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Fast Self Switching type Frequency Agile Radar Processing Unit Implemented on Xilinx FPGA

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Abstract: Searching radar or surveillance radar has to resist diversified jamming; self-adaptive frequency agility is an important and effective function for radars to resist jamming. The detailed steps to achieve this function are described, and the function is realized with FPGA using Hardware description Language, the validity is proved by online sampling and simulation. The self-adaptive frequency agility module can analyze the type of jamming to select transmitting frequency to avoid the frequencies which have interference, under frequency diversity and fixed frequency, respectively. The practical application on a searching radar shows that the module has good real-time and anti-jamming capacity.

Keywords: frequency agility, frequency diversity, jamming analysis, self-adaptive frequency changing, FPGA, searching radar.

I.INTRODUCTION

Many kinds of technology can be applied to modern pulse radar to meet diversified jamming [1]~[3]; in a word, they all enhance useful echo signals and avoid or weaken interference signals in order to ensure the radar works properly to the maximum extent. Among so many anti-jamming technologies, frequency selection is widely used and also very effective. The common frequency selection method includes manual frequency modulation, frequency agility, frequency diversity, spread spectrum technology, etc.

Frequency agility can be divided into random frequency agility and self-adaptive frequency changing, which are effective methods to resist jamming. Self-adaptive frequency agility can adapt the changing of the jamming environment to a certain extent. It analyzes jamming spectrum real time so that to control the radar frequency it make the radar signal spectrum center locate at the weak part of the jam spectrum all the time, so as to improve the signal interference ratio. Self adaptive frequency agility cannot only deal with narrow band aiming jam, but also control wide band block jam to a certain extent. Self-adaptive frequency agility is mainly implemented by Jamming Analysis Transmission Selection (JATS).JATS was realized on a DSP chip of TMS320C25 in [4] and on a Micro Control Unit (MCU) in [5], and is developed with FPGA in this paper. The implementation with FPGA has many merits [6], the most important of all is that FPGA can get good real time capacity, thus achieving the real frequency agility.

II. JAMMING ANALYSIS MODULE

Our searching radar also needs anti-jamming ability. It can work with fixed frequency and frequency diversity. The working mode of frequency diversity can avoid the mutual interference between wide transmission pulse and narrow transmission pulse, prevent the target second-time echo effectively, reduce the signal loss because of the target signal fluctuation, and thus reduce the probability of losing targets. The receiver exciter can produce 25 frequencies. The radar system will select 4 transmission frequencies that jump during successive time periods to achieve frequency diversity. Five transmission signal pulses are one group, the jumping happens between these groups. There is a 10MHz frequency offset between two groups of transmission signals, which will make the statistics characteristic of rain drop echo similar with the channel noise so as to reduce the fluctuation of the weather echo and improve the detecting precision of the weather echo power. The accurate evaluation of weather echo is helpful to searching targets.

The relationship between the jamming analysis module and other sub-systems is shown in Fig. 1. Frequency amplitudes obtained from jamming analysis are stored in a memory, which will be transferred to a monitor and control terminal for every coherent processing interval. An effective self-adaptive frequency agility module must meet these three conditions.

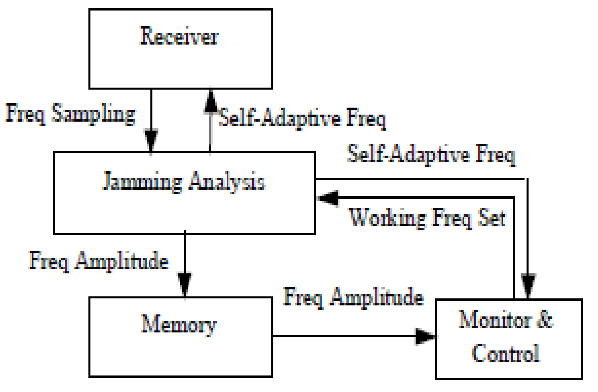
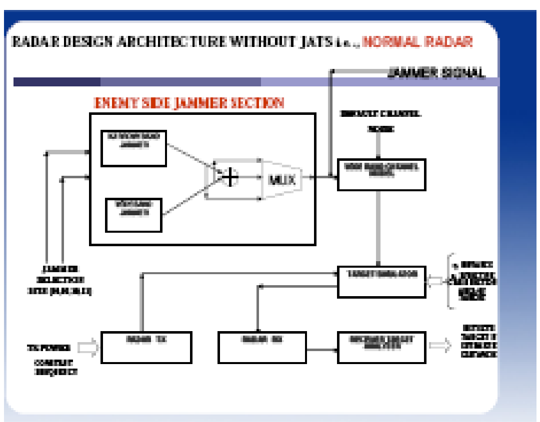


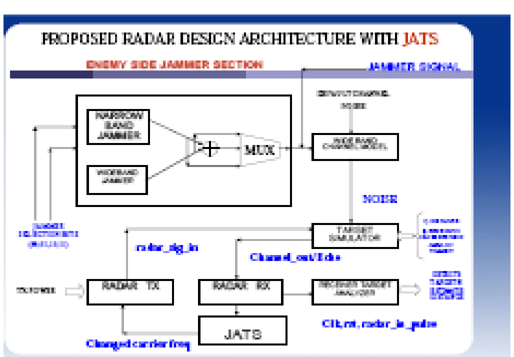
Fig. 1 Jamming analysis schematic chart

First, it analyzes the jamming fleetly; second, it changes frequency in a wide range; third, it changes the working frequency quickly [7]. In the following section we will discuss how to facilitate such a module with FPGA.

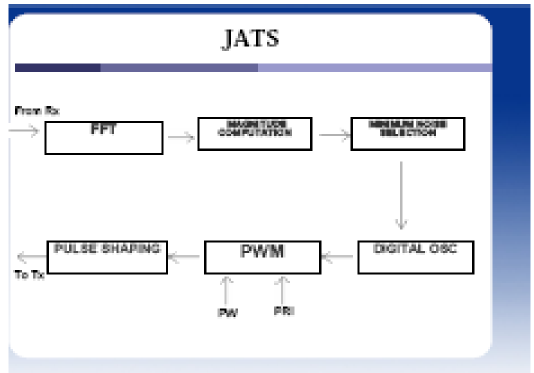
NORMAL RADAR



III . FREQUENCY AGILE RADAR



INTERNAL BLOCK DIAGRAM OF JATS



IV. REALIZATION WITH FPGA

Changing periods between pulse groups is applied to our searching radar to remove blind speed, and changing three periods between pulse groups is applied. Among these three periods, the longest is selected. During its rest period, jamming analysis is performed, thus not affecting the processing of useful data.

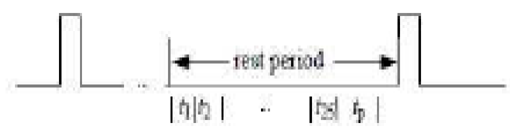


Fig. 2 Time assignment for sampling and processing

When the local oscillation changes its frequency one by one during the rest period, the receiver can obtain the jamming amplitude at each frequency point. The time assignment for sampling and processing is shown in Fig. 2, where t1, t2, … ,t25 are sampling time for each frequency point and t are the processing time after which the optimized frequency point is obtained.

The JATS module is developed using two conditions. One is that the transmitter works with frequency diversity; the other is that the transmitter works with fixed frequency. On either condition, 6 data are sampled at one frequency; these 6 data are processed together to obtain an average amplitude, which can be utilized subsequently. The average amplitude equation is as follows:

$$Amplitude_{aver} = \frac{1}{6}\sum_{i=1}^{6}\log\sqrt{[I_i^2 + Q_i^2]} \qquad (1)$$

in the above equation, Ii and Qi are two quadrature components. For 25 frequency points, we can get 25 average amplitudes, which will perform the judgment, respectively, to obtain jamming signs as follows: Where i=1,2,…,25 and JammThresh means jamming threshold.

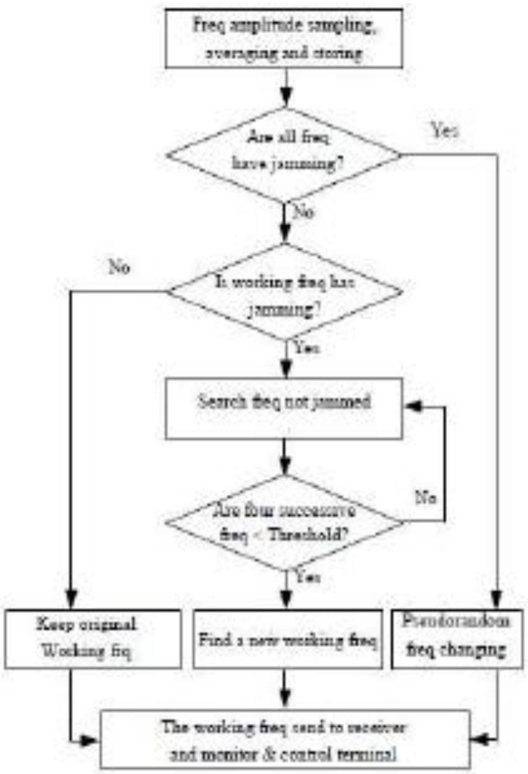


Fig. 3 Jamming analysis with frequency diversity

After the jamming signs are obtained, two logic expressions are implemented as follows:

$$JammingSign_i = \begin{cases} 1, \text{ if } Amplitude_{aver} \geq JammThresh \\ 0, \text{ if } Amplitude_{aver} < JammThresh \end{cases}$$

Where i=1,2,…,25 and *JammThresh* means jamming threshold. After the jamming signs are obtained, two logic expressions are implemented as follows:

$$AllJamming = JammingSign_1 \text{ AND } JammingSign_2 \text{ AND} \ldots \text{AND } JammingSign_{25}$$

$$IsJamming = JammingSign_1 \text{ OR } JammingSign_2 \text{ OR} \ldots \text{OR } JammingSign_{25}$$

If All Jamming equals 1 or **true**, which means that the radar is jammed on all 25 frequencies; then pseudorandom frequency changing is used, and if All Jamming equals 0 or **false**, it means that the radar is not jammed on all 25 frequencies. If Is Jamming equals 1 or **true**, it means that there is jamming among 25 frequencies; if Is Jamming equals 0 or **false**, it means that there is no jamming among 25 frequencies.

For frequency diversity mode, the flow chart is shown in Fig. 3. If there is jamming among the 25 frequencies, the amplitudes of four successive frequencies will compare with a threshold one after another until a frequency group including four frequencies is found with all the four members less than the threshold. This frequency group then becomes the working frequency diversity, which will be sent to a receiver and monitor and control terminal. There are 25 frequencies altogether, and every four neighboring frequencies constitute one frequency diversity mode, so there are 25 types of mode in all. Among them, the preceding 22 types are in the increasing order, and the last three combinations are [f23, f24, f25, f1], [f24, f25, f1, f2], [f25, f1, f2, f3], where the frequencies are selected circularly. Thus, the modular arithmetic is exercised in field programmable logics.

We define variable **i** the working frequency number, which is the same as the first frequency number among the four frequencies. For example, [f23, f24, f25, f1], whose working frequency number is 23 or i=23. So, the frequency number of one frequency diversity can be produced as the expression in Table 1.

TABLE I FREQ NUMBER CALCULATION

Freq order	Freq number
1	i
2	(i+1) mod 25
3	(i+2) mod 25
4	(i+3) mod 25

When the transmitter works at a fixed frequency, the frequency which has the least interference can be found and chosen as the working frequency. First, amplitudes for 25 frequencies are obtained. Then we perform the following procedures: suppose the first frequency amplitude is the minimum; when the second frequency amplitude comes, it will compare with the minimum; if it is less than the minimum, then the second frequency amplitude becomes the new minimum. Otherwise, the minimum remains unchanged. Repeat these steps in turn, after the 25st frequency amplitude is performed; the frequency which has the least interference is reached at last. These procedures are show in Fig. 4 and are the same procedures as Fig. 3

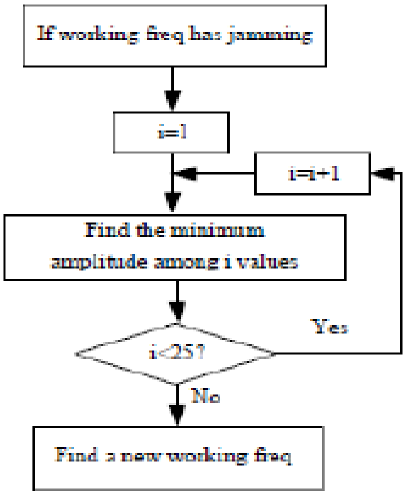


Fig. 4 Jamming analysis with fixed frequency

V.SIMULATION AND DISPLAY

Fig. 5, which contains real data. is captured by online Logic Analyzer Signal Tap II under Compile environment Quartus II 7.2; in this figure, the variable mlog is the original sampling for all frequencies and power_out is a variable which represents the average of samplings for each frequency. After going through the jamming analysis and self-adaptive frequency module, the frequency that has the least interference or the frequency diversity and which has not been interfered with can be given. If there is jamming through all the working frequency areas, the radar will work under pseudorandom frequency changing mode.

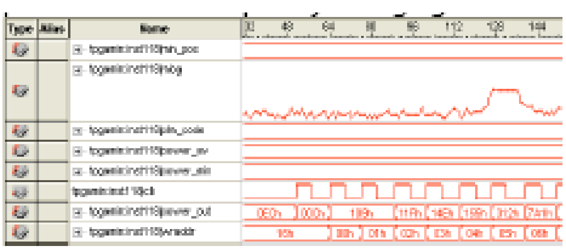
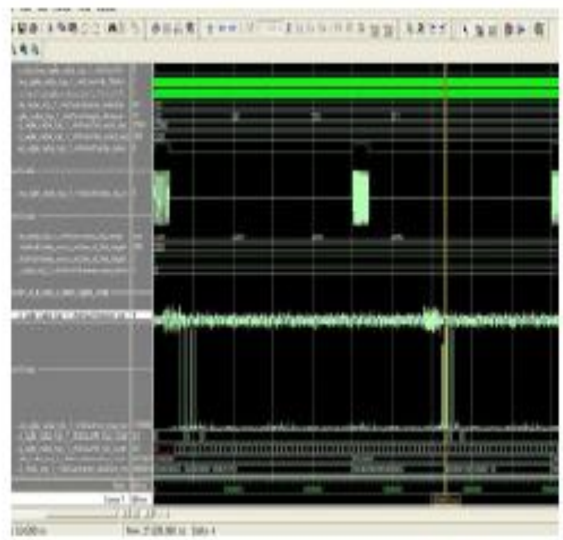


Fig. 5 Simulation picture produced by Signal Tap II

Analysis & Synthesis Summary	
Analysis & Synthesis Status	Successful - Tue Jan 13 14:13:58 2009
Quartus II Version	7.2 Build 151 09/26/2007 SJ Full Version
Revision Name	jets
Top-level Entity Name	jets
Family	Stratix
Total logic elements	992
Total pins	40
Total virtual pins	0
Total memory bits	256
DSP block 9-bit elements	0
Total PLLs	0
Total DLLs	0

The module is developed on a Xilinx Spartan 3E board by VHDL hardware description language. The analysis and synthesis summary is shown in Fig.6. The total logic elements occupied is 992, which is 2% of the chip logic element resource; the total memory bits occupied is 256, which is less than 1% of the chip memory bit resource.



VI .CONCLUSION

Anti-jamming is an issue that must be resolved on searching radar or surveillance radar. In this paper, the jamming analysis and transmission selection module is performed under fixed frequency mode and frequency diversity mode, detailed working flow is discussed, the key steps are considered, and the function is applied to Xilinx Spartan 3E board . The frequency analysis result displays on the monitor and control terminal, which is clear at a glance. During practical application, this module acquires satisfactory real time anti-jamming effects.

VII. REFERENCES

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