A FREQUENCY/TIME DOMAIN CHARACTERIZATION TECHNIQUE FOR FREQUENCY-TRANSLATING DEVICES

N. Boulejfen, F. M. Ghannouchi, A. B. Kouki

Ecole Polytechnique de Montréal
3333 Queen Mary, R220.5 Montréal, PQ, H3V 1A2 Canada

ABSTRACT

A novel approach and a new measurement setup for the characterization of frequency translating devices (FTD) are proposed. The proposed approach allows for an automated, one-step full characterization of FTDs by measuring both the magnitudes and phases of the incident and reflected waves at all signal ports. The application of the proposed approach and the developed measurement setup to the characterization of a double balanced mixer is presented.

INTRODUCTION

Frequency translating devices, which range from simple mixers and frequency multipliers to whole communication payloads on satellites [1], are important components in several microwave applications. However, because such devices are highly non-linear and generally have multiple ports operating at different frequencies, their characterization cannot be performed in a conventional manner. Moreover, the presently available instrumentation for network analysis is almost entirely devoted to linear two-port devices under small signal excitation, e.g., commercial vector network analyzers (VNAs). The most common techniques for FTD measurements are based on the use of VNAs with *standard, or reference, FTD devices* [1-2]. The method used in [1] is limited in that it cannot provide absolute measurement for the phase and the amplitude of the port waves. Consequently, the accuracy of the measurements is directly dependent on how well the FTD standard used is characterized. In [2], the transmission response of the mixer under test is extracted by connecting it with a test mixer and measuring the response of the entire system for up to six different phase shift settings between the LO signals of the two mixers. While this method offers the advantage of providing the phase of the mixer response, it however requires access to the LO port of the mixer under test and cannot, therefore, characterize devices with internal local oscillators. In order to overcome this problem, [3] proposed a novel technique based on the use of the microwave transmission analyzer MTA with a modulation/demodulation scheme. The advantages of this technique are its capability to characterize the FTDs with inaccessible internal LOs and its non-dependence on reference or test mixers. However, it only measures the group delay, its accuracy is lower than that based on the VNA, and it cannot characterize the double side band (DSB) FTDs.

PROPOSED TECHNIQUE

In this paper we present a non-linear network analyzer suitable for characterizing FTDs. The system, shown in figure 1, is based on a high speed, a broadband sampling digital oscilloscope, the microwave transition analyzer (MTA HP 75100, operating over the range DC to 40 GHz) in our case. The source signals, RF and LO in the case of mixer, are routed to the various FTD's ports via a source switching network which allows for software control of port assignment. One of the two channels of the MTA receives the trigger signal of the source which is used for phase reference. This signal should be the largest common sub-harmonic of the LO and RF signals. The second channel receives, in turn, each of the incident and reflected waves sampled with three 10 dB bi-directional couplers and routed via a receiver switching network as shown. For non sinusoidal signal characterization, the DC components of the signals are measured separately via bias Tees. Although the bandwidth of the receiver covers up to 40 GHz, the overall system, receiver and test set, will be limited by the bandwidth of the couplers and switches used. In our application, couplers covering 1 MHz - 2 GHz are used.

During the data acquisition process, the MTA is used in the repetitive time domain sampling mode where up to 1024 samples can be obtained. The sampled data are Fourier transformed into the frequency domain for full vector calibration and de-embedding purposes, i.e., to transfer the measurements' reference plane from the input channel of the MTA to the plane of the DUT. The de-embedded and error-corrected data are then transformed back into the time domain to reconstruct the individual or superposed waveforms at the various FTD ports [4-5].

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The calibration procedure used is based on the approach described in [6] with the addition of an absolute power level calibration step which is necessary for absolute, i.e. not ratios, waveform and spectrum reconstruction. Figure 2 summarizes the various steps of this proposed approach.

EXPERIMENTAL RESULTS

A commercial mixer has been used to test the proposed approach. To characterize this devices, it is important to generate coherent LO and RF signals from a single source for accurate phase measurements. This has been achieved by using the lineup shown in the dashed box of figure 1 where f=200MHz serves as the trigger signal and as the input signal to the SRD frequency multiplier. The power splitter and Yig filters serve to select the LO and RF frequencies.

As a first validation test, the IF port of the mixer was measured in two different ways:(i) with setup as shown and (ii) with the spectrum analyzer. Figure 3 shows the good agreement obtained between both results. The spectra for the LO and RF signals, incident plus reflected, as measured by the system are shown if figure 4.a and 4.b and their corresponding waveforms are shown in figure 4.c. Note that the output signal at the IF port, figure 3, still contains a small contribution due to the LO and RF signals. To recover a clean IF signal, a low pass 400 MHz filter was placed at the output of the IF port. The new results, wich include the filter, are shown in figures (5.a-5.e). It should be noted that with the present system we can measure individual waves as illustrated by figures 5.a and 5.b for the IF port.

CONCLUSION

A new technique for the characterization of frequency-translating devices was developed. A test set was built and used to validate the proposed approach with a mixer. The main advantages of this approach are that i) no reference or standard FTD is required, ii) the method is applicable to both SSB and DSB FTDs, iii) the method includes a full vector error correction and absolute level measurements, iv) the system is not limited to harmonically related LO and RF signals and v) because we can measure individual waves, a comprehensive amplitude and phase characterization of the FTD can be performed, e.g., isolation, gain, conversion losses, group delay, port impedances and conversion matrix.

REFERENCES

[1] C. J. Clark, A. A. Moulthrop and al., «Transmission Response Measurement of Frequency Translating Devices» *1996 IEEE MTT-S International Microwave Symposium Digest, pp. 1285-1288, June 17-21 1996*

[2] HEWLETT PACKARD, «Microwave Component Measurements Amplitude & Phase Measurements of Frequency Translation Devices Using the HP 8510 Network Analyzer», Product Note 8510-7.

[3] HEWLETT PACKARD, «HP 71500A Microwave Transition Analyzer Group Delay Personality», Product Note 70820-10.

[4] J. Verspecht, P. Debie and al., «Accurate On Wafer Measurement of Phase and Amplitude of the Spectral Components of Incident and Scattered Voltage Waves at the Signal Ports of a Nonlinear Microwave Device,» *1995 IEEE MTT-S International Microwave Symposium Digest, Vol 3. pp. 1029-031, May 1995.*

[5] M. Sipila, K. Lehtinen and al., «High-Frequency Periodic Time-Domain Waveform Measurement System,» *IEEE Trans. Microwave Theory and Tech., Vol. 36, NO. 10, pp. 1397 1405, October 1988.*

[6] A. Ferrero, U. Pisani and K. Kerwin, «A New Implementation of Multiport Automatic Network Analyzer,» *IEEE Trans. Microwave Theory and Tech., Vol. 40, pp. 2078-2085, Nov. 1992.*

[7] IMTC'97 paper

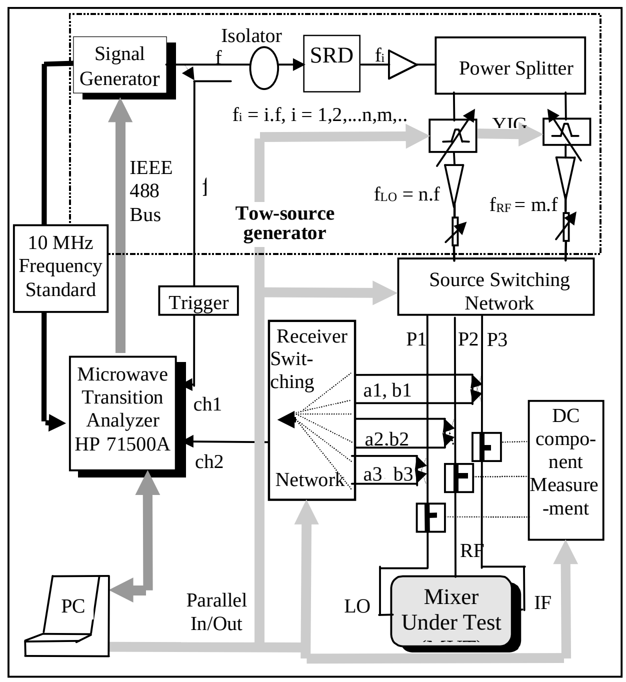


Figure 1: measurement setup configuration for mixer characterization

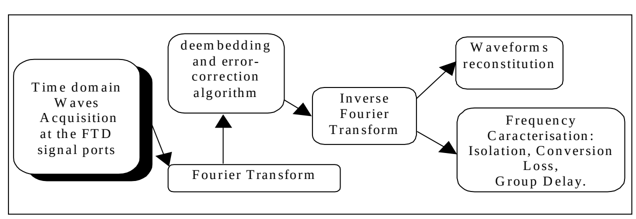


Figure 2: block diagram of the different steps in the characterization of FTDs.

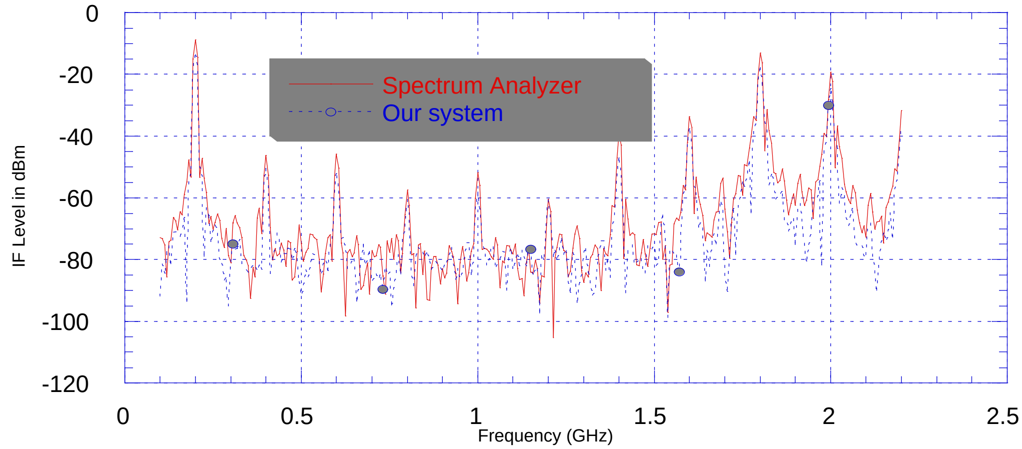
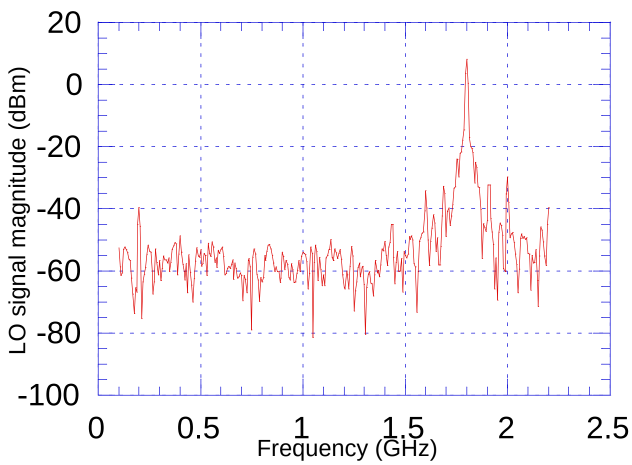
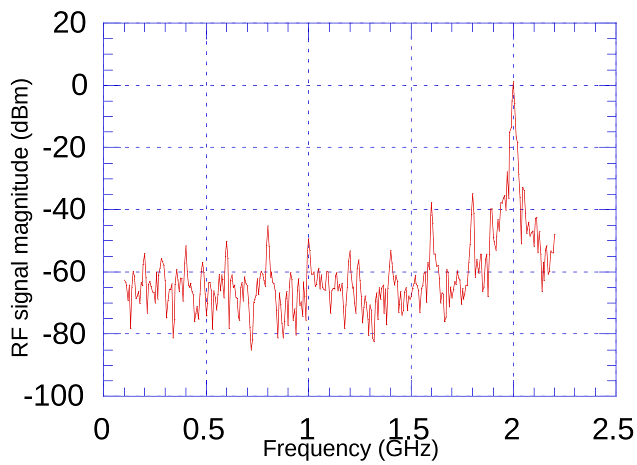


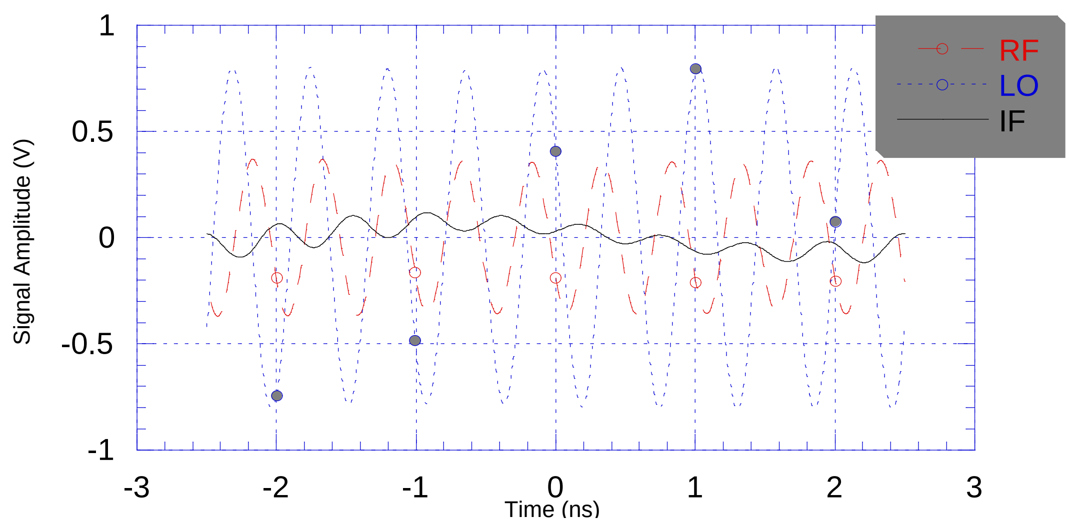
Figure 3: spectrum of the IF signal at the output of the mixer.



(a)



(b)



(c)

Figure 4: various signals at the ports of the mixer
(a) spectrum of LO signal, (b) spectrum of RF signal (c) RF, LO and IF waveforms.

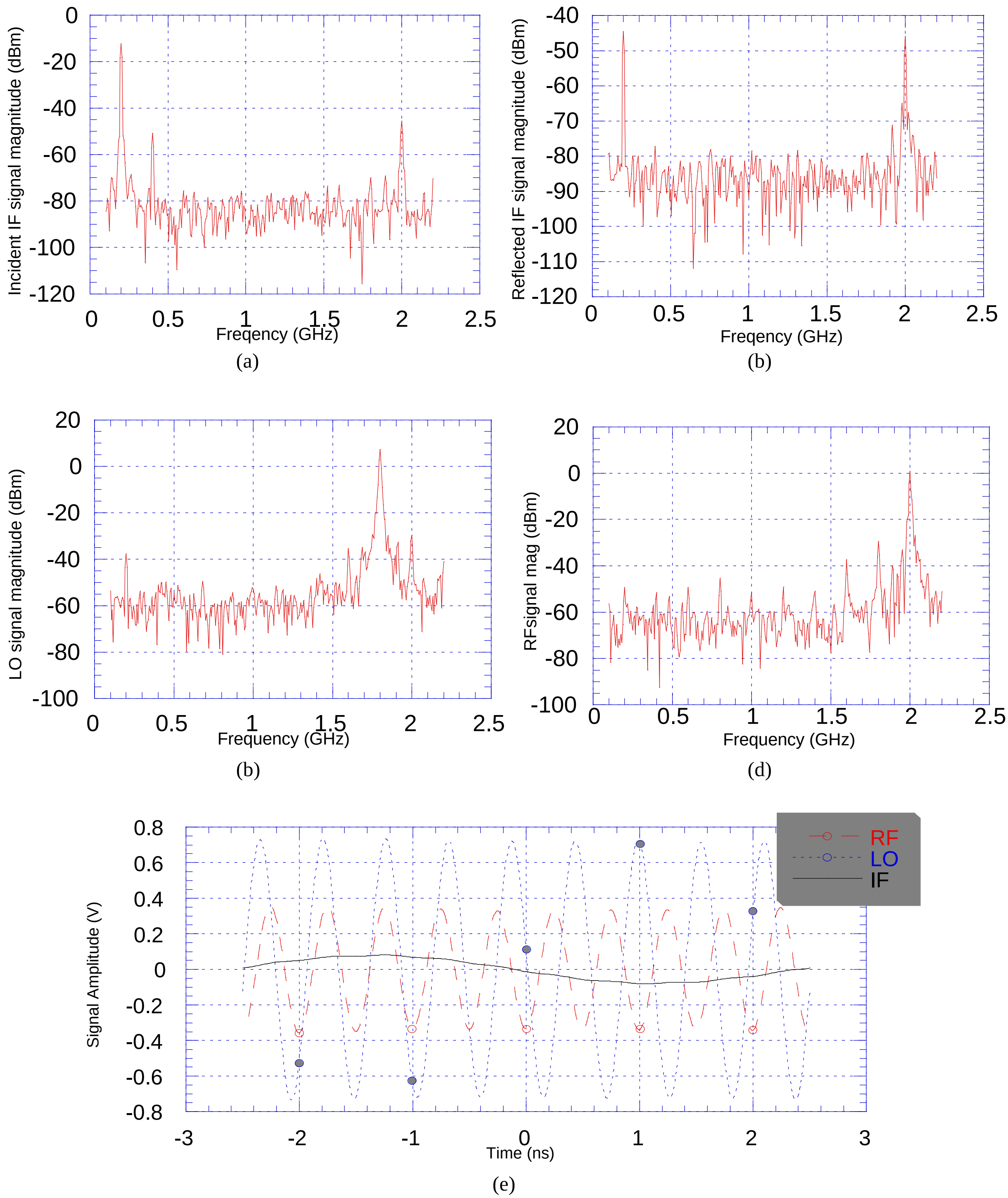


Figure 5: various signals at the ports of the mixer with a low pass filter at the IF port. (a) output IF wave spectrum, (b) reflected IF wave spectrum (c) spectrum of the LO signal (d) spectrum of the RF signal, (e) LO, RF and IF waveforms.