2.5W Amplifier for 10GHz

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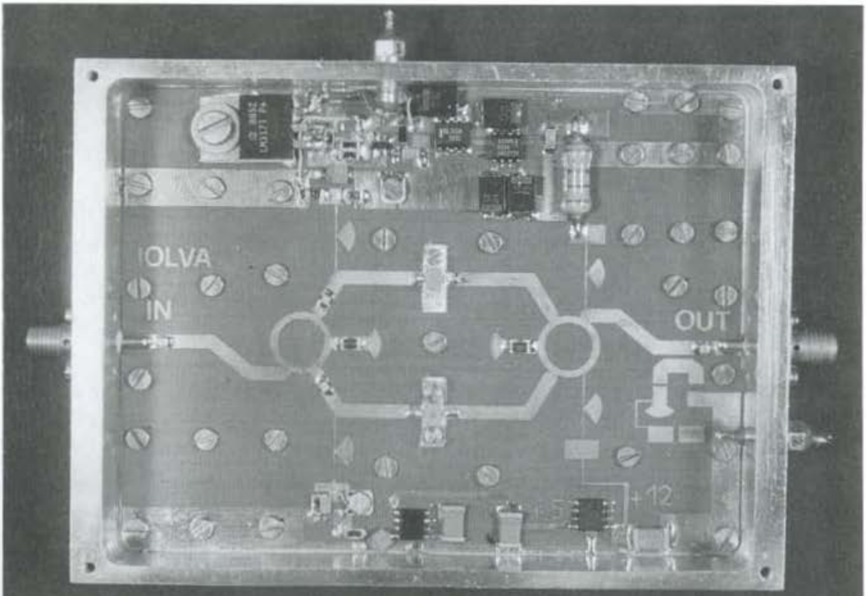
Abstract: The article describes a 2.5W power amplifier for 10GHz. It provides 4.7dB gain. It uses two MGF2445 power GaAs-FETs, which are coupled via two rat-race 180° hybrids.

Kurzfassung: Der Artikel beschreibt einen 2,5W Leistungsverstärker für 10GHz mit 4.7dB Verstärkung. Zwei MGF2445 GaAs-FET's werden mit einem 180° Ringhybrid gekoppelt.



I0LVA Power Amplifier for 10GHz

Introduction

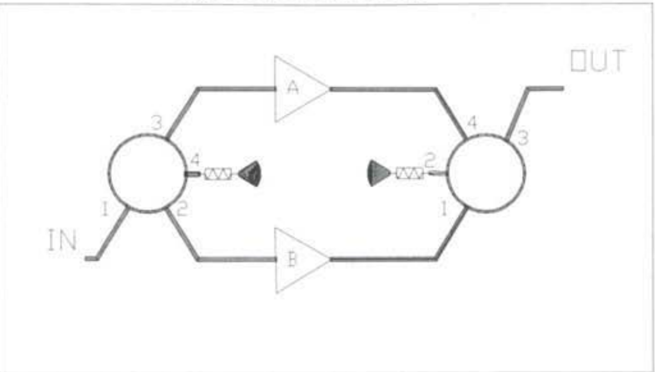
After realizing that I needed more power on 10 GHz I began to think about solutions to increase my power. Two alternatives seemed to be possible:

1. Use a matched power device able to provide 35...38 dBm output. This solution is much too expensive!
2. Use standard device power GaAs - FET MGF 2445 coupled via hybrids.

I have chosen the second solution because it was cheaper than the first one even if it's more difficult and has a larger size.

The result is the linear amplifier that can be seen in the photograph above. The linear amplifier provides a 1 dB compression output power of over 2.5 watts. The devices utilized are Mitsubishi MGF 2445.

Fig. 1: Block Diagram



Einführung

Um die Leistung auf 10 GHz zu erhöhen, gibt es zwei Alternativen:

1. Anwendung eines 4...8 W Transistors
2. Kopplung von MGF 2445 über einen Ringhybrid

Ich habe die zweite Lösung aus Preisgründen gewählt. Es enstand ein 2,5 W Verstärker mit 4,7 dB Verstärkung.

Theory

The two MGF 2445 are coupled with ring type hybrid. The ring is made of 6 electrical quarter waves as shown in the **fig. 1** . The signal at port " **1** " will be equally divided between ports "**2**" and "**3**"; zero power will appear at port "**4**". The phase relationship at port "**2**" is - 90 deg. and port "**3**" is - 270.Signal arriving at port "**4**" from port "**1**" via port "**2**" is -180 degrees relative to port " **1**". The result is that at port "**4**" the signal are 180 degrees out of phase and cancel. Signal to the output ring is fed into port "**1**" and port "**4**". Signal fed into port "**1**" arriving at port "**4**" via port "**2**" is 180 degrees out of phase with that arriving via port "**3**". The net result is that signal from one device is not fed into the other. Signal arrives at port "**3**" in phase as result of the 180 degrees phase difference that exists in the input ring.

Theorie

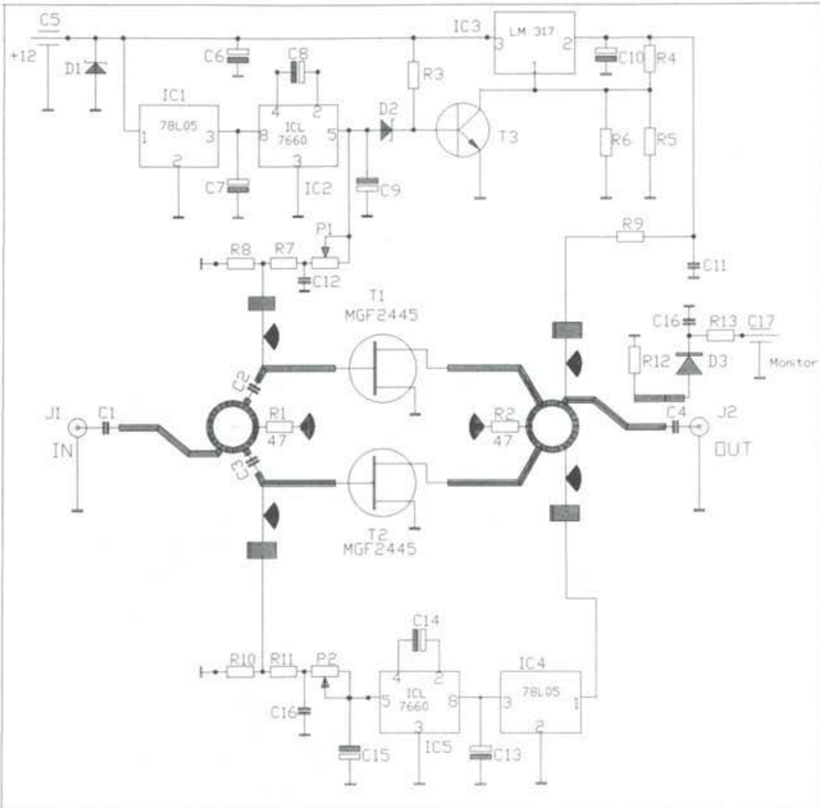
Der Ringhybrid, der beide MGF 2445 Stufen koppelt, besteht aus 6 $\lambda/4$-Leitungen mit 70Ω Wellenwiderstand wie in Abb.1 gezeigt. Das Signal an Tor 1 wird zu gleichen Teile auf Tor 2 und 3 aufgeteilt. An Tor 4 löschen sich die Signale aus, weil sie 180° Phasenunterscheid haben. Zwischen Tor 2 und 3 sind 180° Phasenunterschied. Als Leistungssummierer werden die Signale in Tor 1 und 4 eingespeist. Die Summenleistung wird an Tor 3 entnommen. Die Tore 1 und 4 sind isoliert, so daß sich die Verstärker nicht beeinflussen können.

Circuit description

Fig. 2 shows the circuit of the HPA. It uses a printed circuit board (fig. 3) construction in micro-stripline technique on 0.79 mm thick RT-Duroid 5870 with ε_r = 2.33. The dimensions are 100 x 74 mm standard size that fit into tinplate box or into a brass box silver-plated as I did. This solution provides very good results both from a electrical point of view and for mechanical stability. The size can be learned from fig. 4.

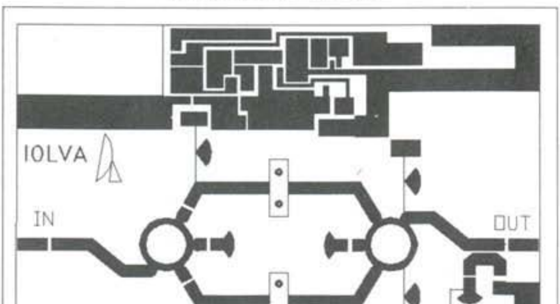
The power supply is integrated into the RF board. It utilizes a LM 317 for the 10 volts of drain voltage and a double bias circuit composed of 78L05 + ICL7660 to supply the negative gate voltage. All components used are SMD with exception of the LM317. With the values shown we have exactly

Fig. 2: Circuit Diagram



10 volts for the drain and variable bias voltage from - 0,4 volts to -2,5 volts.

Bild/Figure 3: PCB

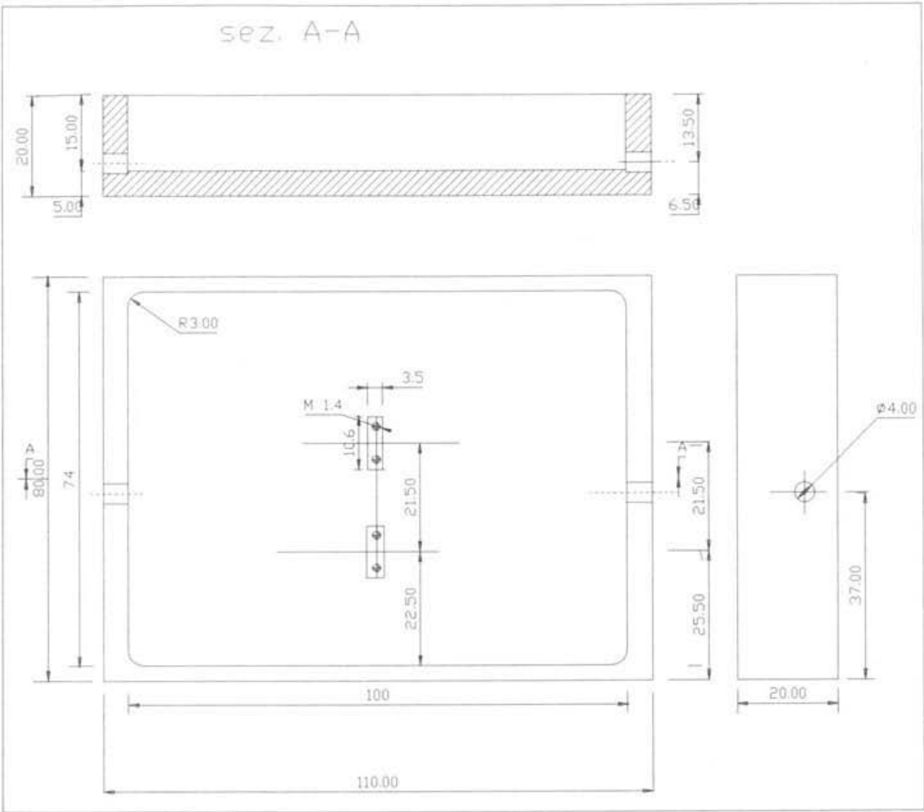


Schaltung

Abb. 2 zeigt die Schaltung des Verstärkers. Er ist auf einer 0,79 mm starken PTFE-Platine (Abb. 3) aus RT-Duroid 5870 aufgebaut. Die Größe ist 100x 74 mm. Ein versilbertes Messinggehäuse ist am besten geeignet (Abb. 4). Aber auch ein Weißblechgehäuse ist möglich.

Die Stromversorgung ist integriert. Ein LM317 liefert 10 V und ein 78L05 sowie ein ICL7660 erzeugen eine regelbare negative Vorspannung für die Gate-Anschlüsse.

Fig. 4: Machined Box

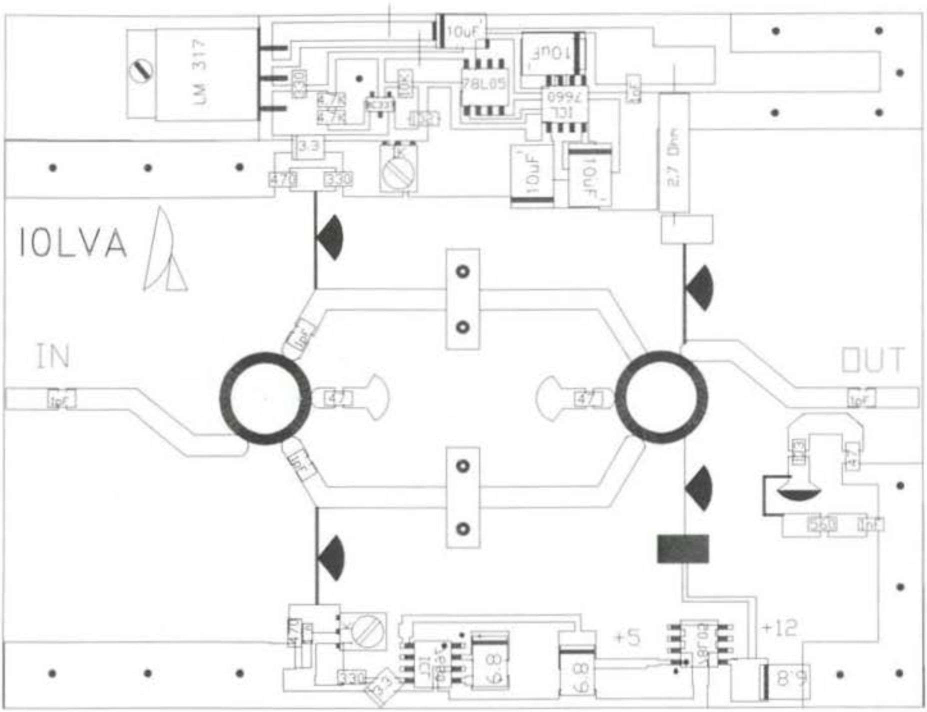


Construction

Fig. 5 shows the layout of the parts. Chip capacitors input, output and interstage are 1pF from ATC.

1. Cut the PCB to fit it into box, the same is fastened with screws M2 on the silver-plated box bottom. If you use tinplate box the PCB has to be soldered to the both sidewalls.
2. Make two rectangular holes of size 3.5x12 mm where the two GaAs-FET MGF 2445 will reside.
3. Since the GaAs-Fets are 1.65 mm high, it is necessary to make two nut type fittings so that gate and drain leads can flush with the microstripline (see drawing on fig. 6).
4. If you use tinplate box, a fitting has to be machined on the top of a copper or aluminium plate fixed at the PCB with M2 screws. By this a good heat transfer is assured.
5. Make the fitting for LM317T voltage regulator.
6. Make holes for input and output SMA connectors. You can select the right solution for your need (choose male or female SMA connector). I have chosen a female SMA connector for input and a male SMA connector for output:

Fig. 5: Parts Layout



in this way the output can be routed directly to the antenna relay.

7. Make holes for 1000 pF feed-through capacitors for power supply and power detector.
8. Make holes of 1.1 mm diameter and a thread M1.4 for fixed GaAs - Fet's.
9. Fix the PCB on the bottom of the brass box silver-plated, mount the SMA connectors, mount feed-throug capacitors, solder all components of the power supply. Test if the voltages are correct (voltages should be around + 10 volts at the drain lead and variable by -0.5 V to -2.5 V at the gate lead)
10. Put GaAs-Fet into nuts and fix them with M1.4 brass screws. Solder leads of drain and gate using only insulated soldering tool, ground the box, your body and the power supply of soldering tool. Never touch the gate lead. Solder operations should be made fast and with a very small amount of solder.

Konstruktion

Abb. 5 zeigt den Bestückungsplan. Alle Koppelkondensatoren sind 1pf ATC-Chips:

1. Platine zuschneiden

2. Zwei Aussparungen mit 3,5x12 mm Größe in den Boden fräsen
3. LM317 befestigen
4. Löcher für SMA-Buchsen, Durchführungskondensatoren bohren
5. M1,4 Gewinde für FETs schneiden
6. Platine mit M2 Schrauben auf den Boden schrauben. SMA-Buchsen montieren. Durchführungskondensatoren montieren. Die gesamte Stromversorgung bestücken.
7. Stromversorgung testen: +10V am Drain und - 0,5 ...-2,5 V am Gate
8. FET's einschrauben und mit der Platine verlöten

Test and tuning

Before connecting the 12 V power supply carefully check all solder connections to the SMD components, as well as the GaAs-FET using a magnifying glass. Connect a 10 GHz transverter with about 850 mW output power to the input of the linear amplifier and apply the supply voltage. Cut six pieces of copper or brass foil of diverse size (5 x4, 5x3 and 5x2 mm), turn the amplifier on, and move a copper foil in contact along the micro-stripline from input to output, holding it with a cleft matchstick, until the power output shows an increase on the power meter. Remove the supply voltage and solder the copper or brass foil to the spot wich has been found. Repeat this operation for the number of pieces of copper foils, tune the SMD pots until the power output rises to a maximum of around 2.5/3 Watts and current rises to a maximum of around 1 A.

Abgleich

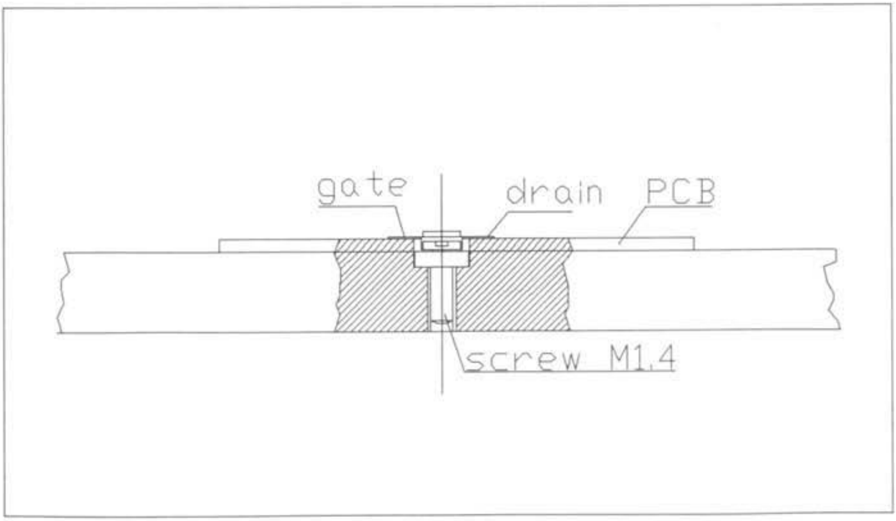
Platine mit Vergrößerungsglas prüfen. Betriebsspannung anlegen. 10GHz Signal mit 800mW anlegen. Sechs Kupferfahnen diverser Größen (5x4, 5x3 und 5x2 mm) zuschneiden. Am Ein- und Ausgang aufbringen und verschieben, bis die Leistung maximal ist. Dann Betriebsspannung entfernen und die Fahnen an den gefundenen Stellen auflöten. Vorspannung ebenfalls optimieren.

Results

The table below shows the test results achieved with two prototypes.

The instruments used for the measure are following:

1. Power meter HP 435 A
2. Head HP 8481A
3. Sweep generator HP 8620 C with plug-in HP 86290 B
4. Network Analyzer HP 8755 C - HP 11664
5. Spectrum Analyzer HP 141 T + HP8552B + HP 8555



Bild/Figure 6: Mounting of FET

Table 1: Parts

Pos	Qty	Reference	Part
1	1	C1,2 3,4	1pF ATC 50mil
2	3	C6,7,8,10	10µF/25V SMD
3	1	C9,15	3.3µF/25V SMD
4	2	C11,12,16,17,18	1nF SMD
5	3	C13,14	6.8µF/25V SMD
6	2	C5,18	1nF FT
7	1	D1	Zener 15V
8	1	D2	Zener 4.7V
9	1	D3	BAT-15
10	1	J1	SMA Socket
11	1	J2	SMA Socket
12	2	P1,2	1k SMD
13	3	R1,2,12	47 SMD
14	1	R3	10k SMD
15	3	R4,7,11	330 SMD
16	2	R5,6	4k7 SMD
17	2	R8,10	470 SMD
18	1	R9	2R7 SMD
19	1	R13	560 SMD
20	2	T1,2	MGF2445
21	1	T3	BC337
22	1	IC1,4	78L05 SMD
23	1	IC2,5	ICL7660 SMD
24	1	IC3	LM317T
25	1	PTFE PCB	100x74mm, 0.79mm (ε_r=2.33)
26	1	Box 100x74x30	Brass, Silver Plated

6. Variable attenuator HP X382

Parameter	Unit	No. 1	No. 2
P_{IN}	mW	870	900
P_{OUT}	mW	2550	2600
Gain	dB	4.67	4.6
I_D	mA	800	850

Good DX on 3 cm band, and good luck with the construction.

For further information please do not hesitate to contact me.

Ergebnisse

Obige Tabelle zeigt die Resultate für 2 Prototypen. Falls Informationen gebraucht werden, stehe ich jederzeit zur Verfügung.