# NEWSLETTER-AMSAT-EA

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## Greencube

This satellite is coordinated by the Department of Astronautical, Electrical and Energy Engineering of the La Sapienza University in collaboration with the National Agency of New Technologies , Energy and Economic Sustainability Development (ENEA) and whose objective is to develop new technologies for human colonization of the moon . It has a 3U Cubesat design format.

A micro-garden 6 thousand km from Earth to cultivate fresh vegetables for future space explorations. GREENCUBE has been designed by a team Italian scientist and will be included, for the first time, in a mini satellite to be launched during the first official trip of European Space Agency´s VEGA-C.

The Sapienza University of Rome, in coordination with the Italian Space Agency, is collaborating with ENEA and the Federico II University of Naples to produce the prototype. It measures 30x10x10 cm and is based on a hydroponic circuit capable of guaranteeing, during the 20 days of experimentation, a complete growth of microgreens, selected among those that best adapt to extreme extraterrestrial conditions.

Located in a confined and pressurized space, the micro-garden will have an integrated system of high-tech sensors for monitoring and control environmental parameters, growth and health status of plants. All information acquired will be sent to Earth autonomously, which will give researchers the opportunity to evaluate the reaction of plants to extremely stressful conditions.

This satellite has a MEO orbit at 6000km from the earth with an inclination of 70° and a period of 228 minutes. It will have a digirepiter on 435.310 Mhz GMSK to 1k2 or 4k8. The launch was from a Vega-C rocket on its inaugural journey last July 13 and is currently receiving telemetry with very good signals.


IberRadio
VII Feria de las Radiocomunicaciones
www.iberRadio.es
17 y 18 de septiembre
Ávila
Sábado de 10:00 a 20:00
Domingo de 10:00 a 14:00
Avenida de Madrid, 102 · Ávila
Lienzonorte
ÁVILA
URE
Ayuntamiento de Ávila
Del Rey · De los Leales · De los Caballeros

# Study of distance records in Leo satellites

*EA1PA - Salva*

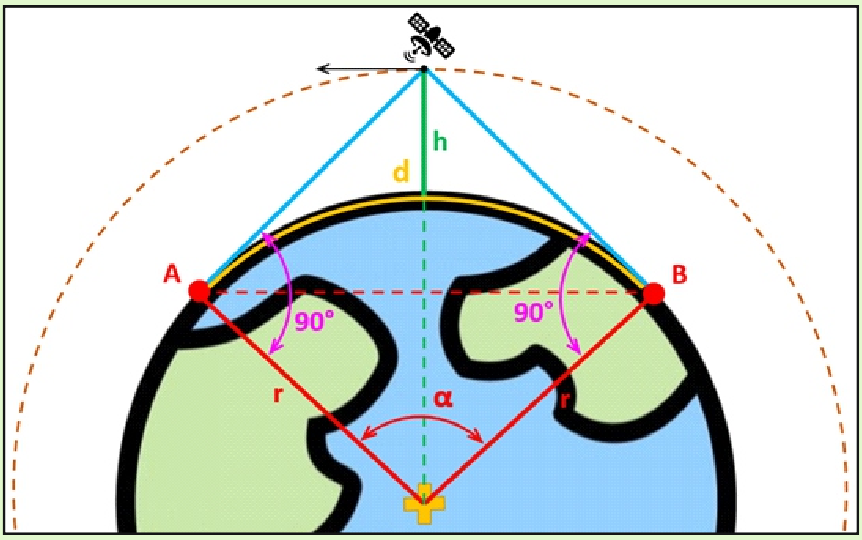
All of us have wondered about the maximum distances that we can achieve when contacting through a ham radio satellite. It is one of the first questions raised to glimpse the possibilities of this facet of amateur radio and thus try to reach the most distant places possible. As you already know, it basically depends on the satellite that we use,its orbital height and therefore the size of the footprint projected on the surface.

For many of us it is especially attractive to try the contacts pushing the limits of the footprint as it poses a challenge to our skills and for the rigs we use. The sensations experienced in those QSOs with Null elevations, or even negative elevations under certain circumstances, are magnificent and make us love this hobby even more.

For all these reasons, a certain desire to improve arises in our community with the objective of maximizing the range of the transponder. On the AMSAT website. You can see the records with the maximum distances achieved so far on the satellites, active and non-active. Paul Stoetzer, N8HM, keeps the page up to date collecting the requests that exceed the previous marks indicating the new distance record holders: https://www.amsat.org/satellitedistance-records/

Thinking about this topic and trying to provide an analytical view, I thought about the possible margins of improvement of the distances currently achieved. My approach is to compare the maximum theoretical distances with those actually achieved in order to identify, on paper, the most favorable satellites to break the distance record and make a classification based on difficulty.

First, we will calculate approximately the maximum distances that can be achieved depending on the radius of the Earth and the height of the Satellite orbit. Consider the following sketch to understand the process:




d = Maximum distance covered by the satellite, "arc between A and B" (km).
h = Height of satellite orbit (km).
r = Radius of the Earth (km).
α= Angle of the arc of the footprint projected on the earth's surface (rad).

The length of the arc "d" is the result of the angle "α" by the radius of the Earth:

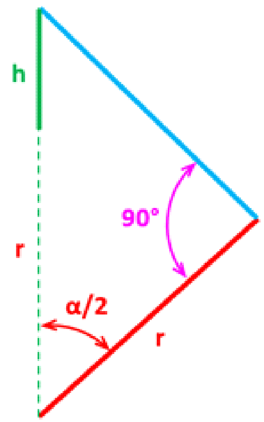
$$d = \alpha \cdot r$$

By trigonometry we can calculate the arc angle "α":

$$\cos\frac{\alpha}{2} = \frac{r}{r+h}$$

$$\frac{\alpha}{2} = \cos^{-1}\left(\frac{r}{r+h}\right)$$

$$\alpha = 2 \cdot \cos^{-1}\left(\frac{r}{r+h}\right)$$




Therefore, the theoretical maxium distance covered by a satellite orbit at a height h would be defined by the following formula (*):

$$\boxed{d = 2 \cdot r \cdot \cos^{-1}\left(\frac{r}{r+h}\right)}$$

The Earth is not a perfect sphere being flattened at the poles. Is by Therefore, we will consider the mean radius:

- Equatorial radius: 6,378.1 km
- Polar radius: 6,356.8 km
- Average radius: 6,371.0 km

On the other hand, the height of a satellite is defined by its orbit. The orbit is not purely circular and best resembles an ellipse. When the satellite orbits the earth the distance to the planet does not remain constant, so that´s why we talk about “perigee” and “apogee”:

- Perigee: Point of the orbit with the least distance to the Earth.
- Apogee: Point of the orbit with the greatest distance to the Earth.

As the objective of this article is to study the maximum distances we can get, we will only look at the apogee values for each satellite. Through the internet we can easily find them, being the website [https://www.n2yo.com](https://www.n2yo.com) very complete and useful. In the following image we show as an example the information extracted for the RS-44 satellite. The apogee is 1517.2 km.

**DOSAAF-85 (RS-44)**

Track DOSAAF-85 (RS-44) now!
10-day predictions
DOSAAF-85 (RS-44) is classified as:

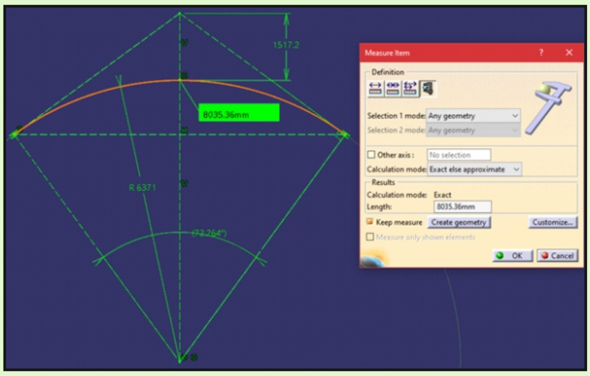
Amateur radio

**NORAD ID**: 44909
**Int'l Code**: 2019-096E
**Perigee**: 1,182.3 km
**Apogee**: 1,517.2 km
**Inclination**: 82.5 °
**Period**: 112.5 minutes
**Semi major axis**: 7720 km
**RCS**: Unknown
**Launch date**: December 26, 2019
**Source**: Commonwealth of Independent States (former USSR) (CIS)
**Launch site**: PLESETSK MISSILE AND SPACE COMPLEX (PKMTR)

In this case, if we apply the formula of the theoretical maximum distance (*):

$$d = 2 \cdot 6371 \cdot \cos^{-1}\left(\frac{6371}{6371+1517.2}\right) = 8035.36km$$

We can verify that the calculation is correct using the graphical method. I have drawn the geometry with a CAD program and we get the same value when measure the length of the arc highlighted in orange:



Once we know how to calculate distances and where to find the apogees, we can make a spreadsheet to collect in a table all the data and results for each of the active satellites.

Finally it is very interesting to add an indicator in a column to show the % of the relative margin of improvement. Basically compares the value of the distance record recorded on the AMSAT page with the theoretical value of maximum distance that could be achieved (what we have previously referred to as “d”).

| SATELLITE DISTANCE RECORDS STUDY | | | 01/07/2022 | EA1PA - Salva | EARTH RADIUS (km) | 6371.00 |
|---|---|---|---|---|---|---|
| SATELLITE | MODE | APOGEE (km) | CURRENT DISTANCE RECORD (km) | HOLDERS | MAX. THEORETICAL DISTANCE (km) | ROOM FOR IMPROVEMENT (%) |
| AO-109 | FT4?? | 507.50 | 2445.00 | ES4RM - F4DXV | 4925.28 | 50.36% |
| AO-07 (Mode A) | SSB/CW | 1466.30 | 7454.00 | F4DXV - VE6WQ | 7921.31 | 5.90% |
| AO-73 | SSB/CW | 666.60 | 5313.00 | A65GC - F4DXV | 5590.65 | 4.97% |
| IO-86 | FM | 656.00 | 5324.00 | 9G5AR - PU4JOE | 5549.55 | 4.06% |
| SO-50 | FM | 703.50 | 5523.00 | F4DXV - N1AIA | 5730.64 | 3.62% |
| TO-108 | SSB/CW | 641.00 | 5298.00 | A65GC - F4DXV | 5490.68 | 3.51% |
| ISS | FM | 427.10 | 4403.00 | G0ABI - VE1PK | 4540.71 | 3.03% |
| UVSQ-SAT | FM | 533.40 | 4896.00 | F4DXV-VE1VOX | 5041.42 | 2.88% |
| PO-101 | FM | 604.50 | 5256.00 | A65GC - F4DXV | 5343.80 | 1.64% |
| HO-113 | SSB/CW | 774.30 | 5898.00 | KE9AJ - MI0ILE | 5986.86 | 1.48% |
| CAS-3H (LilacSat-2) | FM | 537.30 | 5008.00 | F4DXV - VE1CWJ | 5058.61 | 1.00% |
| XW-2C | SSB/CW | 526.20 | 5008.00 | F4DXV - VE1CWJ | 5009.47 | 0.03% |
| JO-97 | SSB/CW | 592.60 | 5300.00 | A65GC - F4DXV | 5294.75 | -0.10% |
| CAS-4A | SSB/CW | 544.50 | 5108.00 | A65GC - F4DXV | 5090.16 | -0.35% |
| CAS-4B | SSB/CW | 544.50 | 5108.00 | A65GC - F4DXV | 5090.16 | -0.35% |
| FO-29 | SSB/CW | 1327.90 | 7634.00 | F4DXV - KG5CCI | 7595.75 | -0.50% |
| AO-27 | FM | 805.10 | 6125.00 | AA8CH - EB1AO | 6093.68 | -0.51% |
| FO-99 | SSB/CW | 496.00 | 4907.00 | F4DXV - VE1CWJ | 4872.58 | -0.71% |
| AO-91 | FM | 805.80 | 6215.00 | G0ABI - KE9AJ | 6096.08 | -1.95% |
| EO-88 | SSB/CW | 472.20 | 4878.00 | F4DXV - VE1CWJ | 4761.19 | -2.45% |
| XW-2A | SSB/CW | 422.40 | 4645.00 | FG8OJ - PY2RN | 4516.97 | -2.83% |
| AO-07 (Mode B) | SSB/CW | 1466.30 | 8204.00 | F4DXV - KE9AJ | 7921.31 | -3.57% |
| RS-44 | SSB/CW | 1517.20 | 8402.00 | F4DXV - KI7UNJ | 8035.36 | -4.56% |

The interpretation is very simple if you order in descending order the calculated percentage. In the first positions are those satellites whose distance records have the greatest theoretical possibility for improvement. Namely, those who are supposed to be the most likely candidates to establish a new record that makes the old one obsolete.

As we go down the table, the current mark is more difficult to beat, the improvement being progressively less likely. In the last positions there are values with negative percentages, in which the current distance record is greater than the theoretical one, which denotes extreme difficulty in improving the distance record. It would only be feasible under very favorable conditions with totally clean horizons and with raised spots on both sides.

Now we can realize that the records achieved by F4DXV, KE9AJ and KI7UNJ on the RS-44/AO-07B are fabulous and impressive. Without detract the following in the table with very remarkable records: FG8OJ,PY2RN, VE1CWJ, G0ABI, ...

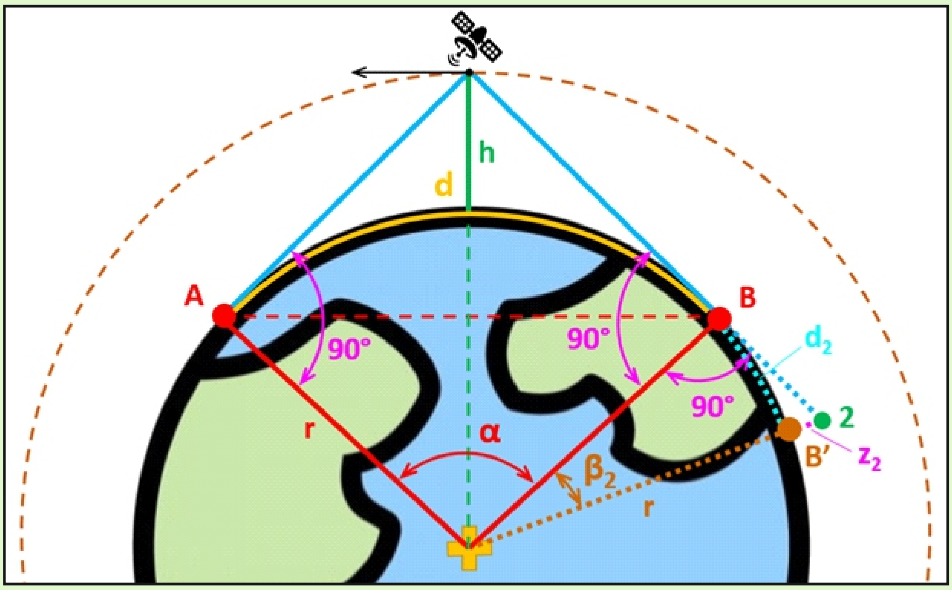
On the other hand, thanks to this study, we are now aware that the AO-07A would be the best candidate to try to beat the distance record and get on Paul's list. Question that remains corroborated by comparison with the distance reached on transponder B. Additionally, its interesting the opportunity we can have with the AO-73. Although it has difficulties due to the accused QSB and lack of stability, there is potential to try.

I exclude the first of the list, the AO-109, since I consider it a very exceptional and particular with such a low transmission power, 8mW, that makes it difficult to cover long distances in SSB due to the weakness of the signal. In this occasion I propose to FT4 lovers with fixed stations to try to get contacts that are close to the limits of the footprint, it would be a good challenge.

It is already known that there is a direct dependence on the flight height of the satellite “h” over the maximum distance “d”. Numerically we can see that influence with the following examples:

- In the case of RS-44, an increase in apogee height of 1km implies an increase of 2.2km in the maximum distance covered by satellite.
- If we now focus on the ISS, a height increase of 1km represents an increase of 5km in the maximum distance.

Another crucial factor on the maximum distance is the height at which both stations are located. So far all calculations have been carried out considering that the operators are at sea level, but if one of them, or both, are located in an elevated position the maximum distance that can be covered increases . Let's see below how we can estimate that increase in the range of the satellite if an operator is located at a height "z" above sea level.



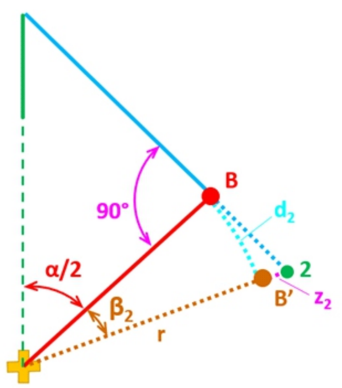

Let's consider point “2” (in green) which would be the new location of operator 2.

$d_2$ = Additional distance covered by the satellite on the operator 2.
That is, the lenght of the arc between B and B' (km).
$z_2$ = Height of operator “2” above sea level - ASL (km).
$\beta_2$ = Additional anglefor arc B-B' (rad).
r = Radius of the Earth (km).

If we proced in a similar way to the previous calculations, the length of the arc “$d_2$” is the product of the angle “$\beta_2$” by the radius of the Earth:

$$d_2 = \beta_2 \cdot r$$

By trigonometry we can deduce the expression for the angle “$\beta_2$” of arc B-B':




$$\cos \beta_2 = \frac{r}{r + z_2}$$

$$\beta_2 = \cos^{-1}\left(\frac{r}{r + z_2}\right)$$

Therefore, the additional distance on the side of operator 2 would be defined by the following formula:

$$d_2 = r \cdot \cos^{-1}\left(\frac{r}{r + z_2}\right)$$

The new maximum distance "D" covered by the satellite would now be:

$$D = d + d_2$$

If operator 1 is also in a raised location, "z1" meters ASL, then we have the complete expression:

$$D = d + d_1 + d_2$$

$$D = 2 \cdot r \cdot \cos^{-1}\left(\frac{r}{r + h}\right) + r \cdot \cos^{-1}\left(\frac{r}{r + z_1}\right) + r \cdot \cos^{-1}\left(\frac{r}{r + z_2}\right)$$

Let's take a numerical example with the RS-44 satellite and suppose that Both operators are in a high "spot", with a clear horizon, at 1000 meters above sea level (ASL). If we substitute the values we will obtain the resulting enlarged value "D":

$$D = 2 \cdot 6371 \cdot \cos^{-1}\left(\frac{6371}{6371 + 1517.2}\right) + 2 \cdot 6371 \cdot \cos^{-1}\left(\frac{6371}{6371 + 1}\right)$$

$$D = 8035.36 + 2 \cdot 112.87 = 8261.11 km$$

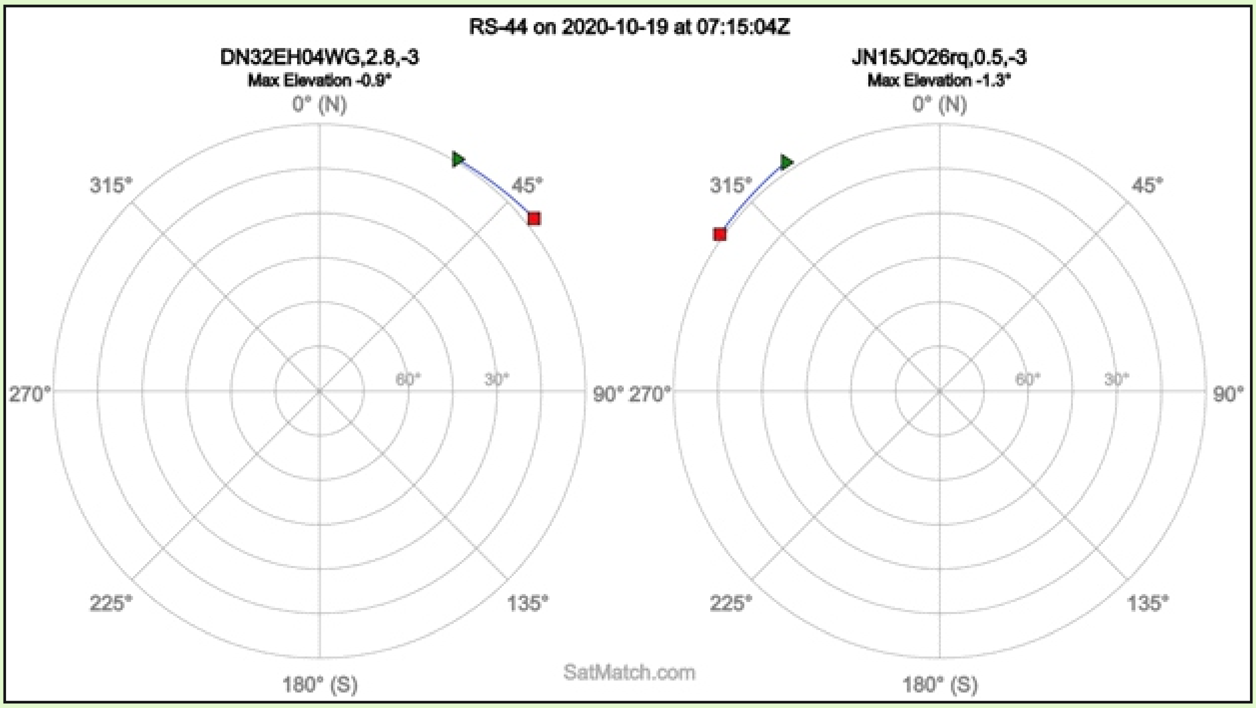
In this way it has been quantified that the maximum theoretical range goes from 8035.36 to 8261.11km (+225.75km) if both operators are within 1000m above sea level. It is a significant increase that makes it easier to achieve the goal of breaking previous distance records.

It is time to concretize and go further with this topic. Next I'm going to focus on the study of the distance record achieved by Jérôme, F4DXV, and Casey, KI7UNJ, on October 19, 2020. I intend to compare the actual result with the theoretical one that I can deduce and that would be described in this article.

I have taken the information from the protagonists themselves. They published the records on their Twitter accounts (links below):

- https://twitter.com/F4DXV/status/1318179108594028544
- https://twitter.com/KI7UNJ/status/1318090868457238530

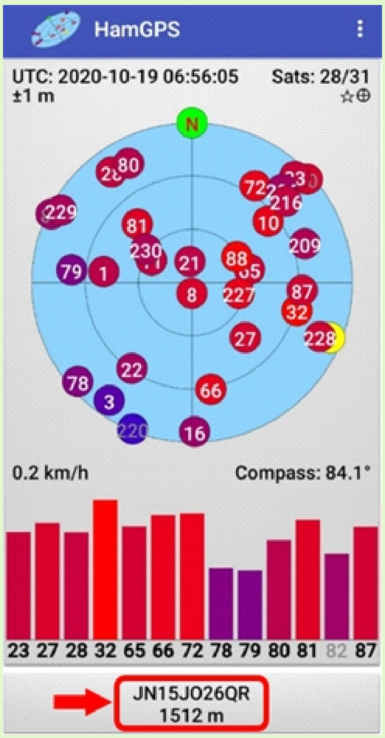
We can see the characteristics of the pass, from both sides, through the SatMatch (https://www.satmatch.com/). As expected, both operators had negative elevations, so the height of their "spots" has been the key to establishing contact and increasing the scope of the satellite.




Through the photographs and GPS locations they have shared we have the starting data we need:

Operator "1" (F4DXV):
z1 = 1512m ASL

Operator "2" (KI7UNJ):
z2= 9251ft=2819.7m ASL

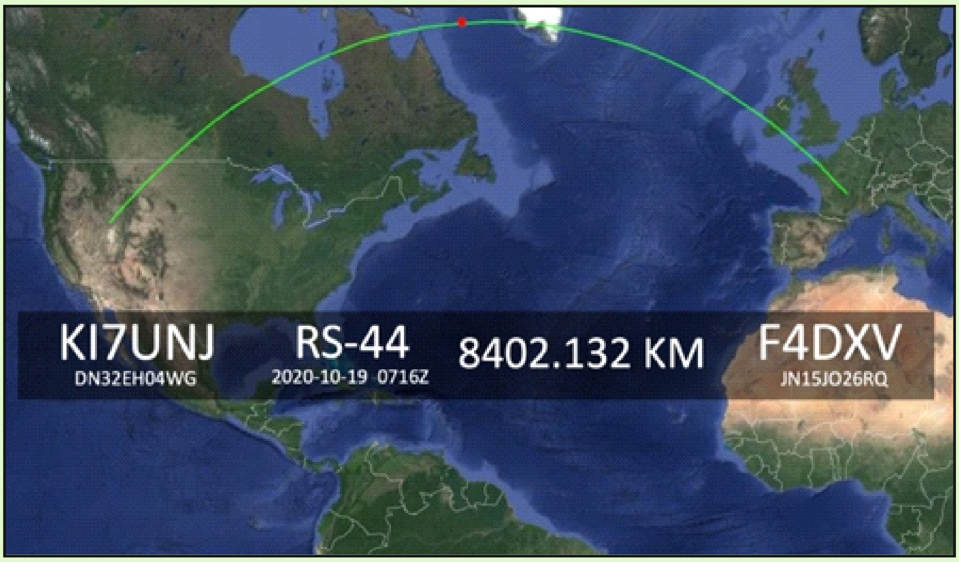



We substitute the values in the formula that we have deduced above to obtain the maximum extended distance value “D”.

D = 8035.36 + 138.79 + 189.51 = 8363.66km

I get a theoretical achievable distance in those conditions of 8363.66km.

For the real distance between the two operators we can use the K7FRY tool (https://k7fry.com/grid/) introducing the“locators/gridsquares” corresponding to both operators. The resulting value is 8402.13km.




Consequently there is a discrepancy of 38.47 kilometers. My distance prediction is approximately 38km lower than the actual value achieved by Jerome and Casey. It's not bad at all, I'm satisfied, I think it's a range of admissible magnitude taking into account that we are considering a average value for the radius of the Earth and that my development is based on very basic calculations .

What we can clearly conclude is that the mark reached for the RS-44 is more than extraordinary, I would say fantastic and great. With this study I bet that the record will be very durable over time. My most sincere congratulations to the two operators for their impressive contact as a result of their effort, time, advance planning and exceptional skill. BRAVO!!!

This has been all I had prepared for the article. I hope you enjoyed it as much as I did analyzing this new point of view. Thanks to the creators of the AMSAT-EA newsletter, EB1AO and EC1AME,for their responsibility and commitment that they demonstrate monthly with each edition.

We heard each other in the “birds”. Greetings to all,

Salva

EA1PA

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