## TechTalk 88

# Amplifier Linearization

**(AMPLIFIER LINEARIZATION in a DIGITAL WORLD)**

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**(drawings by Bob Miller W6KGE)**

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This article is a discussion about the current type of amplifiers most hams have used, their shortcomings and ways to improve them.

For years hams have used SSB capable linear amplifiers for ATV with the power backed down. This worked fairly well with AM ATV but not so well with analog VSB or QPSK digital ATV signals. The three primary shortcomings of the amplifiers are:

1. gain compression,
2. bias and power bypassing and
3. intermodulation distortion (IMD).

Bypassing is the easiest to fix; it is done by adding capacitors to both the bias and collector or drain supplies to stiffen them up during sync or peak signal portions of the modulation. Many ham amplifiers did not provide adequate filtering as needed for complex ATV and QPSK waveforms but some manufacturers made modifications to make them ATV compliant. We can improve most amplifiers by using low ESR (low series resistance) rated capacitors to provide a stiffer supply to the active amplifier devices. RFC choke wire size needs to be large enough to reduce voltage drop to provide the stiff DC supply to the active devices.

Amplifier class is also important for both efficiency and distortion levels. Class A is best for low distortion but has very low efficiency and usually not used for high power final amplifiers. Class AB is much more efficient but distortion at the upper end of the power curve is much higher than class A…class AB is the normal choice for final and driver amplifiers.

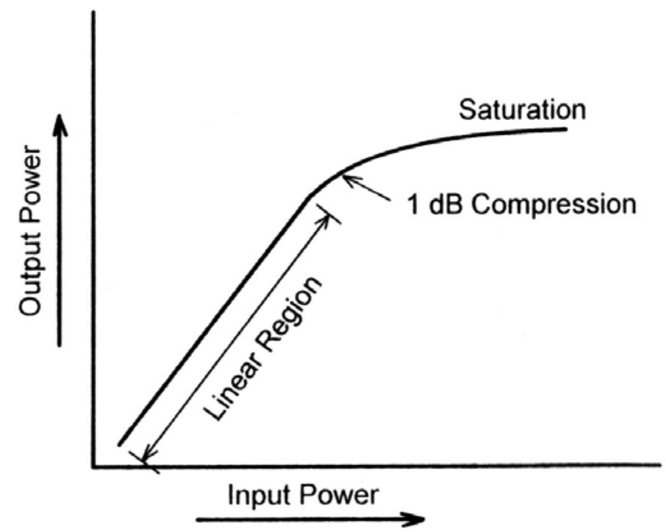


**Figure 1 – Amplifier Curve**

Amplifiers have a gain curve **[Fig 1]** that starts out as linear, then the gain reduces, then saturates as RF drive increases. Amplifier power output is usually rated at both the 1 dB compression point and saturated power output. Most typical ham amplifiers are rated at or near the saturated end of the curve. The 1 dB compression point is usually about 60 to 70% of the saturated output. It is best to not drive an amplifier past the 1 dB compression point during sync time for analog and lower than that for digital.

As the RF drive increases, a change in the junction capacitance and internal resistance will occur. This will cause phase shifting (AM/PM) and compression (AM/AM) these are the primary causes of IMD. Two tone testing is one way to test an amplifier for IMD performance.

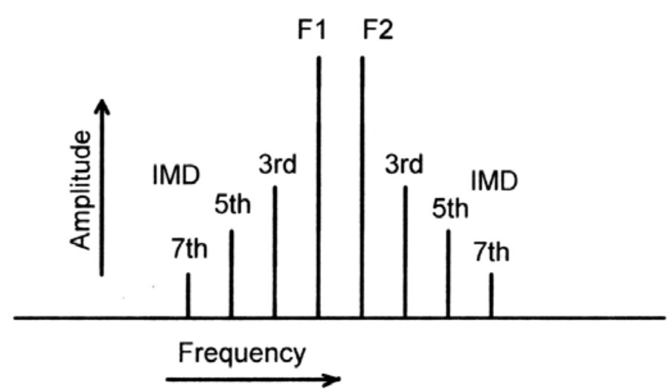


**Figure 2 – Analog IMD (two CW carriers, F1 and F2)**

The procedure is done with two carriers (F1 and F2) of equal level and a usually a few megahertz separation for testing [see **Fig 2**]. Looking at analog a VSB signal at the output of the power amplifier you see the effect of

IMD as drive levels are increased, the lower aural carrier starts regenerating and its level is an indicator of the amplifier's IMD distortion performance.

RF amplifiers using 24 volt devices have lower IMD responses than 12 volt devices. LDMOS devices usually have lower IMD responses than bipolar ones. Bias will affect the gain curve; increasing bias will extend the linear portion of the curve at the expense of efficiency and heat. Amplifier tuning especially loading has an effect on IMD as well.

Although most of the amplifier distortion outside the desired signal channel can be filtered out with an external filter, the IMD is also present within the desired channel causing visible beat patterns with AM or VSB analog and will cause the constellation pattern to distort, EVM and signal to noise will worsen with digital signals. As the drive is increased, IMD increases till at some point the signal cannot be demodulated.

ATV operators have for years put up with IMD on AM or VSB analog and some turning up the sync stretcher level and RF drive to allow pushing the amplifier past the 1 dB compression point to get as much power as needed for ATV DX.

We cannot do the same thing with digital and usually amplifiers used for digital ATV have had to be used backed off well below the 1 db compression point, this is the peak of the signal and digital is measured as average power. Average level is 7 to 10 dB below the peak. An amplifier with a CW power output of 100 watts has its 1 dB compression point about 70 watts (sync in analog ATV) its digital average power is about 15 watts.

Now that we know the shortcomings, how do we get around them for better analog and robust digital performance? Either pre-distortion or bucking out the distortion [called Feed-Forward] is the answer.

**Feed-Forward Technique**

Most [commercial] broadcast transmitters use feed forward techniques. It is done by dividing the drive signal into two paths [see **Fig 3**]; the first is through some delay between the splitter and power amplifier input (coax jumper) and the other path through a variable phase and amplitude adjuster into a combiner. The other combiner input samples the power amplifier's output via a directional coupler.

The combiner's output is first tested with a spectrum analyzer and the phase and amplitude adjusters before the combiner are set so the desired signal is minimized so the IMD (dirty) signal remains. The combiners output is then is then connected to a very linear class A (error) amplifier to overcome directional coupler and adjuster losses.

The now amplified IMD is reapplied 180 degrees out of phase and equal level to the IMD level from the power amplifier using a second set of phase and amplitude adjusters to minimize the power amplifier's IMD products by 20 to 30 dB in many good amplifiers [see **Fig 4**] and at least 15 dB with other less performing amplifiers. DSP processing can be used to make the process more dynamic for different power output levels, temperature and power supply changes.

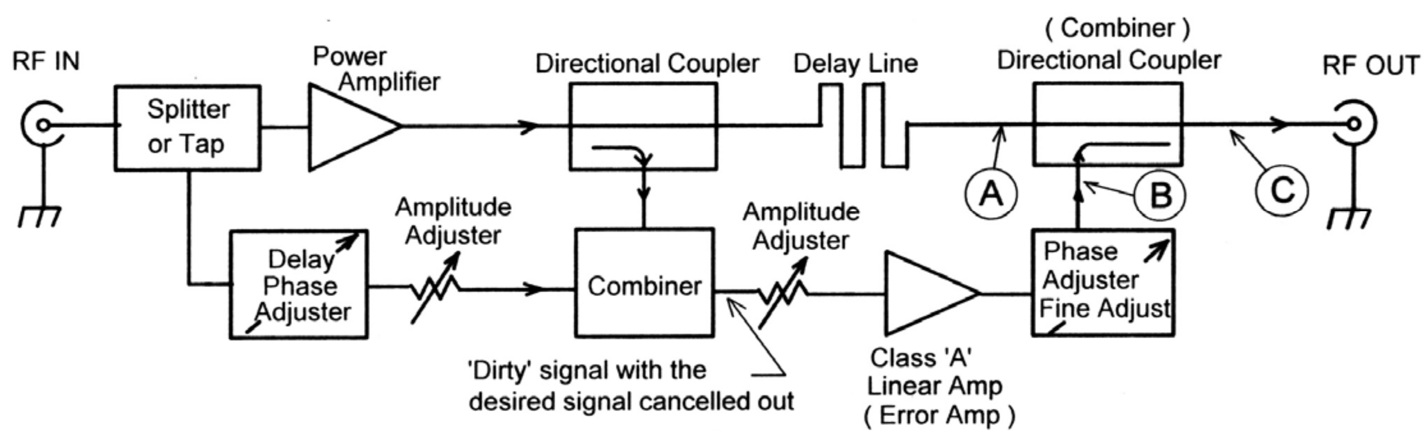


**Figure 3 – Block Diagram for Feed-Forward IMD-cancelling Concept**
**The signal with high levels of IMD at (A) is combined with the out of phase "dirty" IMD signal from (B) which cancels the IMD, to produce a desired clean signal with 20 to 30 dB lower IMD at (C)**

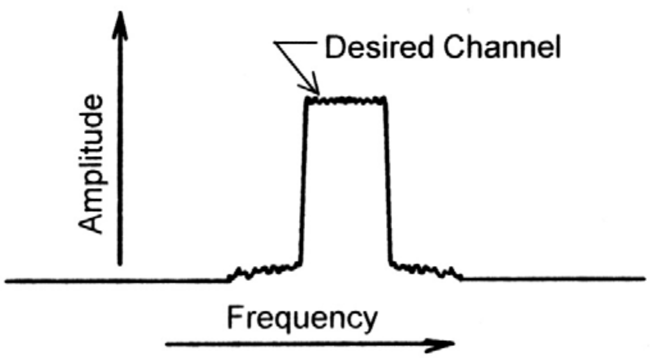


**Figure 4 – Clean Digital Modulation Signal After Feed Forward Compensated Amplifier**

## Pre-distortion Technique

Pre-distortion is usually used in small hand held digital units. A simple version can be done with a diode in series with the RF path prior to the driver amplifier and is slightly biased and its parameters chosen to compliment the drive levels used [see **Fig 5**]. The bias current is adjustable to allow optimizing the pre-distortion; this method can give about a 6 dB improvement in lowering IMD.

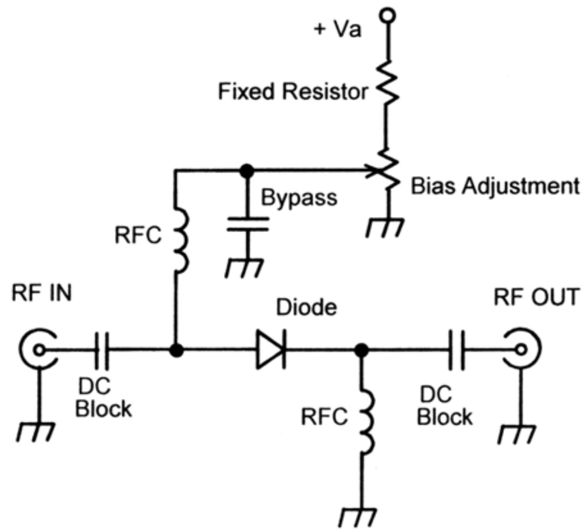


**Figure 5 – Series-Diode Pre-Distortion (for Low Pwr) About 6dB Improvement in Lowering IMD**

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