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Design of phase-coded transmitter and high sensitive receiver of radar system

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Abstract. This paper reports experimental results of a radar system design. In the radar transmitter, a 13-bit Barker code with bit duration 3.24 μs and various other codes are generated by the microcontroller PIC16F877A. This code is then used to modulate IF 10.3 MHz to become BPSK signal. A stable local oscillator is also designed by PLL, VCO, and PIC16F877A. The operation frequency range of the oscillator is from 800 MHz to 900 MHz with an error only about ±10 Hz. A microwave power amplifier is fabricated with structure of two stages of 45 W and 90 W in case of input 300 mW. In this amplifier microstrip technique is implemented for input/output matching network. In the receiver, subsystem can receive and decode very small signal with amplitude from -30 dBm to -108 dBm and frequency range from 800 MHz to 900 MHz.

Keywords: Barker code, BPSK signal, Stable Local Oscillator, Microwave Power Amplifier.

1. Introduction

Radar is identified as a device for detection, ranging and recognition of variety of targets. Because of great diversity of applications in military and civil, the designing of radar system is usually based on purpose. For radar systems in Vietnam, the research results were often used very complex schematics that limited the operation of systems.

Therefore, our working focuses on design radar system components using modern electronic devices and techniques. In radar transmitter, Barker code generator, phase-coded modulator, and local oscillator can be easily created and controlled when taking advantage of microcontroller. High power amplifier is designed with an impedance matching using microstrip technique.

In receiver, we designed and fabricated successfully a very high sensitive UHF receiver model ECC-01. Specifications of ECC-01 have more advantages than some UHF receivers that are used in Vietnam [1,2].

The following sections will report and discuss our results of these fabrications.

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2. Experimental

Block diagram of transmitter and receiver of a radar system is shown in the Fig.1. The code used in the transmitter is the 13 bit Barker code {+++++--++-+-+}.

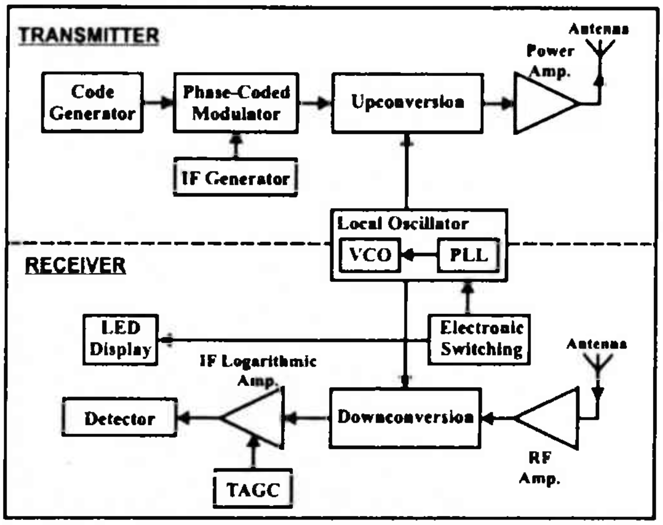

Fig. 1. Block diagram of typical radar system.

Reason of choosing Barker codes are auto-correlation function in echo signal pulse compression process of the Barker code has the magnitude of peak of main-lobe is 13, while the minimum peak of side-lobe is 1 [3,4]. In some methods used in the past to create the complex codes like Barker codes, the circuits were unwieldy and needed so many logic gates with uncontrolled of delay time and bits properties. In our method, the microcontroller PIC16F877A has been selected. The circuit is very simple and with advantage of microcontroller, any different codes can be easily created.

Technique of phase-coded modulation in this work is binary phase shift keying (BPSK) with the phase "0" of the IF sine wave represented for bit "1" and phase "π" represented for bit "0". A IF signal is taken from the Agilent Signal Generator 8648C with help of a transformer to generate two inverted sine waves. IC 4052 with 2-line analog multiplexer connect one of the two inverted waves above to its output depend on logic level of the Barker code at control pin.

Local oscillators in both of the transmitter and the receiver are made from the VCO and PLL circuits that are controlled by the microcontroller PIC16F877A instead of quality crystals used in other receivers.

Final stage of the transmitter is the power amplifier. In this module, besides calculation of DC bias point and stability for high frequency transistor, it is very important to design impedance matching network using microstrip lines.

The receiver ECC-01 can be able to decode an encoded square wave. In Fig.1, the receiver includes modules such as RF Wideband Amplifier, RF Mixer, IF Logarithmic Amplifier and Detector. The IF Logarithmic Amplifier is a non-saturating amplifier which output voltage is linear function of input voltage for low amplitude signals and logarithmic function for high amplitude signals. Therefore, a large signal does not saturate the Logarithmic Amplifier. AD6006 is used to make this amplifier. Good features of the AD6006 are high linearity and large dynamic band enables the amplifier of ECC-01 can receive UHF signals from -30dBm to -108dBm.

Furthermore, a Timing Automatic Gain Controller (TAGC) is used to enhance dynamic band of ECC-01. Sawtooth generator sends a negative sawtooth to Gain Control pin of AD6006. Thus gain of the IF Logarithmic Amplifier is adaptively controlled base on amplitude and incoming time of input pulses.

3. Experiments

3.1 Code generator

The microcontroller PIC16F877A is used to generate any complex code of radar signals. The Barker code 13 bit {+++++--++-+-+} created illustratively that shown in Fig.2 with bit duration 3.24 μs, pulse repetition frequency (PRF) 1 kHz. These specifications are suitable for radar applications.

First signal in Fig.2 is clock for synchronizing and second signal is a single pulse for marking the start of each sequence. Three signals are from three outputs of the PIC16F877A. With zoom function of Yokogawa DL1720E Digital Oscilloscope 500 MHz, we zoom a bit of the code sequence in third signal. The zoomed result is shown in fifth signal. Distance between positions of first cursor and second cursor is exactly 3.24 μs. So the pulse width or width of sequence is 42.12 μs. Fourth signal and its zoom in sixth signal show edge transition time only 12 ns.

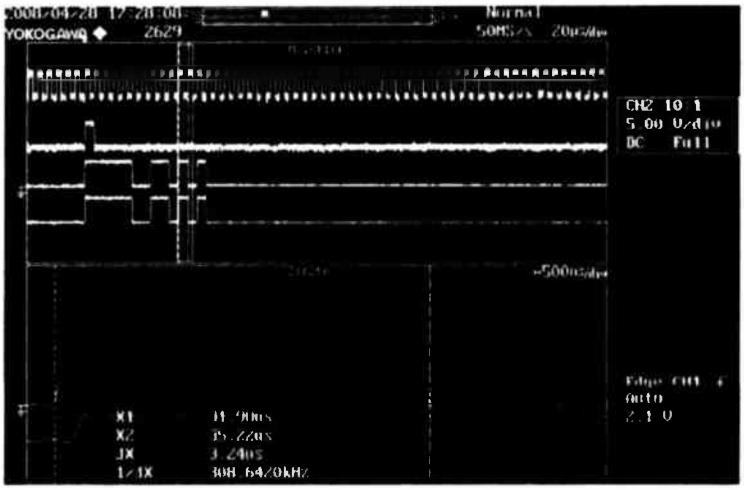

Fig. 2. Barker code 13 bit with bit duration 3.24 μs, PRF 1 kHz.

Advantages of this design using microcontroller are flexibility of changing codes, sequence properties, bit duration. With crystal 20 MHz used as oscillator for PIC16F877A, a period of an instruction of microcontroller is 0.2 μs.

Therefore, our circuit can create sequences that have bit duration down to 0.2 μs. This is very important when people want to create a very short sequence of bits. We knew that when bit duration and of course code sequence duration is shorter, resolution of radar is higher. It is almost impossible if use a complicated circuit with a total long time delay of electronic components.

3.2. Phased-code modulator

With the method of BPSK modulation mentioned above [5], we used the Barker code sequence with bit duration 0.8 μs to control an analog multiplexer IC 4052 of inverted and non-inverted IF sine waves 10.3 MHz. Signal of BPSK is displayed in Fig.3.

When zooming a part of sequence, we can see approximately 8 periods of IF sine wave inside a bit time. Start of bit "1" is represented by a phase 0 of sine wave. Start of bit "0" is marked by a phase π of sine wave. Because of delay of some components, we also observe delay of BPSK signal compare with a bit of sequence.

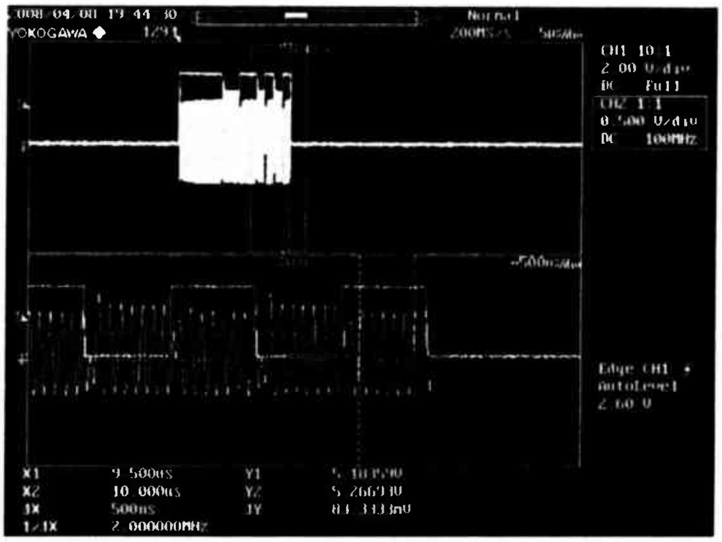

Fig. 3. BPSK signal of Barker code bit duration 0.8 µs and IF 10.3 MHz.

3.3. Local oscillator

The LM2316 is used with VCO circuit to generate a local oscillator of radar transceiver. Frequency of local oscillator can change flexibly by data from the microcontroller PIC16F877A push in 21-bit data register of the LM2316.

In this work, we successfully controlled frequency range from 800 MHz up to 900 MHz. The signal is analyzed by Advantest Spectrum Analyzer R3131A (Fig.4). Frequency error 10 Hz makes quality of this oscillator can be compared with that of crystal oscillator.

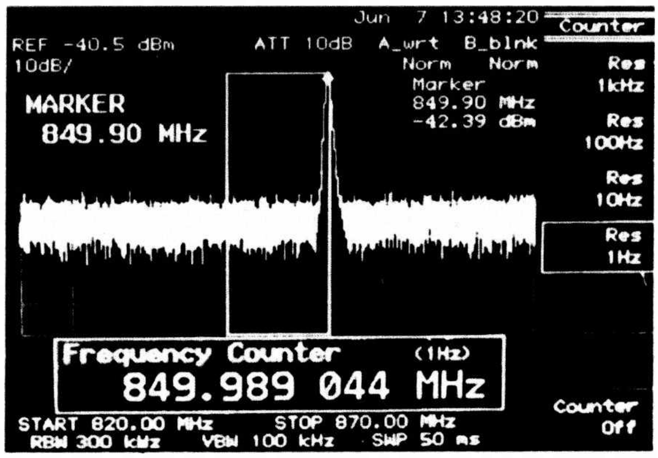

Fig. 4. Local oscillator at 850MHz.

3.4 Microwave power amplifier

To archive high power gain, amplification needs to divide to some stages. In our schematic, first stage is in AB mode, second stage is push-pull structure. First stage has high voltage gain but output power should be medium. Second stage is in inverting strategy. It means low voltage gain but high output power. The first stage we often know as pre-amplifier in microwave power amplification systems of radar stations [6].

Process of circuit fabrication includes: (1) Calculate and simulate of amplifier specifications using Smith chart, ADS software. (2) Design PCB use Protel. (3) Fabricate the PCB using ProtoMat C40 PCB Printed Circuit Board LPKF. (4) Add-in electronic components and measure characteristics.

Fig.5 is a photo of experimental amplifier. The first and second stages have output power of 45 W and 90 W, corresponding, of a standard input 300 mW.

Fig. 6 shows arrangement of facilities in measurement that consists of high quality DC power supply, Signal Generator SG8550, and Spectrum Analyzer ROHDE & SCHWAR ESPI 9 kHz -3 GHz.

Set a signal 300 mW coming in the amplifier and measure the output by Spectrum Analyzer ROHDE & SCHWAR ESPI.

Fig. 5. Microwave power amplifier. First stage of 45W, second stage of 90W of an input 300mW.

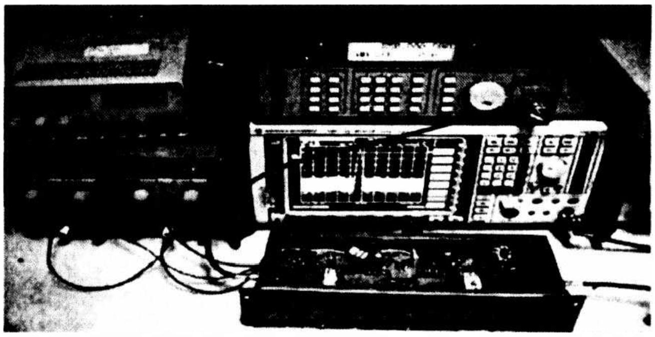

Fig. 6. Microwave power amplifier setup of measurement.

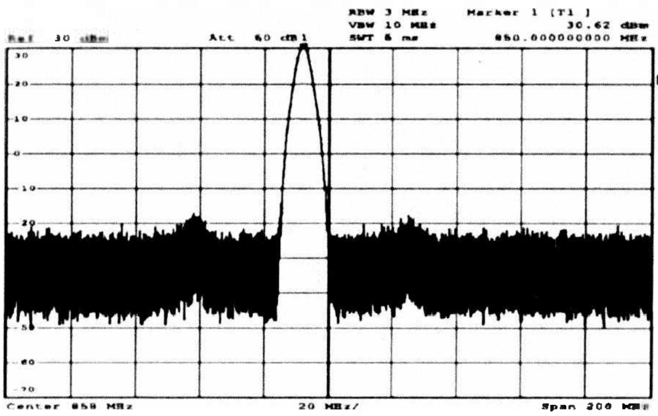

Fig. 7. Microwave power amplifier measurement.

3.5 UHF receiver ECC-01

The ECC-01 has specifications:

- Bandwidth: 6.5 ± 0.5 MHz
- Sensitivity: approximate -90 dBm
- Decoded information voltage: 5 V
- Operating frequency: 800 MHz - 900 MHz
- Input signal level: -30 dBm - 90 dBm

Encoded signal is AM 900 MHz that is created when using Function Generator FG7002C as external modulating source for AM modulation of Signal Generator SG8550 at frequency 900 MHz. This signal is fed to the input of the receiver ECC-01. Output of ECC-01 is the decoded signal, that means square wave of FG7002C, is observed in the Digital Oscilloscope DL1720E (Fig. 9). Level of encoded signal here is -80 dBm and the modulating level is 99.9%.

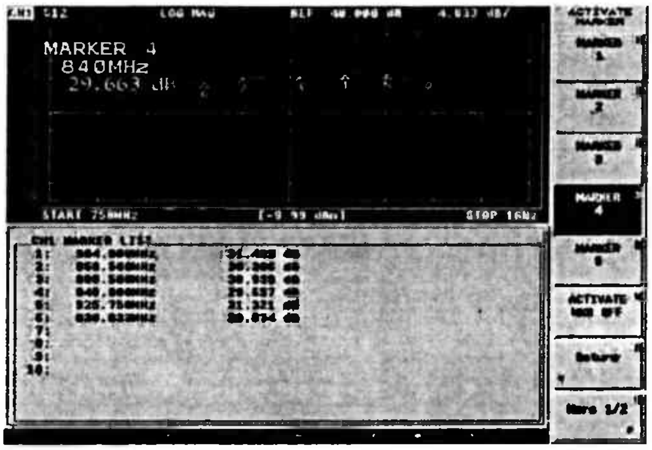

Fig. 8. Amplitude characteristic of the microwave power amplifier.

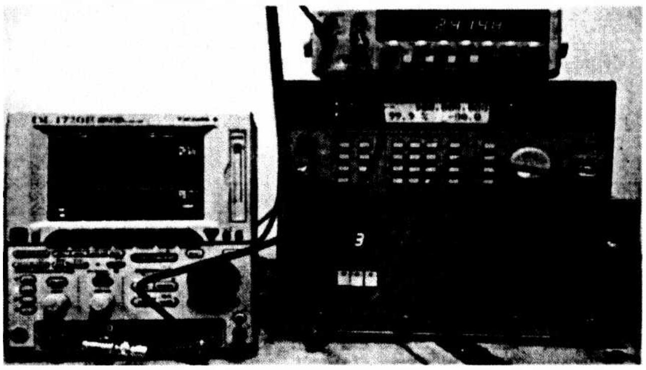

Fig. 9. Decoded signal at 900 MHz, -80 dBm.

4. Conclusion

In conclusion, we summaries some main specifications of the modules of radar system. The main results are Barker code 13 elements with bit duration 3.24 μs, BPSK signal frequency IF 10.3 MHz, stable local oscillator 800 MHz-900 MHz with frequency error 10 Hz, high microwave power amplifier with output power can reach 90W and good impedance matching with antenna 50 Ω, and finally sensitive UHF receiver can receive signal -108 dBm.

In future, we will concentrate on antenna designation, antenna duplexer fabrication. We also want to build echo pulse compression to improve radar resolution. To raise average pulse power at transmitter without affect to resolution, we have plan to create intelligent mode of transmission Barker code 13 bit pulse width 42.12 μs or M code pulse width about 200 μs ÷ 300 μs depend on distance from radar station to targets near or far.

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References

[1] Lav Varshney, *Radar System Components and System Design*, Technical Report, Syracuse Research Corporation 2002

[2] Falih H. Ahmad, *Design of a High-Resolution, Coded, Portable Radar System*, Technical Report, U.S. Army Corps of Engineers 1996.

[3] August W. Rihaczek, Range Sidelobe Suppression for Barker Codes, *IEEE Transactions on Aerospace and Electronics System* Vol. AES-7, No. 6 (1971) c2.

[4] Nadav Levanon, *Radar Signals*, John Wiley and Sons, Inc., 2004

[5] Werner Wiesbeck, *Lecture Script of Radar System Engineering*, 2007

[6] David M. Pozar, *Microwave Engineering, Second Edition*, John Wiley & Sons, Inc., 1998.