Analysis of Wide Band Unknown Microwave Signals Detected by One Antenna

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Abstract – **Acquisition of multi-channel signal where each channel consists a piece of arrived information could be complex operation, if it is considered wide band microwave signals, especially if one of the crucial information is level of arrived signal. First, at all, matching impedance between antenna and detector for a wide frequency band could not be same for all frequencies. Another possible troubleshooting point is transition between analog and digital domain and at end validation of arrived data. This paper should present, at particularly example, how some physical imperfections could be furbish by digital domain with software. Results of this analysis could be used in nuclear, radar, sonar, and medicine application, since all noted applications are dealing with unknown signals and demands hard real-time processing.**

Keywords – **Signal acquisition, Digital Signal Processing, Wide band receiver.**

I. INTRODUCTION

Today, many systems are basing on multi-channel [1], [2] acquisition. Some of them use multichannel acquisition for frequency hopping that allows low signal level detect ability, interference rejection, anti-eavesdrop protection, code division multiplexing and high-resolution ranging, some for one or more process parallelization, some for smart systems that are hoping from channel to channel with lowest noise or interference, and etc.

Let us simplify and consider some system that only acquires signal form the one antenna at the only one channel. That system could provide some data information. Note that for interpreting those information system need some "key" for rightly decoding but we consider unknown signals. There are more information that could be estimate from detected signal such as level and operating frequency. It should be note that frequency information in this system is discrete value and depends on channel wide. For more prescient frequency calculation, this channel should be narrow. At hardware level channel wide is represent with band pass filters that could not be narrow if area of interest is very high frequencies. Now, consider system that is equipped with acquired signal tracking device. In this case, there is one more information that could be detected and that is signal shape in time domain. This information is very powerful, since it can give some answers, like is it some data signal or some triggers or some pulse signal or something else. Furthermore, useful information will be parameters of that signal in both cases – parameters of base signal or parameters of modulation of data signal.

That was simplified version, since that was description of mono-channel system. Multi-channel has same characteristic with one little difference – arrived signal is disperse on several channels. In hardware domain that required a lot of memory and processing power. Now, put in fire wide band of high frequencies with many channels, for more precise frequency resolution, and only one antenna to obtain that band, made analog domain very complex and in real systems very harmful. Wide temperature stability, small size and low coast are the biggest enemy of such systems. Second two input fix degrade characteristic in system but first one not and required software correction.

Is it unique correction in system? Certainly not, since analog to digital converters has non-linear characteristic. On other side, matching impedance between any analog scopes is not same for all frequencies. At least, antenna could be specific problem. Antennas with a narrow beam of radiation should not been big problem, but antennas with wide beam of radiation need some software correction. Both have same problems with reflections. From this perspective, there are many corrections, what imposed main questions: is there sense to make them, could this system be robust and could it works at all? There are questions and let see some answers.

II. ANALYSIS OF BACKGROUND HARDWARE

For purpose of analysis, was build a hardware platform prototype that provides wide band, multi-channel microwave signals processing. Mainly, it consists of three different blocks: antenna, detector and digital signal processing unit.

The task is wide band signals observation and analysis. Horn antenna [3] that covers wide frequencies band, form 8GHz up to 12GHz is shown on Fig. 1.. Main characteristic of horn antenna is wide beam of radiation. Chosen horn antenna has maximal gain 8.5dB. Corresponding to 3dB beam wide [4], as a standard for antennas, beam limits of considered antenna are ±60º (antenna beam wide is 120º). Mostly, in microwave applications antennas dimensions dictates dimensions of whole devices (antennas are the biggest parts of

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devices). That occasion, dimensions [4] of this horn antenna are small 48mm x 38mm x 35mm.

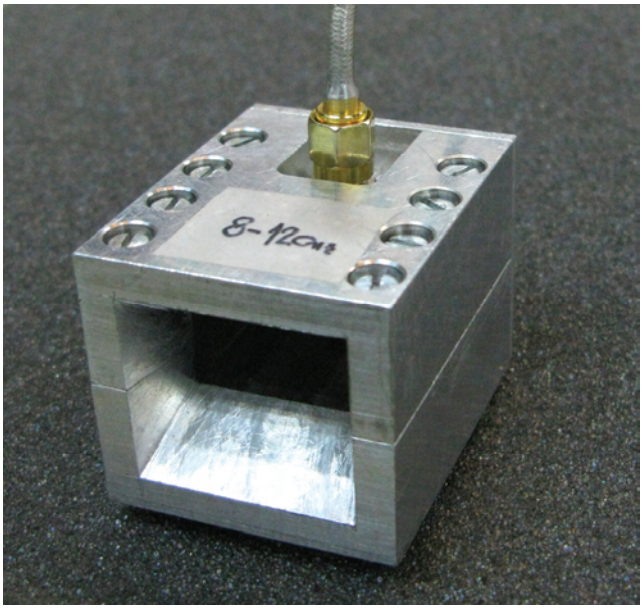

Fig. 1. Small size, wide band, high frequency horn antenna

Theoretical diagram of radiation, obtain by simulation, represented with blue line and measured diagram of radiation represented with red line are shown on Fig. 2..

As it was suppose, measured diagram of radiation has same shape as theoretical, but somewhere with smaller and somewhere with bigger deviation.

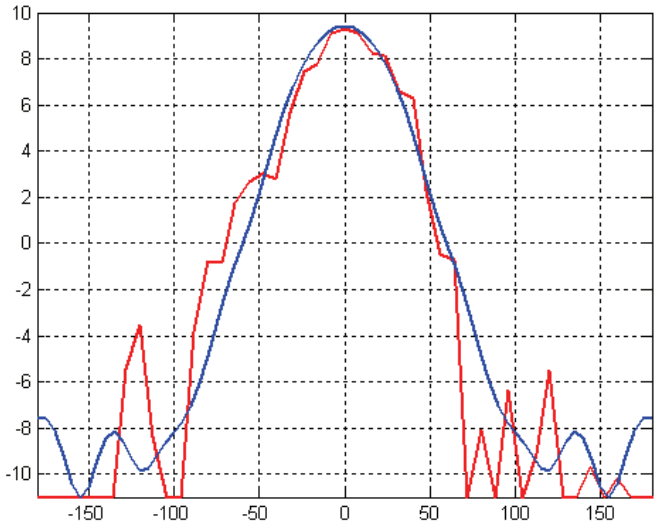

Fig. 2. Theoretical and measured diagrams of radiation

Theoretical and measured diagrams have been shown for 10 GHz frequency of source radiation and they are not same for all operating frequencies of antenna. There are two parents of this anomaly: (1) it is impossible to create wide band antenna with same diagram of radiation for all frequencies, (2) more problems are cause by matching impedance between antenna and detector microwave board. Both problems are physical nature and digital processing unit must deal with them. Fig.3. represent network analyzed horn antenna gain.

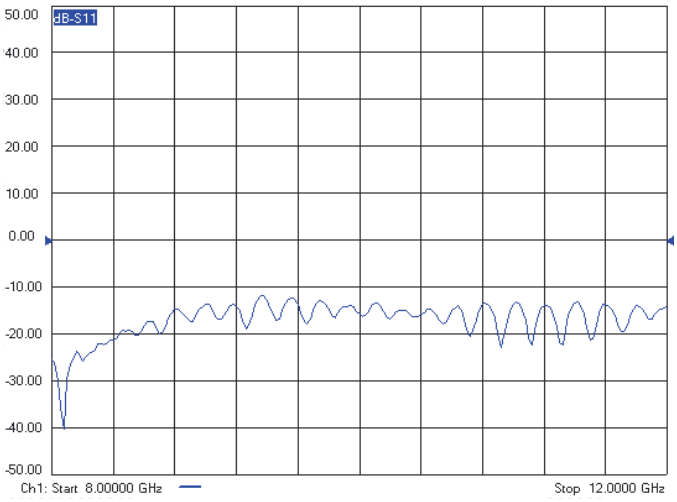

Fig. 3. Network analyzed horn antenna gain

Microwave board with signal detector block in this case is basing on AD8317 chip [5] as it is shown on Fig. 4.. That is wide band chip and operates from 1GHz up to 10GHz, and could detect signals slower then 25ns. Since this detector could not cover complete antenna band, mixer down converted input signal to the band from 1GHz to 4GHz.

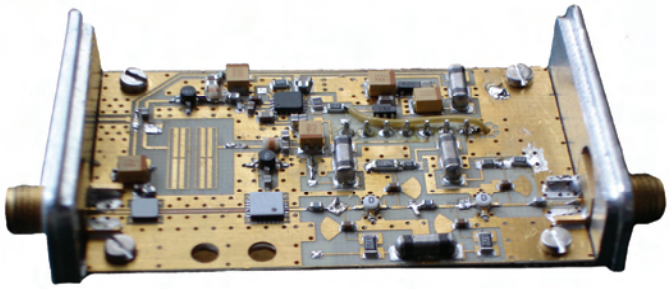

Fig.4. Logarithmic Detector

Note that this describes hardware could obtain only mono-channel processing. Main question is how and could it been modified to afford multi-channel processing? Fortunately, there is solution with using switching synthesizer. Idea is in hopping from channel to channel at some scheme and collecting data. Simplify scheme is hopping to the next channel until the last one is reached and then return to the first one. Little be more complicated scheme would be hopping to channel with lowest noise.

This method collecting data do not capture data exactly at the same time from all channels. This little disadvantage could not be eliminated but could be decrease speeding up switching. On the other side, speeding up has physical limits shown in synthesizer PLL set up time. Today, there are very speed PLL-s and set up time could be around 1μs. Full solution to avoid quasi-parallelization is independent detectors for all channels. This solution is certainly better in electrical sense, but size and price of system are pretty much bigger.

Central part of digital signal processing unit [6] is digital signal processor TMS320F2809 [7] as it shown on Fig.5..

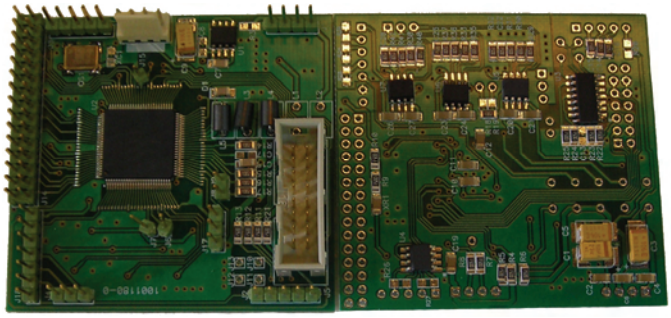

Fig. 5. Digital processing unit

Signal detector hardware allows very high-speed signals detecting that must be capture by interface, corrections of many physical imperfections demands a lot of memory, so DSP is a natural solution for this hardware. Digital signal processing unit has many tasks:

1) Processing digital data information.
2) Synthesis control.
3) Correcting physical imperfection of system.
4) Communication.

Last task is not crucial for determining right signal processing task, but is important for advance system applications.

Synthesis control is proceeding simultaneously with collecting and processing arrived signal data - DSP triggered synthesis to hop on next channel, then read data and at the end process received data.

III. ARRIVED SIGNALS ANALYSIS

Hardware described in pervious section can obtain, with more or less accuracy, next information about arrived signal and radio silence:

1) Observing radio silence (covered band 8-12GHz).
2) Signals frequencies.
3) Each signal power level.
4) Signal shape in time domain.
5) Parameters of signal shape in time domain.

The first level of analysis is continuous process observing radio silence. Breaking radio silence may be caused by one or more signals. Information about breaking radio silence has been triggering unknown signal/signals processing.

Next level is getting number of signal that break radio silence, identifying frequencies and power level of arriving signal or signals. From the moment of trigger, until trigger disappears this level should be pursuing. Hopping from frequency to frequency obtain covering antenna band, but it is not its only purpose. Hopping, also, gives information about arrived signal frequency. That information is not exactly, since it is discrete. That roughly information about frequency is determined by channel filter bandwidth and in this hardware, it is 100MHz.

Third level of signal/signals analysis is determining signal/signals type. This area of analysis has many possibilities and many unknown variables. Arrived signal could be modulated signal, pulse signal, continues wave signal etc. Further, today data signal frequently comes with analog, digital, base band or pulse modulation.

From this perspective, base band signals (modulated or not) could be threat as same thing and in addition base band modulated signals could be demodulated. How to distinguish is arrived signal modulated or not? Unfortunately, if arrived signal is totally unknown there is no way to be sure 100%, but always left solution to start search for some characteristic signals parts. This search needs a lot of time and processor memory and in lot of cases could not be processing in real time. For this case, communication part of digital processing unit, describe in pervious section, may send arrived data for further analysis to specialized non real time hardware and continue with other real time tasks. Sometimes exists some expectations about arrived signal and in those cases, decoding could be obtained by real time.

Digital modulations PSK, ASK and FSK, are often generated and detected using the principle of QAM and required deeper analyze. The I and Q signals are combining into a complex-valued signal I+jQ, where *j* is the imaginary unit. The resulting so-called equivalent low-pass signal or equivalent baseband signal is a complex-valued representation of the real-valued modulated physical signal, the so-called pass-band signal or RF signal. Digital modulation schemes are possible only if the transmitter-receiver pair have prior knowledge of how data is encoded and represented in the communications system. Since, here transmitter is unknown parameter demodulation of arrived signals is impossible, except there are some expectation about it, such as a modulation frequency and quantization parameters.

One bit of data signal is nothing more then presents or absents of pulse signal. Now, consider only ASK where pulse and pause duration and power level are unknown. Usually, short pulses consider a lot of energy followed by long pause, and wide pulses are following by short pause. It is logical, since average signal in both cases are similar. Those two cases are worst cases for analyzing pulse parameters and have one big similarity and one difference. Similarity is in shape since one case is inversion of second, on the other side difference is in power level. Quality of measuring parameters of arrived pulses is in directly connection with resolution of measuring shorter part of pulse (pulse or pause). On a hardware level, quality of measuring depends on AD converter resolution. In this case, resolution of AD converter is 12MSPS that mean all pulses slower then 80ns could be measure. Using pick detectors, signals faster then 80ns could be only conclude, but exactly measuring of pulse can not be obtain. Why this is important? It is important for measuring pulse level. This way is possible to measure pulses level, even, they are faster then AD converter and with backward reconstruction pulse time could be estimate. Estimation must use assumption that arrived signal has consistence at the energy filed. At the end for periodicals pulses, frequency and pulse/pause ratio could be measuring too.

IV. TROUBLESHOOTING

Observing and analyzing some radio band is complex task, since it is requiring understanding of a several electrical

science fields. At first antennas, second RF, third digital signal processing and connections between those fields. Each junction produced one non-linearity in system. Until that non-linearity is monotone, everything is fine, since it represent bisection in system.

Bottlenecks on hardware level are matching impedance between antenna and detector, conversion from analog to digital domain and temperature and frequency stability. Temperature stability refers to logarithmic and picks detector exerciseing on detecting level. It is recommended to capture operating abilities of detectors in a wide temperature band and use them in digital domain for correction input data, before digital signal processing start. This solution is a kind of normalization that provides same reference level for the considered temperature band. Same, temperature has some influence on stability of synthesized frequencies. Solution could use similar principle, only here temperature variation brings corrections in setting parameters of synthesis. In both cases, system must be equipped with temperature sensor. Those calibrations are necessary for more prescient measuring and they do not entering degradation of system functionality.

Influence of temperature to synthesizing frequencies is one trouble, but system response on different frequencies is something completely different. At first, antenna and logarithmic detector are providing different matching impedance in wide frequency band. Consequences are non-consistent dedicating power level in considering band. It shows on two levels: first same level is representing with different value and second increment/decrement is not appropriate. Those deviations in some applications have not large influence but here they have to be press. On the other side, this correction leads to decreasing dynamic range of detectors.

V. CONCLUSION

Topic of this paper is analysis and dedicating radio signals and that is always unfathomable. Fortunately, there are stuffs that could be reachable and analyzable. First, observing radio silence is certainly possible. If radio silence is broken then it is possible to determinate carrier frequencies and power levels in each channel of arrived signals. In addition, some signals shapes in time domain are easily to determinate (basic shape), but modulated signals are more sophisticated and required more patients. Some types of modulation are possible to admeasure and some not. It is interesting to create advanced analysis for possibility of signals demodulation and investigate probability of success demodulation.

Hardware, made for this analysis has many advantages, since it provide all further analysis. Another good thing of this hardware is many communication protocols that allow this system to be a STIM sensor part that communicate with some NCAP like in IEEE1451 protocol [8].

Results of this analysis could be used in nuclear, radar, sonar, and medicine application, since all noted applications are dealing with unknown signals and demands hard real-time processing.

REFERENCES

[1] N. M. Mitrović, D. D. Obradović, S. A. Tasić, "High frequency low cost fast channel switching synthesizer", TELSIKS'09, IEEE Conference Proceedings, pp., Nis, Serbia, 2009.

[2] N. M. Mitrović, D. D. Obradović, S. A. Tasić, Z. . Gajić, "Digital frequency synthesizing (DDS and PLL) control using Silabs 8051F121 microcontroller", TELFOR'09, IEEE Conference Proceedings, pp., Beograd, Serbia, 2008.

[3] N. M. Mitrović, D. D. Obradović, P. S. Manojlović, "One method source radiation azimuth finding using horn antennas", ETRAN'09, Conference Proceedings, pp., Vrnjacka Banja, Serbia, 2009.

[4] C.A. Balanis, *Antenna theory – Analysis and design*, New York, John Wiley & Sons. Inc., 1997.

[5] *1 MHz to 10 GHz, 50 dB Log Detector/Controller*, Analog Devices, USA, 2005.

[6] J. Basílio Simões, João Cardoso, Nuno Cruz, and Carlos M. B. A. Correia, "A PC104 Multiprocessor DSP System for Radiation Spectroscopy Applications", ICSPAT'99, Conference Proceedings, Orlando, USA, 1999.

[7] *TMS320F2009, TMS320F2008, TMS320F2006, TMS320F2002, TMS320F2001, TMS320F2801, TMS320F2802, TMS320F2801x DSPs Data Manual*, Texsas Instruments, USA, 2009.

[8] *IEEE Standard for a Smart Transducer, Interface for Sensors and Actuators-Common Functions, Communication, Protocols, and Transducer Electronic Data Sheet (TEDS) Formats*, IEEE Instrumentation and Measurement Society, New York, USA, 2007.