Dec. 2024: S21DX on FT8 – SNR and path analysis with Proplab-Pro.

At the search of DUCTING mode.

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This is a follow-up of my path analysis of S21XX DXpedition in Feb. 1997 with 3D ray tracing of Proplab-Pro. The path is the same, just 200 km. longer as S21DX was operating from Kutubdia island. Let's start at 23.00 UTC, just after my QSO, which was the sunrise time there at the TX location.

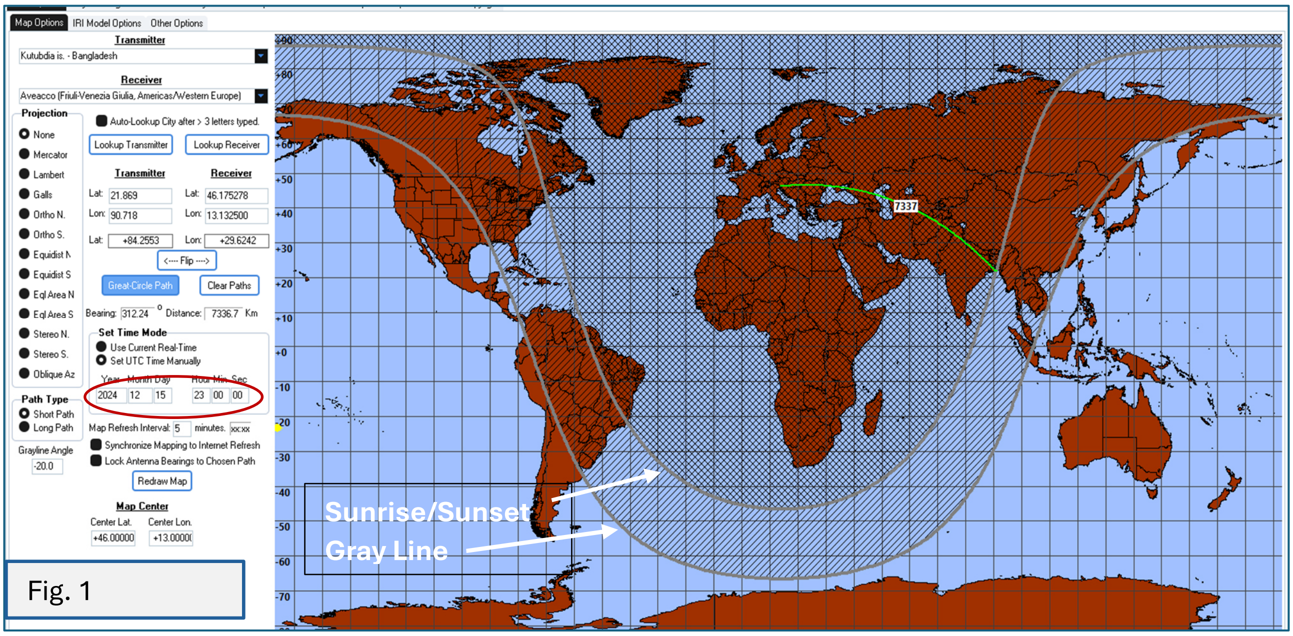


Fig. 1

The solar numbers found by the program for that date are: SSN = 151 and Ap index = 7, as indicated in Fig. 2, where the *Electron Density Profile* shows a possible "Duct" valley:

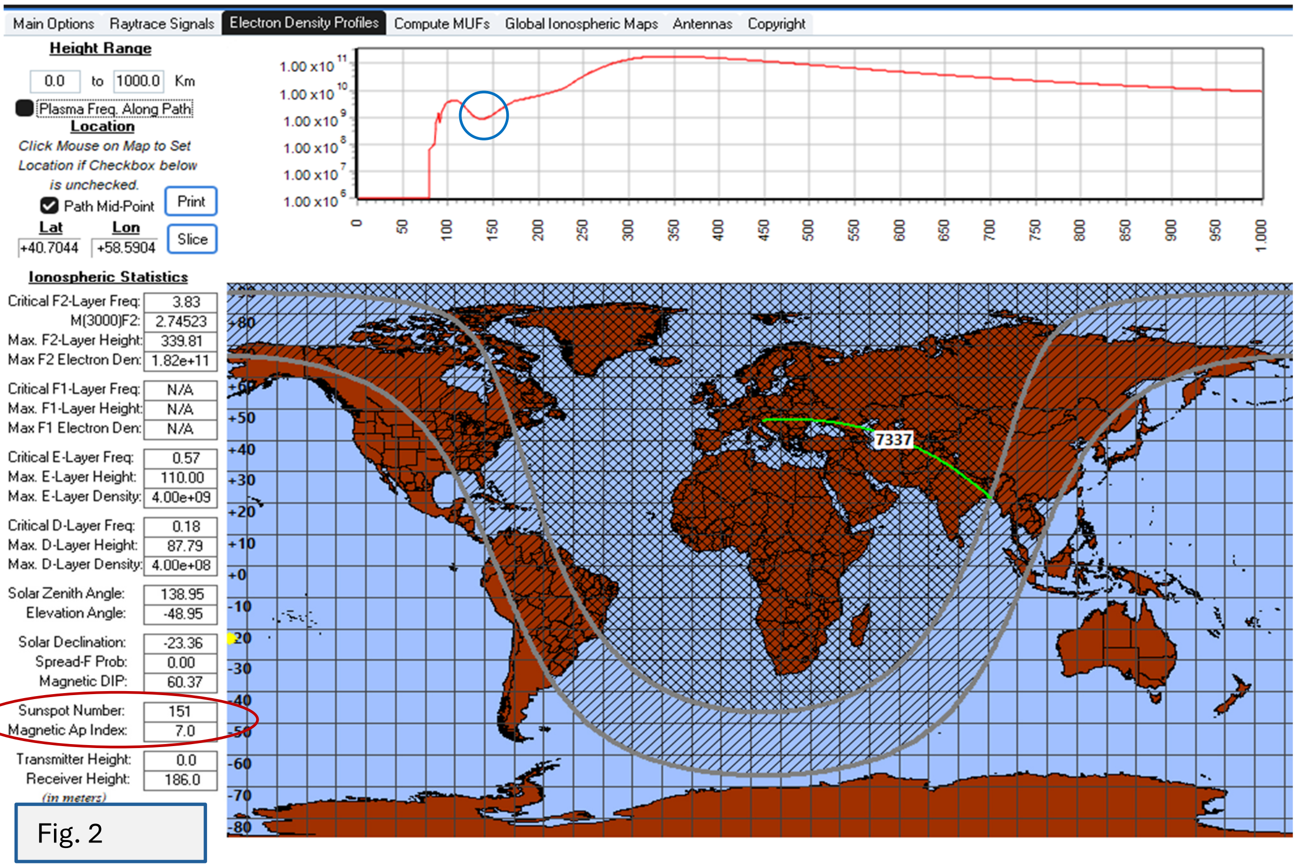


Fig. 2

All the explanations about these maps, plasma frequency and ducting have been given in the preceding analysis of this path (S21XX), so check part 3 of this series with more images for reference and you will be surprised by quite different results.

I started my ray-tracing analysis by sweeping on 5-, 15- and 25-degrees elevation angles:

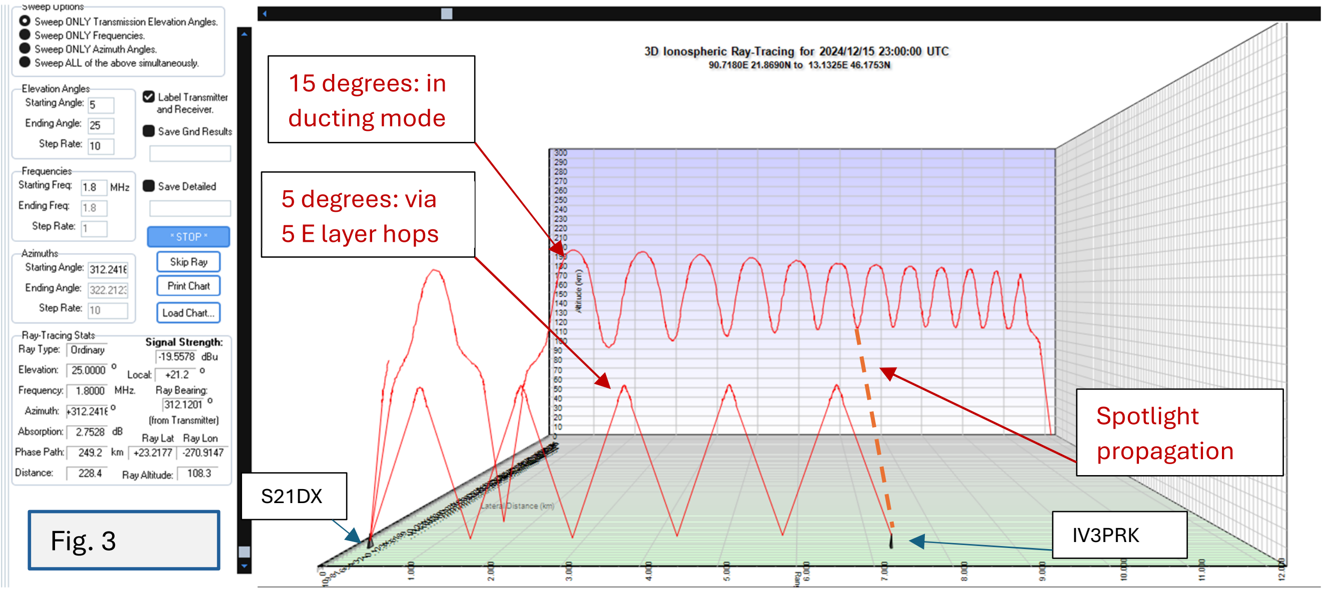


Fig. 3

At 5 degrees the entire path is exactly covered by 5 E layer hops and the ray, after 40 dB of ionospheric absorptions, arrives with a signal strength of -80.75 dBµV/meter, too weak to be detected. It corresponds to -163 dBm, which is below the noise floor, or MDS, of any receiver (Fig. 3).

If we raise the radiation angle to 15 degrees, after a first F layer hop, the ray enters in ducting mode but is trapped there and travels 12 thousand km. before going down to earth in the Atlantic Ocean with a good signal strength (-19.55 dBµV/m = -103 dBm) that could be S4 on a receiver's S-meter. If the ray finds a hole – or ionospheric irregularity – in the E layer above our QTH, it exits the duct and comes down with a strong signal: sometimes it happens, and this is a SPOTLIGHT propagation!

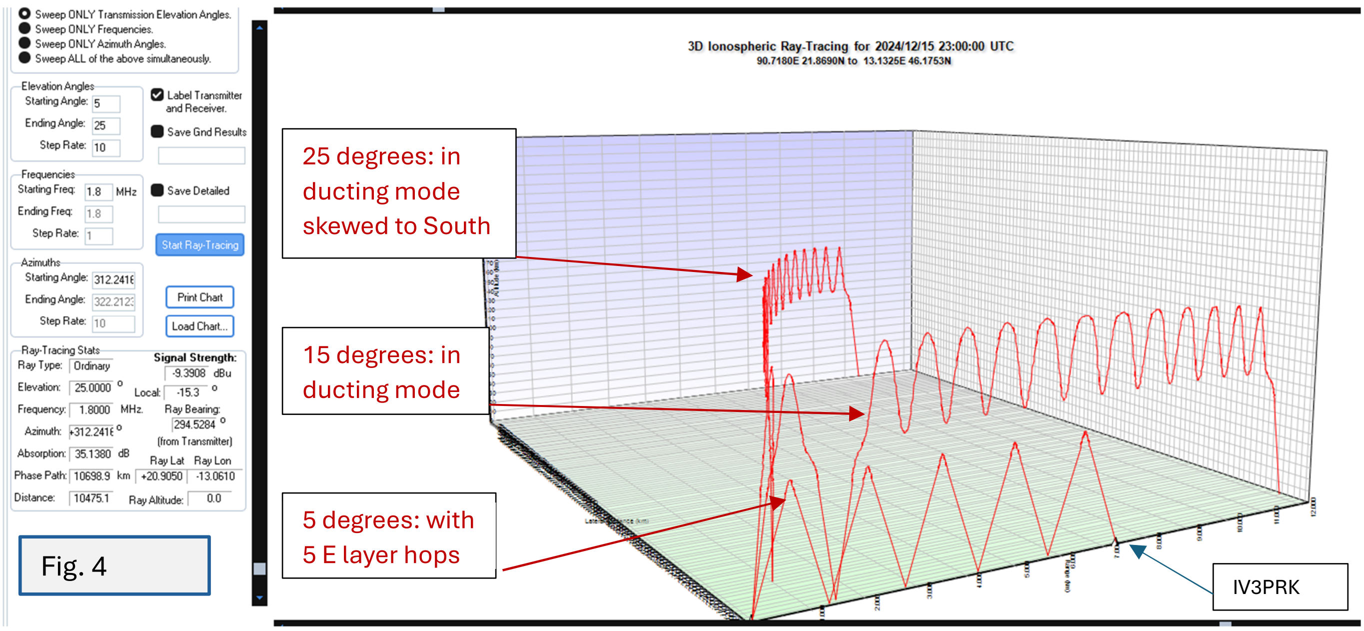


Fig. 4

At 25 degrees, contrary to what happened in the S21XX path analysis – made at the same time, but during solar cycle minimum – where ducting was indicated only at very low angles (4 and 5 degrees), we find the appearance of another ducting mode, with a remarkable deviation to the South.

Just to make clear the difference, I copy here the screenshot of the old S21XX analysis with the same elevation angle sweep. We see ducting only at 5 degrees, while at 15 and 25 degr. the propagation mode was through lossy E and F hops, ending in extremely weak and useless signal strengths (Fig. 5).

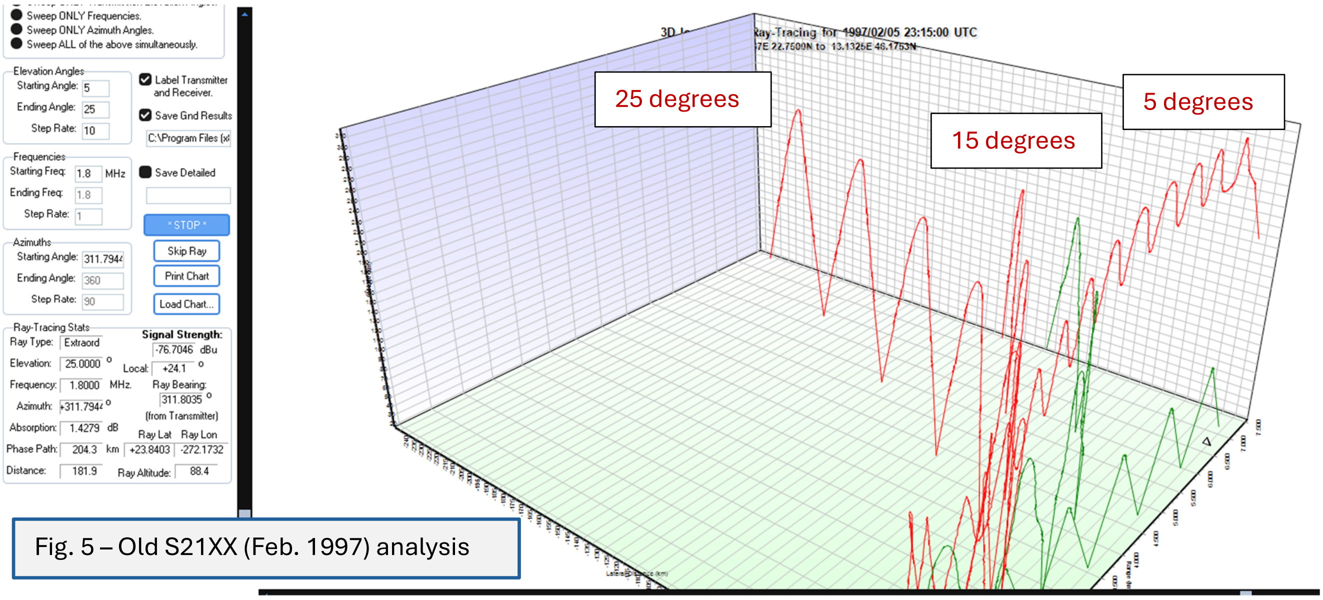


Fig. 5 – Old S21XX (Feb. 1997) analysis

We note almost the same skewing to southern direction but, instead of entering in a duct, the whole path is done through F layer hops with too many losses nulling out the arriving signal strength.

Now let's go back to Fig. 4, and we see – in Dec. 2024 during solar maximum – a different behaviour on S21DX: at 25 degr., after a first F hop, the ray enters in a duct, skews about 20 degr. to the south and exits in Niger (10.475 km) with a respectable signal of -9.39 dBµV/m (-92 dBm). Unfortunately, this ducting path doesn't transit over Europe, but at lower latitudes, through Middle East and North Africa, so no spotlight could be expected in this case. I checked also at close elevation angles (23 and 27 degrees) and, curiously, no ducting there but all F layer hops, with almost the same skew, as shown in this *Ground Reflection Map*. Here, the 25 degrees ducting path doesn't appear, as there are no ground reflections, and terminates below the left corner of the map at 21 lat. and -13 longitude.

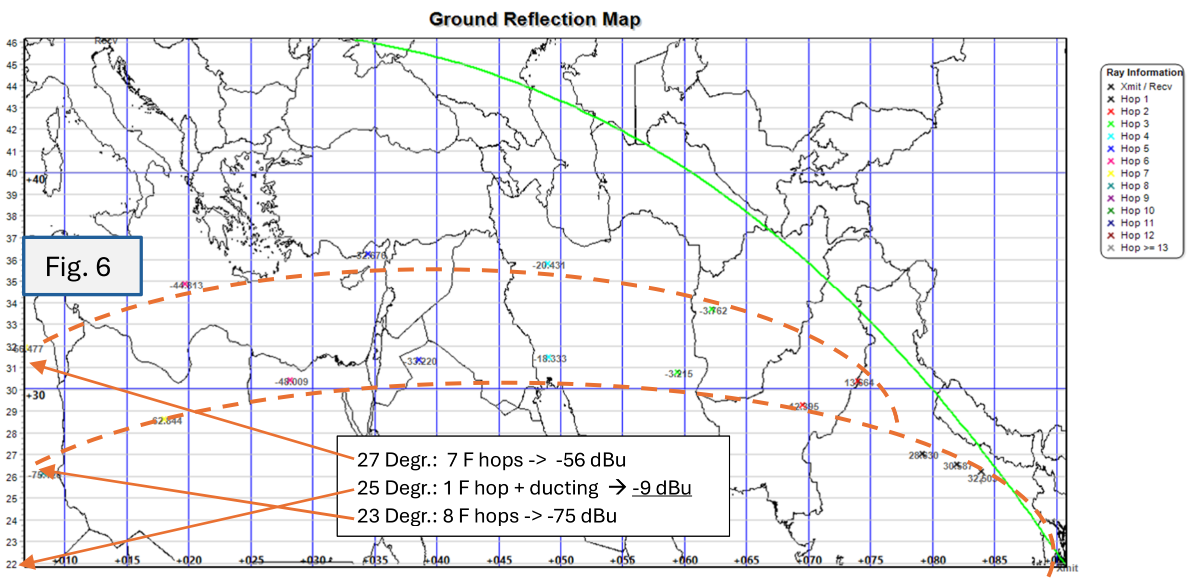


Fig. 6

As I worked S21DX on 160 m. FT8 at 22.40 UTC, it must had been at lower angles. We already found a ducting mode at 15 degrees, so I made another ray tracing from 11 to 19 degrees to verify how wide were these ducting conditions. We see that at 11 degr. the path was covered with 9 E layer hops, but without any contact possibility as the signal strength results -132 dBµV/meter. The same at 12 degr., but at 13 and 14 degr. the ray enters in a full duct which carries it for about 14.000 km and exits in the Atlantic Ocean with a strong 8 dBµV/m signal (Fig. 7).

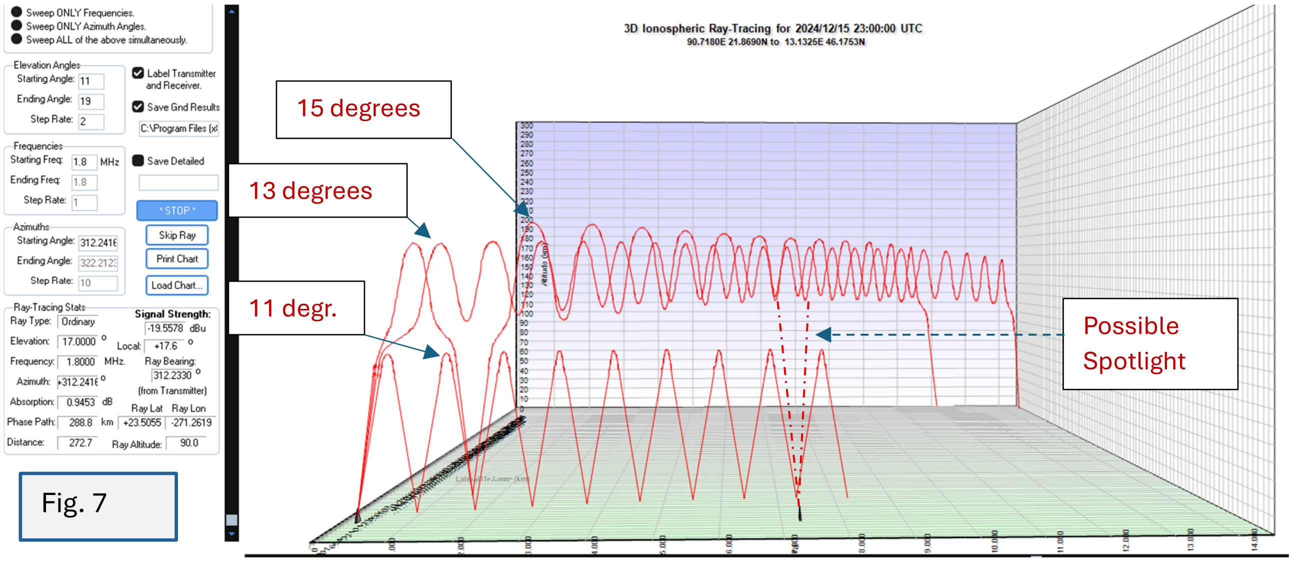


Fig. 7

At 15 degrees, the ray enters in the duct after a first F layer hop, then, at 16 degr. that happens after two F layer hops, at 17 degr. after three F hops, at 18 degr. after four F hops. At 19 degrees, the ducting mode ends, and the whole path is covered with five F layer hops, but the signal strength is very low (-50 dBµV/m, corresponding to -133 dBm), just at the noise floor. The following map shows the reflection points on the ground for the five paths with their signal strength in dBµV per meter.

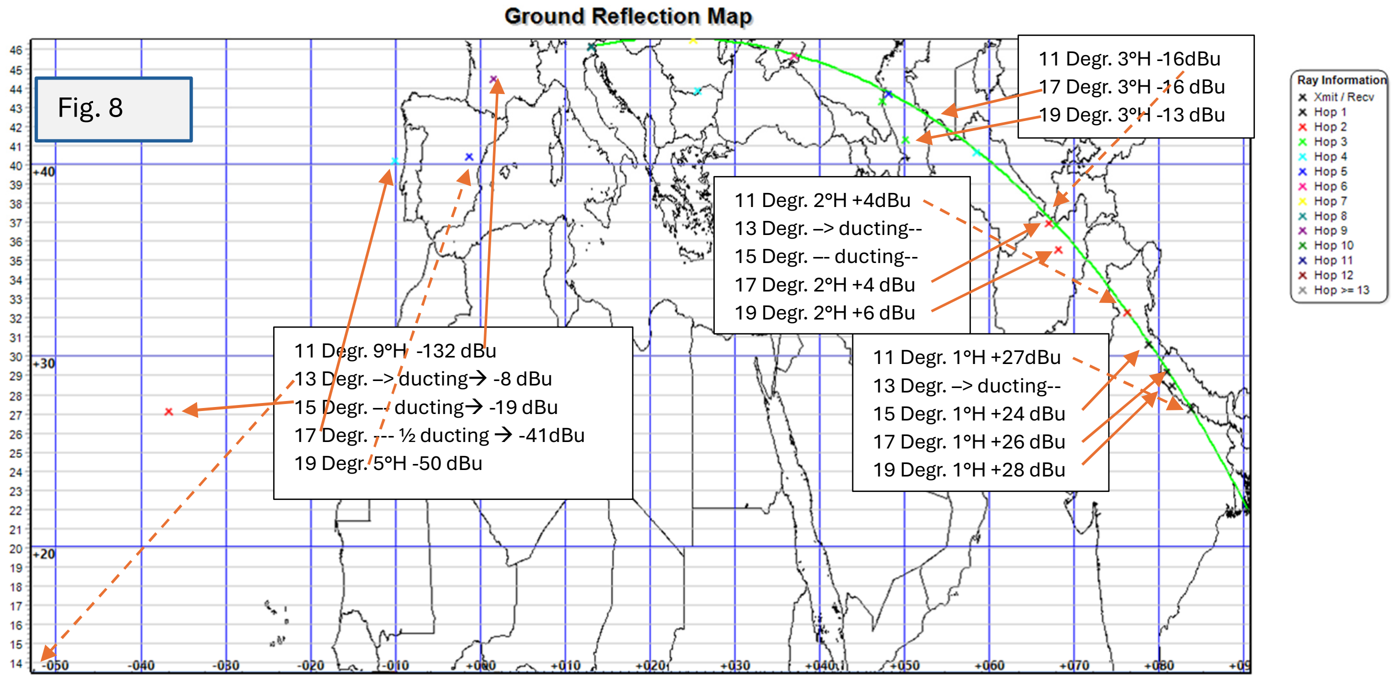
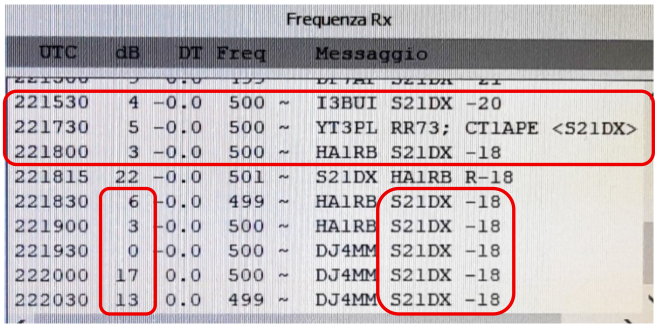


Fig. 8

The map shows also that at 19 degrees the ray starts to bend towards the south, a trend that becomes stronger as the angle increases, as illustrated earlier in Fig. 6. The best situation occurs between 13 and 17 degrees, where ducting follows the great circle route, offering favourable conditions for spotlight propagation in northern Italy. When I made my FT8 QSO with S21DX on Dec. 15th, I noted a stable and flat SNR of -18 to -20 dB on both sides. It was quite different the next evening: my received SNR on S21DX was jumping from zero to +17 dB within one minute, while they were passing to all their worked stations a stable -18 -20, as usual. It was an evident spotlight occurrence on my side.

This a partial screenshot of FT8 receiving window on December 16th ===>



UTC	dB	DT	Freq		Messaggio
221530	4	-0.0	500	~	I3BUI S21DX -20
221730	5	-0.0	500	~	YT3PL RR73; CT1APE <S21DX>
221800	3	-0.0	500	~	HA1RB S21DX -18
221815	22	-0.0	501	~	S21DX HA1RB R-18
221830	6	-0.0	499	~	HA1RB S21DX -18
221900	3	-0.0	500	~	HA1RB S21DX -18
221930	0	-0.0	500	~	DJ4MM S21DX -18
222000	17	0.0	500	~	DJ4MM S21DX -18
222030	13	0.0	499	~	DJ4MM S21DX -18

With an SNR of 17 dB and my estimated noise of -112 dBm on FT8 bandwidth, the signal should have been -95 dBm, corresponding to -12 dBµV (see SNR page on my website).

The next day (Dec. 17th) I began to watch on 1.836 MHz at 17.00 UTC:ll Europe was calling and making contacts, but not a trace here. I made another Proplab ray tracing at that time and found standard E layer hops at 5 and 10 degrees, and standard F layer hops above 15 degrees, all with too many lossy ground reflections (Fig. 9).

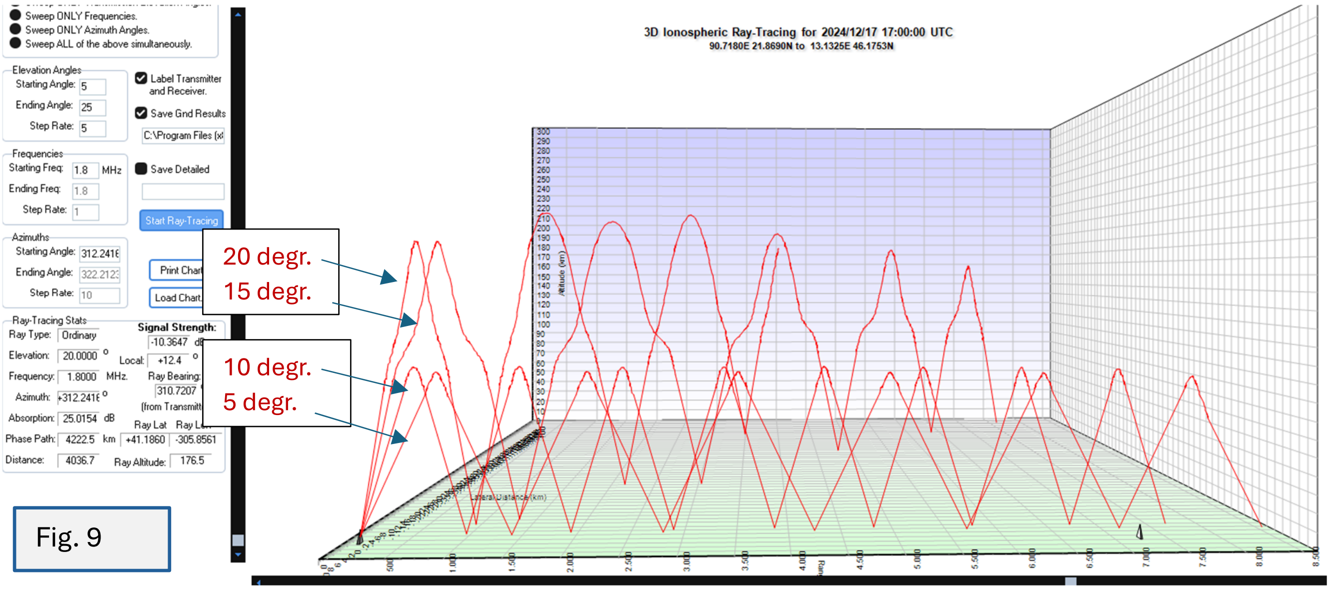


Fig. 9

From the above screenshot, I noted that at 15 degrees elevation, the ray bends a little bit to south instead of passing straight along the great circle. I then checked what happens at closer angles (Fig. 10).

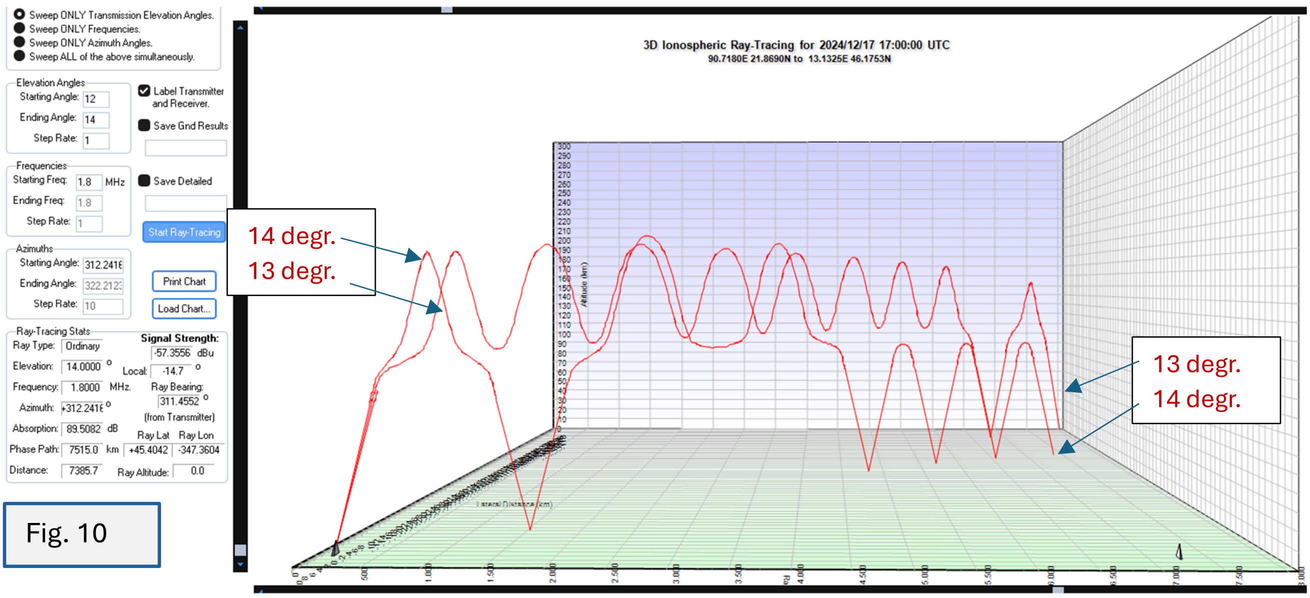


Fig. 10

At 13 degrees, the ray travels through the duct, exits at 7,000 km with a strong signal (+3.72 dBµV), and after a final F hop, ends past the target at -12.40 dBµV. Just raising the radiation angle by one degree, at 14 degrees, it penetrates the E layer, completes an initial F hop, then enters a brief (3,000 km) duct before three E hops, finishing with a weak -57 dBµV signal. Thus, from Proplab 3D ray tracing, the only possibility of a contact should be granted by a ray radiated a 13 degrees angle.

Later, 18.30 - 18.40 UTC, also my friends IV3RAV and IV3HYD made it, while I was not getting a trace of S21DX.

The brothers are using a receiving antenna which is an exact copy of my Waller Flag but installed in quite a different location: in a business area, among industrial buildings (they manage a printing industry) and close to a big tower with all other HF antennas. Thus, from the graphic below, they should have about 15 dB of more man-made noise than me.

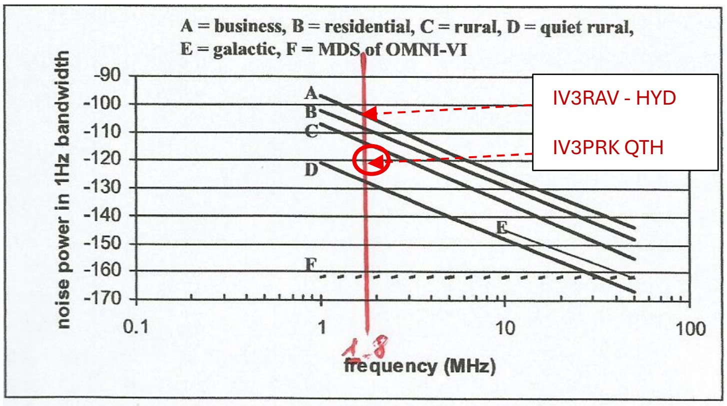


Figure 1 – Man-made noise and galactic noise versus frequency

Converting this noise power from 1 Hz bandwidth to 6.25 Hz of FT8 we get: 10*Log (1/6,25) = -8dB; so, local noise on FT8 for IV3PRK becomes -112 dBm and for IV3RAV/IV3HYD -97 dBm.

15 dB is generally the difference I hear better than my friends, not depending on the DX signal strength but on the noise, the other factor of SNR. But this time I had no trace of S21DX, so spotlight was favouring them and not me, despite no more than 10 km. distance between us!

To leave no stone unturned, I repeated the same analysis at 18.40 UTC and found some small improvements: at 13 degrees the full ducting path ends with -10.40 dBµV, and even better at 14 degr., with a longer duct ending at 7.000 km. with a -11.67 dBµV and, after a single F hop, arrives beyond the target with -28.25 dBµV/m. No changes in other elevation degrees: only E layer hops at 12 degrees and below, and only F layer hops at 15 degrees and above (Fig. 11).

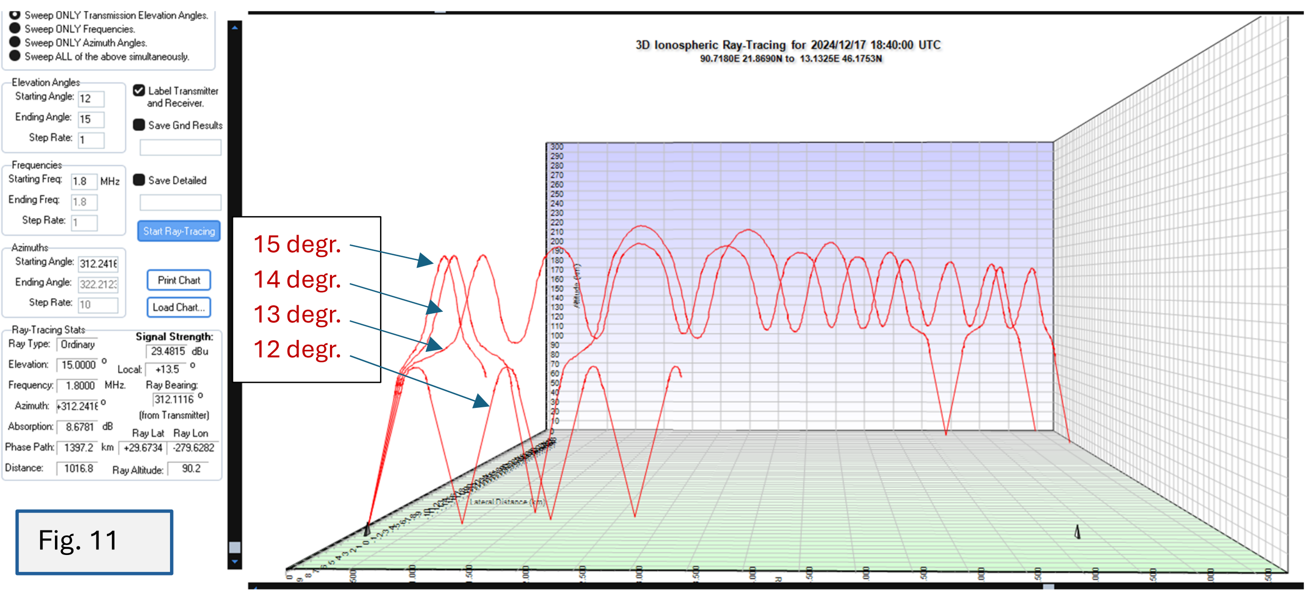
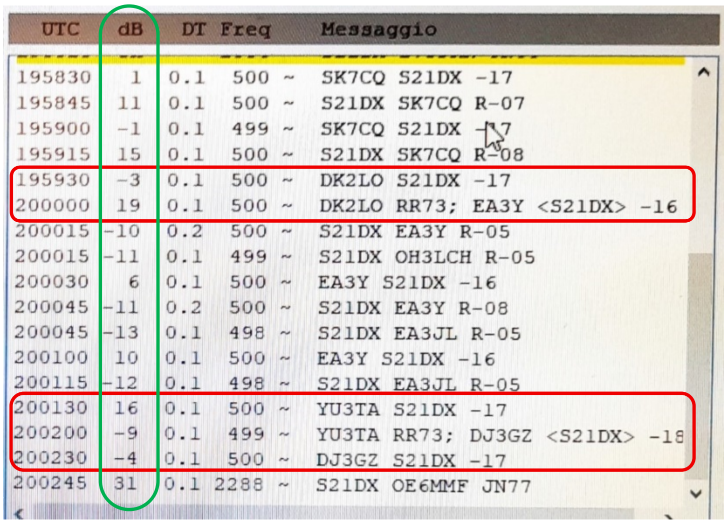


Fig. 11

The next day, Dec. 18th at 20.00 UTC, S21DX signals came up again on my FT8 window as shown here. ====>>



UTC	dB	DT	Freq		Messaggio
195830	1	0.1	500	~	SK7CQ S21DX -17
195845	11	0.1	500	~	S21DX SK7CQ R-07
195900	-1	0.1	499	~	SK7CQ S21DX -17
195915	15	0.1	500	~	S21DX SK7CQ R-08
195930	-3	0.1	500	~	DK2LO S21DX -17
200000	19	0.1	500	~	DK2LO RR73; EA3Y <S21DX> -16
200015	-10	0.2	500	~	S21DX EA3Y R-05
200015	-11	0.1	499	~	S21DX OH3LCH R-05
200030	6	0.1	500	~	EA3Y S21DX -16
200045	-11	0.2	500	~	S21DX EA3Y R-08
200045	-13	0.1	498	~	S21DX EA3JL R-05
200100	10	0.1	500	~	EA3Y S21DX -16
200115	-12	0.1	498	~	S21DX EA3JL R-05
200130	16	0.1	500	~	YU3TA S21DX -17
200200	-9	0.1	499	~	YU3TA RR73; DJ3GZ <S21DX> -18
200230	-4	0.1	500	~	DJ3GZ S21DX -17
200245	31	0.1	2288	~	S21DX OE6MMF JN77

I never saw such a strange QSB or spotlight propagation: within 30 seconds, the SNR jumped from -3 to +19 dB and, two minutes later, fall from +16 to -9 dB in other 30 seconds. Of course, I didn't make any change in antennas or receiving setup. What does it mean? Given my estimated local noise on 6.25Hz FT8 bandwidth of -112 dBm, an SNR of -9 dB must be originated by a signal power of -121 dBm (-121 -112 = -9) and, for an SNR of 19 dB the signal power must be -93 dBm (-93 -112 = +19). Then, from the table in the SNR page of this site, we can convert the calculated power value, into the voltage signal strength in dBµV per meter given by Proplab program; thus, -121 dBm is equivalent to -38 dBµV, and -93 dBm is equivalent to -11 dBµV.

I went again on Proplab-Pro for a last run at 20.00 UTC to verify if and how such signal strengths could be found. Again, it was confirmed that propagation on this path could be possible via E layer reflections at low angles of radiation, and via F layer reflections at angles higher than 15 degrees but, in both cases, with prohibitive ionospheric and ground losses. Thus, I made a 3D analysis from 12 to 16 degrees, which doesn't differ too much from previous one (Fig. 12).

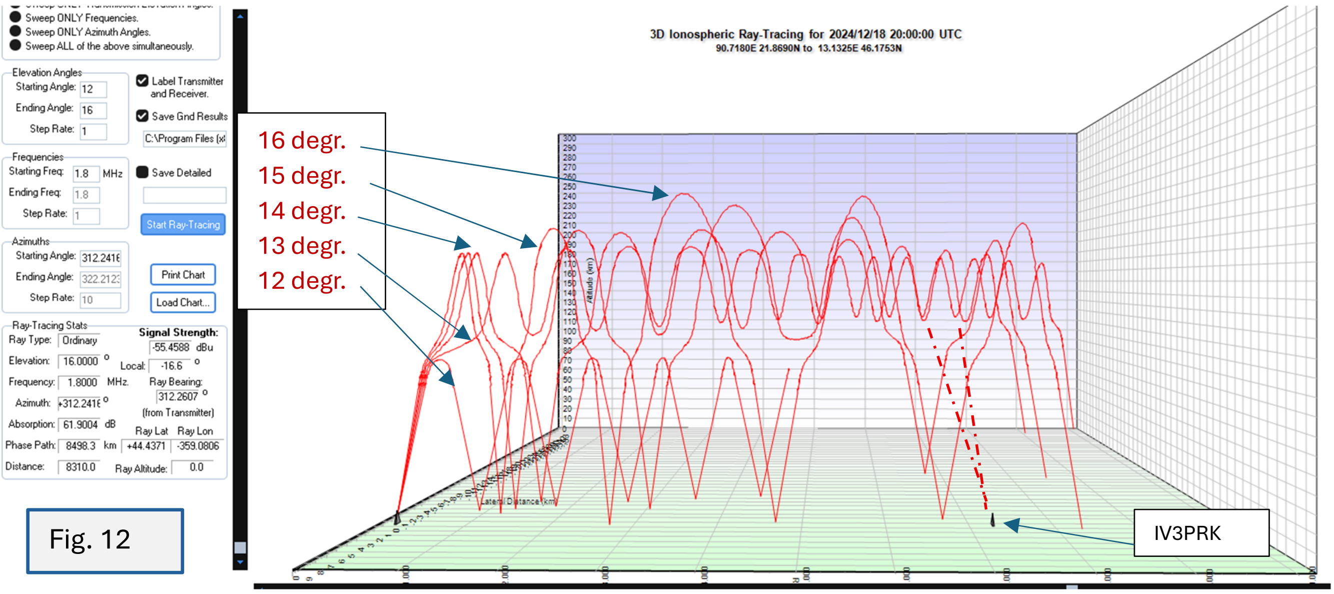


Fig. 12

There are additional ducting chances at 13, 14, and 15-degrees elevation. These paths follow the great circle over our area and can – unpredictably - exit from the duct due to hourly electron density changes, reaching the receiver with strong signals, surely including -38 and -11 dBµV/m.

The map in Fig. 13 shows the signal strength at each ground reflection point. As usual, for ducting, only the output signal strength is recorded, and those at 13 and 14 degrees are very good; the one at 15 degrees is significantly lower due to the duct only entering the path at the end, while both non-ducting paths, at 12 and 16 degrees, end with -55 dBµV (-139 dBm, just at the MDS level). However, with five E hops at 12 degrees, we are only halfway there, while with five F hops at 16 degrees we reach southern France.

The 160 meters signal at the end of the duct at 13, 14, and 15 degrees reaches much further the Atlantic coast, with good strength, but it would be even better if it could find a way to exit earlier, above our QTH, due to occurrences described in my earlier papers, i.e. a case of SPOTLIGHT propagation.

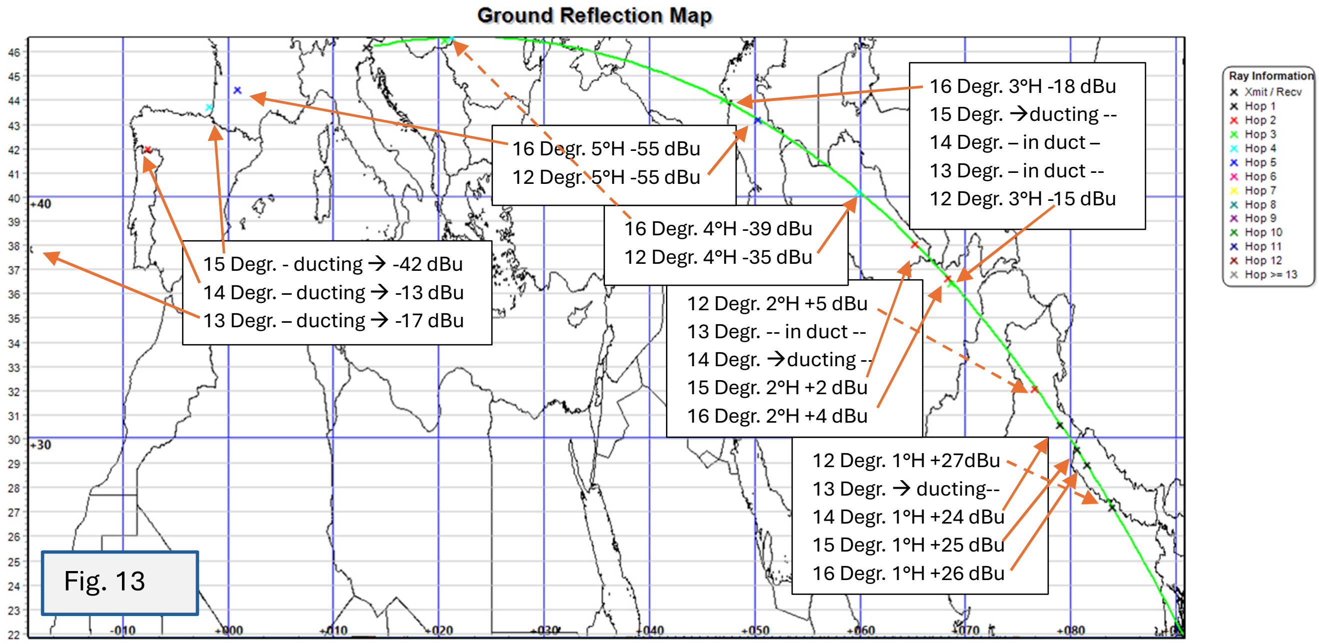


Fig. 13