# "SOME THOUGHTS ON SUPERMODULATION"

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The purpose of this paper is to acquaint you with 125% positive peak modulation of AM medium wave transmitters - also called "supermodulation". We have always said our current transmitters will make at least 130% - and they do - every one of them! They will make this extra modulation because they have been designed with reserve in the drive circuits and power supply which is just where the demand comes from. Manufacturers who have skimped in their transmitter design are "paying the penalty". Either they admit flat out their equipment won't supermodulate or they deviate slightly from the truth.

Now, some transmitters will supermodulate when new, but as they age, the ability to do so falls off. RCA Ampliphase transmitters, however, will supermodulate all the time. Tubes are run at only half their capabability, extra power is available from the power supply, and the drive regulator will provide all the drive necessary to provide at least 130% positive peak modulation.

To understand the need and derivation of this swing to supermodulation, let's spend a minute and look at the way this all came about.

For years, the broadcaster's only concern about his AM medium wave transmitter was - did it modulate and did it sound good? If the answer to both was "yes", he was satisfied. The broadcaster assumed that if the transmitter was limited to 100% negative peaks of modulation, then the positive peaks were also limited to 100%.

However, through the years the rules for new radio stations were changed which placed stations closer together, which in turn found stations wanting to sound louder to overcome adjacent stations. Additionally, with the population shift to the suburbs and increased competition from other stations (FM and TV included), the broadcaster recognized the need for higher averages and peaks of modulation. Now the broadcaster began to look at his equipment and ask, if audio peaks go beyond the "normal" excursion, will the transmitter pass it?

To answer this question, let us look at what a transmitter is made up of. With the exception being our phase-to-amplitude (Ampliphase) and Continental's Class B linear (Dougherty), the other transmitters in use today use a high powered audio amplifier to modulate a Class C RF amplifier. The Gates PDM system also uses this approach. In these transmitters, a single high voltage power supply powers both the modulators and RF amplifiers. It is in this single high voltage supply that the problem of providing for higher peaks of modulation develop. As the modulation draws more current to follow the audio peak, the RF amplifier is also drawing more current in order to supply the demand for more RF. In the plate modulated transmitter, the instantaneous plate voltage can vary by 20 to 25% between 100% and 125% positive peak modulation. If the power supply is marginal to begin with, the positive peak excursions will round off and the transmitter will exhibit carrier shift. This is due to the drop in voltage caused by the big demand for more audio and RF power. This voltage drop reduces the RF level and the modulation B+ from the modulator itself.

Before proceeding any further, let's dwell a little on carrier shift. Earlier we spoke of a voltage drop causing carrier shift. Just what is carrier shift and how does it apply to "supermodulation"? We can define carrier shift as a change in the average value of current produced by a carrier--modulated or unmodulated. Under modulation, produced by a symmetrical wave shape, the value of carrier decreases at the trough (negative) of modulation as much as it increases at the peak (positive) of modulation. As a result, we will see no change in the average value of the carrier.

What about a transmitter not capable of symmetrical modulation below 100% or stated another way - a transmitter that doesn't have enough RF to make the crest of modulation or enough modulator power to close the carrier.

In the case of the insufficient RF, as the modulator calls for more RF needed to make peaks, the RF supply runs out and the peaks are rounded or flattened. Assuming the transmitter had enough modulator power to close the carrier, the average value of carrier will decrease because peak power was not attained and the transmitter will exhibit negative carrier shift.

In the case of insufficient modulator power to close the carrier but enough RF power to achieve positive peaks, the transmitter will experience an increase in the average value of the carrier and a positive carrier shift.

So what! Well, the transmitter's output will increase or decrease depending upon whether the carrier shift is positive or negative. This is important when you consider the FCC regulation regarding over and under power. The FCC permits AM transmitters to operate at a maximum of 10% below or 5% above the transmitter's rated output. If a 1000 watt transmitter has a 5% carrier shift, that 1000 watts is down to 900 watts and the maximum underpower permitted by the FCC. We arrived at 900 watts by the following:

$$100\% - 5\% = 95\%$$

$$(95)^2 = 90\%$$

Since power is equal to the square of the voltage, then 95% squared is equal to 90% power. The same applies for positive carrier shift except in this case a 5% positive carrier shift would put the transmitter at 10% over power which is 5% more than permitted by law.

Up to now, our discussion has centered primarily around symmetrical sinusoidal waveforms. However, as we all know, music and speech are complex waveforms and asymmetrical by nature. Thus, the need for reserve in the power supply is even magnified when one tries to reproduce or enhance this asymmetry.

The next consideration, therefore, is the audio processing in front of the transmitter. It is not the purpose of this paper to be involved in audio processing techniques. The subject is well covered elsewhere. It is wise, however, to be aware of the need for proper processing and that RCA has the proper equipment.

We have discussed plate modulated transmitters and their ability or inability to supermodulate. What about RCA transmitters?

RCA uses plate modulation in only one transmitter - the BTA-1S 1 kw transmitter. This transmitter uses a pair of 4-400A tetrodes to modulate another pair of 4-400A tetrodes. The circuit is not new to RCA - we have used it since 1958 when we shipped the first

BTA-1R series transmitter to Station WBMK in West Point, Georgia. Since then, we've shipped over 450 BTA-1R series and over 25 BTA-1S transmitters all over the world. Just for the record, we are in our second shop order of 25 BTA-1S Transmitters. And you know what - every single one of them will "supermodulate", not only to 125% on positive peaks, but to 130%. In fact, we are sending out a field letter to every customer advising him how - for a 25 cent resistor change - he can get 130% from his transmitter. We've made the change in the current shop order so all BTA-1S transmitters inherently "supermodulate" when they leave Meadow Lands.

In our other transmitters, we use Ampliphase which is described in detail elsewhere. However, since modulation takes place at a low level, the power supply only has to respond to the power amplifier section. The drive regulator takes care of shaping the audio to follow the pre-processed audio and the power supply will supply B+ for all the RF the transmitter wants. As a result, a BTA-5L1 has gone to 147% (125% maximum permitted in the U.S.), a BTA-10L1 regularly operates at 138% in the Dominican Republic (pretty loose rules there), and a BTA-50J and BTA-100J easily make 130% positive peaks in continuous tone modulation (probably 150% on randomly occuring peaks).

Now that we have reviewed some of the aspects in the supermodulation of AM medium wave transmitters, let us consider the mathematical justification of these statements.

First, we should address ourselves to determining just what is necessary in the way of increased audio power for 125% positive peak modulation. As we all know, the modulated power of an AM transmitter is in the side bands and it is this side band power that we are concerned with. At 100% modulation, the side band power is equal to 50% of the carrier power.

$$\text{Side band power} = \frac{M^2}{2} \times P_C$$

where $M = \dfrac{\%\ \text{of modulation}}{100}$

$P_C$ = carrier power

Thus, for a 1000 watt transmitter at 100% modulation, we have 500 audio watts in the side bands.

$$(1)^2 \times 1000 =$$
$$0.5 \times 1000 = 500 \text{ watts}$$

Since no transmitter is 100% efficient, the power consumption by the transmitter will be greater than the power output. Let's now determine how much power it takes for 100% modulation. A typical 1000 watt transmitter will draw 3100 V DC at 400 milliamperes (0.4A) in order to produce its rated output. Thus, we can see that 1240 watts (3100 x 0.4) is needed to get 1000 watts out. Using our side band power formula from before, we learn that for 1000 watts output at 100% modulation, we need 620 audio watts.

$$\frac{M^2}{2} \times P_c = \frac{(1)^2}{2} \times 1240 = .5 \times 1240 = 620 \text{ watts}$$

Now that we know what is needed for 100% modulation, let us look at 125% positive peak modulation. Referring to our side band power formula once again, we note that for 125% positive peak modulation, the side band power for the same carrier power, is up to 781.25 watts.

$$\frac{M^2}{2} \times P_c = \left(\frac{1.25}{2}\right)^2 \times 1000 = \frac{1.5625}{2} \times 1000 = 781.25 \text{ watts}$$

However, the input power needed to generate that extra side band power also climbs as we see in the following exercise.

It can be readily determined the difference between the input power at 100% and 125% is almost 20% and this difference has to come from the power supply. Now one can understand why some transmitters will not "supermodulate". The power supply is just not large enough to deliver the extra power needed.

What has all this "supermodulation" brought us? To begin with, the supermodulation itself does nothing for the loudness of the received signal. The difference between 100% positive peak modulation and 125% positive peak modulation is only 1.938 dB in average side band power and it's the side band power we hear. How come only 1.938 dB, you ask?

Remembering our 1000 watt transmitter again, we determined that at 100% positive peaks we have 500 audio watts in the side bands and at 125% positive peaks, we have 781.25 audio watts in the side bands. Thus, the true average side band power difference is:

$$\frac{781.25}{500.00} - 1.5625 \times 10 \log_{10} = 1.938 \text{ dB}$$

The real reason we want the transmitter to "supermodulate" is that the process raises the "head room" of the modulation capability of the transmitter and signal processing may be used to effectively raise or increase the "average level of modulation". It is this increase in the average level of modulation that makes the transmitter sound louder -- not the 125% positive peaks. The 125% positive peaks occur randomly and usually are of short duration. But, if the transmitter is capable of passing 125% on positive peaks, then it is capable of producing a higher average level of modulation.

So, there you have it. We have tried to put this down informally so everyone will understand "the secret of supermodulation" and be able to talk effectively about our equipment as well as what the customer can expect from ours as well as the competition.