WHY USE A MASTHEAD MOUNTED PREAMPLIFIER?

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When is it appropriate to use a Masthead amp, why do we mount it close to the antenna, what is Noise Figure and why does it matter?

Some hams believe that pre-amps are a waste of time and that they add as much noise as signal. In some situations they are right! High gain preamplifiers can be overloaded by strong signals and may add significant intermodulation and noise to your received signal. It is undoubtably true that a better antenna is more use than a preamplifier for HF and the same is true at VHF and UHF if you are only planning to access the local repeater. However for weak signal work such as EME or Satellite operation a low noise pre-amp can be indispensable.

At microwave frequencies most receive systems use a "Low Noise Block" (LNB) mounted right at the dish antenna. An LNB combines a low noise preamplifier with a frequency down converter. Since feeder loss is proportional to the frequency, reducing the output frequency to an IF frequency, eliminates the need for expensive low loss coax or waveguide, and coax loss to the receiver is reduced. A good example of this is your Satellite TV dish and receiver.

Every item in your receive chain from the receiver to the antenna, including coax feeder cables, attenuators, filters, and amplifiers, adds noise or loss to the received signal. This noise is due to the thermal noise characteristic of each device. However, I am not going to discuss noise temperature in this article because it is complex and I don't feel that it is necessary when discussing the merits of using a masthead preamplifier.

Preamplifiers are often advertised as having a low Noise Figure or Noise Factor. The Noise Factor is the amount of noise that a device adds to the signal as it passes through. Noise Factor (F) is used in calculations but for most other purposes it is usually converted to the logarithmic decibel scale. The Noise Figure (NF) is the Noise Factor expressed in Decibels (dB). [NF=10log(F)].

When you are buying a masthead pre-amp the two most important specifications are the gain and the Noise Figure. Other important considerations are whether or not if can be bypassed so that you can transmit on the same antenna, bandwidth, how the power feed works, weatherproofing etc.

- Too much gain can cause overload and intermodulation problems – gain should be enough to overcome the loss in your feeder cable, 'plus a bit'

- The amp must be at the mast head as close to the antenna as possible – many people who say that preamps are no good are putting them at the transceiver end of the feeder. Noise figure is dominated by the first device in the feeder chain, so that is where your low noise pre-amp needs to be

- Lower noise figure is better – but more expensive. For EME or VHF DX it needs to be as low as possible, for Satellites noise figure is less important and for your local repeater any preamp on the market will probably be OK

- Power feed over the coax means that you do not need to run a separate power feed. In an amp with bypass relays no power will normally make the amplifier relays drop back to a bypass mode, for transmit. Some transceivers can feed a masthead amp without the need for an external power injector.

Because each item in the receive chain is adding noise to the received signal, each item is having an effect on the quality of the signal. The quality of the signal is often referred to in terms of the Signal to Noise Ratio (SNR). The higher that the signal level arriving at the receiver input connector is above the background noise, the better the Signal to Noise Ratio and the better you can copy the signal. Signal to Noise Ratio is also usually expressed in Decibels. Since Noise Figure is the amount of noise added by a device, Noise Figure (NF) = SNR (input) – SNR (output).

'Passive' devices with no gain such as attenuators, filters or the coax in your antenna feeder have a Noise Figure equal to their attenuation, (loss). So if your feeder cable has 3dB of loss at the frequency of operation, then the NF of the feeder cable will be 3dB and it will degrade the Signal to Noise ratio by 3dB.

It is important to use good quality coax feeder cable. The higher the frequency the more loss the coax will have and the better quality it needs to be. For example, at 435MHz 20m of RG213 coax cable will have about 3.2dB of loss, but 20m of RG58 will have 5dB – 6dB of loss.

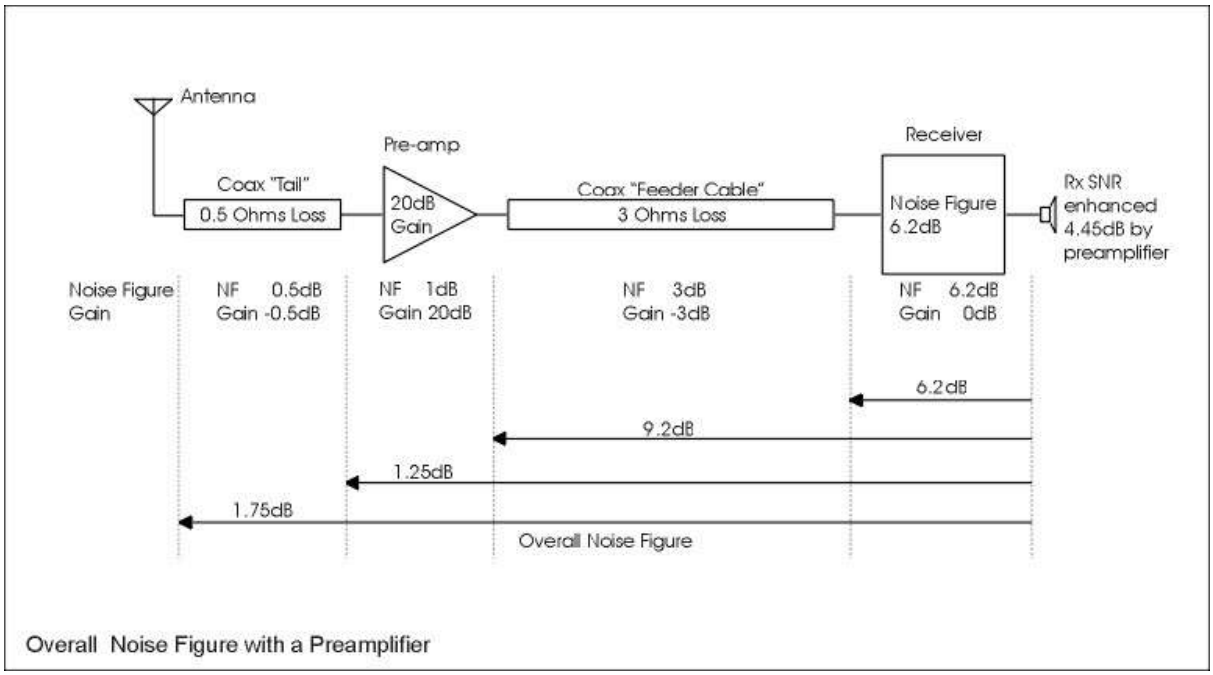
If your UHF receiver has an SSB MDS, (Minimum Discernible Signal), of –140dBm, an input level of –130dBm will give a SNR of 10dB, which is about the minimum for acceptable copy. A loss of 3dB in the feeder coax cable will reduce the input level to –133dBm and the Signal to Noise Ratio will reduce to 7dB, which would make the signal difficult to copy. However a loss of 6dB in the feeder coax cable would reduce the input level to –136dBm and the Signal to Noise Ratio will reduce to 4dB, which would make the signal almost impossible to copy. A pre-amp can make up the coax loss and boost the signal, but will it improve or degrade the overall quality of the signal, as measured by the Signal to Noise ratio?

Active devices such as amplifiers have a Noise Figure related to the bandwidth, input impedance, gain and thermal noise of the semiconductors and other components. A really good low noise amp might have a Noise Figure between 0.5dB and 0.8dB. Most FET pre-amps can manage a Noise Figure less than 3dB and your VHF or UHF receiver will probably have a Noise figure between 6dB and 20dB.

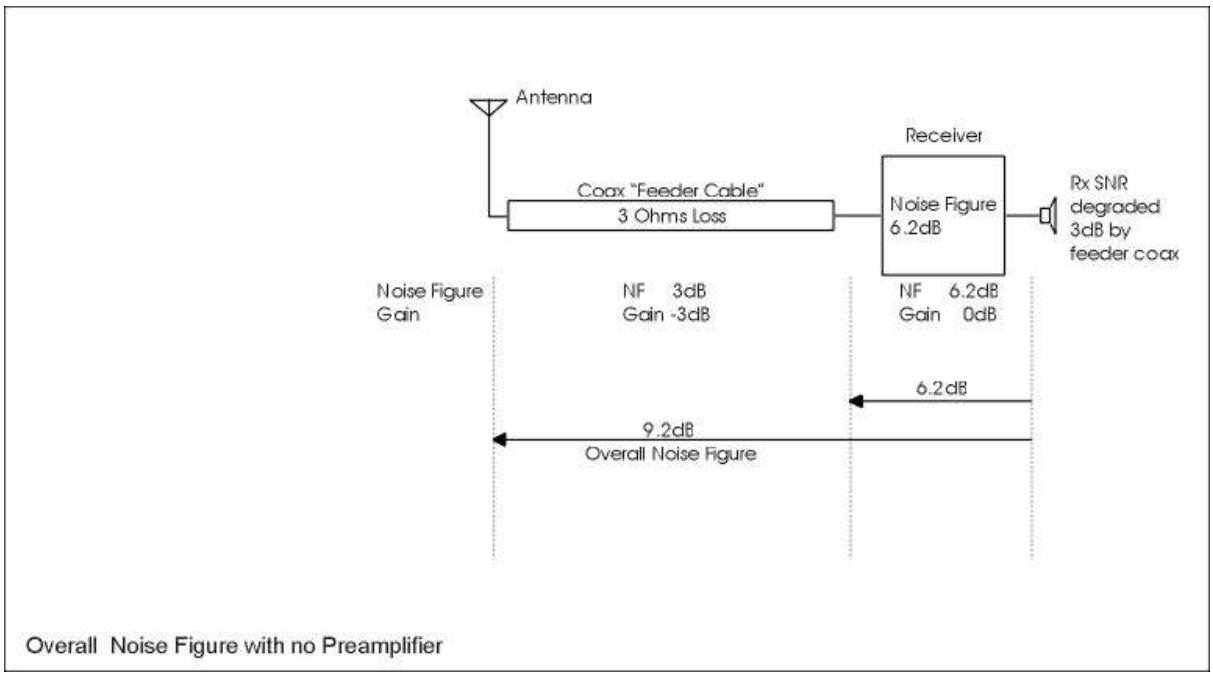
The Noise Figure of the overall chain, from the antenna – coax tail to masthead amp – masthead pre-amp – coax to shack - receiver, is dominated by the first device in the chain. This is why it is important to have the amplifier with its high gain and low Noise Figure as close as possible to the antenna.

$$F = F1 + \frac{F2-1}{G1} + \frac{F3-1}{G1G2} + \frac{F4-1}{G1G2G3}$$

F = Noise Factor of device =10^(NF of device in dB/10))
G = Gain of device (linear ratio not dB) =(10^(Gain in dB/10))
NF (noise figure in dB) =10*log(F)



Overall Noise Figure with a Preamplifier



Overall Noise Figure with no Preamplifier

In this example, adding a good 20dB pre amplifier with a 1dB Noise Figure improves the overall Noise Figure from 9.2dB to 1.75dB and the S/N ratio by 7.45dB. The 3dB degradation from the feeder loss becomes a 4.45dB enhancement due to the gain and improved Noise Figure.

Any loss from coax between the antenna and the preamplifier degrades the overall Noise Figure and therefore the Signal to Noise ratio of the received signal. Having the pre-amp close to the antenna can result in a reduced overall Noise Factor, (compared to no amplifier or one situated in the shack). This results in an improved Signal to Noise ratio and we can hear signals we could not hear before. If we put the pre-amp at the shack (like the ones on cheap 2m linear amps) the combination of a pre-amp with a relatively high Noise Figure and loss due to coax cable between the pre-amp and the antenna can result in degraded Signal to Noise even if the gain of the amplifier easily exceeds the coax loss. In other words put the amp before the feeder loss, not after it.

Don't use too much pre-amp gain. The masthead pre-amp gain only needs to be enough to make up for the coax loss, plus around 10dB. More gain has little effect on the Signal to Noise ratio and increases the risk of intermodulation and overload on strong signals. A rule of thumb is that the pre-amp gain should be set so that the receiver is showing S0 – S1 with the antenna and pre-amp connected but with no received signal. Any more gain than that will result in you listening to background noise and will limit the receiver's dynamic range on strong signals. Some operators switch in the receiver's attenuator or add external attenuators at the receiver input. This will reduce the receiver input level, but because the overall Noise Figure is mostly related to the pre-amp at the mast head, the SNR will not be badly affected.

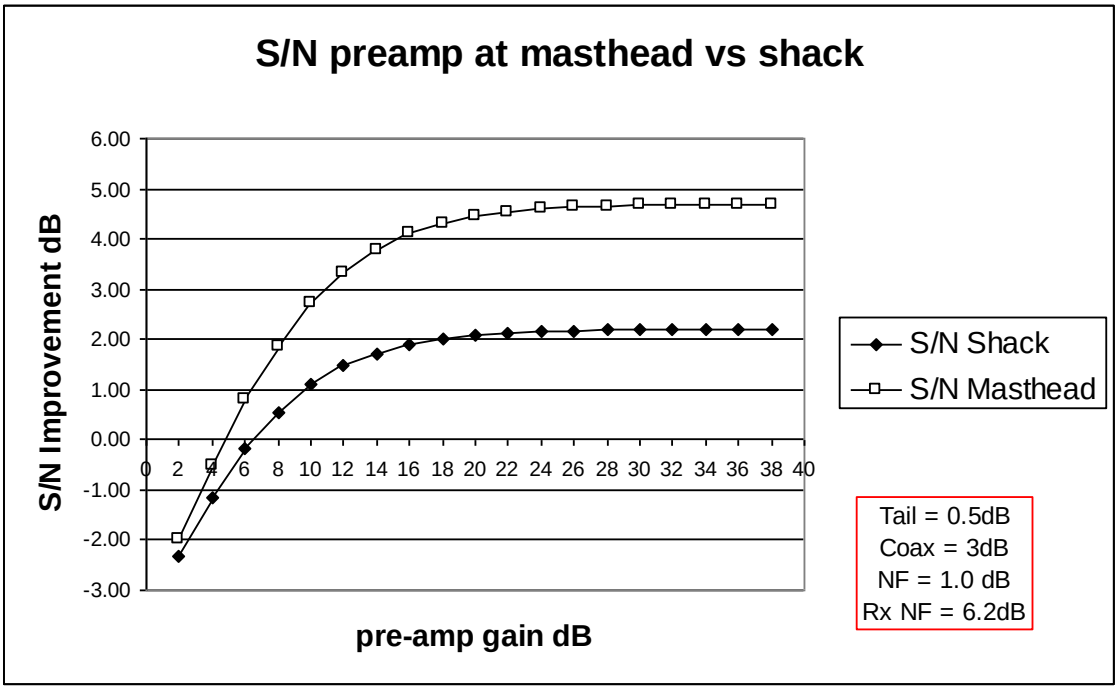


Fig 1: Because the coax loss before the pre-amp has a large effect on the overall Noise Figure, it is better to keep it to a minimum by placing the pre-amp close to the antenna.

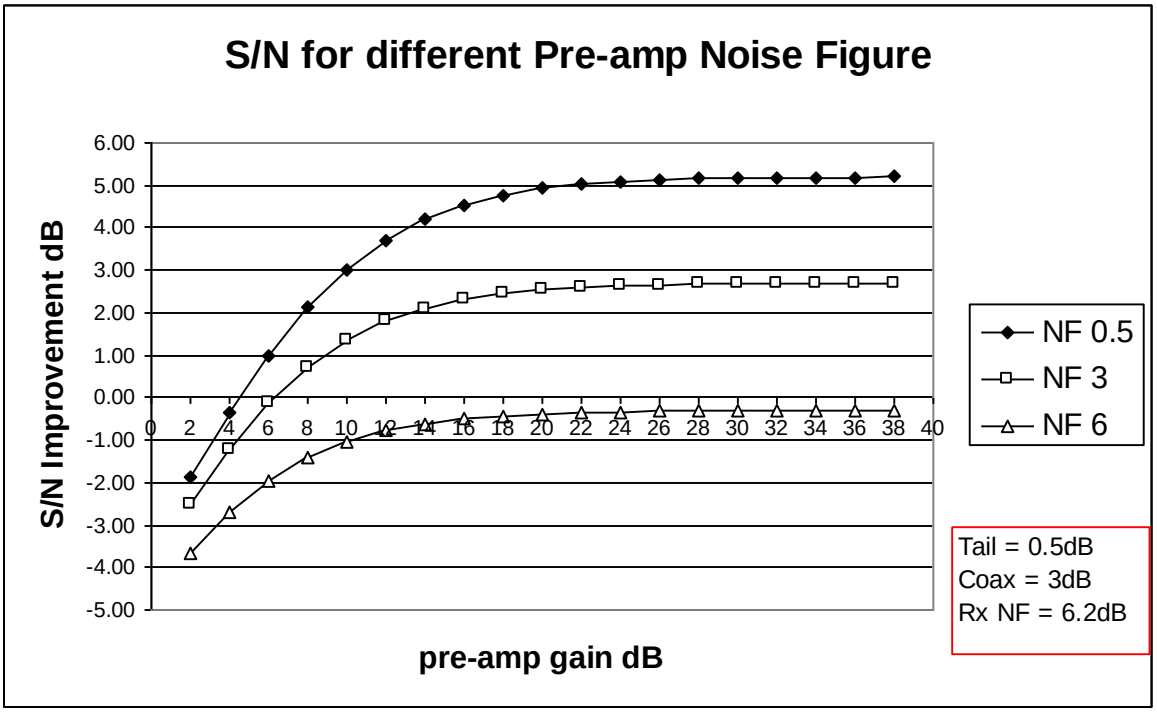


Fig 2: If the pre-amp or overall Noise Figure is poor, no amount of gain will result in an improved Signal to Noise ratio.

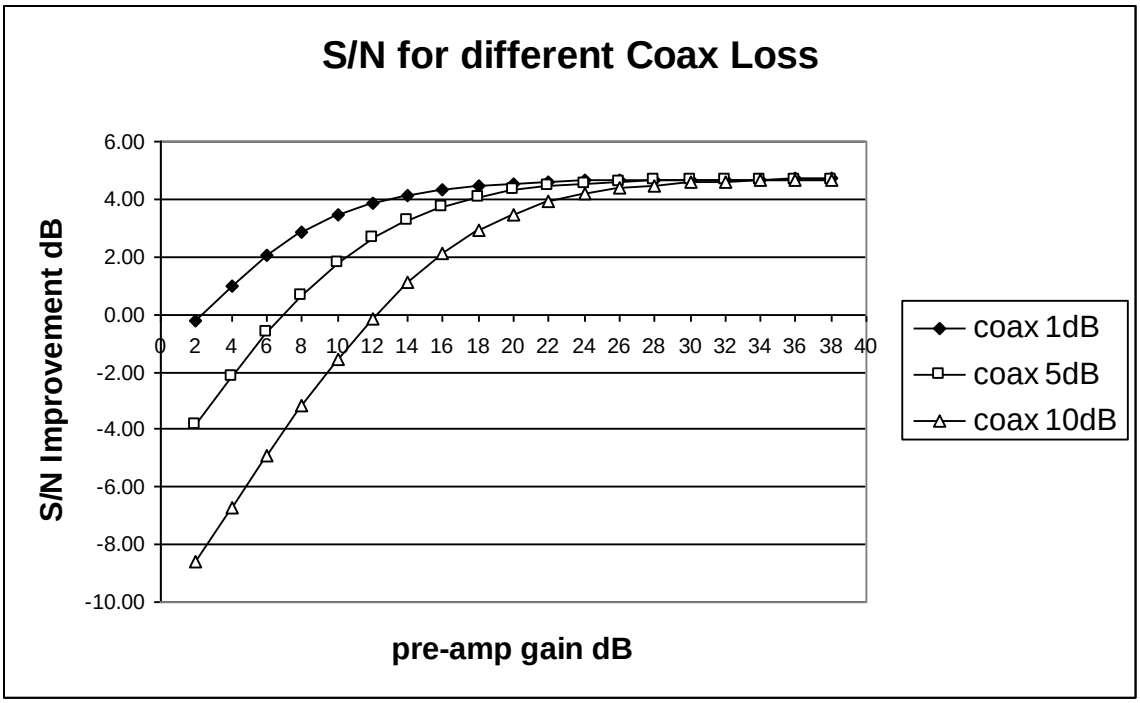


Fig 3: Coax loss after the pre-amp can be made up with pre-amp gain. Increasing pre-amp gain past a certain point has little effect on the overall Signal to Noise improvement, but will reduce the receiver's dynamic range and can add intermodulation distortion in the presence of strong signals.

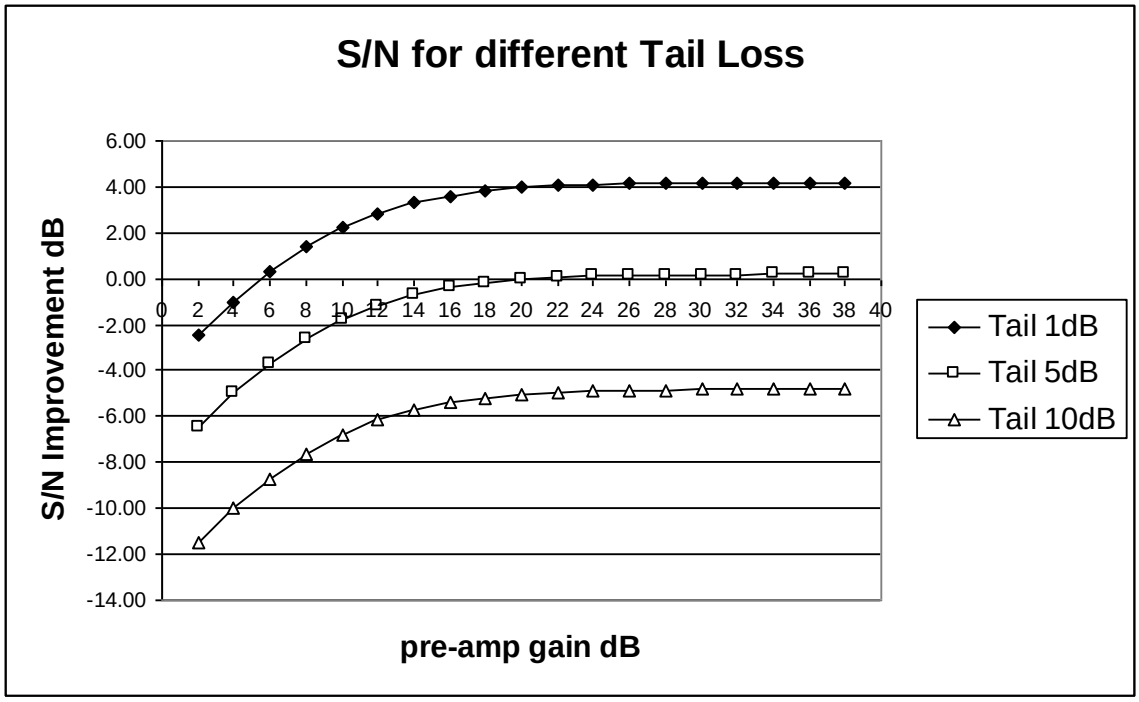


Fig 4: Coax loss before the pre-amp adds directly to the overall Noise Figure and should be kept as low as possible. Too much loss before the pre-amp will result in no Signal to Noise ratio improvement or a degraded Signal to Noise ratio, no matter how much gain the amplifier has.

Rules for masthead pre-amp use:

1. If the **overall** Noise Figure is lower than the receiver's Noise Figure, the Signal to Noise ratio will be improved.

2. If possible use a pre-amp with a low Noise Figure, but almost any masthead mounted pre-amp will improve the overall Noise Figure.

3. Mount the pre-amp as close as possible to the antenna and use low loss (but flexible) coax and high quality connectors to connect it to the antenna

4. Coax loss after the pre-amp has little effect on performance provided the amplifier gain is higher than the coax loss

5. Coax loss before the pre-amp has a large effect on performance no matter how much gain the pre-amp has

6. Pre-amp gain should be kept as low as possible to avoid overload on strong signals and unnecessary background noise

7. The FET devices in masthead pre-amps are very easily damaged. Buy a pre-amp with bypass relays that bypass the amp when the DC supply is off. That way the amp will have some protection from static discharge during lightning storms.

8. If you want to transmit on the same antenna, the amp MUST have bypass relays. These may be switched by sensing the RF from your transmitter or via DC control usually over the coax cable. I prefer pre-amps that have both control methods.