Dragoslav Dobričić, YU 1 AW

An Unconditionally-Stable, Low-Noise GaAs-FET Pre-Amplifier

The appearance of the GaAs-FET with its extremely low-noise figure at very high frequencies, has led to the wideband belief that all problems of constructing low-noise pre-amplifiers have been solved. That, unfortunately, is not the case. Because these devices were designed to provide high gain at SHF, attempts to construct amplifiers at frequencies below 2 GHz is a very serious undertaking.

The success in their employment depends upon the solution of a few problems, each of which requires careful consideration and a planned approach. They are as follows:–

1. **A very low-loss input circuit and very good matching to the transistor is essential for a good noise-figure. The optimum impedance for the lowest noise will be very high and have a reactive component, which will make this quite difficult.**
2. **Almost all GaAs-FETs exhibit unconditional stability at frequencies above 4 GHz and their operation at lower frequencies is attended by a significant tendency to self-oscillate. Owing to the high gain and only conditional stability at the lower frequencies, it is very difficult to design and build a really stable amplifier (6).**
3. **Because of the conditional stability and that over only a very limited range of impedances, the output matching of the transistor is very critical. This tends to result in an improperly tuned amplifier together with a poor performance.**

1.
MATCHING FOR OPTIMUM INPUT

The problem of the input matching, that is, achieving the lowest noise figure together with minimum input ciruit losses, has been discussed in (1). The salient points arising were:–

1. The input tuned circuit matching the antenna to the input of the active device must have the highest possible unloaded Q (Q_U).
2. The matching circuit must be so dimensioned that it has the lowest-possible loaded Q (Q_L).

For the 2-metre band, a helical resonator should be provided since it possesses a Q_U of double that of conventional LC-tuned circuits, as discussed in (1).

At 432 MHz and higher frequencies, the best solution is the use of a coaxial resonator for the input circuit but air-insulated, stripline resonators have quite a high Q_U and are acceptable for this purpose.

Resonator losses are directly proportional to the circulating currents and to keep these low, the dimensions of the resonator are important. Both the inner and the outer diameter and their ratio are factors for attaining a maximum Q_U and thereby minimum losses (2).

The unloaded Q of a coaxial resonator, made from copper or silver, can be evaluated by means of the following formula:–

$$Q_u = D * \Theta * \sqrt{f} \qquad (1)$$

$$\Theta = 151 * \frac{\ln (D/d)}{1 + D/d} \qquad (2)$$

where,

D = outside diameter (cm)
d = internal diameter (cm)
f = frequency (MHz)

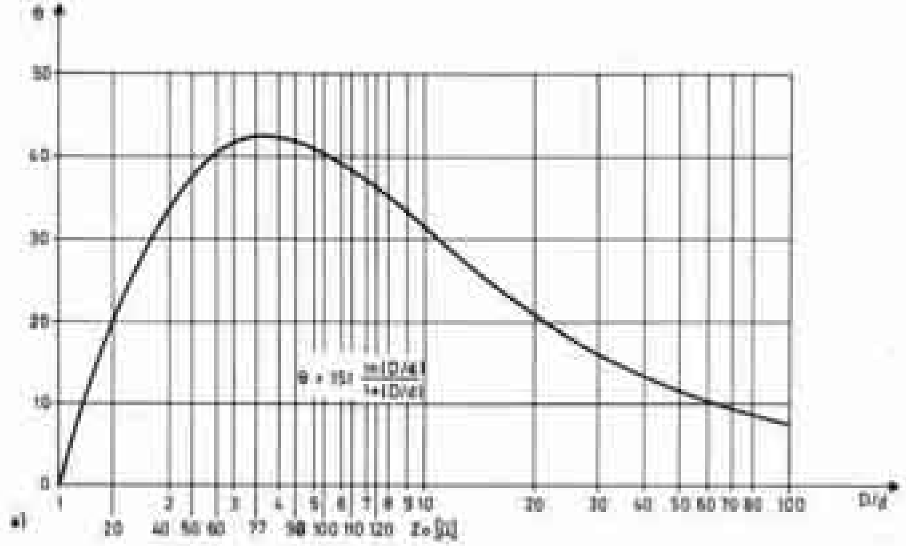

Fig. 1a:
Θ Value for coaxial resonator, in dependance of D/d ratio of characteristic impedance Z_0

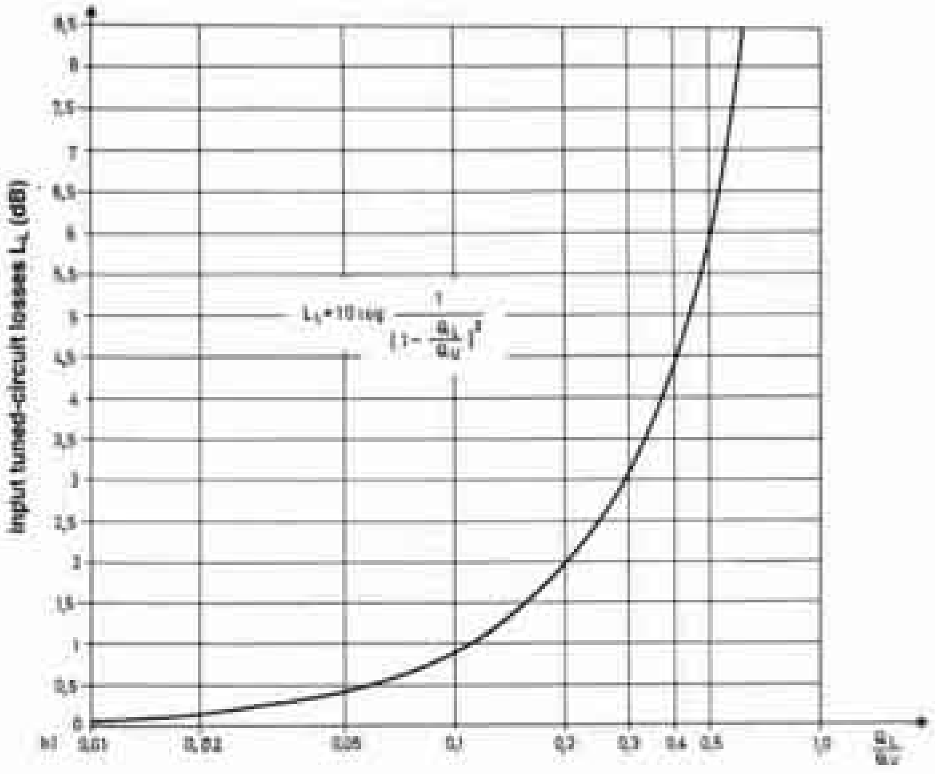

Fig. 1b:
Input resonator loss L_L in dependance of Q_U/Q_L ratio

The values of Q_U calculated from this formula conform very well to those measured in practice.

Equation (1) indicates that the unloaded Q at any given resonator diameter and frequency will be a maximum when Θ has a maximum. The equation (2) for Θ, in turn, has a maximum value when D/d = 3.6 as shown in **fig. 1a**.

From the well known formula for the characteristic impedance of a coaxial resonator: –

$$Z_O = 60\, L_n\, (D/d)..(\Omega)$$

and plugging in 3.6, a resonator Z_O of 77 Ω is obtained.

The resonator having the highest possible unloaded Q must have silvered surfaces, a characteristic impedance of 77 Ω and as large a diameter as possible. When the side of a square resonator has the same dimension as the diameter of a round one, then Q_U will be some 20 % higher.

The next task is to calculate the impedance transformation for the input circuit under the minimum working Q (Q_L) conditions.

In order that the antenna impedance of $R_L = 50\,\Omega$ is transformed with the optimum impedance for the lowest noise-figure of the transistor:

$$Z_{NF} = R_{NF} \pm jX_{NF}$$

the input tuned circuit must have a Q_L which is higher than two certain minimum values, Q_M and Q_D. Both these minimum values of Q_L will be determined by the impedance Z_{NF}.

$$Q_M = \sqrt{\frac{R_{NF}}{R_L} - 1}$$

$$Q_D = X_{NF}/R_{NF}$$

The Q_L of the input circuit should be higher than Q_M and Q_D, or at least, be equal to the value of the higher of the two. The importance of the impedance Z_{NF} for the final results and for the choice of a suitable transistor is now clear.

Finally, it is now possible to calculate the loss in the coaxial resonator:

$$L_L = 10\log\left(\frac{1}{1 - Q_L/Q_U}\right)^2 \qquad (3)$$

The electrical loss in a resonator L_L, in dB, for a given ratio Q_L/Q_U is shown in **fig. 1b**.

Besides the resonator, the input circuit comprises tuning and loading capacitors and the losses in these can be calculated in a similar fashion, if their respective Q_Us are known for the frequency of operation. Alternatively, the use of known high-quality components will ensure a negligible loss.

The main losses in capacitors at high frequency are caused by skin effect, dielectric absorption, resistance of sliding surfaces in trimmers and losses in the component constructional insulating material. If, however, silvered plate capacitors having air-dielectric and without sliding surfaces are used, the loss is very low indeed. A capacitor of this type can be easily formed by using two plates and moving one of them. This type of trimmer capacitor is often used in UHF tube power-amplifiers having stripline resonators. The very expensive "Johanson" trimmers are very high-quality components with Qs of a few thousand at frequencies below 1.5 GHz.

The capacitance value of a tuning capacitor C_t connected across the input of the transistor must be very low. A high value of this capacitor would increase Q_D and also decreases the LC-ratio of the input circuit, thus lowering its dynamic resistance R_D. As a consequence, higher losses and higher noise-figure are to be expected. The noise-factor F at the transistor's input can be expressed by the following equations:

$$F = 1 + R_{NF}/R_D \qquad (4)$$

$$R_D = Q_U \bullet X_L = Q_U \bullet X_C \qquad (5)$$

Almost all GaAs-FETs below 1.5 GHz have a high value of R_{NF} and it could easily occur that an injudiciously chosen, lower value of R_D has the same order of value as R_{NF}. This could result in the noise figure being increased by 3 dB even before the transistor's noise figure has been taken into account (3).

In conclusion, for optimum input matching and to achieve the minimum noise and loss, the following rules must be observed:

1. Use resonators with the highest possible Q_U.

2. The Q_L of the input tuned-circuit must be as low as possible but higher than Q_M and Q_D.

3. The tuning capacitance C_t must be as low as possible, just sufficient to ensure a positive tune. The L/C-ratio of the input circuit must be held as high as possible.

2.
STABLE OUTPUT MATCHING

Matching a transistor output for stable working conditions is usually much more difficult than optimum input matching. The output matching has no influence on the noise-figure as almost all GaAs-FETs below about 1.5 GHz have a scattering parameter S_{12} of practically zero. **The transistor's output matching, however, is of paramount importance for its gain and stability.**

As already mentioned, most GaAs-FETs are only conditionally stable below frequencies of around 4 GHz. The stability-factor calculations and the superimposing of stability and constant-gain circles onto the Smith Chart will present a clear picture of the problem to be solved, **see fig. 2**.

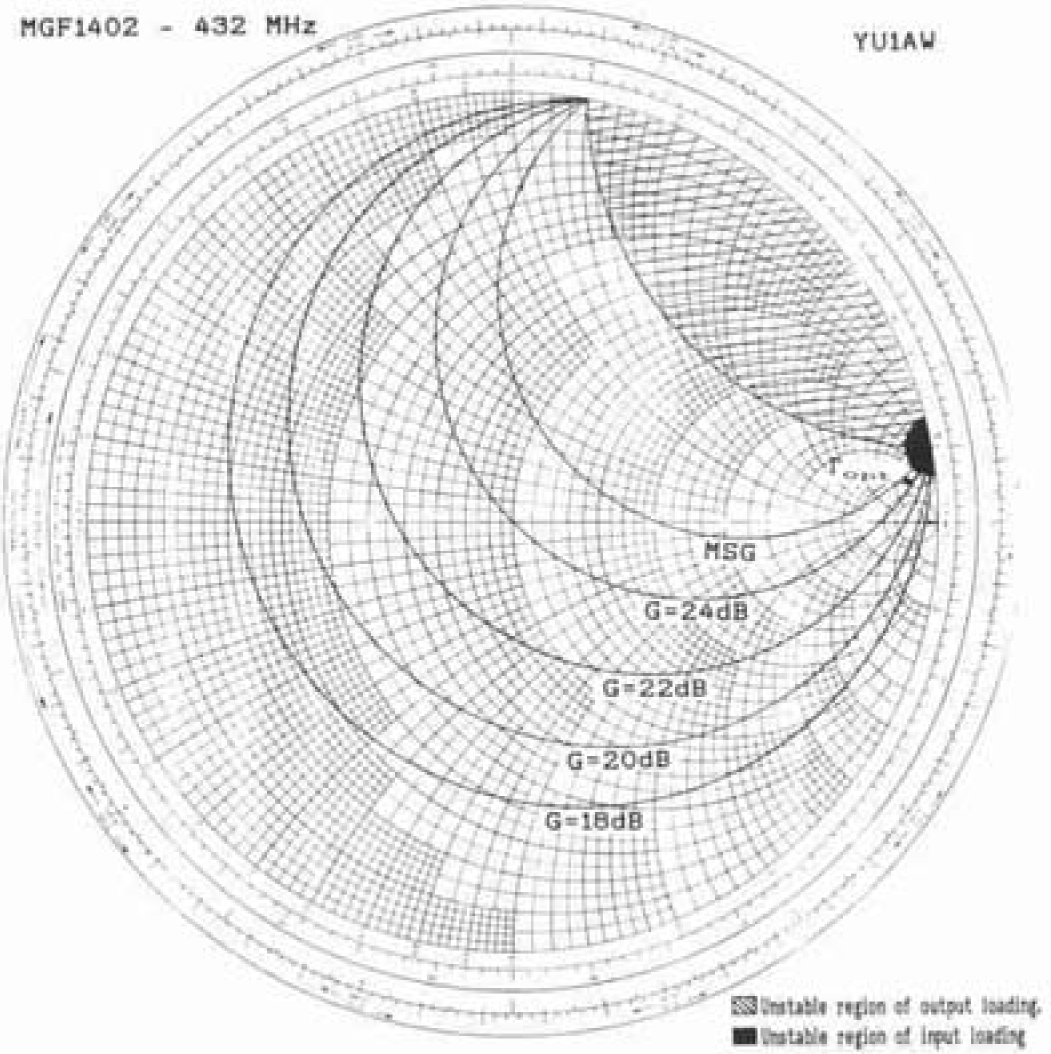

Fig. 2: Stability and constant gain circles for MGF 1402 on 432 MHz, with given unstable regions of input (black) and output (lined) impedances

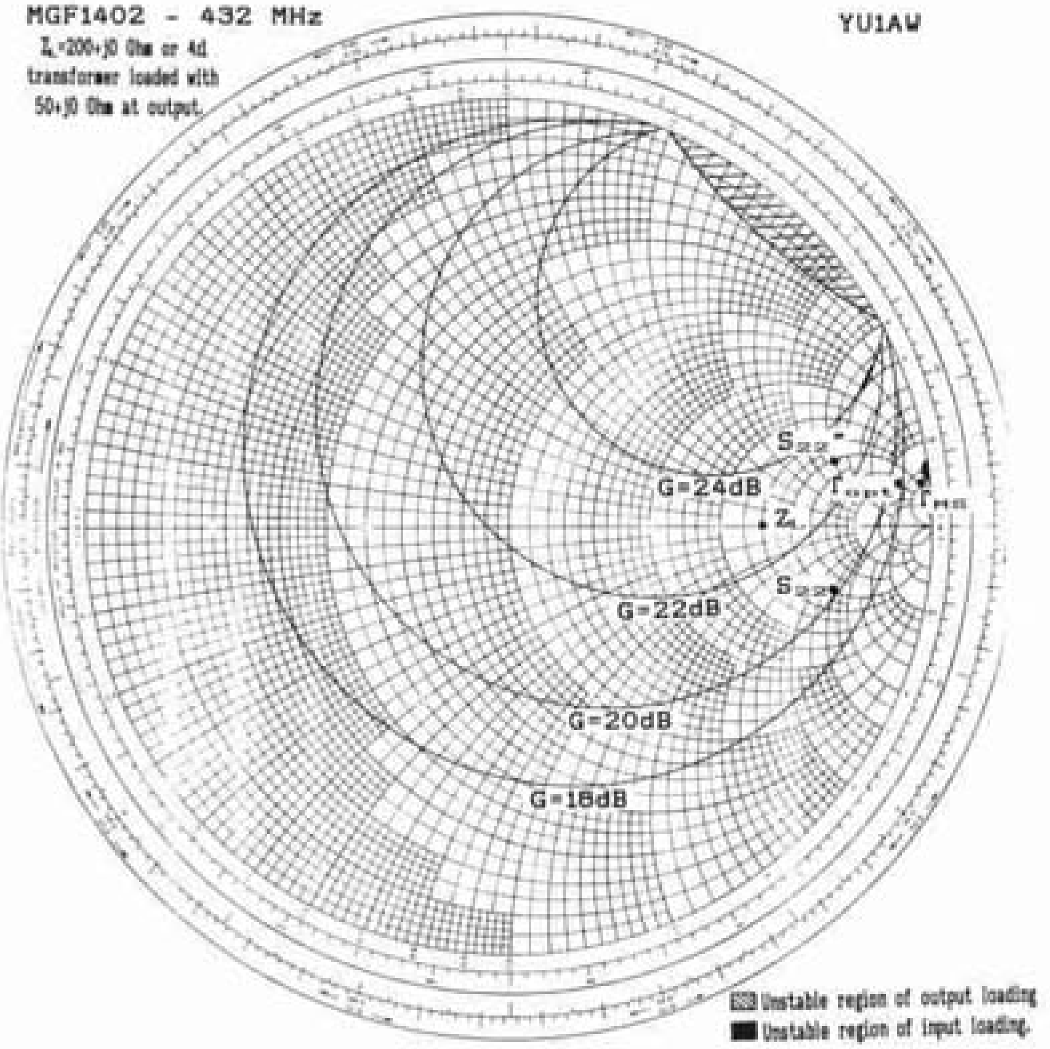

Fig. 3: Constant gain and stability circles for MGF 1402 on 432 MHz, loaded on output with transformer 4 :1 or resistor 200 Ω

Many constructors have come across this problem and have tackled it usually by using either a resistive output load (1) or 4 : 1 ferrite transformers (6). Following these concepts, many pre-amplifiers have been constructed and published but undoubtedly were only conditionally stable over a certain range. The Smith Chart of **fig. 3** shows the conditions when a 4 : 1 transformer is connected to the output or loaded by a 200 Ω resistor. The construction confirms that the transistor is only conditionally stable.

This means that the amplifier, when subjected to certain output load conditions and input source admittance, will self-oscillate. This critical condition can occur very easily, for instance, when two amplifiers are cascaded and the pre-amplifier has been loaded by an impedance which has been transformed by a 4 : 1 transformer. The transformers are usually wound on a ferrite core, or bead, whose permeabilities are not known above a few hundred megahertz.

Many of these transformers having various sizes, types of core, number of turns and winding diameters have been checked by a network analyzer. All examples of this type of transformer displayed a very high reactive component of input or output impedance when terminated by a resistive load (7).

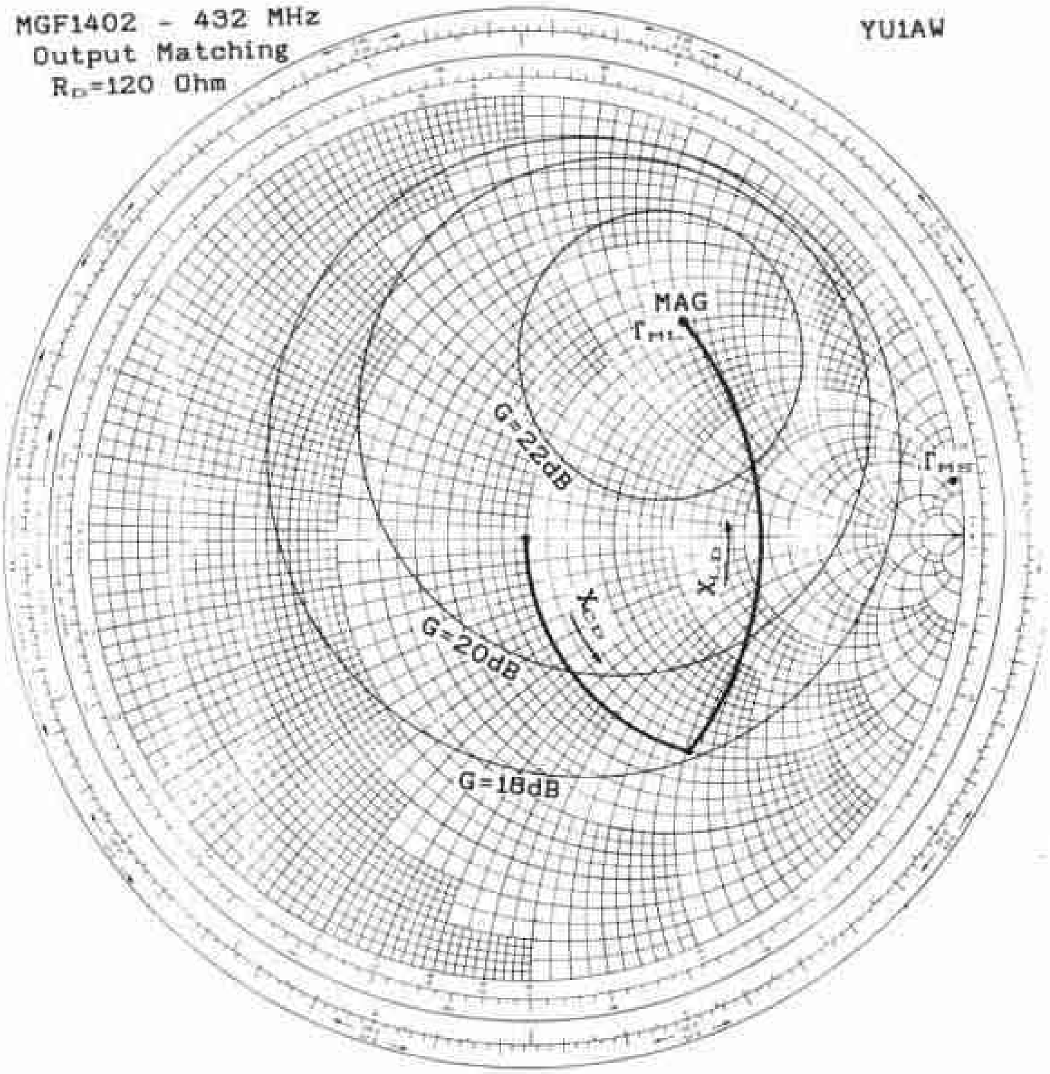

Fig. 4: Constant gain circles and the way of output matching of MGF 1402 on 432 MHz with shunt-resistor $R_D = 120\,\Omega$ and high-pass L matching network, as suggested in text. Amplifier is unconditionally stable and with aid of reactances of coil X_{LD} and capacitor X_{CD} it is very easy to achieve max. gain (MAG)

It must therefore be concluded, that these transformers perform very poorly, even at frequencies in the 2-metre band, and introduce stability problems because of their high component of reactance. The resistive loading has therefore the advantage that it enables stable operation over a much wider range of output impedances but fig. 3 makes it clear that the transistor will self-oscillate over quite a large range of inductive impedances.

Quite apart from the problem of stability, there is the potentially even more difficult problem of output matching (4). This can mean that the amplifier presents a very poor source impedance to the following stage. It is left to the imagination what will happen if two conditionally-stable amplifiers are connected in cascade – either a two-stage oscillator is created, or an amplifier which is working well below its potential performance.

It may be concluded that the output matching of GaAs-FETs working at low frequencies is not an easy task to solve. Every constructor's aim is to build an unconditionally-stable amplifier with high gain, extremely low noise and a low output VSWR.

The design presented in this article will go a large way in realizing this objective.

3.
CALCULATING FOR UNCONDITIONAL STABILITY

The characteristics and behaviour of a transistor at a specified frequency, are defined by scattering, or S-parameters. The use of these parameters enables many important values to be revealed:–

1. The stability factor K is a measure of the transistor's tendency to oscillate. When K is greater than unity, the transistor is unconditionally stable, that is, the connection of any passive load or source admittance will induce oscillation.
2. The Maximum Stable Gain (MSG)
3. The Maximum Available Gain (MAG). This is the forward power gain when the input and output are simultaneously, conjugately

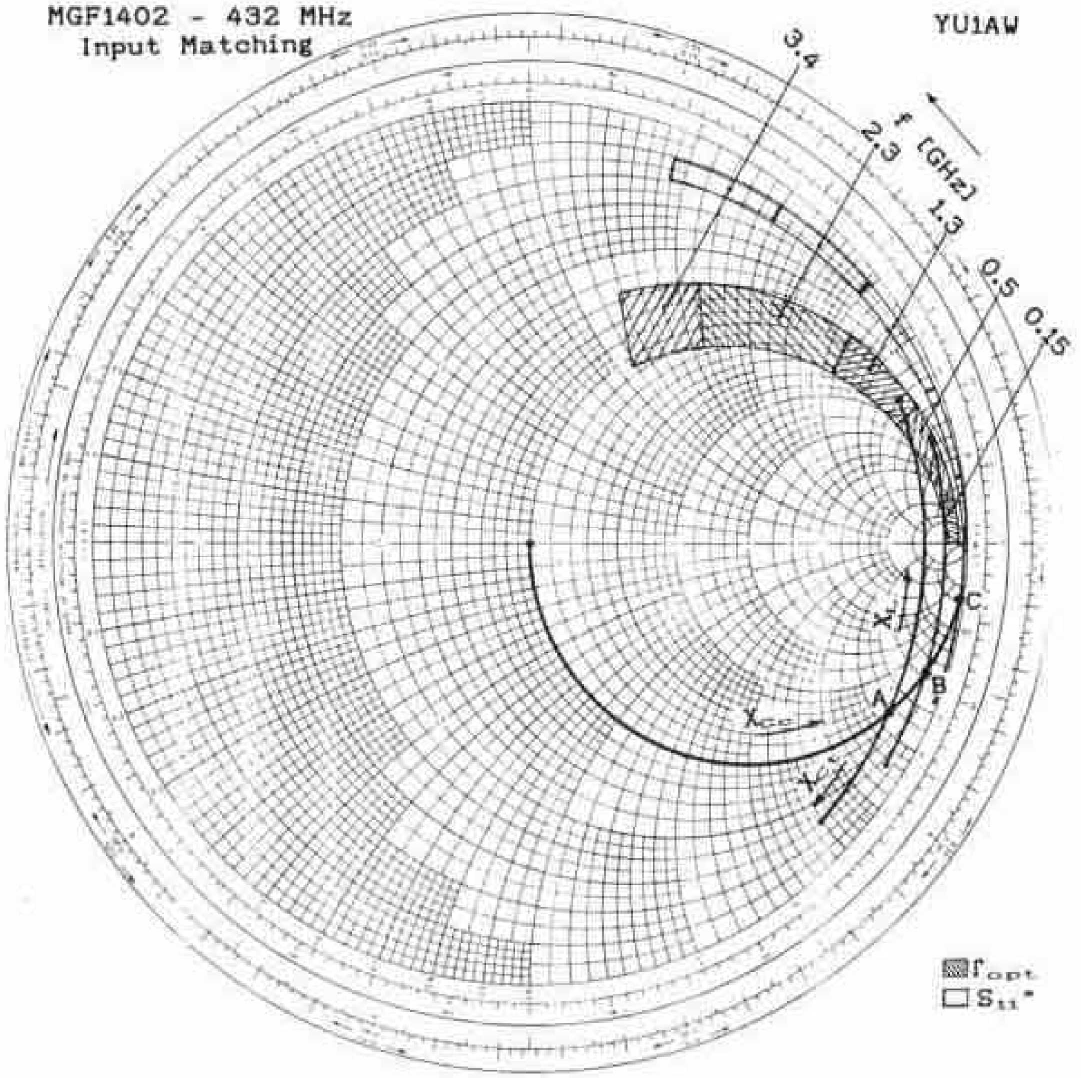

Fig. 5: Input matching of MGF 1402 on 432 MHz with aid of reactances of coil X_L and capacitors X_{Cc} X_{Ci} to minimum noise or maximum gain.

matched. The MAG is only defined for a device which is unconditionally stable (K > 1).

A conditionally-unstable device may be made stable by connecting a resistive load at its output. As it has already been seen, however, it is not possible to use just any value of load resistance as the device can remain unstable or even start oscillating. The resistance value must be determined by calculating the new S-parameters of the device together with the resistor-cascaded network (4). From the S-parameters, the stability factor K can be determined. When K is greater than unity, the value of resistance has been found which will make the amplifier unconditionally stable (4). After the value of the shunt resistance has been found using the new S-parameters, the input and output reflection coefficients for the maximum available gain (MAG) can be found (5). See fig. 4.

The value of the gain obtained for the MAG is smaller than of the MSG of the potentially unstable device before the addition of the shunt resistor, but it nevertheless represents a good trade-off. A few dBs of gain has been sacrificed in order to make the amplifier unconditionally stable. High frequency GaAs-FETs also have a very high gain at lower frequencies and there is still sufficient gain left.

The output matching for MAG is accomplished by the use of a high-pass L-network. This circuit will achieve simple and effective matching together with DC-blocking whilst using the minimum number of components. **Fig. 6**.

The MAG for the majority of GaAs-FETs is around 20 - 22 dB, lower than the MSG about 2 - 5 dB depending upon type and frequency. As mentioned previously, the MAG is achieved under conditions of a simultaneous, conjugate match of input and output. But, an input match for minimum noise and not the maximum amplification, is what is required. The input match for minimum noise entails a gain of around 2 - 3 dB lower than MAG.

The output return-loss is about 40 dB (VSWR = 1.02 : 1) which is much higher than that achieved by using a 4 : 1 transformer or a resistive output load (VSWR = 3.5 : 1).

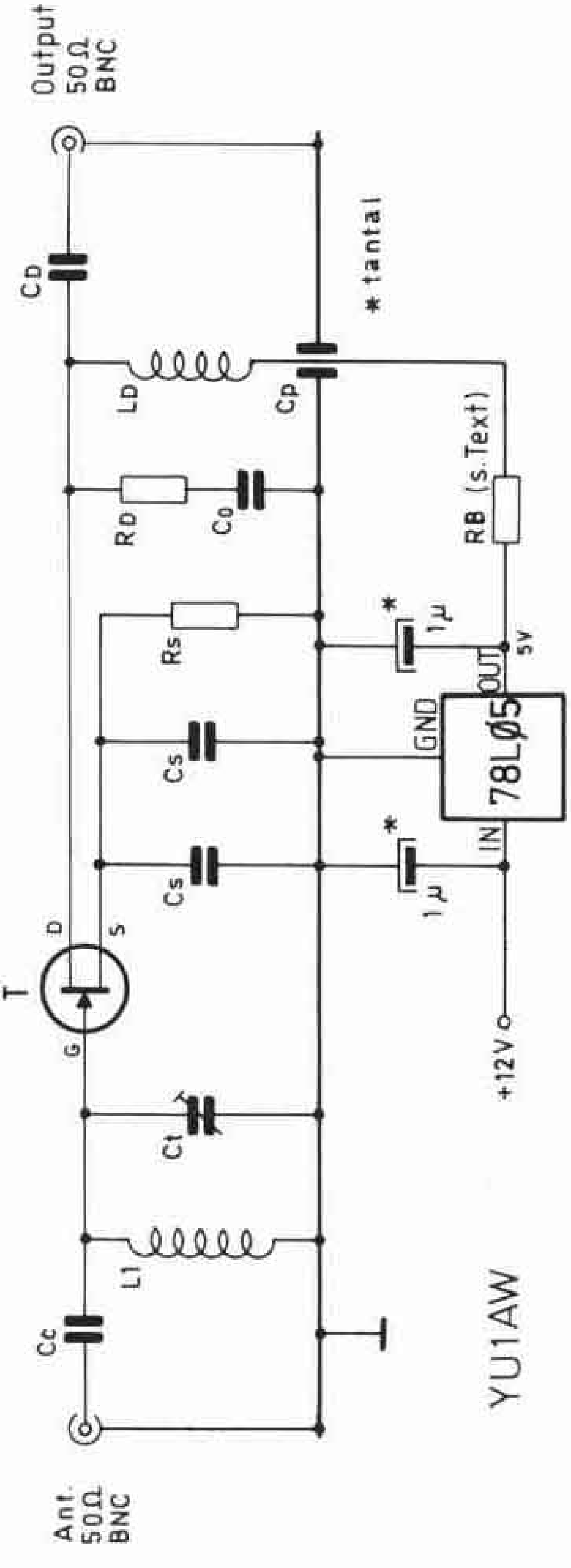

Fig. 6: Schematic diagram of unconditionally stable GaAs-FET preamplifier for 144 MHz

4.
INPUT CIRCUIT CALCULATION AND TUNING

Almost all GaAs-FETs below about 4 GHz, have a high input impedance with a large capacitive component. Conjugated values (marked with *) of input reflection-coefficients S_{11} are shown on the Smith Chart in **fig. 5**. The optimum input reflection-coefficient for minimum noise Γ_{opt} or impedance Z_{NF} is also shown on the same Smith Chart. It may be readily concluded, that the reflection coefficients S_{11}^* and Γ_{opt} are similar in phase but differ in amplitude.

This fact can be used to tune the amplifier input tuned-circuit for minimum noise in a simple but precise manner without the use of instruments.

The transformation of the antenna impedance $R_L = 50 + j0$ to the optimum noise-figure impedance Z_{NF} using input circuit components C_t, C_c and L_1 (fig. 6) are given on the Smith Chart of fig. 5. Capacitor C_c transforms to the real part of the impedance R_{NF} whilst C_t together with inductance L_1, set the imaginary part of the impedance X_{NF}. From fig. 5, it is quite clear that different values of C_c, i.e. reactance X_{Cc}, will have a direct influence on whether the input matching will be for maximum power gain or for minimum noise. If the value of C_c is low, i.e. high X_{Cc}, the transformation will be on the line, Smith Chart centre (point C) and the amplifier will be tuned for maximum power gain. If, however, C_c is lower, i.e. lower X_{Cc}, then the transformation will be on the line, Smith Chart centre point (B or A), and consequently the amplifier will be tuned for minimum noise.

Thus, in order that the amplifier be tuned for minimum noise, it is necesary that the value of capacitor C_c be determined. Once this is established and fixed, the amplifier will be automatically adjusted for minimum noise and an adjustment of C_t will only result in a variation of the power gain. The power gain so attained, is some 2 to 3 dB lower than if C_c had been adjusted for a maximum gain MAG. This is normal and is the small price that must be paid to obtain the minimum noise figure.

For illustration purposes, **table 1** contains various values for the input circuit elements together with the consequent values of Q_L and input circuit losses. The calculations were made for different antenna matchings. It may be readily seen that with an accurately determined value for the coupling capacitor C_c no mis-tuning is possible, even under conditions of high antenna VSWR. Moreover, there is a wide range between points A and B on the Smith Chart for which minimum noise is possible and this allows a tolerance of some ± 20 % in the value of C_c making it relatively uncritical.

This begs the question of what is actually critical since there are many examples of poorly designed amateur preamplifiers in operation! The answer is rather simple and logical: for the amplifier described in this article all elements were optimized and very carefully calculated in order that no performance degradation will occur when a reasonable degree of component tolerance is adhered to. This, however, is not valid for any poorly designed amplifiers of the type mentioned earlier.

Another reason for poor performance is that the amplifier has been tuned to minimum noise literally by ear and this is always misleading. There will always be amateurs who will believe that the prerequisite for a good pre-amplifier is an extremely high gain. This misconception can lead to the lowering of the value of C_c to obtain the maximum possible gain (MAG). This is the sort of result which can be arrived at when the amplifier is tuned by ear and without the use of instruments. It really is difficult to convince some people, that the amplifier must be detuned in order to improve reception – but that is the fact of the matter.

5.
A 144 MHz GaAS-FET PREAMPLIFIER

The preamplifier described here is a modified version of that described in the author's earlier

VSWR	Tuning for	C_t pF	C_c pF	Q_L	Input-circuit losses
1,0	min. noise	1,5	1,3	8,5	0,04 dB
	max. gain	2,4	0,7	49,3	0,16 dB
1,2	min. noise	1,2 - 1,5	1,2 - 1,4	8,5	0,04 dB
	max. gain	2,4	0,6 - 0,8	49 - 51	0,17 dB
1,5	min. noise	1,1 - 1,6	1,1 - 1,6	8 - 10	0,04 dB
	max. gain	2,3 - 2,5	0,5 - 0,8	48 - 53	0,18 dB
1,8	min. noise	1,1 - 1,6	1,0 - 1,7	8 - 10	0,04 dB

Table 1: Component values for the 432 MHz input tuned-circuit, its Q_L and losses in relationship to the antenna VSWR and the tuning objective

article on the subject (1). This had been designed as a conditionally stable amplifier with resistive output loading, an RF choke to feed in the DC-supply and a capacitor for DC-blocking. The modification to that circuit represents a further development and entails making it unconditionally stable in the afore-mentioned manner.

A third capacitor C_o, for DC-blocking of R_D, has been added to the two existing chip capacitors C_s soldered to the screening wall. All components together with their values are given in **table 2** and the ciruit schematic is shown in fig. 6. The amplifier's method of construction is given in the three sketches of **fig. 7**. No changes have been made to the helical-resonator, input circuit. This is effected with 5 turns of 2 mm silvered wire wound on a 18 mm-long, 13 mm-diameter forming tool. This inductor (1) has always proved itself very effective in practice.

The only modification concerns the coupling capacitor C_c which replaces the trimmer capacitor connected to the 3.3 pF ceramic disc. This is the fixed capacitor mentioned earlier which enables the amplifier to be tuned easily for minimum noise. The earlier inclusion of a ferrite bead was dropped on the grounds that it made the amplifier conditionally stable.

Trans. Type	f MHz	G_{max} dB	Stab.-F. K	loss dB	C_t pF	C_c pF	R_D Ω	C_D pF	L_D nH	D_D mm	l_D mm	n_D Turns
MGF 1200 *	144	20	+ 1.2	0.13	2.5	3.3	68	22	44	3	6	5.5
MGF 1200	432	19	+ 1.2	0.04	1.5	1.3	60	8.2	13	3	4	2.5
MGF 1402 *	432	22	+ 1.3	0.04	1.5	1.3	120	4.7	20	3	5	3.5
MGF 1402 *	1296	18	+ 1.3	0.04	0.8	0.5	82	2.5	5	3	–	1

L_D: drain inductor
D_D: inductor internal diameter
l_D: length of L_D
n_D: numbers of turns of silvered wire 0.5 - 0.8 mm dia. for L_D

Table 2: Calculated of component values on the amplifier's characteristics. The following devices can be used in all amplifier versions without entailing component changes: MGF 1202, -1302, -1400, -1412, -1303, CFY 12, -13, -14.

The preamplifier housing is fabricated in accordance with **fig. 8** from 0.5 - 0.6 mm copper or brass sheet. The chip capacitors are soldered onto the screened wall on the same side as the screen is soldered to the box sides. This ensures that solder is kept from the vicinity of the helical resonator thus tending to keep losses low. The lower end of the coil L_1 is passed through a hole in the screen wall and then soldered. The trimmer capacitor C_t is a Johanson Air Tronic type 5200, 5270 or 5202. The coaxial connectors can be either "N" or BNC-types and are soldered on to the box. A degree of protection, as well as a stable supply voltage, is afforded by the three-terminal regulator 78L05.

6.
A 432 MHz GaAs-FET PREAMPLIFIER

The circuit schematic of **fig. 9** indicates its close relationship with the 2-metre version. The output is also loaded with a resistance R_D in order that the amplifier is rendered unconditionally stable. A high-pass L-network, comprising a miniature disc or chip capacitor C_D and inductor L_D, matches the resistor/transistor to the 50 Ω output impedance.

In accordance with what has been discussed earlier, it is apparent that the optimal form of input circuit on this frequency is a coaxial resonator having a characteristic impedance of 77 Ω. Capacitive coupling is effected to the antenna. Fine tuning to resonance is carried out by a Tekelec or Johanson trimmer type 5200, 5202, 5700 or 5800 and the antenna coupling is made by a plate-capacitor fabricated in accordance with **figs. 10c and 10d**.

This type of trimmer ensures a minimum of circuit losses. Its dimensions and its distance to the resonator have been carefully dimensioned that the optimum calculated capacitance can be achieved in practice. This is important for the correct tuning of the amplifier for minimum noise as discussed earlier in the opening chapter.

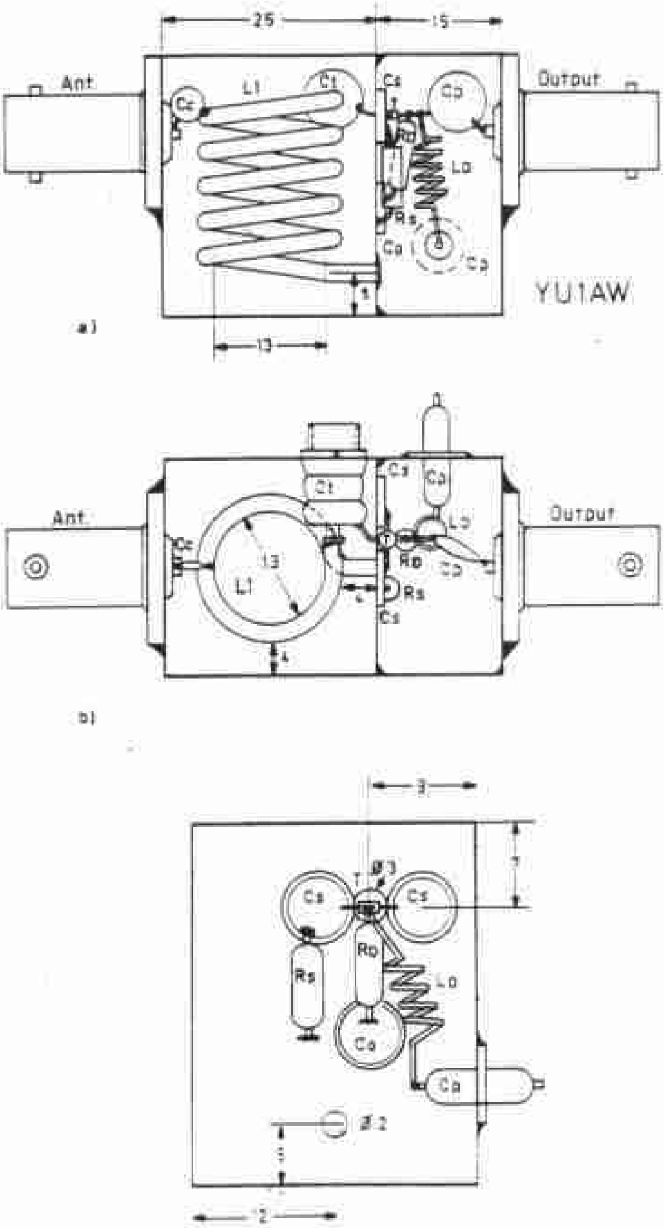

Fig. 7: Constructional details for the amplifier of fig. 6, a)side view, b) upper view, c) screen wall with mounted components

The drain current has to be adjusted to 10 to 15 mA (approx. 20 % of I_{DSS}) for each individual transistor. This is carried out by a process of changing the source resistance R_s until this current has been obtained. The source voltage U_{DS} will then be close to 3 V for FETs in the MGF-series, necessitating a value of 100 Ω for R_B, and 4 V for the CFY-series, R_B = 10 Ω.

The transistors MGF 1200, -1202, -1402, - 1400, -1412, -1302 and the CFY 12, -13 and -14, have

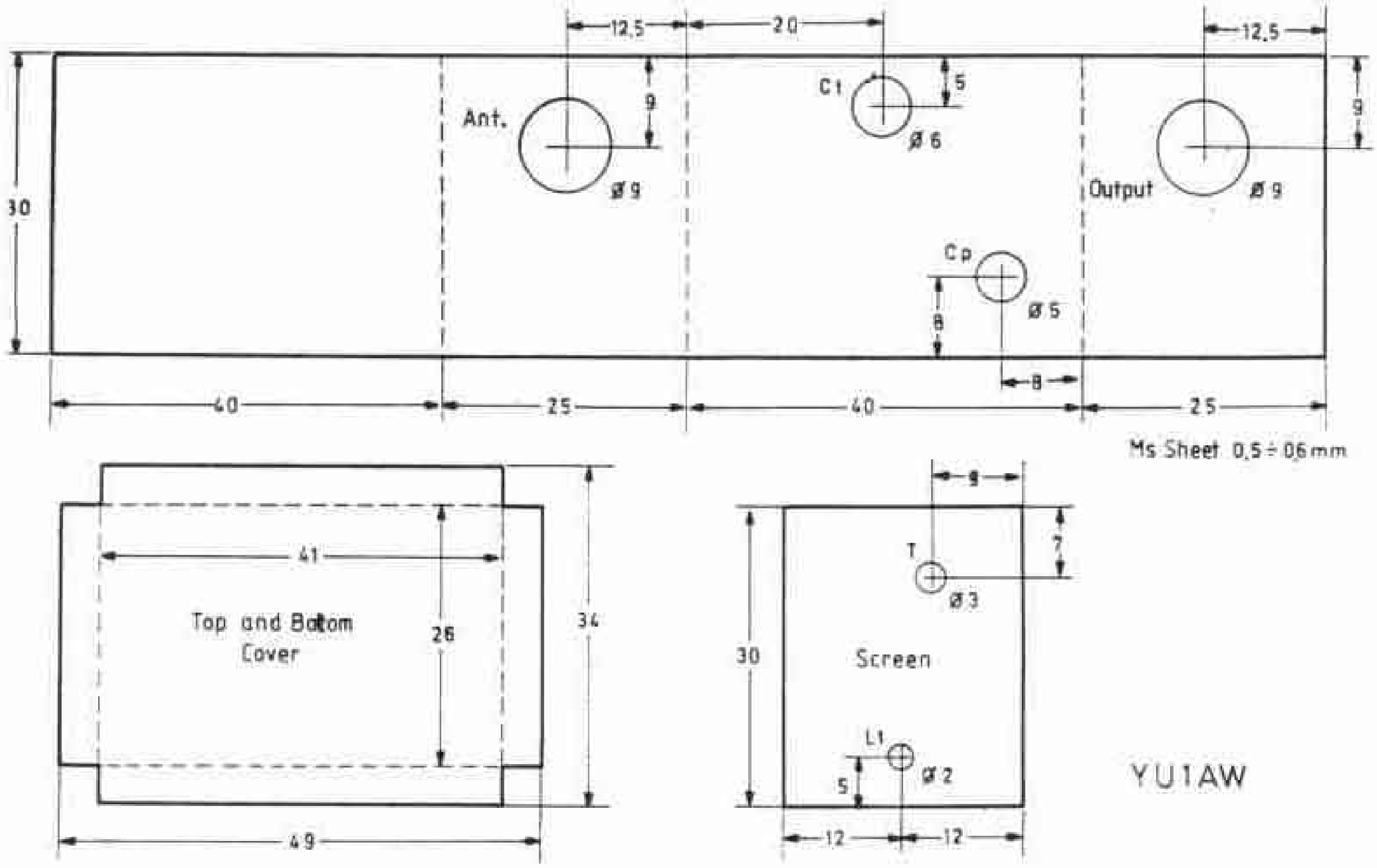

Fig. 8: Sheet brass parts for the amplifier of figs. 6 and 7

very similar S-parameters at this frequency and can be interchanged without any circuit alterations.

The housing, shown in **fig. 11**, is made from silvered brass sheeting 0.5 to 0.6 mm thick. It is fitted with a cover. The resonator is also silver-

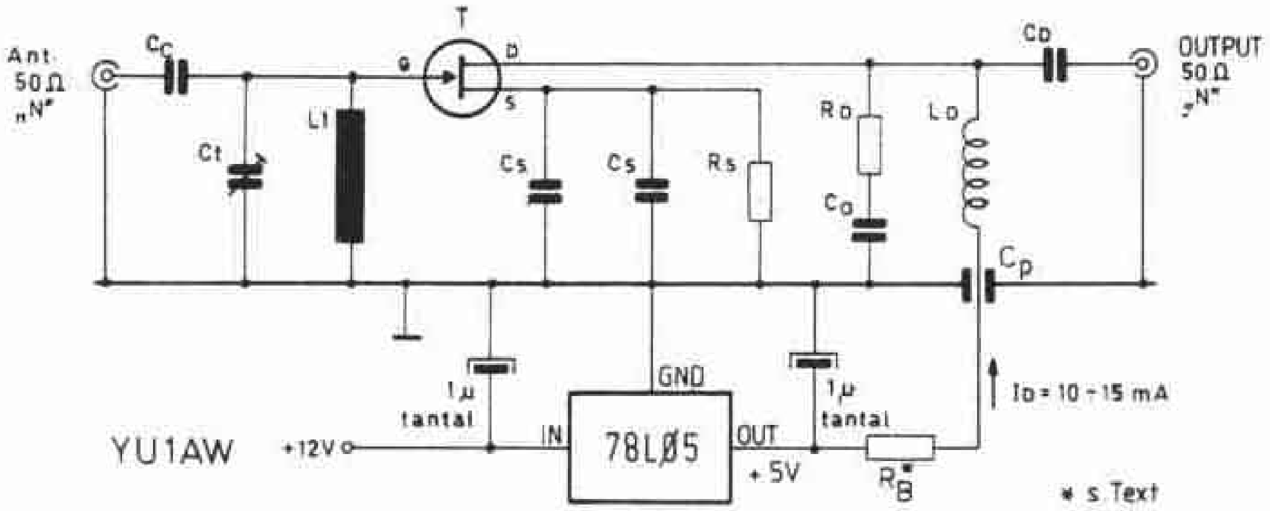

Fig. 9: Schematic of an unconditionally stable GaAs-FET preamplifier for 432 or 1296 MHz

coated and is fitted through a hole in the housing wall, protruding some 0.5 mm to the outside. It is then soldered to the wall. As by the 2-metre construction, there should be no solder in the interior of the coaxial resonator, this keeps losses low.

The capacitor C_c is also silvered brass plate from the same material as the housing. It is bent and fitted exactly 1 mm from the resonator and soldered. This is achieved conveniently by cutting a suitable piece of 1 mm cardboard and forming both cardboard and plate into the required shape. The combination is then pressed against the resonator and the plate soldered into position on the inner of the connector – the cardboard spacer is then, of course removed. Both the input and the output connectors are of the type N. The input socket is soldered to the case but it is probably better to fasten the output sockets with screws after assembling the output circuit.

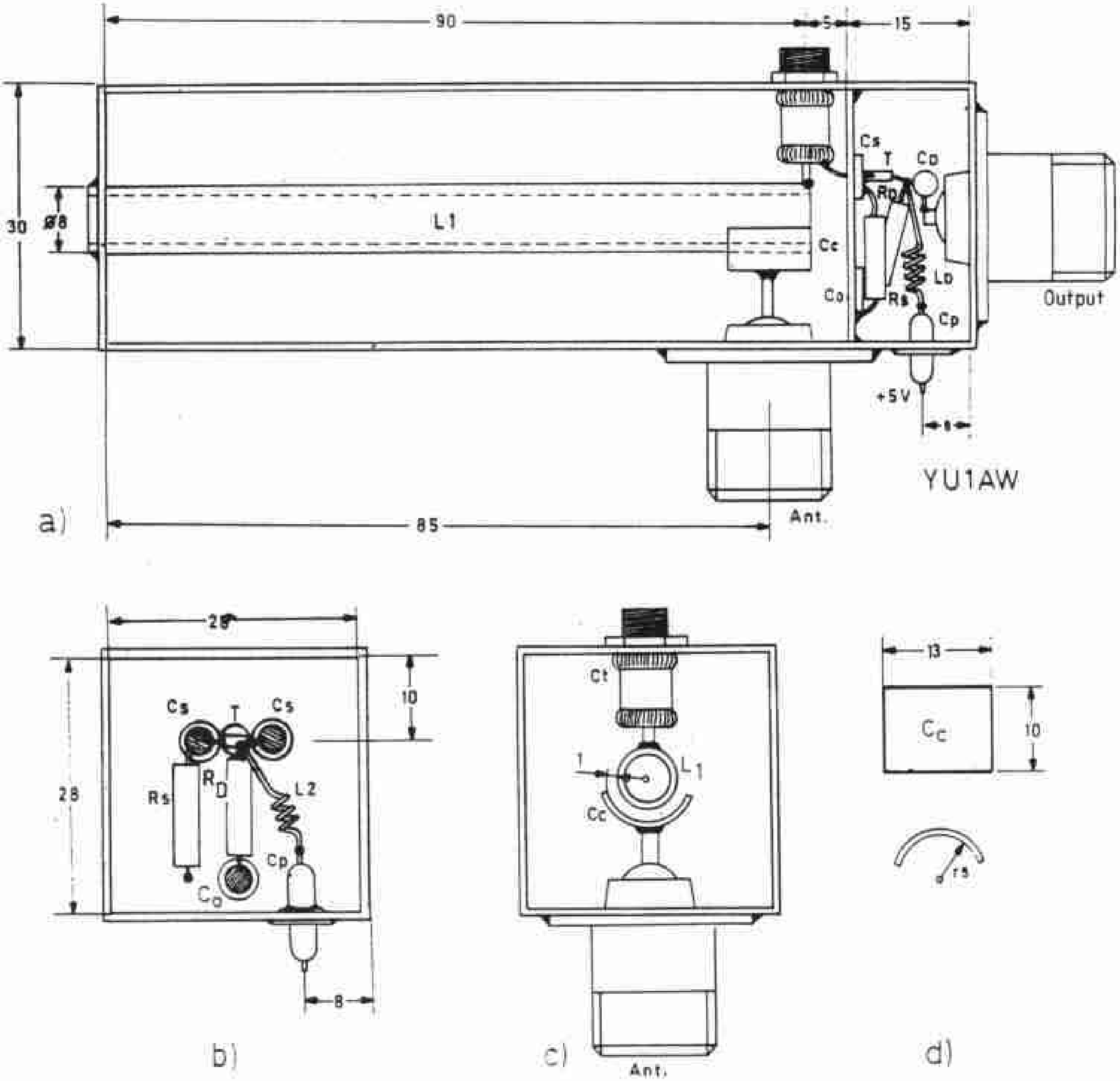

Fig. 10: Constructional details for the 432 MHz-version of the amplifier of fig. 9

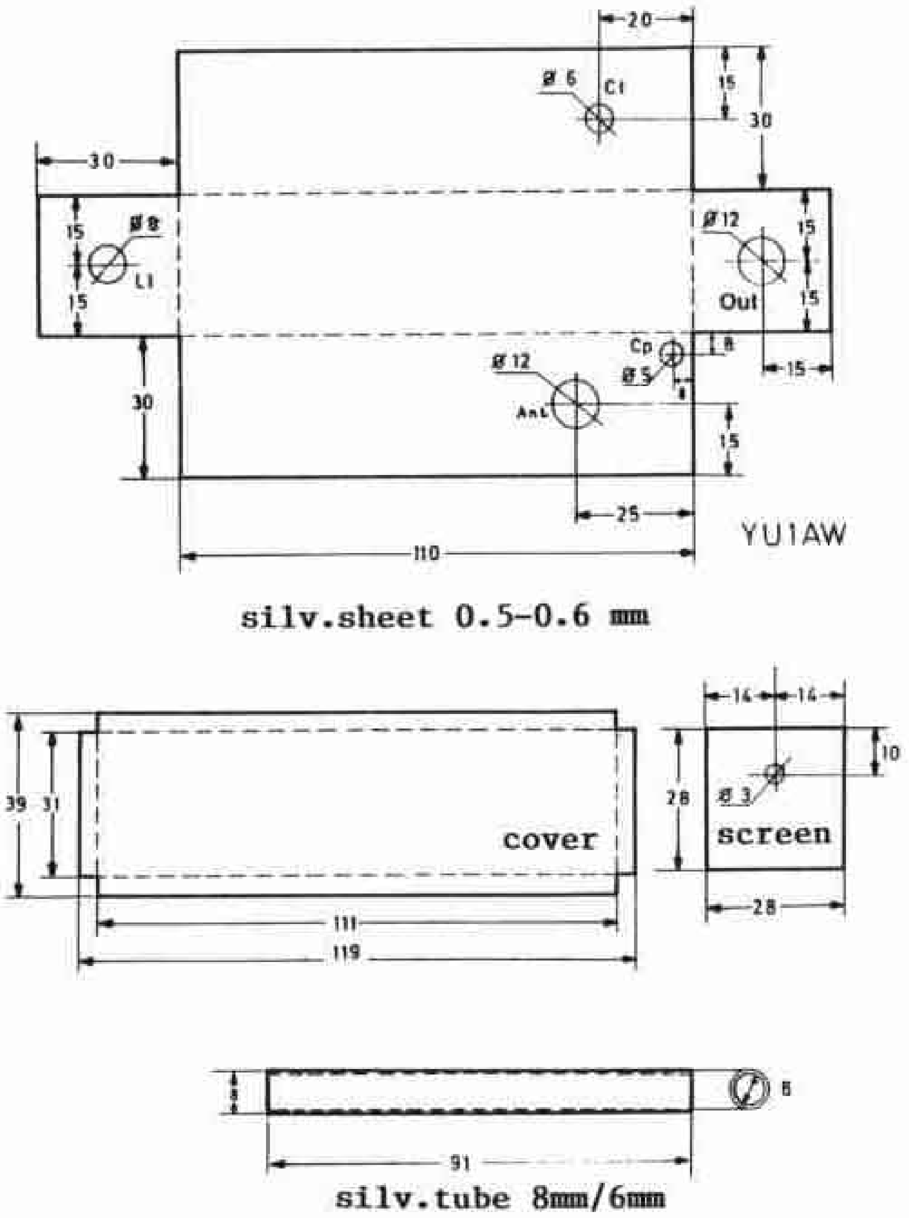

Fig. 11:
Dimensions for fig. 10

7.
GaAs-FET PREAMPLIFIER FOR THE 23 cm-BAND

As can be seen from **figs. 9 and 12**, only the size of the resonators differentiates the amplifiers for the 70 cm and the 23 cm bands. This also determines the overall size of the construction – the 23 cm unit being smaller.

Owing to the high frequencies particular care must be taken in the construction of the housing (**fig. 13**). The cover must be of a very good electrical fit all the way around its perimeter. The cover should be spot-soldered to the housing at a few equi-distant points around its edge after the assembly has been finished. Perhaps a better solution to this problem is that adopted by YU1IQ, who also constructed a version of this amplifier. This uses a box construction made from brass sheet (25 x 25 x 38 mm long) and is shown in **fig. 14**. The screening wall and the end walls are silver-soldered.

In order to circumvent the problem of the poor cover contact, two small windows were cut which were just large enough to permit the installation of the transistor, the plate capacitor C_c and the

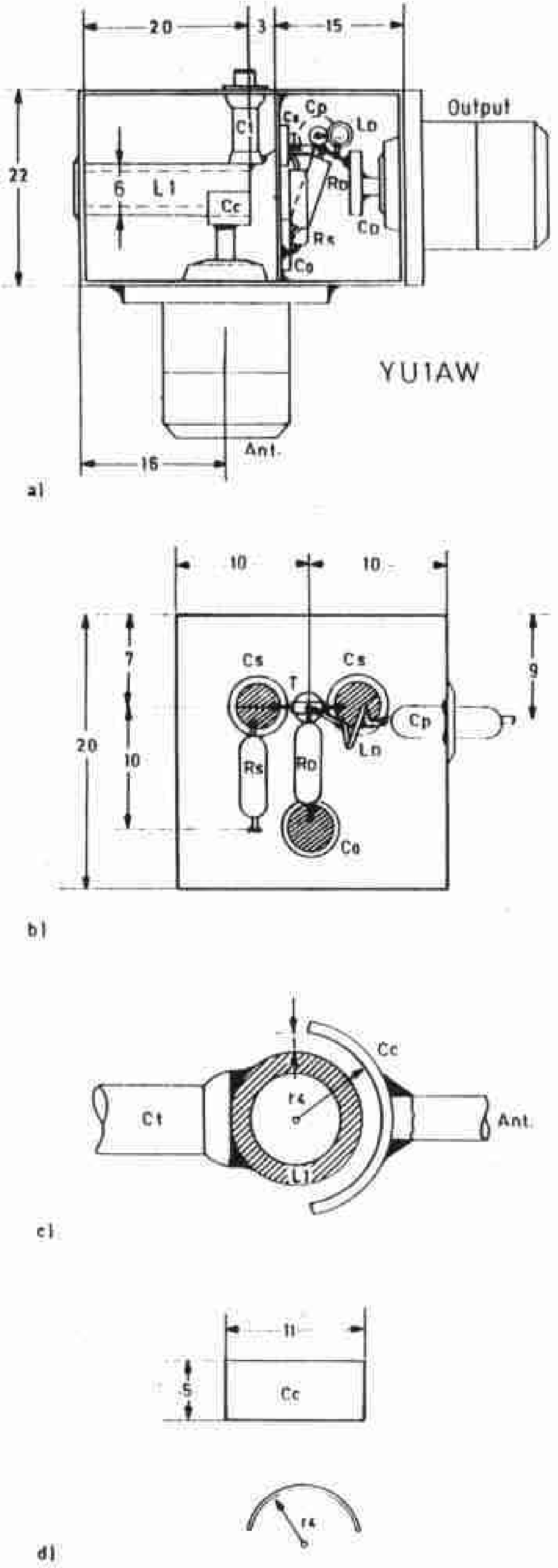

Fig. 12: Constructional details for the 1296 MHz-version of the preamplifier in fig. 9

other parts. The output circuit components can be assembled through the output connector hole. The windows can then be sealed by a cover using many small screws. The two sockets for input and output are also screwed on to the housing.

The silvered resonator has a 6.5 mm diameter and has a characteristic impedance of 77 Ω. It is provided with a 3 mm internal threaded end and is fastened to the housing with a good electrical contact by means of a suitable screw.

It is very important that at this frequency the highest grade of trimmer capacitor is employed for C_t. Suitable types are Tekelec and Johanson types 5700 or 5800 (0.3 - 3.5 pF). It is connected to the resonator by a screw-thread (see fig. 14).

The test measurements on both prototypes showed a very good conformity both with each other and with the theoretical predictions for amplification, noise-figure, input circuit loaded-Q and the output circuit matching. The unconditional nature of the stability was manifest under all input and output conditions. Also, the simple and precise tuning for minimum noise was carried out and then confirmed by measurement.

8.
CONCLUSIONS

Even nowadays, many antenna preamplifiers designs are published and also manufactured without a consequent consideration of the problems concerning output matching and its wideband stability. The consequence is, that they are only conditionally stable over a limited range of frequencies and/or input and output impedances.

They appear to give satisfactory results thanks largely to the very low-noise factor of the active device employed. However, owing to poor design, the noise caused by input circuit losses often overshadows that from the transistor itself. The most agressively priced preamplifiers are among some of the worst cases in this respect. They are also adjusted to unnecessarily high gain (sells well!) making them unstable and problematical in operation.

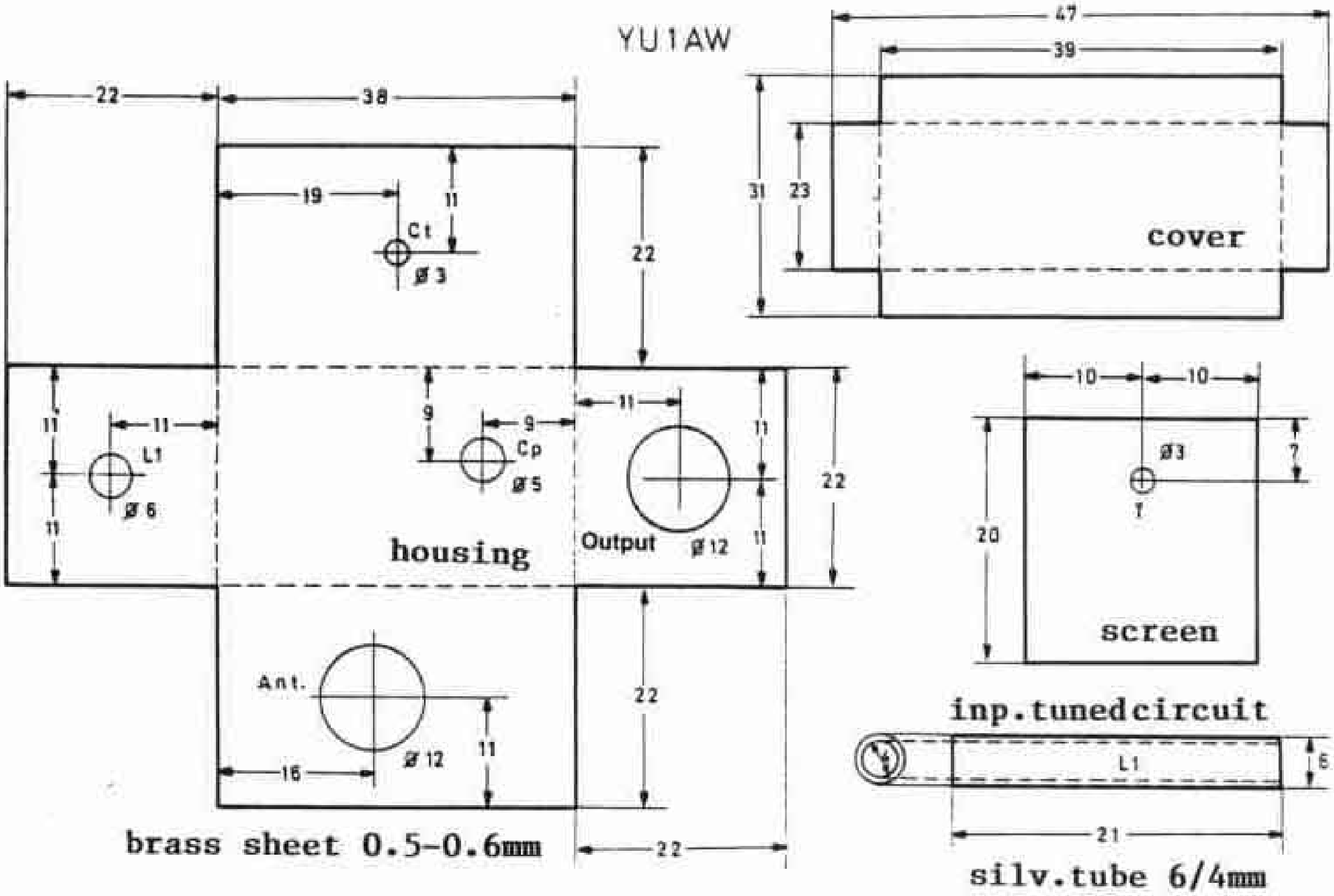

Fig. 13: Dimensions of the metal work for fig. 12

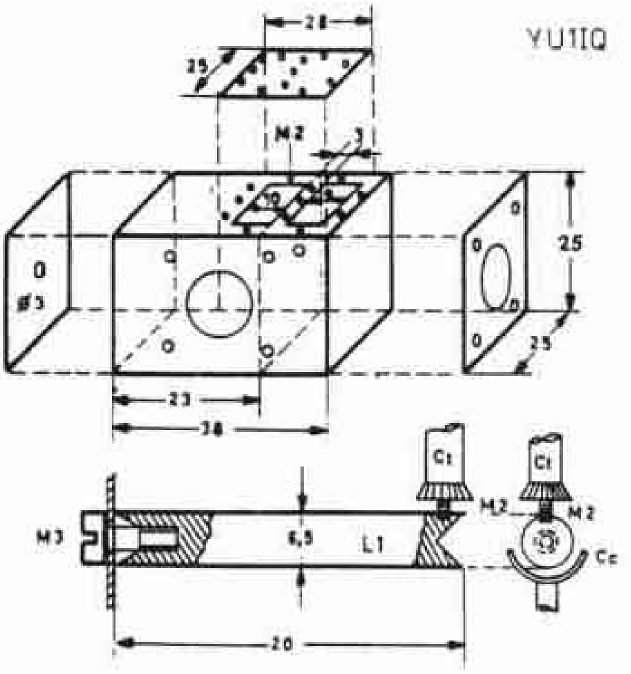

Fig. 14: YU1IQ's alternative version of the 1296 MHz-preamplifier based on a square-section tube of brass 25 x 25 mm

In order to make a valid evaluation of the performance of a preamplifier, the following criteria are offered:–

- The input circuit transformation must be adjusted for minimum noise and not for maximum overall gain.
- The input circuit must have a minimum of losses in order to keep the noise due to these losses from exceeding that produced by the active device itself.
- Over a wide range of frequencies and also input/output impedances, the amplifier must show no signs of instability.
- Output matching to the following stage must be good (low VSWR) thus providing it with a good source impedance.
- Posses just sufficient gain to minimize the second-stage noise contribution to the overall noise figure.

The application of these criteria to the preamplifiers described in this article have the following consequences:

1. A fixed capacitor C_c enables the input to be precisely and easily tuned to the minimum noise condition.
2. A careful calculation of the optimum values for the input circuit elements for minimum loaded-Q, choice of resonator type for the maximum possible Q_u and the use of high-Q trimmers all ensure a minimum of circuit loss.
3. The calculation of the exact loading of the device's output circuit to achieve an unconditional stability factor i.e. $K > 1$.
4. The above drain-circuit evaluations entail repeated calculations of the S-parameters of the device plus resistor, then output matching for maximum gain. This ensures an unconditionally stable amplifier with a low output VSWR together with a high gain.
5. The gain degradation resulting from the loading of the device by the drain resistor R_D should only result in the loss of a few dBs but this loss is easily accommodated by the very high gain exhibited by GaAs-FETs at these low frequencies. The overall gain available is usually in the region of 20 dB – more than enough for all practical applications.

9.
REFERENCES

(1) Dobričić, D., YU 1 AW: Low-Noise 144 MHz
Pre-Amplifier using Helical Tuned Circuits
VHF COMMUNICATIONS, Vol. 19,
Ed. 4/1987, P. 243 - 252

(2) Nollis, W.C.:
Design of Transmission Line Tank Circuits
Electronics Manual for Radio Engineers,
1949, P. 748 - 752

(3) Motorola AN-421:
Semiconductor Noise Figure Considerations
Motorola RF-Data Manual 1980

(4) Vatt, G., KB 0 O:
Computer-aided UHF Preamplifier Design
Ham-Radio Magazine, Oct. 1982, P. 28 - 35

(5) Froehner, W.H.: Quick Amplifier Design with
Scattering Parameters
Electronics, Oct. 1967, P. 5 - 2 to 5 - 11

(6) Bertelsmeier, R., DJ 9 BV: How to achieve
a low system temperature on 432 MHz EME
Paper prepared to the 3rd Intern. EME
Conference in Thorn/Nederlands, Sept. 1988

(7) Molitor, L., W 7 IUV: Taming a Preamp
2 Metre EME Bulletin, No. 45, Dec. 1987