CAVITY STABILISED OSCILLATORS FOR ADVANCED ANALOG AND DIGITAL RADIO LINKS

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ABSTRACT

This paper describes design and realisation criteria for a complete new line of cavity stabilised oscillators operating in the 2 to 15 GHz frequency ranges. Oscillators, using bipolar transistors and GaAs FET's, are characterised by: a 0 to 45° C frequency stability of 40 ppm in the tunable and of 20-30 ppm in the single frequency version, an RF-to-power supply efficiency of 5 to 10% and direct frequency modulation by order wire.

Introduction

Typical advantages of cavity stabilised oscillators are:

- Higher reliability due to the reduced number of active components employed
- Low power consumption
- Consistent cost reduction
- Less spurious frequencies
- No problems for jitter or phase jump that may be present in VCO's and in multiplier LO's

The last feature makes the cavity LO qualified for employment in multilevel digital radio links where jitter in the signal reduces the system margin until producing synchronism loss when the oscillator has a phase jump.

Many cavity stabilised oscillators have been reported in the last years (Refs. 1-3), but a few papers have been dealing with mass production on industrial scale (hundreds per month) and with a wide frequency coverage.

Our know-how based on production in the last four years of 5000 cavity stabilised oscillators from 2 to 13 GHz (Refs. 4-6) and the availability of new technologies have permitted to realise a new generation with consistent advantages in frequency stability (20-30 ppm), power consumption (GaAs FETs instead of Gunn diodes) and frequency tunability on a 1% relative band with the declared stability.

Fig. 1

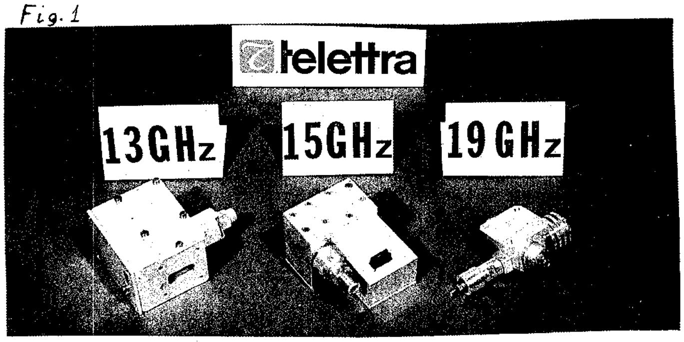
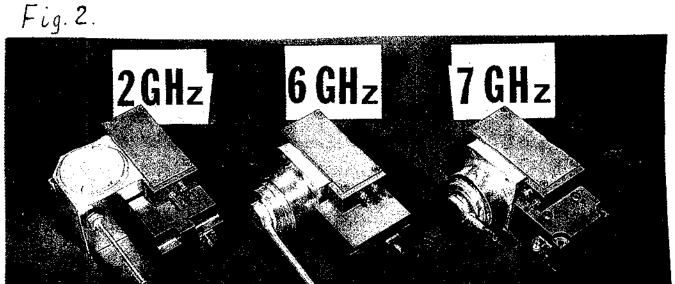


Fig. 2.



Cavity oscillator classification

The cavity oscillators of the new generation may be classified in three separated frequency stability classes.

Each class has well distinguished characteristics of frequency tunability, thermal compensation and cavity used, as is summarised in table 1.

Table 1

Cl	0-45°C freq. stab. (ppm)	Frequency tunability Fine (ppm)	Gross	Thermal compensation of frequency unstability	Type of cavity
1	±40	±40	1%	mechanical	Hermetical invar cavity (HIC)
2	±30	±40	/	mechanical	HIC or dielectric resonator
3	±20	±30	/	mechanical & electrical	Dielectric resonator

Class 1, performing a 0 to 45°C frequency stability of ±40 ppm, uses super invar cavities.

The particular mechanical configuration of this cavity, with independent gross and fine frequency adjustment screws, prevents moisture effects on frequency stability.

The gross frequency adjustment screw is a bimetallic structure sized to achieve a compensation of thermal frequency unstability in the overall tuning range.

Class 2, performing a 0 to 45°C frequency stability of ±30 ppm adopts a different amount of mechanical compensation for each operating frequency.

Class 3 performs a 0 to 45°C frequency stability of ±20 ppm by means of combined mechanical and electrical compensation.

In particular electrical compensation is achieved by a proper thermistor network inserted in the active device bias circuit.

Each class of cavity oscillators requires different alignment procedures with an adequate number of temperature cycling steps.

In particular dielectric resonators are well suited for single frequency operation of classes 2 and 3, allowing for compact and cheap oscillator realisations in the 4 to 12 GHz bands.

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Design and realisation criteria

Active circuit topology

Bipolar transistors for 2 and 4 GHz oscillators are used.

For higher frequency ranges and output levels up to +13 dBm, GaAs FET's in a direct channel configuration with source feedback reactance are implemented.

For higher output levels oscillator circuits employ medium power flange packaged GaAs FET's in the reverse channel configuration (fig. 3).

This configuration allows to obtain a common drain topology with minimum thermal resistance values.

Polarisation circuits for direct and reverse channel configurations make use of a control loop to stabilise ID.

The oscillator microstrip networks are arranged on a low εr teflon-fiberglass substrate up to 15 GHz.

Cavity topology

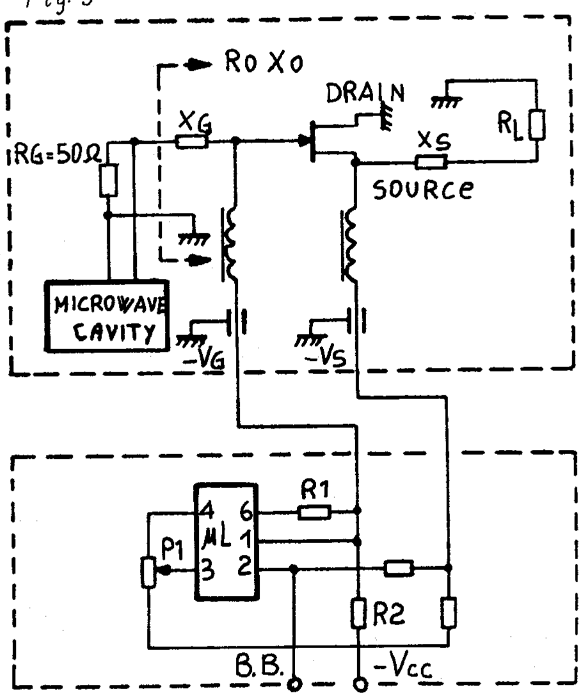
Interconnections between cavity, active circuit and load may be classified in two groups with the following characteristics:

i) The stabilising cavity is parallel coupled to the gate 50 ohm line terminated in a 50 ohm resistor (fig.3).
   This topology allows a maximum RF-to-power supply efficiency with a wide tuning range free of spurious frequencies.

ii) The stabilising cavity is parallel coupled to the 50 ohm load line.
   This topology allows to obtain better figures at the expense of RF-to-power supply efficiency.

Whereas solution i) is typical for transmission local oscillators of directly modulated digital radio links, solution ii) is used for receiver local oscillators to avoid the need of isolation between a mixer and LO.

Fig. 3



High Q cavity

Three hermetically sealed super-invar cavity types have been used:

TEM type for 2 and 4 GHz oscillators, TM010 for 6 and 7 GHz, TE011 for frequencies higher than 10 GHz.

The 7 and 11 GHz realisations of table 2 use barium titanate resonators operating in the lowest order cylindrical TE010 mode.

A bimetallic tuning plate ensures fine tuning and mechanical thermal compensation at the same time.

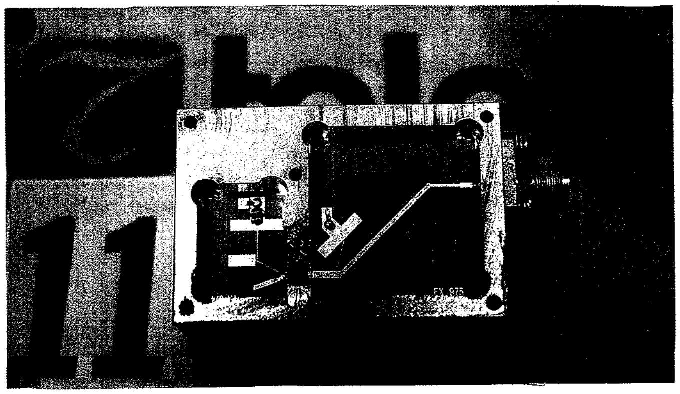
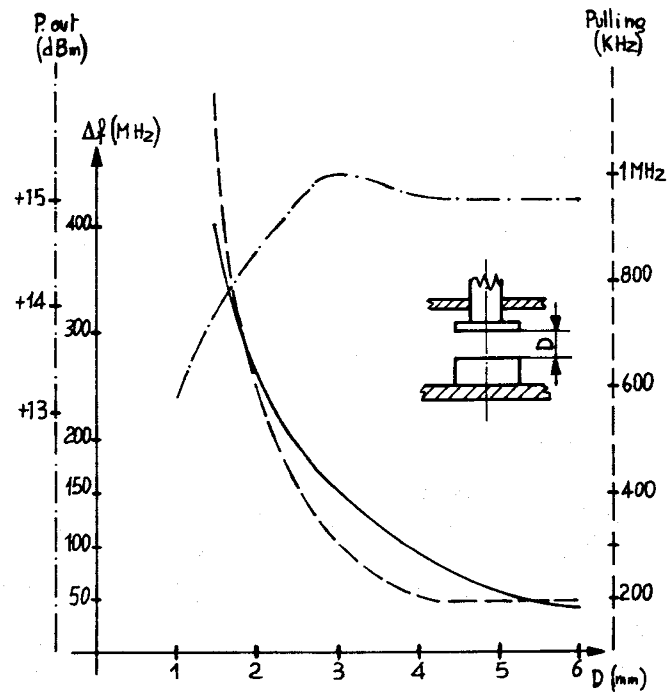


Fig. 4



Frequency modulation by order wire   Fig. 5.

Direct modulation of transmission oscillator frequency is typically required for order wire insertion in the 4 PSK repeaters and terminals.

Without the need of a specific tuning diode circuit, the modulation of cavity oscillator frequency has been achieved superimposing the low frequency BB signal to the V_{GS} of GaAs FET's through the same bias control circuit (fig.3).

In particular the linearity characteristics of this modulation system depend on the dc component of the V_{GS} value, that must be properly compensated versus temperature.

Production run sheet

The production run sheet of cavity stabilised oscillators includes 20 to 25 different steps for assembly and testing.
In particular for compensation alignment a temperature cycling is used to evaluate the slope of frequency drift versus temperature.
After that a computer program gives the amount of mechanical and electrical compensation taking the mechanical and electrical sensitivity of the oscillator into account (fig.6).
After temperature drift compensation the oscillators are pre-aged in the factory for two weeks at 65°C, obtaining a total frequency drift lower than 15 ppm.
At the end of the burn-in period the oscillator frequency is readjusted to the nominal value by trimming the microstrip circuit.
The aging frequency drift evaluated in field is about 2 ppm/year that is well inside the 30-40 ppm fine tuning capability of each oscillator.

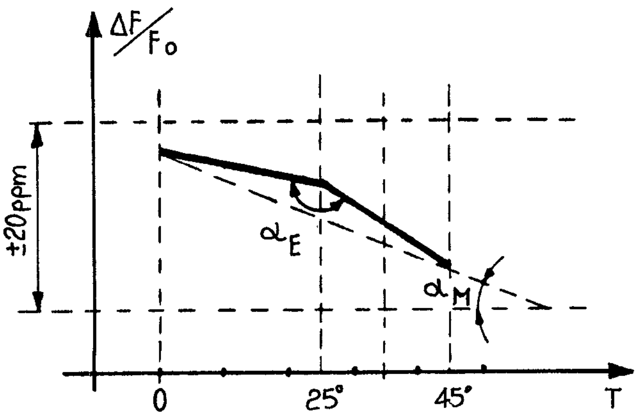


Fig.6 - Typical frequency vs temperature characteristic of a mechanical and electrical compensated cavity oscillator slope α_M depends on mechanical compensation, while angle α_E- depends on electrical compensation.

Performances

Performances of various cavity stabilised oscillators with corresponding frequency stability class are summarised in table 2.
Fig.1 gives some examples of cavities realised at 13, 15 and 19 GHz corresponding to class 1 of table 1.
The screw permits gross tuning and mechanical compensation of thermal drift simultaneously.
Fig.2 shows an example of class 2 cavity oscillators at 2, 6 and 7 GHz. The small pipe on the cavity top permits to fill the cavity with dry nitrogen.
Fig.4 represents a dielectric resonator oscillator realised on alumina and operating at 11 GHz.
Fig.5 gives performances of the 7 GHz dielectric resonator oscillator versus tuning plate position.
The order wire characteristics of order wire FM listed in table 2 may be summarised as follows:

- Base-band frequency range 300 Hz-18 kHz
- Sensitivity 0.3 kHz/mV
- Flatness 1 dB
- Psophometric S/N
  - 43 dBmOp in the GaAs FET oscillators
  - 46 dBmOp in the bipolar transistor oscillators

In particular comparative noise measurements have been made between bipolar and GaAs FET oscillators.
In the lower order wire band (300 Hz-16 kHz) the noise of GaAs FET oscillator is 3 to 5 dB worse than for bipolar oscillators.

Table 2

Performance summary of the cavity stabilised oscillators

Cl	fg	Freq. range (GHz)	Output level (dBm)	Bias supply at-12V (mA)	Pulling (MHz)	S/N pWOp
1	1	12.75-13.25	+ 1	20	.3	
1	1	12.75-13.25	+ 16	150	1	
1	1	14.25-14.5	+ 11	70	.5	
1	/	14.25-14.5	+ 3	20	.3	
1	/	14.5-15.35	+ 21	300	1	
1	/	14.5-15.35	+ 6	70	.3	
2	2	1.7-2.3	+ 11	15	.15	30
2	/	6.4-7.1	+ 11	25	.3	60
2	/	6.4-7.1	+ 15	80	.3	100
3	4	7.1-7.7	+ 15	80	.4	
3	/	10.7-11.7	+ 15	150	.4	70

NB1: Pulling has been measured with a 10 dB attenuator at the output of the oscillator.

NB2: S/N has been measured at 14 kHz with f rms = 50 kHz, at 70 kHz all the oscillators give a contribute noise less than 1 pWOp.

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