High Frequency RF Amplifiers
What do I need to know?

Barry G. Kery, KU3X

- How much RF output power do I need?
- Do I need an amplifier with tubes or solid-state devices?
- If tubes, is one tube enough?
- Pi or Pi-L?
- Why do I need a 3 KVA power supply when I can only run 1500 watts out?
- Can I use an RF amplifier on my 120 volt @ 15 amp wall outlet?
- What would be a good amplifier to purchase?

Let me first start out by saying one important thing, **"Put your money into a good antenna system before buying an amplifier."** If you can't hear them, you can't work them.

A good antenna gives gain in two directions, receive and transmit. If you use a poor antenna, you will get poor performance in both directions. If you install an antenna that has a 5 DB gain over a dipole, you will get 5 DB gain in ERP (effective radiated power) as well as 5 DB gain in receive that will show on the S meter. Also, don't forget to use quality transmission line. You won't go wrong with RG-213.

If you are not a, "Big Gun" contester, you probably do not need an amplifier that is designed to operate at 1500 watts of output power all day long. You will find that an amplifier that can produce anywhere from 500 to 800 watts of output power is more than enough power for the average ham.

Let's see what the S meter reads when we increase output power. First we have to understand what the S meter is telling us. Each increase of one S unit is about 5 to 6 DB, depending on how the manufacture calibrates their rigs. To go from a reading of S6 to S7 you will need to increase your output power by 5 to 6 DB. Let's use 6 DB as our reference since most modern rigs are closely calibrated to this scale. Every time you double your output power you increase your power by 3 DB. If you again double your output power you will get another 3 DB increase in power which is a total of 6 DB from your original power level. If you are transmitting at a 100 watt power output level and the ham on the receive end of your signal is seeing an S5 on his S meter, in order for him to see an S6 on his meter you would have to increase you power output level by 6 DB or go from 100 watts to 400 watts. In order to go from an S6 to an S7 on the receive end of the same signal you would then have to go to 1600 watts of output power. Seeing 1500 watts of output power is the legal limit, that's as close as you are going to get to an S7 meter reading.

If you have an amplifier that produces 750 watts of output power you will have an 8.75 DB gain over a 100 watt radio which comes out to about an S unit and a half. If you go from 750 watts to 1500 watts, you will have a 3 DB advantage which is only one half of an S unit. "So why go to 1500 watts?" If you are in a DX pileup or going one on one with another ham, that 3 DB may be enough for you to be first in the pileup. If you and your friend are both running 750 watts of output power and both of you are giving the ham on the receive end of you signal exactly the same S meter reading, by you increasing your power to 1500 watts you will have a half of an S unit advantage which will get you through to the other ham first, all things being equal.

Tubes in general are more forgiving than solid-state devices in today's amplifiers. Most of the older and smaller tube amplifiers have little, if any, protection circuitry. Going back in time and looking at RF amplifiers like the old dependable Heathkit SB200 or the SB220, the only protection they had were fuses in the AC primary lines. You just had to watch how you tuned the amplifier. The only value the fuses offered were to give some protection after a catastrophic failure like a shorted power transformer. If a tube shorted, the meters would blow and maybe the fuse would eventually blow. The first real level of protection amplifier manufactures incorporated in amplifiers was grid protection. If you drove the amplifier with too much power or did not tune the amplifier properly, you would over drive the grid(s) and do possible damage to the tube(s). With grid trip protection, if the grid current went past a predetermined value, the grid protection relay would drop out and the amp went into a standby mode.

Tube type amplifiers of today are either grounded grid or grid driven, class AB1 or AB2. These make for good linear amplifier designs. Some of the older amplifiers were grid driven class AB1 and could also be driven into class C. You should not drive any amplifier into class C and use it on SSB. If you did, the signal would be distorted and cause splatter on the band. Class C would be for CW only. The efficiency of a class AB1 or AB2 amplifier would be in the range of 55 to 65%. In class C you would increase the efficiency to a range of 70 to 75%. Many years ago amplifiers were rated on input power and class C would give an advantage of more power out with less power in.

Let's talk efficiency. "What does it mean?" Hams debate the following formula all of the time. Go to any forum on the internet that talks about amplifiers and you will see what I mean. Bill Orr, W6SAI worked at Eimac tube division and wrote many books about ham radio in general and also wrote what was referred to as, "The West Coast Handbook." These were a series of handbooks that gave, what I call, the best place to read and learn about RF amplifiers. I refer to them as, "The Amplifier Builder's Bible." Bill Orr's formula is comparing power output to power input. He does not subtract drive power, from the radio, in his formula. Example: 1500 watts of output power divided by 2400 watts of input power equals .625 or 62.5% efficiency. Your next question is, "how do we figure input power?" We multiply plate voltage times plate current under load. Example: 3000 volts key down times 800ma equals 2400 watts of input power.

Here is where efficiency really comes into play. It not only tells you how good of a job the manufacture did when they designed the amplifier but it tells you how to choose the proper tube or tubes for the RF section. Looking at the above formula we can see the amplifier starts out with 2400 watts of input power but only produces 1500 watts of output power. What happened to the difference in power of 900 watts? Well, that is what the tube has to dissipate. If the tube is not designed to dissipate that much heat, or the tube is not cooled properly, the tube will fail. If your amplifier is only 50% efficient, that means you will need 3000 watts of input power to produce 1500 watts of output power. Now the tube will have to be able to dissipate 1500 watts of power that is turned into heat.

When it comes to transmitting tubes, the old dependable 3-500Z tube is still a great tube to use in RF amplifiers. They are still reasonable in price, take a lot of abuse before failure and produce a lot of power. A properly designed RF deck with a single 3-500Z is capable of producing 1000 watts of output power. I have never seen any design on the market that can do this without abusing the tube. The Ameritron / MFJ AL80 series amplifiers advertise 1000 watts of output power and they will do it. The problem is, they are overdriving the tube, producing IMD on the bands and shortening the tube life. Their plate voltage is too low and the tube is not cooled properly. A pair of 3-500Z's is a nice amplifier, can produce 1500 watts of output power if designed properly and can give you years of dependable service. The old 572B series tubes are still available and are still widely used. Four of these tubes will generally produce 1200 watts of output power. Some amplifiers still use 811A's and are inexpensive to replace. I would not run RTTY on an amplifier using 811A's. Going up the list of tubes, the 3CX1500 / 8877 tube is a very rugged tube but very expensive. One of these tubes is capable of producing as high as 3000 watts of output power. The 4-1000 tube is still readily available and can easily product 1500 watts of continuous output power all day long.

Svetlana, a Russian tube manufacture, has been supplying tubes for amplifier manufactures for many years. Some top of the line RF amplifier manufactures are using Svetlana tubes, like the 4CX800, 4CX1000 and 4CX1600 series tubes.

Pi and Pi-L refer to the tank circuitry in your tube amplifier. Pi-L uses an extra inductor or the addition of a 4:1 unun in the tank coil assembly. A properly built Pi network will offer about 45 DB of third order harmonic attenuation. This will vary with plate load impedance and does comply with FCC specification. Pi-L offers 65 DB of third order harmonic attenuation and is not affected with plate load impedance. A second advantage Pi-L offers is smoother tuning on 80 and 160 meters.

Power supply requirements can vary. There are two types of ratings, CCS and ICAS. CCS stands for, "continuous commercial service." This rating means the amplifier can put its rated power out, non stop, 24 hours a day 7 days a week. That would equate to a 100% duty cycle. TV and radio broadcast stations look for these ratings. ICAS stands for, " Intermittent commercial amateur service." This usually equates to a 50% duty cycle. VA stands for Volt - Amp ratings. KVA is 1000 Volt - Amp rating. If it takes about 2400 watts of input power to produce 1500 watts of output power, a good choice for a rugged power supply would be a supply ratted at 2.4 KVA. If the transformer produces 3000 volts and can handle 800ma of current load, the transformer is rated at (3000 x .8) 2400 VA or 2.4 KVA. If the transformer is rated at 2.4 KVA, it does not mean the power supply is rated at 2.4 KVA. Remember, there are bleeder resistors across the capacitors in the power supply and that will generate a partial load on the transformer. That load can be as high as 10% of the total load. Watch how the manufactures advertise their power supply ratings, it's all in the wording.

Very few amplifiers have high KVA ratings for their power supplies. Most of them are rated well below the 2 KVA. Unless you get an amplifier, like a Command, QRO or an Alpha top of the line models, the KVA rating of most amplifiers are in the range of 600 VA to around 1.2 KVA. The high rating is not really needed unless you are running a very high duty cycle. A 600 VA power supply can easily supply a tube with enough power to produce a comfortable 800 watts of output power. This is the reason most manufactures tell you to reduce the power output of their amplifier when running RTTY or SSTV.

You can gauge the capacity of a transformer by its weight. A transformer that weighs 30 pounds has a capacity of 700 watts of commercial service. This same transformer has a rating of 1500 watts of CW service and 1900 watts of SSB service. These ratings are watts delivered to the RF deck, not power output from the amplifier.

Years ago Dentron made a 2000 watt PEP input amplifier model number MLA-2500. This amplifier weighed only 47 pounds. Although the tubes were the weak link in this amplifier, it could run 1200 PEP watts out all day long and not overheat the power supply. I am not suggesting you look for a lightweight RF amplifier. I am just trying to give you an idea of a duty cycle comparison between commercial service and amateur radio service.

Solid-state amplifiers have come a long way and have become very popular with contesters. The reason is, they do not have to be tuned which makes for fast band changing. The Icom and Yaesu amps are very popular as well as the Tokyo Hy Power amplifiers. The efficiency of SS amplifiers is in the range of 50%. For these amps to produce 1000 watts out you must have a power input of 2000 watts. That means you have to dissipate 1000 watts of heat. SS devices are not as forgiving to high SWR or over driving as tube type amps. SS amps have a lot of protection built in. They trip if the SWR goes over 1.5 :1, if you over drive them, if you put them on the wrong band or if they get too hot. Remember, the amp's protection is the last line of defense before failure. Watch carefully how you treat a solid-state amplifier. Don't learn to depend on the protection circuitry built into the amplifier for everyday use. Most tube amplifiers can easily handle a 2:1 SWR or higher without doing any damage to the tube(s) or the RF deck. Solid-state amplifiers can not handle high SWR without failure. Your only choice is to either use a transmatch to get the SWR down or reduce the output power. SS amps read reflected power, not SWR.

The standard wall outlet can deliver 120 volts at 15 amps (1.8 KVA). This is a variable and depends on the wiring, not only in your house, but in your neighborhood. Even the time of day and the season of the year can come into play. On a very hot summer afternoon everybody who has air conditioners on adds more of a load to the power grid. This can cause the voltage to drop.

Just because you can supply 1.8 KVA from your standard wall outlet, it does not mean that you can run 1200 watts of output power from your amplifier. Remember, you may think you are delivering 1800 watts to the tube to get 1200 watts out, but you are actually pulling more than 1.8 KVA from the wall outlet. Don't forget the lights, relays, filament transformer, ALC and the bleeder resistors in the power supply are all using power from the same wall outlet. If your amplifier is the only item that is on your 120 volt line that goes from the breaker box to your shack, you should not have any problems running your amplifier at a 750 watt output level. Remember, the circuit breaker in your house's power distribution panel has a small time delay. If you are using a 15 amp breaker, it won't trip as soon as you draw 15.2 amps or even 16 amps. Your voice peaks can easily draw 16 amps, for a very short period of time, off of a 15 amp breaker and not trip the breaker. But key down on RTTY and draw 16 amps off of a 15 amp breaker and the breaker will trip in a very short time.

Here are some nice choices for some new or used HF amplifiers:

- Heathkit SB-200 Two 572B tubes 10 to 80 meter 500 watts out
- Heathkit SB-220 Two 3-500Z tubes 10 to 80 meters 1200 watts out
- Ameritron AL-80A One 3-500Z tube 10 to 160 meters *** see note below**
- Heathkit SB-1000 Clone of the Ameritron AL-80A *** see note below**

- B&W PT-2500 Two 3-500Z tubes 10 to 160 meters 1500 + watts out
- Drake L4 Two 3-500Z tubes 10-80 meters. 1200 watts out
- Drake L7 Two 3-500Z tubes 10 to 160 meters 1200 watts out
- Kenwood TL-922 Two 3-500Z tubes 10 to 160 meters 1200 watts out
- Ameritron AL-1200 One 3CX1200 tube 10 to 160 meters 1500 + watts out
- Ameritron AL-1500 One 3CX1500 tube 10 to 160 meters 1500 + watts out
- BTI LK-2000 One 3-1000Z tube 10 to 80 meters 1200 + watts out
- Alpha 8410 Two 4CX1000 tubes 10 to 160 meters 1500 + watts out
- Alpha 77DX One 3CX1500 tube 10 to 160 meters 1500 + watts out
- Command HF-2500 Two 3CX800A7 tubes10 to 160 meters 1500 + watts out
- QRO HF2500DX Two 4CX800A tubes 10 to 160 meters 1500 + watts out
- Dentron Clipperton L Four 572B tubes 10 to 160 meters 1200 watts out
- Icom PW1 Solid-state 10 to 160 meters 1000 watts out
- Yaesu VL-1000 Solid-state 10-160 meters 1000 watts out
- Tokyo Hy Power 1.5 Solid-state 10-160 meters 1000 watts out

* **AL80A / SB-1000** These amplifiers were grossly over rated. They are advertised to product 1000 watts of output power. By doing so you would be overdriving the grids and this not only leads to premature tube failure but poor IMD and splatter on the bands. The absolute maximum grid current for a single 3-500Z tube is 150ma. The manual tells you to drive these amps to 230 ma of grid current. These amplifiers will usually produce about 700 to 800 watts of clean output power with good power line regulation.

A word of caution pertaining to tube type amplifiers and their power supplies. Most tube amplifiers have voltages ranging from 2000 to 4000 volts. **These voltages WILL KILL YOU!** They only use 2000 volts in the electric chair to put people to death. The capacitors used in amplifier power supplies also pack a high amperage charge. If you touch the high voltage line in an amplifier, you will get a charge of 2000 or more volts plus, over 100 amps of surge current. You won't get a second chance.