DESIGN AND FABRICATION OF AN RF ENERGY METER PART 2: DESIGN OF THE RF FRONT END

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Introduction

Although the microwave circuit design is a mature technology, design and fabrication of electronic circuits in the microwave frequency band (1.0-30 GHz) is a novelty in Sri Lanka. Designs in the microwave region differ from low frequency designs in many aspects. Firstly, the theoretical tools required to analyze circuits are different as the wave phenomena dominates in this region. The characterization of active devices takes a different form as microwave circuit analysis demands the use of scattering parameters. The measurement techniques take a totally different approach as correct data are to be extracted from measurements flooded with unwanted reflections and couplings. At present, this is done by using sophisticated test equipment such as network and spectrum analyzers. Finally, circuit fabrication needs special equipment as a high precision (better than 50 micron) is required.

The work presented in this paper focuses on the design and fabrication of the front end of an RF energy meter. This project is funded by the National Science Foundation (NSF), Sri Lanka. The same project includes the development of a wide-band antenna system and a fast data acquisition module. Developments in these parts are reported as separate abstracts in this proceeding.

The paper describes the methodology used for the design and key issues. All work covered in this extended abstract are new technical know-how and experiences from a Sri Lankan context. The principle objective of the paper is to share the new experience and technical know-how gathered in the design process.

Design of the RF front end

As with any design, the starting point is the design specifications to be satisfied. In this design, we try to meet the following specifications (Table 1).

Table 1. Design specifications

Parameter	Specifications
Frequency range	1-1300 MHz
Spurious free dynamic range	70 dB
Final I.F	1 MHz
I.F. Bandwidths (of the final stage)	500 kHz, 200 kHz, 30 kHz
Min detectable signal at 200 kHz of resolution bandwidth	-110 dBm

A super-heterodyne architecture is selected for the design to avoid stringent specifications of tunable

Table 2. Specifications of individual stages

	Stage 1	Stage 2	Stage 3	Stage 4
Gain/(dB)	14.6	3.4	2.7	2.7
Max.Noise Figure/(dB)	6.6	11.1	12.2	12.1
IP3 at input /(dBm)	21.2	19	26.4	26.4
L.O. frequency/ (MHz)	2300-3600	2229	60	10
I.F. Bandwidth / (MHz)	40	4	0.5	0.5, 0.3, or 0.03
I.F. Frequency / (MHz)	2300	71	11	1

bandpass filters and unwanted oscillations due to feed back from high gain stages (Carlson, 1988). The first step of the design process is converting the given specifications (see Table 1.1) to the specifications of each individual conversion stage. The minimum detectable signal (*MDS*) in dBm is linked to the noise figure, F (in dB) as shown in equation (1), (Chang, 2000)

$$MDS = -174 + F + 10\log B + SNR \tag{1}$$

where B is the noise bandwidth and SNR is the minimum detectable signal to noise ratio of the detector in dB. The spurious free dynamic range (DR_{sf}) is linked to the overall third order intercept point ($IP3$) and the MDS by equation (2), (Chang 2000).

$$DR_{sf} = \frac{2}{3}(IP3 - MDS) \tag{2}$$

Therefore, the required over all noise figure and $IP3$ can be calculated. The key specifications of a conversion stage are, the I.F frequency and bandwidth, the noise figure, gain, and the third-order intercept point ($IP3$). In this design, rather than using cascade formulas explicitly, we use *RF Workbench*, a freely available design package to avoid repetitive and tedious calculations. The design resulted in four stages and their specifications are shown in Table 2.

In obtaining the values in Table 2, we also considered several practical aspects. These include, limiting the gain of each individual stage to a maximum of 20 dB to limit potential oscillations and limiting noise figure, $IP3$, and the fractional bandwidth of each I.F. filter to practically achievable values. Apart from these, there are many other considerations we do not wish to elaborate here in order to limit the length of this article. However, we describe few design issues related to the design of the 1st stage as it is the most crucial in the whole design.

Issues in the first stage

The frequency band we want to measure is from almost d.c. to 1300 MHz. A down conversion in the first stage leads to many complications such as the possible leakages from RF to IF. We avoid all these problems by up-converting to 2300 MHz. Out of the two resulting mixer components, we select the difference component, $(f_{LO} - f_{RF})$. This particular selection has many advantages. Firstly, the

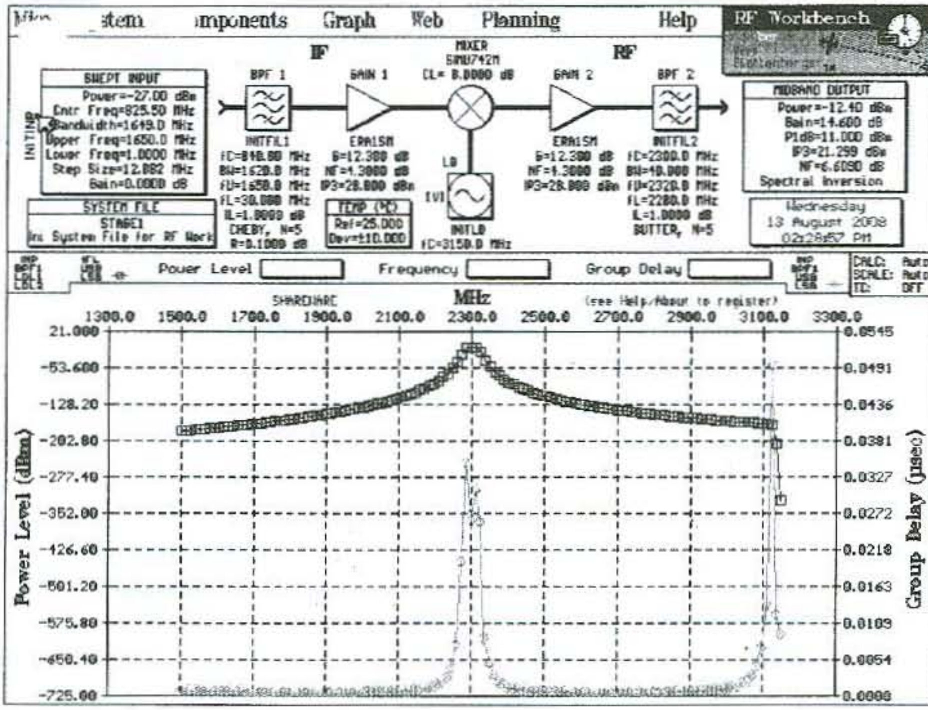

Figure 1. Schematic diagram of the first conversion stage and simulated results

image is well separated from the input R.F. signal making image suppression an easy task. Secondly, there are no in-band spurious components due to the LO which would have been hard to suppress. This selection also has the additional advantage of using the LO leakage to the IF as a marker to calibrate the d.c frequency. This is similar to the d.c. marker signal in most commercial spectrum analyzers.

Design methodology

The schematic diagram of the 1st conversion stage is shown in Figure 2. Although we use *RF Workbench* for system planning, all system simulations were done using the high-end package, Ansoft Designer V3.5. This is because Ansoft Designer simulations are more accurate as measured S-parameter and mixer spur table data can be included. In addition, Ansoft Designer can directly generate layouts from the schematic diagrams. In this simulation, we used measured S-parameter data and spur-table data published by the manufacturers. The simulation of all microstrip filters was done using Ansoft HFSS 10.1 structure simulator to exploit the high precision of finite element based electromagnetic field solvers.

Results

Figure 1 shows how the 1st conversion stage tunes to pick an 850 MHz signal with the selection of components.

References

Carlson, A.B. (1988). Communication Systems. McGraw-Hill.

Chang K. (2000). RF and Microwave Wireless Systems.