**Response to Reviewers**

**[Cover Letter]**

Dear Editor, Reviewers,

First of all, we hope you and your family are safe and healthy during this hard time.

We appreciate you and the reviewers for your precious time in reviewing our paper and providing valuable and accurate comments. We also greatly appreciate the reviewers for their suggestions. The authors have carefully considered the comments and tried our best to address every one of them. Below we provide the point-by-point responses. All major modifications in the manuscript have been highlighted in yellow.

List authors in reference 3

Actually, there are no name Authors on IEEE Library, but we added them knowing their names.

Suggesting condensing Fig. 2 into 2 graphs. Also, there is no detail on how Fig. 2 is created?? It is completely unjustified to show performance of different Doherty PAs and claim merits of one over the other without providing any detail of the actual circuits and devices involved!!! I do agree with your general assertion regarding 3-way vs 2-way symmetric and asymmetric Doherty PAs, but please justify Fig. 2 with references or other methods..

As recommended, we justify it with references and by discussion.

Pg. 8. The following statement is not understood “The video bandwidth is measured at 38dBm with 3dBm margin higher than the real operating power.” What is “real operating power”?? Should 3 dBm be replaced by 3 dB? Note 3 dBm = 2 mW, so is the power level 2 mW higher than 38 dBm??

Typo issue, we rephrase all paragraphers to not confuse reader and to be clearer with the message we want to deliver.

Regarding Fig. 8. The power delta between upper and lower IM products begins to diverge at a delta f of about 150 MHz for IM7 and about 300 MHz for IM3. And by 400 MHz delta f, the power in the upper/lower tones is quite different. Please provide some explanation to the claim the low frequency resonance and VBW is above 600 MHz, i.e., some explanation in interpreting this graph / identification of resonance would be helpful. Seems somewhat arbitrary as to the "conditions" which identify resonance. Similar comment applied to Fig. 20

Right, resonance is at 300MHz which more logic regarding Low frequency resonance at 600MHz. We also rephrase paragrapher to be clearer on the reason of IMD divergence and remove IMD7 which are not useful on the graph. We added reference on work paying attention on LFR decoupling to improve video bandwidth thanks output and input network.

Pg. 9 & 10 regarding DPD linearized results. Please provide some explanation of the DPD system utilized in this work to realize the performance shown in Figs 9 & 10. With sufficient DPD complexity and power, even highly non-linear PAs can often be linearized. Therefore, please provide some description of the DPD system so as the reader can place the results in proper context.

We added some explanation on different DPD algorithm mostly used in industry. We added a picture of the laboratory setup hardware use. We also commented the notion between engineering DPD and industrial DPD and that we need to achieve same linearize efficiency with commercial DPD. We gave our model complexity to allow reader familiar with known piece wise DPD algorithm to judge results.

The paper lacks novelty from scientific perspective. The design of the HW is not detailed, there are only few well-known concepts.

From research point of view, it’s not the state-of-the-art PA as work that you shared to us during the revision. However, from industry point of view we think they are state of the art DPAs. From our best knowledge there are no other multistage fully integrated 3-way DPA in small package and low cost in the industry. We think that the innovation part is to succeed to implement this “well-known concepts” in industrial product with all the constraints imply, performances, compactness, cost, stability, ruggedness, life cycle. Moreover, most of the recent outstanding linearized efficiency are published with GaN technology. We think it’s innovating to reach same performance with LDMOS iDPA than GaN thanks to the implemented architecture. Our goal was to show current challenges in RF PA industry and how to address 5G with state of the art industrial DPAs. We also wanted to present issues with faced and how we improved our general design workflow to answer these challenges in a short cycle time to give some idea to the engineering community.

It resembles more a catalogue product rather than a scientific paper.

It was not our intention to make a catalogue product, but it is difficult to balance relevant information and non-disclosure API. On the second revision we take in account you comment to make a proper paper from scientific point of view. We hope our efforts will be visible in the second revision.

The references are limited, not completed, and in some cases not useful at all.

We added several references to emphasize or complete our comments in the manuscript.

There are several sections that need to be properly revised and better explained.

We revised the sections the most accurately possible according to your comments.

Introduction

It is stated that “2-way asymmetric DPA has several limitations in BW and linearity”.

Nevertheless, these issues was investigated and discussed in several papers, which are not considered by the authors.

For example, the BW issue has been deeply discussed in the following papers

We took in account your comments, adding theses references and mitigating our comment. Now we concluded that several papers demonstrated outstanding bandwidth can be achieve however they are not suitable for integrated solution. Moreover, we think there is a misunderstanding using the term broadband between research and industry. In research it is corresponding to octave PA while in industry it is corresponding to 200/400MHz linearized band.

• R. Giofré, et l., “A Doherty Architecture with High Feasibility and Defined Bandwidth Behavior,” MTT-61/9, 2013 (DOI: 10.1109/TMTT.2013.2274432).

• R. Giofrè, et al., “A Closed-Form Design Technique for Ultra-Wideband Doherty Power Amplifiers,” IEEE MTT-62/12, 2014 (DOI: 10.1109/TMTT.2014.2363851).

• J. J. Moreno Rubio, et al., "Design of an 87% Fractional Bandwidth Doherty Power Amplifier Supported by a Simplified Bandwidth Estimation Method," IEEE MTT-66/3, 2018 (doi: 10.1109/TMTT.2017.2767586).

• H. Liu, et a.., "Bandwidth Enhancement of Frequency Dispersive Doherty Power Amplifier," IEEE MWCL 30/2, 2020 (doi: 10.1109/LMWC.2019.2963542).

While the linearity issue and its mitigation has been deeply discussed in the following

We took in account your comment, adding theses references and mitigating our comment. However, as comment in the paper raw linearity doesn’t imply good correctability by DPD system especially with wideband modulated signal (200MHz IBW) which are not used in most of literature paper.

• L. C. Nunes, et al., "AM/PM distortion in GaN Doherty power amplifiers," IMS2014 (doi: 10.1109/MWSYM.2014.6848333)

• L. Piazzon, et al., “Effect of load modulation on phase distortion in Doherty Power Amplifiers,” IEEE MWCL-24/7, July 2014 (DOI: 10.1109/LMWC.2014.2316507).

• L. C. Nunes, et al., "AM/PM distortion physical origins in Si LDMOS Doherty power amplifiers," IEEE IMS2016, (doi: 10.1109/MWSYM.2016.7539986).

• R. Giofrè, P. Colantonio, “A High Efficiency and Low Distortion 6W GaN MMIC Doherty Amplifier for 7 GHz Radio Links,” IEEE MWCL-7/1, 2017, (DoI: 10.1109/LMWC.2016.2629972).

• V. Camarchia, et al., “A design strategy for AM/PM compensation in GaN Doherty Power Amplifiers,” IEEE Access/5, 2017, (DoI: 10.1109/ACCESS.2017.2759164).

• R. Giofrè, et al., “A Design Approach to Maximize the Efficiency vs. Linearity Trade-Off in Fixed and Modulated Load GaN Power Amplifiers,” IEEE Access/6, 2018 (DoI: 10.1109/ACCESS.2018.2807479).

I guess that the authors should revise the sentence and make more impartial comment on these aspects referencing these works.

Comment above

Sect. II.A

The operating principle of 3-way DPA should be at least described to allow the reader to clearly understand the content of this section. Moreover, it is required to avoid confusion among 3-way or 3-stage definition (as described for instance in the book “HIGH EFFICIENCY SOLID STATE POWER AMPLIFIERS”, chapter 11). In this design it is not clear what is the operating mode, thus rather than the fig.2 alone, it was much more appreciated and useful to resemble what kind of operation/behavior is expected from the Carrier and 2 Peaking amplifiers.

Please check the text since there are several English mistakes and one sentence without meaning (maybe it has been cut some part) “In this work the combiner design which will be described in the next section”

We described what is a multi-stage multi way Doherty PA in this work. We also added the theorical behavior expected for N-way DPA. We removed this sentence.

Sect. II.B

The design should be described more in details, to be appreciated from a scientific point of view, e.g.

• how the devices ‘sizing was selected,

• their stability issues, if considered

• the design of the input splitting and proper phase compensations

• how the bias points were selected

• etc.

Moreover, a section and three references (3-4-5) to discuss about a quite “standard” approach, i.e., the compensation of CDS in the design of a lambda/4, seem to be exaggerated (while other more useful references were completed omitted!).

Section II was re-structured with further explanations in II.A and II.B, in order to explain more clearly the context, ideas and emphasize on importance of 3-way, and Cds cancellation in this approach. A new section II.C was written to add further design relevant techniques used in the presented work. We did not mention them before as we thought them to be too much a “standard” way of design but appreciate to include this here to allow the reader a better judgement of how we got to the results.

In this section, please check the English also, some sentences are not clear and seem to be not correct/truncated.

Corrected

Sect. III

It starts with the motivation… referring to a catalogue! It is a self-citation without any added value!

It was not the goal, we wanted to refer to the datasheet giving to the reader the possibility to see more technical information as ruggedness, repeatability in production. We removed it from this section. Actually, the reference is not a catalogue, but the outcome of this work, which is a product with its datasheet as reference. It was added for scientific comprehensiveness, but without the intention of self-citation (the cited datasheet is not a journal article and has no official citation ratings, nor any specific authors which would benefit from it). In other words, we are completely open to remove this reference, if the reviewer does not agree on this.

Sect. III-A

It should be motivated (by discussion or references) why the lambda/4 feeder does not allow high IBW (if it was the responsible and not the cap-decoupling…).

We added discussion to explain more why LFR is limited by parasitic Cds and parasitic inductors seen by the carriers. Moreover, we added references.

The results reported in fig. 5 shown the right movement of the base-band resonance, but also the strange effect at the limit of the amplifier BW (around 1.4-1.5GHz). It should be at least commented and discussed!

We commented it.

Sect.III-B

Even if it is quite ambiguous to define exactly the Doherty region (i.e., the BO), from fig. 7 it seems to be roughly from 40 to 47dBm of output power (7dB). It should be discussed.

We commented it.

Moreover, if possible I suggest to use for the efficiency a more readable scale (i.e., the tick labels should correspond to the horizontal lines to help the reading of correct values…)

We splittered results in two graphs.

Sect.III-D

Summary?

We modified it in “Discussion of measurement results”.

The title is at least confusing and does not reflect the content (I was expecting a sort of comparison with state of the art).

We compared with “state of the art” PAs regarding in both case the application. We chose PAs presenting wideband linearized efficiency in the interest frequency band (and also design for Macro or m-MIMO application). We think it’s not relevant to compare DPAs which are not displaying linearized results for wideband signal because in industry it’s the most complicated performance and it’s impossible to judge PAs without taking in account this key parameters for cellular industry, especially for 5G.

Please revise the English content of this section also.

Corrected

Sect.4

It could be interesting, but in this form its reading is quite difficult. If there is any scientific novelty it should be properly put into evidence. Otherwise it is a classical activity performed to design the packaging/amplifier without any new relevant contribution.

We tried to improve the text to point out better the novelty and achievements. Please note that in in general (especially in industry) usually 2D/2.5D EM simulators are used for MMIC design, while 3D EM simulators are used to simulate the package environment. In most cases, this leads to an acceptable tradeoff between simulation accuracy and simulation time. However, for more complex 3-way multi-stages architectures with high gain (e.g. 30dB) we see that it was not enough due to the multiplication of passives components to realize the splitter and combiner, the different phases present in the amplifier branches and the compactness of the design (all together leads to frequency dispersion, which is different in each amplifier branch and therefore significantly degrades the results). It was the first time that we implemented a full 3D simulation workflow to analyze this impact (3D EM sim of the MMIC passives + wires + package all together). We think that this is not a standard approach in engineering, as in many cases is it either not needed (lower gain, less compact), or wideband linearizability is not measured, or due to a less complex DPA architecture, the impact is less visible. Also, often 3D EM simulation is worse for accuracy when simulating MMIC (compared to 2.5D) due to practical issues in meshing etc (e.g., need to simulate MIM caps with nm thickness as well as package with mm dimensions). The problematic is the same than with envelope simulation for wideband signal, from theorical point of view this is the “best” model to use however depending the boundaries conditions you can have converge issues and wrong results. In this case it was the same due to the high complexity and integration of the 3-way DPA many efforts has been put to work out the good conditions and to have a good prediction of the coupling effects.

In summary, we hope that we could point out that the novelty lies in design approach which allows excellent prediction of RF performance and wideband DPD linearizability, with good agreement btw. sim and meas., proven by good results compared to literature (especially for LDMOS, but also when comparing to GaN). And also to give some clues for engineers to solve this potential issue which should appear more and more with the integration request, high gain in small package (LGA, MMIC) and complex architecture to constantly increase efficiency.

Again the last sub-session title is confusing (summary)

We modified it in “Discussion of measurement results”.

Sect.5

It has been jumped in the enumeration…

Corrected

References

Most of them are not reported in a standard form For example, in 3 are missing the authors, in 4 and 5 the page numbers, etc.

Please check and complete as in standard way!

We corrected the one we made mistakes on authors names or page but for some pages were missing on IEEE library too.

At the end, the paper misses a comparison with state of the art, which should be mandatory to properly validate the scientific content and deserve a publication status

As discussed above we compared each PAs with the most relevant state of the art PAs in each section “Discussion of measurement results”. Or we missed the interpretation of “at the end”, in the sense at the end of the paper (physically) or in general.

We wish you excellent Christmas holidays.

Regards

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