A 4-Device Powercombiner used as a Lossless High Power Switch at 94GHz

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Abstract

In the millimeter wave range PIN-diode switches are rather lossy (ca. 2dB at 94 GHz). Additionally, the power handling capability of beam-lead diodes is limited to some 100 mW average power. To overcome switching problems in high power applications, i.g. for a pulse radar, the injection power for a symmetrical four coupler power combiner is switched from on of its two input ports to the other. Hence, the combined power alternately appears at one of the both output ports. If power and phase of the combined oscillators are balanced within .5dB and ±10°, the power level at the difference port is more than 25dB below the power level at the sum port. In this manner,the insertion loss of the lossy single port, double throw PIN-diode switch reduces only the low level injection power while the combined power of the four devices is switched lossless between the two output ports of the combiner network. In our application, this performance is used to switch the radar transmit power from left to right hand circular polarisation.

INTRODUCTION

In the millimeter wave range PIN-diode switches are rather lossy -i.g. at 94 GHz a switch has an insertion loss of about 2dB while offering only an isolation of less than 25dB [1,2]. Because of the dissipation loss, the power handling capability especially of beam-lead diodes, the most commonly used devices, is limited to some 100mW average power. High power pulses of more than 20 W can burn out fin-line switches by flash across.

In this paper a methode suitable to overcome this high power switching problems is described. Basic idea is to switch the synchronisation power for an (anyhow necessary) power combiner consisting of four oscillators and four hybrid-couplers from one of its two input ports to the other. This leads to an exchange of sum and difference power at the two output ports. In this manner the insertion loss of the PIN-diode switch decreases only the low level synchronisation power, hence the poor power handling of the PIN-diodes used remains without consequences. Above all - the output power is switched lossless.

The power combiner is part of an instrumentation radar system using circular polarized waves for target signature measurements.

To obtain circular polarisation, the two output ports of the combiner are connected with the two rectangular waveguide ports of a turnstile junction [3]. At the circular waveguide port of the junction right or left hand circular polarized waves are produced depending on the state of the PIN-switch .

SET-UP

FIG.1 shows the block diagram of the arrangement used as high power switch. Four IMPATT-oscillators are powercombined by the four 3 dB/90° hybrid-coupler network shown in the middle.

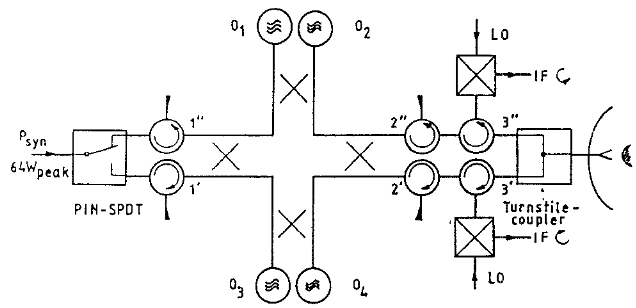

FIG. 1 : Block Diagram of the Set-Up

A PIN-diode switch is used to inject the synchronisation power by choice in one of the two input ports of the combiner. If port 1' is chosen, port 2'' puts out the sum power while the powerdifference comes out at port 2' - and vice versa.

Both output ports are connected with the input ports 3' and 3'' of a turnstile junction. It converts the incoming TE_{01} wave - depending on which port is fed - either in a right or left hand circular polarized wave that finally is transmitted by a Cassegrain-antenna.

The combiner is matched by means of broadband isocirculators inserted between PIN-switch and combiner input as well as between turnstile coupler and combiner output.

The circulators between isocirculators and turnstile coupler are used as transmit/receive diplexers. In case of receiving the turnstile junction again separates the incoming echos in regard of their polarisation.

COMBINER NETWORK

The combiner network is composed of four 3dB 90° hybrid-couplers. Best results have been achieved using ridged shaped narrow wall couplers [4] providing low loss, correct power splitting and very high directivity. FIG.2 shows the most important characteristics of the accordingly realized network. The high directivity (>30dB from 89 to 98 GHz referring S_{21} in FIG.2) is advantageous for decoupling between the oscillators from each other to prevent moding. The reflection loss (e.g. S_{22} in FIG.2) is >25 dB from 88 to 98 GHz. Therefore, significant distant reflections [5] that could distort the combiner function only occure, if the output ports are mismatched.

Such a mismatch is prevented by terminating the combiner with H-plane circulators [6] having an insertion loss of .4 dB, an isolation (and reflection loss) of > 25 dB over a band of 92 to 96 GHz.

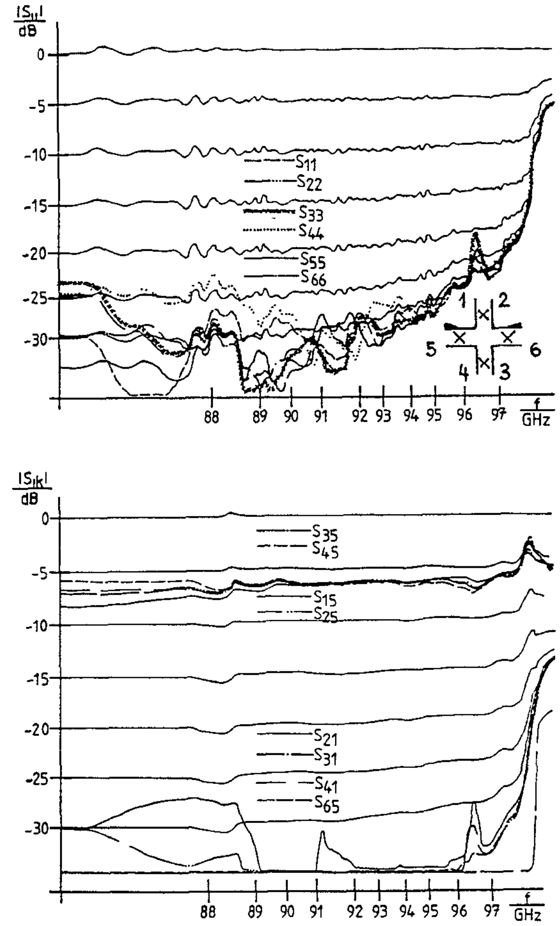

FIG. 2 : Performance of the Combiner Network

IMPATT-OSCILLATOR

FIG.3 shows a cross sectional view of the IMPATT-oscillator developed for this application [7].There are four dominant tuning mechanisms: The diode current, the position of the diode with respect to the waveguide bottom, the backshort position and the diameter and length of the coupling pin between choke and diode. The impedance of the diode depends on the current flowing through the diode. A change of the diode position alters the fringing capacitance between choke section and the waveguide bottom. Increasing diameter and decreasing length changes the series inductance of the coupling pin. The backshort position determines a reactance in parallel to the diode.

This backshort is formed as double loop to reinforce the pressure of the first loop . Slots in the

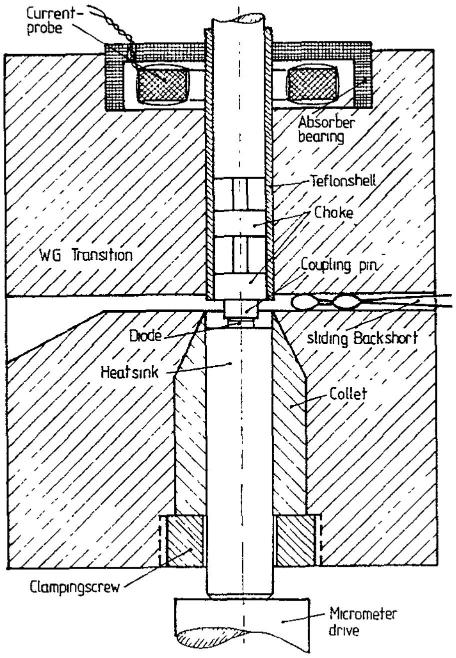

FIG. 3 : Set-UP of the IMPATT-Oscillators

first loop improve the contact to the waveguide wall. The diode is mounted in a certain position relative to the heigth reduced waveguide cavity by a moveable heat sink wich can be fixed by the clamping screw closing the collet as shown in FIG.3. The bias pulse is fed through a teflon covered, spring loaded and therefore also moveable bias pin having a choke structure and the coupling pin at its end. The bias pulse can be monitored by a small pulse transformer embedded in a bearing made of absorbing material wich is used for shielding and fixing the bias pin. The diode heatsink can be moved precisely by means of a micrometer drive. FIG.4 shows an example of the detected output power.

The current pulse of about 12 A_{peak} is shown in the same figure. Pulse shaping was done by a digitally controlled pulse modulator. The peak output power of the oscillators was measured to 16.5 ±.5Watt each at 94 ± .5 GHz.

TUNING

The combiner was tuned in the following manner:

1. Tuning the single oscillators to their related combiner ports under synchronisation. The three remaining ports are matched by absorbers. FIG.4 shows the detected output power and the bias-pulse.

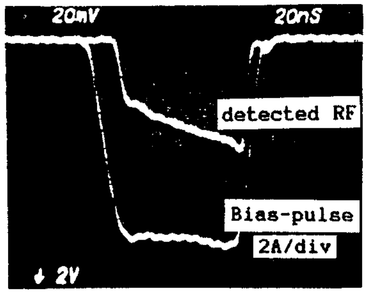

FIG. 4 : RF-Output Pulse and Bias-Current Pulse

2. Tuning one half of the power combiner, while the remaining ports are matched - then the other half. FIG.5 shows the detected sum and difference power (P_Σ and P_Δ) of one half.

3. Tuning the entire combiner to minimize the power difference pulse and to optimize the sum power as well as the synchronisation range.

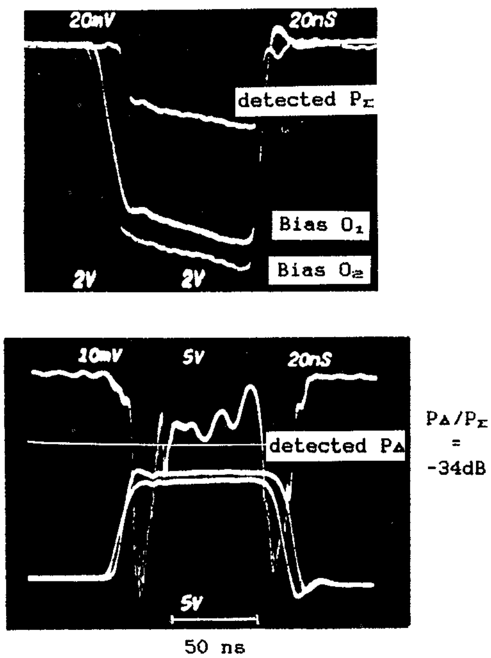

Fig. 5 : Sum- and Difference Power P_Σ and P_Δ of 1/2 Combiner (2 Oscillators combined)

RESULTS

It should be pointed out, that to avoid significant elliptical polarisation of the output wave the ratio of difference power to sum power P_Δ/P_Σ should be lower than - 15 dB. FIG.6 shows the difference power pulse in a linear plot for different frequencies from 93.8 to 94.3 GHz. Herein, a detector voltage of 10 mV (= 2 div) indicates a ratio of -34 dB marked by the white line. For 50 ns of the 80 ns pulse, the ratio is even lower than -34 dB. The -15 dB condition mentioned above is met for the entire pulse.

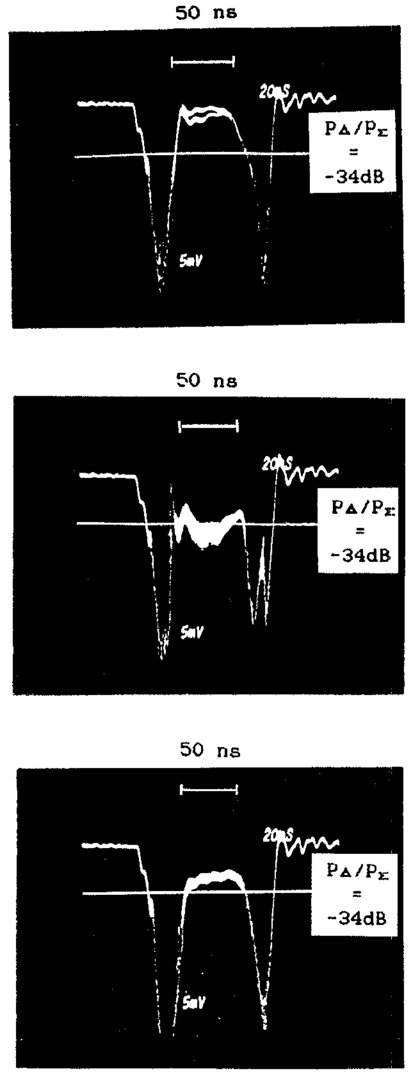

FIG. 6 : Difference power response P_Δ at the decoupled port for the frequencies 93.8 GHz, 94.1 GHz and 94.3 GHz

The overshoots at rise and fall of this power difference pulses shown in the figure are caused mainly by differences in pulse duration and in the time shift between the output pulses of the four oscillators. Different rise times, spurious responses and noncoherence at the beginning of the pulse will also cause overshoot at the rise of the pulse. However, only the coherent part of the pulse is processed.
Calculations and simulations have proven, that a ratio of < -20dB can be achieved easily, if the oscillators don't differ more than ± 20% in power and the phase difference caused by synchronisation is less than ± 10°. This has been verified by the experiments.

The following results have been achieved:

Output power of the single oscillators	: 16.5 $Watt_{peak}$ ± 3%
Combined (sum) power P_Σ	: 56.0 $Watt_{peak}$
Combining efficiency	: 85%
Interpulse phaseripple	: < ± 5°(c.o.FIG. 7)
Synchronisation bandwidth	: .8 GHz
Difference power divided by sum power P_Δ/P_Σ	: <-15dB entire pulse <-34dB over 50nsec

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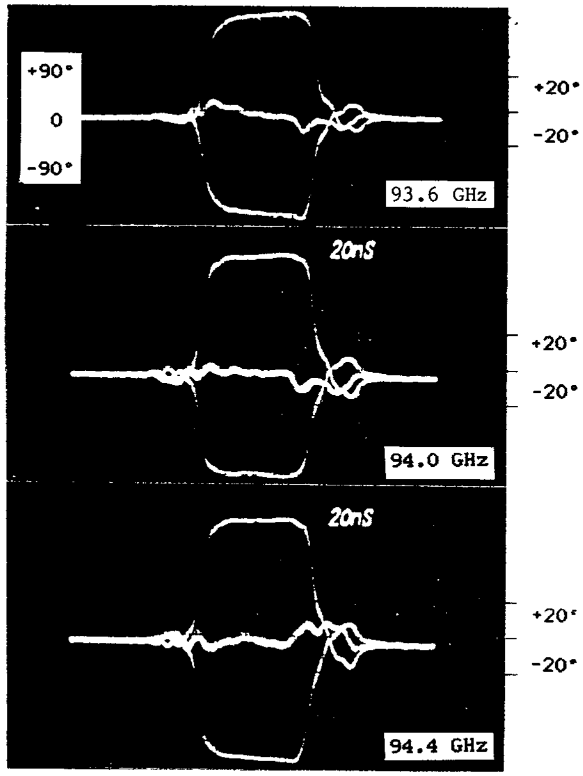

FIG. 7 : Phase Ripple of the Output Signal P_Σ

measured by mixing the synchronisation signal with the output signal by means of a balanced mixer as phase detector