How much gain do you need in your preamp?

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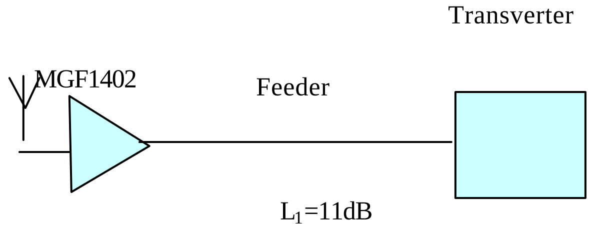
Some recent tests I ran on my 2.3GHz system highlighted the need to have enough gain in the preamp to well exceed cable losses. My preamp is based on the OE9PMJ design in the Microwave Handbook Volume 3, P15.9, but with an NE64535 bipolar transistor second stage in place of a GaAsFET, and an MGF1402 in the first stage. This has worked well for many years, but earlier this year the NE64535 died, and not having a replacement to hand I bypassed it with a short length of semi-rigid coax, retuned the first stage and put it all back into service. I suspected it was rather deaf, as disconnecting the RX feeder at the transverter made little difference to the noise level. I was recently able to use an automatic NF meter to check the system in-situ, and discovered that the overall system noise figure was 4dB measured at the antenna connector. This explained why I was having difficulty hearing stations! I decided to add a new second stage, this time using the MAR6 MMIC. After retuning the preamp I now have an overall system NF of 1dB. The improvement this provides in signal to noise ratio depends on what assumptions are made about the antenna noise temperature. With an antenna noise temperature of 290K, the SNR improvement is equal to the difference between the NF values, i.e. about 3dB. However, the actual noise temperature of an efficient antenna beaming at the horizon should be lower than this, as half the lobes point at cold sky (less than 10ºK at this frequency) and half at warm ground (say 290ºK), so the average noise temperature contributed by the antenna is about 150ºK. An NF of 4dB is equivalent to a noise temperature of 440ºK, whereas 1dB equates to 77ºK. In the first case the total receiver noise temperature is 590ºK, in the second it is 227ºK, a ratio of just over 4dB. So improving the NF by 3dB can actually provide 4dB of SNR improvement, and even bigger gains can be achieved by getting the RX NF lower still.

The result is that a fairly modest second stage device (3.5dB NF, 12dB gain) can provide a quite dramatic improvement in performance. A theoretical analysis of the receiver chain as shown below backs this up. As you can see I have a lot of feedline loss, which includes the effects of two triplexers which allow the same W103 cable to be used for 144 and 432MHz TX as well as 2320MHz RX. On the lower bands excessive receive gain can cause inter-modulation and blocking problems in the presence of strong signals, but on microwaves lower activity and highly directive antennas make this less of a consideration. It is therefore preferable to err on the side of gain and noise figure rather than dynamic range, by adding extra gain stages to be sure that the front end dominates the overall equation. The MGF1402 is not state of the art these days, devices such as the NE32584, MGF4919 and FHX34 will achieve less than 0.5dB if carefully constructed. G3WDG has a kit for a preamp based on the DJ9BV design that can also include a MAR6 second stage, and there are also ready built units available from other suppliers. In general 2 stage preamps should fit the bill for most stations, but EME stations looking for every last fraction of a dB may benefit from going to 3 stages.

SINGLE STAGE PREAMP



L_1=11dB
(x12)

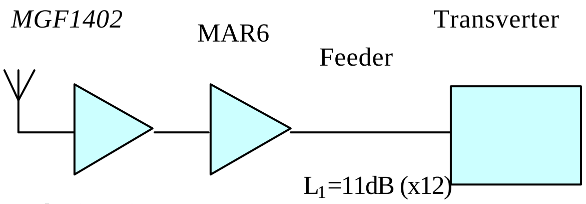
N_1=0.55dB (39ºK)
G_1=15dB (x32)

N_2=5.5dB (739ºK)

$T_1=290((10^{N1/10})-1)$	T_1=39ºK
$T_2=290((10^{(L1+N2)/10})-1)$	T_2=12664ºK
$T= T_1+T_2/G_1$	T= 435ºK

N=4.0dB

TWO STAGE PREAMP



L_1=11dB (x12)

N_1=0.55dB (39ºK)
G_1=15dB (x32)

N_3=5.5dB (739ºK)

N_2=3.5dB (360ºK)
G_2=12dB (x16)

$T_1=290((10^{N1/10})-1)$	T_1=39ºK
$T_2=290((10^{N2/10})-1)$	T_2=360ºK
$T_3=290((10^{(L1+N2)/10})-1)$	T_3=12664ºK
$T= T_1+T_2/G_1+T_3/(G_1G_2)$	T= 39+11+25=75ºK

N=1.0dB