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L Band power amplifier for AO-40 Uplink

Amateur radio satellites offer many options for experimentation. The AMSAT-OSCAR 40 (AO-40) satellite is currently in orbit. In addition to operating on other bands, it has an uplink in the L Band, 1296MHz. However, the power required for satisfactory radio contact is above the output of a normal transceiver, which makes it necessary to use a suitable power amplifier. A concept for such an RF power amplifier is shown below.

1. General

The experiences of many AO-40 users have demonstrated that a PEP power of approximately 50W at the input of a circular radiating antenna with approximately 20dB gain is sufficient for the L Band uplink, even using squint angles. Looked at from the point of view of cable losses it makes most sense to generate the power at the point where it is used: directly at the antenna power feed.

The amplifier described here has the following characteristics:

- Popep = 50W
- Uds = 28V
- G = 12dB
- Iq = 300mA

The direct mounting of an L Band helix or a patch antenna on the rear of the reflector offers the ideal solution.

The reflector plate of an antenna (e.g. made from 3mm aluminium) having the normal area of approximately 400cm², is not quite adequate for a heatsink at ambient temperatures of > 25°C. One remedy can be an additional "chimney", consisting of approximately 1mm thick aluminium plate, with an associated cover. This additional cooling makes it possible to obtain thermally stable functioning, even in summer, for normal SSB mode with a PEP of approximately 55Watts.

2. The amplifier

The L Band amplifier uses a fairly standard circuit (Fig 1). Printed line transformers are used to transform the relatively low complex input and output impedances of the L-DMOS transistor used (UPF 1060P from ULTRA RF). These transformers are made on the familiar material RO 4003, substrate thickness 0.79 mm, ε_r = 3.35, using stripline technology.

The general calculations for transforma-

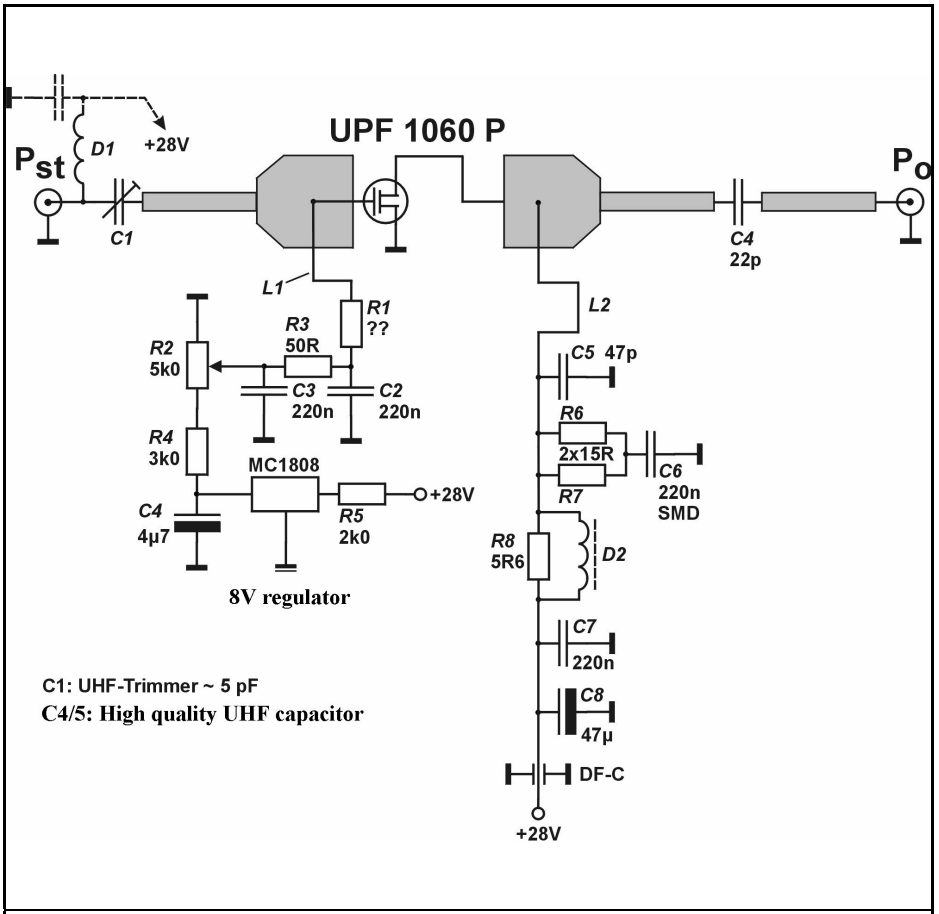

Fig 1: Circuit diagram of L band amplifier.

tion networks of this type can be found, among other places, in [1]. The printed matching networks are shown in Figs 2 and 3. Since the most important dimensions of the lines are shown, you can easily construct them yourselves.

The first specimens of the amplifier circuit boards were designed with Indian ink, using the age-old procedure, and then etched in the usual way. The undersides of the circuit boards naturally have a copper coating.

In the present circuit, for the sake of simplicity, no stabilisation is provided for the 300mA zero signal current. It would also be expedient to incorporate temperature compensation, to be prepared for "extreme cases". A cut out when excessive temperatures arise can also be recommended!

The DC wiring can be laid out as you wish, and/or in accordance with the mechanical size of the components used. This applies even to the M3 holes needed to fasten the circuit board (heat dissipation required for copper plate housing).

It can be seen from Figs 2 and 4 that, in addition to the transformer lines, some

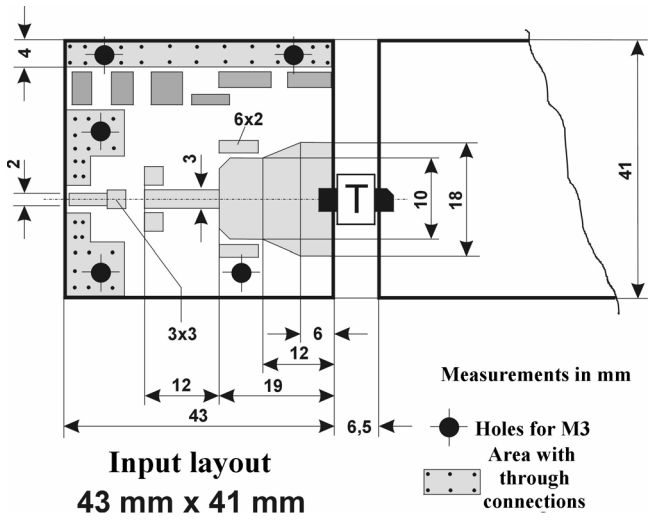

Fig 2: Input circuit layout showing measurments of matching networks.

small additional areas are also laid out. These are the so-called trim elements, used to fine tune the amplifier for the best input matching and/or for maximum output power and linearity. This is needed to compensated for, for example, when similar transistors are used, divergences in the input and output impedances occur or there are tolerances in the mounting of the transistor.

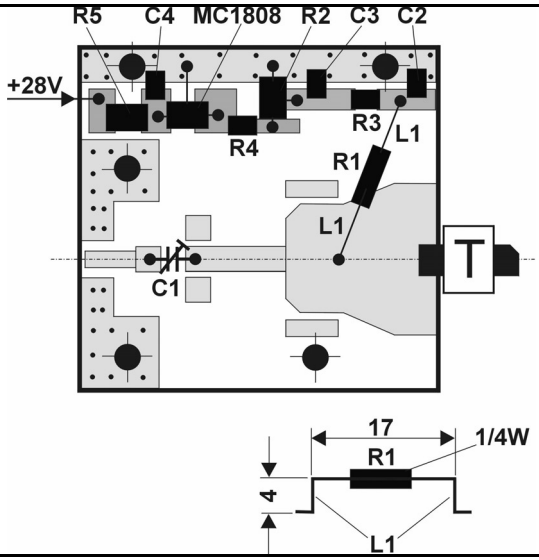

Fig 3: Component layout for input circuit showing details of L1 and R1.

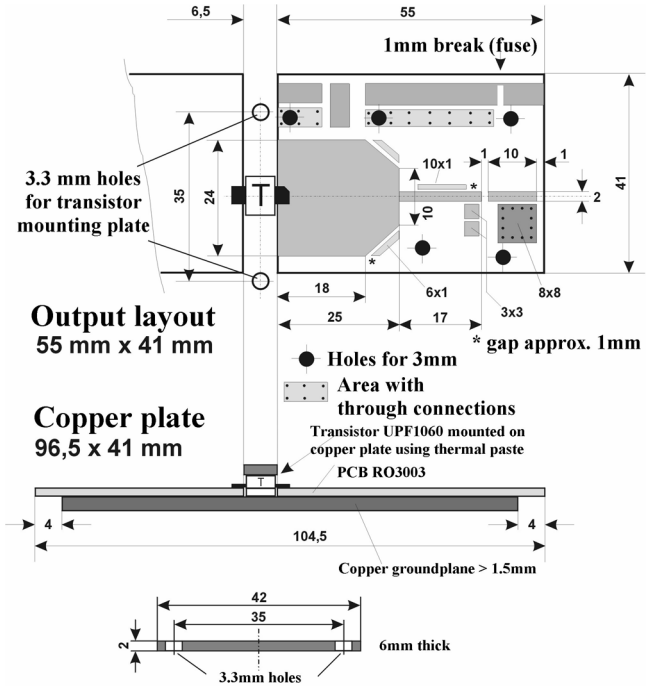

Fig 4: Output circuit layout showing measurments of matching networks and details of transistor mounting.

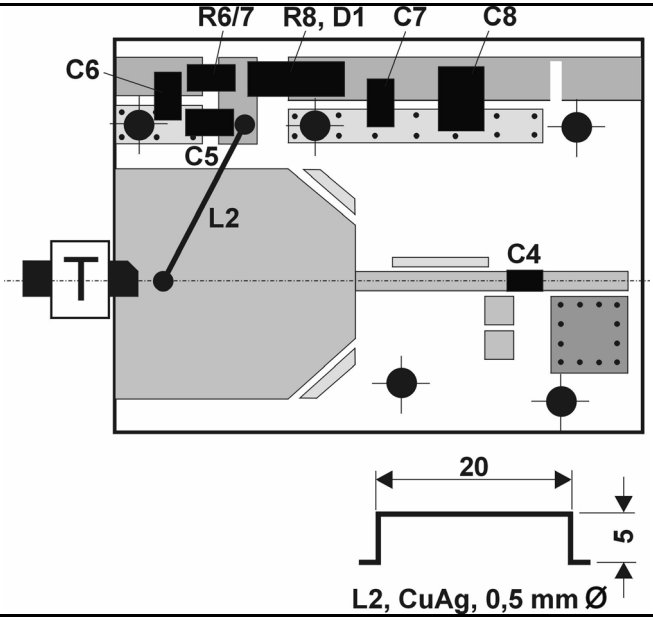

Fig 5: Component layout for output circuit showing details of L2.

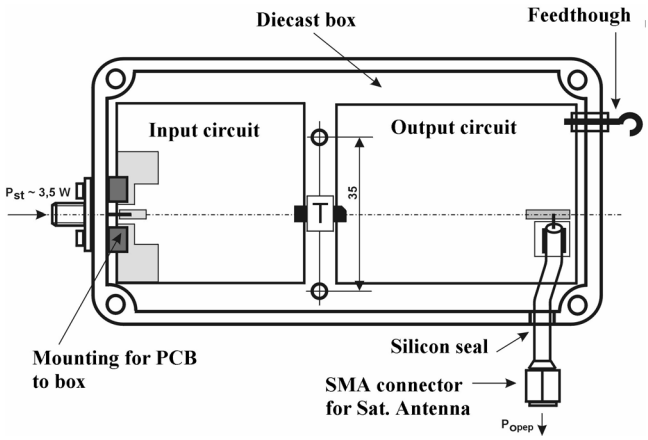

Fig 6: Installing the amplifier in an Eddystone diecast box measuring 111mm x 61mm x 30mm.

3. Mechanical and electrical assembly

The semiconductor type selected, UPF 1060 P, is a flangeless model, because of price. Figs 4, 6 and 7 show one possible assembly, using a 3mm thick carrier plate made from copper as a heat spreader! This mounting plate should be as level as possible on both sides; it should preferably be finished by surface milling on both sides! The individual circuit boards are soldered onto the copper plate using a hotplate. The distance of 6.5mm between the circuit boards should be adhered to, the copper surface must not be tinned in this area!

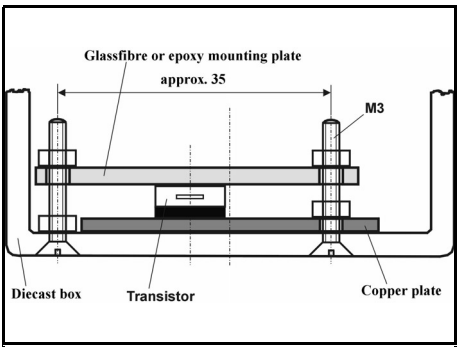

Fig 7: Details of transistor mounting using mounting plate.

When the circuit boards have been assembled, the transistor is put in place, but initially without it's connections soldered to the striplines. The module (copper plate with soldered-on circuit boards) is screwed into the housing, the base of which has been finished by surface milling! Sparing use a uniform application of heat-conducting paste between the transistor, the copper plate and the housing base. The transistor is now pressed onto the copper plate by means of a flexible implement (un-coated printed circuit material, fibreglass). You must naturally treat the equipment carefully! Now the connecting lugs can be soldered. (Figs 6 and 7).

The amplifier must now be mounted flat onto the chimney/radiation reflector installation in its housing for best heat dissipation. The holes required for M3 countersunk screws can be made in the reflector. Another solution is to cut M3 threads into the reflector and then screw the entire unit onto the reflector from the amplifier side. (Figs 8 and 9).

Various mechanical solutions can be made, depending on the application. For simplicitys sake, the power supply in this

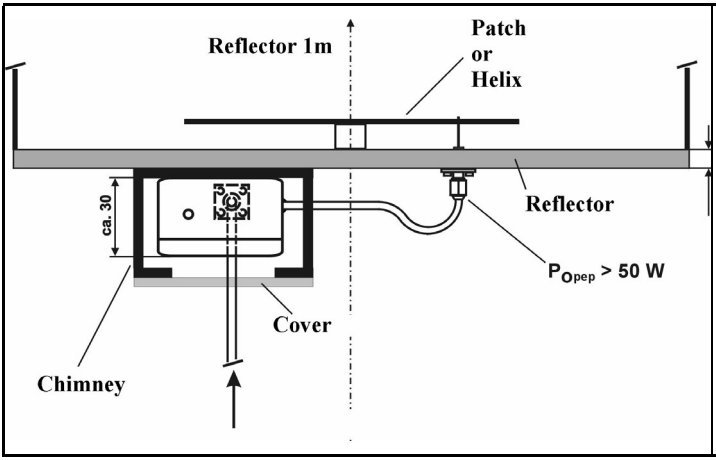

Fig 8: Mounting the amplifier on an antenna with cooling chimney approximately 150 x 200mm.

layout is provided using a lead-through filter mounted in the housing wall. The supply voltage of 28V can be fed through the coaxial feeder cable.

The entire structure should be painted white to keep the temperature as low as possible, even when the sun is shining!

The circuit has been assembled and tested many times. The characteristic, interpolated from the worst values of three amplifiers, is shown in Fig. 10. The typical measurments of the RF power amplifier for single-tone control are as follows:

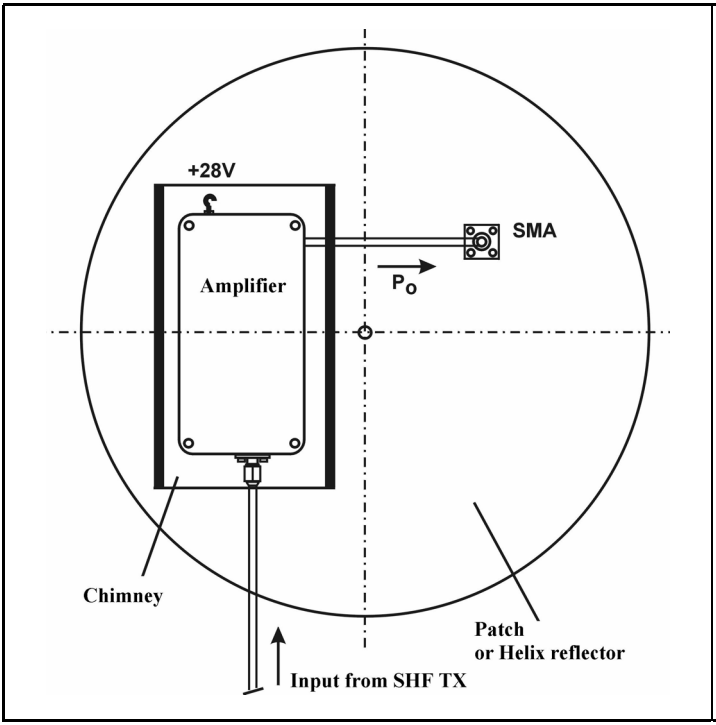

Fig 9: Rear view of mounting the amplifier on an antenna with cooling chimney approximately 150 x 200mm.

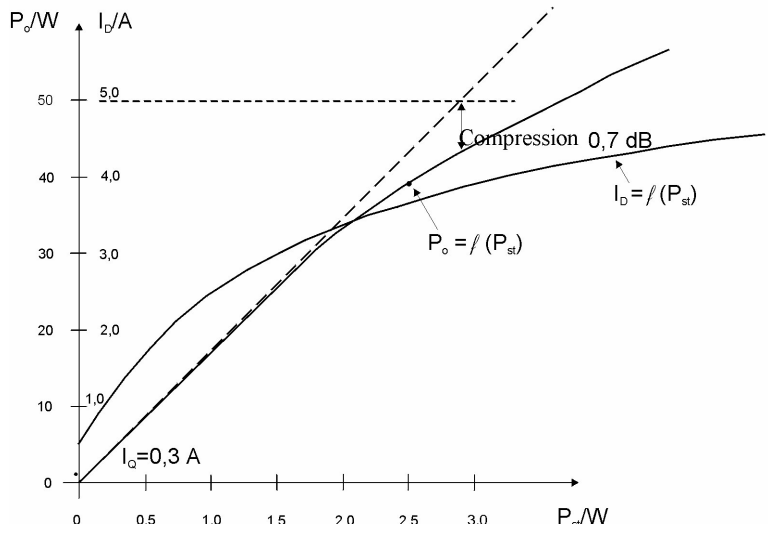

Fig 10: Transfer charactetristics of the L band amplifier.

- P_0 = 50W (with compression approximately 0.6dB)
- JD = 4.5A
- JDQ = 300mA
- Pst = 3.2W
- G = 12dB
- = ≥ 49 %

Incidentally, this description should be merely a stimulus to constructing an RF amplifier; it should not in any way restrict my own ideas regarding design.

The author will be happy to supply any additional information regarding the practical execution of the amplifier and to exchange experiences.

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4. Literature

[1] Matching an LDMOS power transistor at 1.3GHz with an output of 120W; Proceedings of Congress on VHF-UHF 2002; Munich Technical College, 9th. 10th March, 2002

[2] DATA BOOK, Ultra RF Power, www.globes.de