RF Signal Calculations

By G8MNY   (Published BATC's CQTV 177, Updated Sep 08)

With several radio path loss programmes now available to amateurs, it becomes possible to predict the P grade (or S meter for phone) for any contact not via the ionosphere.

Data is needed for these 5 parts of the problem.

```
<---------1--------><----------2----------><-----3----><----4---><---5--->

      Tx Aerial  IERP           Sky Noise ->  Rx Aerial ┌───────────────┐
┌─────┐ Gain \│/ —> : : : : : : : : : : : —> \│/ Gain    │ Rx Noise Fig  │ S/N
│ Tx  ├───────┘       Path Losses          Rx └──────────┤ Rx Bandwidth  ├->Output
│Power│ Feeder       (Free space)        Field    Feeder  │ S Meter Mode  │
└─────┘  Loss        ( + Others )       Strength    Loss  └───────────────┘
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1/ TX IERP           TX power.
                     Coax & connector losses.
                     Aerial gain dBi.

2/ PATH LOSS         NGRs for distance, )
                     Aerial height,     ) used with a terrain database
                     Frequency          ) for loss calculations.

3/ RX SIGNAL         Aerial gain dBi.
                     Coax & connector losses.
                     With 1/ & 2/

4/ RX SENSITIVITY    Sky Noise + Noise figure (preamp & Rx).
                     Bandwidth.

5/ 'R' or 'P' GRADE  S/N Conversion for that mode.
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Most people can only make a guess at these, or use makers figures where believed!

IN DETAIL..

TX ISOTROPIC EFFECTIVE RADIATED POWER.
This is a straight forward calculation best done in dBW.

TX IERP = TX dBW - ALL LOSS + AERIAL GAIN

PATH LOSS.
This has 2 parts:- the Free space loss & other losses. The free space path loss can be calculated directly from the distance & frequency, where D is in km & is in MHz.

FREE SPACE LOSS dB = 20LogD + 32.4 +20LogF

However, on VHF & UHF it is heavily modified by obstructions like hills, buildings, trees etc. The use of Path loss programme with a UK heights database can take into account hill diffraction loss, reflection loss etc, but this will still be only a best path guide. Under lift conditions losses can get close to the free space loss. If you don't have a programme you will have to guess at these additional losses. I use a programme called Tempath.

PATH LOSS = FREE SPACE + DIFFRACTION + REFLECTION + OTHERS.

RX SIGNAL.
The level is now just the Rx losses added to the other figures & converted to dBm. (Decibel ref to 1mW)

SIGNAL (dBm) = TX IERP +30, -PATH LOSS + AERIAL GAIN - COAX LOSSES.

RX SENSITIVITY.
This should include the sky noise term, but I have ignored this as @ VHF & UHF it is usually only a dB or so above the thermal noise, so it does not really alter a prediction by much.

The Rx sensitivity calculation is slightly more complex with bandwidth (in Hz) & overall noise figure (dB) needed to get the noise floor with the -174dBm/Hz from Boltzmann's constant (at room temp). The bandwidth figure assumes an ideal square I.F. response shape, so for example a Sat Rx with normal I.F. filtering will be 30MHz wide, a dedicated FM ATV RX good on sound & colour Rx may be 13MHz, & a narrow DX RX for B/W Dxing only may be 6MHz wide! On 70cms AM TV will be 5MHz unless a narrow I.F. is used. Wide FM is 200kHz I.F., NBFM 25kHz system uses 20kHz I.F., 12.5kHz system should be using a 7kHz IF, SSB uses 2.4kHz I.F., & CW whatever I.F. you have.

Noise figures of preamps & Rx are additive, the preamp adds noise to the signal, but as long as the Rx noise is drowned by the amplified band noise + preamp noise by 10dB or so (not much more as you loose headroom performance), then take just the preamp noise figure as the system noise as this will then be quite accurate without calculating it. Noise figures of just the preamp device itself can be very misleading as input socket, input tuned circuit & radiated/ PCB losses can often add 1-2dB to this!

NOISE FLOOR (dBm) = NF -174 + 10Log Bandwidth (in Hz)

RX SIGNAL/NOISE RATIO.
This is just the difference between the noise floor & the Rx signal. This is what is in the IF before the FM discriminator or AM detector.

S/N (dB) = SIGNAL - NOISE FLOOR

'P' GRADE CALCULATION.
This is an arbitrary conversion, assuming for ATV P5 is 35dB S/N (eg good VHS tape) going down to P0 at no signal. With FM there is a capture affect & also the visible noise is quite different, but with narrow FM ATV (not a Sat Rx) the effect is not as far from linear as you might expect.
I have found this formula gives quite an acceptable conversion.

P Grade = (S/N +3) x 0.13

'S' METER CALCULATION.
This is also a simple conversion, assuming 3dB/S point, that gives a good 27dB S/N @ S9 on VHF & above, but with an added 1dB to get started makes 28dB S/N, which is a very good contact.

S Meter = (S/N -1) x 0.3

Note for HF 6dB/S point is normally used as these Rx are quite deaf & the band noise is usually 10-30dB above thermal noise, & gives a greater meaningful range for the meter.

Fig.1 Example of a Path loss Programme (Tempath + Graphics to Print)

```
                            Path loss : 134
                            ---------------
                     Free Space Loss:     129.3 dB
                     Diffraction Loss:      0.0 dB
                     Reflection Loss:       0.0 dB
                     Siting Loss:           0.0 dB
                     Round Hill Excess:     4.4 dB
                     At Frequency:       1248.0 MHz
                     Over a Distance of:   55.80 km

                          TQ335643 to SU850919

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   TQ335643            Quit (Q) or run again (return)            SU850919
   G8MNY Croydon                                       GB3HV High Wycombe
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Fig 2 Example of my basic programme calculator.. (I you want a copy I can send)

CALCULATED SIGNAL FROM G8MNY TO GB3HV

INPUTTED PARAMETERS:-

```
FREQUENCY 1248 MHz           POWER 20 W = 13 dBW
TX COAX    -2 dB             TX AERIAL   17 dBi
RX COAX    -1 dB             RX AERIAL    9 dBi
PATH LOSS  -134 dB           NOISE FIGURE 1 dB
BANDWIDTH   13 MHz
```

CALCULATED RESULTS:-

```
TX IERP    = 632.4 Watts = 28 dBW

RX SIGNAL  = -68 dBm  =  89 uV (in 50 ohms)
RX NOISE FLOOR        = -101.9 dBm
RF SIGNAL to NOISE    = 33.9 dB

'S' METER          = S 9
'P' GRADE          = P 4.7
```

Why don't U send an interesting bul?

73 de John G8MNY @ GB7CIP