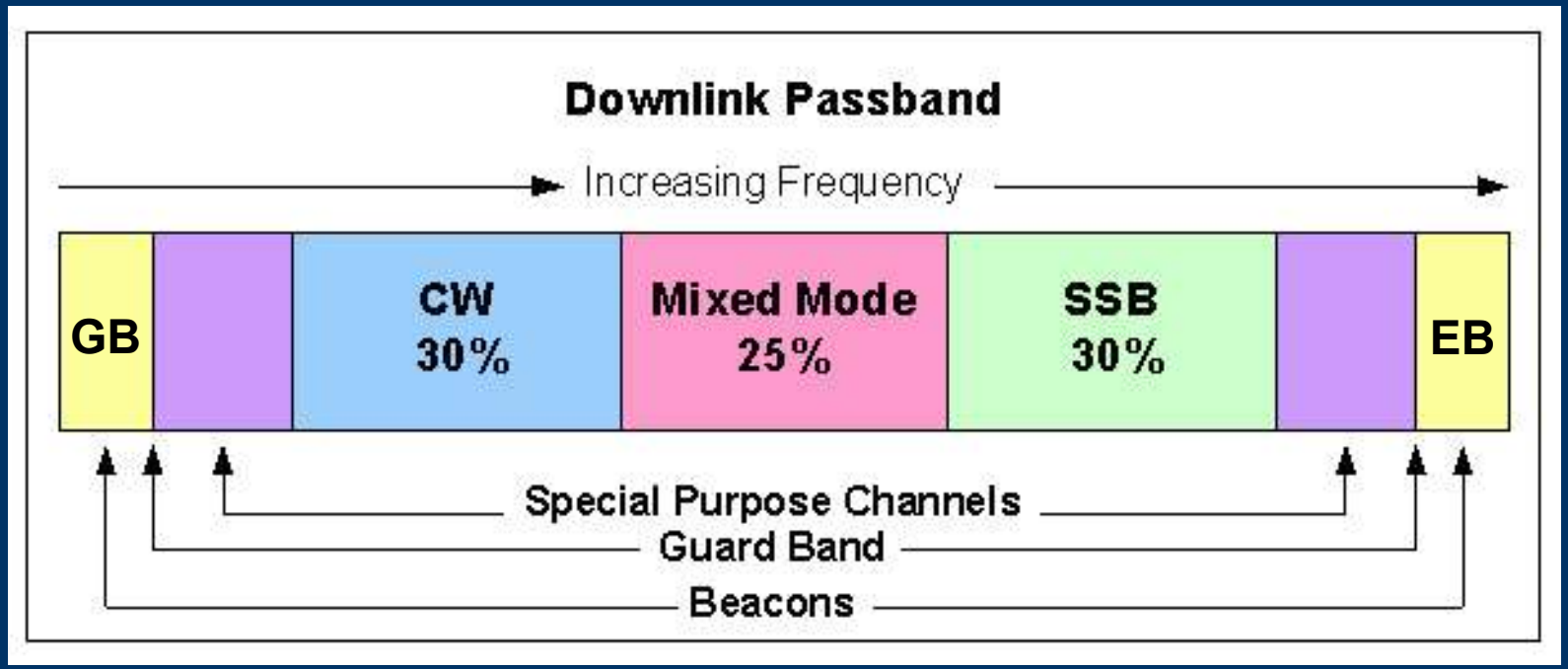
- X-Band Downlink (SAT-TV dish):
  - 90 cm dishes in rainy areas at EOC like Brazil or Thailand
  - 60 cm around around coverage peak
  - 75 cm dishes at peak -2dB

- Downlink Polarisation on X-Band is Vertical !

- Uplink Polarisation on S-Band is RHCP
- Uplink transmitter 5-10W PEP (22.5 dBi antenna gain, 75cm dish)

"NB" Transponder band planning

- proposal (t.b.d)
- no transmission below GB allowed !
- no transmission above EB allowed !



GB = General Beacon (pseudo beacon)
EB = Engineering Beacon (pseudo beacon)

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"WB" Transponder (wide band)

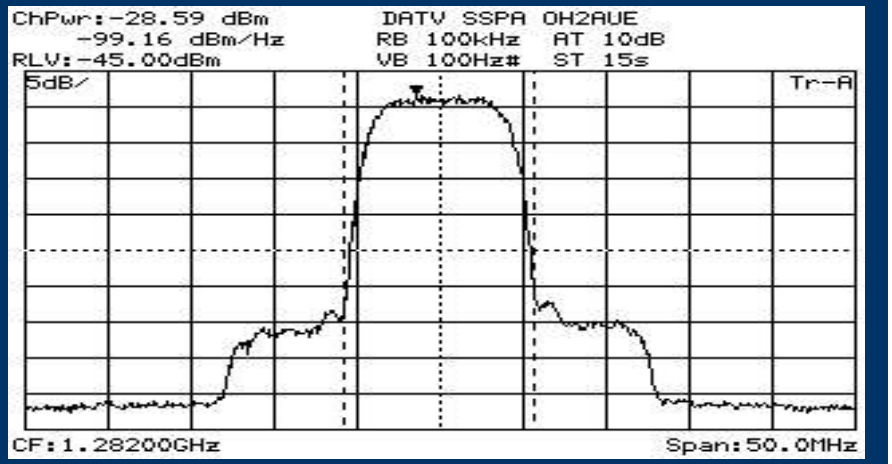
Linear Transponder for Digital Amateur Television (DATV) and other highspeed data transmissions.

- **First DATV transponder in space!!**

- with 8 MHz bandwidth one or two DVB-S2 carrier in HD quality will be possible
- in SD or lower quality more channels possible

- Assumes S-Band Uplink peak EIRP of 53 dBW (100W PEP into 2.4m dish)

- X-Band Downlink (SAT-TV dish):
  - 90 cm dishes in rainy areas at EOC like Brazil or Thailand
  - 60 cm around around coverage peak
  - 75 cm dishes at peak -2dB



- Uplink Polarisation on S-Band is RHCP
- Downlink Polarisation on X-Band is Horizontal !

- DVB-S2 "beacon" from Qatar is planned with Live WebCam and promotional videos for Ham radio activities.

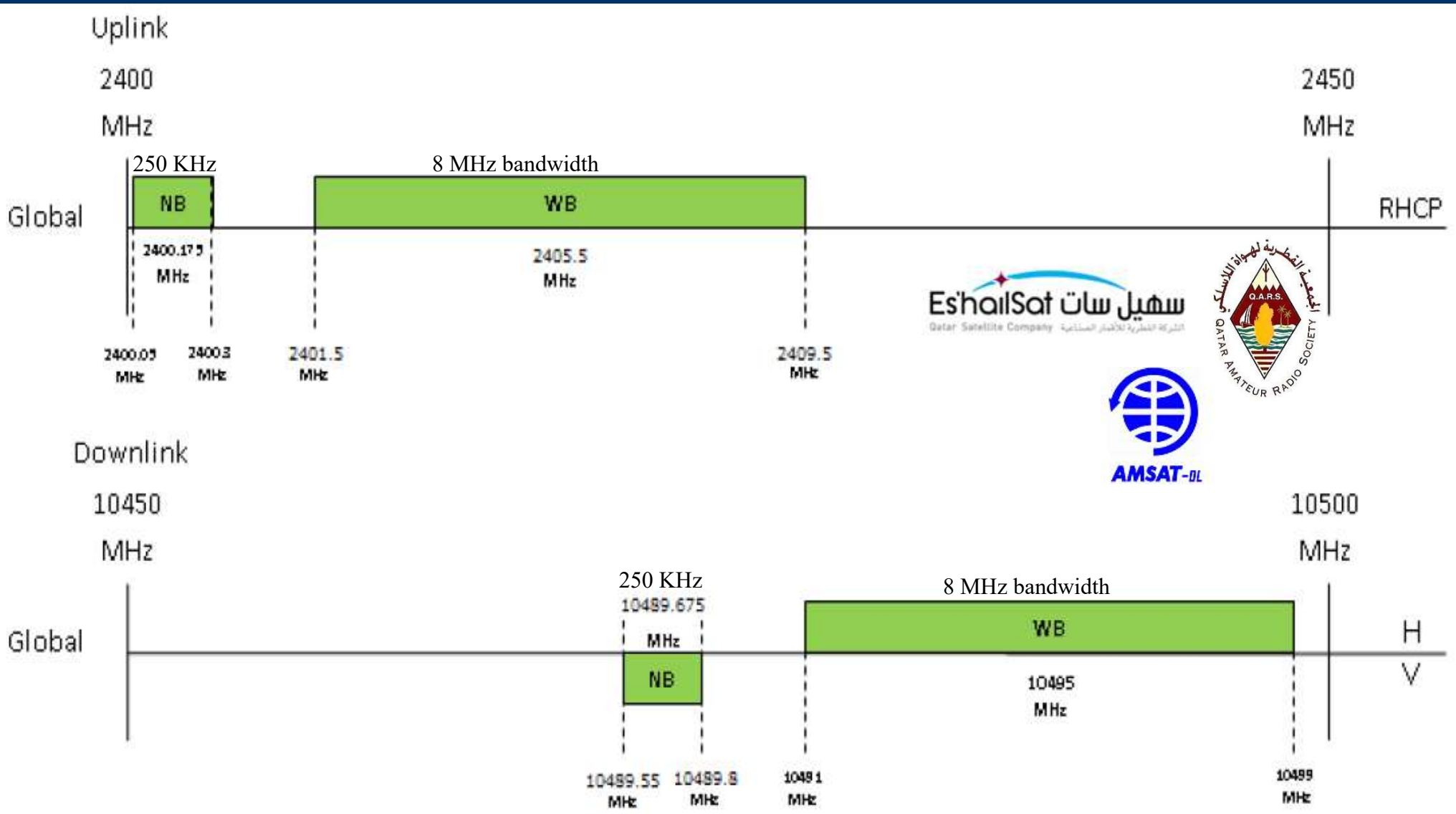
Target user stations

Setup for **SSB** communications:

RX Antenna	60-90 cm SAT-TV dish
Receiver	LNB with power injector and DVB-T dongle + SDR software (for example SDR#) OR 3 cm LNA with downconverter to 70cm
Transmitter	10W PEP in 60-90 cm dish plus upconverter from 144 MHz

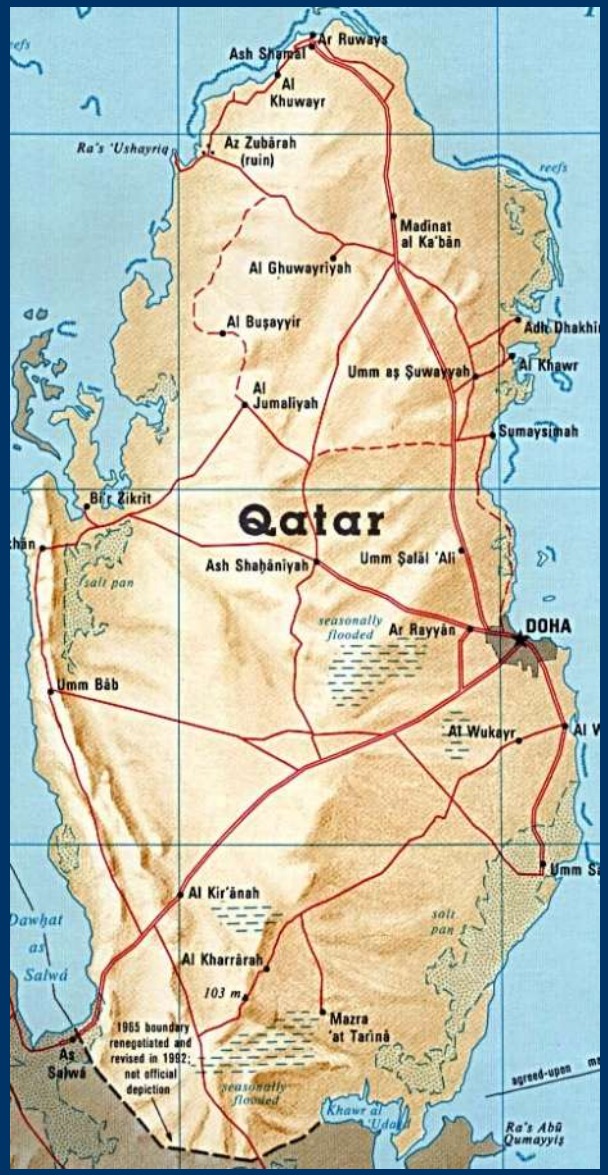
Setup for **DATV** (DVB-S2) communications:

RX Antenna	60-90 cm SAT-TV dish
Receiver	modified LNB with standard satellite receiver box (DVB-S2) OR modified LNB with PCI DVB-S2 cards for PC use
Transmitter	100W PEP in 2.4m dish plus DVB-S2 modulator



Xpdr	U/L FREQUENCY (MHz)				D/L FREQUENCY (MHz)				LO	BW
No	Pol	Begin	Center	End	Pol	Begin	Center	End	(MHz)	(MHz)
NB	RHCP	2400.05	2400.175	2400.3	V	10489.55	10489.675	10489.8	8089.5	0.25
WB	RHCP	2401.5	2405.5	2409.5	H	10491	10495	10499	8089.5	8

Es'hailSat Satellite Control Center



Es'hail-2 SCC

. Location of AMSAT transponder ground segment is close to Es'hailSat Satellite Control Center (SCC) near Doha in 'shelter' close to main Es'Hail 2 SCC uplink/downlink antennas

. CONOPS -unattended but remote access to tweak LEILA-2 parameters should be possible.

. Includes a dedicated 2.4 Meter Uplink antenna for AMSAT on S-Band

. In-Orbit-Verification and Monitoring of the AMSAT transponder with FFT passband (NB+WB) displays for quick assessment of usage

.On NB ONLY LEILA-2 (LEIstungs Limit Anzeige) will analyse passband of NB transponder and send Marker tones on all stations which use too much uplink power.

.On NB ONLY LEILA-2 will generate pseudobeacon(s) and add them to the uplink signal (400 Bit/s PSK Telemetry with FEC). Telemetry will be derived from Es'hail-2 telementry.

. SCC will inlcude a hamradio shack equipped with SSB equipment for Voice and DVB-S equipment for DATV transmissions directly from Doha.

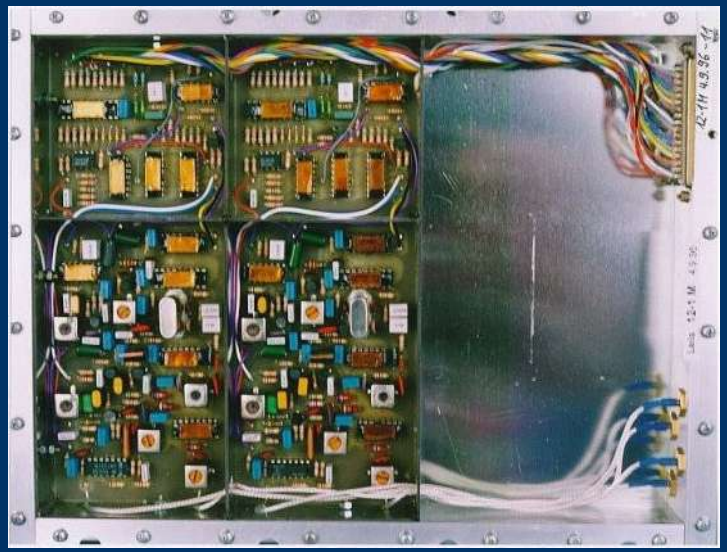
. Backup station for LEILA will be located in Bochum at AMSAT-DL HQ

LEILA on OSCAR-40 (P3-D)

- LEILA is an german acronym for "LEIstungs Limit Anzeige", which means: Power Limit Indicator.

- The original concept of an hybrid analog/digital LEILA on AO-40 was developed by Dr. Karl Meinzer DJ4ZC and Dr. Matjaz Vidmar S53MV. It was the first time that such a system was used as part of an transponder with ***uncoordinated multiple access***. LEILA was also supported by the German Ministry of Science and Technology.

- Analog IF processor with
- tunable notch filter
- Jam signal source (siren)
- part of the 10.7MHz IF matrix



NB ONLY Pseudobeacon

- AMSAT-DL will transmit beacon signals to provide users a signal reference (frequency and level)
- Pseudobeacon: beacon generated on ground, not inside spacecraft
- Proposal to use flight-proven Phase 3, 400 bit/s BPSK telemetry with FEC
- Pseudobeacons at both ends of the Passband (transmissions outside these limits are not permitted)

LEILA-2 for Es'hail-2

- this LEILA system is ***ground-based !!***

- No notch filter in transponder possible
- Only on siren marker (sufficient if operators work full duplex)

- Use down-/upconverters with DSP on IF

- Currently prototype (BBM level) based on the Red Pitaya board

redpitaya

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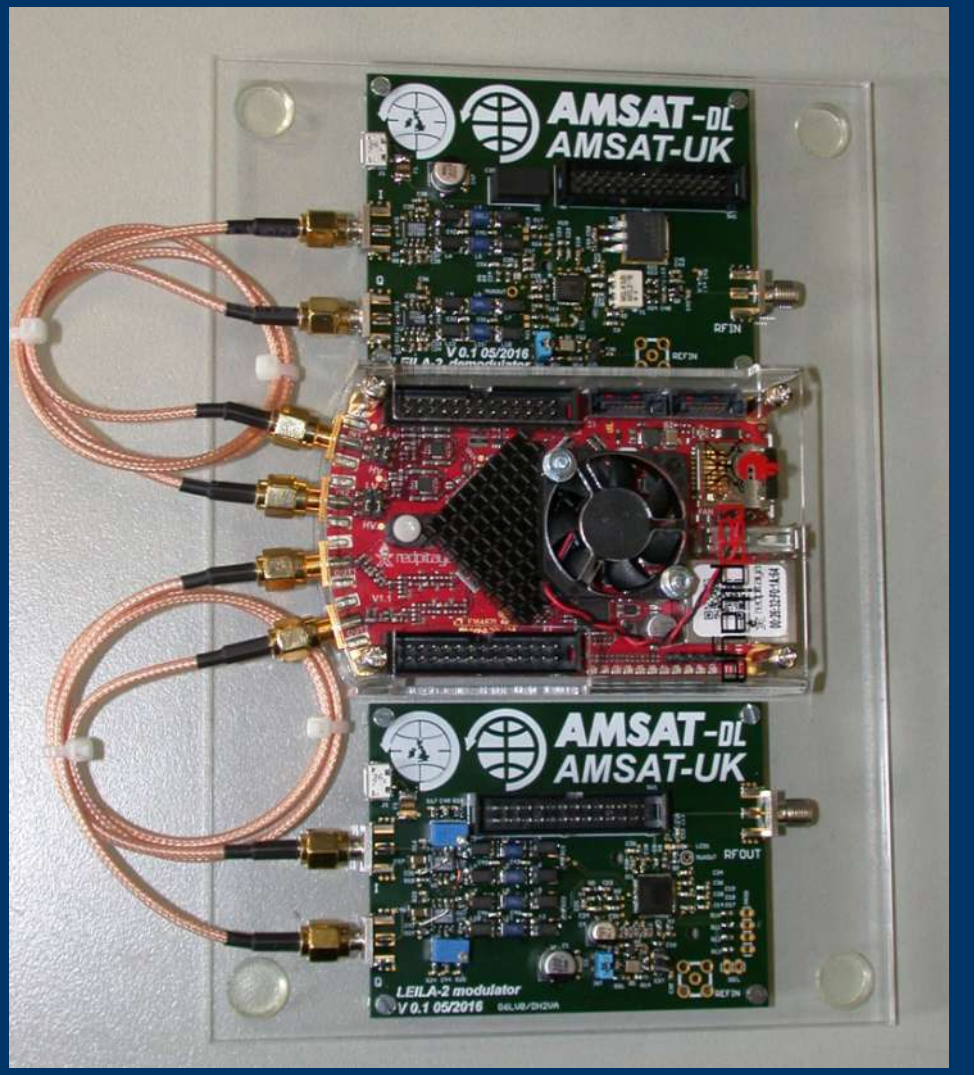
LEILA-2

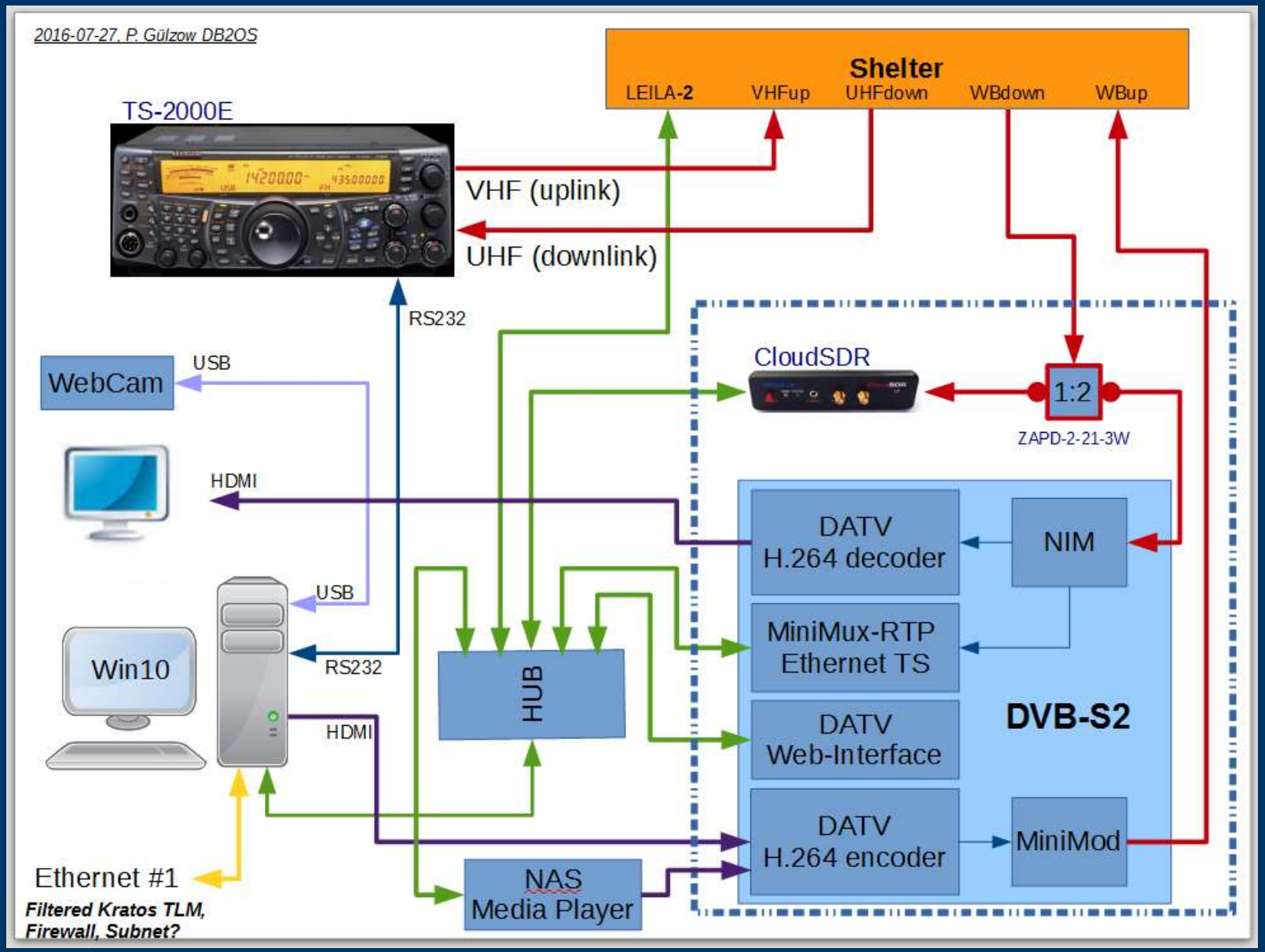
- Red Pitaya analyzing the passband (FFT) and generating siren markers

- Also encoding (FEC) and generating pseudobeacon
- Accessible via ethernet (embedded linux) to tune settings and provide TLM data

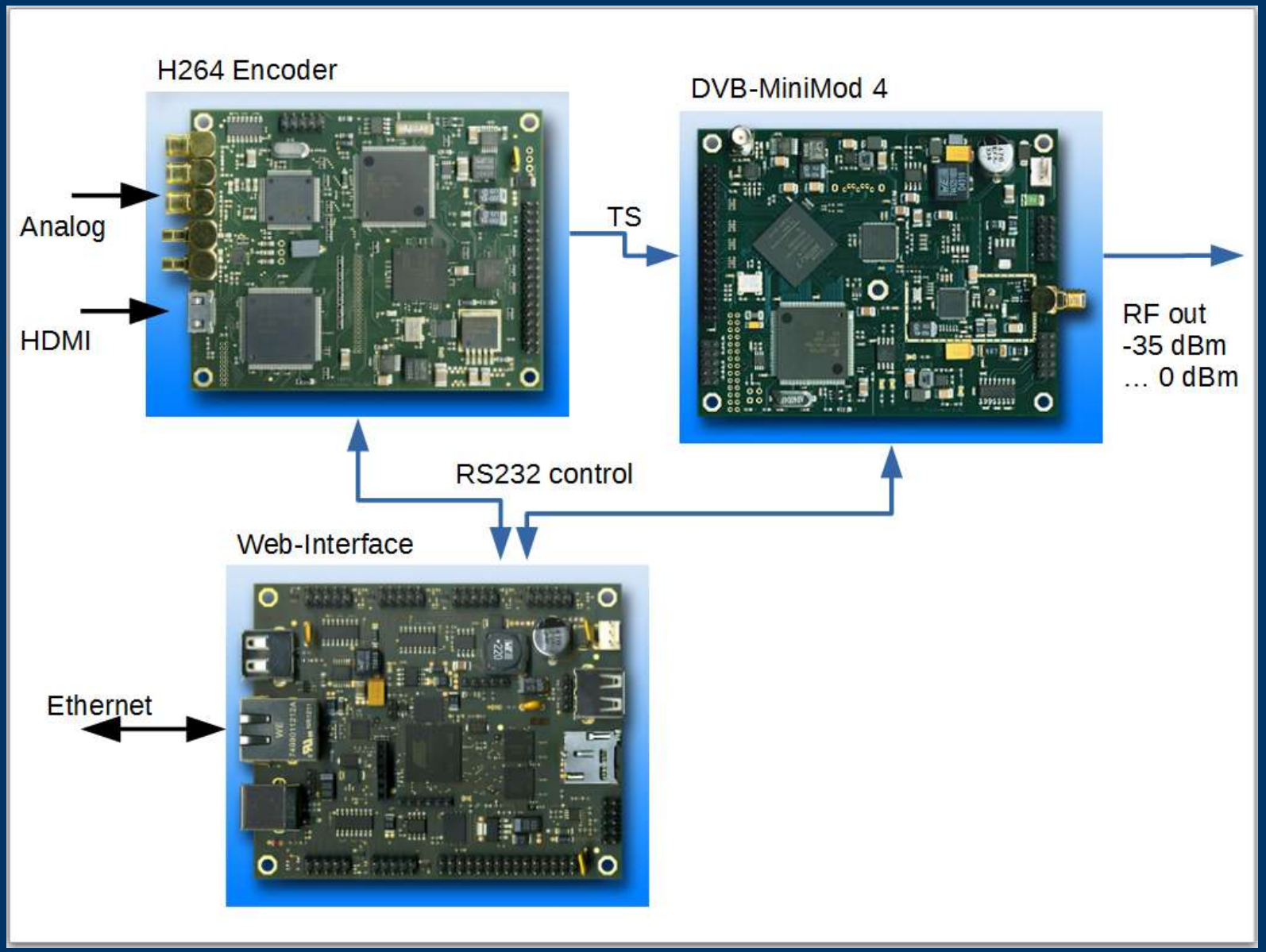
- Up-/downconversion boards developed by AMSAT-DL/UK (DH2VA/G6LVB)



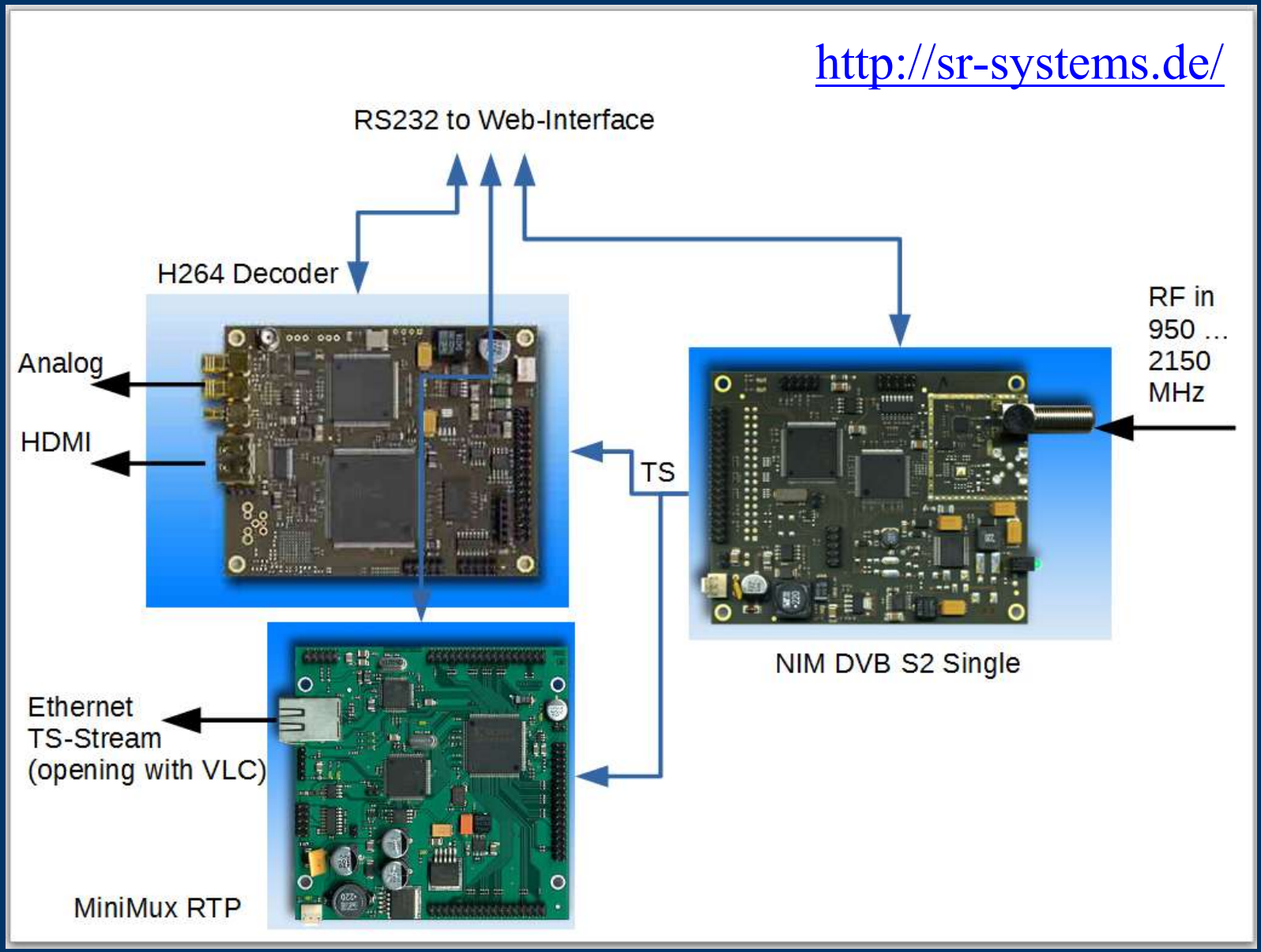
Radio Shack


2016-07-27, P. Gülzow DB2OS
Shelter
LEILA-2
VHFup
UHFdown
WBdown
WBup
TS-2000E
VHF (uplink)
UHF (downlink)
RS232
WebCam
USB
CloudSDR
1:2
ZAPD-2-21-3W
HDMI
DATV
H.264 decoder
NIM
USB
MiniMux-RTP
Ethernet TS
Win10
RS232
HUB
DATV
Web-Interface
DVB-S2
HDMI
DATV
H.264 encoder
MiniMod
Ethernet #1
Filtered Kratos TLM,
Firewall, Subnet?
NAS
Media Player

DVB-S2 Uplink



DVB-S2 Downlink



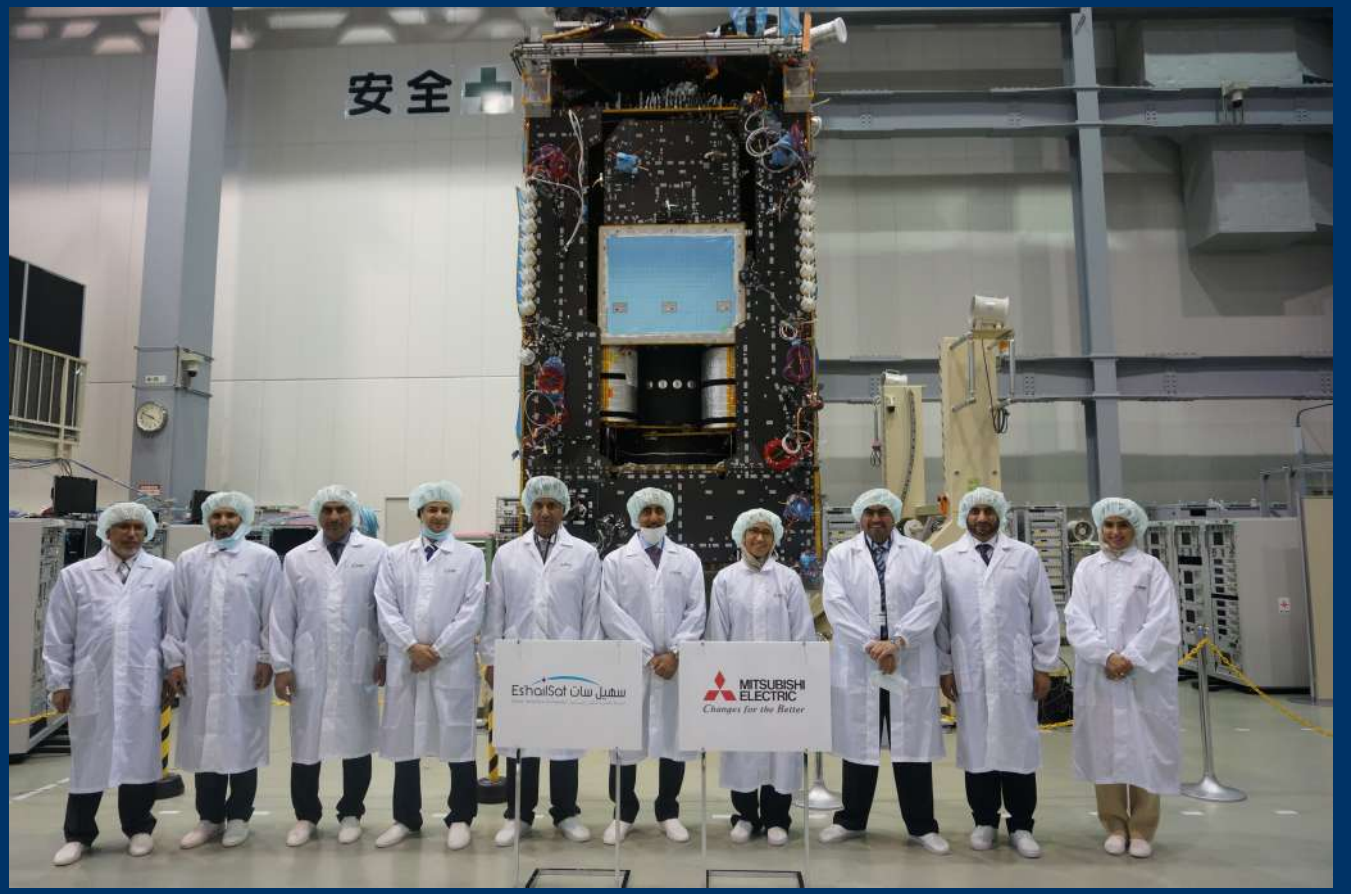
Es'hail-2 status

Es'hail-2 successfully passed critical design review (CDR)

Undergoing now final testing:

- Thermal vacuum
- Vibration

Launch is planned for ??Q3??/2017 with SpaceX (Falcon 9) from Cape Canaveral.



Executives from Qatar's Es'hailSat and Japan's Mitsubishi Electric Space Systems (MELCO) in Kamakura, outside of Tokyo, Japan, to observe the vacuum chamber test of Es'hail-2. Photograph courtesy of Es'hailSat, June 2016.

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Partners

Es'hailSat سهيل سات
Qatar Satellite Company الشركة القطرية للأقمار الصناعية

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KENWOOD

JAMSAT

AMSAT-UK

BATC

AMSAT-OH

maintech GmbH

SR-Systems

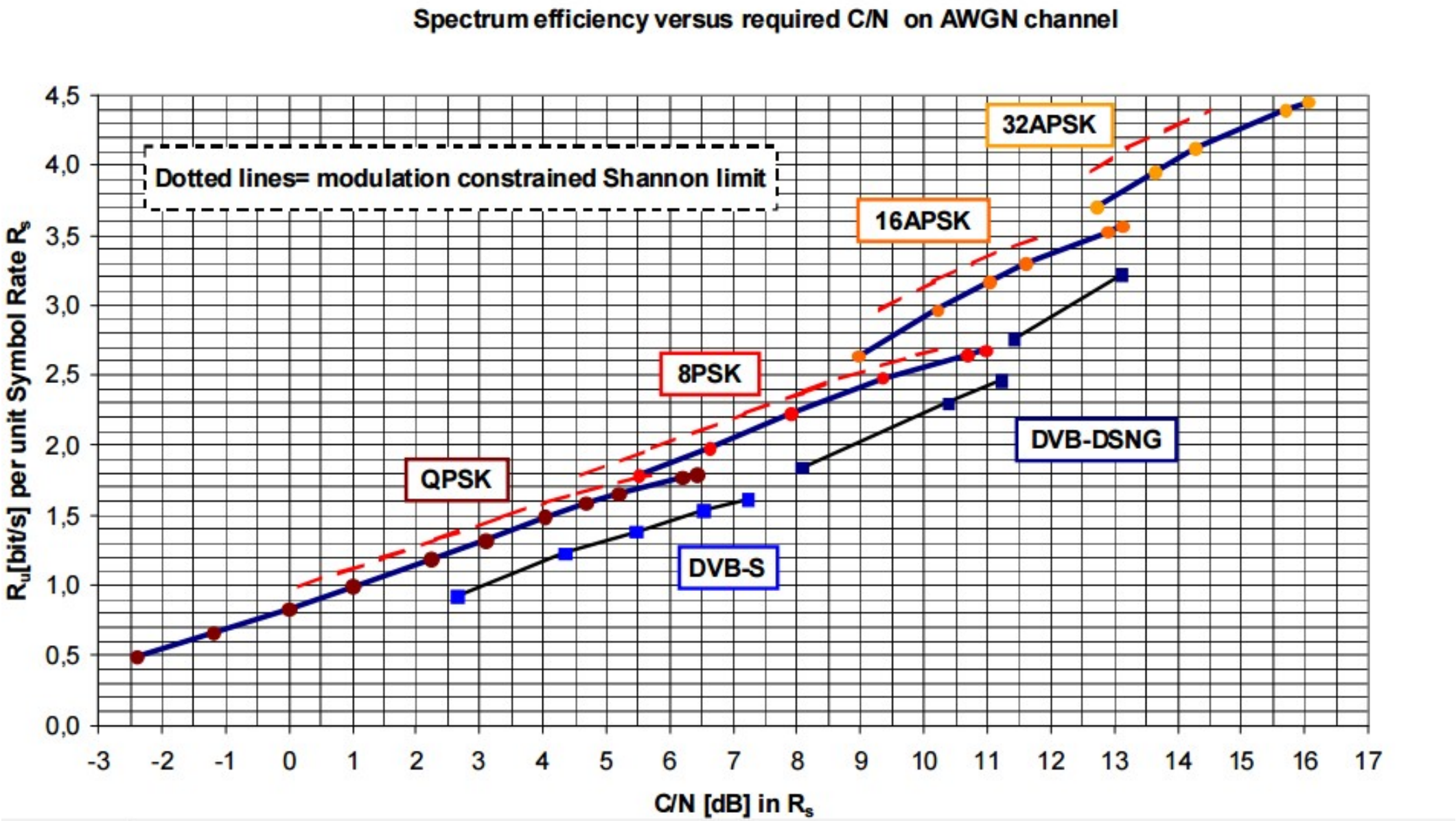
BATC Involvement

- AMSAT-DL requested BATC help to manage and develop WB transponder use
- Hub of experimental DATV experience seems to centre on UK

Es'Hail-2 P4A WB

- Es'Hail-2 wideband is an “ 8 MHz bent pipe” transponder
- There are many potential modes and uses by the amateur TV community
  - Two standards: DVB-S and DVB-S2
  - Four Modulations: QPSK, 8PSK, 16APSK and 32APSK
  - Eleven error corrections (eg 1/2 7/8)
  - Variable Symbol Rate
  - Three video encoders: MPEG-2, H264 and H265
  - 2-way QSOs or broadcasts
- Occupied bandwidths can be 200 KHz – 8 MHz
- Most in-use amateur equipment currently only supports DVB-S QPSK

What Mode?


Spectrum efficiency versus required C/N on AWGN channel
Dotted lines= modulation constrained Shannon limit
32APSK
16APSK
8PSK
QPSK
DVB-DSNG
DVB-S
R_u[bit/s] per unit Symbol Rate R_s
C/N [dB] in R_s
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
-3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

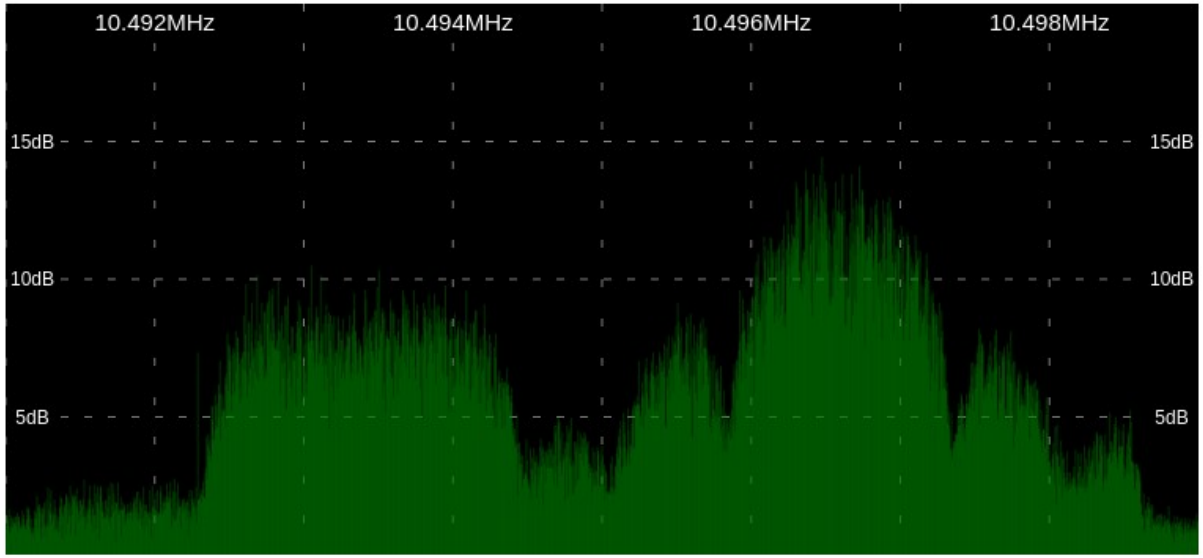
Choice and Co-ordination

- Easiest mode to start with is “standard” DVB-S QPSK DATV at 2 or 4 Msymbols/Sec 1/2 FEC
- But we should encourage and allow experimentation as well as the standard QSO operation
- DATV receivers need to know basic info about the signal they are receiving
  - Modulation, symbol rate and possibly FEC
- With so many modes and bandwidth combinations possible simultaneously we need co-ordination
- BATC is working with AMSAT-DL to produce a web-based monitor and analysis tool
  - Without it, it just won’t work!
  - Will include a chat window for questions

Proposed Web-based Spectrum Monitor

file:///home/phil/Projects/websocket-fft/index.html

Es'hailSat Spectrum Monitor



Users currently monitoring the spectrum: 1

23/07/2016

19:05 **Phil_M0DNY**
Hello!

19:05 **Phil_M0DNY**
*World!

Type '/nick your_name' and press enter to join.

Possible Frequency Plan

- A basic frequency / usage plan will help co-ordination - for example:
- 10,491 – 10,493 MHz = Reduced bandwidth TV
  - Up to 4 channels
- 10,493 – 10,495 MHz = IP based & experimental
  - Multiple channels depending on config
- 10,495 – 10,499 MHz = DVB channel
  - 2 * 2 MHz SD or 1 * 4 MHz HD
  - 1 * 8 MHz for super HD
- Usage can be varied on day to day basis

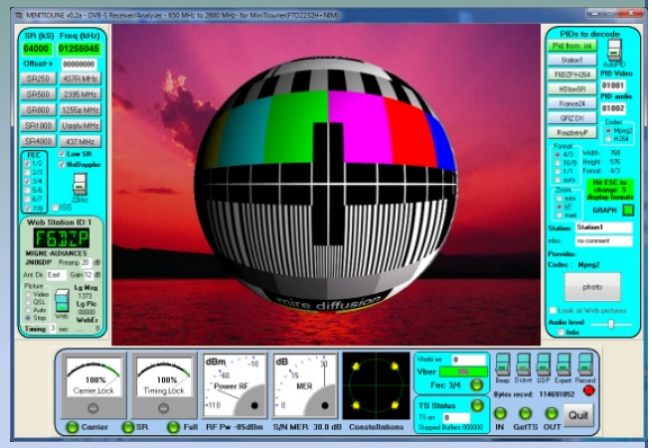
Reception

- Downlink power levels should enable use of fixed 80cm dish in most areas ☺
- Downlink frequency is 10,491 – 10,499 MHz and within pass band of standard consumer LNB ☺
- PLL LNBs must be used to give stability for RB-TV below 1 Msymbol/sec
  - Octagon PLL LNB = £25 on ebay
- However 9,750 MHz LO puts IF outside consumer set top box tuning ☹
  - Standard STB range = 950 – 2,150 MHz
  - 10,491 MHz – 9,750 MHz = 741 MHz

Receiver – 3 Possible Solutions

- Move the local oscillator by using a modified LNB with 9GHz LO
  - Used to be available from Germany?
  - Will work but not suitable for RB-TV due to stability of “pulled” DRO oscillator
- Use a wider frequency range tuner
- BATC USB Minitiouner card with Sharp tuner covers 741 MHz
  - Gives totally flexible receive system
  - HD-TV, DATV and RB-TV
- Up-convert: SUP-2400 or G0MRF Converter?

USB Receiver



LNB → USB Tuner → PC

Uplink issues

- Uplink band is 2,401.5 – 2,409.5 MHz = Secondary allocation = WiFi Channel 1(2412)
- Uplink must not cause interference to other users, both in-band and on adjacent bands
- Spectral re-growth – adjacent channel interference will be a real issue

TX Option 1: Up-convert

- Generate DATV signal at lower frequency and up convert - possibly from 437 MHz?
  - Use standard encoder/modulator
  - DTX1, DigiLite, DATV-Express or ex-broadcast
- Up-converter options:
  - Use narrow-band 13cms up-converter
    - 80 MHz away from 13cms terrestrial NB section
  - Kuhne KU UP 2325 A up-converter?
    - Eur500

TX Option 2: Generate at 2400

- DATV Express
  - Very flexible but requires PC etc
- DigiLite – BATC Homebrew Project
- Modified DTX1
  - Standalone system

- All solutions are low power (0 – 10 dBm) and will require extensive amplification and filtering

Uplink Power Budget

- Starting point is that an 8 MHz of DVB-S2 transmission will require 100W into a 2.4m dish

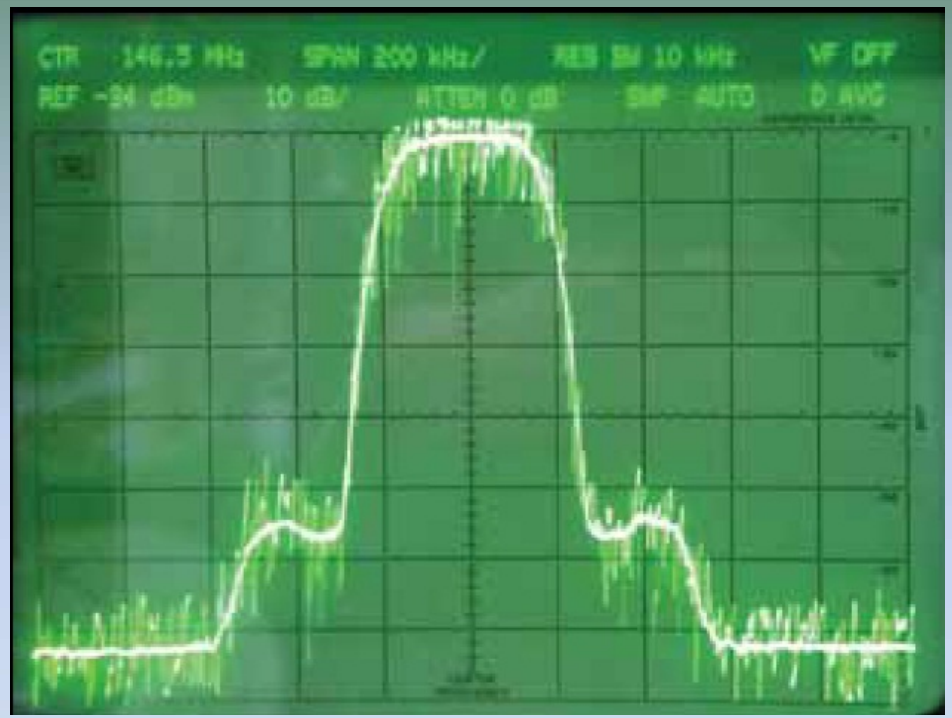
Power Budget (Watts)					
	8 MHz	4 MHz	2 MHz	1 MHz	0.5MHz
2.4m	100	50	25	12.5	6.25
1.7m	200	100	50	25	12.5
1.2m	400	200	100	50	25
0.85m	800	400	200	100	50

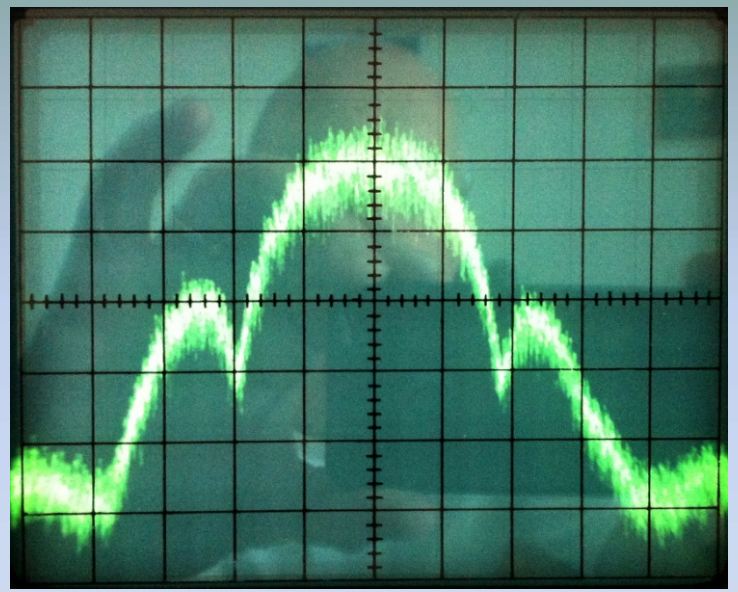
Credit M0DTS

Uplink Power Budget

- Crucial to manage spectral re-growth
  - "Shoulders" should be at least 30 dB down
  - Crucial to avoid co-channel interference
- The average DATV transmission uses "linear" PAs backed off by at least 6 dB
  - On 146 MHz we need 45 dB+ and use an 80 watt PA to generate 6 watts!!
  - 500 KHz wide and 6 amps at 12 volts!

Spectral Re-growth



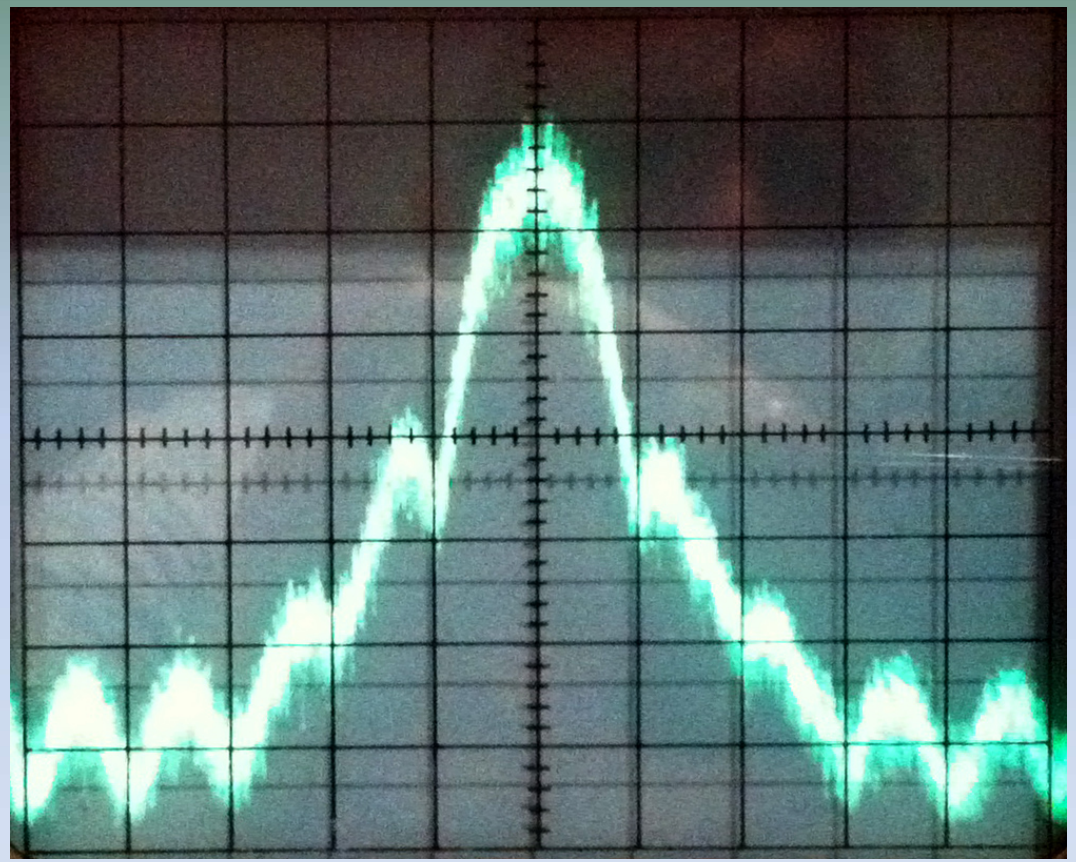


Excellent: -55 dB

But is a 70 watt amplifier running 5 watts!

Awful: -20 dB

Spectral Re-growth

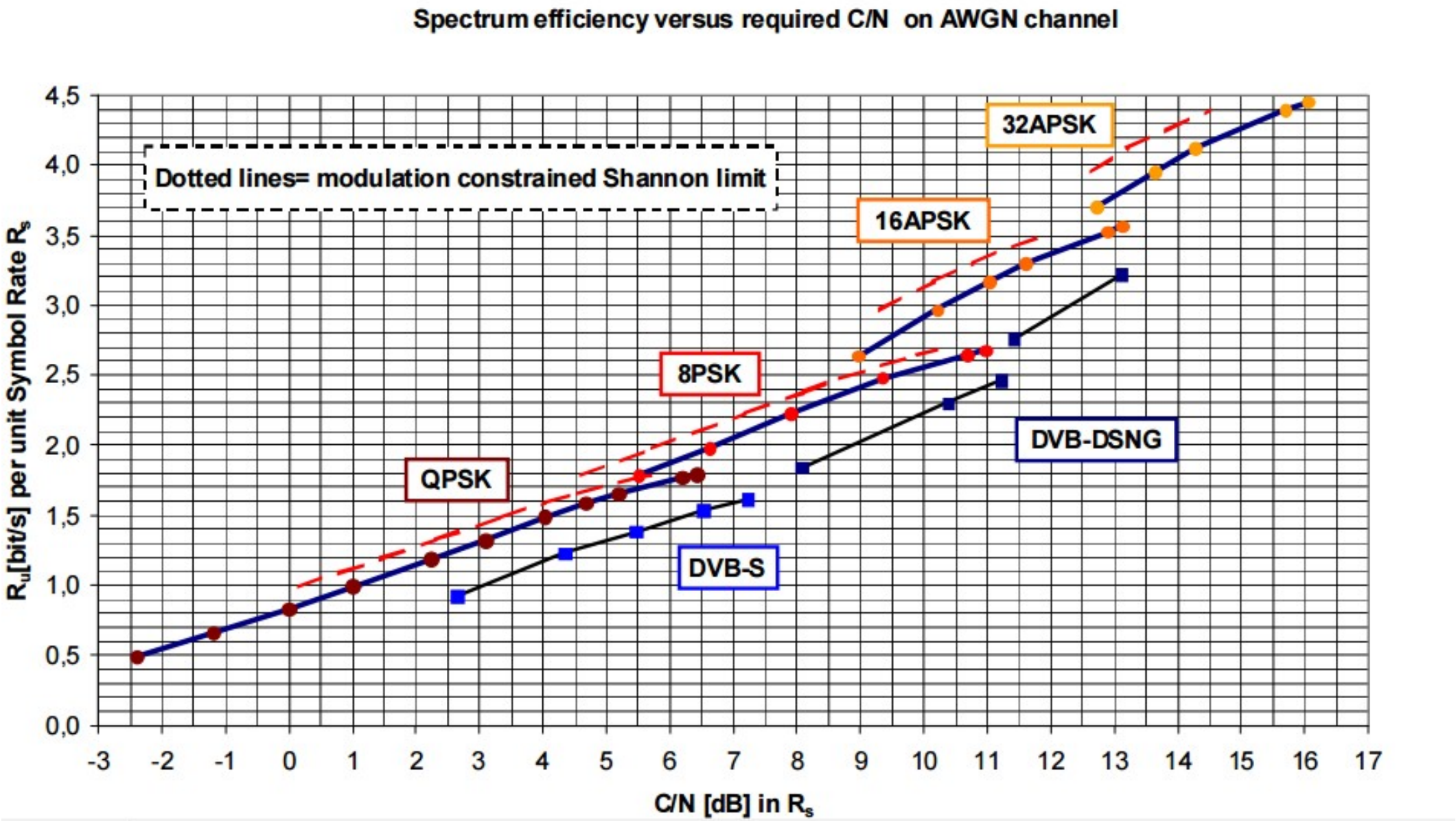


Achievable: -30 dB

DVB-S2

- AMSAT-DL are pushing the use of DVB-S2
- Why DVB-S2?
  - Increase data rate in limited bandwidth (but increase C/N)
  - Decrease C/N required (=TX power) for similar bandwidth
- To increase the data rate we can use 8PSK
  - But double the data rate needs double the power

What Mode?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DVB-S2

- Why DVB-S2?
  - Increase data rate in limited bandwidth (but increase C/N)
  - Decrease C/N required (=TX power) for similar bandwidth
- To increase the data rate we can use 8PSK
  - But double the data rate needs double the power
- To decrease data rate we use QPSK with better error correction
  - DVB-S2 QPSK FEC ½ needs 2 dB less power than DVB-S QPSK FEC ½

DVB-S2

- AMSAT-DL are pushing the use of DVB-S2
- SR Systems market a full range of DVB-S2 products
- Homebrew or cheaper options include:
- Transmit:
  - DATV Express with Linux Software
  - DATV Express with Windows 1.14 software
- Receive
  - Up-converter into HD Domestic Receiver (SR > 1MS)
  - MiniTiouner and latest software (QPSK/8PSK FEC ½)
  - MiniTiouner Pro ?????

Conclusions

- Es'Hail-2 is a fantastic opportunity for amateur experimentation
- It will need flexible ground station solutions
- A good transmit capability will be a challenge!
- Amateur service coordination is essential if we are to maximise the benefit
- Start simple
  - Get a receiver working!