APPLICATION NOTE

MITSUBISHI ELECTRIC
Silicon RF Power Semiconductors

Document NO. AN-UHF-112
Date : 27th May 2011
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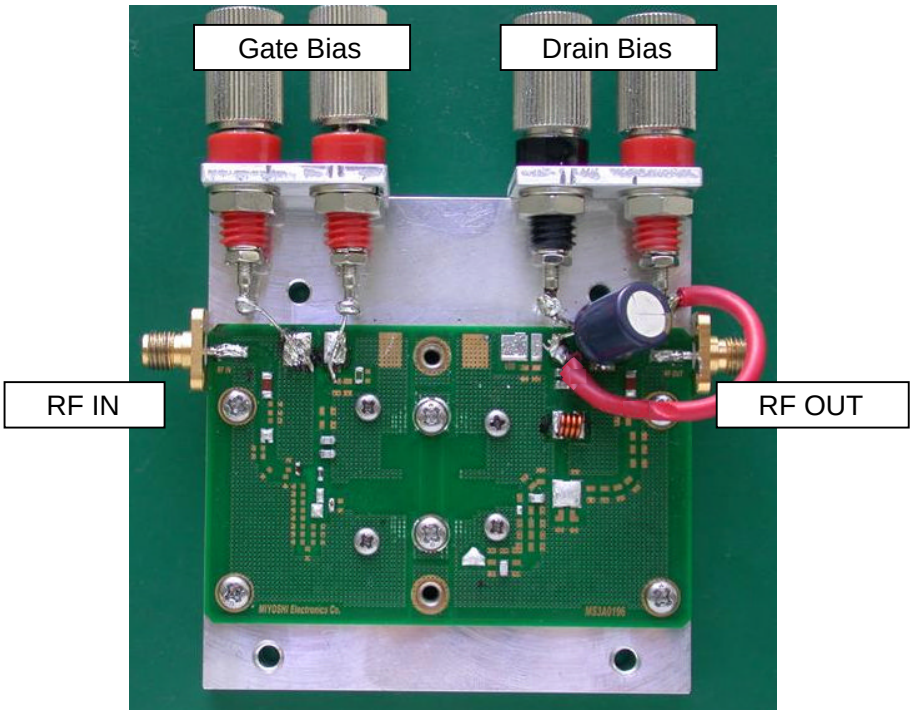
(Taking charge of Silicon RF by
MIYOSHI Electronics)

SUBJECT: RD35HUF2 single-stage amplifier with f=450-530MHz evaluation board

Features:

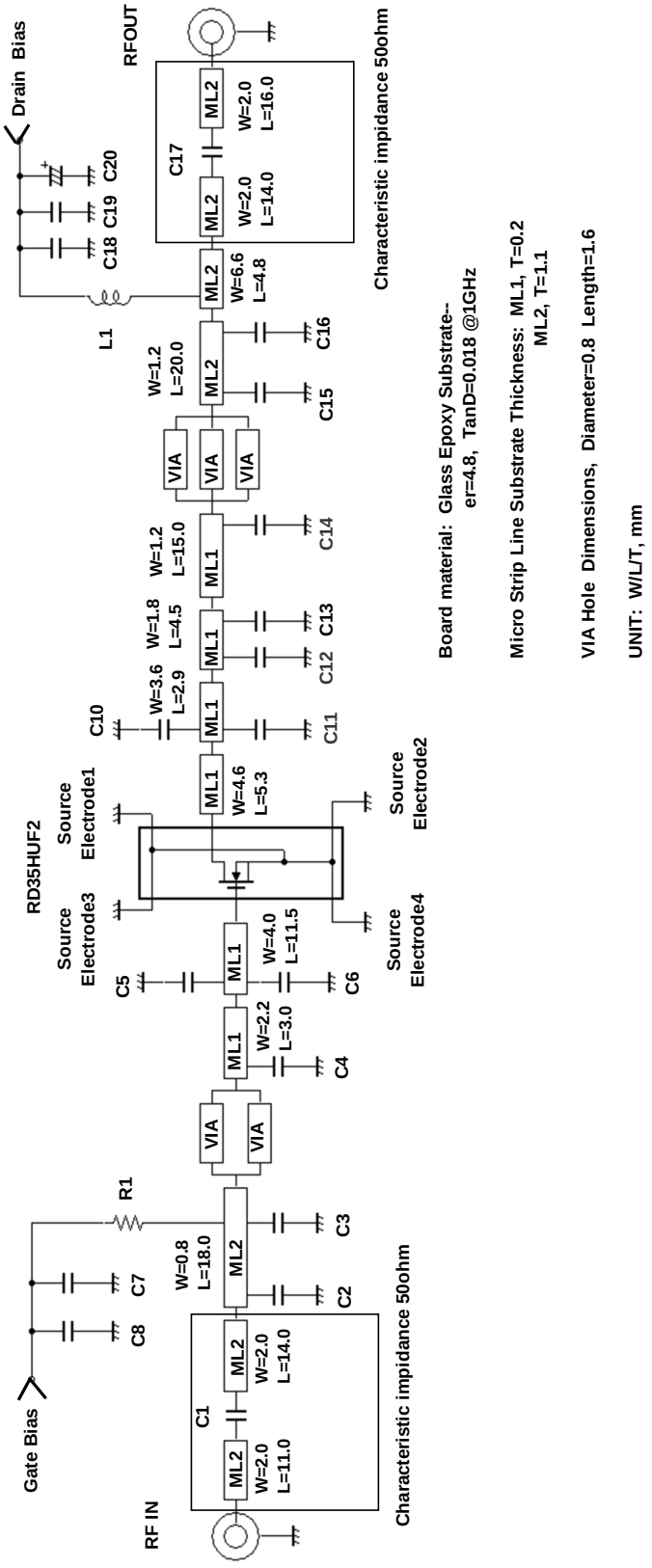
- The evaluation board for RD35HUF2
- Frequency: 450-530MHz
- Typical input power: 3W
- Typical output power: 40W
- Quiescent current: 500mA
- Operating current: approx. 6A
- Surface-mounted RF power amplifier structure



PCB L=75mm W=46mm

Contents

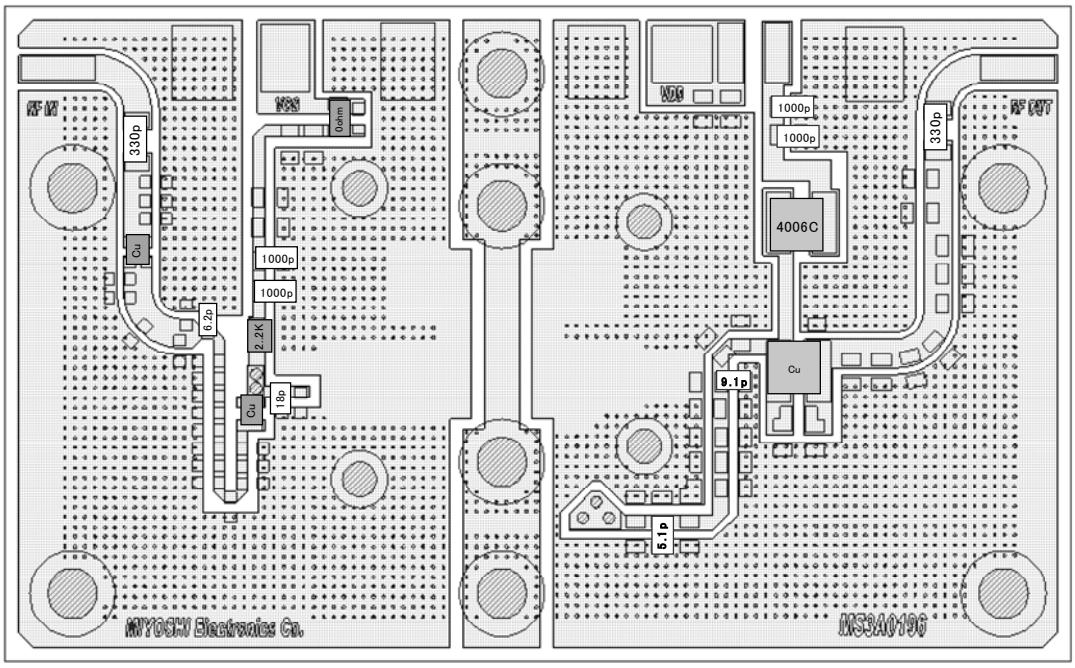
1. Equivalent Circuitry



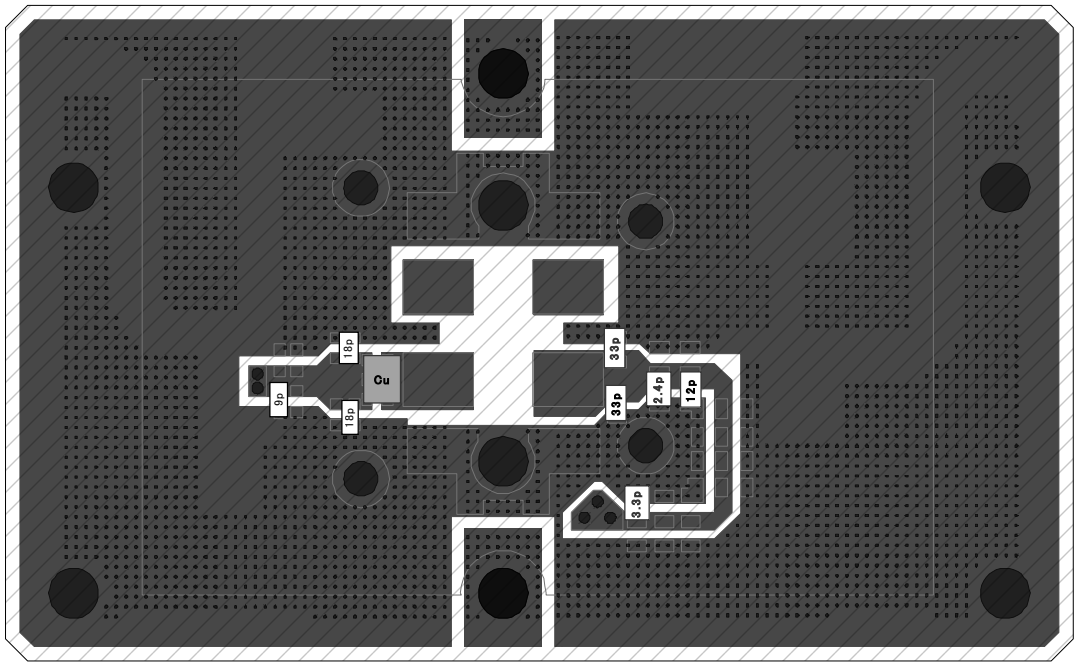
2. PCB Layout

BOARD OUTLINE: 75.0*46.0(mm)

TOP VIEW (Layer 1)

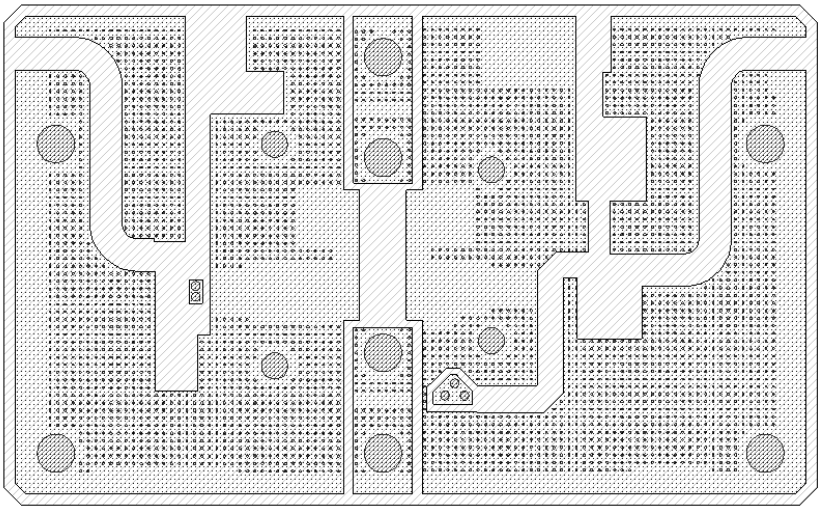


BOTTOM VIEW (Layer 4), Perspective through Top View

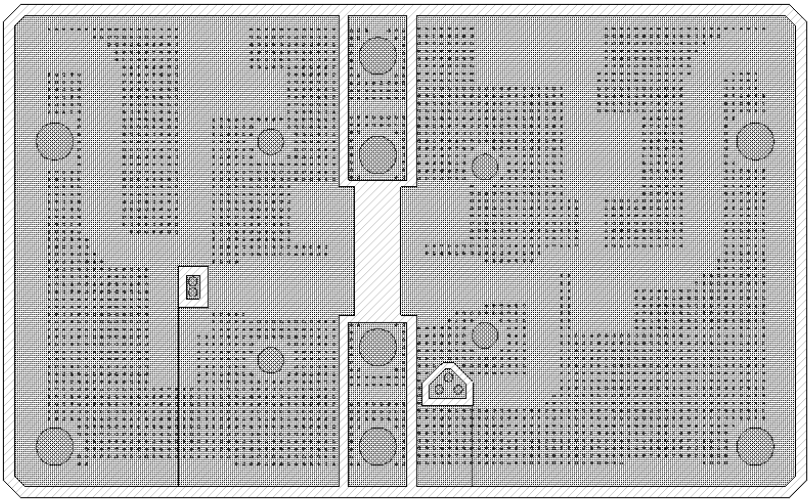


BOARD OUTLINE: 75.0*46.0(mm)

Internal Layer (Layer 2) , Perspective Through Top View

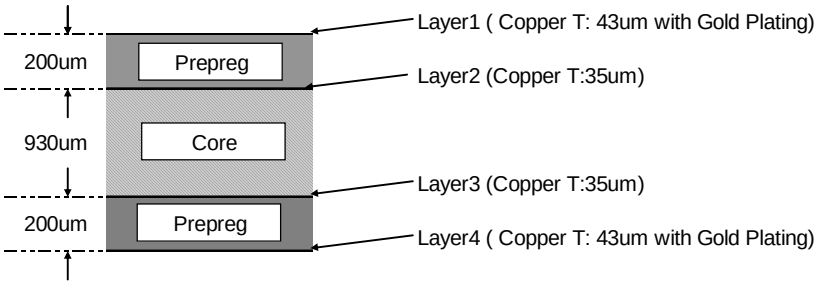


Internal Layer (Layer 3) , Perspective Through Top View



Substrate Condition

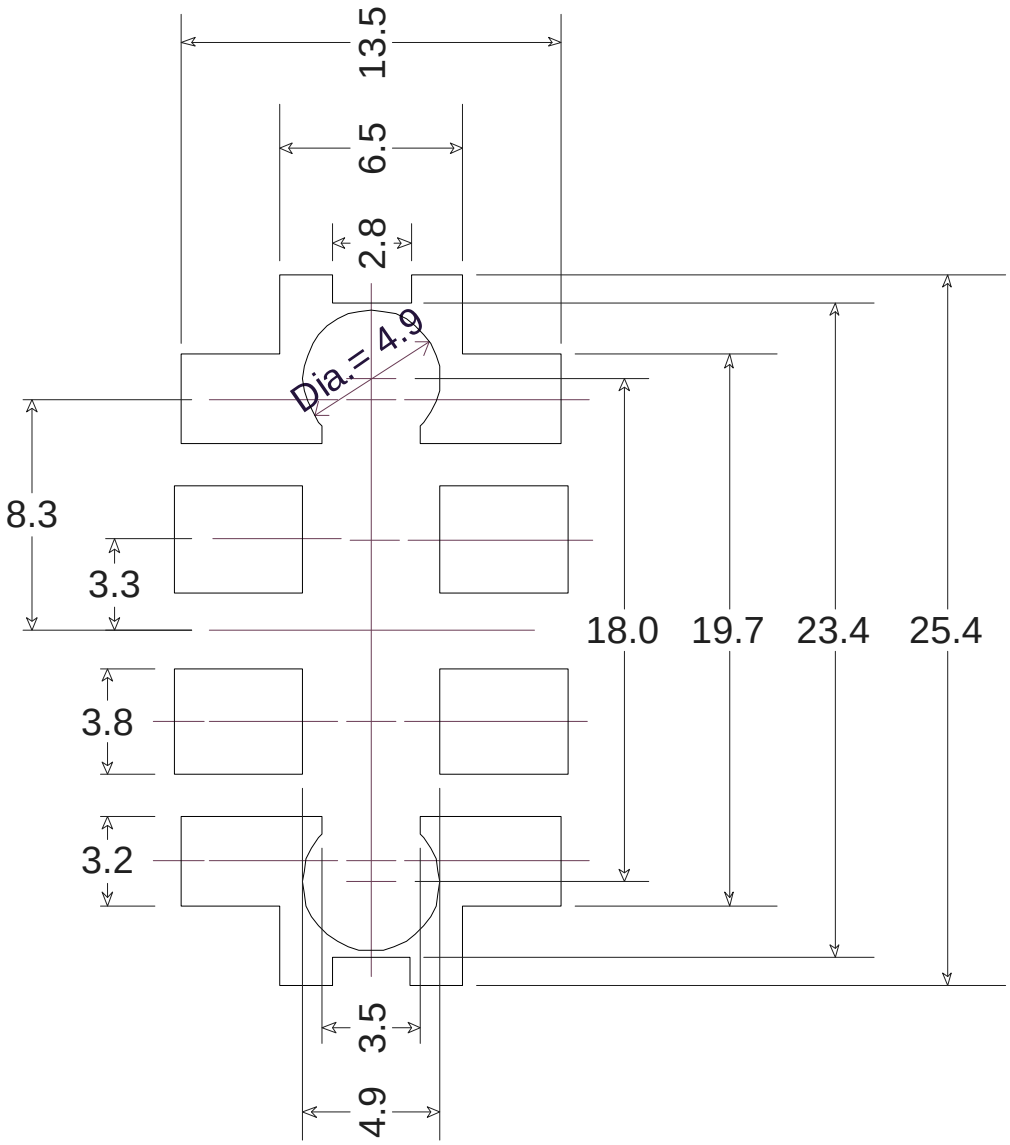
Nomial Total Completed Thickness (included resist coating): 1.6mm



Er: 4.7 @ 1GHz
TanD: 0.018 @ 1GHz

Material: MCL-E-679G(R), Hitachi Chemical Co.

3. Standard Land Pattern Dimensions



UNIT: mm

4. Component List and Standard Deliverable

- Component List

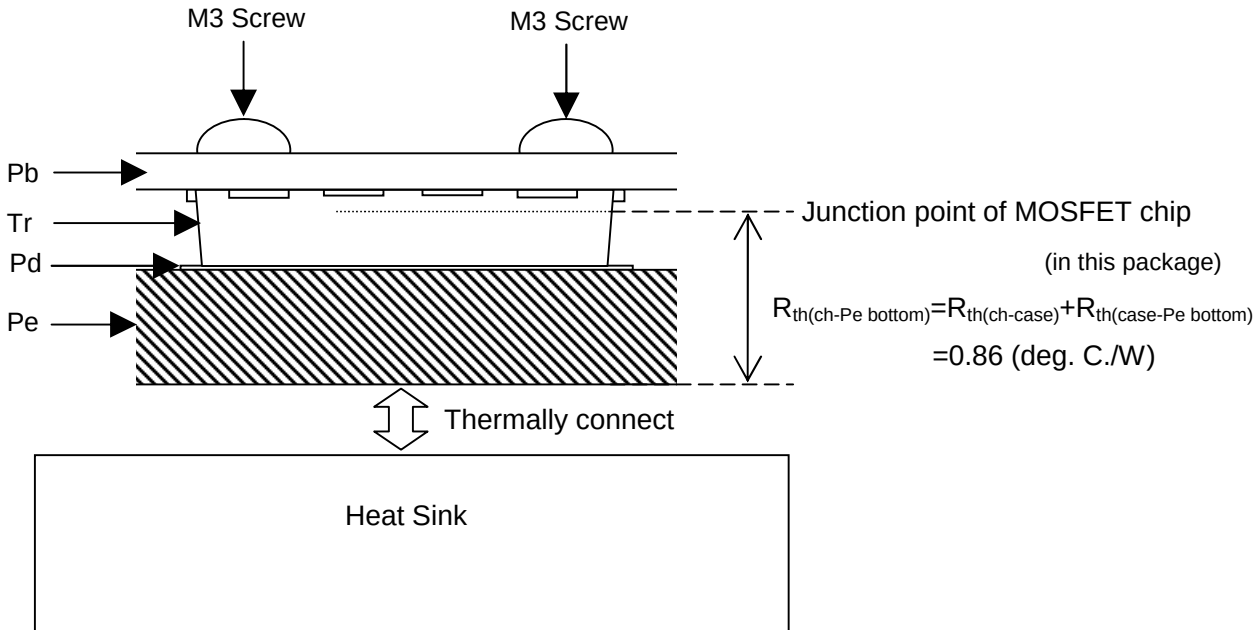
No.	Description	P/N	Qty	Manufacturer
Tr	MOSFET	RD35HUF2	1	Mitsubishi Electric Corporation
C 1	330 pF 3216 200V	GRM31M2C2D331JY21B	1	MURATA MANUFACTURING CO., LTD.
C 2	6.2 pF 1608 Hi-Q 100V	GQM1882C2A6R2DB01	1	MURATA MANUFACTURING CO., LTD.
C 3	18 pF 1608 Hi-Q 50V	GQM1882C1H180JB01	1	MURATA MANUFACTURING CO., LTD.
C 4	9 pF 1608 Hi-Q 50V	GQM1882C1H9R0DB01	1	MURATA MANUFACTURING CO., LTD.
C 5	18 pF 1608 Hi-Q 50V	GQM1882C1H180JB01	1	MURATA MANUFACTURING CO., LTD.
C 6	18 pF 1608 Hi-Q 50V	GQM1882C1H180JB01	1	MURATA MANUFACTURING CO., LTD.
C 7	1000 pF 2012 50V	GRM2162C1H102JA01B	1	MURATA MANUFACTURING CO., LTD.
C 8	1000 pF 2012 50V	GRM2162C1H102JA01B	1	MURATA MANUFACTURING CO., LTD.
C 10	33 pF 2012 Hi-Q 50V	GQM2192C1H330JB01	1	MURATA MANUFACTURING CO., LTD.
C 11	33 pF 2012 Hi-Q 50V	GQM2192C1H330JB01	1	MURATA MANUFACTURING CO., LTD.
C 12	2.4 pF 2012 Hi-Q 100V	GQM2193C2AH2R4CB01	1	MURATA MANUFACTURING CO., LTD.
C 13	12 pF 2012 Hi-Q 100V	GQM2192C2A120JB01	1	MURATA MANUFACTURING CO., LTD.
C 14	3.3 pF 2012 Hi-Q 100V	GQM2193C2AH3R3CB01	1	MURATA MANUFACTURING CO., LTD.
C 15	5.1 pF 2012 Hi-Q 100V	GQM2192C2A5R1DB01	1	MURATA MANUFACTURING CO., LTD.
C 16	9.1 pF 2012 Hi-Q 100V	GQM2192C2A9R1DB01	1	MURATA MANUFACTURING CO., LTD.
C 17	330 pF 3216 200V	GRM31M2C2D331JY21B	1	MURATA MANUFACTURING CO., LTD.
C 18	1000 pF 2012 100V	GRM2162C2A102JA01B	1	MURATA MANUFACTURING CO., LTD.
C 19	1000 pF 2012 100V	GRM2162C2A102JA01B	1	MURATA MANUFACTURING CO., LTD.
C 20	220 uF 35V	EEUFC1V221	1	Panasonic Corp.
L 1	29 nH * Diameter: Wire=0.8mm Inside=2.2mm T/N of coils=6		1	YC CORPORATION Co.,Ltd.
R 1	2.2k ohm 1608	RPC05T222J	1	TAIYOSHA ELECTRIC CO.,LTD.
Pb	PCB	MS3A0196	1	Homebuilt
Rc	SMA female connector	PAF-S00-002	2	GIGALANE Corporation
Bc 1	Bias connector red color	TM-605R	2	MSK Corporation
Bc 2	Bias connector black color	TM-605B	2	MSK Corporation
Pe	Aluminum pedestal		1	Homebuilt
Pd	Thermal Silicon Compound	G746	-	Shin-Etsu Chemical Co.,Ltd
Sbc	Support of bias connectors		2	Homebuilt
	Conductiong wire		4	Homebuilt
	Screw M3		10	-
	Screw M2.6		4	-
	Screw M2		4	-

* Inductor of Rolling Coil measurement condition : f=100MHz

- Standard Deliverable

TYPE1	**Evaluation Board assembled with all the component including the option**
TYPE2	**PCB (raw board)**

5. Thermal Design of Heat Sink



$Tch_{(delta)}$=(Pout/Efficiency-Pout+Pin) x $R_{th(ch\text{-}Pe\ bottom)}$=(35W/50%-35W+3) x 0.86=32.7 (deg. C.)

Also, operating Tj("$Tj_{(op)}$")=140 (deg. C.), in case of RD series that $Tch_{(max)}$=175 (deg. C.)

Therefore $T_{Pe\ bottom\text{-}air}$ as delta temperature between Pe bottom and ambient 60 deg. C.* is

$T_{Pe\ bottom\text{-}air}$="$Tj_{(op)}$" - $Tch_{(delta)}$ - $Ta_{(60deg.C.)}$=140-32.7-60=47.3 (deg. C.)

*: an instance assuming high temperature of standard ambient conditions is 60 deg. C.

In terms of long-term reliability, "$Tj_{(op)}$" has to be kept less than 140 deg. C. i.e. $T_{Pe\ bottom\text{-}air}$ has to be less than 47.3 deg. C..

The thermal resistance of the heat sink to border it:

$Rth_{(Pe\ bottom\text{-}air)}$=$T_{Pe\ bottom\text{-}air}$/(Pout/Efficiency-Pout+Pin)=47.3/(35W/50%-35W+3)=1.2 (deg. C./W)

Therefore

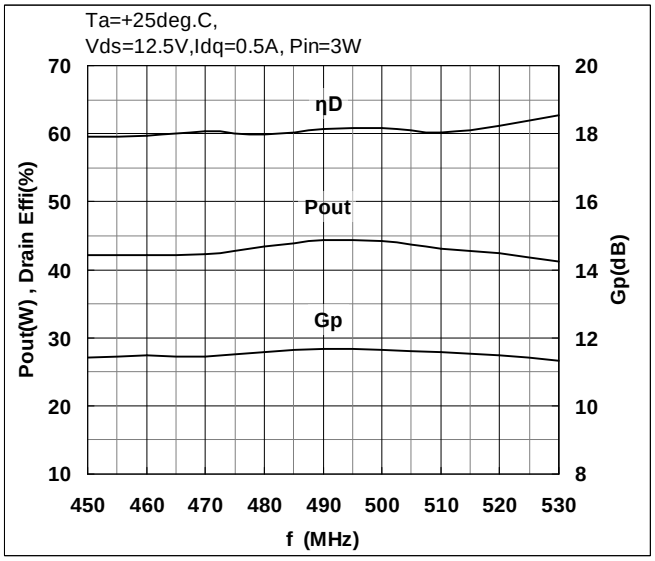
it is preferable that the thermal resistance of the heat sink is much smaller than 1.2 deg. C./W.

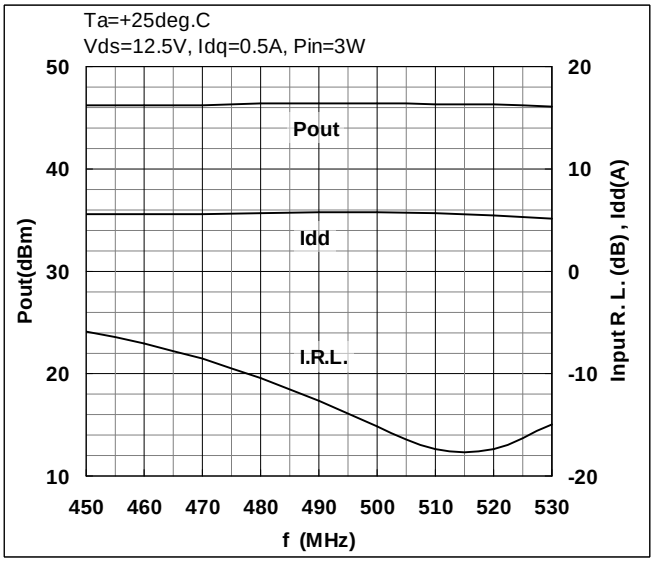
For assembly method including relevant precaution, refer to AN-GEN-070

6. Typical RF Characteristics

6-1. Frequency vs.

OUTPUT POWER, POWER GAIN, DRAIN EFFICIENCY, DRAIN CURRENT and INPUT RETURN LOSS



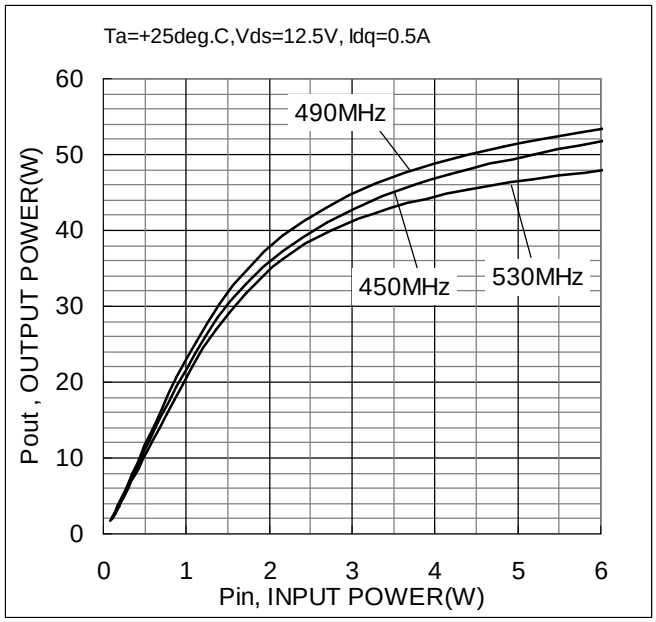


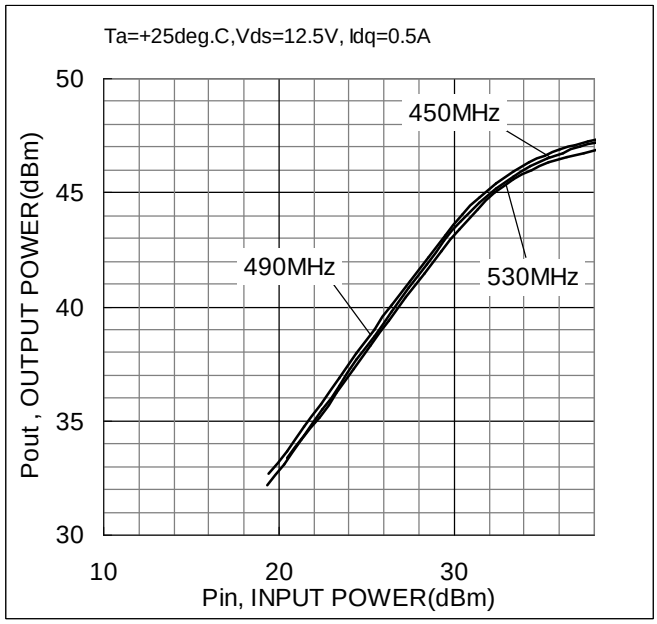
Ta=+25deg. C., Vds=12.5V, Idq=0.5A, Pin=3.0W

Freq.	Vgg	Pin		Pout		Gp	ID(RF)	ηadd	ηD	I.R.L.
(MHz)	(V)	(dBm)	(W)	(dBm)	(W)	(dB)	(A)	(%)	(%)	(dB)
450	2.72	34.8	3.0	46.2	42.1	11.4	5.59	55.7	60.0	-5.9
460	2.72	34.8	3.0	46.2	42.1	11.5	5.56	56.0	60.3	-7.1
470	2.72	34.8	3.0	46.3	42.3	11.4	5.54	56.5	60.8	-8.5
480	2.72	34.8	3.0	46.4	43.4	11.6	5.73	56.1	60.3	-10.4
490	2.72	34.8	3.0	46.5	44.4	11.7	5.78	57.1	61.2	-12.7
500	2.72	34.8	3.0	46.5	44.3	11.6	5.75	57.1	61.3	-15.1
510	2.72	34.8	3.0	46.4	43.2	11.6	5.68	56.4	60.6	-17.4
520	2.72	34.8	3.0	46.3	42.5	11.5	5.49	57.3	61.7	-17.3
530	2.72	34.8	3.0	46.2	41.2	11.3	5.20	58.5	63.1	-15.0

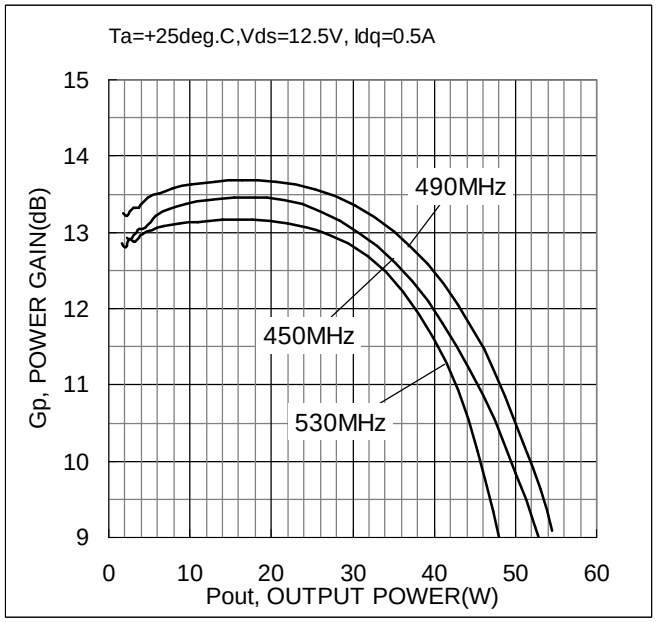
6-2. RF Power vs.

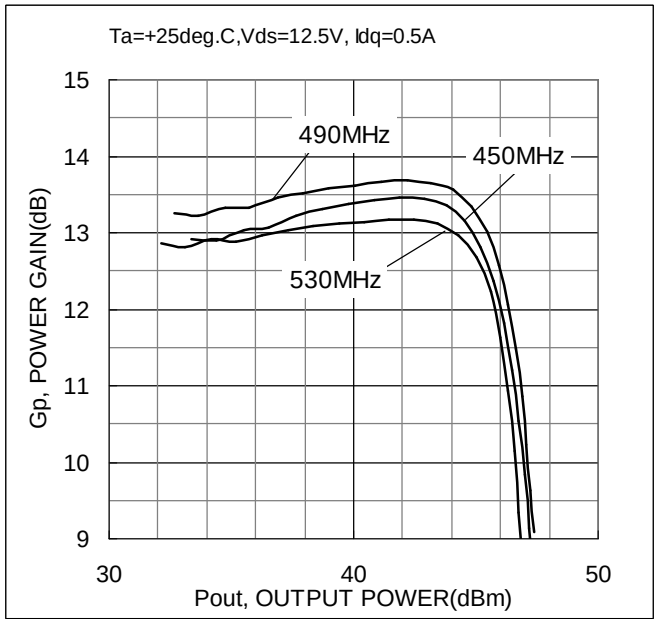
INPUT POWER



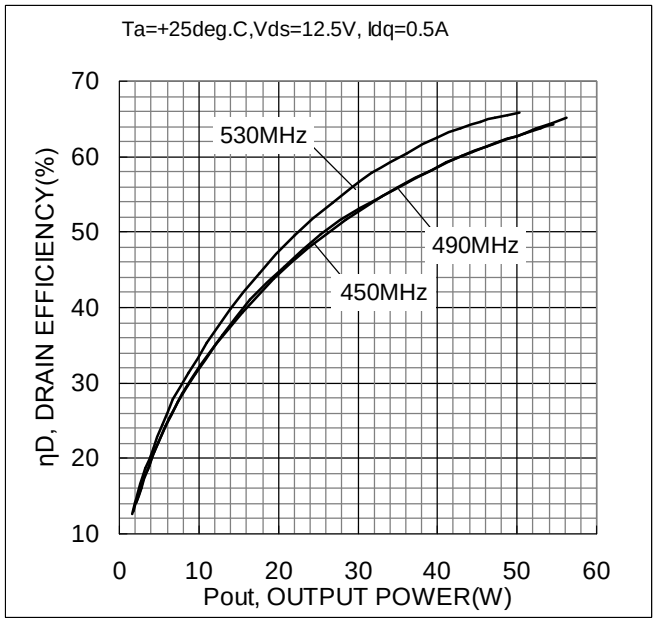


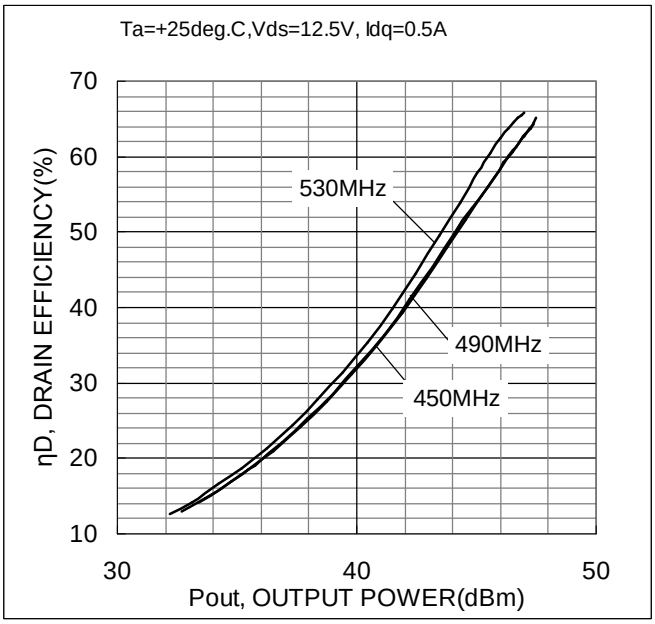
POWER GAIN



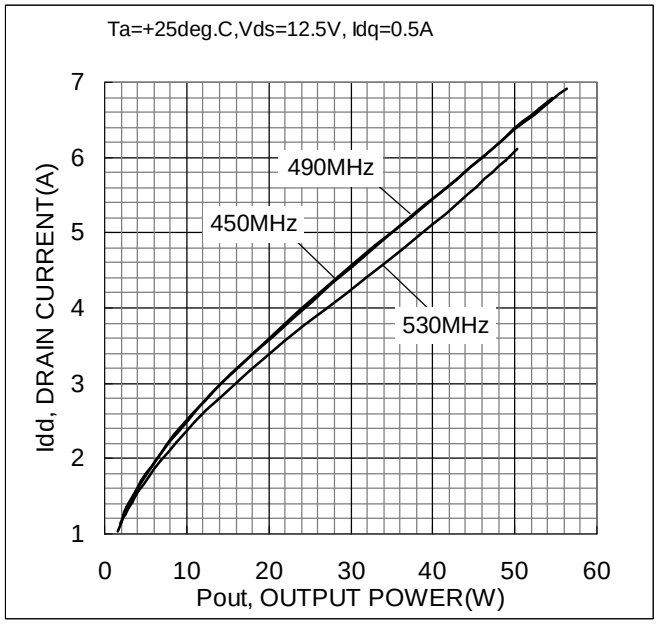


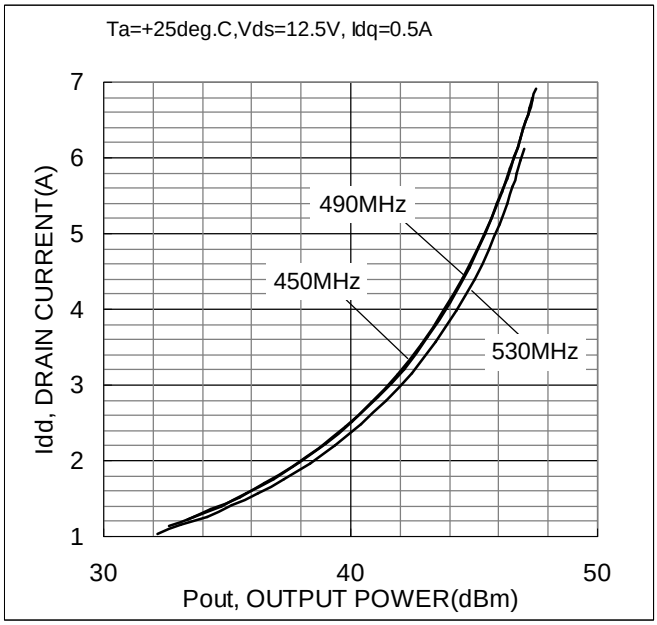
DRAIN EFFICIENCY



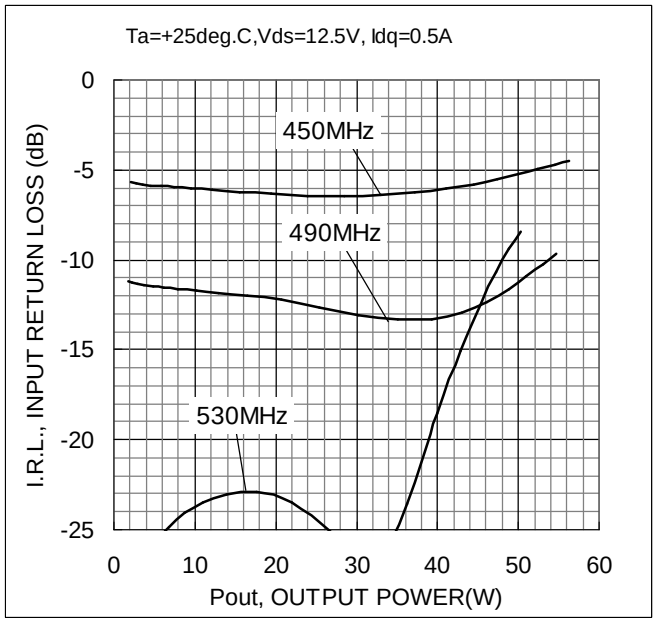


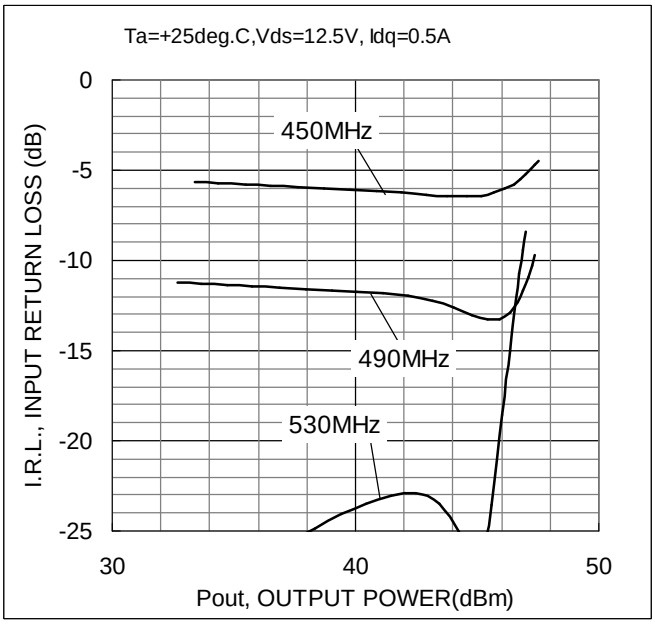
DRAIN CURRENT





INPUT RETURN LOSS





Ta=+25deg. C., Vds=12.5V, Idq=0.5A

450MHz	Vgg	Pin		Pout		Gp	ID(RF)	ηadd	ηD	I.R.L.
	(V)	(dBm)	(W)	(dBm)	(W)	(dB)	(A)	(%)	(%)	(dB)
	2.72	20.5	0.11	33.4	2.2	12.9	1.23	13.5	14.2	-5.7
	2.72	21.5	0.14	34.4	2.7	12.9	1.36	15.2	16.0	-5.7
	2.72	22.4	0.18	35.5	3.5	13.0	1.53	17.6	18.5	-5.8
	2.72	23.4	0.22	36.5	4.5	13.1	1.71	19.9	20.9	-5.9
	2.72	24.4	0.28	37.7	5.8	13.2	1.93	23.1	24.2	-5.9
	2.72	25.4	0.35	38.7	7.5	13.3	2.18	26.2	27.5	-6.0
	2.72	26.4	0.44	39.8	9.5	13.4	2.45	29.6	31.1	-6.1
	2.72	27.4	0.55	40.9	12.2	13.4	2.78	33.5	35.1	-6.1
	2.72	28.4	0.70	41.9	15.4	13.5	3.14	37.6	39.4	-6.2
	2.72	29.4	0.88	42.9	19.4	13.5	3.54	41.9	43.9	-6.3
	2.72	30.4	1.10	43.8	23.9	13.4	3.98	45.8	48.0	-6.5
	2.72	31.4	1.38	44.6	28.5	13.2	4.41	49.2	51.7	-6.5
	2.72	32.4	1.73	45.2	33.0	12.8	4.83	51.9	54.7	-6.4
	2.72	33.4	2.16	45.7	37.3	12.4	5.21	53.9	57.2	-6.3
	2.72	34.3	2.70	46.1	41.1	11.8	5.55	55.3	59.2	-6.0
	2.72	35.3	3.37	46.5	44.5	11.2	5.86	56.1	60.7	-5.8
	2.72	36.2	4.19	46.8	47.4	10.5	6.14	56.3	61.8	-5.5
	2.72	37.2	5.20	47.0	50.0	9.8	6.38	56.3	62.8	-5.2
	2.72	38.1	6.40	47.2	52.4	9.1	6.58	56.0	63.7	-5.0
	2.72	38.9	7.80	47.4	54.5	8.4	6.76	55.2	64.4	-4.7
	2.72	39.7	9.40	47.5	56.3	7.8	6.91	54.2	65.1	-4.5

490MHz

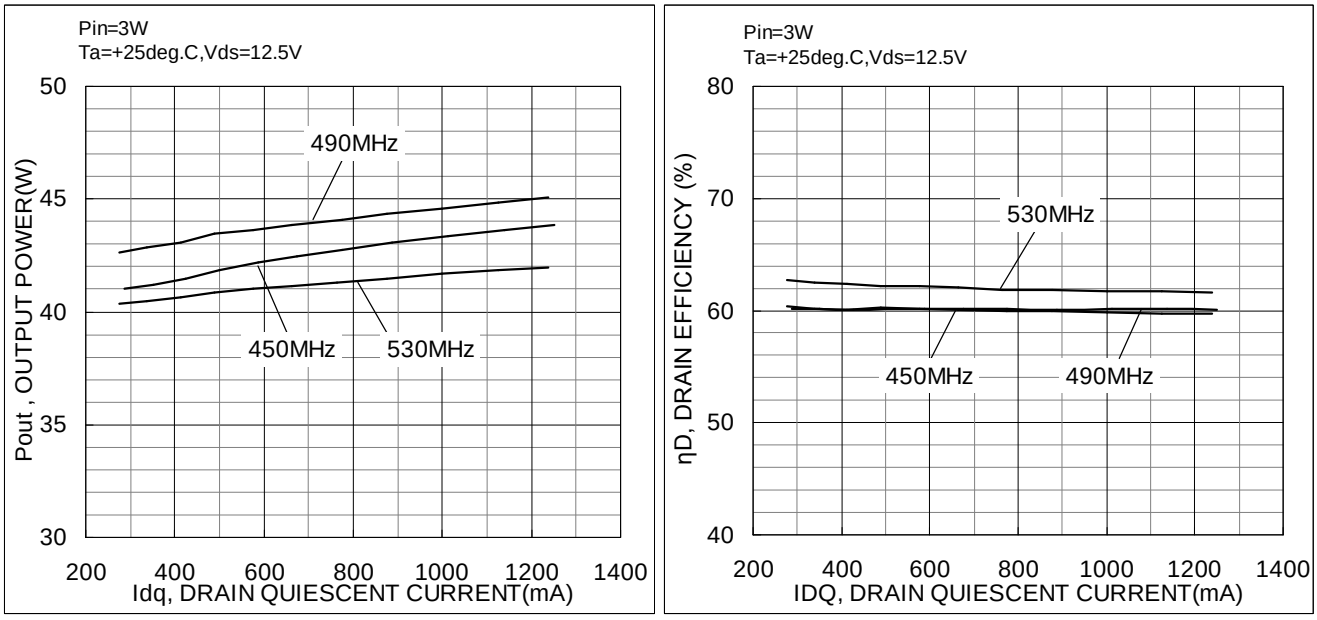
Vgg	Pin		Pout		Gp	ID(RF)	ηadd	ηD	I.R.L.
(V)	(dBm)	(W)	(dBm)	(W)	(dB)	(A)	(%)	(%)	(dB)
2.72	19.4	0.09	32.7	1.8	13.3	1.14	12.4	13.0	-11.2
2.72	20.4	0.11	33.6	2.3	13.2	1.26	14.0	14.7	-11.3
2.72	21.4	0.14	34.7	3.0	13.3	1.40	16.2	17.0	-11.4
2.72	22.4	0.17	35.7	3.8	13.3	1.58	18.2	19.1	-11.4
2.72	23.4	0.22	36.9	4.9	13.5	1.76	21.1	22.1	-11.5
2.72	24.4	0.28	37.9	6.2	13.5	1.98	24.1	25.2	-11.6
2.72	25.4	0.35	39.0	8.0	13.6	2.23	27.4	28.6	-11.6
2.72	26.4	0.44	40.1	10.2	13.6	2.51	30.9	32.3	-11.7
2.72	27.5	0.56	41.1	13.0	13.7	2.85	34.8	36.4	-11.8
2.72	28.5	0.71	42.2	16.5	13.7	3.21	39.2	41.0	-12.0
2.72	29.5	0.89	43.1	20.6	13.7	3.64	43.4	45.4	-12.2
2.72	30.5	1.12	44.0	25.4	13.6	4.09	47.4	49.6	-12.6
2.72	31.5	1.40	44.8	30.3	13.3	4.55	50.7	53.2	-13.0
2.72	32.4	1.75	45.4	35.0	13.0	5.00	53.2	56.0	-13.3
2.72	33.4	2.17	45.9	39.2	12.6	5.39	55.0	58.3	-13.3
2.72	34.3	2.68	46.3	43.0	12.1	5.73	56.3	60.1	-12.9
2.72	35.2	3.29	46.6	46.1	11.5	6.01	57.0	61.4	-12.4
2.72	36.0	4.00	46.9	48.8	10.9	6.26	57.2	62.3	-11.6
2.72	36.8	4.83	47.1	51.0	10.2	6.48	57.0	63.0	-10.9
2.72	37.6	5.77	47.2	53.0	9.6	6.65	56.8	63.8	-10.3
2.72	38.3	6.75	47.4	54.6	9.1	6.79	56.4	64.4	-9.7

530MHz

Vgg	Pin		Pout		Gp	ID(RF)	ηadd	ηD	I.R.L.
(V)	(dBm)	(W)	(dBm)	(W)	(dB)	(A)	(%)	(%)	(dB)
2.72	19.3	0.09	32.2	1.6	12.9	1.04	12.0	12.7	-30.8
2.72	20.3	0.11	33.1	2.0	12.8	1.15	13.5	14.2	-29.8
2.72	21.3	0.13	34.2	2.6	12.9	1.26	15.8	16.6	-28.8
2.72	22.3	0.17	35.2	3.3	12.9	1.41	17.6	18.6	-27.8
2.72	23.3	0.21	36.2	4.2	13.0	1.58	20.3	21.3	-26.7
2.72	24.3	0.27	37.3	5.4	13.0	1.76	23.2	24.4	-25.7
2.72	25.3	0.34	38.3	6.8	13.1	1.96	26.4	27.8	-24.8
2.72	26.3	0.42	39.4	8.7	13.1	2.21	29.9	31.4	-24.1
2.72	27.3	0.53	40.4	11.0	13.1	2.49	33.6	35.4	-23.5
2.72	28.3	0.67	41.4	14.0	13.2	2.80	38.0	39.9	-23.0
2.72	29.3	0.85	42.5	17.6	13.2	3.16	42.4	44.6	-22.9
2.72	30.3	1.07	43.4	22.0	13.1	3.56	47.0	49.5	-23.5
2.72	31.3	1.35	44.3	26.9	13.0	3.99	51.2	53.9	-25.2
2.72	32.3	1.71	45.0	31.8	12.7	4.40	54.7	57.8	-27.3
2.72	33.4	2.17	45.6	36.2	12.2	4.79	56.9	60.5	-23.6
2.72	34.4	2.75	46.0	39.9	11.6	5.11	58.2	62.5	-18.6
2.72	35.4	3.47	46.3	42.9	10.9	5.39	58.6	63.7	-15.0
2.72	36.4	4.39	46.6	45.3	10.1	5.61	58.4	64.6	-12.5
2.72	37.4	5.49	46.7	47.2	9.3	5.80	57.6	65.2	-10.7
2.72	38.3	6.80	46.9	48.9	8.6	5.96	56.4	65.5	-9.4
2.72	39.2	8.33	47.0	50.3	7.8	6.11	54.9	65.8	-8.4

6-3. Drain Quiescent Current vs.

OUTPUT POWER and DRAIN EFFICIENCY



Ta=+25deg. C., Vds=12.5V, Pin=3.0W

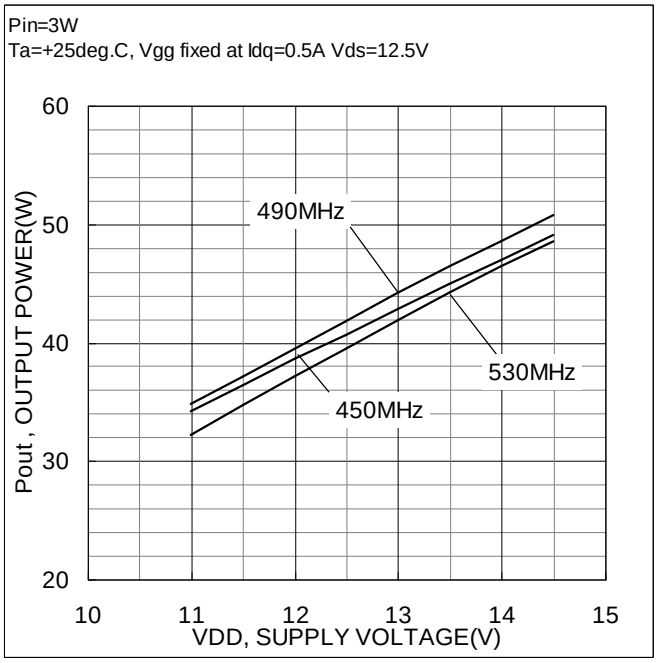
450MHz	Vgg	Idq	Pin		Pout		Idd	ηD	ηadd	Gain	I.R.L.
	(V)	(mA)	(dBm)	(W)	(dBm)	(W)	(A)	(%)	(%)	(dB)	(dB)
	2.62	288	34.8	3.0	46.1	41.0	5.35	60.2	55.7	11.3	-5.9
	2.65	350	34.8	3.0	46.2	41.2	5.38	60.2	55.8	11.3	-6.0
	2.67	425	34.8	3.0	46.2	41.5	5.43	60.1	55.7	11.4	-6.0
	2.70	500	34.8	3.0	46.2	41.9	5.46	60.2	55.8	11.4	-6.0
	2.73	588	34.8	3.0	46.3	42.2	5.50	60.2	55.9	11.4	-6.0
	2.75	675	34.8	3.0	46.3	42.5	5.54	60.2	55.9	11.4	-6.0
	2.78	775	34.8	3.0	46.3	42.8	5.58	60.2	56.0	11.5	-6.0
	2.80	888	34.8	3.0	46.3	43.1	5.63	60.1	55.9	11.5	-6.0
	2.83	1013	34.8	3.0	46.4	43.4	5.66	60.1	55.9	11.6	-6.0
	2.85	1138	34.8	3.0	46.4	43.7	5.70	60.1	55.9	11.6	-6.0
	2.87	1250	34.8	3.0	46.4	43.9	5.74	60.0	55.9	11.6	-6.0

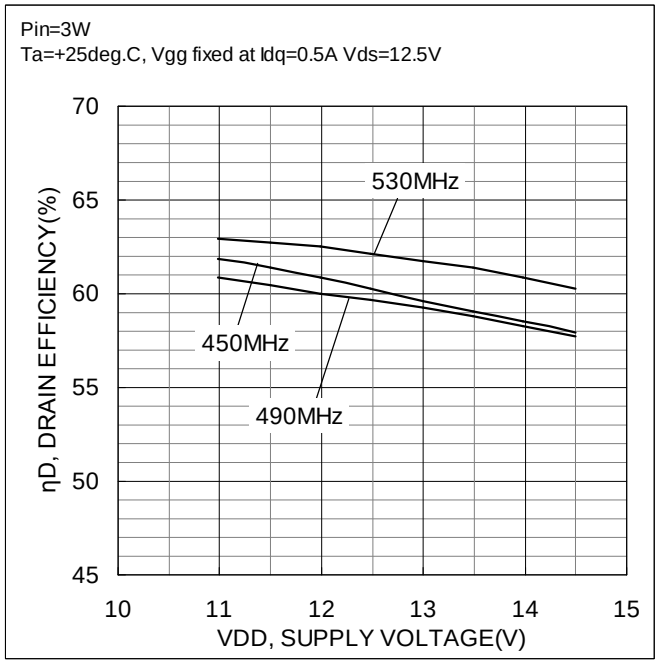
490MHz	Vgg	Idq	Pin		Pout		Idd	ηD	ηadd	Gain	I.R.L.
	(V)	(mA)	(dBm)	(W)	(dBm)	(W)	(A)	(%)	(%)	(dB)	(dB)
	2.62	275	34.8	3.0	46.3	42.7	5.55	60.3	56.1	11.5	-12.7
	2.65	338	34.8	3.0	46.3	42.9	5.59	60.2	56.0	11.5	-12.7
	2.67	413	34.8	3.0	46.3	43.1	5.63	60.1	55.9	11.5	-12.7
	2.70	488	34.8	3.0	46.4	43.5	5.66	60.2	56.0	11.6	-12.7
	2.73	575	34.8	3.0	46.4	43.7	5.70	60.1	56.0	11.6	-12.7
	2.75	663	34.8	3.0	46.4	43.9	5.74	60.0	55.9	11.6	-12.8
	2.78	775	34.8	3.0	46.4	44.1	5.78	59.9	55.8	11.6	-12.8
	2.80	875	34.8	3.0	46.5	44.4	5.81	59.9	55.8	11.7	-12.8
	2.83	1000	34.8	3.0	46.5	44.6	5.85	59.8	55.8	11.7	-12.8
	2.85	1125	34.8	3.0	46.5	44.9	5.90	59.7	55.7	11.7	-12.8
	2.87	1238	34.8	3.0	46.5	45.1	5.93	59.8	55.7	11.7	-12.8

530MHz	Vgg	Idq	Pin		Pout		Idd	ηD	ηadd	Gain	I.R.L.
	(V)	(mA)	(dBm)	(W)	(dBm)	(W)	(A)	(%)	(%)	(dB)	(dB)
	2.62	275	34.8	3.0	46.1	40.4	5.05	62.7	58.0	11.2	-15.3
	2.65	338	34.8	3.0	46.1	40.5	5.08	62.6	57.9	11.3	-15.3
	2.67	413	34.8	3.0	46.1	40.6	5.11	62.4	57.7	11.3	-15.3
	2.70	488	34.8	3.0	46.1	40.8	5.15	62.2	57.6	11.3	-15.3
	2.73	575	34.8	3.0	46.1	41.0	5.18	62.2	57.6	11.3	-15.3
	2.75	663	34.8	3.0	46.1	41.1	5.20	62.1	57.5	11.3	-15.3
	2.78	763	34.8	3.0	46.2	41.3	5.24	61.9	57.3	11.3	-15.3
	2.80	875	34.8	3.0	46.2	41.5	5.26	61.9	57.4	11.4	-15.3
	2.83	1000	34.8	3.0	46.2	41.7	5.30	61.7	57.2	11.4	-15.2
	2.85	1125	34.8	3.0	46.2	41.9	5.33	61.7	57.3	11.4	-15.2
	2.87	1238	34.8	3.0	46.2	42.0	5.35	61.6	57.1	11.4	-15.2

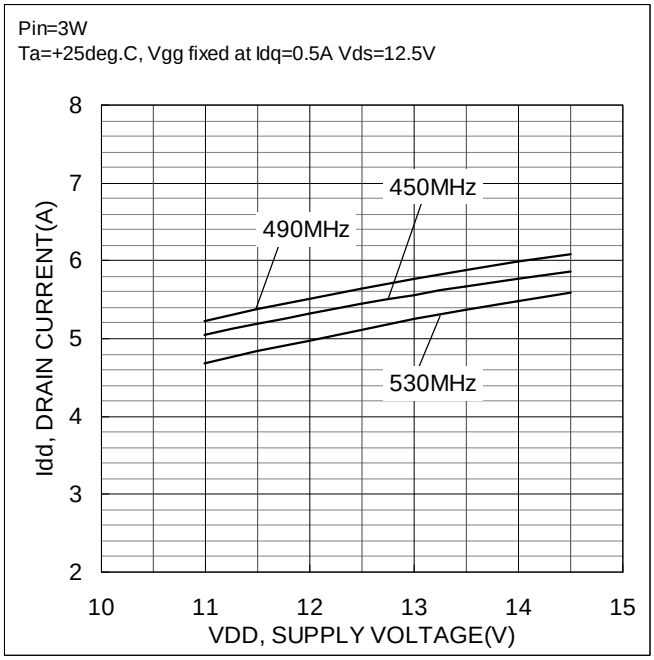
6-4. DC Power Supply vs.

OUTPUT POWER and DRAIN EFFICIENCY





DRAIN CURRENT



Ta=+25deg. C., Pin=3.0W

450MHz	Vgg	Vdd	Idq	Pin		Pout		Idd	ηD	ηadd	Gain	I.R.L.
	(V)	(V)	(mA)	(dBm)	(W)	(dBm)	(W)	(A)	(%)	(%)	(dB)	(dB)
	2.71	10.99	488	34.8	3.0	45.3	34.2	5.05	61.9	56.4	10.5	-5.6
	2.71	11.5	500	34.8	3.0	45.6	36.5	5.19	61.4	56.3	10.8	-5.7
	2.71	11.99	513	34.8	3.0	45.9	38.6	5.32	60.9	56.1	11.0	-5.8
	2.71	12.49	525	34.8	3.0	46.1	40.7	5.44	60.2	55.7	11.3	-5.9
	2.71	13	538	34.8	3.0	46.3	42.9	5.55	59.6	55.4	11.5	-6.0
	2.71	13.49	550	34.8	3.0	46.5	45.0	5.67	59.1	55.1	11.7	-6.1
	2.71	13.99	563	34.8	3.0	46.7	47.0	5.77	58.5	54.7	11.9	-6.2
	2.71	14.5	575	34.8	3.0	46.9	49.1	5.87	58.0	54.4	12.1	-6.2

490MHz	Vgg	Vdd	Idq	Pin		Pout		Idd	ηD	ηadd	Gain	I.R.L.
	(V)	(V)	(mA)	(dBm)	(W)	(dBm)	(W)	(A)	(%)	(%)	(dB)	(dB)
	2.71	10.99	488	34.8	3.0	45.4	34.8	5.23	60.9	55.6	10.6	-11.4
	2.71	11.5	513	34.8	3.0	45.7	37.2	5.38	60.5	55.6	10.9	-11.9
	2.71	11.99	525	34.8	3.0	46.0	39.5	5.52	60.0	55.4	11.2	-12.2
	2.71	12.49	538	34.8	3.0	46.2	41.9	5.64	59.7	55.4	11.4	-12.5
	2.71	13	538	34.8	3.0	46.5	44.3	5.77	59.3	55.3	11.7	-12.8
	2.71	13.49	550	34.8	3.0	46.7	46.5	5.88	58.8	55.0	11.9	-13.1
	2.71	13.99	563	34.8	3.0	46.9	48.6	5.99	58.3	54.7	12.1	-13.3
	2.71	14.5	575	34.8	3.0	47.1	50.8	6.09	57.8	54.3	12.3	-13.5

530MHz	Vgg	Vdd	Idq	Pin		Pout		Idd	ηD	ηadd	Gain	I.R.L.
	(V)	(V)	(mA)	(dBm)	(W)	(dBm)	(W)	(A)	(%)	(%)	(dB)	(dB)
	2.71	10.99	475	34.8	3.0	45.1	32.3	4.69	62.9	57.0	10.3	-12.5
	2.71	11.5	500	34.8	3.0	45.4	34.8	4.84	62.7	57.3	10.6	-13.6
	2.71	11.99	513	34.8	3.0	45.7	37.2	4.98	62.5	57.4	10.9	-14.7
	2.71	12.49	525	34.8	3.0	46.0	39.5	5.11	62.2	57.4	11.2	-16.0
	2.71	13	538	34.8	3.0	46.2	42.0	5.25	61.7	57.3	11.4	-17.5
	2.71	13.49	538	34.8	3.0	46.5	44.3	5.36	61.4	57.2	11.7	-19.2
	2.71	13.99	550	34.8	3.0	46.7	46.5	5.48	60.9	56.9	11.9	-21.2
	2.71	14.5	563	34.8	3.0	46.9	48.6	5.59	60.3	56.5	12.1	-23.8