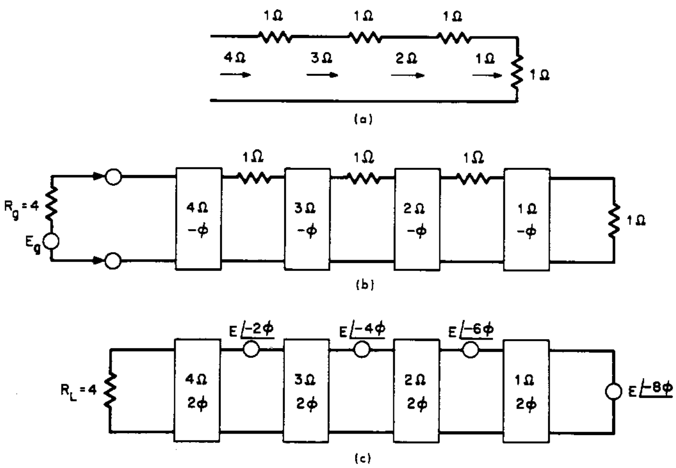

Fig. 1. (a) Equivalent circuit at input frequency of four resonated varactors in series. (b) Equivalent input circuit of four varactors in series separated by networks of specified image impedance and phase shift $-\phi$. (c) Equivalent circuit at output frequency of four resonated varactors separated by networks of specified image impedances and phase shift $+2\phi$.

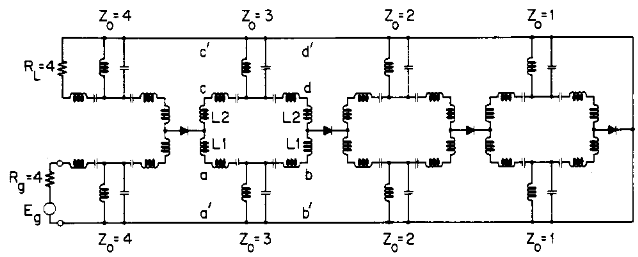

Fig. 2. A circuit configuration for a series array of varactors.

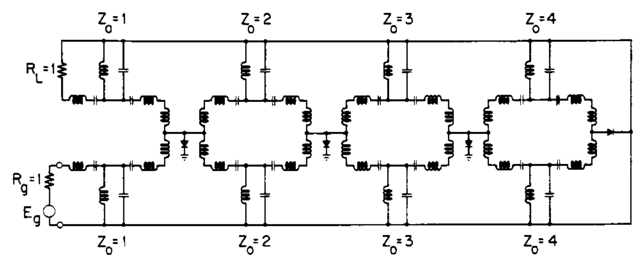

Fig. 3. A circuit configuration for a parallel array of varactors.

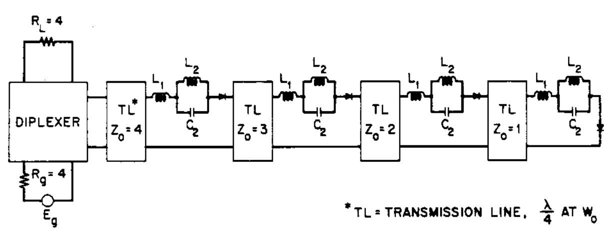

Fig. 4. A circuit configuration for realizing a series array of varactors where both the input and the output frequencies flow on the same line.

Figure 2 shows a possible circuit configuration for a series array of varactors. The T-network a-a', b-b' represents a bandpass filter which passes the fundamental frequency ω but not 2ω and has the appropriate image impedance and phase shift $-\phi$. The T-network c-c', d-d' represents a bandpass filter which passes 2ω but not ω; and, in addition to the appropriate phase shift 2ϕ, the image impedance of each section, increases by R_L/n to the left. Figure 3 shows a circuit configuration where the diodes are effectively in parallel. In Fig. 4 is shown a configuration where both frequencies flow on the same line. The source and the load are isolated by a diplexer. Transmission lines $\frac{1}{4}$ wavelength long at the fundamental frequency are used to achieve the required phase shift of $+90°$ at ω and $180°$ at 2ω, and the required image impedances. The lumped elements L_1, L_2, and C_2 are used to resonate the varactors at both the input and output frequencies.

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Oscillators, Modulators, and Mixers Suitable for Integrated Circuit Realization

Abstract—**It is shown how the variable grounded gyrators now becoming available in integrated-circuit form can be used in conjunction with transistors and capacitors to obtain oscillators, modulators, and mixers.**

Recent work [1], [2] has outlined proposed realizations in integrated form of adjustable grounded gyrators. With such gyrators on hand, one can readily obtain single and coupled tuned circuits [3] which are adjustable in center frequency and coefficient of coupling. Likewise, microminiature delay lines [4] and integrated circuit filters [5] become available. In fact, with the use of capacitors and gyrators almost any circuit operation can be performed, except that care must be exercised to obtain the grounding required. Here we show how standard circuits can be modified for incorporation of gyrators to obtain oscillators, modulators, and mixers.

The basic gyrator has the port description

$$v_1 = -R_b i_2 \tag{1a}$$

$$v_2 = R_a i_1 \tag{1b}$$

where the two resistance parameters R_a and R_b are electronically adjustable. Using these relationships, the equivalence of Fig. 1, which is a special case of that in [3], is readily shown. We have, in fact, for Fig. 1,

$$L\begin{bmatrix} T^2 & T \\ T & 1 \end{bmatrix} = C\begin{bmatrix} R_{a_1}R_{b_1} & R_{b_1}R_{b_2} \\ R_{a_1}R_{a_2} & R_{a_2}R_{b_2} \end{bmatrix} \tag{2}$$

which determines the gyrator parameters when L, C, and the (ideal) transformer turns ratio T are given. Note that if port two is ignored (open-circuited), then at port one an inductor of inductance $CR_{a_1}R_{b_1} = LT^2$ is seen.

Using Fig. 1, and its special cases when port two is ignored, Fig. 2 shows some proposed oscillator circuits in which a common feature is that it is always possible to ground the gyrators. In all cases of Fig. 2, standard circuits [6, p. 308], [7, p. 14–4], [8] were used with gyrator-capacitor replacements of inductors via the equivalence of Fig. 1. Consequently, standard design procedures [6, p. 316] can be used, with (2) giving the gyrator parameters.

Voltage-controlled oscillators are immediately available by observing that the inductance values in the preceding circuitry are all dependent on the gyrator parameters, while the latter are electronically variable. For example, when port two of Fig. 1 is open-circuited, the describing equation is

$$v_1 = R_{b_1} \frac{dR_{a_1}C i_1}{dt} \tag{3}$$

in which case the equivalent inductance can be varied by varying R_{b_1}, with R_{a_1} (and C) held fixed. Thus, variations in oscillation frequency can be obtained by electronically adjusting the equivalent inductance through gyration resistance variation. Considerations for the coupled-coil case are in principle the same.

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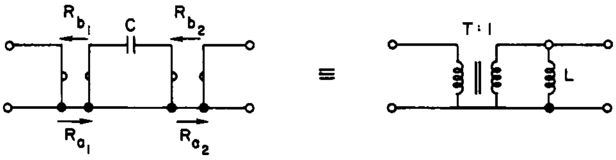

Fig. 1. Coupled coil realization.

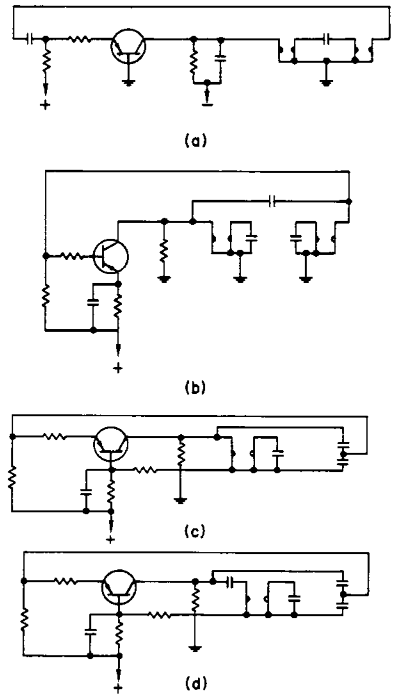

Fig. 2. Oscillator circuits. (a) Hartley-transformer feedback. (b) Hartley. (c) Colpitts. (d) Clapp.

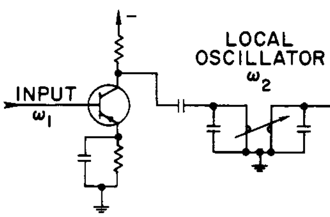

Fig. 3. Mixing circuit.

For frequency modulation we can vary an equivalent inductance through a gyration resistance which varies directly with a modulating voltage. Thus, any of the oscillator circuits of Fig. 1 can be appropriately designed to obtain a frequency modulator through suitable gyrator variation. From (3) we note that the variation can be made linear by varying only R_b, but that it also can be quadratic if R_a is also varied (though, of course, slowly with respect to variations in the current).

As with frequency modulators, we can avoid using nonlinearities of active devices in mixing circuitry. Such a mixing circuit is shown in Fig. 3, where a frequency of ω_1 is the input to the transistor, and a signal of frequency ω_2 is used to modulate a gyrator parameter or parameters. By choosing the two capacitors on each side of the gyrator so that the resulting circuit is resonant when there is no modulating signal at, say, $\omega_1 - \omega_2$, a suitable mixing circuit results. The selection of the relevant frequencies is governed by precisely the same set of considerations as for any other mixer. If desired, the simple tuned circuit of the figure can be replaced by a double tuned circuit of the type described in [3].

It should be pointed out that the idea presented here for obtaining oscillators is but one among many suitable for integrated circuit techniques. For example, one can use operational amplifiers [9] or bistable circuits [10]. However, the circuits described here should have the advantage of being easily adjusted and varied as desired.

Although lumped oscillators and frequency modulators have been constructed and satisfactorily operated using the philosophy of this letter, continued theoretical and experimental investigations are currently in progress.

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The Covariance Matrix of Vocoder Speech

***Abstract*—W. R. Crowther and C. Rader have found an efficient linear encoding for vocoder channels which uses the Hadamard matrix. Minimization of expected mean square error leads to the conjecture that the Hadamard matrix diagonalizes the covariance matrix of the logarithm of 16 vocoder channels. The resulting covariance matrix has been computed for different choices of characteristic values.**

Recently, Crowther and Rader[1] announced a bit reduction scheme for a sixteen-channel vocoder that is similar in some respects to the reduction scheme discussed by Kramer and Mathews.[2] In the first work,[1] the logarithms of the outputs of a sixteen-channel vocoder are combined linearly by a Hadamard matrix.[3] The resulting linear combinations are quantized into a number of levels that varies with the energy content, the 0th output being quantized into 32 levels and the 15th output into only 2 levels. After quantization of the spectrum, the adjoint transformation (which happens to be the same as the original) is applied to restore speech spectrum channels. The resulting vocoder speech which contains only 1650 bits per second is difficult to distinguish, it is stated, from speech produced with the unadulterated 4000 bit per second representation.

Because of this success it is reasonable to conjecture that the Hadamard matrix may be close to the matrix that diagonalizes the covariance of the

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