Amplifier Operational "Sweet Spot"

Almost every day, someone asks me: **"What are the best input and output levels for this amplifier?"** That is a good question which can be answered **easily** or with **complex analysis.** As always, the simple answer is the best. So here goes: **Always choose the correct amplifier for the job at hand. That may not sound like the answer you expected, but it is the right one. Now the details...**

Rule 1. Input signal levels should ALWAYS exceed the noise figure of the amplifier by 3 to 6 dB. This may sound easy, but some folks are fooled. Here's why. **For practical purposes, the input gain device of a two-stage amplifier establishes the noise figure for the entire amplifier. This rule can be broken by too much interstage loss due to equalizers, pads, attenuators and response networks.** And of course the input noise figure of the amplifier is equal to the noise figure of the input gain stage (hybrid, transistor, etc.) **plus the loss** of any input passive devices (equalizer, diplex filter, test point, power chokes, etc.) that precede that gain stage. **Don't forget that the noise figure of this input gain stage may have a different dB rating at 50 MHz from the value at 450/550/750 MHz.** Be sure to check these specifications. If the published data does not specifically say that there is a different noise figure at a given frequency, it "should" be safe to "assume" the published value is at the highest amplifier operating frequency. Typically the noise figure for a 450 or 550 MHz hybrid amplifier chip is 1 dB better at 50 MHz than it is at the top frequency. It could be as much as 1.5 to 2 dB for a 750 MHz chip.

"Well now, with a noise figure like that, why can't I hit the input hybrid harder and get a better carrier to noise ratio?" That brings us to the other battle cable TV has waged since cable began: unwanted mixer products, lines in the pictures, composite-triple-beats (CTB), etc. This is of course, the result of over-driving any amplifier to the point where intermodulation (unwanted mixing of signals) produces other undesired signals (CTB, etc.). It can happen in the input stage of an amplifier if the input levels are too high, but is usually most prevalent with the higher signal levels produced at the output stage of the RF amplifier.

Rule 2. Match required output levels to the correct amplifier hybrid technology. A "rule of thumb" was published in our full page ad in the April and June 1998 issues of Communications Technology. Here it is in simple terms:

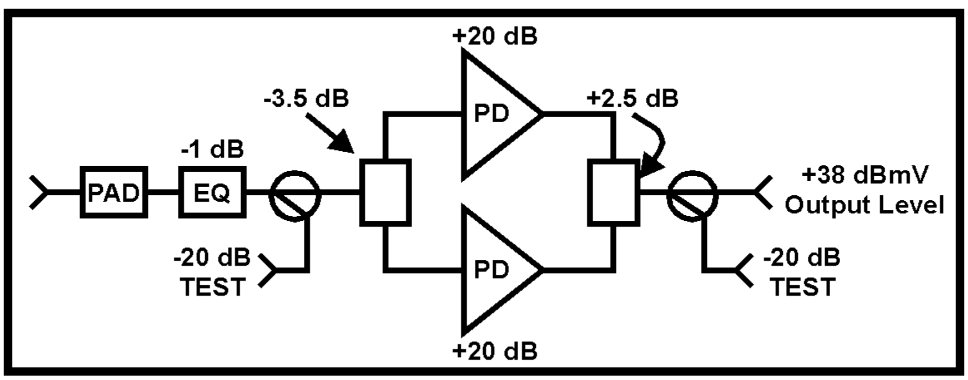
RF Output Level	Hybrid Technology
25 to 32 dBmV	Push-Pull (PP)
32 to 36 dBmV	Power-Doubled (PD)
36 to 40 dBmV	Quadra-Powered
40 to 45 dBmV	Feedforward/GaAs PD

This chart is a suggested general rule for broadband signal amplification solutions. There are exceptions to the rule based on the number of RF carriers to be amplified which will be addressed later in this text. **< Next Page >**

A comparison of the manufacturer's specifications for the hybrids demonstrates that CTB gets better as the level of technology is increased. Push-pull is the lowest common denominator widely used today. Power-doubled hybrids have 5 to 6 dB better CTB than push-pull hybrids at a given output level. Push-pull hybrids usually have a noise figure advantage over power-doubled hybrids. That is why push-pull hybrids are used at the input of an amplifier module where signal levels are low. There are some exceptions to this rule as I will explain later in the text.

A quadra-powered amplifier uses two power-doubled output hybrids on parallel paths. (I know, I heard your confusion.) In the 1980s, SA had a line of amps they called "parallel" hybrids. The first power-doubled trunk modules made by QRF used "parallel path" push-pull hybrids to achieve the same performance we get today from a single power-doubled hybrid. When real power-doubled hybrids are dropped into the parallel amplifier pathways, the amplifier is said to be **"quadra-powered."** The advantage is better CTB performance or higher output levels.

In each case, the power addition of two sets of "in-phase" RF signals will produce a 3 dB power addition at every frequency. In the real world, the magnetic loss of the ferrite "RF splitter / combiner" is around 0.5 dB. The net signal gain is then 2.5 dB. Remember that the same splitter has 3.5 db splitting loss to feed the input of each hybrid in the parallel paths. The block diagram below of our **QRAM750-17Q** headend amplifier depicts this.



Looking at the diagram above, the levels at each point in the RF path become apparent. The -20 dB directional couplers have about 0.5 dB through loss. **With the +38 dBmV output, the hybrids are each producing an output level of +36 dBmV.** The input level to the hybrids would be 20 dB less or +16 dBmV. The noise figure for a modern 750 MHz, 20 dB power-doubled hybrid (MHW7205C) is 7 dB at 750 MHz. Using an older similar hybrid with a 9 dB noise figure, the amplifier is still 7 dB over the rated noise figure of the hybrids with levels shown above. With this information, it becomes obvious that the output of this amplifier could be lowered by as much as 3 dB without a significant impact on the carrier-to-noise (C/N) ratio of the signals being amplified. The performance advantage is a 2 dB improvement in CTB for every 1 dB of output level reduction. **< Next Page >**

Summing this all up, the amplifier on the previous page works fine in the range of +36 to +40 dBmV RF output with 110 NTSC television channels. Below that output range, the C/N would suffer. Above that range, the CTB would suffer. To get more output, feedforward (FF) hybrid technology comes into the picture. (Actually, feedforward saves your picture quality.) The internal losses of the delay lines and directional couplers inside the feedforward hybrid provide the cancellation of unwanted distortions (CTB, etc.). These same internal losses degrade the noise figure of the feedforward hybrid. **A 750 MHz feedforward chip has typical noise figure ratings of 9 dB at 50 MHz and 13 dB at 750 MHz. The noise figure of the output gain stage limits the MINIMUM RF output level.**

For the 750 MHz feedforward hybrid, the numbers add up like this: Noise figure = 13 dB. Add 3 dB minimum signal level above noise figure = +16 dBmV input at 750 MHz. Now add the 24 dB gain of the hybrid to reach a minimum output level of +40 dBmV. With the input signal level at 5 dB above the noise figure, the output would be +42 dBmV for the "sweet spot" operational levels. It's that easy!

The last thing to consider (in case you did not notice above) is the noise figure difference at 50 MHz versus the top frequency of the feedforward hybrid. Let's say that the **QRAM750-30F** headend amplifier is installed in a master headend feeding broadcast signals to a large array of laser transmitters in the next room from the modulators and satellite receivers. This layout would have a length of cable from 50 to 100 feet in length followed by splitters and couplers to feed the lasers. **Here is the way to improve the CTB performance:** set the output slope of the QRAM driver amplifier with some slope (not flat) to reach the majority of lasers with flat signal levels. The signal advantage here is for every 1 dB of slope change out of the QRAM, there is approximately 0.7 dB improvement in the CTB. The thing to remember is that you should not exceed 4 dB of slope on the amplifier. Why? **What was the noise figure of the feedforward hybrid at 50 MHz?** It was 4 dB better than the noise figure at 750 MHz! If you exceed 4 dB slope output, the C/N will suffer for the low band channels. The result is another amplifier "sweet spot" has been found. Use it to your advantage!

Before we leave QRAM, there is one more thing that recently came up. **With ONE channel, the QRAM750-17Q can really put out a strong signal. A single MHW7205C power doubled hybrid has its 1 dB compression point at +82 dBmV.** Do the math if you need to do a number on just ONE channel: output around +84 dBmV is possible. Feedforward cannot do this due to higher internal hybrid passive losses.

Now, the special case when the input of trunk module is not push-pull: SA 550 MHz feedforward "FT" series amplifiers used a power-doubled input hybrid to drive a feedforward output hybrid. The output chip has a noise figure of 9 and 11 dB at 50 and 550 MHz respectively. Considering the 3 to 5 dB signal level over the noise figure rule: the minimum output level for the low band from the amplifier would want to be 9 + 3 + 24 = 36 dBmV. Channel 78 must be at least 2 dB higher.

And last of all, for those of you using a **single hybrid line extender,** it is probably a **34**

dB gain chip. The noise figure rule still applies. Typical noise figures for 450 and 550 MHz 34 dB hybrids are about 5 to 6 dB. Add 3 dB plus the gain of the hybrid and the minimum output level for these LEs is around 43 dBmV for the low band unless you are willing to sacrifice the C/N since this is one of the last two amplifiers in the system. It's that simple.

When I first wrote this article, the **gallium arsenide (GaAs) hybrid** from Motorola was not in production. Now that QRF is building amplifiers with this new hybrid technology, a **page four of amplifier sweet spot is needed** to complete the story! **Click here for page 4.**

The newest and most advanced RF hybrid technology of today is the **Gallium Arsenide (GaAs)** push-pull and power-doubled hybrids. **The power-doubled designs can operate at output levels with low distortions similar to feedforward hybrids.** They accomplish this level of performance and yet consume less power than the silicon power-doubled hybrids that preceded them.

The noise figures of this new family of hybrids are lower than their silicon brothers, on the order of **3 to 4 dB noise figure** across their entire frequency range. The second-order and third-order distortion levels are also improved! **The bottom line: Amplifiers built with GaAs hybrid technology have a wider dynamic range of input and output levels than any amplifier design that has come before them.**

Given this new level of performance, one should not lose sight of the original premise of this article. Always exceed the noise figure of any amplifier gain stage by 3 to 6 dB to minimize the noise contribution from that gain device. Choose an output level from any amplifier gain stage that does not violate that noise figure rule, yet still provides a suitable output level with acceptable second-order and third-order distortion levels.

So, there you have it - the secret to operating wideband RF amplifiers in "The Sweet Spot