VARACTOR FREQUENCY HALVERS WITH ENHANCED BANDWIDTH AND DYNAMIC RANGE

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ABSTRACT

A one-and-one-third-octave frequency halver has been developed to accomodate the 7-18 GHz input band, the widest bandwidth yet reported. Dynamic range capabilities of varactor halvers can be increased from 7 dB to about 20 dB by means of a novel "sliding bias" circuit.

INTRODUCTION

This paper reports significant extensions of both bandwidth and dynamic-range capabilities of varactor frequency halvers.

An ultra-wideband frequency halver has been developed to accomodate an input range of 7 to 18 GHz, corresponding to one and one-third octaves. This 11 GHz bandwidth is believed to be the largest yet reported for any type of frequency-division circuit. This includes digital dividers, for which a maximum frequency of operation of 10.1 GHz (at 77° K) has been obtained. For non-digital dividers, the widest bandwidth previously obtained was 7.3 GHz [2]. In Fig.1 several aspects of the performance of this new design are compared with those of frequency halver realizations based on other principles. Here the absolute bandwidths of 12 different analog frequency dividers are plotted versus their conversion gains. The following divider types are represented: varactor [2,3,4], step-recovery diode [5], transferred-electron device [6], mixer-with-feedback (Miller divider) [7], single-gate GaAs FET [8], dual-gate GaAs FET [9] and injection-locked oscillator [10]. Also included are a divide-by-3 based on an IMPATT oscillator [11] and a divide-by-9 which uses a tunnel diode [12]. The ultra-wideband halver realized in this work is identified by [*]. Fig.1 reveals that, regardless of the technique used, all the dividers have gain-bandwidth (GBW) products in the 0.1~4.0 GHz range. Interestingly, the 4.0 GHz figure is achieved by both varactor [4] and GaAs FET [9] halvers, as well as by the tunnel-diode design [12]. This suggests that with balanced varactor halvers, it should be possible to achieve bandwidths of the order of 10 GHz with conversion loss as low as 5 dB.

Fig.2 shows the threshold input power for frequency division versus input frequency range for a variety of divide-by-2 circuits. Included is the highest-frequency divider known to the present authors [13]. Although little correlation is seen between minimum input power and input frequency range, the high frequency and wide bandwidth capabilities of the present design are apparent.

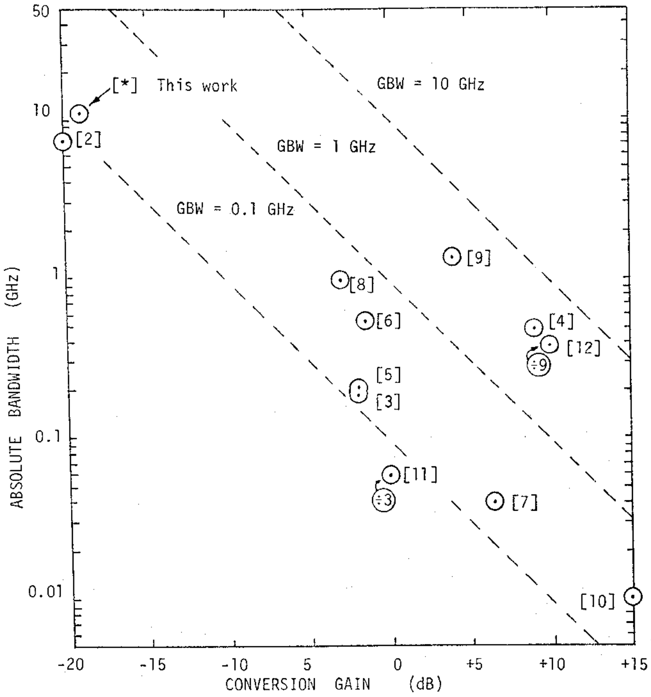

Fig. 1 Gain-bandwidth performance of representative divide-by-two circuits. The present design is indicated by [*].

Wideband Frequency Halver

The 7-to-18 GHz bandwidth of the present design, corresponding to one-and-one-third octaves, was achieved by a modification of a balanced varactor halver topology previously reported [16]. As indicated in Fig.3, instead of relying on a relatively large slotline/microstrip subharmonic resonator, which leads to bandwidth limitations, the modified configuration employs a quasi-lumped resonator in which small wirebonds L_W act as the resonator inductances. As has been previously shown

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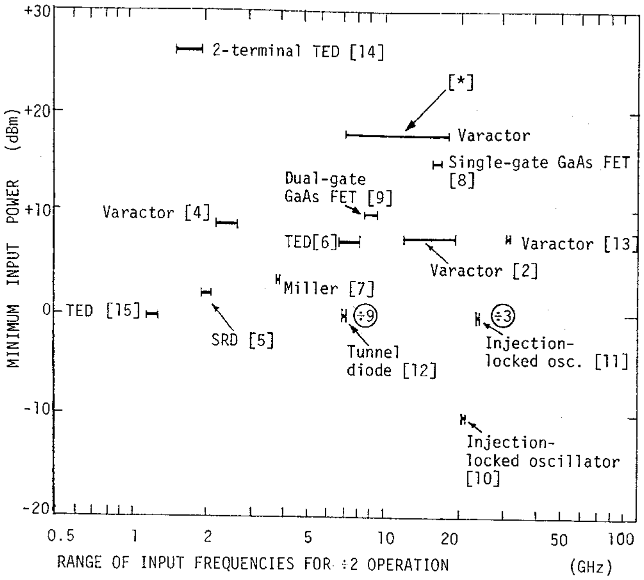

Fig. 2 Minimum threshold input power versus range of input frequencies for various divide-by-two circuits. The present design is indicated by [*].

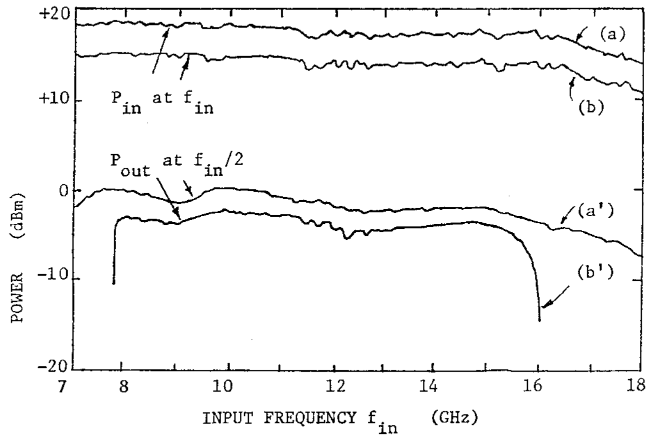

Fig. 4 (a) Input power and (a') output power of ultra-wideband halver over the 7.0-18.0 GHz band for P_{in} = +18 dBm (at band centre) and bias = 0.71 V. (b) Input power and (b') output power for P_{in} = +14.2 dBm (at band centre) and bias = 0.775 V, showing bandwidth reduction to 1.0 octave.

theoretically [17], such lumped-element structures should offer superior wideband properties. The performance of the present design supports this prediction.

Fig.4 shows the division-frequency response under conditions of input power and varactor bias which yield maximum bandwidth (a,a'). The conversion loss lies in the range 17.5 to 23 dB over the entire 7.0-18.0 GHz input range. The effect of reducing the input power and increasing the bias (b,b') is also shown: the division bandwidth is now the 8.0-16.0 GHz octave. On the other hand, the conversion loss has now been reduced to between 16 and 20 dB across the band.

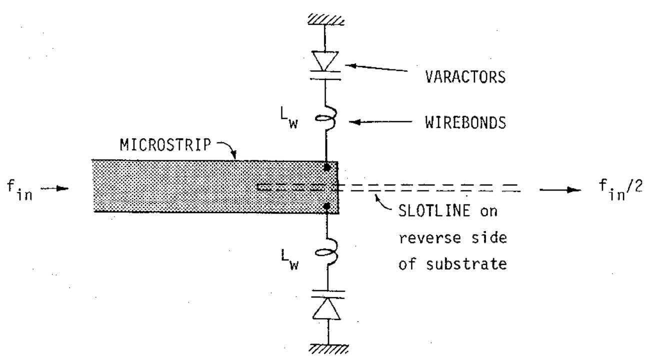

Fig. 3 Wideband frequency-halver configuration.

Dynamic Range Enhancement

The dynamic range of a varactor frequency halver may be defined as in the range of input powers P_{in} between the threshold of frequency division and the onset of spurious-frequency generation. Hitherto this range has been limited to about 7 dB. For a given halver circuit and a given input frequency, the choice of varactor bias determines what values of P_{in} will correspond to the extremes of the dynamic range. Thus the minimum P_{in} required for turn-on can be reduced by increasing the forward bias voltage. However, this means that the maximum allowable P_{in} for spurious-free operation is also reduced. Alternatively, a higher value of P_{in} can be tolerated if the forward bias is reduced, or even made negative, but at the expense of increased values of threshold power level.

The simple "sliding bias" circuit of Fig.5 provides a means of automatically varying the bias in accordance with P_{in} in such a way that significant enhancement of dynamic range can be obtained. The key feature is the intentional provision of a bias source with a finite internal impedance at low frequencies. In Fig.5 this consists of the V_{bias} supply and the resistors R_1 and R_2. This arrangement, which has the additional advantage of making the halver operable from a standard +5V supply, allows the varactors to rectify a portion of the applied RF power. The resulting self-bias increases with P_{in} and tends to oppose the original bias, thereby moving the total bias as required to increase the dynamic range. It is, of course, necessary to ensure that the bias supply has a very low impedance at all microwave frequencies of operation.

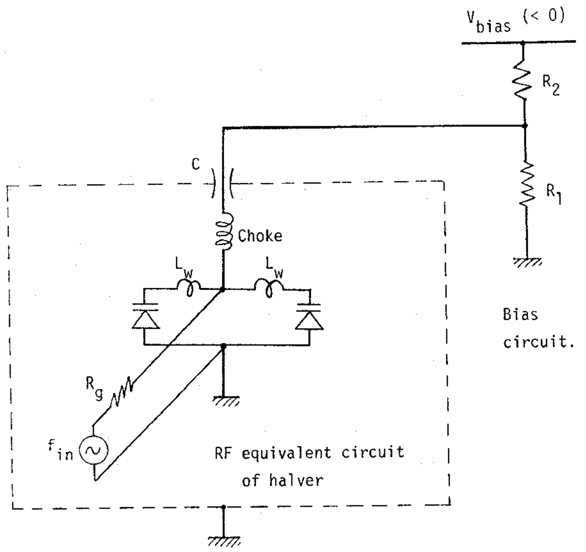

Fig. 5 Circuit configuration for dynamic range enhancement.

Fig.6(a) shows the division-frequency response of a moderate-bandwidth halver without dynamic range enhancement. The useful dynamic range is about 5 dB. Note that there is no frequency division for P_{in} < +12 dBm. The corresponding response for the same halver with dynamic range enhancement is given in Fig.6(b). A dynamic range of 18 dB is now seen, an improvement of 13 dB.

Applications

In multi-octave signal processing systems, frequency halvers with enhanced bandwidth can make possible significant simplifications compared with systems employing traditional down-conversion techniques or narrow-band frequency halvers. In the former case, all problems associated with LO-stability are eliminated. In either case, the design of the input multiplexer can be simplified since fewer channels will be required for a given overall bandwidth of operation.

In phase-locked loops (PLLs) employing frequency halvers, the microwave VCO frequency is divided down so that the phase-comparison can be done directly at the reference frequency. Compared with the conventional method, in which the stable reference is multiplied up to the VCO frequency at which the phase-comparison is performed, this has the advantages of reducing phase noise and eliminating multiplier-generated spurious frequencies. In wideband PLL synthesizers involving broad frequency range VCOs, the division process also divides the absolute bandwidth, so that the phase-comparator need only operate over a narrow bandwidth.

Dynamic range considerations can also be important in signal processing systems, as well as in prescalers for frequency counters. In certain applications the dynamic range can be effectively enhanced through the use of limiting preamplifiers at the expense of degraded transient response. If linear preamplifiers are to be used, however, dynamic-range-enhanced frequency halvers offer a useful alternative.

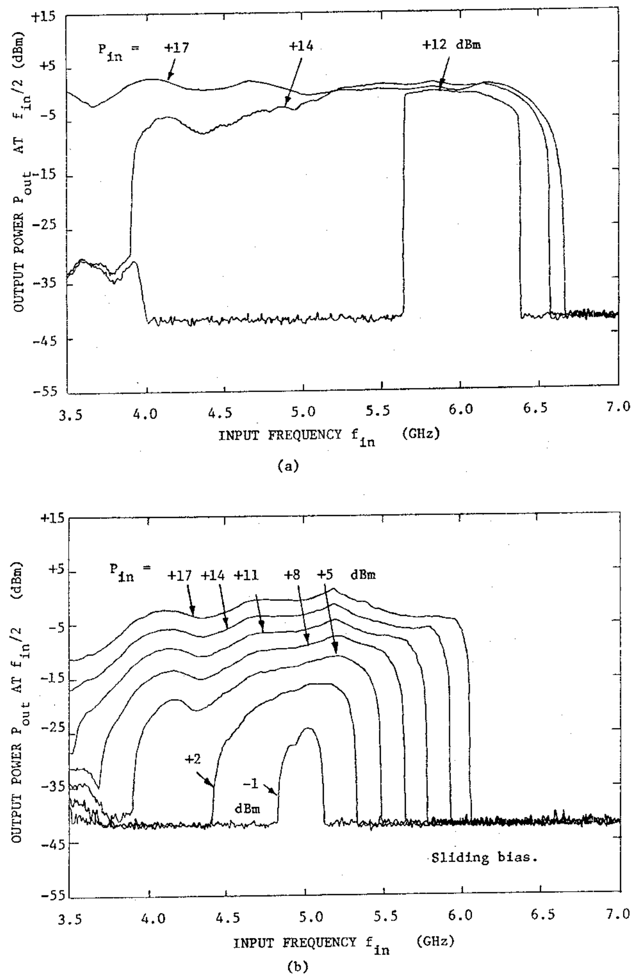

Fig. 6 (a) Moderate-bandwidth halver without dynamic-range enhancement.
(b) Same halver with dynamic-range enhancement.

CONCLUSIONS

Techniques for obtaining improved performance from varactor frequency halvers have been presented. One technique yields a division-frequency bandwidth of one-and-one-third octaves; the other provides a significant increase in dynamic range.

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