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Comb Generator for Measurement Receiver Test

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Abstract – **Quick testing of measurement receiver needs rich frequency spectrum signals, with each component known frequency and level. This can be done with comb generators having outputs in equal frequencies distances. They work using very sharp - and consequently very wide spectrum - pulses, distance between two harmonics being equal with repetition - or clock - rate of impulses.**

This paper shows the performances of a portable comb generator working on this principle, used in verifying measurement receivers in 30MHz-2GHz areas, as well as experimentally obtained results.

1. INTRODUCTION

In the last years EMC extends its applicability area, leading to new standards and due these to new measurements requirements. Also EMC used equipments were modified in terms of performance and construction principle.

After their use, EMC equipments can be: measurement equipments (which are usually measuring the level of perturbations) and test equipments. First category means for instance *measuring receivers*, and the second consists of generators simulating all kinds of perturbations. This means generators like ESD (electrostatic discharge), burst generators or burst generators. Recently, new kinds of generators are appearing answering to standard's requests but allowing also checking of some specific measurement equipments.

Such a generator is the *comb* type, which generates a wide spectrum of equally distanced harmonics, so the output spectrums looks like the teethes of a comb - and here from derives the name.

Comb generators are used in wideband applications where lots of spectral components - correlated with a low frequency signal - are required. Having in mind their wide area of frequency and the fact that the level of harmonics is known, comb generators are being used more and more in EMC, especially in immunity precompliance tests. On the other side, they are usually portable and that makes them very useful in case of inter-site measurements comparison.

Advantages of comb generators can be itemized like this:

- They can be calibrated referring to known standards;
- They work from a few kHz to tens of GHz;
- Low influence of existing interferences in the measuring site;
- High immunity to other perturbations;
- Can generate conducted or radiated interferences;
- Lightweight, portable tools.

2. OPERATION PRINCIPLES

Comb generators are made either starting from a very short - very low width ratio -pulse, either with pronounced unlinear characteristics circuits. Originating pulse can be ready generated by a included pulse generator or shaped from a sine wave, which can come also from outside.

The comb spectrum is theoretically obtained from a scaled version of periodic Dirac distribution (see fig.1) of type:

$$\delta_T(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT) \qquad (1)$$

"*A*" value from figure 1 is not the impulse amplitude, but its area. It can be shown that the Fourier transform of Dirac distribution has a similar look:

$$F\{A\delta_T(t)\} = A\Omega\delta_\Omega(\omega) = A\Omega \sum_{k=-\infty}^{\infty} \delta(\omega - k\Omega), \qquad (2)$$

where $\Omega = 2\pi/T$.

Comb spectrum is shown in figure (2).

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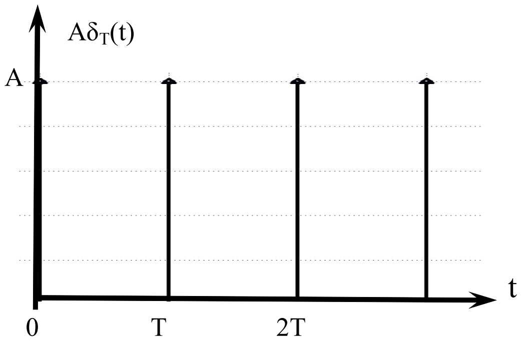

Fig. 1. Dirac periodic distribution.

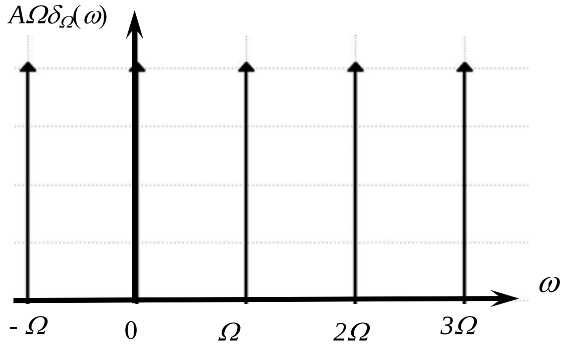

Fig. 2. Fourier transform of a Dirac periodic pulse.

Obviously in practice we can't generate a Dirac pulse, which remains only of theoretical value, and thus we cannot obtain a comb spectrum. But it can be generated a small width factor rectangular signal with finite amplitude, as shown in fig.3.

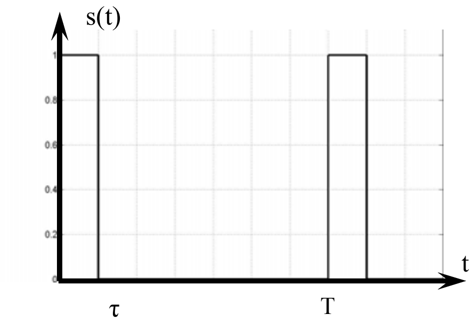

Fig. 3. Rectangular signal with width factor of 1/7.

Developing its exponential Fourier series we get:

$$x(t) = \sum_{k=-\infty}^{\infty} a_k \exp(jk\Omega t), \qquad \Omega = \frac{2\pi}{T} \tag{3}$$

where:

$$a_k = \frac{A\tau}{T} \frac{\sin\frac{k\Omega\tau}{2}}{\frac{k\Omega\tau}{2}} \exp(-j\frac{k\Omega\tau}{2}) \tag{4}$$

For graphical representation of spectrum we will use the harmonic form of associate Fourier series:

$$x(t) = c_0 + \sum_{k=1}^{\infty} c_k \cos(k\Omega t + \varphi_k) \tag{5}$$

The connection between identities (3) and (5) is:

$$\begin{aligned} &c_0 = a_0, \\ &|c_k| = 2|a_k|, k \geq 1 \quad \text{And} \\ &\varphi_k = \arg(a_k) \end{aligned} \tag{6}$$

where c_k are the coefficients of harmonic Fourier series.

The representation of the coefficients of the harmonic Fourier as a function of frequency is shown in fig.4. The continuous component c_0, was not represented, being useful in this case.

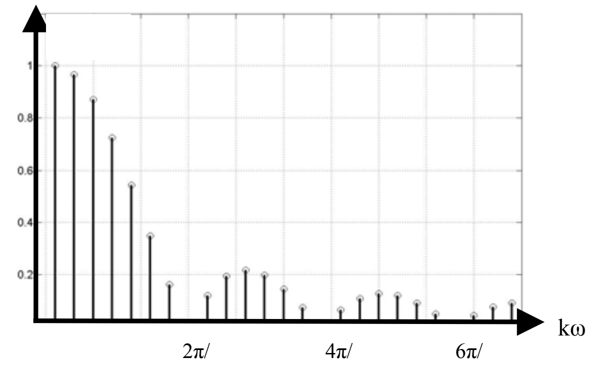

Fig. 4. Frequency spectrum of the signal

We can see that the spectrum contains harmonic components positioned at integer multiples of fundamental frequency and the spectrum is having more lobes which are zero at integer multiples of π/τ.

In order to obtain a closer signal to the comb spectrum we will use a part of the first lobe. In conclusion, in order to have more harmonics in the first lobe, it is necessary for the pulse train to have a big period *T*. On the other side, in order to have a wide bandwidth, τ has to be as short as possible or the width factor τ/T to be as short as possible. If the amplitude of pulses will remain constant, the energy of a pulse will be lower by lowering the width factor and thus a low width factor will impose high amplitude of pulses; this is increasing design complexity.

The frequency bandwidth of a comb signal is selected by an application that imposes a maximum delta between the amplitude of useful harmonics of the first lobe. Usually are accepted the harmonics bigger than $1/\sqrt{2}$ of the maximum of the main lobe envelope. The equation $(\sin x)/x = 1/\sqrt{2}$ is having the root $x_0 = 1{,}3916$. The bandwidth will be then between 0 and $x_0/\pi\tau$.

3. OPERATION OF THE GENERATOR

The block schematic is shown in fig.5. It contains the power source SA that from portability reasons it is a battery. Since the battery voltage is not constant in time, there is a level detector DN that supervises that the voltage is in safe range - and that means that the comb it is in its intended parameters.

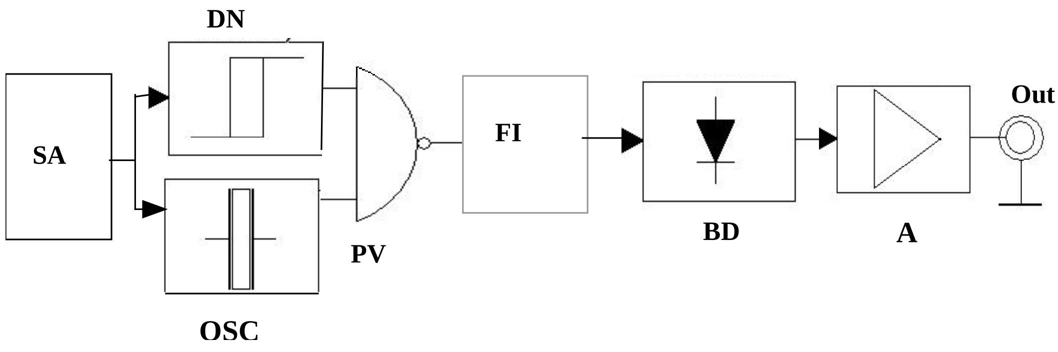

Fig. 5. Bloc schematic of a comb generator

As long as the battery voltage is not decreasing under a certain level (approx. 6V) DN is driving the validating gate PV with a logical "1" and the signal generated by the quartz oscillator OSC is passing further to the other blocks.

The pulse shaper FI is making a short pulse, rich in harmonics. Further more, the distortion block BD is taking the harmonics of the pulse to the maximum of BFR96 capabilities. Resulting signal is amplified by the amplifier A and delivered to the output.

The electrical schematic is given in fig.6. The oscillator is realized with IC1A and IC2A gates of a F-series 7400 driven by Q1 20MHy quartz. The oscillator gives signal into IC1C gate, which is the validating gate. The validating signal is coming from the battery level control block. There is a 7805 IC that stabilizes the supply voltage of comb generator. The level detector is an Schmitt trigger made of T1 and T2 transistors. When battery voltage falls beyond 6.5 V it is locking the validating gate. The state of generator is signaled with two LEDS: LED1 on - means enough voltage; LED2 on means - not enough voltage and blocked output. The oscillator gives basically a 1/2 width factor. The oscillator establishes the step of the harmonic components of the spectrum. This signal it is not good enough for our application so it needs more harmonics. We will form a short pulse using the gates IC1C and IC1D. This block's operating principle is based on logic gate delay. The signal $s_1(t)$ is going into the gate IC1C which outputs $s_2(t)$. $s_2(t)$ is going to one of IC1D inputs, $s_1(t)$ being at the other input. Here comes an $s_3(t)$ very short pulse with ns fronts. Further on, there is the distortion circuit of BFR96 with a RF diode. This stage is working in nonlinear area like a derivation. The diode is getting out faster the transistor from saturation. Last stage is also a BFR96. It is biased with R3 and amplifies the signal since the output power of the distortion stage is relatively small. The transistor is used to the maximum extent of its frequency bandwidth. (Cutoff frequency is about 5GHz). Its gain is about 10-15 dB, but the linearity is strong affected upon 2GHz.

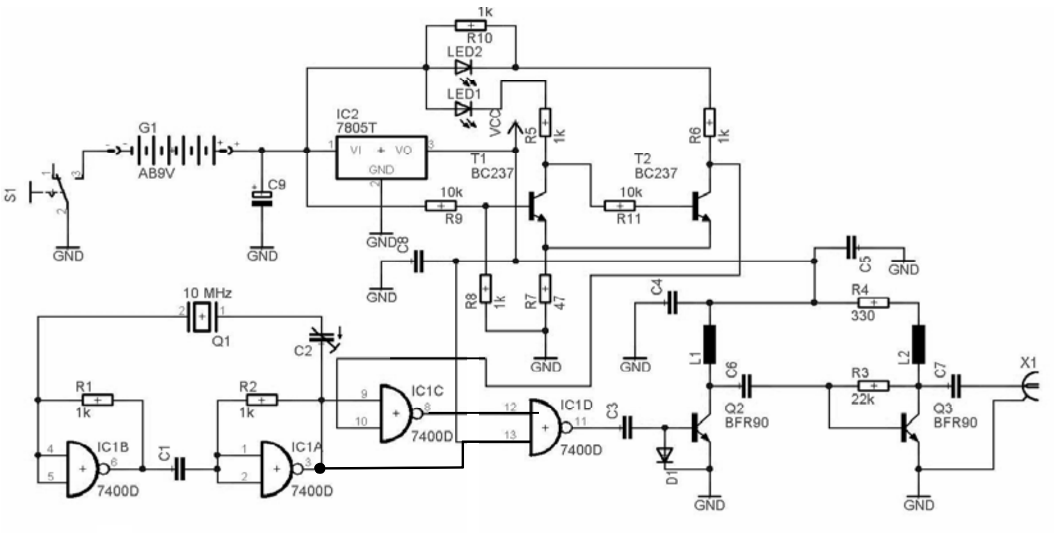

Fig. 6. Electrical schematic of a comb generator

4. EXPERIMENTAL RESULTS

Here are the measurements made for this comb generator. There were used a spectrum analyzer Agilent E4406 VSA (F_{max}=2,7 GHz) and a digital oscilloscope TDS3502 (with F_{max} = 500 MHz, 5 Gs/s, was having an inferior bandwidth than our application since the useful spectrum shows usable harmonics over 2.5 GHz - at 2.5 GHz, there is 1 mV amplitude harmonic!).

Fig.7 shows the wave shape of the obtained pulse at generator's output and also its Fourier spectrum made in Matlab. We can see a parasitical oscillation of obtained pulse on its negative crest. This happens due to the oscillating LC equivalent circuit that appears when Q2 is blocked.

The oscilloscope bandwidth spectrum is inferior to the one obtained from the spectrum analyzer due to the limited bandwidth of oscilloscope (Fig.8).

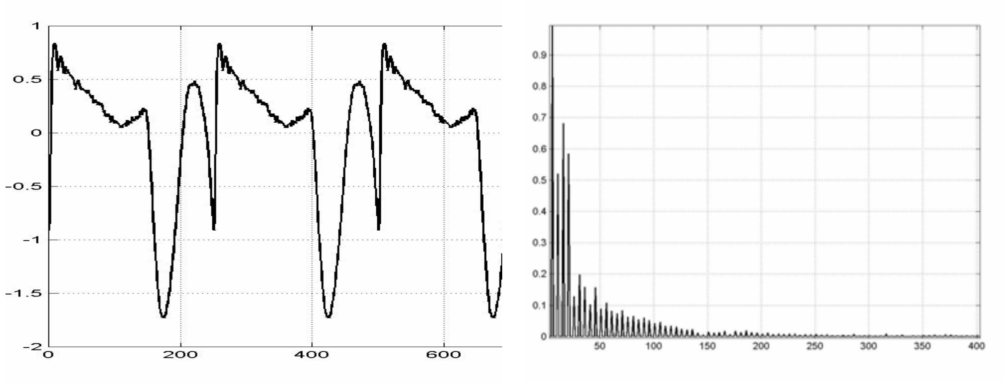

Fig. 7.The pulse obtains at the output of the generatorului and his spectrum.

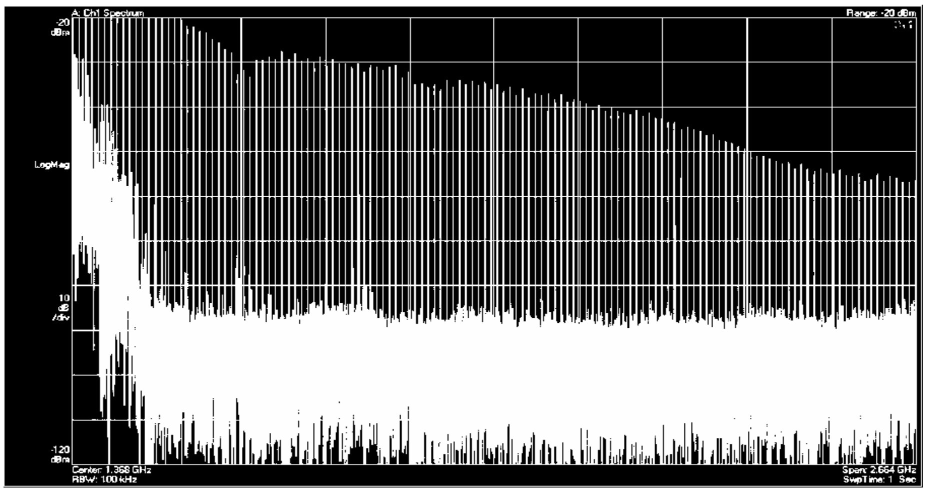

Fig. 8. The measured spectrum by the spectrum analysor Agilent E4406 VSA

The conclusion is that the comb generator is producing a complex signal that has a rich spectrum of equally distanced harmonics of 20 MHz and it goes until 2GHz with useful values. The levels of spectral components in low frequency are about 0dBm (appreciatively 0,2 V), and it goes down to -26 dBm (about 1 mV), at 2 GHz (100 harmonic component).

The comb was made under contract INFRAS nr. 247/2004.

Bibliography

[1] C. Diller, Create short pulses with a function generator, Test & Measurement World, 2/1/2001

[2] A. Ignea, Introducere în compatibilitatea electromagnetic, Ed. de Vest, Timişoara, 1999

[3] ***, Pulse generator calibrates CISPR14 click analyzer, New Product information from Schaffner EMC, 4 October 2001

[4] H. G. Skinner, Tiny Comb Generator Emitter Enables Earlier Emissions Testing, Developer UPDATE Magazine Intel, December 2002

[5] ***, Harmonics and Flicker Generator HFG01, York EMC Services Ltd, http://www.yorkemc.co.uk [6] ***, COMB GENERATOR - Radiated Emissions Reference Source,RN Electronics

[7] ***, 2-18 GHz, Comb Generator, www.nardamicrowave.com

[8] ***, Model 5660 Comb Generator Module, www.picosecond.com

[9] ***, High Performance Comb Generator Multipliers, MICROWAVE JOURNAL, April 2003.