Single-resistance-controlled sinusoidal oscillator using two FTFNs

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Indexing terms: Oscillators, Current-mode circuits

A new single-resistance-controlled sinusoidal oscillator using two four-terminal floating nullors (FTFNs) is presented. The proposed oscillator has good frequency stability, single-element-controlled ability and low passive and active sensitivities. Moreover, this oscillator needs only grounded capacitors and its oscillation frequency can be independently controlled by a grounded resistor. Experimental results are given to verify the theoretical analysis.

Introduction: Current-mode circuits have received significant attention since they have the potential advantages of accuracy and a wide bandwidth compared with their voltage-mode counterparts [1]. Several current-mode amplifiers have been developed [1, 3]. Among them, the floating operational amplifier [2] and four-terminal floating nullors (FTFNs) [3 – 6] have been found to be versatile to realise various applications such as amplifiers, current-mode filters and oscillators etc. In this Letter, a new sinusoidal oscillator using two FTFNs is presented. Experimental results are given to verify the theoretical analysis.

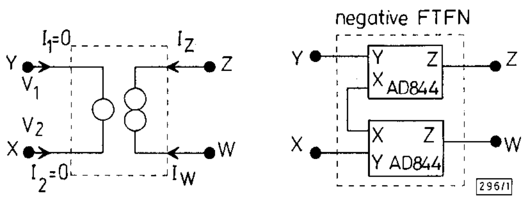

Fig. 1 *Nullor model of FTFN*

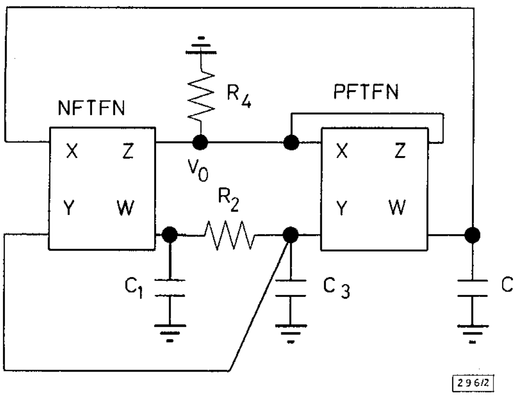

Fig. 2 *Proposed sinusoidal oscillator using two FTFNs*

Circuit description: An FTFN is equivalent to an ideal nullor [3, 4] or is called an operational floating amplifier [2]. The port relations of an FTFN, as shown in Fig. 1, can be characterised as $I_X = I_Y = 0$, $V_X = V_Y$ and $I_Z = \pm I_W$, where the positive sign denotes a positive FTFN and the negative sign denotes a negative FTFN, respectively. Consider the proposed oscillator as shown in Fig. 2; it consists of a negative FTFN, a positive FTFN and five passive components. Its characteristic equation can be derived as

$$s^2C_1C_3R_2R_4 + sR_4(C_1 + C_3 - C_5) + 1 = 0 \quad (1)$$

The oscillation condition and oscillation frequency of the proposed oscillator can be given as

$$C_1 + C_3 = C_5 \quad (2)$$

and

$$\omega_o = \frac{1}{\sqrt{C_1C_3R_2R_4}} \quad (3)$$

The passive sensitivities of this oscillator can be obtained as

$$S^{\omega_o}_{C_1} = S^{\omega_o}_{C_3} = S^{\omega_o}_{R_2} = S^{\omega_o}_{R_4} = -1/2 \quad (4)$$

The classical frequency stability factor S_F is defined as [4]

$$S_F = \left.\frac{d\Phi(u)}{du}\right|_{u=1} \quad (5)$$

where $u = \omega/\omega_o$ and $\Phi(u)$ represents the phase function of the open loop transfer function of Fig. 1. The stability factor S_F can be found to be

$$S_F = \sqrt{n} \quad (6)$$

where $C_1 = C_3 = C$, $C_5 = 2C$, and $R_4 = R_2/n$ for this oscillator. Good stability can be obtained by choosing the larger value of n [4].

Taking into account the nonideal FTFN, namely $V_X = \alpha V_Y$ and $I_Z = \pm\beta I_W$, where $\alpha = 1 - \varepsilon_1$, ε_1 ($\varepsilon_1 \ll 1$) denotes the voltage tracking error of an FTFN, $\beta = 1 - \varepsilon_2$ and ε_2 ($\varepsilon_2 \ll 1$) is the current tracking error, eqn. 3 can be rewritten as

$$\omega_o = \sqrt{\frac{\alpha_2}{\beta_1C_1C_3R_2R_4}} \quad (7)$$

Its active sensitivities can be expressed as

$$S^{\omega_o}_{\alpha_1} = S^{\omega_o}_{\beta_2} = 0 \qquad S^{\omega_o}_{\alpha_2} = -S^{\omega_o}_{\beta_1} = 1/2$$

The advantages of this oscillator are: (i) only grounded capacitances are required [8]; (ii) its oscillation frequency can be independently controlled by the grounded resistor R_4; (iii) it has a good frequency stability; (iv) it has low passive and active sensitivities.

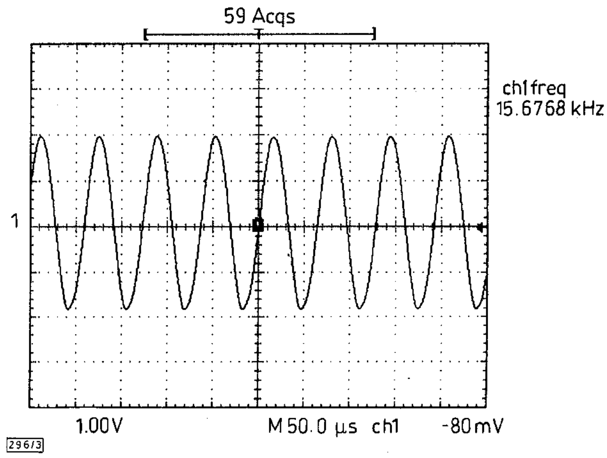

Fig. 3 *Typical output waveform of Fig. 2*

$C_1 = C_3 = 1\text{nF}$, $C_5 = 2\text{nF}$ and $R_2 = R_4 = 10\text{k}\Omega$

Experimental results: To verify the theoretical analysis, the proposed oscillators were built with commercial AD844s [9]. The negative FTFN consists of two AD844 [9] op amps as shown in Fig. 1. The positive FTFN with shorted terminals Z and X can be realised by an AD844 op amp. The supply voltage is ± 5V. The proposed oscillator has been realised with $C_1 = C_3 = 1\text{nF}$, $C_5 = 2\text{nF}$, and $R_2 = 10\text{k}\Omega$. Fig. 3 shows a typical output of this oscillator with $R_4 = 10\text{k}\Omega$. Its horizontal scale is 50μs/div and the vertical scale is 1V/div. Fig. 4 shows the experimental results with variable R_4. Experimental results confirm the theoretical analysis.

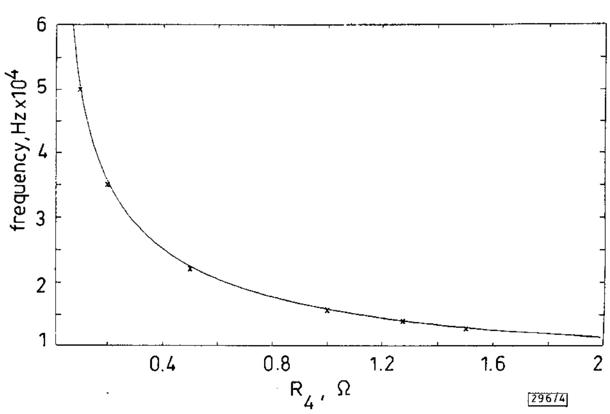

Fig. 4 *Comparisons between theoretical and experimental results for Fig. 2*

$C_1 = C_3 = 1\text{nF}$, $C_5 = 2\text{nF}$ and $R_2 = 10\text{k}\Omega$

Conclusions: The proposed sinusoidal oscillator has been thoroughly verified by experimental results and its advantages have also been discussed in this Letter. Our experimental results have confirmed the theoretical analysis. The proposed circuit is expected to be useful in analogue applications.

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Four-element varactor diode loaded polarisation-agile microstrip antenna array

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Indexing terms: Microstrip antenna arrays, Varactors

A square, varactor diode-loaded polarisation-agile microstrip patch, radiating either circular polarisation (left or right hand) or linear polarisation (in two orthogonal planes) is described. A linear array comprising four such patches has been designed. Measurements show, when operated in circular polarisation, axial ratios better than 0.5dB and, in linear polarisation, cross-polar levels better than –20dB.

Introduction: In [1], we described a varactor diode-loaded frequency and polarisation-agile patch antenna radiating either left or right hand circular polarisation, or linear polarisation in the diagonal plane, (θ = 45°, see Fig. 1) with continuously variable polarisation adjusted by the diode bias voltages. In [2], we demonstrated that by independently biasing each diode, the change in input impedance observed when switching between linear and circular polarisation could be compensated for, thus achieving optimum matching in all polarisations. Here, we describe an alternative method of operation of this versatile antenna more appropriate to array application when simple control circuitry is desirable. At the cost of a marginal increase in cross-polar level, the antenna can be made to radiate linear polarisation in both the θ = 0 and θ = 90° planes, instead of the θ = 45° plane, simply by shorting opposite diode pairs. With this method, the feed position is simultaneously optimised for both linear and circular polarisation, and, with the diodes connected in pairs, the control circuit is simpler.

Patch operation: If either diode pair D1, D3 or D2, D4, (Fig. 1) is maintained at zero volts, or, if required, given a small forward bias to ensure that they remain conducting throughout the radio frequency cycle, they effectively become short circuits, suppressing the radiating mode in the θ = 0 or 90° planes, respectively, as described by Schaubert *et al.* [3]. Radiation is then linearly polarised, arising from the unsuppressed orthogonal mode with the resonant frequency controlled by the reverse bias on the diodes located in that axis, and the input resistance R_{in} is predominantly the transformed value of the mode radiation resistance seen at the connector. Hall *et al.* [4] show that the input resistance of a circularly polarised antenna using detuned orthogonal modes will also have an input resistance equal to R_{in}, and therefore after allowing for small differences due to stray reactances etc., the input impedance will be the same for all polarisations.

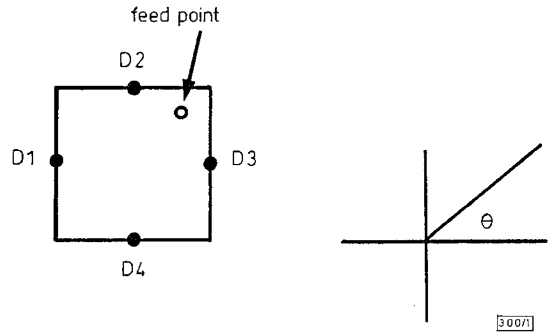

Fig. 1 *Polarisation-agile patch element with diode locations and plane co-ordinates*

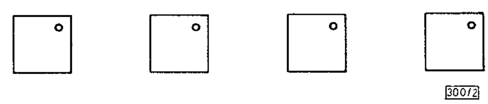

Fig. 2 *Array geometry*

However, because the feed point is located on the patch diagonal, (to excite orthogonal modes when required), the current flow will be non-symmetrical when linearly polarised in this way, hence levels of cross-polarisation, typically 5 to 10dB higher than in [1], are observed. Nevertheless, cross-polarisation for a single patch remains in the order of –20dB at boresight and better than –15dB elsewhere in the pattern, which may be acceptable for many applications.

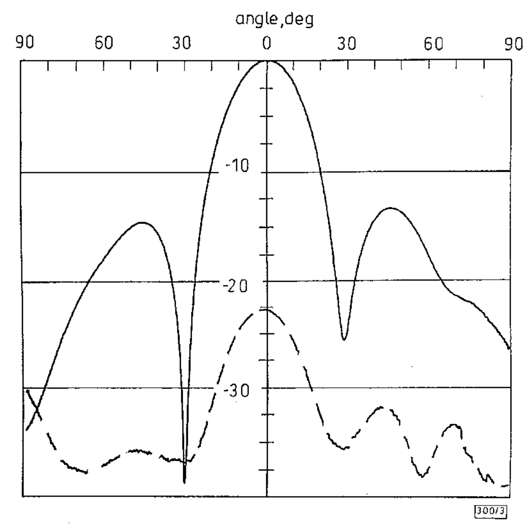

Fig. 3 *Measured radiation pattern*

Linearly polarised with E-vector in θ = 0° plane at 2.5GHz
——— copolar
– – – – cross-polar

Array operation: A four element linear array of varactor diode-loaded patches (Fig. 2), connected via a four-way power divider, has been constructed and the measured radiation patterns for linear polarisation in the θ = 0° plane indicate cross-polar levels better than –15dB in all cases, and generally better than –20dB, (Fig. 3). For linear polarisation in the θ = 90° plane, cross-polarisation is better than –20dB in all cases, and generally better than –25dB,