MICROWAVE OSCILLATOR CONTROL USING A SWITCHED DELAY-LINE TECHNIQUE

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ABSTRACT

A novel arrangement is described which uses an oscillator feedback network, incorporating a switched delay line, to stabilize the oscillator frequency and to permit electronic frequency selection. The circuit, which has been fabricated and tested in hybrid MIC form, makes use of two simple microstrip circuits to achieve the delay line and switching functions. A three-port discriminator is used to provide the effective delay line and single PIN diode phase shifter is used to achieve delay switching. Results are presented which show that the circuit provides good frequency stabilization, together with predictable frequency switching and a reduction in oscillator phase noise.

INTRODUCTION

The technique whereby an oscillator is stabilized using a feedback network incorporating a delay line has been well established in the literature. Generally, however, this is achieved using some form of lumped delay line, such as the bulk-wave line employed by Amblart and Peyrat [1]. The principal disadvantage of the existing techniques, particularly where SAW devices have been used, is a limitation in frequency, since suitable delay devices are not available at the higher microwave frequencies. In this paper we show that the stabilization can be achieved using a simple three-port microstrip discriminator, based on the circuit of Free and Aitchison [2] and, moreover, that the frequency of the oscillator can be altered by incorporating a switched phase shifter in the discriminator ring. Thus the basis is provided for the development of a digitally controlled oscillator, with good frequency stability, but at considerably less cost than a conventional discretely stepped frequency synthesizer. The arrangement is simple and there is no inherent frequency limitation to its operation or circuit implementation. Although a hybrid circuit has been investigated, the choice of simple circuit geometries makes the arrangement viable for integration in monolithic form.

Figure 1 shows the conventional arrangement of a delay line stabilized oscillator.

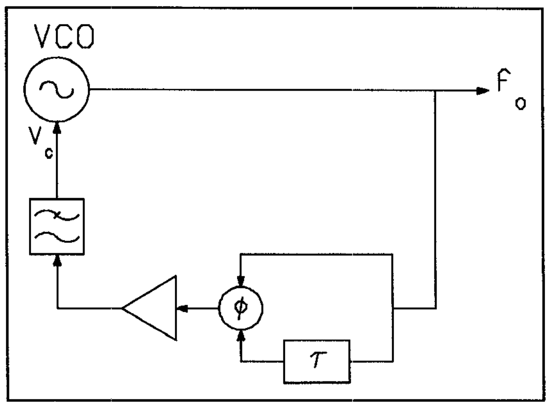

Figure 1 Delay-line stabilized oscillator

The circuit is essentially that of a microwave frequency discriminator, where the value of delay, τ, is chosen to centre the discriminator characteristic at a particular frequency. Should the oscillator frequency change, due to noise or long-term drift, then an error voltage is produced at the phase detector output and applied as a controlling voltage to the VCO to maintain the original frequency.

If the delay is switched to a different value an offset voltage, V_c, will be produced at the feedback input to the VCO, which will lock to a new frequency, but still with the stabilization characteristics determined by the discriminator circuit. In the circuit proposed here, and shown in figure 2, the delay switching function is achieved by including a single PIN diode phase shifter, originally proposed by Free and Aitchison [3], within the ring. Thus the effective delay within the three port ring is controlled by the diode state.

One further advantage of the proposed arrangement is that the frequency stability, which depends ultimately on the delay line stability, will be high since the delay line is fabricated on relatively stable microstrip substrate. It also follows that there will be a reduction in oscillator phase noise, yielding an overall noise peformance between that of a fully variable frequency oscillator and a more complex, and expensive, conventioal frequency synthesizer.

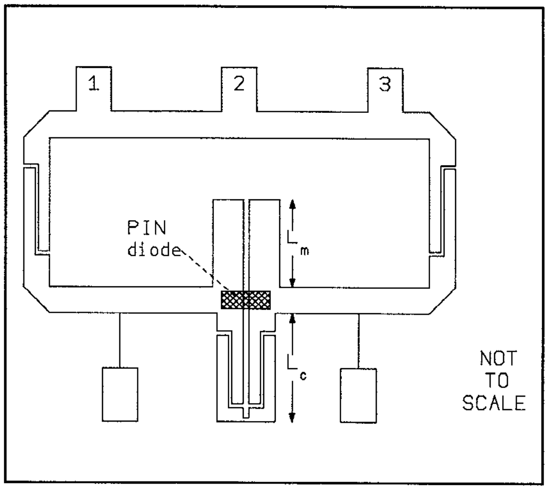

Figure 2 Configuration of microstrip switched delay-line discriminator

CIRCUIT DETAILS

The layout of the microstrip circuit investigated is shown in figure 2. The ring dimensions and port spacings were determined through the theory established in reference [2], to give input and output port impedances of 50Ω.

The oscillator output was applied to port 1 and a matched pair of coaxial detectors (HP8472A) was connected to port 2 and 3. The detector outputs were combined in a differential amplifier to yield a discriminator characteristic. It can be seen that DC finger breaks have been included in the ring to permit biasing of the PIN diode and to prevent the DC bias from affecting the two detectors. In calculating the dimensions of the ring, appropriate allowance was made for the transmission phase through the breaks, and this included the excess phase due to the finger discontinuities.

The circuit was fabricated on RT/duriod 6010, having a substrate thickness of 635μm and a relative permittivity of 10.4. A low-loss beam-lead PIN diode (HP5082-3900) was surface mounted at the centre of the single PIN diode phase shifter. The magnitude of the phase shift was determined by the length, L_c, of the coupled line region, as described in [3]. DC zig-zag breaks are shown in the coupled lines, again to permit biasing of the PIN diode. These breaks were included in both of the coupled lines to maintain the symmetry of the structure and the appropriate transmission phases included in the calculation of L_c. The matching frequency was set by the length, L_m, of the open circuited stub.

The circuit shown in figure 2 also includes two conventional bias pads.

DISCUSSION OF RESULTS

Typical results for a three port ring incorporating a single PIN diode phase shifter are summarized in table 1, with an example of the close-carrier phase noise performance for one of the PIN diode states being shown in figure 3.

Carrier frequency	11GHz
Stabilization ratio	25
Switched freq. step	30MHz
Change in input return loss between states	0.31dB
Open-loop phase noise 5kHz off carrier	-75dBc/Hz
Closed-loop phase noise 5kHz off carrier	-91dBc/Hz

Table 1: Summary of typical results

The results in the table show that a significant frequency step, 30MHz, can be achieved without a significant change in the input matching of the three-port ring between diode states. Clearly, any change in the return loss between diode states is of particular significance for this type of arrangement since any mismatch within the ring, due to the switching of the phase shifter element, will cause a change in level at the detector diodes. This means that the offset voltage will be a function of the mismatch in addition to the designed change in delay. The fact that a predictable frequency step can be achieved, with only a 0.31dB change in return loss indicates that the change in match is not significant.

The value of the stabilization ratio, measured as the frequency deviation of the oscillator to a dc control stimulus under open and closed loop conditions is a direct function of the sensitivity of the differential amplifier, and can be set to any desired value.
The bandwidth was found to be relatively narrow, of the order of 5%, as expected from [2]. This could be improved by including some form of broadband matching in the ring, following the techniques used for four-port hybrid rings.

The phase noise, shown in figure 3, was measured using an HP8472B low-frequency dynamic signal analyzer connected across the output of the low-pass filter in the feedback network. A continuous averaging function was selected on the analyzer to display the rms noise. Figure 3 shows the reduction in phase noise when the circuit is in lock. This reduction was observed in both diode states. The magnitude of the reduction is also a function of the sensitivity of the differential amplifier circuit.

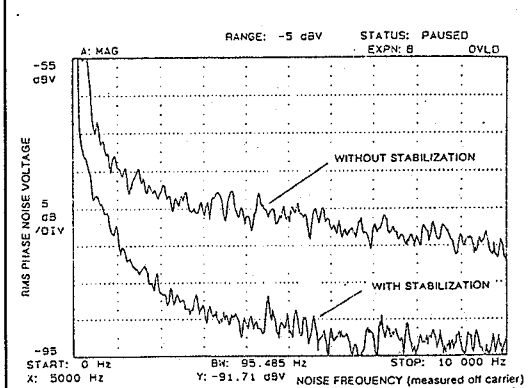

Figure 3 Phase noise responses

Table 1 gives two examples of the measured phase noise, expressed in conventional units of dBc/Hz, using values taken from figure 3. In figure 3 itself the phase noise is left as a relative level, since the absolute value of phase noise is a function of the particular test oscillator being used and is not of primary interest here.

CONCLUSIONS

The predicted functions of a delay line stabilized oscillator incorporating a frequency selection capability have been verified through practical measurement. The novel technique, together with the use of simple circuit geometries, offers significant potential for the development of digitally controlled microwave oscillators, either in hybrid or monolithic form.

REFERENCES

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