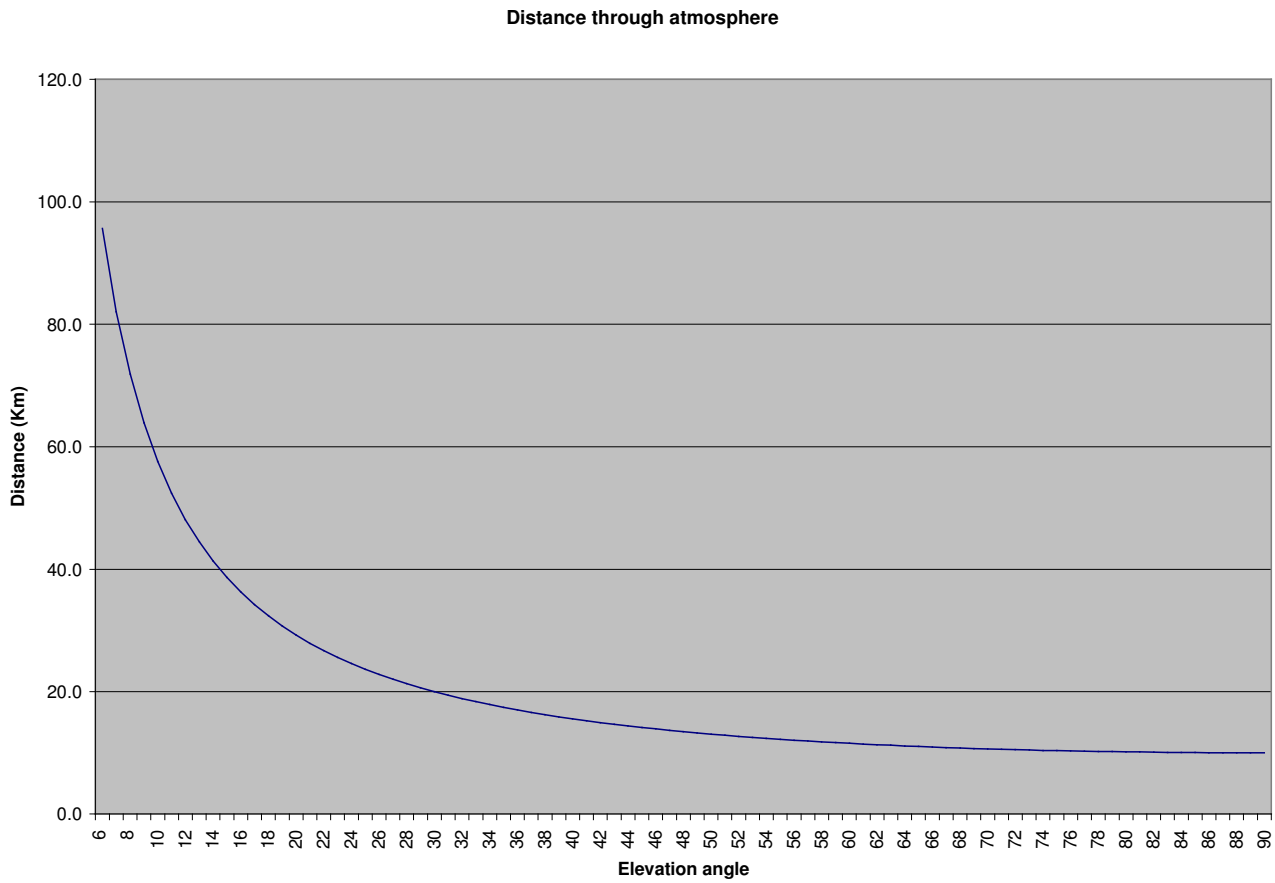
Atmospheric attenuation in microwave 47 GHz EME and VK3UM calculator results

On millimetre frequencies like 47 GHz we encounter losses in propagation of millimetre waves through atmosphere.
For earth based point to point communication the losses are reasonably well known.
For Earth Moon Earth communications there is a lot more needed to determine the introduced losses by waves travelling trough atmosphere.

I tried to start with a set-up in which I calculate losses in the lowest 10 kilometres from the atmosphere. In this I used an assumption that the loss in these lowest 10 km would not change while getting at a higher altitude.
In literature the losses per kilometre trough atmosphere can be found for 47 GHz as 0.27 dB/kilometre at a temperature of 10 degrees.
It is clear that this is not a very good starting point as we know that temperature drops when altitude gets higher.
Important also on EME communication is the elevation angle used to target the moon or any other object like sun or cold sky.
The shortest way from ground out into the universe is when using 90 degrees elevation. For EME purposes we often need a much lower elevation.
At an elevation of 10 degrees it is easy to understand that the distance the radio wave has to travel through the atmosphere is much longer than at a much higher elevation.
To calculate the travel distance through the lowest 10 kilometre of the atmosphere for different elevation angles one can use simple mathematical tools.

For an elevation of 10 degrees the travel distance will be 58 kilometre
For an elevation of 20 degrees the travel distance will be 29 kilometre
For an elevation of 30 degrees the travel distance will be 20 kilometre

In a diagram it is visible for all elevations up to 90 degrees



In using the distance and the attenuation/km it's possible to calculate the attenuation for a given distance of elevation

For an elevation of 10 degrees the attenuation will be 15.7 dB
For an elevation of 20 degrees the attenuation will be 7.8 dB
For an elevation of 30 degrees the attenuation will be 5.4 dB

This can be done for different temperature levels, but for now I want to further improve the model by following the international standard atmosphere. In the real atmosphere the temperature will drop at higher altitude and also the air pressure will drop at higher altitude.

I divided the 10 km altitude in 10 different layers each 1 km thick and determined the attenuation for each of these layers at a surface temperature of 10 degrees Celcius.
When adding the different layers attenuation I get a more realistic model of the atmospheric attenuation.
For this I start with a elevation of 90 degrees so straight up.
The attenuation for the first layer will be 0.27 dB/km
For the second layer the attenuation will be 0.25
For the third layer the attenuation will be 0.20
For the fourth layer the attenuation will be 0.10
For the fifth layer the attenuation will be 0.08
For the sixth layer the attenuation will be 0.07
For the seventh layer the attenuation will be 0.06
For the eight layer the attenuation will be 0.05
For the ninth layer the attenuation will be 0.03
For the tenth layer the attenuation will be 0.02
Giving a total of 1.13 dB

For an elevation of 30 degrees, the result will be 2.26 dB loss
For an elevation of 20 degrees, the result will be 3.28 dB loss
For an elevation of 10 degrees, the result will be 6.55 dB loss

I divided the 10 km altitude in 10 different layers each 1 km thick and determined the attenuation for each of these layers at a surface temperature of 20 degrees Celcius.
When adding the different layers attenuation I get a more realistic model of the atmospheric attenuation.
For this I start with a elevation of 90 degrees so straight up.
The attenuation for the first layer will be 0.4 dB/km
For the second layer the attenuation will be 0.35
For the third layer the attenuation will be 0.30
For the fourth layer the attenuation will be 0.2
For the fifth layer the attenuation will be 0.15
For the sixth layer the attenuation will be 0.10
For the seventh layer the attenuation will be 0.09
For the eight layer the attenuation will be 0.05
For the ninth layer the attenuation will be 0.03
For the tenth layer the attenuation will be 0.02
Giving a total of 1.69 dB

For an elevation of 30 degrees, the result will be 3.38 dB loss
For an elevation of 20 degrees, the result will be 4.90 dB loss
For an elevation of 10 degrees, the result will be 9.80 dB loss

These are results from my trial to find the atmospheric losses involved

Surface temperature 10 degrees Celsius	Surface temperature 20 degrees Celsius
elevation of 10 degrees, 6.55 dB loss	elevation of 10 degrees, 9.80 dB loss
elevation of 20 degrees, 3.28 dB loss	elevation of 20 degrees, 4.90 dB loss
elevation of 30 degrees, 2.26 dB loss	elevation of 30 degrees, 3.38 dB loss

When searching internet for more information I found the following:
https://www.moonbouncers.org/Orebro2017/UA3AVR_Calibrations of mm-wave antennas and RX systems using Moon radiation_Orebro2017.pdf
I think it is advised to all interested in 47 GHz EME to read this presentation.
I downloaded the excel spreadsheet to make some further calculations :
qsl.net/ua3avr/papers/Moon-Ground_Cal_2015+rus.zip

From the Excel spreadsheet by UA3AVR I found the next values

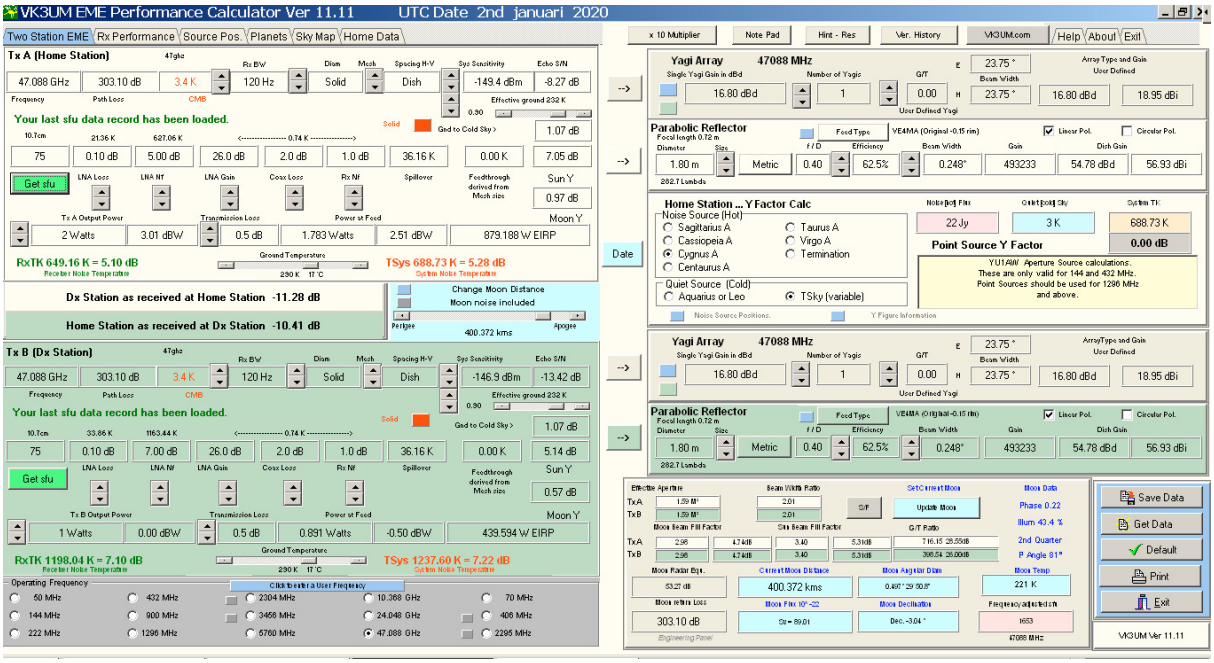
Surface temperature 10 degrees Celsius	Surface temperature 20 degrees Celsius
elevation of 10 degrees, 5.4 dB loss	elevation of 10 degrees, 6.3 dB loss
elevation of 20 degrees, 2.8 dB loss	elevation of 20 degrees, 3.2 dB loss
elevation of 30 degrees, 1.9 dB loss	elevation of 30 degrees, 2.2 dB loss

These two models are approaching each other within acceptable tolerance so I choose to start using the UA3AVR spreadsheet as my preferred model.

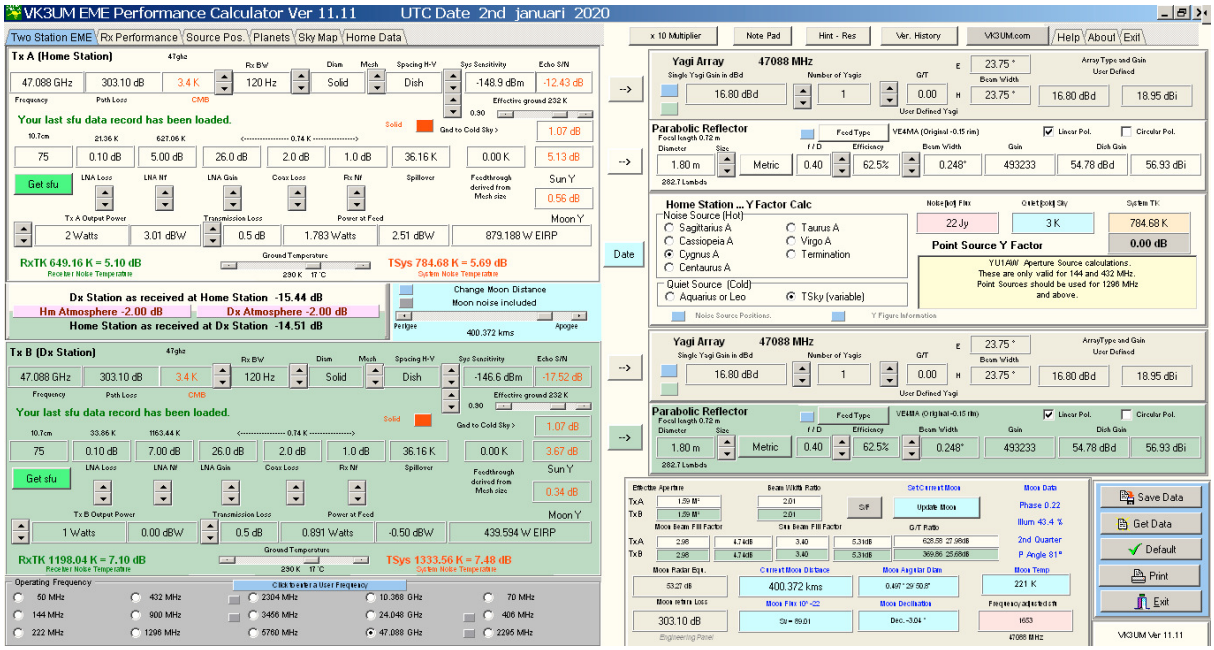
With the now found atmospheric attenuation it is possible to calculate the different levels by using the VK3UM EME calculator.

In using the VK3UM calculator we can enter atmospheric attenuation. Probably it is best to first start calculating with atmospheric attenuation values set to 0 dB and if all parameters are correct enter the atmospheric attenuation values. For reference I am using the latest available calculator version 11.11.0.0 date 20-2-2016.
The atmospheric attenuation can be found using the UA3AVR spreadsheet.
First results of calculations from the EB3FRN data look pretty good. Results are well within 1 dB of practical measured results.
I would like to compare this to the other stations to get a better overall result for the atmospheric losses.

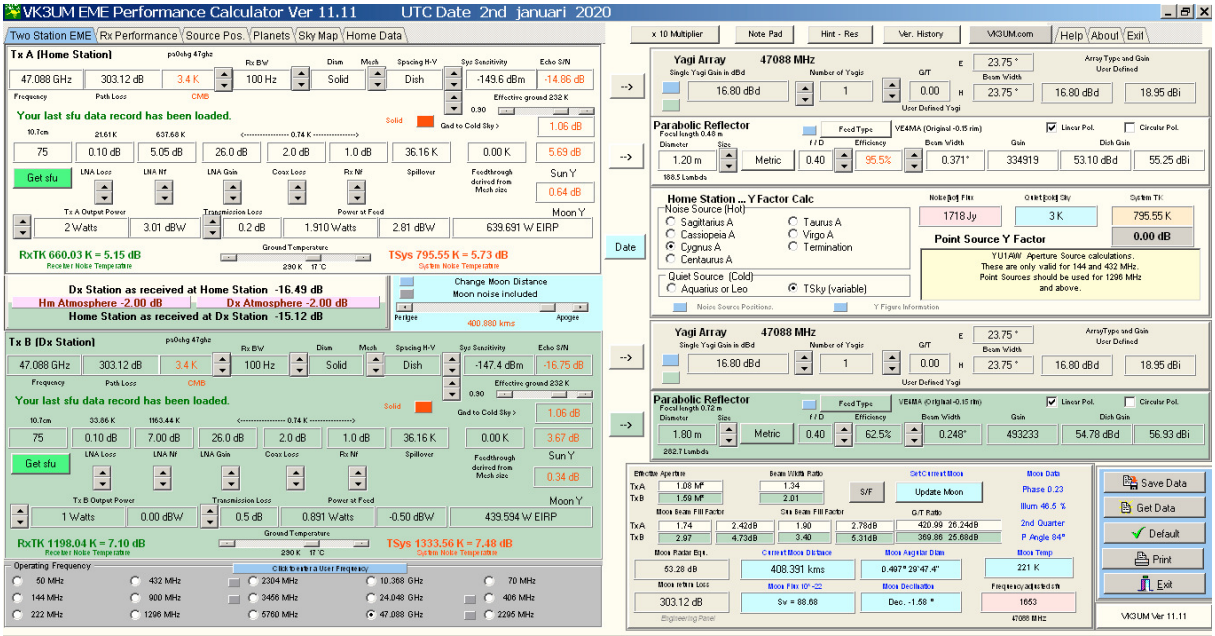
In the VK3UM calculator I calculated in a resolution (filter) bandwidth of 100 Hz but this should probably be set to an ssb filter to allow the JT signal to come through.
I know that JT will decode until –16 or –18 dB but I don't know if this is in a filter bandwidth of 2400 Hz or that it is in a filter bandwidth of 100 Hz, any advice would be helpful.
I contacted G3WDG for this with result that I have to use 2400 Hz as bandwidth in the calculations.



Calculation with inserted Atmospheric attenuation



After this I made some calculations for EB3FRN with his 1.2 mtr offset dish.
I increased the dish efficiency in the calculation as it is a offset dish.
This results in a moonnoise and solar noise level within 1 dB off measured result which is 5.8 dB sun noise and 0.31 dB moon noise



I also used the UA3AVR spreadsheet to calculate the atmospheric attenuation and calculate the moon noise. Also this calculation fitts well within the measured results from Iban.

Freq= 47 GHz
Lambda= 0.00638 m

Receiver:
NF(rcvr)= 5.05 dB
Trcvr= 637.68 K

Moon:
Moon size= 0.5 deg
Moon temp distribution parameter:
Sigma= 0.72
Moon phase 64 deg

Full Moon 0/180 deg switch

Full Moon 180 deg

Antenna:
Dant= 1.3 m (Reflector Diam)
Eps_main= 0.72 Main beam efficiency
k= 0.75 Eps_app=k*Eps_main
Eps_app= 0.54 Aperture efficiency
Dmax= 53.45 dBi (Antenna Gain)
HPBW= 0.34 deg (Half Power Beam Width)
Tspill= 70 K (antenna spillover Temp)

Space and atmosphere:
Tspace= 3.4 K (CMB)
Tatm= 275 K
Atm. att= 1.68 dB
Latm= 1.47

Enter data in -> cells like me

Yfact measured= **Moon:** 0.31 dB

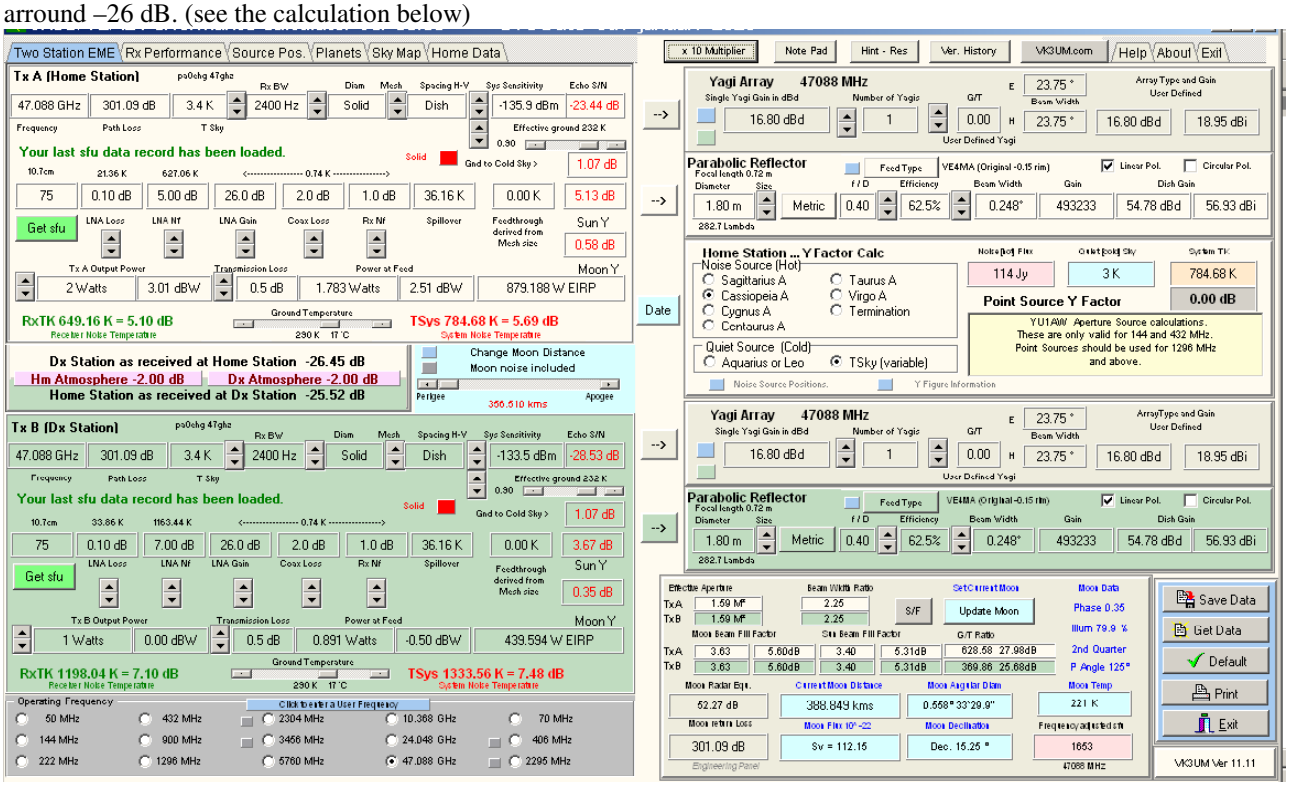
Yfact measured= **Ground:** 0.72 dB

Results

Moon temperature (seen):
Tmoon= 177.45 K
Moon temperature (data):
Tmoon_data= 178.68 K
± 8.63 K

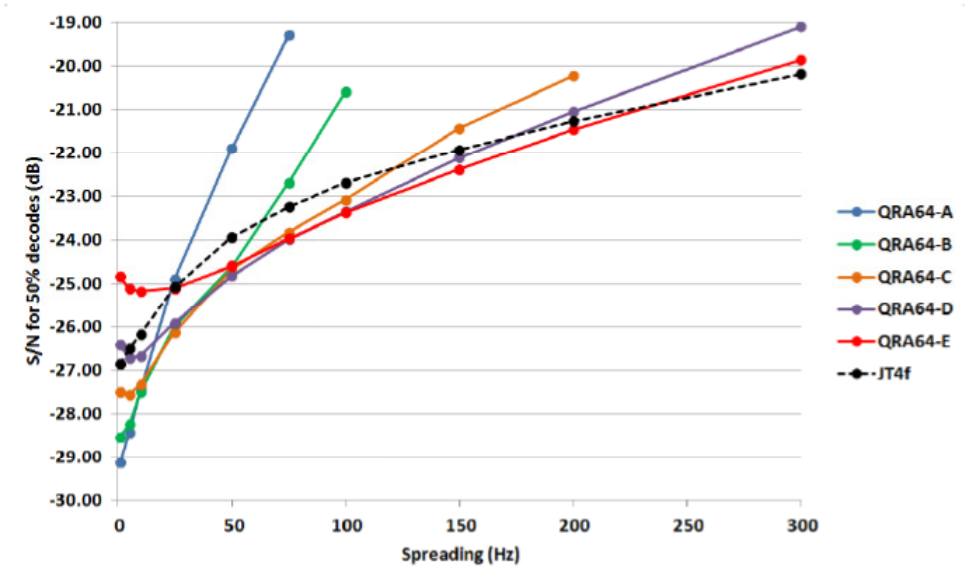
Ground temperature (seen):
Tground= 284.27 K

Now it's time to calculate the possibilities for an EME QSO using WSJT as operation mode.
For this we have to calculate using a 2.4 kHz bandwidth filter.
I have made calculations based upon a 1.8 mtr prime focus dish both sides and 2 dB atmospheric losses both sides.
Using 2Watt output or 1 Watt output and an noise figure off 7 dB or 5 dB would result in received levels off arround –26 dB. (see the calculation below)



Varying the Spreading

For Calls and Report e.g. VK7MO G3WDG -24



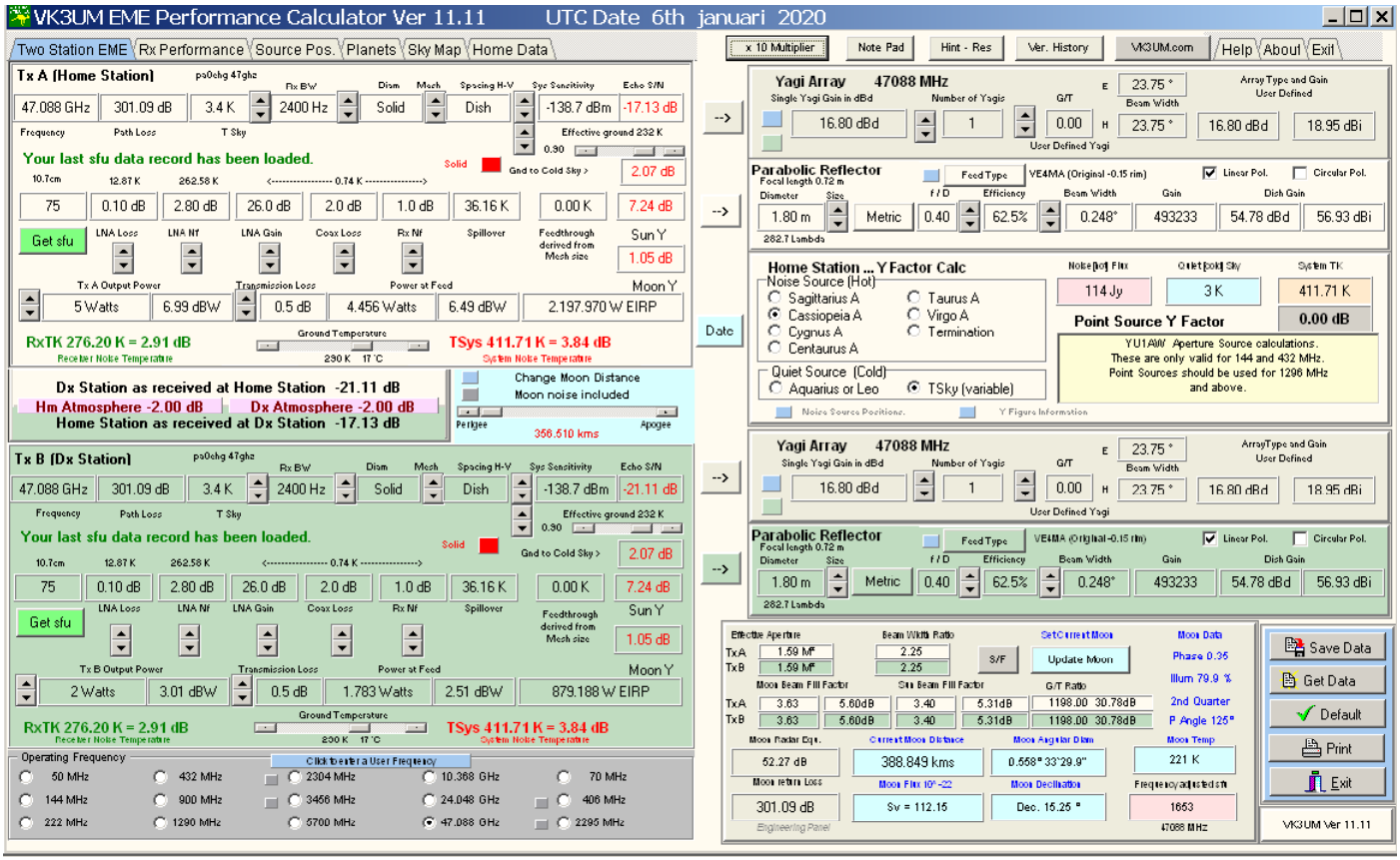
When looking into the picture off needed S/N for 50% decodes the lowest level for decodes will be arround –22 dB. Important is to have low libration spreading.

This calculation is done at Perigee distance and atmospheric losses using antenna elevations above 30 degrees.

Result is that we still have 6 dB short off making a QSO, so in my opinion the only way is to use more antenna gain, a better noise figure, the 2.8 dB at Manfred will already help a lot and some more output power up to 5 Watt level.

If possible I would like to have more measured data on solar noise and moon noise levels with information on system setup and measurement conditions like used antenna elevation and temperature and humidity during measurement.

Using 5 Watt and 2.8 dB noise figure would get us to a level off –17 dB, this should do the job. A combination with 2 Watt and 2.8 dB noise figure would already get doubtfull.



For succesfull EME QSO's we need to use high antenna gain, moonposition at or close to perigee, antenna elevation higher than 30 degrees on both ends, temperature preferably well below 20 degrees Celcius, low libration smear, power levels higher than 2 Watt and prefer higher than 5 Watt, noise figure levels below 5 dB prefereably below 3 dB.