International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 12, Issue 9 [September. 2023] PP: 70-75

Research Technical DIFM in Recording, Determination of Radar Signal Parameters on Combat Aircrafts

Nguyen Tuan Ngoc, Nguyen Manh Tuong, Do Van Phuong,
Nguyen Dong Anh, Phung The Anh, Nguyen Van Thuy
Air defence-Air force Academy, Viet Nam
**Corresponding author Email: Dungnghia1215@gmail.com*

Abstract:*In recent decades, thanks to the development of electronic technology, low-power, high-camouflage complex structural radar signals have been widely applied in most means of observation and indication. targeting and fire control. In addition, modern combat situations also have many differences: the increase in the number and types of electronic radio means, interference sources... Therefore, updating the application of new techniques and technologies in combat operations is important. Electronic warfare in general, or in the reconnaissance module on fighter aircraft in particular, is an inevitable and urgent need. This article presents the DIFM (Digital Instantaneous Frequency Measurement) technical algorithm model to determine the radar signal carrier frequency in some typical reconnaissance situations.*

Keywords:*DIFM, Radar signals, electronic warfare, noise sources*

Date of Submission: 04-09-2023 Date of acceptance: 16-09-2023

I. Introdution

Electronic reconnaissance is technical actions and measures aimed at detecting and providing necessary information about the enemy's systems, means, and electronic technical equipment to serve the purpose of piezoelectric suppression. electronics and electronic protection. Electronic reconnaissance solves the following tasks:

- Search and collect characteristic signals for the enemy's vehicle systems and electronic equipment;
- Determine the location and coordinates of detected electronic targets;
- Synthesize, analyze, and process signals and signs obtained to determine parameters and identify the enemy's systems, means, and electronic equipment;
- Collect signals - characteristic signs for our systems, vehicles, and electronic equipment to check their ability to work and maintain radiation security mode;
- Transmit necessary data to represent the electronic situation and indicate the target for electronic suppression as well as electronic protection.

Results obtained through electronic reconnaissance are used to:

Determine the number of electronic devices used for command and control for electronic suppression and identification.

In parallel with measures such as using intelligence sources, military intelligence, etc., the above tasks are carried out mainly with reconnaissance equipment. With the main combat object being radar and homing heads, the reconnaissance subsystem on fighter aircraft belongs to the radio technical reconnaissance type.

Electronic reconnaissance is technical actions and measures aimed at detecting and providing necessary information about the enemy's systems, means, and electronic technical equipment to serve the purpose of piezoelectric suppression. electronics and electronic protection. In order to promptly take appropriate self-protection measures, it is necessary to detect and determine the basic parameters of irradiated signals from enemy radar means. Due to limitations in size, weight and technological capabilities, the reconnaissance subsystem of domestically equipped fighter aircraft can only partially meet the technical and combat requirements set out at the time of design. make. Achievements in digital signal processing based on modern microelectronic techniques allow to significantly expand reconnaissance capabilities and determine emission source parameters, especially in the aspect of: ensuring computing ability. High performance, real-time response with extremely compact device size and weight (meeting specific requirements for fighter aircraft). One of the techniques that has been strongly researched and developed is the technique of measuring instantaneous frequency using digital methods.

II. DIFM technique

2.1. Operating principle of DIFM

IFM (Instantaneous Frequency Measurement) is a technique for measuring instantaneous frequency through the phase delay of the signal after being delayed. A diagram illustrating this principle is shown in Figure 1.

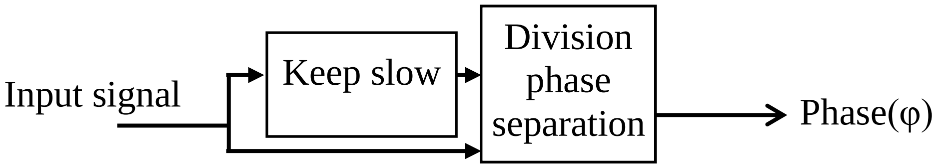


Figure 1. Diagram illustrating the IFM principle

Consider a simple sinusoidal input signal: $y(t) = A\cos(2\pi ft)$

Where A is the amplitude of the signal, *fis the frequency of the signal.*

This signal will follow 2 routes. One route is not delayed and one route is delayed with a certain delay τ. The signal after a slow hold is:

$$y_{gc} = A\cos[2\pi f(t-\tau)] = A\cos[2\pi ft - \varphi] \qquad (1)$$

While $\varphi = 2\pi f\tau$ is the phase delay due to slow holding.

The two signals are then sent to the phase discriminator, which multiplies the delayed and non-delayed signals to get:

$$y_{\min} = y(t).y_{gc}(\mathrm{t}) = \mathrm{A}\cos(2\pi\,\mathrm{ft}).\mathrm{A}\cos[2\pi f(t-\tau)]$$
$$= \frac{A^2}{2}[\cos(2\pi \mathrm{f}\tau)+\cos(4\pi\mathrm{ft}\text{-}2\pi\mathrm{f}\tau)]$$

As an output, we obtain a signal consisting of 2 oscillating components, one oscillating with frequency 2f, one component with frequency 4f. If we use a low pass filter to remove high harmonics we obtain:

$$y_{filt} = \frac{A^2}{2}\cos(2\pi \mathrm{f}\tau) \qquad (2)$$

$$\Rightarrow f = \frac{1}{2\pi\tau}\arccos\left[\frac{2y_{filt}}{A^2}\right] \qquad (3)$$

DIFM is the implementation model of IFM using digital. The basic algorithm of frequency measurement in DIFM technique is similar to that in equipment using IFM technique, which is to compare the phase difference between the live signal and the delayed signal using a phase correlator, is then linearly mapped to the corresponding frequency. The output of DIFM will be the frequency code corresponding to the frequency within the measurement frequency range [4]. A simple DIFM technique diagram using a delay line is shown in Figure 2.

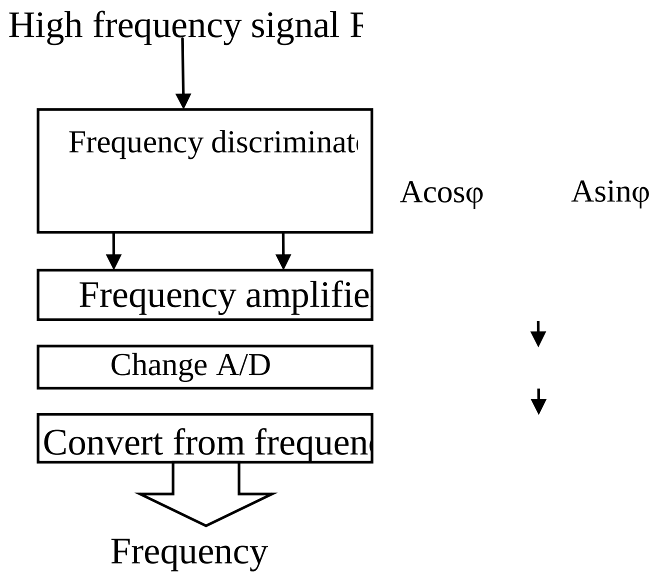


Figure 2. DIFM block diagram

The RF input high-frequency signal with frequency f is fed to the frequency discriminator. The frequency discriminator generates two visual frequency signals Asinφ and Acosφ. Where A is the signal amplitude and φ is the phase angle proportional to frequency. The frequency discriminator is often called a Delay Line Discriminator (DLD).

The two components sin φ and cos φ obtained from the output of the frequency discriminator will be amplified in the visual frequency amplifier, then sent to the AD converter to perform phase 2 quantization of the visual frequency signal. The phase difference angle φ in the range 0 to 2π will be encoded in binary bits. The frequency code converter circuit converts from phase code to binary code corresponding to the frequency of the input high-frequency signal. Frequency accuracy depends on the number of bits of the phase difference angle measurement encoder.

2.2. Frequency discriminator

Figure 3 shows the components of a frequency discriminator including the holding wire τ, the mixer, the low-pass filter, and the phase shifter π/2. The delayed signal is multiplied by the direct signal to produce the sine and cosine components.

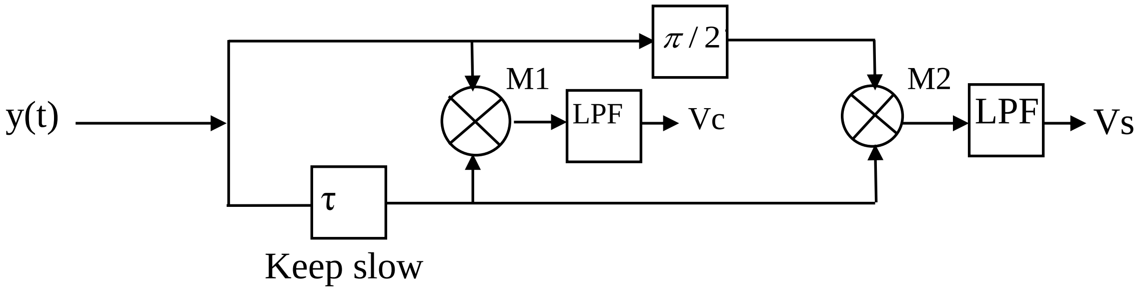


Figure 3. Frequency discriminator diagram

With input signal $y(t) = A\cos(2\pi ft)$ Here f is the frequency and A is the amplitude. The delay holder output signal τ is $A\cos(2\pi ft - \varphi)$. Mixer output M_1:

$$M_1 = A\cos(2\pi ft).A\cos(2\pi ft - \varphi) = \frac{A^2}{2}\cos(\varphi) + \frac{A^2}{2}\cos(4\pi \text{ft-}\varphi)$$

Through the low pass filter, the V_c signal is obtained: $V_c = \frac{A^2}{2}\cos(\varphi)$

2nd mixer input includes Acos (2πft – π/2) end Acos(2πft-φ). Mixer output M_2:

$$M_2 = A\cos(2\pi ft - \pi/2).A\cos(2\pi ft - \varphi)$$

$$M_2 = \frac{A^2}{2}\cos(\varphi - \pi/2) + \frac{A^2}{2}\cos(4\pi \text{ft-}\varphi - \pi/2)$$

Through the low pass filter obtained: $V_s = \frac{V^2}{2}\sin(\varphi)$

2.3. Method for selecting slow hold time value

If a slow holding line has length L, the phase difference φ of the two signals:

$$\varphi = 2\pi f\frac{L}{V} = kf \quad (4)$$

In which: V is the propagation speed of electromagnetic waves in the wire

k is constant $k = \frac{2\pi}{V}L$;*f*is the frequency of the input signal

We see that the instantaneous phase difference is proportional to the frequency of the signal and can be used to measure frequency. If f_1 and f_2 are the edge frequencies of the DLD bandwidth and $f_1 > f_2$, from (4) we have: $\varphi_1 = kf_1$; $\varphi_2 = kf_2$

therefore $\varphi_2 - \varphi_1 = k(f_2 - f_1)$ (5)

The condition for there to be no uncertainty in measurement is: $\varphi_2 - \varphi_1 < 2\pi$

If f_{WB} is the bandwidth of DLD ($f_{WB} = f_1 - f_2$) then from (5) we have:

$$f_{BW} = \frac{\varphi_2 - \varphi_1}{k}$$

The largest bandwidth is: $f_{BW} = \frac{2\pi}{k} = \frac{V}{L}$ (6)

From equation (6) we see that if the delay length is short, the bandwidth will be large. The frequency measurement accuracy of the DLD depends on the accuracy of the PD phase detector. Phase measurement inaccuracies can reduce frequency and bandwidth measurement accuracy. However, in reality, frequency and bandwidth measurement accuracy contradict each other. From (4) an index of frequency accuracy is given by:

$$\frac{d\varphi}{df} = \frac{2\pi}{V}L \quad (7)$$

From (7) it is shown that the longer the delay line, the more accurate the frequency measurement, which conflicts with the bandwidth requirement. Therefore, it is necessary to choose a slow holding wire to achieve these two requirements of the receiver.

From formulas (6) and (7), it can be seen that if using a slow holding wire with a short length, it will reduce measurement accuracy, and if using a slow holding wire with a large length, it will allow for more accurate frequency measurement. But at the same time, the bandwidth is also inversely proportional to the delay length L. Therefore, if the delay wire length is larger, the operating bandwidth will be lower. Therefore, for a required bandwidth, if a delay line longer than the specified time is used, the result will be phase uncertainty or measurement frequency uncertainty. This shows that DIFM with one delay line is not enough to guarantee the frequency accuracy and bandwidth requirements at the same time. The solution is to use multiple delay lines with different lengths.

Starting from the nature of the above uncertainty problem, we have the limit of the minimum and maximum slow holding wire value as follows:

$$\tau_{\min(\max)} = \frac{1}{f_{\max(\min)}} \qquad (8)$$

While $\tau_{\min(\max)}$ is the maximum (minimum) value of the slow holding wire.

$f_{\max(\min)}$ Is the maximum (minimum) value of the frequency to be scouted.

The number of delay seconds required (number of channels of the DIFM receiver) can be determined by the formula:

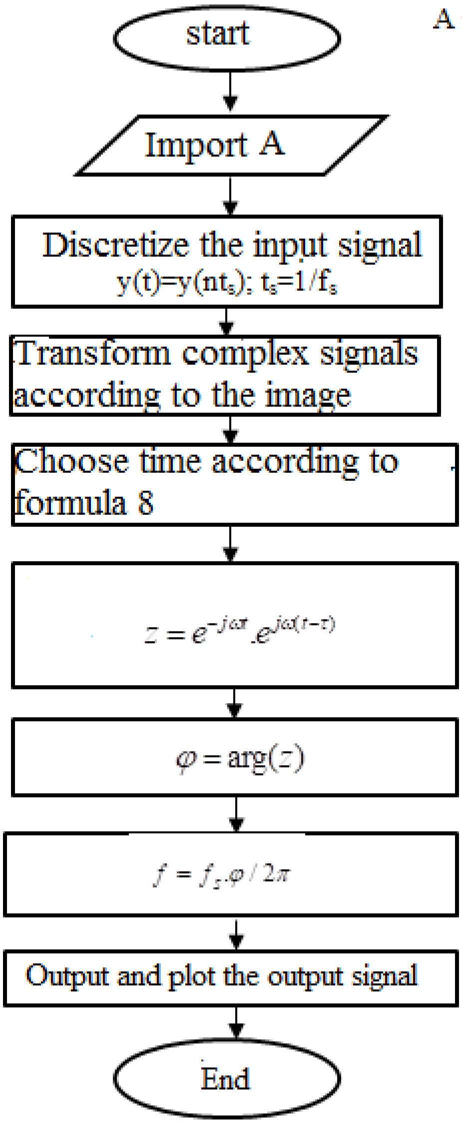
$$N = \log_2\left(\frac{f_{\max} - f_{\min}}{\Delta f_{\text{DIFM}}}\right) + 1 \qquad (9)$$

In which: Δf_{DIFM} is the required resolution.

Thus, with a not too large number of slow wires, the DIFM receiver can cover the frequency bands that need reconnaissance with the required cluster resolution.Như vậy, với số lượng dây giữ chậm không quá lớn, máy thu DIFM có thể bao trùm các dải tần số cần trinh sát với độ phân giải đám ứng yêu cầu.

3. Survey and evaluate the ability of DIFM technique to determine radar signal frequency

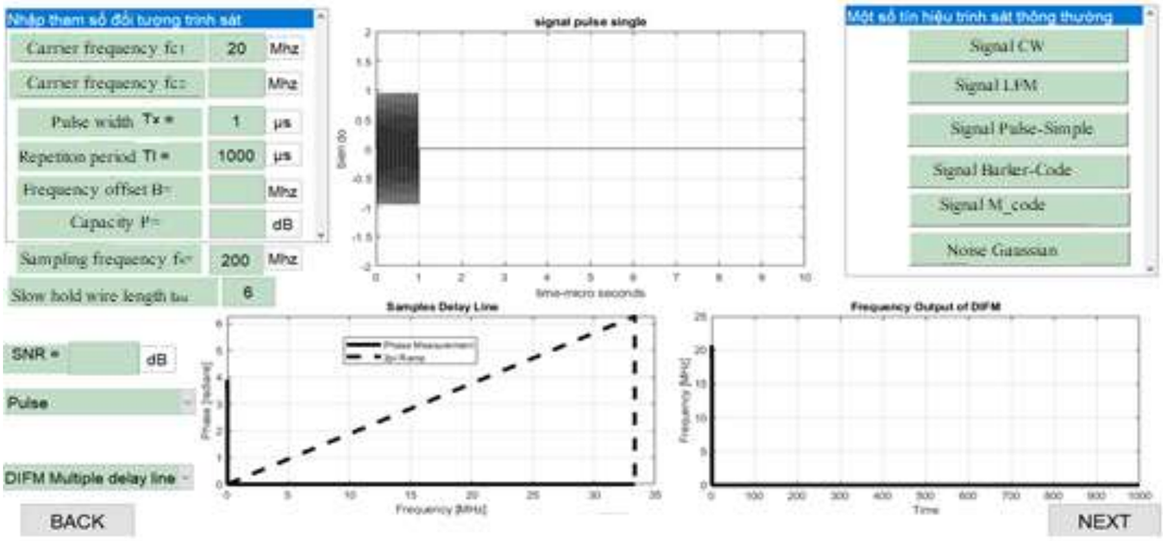
DIFM receiver algorithm flow chart is shown in Figure 4.



A is the scout object parameter

$$A = \begin{bmatrix} fc1 & (MHz) \\ fc2 & (MHz) \\ Tx & (\mu s) \\ Tl & (\mu s) \\ B & (MHz) \\ P & (dB) \\ fs & (MHz) \\ SNR & (dB) \end{bmatrix}$$

Consider the situation when the receiver input signal is a pulse signal: carrier frequency f_{c1}=20MHz, pulse width T_x=1µs, repetition period T_l=1ms=1000 µs. We choose the sampling frequency f_s = 200MHz; slow hold $\tau = 6.\frac{1}{f_s} = \frac{6}{2.10^8} = 3.10^{-8}(s)$.



Nhập tham số đối tượng trinh sát
Carrier frequency fc1 20 Mhz
Carrier frequency fc2 Mhz
Pulse width Tx = 1 µs
Repetiton period Tl = 1000 µs
Frequency offset B= Mhz
Capacity P= dB
Sampling frequency fs= 200 Mhz
Slow hold wire length tau 6
SNR = dB
Pulse
DIFM Multiple delay line

Figure 5. DIFM simulation results with the input signal being a simple pulse signal

From the results of Figure 5 with an input signal with a frequency of 20MHz, the DIFM receiver can measure the frequency accurately. Similar to reconnaissance situations when the input signal is a linear frequency-modulated signal, a 13-bit Barker code signal and a continuous signal, the DIFM receiver also gives accurate measurement results.

4. Conclusion

The DIFM technique gives us accurate frequency results in situations where there is a signal arriving at the receiver and the SNR ratio is large enough. DIFM receivers provide instantaneous frequency values, so they have the potential to evaluate the law of changing the frequency of the emission source. With DIFM accuracy can be ensured by using a slow hold wire with the desired delay.

REFERENCES

[1]. J. P. Coupez, H. Gruchala, A. Slowik, C. Recko and A. Rutkowski, "High Resolution IFMs", *Microwaves Radar and Wireless Communications 2002. MIKON-2002. 14th International Conference*, vol. 2, pp. 484-487, 2002

[2]. A.Ramya Sree, Tavanam Venkata Rao(2014), Sensitivity Enhancement in Digital Instantaneous Frequency Measurement, International Journal of Innovative Research in Science, Engineering and Technology (vol.3).

[3]. James B. Y. Tsui, Centerville; William S. McCormick, Dayton, both of Ohio(1990), Instantaneous frequency measurement (efm) receiver to measure frequency and angle of arrival (aoa) of multiplesignals, United States Patent.

[4]. Kobus Myburgh (2015), The Design and Development of a Co-pulse IFM Receiver, Stellenbosch University, South Africa.

[5]. R. G. Ranson and S. G Gibbons, "A rapid channel detection system for EW receivers", *Microwave Symposium Digest. 1990 IEEE MIT-S International*, vol. 2, pp. 961-963, 1990

[6]. James Bao-Yen Tsui, "Microwave Receivers with Electronic Warfare Applications" in , John Wiley & Sons, 1986