How to add a power trace to the VNWA in spectrum analyzer mode

Preface:

By use of a custom trace it is possible to add a power trace, when running the VNWA in spectrum analyzer mode. By small trick and using external attenuators, you may display the power in both dBm as well as kW, W, mW or nW down to less than 10nW. Up to 50MHz my VNWA3E TX output is flat at -17dBm within + - 0.1dB, and more accurate than most available signal generators as digitally originated. A second VNWA3E I have is with -17.35dBm. The VNWA2 has also -17dBm output and I am convinced all VNWA's have very little deviation from e.g. -17.1dBm Thus it can be used for sensitivity calibration of the VNWA in spectrum analyzer mode. The drop is 0.3 dB at 100MHz (-17.3dBm), 0.8dB at 145MHz (-17,8dBm) and 6.3dB at 435MHz(-23.3dBm) so for these HAM bands it is still possible, in a narrow frequency range around these frequencies, to use the VNWA TX out for calibration, as will be commented in the Appendix

PLEASE NOTE the DDS multipliers are to be set to Auto x3 Auto for these levels and thus also compatible with the VNWA2. You may use 3xauto but then you have to measure yourself.

More on this subject in the Appendix.

These below shown methods are done with the new Audio Setup settings, as per spring 2017 where IF is changed from 1.2KHz to 12KHz. You may still use standard 1.2KHz, as it has no big impact on the Spectrum Analyzer Settings, as in the Sweep Settings these parameters is changed, as per what settings are chosen with respect to Resolution Bandwidth. These new settings are giving less noise and facilitate fast sweep at all times down to 0.17ms per point.

v lesolution bit Bit Bit Hz v 737	Audio Buffer Length in Samples Samples / IF Period 1 x4 => # Presamples 2 => # Postsamples 2 Calibrate Sample Rate	3000 IF = 11999.89 Hz Minimum Sampling Time = 0.17 ms
	Measd. Sample Rate = 47999.6 igno	re overload
	Auviliaru Audio Settings	
esolution iit Bit Bit	Aux. Audio Channels measure TH Main Audio Channels measure REFLEC Measd. Sample Rate = 47999.6 Aux. Reference = Right Channel	RU
	Lesolution Sit Bit Bit 243 codecs only	Auxiliary Audio Settings Auxiliary Audio Settings Aux. Audio Channels measure TH Main Audio Channels measure REFLEC Measd. Sample Rate = 47999.6 Aux. Reference = Right Channel codecs only

Below a Resolution Bandwidth of 250Hz (the smallest) chosen and the Audio Buffer length now only 19 samples, the IF = 75Hz and running with 300 samples per second

🛒 Spectrum Analyzer Sweep Settings 🛛 🗙	🛒 PC and Instrument Hardware Related Setup	×
Sweep Control	USB Settings Audio Settings Audio Level Aux. Audio Level Instru	iment Settings Misc. Settings
Number of Datapoints = 1000	Audio Capture Device	Misc Audio Settings
Measurement Time:	Linje (2- USB AUDIO CODEC)	Audio Buffer Length in Samples 19
	ADC Resolution	Samples / IF Period 1 x4 => IF = 75.00 Hz
Time per sweep = 10.00 secs Time per data point = 10.00 ms	C 24 Bit	# Presamples 2 => Minimum Sampling Time = # Postsamples 2 26.67 ms
Resolution Bandwidth = 250 Hz	Test Audio 300 Hz 💌	Calibrate Sample Rate
Point spacing = 0.2 kHz <= Res. Bandwidth = 0.25 kHz	Max=10730 Min=-10737	Measd. Sample Rate = 300.0
Sweep Progress Display	🔽 Auxiliary Audio Capture Device available	Reference = Left Channel 💌 restart on no sync 💌
	Auxiliary Audio Capture Device	Auxiliary Audio Settings
✓ Progress Bar On Progress Bar Color	Linje (USB AUDIO CODEC)	Aux. Audio Channels measure THRU
Progress Text On	ADC Resolution	Main Audio Channels measure REFLECT
General	C 24 Bit	Measd. Sample Rate = 300.0
RX frequency = displayed frequency (Spectrum Analyzer)	Min=-10240 Max=10243	Aux. Reference = Right Channel
Frequency Offset TX to RX 0 MHz	Auto-Setup Audio Devices check USB codecs only	
Level Offset -100 dB	Real Sampling Rate = 300.0 samples/sec	

For a Resolution Bandwidth of 40KHz (the largest) then settings revert to default except the buffer changed to 3040 instead of 3000. Going back to VNWA mode this setting of buffer size maintained.

🛒 Spectrum Analyzer Sweep Settings 🛛 🗙	🜉 PC and Instrument Hardware Related Setup	×
Sweep Control	USB Settings Audio Settings Audio Level Aux. Audio Level Instru	ument Settings Misc. Settings
Number of Datapoints = 1000	Audio Capture Device	Misc Audio Settings
Measurement Time:	Linje (2- USB AUDIO CODEC)	Audio Butter Length in Samples 3040
J	C 8 Bit	Samples / IF Period 1 x4 => IF = 11999.89 Hz
Time per sweep = 10.00 secs Time per data point = 10.00 ms		# Presamples 2 => Minimum Sampling Time =
Besolution Bandwidth = 40000 Hz		# Postsamples 2 0.17 ms
	Test Audio 48000 Hz	Calibrate Sample Rate
Point spacing = 0.2 kHz <= Res. Bandwidth = 40 kHz	Max=10730 Min=-10737	Measd. Sample Rate = 47999.6 ignore overload
Sweep Progress Display	🔽 Auxiliary Audio Capture Device available	Reference = Left Channel 💌 restart on no sync 💌
_	Auxiliary Audio Capture Device	Auxiliary Audio Settings
Progress Bar On Progress Bar Color	Linje (USB AUDIO CODEC)	Aux. Audio Channels measure THRU
Progress Text On	ADC Resolution	Main Audio Channels measure REFLECT
General	○ 24 Bit	Measd. Sample Rate = 47999.6
RX frequency = displayed frequency (Spectrum Analyzer)	Min=-10240 Max=10243	Aux. Reference = Right Channel
Frequency Offset TX to RX 0 MHz	Auto-Setup Audio Devices check USB codecs only	
Level Offset dB		
	Real Sampling Rate = 47999.6 samples/sec	11

The calibration of the VNWA sensitivity

First of all select the "Options/Setup/Instrument Setting and set as shown below, maintaining compatibility with VNWA2 by choosing auto x3 auto multiplier settings.

	ettings Audio Level Aux. Audio Level	Instrument Settings Misc. Settings
WA Type:	S-Parameter Test Set:	S11 = low save prof
NWA 3 🔻	none	load profi
RF DDS		LO DDS
AD 9859, AD 9951	•	AD 9859, AD 9951 🗨
Clock = 12	× auto - MHz × 3	▼ Clock = 12 × auto ▼ MHz × 3
=> Clock = auto	k 4	=> Clock = auto
Calibrate Clock Freque	ncy	
Calibrate DDS Clo	ck Frequency	
fo calibrate the DDS (clock frequency, you need to measure the	output frequency at the TX port with a frequency counter.
	Seta	as shown

Next select Options/Operation Mode and select Spectrum Analyzer as shown below

Options	s Help				
0	peration Mode	>		VNWA	Ctrl+V
. Se	tup			VNWA, external Bridge	Ctrl+E
_ Sc	reensaver	>		VNWA, RF-IV	Ctrl+R
Pr	eset	>	~	Spectrum Analyzer	Ctrl+A
				Frequency Meter	Ctrl+M

Next choose the frequency and span you want to investigate, here used 10MHz Span 0.2 MHz. Next right click in window and choose Trace Options and see below on the left side what to do.

🚆 Input 🛛 🗡	Add Frequency Marker >
Start Stop Unit 3.9 10.1 MHz ▼	Clear last Marker Clear all Markers
Center Span	Add Trace
	Marker Caption >
Sweep Mode #X-Divisions	Cursor >
	Realtime Expression Evaluator >
Mouse Wheel Increments for Center, Start, Stop Span	Trace Options
1 MHz 1 MHz	Grid Options

Beyond the Display Settings chose Settings/Sweep from the menu and select as shown to the right. This is just an example for the settings. Number of point, Measurement time and Resolution Bandwidth may vary considerable pending the purpose of the measurement to perform.

	📰 Spectrum Analyzer Sweep Settings 🛛 🗙
	Sweep Control
	Number of Datapoints = 1000
	Measurement Time:
	Time per evidence 10.00 erec Time per data peint 10.00 me
	Resolution Bandwidth = 5000 Hz
📱 Display Settings 🛛 🗙	Point spacing = 0.2 kHz <= Res. Bandwidth = 5 kHz
	Sweep Progress Display
Grid Color I none RefLine Color ✓ none Smith Grid Color I none RefCircle Color ✓ none	Progress Bar On Progress Bar Color
	Progress Text On
extend background to full window I ext Color	Consul
Trace Enable	Reguency – displayed frequency (Spectrum Analyzer)
	The meduency – displayed incluency (opectrum Analyzer)
	Frequency Offset TX to RX 0 MHz
	Level Offset -100 dB
	Leave Level Offect as it is
	Leave Level Offset as it is
	Set Bandwidth to 5000Hz
Enable trace 1 only and	Set time per points to 10ms
select it as S21 dB	Set number of points 1000

Next we must connect the TX port with the RX port with a short test cable.

DO NOT PERFORM any kind of calibration and check it is disabled even master calibration

🚆 Full Calibration		×
Exit Calibration Master Calibration	n Cal Kit	
Calibration Menu Correction Schemes		
Cal Kit = Rosenberger new Female Kit oct	-Thus Calibration	
herect Calibration	i nru Calibration	
<u>S</u> hort	<u>C</u> rosstalk Cal	🔲 on / off
<u>O</u> pen	Ihru Cal	🔲 on / off
Load 🔴	Thru Match Cal	🔲 on / off
Cal 🗖 on / off	Invalidate All Thru Calibra	ations
	veen Progress]
Do not i	perform any	
call	bration	

Now run a single sweep and observe the dB reading being close to the VNWA TX output of -17.35dBm for this particular VNWA3E measured by a HP4327B power meter. The difference is 1.31dB to be added to the Offset level of -100dB for the new value to be entered as - 98.7dB

🖭 File	DG8SAQ Measure	-Veo se	tor Network Ar ttings Tools	nalyzer Softwar Options H	e - Spectrum elp	Analyzer Mode	e - A5004 licens	ed to Kurt Pou	lsen OZ7OU	_		×
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												-
			Enabl slightl	e a no y off o	ormal cente	mark r (1Kł	er₋ano Iz aw	d ente ay at	r freq 9.999	uency MHz)	y	-
				and	enabl	eam	aximu	im ma	arker			-
=> T× Att	Rx Start = = 0 dB	9.9 M >	Hz 1em 1 💌	S21 dB		Center = Span =	: 10 MHz 0.2 MHz				Stop = 10.1 MHz Continu Single St	z Jous weep

🧾 Spectrum Analyzer Sweep Set	tings	×
Sweep Control		
Number of Datapoints = 1000		
Measurement Time:	J	
Time per sweep = 10.00 secs	Time per data point = 1	0.00 ms
Resolution Bandwidth =	5000 Hz	•
Point spacing = 0.2 kHz <= Res. Ban	dwidth = 5 kHz	
Sweep Progress Display		
🔽 Progress Bar On	Progress B.	ar Color
🥅 Progress Text On		
General		
RX frequency = displayed frequency	(Spectrum Analyzer)	•
Frequency Offset TX to RX	0	MHz
Level Offset	-98.7	dB





Next topic is to create a custom trace which displays the Power Level of the measured signal.

You may use the TX output or a signal generator but in any case the Resolution Bandwidth must not be chosen too high, as the top must be flat and e.g. 40KHz does have "slanted" top, and thus measuring a lower value when TX out signal used for calibration, and when an accurate signal generator is not available. 5KHz ideal for the span used in this example. See later on this matter where all available resolution bandwidth shown with history trace (Storage Screen) enabled. Actually this is not a problem when using an external signal generator when setting of Level Offset.

🧱 Display Settings	×
Miscellaneous	
Grid Color 🛛 🗖 none	RefLine Color 🔽 none
Smith Grid Color 🔲 none	RefCircle Color 🔽 none
Background 🔽 none	RefCircle R = 0.5
extend background to full window	Text Color
Trace Line Width = 2	Grid Line Width = 1
Trace Enable	□4 □5 □6
Enable Trace Markers	▼ 4 ▼ 5 ▼ 6
Trace 1	
dB	
521 -	
-Trace 3	
lin. magnitude	-
Custom1 💌	_
Enable Trace C and present it a	3 as Custom1 s lin magnitude

Double click on the new Custom Trace and change the caption to **PWR** so the Custom Trace is named, and enter the formulas as shown. As we are dealing with power S21 must be squared (s21)² and multiplied by a "**constant**" so the power of the signal can be presented as KW, W, mW, nW or pW. The constant set to **1** as a start. Any attenuator place in front of the RX port can be entered in Sub2 with the dB value, initially entered as **0 dB** and the factor **ATT** calculated in Sub1 as 10dB is attenuating power with a factor of 10.

	Enter Expr	casion non								`	
	Expression:									_	
	(s21)^2*c	constant*,	ΑΤΤ ┥	-					~ ~ ~		
	Global Sube Name Alia Sub1 = AT Sub2 = dE Sub3 = DOI Sub4 = Sub5 = Sub6 = Aliases: S21 = Mem1 =	expressions s □□ = 3 = nstant = = = = = =	(available Expression 10^(dB 0 1 1 1 1 1 511 = ∫ Mem2 = ∫	in all ex, /10) ◀	S12 =	expressions m	ay use other s S22 = Mem4 =		Caption:		
DG8SAQ - Va	ector Network /	Analyzer Sof	ftware - Sp	ectrum /	Analyzer Mode	e - A5004 licens	sed to Kurt Po	Save ulsen OZ7OU	Load	-	×
Measure	Settings Tool	s Options	Help							2	
Measure (Settings Tool	s Options	7 36dB	158	1021.98m					₹	
Measure 1: 9	Settings Tool 0.9990MH: 0.0932MH	z -1 ⁻	7.36dB	158 158	1021.98m 2074.69m	2 1 1				2	
1: 9 2010	Settings Tool 0.9990MH2 0.0932MH	z -1 ⁻ z -1 ⁻	7.36dB 7.36dB	158 158	∜ 1021.98m 2074.69m) 				2 2 2	
Measure 1: 9 21 1(Settings Tool .9990MH: 0.0932MH t: Trace 3	z -1 z -1	7.36dB 7.36dB 7.36dB	158 158	√ 1021.98m 2074.69m 1√					2 2	
Measure : 1: 9 2: 1(Settings Tool 9990MH2 00932MH t: Trace 3 m/Div	z -1° Iz -1° Y-Range = *	7.36dB 7.36dB 7.36dB ×	158	1021.98m 2074.69m ↓	Trace	e 3 sel	ected	to disp	2 2	
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Measure 1: 9 2 1(2 1(10 Reference 0	Settings Tool .9990MH: 0.0932MH t: Trace 3 m/Div ▼ at Trace 3 m/Div ▼ at Trace 3	s Options z -1° z -1° Y-Range = ° Reference F 0	7.36dB 7.36dB 7.36dB × 100 m Position Divs	158	1021.98m 2074.69m ↓ The m/l	e Trace Div (m 7.36dl	e 3 sel W) an Bm ley	ected d as s	to disp hown t	∂ 2 lay he a	
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Use this link for calculation of power from dBm values http://rapidtables.com/convert/power/dBm to mW.htm

🚆 Enter Expression 1 for	trace 3:	×
Expression:		
(s21)^2*constant*	ΆΤΤ	\sim
Global Subexpressions	(available in all expressions, subexpressions may use other subexpressions	s from above):
Name Alias	Expression	
Sub1 = ATT =	10^(dB/10)	
Sub2 = dB =	0	
Sub3 = constant =	11.615E-9 The constant is	
Sub4 = =	1 IIIe constant is	
Sub5 = =	18.365E-6/1581021.9	8E-3
Sub6 = =	1	
Aliases:		Caption:
S21 =	S11 = S12 = S22 =	PWR
Mem1 =	Mem2 = Mem3 = Mem4 =	
ok	Save	Load

1. 5.5550	MHz -17.36dB	18.36µ 🔶			
2 10.0932		18.38µ			2
🛒 Input: Trace 3	×				
10 µ/Div	▼ Y·Range = 100 μ				
Reference L p/Div	Reference Position	Scal	echange		
0 µ/Div m/Div	0 Divs	and	the powe	r shown	
# Y-Division /Div k/Div	Ref.Line Positions	corr	ectly as 1	8.36uW	
10 M/Div	8 Divs				
	5 Divs				
		1			2

That concludes the calibration of the VNWA sensitivity settings and custom trace creation and calibration

To measure higher power level than the VNWA TX out it is required to use attenuator in front of the RX port. The attenuation can be inserted in the PWR custom trace. VNWA is a precision instrument, which very accurate can measure the exact attenuation, so next we will do so, but before we do it, a really good idea is to save the setup saved in an instrument state file before we revert to standard VNWA mode. Then after we have measured the exact attenuation we quickly can revert back to the SA mode, by retrieving the instrument state file saved.

<u></u>	DG8SAQ - Vecto	or Network	Analyz	er Sof	twa	re - Spec	trum	Analyzer Mo	ode - /	45004 license
File	Measure Set	tings Too	ls Op	tions	Н	elp				
	Exit			1						
	SaveScreen		>	41	73	6dB	-	18.360		
	Print	Ct	rl+P	L.	7.3	6dB		18 380		
	Export Data		>	Γ'		Pub		10.00µ	1	
	Import Data		>						_	
	Save		>		Ca	libration				Alt+C
	Retrieve		>		Ca	libration t	to Ma	ister-Cal.		Alt+M
	Software Updat	tes	>		Dis	play State	e			Alt+D
			_		Ins	trument S	State		Shi	ft+Ctrl+I
				~	Au	tosave M	emor	y Spaces		Alt+A

📆 Enter Comment		\times
10MHz Power Custom trace	Enter a text and mark it, followed by a right click on the text to copy for use as the file name for the	
No Comment OK	instrument * zip file	

📇 Gem som			×
Gem i:	VNWA 💌	← 🗈 💣 📰 -	
Hurtig adgang Skrivebord Biblioteker	Navn Calibration Kits DG8SAQ-USB-Driver firmwares HELP backup Instrument States tmp Touchstone files	Ændringsdato 05-03-2017 21:46 01-03-2017 01:10 01-03-2017 01:10 05-03-2017 22:06 14-03-2017 10:17 05-03-2017 21:53 05-03-2017 22:26	Type Filmappe Filmappe Filmappe Filmappe Filmappe Filmappe
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Denne pc	filenam	he file nam	e into Save	
Netværk				
	<	-		>
	Filnavn: 10MHz Pov	ver Custom trace	•	Gem
	Filtype: zipped bac	kup files	•	Annuller

Now revert to standard VNWA Instrument mode

Options Help				
Operation Mode	>		VNWA	Ctrl+V
Setup			VNWA, external Bridge	Ctrl+E
Screensaver Clear	> >	~	VNWA, RF-IV Spectrum Analyzer	Ctrl+R Ctrl+A
Preset	>		Signal Generator Frequency Meter	Ctrl+G Ctrl+M

Next perform a complete SOLT calibration after a Sweep Setting done







After the measurement of the attenuation we revert to the Spectrum Analyzer mode by loading the retrieving the Instrument state file



🛒 Instrument State Manager	×
Browse Path Home View Rename State Zip State Unzip State Delete State	
Name Ext Date Comment	
10MHz Power Custom trace zis 14-03-2017 10:24 10MHz Power Custom trace	
Select the previously saved instrument state with audio and clock settings	
also load instrument mode, audio and clock settings	
10MHz Power Custom trace.zis)pen
all instrument states [(*.bck_vncom; *.zis)	Abort
C:\VNWA\Instrument States\	
🜉 Enter Expression 1 for trace 3:	\times
Expression-	
(s21)^2*constant*ATT	~
	\sim
Global Subexpressions (available in all expressions, subexpressions may use other subexpressions from ab	ove):
Name Alias Expression	
$Sub1 = ATT = 10^{(dB/10)}$	
Sub2= dB = 30.37	
Sub3 = constant = 11.615E-9 Enter the measured	_
Sub4 = 1 attennuation and click on Ok	()
Sub5 = = 1	_
Sub6 = = 1	
Aliases: Caption	1:
S21 = S11 = S12 = S22 = PWB	
Mem1 = Mem2 = Mem3 = Mem4 =	
ok Save Lo	bad

We are now ready to see how accurate the power measurement are by applying the previous used test signal of -20dBm from the HP8464A signal generator.

In fact the VNWA and the HP8464A had been switched off overnight, so there might be small temperature drifts in the VNWA, but that was not the case. Let the VNWA be on for 30 minutes to stabilize.

1: 9.9 2 9: 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	9990MHz 9989MHz 9989MHz 90 dB/Div Reference Level 30 dB 97-Divisions 10	-50.25 dB -50.24 dB > Y-Range = 100 dt Reference Position ■ 10 Div Ref.Line Positions 8 Div 5 Div	10.20µ 10.22µ 10.22µ		attennuator in place to the signal source previously used of -20dBm equal 10uW. Now measured to 10.2uW The dB(m)level of cource 30:37dB lever but you may create another custom trace to compensate by 30:37dB Reference level changed to -30dB
Rx Start = 9.9 M Att. = 0 dB	Hz I S21	dB 🔽	Cento Spar PWR Mag	er = 1 h = 0.3	L Continuou

That's it Gents. Concept proven. A number of subsequent sweep showed from 10.0 to 10.3uW, indeed perfect

The Appendix:

A number of trails performed

Monitoring over several hours of a 10MHz signal from the Leobodnar GPSDO via a SMA 30dB inline attenuator

1: 9.9990M 2⊡ 10.0011M	Hz -13.75dB Hz -13.69dB	43.14µ 43.69µ							
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Start = 9.9 MHz	a anda tanah	• • • • • • • •	la te an de c	Cen	ter = 10	MHz			Stop = 10.1 !

All available Resolution Bandwidth selected and shown as history traces for the HP8664A signal of -20dBm

Contraction Crief Length	Guid Deles Guid Custom Backmanned Traces and Backmanned Miles	
Marker Size and Color	Tanu Folaranu Custom Background Traces and Background Trace.	
•		
Apply Size	I I Marker Color = Graph Color ↓	
Default Size	Marker Color	
Zana Cala Diandina		
•		
maximum	off	
Storage Screen Funct	ionality	
	-	
To enal	ble history traces select by a right click	in
the	VNWA window the Grid option/Misc	
Tick	mark the Storage corean Eurotionality	



Same as above for a signal from the Lebodnar GPSDO signal generator



What about higher frequencies ?

As an example the 2 meter band from 144 to 146MHz and the 70cm band from 432 to 438Mhz is of interest. In previous published documents the TX Level as function of frequency documented, so even for these frequencies you will obtain decent results. Alternative if you have access to a reliable signal generator it might be used as well. However, note that the fundamental signal is still present at the TX out, so the Level Offset might be handled with care, not to let the fundamental signal create overload. Alternative use a high pass or even better a band pass filter for those frequencies where harmonics of the fundamental being used.

The level drops across the span can actually be compensated as an extra frequency dependent factor as a formula in the custom trace, so have fun.

I have written 4 documents before, where such details are described in depth.

http://www.hamcom.dk/VNWA/How to calibrate the VNWA Spectrum Analyzer using the TX output as signal source.pdf

http://www.hamcom.dk/VNWA/How to calibrate the VNWA sensitivity in Spectrum Analyzer mode.pdf http://www.hamcom.dk/VNWA/RF Generator-Output-VNWA3-and VNWA2rev1.pdf http://www.hamcom.dk/VNWA/RF Generator-Output-VNWA3-version-35.2.u.pdf

The first article contains an error, as it describes the use of Thru and Thru Match calibration. Thru Match must not be used, as can create unexpected result in the VNWA software. In addition, as described in the beginning of this report, it is much better to use totally uncalibrated method, as then Resolution Bandwidth, Number of Points, Frequency and Span can be modified without any recalibration, just fine tuning when final setup found, as when using Thru calibration any single change will cancel calibration. So this document will be totally rewritten soonest possible

Kurt de OZ7OU Marts 14 2017