DESIGN AND FABRICATION OF AN RF ENERGY METER PART 1: SIGNAL ACQUISITION AND ENERGY ESTIMATION

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Introduction

Most mobile and wireless communication systems utilize various frequency bands in the UHF region ranging from approximately 0.3 – 3GHz. For example, the ISM band at 2.4GHz is used for Industrial, Scientific and Medical applications and is unlicensed. Next most popular is the 800-900MHz frequency band used by most digital mobile systems, (Frederic, 2007). In any case, one of the major problems is measuring the received signal strength (RSS) of various sub frequencies. The RSS should be high enough within the cell and the cell edge strength should be according to the specifications. If the cell edge strength is too high, the adjacent channel and co-channel interference degrades the signals in surrounding cells. In addition, excessive RF power may cause health hazards. However, very low power levels may limit the functionality of mobile and wireless equipment.

This paper describes the system design issues of an RF energy meter which is to be light weight, low cost and fabricated mainly in Sri Lanka. The initial prototype constructed for the 300 – 1300MHz spectrum, will consist of three main modules, a fast data acquisition module, a microwave down converter and a precision light weight wide band antenna. The description of the second (Part 2) and third (Part 3) modules are included as separate extended abstracts under the same title in these proceedings.

Methodology

The RF signal must be down converted to a convenient working frequency for A/D conversion and acquisition in a computer. A frequency of 1MHz was selected for this purpose for two main reasons. The first is that it should be low enough so that sample acquisition will be possible using a circuit based on an available USB microcontroller, (PIC18F4550, 2004). If the sampling rate is in the order of 1Ms/s, the design and fabrication of acquisition circuits pose significant challenges making it costly and complex. Secondly, the working frequency should be as high as possible such that wideband signals can be measured. The selected 1MHz frequency has a maximum signal bandwidth of 2MHz permitting to evaluate all narrowband 2G mobile signals and 1.25MHz 3G W-CDMA signals.

In this way, the energy and power can be evaluated by mathematical processing of sample values after acquiring them into the computer. However, there are a number of more parameters which need to be considered.

i) Minimum sampling rate for the purpose of power measurement: This is found to be at least four times the frequency of a sinusoid.

ii) Signal bandwidth and frequency range: This determines the sampling rate and the A/D converter specifications. For example, for a signal with 200kHz bandwidth, the sampling rate > 4.4 MS/s, i.e. (1MHz + 200kHz/2)×4.

iii) Dynamic range, number of bits per sample and the bit rate: To cover a 2.56v dynamic range with a 10mv accuracy 8bits/sample is required ($2.56v/2^8$levels= 10mv), which sets a data rate of 35.2Mbps (4.4MS/s×8).

iv) Interfacing hardware for the computer: The USB interface of the microcontroller (PIC18F4550, 2004), supports a maximum data rate of 12Mbps. Therefore, this necessitates using some form of delta modulation, (Ciarcia, 2002), to reduce the original bit rate for real time streaming of data. Otherwise, store and forward interfacing where some signal samples are stored in the microcontroller and fed to the computer at a lower rate, can be used for this purpose. However, the signal can be observed only intermittently with this approach.

N-bit delta modulation with fractional differences (DMFD)

An approach to improve normal 1-bit delta modulation is to increase the number of bits/sample which carries the fractional differences of the previous and current samples. If the number of possible fractions is L, encoding requires N bits per sample where $N = \text{Log}_2(L)$. However, depending on the power spectrum, even over a bandwidth of 200kHz, a large number of fractions can yield making N too high to be beneficial. If some of the fractions are very common, N can be made low by neglecting those fractions which occur infrequently. In this way, continuous streaming of data samples to the computer becomes possible. This kind of a simple approach, compared to more efficient delta-sigma modulation, (Feldman et al., 1998), has been taken because such algorithms cannot be realized with devices having limited memory and speed.

Simulations

For example, the composite signal in Fig. 1 was formed by adding 8 nearby frequencies to the 1MHz centre frequency, over a bandwidth of 200kHz. Once this composite signal was sampled at 4MHz (90.9% under-sampling), there were a large number of different fractions as in Fig. 2 but most of them were either very similar or occurred rarely. Those fractions which are very frequent compared to the rest are about eight for this test signal making N = 3. This reduces the bit rate to 12Mbps which is the maximum rate possible with the PIC18F4550.

Results

Fig. 3 illustrates the accuracy of signal reconstruction and power estimation once the signal samples are encoded and decoded using all possible fractions (N-DMFD). Note that the power has been estimated as $\frac{1}{n}\sum_{i=1}^{n} x_i$ where x_i is the i^{th} sample and n is a reasonably large integer. There is almost no discrepancy in signal tracking and power estimation in this case. However, using a set of most common 8 fractions and then 3-bit encoding per sample (3-DMFD), a reasonably good approximation can be made to the test signal as illustrated in Fig. 4. The discrepancy here is both due to under-sampling and limiting fractional differences.

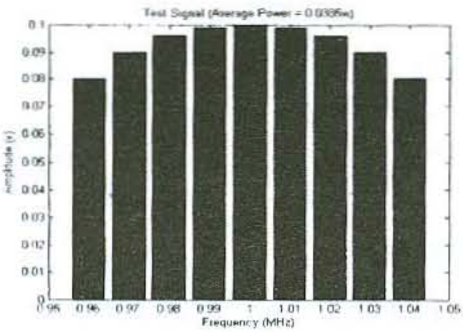

Figure 1. Composite signal

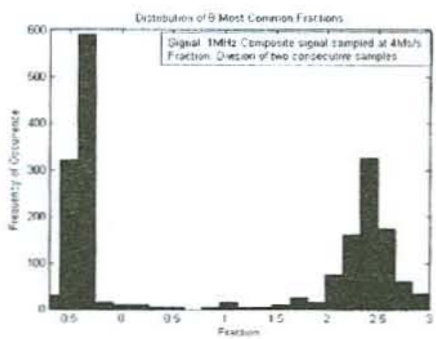

Figure 2. Common fractions

Conclusions

The illustrated example considers a signal with very steep changes in the time domain envelope every 0.1ms. Three-bit DMFD can reconstruct even this signal with a reasonable degree of accuracy implying that it would be very accurate for a signal with smoother fluctuations. If DMFD fails to track the original signal after some time, as evident from Fig 4.2, a reference sample can be included in the data stream regularly. This permits the demodulator to resynchronize with the original signal. The DMFD, which consumes less program memory, is simple enough to implement and suits for high rate applications.

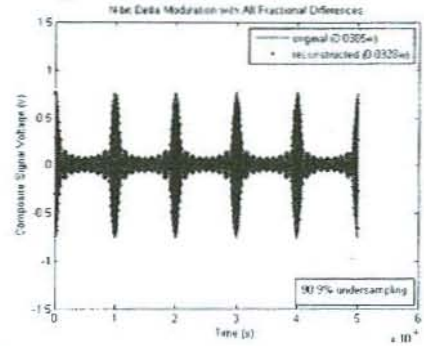

Figure 3. Ideal DMFD

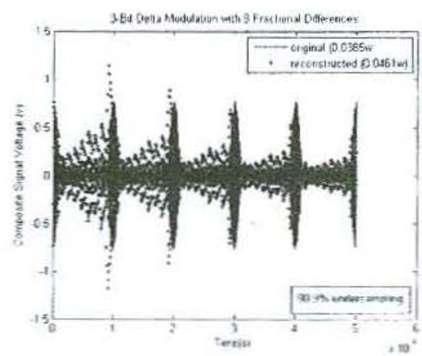

Figure 4. Three-bit DMFD

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