High Linearity, High Efficiency RF Power Amplifier

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Function of PA

High-power (over 20W), high-frequency （200MHz～2690MHz）, high-efficiency and high-linearity power amplifier plays a very important role in modern wireless communications. For instance, in wireless mobile communications base station, it usually use non-constant envelop modulation, like QAM，QPSK modulation etc., to increase the utilization rate of frequency spectrum and solve the problem of limited spectrum resources. Therefore, it requires that RF power amplifier should have high-linearity. For a power amplifier with 50W（47dBm）output power, it should have in-band and edge 3-order IMD ≤-12.5dBm, which means that PA IMD attenuation should be more than 47-（-12.5）=59.5dBc. It usually uses the semiconductor-field effect transistor which doesn't have good linearity in modern wireless technology. However, such high linearity requirement is not easy to achieve.

Therefore, conventional PA adopts a back-off or feedforward method to achieve necessary linearity, in which case it uses a 200W field effect transistor in Class A with high power consumption to yield a PA with 20W output power, which will cause problems like high power consumption, low power efficiency (less than 10%), high heat dissipation, low reliability and high cost etc. for high-power RF PA.

A lot of national and international experts in wireless technology have been working on the solution of the dilemma. Our company takes the lead to develop over 50W WCDMA PA (2110～2170MHz) by using the combination of Modified Doherty PA + digital predistortion (DPD) technology. The efficiency of PA system is over 30% simultaneously achieving high-linearity, which is 3 times more than the one of most conventional backed-off or feedforward PA.

Since the company's PA uses advanced technology which is modulation agnostic, it can not only be used in narrow-band WCDMA single carrier, but also in broadband multi-carriers mode. It can be used in 3G WCDMA mobile communications system and CDMA 2000，TD-SCDMA，LTE，UMB and WiMAX system's single-carrier and multi-carrier application. In the future, the PA may also be used in mixed-mode broadband system, like 2G+3G，3G+4G mixed system etc., which can further reduce CapEx and OpEx, at the same time reduce BTS size and repetitious construction.

Because the modified PA has the features of high-efficiency, high power consumption and low heat dissipation, we can reduce the size and weight of base station as well as backup batteries to a large degree. These advantages can solve difficulties in installing base station where power supply is not enough (the system which depends on solar panel to generate electricity), densely-populated area or limited space.

The company's new PA technology can be applied to cellular handsets, which can reduce cellular power consumption and increase PA efficiency. Since current 3G handsets are challenged by high power consumption and short standby time, the new PA technology means a lot for 3G cell phone.

Besides, it can also be used in satellite communications system and digital television broadcast, etc..

Conventional vs. DPD PA Principles

Conventional power amplifiers have mainly utilized back-off techniques to achieve the necessary linearity for wireless communications. Later Feedforward (FF) technique became popular, based upon the principle of error subtraction and cancellation with hardware circuitries, to increase PA linearity. However, one major drawback of conventional PA, back-off or FF, is poor power efficiency, too heavy but necessary additional heatsink and large size, the reduction of PA performance affected by environment, etc.

Digital predistortion (DPD) techniques have gained popularity in recent years due to advancement in digital signal processing (DSP) technology. In addition, Doherty power amplifiers have also been applied to these linearization systems to maximize the power efficiency. A summary explanation of DPD principles is depicted in Fig 1a and Fig 1b.

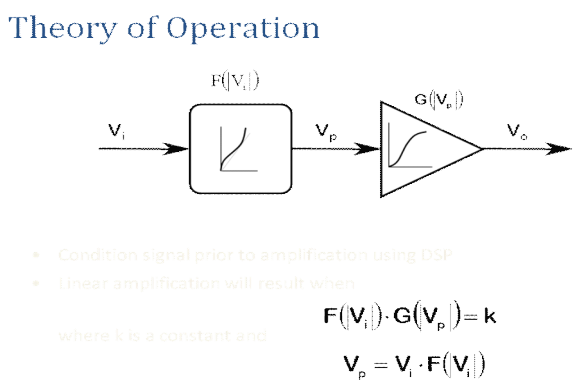


Fig 1a DPD anticipates distortions digitally

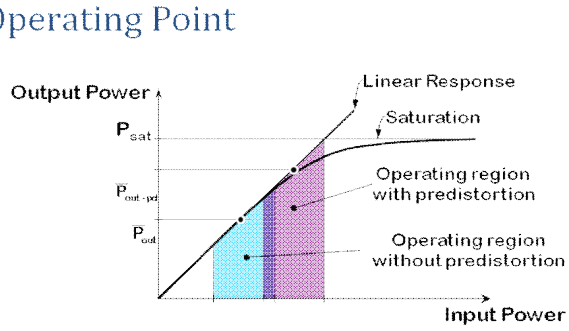


Fig 1b DPD improves PA operating region

From a product viewpoint, FF have been the most common state-of-art power amplifiers used by base station OEMs and mobile operators. Powerwave and Andrew/CommScope, 2 US companies, are the international leaders in FF PA, which range from about 8-15% in power efficiency.

DPD RF PA, which offers a promise in higher power efficiency potential, have largely been confined in research and development stage. Over the last decades, a number of large public enterprises and private enterprises supported by venture capital in North America and Europe have invested hundreds of millions of US dollars in the aggregate to develop a high-linearity, high efficiency PA to replace FF PA in the commercial PA market. Most of those companies have chosen the ASIC approach to DPD, and results have not been satisfactory. Those DPD PA efforts have encountered bandwidth, reliability, modulation scheme restrictions, and/or prohibitive cost issues. For practical applications, PA have multi-dimensional dynamic parameters that are dependent on temperature, powers, input signal bandwidth, and so on, so that presented a major challenge to most existing DPD vendors in North America and Europe.

The difficulties in DPD designs and lack of available high linearity, high efficiency RF PA in the merchant market have induced large base station OEMs to develop their own proprietary PA solutions. In the case of one large Scandinavian OEM, its engineers integrated the RF PA tightly into its base station design in order to achieve increased performance and power efficiency than FF PA that are currently available in the merchant market. To the company's best knowledge, there is no company in the world that has yet developed a commercially viable RF PA with over 30% power

efficiency at complete system level while meeting 3G specifications and reliability requirements.

Breakthrough Value Propositions

Our company has successfully developed a high linearity, high efficiency RF PA that is based upon a combination of DPD, Doherty, and other proprietary techniques (see Fig 2a, Fig 2b & Fig 2c). This revolutionary PA solves both operators and OEMs problems with the following breakthrough value propositions

- **Plug-and-play "blackbox" approach**

  Easy to specify, use and install

  Compatible with current systems for instant replacement

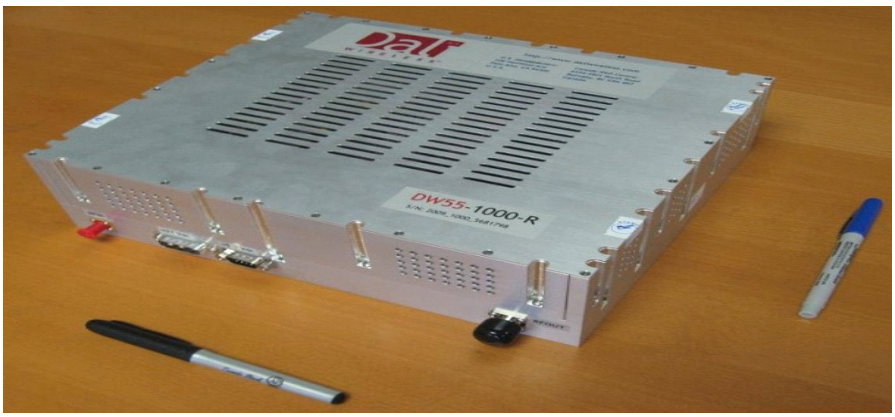
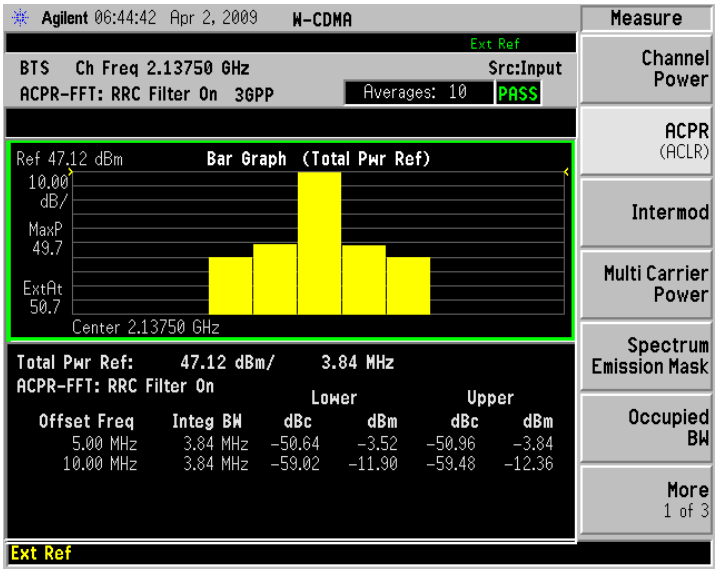


Fig 2a Revolutionary DPD RF PA



Parameters	Specifications	Notes
Frequency	2110 – 2170 MHz	
Instantaneous Bandwidth	20 MHz	
RF power	60 Watts	
RF gain	55 dB	
Input	RF	No I/Q required
EVM	< 12.0%	
ACLR	< - 48 dBc	DPD+CFR
Efficiency	33 %	@ RF power

Fig 2b Actual Measured Performance

Fig 2c Detailed Specifications

- **Revolutionary RF power amplifiers**

  - Software-based architecture for rapid, flexible development and upgrades

  - Self-adapt: maintain best performance in any environment and circumstances.

  - Small form-factor and light weight enable pervasive deployment

  - “Future Proofed” – modulation agnosticism (2G, 3G, 4G, WiMAX, DVB, etc.) allows mixed-mode RF transmissions, a key feature in accommodating rapidly changing standards

  - Remote connectivity allows direct communication between the operating PA and mobile operator for firmware or standards upgrades and early PA failure detection via the internet or wireless network

  - Over 100Mhz wide bandwidth potential for frequency spectra and reduce repetitious construction

- High reliability due to high power efficiency, less thermal dissipation

- **Solving the Cellular Industry Dilemma (see Fig 3)**
  - Significantly reduces CapEx and OpEx costs, the key driver in ARPU growth
  - Promotes public and private green initiatives by cutting 50% BTS energy usage
  - Preserves capital investment by extending the life-cycle of existing BTS
  - Reduce the size and weight of base station backup battery.
  - Pole-mount and pole-top models enable new cell sites where ground BTS are not possible
  - Remote connectivity of PA will allow mobile operators to communicate, control, monitor, and upgrade the power amplifiers of their entire radio networks within their offices.

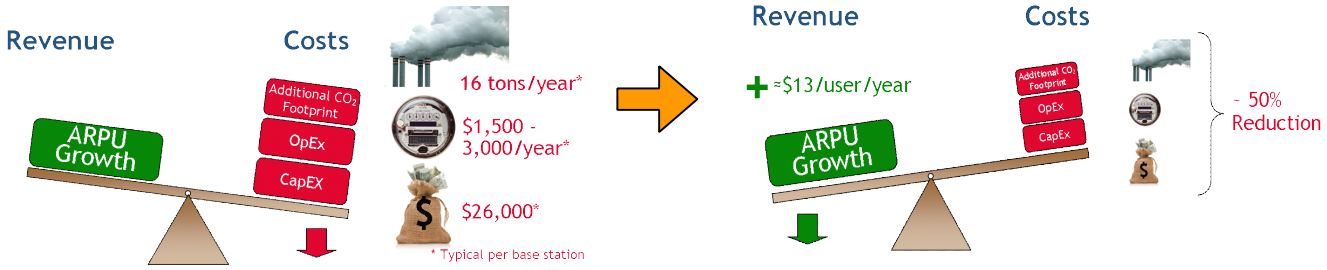


Fig 3 Tipping the balance scale to ARPU growth while reducing carbon emissions

Conclusion

The quest for greater capacity and higher data rates in radio access networks has placed increasing demands on the output power from base stations. These

demands must be met within the existing base station. It has always been the bottleneck for industry to guarantee PA's high efficiency and low power consumption.

Our company has developed a revolutionary RF power amplifier that breaks the wireless bottleneck by tripling the power efficiency of today's base stations while simultaneously reducing the OpEx of reducing power consumption and CapEx costs in multi-carrier construction.

Therefore, the modified RF power amplifier with high efficiency and linearity is very important and can play critical role in China's 3G network construction and application.