SIMPLE MICROWAVE SYSTEM BENCHMARKING

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This article describes a simple way to test the receive performance of your microwave system. It requires that you are able to receive a signal from a known source from within 0-25 km (e.g. a beacon or a neighboring amateur).

The method relies on free space propagation theory, so it is important to have an unobstructed path to the source. The method does not include any compensations for refraction, reflection, atmospheric losses or ground gain, hence results should be used with caution. Neither does it take account of antenna illumination efficiency and receiver performance. The idea is to keep the calculations as simple and clean as possible. Afterwards the figures can be seen in the light of the omissions.

To further increase transparency and simplicity the units for antenna gain has been adapted to the free space propagation formula, so that the frequency independence of the spreading of energy over the path becomes apparent. Therefore the effect of the transmitter antenna is characterized in dBi and the receive antenna in aperture. This approach and the use of dB as unit makes the calculations a matter of adding together some figures.

Note that anything but the TX EIRP are frequency independent, which is convenient when comparing different bands, where the same multiband parabolic dish is used. The antenna aperture is approximated to be equal to the area of the parabolic dish used.

To perform the benchmarking you need to be able to determine the signal-to-noise (S/N) ratio of the incoming signal. This is most easily done using a adjustable attenuator in the IF line (e.g. 144 or 432 MHz) of the microwave transverter. You should preferably have so much IF gain that the noise without attenuation produces a S-meter reading. After having determined that S-meter reading (with fast AGC), you tune to the signal for a maximum reading, afterwards you add attenuation until a reading equal to the noise reading is achieved. The S/N should be at least 20dB for this method to work.

Now you are ready to fill in a table like the one below. You need to know the EIRP of the source signal, the distance to the source, the radius of the parabolic dish used and the bandwidth used for the measurements (normally 3kHz). Start at the top, and calculate your way to the bottom.

When comparing the calculated and measured figures, be aware that at least the first 7 - 10dB of difference is accounted for by the omissions in the calculations. The antenna illumination efficiency accounts for 5 - 6 dB, receiver noise figure and feeder loss for another 2 -3 dB. The rest can be attributed to propagation factors, faults in the system or inaccuracy of the data used (e.g. the true EIRP of the source).

Calculations		Unit
TX EIRP	10 * Log [power in mW] + TX antenna gain (dBi)	dBm
Path gain	-10 * Log (4 * ? * [distance in meters]²)	dB
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Power density at RX antenna		dBm/m²
RX antenna aperture (ideal)	10 * Log (? * [parabola radius in meters]²)	dB/m²
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Power at RX input		dBm
Noise floor @290K,0dB NF	10 * Log [bandwidth in Hz] - 174 dBm/Hz	dBm
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Ideal free space S/N		dB
Measured S/N		dB
<>		
Difference ideal to measured		dB

Conversion between dBi and antenna aperture can be made using the following formulas:

Antenna gain [dBi] = [Aperture in dB/m²] + 10 * Log ((4 * ?) / [wavelength in meters] ²)

Below are my own benchmarking using PI7EHG at Schiphol airport. The distance is 25km, and is very close to line-of-sight because the beacons are placed 90 meters higher than the receive antennas. I use the benchmarking to get a picture of absolute performance, but more importantly to track any changes in system performance over time.

PA5DD JO22IC22	3400 MHz	5760 MHz	10368 MHz	24192 MHz
PI7EHG (JO22JH14) EIRP	+ 39 dBm	+ 41.5 dBm	+ 32 dBm	+ 26 dBm

Path gain (25km)	- 99 dB	- 99 dB	- 99 dB	- 99 dB
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Power density at RX antenna	- 60 dBm/ m^2	- 57.5 dBm/ m^2	- 67 dBm/ m^2	- 73 dBm/ m^2
RX antenna aperture (ideal)	- 4 dB/m^2	- 4 dB/m^2	- 4 dB/m^2	- 7.5 dB/m^2
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Power at RX input	- 64 dBm	-61.5 dBm	- 71 dBm	- 80.5 dBm
Noise floor @3kHz,290K,0dB NF	- 139 dBm	- 139 dBm	- 139 dBm	- 139 dBm
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Ideal free space S/N @3kHz	75 dB	77.5 dB	68 dB	58.5 dB
Measured S/N @3kHz	57 dB	52 dB	56 dB	36 dB
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Difference ideal to measured	18 dB	25.5 dB	12 dB	22.5 dB