

# **EXPERIMENTAL VERIFICATION OF A DISTRIBUTED AMPLIFIER OSCILLATOR**

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## **ABSTRACT**

New electronically tunable oscillator arrangement, based on a distributed amplifier, has been verified experimentally. The device possesses broadband, continuous and instant tuning and a good harmonic purity of the output signal. It is found suitable to be used in MMICs.

## **INTRODUCTION**

Manifold electronic devices contain oscillators. New applications require in fast tunable devices. It could be advantageous if such oscillators do not require externally magnetised materials such as YIG ferrites. A new idea of an oscillator making use of the broadband operation of a distributed amplifier has been introduced (Aitchison et al [1]). The idea has been demonstrated and verified theoretically, using ideal devices. The next step - an oscillator, consisting of real transistors, inductors and capacitors - is depicted in this paper.

## **THEORETICAL BACKGROUND**

The idea of this oscillator arrangement is based on a distributed amplifier. A typical distributed amplifier consists of a pair of artificial transmission lines, coupled by active devices. Let us consider field effect transistors in this paper. Input signal is fed into the gate line, it drives all transistors and finally vanishes in the gate load. The signals, amplified by each transistor, are of the same phase at the output of the drain line, which is the output of the device. This drain line is loaded by a resistor, which cancels the other part of the output wave, propagating in the reverse direction.

[1] brought the idea of omitting the drain line resistor while connecting the former idle drain output directly to the distributed amplifier input. This approach makes use of the so-called reverse gain to form an oscillation loop. The remaining amplifier port becomes an oscillator output now (see Fig. 1.). Each oscillator section consists of two artificial transmission line sections, one of those connected to the drain, the other to the gate of the transistor. Transistor  $T_{12}$  is an exception from this rule; it is introduced to overcome problems caused by small reverse gain value at the frequency where the phase shift over one artificial line section approaches 90 degrees [1].

## **DIFFERENTIAL BIAS**

Now, let us imagine that the transistors are biased individually. Say, that only one transistor is opened. The oscillation frequency becomes

$$f = f_c \cdot \sin\left(\frac{\pi - \phi}{4r - 2}\right) \quad (1)$$

where  $r$  stands for the transistor index and  $\phi$  is a phase offset corresponding to the connection from the idle drain output to input of this distributed amplifier. When the leftmost transistor is biased, the oscillation frequency approaches the critical frequency of the artificial transmission line  $f_c$ , while it reaches its minimum when the rightmost device is the only active one. Besides four discrete frequencies, each belonging to one active transistor, this oscillator is capable of generating all frequencies between the oscillating frequency of the first and the last transistor. This is achieved by simultaneous biasing of two adjacent transistors at one time. Varying the bias of these transistors, one could obtain different amplifications of the two devices. As the signals amplified by two transistors are of different phase, differential biasing results in frequency change. The oscillation build-up condition is obtained from small signal loopback gain, where

$$|G| = \frac{Z_\pi}{2} \sqrt{g_{n1}^2 + g_{n2}^2 + 2g_{n1}g_{n2}\cos((n_2 - n_1)2\beta)} \quad (2)$$

and the phase of the loopback gain is

$$\varphi = \frac{((2n_1 - 1)\beta + 180)g_{n1} + ((2n_2 - 1)\beta + 180)g_{n2}}{g_{n1} + g_{n2}} \quad (3)$$

where  $Z_\pi$  is the impedance of  $\pi$ -network element of the artificial transmission line and  $\beta$  is the phase shift of this element. The  $n_1$  and  $n_2$  are the positions of the active transistors and the  $g_{n1}$  and  $g_{n2}$  are the transconductances of these transistors.

## **DESIGN CONSIDERATIONS**

Distributed oscillator performance is strongly affected by mismatches, causing changes in feedback loop phase shift and in oscillation frequency, consequently. Mismatches are inherently caused by the fact that the image impedance of the artificial transmission line varies with frequency in a manner that is impossible to match to a fixed load exactly. The impedance becomes

$$Z_\pi = \frac{Z_0}{\sqrt{1 - \left(\frac{f}{f_c}\right)^2}} \quad (4)$$

where  $Z_0$  represents the impedance of the artificial line. Extensive CAD modelling has shown, that the key point is to keep reflection under -20 dB (Vandělík [2]). Such a value results in smooth tuning. This could be achieved by a single stage m-derived half-section with  $m = 0.6$ .

Computer simulation has predicted that the active devices should possess quite large gains [1]. These gains have been calculated, taking into account connecting lines and losses in inactive transistors, and plotted at Fig. 2. Due to this requirement, ATF-35376 P-HEMT devices produced by Hewlett-Packard have been chosen. The other advantage is that these transistors work at low feeding voltages; we have used 1.5V or 2V feeding respectively.

## **GAIN CONTROL**

The transconductance of a P-HEMT device could be controlled in several ways including bias point, temperature, illumination; however, the first mentioned method is the only attainable one. Basically, there are several choices:

- to set up a common drain voltage for all devices while controlling gains via individual gate voltages, or
- to set up one common gate voltage while changing drain voltages individually, or
- to change both drain and gate bias voltages individually.

Of those, we have selected the first possibility. The oscillator built is depicted at Fig. 3.

Drain voltage, common to all transistors, has been supplied through the drain artificial line via the oscillator output. We have used a standard commercially available bias T circuit providing DC/AC blocking of the output port.

Individual transistor gates have been connected to the gate line through capacitors large enough so that they formed RF shorts. Each gate is fed through a third-order lowpass network. These bias networks are quite vital to the oscillator operation as they should not affect loopback transmission phases (i.e. their input impedance seen by the gate should approach infinity in the whole tuning range).

## **MEASURED CIRCUIT PARAMETERS**

Single oscillation frequencies: Biasing only one transistor at a moment, four discrete frequencies have been achieved. These frequencies are tabulated in tab. I.

Tuning : As can be seen from Tab. I., this oscillator possesses a tuning range of 52.65 to 112.3 MHz. There is some ambivalence as each frequency can be achieved by several tuning voltages. There is a number of different tuning possibilities. Of those, one can select tuning strategies providing maximum output power or minimum harmonic distortion.

Harmonic purity and output power: At frequencies about  $0.9f_c$  the output power rated about 0 dBm and the second harmonic generated by the oscillator was about -60 dBm. In the frequency range  $0.5$  to  $0.85f_c$  the second (third) harmonic levels have been better than -45 (-65) dB. Between  $0.35$  and  $0.5f_c$  this figures shown at least -20 (-35) dB. Below  $0.35f_c$  the harmonic suppression dropped to -16 (-20) dB respectively. An example output spectrum could be seen at Fig. 4. Decreasing frequency, the output power rose reaching 12 dBm at 35 MHz. (These values have been obtained while tuning the amplifier for good harmonic purity.)

The way of optimal tuning needs further investigation. It is believed, that smoother tuning curves as well as better harmonic purity over the whole tuning range can be achieved using better tuning algorithm.

## **CONCLUSION**

The idea of a distributed amplifier oscillator has been verified. Experimental results have shown that the device can be tuned as theoretically predicted. This oscillator would possibly be used as

a fast electronically tunable VCO. Containing no externally magnetised or polarised tuning elements, it could be easily implemented into MMICs.

At the time being, the tuning diagram is under investigation with the main objective of getting simple smooth tuning voltages. Another version, providing frequencies up to 2GHz, is being designed.

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Literature:

- [1] Škvor, Z.-Saunders, S. R.-Aitchison, C. S.: Novel decade electronically tunable microwave oscillator based on the distributed amplifier, ELECTRONICS LETTERS 13th August 1992 Vol.28 No.17 pp. 1647-1648
- [2] Vandělík, K.: Distributed Amplifier Oscillator. Diploma thesis. Department of Electromagnetic Field, Czech Technical University in Prague, 1995. (In Czech.)

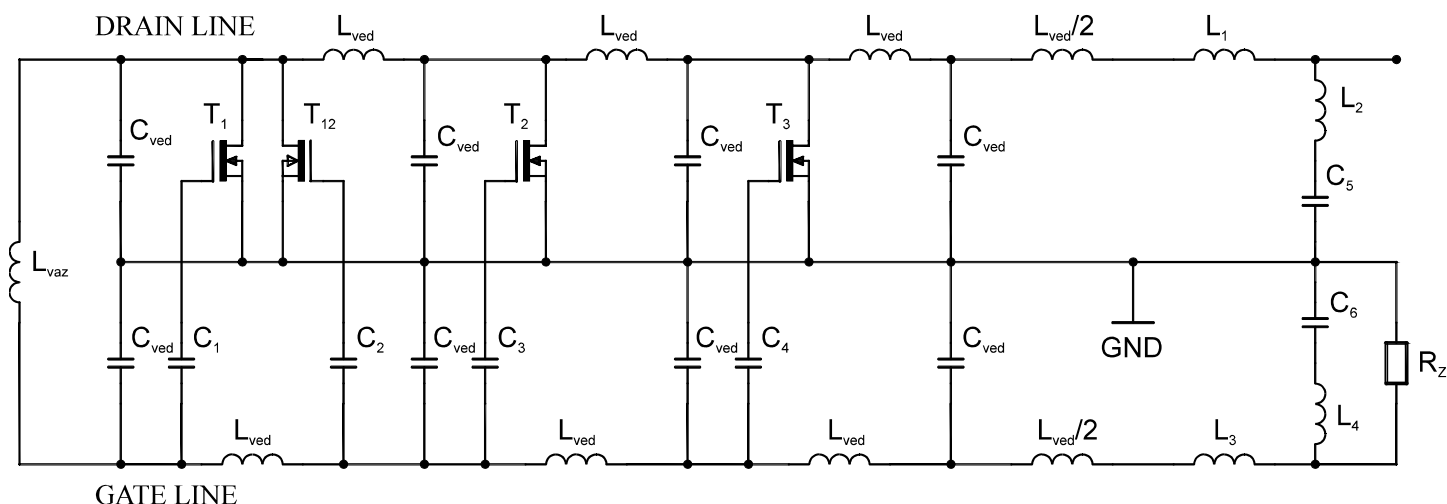


Fig. 1. Distributed amplifier oscillator.

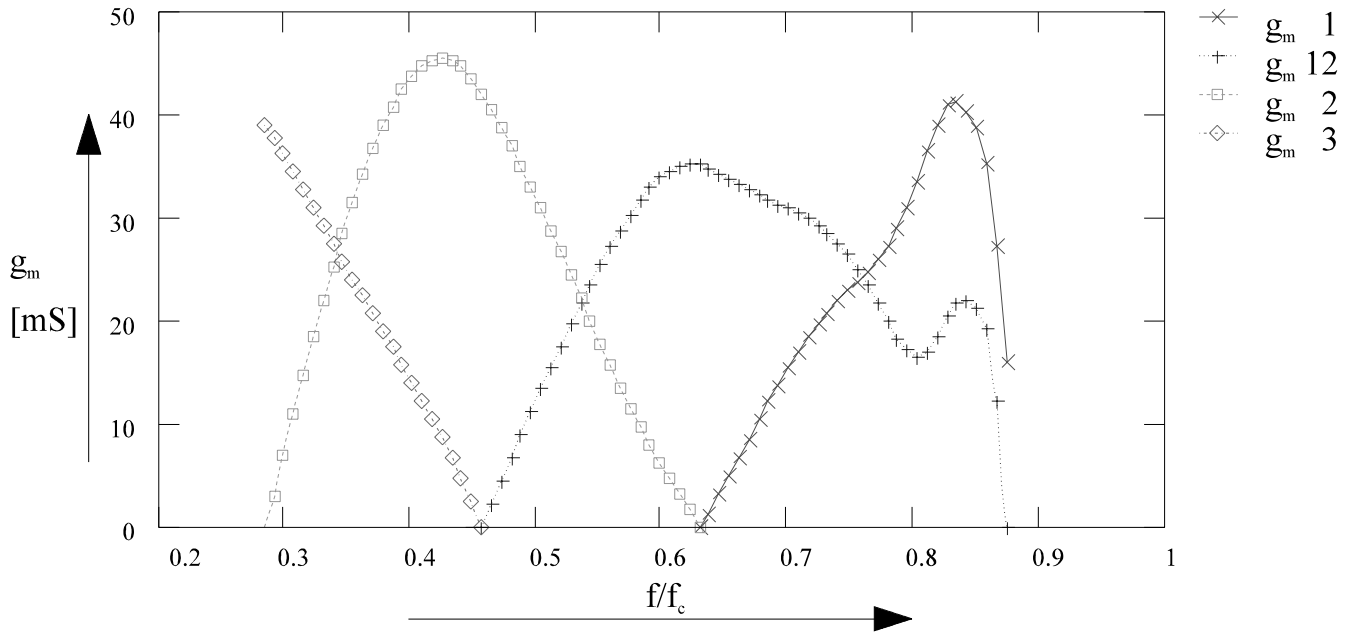
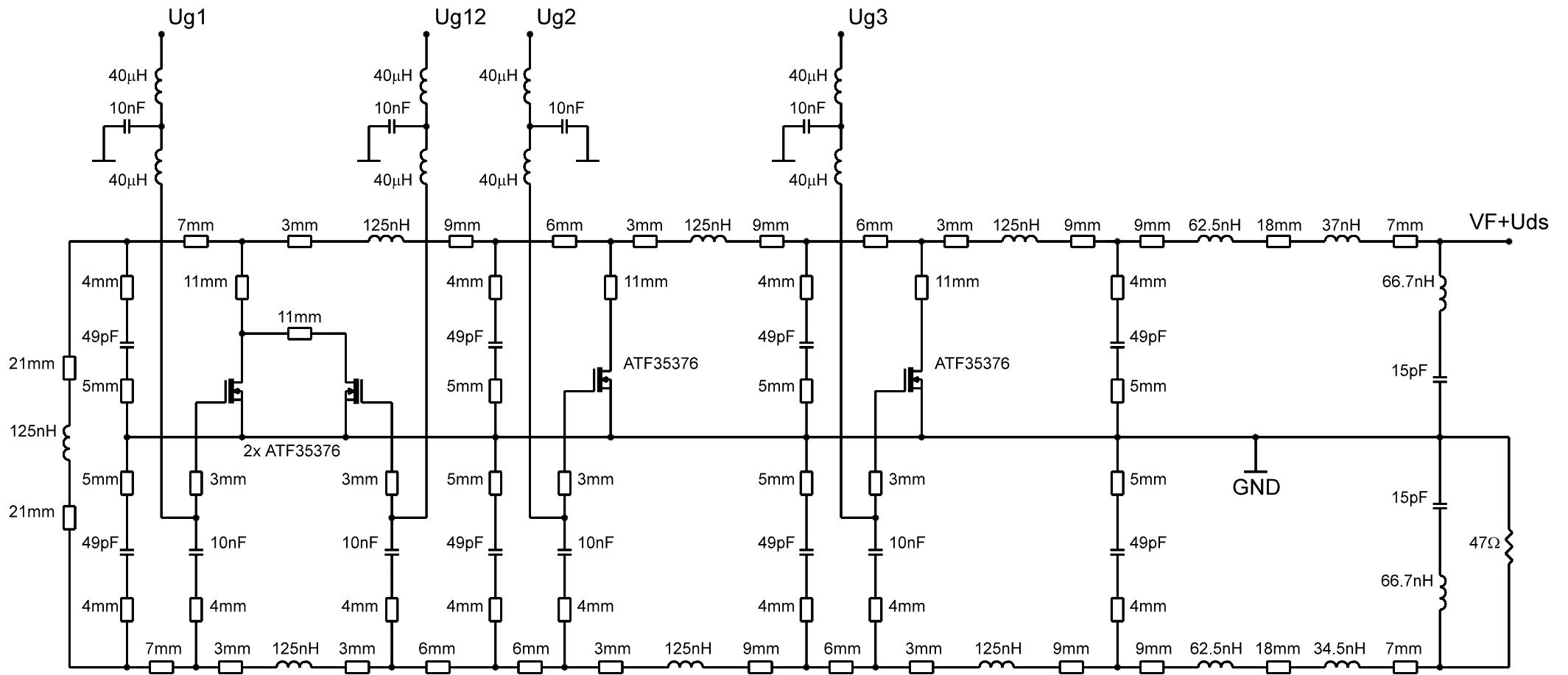


Fig. 2. Calculated transistor transconductances (providing for tuning) of a realised distributed amplifier oscillator plotted against normalised oscillation frequency.



—□— Microstrip Line  $h = 1.5\text{mm}$ ,  $w = 0.5\text{mm}$ ,  $t = 30\mu\text{m}$ ,  $\epsilon_r = 4.4$ ,  $\sigma = 5.7e7\text{S/m}$ ,  $\delta = 5e-3$

Fig. 3. Detailed scheme of the distributed amplifier oscillator.

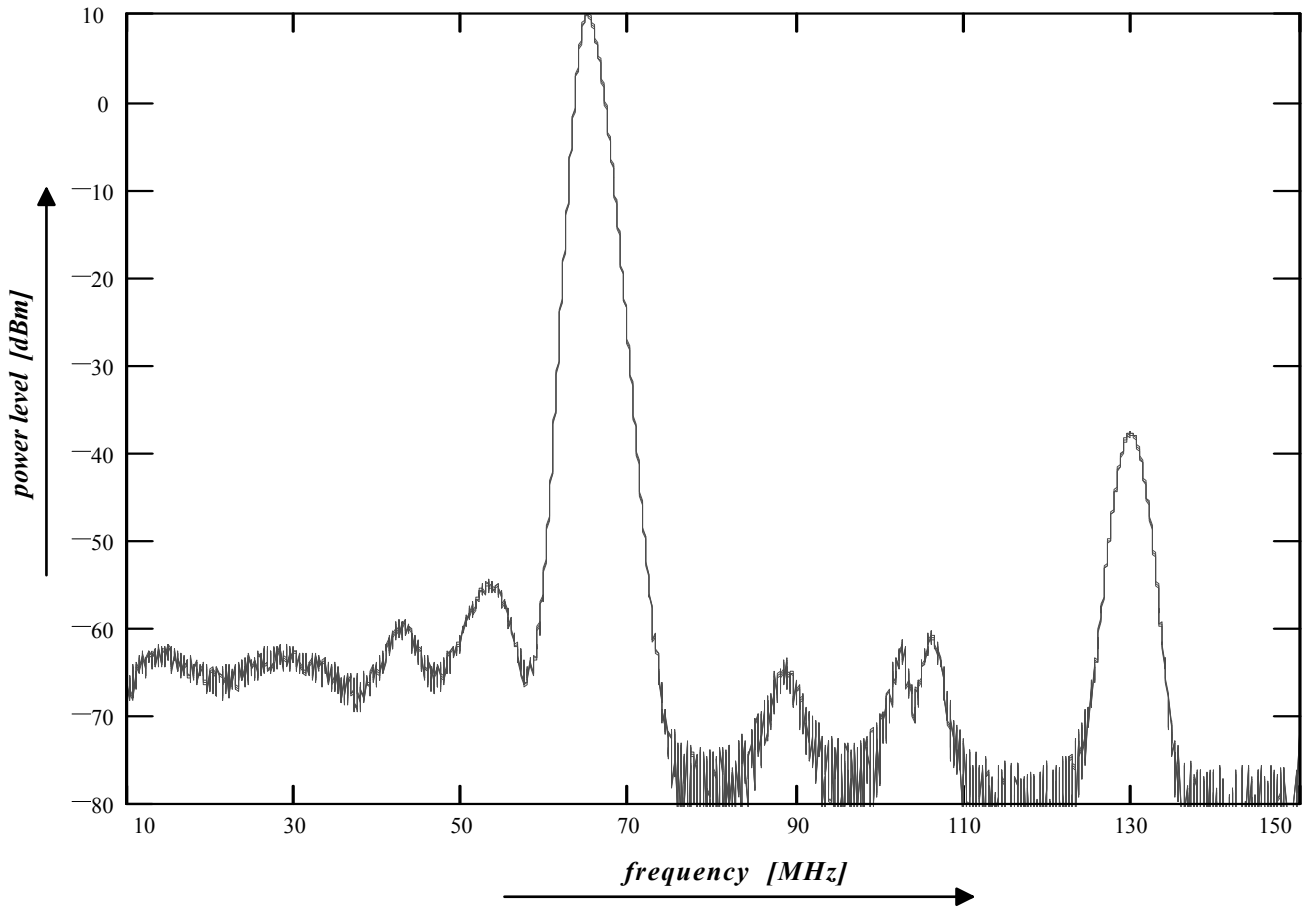


Fig. 4. An example of measured frequency spectrum produced by the oscillator.

Active	$U_g$ [V]	$f_{osc}$ [MHz]	$f_{osc}/f_c$
$T_1$	-0,43	112,3	0,9
$T_{12}$	-0,49	72,7	0,58
$T_2$	-0,72	52,65	0,42
$T_3$	0,14	35,45	0,28

Tab. I. Oscillation frequencies achieved with just one transistor biased in the active region. Drain voltage 2 V.