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Review of High RF Power Amplifier for 5G Applications

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ABSTRACT

One of the most important circuits in any wireless communications transmitter is the power amplifier. The 5G base station requires power amplifiers with high output powers, excellent efficiency, and high-power gain. A review of 5G sub-6 GHz base station power amplifier is offered in this paper. This study examined reviewed power amplifier high electron mobility transistor (HEMT) semiconductor technology based on gallium nitride (GaN). The researchers claim that the highest choice for offering high power in the output, high back-off power, and high efficiency is a gallium nitride (GaN HEMT)-based Power amplifier (PA). This study presented a review of class J power amplifier based on GaN HEMTs. Also, the evaluation of Doherty power amplifiers (DPAs) based on class J will be presented in this work.

Keywords:

GaN, Class J Power amplifier, 5G, Device technologies, Doherty power amplifier.

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1 INTRODUCTION

The power amplifier device, which increases RF power transmissions, is an essential part of base stations. It is either based on the two competing technologies of RF gallium nitride (GaN) or silicon-based LDMOS (laterally-diffused metal-oxide semiconductor). Since GaN technology, performs better than LDMOS, it is suitable for 5G's high-frequency requirements. Traditional PAs are forced to operate at significantly lower efficiency than their maximum attainable levels by the new LTE/LTE-Advanced (4G standard) communication protocols. The latter problem arises as a result of these communication protocols' amplitude modulation. The same can be said of 5G specifications. Other characteristics of these new communication technologies include their high peak-to-average power ratio (PAPR). For traditional RF PAs, high PAPR values result in low and medium efficiency. As a result, the primary goal for this generation is to reduce energy usage while maximizing operating efficiency [1],[2],[3]. The two main challenges to implementing 5G technology for these applications are a decrease in power consumption and an increase in bandwidth[4]. A power amplifier that can increase PAE without compromising linearity and bandwidth is necessary since the PAE of the power amplifiers[2], [5]is used in R.F. transmitters which is crucial in determining the total energy consumption of the 5G wireless communication network. In order to obtain high-efficiency linear amplification, several PA topologies have been discussed by other researchers as in [6], [7]. PAs with a switching mode, like Class-E/F, have the ability to provide good PAE, but their limited bandwidth harmonic terminations make them unsuitable for expanded bandwidth 5G applications. On the other hand, Class-A/B and linear-mode PAs are more linear but have a lower performance compared with the switching-mode PAs. Despite this, the bandwidth of the Class-B is the difficulties of obtaining termination over a large bandwidth; PAs with harmonic tuning can potentially reach a peak efficiency of roughly 78.5%. In some applications, efficiency takes precedence over linearity and gain. A highly efficient power amplifier, as in a Base Station, for example, can assist in the reduction of power loss (dissipation) and, thus, the demand for cooling. Most cooling systems are challenging to design are expensive and require a big space[8], [9]. In a noisy environment, output power, not efficiency, is a critical issue in long-range communications. As

the communication channel narrows, high linearity is required to reduce inter channel interference[10]. Applications requiring more power and frequency necessitate semiconductors with wider band gaps, higher electron mobility, and higher breakdown voltage. [11],[12]. Due to its straightforward circuit construction, the Doherty PA (DPA) is one of these possible approaches that is frequently utilized in base-station systems [13]. By using dynamic load modulation, High efficiency may be achieved by the DPA in both the Output of Back-off (OBO) area and the saturated power. Due to dynamic load modulation, the DPA can function extremely efficiently in both the OBO and saturated power regions. The quarter-wavelength impedance inversion, which only performs the ideal impedance transformation at a specific frequency, continues to limit the bandwidth of conventional DPA. Recent research replaces quarter-wave transmission lines with low-order impedance inverters, increasing bandwidth.
The purpose of the application is essentially to decide what kind of PA use is suitable. Class AB is a good choice for satellite and radar applications that require a lot of power. Class AB has a high output power and strong linearity; however, it is inefficient. The efficiency and linearity of the Class-J mode are theoretically equivalent to those of the standard Class-AB mode. Class-J mode, as described in [13], extends the design space while maintaining class-B mode's efficiency and power efficiency throughout a broad range of second harmonic terminations, making it an appropriate method for realizing broadband PAs. So, the design of class J in DPA which provide a combination of the output matching network (OMN) with a second harmonic suppression will be reviewed in this paper. As a result, there is a set second harmonic reactance at the saturated power as well as the OBO region. By doing this, the effect of the dynamic load modulation on the second harmonic part is removed. The structure of this paper is as follows. In Section two, the Compromise between linearity and efficiency is chosen. The RF power amplifier is introduced in Section three. In Section Four Class J and Class-J DPA design strategy. In Section five, the conclusion is presented.

2. Compromise between linearity and efficiency

In order to achieve a balance between linearity and efficiency, a compromise must be reached. In power amplifiers, linearity and efficiency are two essential components. Most of the time, decreasing the power-efficiency-related nonlinearity requirements leads to the transmission of signals with peak amplitudes below the amplifier's compression point. In this section, linearity and effectiveness will be discussed at three resolution levels (device level, system level, and circuit level). The semiconductor technologies are being employed to provide **device-level** solutions for PAs linearization and efficiency. RF power amplifiers employ a variety of semiconductor technologies, including Si BJT, SiGe HBT, SiC MESFET, GaAs MESFET, GaAs HBT, Si LDMOS FET, GaAs HFET, and GaN HEMT. The properties of SiC, GaAs, Si, and GaN are displayed in Table.1.

Table 1 : The Properties of Si, GaAs, SiC, and GaN[12]

Parameter	**Materials**			
	GaN	**si**	**SiC**	**GaAs**
Electron mobility µn (cm2/Vs)	2000	1500	650	8500
Band Gap Eg (eV)	3.4	1.12	3.2	1.4
Hole mobility µp [cm2/V s]	300	480	120	400
Velocity Saturation (107 cm/sec)	2.5	1.0	2.7	1.2
Electric Field Breakdown (Mv/cm)	3.3	0.3	3.5	0.4
Transit Frequency f_T (Ghz)	150	20	20	150
Breakdown field E_br [mv⁄cm]	3.3	0.3	3.5	0.4
Dielectric Constant	9.5	11.9	10	12,5
Thermal conductivity K [w⁄mC]	130	150	450	550

GaN technology became more significant in the RF and microwave industry as a result of the rising need for high-power devices at higher frequencies. Additionally, compared to other technologies, GaN technology is better suited for systems with higher efficiency. There are currently five semiconductor technologies used in power amplifier designs: GaAs HBTs, GaAs HEMTs, GaN HEMTs, silicon LDMOS transistors, silicon-carbide (SiC) MESFETs, and gallium-arsenide (GaAs) HBTs are examples of semiconductor devices. According to Figure 1, GaN may have the most potential among them in terms of high frequencies and power.

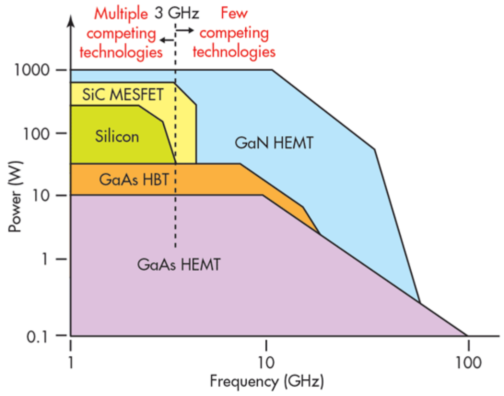


Figure 1: Five different semiconductor technologies for RF power-amplifier [13].

Also, GaN beats LDMOS and is hence appropriate for the high-frequency requirements of 5G.as shown in Figure (2).

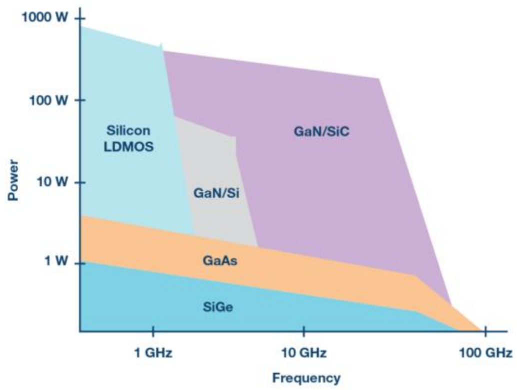


Figure 2: Comparing power and frequency of different materials [13]

At the circuit level, the Class of PA function types serve as the basis of the overall approach for this level. Power amplifiers come in a variety of types, including Class A, AB, B, C, D, E, F, and J. Table 2 shows working mode, power amplifier's theoretical maximum efficiency and linearty for various class of PAs.

Table 2: Efficiency and linearity performance for various PA operation classes according to theory

Class	**Working Mode**	**The highest possible efficiency theoretical (%)**	**Linearity**
Class A	Linear	50	Good
Class AB	Linear	50-78.5	higher to class-B, lower to Class-AB
Class B	Linear	78.5	Poor
Class C	Linear	100	Poor
Class D	Switch	100	Poor
Class E	Switch	100	Poor
Class F	Harmonically Tuned	100	Poor
Class J	Harmonically Tuned	78.5	Good

Power amplifiers come in a variety of forms, including switching type amplifiers, Class E, F, and linear Class A, non-linear Class AB, B, and C. Although the Class A amplifier is the least efficient, it offers the best linearity of all the classes. In switching amplifiers, linearity is sacrificed in favor of efficiency, making them ideal for situations that do not require strong linearity.

At the system level, envelope elimination and restoration (EER), envelope tracking (ET), Chireix, and DPA are five different ways to organize this level. New 5G standards state that the rising need for high user data rates results in high peak-to-average power ratios (PAPR) and a wide signal bandwidth. The power amplifier (PA), which is an important part of the transmitter in this case, has to become more efficient in the OBO zone throughout a wide range of frequencies. Several PA designs, including ET [14], linear amplification with nonlinear components (LINC) [15], and EER [16], Doherty [17], have been developed to address this difficulty.

2.1 Doherty power amplifier technique DPA:

The Doherty amplifier was first proposed by W. H. Doherty in 1936[17]. High-efficiency GaN Doherty power amplifier (PA) with an instantaneous bandwidth of 100 MHz for 3.5-GHz long-term evolution (LTE)-advanced applications is presented in [37]. This technique can be utilized to obtain a high average efficiency. Doherty power combining is commonly utilized in base station transmitter applications; however, Doherty power combining is frequently used in base station transmitter applications, but because of improvements in linearity and efficiency, it is now being seriously investigated for portable applications. As mentioned, the Doherty amplification is one of the multi-transistor approaches for solving low-efficiency PAs driven by high PAPR communication signals. Figure 3 depicts the DPA architecture, in which the Main (or Carrier) amplifier's active load is essentially provided by the Auxiliary (or Peaking) amplifier.

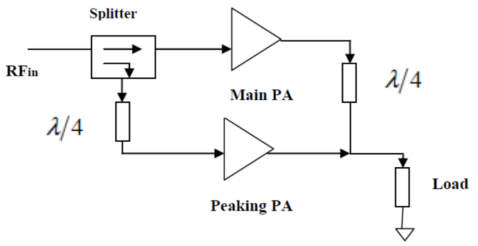


Figure 3: DPA technique [18]

A traditional Doherty amplifier is often made up of two amplifiers, a class B or AB **primary power stage** is one of them; **class AB** is preferred due to its superior linearity [18], and a **class C peaking power stage** for the other. It is necessary to have the largest output voltage swing and efficiency for each input power level between the defined break point and the maximum. The Main maximum current in the typical DPA implementation contributes only half of the maximum total current, hence the break threshold is set at 6 dB OBO. The auxiliary device is off when input power falls below the break point value, and on when it exceeds this value. When activated, it injects current into the combined load, boosting output power and altering the load that the primary amplifier perceives. Basically, there are two primary areas of DPA behavior that may be characterized: the first area is the low-power zone, when the auxiliary device is really off, and the second area is the Doherty region, where both devices are active. Figure 4 demonstrates the DPA's simplified output component in the two operating domains. Active devices behave basically as current sources up until saturation in a common-source configuration. In the region of low power (Figure 4a), the output should preferably solely come from the Main device, with the Auxiliary device's output impedance acting as an open circuit. As with a Class-AB PA, efficiency rises as power does (Figure 5, red curve). When the Main device drain voltage hits the break point, it can no longer rise any higher, and the Auxiliary switches on. The output power in the Doherty region (Figure 5b) is a result of both PAs. The actual contribution of the other stage raises the impedance observed from the output section of each branch[18]:

$$Z_M = R_L\left(1 + \frac{I_A}{I_M}\right) \quad and \quad Z_A = R_L\left(1 + \frac{I_M}{I_A}\right). \ (1)$$

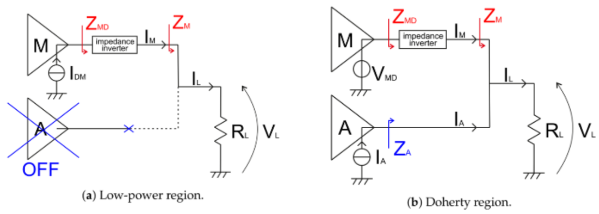
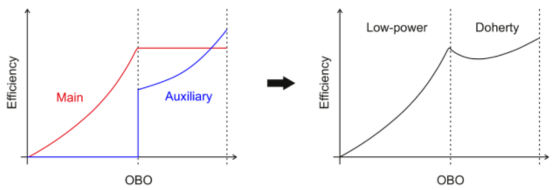


Figure 4: Simplified equivalent output section of a Doherty Power Amplifier (DPA)[18].



(a) (b)

Figure 5: Efficiency of a Doherty power amplifier[18].

Figure 6 displays a typical class AB-C DPA's block diagram. A less complicated model is utilized in place of transistors, consisting of an ideal current source and an output LC circuit that models reactive parasitic effects in the desired band. The reflection coefficient is written before the IIN (a line of quarter wavelength with a characteristic impedance equal to R_{opt}) as:

$$\Gamma_{M1} = \frac{Z_{M1} - R_{opt}}{Z_{M1} + R_{opt}} \ . \ (2)$$

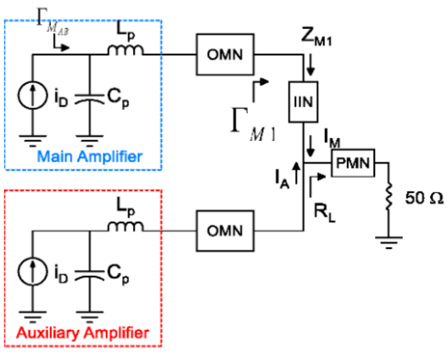


Figure 6: Schematic representation of the traditional DPA[19].

One of the biggest challenges in the design of DPAs is achieving very broad bandwidths. This is hampered by a number of factors, including the presence of offset lines or band pass post-matching networks, the reactive parasitic effects of the active devices, and the quarter wavelength transmission line used as an impedance inverting network (IIN) between the primary device and the common node [20, 21]. Impedance inversion (IIN) is removed from the main channel and placed in the output matching network (OMN), to increasing the bandwidth at the same time maintain good gain and efficiency over a 700MHz bandwidth can be achived by utilizing the impact of the second harmonic.

3. Amplifier for radio frequency signals:

An RF power amplifier, also known as a radio frequency power amplifier, is an electrical amplifier that increases the strength of a radio frequency signal. The antenna control for the transmitter is typically performed by RF power amplifiers. Power output, gain, power efficiency, bandwidth, linearity (minimal signal loss at maximum output), input and output impedance matching, and heat dissipation are examples of typical design objectives. Power amplifiers are frequently created for specific purposes or requirements (such as LTE and point-to-point microwave radios).

Due to both stability and inexpensive cost, silicon LDMOS transistors are the standard for these Power Amplifiers (PAs). GaN continues to advance, due to its four to five times greater power densities than LDMOS; this is why high efficiency PA designs, such as Doherty, GaN for designing some time of high efficiency PA such as DPA, using GaN in more preferable than using LDMOS[20]. Figure 7 below shows the simplest form a power amplifier schematic.

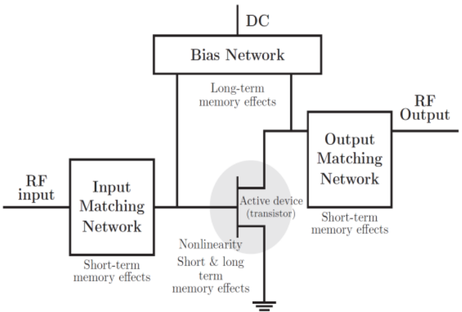


Figure 7: Power amplifier schematic in a simplified form [22].

GaN can be used to make BJTs, FETs and HEMTs types of transistors. GaN is very effective because of its high power density, which allows it to remove heat from a tiny device. GaN can enhance signals well into the higher gigahertz levels because of its great electron mobility. However, because the production methods are expensive, GaN enabled equipment is costly.

Table 3: Advantages of GaN-HEMT amplifier

Parameters	Features of the GaN-HEMT technology	Features of using a GaN-HEMT amplifier
High breakdown voltage	High voltage operation. Good linearity. High load impedance.	Easy harmonic processing (high efficiency). Simplified voltage conversion. Low match loss.
Wide band gap	High temperature operation. Low noise.	Small. Lightweight cooling system. High power density.
Low capacitance	High efficiency. Low distortion.	Wide band operation. Smaller heat sink. Lower (AM-PM) distortion.

From table.3 above, using GaN HEMT semiconductor technology at power amplifier can reduce size, complexity, cost, noise and cooling system of the power amplifier. Also, GaN HEMT can provide high efficiency, high power density, high linearity, and high frequency operation.

Researchers were motivated by GaN-based HEMT technology to investigate numerous classes of PAs, such as D, E, and F, as well as discover unique modes of PA, such as Class J. [18], [19]. Efficiency obviously rises from class A to higher classes. However, it should be emphasized that classes higher than C, D, E, and F have less linearity. Class A, B, and AB may still provide a lot of output power while being less efficient because of their higher linearity. applications involving base stations [20] designed and implemented a highly efficient class J GaN power amplifier.

One of the most difficult design problems for DPAs is achieving very broad bandwidths, which is one of the DPA's key limitations. This challenge is affected by a variety of variables, such as the quarter wavelength transmission line utilized as IIN between the basic element and the common branch. Table 4 shows a review of several papers designing DPA based on the GaN techniques. From Table 4, by using GaN techonogy good linearty and efficiency can be can achived to design DPA.

Table 4:performances Comparison of the DPA

Ref.	Years	Freq. GHZ	Pout (dbm)	Sat. DE (%)	DE OBO (%)	Gain (dB)	Tech.
[21]	2014	2	42	67	-	10.4	GaN
[22]	2016	1.95	44	68	43	9.5	GaN
[23]	2017	2.1	42	72	-	10.2	GaN
[24]	2017	2.3	45	68	-	11	GaN
[25]	2019	2.2	43.6	71	50	9.7	GaN
[26]	2018	1.7	42	71	-	-	GaN
[27]	2019	2.2	44	69	-	10.5	GaN
[28]	2019	3.1	44	71	-	10	GaN
[29]	2020	3.5	43.7	70.8	48.7	10.7	GaN
[30]	2021	2.55	52	53	53	2	GaN

The usage of a quarter-wavelength transmission line as an impedance inverting network (IIN) between the primary device and the common node is one of the numerous challenges that make it difficult to attain very wide bandwidths when developing DPAs. Class-C amplifiers offer less current than Class-B or ClassAB ones more so.

To achieve equal maximum currents at saturation, one of two device sizes (with the Auxiliary being the larger one) or an unbalanced input power splitter must be used to achieve equal maximum currents at saturation. Class-C biased transistors also exhibit poorer linearity and lower power increases. Removing the λ/4 line operating as the IIN and constructing the main device's OMN to carry out the impedance inversion necessary for the Doherty load modulation are two potential solutions to band limitation. While a conventional class AB-C DPA assumes a short-circuit termination at all higher harmonics, it only considers the load at fundamental frequency f_o. The devices inside this design are operated in class J by the OMNs because successfully terminating the higher harmonics may significantly improve performance.

The usage of a quarter-wavelength transmission line as an impedance inverting network (IIN) between the primary device and the common node is one of the numerous challenges that make it difficult to attain very wide bandwidths when developing DPAs. More so than Class-B or Class-AB amplifiers, Class-C ones offer less current. Therefore, one of two device sizes (with the Auxiliary being the larger one) or an unbalanced input power splitter must be used to achieve equal maximum currents at saturation. Class-C biased transistors also exhibit poorer linearity and lower power increases. Removing the λ/4 line operating as the IIN and constructing the main device's OMN to carry out the impedance inversion necessary for the Doherty load modulation are two potential solutions to band limitation. While a conventional class AB-C DPA assumes a short-circuit termination at all higher harmonics, it only considers the load at fundamental frequency f_o. The devices inside this design are operated in class J by the OMNs because successfully terminating the higher harmonics may significantly improve performance.

4. Class J power amplifier:

One of the PA type called Class-J, defined as a linear amplifier in the same way as conventional high-efficiency linear amplifiers like Class B, allows the measurement of the drain voltage (VDS) and drain current (ID) as half-rectified sinusoidal waveforms with a small overlap between VDS and IDS[31]. Figure (8) below shows a sample of class j mode.

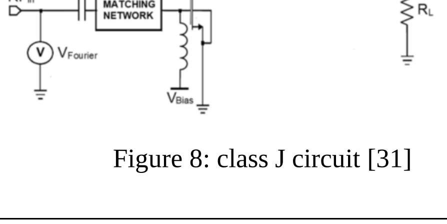


Figure 8: class J circuit [31]

In the case of Class B, it is assumed that all harmonics are short circuited at the output, leaving the fundamental and DC elements as the only parts of the drain voltage. Even at relatively high frequencies, the actual circuit design of such a situation (all harmonics being shorted) is not always possible due to the presence of the internal output capacitance, $Cout$ [32]. The Class-J arrangement also doesn't really need open-circuit or short-circuit harmonic cancellation, which substantially simplifies the matching network design and permits high efficiency and wide bandwidth. The efficiency and linearity of the Class-J mode are equivalent to those of the traditional Class-AB mode, theoretically. Because of this, in 5 G applications, the Class-J mode is a great replacement for PA architecture [33]. By using class J in DPA the limitation of classical DPAs will be solved. Increased bandwidth is achieved by removing the IIN from the main channel and placing it in OMN (i.e. the output matching network). We may also maintain high gain and efficiency over a broad bandwidth by making use of the second harmonic's effect. By using the Class B biasing point and only taken into consideration the fundamental and second harmonics, the drain current can be implied as given in equation (3) below[34] [31].

$$I_{D,J}(\theta) = \left(\frac{I_{max}}{\pi} + \frac{I_{max}}{2}\cos(\theta) + \frac{2I_{max}}{3\pi}\cos(2\theta)\right) \quad \dots (3)$$

I_{max} represent the maximum drain current value of the transistor. The expression of the half-wave rectified drain voltage is shown in equation (4) below[34] [31]:

$$V_{D,B}(t) = V_{PK}\sin(\theta) + V_{dc} \quad \dots. (4)$$

Since $V_{PK} = V_{dc}$ as shown in figure (9) then

$$V_{D,B}(t) = v_{dc}(1 + \sin(\theta)) \quad \dots. (5)$$

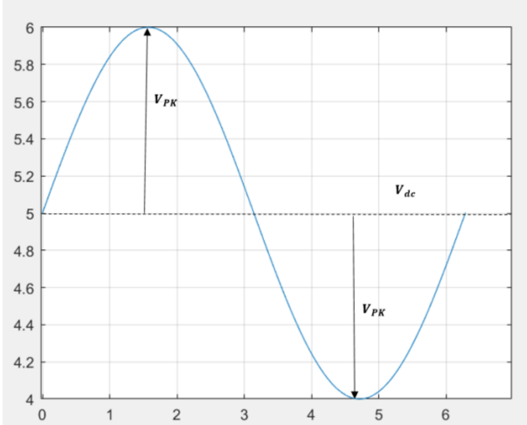


Figure 9: sine wave

class J can be obtained by multipling equation (5) by $(1 + \cos(\theta))$

$$V_{D,J}(\theta) = V_{dc}(1 + \sin(\theta))(1 + \cos(\theta)) \quad \dots. (6)$$

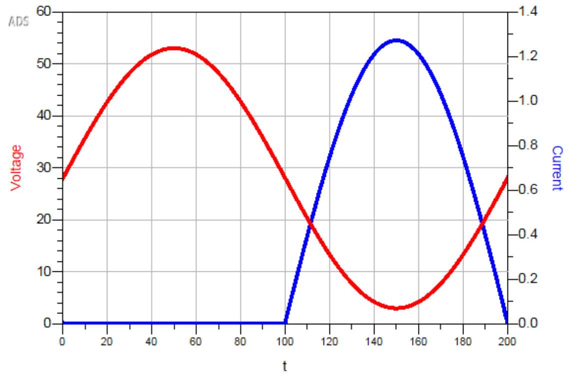
$$= V_{dc} * [1 + \sin(\theta) + \cos + \sin(\theta)\cos(\theta)] \dots (7)$$

Equation's Class-B power amplifier drain voltage may be shifted to produce the Class-J drain voltage. It is clear that adding the sine and cosine functions shifts the fundamental component's phase, and adding the second harmonic voltage boosts the fundamental component by adding in phase. Thus, the DC, fundamental, and second harmonic voltage components make up the voltage waveform[34]. Since $[\sin(\theta)\cos(\theta) = \frac{1}{2}\sin(2\theta)]$, and by adding a factor to the front of the cosine function called Alfa (α), which swept from (-1 to 1) then

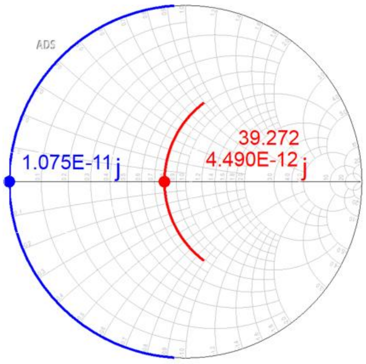
$$V_{D,J}(\theta) = (V_{dc} - V_k)(1 + \sin(\theta))(1 + \alpha\cos(\theta)) \quad \dots\dots. (8)$$

$$V_{D,J}(\theta) = (V_{dc} - V_k)[1 + \sin(\theta) + \alpha\cos(\theta) + 0.5\,\alpha\sin(2\theta)] \quad \dots\dots. (9)$$

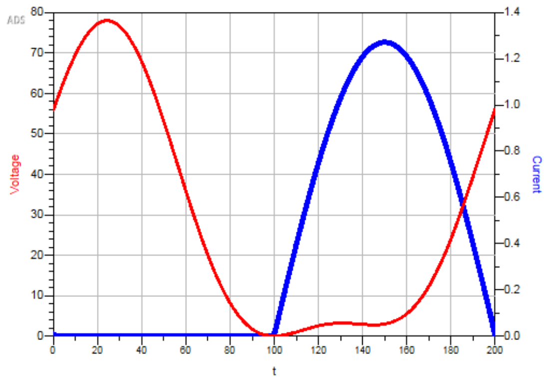
Alfa in equation (9)'s cosine function, which has a range of -1 to 1, may be used to create a family of voltage waveforms by inserting an element to the front of the function[35][36]. There is a case known as Class-J where α equals 1, a case known as Class-B where α equals 0, and a situation known as Class-mirror J's image where α equals -1. The current source's fundamental and harmonic impedances are depicted in Figure 10 by changing α. The Figures (10a , 10b and 10c) are obtained by using the ADS program.



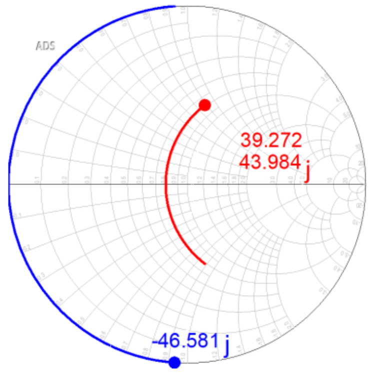
a) Class-B power amplifier at $\alpha = 0$



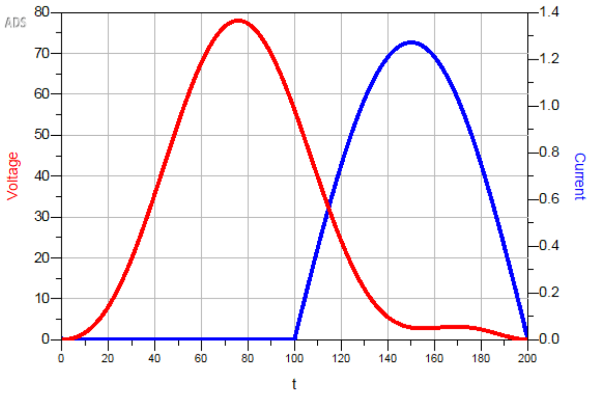
a) Red is the fundamental , blue is the second harmonic (2fo) and all other harmonic are shorted



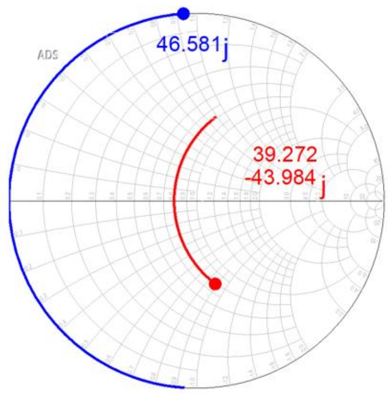
b) Class-J power amplifier at $\alpha = 1$



b) Red is the fundamental, blue is the second harmonic (2fo) and all other harmonic are shorted



C) Class-J^{-1} power amplifier at $\alpha = -1$



C)Red is the fundamental , blue is the second harmonic (2fo) and all other harmonic are shorted

Figure 10: Power amplifiers for different range of α

limiting the drain voltage the bottom part of the new waveform flattens and the second harmonic component is added. This suggests that the fundamental component can rise further without affecting the DC level by the inclusion of a second harmonic component with the proper phase. It is obvious that increased output power and efficiency may result from an increase in drain voltage at the fundamental frequency. The fundamental concept of Class J operation is the flattening effect brought on by the second harmonic component.
In contrast to other similar PAs, (i.e. Class E power amplifier), the Class-J PA requires a unique capacitive second harmonic termination in order to create a rectified sine-wave. Utilizing a reactive component at the fundamental and a low capacitance value at the fundamental and second harmonic frequencies in this mode of operation is an effective technique to recover RF power and efficiency as shown in Figure (10b). The reactive voltage is therefore created by the harmonics crossing the capacitor[34]. The Class-J PA provides the fully reactive second harmonic termination by shifting the phase of the voltage and current waves; however, the PA's performance might be constrained by the waveforms' phase overlap[34] [31].

4.1 Class-J DPA Design Strategy

As mentioned earlier, the classical DPA have limitation in the frequency band. This limitation can be solved by using Class J PA the main and auxiliary power amplifiers in DPA. In order to accomplish class-J DPA operation, The main and auxiliary devices' OMNs are constructed in a modular manner, specifically each OMN is made of three pieces, as illustrated in Figure 11 [19]. A second harmonic matching network (OMN 2nd), which is terminated by a second harmonic short, creates the correct impedance at the second harmonic. The correct load is then set at the fundamental frequency by the matching network OMN 1st without having an effect on the second harmonic[19]. The intrinsic impedance of the primary device at saturation, at the fundamental (Z_{fo}), and at the second harmonic(Z_{2fo}) of class J may be calculated using the equations (10 and 11) below [31]:

$$Z_{fo} = \frac{(V_{DD}-V_{th})(1+j\alpha)}{\frac{I_{max}}{2}} = R_{opt} + j\alpha R_{opt} \quad .... (10)$$

$$Z_{2fo} = -\frac{(V_{DD}-V_{th})j\alpha}{2\left(\frac{2I_{max}}{3\pi}\right)} = \left(\frac{-j3\pi}{8}\right)\alpha R_{opt} \quad .... (11)$$

Where R_{opt} is the optimum load resistance

$$R_{opt} = \frac{2(V_{DD}-V_{th})}{I_{max}} \quad .... (12)$$

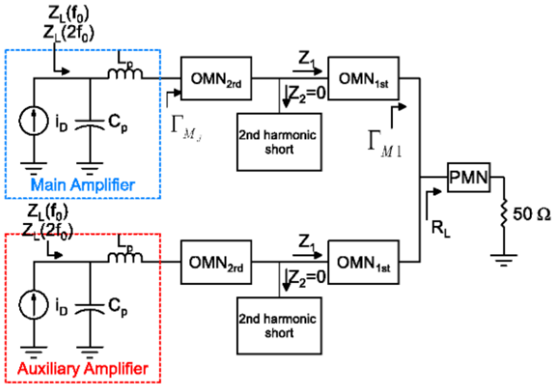


Figure 11: Graphical depiction of the proposedClass-J DPA[19].

There is some design flexibility for the OMN due to the dependence of the reflection coefficient without sacrificing power or efficiency. Finally, Table 5 shows a Comparison of the measurement results of the of the researcher for class J DPA.

Table 5: A Rreview of Class-J DPA

Ref.	Years	Freq. GHZ	Pout (dbm)	Sat. DE (%)	DE OBO (%)	Gain (dB)
[38]	2013	3.4 - 3.5	49.5	58 - 71	46 - 55	8.6 – 9
[39]	2015	1.7 - 2.6	44.6–46.3	57 - 66	47 – 57	10.2 – 11.6
[40]	2016	1.7 - 2.8	44 - 44.5	57 - 71	50 - 55	12 – 14.5
[41]	2011	2.2 - 3	39.5-41.5	50-67	36-48	6 - 8.6
[42]	2012	3 - 3.6	43-44	55-66	38-56	8 - 11
[13]	2017	3.3 - 3.75	48.-48.8	58-71	44-55	11.8-13.5
[43]	2019	1.45-2.45	42 - 44	48–64.2	36–52	6–13
[28]	2019	2.9-3.3	43.9	70	40.6–44.2	6–11
[44]	2019	1.4-2.45	41.8–43.5	47.5–64.2	35.5–52	6–13
[45]	2019	2.2-2.6	43–44	60–65	45–53	-
[46]	2021	2.8-3.6	43–44.2	62–76	44–56	8–13
[47]	2019	2.4	42.3	69.3	54	12
[42]	2012	3-3.6	43–44	55–66	38–56	12
[19]	2022	3-3.7	43–44.2	60–74	46–50	11–13

from Table 5, the efficiency, power gain, frequency band can be improved by using Class J in DPA instead of traditional one.

5. CONCLUSION

This paper presents a short review of the study different works of other researchers to find a suitable design of the power amplifier that can be used for the base station of the 5G, in terms of choosing the suitable materials and the amplifier design. The right choice for producing high output power among all the devices and technologies has been determined to be a gallium nitride device and technology. Furthermore, GaN, a III-V technology, outperforms LDMOS and is thus suitable for 5G's high-frequency needs. It has been determined that the GaN HEMT-based PA is the best of all the modern PA designs with important building blocks. GaN is an excellent option for creating high-power and high-frequency power amplifiers according to its material properties. A GaN power amplifier's efficiency was examined, and it was discovered that the PAE was much higher in a GaN Doherty power amplifier than in a conventional GaN power amplifier. GaN Doherty power amplifiers are therefore the best choice for base station applications since their great efficiency lowers power dissipation and hence minimizes the need for cooling. The band limitation of classical DPA have been solved by using class J in the main and auxiliary power amplifier. The λ/4 transmission line that acted as an IIN has been removed when employing class J power amplifiers, and bandwidth has been increased by applying impedance inversion in the output matching network (OMN).

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مراجعة مضخم طاقة ترددات الراديوية العالي لتطبيقات 5G

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الملخص

يعد مضخم الطاقة من أهم الدوائر في أي دائرة إرسال للاتصالات اللاسلكية. تتطلب محطة G5 الأساسية مضخمات طاقة ذات طاقة إخراج عالية وكفاءة ممتازة ومكاسب عالية. يتم تقديم مراجعة لمضخم الطاقة G sub-6 GHz5 الأساسي في هذه الورقة. فحصت هذه الدراسة تقنية أشباه الموصلات التي تعتمد على نيتريد الغاليوم (.GaN)يدعي الباحثون أن الخيار الأفضل لتقديم طاقة عالية في الإخراج، وقوة تراجع عالية، وكفاءة عالية هو نيتريد الغاليوم (GaN HEMT)القائم على PA . ستقوم هذه الدراسة بتقييم مضخمات طاقة (DPAs) Doherty بناءً على الفئة J.

الكلمات الداله:

GaN، مضخم الطاقة, 5G ، تقنيات الأجهزة ، DPA.