Antennas in EW: Sidelobe Jamming and Space Discrimination

EXERCISE OBJECTIVE

To demonstrate that noise jamming can be injected into a radar receiver via the sidelobes of the radar antenna. To outline the effects of effective sidelobe noise jamming. To present antenna space discrimination techniques.

DISCUSSION

Introduction

Radar antenna radiation patterns when observed, can differ significantly from one antenna to the next. Nonetheless all radar antennas have certain similarities, they possess a mainlobe and numerous sidelobes. Figure 1-33 is an example of the radiation pattern of an antenna. Sidelobes are undesired irregularities in the antenna radiation pattern. When considered collectively, the antenna sidelobes are responsible for a substantial portion of an antenna’s radiated signal power. This portion can be as much as 25% of the radiated signal power in some antennas.

Figure 1-33. H-plane radiation pattern for the Lab-Volt Dual Feed Parabolic Antenna (Tracking Radar antenna).
Strong antenna sidelobe levels can be a source of significant ground clutter. When used in military applications, radars with strong sidelobe signal emissions increase the radar’s susceptibility of being detected by the enemy. Strong sidelobes also give the enemy an effective means of injecting noise jamming signals, or spurious radar echo signals, see deceptive jamming signals, into the radar receiver.

**Sidelobe Noise Jamming**

Jamming is conducted through the sidelobes of a receiving antenna, in an attempt to cover, disrupt, or falsify returned radar signal information received through the antenna mainlobe, is known as sidelobe jamming. Sidelobe noise jamming is the preferred electronic attack used against weapon fire-control radar (tracking radar) in the denial of target range and bearing data. Noise jamming through a radar antenna’s mainlobe is to be avoided because it provides the fire-control radar with a strobe in the direction of the jamming platform, as shown in Figure 1-34 (a).

Effective spot or barrage noise jamming conducted through a radar antenna’s mainlobe and sidelobes completely blinds a radar, no matter what its angular antenna position, as illustrated in Figure 1-34 (b). However, to be effective, a sidelobe noise jamming signal must have enough power to overcome the low signal response associated with the radar antenna’s sidelobes. This forces the sidelobe jamming platform to carry large amounts of jamming resources and to employ a highly directional antenna, implying that a large platform is usually required to perform sidelobe jamming.

![Figure 1-34. The effect of mainlobe and sidelobe noise jamming on a search radar.](image)
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Sidelobe noise jamming can be performed by any support jammer. However, because of the efficiency of sidelobe jamming against radar, the sidelobe jamming platform becomes a high-priority target for fire-control radar belonging to the victim force. Because a rather large platform is required to carry dedicated sidelobe jamming resources, it is difficult for a friendly force to give it proper protection. Thus sidelobe jamming is more often conducted in a stand-off jamming position. The low sidelobe response of the victim radar and the long range between the jamming platform and the victim radar, implies that lots of jamming power and a highly directive antenna must be used by a sidelobe jammer in a stand-off position for radar jamming to be effective.

Stand-Off Jamming

A stand-off jamming platform is a type of support jammer. It is located beyond the interception range of hostile weapon systems. A stand-off jammer is often used to provide noise jamming cover to a force of low-RCS platforms infiltrating the detection range of an enemy acquisition or fire-control radar. The stand-off jamming platform must necessarily conduct sidelobe jamming because it is often placed in a geometrically unfavorable position with respect to the radar antenna mainlobe.

Space Discrimination

The antenna is the only device that connects the radar to its working environment. Consequently, the antenna must naturally be considered the first component of a radar system to merit the incorporation of electronic protection measures. By implementing effective EP in the antenna, the degree of damage done to a radar receiver by electronic attack can be limited. The EP can be implemented using space and/or signal discrimination techniques. Antenna space discrimination is the radar’s ability to discriminate between signals input through its mainlobe and signals input through its sidelobes.

When the victim radar has strong sidelobe levels, the stand-off jammer holds a definite advantage in the jammer/radar energy battle. It is therefore necessary to reduce the antenna sidelobe levels of the radar, a method of implementing antenna space discrimination. Low, very-low, and ultra-low sidelobe antennas (see Table 1-4) can be used not only to avoid sidelobe clutter, but to prevent a radar via its sidelobe radiated signal, from being detected by the enemy. To protect the target detection ability of a radar from the effects of sidelobe jamming, the radar antenna sidelobe levels must be between 40 to 80 dB below the maximum mainlobe level.

<table>
<thead>
<tr>
<th>ANTENNA DESCRIPTION</th>
<th>AVERAGE SIDELOBE LEVEL (dB BELOW MAINLOBE MAX. LEVEL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&gt; -30</td>
</tr>
<tr>
<td>Low Sidelobe</td>
<td>-35 to -45</td>
</tr>
<tr>
<td>Very-Low Sidelobe</td>
<td>-45 to -55</td>
</tr>
<tr>
<td>Ultra-Low Sidelobe</td>
<td>&lt; -55</td>
</tr>
</tbody>
</table>

Table 1-4. Sidelobe levels with respect to the mainlobe maximum level.
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Achieving such low sidelobe levels in practical antenna design is difficult and fraught with complications. To alleviate the difficulties in designing these types of radar antennas, two techniques exist to reduce by approximately 20 to 30 dB the levels of jamming signals arriving through the antenna’s sidelobes. The techniques are known as sidelobe cancellation and sidelobe blanking, both function with the use of one or more omnidirectional auxiliary antennas.

By adaptively controlling the phase and the amplitude of the signals received through the auxiliary antennas, before combining them to the signal received through the main radar antenna, sidelobe cancellation can produce a null in the composite antenna pattern. The term “composite antenna pattern” is used to imply the effective radiation pattern of the main radar antenna and the sidelobe cancellation auxiliary antennas. Through continuous adaptive control, the null can be made to track a jamming signal.

Sidelobe blanking is less complex than sidelobe cancellation, however, it is only effective against low duty cycle jamming signals. The gain of the omnidirectional auxiliary antenna used in sidelobe blanking is designed to be 3 to 4 dB above the maximum sidelobe level. Sidelobe blanking functions by comparing the signal received through the auxiliary antenna to the signal received through the main radar antenna. If the auxiliary antenna signal is stronger than the main radar antenna signal, then the signal must have been received through the radar antenna sidelobes and therefore is not sent to the radar receiver. In effect, a sidelobe blanker, blocks radar receiver signal reception when a signal enters the radar system through the antenna sidelobes.

Space discrimination techniques such as low antenna sidelobes, sidelobe cancellation and blanking circuits, beamwidth control, and antenna scan control, minimize the chances a radar has of receiving unwanted sidelobe clutter and jamming. Antenna electronic protections such as those discussed make stand-off noise jamming difficult to conduct effectively against a radar.

Procedure Summary

In the first part of the exercise, the Tracking Radar system is set up and calibrated. The Target Positioning System is also positioned correctly with respect to the Tracking Radar.

The second part of the exercise demonstrates, from a radar operator’s point-of-view, the difference between sidelobe and mainlobe noise jamming. The difference in the jamming resources required by a sidelobe jammer and a mainlobe jammer are characterized.

During the third part of the exercise, the use of track-on-jamming protection by a radar confronted with sidelobe noise jamming is demonstrated.
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PROCEDURE

Setting Up the Tracking Radar

1. Before beginning this exercise, the main elements of the Tracking Radar Training System (i.e., the antenna and its pedestal, the target table, the RTM and its power supply, the training modules, and the host computer) must be set up as shown in Appendix A.

   On the Radar Transmitter, make sure that the RF POWER switch is set to the STANDBY position.

   On the Antenna Controller, make sure that the MANual ANTENNA ROTATION MODE push button is depressed and the SPEED control is set to the 0 position.

   Turn on all modules and make sure the POWER ON LED’s are lit.

2. Turn on the host computer, start the LVRTS software, select Tracking Radar, and click OK. This begins a new session with all settings set to their default values and with all faults deactivated. If the software is already running, click Exit in the File menu and then restart the LVRTS software to begin a new session.

3. Connect the modules as shown on the Tracking Radar tab of the LVRTS software. For details of connections to the Reconfigurable Training Module, refer to the RTM Connections tab of the software.

   Note: Make the connections to the Analog/Digital Output Interface (plug-in module 9632) only if you wish to connect a conventional radar PPI display to the system or obtain an O-scope display on a conventional oscilloscope.

   Note: The SYNC. TRIGGER INPUT of the Dual-Channel Sampler and the PULSE GENERATOR TRIGGER INPUT of the Radar Transmitter must be connected directly to OUTPUT B of the Radar Synchronizer without passing through BNC T-connectors.

   Connect the hand control to a USB port of the host computer.

4. Make the following settings:

   On the Radar Transmitter

   RF OSCILLATOR FREQUENCY . . . . . CAL.
   PULSE GENERATOR PULSE WIDTH . . . 1 ns
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On the Radar Synchronizer / Antenna Controller

PRF ........................................... 288 Hz
PRF MODE ............................ SINGLE
ANTENNA ROTATION MODE ........................ PRF LOCK.
DISPLAY MODE .................... POSITION

On the Dual-Channel Sampler

RANGE SPAN ......................... 3.6 m

In the LVRTS software

System Settings:
Log./Lin. Mode ......................... Lin.
Gain ................................ as required

Radar Display Settings:
Range .................................. 3.6 m

5. Connect the cable of the target table to the connector located on the rear panel of the Target Controller. Make sure that the surface of the target table is free of any objects and then set its POWER switch to the I (on) position.

Place the target table so that its grid is located approximately 1.2 m from the Rotating-Antenna Pedestal, as shown in Figure 1-35. Make sure that the metal rail of the target table is correctly aligned with the shaft of the Rotating-Antenna Pedestal.

Figure 1-35. Position of the Rotating-Antenna Pedestal and target table.
6. Calibrate the Tracking Radar Training System according to the instructions in Appendix B.

Set the RF POWER switch on the Radar Transmitter to the STANDBY position.

7. Make sure that the Tracking Radar is adjusted as follows:

- Operating Frequency: 10.0 GHz
- Pulse-Repetition Frequency: single, 288 Hz
- Pulse Width: 1 ns
- Observation Range: 3.6 m

Sidelobe Noise Jamming Compared with Mainlobe Noise Jamming

8. Replace the semi-cylinder target installed on the target table mast with the cylinder target placed in the upright position. Position the cylinder target at the following target table coordinates: X = 65 cm, Y = 0 cm (see Figure 1-36).

Place the Radar Jamming Pod Trainer support (part number 9595-10), provided with the Connection Leads and Accessories, onto the target table at the following coordinates: X = 45 cm, Y = 88 cm (as shown in Figure 1-36).

9. Install the Radar Jamming Pod Trainer onto its support (in the horizontal position) using the long support shaft (part number 33125-01).
Align the Radar Jamming Pod Trainer so that its horn antennas are facing the Tracking Radar antenna and aligned with the shaft of the Rotating-Antenna Pedestal. The longitudinal axis of the Radar Jamming Pod Trainer should be aligned with the shaft of the Rotating-Antenna Pedestal.

Rotate the infrared receiver on the Radar Jamming Pod Trainer toward the direction from which you will use the remote controller.

Install the Power Supply (Model 9609) of the Radar Jamming Pod Trainer on the shelf located under the surface of the target table. Connect the Power Supply line cord to a wall outlet.

Connect the power cable of the Radar Jamming Pod Trainer to the multi-pin connector located on top of the Power Supply.

10. Install the antenna positioning stand adapter (part numbers 33156 and 33160) onto the top of the positioning stand (part number 33179). Install the single-feed parabolic radar antenna (the parabolic jamming antenna) onto the positioning stand.

Adjust the height of the positioning stand so that the parabolic jamming antenna is approximately at the same level as the Tracking Radar antenna.

11. Position the parabolic jamming antenna behind and slightly beside the Radar Jamming Pod Trainer, as shown in Figure 1-36. Manually orient the parabolic jamming antenna axis toward the shaft of the Rotating-Antenna Pedestal.

Remove the 50-Ω load connected to the COMPLEMENTARY RF OUTPUT of the Radar Jamming Pod Trainer.

Using a 75-cm SMA cable, make a connection between the SMA female connector (RF INPUT) on the antenna positioning stand adapter, and the COMPLEMENTARY RF OUTPUT of the Radar Jamming Pod Trainer.

12. Turn on the Power Supply of the Radar Jamming Pod Trainer. Turn the Radar Jamming Pod Trainer on. Note that the Radar Jamming Pod Trainer status indicates that the Repeater is on.

Turn the repeater of the Radar Jamming Pod Trainer off by making the following settings on the remote controller:

- **Noise** ............... Off
- **AM/Blinking** ................. Off
- **Repeater** .................... Off
- **RGPO** ....................... Off
- **False Targets (FT)** ........... Off

Verify that the Radar Jamming Pod Trainer status, indicated on its rear panel, shows that no jamming signal is being transmitted.
13. Select the SCAN mode of the Tracking Radar to make the antenna rotate.

On the Radar Transmitter, depress the RF POWER push button. The RF POWER ON LED should start to flash on and off. This indicates that RF power is being radiated by the Dual Feed Parabolic Antenna. Target blips should appear on the Radar Display (PPI display) of the Tracking Radar.

Notice that each target displayed on the Radar Display appears as two adjacent blips and is segmented. This is normal and due to the antenna lobe switching performed by the Tracking Radar.

In LVRTS, set the Lobe Control Rate of the Tracking Radar to Off (Right) to disable antenna lobe switching. Notice that the targets are displayed normally on the Radar Display.

14. While observing the Radar Display, adjust the Gain of the MTI Processor of the Tracking Radar so that the cylinder target echo signal is clearly visible but not immersed in clutter.

Consider that the cylinder target represents a low-RCS platform infiltrating the weapon-intercept range of a fire-control radar in surveillance (search) mode. The Radar Jamming Pod Trainer when transmitting via the parabolic jamming antenna can be viewed as a support noise jamming platform in a stand-off position.

15. Using the remote controller, make the following adjustments to the Radar Jamming Pod Trainer:

Noise ................................................. On
Frequency ........................................... 10.0 GHz
Frequency Bandwidth ......................... 1.0 GHz
Frequency Modulation ....................... Random
Attenuation 1 ...................................... 0 dB
Attenuation 2 ...................................... 0 dB
AM/Blinking ........................................ On
Modulation Frequency ......................... -
Modulation ......................................... External
Repeater ............................................... Off
RGPO .................................................. Off
False Targets (FT) .............................. Off

The Radar Jamming Pod Trainer VCO is set to an operating frequency of 10.0 GHz, the same frequency as that of the Tracking Radar. The Radar Jamming Pod Trainer is transmitting a noise jamming signal through the parabolic jamming antenna which is connected to its COMPLEMENTARY RF OUTPUT, with sufficient power to introduce noise into some of the radar antenna's sidelobes.

Note: If noise does not cover several angular sectors on the Radar Display, make sure that the MTI Processor Gain is properly adjusted. Also make sure that the parabolic jamming antenna is at the correct height and aligned with the shaft of the Rotating-Antenna Pedestal.
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Observe the Radar Display and briefly describe how sidelobe noise jamming is different from mainlobe noise jamming.

Can the cylinder target be detected?

☐ Yes ☐ No

16. While observing the O-Scope Display, use the remote controller to turn the Radar Jamming Pod Trainer AM/BLINKING off. This redirects the RF jamming signal of the Radar Jamming Pod Trainer toward the transmit horn antenna instead of having it sent to the COMPLEMENTARY RF OUTPUT and transmitted through the parabolic jamming antenna.

What is the effect of the sidelobe jamming produced on the Radar Display?

Briefly describe how using the transmit horn antenna on the Radar Jamming Pod Trainer, instead of the parabolic jamming antenna, has had an effect on the level of noise injected into the radar receiver.

17. Using the remote controller, turn the Radar Jamming Pod Trainer AM/BLINKING on. This redirects the RF jamming signal of the Radar Jamming Pod Trainer toward the COMPLEMENTARY RF OUTPUT for transmission through the parabolic jamming antenna.

18. Note that the Radar Jamming Pod Trainer Noise Attenuation is equal to 0 dB.
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Using the remote controller, slowly increase the Radar Jamming Pod Trainer Noise Attenuation 1 dB at a time until there is only a narrow jamming strobe on the Radar Display, as shown in Figure 1-37.

![Figure 1-37. A narrow jamming strobe on the Radar Display.](image)

19. The difference in the radiated noise jamming signal power ($P$) used by the Radar Jamming Pod Trainer to conduct sidelobe noise jamming and mainlobe noise jamming is proportional to the difference between the current and previous attenuation values. Record this difference in the following blank space.

$$\Delta P = \text{______} \text{ dB}$$

What does $\Delta P$ imply about the average signal response of the radar antenna's sidelobes?
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**Sidelobe Jamming and TOJ**

20. Select the MANUAL mode of the Tracking Radar to stop antenna rotation. Lock the Tracking Radar onto the echo signal of the cylinder target.

21. On the Target Controller, make sure that the X- and Y-axis SPEED controls are in the MINimum position, then make the following settings:

```
MODE  .............................................. SPEED
DISPLAY MODE  .................................... SPEED
```

Set the Y-axis SPEED control so that the target speed is equal to approximately 10 cm/s.

You should observe that the Tracking Radar is automatically tracking the cylinder target in both range and angle.

22. Using the remote controller, slowly decrease the Radar Jamming Pod Trainer Noise Attenuation 1 dB at a time, while observing the O-Scope Display.

Note that at a certain point, sufficient noise jamming signal power is inserted through the radar antenna sidelobes to disable the Tracking Radar target lock.

Continue lowering the Radar Jamming Pod Trainer Noise Attenuation until it is at its minimum value (0 dB).

23. Enable the track-on-jamming mode of the Tracking Radar by performing the following manipulations:

I. On the Radar Transmitter, disconnect the BNC-connector cable from the TRIGGER INPUT of the PULSE GENERATOR. This disables radar pulse transmission, however reception is maintained.

II. In LVRTS, set the Range Lock Disable to On. This disables automatic range tracking.

III. Orient the axis of the radar antenna toward the cylinder target. Remember that the cylinder target has the role of the infiltrating platform. Lock the Tracking Radar onto noise jamming.

Is the Tracking Radar's antenna pointing toward the cylinder target (infiltrating platform)?

□ Yes  □ No

Move the stand-off jamming antenna sideways while keeping it pointed toward the shaft of the Rotating-Antenna Pedestal.
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Is track-on-jamming an effective countermeasure to sidelobe noise jamming? Briefly explain.

☐ 24. Turn off the Tracking Radar and the Radar Jamming Pod Trainer. Disconnect all cables and remove all accessories.

CONCLUSION

Antennas in electronic warfare must be the first component of a radar system to be considered for incorporation of electronic protection measures. An antenna must incorporate space discrimination techniques to provide the radar with the capability of discriminating between signals input through its radar antenna sidelobes and its antenna mainlobe.

You demonstrated that when effective sidelobe noise jamming is conducted against an acquisition (search) radar, it reduces the radar’s ability of detecting low-RCS targets, no matter what their bearing. You showed that sidelobe noise jamming can disable a tracking radar’s target lock. You also demonstrated that the track-on-jamming capability of certain tracking radars is ineffective against sidelobe noise jamming.

You showed that a stand-off jamming platform requires a high-gain antenna and a strong noise jamming signal to penetrate effectively a radar antenna’s sidelobes.

REVIEW QUESTIONS

1. From the point-of-view of a radar operator, how does sidelobe noise jamming differ from mainlobe noise jamming?

2. Briefly explain antenna space discrimination.
3. Why is it important for an antenna to have a low sidelobe signal response?

4. Why is sidelobe noise jamming, as opposed to mainlobe noise jamming, the preferred electronic attack against weapon fire-control radars in the denial of target range and bearing data?

5. Briefly explain the difference between sidelobe cancellation and sidelobe blanking.