How To Run Your Linear

What It Can Do and What It Shouldn't Do

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Although amateurs always have operated and, by the nature of the service, always will operate in an environment of interference, much of the interference is avoidable. One such type is the spurious radiation that falls outside the necessary communication band. This article takes up one special case, the linear amplifier, and the spurious radiation that results from its mistreatment. Other aspects of the spurious-radiation problem will be treated in subsequent articles.

No mode of communication used by amateurs is free from a tendency to occupy more bandwidth than is actually needed. This is merely a way of saying that the devices we use are something short of perfect. Nor is it realistic to expect that perfection will ever be reached. In some degree, spurious radiations — those outside the frequency band essential to the intended communication — always will be with us.

Pessimistic? Only on the surface. The fact is acknowledged simply to emphasize a more pertinent one: The present state of the art offers the technical means for generating signals that are *acceptably* free from spurious radiation. Moreover, these means are commonly incorporated in equipment.

For example, the application of well-known principles can develop a single-sideband signal in which the output in the unwanted sideband is 30 db. below the peak-envelope output in the desired sideband. That is, a signal peak of a kilowatt in the desired sideband will generate no more than one-watt peak in the "undesired." While not wholly negligible, this is hardly the sort of power level destined to make a big noise in the world.[1]

The state of the art gives a measure of the spurious radiation, and thus interference to others, that is *technically* unavoidable. But most of the spurious that causes interference troubles isn't of this nature. It is strictly in the *unnecessary* classification. The deficiencies which cause it are not in the equipment but in the operator. A major one is simply lack of knowledge of how things are supposed to work. This can be overcome. A less pleasant one is lack of good citizenship — deliberate misuse of the equipment for some hoped-for advantage. Whether this can be overcome is dependent on moral pressure from those who believe in letting others have the same chance for good contacts that they want for themselves.

Most hams would stay within decent bounds if they knew how. Their equipment has the capability of good performance, so it's mostly a question of appreciating that it does have limitations. These vary with the kind of emission — c.w., s.s.b., a.m., and so on. As they can't all be covered at one sitting, let's look at s.s.b. first.

S.S.B. Spurious

A single-sideband transmitter has four principal sections:

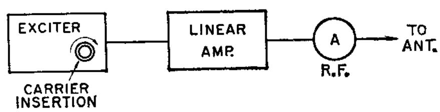
1) A balanced modulator, in which the carrier is suppressed and the two sidebands are generated. This usually operates at a fixed frequency.

2) A means for suppressing one of the sidebands.

3) Circuits for shifting the remaining sideband to the desired amateur band.

4) A linear amplifier for building up the output power.

Spurious frequencies can be generated in any



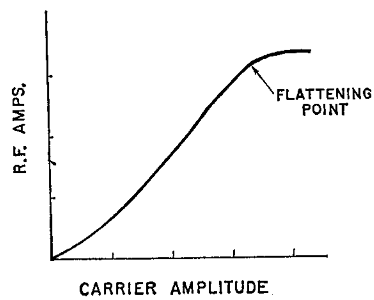


Fig. 1—Simple test setup for determining the proper operating limits of a linear amplifier. The curve below is typical of what would be obtained if the amplitude of the signal at the grid and the amplitude of the linear's output could be measured accurately. However, it isn't necessary to make such measurements to find the flattening point.

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[1] Except, perhaps, within a few hundred yards of the transmitter. But here the receiver becomes suspect, because it is quite capable of manufacturing its own spurious from the exceptionally strong "desired" that it is trying to eliminate. Under such circumstances the interference probably would be there even if the transmitter were perfect.

of these four sections, but in practice the contributions of the first three usually are much less bothersome than that of the fourth.[2] These three sections operate at rather low signal levels, in most designs. This is a favorable condition for minimizing the distortion that is the root cause of spurious.

We'll therefore lay aside the first three at this point, not because they will not later require attention, but because doing something about No. 4, the linear amplifier, is much more urgent. Possibly not doing so much about the amplifier itself as about its operator, because it isn't use but *abuse* that accounts for most of the unnecessary QRM.

The Envelope Peak

The evidence strongly suggests that the main reason for the abuse of linear amplifiers is that the operator doesn't understand the difference between peak and average power. You can't just say "power is power" and let it go at that. In s.s.b., the only meaningful way of rating a linear amplifier is in terms of the *peak-envelope* power it can handle without exceeding some specified degree of spurious output.

The peak-envelope power doesn't show on a meter, and therein lies the difficulty. Only an oscilloscope pattern gives a visible measure of it; even then you have to know what to look for. In voice transmission, peaks come along irregularly and fleetingly; they don't last long enough to let a meter show them.

If your transmitter has provision for inserting an adjustable amount of carrier up to the c.w. level, you can get the "feel" of it by performing a simple experiment. Connect an r.f. indicator to the output end of the transmitter (Fig. 1). An r.f. ammeter is good because its calibration will be reasonably accurate, but the more common rectifier-type r.f. voltmeter will do. (Many such voltmeters tend to give square-law rather than linear response, but this does not affect the end result.) Start with the carrier balanced out, and then gradually increase the inserted-carrier amplitude. Watch the output meter as you do this.

If the amplitude of the carrier voltage at the linear's grid and the amplitude of the output current in the transmission line can be measured, both with good accuracy, the relationship between the two will be something like the graph in Fig. 1. Doubling the driving voltage will double the output current (or voltage) — that is, the plot of the input and output amplitudes will be essentially a straight line — *up to a point.* After a while you will find that the output stops increasing as you continue to increase the carrier level. The point where the plot begins to depart from straightness is the flattening point. When the amplifier is driven by an s.s.b. signal instead of with unmodulated carrier, the proper peak-envelope level is just below this. As you go farther into the flattening region with an s.s.b. signal the spurious output rapidly increases. (On your carrier insertion test nothing of the sort happens, because at least *two* frequency components have to be present before spurious is generated. With voice, there are many such frequency components.)

The flattening point can usually be observed quite plainly in this test even if the r.f. indicator is not very linear. Above some setting of the carrier control there is simply no change in the linear's output amplitude. When you find this region, back off on the carrier insertion until the output starts to drop. This is the proper peak-envelope level in most linears, particularly in the Class AB_1 type where the flattening point is usually unmistakable.

[2] This is not so in every case, of course. It can be assumed that the statement is accurate in the case of factory-built equipment that is in good alignment. It is also accurate for homemade transmitters that have been properly designed and adjusted.

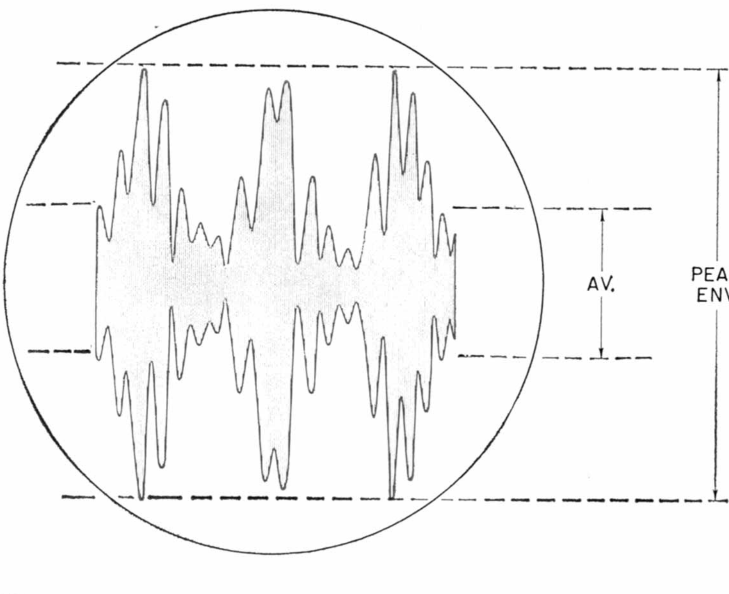

Fig. 2—An s.s.b. signal will have this general appearance on an oscilloscope when the amplifier is operating within its capabilities.

Average Amplitude

Having found the flattening point, leave the carrier adjustment there and connect in a key, preferably a bug. Make a series of fast dots, trying for ideal spacing — space and dot both the same length. Watch the output indicator. If it's an r.f. ammeter, it should read just about half what it did at the peak-envelope level. If it's an r.f. voltmeter with poor linearity, the reading may be considerably less than half. The meter is now reading *average*, not peak-envelope, amplitude, and if your dot/space timing is perfect you're seeing the average output amplitude with a 1 to 2 average-to-peak ratio. Remember that *fast* dots have to be used so the meter doesn't have time to get up toward the peak level.

With voice modulation, the ratio of average to peak almost never is any higher than this, and generally is considerably less. If you regularly use an r.f. indicator in your s.s.b. transmissions and it has been reading higher than what you've just seen, better turn down the audio gain control until you don't go over this dot/space reading at any time. Even such a reading may be too high for *your* voice.

The r.f. output amplitude, which is what was looked at in this test, is zero with a linear when there is no r.f. at its grid. This won't be true of the amplifier's plate current, usually, because there is nearly always a certain amount of "resting" current. However, the linear's plate current can easily be correlated with r.f. readings. Simply observe the plate current that corresponds to the two conditions — peak-envelope and average — and especially the average plate current with the fast dots. This is the value of plate current that you should never exceed when you talk.

The test as described is at best a rough-and-ready way to find out the greatest permissible meter swing. Its principal value is to bring home the difference between peak-envelope and average when the signal amplitude is varying, as it does in a modulated signal. But even this optimistic reading may come as a somewhat unpleasant surprise in view of what you've been doing customarily. The proper average reading may be considerably less, for your voice. With an oscilloscope you can not only establish the proper levels but also can keep tabs on your transmissions continuously.

Oscilloscope Pattern

Whether or not you have a scope, the type of picture you would see on its face will further illustrate the difference between peak-envelope and average power. Fig. 2 shows what an s.s.b. signal might look like when displayed on a scope. The scope shows the amplitude of the voltage variations in the signal, against time. The signal in this picture is assumed to be properly generated and amplified, and would produce no spurious output frequencies. Notice that even the highest peaks are clean — the tips are rounded somewhat like the tips of a sine wave are rounded. The tips may be a little hard to see in an actual display using a 60-cycle sweep, because only the lower voice frequencies would be wide enough to be distinguished in the scope picture; the higher-frequency components would tend to look more like straight vertical lines. However, they can be seen if the sweep is expanded enough, even if this means that a large part of the picture is off both sides of the screen. You only need to see a small part to appreciate what's going on.

The drawing indicates the peak amplitude of this envelope. It also shows the *average* amplitude of this particular waveform (determined graphically in this case). Here the ratio of peak to average is about 3 to 1, so if the peak-envelope amplitude was represented by an r.f. current of 2 amperes the average meter reading would be ⅔, or 0.67 amp.

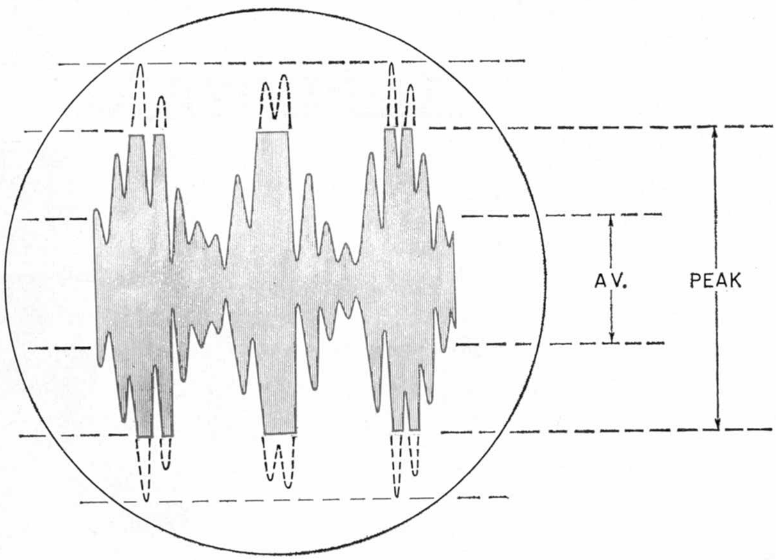

Fig. 3—The signal of Fig. 2 with peaks clipped, caused by driving the amplifier into the flattening region.

Now imagine this same waveform applied to the grid of a linear amplifier which is being driven into the flattening region. The amplifier clips off the peaks as shown in Fig. 3, where the height marked "Peak" represents the maximum possible output amplitude — the peak-envelope amplitude for that amplifier. There are several distinguishing features in this picture. One is that the peaks are no longer nicely rounded but are clipped off flat. Furthermore, the signal is at the peak level a lot of the time — far more than in Fig. 2, where only occasional peaks got up to the highest level. This means that the ratio of peak to average is lower — or, relative to the peak level, the average meter reading is higher. The peak-to-average ratio here has dropped to 2.4 to 1, so if the meter reads 2 amp. at the real peak-envelope level it will read 2/2.4, or 0.85, on a flattened signal such as this. More satisfying to the eye than the properly-amplified signal of Fig. 2, no doubt, since the ammeter's pointer swings almost twice as far.[3] But this flattened signal is putting a lot of its power into regions that aren't of any benefit to a receiver that is tuned to it. At this stage a lot of operators who might not otherwise know it are aware that you're on the air. But they are not *pleased* to know it.

With continuous scope monitoring you can easily determine whether your output is within proper bounds, once the peak-envelope level has been found. To find it, start talking with the audio at a low level and gradually increase the gain until the tips of the highest peaks just begin to be clipped. Then keep *below* this level with your audio. A few checks will show how far up the plate meter or r.f. meter should kick when you're just reaching the right peaks. You may find it easier to watch a meter than the scope face while transmitting.

Keeping the output clean will take a good deal of self control. But it pays off: Not only will others no longer have reason to cuss your operating tactics, but your signal will sound better. You'll be a decent citizen.

[3] There are far worse cases than this in practice. The clipping shown in Fig. 3 is really moderate, compared with what frequently goes on.

Amplitude vs. Power

This discussion has been in terms of amplitude — current or voltage — because that is what meters and scopes show. Power, which is proportional to the square of the amplitude, is what is talked about most. In the fast-dot experiment, the average amplitude was one-half the peak amplitude, so the average power output was one-fourth the peak power. In Fig. 2, where the amplitude ratio is 1 to 3, the average output power is one-ninth or about 11 per cent the peak power. Going into the flattening region of the linear raises this to nearly 18 per cent of the peak power, in the example in Fig. 3, but the increase is accompanied by most undesirable results.

If you've attempted to correlate the plate-meter readings of your linear with the average r.f. output amplitude of a *properly* amplified signal, it should be clear by now that d.c. input has only a vague relationship to either peak-envelope amplitude or power. The only justification for rating a linear amplifier in d.c. input is that measuring input is the traditional way of setting a power figure that can be used for the purposes of government regulation. What the amplifier actually can handle is determined by its *peak-envelope* rating. If you're shopping, it pays to concentrate on the p.e.p. rating, and find out what that rating is based on — what percentage of spurious, and how it is calculated and measured. With the equipment you now have, forget about d.c. input except as a plate-meter reading that you've established as the *right* average for your voice when a voice peak is just below the flattening point. Unless, of course, the figure runs over a kilowatt! But that isn't likely, with any of the current transmitters on the market, or with high-power linear-amplifier designs that you've seen in QST—