Design and implementation of a 10 W broadband power amplifier at the broadcast systems

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Abstract

This paper proposes a design of push-pull power amplifier using a DMOSFET transistor, where the circuit was designed by applying the optimization technique in finding the appropriate input and output impedance to obtain a 40 dBm(10w) output power and an efficiency (33.9%) suitable for working in the broadcast systems, in addition to the appropriate design of the matching circuit using a transformer BALUN with ferrite, which provided wide performance up to several octaves from 100 MHz to 700 MHz and gain (12.5dB) within ±0.5dB, and VSWR<1.8. the design was simulated by(NIAWR) software, then the circuit was implemented and practical measurements were made. We have good convergence between the theoretical and practical results, thus the design and implementation is simple and less expensive compared to GaN HEMT type power amplifiers.

Keywords: broadband , pushpull power amplifier , ferrite,matching circuits.

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تصميم وتنفيذ مكبر استطاعة 10 W عريض المجال يعمل في أنظمة البث

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الملخص

هذا البحث يقدم تصميم مكبر استطاعة دفع جذب باستخدام ترانزيستور نوعDMOSFET، حيث تم تصميم الدارة بتطبيق تقنية الأمثلية في إيجاد ممانعة الدخل والخرج المناسبة للحصول على استطاعة خرج (40dBm(10w وفعالية (33.9%) مناسبة للعمل في أنظمة البث، بالاضافة الى التصميم المناسب لدارة الموافقة باستخدام محول BALUN مع الفرايت، الذي قدم أداء عريض يصل الى عدة أوكتاف،[100−700]MHz، وبربح (12.5dB) في حدود تباين ± 0.5dB، ومعامل VSWR<1.8، تمت محاكاة التصميم بالاعتماد على برنامج (NIAWR) من ثم تنفيذ الدارة واجراء القياسات العملية المناسبة وحصلنا على تقارب جيد مابين المحاكاة النظرية والعملية، وبالتالي تم التصميم والتنفيذ ببساطة وأقل تكلفة مقارنة بمكبرات الاستطاعة نوعGaN HEMT.

الكلمات المفتاحية: المجال الترددي العريض، مكبر الاستطاعة دفع جذب، الفرايت، دارات الموافقة.

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I.Introduction:

This Broadband power amplifiers are considered as key components in broadcast communication systems. In principle, application of a linear, wide band amplifier can replace several narrow band power amplifiers, yielding reduced costs and size [1], as shown in Figure 1 . This paper uses D2003UK a transistor to achieve a 10 Watt amplifier for broad band . It is a Diffused Metal Oxide Transistor (DMOS) and is developed by the company Semelab , the figure 2 shows spice model of D2003UK [10].

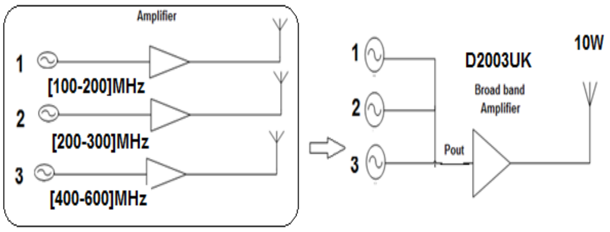

Figure (1). the block diagram of Broadcast Transmitter system

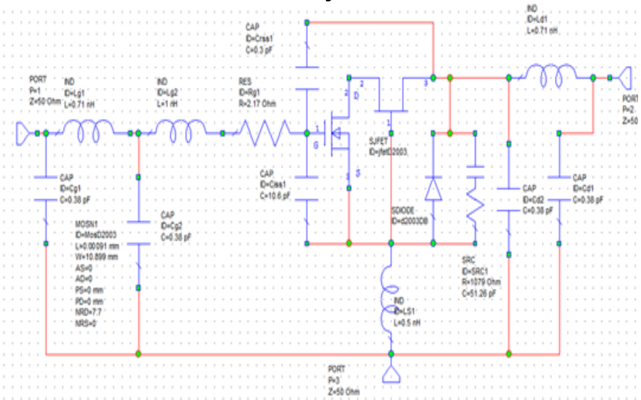

Figure (2). Spice Model of D2003UK

The Push-pull amplifier module consists of two power amplifier modules within the same package .

The designer has to make a trade-off between gain and VSWR of broad band width, which improves one of them The D2003UK was produced for push-pull applications, After the benefit of the Technical data sheet of transistor.[10]

DMOS transistor model suitable for broadcast communications, because it has very low C_{rss} , simple bias circuit and less expensive compared to (gallium nitride) GaN HEMT transistors.

D2003UK transistor has the following characteristics: 35W Power Dissipation, low noise , high gain 13 dB minimum and the optimum source and load impedance of 1000MHz is:

$Z_s = 1.1 - j2.5\Omega$, $Z_l = 5.1 - j17.1\ \Omega$

But these impedances do not fit the broadband design ,so it will be chosen the optimal input and output impedance at maximum power by loadpull and sourcepull which is provided microwave office program.then the matching network is well designed for *conjugate matching*:

$$Z_{IN} = Z_S{}^*, Z_{out} = Z_l{}^* \quad \text{..........(1)}$$

II.Design of the Broadband Balun:

In the push-pull configuration the main factor is the balun. The balun functions as a splitter in the input circuit and blends the voltages in the output circuit, which are distorted out of phase. It is a passive splitter / combiner with a phase difference of 180° between the output / input ports.[2]

A Balun is a device that is used to join a balanced line to an unbalanced line. A balanced line is one that has two terminals, neither of which are connected to the ground, whereas an unbalanced line has one terminal connected to ground. Broadband balun with a transformation ratio of 1:1 impedance is used to provide the input and output of each individual system with 25Ω impedances. [3,4]

The best length of balun with "61" ferrite[6] is 66 mm for the corresponding high cut-off frequency 700MHz .

The coaxial cable of the balun is consist of 50Ω semi-rigid with a diameter of 1.45mm(57mil) to allow investigationin to the effect of ferrite beads on the balun performance, as shown in Figure 3.

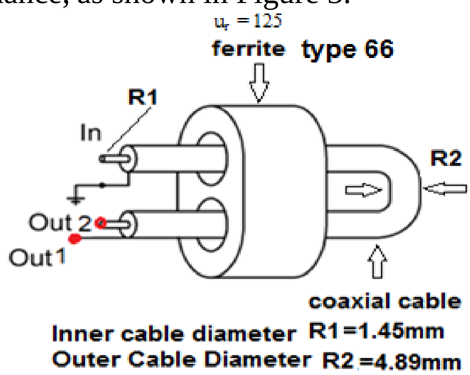

Figure (3). The physical form of a balun[6]

When common mode impedance substantially increases, common mode current on feedline will be greatly decreased. The combination of proper grounding and high common mode balun impedance can reduce unwanted currents to immeasurable or unnoticeable values.so The ferrite material with coaxial cable prevents the effect of the common mode.[2]

A conventional two-conductor transmission line, even if one conductor is called the "shield," must have exactly equal and opposite flowing currents into each conductor at each end. Without equal and opposite (differential mode) currents flowing at every point in a transmission line, it will radiate and receive signals. A transmission line with purely differential mode operation would never radiate unwanted energy. It also would not respond to outside radiation or signals , As ahown in (2)

CMRR dB =20*log $(S_{21}+S_{31})/(S_{21} - S_{31})$………(2)

This concept is especially important for broadband circuits intended to cover HF to UHF to determine what the frequency limit for the balun is (usually when the CMRR drops below 25dB).

III. Matching and biasing network design:

For the matching input and output impedance of transistor to Z=25Ω, A block diagram of 10W amplifier circuit design is shown in Figure 4.

the L transformer is adding to the output transistor port and RC parallel network is adding to input transistor, .[4] which achieves a return loss of better than 15, The shunt-feedback topology is beneficial for broadband operation with gain flatness and high linearity[5]

the figure 5 shows the schematic circuit of prototype power amplifier and simulation results is shown in Figure 6

Biasing circuit provides a suitable voltage to the gate and drain DC bias for the DMOS modules, Vds=28V, Vgs=3.1V which is important for ensuring the device's reliability and preventing instability. And we designed a choke system on the ferrite core u_r = 125 and 2 turns of enamel copper coil.

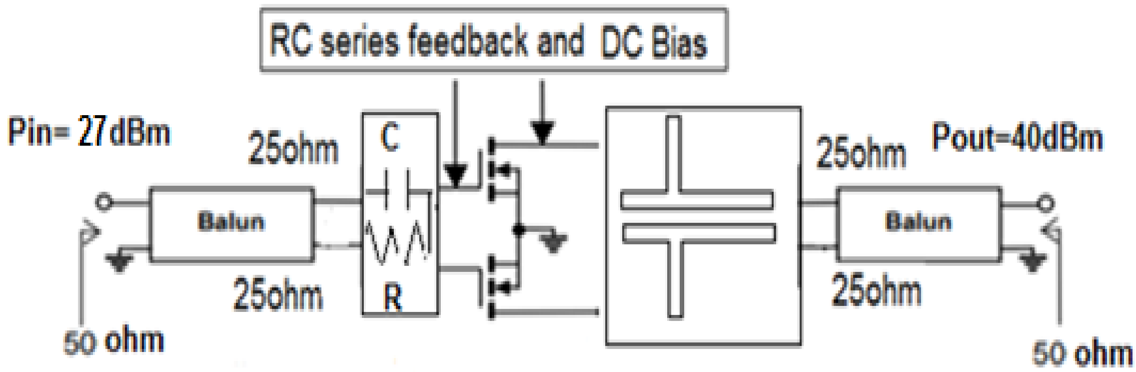

Figure (4): the block diagram of 10W amplifier circuit design

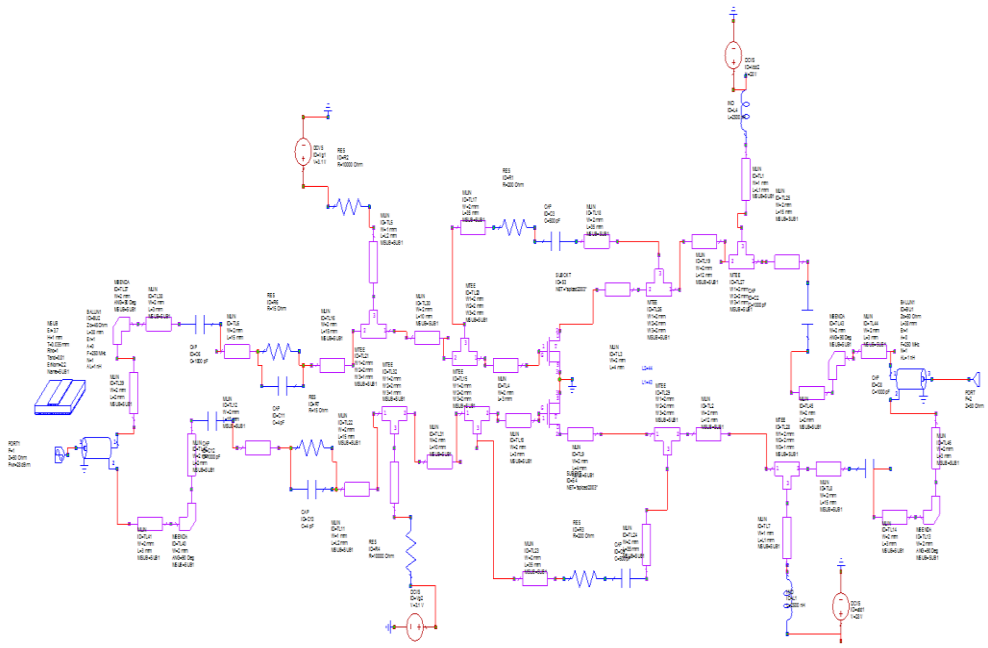

Figure (5) schematic circuit of prototype power amplifier

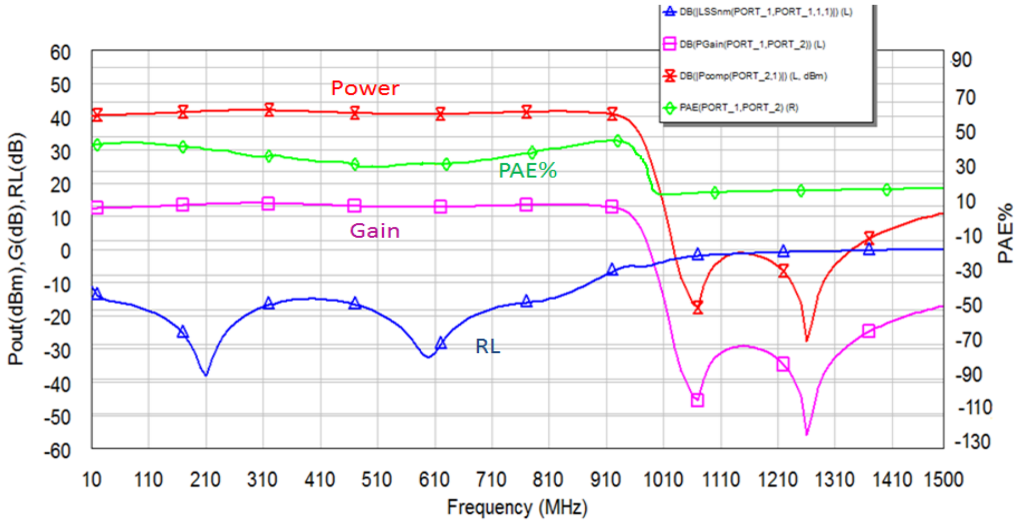

Figure (6) simulation results of prototype Power Amplifier

The first parameter needed to be checked when we designing amplifier is VSWR factor. The amplifier must be stable over the range of the required frequency band. The Rollett factor K is used as a measure of stability and must be greater than one in order for an amplifier to be stable[3][5], and the *RL* of PA is shown in figure 7 with in VSWR circle of 1.8

IV. Measurent and Simulation Results

The circuit response has been improved by using the adjustment provided by the MWO / AO program for each circuit component so that we get the best amplifier response.

The circuits are implemented on a N25 substrate, with ε_r= 3.7 and thickness of 1mm.

The circuit was printed on the insulating base and install the transistor with screws directly on the floor of the metal case to take good grounding in addition to installing the board on a cooler with appropriate dimensions to dissipate the heat resulting from the amplification power,And Figure 8 shows the final shape of the performing amplifier is expressed.

the design shows the good convergence between the theoretical and practical results when the input power 27dBm, as shown as Figure 9 for the return loss

RL(dB)=-20 Log | Γ | ………………… *(3)*

and Figure 10 for the gain. The estimated gain was 12.8-14dB for 27 dBm input power,But The measured gain is decrease due to the loss of conduction cables and insulation material ,but the measured return loss was always better than

estimated return loss because to The ferrite 61 material shows bad effect at high frequency .

in addition to the measured isolator parameter between ports is $S_{12} < -40dB$.

The DMOS amplifier can deliver (9-10)W to a 50 ohm load and has 12.5dB gain flatness in addition to high bandwidth ratio by simply design and less expensive compared to GaN transistors at VHF and UHF frequency bands .

The findings of this work are summarized in Table 1 and contrasted with previously published papers on GaN power amplifiers operating in broadcast frequency bands,

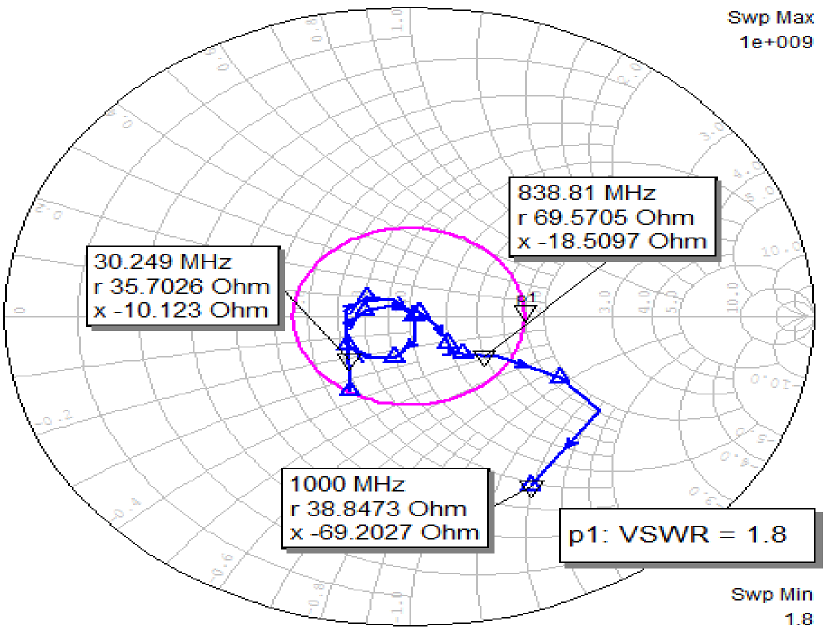

Figure (7): Simulation result of RL in VSWR circle of 1.8

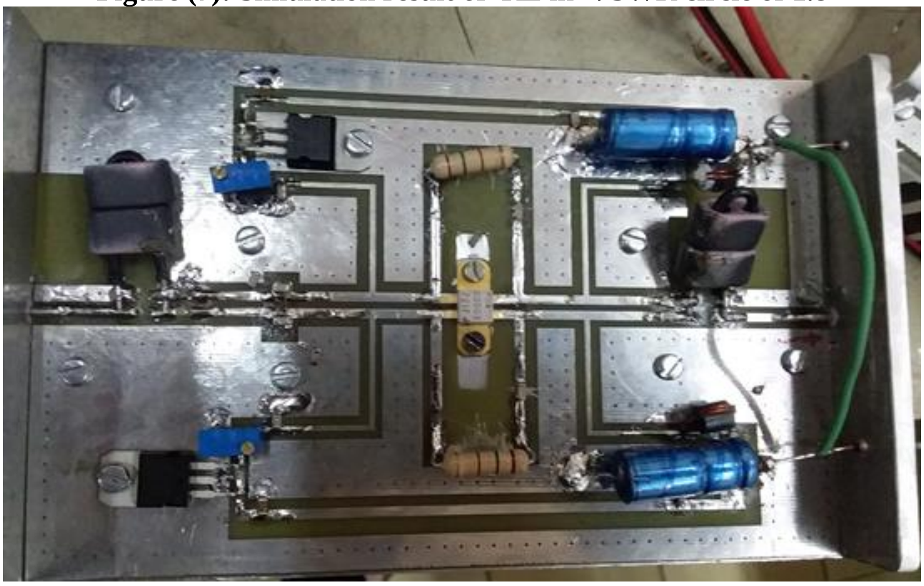

Figure (8) Photograph of the implemented PA.

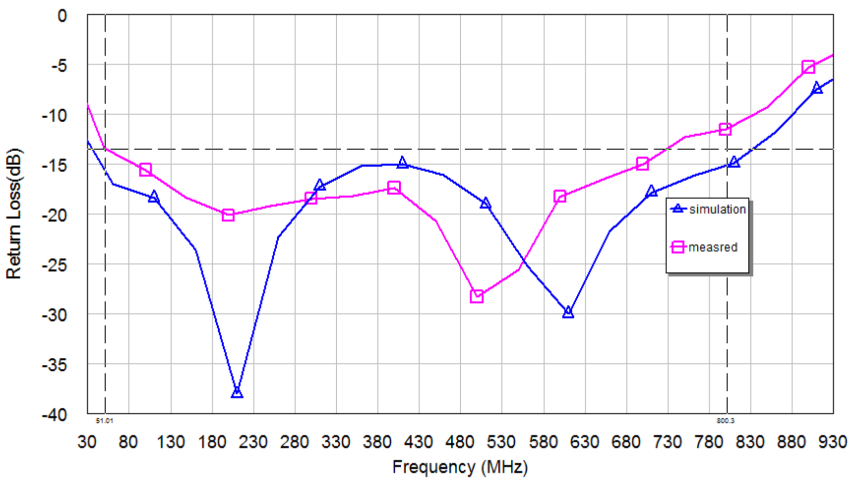

Figure (9):Simulation and measured Input Return loss of power amplifier.

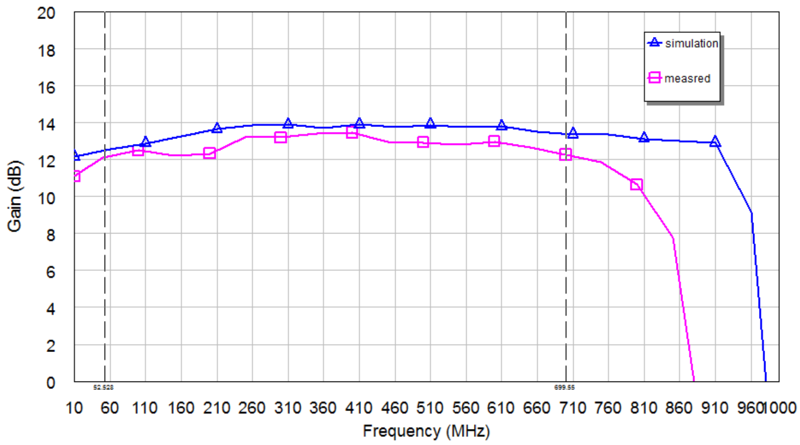

Figure (10):Simulation and measured Gain of power amplifier.

The power adde efficiency of the power amplifier is given by (4) and the bandwidth by (5):

$$PAE = \frac{(Pout-Pin)W}{Pdc} = \frac{10-0.5}{28v*1A} = \%33.9 \ldots\ldots(4)$$

$$BW\% = \frac{100*(F_{max}-F_{\min})}{F_c} = 100*(700-100)/400 = 150\% \ldots\ldots(5)$$

Table(1): Comparison among power amplifiers at broadcast frequencies.

REF.	TYPE	Matching network	Gain (dB)	Eff(%)	Output POWER	Operating Frequency (MHz)	BW (%)
[7]	GaN HEMT	Smith chart utility tool (multy steps)	15-17	83-64	10w	500-1500	%100
[8]	GaN HEMT	A low-pass LC-ladder network(multy steps)	-	60-73.8	25 W	500-2200	125.9%
[9]	GaN HEMT	A low-pass LC-ladder network(multy steps)	10	11.4-31	3.4-7.2w	2-20	163.63%
THIS WORK	D MOSFET	Microstrip(one step) with balun	12-14	33.9	9.2-10w	100-700	150%

I.Conclusion

Broad band power amplifier for [100-700] mhz has been designed and simulated successfully using microwave office (AWR). The technique used in this design is pushpull. The results show that input return loss (S_{11}) less than -15 dB, gain S_{21} higher than 12dB.Balun,RC network and RC feedback techniques can used in order to minimize the return loss and gettin flat the gain. The designed amplifier can be used in broadcast communications,SDR, wireless applications, and other applications in ISM.

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