FINLINE FREQUENCY DIVIDERS

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ABSTRACT

The finline technique has been used for the design and realization of a parametric frequency divider with two varactor diodes, and a harmonically synchronized GaAs FET oscillator-based frequency divider. Their operational characteristics have been tested in the laboratory over the frequency range from 6 to 22 GHz. These results clearly indicate that finline frequency dividers are very promising for millimeter-wave applications. Performance limiting factors such as mismatch end effects and phase noise are discussed as well.

INTRODUCTION

During the past decade, microwave frequency dividers have been successfully used in many applications below 26 GHz, such as frequency synthesizers and PLOs. Various concepts for their realization have been proposed using planar microstrip technology, such as the parametric divider [1], the Phase-Locked-Loop (PLL) divider [2], the Miller divider [3] and the harmonically synchronized oscillator [4].

Parasitic radiation associated with planar microstrip waveguides make the use of such devices problematic, especially for millimeter-wave applications. However, it is well known [5] that such problems can be avoided by the use of finline. Moreover, since the fundamental mode of a finline guide is similar to that of a rectangular waveguide, transitions between these two guides are easy to realize and have a low insertion loss and VSWR over the entire waveguide band.

This paper describes two finline based frequency dividers, capable to work well up to millimeter-wave frequencies. The first frequency divider is a parametric device with two varactor diodes, generating very low phase noise. The second frequency divider, presenting very good nonlinear characteristics combined with gain capabilities, is a harmonically synchronized oscillator device using a microwave transistor. In both cases a waveguide housing simultaneously serves as a support for the substrate and as a shield against radiation from the planar structure. Both types of frequency divider have low conversion losses combined with a simple construction. In addition, low-loss variable shorts like those used in waveguide techniques have proven to be excellent tuning elements. Thus both devices combine the advantages of MIC and conventional waveguide technology. Finally, measurements have been made between 6 and 22 GHz, although our ultimate goal is to scale both devices to millimeter-wave frequencies.

CIRCUIT DESCRIPTION

a) The Parametric Frequency Divider

The most important part of this frequency divider is a planar T-junction completely integrated in a rectangular waveguide. The purpose of this junction is twofold. Firstly, it splits the input signal power between the two nonlinear elements (varactors), and secondly it blocks the subharmonic output signal from leaving through the input port.
The even and odd mode parameters of the coupled uniform finline region, and the single finline section were computed using the spectral domain method. As known [6], [7], this method is very efficient when the edge condition is incorporated in the choice of the basis functions for the electric field in the slots. Indeed, after many successful tests reported in [8], this method appears to be an adequate CAD tool for practical applications, such as the one presented here.

The hybrid T-junction used here, is directly connected to the parallel-coupled lines (see Fig. 1), [6].

The two symmetrical slots form a coupled transmission line arrangement, which supports two normal modes of propagation, namely the odd and even modes having equal voltage amplitude, but the same and opposite polarity respectively. It is this property of the coupler that makes parametric frequency division possible. The two varactor diodes, located closely to the T-junction, are simultaneously excited at $f_{in}$ in the even-mode (see Fig. 1). Given the appropriate DC-bias, the two nonlinearly operating diodes generate frequency components at $f_{in}/2$, $f_{in}$, $3f_{in}/2$, $2f_{in}$.... These frequency components propagate in the odd-mode through the coplanar resonator, are extracted through the 50 Ohm microstrip line, and appear at the output. The coplanar resonator is designed to resonate in the $f_{in}/2$ component. Hence, this particular frequency divider can be considered as a "frequency dividing by two" device ($HALVER^TM$).*

* The word $HALVER^TM$ is a trade mark by TELEMUS Inc.

FIG. 1: Parametric Finline frequency divider

(a) Cross-section of a coupled line section
(b) Layout of the finline circuit

FIG. 2: Layout of the harmonically synchronized oscillator finline frequency divider
The finline circuit, chosen for operation at both
the fundamental \( f \) and the second harmonic \( 2f \), is
shown in Fig. 2. In order to avoid the use of via holes,
a unilateral finline configuration was chosen for op-
eration in the Ku frequency band. Hence, both the
input and the output taper were designed accord-
ingly, with a circular-arc profile \([9]\). Furthermore, a
metal strip on the back of the finline circuit assures
the necessary positive feedback. The length of this
metal strip, corresponding to the loop size in a regen-
erative frequency divider \([10]\), was found to be crucial
for the overall operation of this frequency divider.
Finally, isolated sliding shorts in the source-gate and
the source-drain circuit were used for input/output
power matching.

MEASUREMENTS AND
PERFORMANCE EVALUATION

Both dividers were printed on a 0.508mm thick
RT/Duriod 5880 substrate (\( \epsilon_r = 2.2 \)). For the real-
ization of the parametric frequency divider, two MA
454225 packaged varactor diodes were used, while for
the harmonically synchronized oscillator a NEC-NE
720 packaged microwave FET transistor was chosen.
Referring to the finline, the width of the coupling slots
in both dividers was chosen such as to represent a
compromise between ease of manufacturing and ef-
cient coupling requirements. Finally, DC-isolation
was realized using additional dielectric strips placed
on the mounting grooves in connection with standard
serration techniques. (see Fig. 1 and Fig. 2).

Fig. 3 presents the output spectrum of the var-
actor frequency divider, excited at \( f_{in}=11.1 \) GHz.
This diagram clearly demonstrates the halving op-
eration of this frequency divider. Indeed, the spectral
component at \( f_{in}/2 \) shows an output power level al-
most 12dB above the power at \( f_{in} \) and of 25 dB above
the power at \( 3f_{in}/2 \). This frequency divider was
found to be a narrowband device (spot frequency).
since the operational bandwidth did not exceed 50
MHz in the best case (see Fig. 4; \( V_{bias}=0 \) Volt,
\( f_{in}=6.52-6.572 \) GHz, \( P_{in}=10dBm \)). However by vary-
ing the DC bias, the halving operation could be
achieved over the entire frequency band from 6 to
11.5 GHz, for a given fixed length of the coplanar
resonator (see Fig. 1). This performance was fur-
ther improved by the use of a low-loss movable step
in the width of the housing along the coupled line
section to optimize impedance matching of the two
varactor diodes to the input signal.

![FIG. 3: Output spectrum of the parametric frequency divider \( P_{in}=15dBm, V_{bias}=+5.33/-
0.14V, f_{in}=11.1 \) GHz](image)

![FIG. 4: Operational bandwidth of the parametric frequency divider \( P_{in}=10dBm, V_{bias}=0.V \)](image)

The harmonically synchronized frequency divider,
has been tested for excitation frequency from 9 to 22
GHz. The first experimental results (see Fig. 5)
show that the divider is operating satisfactorily at
\( f_{in}=13.8 \) GHz, generating frequency components at
\( f_{in}/2 \) and \( 3f_{in}/2 \). Higher frequency operation can
be achieved by using the appropriate FET (NEC -
NE 720, cut-off frequency = 14 GHz).
FIG. 5: Output spectrum of the harmonically synchronized oscillator based frequency divider ($P_{in}=15$ dBm, $V_{ds}=-2.46$ V, $V_{sd}=3.6$ V, $f_{in}=13.8$ GHz)

CONCLUSION

Two finline frequency dividers having completely different operational principles, have been designed and tested within the frequency range 6-22 GHz. The experimental results agreed with the requirements for frequency division widely accepted by industry, and indicate that these frequency dividers can be scaled for operation to millimeter-wave frequencies.

REFERENCES


8. C. Rauscher "A 16 GHz GaAs, FET Frequency Divider" IEEE MTT-S Digest, Boston 1983, pp 349-351

