Proceedings Letters

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Integrated Variable Capacitors for Large Capacitance Variations

Although capacitors are readily available in integrated circuits [1, pp. 161, 185], still their values are somewhat limited (between 10–1000 pF) due to the small surface areas usually available. Likewise, the actual capacitance values are generally fixed due to the unavailability of moving plates, etc. Here we describe, by the use of a variable gyrator [2], how rather large and electronically variable capacitance values can be obtained.

Even though a generalized gyrator [2] with an impedance matrix given by

$$Z = \begin{bmatrix} 0 & -R_b \\ R_a & 0 \end{bmatrix} \tag{1}$$

is not necessarily passive, a cascade connection of two such gyrators as shown in Fig. 1 has the very useful property of impedance transformation and, as a consequence, such a cascade can be used to transform capacitor values.

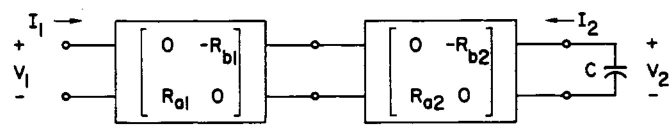

Fig. 1. Transformation of a capacitor.

With a capacitor C connected to the output terminals at the right, as shown in Fig. 1, the input admittance looking into the network at the left, with all "gyration resistances" fixed, is given by

$$\frac{I_1}{V_1} = \left(p\ \frac{R_{b2}R_{a2}}{R_{b1}R_{a1}}\right)C. \tag{2}$$

The network thus transforms C into $(R_{b2}R_{a2}/R_{b1}R_{a1})\ C$. By using variable gyrators [2], one or more of R_{a1}, R_{b1}, R_{a2}, R_{b2} can be varied to adjust the capacitance value seen at the input of the network. In a typical setup we may fix R_{a2} and R_{a1} and change R_{b2} and/or R_{b1} to obtain a wide range of effective capacitance values from a capacitance value that is most easily obtained for use in an integrated circuit. It can be seen that the same cascade arrangement can be used to adjust the value of a resistor or inductor.

It should be observed that the input capacitance of the input "gyrator" places a lower limit on the capacitance obtained. Nevertheless, cascading of more transforming sections allows almost arbitrarily large capacitors to be obtained, and these can be "varied" over an equally wide range by variation of the gyration resistances. Consequently, such circuits could, for example, be used to implement the tuning capacitors for ordinary radio receivers in integrated form.

Because of the original blocking capacitors [1] it is more convenient to realize the cascade connection by using the more recent direct coupled variable gyrator circuits [3], [4].

The size of resistors that can ordinarily be achieved in integrated circuits is limited inherently by the range of ohms per square of the available materials. The use of gyrators however permits resistors outside the usual range to be obtained; to obtain a large resistor, one need only terminate a gyrator in a small resistor, and vice versa. Alternatively, of course, two gyrators may be used to simulate a transformer.

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Down Conversion and Sideband Translation Using Avalanche Transit Time Oscillators

An avalanche transit time diode has been operated as a sideband translator and a combination local oscillator-mixer at X band. The diode used in this experiment was a silicon *p-n* junction diode made by diffusing boron into *n*-type silicon epitaxial wafers. The diode chip was packaged into a high-Q microwave varactor cartridge which was mounted across the broad wall of a WR-90 waveguide in a manner similar to that described by Grace and Minden [1]. Provisions were made to introduce the dc bias and to couple in or out the VHF frequency signal. A schematic and block diagram of the experimental equipment is shown in Fig. 1. Microwave oscillations were obtained at 9540 MHz when the diode was reverse biased beyond its 60 volt breakdown and the current exceeded 11 mA. The frequency of oscillation could be mechanically tuned over a 20 percent band by varying the position of the sliding short circuit behind the diode. At a reverse bias current of 30 mA, the measured CW output power was 17 mW.

The oscillator was operated as a down converter by injecting an external signal whose frequency is different from that of the oscillator frequency and detecting the difference frequency at the biasing port. Figure 2 shows a spectrum analyzer display of the oscillator and the external input signal, which is 30 MHz lower than the oscillator. The input signal was at 9510 MHz and the power level was −25 dBm. It is observed that upper sidebands are generated which are displaced in frequency by the frequency difference between the oscillator and the input signal. Power at the difference frequency was measured across a 50 ohm load, which was not the optimum load impedance at the difference frequency. The conversion loss from the microwave signal at 9510 MHz to the difference frequency at 30 MHz was 7 dB. The noise figure of the down converter was estimated to be approximately 50 dB by measuring the minimum detectable microwave signal. It is believed that the high noise figure is due to the multiplied shot noise [2] from the diode at 30 MHz. The down conversion is probably due to the nonlinear negative resistance of the transit time oscillator.

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