## 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

## Distance through atmosphere



**Elevation angle** 

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 : <u>qsl.net/ua3avr/papers/Moon-Ground\_Cal\_2015+rus.zip</u>

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.

VK3UM EME Performance Calculator Ver 11.11 UTC Date 2nd januari 20.	20
Two Station EME Rx Performance Source Pos. Planets Sky Map Home Data	x 10 Multiplier Note Pad Hint - Res Ver. History VK3UM.com /Help \About \Exit
Tx A (Home Station)     41pla     PiL EV     Dian     Much.     Specing HV     Specing HV     Specing HV     Specing HV     Edu S/H       47,088 GHz     303.10 dB     3.4 K     \$\$\$\$ 20 HZ     \$\$\$ Solid     \$\$\$ Dian     \$	Yaqi Array     47068 MHz     €     23.75 °     Array Type and Guia       Stepic Yopi Guin dEd     Namber of Yagir     0/7     Buse Yopi Array     User Doffined       →     16.80 dBd     ↓     1     ↓     0.00     #     23.75 °     15.80 dBd     18.95 dBr
Control of a class to section     Section     Gard to Cald Stay>     1.07 dB       75     0.10 dB     5.00 dB     2.0 dB     1.0 dB     36.16 K     0.00 K     7.05 dB       Get true     UNA (sing)     1.07 dB     36.16 K     0.00 K     7.05 dB       Get true     UNA (sing)     Constructions     Find World from     Find World from	Parabolic Reflector     reatTps     VEAMA (0riginal - 65 rin)     C three Pol     C crodue Pol       Pointer     Bineter     Bin     110     FreedTps     Bineter
Tra A Oppup Pever     Transmitrifes Loss     Pever xt Feed     Moon Y       2 Watts     3.01 dB/W     0.5 dB     1.783 Watts     2.51 dB/W     873 188 W EIRP       Fx K 64.9.16 K = 5.10 dB     Conent Temperatures     Tsys 688,73 K = 5.28 dB     Software Res     Software Res	Home Station Y Factor Calc     Hearled Par     Centrol gay     Optimit       Nose Source [Hot]     C     Taurus A     22 Jy     3K     688,73K       C Sogitarius A     C     Vigo A     Optimit Source Y Factor     0.00 dB       C CentropiesiA     C     Termination     VULRW Aprilume Source calculations.     There are only valid for Hand 482 Metric
Dx Station as received at Home Station -11.28 dB     Change toon Distance toon noise included       Home Station as received at Dx Station -10.41 dB     Prepare toon Distance Prepare toon Distance	Cuiel Source [Cold] C Aquatius of Con  TSky (variable) Notice Source Patitions Viewer Should be used for 1280 MHz Notice Source Patitions Yrigers Management Yrigers Management Yadi Array 47088 MHz 275* ArrayType vad Gain
T.B (Dox Station)     4*/size     PL BV     Dian     Math.     Spring BV     Pr Statistiny     Pr Statistiny     Exts SNI       47.086 GHz     303.10 db     34.K 120 Hz Sold Deh 14.65 dBm          Lata SNI       Frequesp     Publics          CHE          Sold Che          Leto SNI          Lata SNI         Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI          Lata SNI	→ Index ray Gas in d8d Intervent Yragi Or E 2010 Intervent Yragi Or E 201
Your last afu data record has been loaded.     •••     •••     •••     •••     •••       92ca     33.65 K     #63.44 K     ••••     0.74 K     ••••     <	Parabolic Reflector     read type     VEBA4,010 jual 4.15 min     ✓     Lineer PoL     Circular PoL       →     Disactor     160     Efficiency     Buon Vidia     Dain     Diah Gain     Diah Gain       180 m     +     Metric     0.40     +     625%     +     0.248*     493233     54,78 dBd     56,93 dBi     56,93 dBi     56
Get stu     Unit value     Const value     Per value     Spinor 0     Freedwards     Sun T       Tr.8 Dutyer Perer     Transmitrine Loss     Perer value     To 37.68     Mon Y     Mon Y       I Watts     0.00 dBW     I S.5 dB     0.831 Watts     -0.50 dBW     433 594 W EIRP	Bits Supplin     How With Fub     Sett inst files     Bits Suppling     Bits Suppling       TA     1.59 W     201     ST     Option Bits     Phane 0.22       To B     201     ST     Option Bits     Phane 0.22     Dial       Boos Head Fill Factor     States Fill Factor     States Fill Factor     Dial     Dial
Conset Temperature	TA     2.86     3.06     5.56     This 20008     2.00 dualer     ✓     Ø deal       Ta     2.96     2.96     5.96
C     50 MHz     C     432 MHz     C     10.388 GHz     C     70 MHz       C     144 MHz     C     600 MHz     C     3468 MHz     C     24.048 GHz     C     406 MHz       C     222 MHz     C     1206 MHz     C     5450 MHz     C     44.08 MHz       C     222 MHz     C     1206 MHz     C     5700 MHz     C     47.088 GHz     C     21295 MHz	Book Hill List     Book Field 22     Book Field 24     Fingency of stretch 16       303 10 dB     Star = 6601     Book Start 24     Book Start 24     Book Start 24       Expression Field     Start 24     Book Start 24     Book Start 24     Book Start 24

## Calculation with inserted Atmospheric attenuation

VK3UM EME Performance Calculator Ver 11.11 UTC Date 2nd januari 202	
Two Station EME Rx Performance Source Pos. Planets Sky Map Home Data	x 10 Multiplier Note Pad Hint - Res Ver. History VK3UM.com /Help\About\Exit
Tx A (Home Station)     4*s/s     Pic BV     Dun     Much.     Specing HV     2yr Statilhithy     Edo SN       47.088 GHz     303.10 dB     3.4 K     ¥ 120 Hz     Sold     Image: Constraint of the second s	Yagi Array     47088 MHz     Office     Car     €     23.75*     Arry Type sed Guia       Step /r yo Guia Mdd     Nember ef Yegi     Off     E     Dana Vidia     Uuz Dafied       ->>     16.80 dBd     1     000 H     23.75*     16.80 dBd     18.95 dBi       Parabolics Reflector     r     r     000 H     23.75*     16.80 dBd     18.95 dBi       Databolics Reflector     r     r     r     Official 75.8     To block Official 76.5     To block Official 76.5       Dianet / Bit     0.00     H     25.5%     October Vel.     Circober Pel.       ->     18.00     Meric     0.40     R 25.5%     October Vel.     Dianet 94.8
Get stu     UbA kos     LBA MY     UbA Kos     Cess Less     Fk W     Epitoru     Freedword     Freedword     Sun Y       Tr. A Ourget Power     Transmission Loss     Power Freed     Moon Y     0.56 dB     Moon Y       V Wats     3.01 dBW     0.58 dB     1.783 Wats     2.51 dBW     879 188 W EIRP       Rx Ft 6449, 164 5, 5.10 dB     Greend Tongorither     TSys 764.68 K = 5.69 dB     Software Tongorither       Root British Tegaratile     200 K TT C     Chane Moon Differee     Chane Moon Differee	Date     Totom     memory     0400     02.00     02.400     40.000     00.0000       Battoria     Home StationFactor Calc     Hote pig 1 / 20     0410 / 20     0410 / 20     0410 / 20       Date     C paralities     C paralities     C paralities     1000 / 20     000 / 20       Date     C paralities     C paralities     C paralities     0000 / 20     0000 / 20       Date     C paralities     C paralities     C paralities     0000 / 20     0000 / 20       Date     C paralities     C paralities     C paralities     C paralities     0000 / 20       Date     C paralities     C paralities     C paralities     C paralities     0000 / 20
Dir Station as received at Name Station 14.51 dB Ioon notes included Him Atmosphere 2.00 dB Dir A Kinosphere 2.00 dB Proteine groups and a station 14.51 dB Ioon notes included Hume Station as received at Dir Station 14.51 dB Ioon notes included Tx B (Dir Station) 41/24 Tree Ioon Notes included 400.372 Ions 400.372 Ions 400.3	C Aquanus of Leo (* 15k) (vanade) Totois Severs Public  Vagi Array 47088 MHz Seyler Space States Vagi Array 47088 MHz Seyler Space States Vagi Array 47088 MHz Seyler Space States Vagi Array 1  vagi Array
Your last if u data record has been loaded.     Sold     End to Call Bary     107 dB       107m     0.10 dB     7.00 dB     2.0 dB     1.0 dB     36.16 K     0.00 K     36.7 dB       75     0.10 dB     7.00 dB     2.0 dB     1.0 dB     36.16 K     0.00 K     36.7 dB       Get thu     UN Kess     UN Kess     UN Kess     Selforer     Fundbreigh     0.02 KP	Parabolic Kellector     real type     Vetta 0 tiptal -0.100 pr     Calcular Pol.     Concurso Pol.       →     Dim with 0 tiptal -0.100 pr       323 Taskets     Bas With 0 tiptal -0.100 pr     Disc With 0 tiptal -0.100 pr     Disc With 0 tiptal -0.100 pr     Disc With 0 tiptal -0.100 pr       Becks print     Isas With 0 tiptal -0.100 pr     Disc With 0 tiptal -0.100 pr     Disc With 0 tiptal -0.100 pr     Disc With 0 tiptal -0.100 pr
Tx8 Dorpe Power     Taxamicities Loss     Power at Fixed     Moon Y       1 Watts     0.00 dBW     0.5 dB     0.831 Watts     -0.50 dBW     439 594 W EIRP       RxTK 1198.04 K = 7.10 dB     280 K H c     Ts     15ys 1333.56 K = 7.48 dB     System Active PowerActive	TxA     1.05 H     201     Cir     Update Blos     Phase 0.22     Bins 40.4 %       Mox Ham / Firster     201     Cir     Or Fisto     Bins 40.4 %     Bins 40.4 %       TxA     206     1758     3.00     State     0.7 Fisto     Did Outer       TxA     206     1758     3.00     State     50.06     2.00 Outer     Vol Outer       Boos Faster Syn     2.06     1758     3.00     State     50.06 States     Vol Outer       Boos Faster Syn     2.06     1758     Boos Faster Syn     Boos Trate     Vol Faster     Vol Faster
Operating requiresy     Citits bala 30 and Fragments       50 MHz     422 MHz     10.308 0Hz     70 MHz       144 MHz     600 MHz     3440 MHz     24 0H6 0Hz     400 MHz       222 MHz     1209 MHz     570 MHz     400 MHz     220 MHz     220 MHz	Stat? of     400.372 kms     0.0125 kms     221 k       Bios whit Loss     Bios Calabia     Frequency at whitin       300.10 dB     Gal = 6631     Dec -304*     Frequency at whitin       Digreeming Proce     Frequency at whitin     Frequency at whitin     WOULD WHY 11.11

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

🎇 VK3UM EME Performance Calculator Ver 11.11 👘 UTC Date 2nd januari 20	)20
Two Station EME (Rx Performance Source Pos.) Planets (Sky Map (Home Data)	x 10 Multiplier Note Pad Hint - Res Ver. History VK3UM.com /Help\About\Ext1
Tx A (Home Station)     px0-bg 47gHz     Re EV     Dim     Mr.6     Spxdeg HV     Spxdeg HV     Spxdeg HV     Eds SN       47.088 GHz     303.12 dB     3.4 K     100 Hz     Solid     Dim     -149.6 dB	Yagi Array     47088 MHz     c     23,75*     Array Type sud Guin       →     Togic Yagi Guin a did     Number of Yagis     Orr     Euron Yoda     User Onlined       →     16.80 dBd     1     ↓     0.00 H     23,75*     156.80 dBd     18.95 dBi
Total rate and record in the Street in Note of the Street in Note	Parabolic Reflector     readType     VEAMS (Singlad -0.5 min)     If there Pol.     Circular Pol.       →     Disector     88c.     1/0     Bisector     Disector     Disector     Disector     Size     0.0371*     334919     53.10 dBd     55.25 dBi       885 Lindeds     885 Lindeds     95.55     0.371*     334919     53.10 dBd     55.25 dBi
A Durge Power Tanseteria Less Power 4 Fed Moon Y August Power Tanseteria Less Power 4 Fed Moon Y August Power Tanseteria Less Power 4 Fed Moon Y August Power Tanseteria Less Power 4 Fed Moon Y August Power Tanseteria Less Power 4 Fed Moon Y August Power Tanseteria Less Tanseteria Less Tanseteria Less Tompetation Determine Competation Determine Competation Tompetation Determine Competation Tompetation	Home Station Y Factor Calc     Hose gr /m     Out (bit) (bit)     Out (bit)     <
Hin Atmosphere - 2.00 dB     Dx Atmosphere - 2.00 dB	Notes Device Patilists.     Y Figure Information       Yagi Atray     47088 MHz       Stage Vyog Cain in 88d     Number of Yogis       0     1       4     0.00       μ     23,75°       Lis 80 dBd     1       User Collined       User Collined       User Collined
Your last sfu data record has been loaded.     State     0.00	Parabolic Reflector     read Type     vEBBA 6rtpst 0.15 min     I/// Encode Pol.       ->     Disector     1/0     Encode Pol.     Encode Pol.     Encode Pol.       ->     10.0 m     ↓     Metric     0.40     ↓     Encode Pol.     Encode Pol. <td< td=""></td<>
Image: State Date Prover     Trunchicsics Loss     Power M Ford     0.34 dB       To Druget Prover     Trunchicsics Loss     Power M Ford     Moon Y       Image: State Date Prover     Trunchicsics Loss     Power M Ford     Moon Y       Image: State Date Prover     Trunchicsics Loss     Power M Ford     Moon Y       Image: State Date Prove M Ford     To State Date Prove M Ford     To State Date Prove M Ford     To State Date Prove M Ford       Operating Frequency     Cable Links Tragetory     Cable Links Tragetory     Cable Links Tragetory     To Date Date Prove M Ford       State Date Prove Date Prove Date Prove Date Prove Prove Date Date Prove Prove Date Date Prove Date Date Prove Date Date Prove Date Date Prove Prove Date Date Date Prove Date Date Date Prove Date Date Prove Date Date Date Prove Date Date Prove Date	Effects Agentin     Even UNB #200     Oct Contribution     Bios Othe     Press 0.25       TxA     1.26 M <sup>-1</sup> 1.24     57     Update Moon     Press 0.25     Dial

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	Antenna:	
Lambda=	0.00638 m	Dant=	1.3 m (Reflector Diam)
		Eps main=	0.72 Main beam efficiency
Receiver:		k=	0.75 Eps app=k Eps main
NF(rcvr)=	5.05 dB	Eps app=	0.54 Aperture efficiency
Trevr=	637.68 K	Dmax=	53.45 dBi (Antenna Gain)
		HPBW=	0.34 deg (Half Power Beam Width)
Moon:		Tspill=	70 K (antenna spillover Temp)
Moon size=	0.5 dea		
Moon temp dis	Moon temp distribution parameter: Space and atmosphere:		
Sigma=	0.72	Tspace=	3.4 K (CMB)
Moon phase	64 deg	Tatm=	275 K
-		Atm. att=	1.68 dB
Full Moon (	180 deg switch	Latm=	1.47
Full Moon	180 deg		
		Enter data in ->	cells like me
Yfact	Moon:	Yfact	Ground:
measured=	0.31 dB	measured=	0.72 dB
Results			
Moon tempera	ture (seen):	Ground temperat	ure (seen):
Tmoon=	177.45 K	Tground=	284.27 K
Moon tempera	ture (data):		
Tmoon_data=	178.68 K		
±	: 8.63 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.





## Varying the Spreading

-19.00 -20.00 1 martin -21.00 -22.00 decodes (dB) -23.00 QRA64-A -24.00 QRA64-B 50% ORA64-C -25.00QRA64-D ē -26.00 QRA64-E -27.00 ←-JT4f -28.00 -29.00 -30.00 0 50 100 150 200 250 300 Spreading (Hz)

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.

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

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.