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EXCEPTIONALLY EFFICIENT AND MULTIPACTION-FREE P-BAND GAN HIGH-POWER AMPLIFIERS FOR SPACE APPLICATIONS

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Abstract— *on this paper, the authors file upon the improvement of multipaction-loose P-band (UHF) GaN high-power amplifiers (HPAs) with goal RF output power values of a hundred and forty W and electricity-delivered performance beyond 70%. initially, two exceptional 80-W magnificence single-ended energy modules have been designed, synthetic, and examined the usage of GaN devices from different producers. Load–pull strategies had been used in each designs to achieve the fine tradeoff in terms of RF output energy, performance, and balance. Secondly, two equal energy modules had been blended in a balanced architecture as a way to attain the specified level of RF output strength. Multipaction analyses and assessments have been completed to assure dependable operation in area. The HPAs had been characterized over temperature from 15 C to fifty five C in pulsed and regular-wave situations, displaying negligible drifts over temperature and multipaction-free operation. RF output power in extra of one hundred eighty W at 70% drain performance is also verified.*

Index terms—Balanced amplifier, GaN, excessive performance, excessive-power amplifier (HPA), multipaction, satellite, stability.

I. INTRODUCTION

BIOMASS is the 7th eu space-borne Earth Explorer mission. the overall objective of the undertaking is to reduce the uncertainty in the international spatial distribution of the forest biomass and to reveal its dynamics from space for you to enhance cutting-edge exams and destiny projections of the global carbon cycle [1]. since the spacecraft is planned to be launched in 2020, pre-trends for the crucial components are currently ongoing the principle device of the spacecraft is a P-band (UHF) completely polarimetric synthetic aperture radar (SAR) this is extensively utilized for appearing interferometry [2]. preliminary system studies found out the need to produce an RF output power in excess of 100 W (50 dBm) at the output of the RF amplifier [1]. but, although most of the required passive microwave devices inclusive of filters, switches, and couplers are already industrial off-the shelf, no commercial product is to be had for the highpower amplifier (HPA) function. due to the provider frequency at 435 MHz, a vacuum tube device could be very large and heavy for its lodging on the spacecraft, and consequently, solid-nation technology are considered for amplifying the radar sign. There are few semiconductor technologies qualified for excessive RF electricity operation in space. For years, GaAs has been the workhorse for this sort of programs. however, the desired RF output energy requires greater powerful semiconductor technology on account that using GaAs strategies would require complex energy combination schemes and more hard thermal management. GaN generation alternatively appears to be better acceptable for this application. for example, the paintings in [3] and [4] demonstrates the competencies of GaN generation to satisfy those necessities.

The need to perform RF hardware at this frequency and RF electricity degrees in space makes the device very at risk of suffer from Multipaction and Corona discharges, as defined in [5]–[7]. those phenomena are widely discussed in the literature for the layout of filters, diplexers, and waveguides. on this paper, the paintings in [4] is improved with a deep research on multipaction discharge inside the layout of stable-nation power amplifiers (SSPAs). To the authors' information, it's far the primary time such analysis and studies is mentioned.

This paper is organized as follows. section II describes, in a more distinctive way than in [4], the design of 80-W GaN power modules by using RF power transistors from two different manufacturers. Simulated and measured results of the RF energy modules are given and as compared. segment III tackles the design of excessive-energy sections for the SSPA, wherein multipaction phenomenon is

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extensively mentioned. segment IV describes the producing and take a look at consequences of the SSPA. This paper ends with conclusions in section V.

I. DESIGN, MANUFACTURE, AND TEST OF POWER MODULES

manufacturers have been selected most of the distinct suppliers with commercially to be had space qualified GaN transistors. United Monolithic Semiconductors (UMS) provide an 80-W device (CHK080A) in a ceramic–steel-flange package, using the distance qualified 0.5- m gate-period GaN HEMT on an SiC method with 65% traditional electricity-delivered efficiency (PAE) at 435 MHz. further, Mitsubishi electric powered offer an unequalled 80-W area certified device (MGF0849GS) the use of a zero.7- m gate-duration GaN HEMT on an SiC method with 66% ordinary PAE at 435 MHz. both transistors are nicely desirable for area applications and gift a mean time to failure 10 h. primarily based at the manufacturers' information sheets and nonlinear fashions of the electricity devices, the layout of the strength modules has been done. The modules are collection tuned transfer mode amplifiers, where the active tool behaves like a switch operated by using the gate–source voltage. nevertheless, they may be now not

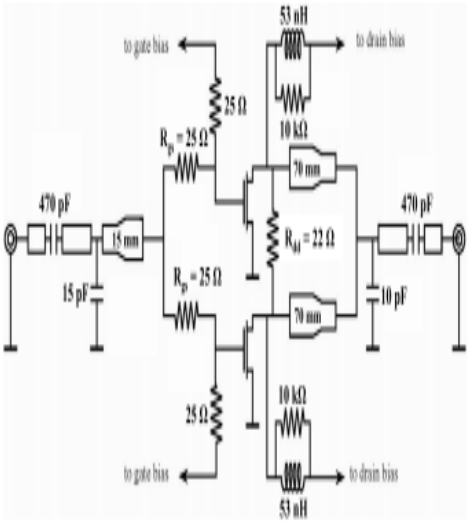

Fig. 1. Detailed schematic of the RF power module based on dual-gate dual drain GaN HEMT device from UMS (CHK080A). Location is shown.

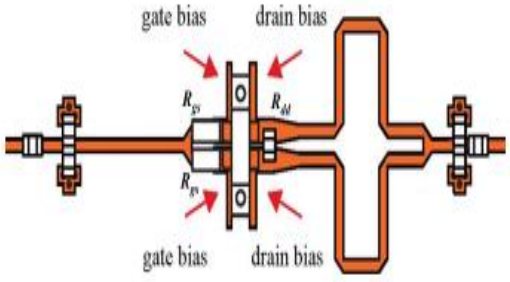

Fig. 2. Layout of the RF power module based on GaN HEMT device from UMS (CHK080A). The dual-gate–dual-drain matching is illustrated.

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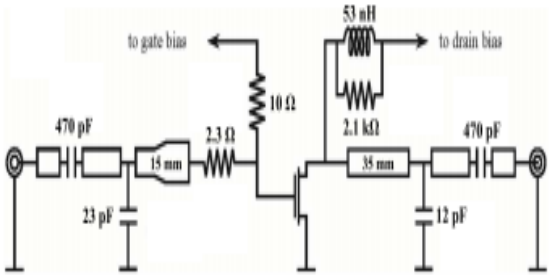

Fig. 3. Detailed schematic of the RF power module based on dual-gate and dual-drain GaN HEMT device from Mitsubishi (MGF0849GS).

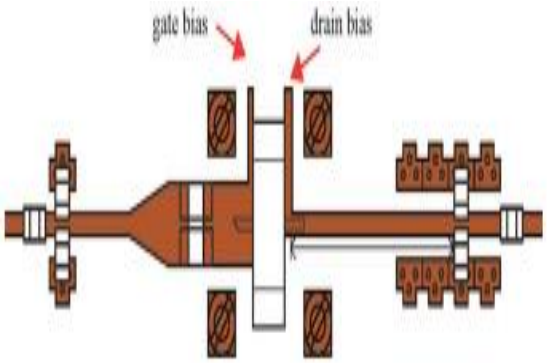

Fig. 4. Layout of the RF power module based on GaN HEMT device from Mitsubishi (MGF0849GS).

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true elegance-E, as neither the drain voltage nor the drain contemporary is 0 at the switching instantaneous [4], [8].

two single-degree single-ended circuits have been designed counting on CHK080A and MGF0849GS GaN HEMT gadgets from u.s.a.and Mitsubishi, respectively. Load–pull simulations were executed buying and selling off RF output strength, balance, and dc-to-RF efficiency and reliability. certainly, the latter is of fundamental significance in space programs because of the truth that the SSPAs are expected to paintings nominally after several years of non-stop operation without the want for renovation and even as struggling the worrying and dangerous conditions of space (i.e., radiation, getting older, and temperature versions). consequently, more relaxed operating conditions are installed with the aid of design, additionally known as derating, in which GaN HEMT devices are operated at around 75% in their absolute electric most rankings and underneath a given junction temperature value ( ). by doing so, the risk of failure and degradation through the years is minimized with a fee to pay on RF performances, mainly at the maximum possible PAE and RF output strength concerning the layout of the electricity module based on the u.s.GaN transistor, enter and output matching networks with a dual-gate–dual-drain configuration were applied (Fig. 1). tremendously large series resistors at input reduce the interactions among the 2 paths at the running frequency, also preventing low-frequency oscillations. As shown in Fig. 1, series impedances to every drain before the 2 paths are joined together at the output tuning capacitances minimizes the interplay underneath nominal, even operation of the two drain paths. Resistor prevents asynchronous operations inside the shape of odd-mode oscillations.

TABLE I
SUMMARY OF SIMULATED POWER MODULE CHARACTERISTICS

Parameter	Module CHK080A		Module MGF0849GS	
	Simulated	Measured	Simulated	Measured
V_{ds} (V)	40	40	40	40
Output Power (dBm)	49.03 (80 W)	49.75 (94.4 W)	49 (79.4W)	49.3 (85.3 W)
Gain compression (dB)	2.4	2.6	2.3	2.4
Drain Efficiency (%)	66	74.14	72	68
Linear gain (dB)	22	21	21	23

The layout of this layout is proven in Fig. 2. A Rogers RT6002 substrate has been used with a thickness of zero.762 mm. The layout of the strength module based at the Mitsubishi GaN transistor is shown in Fig. 3. A low-frequency stabilization network is carried out via a combination of parallel and collection losses inside the sign route (i.e., series resistors on the gate signal route).

Matching networks are of a chain tuning kind with an L–C filter out at each the enter and output. The format of this version is shown in Fig. 4. The same substrate from Rogers has been used, reaching a similar layout length (eleven.5 cm five cm). the two synthetic forums were examined and results were reported in [4].

A precis desk is reported right here again for comfort (desk I). In popular, both designs are capable of acquire the desired levels of output energy, but the power module based totally at the u.s.a.GaN device provides better ranges of efficiency. As may be discovered, the usanonlinear model underestimates the real performances of the transistor.

To verify this factor, one of a kind GaN devices from the same batch have been assembled inside the same board, acquiring negligible drifts within the RF performances. as a substitute, the nonlinear model of the Mitsubishi GaN HEMT tool seems to be more particular and is capable of expect greater accurately the actual RF performances the stability of the linear and nonlinear regimes become analyzed from the

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very early degrees of the layout with the aid of the usage of automated pole-0 identity strategies defined in [9] and

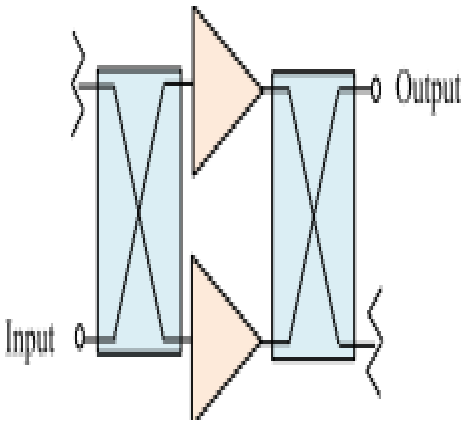

Fig. 5. Balanced architecture of the high-power final stage of the SSPA.

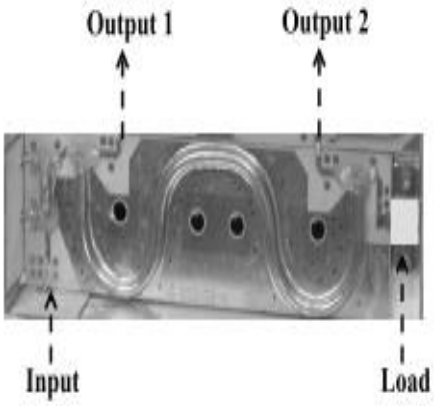

Fig. 6. Photograph of the wireline coaxial coupler. Input and output ports are also shown in the photograph. [10]. Unconditional balance became performed by way of the use of stabilization resistors at the gate ( ) and inter-department resistors between the drains of the transistor ( ). Following the approach described in [11], a price of became calculated. No oscillations have been located in the manufactured amplifiers.

III. DESIGN OF THE HPA

The SSPA overall performance relies upon essentially at the characteristics of its RF excessive-power section. In this example, a 50- matched balanced architecture through the use of quadrature couplers for the energy splitting and combining capabilities is followed with identical eighty-W class GaN HEMT strength modules in parallel (Fig. 5). consequently, the development of the unmarried-level single-ended amplifiers in Figs. 1 and three is of fundamental importance on the way to achieve the desired tiers of RF output power and efficiency even as booking a stable conduct.

The balanced architecture with quadrature couplers is extensively carried out in space-borne SSPAs because the structure gives inherently exact go back losses at input and output interfaces and enhances the linear and nonlinear stability thanks to the isolation between branches, stopping undesirable loops with gain 0 dB. mainly, the design is primarily based on 3-dB ninety Wireline quadrature coaxial couplers produced by means of Sage Laboratories, St. Louis, MO, united states. these coaxial couplers include a couple of wire middle conductors (tousled to three turns per inch) surrounded by a continuous dielectric insulator and shielded with the aid of a drawn or extruded outer jacket. the consequent production has the physical attributes of a semi-rigid coaxial cable and the electric overall performance of a precision TEM mode parallel coupled line coupler with low insertion loss and high directivity. common insertion loss at 435 MHz is 0.25 dB with 20-dB go back losses over an octave bandwidth. A photo of this coupler is shown in Fig. 6.

An output isolator is commonly added downstream to the output coupler in an effort to present a consistent load impedance to the amplifier, stable conduct, and more desirable robustness against any voltage status-wave ratio (VSWR) mismatch conditions

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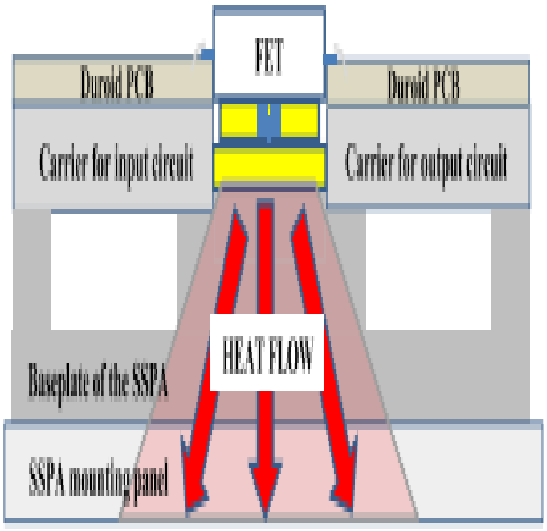

Fig. 7. Thermal flow diagram used for the calculation of the junction temperatures on the GaN HEMT devices.

irrespective of the VSWR tolerance of the lively gadgets. balance analyses by the usage of computerized pole-zero identification strategies [9], [10] were additionally performed on this balanced layout, confirming over again the stable operation of the HPA.

A. Thermal Management

in addition to the electric derating rules described previously, a derating rule for optimum junction temperature is likewise implemented for area-borne SSPAs. In this situation, and primarily based on MTTF exams accomplished on each GaN HEMT gadgets, a maximum of a hundred seventy five C was installed as a requirement. An evaluation has been made based totally on thermal resistances of the different layers where the gadgets are installed (Fig. 7). The HPAs are installed onto 2.five-mm-thick aluminum metallic vendors using a Rogers RT/Duroid 6002 substrate with a thickness of 0.762 mm. The companies are established onto a 13-mm-thick baseplate as part of the SSPA package, and sooner or later, the SSPA bundle is assembled onto a final baseplate at the mounting panel of the spacecraft. primarily based in this assembly, a easy thermal calculation can be achieved by means of the usage of (1), where is the temperature of the mounting baseplate, is the thermal resistance of the packaged transistor given with the aid of the manufacturer, is the height electricity dissipated, is the thermal resistance of the mounting meeting, and is the averaged dissipated power over the place of the HEMT packaged transistor primarily based at the measured RF performances, the thermal calculation in (1) suggests maximum values of 160 C and 126 C for the united states of americaand Mitsubishi GaN gadgets, respectively, while working inside the CW mode, and values of 137 C and 108 C while operated in pulsed conditions (60- s pulse-width, 12% responsibility cycle). those values are well underneath the most derated price considered for a dependable operation in area.

B. Multipaction, Corona, and Passive Intermodulation

when designing high RF energy gadgets, the subsequent phenomena can typically occur [7]:

• multipaction breakdown;

• ionization breakdown, also referred to as corona discharge;

• thermal related high-energy breakdown;

• passive intermodulation (PIM). As defined in [5], multipaction breakdown is an RF vacuum breakdown mechanism wherein secondary electron emission in resonance with an alternating electric powered discipline ends in exponential electron multiplication due to the boom of loose electron area fee between two surfaces (steel or dielectric). Corona is an electrical discharge brought on by means of the ionization of a gas or

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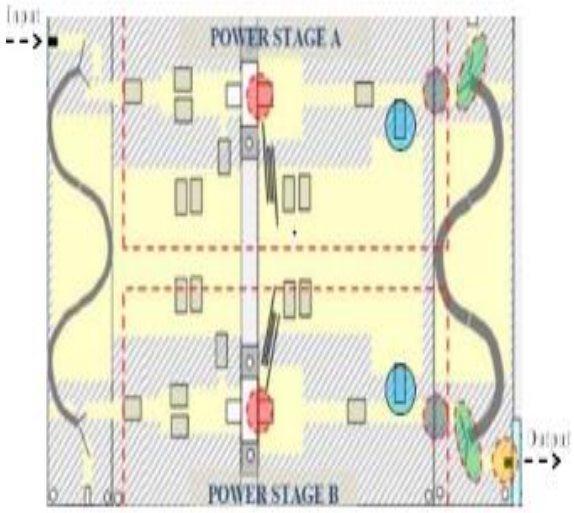

Fig. 8. Simplified top view diagram of the HPA. Five critical points are identified in dashed circles.

fluid surrounding a conductor that outcomes in the generation of plasma. If the ionized region continues to develop until it reaches another conductor at a decrease capability, a low-resistance conductive course among the two will be fashioned, resulting in an electric powered arc. opposite to multipaction, Corona discharge wishes the presence of air or fluid, which best happens in low-pressure environments. Thermal related breakdown can also appear if a device dissipates warmth. most of the substances used for manufacturing high-power RF hardware launch gas whilst they're heated up (outgassing). If now not properly vented, the released air can't escape and creates domestically an boom within the atmospheric strain that may finally cause a Corona discharge. eventually, PIM are intermodulation products generated with the aid of passive hardware along with filters, isolators, switches, and waveguide additives when they may be operated under multicarrier or digitally modulated alerts. it's far of precise interest in satellite transponders since the nonlinearities produced in the transmit chain can lie inside the frequency variety of the get hold of chain. nevertheless, the SSPA is according to se a nonlinear tool, and subsequently, PIM generated by means of the SSPA is well beneath the standard intermodulation produced through the amplifier itself.

amongst all high RF power phenomena described, multipaction is within the gift case the most important breakdown effect that wishes to be analyzed due to the fact that hermetically sealed gadgets are used to prevent Corona discharges and the housing of the SSPA consists of sufficient venting holes to reduce outgassing and thermal breakdown associated problems

A simplified pinnacle view schematic of the HPA is shown in Fig. eight, in which five critical areas at risk of trigger multipaction discharge are diagnosed because of the present gaps among steel surfaces. all these factors are downstream to the two electricity modules, which is the most effective location of the SSPA where excessive RF voltages and currents are present

The five points are, from left to proper, as follows:

1) connection from RF area-impact transistor (FET) to microstrip;

2) tuning capacitors between RF transmission line and floor;

3) transition from power module to output coupler;

4) transition from output coupler to microstrip;

5)transition from output microstrip to coaxial connector.

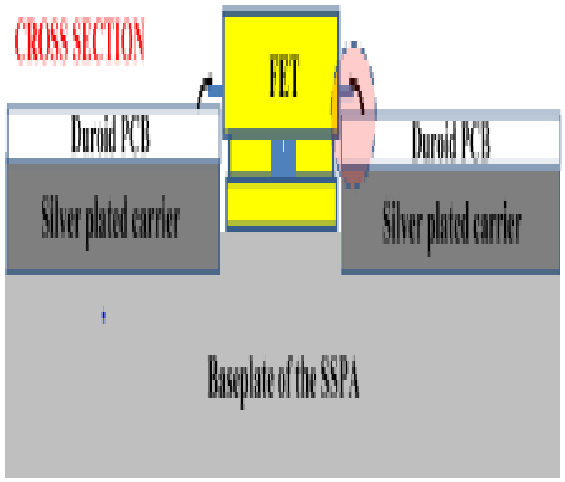

Fig. 9. go segment of the connection from RF FET and microstrip. The critical location for multipaction breakdown is represented by a dashed circle.

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dashed circle highlights the important location around the transistor's drain lead. in particular, the vital factor is the space among the drain lead and the microstrip steel floor, whose proximity can result in multipaction [5].

On one hand, the analysis based on the parallel-plate model is, in this example, no longer rigorous because it is not consultant of the actual geometry of the meeting, leading to very low discharge thresholds [5]. on the other hand, every other vital situation for the multipaction discharge is the presence of RF alternating fields. in the gift case, because of the followed elegance-E design method, the time-area drain-voltage waveform remains fine all through the total operation cycle, and consequently, the electrical subject has the same course at any given time. should the HPA present barely terrible voltages, the deliver voltage carried out to the drain line biases the electrical subject with appreciate to RF ground (chassis). This tends to prevent the initiation of an electron avalanche irrespective of the fee of the secondary electron-emission yield (SEY) of the surface fabric [12]. for this reason, this area is considered multipaction free.

2) Tuning Capacitors Between Transmission Line and Ground:

chip capacitors are related in parallel to the 50-transmission line at the output matching community of every power module (Figs. 2 and four). the height voltage on each capacitor spans preferably from a hundred thirty to 50 V, that is the variety similar to the 80 W of RF output electricity into the 50- load, with 40-V drain supply voltage offset. because of the size of each capacitor (kind CDR14), the gap between the microstrip and the floor metallization is best 1.6 mm, which leads to a frequency distance manufactured from zero.7 GHz mm at 435 MHz. due to this product cost and to the predicted voltage swing, this hole is liable to multipaction breakdown considering it is in the Hatch and Williams multipaction susceptibility location for aluminum metallic plates [5]. Fig. 10 shows the Hatch and Williams multipaction susceptibility sector for aluminum parallel plates extracted from [5], wherein a few measured factors on check samples affirm the validity of such a theory.

One manner of overcoming multipaction issues in the final design is to increase the gap between the RF sign direction and the floor metallic direction this could be executed by changing the chip capacitors through meandered open stubs of a given period sufficiently separated from the floor path. for example, a frequency distance made of 3.2 GHz mm gives a distance of 7.four mm at 435 MHz. This distance gives a threshold of a hundred and seventy W of RF electricity, which brings greater than three-dB margin to the existing case. three) Transition From power Module to Output Coupler: the 2 power modules are linked to a ninety quadrature coaxial coupler that is bodily assembled right into a unique silver-plated metallic service. A simplified drawing of the gap

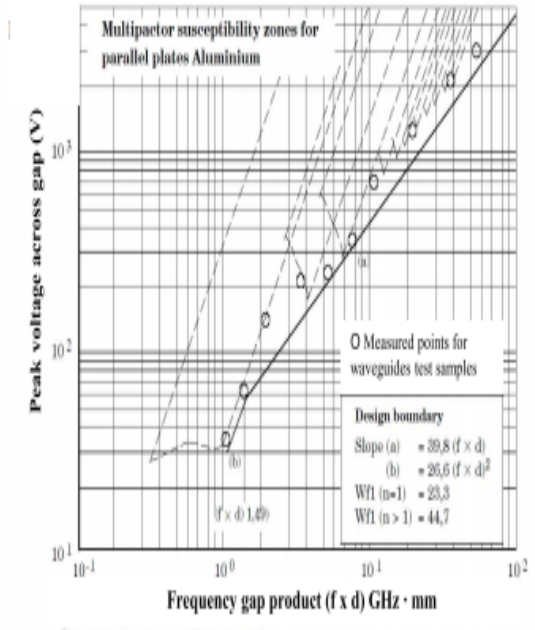

Fig. 10. Multipaction susceptibility quarter for parallel plates. Dashed strains represent the Hatch and Williams theoretical curves. stable line represents the bounds for the design of RF hardware prone to

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multipaction breakdown.

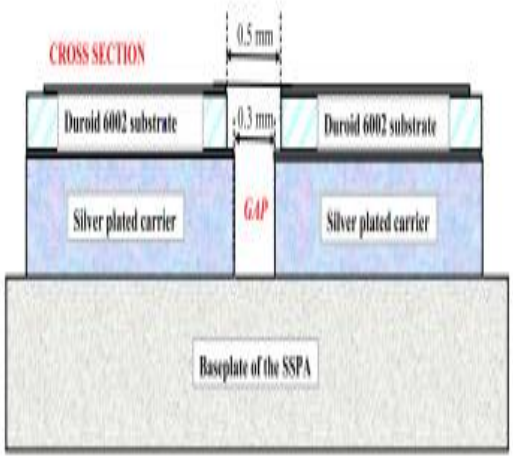

Fig. 11. pass segment of the transition from power module to output hybrid coupler.

among two interconnected microstrip strains is illustrated in Fig. 11. a gap of zero.five mm among the two steel vendors is described, that is guaranteed by using the use of a calibrated zero.three-mm spacer in the course of the module meeting within the SSPA. the 2 elements are connected by using the usage of a 3.8-mm-wide SnPb ribbon. For the multipaction evaluation, two exceptional substrate thicknesses are considered, 0.762 and 1.524 mm. The parallel-plate analysis may result in faulty consequences in this example since the SEY of the silver-plated copper metal surfaces is specific than the only for aluminum. consequently, a particular multipaction evaluation has been executed by using Aurorasat, Valencia, Spain. A three-D model of the shape has been created with CST Microwave Studio so as to calculate the S-parameters and extract the electromagnetic (EM) fields of the structure. The EM fields are then imported to SPARK3D, which is an evolution of the FEST3D software tool from Aurorasat able to decide the multipaction breakdown stage also in microstrip structures. effects of these analyses indicate margin degrees of 18 dB over the nominal RF energy (eighty W). certainly, because of the small distance among the substrates and among the two carriers, electrons that journey from the ribbon to the mounting plate are not likely to do it with out impacting the lateral partitions, breaking a probable resonance and leading to the absorption of electrons at the lateral walls despite the fact that, threshold consequences are very dependent on SEY values. consequently, with a view to verify simulated outcomes, a representative check jig of a connection between microstrip traces (Fig. 12) has been designed, manufactured, and tested inside the ecu.

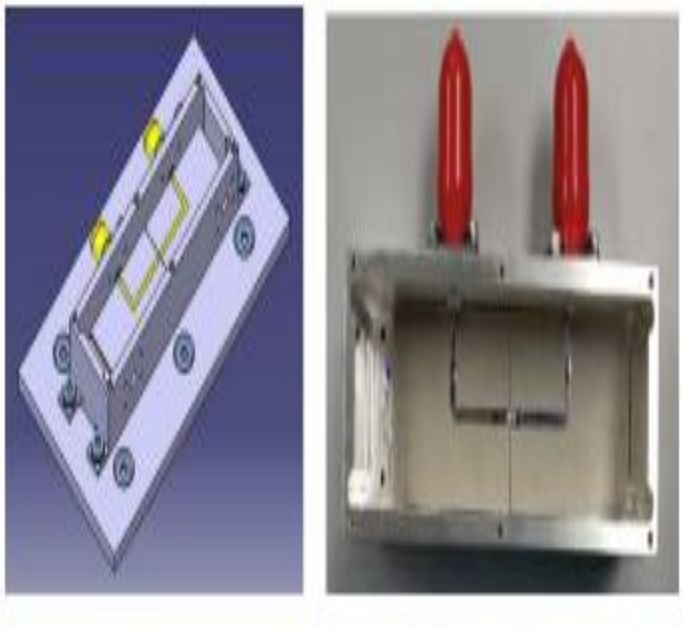

Fig. 12. 3-D structure and synthetic check pattern for multipaction verification of a connection between microstrip traces.

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Fig. 13. element of the inner conductor coaxial coupler connected to the microstrip. A resin with unknown SEY is used to prevent discharges.

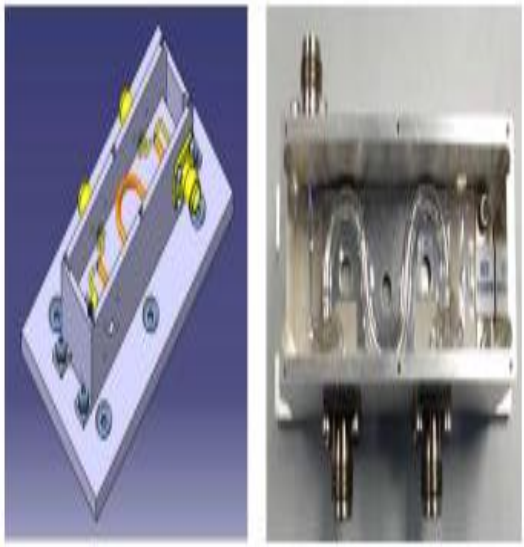

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Fig. 14. 3-D structure and synthetic take a look at sample for multipaction verification of a connection among output coupler and microstrip strains.

ropean space organization–Val space Consortium (ESA-VSC) european high power RF Laboratory, Valencia, Spain. The test turned into carried out with the device-underneath-test (DUT) operated at 435 MHz, five 10 mbar of pressure, temperature of fifty C, 60- s pulse width with 12% obligation cycle, and as much as an RF strength of 1.five kW (most available RF strength). previous to the take a look at, a bake-out of 18 h changed into performed at 60 C for outgassing functions. The DUT did now not present any discharge event up to at least one.five kW, confirming a multipaction margin level of at the least 12.76 dB via take a look at. four) Transition From Output Coupler to Microstrip: The wireline coaxial coupler defined in Fig. 6 is soldered to the microstrip lines. As you may look at in Fig. thirteen, the output of this coupler is covered by using a shielding resin, which targets to save you any discharge. it's far well worth noticing that the SEY of this resin isn't known, and consequently, a rigorous evaluation cannot be completed by way of manner of simulation.once more, a test pattern (Fig. 14) has been designed, synthetic, and examined within the equal facility.

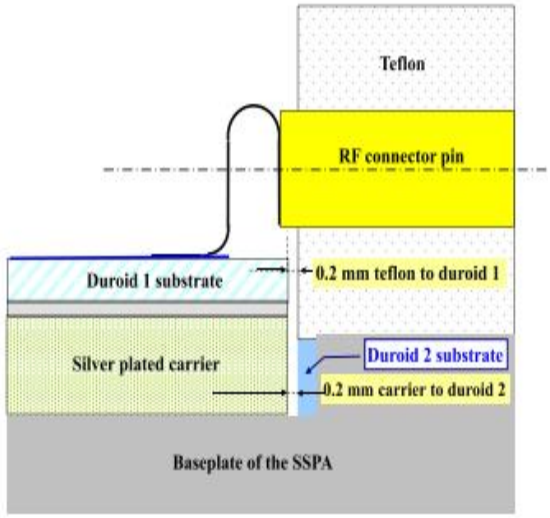

Fig. 15. cross segment of the transition from output microstrip to coaxial connector. vital gaps for multipaction breakdown are shown

check situations and bake-out have been the same as for the DUT of Fig. 12. A multipaction discharge become detected at a energy of 1375 W, organising in this example a margin of nine.38 dB for the reason

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that nominal RF output electricity at this factor is 160 W (two parallel power modules of 80 W).

5) Transition From Output Microstrip to Coaxial Connector:

A simplified drawing of a microstrip to coaxial connector transition is described in Fig. 15. The opportunity to cowl the distance between the connector and the provider through a dielectric fabricated from zero.25-mm-thick Duroid substrate (called Duroid 2 in Fig. 15) has been taken into consideration to prevent discharges around the floor of the wall. once more, substrate thicknesses (referred as Duroid 1 in Fig. 15) of zero.762 and 1.524 mm have been analyzed with and with out a Duroid filling plate on the connector aspect. SEY of aluminum turned into taken into consideration for the multipaction evaluation. in addition to the evaluation finished for the transition from the energy module to output coupler, CST Microwave Studio has been used to acquire the EM fields of the 3-D shape and the fields were imported to SPARK3D for the multipaction evaluation up to a maximum simulated energy of 10 kW. results are the subsequent.

• Case 1: zero.762-mm Duroid substrate with filling plate 10 kW (18-dB margin).

• Case 2: zero.762-mm Duroid substrate without filling plate 10 kW (18-dB margin).

• Case three: 1.524-mm Duroid substrate with filling plate 3 kW (12.77-dB margin).

• Case 4: 1.524-mm Duroid substrate with out filling plate 1.6 kW (10.04-dB margin).

The motive at the back of the distinctive consequences for each substrate thicknesses is the ensuing geometry of the overall shape that does not permit sustained electron resonance trajectories among special zones in the connector. Electrons easily escape from the connector vicinity entering the unfastened area wherein they're lost. the use of the filling plate allows an additional margin of 3 dB inside the case of the thicker substrate because of the truth that the distance distance is reduced, which does not allow electrons to benefit sufficient kinetic power.

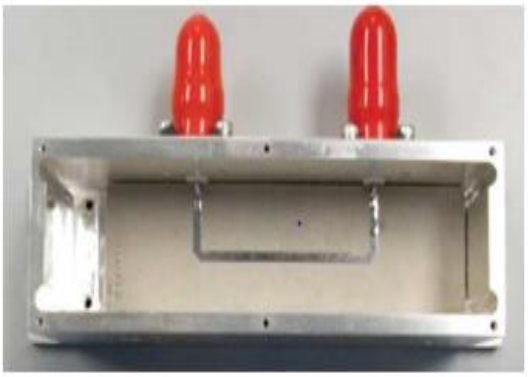

Fig.16. manufactured check pattern for multipaction verification of a transition from output microstrip to coaxial connector.

TABLE II
SUMMARY OF MULTIPACTION ANALYSIS AND TEST CAMPAIGN

ID No.	Assembly	Conclusion
1)	Connection from RF FET to microstrip	Multipaction free (No alternating Electric fields)
2)	Tuning capacitors between transmission line and ground	Risk for Multipaction: design modification replacing chip capacitors by open stubs, achieving > 3 dB margin
3)	Transition from power module to output coupler	Risk of Multipaction: Discharge predicted at 18 dB above nominal RF power, measured > 12.76 dB margin (limited by RF power available)
4)	Transition from output coupler to microstrip	Risk of Multipaction: Simulations not reliable due to unknown SEY. Measured + 9.38 dB margin above the nominal RF power. Prevention by surfaces protection with resin
5)	Transition from output microstrip to coaxial connector	Risk of Multipaction: Discharge predicted at > 10 dB margin above the nominal RF power. Measured > 9.76 dB margin (limited by available RF power)

despite the fact that a margin of 18 dB is discovered out inside the evaluation with SPARK3D, a take a look at pattern has been also designed, manufactured, and tested inside the ESA-VSC laboratories a good way to verify the consequences (Fig. sixteen). check conditions and bake-out have been the same as for the DUT of Fig. 12. No multipaction phenomenon became observed as much as the maximum to be had RF energy of one.5 kW, giving a threshold margin of at least nine.76 dB by using take a look at.

The multipaction important regions of the proposed HPA were described and punctiliously analyzed.

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results of these analyses and tests have been the intent for the adopted design approach on the way to save you multipaction discharge. table II summarizes the primary consequences for the five essential areas recognized.

IV. MANUFACTURING AND TESTING OF GaN HPAs

primarily based on the layout concerns described in the previous paragraphs, two specific balanced GaN HPAs had been synthetic and examined over temperature in the variety from 15 C to 55 C and in pulsed conditions (60 s, 12% duty cycle). The snap shots and dimension effects of the HPAs are reported in [4]. although, the main RF performances are stated right here again for completeness. Fig. 17 reviews RF performances of the balanced HPA based at the americaGaN devices. It grants extra than 18 dB of linear.

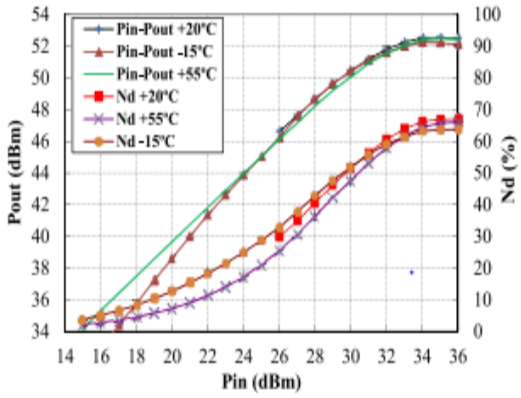

Fig. 17. Measured pulsed RF output strength and drain performance from 15 C to fifty five C of the usabalanced

HPA.

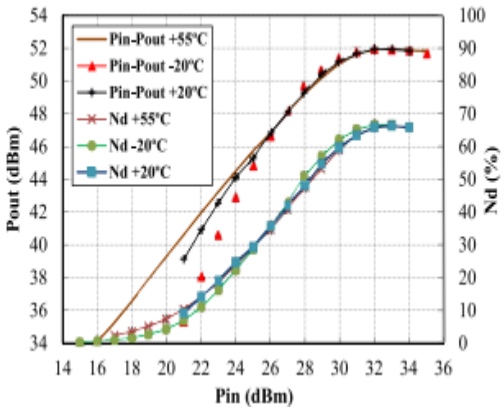

Fig. 18. Measured RF output power and drain efficiency from 20 C to fifty five C of the Mitsubishi balanced HPA.

gain, an RF output energy of a hundred and eighty W, and a drain performance exceeding sixty five% whilst operated at ambient temperature. A excellent stability over temperature is received for the nominal running point (2.5-dB output compression). in addition, Fig. 18 shows measured RF performances obtained from the balanced HPA based at the Mitsubishi GaN gadgets. It reports at ambient temperature greater than 150 W of RF output energy with 19 dB of linear benefit and 66% of drain performance while operated in saturation. The variation of the RF performances over temperature (from 20 C to fifty five C) around the running factor is negligible.

V. CONCLUSIONS

two distinct 80-W elegance P-band GaN energy modules were designed, manufactured, and tested with GaN HEMT devices from u.s.and Mitsubishi. The layout approach has traded-off RF performances which include efficiency, RF output energy, and derating issues for a reliable operation in area. using the 80-W class strength modules, distinctive balanced HPAs had been designed, synthetic, and tested, demonstrating its feasibility to cowl the destiny wishes for the biomass undertaking. A committed a part of the paper has furnished an in-depth analysis on excessive RF electricity phenomena in space such

as multipaction, Corona discharge, and thermal managing effects for this kind of equipment. crucial areas for multipaction discharge were identified and analyzed in detail by means of theoretical curves,

specific simulation gear, and devoted checks campaigns on numerous assemblies. those analyses had been used to put in force the specified changes inside the design if you want to save you electrical discharges even as working in area.

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