MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

October 20, 2005

Telephone: 781-981-5407
Fax: 781-981-0590

To: RFI Group

From: Alan E.E. Rogers

Subject: Wideband spectrum measurements

In the future I expect spectrum analyzers will consist of an ADC followed by FPGA spectrometer. In this case the dynamic range is limited by the ADC. ADC's have non linearities in the analog section which lead to intermodulation products and a finite number of bits which lead to quantization noise. Both of these deficiencies can be ameliorated by adding noise following the low noise preamplifier and taking the difference between a "signal" spectrum with the switch in front of the preamplifier connected to the antenna and a "comparison" spectrum with the switch in front of the preamplifier connected to a load. The dynamic range is extended by keeping the total signal to the ADC just below the maximum level so that the signal from the antenna is a small fraction of the total signal.

In the case of intermodulation the dynamic range in dB is given by

$$DR2 = \left(IIP2 - Nref + Gincoh \right)/2$$
$$DR3 = \left(IIP3 - Nref + Gincoh \right)2/3$$

where   IP2, IIP3 are the input intercept point of ADC with input noise Nref

Gincoh = averaging gain $= 5\log_{10}\left(bT\right) - 6$

In the case of quantization noise the optimum dynamic range is obtained when the added noise is about 10 dB above the quantization so that the dynamic range dB is given by

$$DR \approx -10 + 6\left(N-1\right) + 10\log_{10}\left(B/b\right) + Gincoh$$

where   N = the number of bits in the total signal

B/b = ratio of bandwidth to resolution

$G_{incoh} = 5\log_{10}\left(bT\right) - 6$

For $G_{incoh} = 14dB$ and $(B/b) = 30dB$ the following were the results from a simulation

# of bits	measured DR dB	Calculated DR dB
1	30	34
2	40	40
3	50	46
4	55	52
5	60	58
6	65	64

The formula suggests that a digital spectrum analyzer using an 8-bit ADC at 3 Gs/s sample rate to analyze 1500 MHz of bandwidth with 1 MHz resolution could achieve a dynamic range of 98 dB in 100 seconds assuming 100% spectral efficiency.