P29VXX: at the search of a DUCTING mode with Proplab Pro – Part 1.

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Unfortunately, NM7M died in the year 2010 and, meanwhile, the Solar Terrestrial Dispatch came out with the new powerful version 3 of Proplab-Pro. I was already using version 2, but, when it was first created, computers had only a fraction of the computing and memory power that they do today. The new technology in computers has provided the base structure upon which to build truly useful ray-tracing techniques. The three-dimensional ray-tracing engine used in Proplab-Pro version 3 now makes computations of ionospheric electron densities and three-dimensional layer gradients directly, rather than through the use of pre-built profiles. In addition, the new 2007 International Reference Ionosphere is substantially more complex than the old 1995 version of the IRI that was used in Version 2.

Proplab is equipped with one of the largest location databases in the world. Quickly scrolling over 5 million city and place names included, I found also my small village "Aveacco" (less than one hundred habitants) to look up as TX or RX location with geographic coordinates and precise altitude in meters. Using this large global topographical database (with a resolution of less than one square km.) it has the unique ability to compute accurate ground-reflections, by determining ground tilts (i.e. reflections off mountain ranges) that can cause non-great-circle propagation and signal spreading or multipathing. This is considered a major enhancement for the software which incited me - almost thirty years later - to go back to that old P29VXX analysis, after having examined the easier path of the S21XX DXpedition in the same month.

This is the main window of Proplab where we set transmitter and receiver parameters, automatically given by the program database - which determines the path length of 14,485 km. - and select the day, Feb. 25, 1997. We start the analysis at 17.00 UTC, just after sunset at my QTH in Europe and still full night in Papua New Guinea.
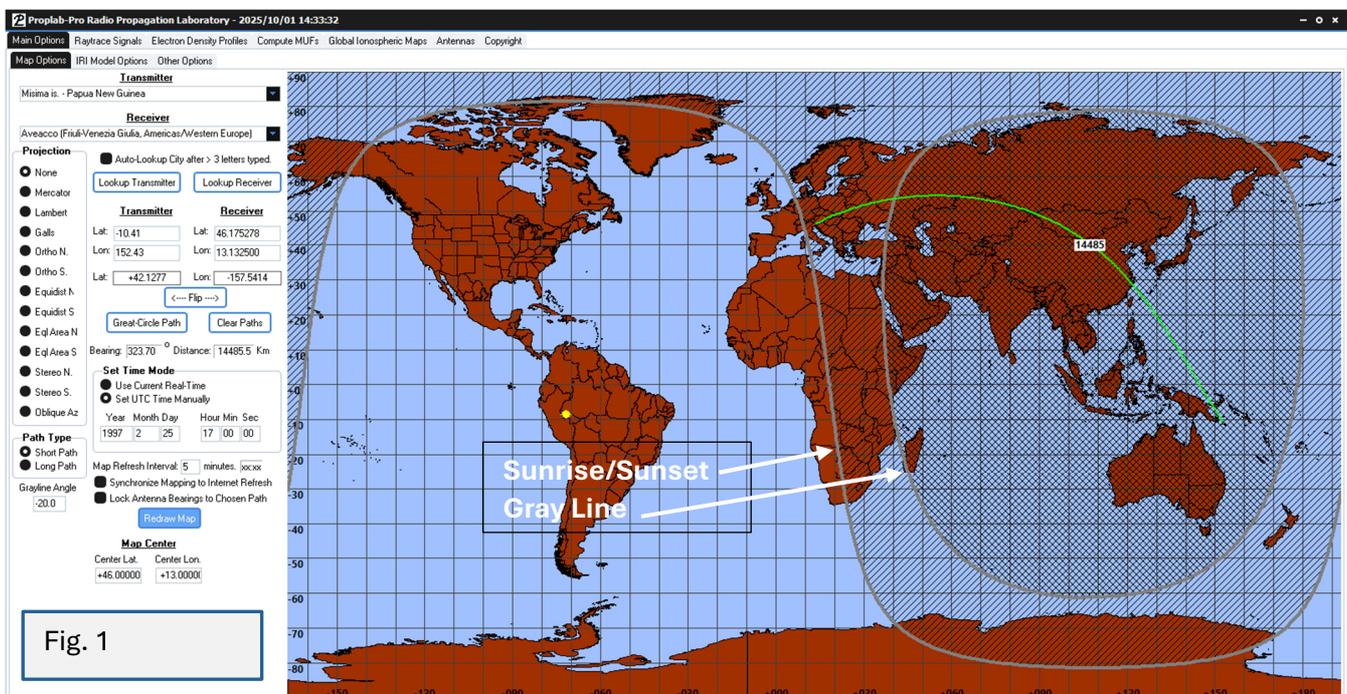

Fig. 1

The program automatically searches on internet the daily solar and geomagnetic numbers (even thirty years back) and produces 18 types of "Global Ionospheric Maps" for that day and time. This is for the critical frequency of the F2 layer - also known as *Plasma Frequency* at 17.00 UTC with the superimposed path of interest (Fig. 2).
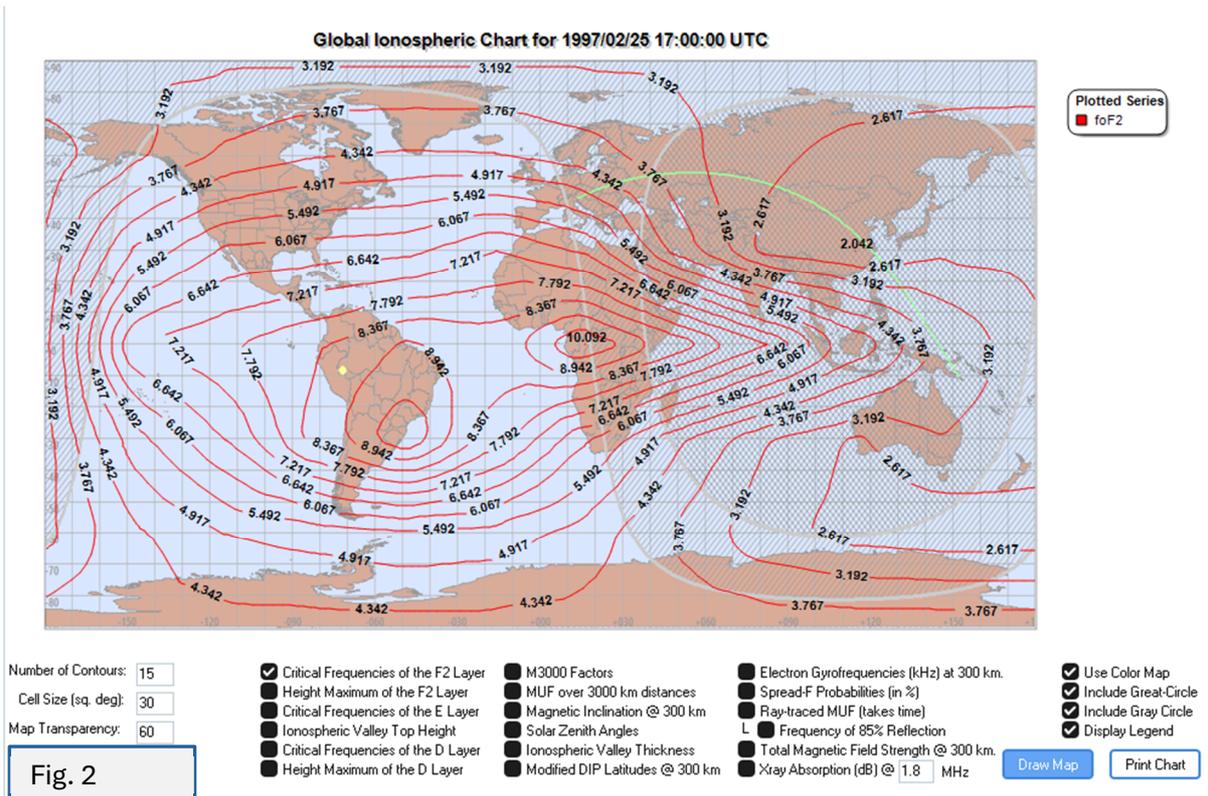
Fig. 2

The plasma frequency contours along the entire great-circle path from P29 to IV3 is shown in this *"Electron Density Profile"* chart and is useful to examine ionospheric gradients and tilts, which can cause an exit probability from a possible duct. (Fig.3):
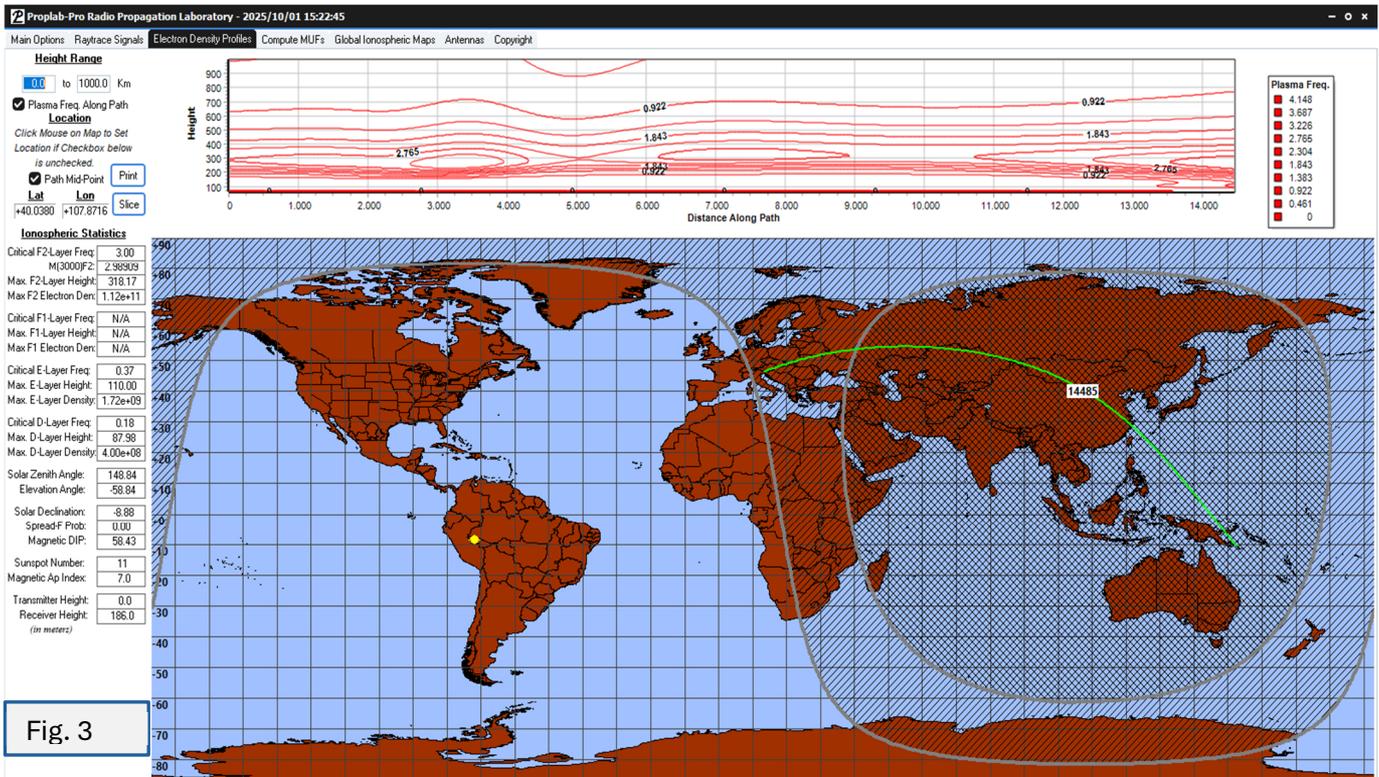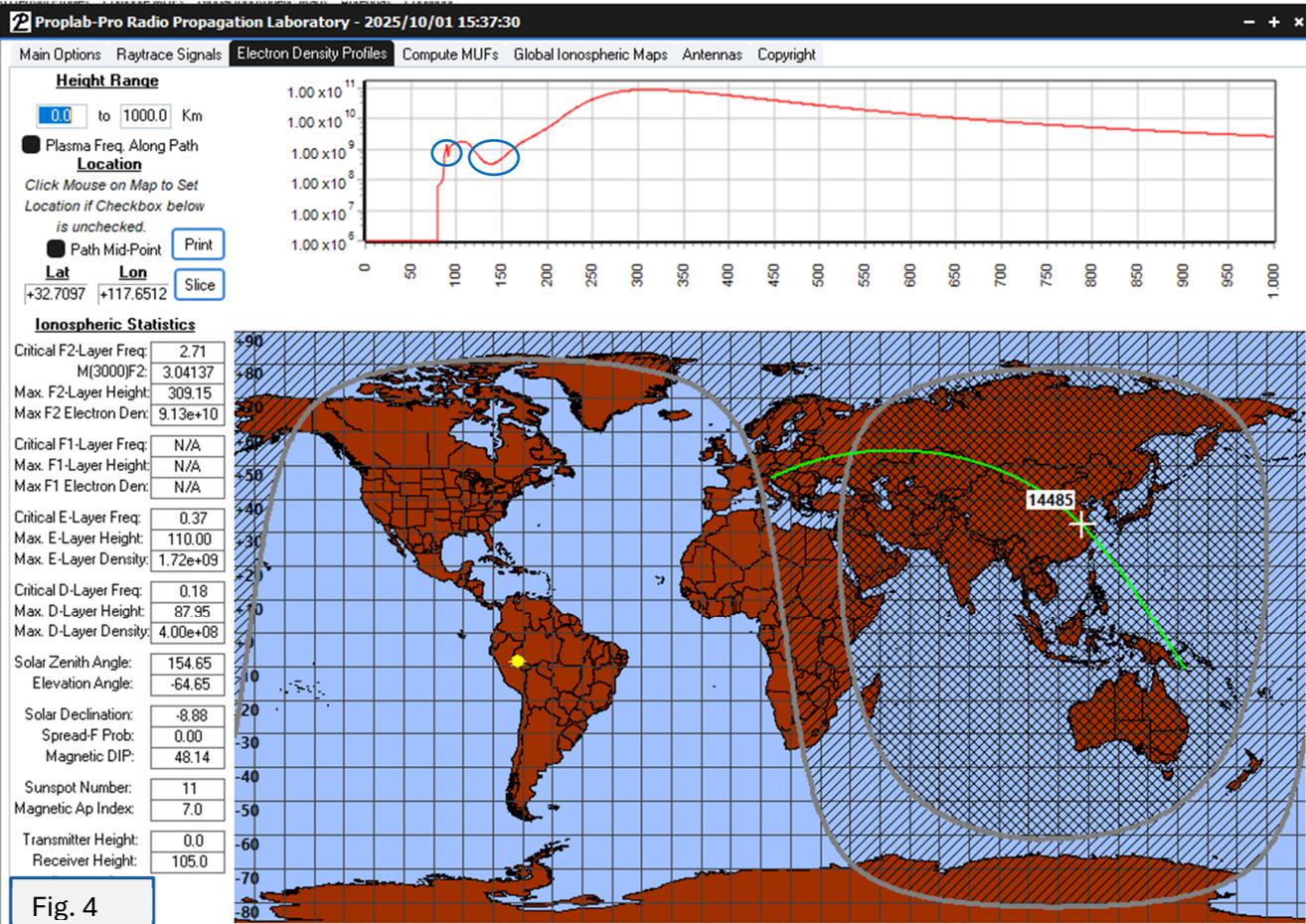

Fig. 3

Un-checking the *"Plasma freq. along path"* button, the top graph changes to the vertical electron density profile over the path mid-point, or whatever point we click along it, to find a possible DUCT. In the following case (Fig. 4), a good, pronounced duct is found at about 5.000 km. distance, 130-150 km. high, associated with a lower very small one, at about 90 km. height.

Fig. 4

The duct is a valley formed by a different electron density between E layer and the lower part of F layer, where a low frequency radio signal can enter and travel for thousands of kilometres without reflections on the ground. Fig. 4 shows an effective one associated with a small irregularity below it. Clicking on the path with the mouse, we find them until 11.000 km. and then, out of the gray-line area, they disappear. Now let's search at which elevation angle the radiated signal finds the way to enter in the duct, and how - or if - it can exit and go down to the receiver at this time of the evening
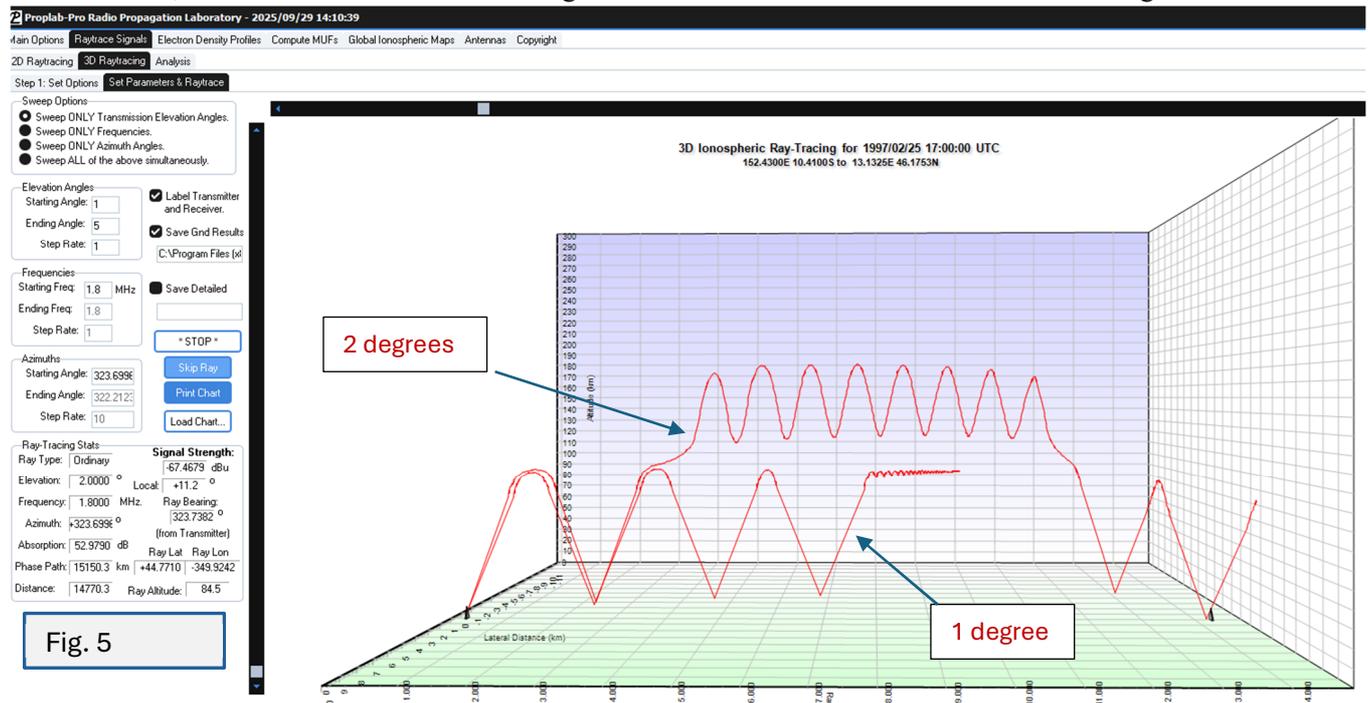
Fig. 5

From a preliminary check on this path, I found some kind of duct only at very low elevation angles, so I performed a very detailed 3D analysis from 1 to 5 degrees. In the previous fig. 5 we see the 1-degree ray, after 3 E layer hops, entering, at the path mid-point, in a very small duct (ref. to fig. 4) – a trap more than a duct - where it extinguishes itself, due to two hundred dB of absorptions accumulated in infinite attempts to go up or down. With 2 degrees, the ray enters in an efficient duct at 5.000 km. and exits at 12.000 km with sufficient signal strength in Ukraine, but the high losses in the last two E hops reduce it to a level absolutely useless (-150 dBm) in Western Europe.
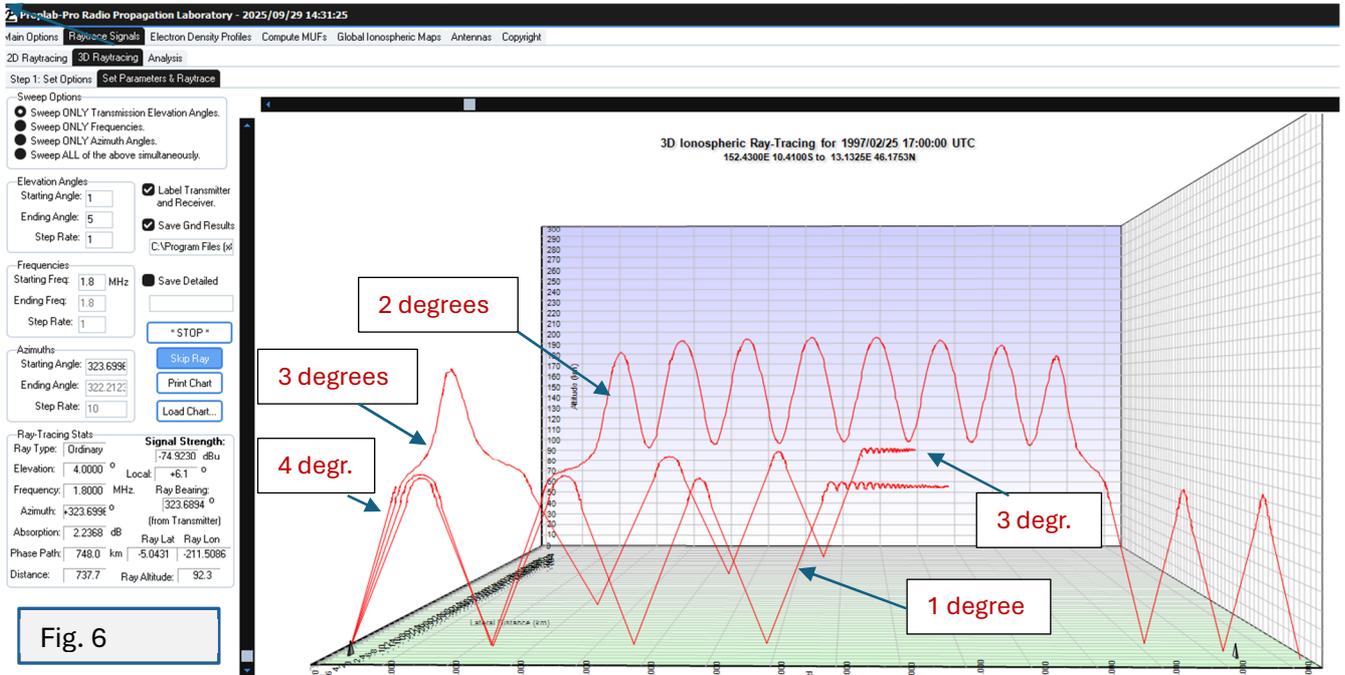
Fig. 6

Funny, at 3 degrees, after one F hop and two E hops, the ray enters again in the 90 km. sharp duct and is trapped there, extinguishing after huge absorptions as happened with 1 degree (Fig. 6).
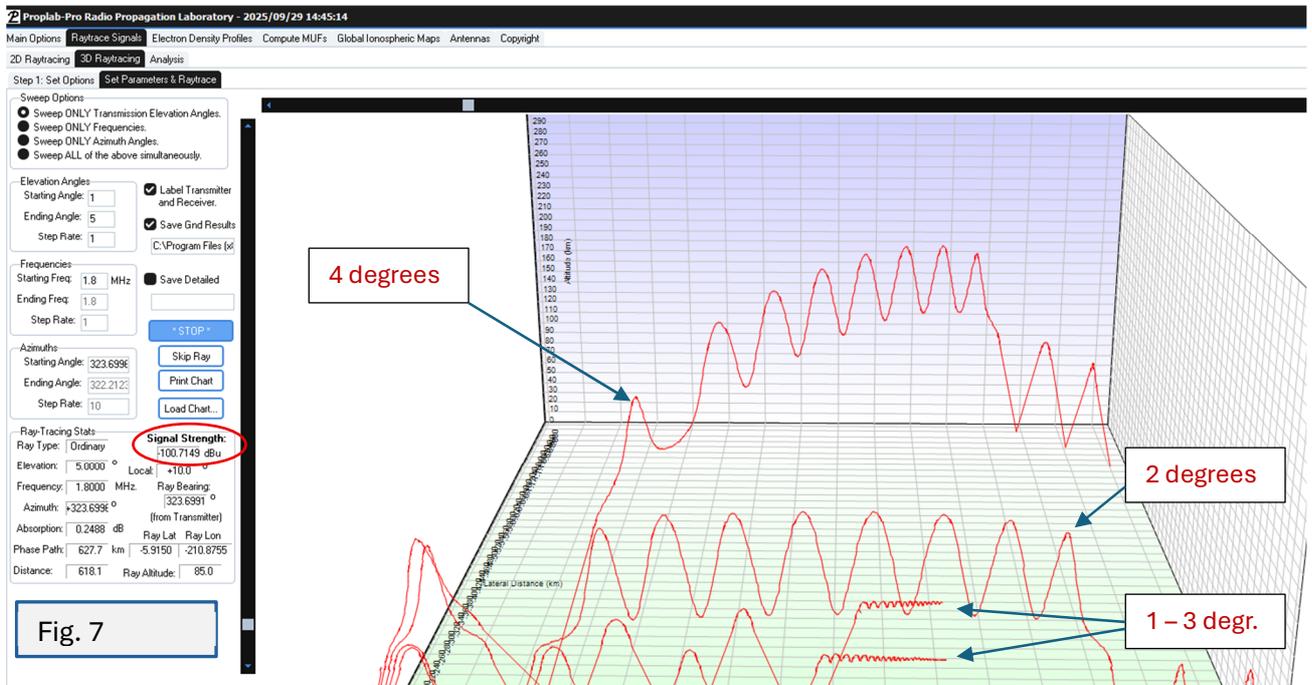
Fig. 7

Incredibility, at 4 degrees, after an F layer hop, the ray founds a regular duct and exits as the 2-degrees one, but with a strange skewing, about one thousand km. towards the south, ending with two E hops but too weak signal strength to be received (Fig. 7).

The next screenshot looks too crowded with all the five paths, but it shows how many ways can be encountered by a 1.8 MHz ray – along this path at the specified date, time and solar conditions – by just varying the elevation angle from 1 to 5 degrees. Of course, the antenna is not a single-shot rifle, since its transmission lobe is quite wide and involves several angles: this work must be taken as theoretical, but it is useful for understanding what is happening and what to expect on 160 meters.

Fig. 8

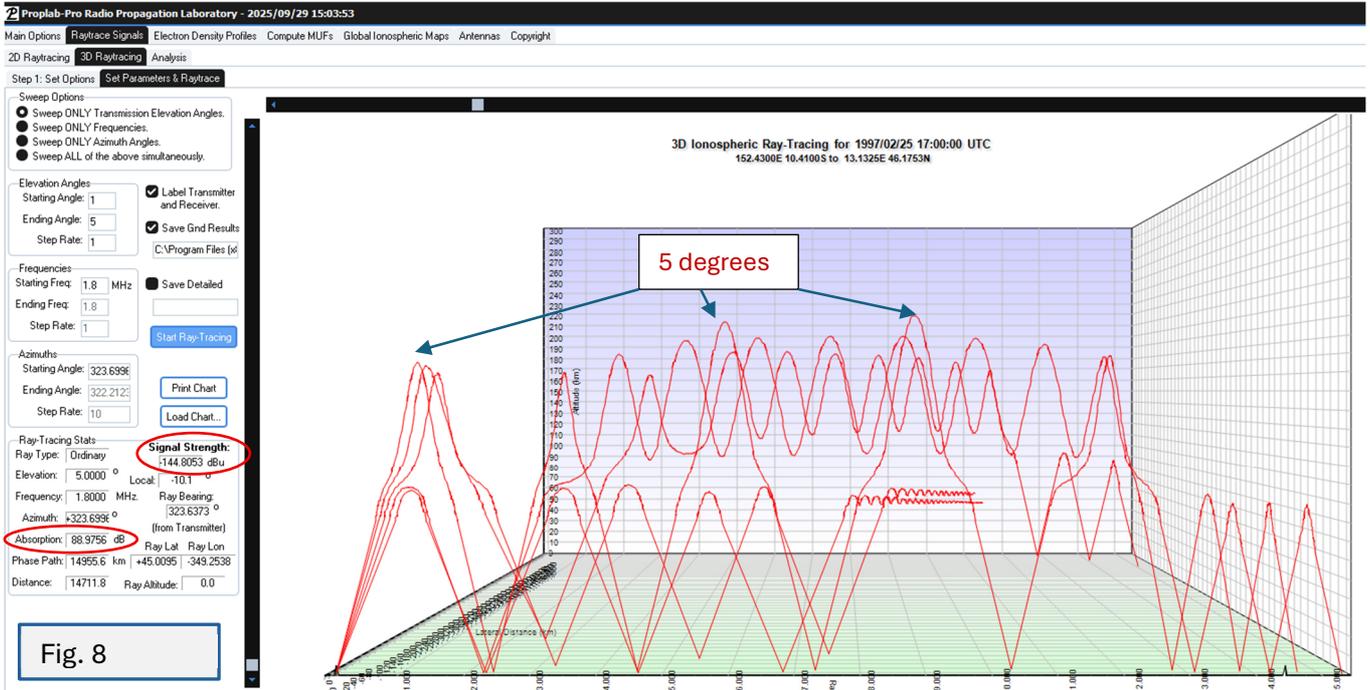Fig. 8 ends up with the <u>5 degrees</u> elevation run consisting in five F hops (two of them reaching the height above 200 km.) and two last E hops, but – due to excessive absorptions (89 dB) and reflection losses – a resulting signal strength at the receiver of -144 dBμV/m, out of any possible detecting.

The same results are given in Fig. 9, which shows the strange southern wards skewing of the path at 4 degrees.
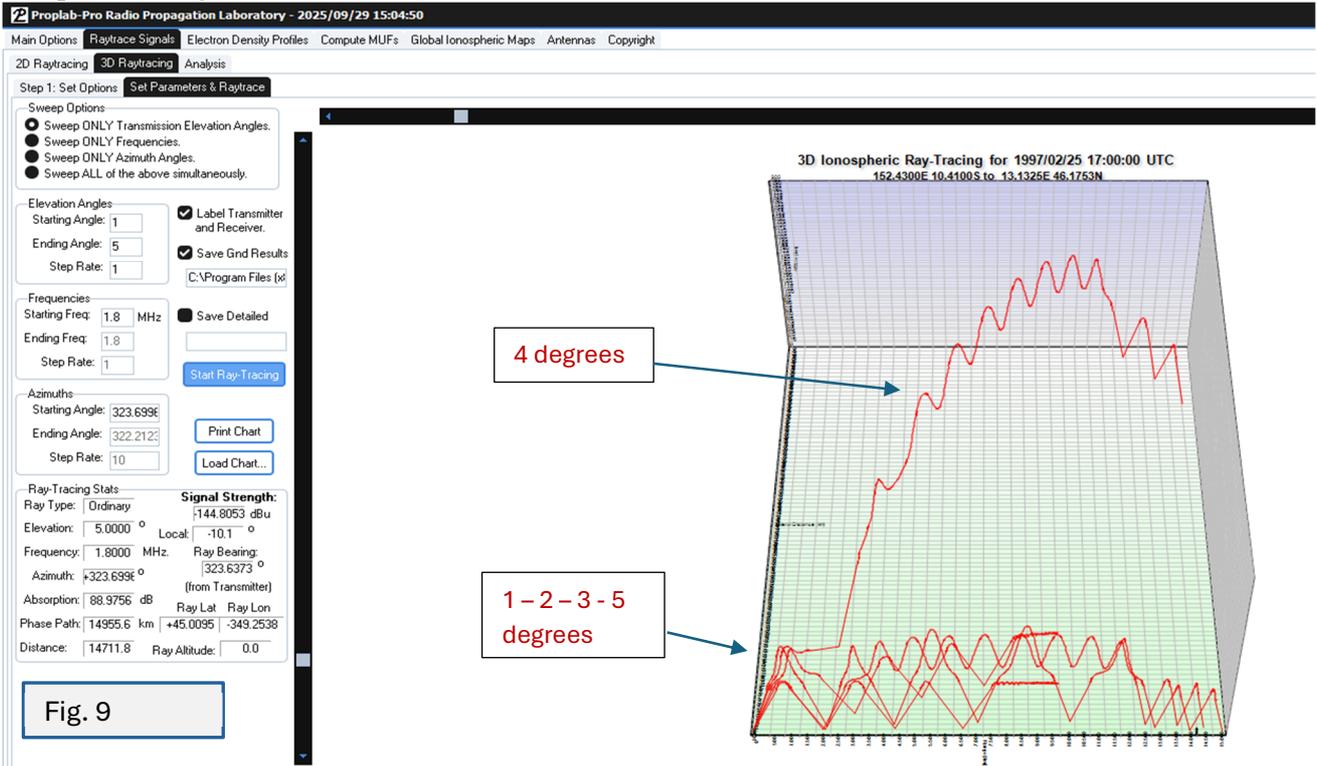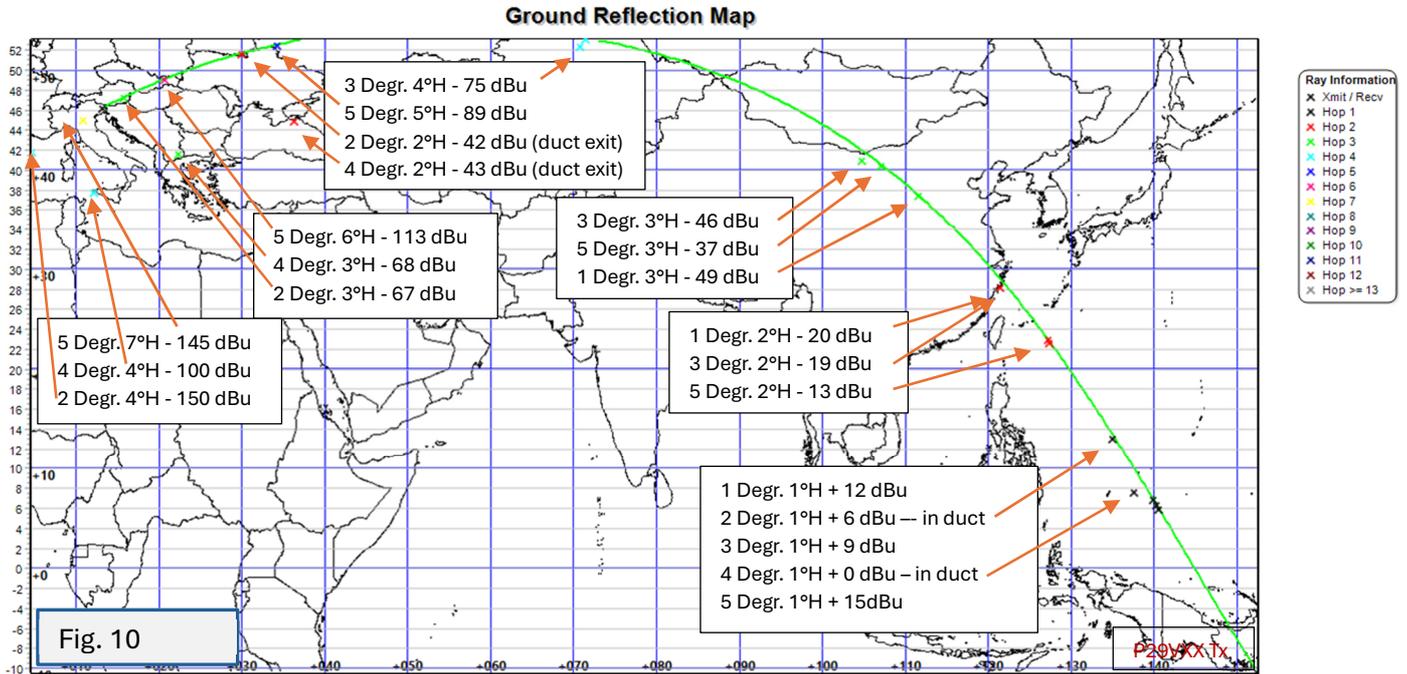

Fig. 9

Although it has been shown that there was no concrete possibility of receiving P29VXX at our sunset with signals above the noise threshold, let's check on this map – just for a study purpose – the reflection points with the relative signal strengths in dBµV per meter

Ground Reflection Map

3 Degr. 4°H - 75 dBu
5 Degr. 5°H - 89 dBu
2 Degr. 2°H - 42 dBu (duct exit)
4 Degr. 2°H - 43 dBu (duct exit)

5 Degr. 6°H - 113 dBu
4 Degr. 3°H - 68 dBu
2 Degr. 3°H - 67 dBu

5 Degr. 7°H - 145 dBu
4 Degr. 4°H - 100 dBu
2 Degr. 4°H - 150 dBu

3 Degr. 3°H - 46 dBu
5 Degr. 3°H - 37 dBu
1 Degr. 3°H - 49 dBu

1 Degr. 2°H - 20 dBu
3 Degr. 2°H - 19 dBu
5 Degr. 2°H - 13 dBu

1 Degr. 1°H + 12 dBu
2 Degr. 1°H + 6 dBu — in duct
3 Degr. 1°H + 9 dBu
4 Degr. 1°H + 0 dBu – in duct
5 Degr. 1°H + 15dBu

Ray Information
× Xmit / Recv
× Hop 1
× Hop 2
× Hop 3
× Hop 4
× Hop 5
× Hop 6
× Hop 7
× Hop 8
× Hop 9
× Hop 10
× Hop 11
× Hop 12
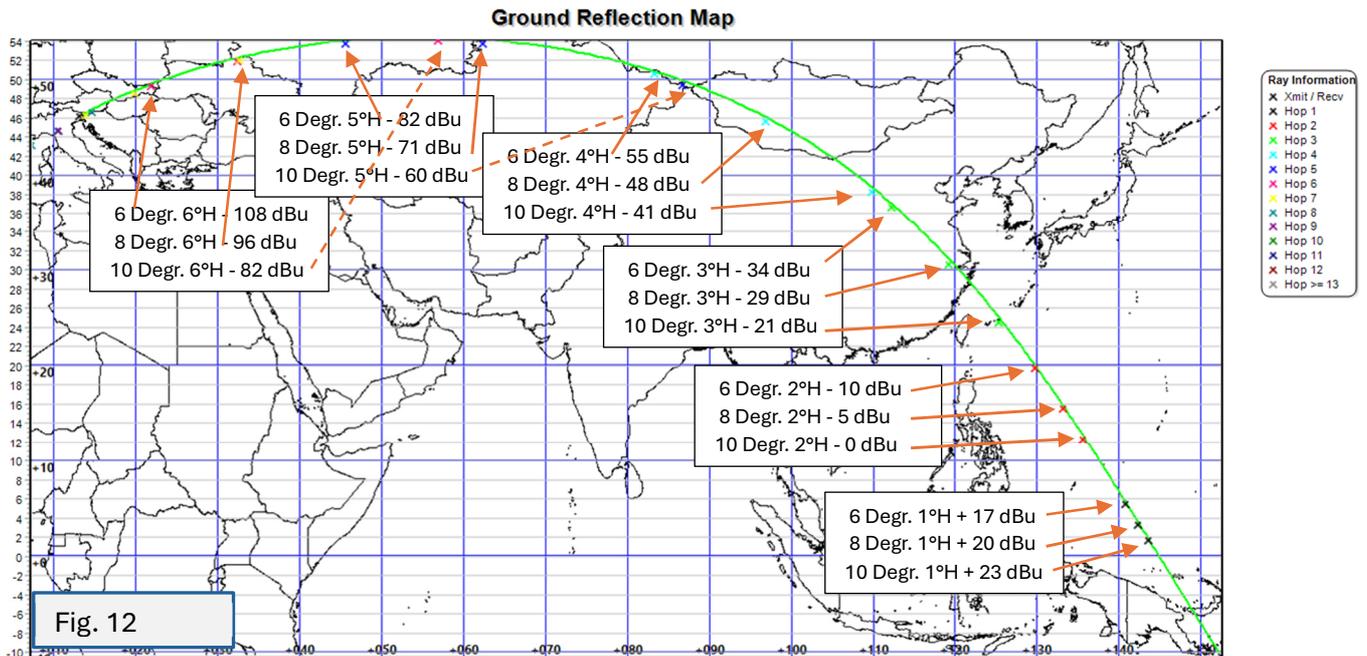× Hop >= 13

Fig. 10

P29VXX Tx

In this case we see that some kind of ducting occurs only at elevation angles of 2 and 4 degrees. But ionospheric absorptions on 1.8 MHz increase as the elevation angle decreases, so just one or two hops after the duct exit are enough to null out any real contact possibility. As an example, for a 10,000 km. (5 hops) path at 20 degrees, an absorption loss of 16 dB is calculated, doubles to 31 dB at 10 degr., to 61 at 5 degr.; then 77 dB at 4 degr., 102 dB at 3 degr., 153 dB at 2 degr. and 307 dB at 1 degree. These rough calculations agree with Proplab results in dBµV/m indicated in the above map.

Now let's rise the angle with the 3D analysis, in three steps, from 6 to 10 degrees (Fig. 11).

10 degrees   8 degrees   6 degrees

Fig. 11
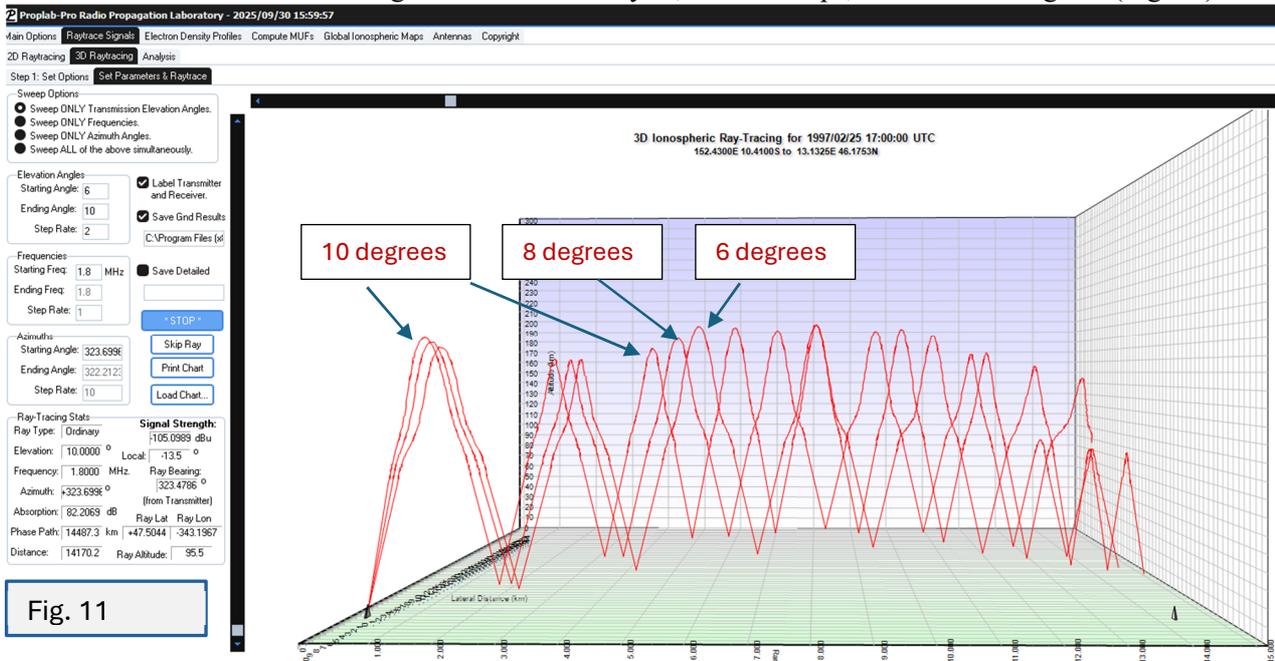
No other propagation modes occur at these angles than ordinary six F layer hops followed by two or three E hops with excessive ionospheric absorptions and ground reflection losses, which reduce the signal strength to an unmanageable value, as better shown in the following map (Fig.12).

Ground Reflection Map

6 Degr. 5°H - 82 dBu
8 Degr. 5°H - 71 dBu
10 Degr. 5°H - 60 dBu

6 Degr. 4°H - 55 dBu
8 Degr. 4°H - 48 dBu
10 Degr. 4°H - 41 dBu

6 Degr. 6°H - 108 dBu
8 Degr. 6°H - 96 dBu
10 Degr. 6°H - 82 dBu

6 Degr. 3°H - 34 dBu
8 Degr. 3°H - 29 dBu
10 Degr. 3°H - 21 dBu

6 Degr. 2°H - 10 dBu
8 Degr. 2°H - 5 dBu
10 Degr. 2°H - 0 dBu

6 Degr. 1°H + 17 dBu
8 Degr. 1°H + 20 dBu
10 Degr. 1°H + 23 dBu

Ray Information
× Xmit / Recv
× Hop 1
× Hop 2
× Hop 3
× Hop 4
× Hop 5
× Hop 6
× Hop 7
× Hop 8
× Hop 9
× Hop 10
× Hop 11
× Hop 12
× Hop >= 13

Fig. 12

The last E layer hops have been left off the picture because already well down the noise threshold (or MDS) of the best possible receiver (about 145 dBm): a signal strength of -80 dBµV per meter corresponds to -163 dBm (milliwatt), just at the last row of the conversion table published on the page "S/N ratio" of this web site. The conversion formula is as follows (Tnx Carl, K9LA):

dBm = dBµV/m - 77.21 - 20*LOG(freq. in MHz) + Rcv. Ant. Gain (For simplicity, we keep the receive ant. gain to 0, considering the use of isotropic antennas also at each reflection point).

Then, before going on with ray tracing to see what happens at higher angles and different times, I must cut here this paper in order to keep PDF file dimensions within the limits allowed for my website uploading. So, please close this document, go back, and click on:

P29VXX: at the search of a DUCTING mode with Proplab Pro – _Part 2._