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BIPOLAR TRANSISTOR KU-BAND OSCILLATORS WITH LOW PHASE-NOISE

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ABSTRACT

The frequency range of low cost silicon bipolar transistors can be extended using finline technique. Oscillators buildt up this way show high efficiency and output power up to Ku-band. The biggest advantage over the GaAs-FET is the very low phase-noise near the carrier of the bipolar oscillator.

INTRODUCTION

Up to now large efforts have been made in developing stabilized GaAs-FET oscillators which are suitable for mass production in applications like direct broadcasting satellite receivers. FETs combine the high efficiency of IMPATT-diodes with the low phase-noise of Gunn devices. The bipolar transistor was not taken into account for these applications because its usable frequency range was assumed to be limited to 10 GHz. The bipolar transistor, on the other hand, is advantageous with respect to the FET in that it does not suffer from high 1/f-noise. In this paper it is shown how a bipolar transistor oscillator with a simple 5 $-device can provide Ku-band power with low phase noise.

THE FINLINE MOUNT

In microstrip circuits it is often difficult to reach the upper frequency limit of a given device because the parasitics of the circuit mount are large. Most important for a transistor lay-out is the inductance from emitter to ground which lowers the available gain and in the same way the maximum oscillation frequency. The plated-through-hole from the emitter contact to the ground of the microstrip circuit establishes this inductance. Its influence increases with frequency. In a finline circuit, however, the transistor can be mounted to the metallization of the substrate directly thus minimizing any parasitics. In the following it is described how to mount transistors with the stripline package shown in fig. 1 to finline structures.

All experiments were carried out with Avantek's AT 41 435-5 in the micro-X ceramic package, a low noise and low cost device designed for applications up to 6 GHz. The demand for mounting it with low inductance can be fulfilled by the arrangement shown in fig. 2 which had been developed earlier /1/ for FET devices. The leads of the transistor were removed directly at the ceramic carrier. The shortened package is then soldered centrally onto the metalized patches which are formed by the two crossing finlines. The fins are thus connected to the transistor contacts without any parasitic inductances between them. Moreover, there is an inherent dc-isolation.

Terminating three waveguide arms with a sliding backshort and connecting the load to the left port results in the equivalent circuit of fig. 3. The feedback element X_{fb} is established on the back side of the substrate with the help of a small strip. The DC power is connected via low pass filters to the edges of the finline cross. For preventing a DC-short through the metal housing, its aluminium material is either anodized or the two halves of the housing are seperated by a thin teflon foil. The substrate used is RT-duroid 5880 with a thickness of 0.25 mm. The finline's slotwith is 0.2 mm.

MEASUREMENTS

With the backshort a variable reactive load can be presented to the corresponding transistor contact. Thus any combination of purely reactive loads can be achieved in the experimental mount. Other degrees of freedom are the dimensions of the feedback strip and/or matching elements in the load line. The maximum power available at the output port is plotted versus the frequency in fig. 4. The data below 10 GHz were taken with the finline in a X-band waveguide (WR 90) and the other measurements were taken using a Ku-band waveguide housing (WR 62). Up to 13 GHz, oscillation in fundamental mode was obtainable. Using first harmonic operation, 18 GHz was the upper limit with useful output power. The output power decreases of course with increasing frequency so that applications as local oscillators are limited to frequencies below 13 GHz.

The next fig. 5 shows the measured DC to RF efficiency of the realized circuits. Like output power, the efficiency in harmonic mode operation does also not reach the values of the fundamental mode. It was generally easy to distinguish between fundamental- and harmonic-mode operation because a small amount of the fundamental frequency signal is always detectable at the coaxial bias line. By varying only one of the sliding shorts a typical tuning range of about 100 MHz was obtained with 3 dB power variation as is shown in fig. 6. This gives a hint what one could obtain replacing one of the sliding shorts by a tuning varactor for VCO applications. For a broader tuning range it seems useful to mount the varactor into the feedback strip on the back side. Thus an additional advantage of seperate DC power supply for the varactor-diode is easily obtained.

NOISE PERFORMANCE

Up to now, only qualitative measurements were taken with a spectrum analyzer. Fig. 7 and 8 show a comparison of typical output spectrums from unstabilized FET and bipolar transistor oscillators. Both devices were mounted alternately in the same finline housing, guaranteeing similar circuit-Q-values. With respect to the different device parameters the positions of the sliding backshorts had to be changed (of course) for tuning to the same frequency and output power. The FET was a Siemens CFY 11, a 1 μm GaAs device. The near carrier noise is much lower for the silicon bipolar transistor, the improvement is about 10 to 20 dB close to the carrier. This is well-known according to the high 1/f-noise of the GaAs-FET which is upconverted into the oscillation-frequency-band. In the first experiments the bipolar device showed a bad output spectrum in some cases. This was due to parasitic low-frequency bias oscillations and could be turned off easily by adding some additional R-C elements into the bias circuit. The pushing and pulling figures are similar to what can be achieved with a FET.

In the last step, the feedback strip on the back side of the substrate was removed and replaced by a dielectric resonactor (DR) mounted centrically below the substrate. The coupling strength can be varied by the distance between finline and DR. With stabilization an improvement of the pushing and pulling figures is clearly visible on the frequency meter or spectrum analyzer.

TEMPERATURE BEHAVIOUR

The unstabilized oscillator showed a linear slope of -260 kHz/K in the range from -20° C to +60° C (-4° F to 140° F) at an oscillation frequency of 10.0 GHz. After stabilization with dielectric resonator material from Siemens the value was reduced to -70 kHz/K (-7 ppm/K), nearly constant in the whole temperature range. This linear slope could be reduced using dielectric material with positive temperature coefficient instead of zero-material used here. Slight hysteresis effects were observed at about 20° C. This is probably due to changes of the molecular structure of the RT-duroid (Teflon) substrate material and is also known from other oscillator circuits with Duroid substrates. Avoiding this effect should be possible using other substrate materials like quartz or alumina.

CONCLUSION

It was shown that a finline mount with remarkably low parasitics increases the usable frequency limit of bipolar transistor oscillators. In fundamental mode the output power ranges from 16 dBm at 8 GHz to 7 dBm at 13 GHz. With harmonic mode operation, -5 dBm can be obtained at 18.5 GHz from the low cost Avantek AT 41 435 transistor. The most important advantage is the low phase-noise even close to the carrier. With a price of only half or even less of that of a GaAs-FET the silicon bipolar transistor seems to be the best choice for local oscillators in direct broadcasting satellite receivers. Additional stabilization is easily obtainable using a dielectric resonator as feedback element.

REFERENCE

/1/ Jacob, A., Ansorge, Ch.: "Stabilized Fin-Line FET-Oscillators".
Proceedings of 13. EuMC Conf., Nürnberg, 1983, pp. 303-307.

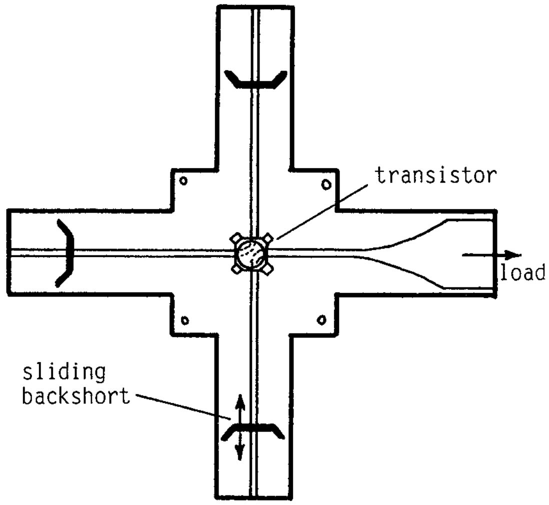

Fig. 2: Oscillator configuration

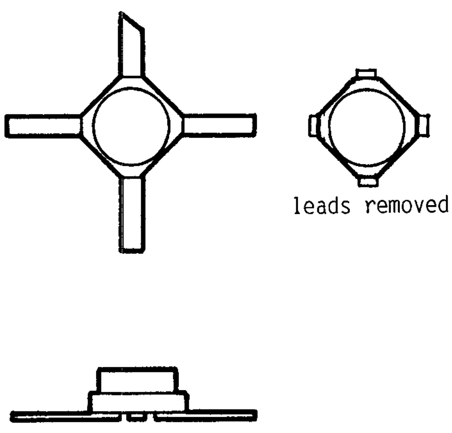

Fig. 1: Micro-X package

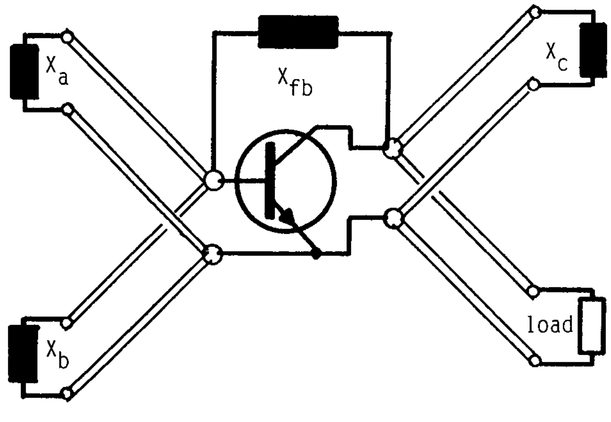

Fig. 3: Equivalent circuit

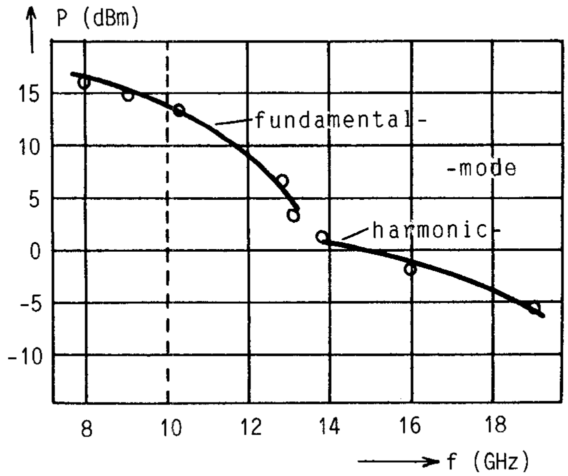

Fig. 4: Output power vs frequency

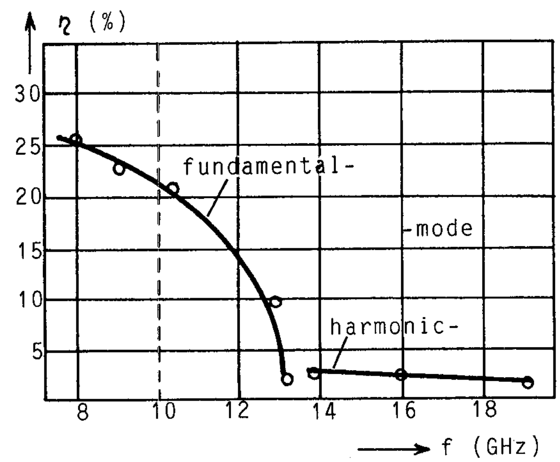

Fig. 5: Power-efficiency (η)

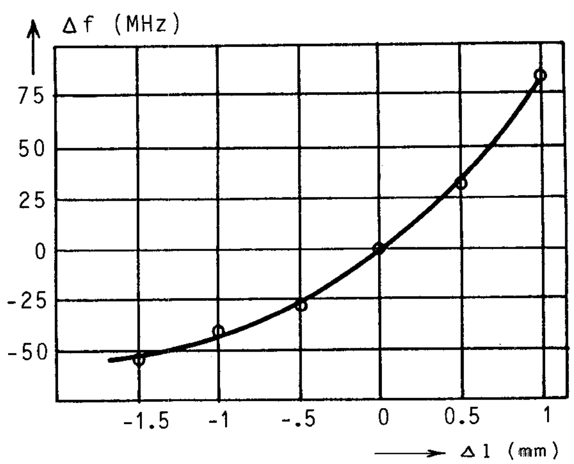

Fig. 6: Mechanical tuning

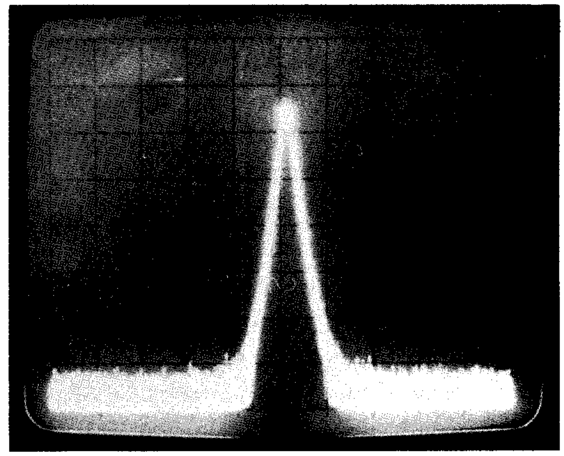

Fig. 7: Output spectrum of the silicon bipolar oscillator (center frequency 10.0 GHz, horizontal resulution 200 kHz/div)

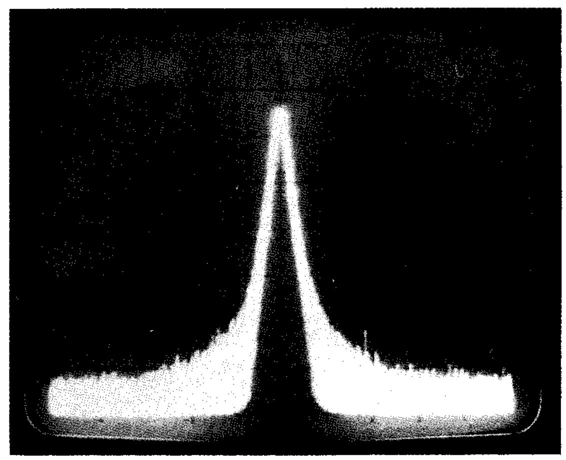

Fig. 8: Output spectrum of the GaAs FET-oscillator (center frequency 10.0 GHz, horizontal resulution 200 kHz/div)