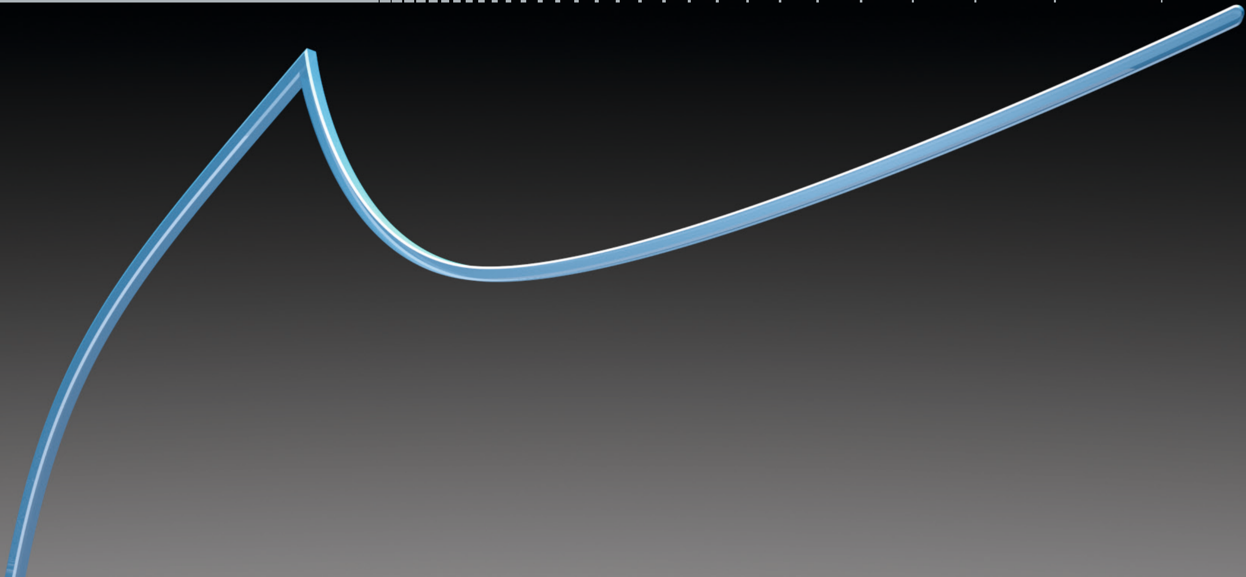
The next level of efficiency for broadcasting amplifiers

ROHDE&SCHWARZ



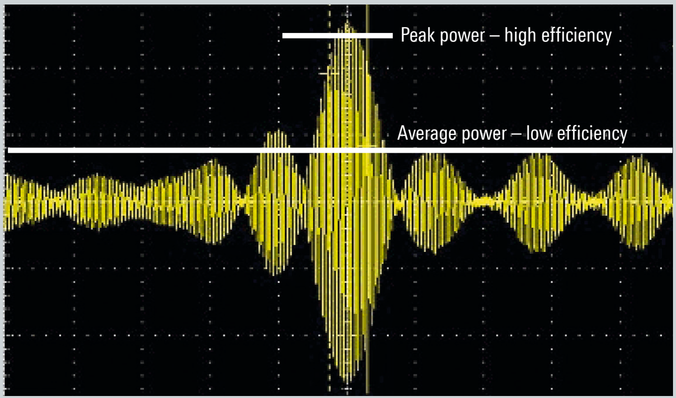
Background

Energy efficiency is becoming increasingly important in today's world. Current broadcasting transmitters typically require four to five times the energy they transmit on-air. There are several technologies available for improving the efficiency of broadcast transmitters. In the following, some of the technologies and their advantages and disadvantages will be discussed.

General

The difference between the energy required by the transmitter and the energy transmitted on-air is defined by the signal characteristics of a COFDM or 8VSB broadcasting signal. These signals have a high average power level, but they also contain signal peaks that have to be amplified.

DVB-T COFDM signal.



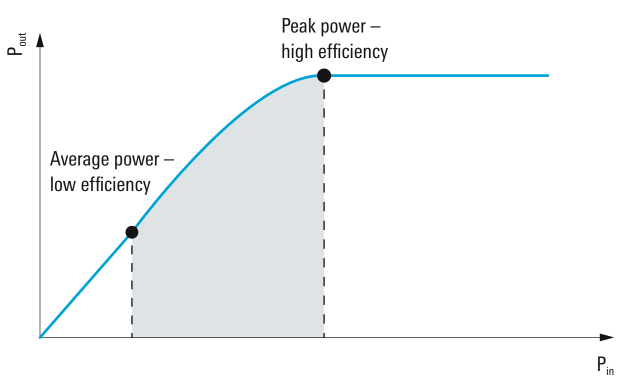
Maximum amplifier efficiency is achieved when the amplifier is working at its saturation point. For COFDM or 8VSB signals, the amplifier cannot work at its saturation point because it is only possible to reach the saturation point when the amplifier is operating at peak power.

When the amplifier is operated at a lower power level, it is less efficient. This relationship between average and peak power is represented by the crest factor or peak-to-average power ratio (PAPR). A lower value yields greater potential efficiency.

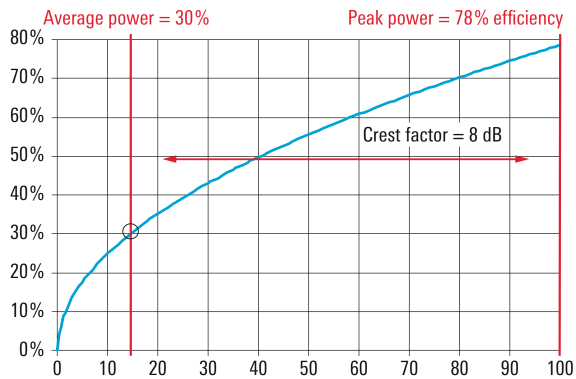
Low crest factor = high efficiency

When using a broadcast amplifier in normal class A/B mode, the theoretical power efficiency of the amplifier is 78 %. The typical value of the crest factor for a Rohde & Schwarz amplifier is 8 dB. By converting this value to its linear value of 6 and using the formula crest factor (CR) = peak power/average power, the possible average power that can be amplified with a broadcasting amplifier in class A/B mode is only 1/6 the peak power. Adding the CR to the characteristic curve of the transistor yields an overall amplifier efficiency in class A/B mode of approximately 30 %.

Characteristic of an amplifier in class A/B mode



Theoretical efficiency of an amplifier in class A/B mode with CR = 8 dB



Taking into account all losses such as those caused by broadband use or by combining components, an excellent value for amplifier efficiency is 30%. R&S®Tx9 amplifiers make it possible to achieve this level of efficiency thanks to their intelligent system design. Yet how can efficiency be improved even more?

General approaches

There are several approaches for optimizing the energy efficiency of a broadcasting transmitter:

- Crest factor reduction
  - Tone reservation
  - Active constellation extension (ACE)
  - Rohde & Schwarz crest factor reduction method
- Switched mode power amplification (SMPA)
- Drain voltage regulation/envelope tracking
- Doherty amplification technology

Crest factor reduction

The most obvious approach is to reduce the crest factor. However, this requires closely examining the signal quality of the transmitter because simply clipping the peaks by reducing the voltage supply to the transistors would prevent certain signal peaks from being transmitted. This would result in a MER reduction. There are currently three solutions for reducing the crest factor.

1. Tone reservation

With this method, subcarriers without signal information are reserved for being switched on and off and being modified to improve the crest factor. This results in a slight increase in bandwidth due to the additional subcarriers. Efficiency can be improved by approximately one percentage point.

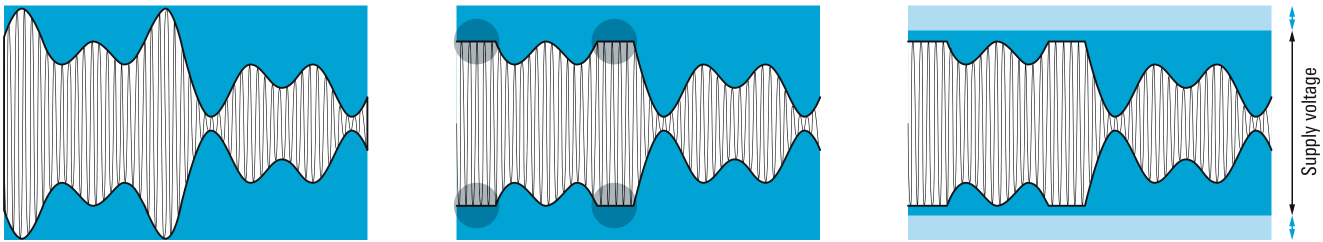
2. Active constellation extension (ACE)

This approach involves adjusting the constellation diagram, taking advantage of the fact that the outer constellation points can be moved further outward. Adding all the carriers and changing their amplitude makes it possible to reduce the crest factor. This approach does not work for rotated constellation diagrams as specified in DVB-T2.

3. Rohde & Schwarz crest factor reduction method

The Rohde & Schwarz crest factor reduction method analyzes the signal and reduces the peak values, without affecting signal quality. This algorithm allows a gain of up to two percentage points.

Crest factor reduction



Without crest factor reduction | With crest factor reduction | Reduced voltage supply – higher efficiency

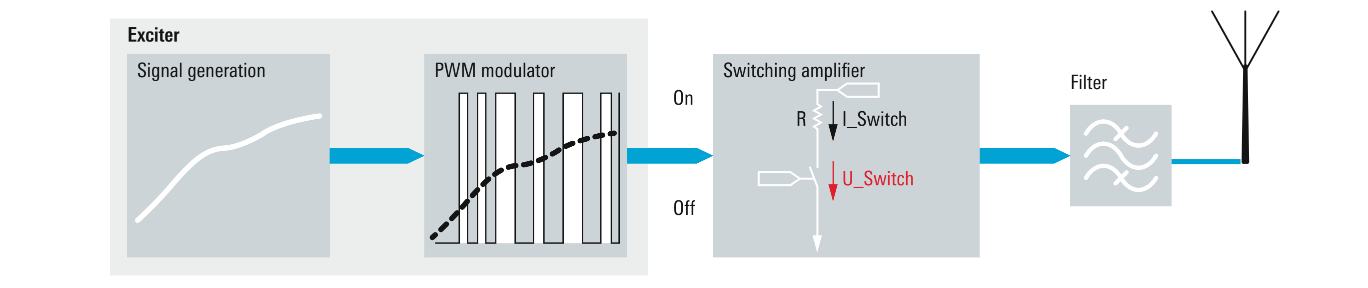
Switched mode power amplification (SMPA)

One new approach used to improve efficiency involves what is referred to as switched mode power amplification (SMPA). The transistor is operated in this mode with a pulse code. This means that the amplifier is switched either on or off. No power is required in "off" mode, whereas the amplifier works with full saturation and maximum efficiency when in "on" mode.

The challenge accompanying this technology is that an amplitude modulated signal has to be converted into a pulse width modulated signal. This conversion requires very high switching frequencies, which results in unwanted signals in the spectrum. These signals then have to be filtered out in the RF spectrum, turning the system into a narrowband solution. This again reduces the power efficiency of such a system.

This technology is the most complicated of all the presented technologies in terms of both the modulators and amplifiers that have to be developed. New transistors are required for this technology, but these have not yet been field-tested for broadcasting applications. It is expected to take a few more years for this technology to appeal to the broadcasting market. The expected increase in power efficiency is 10 to 15 percentage points.

Theoretical block diagram of an SMPA system

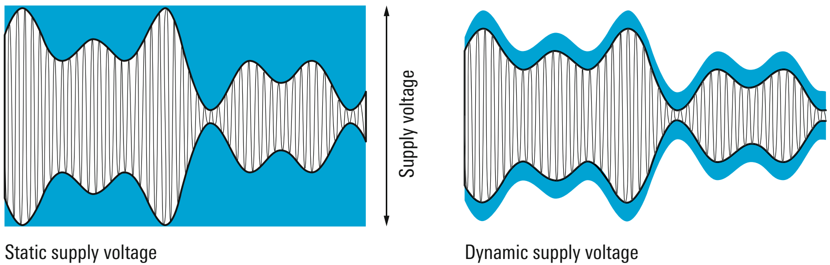


Envelope tracking/ drain voltage modulation

Another solution for improving the efficiency of a broadcast amplifier is drain voltage modulation, or envelope tracking. This solution is used to adjust the supply voltage of the transistors to match the respective signal. This technology requires a large amount of additional hardware and software components, e.g. to analyze the signal, modulate drain voltage and adjust the characteristics of the transistors.

These factors increase hardware costs and reduce the power density of the ampilifier. Because more components are needed, the availability of these systems is diminished. The expected increase in power efficiency is about 10 to 15 percentage points.

Envelope tracking



Doherty amplification technology

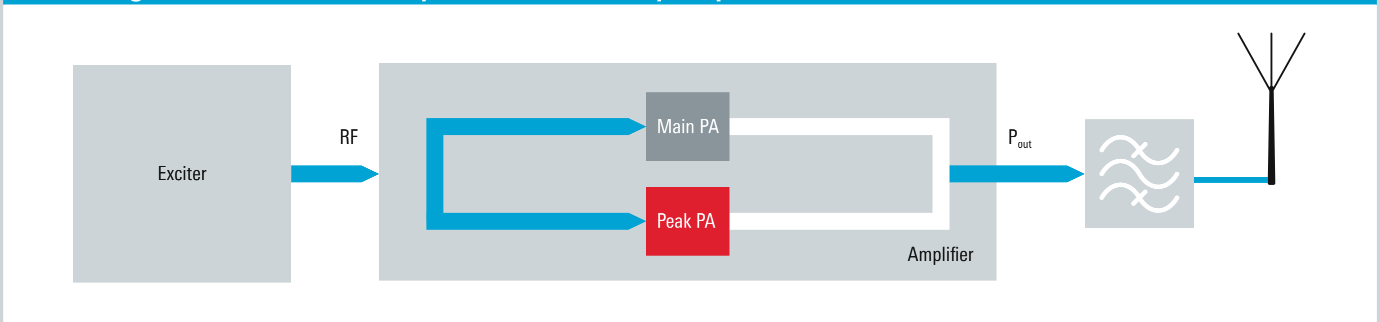
The most impressive technology, however, is based on an invention developed by William H. Doherty. His basic idea was to separate the amplification of peak and average power by using a main and peak amplifier.

Doherty amplification

The main amplifier constantly works in saturation after reaching the back-off point. This is achieved with load modulation. In the following example, a load resistor with twice the load is used. Here, the back-off point is –6 dB.

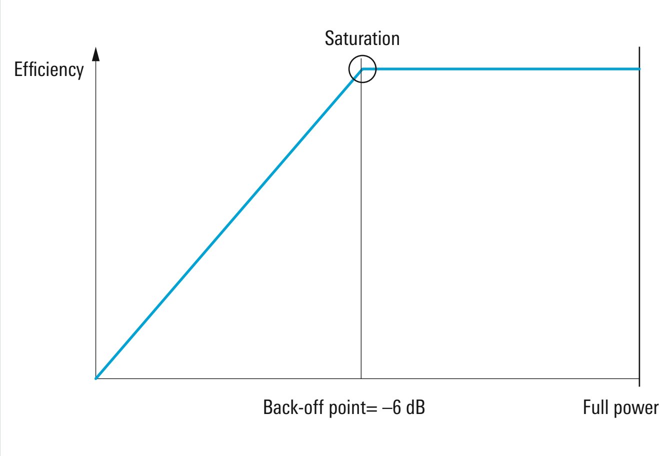
The peak amplifier works in class C mode until the back-off point is reached, meaning that no energy is required before reaching this point.

Block diagram of a transmitter system with Doherty amplifier

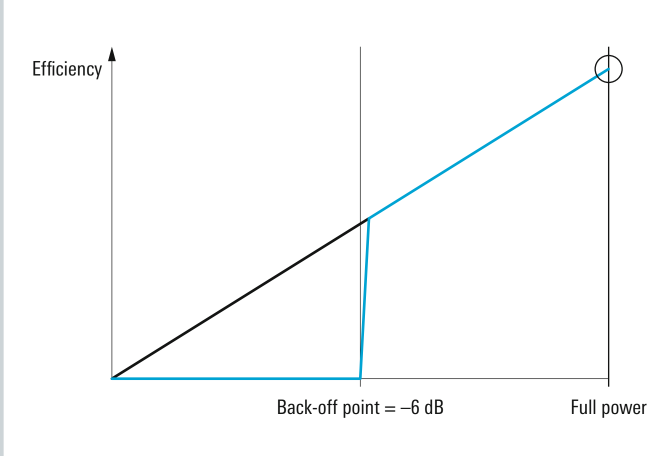


At this back-off point, the peak amplifier starts reducing the load resistance of the main amplifier, which now provides more power but is still working in saturation.

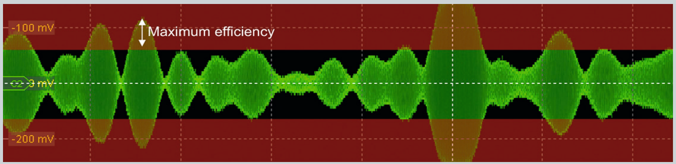
Main amplifier – with double load resistor in saturation



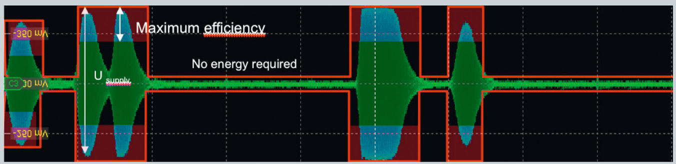
Peak amplifier – not operating until back-off point



DVB-T2 signal – main amplifier in Doherty mode.

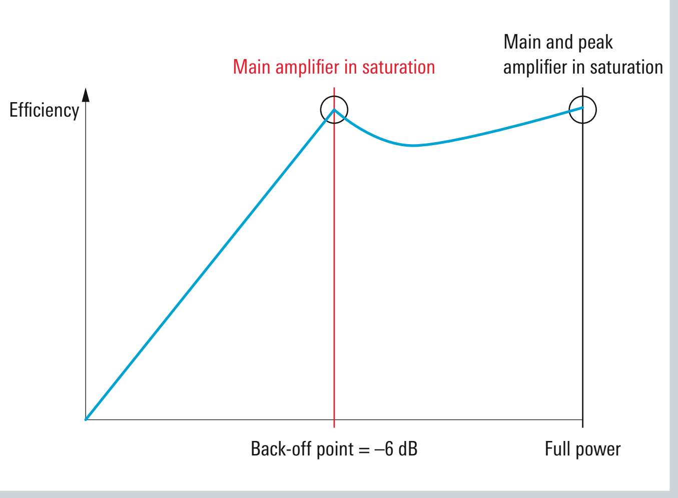


DVB-T2 signal – peak amplifier in Doherty mode.



The peak amplifier further reduces the load resistance until the normal value is reached. Now half of the nominal output power is supplied by the peak and the other half by the main amplifier.

Theoretical Doherty efficiency



Because the peak amplifier is not operating before the main amplifier approaches its saturation point and the headroom required for the main amplifier is very low, the level of efficiency that can be reached with a Doherty amplifier is 10 to 15 percentage points greater than that of a class A/B amplifier.

This technology was originally conceived as a narrowband solution featuring a possible relative bandwidth of about 10%. This is because a λ/4 matching line is required to handle load modulation. However, this can be avoided by means of an intelligent amplifier design. The Doherty technology is already used extensively in mobile base stations and has proven to be reliable. After examining each of these possible solutions for improving the power efficiency of a broadcast transmitter, the Doherty technology turned out to be the best approach.

Summary

There are various approaches available for improving amplifier efficiency, but only few are truly useful solutions for implementation in broadcasting transmitters. The Doherty amplification technology is the most promising technology in terms of stability and overall efficiency gain. This is because it is very similar to the technology used for the current generation of broadcast amplifiers and its application is already field-proven in mobile base stations.

The Doherty technology makes it possible to improve the efficiency of a broadcast amplifier with COFDM modulation from an average 20 % in the past to 39 %, thereby offering energy savings of almost 50 %.

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