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# RESEARCH ON THE DISTORTION EFFECT OF ULTRA-WIDE BAND RADAR ANTENNA

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## ABSTRACT

This work focuses on the design and measurement of the distortion impact of an Ultra-wide-band radar antenna. The low-pass prototype with equal parts was used as the model. The model is capable of minimizing the insertion-loss while also delivering the required stop-band attenuation. The network model was constructed based on the low-pass prototype model, using the theory of coupled cavity resonator. The construction of narrow-band filters relied on the coupling coefficients between resonators and the external Q factors at the two terminal resonators, which served as fundamental parameters. The microwave implementation included the utilization of λ/4 inductive coupled TEM-mode coaxial resonators. The suggested filter exhibits characteristics of being small, stable, readily manufacturable, and cost-effective.

## I. INTRODUCTION

The antenna is an indispensable component of any radio system. Its function is to radiate or receive radio waves. It converts conductive magnetic waves into free-space radio waves in the transmitting system, or vice versa in the receiving system. So as to realize the transmission of radio signals between any two points. With the advancement of science and technology, the radio spectrum has been continuously developed, and the bandwidth of the radio system has also been continuously expanded.

Ultra-wideband technology is a new type of wireless communication technology. It directly modulates the impulse pulse with very steep rise and fall time, so that the signal has a bandwidth of GHz order. Ultra-wideband antenna refers to the antenna used in ultra-wideband technology. Ultra-wideband technology directly modulates impulse pulses with steep rise and fall times, so that the signal has a bandwidth of GHz order.

In the design of ultra-wideband antennas, the most important requirement is to enable the antenna to simultaneously receive signals in all frequency ranges. This requires the antenna to have a constant or predictable impedance characteristic over the entire frequency band. Ultra-wideband technology It solves the major problems related to propagation that have plagued traditional wireless technology for many years. Compared with traditional antennas, ultra-wideband technology has simple structure implementation, supports high-speed data transmission, low power consumption, and has low interception and low detection probability. The physical layer technology of the communication system has natural security performance. It is resistant to multipath interference, accurate positioning, and can also dynamically adjust the data rate. The ultra-wideband antenna is first of all non-frequency-variable and has a fixed phase center.

## II. CHARACTERISTICS OF ULTRA-WIDE-BAND RADAR TECHNOLOGY

A large number of basic theoretical and experimental studies have shown that Ultra-wide-band radar has a series of advantages over conventional narrow-band radar[1]

### 1. High range resolution

Ultra-wide-band radar launch has very wide signal bandwidth and fine structure to distinguish targets. Another advantage of narrow pulse is that it can overcome the short-range blind area of conventional radar, and can be used for close range detection, especially for spacecraft docking, missile fuze initiation, automobile collision avoidance, etc

### 2. Anti stealth capability

The abundant low-frequency components of Ultra-wide-band radar can resist shaped stealth. At the same time, since ram is only suitable for conventional radar spectrum, it still has strong reflection echo outside the absorption band for broadband impulse signal, so Ultra-wide-band radar can also resist ram stealth

### 3. Target recognition ability

In conventional narrow-band radar, point target has become a body target for Ultra-wide-band radar. The response of target to impulse radar can be divided into global response and local response. Poles of target transfer function can be obtained from global response, and radial distribution of target scattering center can be obtained from local response. Both of them can be used for target recognition

### 4. Penetrability

A large number of experiments have proved that Ultra-wide-band radar working in VHF and UHF frequency band has good penetration ability to leaf clusters, ground surface and walls, and is suitable for detecting underground tunnels, pipelines, geological faults and weapons in bunkers or woods

### 5. High precision imaging capability

High range resolution and azimuth resolution are required for high-precision imaging of targets. Ultra-wide-band radar has centimeter level range resolution due to its wide-band narrow pulse signal. If Ultra-wide-band radar is combined with synthetic aperture or inverse synthetic aperture technology and can provide high azimuth resolution, it can be used for fine imaging of targets.

It is the advantages of Ultra-wide-band radar that make it have a wide range of development and application prospects in the fields of target detection, recognition and imaging.

The Ultra-wide-band radar which treats the electric dipole antenna as receiving antenna does not generate wave distortion to the wave form of receive signal. And this is the real reason that makes wave distortion. The space propagation vector makes a very small attenuation to the microwave signal in the short-range transmission situation. So it makes a small influence on the signal waveform, and it can treat as the negligible quantity.

## III. THEORY

In recent years, with the popularization of wireless communication products and the development of ultra-wideband technology, people have put forward higher and higher requirements for antenna bandwidth. Since 2002, the Federal Communications Commission (FCC) passed a resolution allowing the 3.1-10. 6 GHz frequency band to be used in the commercial field. UWB communication systems with high data transmission rate, low cost, low power consumption and strong anti-interference ability have been obtained Has developed rapidly. The antenna used in the UWB communication system terminal must have the following characteristics: such as linear phase response, omnidirectional radiation pattern, and stable gain. Therefore, the design of ultra-wideband antennas has become one of the main challenges of UWB systems. Planar printed antennas, such as rectangular, circular, elliptical, butterfly monopoles, dipoles, etc., have the advantages of broadband, low dispersion, low loss, low profile, light weight, easy production, and low price. It is widely used in UWB communication systems. The planar printed antenna fed by CPW has easy serial-parallel connection with active and passive devices, easy integration of MMIC, and favorable impedance matching and gain improvement. However, this frequency band includes wireless local area network (WLAN) 5.2 GHz and 5.8 GHz operating frequency bands. In order to avoid interference with the wireless local area network, it is necessary to add a band-stop feature in the 5-6 GHz frequency band. Therefore, UWB antennas with band-stop characteristics have received extensive attention and research[2].

### 1.1. The radiated characteristic and receive characteristic of the wantonly radiating antenna

As a linearity time-space conversion element, the characteristic of radiating antenna is commonly in the connotative form, which described as complex normalized directivity pattern *D*( *j*w,q ,j ) and the input impedance Z ( jω) a in the arbitrary frequency thread radiation state. In principle, there exists the single value contact among those characters. But it is very complicated to divide them into explicit. So it need special method to research those characters, and we treat them as known.

With regard to the transmitting antenna, the property of energy dissipation process which is provide to transmitter by the feeder line was determined by Z ( jω) a , and the directivity diagram is the distribution process that energy in the space. So the frequency characteristic of antenna H ( jω,θ ,φ) TA can be expressed as the product of two frequency characteristic components-dissipation component H ( jω) L and the radiation component H ( jω,θ ,φ) R [3].

$$H_{TA}(j\omega,\theta,\varphi)=H_{L}(j\omega)H_{R}(j\omega,\theta,\varphi) \tag{1}$$

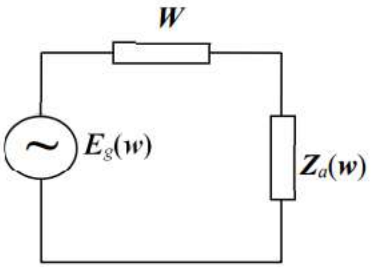

Fig.1 Equivalent-circuit diagram of transmitter

The equivalent circuit of aerial feed is shown as Fig.1. When determining the complex amplitude of equivalent supply voltage, the signal's power spectrum density of matched load P(ω) which supplied by transmitter is the primary data in the frequencyω . In this status, the mod of complex amplitude is $E_g(\omega)=\sqrt{P(\omega)W}$ it's argument can chose arbitrary value including zero. If we describe P(ω) as the equivalent complex amplitude ( ) U0 jω of transmission line voltage which matched by impedance transformer, the amplitude of equivalent source is $E_g(\omega)=U_0(j\omega)\sqrt{W}$ .

With respect to the feed system, the frequency characteristic of antenna in the radiating state can be written as:

$$H_{EA}(j\omega,\theta,\varphi)=\lim_{r\to\infty}\frac{4\pi r E(j\omega,\theta,\varphi,r)\exp(j\omega r/c)}{U_0(j\omega)} \qquad (2)$$

The through current of $Z_a(j\omega)$ is:

$$I_a(j\omega)=U_0(j\omega)\sqrt{W}/[W+Z_a(j\omega)] \qquad (3)$$

$$E(j\omega,\theta,\varphi,r)=-j\,\mathrm{sign}(\omega)F(\omega)d(j\omega,\theta,\varphi)$$

$$\times\sqrt{\frac{Z_0R_a(\omega)}{4\pi r^2}}\exp(-j\omega\frac{r}{c})I_a(j\omega) \qquad (4)$$

Here Z0 is the impedance of free space wave; F(ω) is the antenna field gain in the frequencyω , the function between F(ω) and the power gain G(ω) can be described as: F(ω) = G(ω) ; R Re | Z ( jω)| a = a ; sign(ω) is the symbolic function. In order to define G(ω) and F(ω) , we need to know the normalization pattern of the antenna.

$$G(\omega)=\frac{4\pi}{\int_S|D(j\omega,\theta,\varphi)|^2\,dS} \qquad (5)$$

Concerning Eq. (2), Eq. (3) and Eq. (4), we can obtain the frequency characteristic of antenna radiation.

$$H_{EA}(j\omega,\theta,\varphi)=-j\,\mathrm{sign}(\omega)F(\omega)D(j\omega,\theta,\varphi)$$
$$\cdot\sqrt{30R_a(\omega)W}/[W+Z_a(\omega)] \qquad (6)$$

Based on Eq. (1), Eq. (6) can be written as:

$$H_r(j\omega)=\frac{2\sqrt{R_a(\omega)W}}{W+Z_a(j\omega)} \qquad (7)$$

$$H_E(j\omega,\theta,\varphi)=-j\,\mathrm{sign}(\omega)\sqrt{7.5}F(\omega)D(j\omega,\theta,\varphi) \qquad (8)$$

$$H_{EA}(j\omega,\theta_0,\varphi_0)=-j\,\mathrm{sign}(\omega)F(\omega) \qquad (9)$$

Commonly, $F(\omega)=|\omega|$ , then

$$H_{EA}(j\omega,\theta_0,\varphi_0)=-j\omega \qquad (10)$$

If $F(\omega)=const$ , then

$$H_{EA}(j\omega,\theta_0,\varphi_0)=-j\,\mathrm{sign}(\omega) \qquad (11)$$

The antenna proceeds the Hilbert's transform to the input signal. Because the amplitude of signal is undistorted3, Eq. (11) can be treated as the undistorted radiation condition of the matching antenna. At the same argument, the frequency characteristic of receiving antenna is:

$$H_{RA}(j\omega,\theta,\varphi)=j\frac{c}{\omega\sqrt{30}}\frac{\sqrt{WR_a(\omega)}}{W+Z_a(j\omega)}F(\omega)D(j\omega,\theta,\varphi) \qquad (12)$$

Eq. (12) can be divided into two factors, one attributes the degree of matching, another attributes the power of electromagnetic field transformed into the power of induced current.

$$H_{RA}(j\omega,\theta,\varphi)=H_m(j\omega)H_r(j\omega,\theta,\varphi) \qquad (13)$$

Where

$$H_m(j\omega)=2\sqrt{WR_a(\omega)}/[W+Z_a(j\omega)] \qquad (14)$$

$$H_r(j\omega,\theta,\varphi)=\frac{1}{\sqrt{7.5}}\frac{c}{\omega}F(\omega)D(j\omega,\theta,\varphi) \qquad (15)$$

$$H_{RA}(j\omega,\theta_0,\varphi_0)=F(\omega)/\omega \qquad (16)$$

Where

$$F(\omega)=\omega \qquad (17)$$

Here, the frequency characteristic of the matching antenna can be described as:

$$H_{RA}(j\omega,\theta_0,\varphi_0)=j\,\mathrm{sign}(\omega)$$

This equal to make Hilbert's transform to the time structure of incident field. But in fact we can treat Eq. (17) as a condition of unsteady state wave undistorted receive. From Eq. (11) and Eq. (17) we can draw an important conclusion, there are difference between the condition of undistorted emission and undistorted receive. We can prove in the same way that, when using super-broadband signal, we can not think that the characteristic of antenna in the state of emission and receive is the same[4][5][6].

### 3.2. The attenuation of ultra-wide-band signal in the atmospheric propagation

According to the knowledge of electric wave propagation, the microwave signal which is propagating below the frequency of 10GHz make a very small propagate attenuation in the atmosphere, and it's about the level of 0.05dB/km. So in the process of short-range transmission, the effect of atmospheric attenuation to ultra-wide-signal can be totally neglected.

## IV. DEMONSTRATION

As we have described above, the electric dipole antenna can make distortion to the super broadband signal in the emission and receive mode.

Because the effective aperture and the frequency of electric dipole in direct proportion, according to the theory of antenna, the directivity of an antenna and the effective aperture an antenna in direct proportion. So to speak, the antenna field gain coefficient F(ω) ~ω of electric dipole antenna in the frequencyω , satisfying the undistorted received condition of super broadband antenna. And now the radiated characteristic of antenna is:

$$H_{TA}(j\omega,\theta_0,\varphi_0) \sim -j\operatorname{sign}(\omega)F(\omega) = -j\omega$$

This equal to make a derivation transform to the initial signal radiated (emission voltage signal of transmitter), the result shown as Fig.2 and Fig.3.

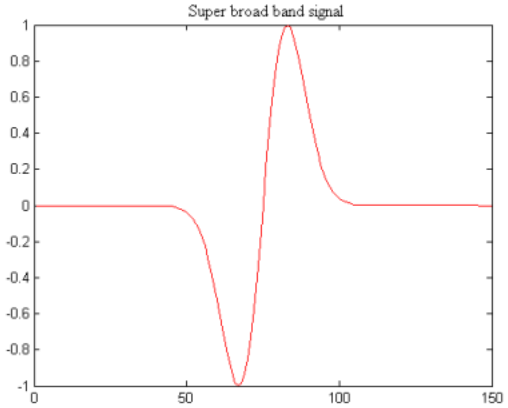

Fig. 2 The super broad band signal

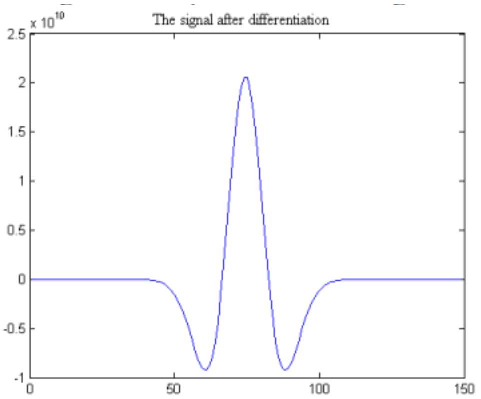

Fig. 3 The signal after differentiation

To verify the method discussed above, we design a S-band narrow-band band-pass filter with λ/4inductive coupled TEM-mode coaxial resonators filter. The main specification is:

Center frequency: 2.35GHz
Pass-band insertion loss: 1dB
3dB bandwidth: 12MHz
Stop-band bandwidth: 80MHz
Stop-band rejection: >30dB
Return loss: >15dB

The design procedure can be list as below:

1. Calculate the number of resonators;
2. Calculate the Q-factor and its size of metal TEM-mode coaxial resonators filter;
3. Get the network model according to the filter prototype;
4. Obtain the size and place of the coupling structure according to the filter equivalent circuit model.

The receive voltage signal in the front-end of receiver is the antenna radiation signal: invert M style.

This phenomenon anastomoses the signal observed from experiment.

## V. CONCLUSION

Ultra-wide-band phased array radar technology is a crucial focus for advancing present phased array radar technology. It is mostly associated with the many new duties that phased array radar has to do in complex scenarios involving multiple targets and functions. As phased array radar technology advances, there is a need to enhance its combat effectiveness and range. This necessitates the radar antenna to possess an extremely broad operating frequency range, as well as the capacity to cover a huge airspace and perform wide-angle scanning. Hence, enhancing the operational capacity of the phased array antenna while effectively mitigating antenna distortion has emerged as a serious issue that requires immediate attention. This study presents the measurement of the distortion effect caused by an Ultra-wide-band radar antenna, as well as the construction of a narrow-band filter. Both theoretical analysis and simulation computation demonstrate that the developed filter has characteristics of being small, stable, readily manufacturable, and cost-effective.

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