A HIGH EFFICIENCY GAAS FET HIGH POWER AMPLIFIER APPLICABLE IN HANDY PHONE EQUIPMENT

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ABSTRACT

Recenty a handy telephone has been developed and is going to replace a mobile telephone. A handy telephone utilizing batteries uses most of its DC power for its transmitter power amplifier. Therefore the transmitter power amplifier applicable to a handy telephone has to be high efficiency (low power consumption). Also spurious specification of a telephone needs a stable transmitter power amplifier.

In this paper,we will describe the design philosophy of a high stability and high efficiency GaAs FET power amplifier applicable to a handy telephone. Also we will report the performance of the high stability and high efficiency GaAs FET high power amplifier we developed.

INTRODUCTION

The basic rf block diagram of a handy telephone which has been developed is shown in Fig.1. This equipment is composed of an antenna,a duplexer,a mixer a low noise amplifier,a demodulator,a frequency synthesizer,a modulator,an up convertor,a power amplifier and so forth. And the power consumption of the circuits except transmitter power amplifier is less than about 1 Watt. Therefore,it is indispensable to realize a high efficiency transmitter power amplifier for longer talking time as a handy telephone operates with small batteries. Also the power amplifier must have an automatic power control(APC) function because the output power has to be adjusted to proper value to the

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distance between the telephone and the base station. Furthermore a power amplifier has to operate without any spurious oscillation with duplexer load.

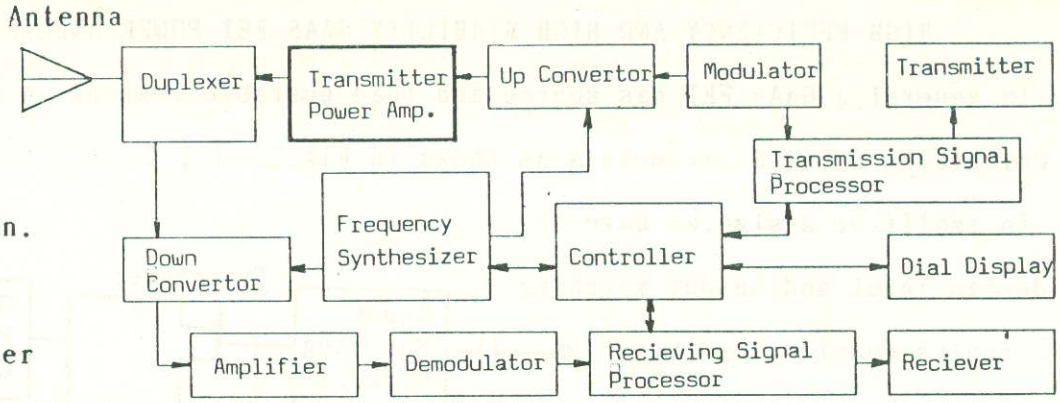


Fig.1 Basic rf block diagram of a handy telephone

A GaAs FET is a better device than a silicon bipolar transistor for a power amplifier for use in a handy telephone because it is high in gain and high in efficiency and because it can operate with a low voltage. But a GaAs FET power amplifier sometimes oscillates under APC operation or with load conditions. An analisis of the oscillation frequencies was done and we found that the small signal stability analysis helps for suppressing the oscillations.

Based on amplifier design mentioned above, we have developed a power amplifier applicable to a handy telephone.

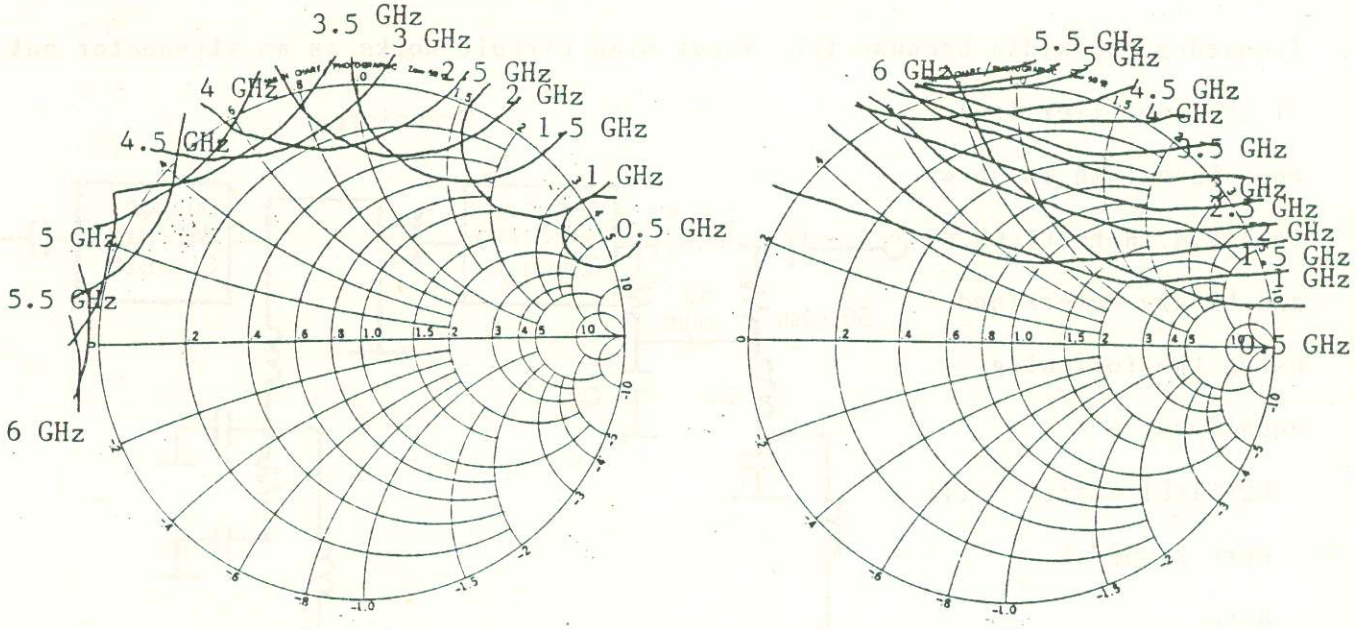


Fig. 2 An example of GaAs FET unstable region.

HIGH EFFICIENCY AND HIGH STABILITY GAAS FET POWER AMPLIFIER DESIGN

In general,a GaAs FET has source and load unstable regions on Smith Chart calculated using S parameters as shown in Fig.2. [1]

In amplifier design,we have to design input and output matching circuits considering these unstable regions. Simultaneously the amplifier is required to offer high efficiency. Fig.3 shows a conventional circuit construction. This unit amplifier is stabilized by the bias circuit with 50Ω which prevents low frequency oscillations of the amplifier. But the stabilizing effect of this bias circuit in a frequency region near the amplifier frequency bandwidth is not enough for the low Q circuit.

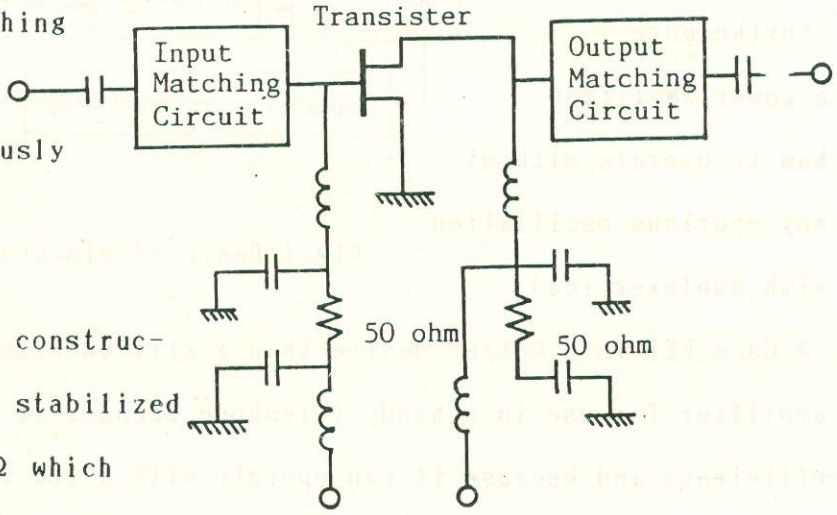


Fig. 3 (a) Conventional circuit construction

Fig.3 (b) shows the improved circuit construction we made. The input bias circuit with two 50 ohms stabilizes the all frequency regions out of amplifier frequency bandwidth because this input bias circuit works as an attenuator out of the amplifier frequency bandwidth as shown in Fig.4. Here C1,C2,L1 and L2 are determined using the following equations.

$$L2/C1=L1/C2=Z_0^2 \quad --(1)$$

Here $Z_0=50\ \Omega$

Also

$$J\omega L1+1/J\omega C1 \ll 50\ \Omega \quad --(2)$$

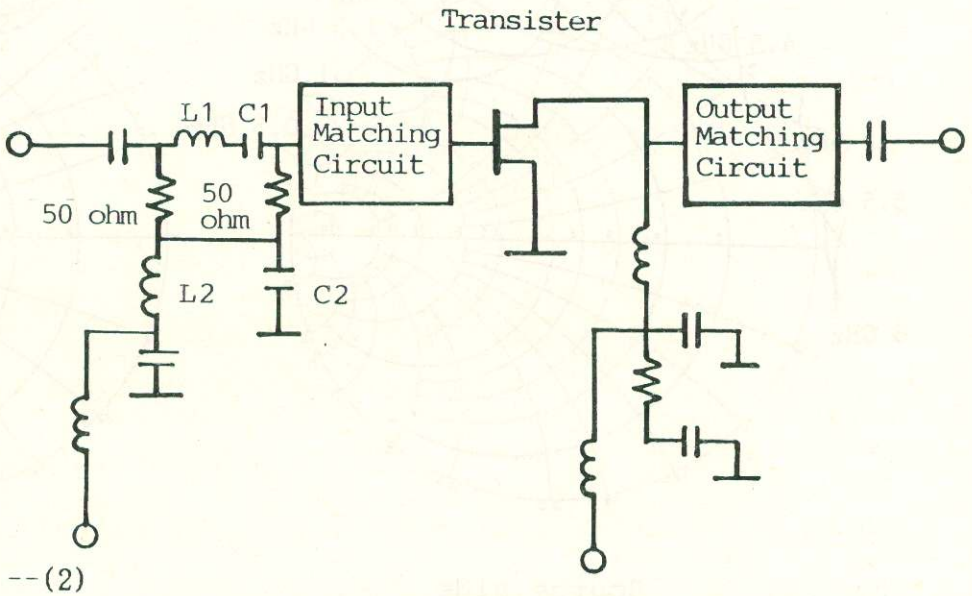


Fig.3 (b) New fundamental unit amplifier

The transmission loss of

of this bias circuit within amplifier frequency bandwidth is less than 0.5dB. Also this circuit shows 6dB/ octave attenuation characteristics outside of amplifier frequency bandwidth while the return loss are relatively good.

And in a multi-stage amplifier using new unit amplifiers, the impedance outside of the amplifier frequency bandwidth between each amplifier is improved and the total amplifier module is stabilized by the input bias circuit attenuation effect.

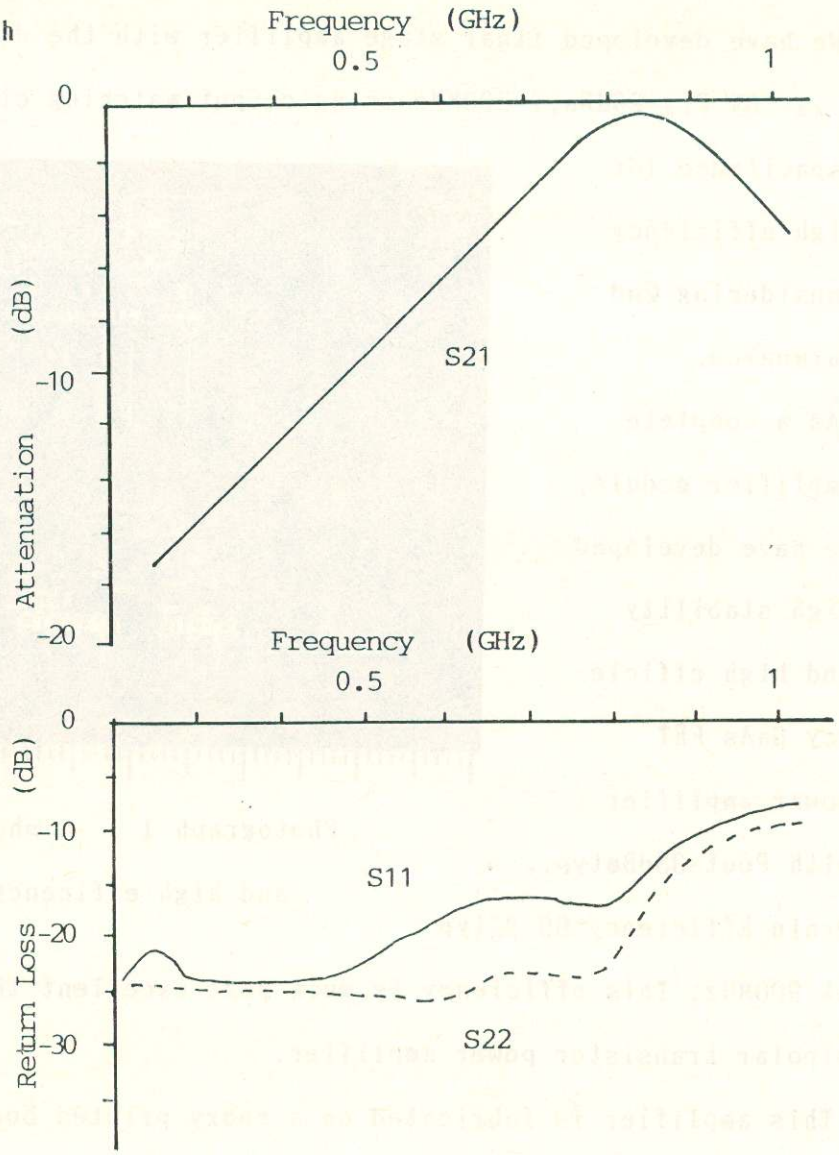


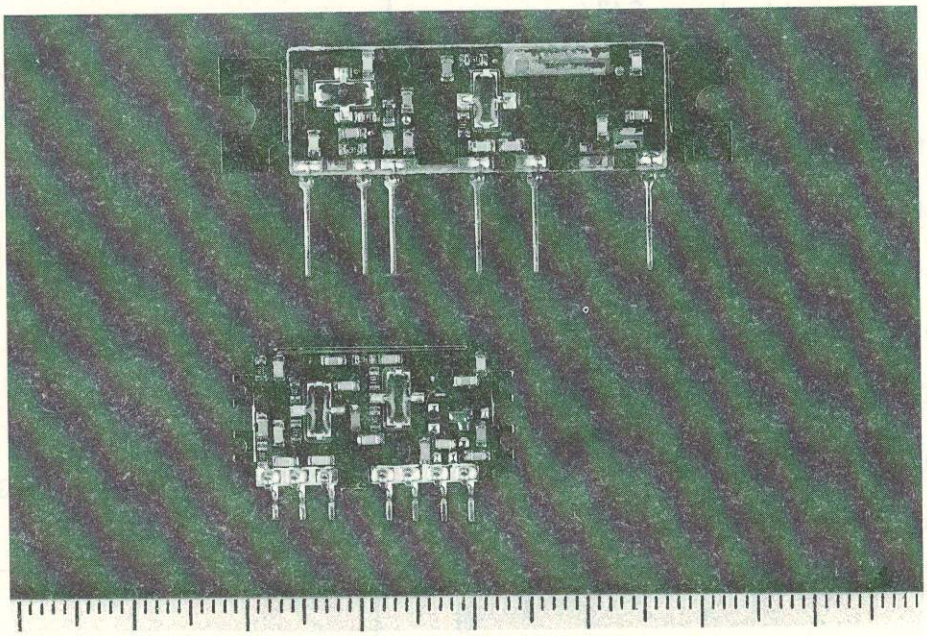
Fig. 4 A chracteristic example of stabilizing bias circuit shown in Fig.3 (b)

Photograph 1 shows the high stability GaAs FET power amplifier we have developed based on the design philosophy mentioned above. We have confirmed this amplifier stably operates with a duplexer load and under all APC conditions.

Furthermore, high drain efficiency is required to this amplifier. So the final stage amplifier must be high drain efficiency because the efficiency of a multi-stage amplifier is mainly determined by the final stage amplifier. A high drain efficiency of nonlinear amplifier is realized by operating the FET with

class AB. [2] [3]

We have developed final stage amplifier with the drain efficiency of 85% at V_{dd}= 6V, P_{in}=20dBm, f=900MHz using output matching circuit with one parallel capacitance for high efficiency considering 2nd harmonics.



Photograph 1 A photograph of high stability and high efficency GaAs FET amplifier

As a complete amplifier module, we have developed high stability and high efficiency GaAs FET power amplifier with Pout=33dBmtyp., Drain Efficiency=60 %typ. at 900MHz. This efficiency is much more excellent than that of a silicon bipolar transistor power amplifier.

This amplifier is fabricated on a epoxy printed board (ε_r =4.7, t=0.8mm) with microstrip circuit as shown in Photograph 1 . Also the new amplifier fabricated on a softboard (ε_r =10 , t=0.8mm) shown in Photograph 1 is the smallest in the world.

The APC dynamic range and harmonics of these amplifier are more than 25dB and -40dB, respectively. Photograph 2 shows the top view of the new power amplifier.

CONCLUSION

(1) We have developed a GaAs FET power amplifier for a handy telehpone using a new stability bias circuit considered GaAs FET unstable region on Smith Chart caluculated by S parameters.

(2) We have attained a high drain efficiency power amplifier using output

matching circuit with one parallel capacitance for high drain efficiency. (Pout=33dBmtyp. Efficiency=60 %typ. at 900MHz)

(3) We have realized a small size, light weight and low cost amplifier using a epoxy printed board (ε_r =4.5, t=0.8) or a softboard(ε_r =10 , t=0.8) with microstrip circuits.

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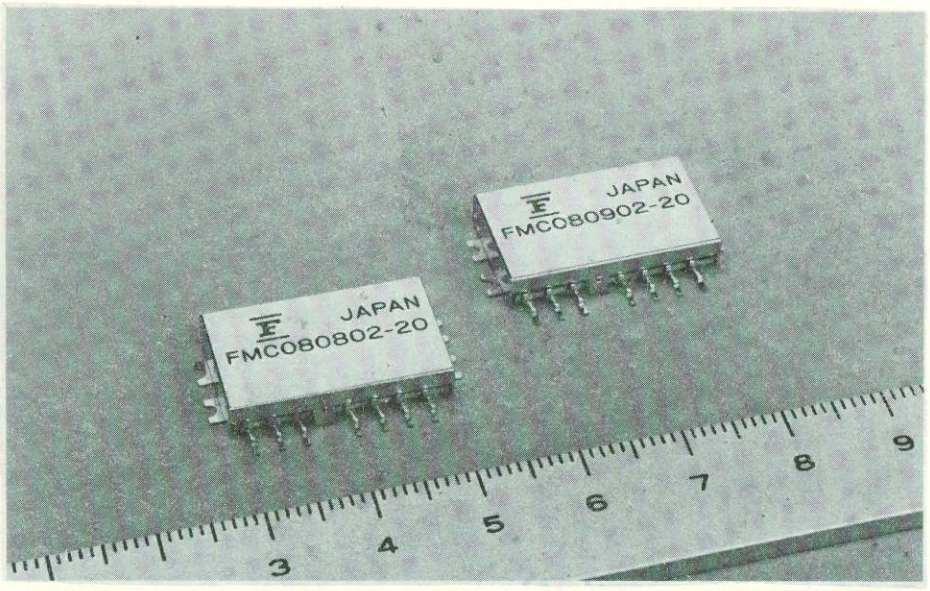

Photograph 2 The small GaAs FET high power amplifier applicable in handy phone equipment.