A comparison between 4-bit fixed and reconfigurable microwave discriminators for frequency identification

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***Abstract*—** This paper presents a comparison between fixed and reconfigurable 4-bit microwave discriminators. The fixed discriminator is implemented by using multi-band-stop filters to define bits used for frequency identification. The reconfigurable discriminator is implemented by using delay lines and two SPQT switches. Both designs operate at L and S bands, a comparison between both devices is provided, including simulated and measured responses for both designs.

***Keywords*—** *delay lines; fixed discriminator; reconfigurable discriminator, SPQT switch, band-stop filters.*

I. INTRODUCTION

Microwave Discriminators (MD) play an essential role in Instantaneous Frequency Measurement (IFM) receivers, where MDs generate the bits used to identify an unknown Radio Frequency (RF) or microwave signal.

This paper focuses on the comparison between a fixed and a reconfigurable MD. The comparison is made in terms of resolution, power consumption, size, response time, implementation and other characteristics.

Section II describes the two circuits to be compared, section A deals with a fixed MD made with multi-band-stop filters. Section B describes the reconfigurable MD. Section III discusses the fabrication used for both devices, section IV shows the simulated and measured results for both designs. Finally, section V provides the comparison between the designs and section VI provides an overall conclusion to this work.

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II. DISCRIMINATOR DESIGNS

The two designs to be compared are described in this section. Both designs operate at L and S frequency bands and use 4-bits for frequency identification. One design is fixed and the other is a reconfigurable design.

A. Fixed microwave discriminator

Fig. 1a shows the 4-bit fixed MD device with an input port and four output ports to provide an instantaneous readout. This IFM implementation requires the following components on each of its branches: limiting amplifier, microwave discriminator, detector, amplifier and analogue to digital converter [1-4]. The design is compact compared to a fixed delay line implementation [5], resulting from the use of multi-band-stop filters to produce the bits for frequency identification [4]. The filters are composed of rectangular microstrip open loop resonators, placed near a 50 Ω transmission line. The resonators de-couple electromagnetic energy from the transmission line, at the resonant frequency of the resonators, while other frequencies are able to go through the main transmission line [3, 4]. The response of this device is similar to an interference pattern obtained by interferometry, making it suitable for frequency identification. The device uses a power divider bank, formed by three Wilkinson power dividers with double stage [6] to produce a wideband response over the operation bandwidth of the device, which is from 1.5 to 4.66 GHz.

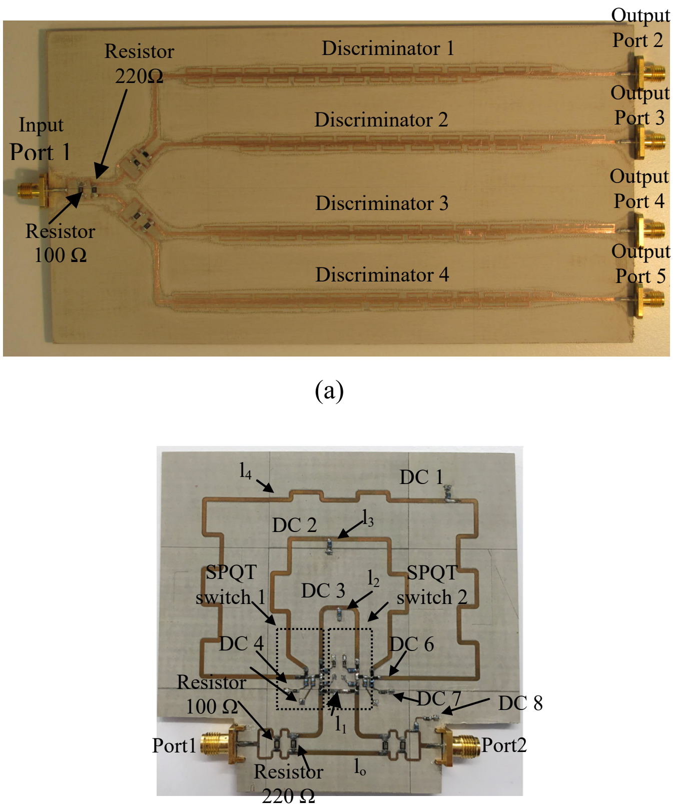
B. *Reconfigurable microwave discriminator*

Fig. 1b shows a 4-bit reconfigurable MD. This device has a two port configuration, which is able to produce 4 bits for frequency identification by switching between a set of 4 delay lines [7]. A 2-bit reconfigurable MD can also be found in [8]. The 4-bit reconfigurable MD is designed based on a reference line (l_0) with a length of $\lambda_g/2$, four delay lines (l_1, l_2, l_3 and l_4) with a length of λ_g, $3\lambda_g/2$, $2\lambda_g$ and $5\lambda_g/2$ respectively, where λ_g is the guided wavelength at 2.5 GHz. The design includes a Wilkinson power divider and combiner, and two Single Pole Quadruple Throw (SPQT) switches. The device operates from 1 to 4 GHz and identifies an unknown signal by switching between delay lines, providing a serial output by using only two ports.

III. Discriminator Fabrication

Both MDs shown in fig. 1 were fabricated on an ARLON AD1000 substrate using a LPKF Protolaser S machine. The substrate has a dielectric constant of 10.2, loss tangent of 0.0023, with conductor and dielectric thickness of 0.035 mm and 1.27mm, respectively. Each power divider uses two resistors of 100 Ω and 220 Ω. The reconfigurable MD design in fig. 1b uses a bias network made of an inductor and resistor [8].

The fixed MD design, shown in fig. 1a, measures 199 x113 mm, and uses 5 SMA connectors. Fig. 1b shows the reconfigurable MD, which measures 102 x 96 mm and uses two SMA connectors.



(a)

(b)

Fig. 1. Photograph of fabricated devices, (a) fixed MD, (b) reconfigurable MD.

IV. Results and Discussion

Fig. 2 shows the simulated and measured response of the fixed MD. The simulated and measured responses agree well, however, there is a frequency shift of 350 MHz in all operating states. The simulated and measured responses of the reconfigurable MD are shown in fig. 3. The simulated and measured results present a frequency shift of 27.96 MHz for state 1, 112.17 MHz for state 2, 65.84 MHz for state 3 and 50.59 MHz for state 4. This frequency shift for both cases might be due to a slight dielectric constant variation of the substrate.

The response of state 1 and 4 in fig. 2 correspond to the Most Significant Bit (MSB) and the Least Significant Bit (LSB) for frequency identification, generated by the discriminator 1 and 4 of the fixed MD, respectively. Similarly, the responses of state 1 and 4 in fig. 3 correspond to the MSB and LSB generated by the reconfigurable MD.

V. Comparison Between Fixed and Reconfigurable Discriminator Designs

Table 1 summarizes the comparison between fixed and reconfigurable MD designs. Considering complete receiver architectures, the fixed MD consumes more power compared to the reconfigurable MD design, due to the fact that the fixed MD requires four times more electronic components for its implementation [8]. On the other hand, the reconfigurable MD requires time to switch through all four delay lines before providing the final readout, the switching speed of the PIN diodes used is of 10ns, time that will be needed to switch from one state to another on the reconfigurable MD design. The fixed MD will provide an instantaneous readout through the four parallel output ports.

Since considering full receiver architectures, the reconfigurable MD requires only one quarter of the total of electronic components used in the fixed MD. This allows generating light and compact Reconfigurable Frequency Measurement (RFM) receivers, with low power consumption [7, 8] and reduced size.

VI. Conclusion

In this paper, a comparison between fixed and reconfigurable MDs is presented. Both designs are implemented using low cost PCB techniques. The reconfigurable MD has some advantages over the fixed MD designs such as smaller size and it can be used to reduce the number of electronic components considering complete receiver architectures, resulting in low power consumption. The reconfigurable MD does the frequency identification process serially, while the fixed MD provides an instantaneous readout.

Table 1. Comparison between 4-bit fixed and reconfigurable MDs.

	Reconfigurable MD	Fixed MD
Frequency Bandwidth (GHz)	1-4	1.5-4.6
Calculated Resolution (MHz)	187	62.5
Power Consumption by Discriminator	53 mW	0
Tecnology	Microstrip	Microstrip
Discriminator/Bits	1/4	4/4
Response time	40 ns	Instant
Implementation of Discriminators	based on delay lines and SPQT switches	Open-loop resonator based bandstop filters
Dimensions (mm)	102 x96	199 x 113
Type of System	Reconfigurable	Fixed
Reference	[7]	[4]

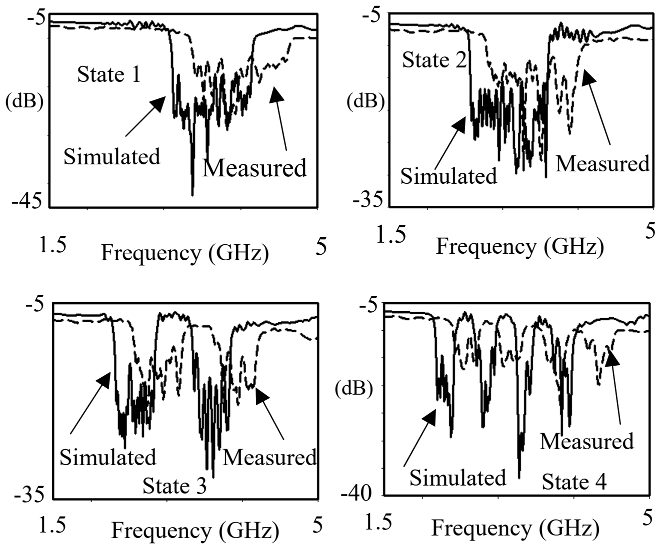


Fig. 2. Simulated and measured responses generated by the fixed MD.

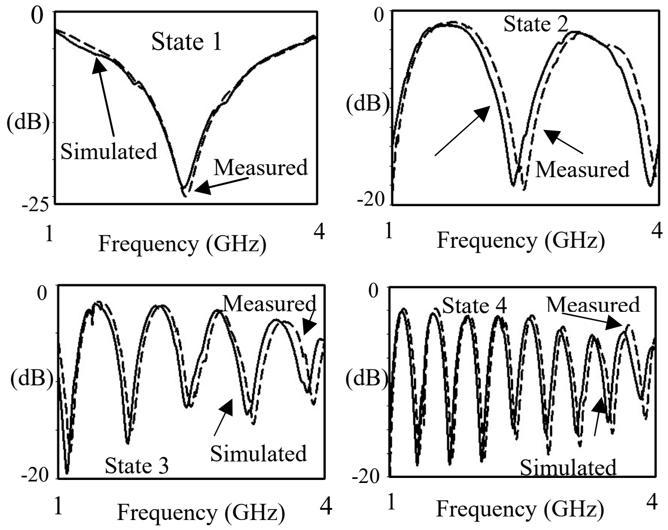


Fig. 3. Simulated and measured responses generated by a reconfigurable MD.

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