Extreme Tropo Propagation on 144 MHz and up

Presentation given at the 41st Nordic VUSHF Meeting 2019 at Skjeberg

Stefan Heck - LA0BY
(e-mail: la0by@nrrl.net)
Overview

- Intro to tropospheric propagation modes
  - It all happens below 10000 m in altitude …

- My journey to 2000 km and beyond
  - Examples from own experience from JO59IX
  - Comparing predictions and observations
  - Operational considerations
  - The next frontier - where is the limit?

- Summary and conclusions
  - Preparations (checklist)

LA0BY 2019
Tropospheric propagation modes

Normal (Groundwave, Line-of-Sight)
- Most common type of propagation for radio; works for all frequency bands
- Communication path follows a (more or less) straight line
- Propagation loss depends on distance & frequency
- High altitude gives larger radio horizon

RX has no reception - TX is below the horizon.
Tropospheric propagation modes

Tropospheric enhancement (TrE)

Tropospheric ducting (TrD)

LA0BY 2019
Tropospheric propagation modes

Elevated tropospheric ducting

- Top of inversion is very high above ground
- Receiver must be in the layer for maximum signal
- May support very long distance communications

Signals trapped in an elevated duct
No signal received at RX, but occasionally signals escape the duct.
Tropospheric propagation modes

Tropospheric scattering
- Refraction from minor irregularities – needs high power

Tropospheric sub-refraction
- Generated by unstable troposphere where temperature gradient drops-off with altitude faster than normal
- «anti-Tropo» condition that is worse than normal

Diagram:
- Cool moist air
- Warm dry air
- Signal bends up. Range is reduced.
- RX has no reception.
Tropospheric propagation summary

- Enhanced modes require some kind of temperature inversion
  - Temperature in lower atmosphere normally lapses by 6.5°C/km
  - Inverted profile up to 10-15°C/km

- Refraction index involves both temperature and humidity

- Effect is frequency dependent (inversion altitude and layer thickness)

- Long paths may involve portions of different modes

Inversion Definitions

- $z_t$
- $z_b$
- $T_b$
- $T_l$
Real life signature of ducts

- Source: VK3KAQ – Characteristics of Ducts
- 7° C change over just 20 m in altitude
How to discover tropo ducting?

- Watch and interpret weather forecast
  - Look out for stable high pressure areas
- Monitor tropo propagation forecasts
  - Hepburn (since 2000), F5LEN
- Listen on the radio (beacons, repeaters)
- Monitor DX-Maps
- Observe nature
  - Fog in lowlands
  - Hilltops in the clear
  - Little wind, wet ground
- Webcams on hilltops …
The ultimate experience: Extreme long-distance Tropo

- Typical path across calm waters
- Coastal regions are favoured
- Distances >> 2000 km
- See DF5AI articles in 2006
## Tropo Records – World & IARU R1

<table>
<thead>
<tr>
<th>Band</th>
<th>Type</th>
<th>Station 1</th>
<th>Loc 1</th>
<th>Station 2</th>
<th>Loc 2</th>
<th>km</th>
</tr>
</thead>
<tbody>
<tr>
<td>144 MHz</td>
<td>World</td>
<td>KH6EME</td>
<td>BK29GO</td>
<td>W1LP/mm</td>
<td>DL51CE</td>
<td>4755</td>
</tr>
<tr>
<td>144 MHz</td>
<td>R1</td>
<td>G3SMT</td>
<td>IO82KV</td>
<td>D4Z</td>
<td>HK76MU</td>
<td>4431</td>
</tr>
<tr>
<td>432 MHz</td>
<td>World</td>
<td>KH6EME</td>
<td>BK29GO</td>
<td>XE2/N6XQ</td>
<td>DL29CX</td>
<td>4151</td>
</tr>
<tr>
<td>432 MHz</td>
<td>R1</td>
<td>G4LOH</td>
<td>IO70JC</td>
<td>D44TS</td>
<td>HK77KE</td>
<td>4064</td>
</tr>
<tr>
<td>1296 MHz</td>
<td>World</td>
<td>KH6EME</td>
<td>BK29GO</td>
<td>XE2/N6XQ</td>
<td>DL29CX</td>
<td>4151</td>
</tr>
<tr>
<td>1296 MHz</td>
<td>R1</td>
<td>M0VRL</td>
<td>IO70PO</td>
<td>EA8AVI</td>
<td>IL28FC</td>
<td>2660</td>
</tr>
</tbody>
</table>

- **Source:** [http://www.ok2kkw.com/dxrecords.htm](http://www.ok2kkw.com/dxrecords.htm)
- Reception of VK6 beacon by FR1GZ over > 6000 km?
- Europe: What if you are not located in Western UK?
- What is possible from LA (or Scandinavia in general)?
LA0BY in JO59IX

- Hilltop near Oslo: Tryvann, 500 m asl
- Radio horizon (flat)
  - 800 km on 2 m
  - 700 km on 70 cm
  - 600 km on 23 cm
- Limited observation options from home
- Need 45-60 min for drive and setup
The great Tropo to East

- 6.-11.11.2003
  - lasting 6 days
  - 70 cm NAC

- Many DXCC
  - OH, UA1/3/4
  - ES, YL, LY
  - EW, UT, SP
  - DL, PA, G

- Best to East

LA0BY 2019
The great Tropo to East

<table>
<thead>
<tr>
<th>LA0BY in JO59IX - 144 MHz</th>
<th>LA0BY in JO59IX - 432 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UA4UK</strong></td>
<td><strong>RW3PF</strong></td>
</tr>
<tr>
<td><strong>LO14MA</strong></td>
<td><strong>KO93CD</strong></td>
</tr>
<tr>
<td><strong>RW3TJ</strong></td>
<td><strong>UA3PTW</strong></td>
</tr>
<tr>
<td><strong>LO16XG</strong></td>
<td><strong>KO93BS</strong></td>
</tr>
<tr>
<td><strong>RW3TI</strong></td>
<td><strong>UA3ARC</strong></td>
</tr>
<tr>
<td><strong>LO16WG</strong></td>
<td><strong>KO85SO</strong></td>
</tr>
<tr>
<td><strong>RW3PF</strong></td>
<td><strong>RA3AQ</strong></td>
</tr>
<tr>
<td><strong>KO93CD</strong></td>
<td><strong>KO85SP</strong></td>
</tr>
<tr>
<td><strong>RU3ACE</strong></td>
<td><strong>RA3LE</strong></td>
</tr>
<tr>
<td><strong>KO95KG</strong></td>
<td><strong>KO64AR</strong></td>
</tr>
<tr>
<td><strong>RA3PG</strong></td>
<td><strong>KO54MQ</strong></td>
</tr>
<tr>
<td><strong>KO84TD</strong></td>
<td><strong>RA3LW</strong></td>
</tr>
<tr>
<td><strong>RX3PR</strong></td>
<td><strong>SP9APC</strong></td>
</tr>
<tr>
<td><strong>KO84TE</strong></td>
<td><strong>JN99QU</strong></td>
</tr>
<tr>
<td><strong>RU3FA</strong></td>
<td><strong>SP7EXY</strong></td>
</tr>
<tr>
<td><strong>KO84RU</strong></td>
<td><strong>KO00QW</strong></td>
</tr>
<tr>
<td><strong>RA3DCI</strong></td>
<td><strong>RX1AX</strong></td>
</tr>
<tr>
<td><strong>KO96CB</strong></td>
<td><strong>KO59EW</strong></td>
</tr>
<tr>
<td><strong>RA3AQ</strong></td>
<td><strong>SP7CNL</strong></td>
</tr>
</tbody>
</table>

- QRV 2 bands, total > 300 QSO, first time > 2000 km on 2 m
- Strong signals, some QSO even in FM (to EW)
- Contacts over the head of SM stations (elevated duct?)

(*) Distance calculated in WGS84 for more km
The great Tropo to East
The great Tropo to East

**UA4UK**, LO14MA, path almost clear, 2050 km

**RW3TI**, LO16WG, path quite clear, 1975 km, 40 W, 2 x 16-ele
Winter Tropo to France

- 10.12.2004
- DXCC
  - SP6, OK
  - DL, PA, ON
  - G, F
- Best to F
Winter Tropo to France

LA0BY in JO59IX - 144 MHz
F6AQI IN96DW 1661 km
F6DZF JN16GB 1638 km
F4DXX IN97LH 1602 km
F6APE IN97QI 1585 km
F5NXU IN97MR 1557 km
F2GL IN97ST 1533 km
F2GL IN97ST 1533 km
F1CIA IN97XW 1508 km
F/ON5KO/P IN98QL 1471 km
F6DKW JN18CS 1360 km

LA0BY in JO59IX - 432 MHz
F6DZF JN16GB 1638 km
F4DXX IN97LH 1602 km
F6APE IN97QI 1585 km
F5NXU IN97MR 1557 km
F6DKW JN18CS 1360 km
F8BRK IN99VF 1338 km
F6CBH JN19BH 1308 km
OK2POI JN99AJ 1266 km
F5PEJ JN09XT 1259 km
F4EMG JO00WU 1155 km

- Widespread tropo, strong signals
- QRV 2 bands, total > 160 QSO, 70 cm almost like 2 m

LA0BY 2019
Winter Tropo to France

Hepburn Tropo Index Valid 0600Z Fri Dec 10 NWrn Europe

Nobody QRV in EA?
EA1 on 144 MHz Tropo - new ODX

- 15.10.2011, 20:45 UTC: QSO between LA0BY (JO59IX) and EA1DDU (IN73EM), CW/SSB, 2135 km
- Result of > 10 year of attention and observation of propagation forecasts, weather maps & attempts

- Challenges
  - Simultaneous ducting over 3 sea- and 3 land areas needed
  - Breaking the wall of ON/PA
  - No other stations QRV from hill-top locations at both ends

- Mode was elevated duct
- Few QSO - F/G/ON/PA/DL

LA0BY 2019
EA1 on 144 MHz Tropo

Path from JO59IX to IN73EM is good!

Equipment

- **LA0BY:**
  - 180W
  - 2 x 9-ele-yagi
- **EA1DDU**
  - 100 W
  - 12-ele-yagi

LA0BY 2019
Crossing mountains: LA to 9A/S5

LA0BY in JO59IX - 144 MHz
9A1CAL    JN86DM  1541 km
S51ZO     JN86DR  1518 km
OM2RC     JN88OL  1345 km
DL6MFK    JN67JX  1341 km
OE5KE     JN78EG  1323 km
DL8NP     JN58SC  1318 km
OK2BRD    JN99ET  1230 km

LA0BY in JO59IX - 432 MHz
9A1CAL    JN86DM  1541 km
S51ZO     JN86DR  1518 km
OE3DSB    JN78FA  1352 km
DL6MFK    JN67JX  1341 km
OM3CLS    JN99FC  1306 km
DL3RBH    JN68IK  1290 km
OK2BRD    JN99ET  1230 km

- Event on 11.2.2015, lasting for ca. 1 day - in winter
- 2 m and 70 cm worked equally well (I was not QRV on 23 cm)
- Very good activity (> 200 QSO on 2 bands), strong signals

Path from 9A and S5 to LA is crossing high mountains!
Crossing mountains: LA to 9A/S5

Hepburn predictions did not indicate path reaching 9A/S5
LA-UA6 Unbelievable distances

- Surprise event on 22.11.2018, ca. 40 stations in CW & SSB
- Focus on 70 cm, but operational on two bands at a time (limited by antenna constraints)

LA0BY in JO59IX - 144 MHz

<table>
<thead>
<tr>
<th>Station</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>UR8GZ</td>
<td>2082 km</td>
</tr>
<tr>
<td>UY5HF</td>
<td>2059 km</td>
</tr>
<tr>
<td>UR3VKC</td>
<td>1911 km</td>
</tr>
<tr>
<td>UR5LX</td>
<td>1899 km</td>
</tr>
<tr>
<td>UT8AL</td>
<td>1705 km</td>
</tr>
<tr>
<td>US8AR</td>
<td>1683 km</td>
</tr>
<tr>
<td>UT9UR</td>
<td>1632 km</td>
</tr>
<tr>
<td>total 12 stations</td>
<td></td>
</tr>
</tbody>
</table>

LA0BY in JO59IX - 432 MHz

<table>
<thead>
<tr>
<th>Station</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>R6AM</td>
<td>2611 km</td>
</tr>
<tr>
<td>RZ6DD</td>
<td>2606 km</td>
</tr>
<tr>
<td>UA6AQN</td>
<td>2448 km</td>
</tr>
<tr>
<td>UR8GZ</td>
<td>2082 km</td>
</tr>
<tr>
<td>UT4LA</td>
<td>1954 km</td>
</tr>
<tr>
<td>UT8LE</td>
<td>1937 km</td>
</tr>
<tr>
<td>UR5LX</td>
<td>1899 km</td>
</tr>
<tr>
<td>UT5VD</td>
<td>1889 km</td>
</tr>
<tr>
<td>UT8AL</td>
<td>1705 km</td>
</tr>
<tr>
<td>UT6UG</td>
<td>1634 km</td>
</tr>
<tr>
<td>total 24 stations</td>
<td></td>
</tr>
</tbody>
</table>

LA0BY in JO59IX - 1296 MHz

<table>
<thead>
<tr>
<th>Station</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>EW6FS</td>
<td>1110 km</td>
</tr>
<tr>
<td>EU4AX</td>
<td>1060 km</td>
</tr>
<tr>
<td>SP4MPB</td>
<td>911 km</td>
</tr>
<tr>
<td>LY2R</td>
<td>902 km</td>
</tr>
<tr>
<td>LY2HM</td>
<td>809 km</td>
</tr>
</tbody>
</table>

LA0BY 2019
LA-UA6 Unbelievable distances

- Pictures show reported contacts on 22.11.2018 from 17-24 UTC
- Working UA6 on 2 m was possible, but I did not focus on it (hrd RA6A)
- Working UA6 on 23 cm may have been possible
Stations worked by RZ6DD
LA-UA6 Propagation predictions

- Hepburn predicted enhanced propagation from Oslo to ES, YL, YL, SP, perhaps extending to EW and UT
- The duct to UA6 was not obvious and far beyond expectations
LA-UA6 Surface pressure map
LA-UA6 Temperature vs altitude

Ground level

**Windy.com**

- Website with weather maps, current and predicted
- Maps display isobars and temperature
- Altitude can be selected (new!)

(tnx RZ6DD)

LA0BY 2019
The duct to UA6 shows in the altitude view (even to 4L/TA?)

900 m

1500 m
LA-UA6 Temperature vs altitude

- It seems the duct ended just above 2000 m

2000 m  3000 m
LA-UA6 Path profile analysis

- JO59IX: Tryvann/Oslo - altitude 500 m
- LN04MX: Armavir - altitude 200 m

Path seems unobstructed, but graph is for flat Earth

=> LA to UA6 is the perfect path for working tropo
LA-U6A Take-aways from event

- The tropo event on 22.11.2018 was predictable with maps showing temperature over altitude.
- There was a wide channel (duct) with significantly inverted temperatures between LA and UA6.
- The duct was more elevated at the LA side. This explains why only LA0BY was able to get into it.
- Looking at Hepburn/F5LEN forecast is not enough.
- We should be able to predict more extreme tropo conditions with the right tools – and work more DX!
LA-UA6 Some observations

- Path from LA to UA6 was quite stable for at least 6-8 hours
- Local weather not typical for standard enhanced mode (rather cold, foggy on hilltop), but perhaps indicating elevated duct.
- Moderate equipment was sufficient on both sides
  - LA0BY on 70 cm: IC-821H, PA 120 W, 17-ele yagi
  - RZ6DD on 70 cm: IC-910, 75W, 2 x 23-ele yagi
  - UA6AQN on 70 cm: IC-9100, 75 W, 2 x 32-ele yagi
  - Most UT/UR stations worked were having only 20-50 W output power into a single yagi (UT3UCP: 20W into 5-ele duoband yagi)
- Activity and total number of contacts seemed a bit low for these extraordinary condx covering a wide area
  - Other LA were alerted, but could not hear much => elevated duct?
  - Distraction from FT8 (people «stuck» on 144,174 MHz)?
Operational considerations

- Working on multiple bands by a single operator can be quite challenging in extreme tropo condx:
  - Complex set-up, perhaps time consuming to get going
  - Hard to decide which band to favour, etc.
  - Stress and distraction from chat (in multiple rooms)

- Activity should be on radio, but raising attention through ON4KST chat and DXC spotting is useful

- SSB and CW go well together; digimode (e.g. FT8) seems to isolate different user groups

- Run beacon loop on one band while operating on another (interference permitting)?
Have I reached my limit?

- Configuration: Never ending improvements
  - Equipment RF performance: more power, better antennas
  - Technological developments: digimodes (FT8, etc)
  - Agility: shorter time to operation, band switching

- Opportunities: Get prepared for the next frontier
  - Location: Assess path limitations
  - Targets: Identify potential Tropo partners further away
  - Awareness: propagation monitoring, alert routines

=> Limit is probably not yet reached!
Dreaming: East beyond UA4

Asiatic Russia, UA9
> 2500 km, UA9FAD, RA9FMT, UA9CCL + many others

LA0BY 2019
Path to LO96KD: clear (2800 km) but over land
Dreaming: South-East beyond UA6

Turkey, TA
2500-2950 km, TA7OM, TA6P

Georgia, 4L
2700-2950 km, 4L1R, 4L5P

Path to TA: Crimea has mountains!
Dreaming: South-West beyond EA1

Madeira, CT3:
3600 km, CT3KN, CT3HF

Canary Islands, EA8:
> 4000 km, EA8BDM, EA8TJ, …
Dreaming: South-West beyond EA1

Azores, CU:
3550 km, CU3EQ

The best bet:
- Paths to UA9, TA and EA8 seem most promising
- None of them is an easy task, not even on 2 m Es
Summary and conclusions

- Working extreme DX on VHF/UHF by tropospheric propagation can be accomplished by everybody
- Equipment requirements are low to moderate
- Operating from a location with good horizon helps
- High mountains on a path are not a show-stopper
- Tropo ducting can be predicted days in advance

The golden rule(s)
Rule 1: Be at the right location at the right time!
Rule 2: Have your equipment ready!
Checklist

- **Preparation (weeks to days ahead)**
  - Equipment, ready in box for portable operations
  - Identify good paths and potential QSO partners
- **Observation (days to hours ahead)**
  - Hepburn and F5LEN propagation forecasts
  - Analyze promising paths in altitude (with Windy)
  - DX-Maps and/or DX-Cluster (proof of something starting)
- **Own activity (when it happens)**
  - Monitor beacons and activity (DXC, calling frequencies …)
  - Call in promising directions, perhaps aided by skeds
  - Spot unusual contacts and own observations on DXC
  - Determine and focus on most attractive band