



Self - Redundant SSPA – the best solution for earth stations

Modern communications needs more and more bandwidth for both end user equipments and hubs, so inducing greater power in order to maintain proper Eb/No for satellite links.

More efficient modulations are also used to concentrate such greater data rates in limited frequency bandwidths, so imposing very linear transmission chains.

This situation imposes hard requirements for power amplifiers :

They must offer simultaneously

- High power
- Very low intermodulation

While maintaining low power consumption and low price

This note presents IN-SNEC's approach for this challenge,

the Self – Redundant SSPA



Available technologies for power amplifiers :

The available technologies for power amplifiers are vacuum tubes based amplifiers (Travelling Wave Tubes – TWT, klystrons, ...) and Solid State Power Amplifiers – SSPA.

Vacuum tubes have been historically the first way to produce high power at microwave frequencies.

More and more, SSPA take the advantage on vacuum tubes amplifiers and steadily replace them for high power applications.

The only remaining lead of TWT and klystron amplifiers is their capacity to provide very high output power. But this advantage is strongly counterbalanced by their inherent highly non-linear behaviour, which induces a maximum power

necessity considerably greater than needed by operational use, this is caused by intermodulation (IMD) problems.

On the other hand Solid State Power Amplifiers (SSPA) offer a high power capability, associated with a much more linear behaviour.

TECHNOLOGY	TWT	SSPA
Power capability	Very high	High
Efficiency	High at maximum power	High
Linearity	Poor	High

Typically, the rated power needed from a SSPA is more than 5 dB lower compared to a TWT amplifier.

Intermodulation issues

All electronic devices, as well as all physical process, are non linear. Nevertheless, the degree of non linearity is strongly dependent of the process itself, or of the technology for electronic devices like amplifiers.

The gain curve (output power vs. input power) of an amplifier can be very near a straight line up to saturation, as for an operational amplifier or a very round curve, as for a logarithmic amplifier, or anything between these two examples.

When a real complex signal (continuous spectrum or at least two carriers) is injected at the amplifier's input, the output shows the properly amplified input signal plus a spurious content which is created by the mixing of input signals.

For example, if two carriers f_1 and f_2 are injected in the amplifier, the output will show amplified f_1 and f_2 , plus $n \times f_1 \pm m \times f_2$. If m and n takes the values 1 and 2, we will have $2 \times f_1 - f_2$ and $2 \times f_2 - f_1$, which are located around f_1 and f_2 ; that is 3rd order intermodulation distortion.

Comparison between TWT and SSPA

Linearity is the main difference between Tubes and SSPAs. It is necessary, with tubes, to have a rated power much more higher than for a SSPA in order to have the same functional output power.

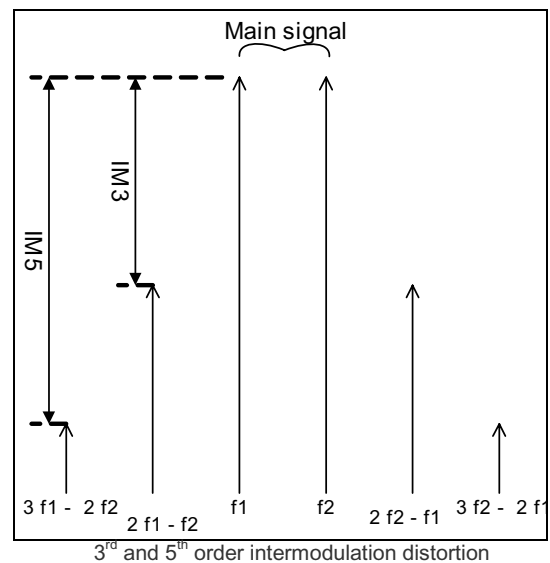
Typically, a TWT amplifier needs a back-off of 8 dB to provide an intermodulation level of 26 dBc (data available in various TWT amplifiers documentation).

For example, for the same output power and intermodulation levels,

- **A 800 W SSPA do the same job than a 2.5kW TWT amplifier**
- **A 400 W SSPA do the same job than a 1.25kW TWT amplifier**
- **A 200 W SSPA do the same job than a 650W TWT amplifier**

This generates **very high cost saving** in terms of

- Amplifier acquisition
- Primary AC power during equipment's life



This case is obviously applicable to continuous spectrum, with the generation of spectrum sidelobes around the main desired output signal.

This feature has a fundamental importance for communication links, where high spectral efficiency is required, due to the lack of spectral resources compared to the volume of informations to transmit.

For the same intermodulation level, a SSPA needs only less than 3 dB back off. The difference between TWT and SSPA back-off is so 5 dB or more.

In other words, for the same functional output power, a SSPA will need a maximum power 5 dB lower than a TWT or klystron amplifier.

Redundancy concepts for power amplifiers

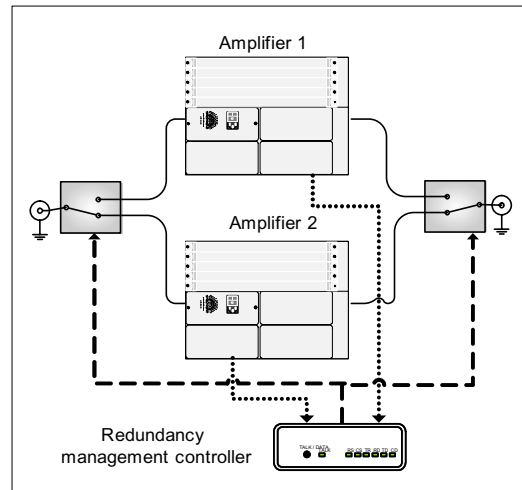
The most classical way to implement redundancy for power amplifiers is the 1+1 redundancy concept, although that for some applications, a 2+1 can be needed.

This mode of redundancy is explained in the following diagram :

This solution needs

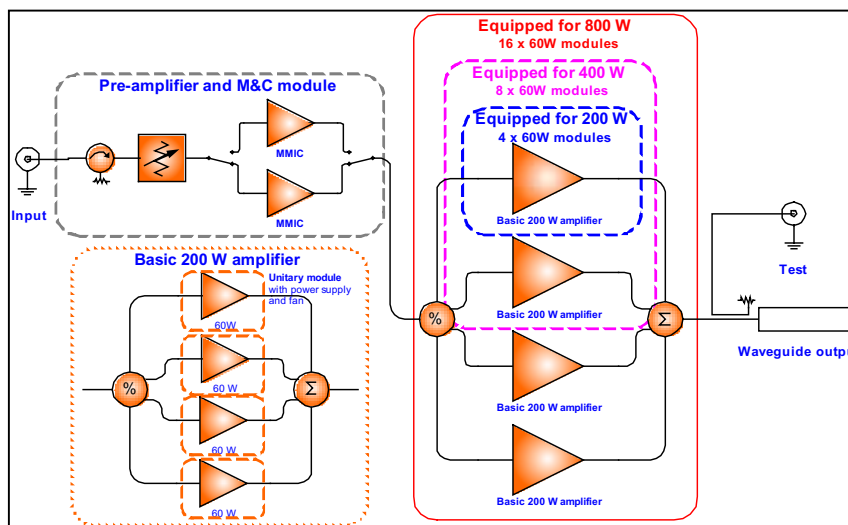
- Two identical amplifiers, with their own, independent, power supply.
- One of the amplifiers is in a hot stand-by mode,
- Two microwave switches, one having to sustain a high continuous power,
- A specific redundancy management system

The second amplifier being in hot stand-by mode, **power consumption is multiplied by two**, compared to a single amplifier.



Another redundancy concept is possible, the **Self - Redundancy** operation :

With this concept, the power generation is distributed between several modules which are summed at the amplifier's output, as described in the following amplifier's architecture :



IN-SNEC self redundant SSPA is equipped of up to 16 elementary 60 watts modules that are combined to provide 200, 400 or 800 watts at amplifier's output.

With this solution **one single amplifier is need** instead of two or more and there is no need to use any switches or specific redundancy management system.

Moreover, compared to the 1+1 mode, **power consumption is divided by two** :

Technology	2.5 kW TWT (1+0)	2.5 kW TWT (1+1)	Self redundant 800 W SSPA
Power consumption	10 kVA typical	20 kVA typical	6 kVA

Output power of IN-SNEC's self-redundant SSPA

This amplifier uses several elementary 60 watts modules. The remaining power if one modules fails is :

$$\text{Power} = \left(\frac{N-1}{N}\right)^2 \times \text{Rated power}$$

For the 800 watts amplifier, equipped with 16 modules, the failure of a module causes a loss of only $20\text{Log}(15/16) = 0.56\text{dB}$, which gives a remaining power of 700 watts, with a failed module!

With IN-SNEC's self - redundant SSPA, you buy only the power you need.

Thanks to self-redundancy, comparison with Tubes amplifiers is still more attractive. For example, for the same output power and intermodulation levels,

- **A 800 W SSPA** do the same job than **two 2.5kW TWT** amplifiers
- **A 400 W SSPA** do the same job than **two 1.25kW TWT** amplifiers
- **A 200 W SSPA** do the same job than **two 650W TWT** amplifiers

Once again, this induce improved cost saving in terms of

- Acquisition of the amplifier (one SSPA instead of two TWT)
- Primary AC power during equipment's life

Energy saving

We compare, in the following table the AC power consumption of various amplification systems

For a secured (redundant) mode, the power consumption economy is 14 kW for the IN-SNEC self-redundant amplifier.

Technology	Power consumption	Consumption saving in redundant mode
2.5 kW TWT (1+ 0)	10 kVA typical	
2.5 kW TWT (1+1)	20 kVA typical	
IN-SNEC 800W self redundant SSPA	6 kVA	14 kVA

This represents an **annual economy of more than 120 000 kWh** of power consumption !

With a medium price of 8.5 €cent/kWh, this generates a **cost saving greater than 10 k€ / year**

Abstract :

1. SSPA is the best solution, compared to TWT, in terms of price and power consumption, due to much greater linearity,
2. Self-redundancy is the best solution, compared to 1+1 mode, in terms of price and power consumption, due to drastically reduced number of equipments and lower complexity,
3. IN-SNEC proposes **the most cost effective solution**, which combines both concepts,

The Self-Redundant SSPA

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