A NEW SLOTLINE-MICROSTRIP FREQUENCY HALVER

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ABSTRACT

A novel frequency-halving structure employs a matched pair of varactors in a configuration composed of both slotline and microstrip transmission-line sections. A planar 4th-order Marchand balun simultaneously provides both output matching and a balance-to-unbalance transition.

INTRODUCTION

Microwave frequency halvers can translate wide bandwidths to lower frequencies for analog or digital signal manipulation [1]. To avoid the presence at the output port of even harmonics of the half-frequency, balanced structures are desirable. This is important for the second harmonic, which equals the input frequency ("feed through"), and can fall in-band for octave-plus designs.

Previous balanced varactor frequency-halvers have been constructed either in microstrip/coplanar waveguide (CPW) or in rectangular waveguide. In the first case [2] a quarter-wave de Brecht balun [3] transforms from the balanced subharmonic resonator to the unbalanced output port. This has the disadvantage of causing residual asymmetry and consequent feedthrough at the band edges. In the second case [4], this problem is avoided by using totally symmetrical rectangular waveguide structures; the penalty is increased size, weight and fabrication expense.

The design described here, Fig. 1, maintains broadband symmetry while being small and easily fabricated. It employs a type 6010 RT/duroid substrate with a dielectric constant of 10.5 and a thickness h = 25 mils. The metal on one side is the microstrip circuit, the ground-plane on the other incorporates the slotline/CPW output circuit. A pair of varactor diodes in conjunction with overlapping slotline and microstrip sections forms the necessary subharmonic resonator.

The new design has shown divide-by-two operation over the entire 3.5 - to - 7.0 GHz input band. A two-frequency method [5] is used to measure the "pumped" impedances of the varactor pair.

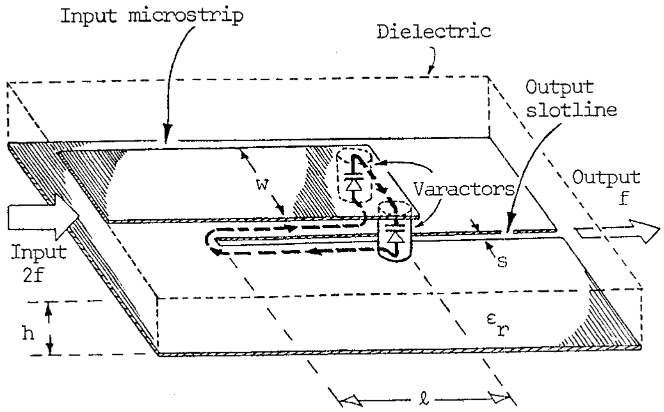

Fig.1 Basic subharmonic resonator structure.

STRUCTURE

The basic subharmonic resonator, Fig. 1, consists of a substrate of permittivity ε_r and thickness h, carrying on one side an input microstrip line of width w and on the other a ground plane containing a slot of width s. The slot is collinear with the microstrip, as viewed from above. The voltage-dependent capacitive reactances of the two varactors, together with the overlapping microstrip /slotline section of length ℓ, form a parametric subharmonic resonator. An input signal at 2f entering via the microstrip line excites the two varactors in phase (even mode). Because of the nonlinear coupling mechanism [6] between this mode and the subharmonic resonance (odd mode), energy is transferred from 2f to f, causing subharmonic currents to flow along the path indicated in Fig.1 in heavy broken line. Since the microstrip electric field is approximately orthogonal to the electric field across the slot, input-output coupling is minimized.

Fig. 2 shows an implementation of the struc-

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ture *. The microstrip sections of lengths ℓ_1, ℓ_2, ℓ_3, ℓ_4 and impedances Z_1, Z_2, Z_3, Z_4 provide a wideband match between the input line (impedance Z_o) and the effective "pumped" input impedance of the varactors D_1 and D_2 in parallel. Bias can be applied via a conventional choke filter consisting of three high-impedance sections and two radial lines. A dc blocking capacitor C is placed at the gap in the input microstrip line.

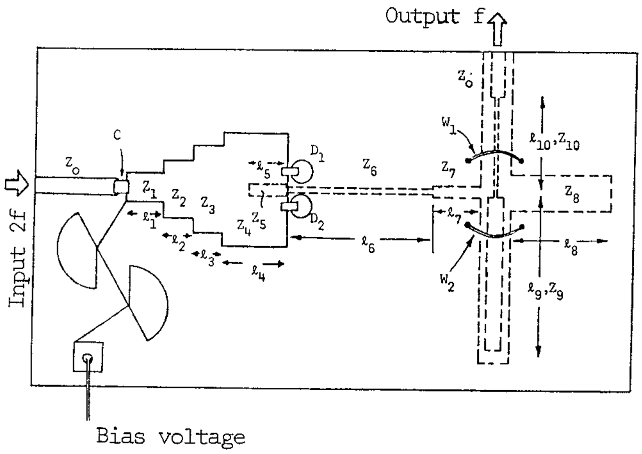

Fig.2 Diagram of a practical implementation.

The short overlapped microstrip/slotline section (ℓ_5, Z_5), together with the varactor reactances, forms the resonator. It has the equivalent circuit shown in Fig. 3. The balanced subharmonic voltage appears across the slotline (ℓ_6, Z_6). A modification of the slot/CPW transition of Houdart and Aury [7] provides an excellent match from the output impedance of the resonator to an unbalanced

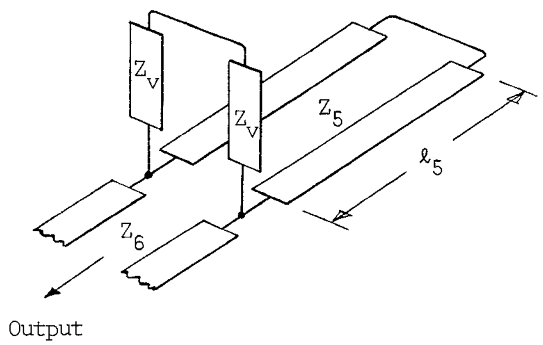

Fig.3 Equivalent circuit of subharmonic resonator at output frequency f. Z_v represents "pumped" varactor output impedance.

* Patents pending

load. This transition is the planar equivalent of the 4th-order Marchand balun [8,9,10]. It consists of the following sections:

(i) a slotline input section (ℓ_7, Z_7),
(ii) a slotline short-circuited parallel stub (ℓ_8, Z_8),
(iii) a CPW open-circuited series stub (ℓ_9, Z_9),
(iv) a CPW output section (ℓ_{10}, Z_{10}).

The bridges W_1 and W_2 maintain the joined "ground" regions at the same potential. Fig. 4 shows an equivalent circuit for this transition. The balun is connected to the 50-Ω output port by the CPW line (Z_0).

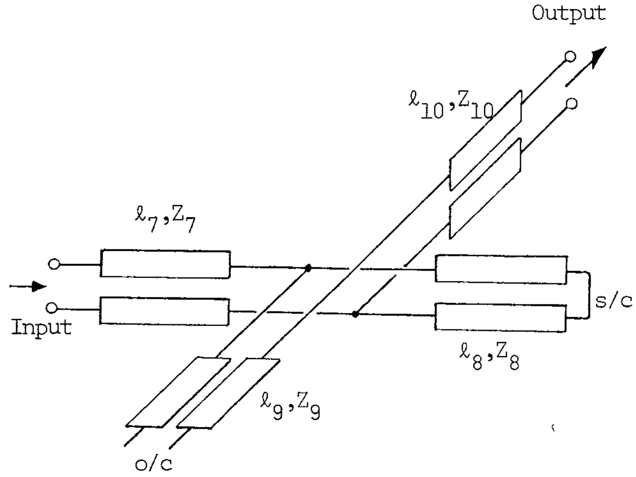

Fig.4 Equivalent circuit of planar form of 4th-order Marchand balun.

According to frequency-halving theory [6], energy is transferred from the input frequency 2f to f by means of the nonlinear reactance of the varactors. The resonant frequency depends on these reactances and the resonator dimensions. The position of the varactors also affects the resonant frequency. The electrical length of the resonator should be small (5^o - 10^o at the centre frequency) in order to obtain a large bandwidth. The resonator should be narrow so that the varactors are close together. Maximization of the bandwidth also requires the small-signal resonant frequency to be set at or slightly above the maximum value of f.

CIRCUIT OPTIMIZATION

COMPACT [11] was used to optimize the input and output matching networks, using the "two-frequency" method described in a previous paper [5]. Using suitable starting estimates for the optimization procedure, a good theoretical performance in terms of output VSWR was easily achieved for the output circuit over a frequency band in excess of one octave, verifying the ability of the 4th-order Marchand balun to match frequency-dependent loads, [12]. Wide (low-impedance) microstrip sections close to the diodes gave low input VSWR's. Narrow longitudinal slots in these wide microstrip lines prevented possible transverse resonance.

EXPERIMENTAL RESULTS

A practical frequency halver built according to the principles described above gave promising results using two silicon varactors* biased at zero volts. Fig. 5 depicts the domain of frequency division by two, and shows operation over an octave bandwidth of 3.5 to 7.0 GHz. Fig. 6 shows the output power versus frequency. Compared with previous designs, the greatly increased output power is apparent: this can be attributed to the improved output matching network.

CONCLUSIONS

The planar 4th-order Marchand balun not only provides a good match to a frequency-dependent source over an octave bandwidth but also gives good slotline-to-CPW transition properties. This, together with CAD methods and a "two-frequency" technique for measuring the large-signal input and output impedances of the subharmonic resonators provides a powerful tool for designing slotline-type frequency halvers with the best performance for a given diode type and substrate material.

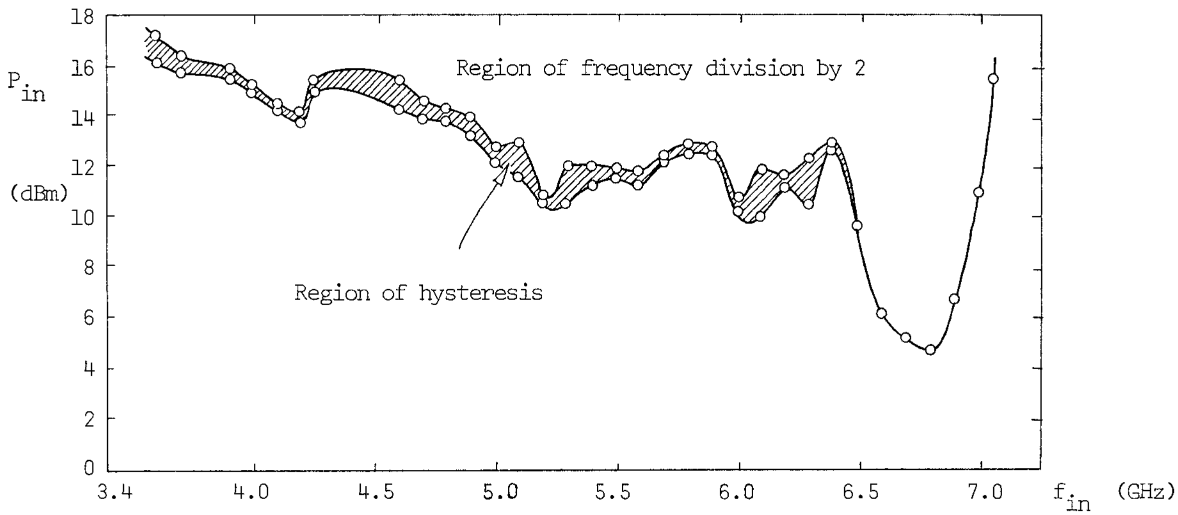

Fig.5 Domain of frequency division by two.

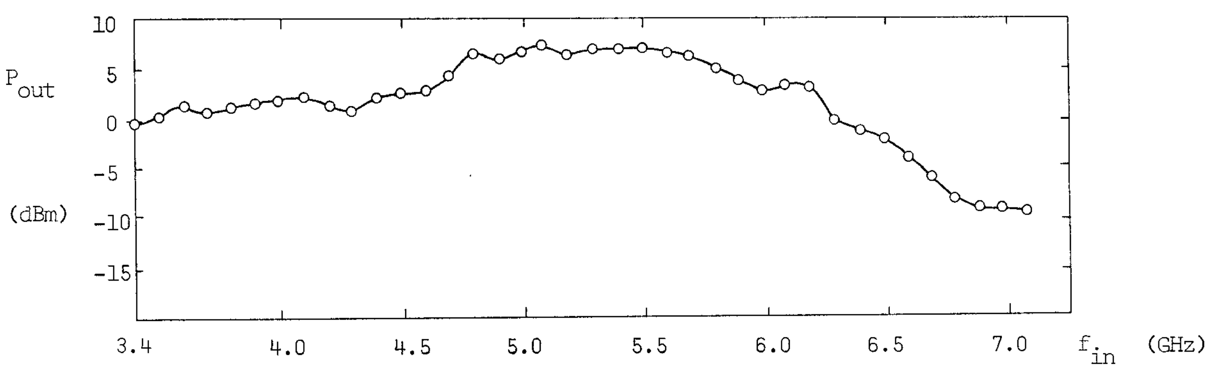

Fig.6. Output power versus frequency for constant input power P_{in} = +16 dBm.

* GC-1504 Si tuning varactors, Frequency Sources Inc., GHZ Division.

ACKNOWLEDGEMENTS

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