

Appendix

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Appendix A: Wireless Networking Basic Security Checklist

1. The wireless network should be treated as inherently unsecured and vulnerable network structure and reside outside any institutional firewalls.
2. Change ALL the default settings on your Access Point, wireless cards, and routers. These include the SSID, Administrative passwords and User passwords, IP address. The default names and passwords are published by the manufacturers on the Internet and are available to anyone.
3. Never use weak password such as your birthday, name of pet, whole word from dictionary which is easy to crack.
4. Change all the passwords periodically.
5. Consider disabling Automatic SSID Broadcast thus SSID is no longer appeared in BEACON packet. This may cause inconvenience problems for those with a multiple AP setup for fast roaming. However, this will help make your WLAN less likely to be discovered to the rogue intruders.
6. Always use encryption (WEP or WPA) on your wireless network. If possible, use 802.11i-compatible equipments and switch to it.
7. If a fixed number of mobile devices are connecting to the AP(s), disable DHCP function and use static IP addresses. Use a MAC address filter to restrict the

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connection.

8. Design the WLAN to limit RF propagation to only those areas needed for coverage. Choosing the correct antenna and RF power levels can also help it.
9. If privacy and security are real concerns, any higher layer security mechanisms should be adopted, such as **IPSec** or **VPN**.
10. The use of **SSH** (Secure Shell) can be utilized for providing secure connections to your applications that are connected to a remote server. One of the SSH application is POP mail. There are lots of free SSH software such as OPENSSH available at <http://www.openssh.org/>.
11. When connect to the web servers, using **SSL** (Secure Sockets Layer) is recommended.
12. Perform regular network scans on both the LAN and WLAN for “rogue” APs.
13. Perform regular audits and review LAN and WLAN logs.
14. As a standard policy, restrict the use of wireless equipments such as AP, router, laptop, NIC to authorized personnel only.

Appendix B: 802.11 Packets Format

Association Request

| | |
|------------------------------------------------|-----------------------------------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x00 |
| Status: | 0x00 |
| Packet Length: | 54 |
| Timestamp: | 13:44:45.190015800 12/02/2004 |
| Data Rate: | 22 <i>11.0 Mbps</i> |
| Channel: | 6 <i>2437 MHz</i> |
| Signal Level: | 51% |
| Noise Level: | 0% |
| <u>802.11 MAC Header</u> | |
| Version: | 0 |
| Type: | %00 <i>Management</i> |
| Subtype: | %0000 <i>Association Request</i> |
| Frame Control Flags: | %00000000 |
| | <i>0... .. Non-strict order</i> |
| | <i>.0... .. WEP Not Enabled</i> |
| | <i>..0. No More Data</i> |
| | <i>...0 Power Management - active mode</i> |
| | <i>.... 0... This is not a Re-Transmission</i> |
| | <i>.... .0.. Last or Unfragmented Frame</i> |
| | <i>.... ..0. Not an Exit from the Distribution System</i> |
| | <i>.... ...0 Not to the Distribution System</i> |
| Duration: | 213 <i>Microseconds</i> |
| Destination: | 00:40:05:C4:BA:F7 <i>Ani Comm:C4:BA:F7</i> |
| Source: | 00:80:C8:2D:26:13 <i>D-link Sys:2D:26:13</i> |
| BSSID: | 00:40:05:C4:BA:F7 <i>Ani Comm:C4:BA:F7</i> |
| Seq. Number: | 79 |
| Frag. Number: | 0 |
| <u>802.11 Management - Association Request</u> | |
| Capability Info: | %0000000001010001 |
| | <i>x..... .. Reserved</i> |
| | <i>.x..... .. Reserved</i> |
| | <i>..0..... .. DSSS-OFDM is Not Allowed</i> |

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```

...x.... ..... Reserved
....0... ..... Robust Security Network Disabled
.....0.. ..... G Mode Short Slot Time [20 microseconds]
.....x. .... . Reserved
.....x ..... Reserved
..... 0..... Channel Agility Not Used
..... .1..... PBCC
..... ..0.... Short Preamble Not Allowed
..... ...1.... Privacy Enabled
..... ....0... CF Poll Not Requested
..... .....0.. CF Not Pollable
..... .....0. Not an IBSS Type Network
..... .....1 ESS Type Network

Listen Interval: 0
SSID
Element ID: 0 SSID
Length: 7
SSID: 802.11b

Supported Rates
Element ID: 1 Supported Rates
Length: 5
Supported Rate: 1.0 (BSS Basic Rate)
Supported Rate: 2.0 (BSS Basic Rate)
Supported Rate: 5.5 (Not BSS Basic Rate)
Supported Rate: 11.0 (Not BSS Basic Rate)
Supported Rate: 22.0 (Not BSS Basic Rate)

WPA
Element ID: 221 WPA
Length: 4
WPA Value:
..(. 08 00 28 00

FCS - Frame Check Sequence
FCS (Calculated): 0x43C8EDD1
```

Association Response

```

Packet Info
Flags: 0x00
```

Appendix B: 802.11 Packets Format

Status: 0x00
Packet Length: 47
Timestamp: 13:44:45.191807800 12/02/2004
Data Rate: 4 2.0 Mbps
Channel: 6 2437 MHz
Signal Level: 56%
Noise Level: 0%

802.11 MAC Header

Version: 0
Type: %00 Management
Subtype: %0001 Association Response
Frame Control Flags: %00000000
0... .. Non-strict order
.0... .. WEP Not Enabled
..0. No More Data
...0 Power Management - active mode
.... 0... This is not a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..0. Not an Exit from the Distribution System
.... ...0 Not to the Distribution System

Duration: 258 Microseconds
Destination: 00:80:C8:2D:26:13 D-link Sys:2D:26:13
Source: 00:40:05:C4:BA:F7 Ani Comm:C4:BA:F7
BSSID: 00:40:05:C4:BA:F7 Ani Comm:C4:BA:F7
Seq. Number: 2142
Frag. Number: 0

802.11 Management - Association Response

Capability Info: %0000000001010001
x..... Reserved
.x..... Reserved
..0..... DSSS-OFDM is Not Allowed
...x.... Reserved
....0... Robust Security Network Disabled
.....0.. G Mode Short Slot Time [20 microseconds]
.....x. Reserved
.....x. Reserved
..... 0..... Channel Agility Not Used
..... .1..... PBCC
..... ..0..... Short Preamble Not Allowed
..... ...1.... Privacy Enabled
.....0... CF Poll Not Requested
.....0.. CF Not Pollable

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```
.....0. Not an IBSS Type Network
.....1 ESS Type Network

Status Code:      0 Successful
Association ID:   0xC001
Supported Rates
Element ID:      1 Supported Rates
Length:          5
Supported Rate:  1.0 (BSS Basic Rate)
Supported Rate:  2.0 (BSS Basic Rate)
Supported Rate:  5.5 (Not BSS Basic Rate)
Supported Rate:  11.0 (Not BSS Basic Rate)
Supported Rate:  22.0 (Not BSS Basic Rate)

WPA
Element ID:      221 WPA
Length:          4
WPA Value:
..(.           08 00 28 00

FCS - Frame Check Sequence
FCS (Calculated): 0x25AEFB56
```

Reassociation Request

```
Packet Info
Flags:           0x02 CRC Error
Status:          0x00
Packet Length:   145
Timestamp:       14:21:29.427397400 12/02/2004
Data Rate:       22 11.0 Mbps
Channel:         6 2437 MHz
Signal Level:    1%
Noise Level:     0%

802.11 MAC Header
Version:         1
Type:            %00 Management
Subtype:         %0010 Reassociation Request
Frame Control Flags: %10010011
1... .. Frames Must Be Strictly Ordered
.0... .. WEP Not Enabled
..0. .... No More Data
...1 .... Power Management - power save mode
```

Appendix B: 802.11 Packets Format

| | |
|-----------------------------------|-------------------------------------------------|
| | 0... This is not a Re-Transmission |
| |0.. Last or Unfragmented Frame |
| |1. Exit from the Distribution System |
| |1 To the Distribution System |
| Duration: | 48260 <i>Microseconds</i> |
| Destination: | 1C:87:39:3F:93:C6 |
| Source: | 18:DC:48:AF:20:DA |
| BSSID: | 75:C6:E7:93:9E:02 |
| Seq. Number: | 3693 |
| Frag. Number: | 11 |
| <u>Application Layer</u> | |
| Continued Data: | |
| ..H.h.....%... | E6 AC 48 88 68 BA CF 9A B6 F1 90 DC 25 93 E3 D3 |
| .ts.,.9S. m...W. | AE 74 73 DD 2C CD 39 53 C3 7C 6D E8 E9 AC 57 8A |
| .R.L.WK%,....W{ | C0 52 9C 4C 00 57 4B 25 FE 2C D8 BD DE F1 57 7B |
|}x.....}Q..] | E9 A2 D3 A0 7D 78 17 D9 F5 BE 94 7D 51 C8 A0 5D |
| b.pO..h...;...WO. | 62 F2 70 4F A1 B1 68 10 1F 3B B4 FF A6 57 4F 0B |
| .x.....w!.V.KO` | CF 78 ED F6 C7 B9 CD 13 77 21 8C 56 E4 4B 4F 60 |
|!....?.....S | D9 A5 AA D8 21 C6 DE E4 BD 3F 7F 06 C8 A8 EA 53 |
| 91.y.F | 39 31 D5 79 E8 46 |
| <u>FCS - Frame Check Sequence</u> | |
| FCS (Calculated): | 0x28A713D0 |

Reassociation Response

| | |
|-----------------------------|--------------------------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x02 <i>CRC Error</i> |
| Status: | 0x00 |
| Packet Length: | 151 |
| Timestamp: | 14:21:17.677108600 12/02/2004 |
| Data Rate: | 22 <i>11.0 Mbps</i> |
| Channel: | 6 <i>2437 MHz</i> |
| Signal Level: | 0% |
| Noise Level: | 0% |
| <u>802.11 MAC Header</u> | |
| Version: | 0 |
| Type: | %00 <i>Management</i> |
| Subtype: | %0011 <i>Reassociation Response</i> |
| Frame Control Flags: | %10001010 |
| | <i>1... Frames Must Be Strictly Ordered</i> |
| | <i>.0.. WEP Not Enabled</i> |

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```
..0. .... No More Data
...0 .... Power Management - active mode
.... 1... This is a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..1. Exit from the Distribution System
.... ...0 Not to the Distribution System

Duration:          8522  Microseconds
Destination:      8C:39:ED:FF:8E:8F
Source:           24:C5:D5:C9:26:67
BSSID:            35:0B:40:5B:64:D7
Seq. Number:      1677
Frag. Number:     6

Application Layer
Continued Data:
h...M.....V.h. 68 FB 95 B1 4D ED D8 EE DE 8B F8 06 56 97 68 C2
.N.S.w...ni..A.. FA 4E C8 53 F4 77 C5 1A 8A 6E 69 86 F4 41 05 91
...)\(3.s....[J( ED DB 80 29 5C 28 33 ED 73 EC F2 05 FD 5B 4A 28
a..uK.....'.21.. 61 EC EB 75 4B 82 9E F3 FE B5 27 8C 32 31 0A A9
.:`V....3.~.?..! 90 3A 60 56 F8 E1 ED E8 33 ED 7E CD 3F 88 CA 21
~M{b.?O.f...'..C. 7E 4D 7B 62 A0 3F 4F CD 66 F4 F2 27 12 8C 43 E5
.....&.....:d... B4 FB 03 D3 EB 26 DF 0B C3 E9 3A C5 64 5F E2 DD
.d....H...x.      8B 64 09 B5 84 1D 48 1E F4 DE 78 93

FCS - Frame Check Sequence
FCS (Calculated): 0xB236C6AC
```

Probe Request

```
Packet Info
Flags:            0x00
Status:           0x00
Packet Length:    47
Timestamp:        13:44:45.049522800 12/02/2004
Data Rate:        2    1.0 Mbps
Channel:          6    2437 MHz
Signal Level:     51%
Noise Level:      0%

802.11 MAC Header
Version:          0
Type:             %00  Management
Subtype:          %0100 Probe Request
Frame Control Flags: %00000000
```

Appendix B: 802.11 Packets Format

0... .. Non-strict order
.0... .. WEP Not Enabled
..0. No More Data
...0 Power Management - active mode
.... 0... This is not a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..0. Not an Exit from the Distribution System
.... ...0 Not to the Distribution System

Duration: 0 *Microseconds*
Destination: FF:FF:FF:FF:FF:FF *Ethernet Broadcast*
Source: 00:80:C8:2D:26:13 *D-link Sys:2D:26:13*
BSSID: FF:FF:FF:FF:FF:FF *Ethernet Broadcast*
Seq. Number: 55
Frag. Number: 0

802.11 Management - Probe Request

SSID

Element ID: 0 *SSID*
Length: 0

Supported Rates

Element ID: 1 *Supported Rates*
Length: 5
Supported Rate: 1.0 *(BSS Basic Rate)*
Supported Rate: 2.0 *(BSS Basic Rate)*
Supported Rate: 5.5 *(BSS Basic Rate)*
Supported Rate: 11.0 *(BSS Basic Rate)*
Supported Rate: 22.0 *(Not BSS Basic Rate)*

Extended Supported Rates

Element ID: 50 *Extended Supported Rates*
Length: 8
Supported Rate: 6.0 *(Not BSS Basic Rate)*
Supported Rate: 9.0 *(Not BSS Basic Rate)*
Supported Rate: 12.0 *(Not BSS Basic Rate)*
Supported Rate: 18.0 *(Not BSS Basic Rate)*
Supported Rate: 24.0 *(Not BSS Basic Rate)*
Supported Rate: 36.0 *(Not BSS Basic Rate)*
Supported Rate: 48.0 *(Not BSS Basic Rate)*
Supported Rate: 54.0 *(Not BSS Basic Rate)*

FCS - Frame Check Sequence

FCS (Calculated): 0x7C7F27C9

Probe Response

Packet Info

Flags: 0x00
Status: 0x00
Packet Length: 65
Timestamp: 13:44:45.050189800 12/02/2004
Data Rate: 4 2.0 Mbps
Channel: 6 2437 MHz
Signal Level: 57%
Noise Level: 0%

802.11 MAC Header

Version: 0
Type: %00 Management
Subtype: %0101 Probe Response
Frame Control Flags: %00000000
0... .. Non-strict order
.0.. .. WEP Not Enabled
..0. No More Data
...0 Power Management - active mode
.... 0... This is not a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..0. Not an Exit from the Distribution System
.... ...0 Not to the Distribution System

Duration: 258 Microseconds
Destination: 00:80:C8:2D:26:13 D-link Sys:2D:26:13
Source: 00:40:05:C4:BA:F7 Ani Comm:C4:BA:F7
BSSID: 00:40:05:C4:BA:F7 Ani Comm:C4:BA:F7
Seq. Number: 2137
Frag. Number: 0

802.11 Management - Probe Response

Timestamp: 9689681819 Microseconds
Beacon Interval: 100
Capability Info: %0000000001010001
x..... Reserved
..x..... Reserved
..0..... DSSS-OFDM is Not Allowed
...x.... Reserved
....0... Robust Security Network Disabled
.....0.. G Mode Short Slot Time [20 microseconds]
.....x. Reserved

Appendix B: 802.11 Packets Format

```
.....X ..... Reserved
..... 0..... Channel Agility Not Used
..... .1..... PBCC
..... ..0..... Short Preamble Not Allowed
..... ....1..... Privacy Enabled
..... .....0... CF Poll Not Requested
..... .....0.. CF Not Pollable
..... .....0. Not an IBSS Type Network
..... .....1 ESS Type Network
```

SSID

```
Element ID:      0  SSID
Length:          7
SSID:            802.11b
```

Supported Rates

```
Element ID:      1  Supported Rates
Length:          5
Supported Rate:  1.0  (BSS Basic Rate)
Supported Rate:  2.0  (BSS Basic Rate)
Supported Rate:  5.5  (Not BSS Basic Rate)
Supported Rate:  11.0 (Not BSS Basic Rate)
Supported Rate:  22.0 (Not BSS Basic Rate)
```

Direct Sequence Parameter Set

```
Element ID:      3  Direct Sequence Parameter Set
Length:          1
Channel:         6
```

WPA

```
Element ID:      221 WPA
Length:          4
WPA Value:
..(.            08 00 28 00
```

FCS - Frame Check Sequence

```
FCS (Calculated): 0x55D6E29C
```

Beacon

Packet Info

```
Flags:           0x00
Status:          0x00
```

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| | |
|-----------------------------------|----------------------------------------------------|
| Packet Length: | 65 |
| Timestamp: | 13:44:45.275876800 12/02/2004 |
| Data Rate: | 4 2.0 Mbps |
| Channel: | 6 2437 MHz |
| Signal Level: | 50% |
| Noise Level: | 0% |
| <u>802.11 MAC Header</u> | |
| Version: | 0 |
| Type: | %00 Management |
| Subtype: | %1000 Beacon |
| Frame Control Flags: | %00000000 |
| | 0... .. Non-strict order |
| | .0.. .. WEP Not Enabled |
| | ..0. No More Data |
| | ...0 Power Management - active mode |
| | 0... This is not a Re-Transmission |
| |0.. Last or Unfragmented Frame |
| |0. Not an Exit from the Distribution System |
| |0 Not to the Distribution System |
| Duration: | 0 Microseconds |
| Destination: | FF:FF:FF:FF:FF:FF Ethernet Broadcast |
| Source: | 00:40:05:C4:BA:F7 Ani Comm:C4:BA:F7 |
| BSSID: | 00:40:05:C4:BA:F7 Ani Comm:C4:BA:F7 |
| Seq. Number: | 2143 |
| Frag. Number: | 0 |
| <u>802.11 Management - Beacon</u> | |
| Timestamp: | 9689907489 Microseconds |
| Beacon Interval: | 100 |
| Capability Info: | %0000000001010001 |
| | x..... Reserved |
| | .x..... Reserved |
| | ..0..... DSSS-OFDM is Not Allowed |
| | ...x.... Reserved |
| |0... Robust Security Network Disabled |
| |0.. G Mode Short Slot Time [20 microseconds] |
| |x. Reserved |
| |x Reserved |
| | 0..... Channel Agility Not Used |
| |1..... PBCC |
| |0..... Short Preamble Not Allowed |
| |1.... Privacy Enabled |
| |0... CF Poll Not Requested |

Appendix B: 802.11 Packets Format

| | |
|----------------------------------------------|-----------------------------------------|
| |0.. <i>CF Not Pollable</i> |
| |0. <i>Not an IBSS Type Network</i> |
| |1 <i>ESS Type Network</i> |
| SSID | |
| Element ID: | 0 <i>SSID</i> |
| Length: | 7 |
| SSID: | 802.11b |
| Supported Rates | |
| Element ID: | 1 <i>Supported Rates</i> |
| Length: | 5 |
| Supported Rate: | 1.0 <i>(BSS Basic Rate)</i> |
| Supported Rate: | 2.0 <i>(BSS Basic Rate)</i> |
| Supported Rate: | 5.5 <i>(Not BSS Basic Rate)</i> |
| Supported Rate: | 11.0 <i>(Not BSS Basic Rate)</i> |
| Supported Rate: | 22.0 <i>(Not BSS Basic Rate)</i> |
| Direct Sequence Parameter Set | |
| Element ID: | 3 <i>Direct Sequence Parameter Set</i> |
| Length: | 1 |
| Channel: | 6 |
| Traffic Indication Map | |
| Element ID: | 5 <i>Traffic Indication Map</i> |
| Length: | 4 |
| DTIM Count: | 1 |
| DTIM Period: | 3 |
| Traffic Ind.: | 0 |
| Bitmap Offset: | 0 |
| Part Virt Bmap: | 0x00 |
| <u>FCS - Frame Check Sequence</u> | |
| FCS (Calculated): | 0xDD8248E4 |

Disassociation

| | |
|---------------------------|-------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x02 <i>CRC Error</i> |
| Status: | 0x00 |
| Packet Length: | 151 |
| Timestamp: | 14:30:51.241237600 12/02/2004 |
| Data Rate: | 22 <i>11.0 Mbps</i> |

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| | | |
|-----------------------------------|-------------------------------------------------|------------------------------------------|
| Channel: | 6 | 2437 MHz |
| Signal Level: | 6% | |
| Noise Level: | 0% | |
| <u>802.11 MAC Header</u> | | |
| Version: | 2 | |
| Type: | %00 | Management |
| Subtype: | %1010 | Disassociation |
| Frame Control Flags: | %10100101 | |
| | 1... .. | Frames Must Be Strictly Ordered |
| | .0... .. | WEP Not Enabled |
| | ..1. | More Data |
| | ...0 | Power Management - active mode |
| | 0... | This is not a Re-Transmission |
| |1.. | More Fragments to Follow |
| |0. | Not an Exit from the Distribution System |
| |1 | To the Distribution System |
| Duration: | 15923 | Microseconds |
| Destination: | 21:08:BF:11:1B:A1 | |
| Source: | 92:9E:99:FC:3D:BB | |
| BSSID: | C5:EA:02:8B:12:9D | |
| Seq. Number: | 3946 | |
| Frag. Number: | 10 | |
| <u>Application Layer</u> | | |
| Continued Data: | | |
|) | F6 9E C2 2C D7 98 98 B7 C6 C5 94 29 BC 09 DE 9E | |
| .U..D...{.O ... | 9B 55 A7 9F 44 CB A1 C3 D6 7B FC 4F 7C EB D6 19 | |
| l<..+M.....F.... | 6C 3C 0E D4 2B 4D 02 C5 F7 8E A9 46 EB E7 0E AE | |
| >.(1..a....N.... | 3E 96 28 6C 83 1D 61 C5 BE 1E 95 4E F9 F0 80 C5 | |
| ..[>.w .CG.e..`. | 9B F7 5B 3E B0 77 7C DC 43 47 C0 65 BF 04 60 8E | |
| ..m.X..u.....P | AF D4 6D 05 58 C4 D9 75 9B E7 F6 0C 8C D9 D8 50 | |
| .}.f.. ...D"...H | DD 7D F3 66 8C 86 20 B9 A8 8D 44 22 1A A4 2E 48 | |
| "._\.J.. | 22 D3 5F 5C EE FD A4 14 D7 4A B7 95 | |
| <u>FCS - Frame Check Sequence</u> | | |
| FCS (Calculated): | 0xF72F6277 | |

Authentication

| | |
|--------------------|-------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x00 |
| Status: | 0x00 |
| Packet Length: | 34 |
| Timestamp: | 13:44:45.188475800 12/02/2004 |

Appendix B: 802.11 Packets Format

| | | |
|-------------------------------------------|-------------------|------------------------------------------|
| Data Rate: | 22 | 11.0 Mbps |
| Channel: | 6 | 2437 MHz |
| Signal Level: | 51% | |
| Noise Level: | 0% | |
| <u>802.11 MAC Header</u> | | |
| Version: | 0 | |
| Type: | %00 | Management |
| Subtype: | %1011 | Authentication |
| Frame Control Flags: | %00000000 | |
| | 0... .. | Non-strict order |
| | .0... .. | WEP Not Enabled |
| | ..0. | No More Data |
| | ...0 | Power Management - active mode |
| | 0... | This is not a Re-Transmission |
| |0.. | Last or Unfragmented Frame |
| |0. | Not an Exit from the Distribution System |
| |0 | Not to the Distribution System |
| Duration: | 213 | Microseconds |
| Destination: | 00:40:05:C4:BA:F7 | Ani Comm:C4:BA:F7 |
| Source: | 00:80:C8:2D:26:13 | D-link Sys:2D:26:13 |
| BSSID: | 00:40:05:C4:BA:F7 | Ani Comm:C4:BA:F7 |
| Seq. Number: | 78 | |
| Frag. Number: | 0 | |
| <u>802.11 Management - Authentication</u> | | |
| Auth. Algorithm: | 0 | Open System |
| Auth. Seq. Num.: | 1 | |
| Status Code: | 0 | Reserved |
| <u>FCS - Frame Check Sequence</u> | | |
| FCS (Calculated): | 0xEE8638F8 | |

Deauthentication

| | |
|--------------------|-------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x02 CRC Error |
| Status: | 0x04 Encrypted |
| Packet Length: | 151 |
| Timestamp: | 15:17:49.002287200 12/02/2004 |
| Data Rate: | 22 11.0 Mbps |
| Channel: | 6 2437 MHz |
| Signal Level: | 0% |
| Noise Level: | 0% |

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802.11 MAC Header

Version: 3
Type: %00 *Management*
Subtype: %1100 *Deauthentication*
Frame Control Flags: %11000101
1... .. Frames Must Be Strictly Ordered
.1.. .. WEP Enabled
..0. No More Data
...0 Power Management - active mode
.... 0... This is not a Re-Transmission
.... .1.. More Fragments to Follow
.... ..0. Not an Exit from the Distribution System
.... ...1 To the Distribution System

Duration: 24961 *Microseconds*
Destination: 04:6B:63:F8:B3:DB
Source: C4:33:D5:37:AF:B9
BSSID: 8D:0B:DA:83:41:E5
Seq. Number: 2828
Frag. Number: 10

Application Layer

Continued Data:

```
...g...U>.....P; B0 92 15 67 A7 F8 D4 55 3E 85 F4 A7 A4 C3 50 3B
9.w..$a&.g1.... 39 9B 77 DB F9 24 61 40 26 0B 67 31 B6 04 A0 82
..' [...]{...5. k 86 B8 27 5B B6 90 98 00 7B 13 0C 8A 35 A7 20 6B
*N....KzV...n.. 2A 4E E4 9B 1D F8 C7 4B 7A 56 C4 B0 82 6E CF FB
..C,.....u.L!. CB 08 43 2C AD C8 08 CE DA 9F 13 75 09 4C 21 C7
.....xp..|![...s. 09 D8 02 02 01 78 70 AA F7 7C 21 5B B5 CC 73 88
...k...~..... C5 99 88 6B D9 BC 7E 19 B4 83 85 94 A5 16 A5 D6
1...4..... 31 D7 84 F4 34 05 87 19 CB E9 B7 88
```

FCS - Frame Check Sequence

FCS (Calculated): 0x0D12CFA1

PS-Poll

Packet Info

Flags: 0x03 *CRC Error*
Status: 0x04 *Encrypted*
Packet Length: 20
Timestamp: 14:48:57.577178400 12/02/2004
Data Rate: 22 *11.0 Mbps*
Channel: 6 *2437 MHz*
Signal Level: 5%

Appendix B: 802.11 Packets Format

| | |
|-----------------------------------|----------------------------------------------------|
| Noise Level: | 0% |
| <u>802.11 MAC Header</u> | |
| Version: | 3 |
| Type: | %01 Control |
| Subtype: | %1010 Power Save (PS)-Poll |
| Frame Control Flags: | %01110001 |
| | 0... .. Non-strict order |
| | .1... .. WEP Enabled |
| | ..1. More Data |
| | ...1 Power Management - power save mode |
| | 0... This is not a Re-Transmission |
| |0.. Last or Unfragmented Frame |
| |0. Not an Exit from the Distribution System |
| |1 To the Distribution System |
| Assoc. ID: | 0x84D7 |
| BSSID: | A6:5F:1E:D6:8A:33 |
| Transmitter: | 5A:6B:4D:A2:13:5D |
| <u>FCS - Frame Check Sequence</u> | |
| FCS (Calculated): | 0x047A86B9 |

RTS

| | |
|--------------------------|----------------------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x03 CRC Error |
| Status: | 0x00 |
| Packet Length: | 20 |
| Timestamp: | 14:30:30.863877600 12/02/2004 |
| Data Rate: | 22 11.0 Mbps |
| Channel: | 6 2437 MHz |
| Signal Level: | 5% |
| Noise Level: | 0% |
| <u>802.11 MAC Header</u> | |
| Version: | 2 |
| Type: | %01 Control |
| Subtype: | %1011 Request To Send (RTS) |
| Frame Control Flags: | %00110000 |
| | 0... .. Non-strict order |
| | .0... .. WEP Not Enabled |
| | ..1. More Data |
| | ...1 Power Management - power save mode |
| | 0... This is not a Re-Transmission |

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| | |
|------------------------------------------|-----------------------------------------------------------|
| |0.. <i>Last or Unfragmented Frame</i> |
| |0. <i>Not an Exit from the Distribution System</i> |
| |0 <i>Not to the Distribution System</i> |
| Duration: | 27131 <i>Microseconds</i> |
| Receiver: | 55:6C:06:67:90:51 |
| Transmitter: | 27:83:A0:28:CF:1D |
| <u>FCS - Frame Check Sequence</u> | |
| FCS (Calculated): | 0x7929BCA8 |

CTS

| | |
|------------------------------------------|----------------------------------------------------|
| <u>Packet Info</u> | |
| Flags: | 0x03 <i>CRC Error</i> |
| Status: | 0x04 <i>Encrypted</i> |
| Packet Length: | 14 |
| Timestamp: | 15:17:19.103472400 12/02/2004 |
| Data Rate: | 22 <i>11.0 Mbps</i> |
| Channel: | 6 <i>2437 MHz</i> |
| Signal Level: | 2% |
| Noise Level: | 0% |
| <u>802.11 MAC Header</u> | |
| Version: | 3 |
| Type: | %01 <i>Control</i> |
| Subtype: | %1100 <i>Clear To Send (CTS)</i> |
| Frame Control Flags: | %11100011 |
| | 1... <i>Frames Must Be Strictly Ordered</i> |
| | .1.. <i>WEP Enabled</i> |
| | ..1. <i>More Data</i> |
| | ...0 <i>Power Management - active mode</i> |
| |0... <i>This is not a Re-Transmission</i> |
| |0.. <i>Last or Unfragmented Frame</i> |
| |1. <i>Exit from the Distribution System</i> |
| |1 <i>To the Distribution System</i> |
| Duration: | 1 <i>Microseconds</i> |
| Receiver: | FF:F1:00:82:CF:68 |
| <u>FCS - Frame Check Sequence</u> | |
| FCS (Calculated): | 0x3AFFD2CA |

Appendix B: 802.11 Packets Format

ACK

Packet Info

Flags: 0x01
Status: 0x00
Packet Length: 14
Timestamp: 13:44:48.857976800 12/02/2004
Data Rate: 4 2.0 Mbps
Channel: 6 2437 MHz
Signal Level: 52%
Noise Level: 0%

802.11 MAC Header

Version: 0
Type: %01 Control
Subtype: %1101 Acknowledgment (ACK)
Frame Control Flags: %00000000
*0... Non-strict order
.0... WEP Not Enabled
..0. No More Data
...0 Power Management - active mode
.... 0... This is not a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..0. Not an Exit from the Distribution System
.... ...0 Not to the Distribution System*
Duration: 0 Microseconds
Receiver: 00:80:C8:2D:26:13 D-link Sys:2D:26:13

FCS - Frame Check Sequence

FCS (Calculated): 0x77269AC0

CF End

Packet Info

Flags: 0x03 CRC Error
Status: 0x04 Encrypted
Packet Length: 20
Timestamp: 13:44:34.387773800 12/02/2004
Data Rate: 22 11.0 Mbps
Channel: 6 2437 MHz
Signal Level: 3%
Noise Level: 0%

802.11 MAC Header

Version: 0

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```
Type: %01 Control
Subtype: %1110 Contention Free (CF)-End
Frame Control Flags: %11101001
1... .. Frames Must Be Strictly Ordered
.1... .. WEP Enabled
..1. .... More Data
...0 .... Power Management - active mode
.... 1... This is a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..0. Not an Exit from the Distribution System
.... ...1 To the Distribution System

Duration: 5558 Microseconds
Receiver: 27:94:10:4E:A0:1B
BSSID: 2A:BF:86:36:40:63
FCS - Frame Check Sequence
FCS (Calculated): 0x6C40095D
```

CF End + CF ACK

```
Packet Info
Flags: 0x03 CRC Error
Status: 0x00
Packet Length: 20
Timestamp: 15:20:51.614744600 12/02/2004
Data Rate: 22 11.0 Mbps
Channel: 6 2437 MHz
Signal Level: 7%
Noise Level: 0%
802.11 MAC Header
Version: 1
Type: %01 Control
Subtype: %1111 CF-End + CF-Ack
Frame Control Flags: %00110000
0... .. Non-strict order
.0... .. WEP Not Enabled
..1. .... More Data
...1 .... Power Management - power save mode
.... 0... This is not a Re-Transmission
.... .0.. Last or Unfragmented Frame
.... ..0. Not an Exit from the Distribution System
.... ...0 Not to the Distribution System
```

Appendix B: 802.11 Packets Format

Duration: 58633 *Microseconds*

Receiver: CF:AB:24:54:3A:92

BSSID: 5E:74:DD:EC:CF:01

FCS - Frame Check Sequence

FCS (Calculated): 0x67A77544

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```
if (~isnumeric(time)) | (length(time)~=1)
    error(' INPUT ERROR: TIME must be a numeric number in seconds');
end
else
    error(' INPUT ERROR: Too many input arguments!');
end

splashImage = im2java(I);
win = javax.swing.JWindow;
icon = javax.swing.ImageIcon(splashImage);
label = javax.swing.JLabel(icon);
win.getContentPane.add(label);

% get the actual screen size
screenSize = win.getToolkit.getScreenSize;
screenHeight = screenSize.height;
screenWidth = screenSize.width;
% get the actual splashImage size
imgHeight = icon.getIconHeight;
imgWidth = icon.getIconWidth;
% set the splash image to the center of the screen
win.setLocation((screenWidth-imgWidth)/2, (screenHeight-imgHeight)/2);
win.pack
win.show % show the splash screen
tic;
while toc<=time
end
win.dispose % close the splash screen
```


Improving Security in WLAN with the Use of Smart Antennas

```
% Choose default command line output for main
handles.output = hObject;
guidata(hObject, handles);
movegui(hObject, 'onscreen')           % To display application onscreen
movegui(hObject, 'center')           % To display
                                       % application in the
                                       % center of screen

axes(handles.axes1);
handles.GU=imread('GU logo.jpg');
image(handles.GU);
set(handles.axes1, 'Visible', 'off', 'Units', 'pixels');

x=[1:2:180]*pi/180;
y=[1:2:180]*pi/180;
for i=1:length(x)
    for j=1:length(y)
        if x(i)/2+y(j) > pi
            z(i,j)=(x(i)/2+y(j))/pi+sin(pi-y(j))/pi-1;
        else
            z(i,j)=tan(x(i)/2).*tan(y(j)/2)./(tan(x(i)/2)+tan(y(j)/2))/pi;
        end
    end
end
set(handles.axes1, 'HandleVisibility', 'OFF')
set(handles.axes2, 'HandleVisibility', 'ON')
mesh(x*180/pi, y*180/pi, log(10./z));
view(55, 10);
shading interp;
xlabel('Beamwidth  $\theta$ ');

ylabel('Beamwidth  $\alpha$ ');

zlabel('Security level  $\eta$ ');
title('Security level definition IV');
grid on;

% Update handles structure
guidata(hObject, handles);

% --- Outputs from this function are returned to the command line.
function varargout = main_OutputFcn(hObject, eventdata, handles)
```

HTAppendix D: Matlab Code for Main MenuTH

```
varargout{1} = handles.output;

% --- Executes on button press in quit.
function quit_Callback(hObject, eventdata, handles)
selection = questdlg(['Close ' get(gcf,'Name') '?'],...
['Close ' get(gcf,'Name') '...' ],...
'Yes', 'No', 'Yes');
if strcmp(selection,'No')
    return;
end
close(gcf);

function next_Callback(hObject, eventdata, handles)
global APVALUE1 APVALUE2 TERVALUE1 TERVALUE2
if (APVALUE2==1) & (TERVALUE1==1)
    close(gcf);run menu2;
elseif (APVALUE1==1) & (TERVALUE2==1)
    close(gcf);run menu3;
elseif (APVALUE2==1) & (TERVALUE2==1)
    close(gcf);run menu4;
else
    close(gcf);run menu1;
end

function file_Callback(hObject, eventdata, handles)

% -----
function new_Callback(hObject, eventdata, handles)

% -----
function help_Callback(hObject, eventdata, handles)

% -----
function about_Callback(hObject, eventdata, handles)
msgbox('This software is designed to demonstrate the procedure of security
level defintion in wireless communication.','About this software');

% -----
function uipanel1_SelectionChangeFcn(hObject, eventdata, handles)
global APVALUE1 APVALUE2
switch get(hObject,'Tag') % Get Tag of selected object
    case 'radiobutton1'
        APVALUE1=1;APVALUE2=0;
```

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```
    case 'radiobutton2'
        APVALUE1=0;APVALUE2=1;
end

% -----
function uipanel2_SelectionChangeFcn(hObject, eventdata, handles)
global TERVERUE1 TERVERUE2
switch get(hObject,'Tag') % Get Tag of selected object
    case 'radiobutton3'
        TERVERUE1=1;TERVALUE2=0;
    case 'radiobutton4'
        TERVERUE1=0;TERVALUE2=1;
end
```

Appendix E: Matlab Code for Sub-Menu1

```
function varargout = menu1(varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% menu1.m
% Calculating corresponding S11, beamwidth and security level
% in scenario 1:
%           AP: Omni-directional antenna
%           Station: Omni-directional antenna
% Author : Zhaohui, 2145340
% Version: 1.0
% Date   : 20.04.2005
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',  gui_Singleton, ...
                  'gui_OpeningFcn', @menu1_OpeningFcn, ...
                  'gui_OutputFcn',  @menu1_OutputFcn, ...
                  'gui_LayerFcn',   [], ...
                  'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end

% --- Executes just before menu1 is made visible.
function menu1_OpeningFcn(hObject, eventdata, handles, varargin)
handles.output = hObject;

guidata(hObject, handles);
movegui(hObject, 'onscreen') % To display application onscreen
movegui(hObject, 'center')  % To display
```

Improving Security in WLAN with the Use of Smart Antennas

```
                                % application in the
                                % center of screen

axes(handles.axes1);
handles.GU=imread('scene1.jpg');
image(handles.GU);
set(handles.axes1, 'Visible', 'off', 'Units', 'pixels');

axes(handles.axes2);
handles.aaa=imread('pattern1.jpg');
image(handles.aaa);
set(handles.axes2, 'Visible', 'off', 'Units', 'pixels');

% Update handles structure
guidata(hObject, handles);

% --- Outputs from this function are returned to the command line.
function varargout = menu1_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;

function edit12_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit12_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit13_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit13_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit14_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit14_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
```

Appendix E: Matlab Code for Sub-Menu1

```
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

% --- Executes on button press in Back.
function Back_Callback(hObject, eventdata, handles)
close(gcf);
run main
```


Improving Security in WLAN with the Use of Smart Antennas

```
% application in the
% center of screen

axes(handles.axes1);
handles.GU=imread('scene2.jpg');
image(handles.GU);
set(handles.axes1, 'Visible', 'off', 'Units', 'pixels');

axes(handles.axes2);
set(handles.axes1, 'HandleVisibility', 'OFF')
set(handles.axes2, 'HandleVisibility', 'ON')

ha=axes('position', [1 1 1 1], 'units', 'normalized');
box off
uistack(ha, 'down')
I=imread('ripple.jpg');
himg=imagesc(I);
colormap gray
set(ha, 'handleVisibility', 'off', 'visible', 'off');
x=[1:2:180];

for i=1:length(x)
    y(i)=log(3600/x(i));
end

plot(x, y, 'r');
xlabel('Beamwidth  $\theta$ ');
ylabel('Security level  $\eta$ ');
title('Security level definition II');
legend('  $\eta=\log(S2/S1)=\log(3600/\theta)$  ');
axis([0 180 0 9]);
guidata(hObject, handles);

function varargout = menu2_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;

function edit1_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit1, 'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider1, 'Min') &...
    val<=get(handles.slider1, 'Max')
    set(handles.slider1, 'Value', val);
else
```

Appendix F: Matlab Code for Sub-Menu2

```
errordlg('Load must be number and greater than -50 and smaller than 50');
set(handles.edit1,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit1_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider movement.
function slider1_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider1,'Value'));
set(handles.edit1,'String',val);

function slider1_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit2_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit2,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider2,'Min') &...
    val<=get(handles.slider2,'Max')
    set(handles.slider2,'Value',val);
else
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit2,'String','');
end

function edit2_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider movement.
function slider2_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider2,'Value'));
set(handles.edit2,'String',val);
```

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```
% --- Executes during object creation, after setting all properties.
function slider2_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit3_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit3,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider3,'Min') &...
    val<=get(handles.slider3,'Max')
    set(handles.slider3,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit3,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit3_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider movement.
function slider3_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider3,'Value'));
set(handles.edit3,'String',val);

% --- Executes during object creation, after setting all properties.

function slider3_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

% --- Executes on slider movement.
function slider4_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider4,'Value'));
set(handles.edit4,'String',val);
```

Appendix F: Matlab Code for Sub-Menu2

```
% --- Executes during object creation, after setting all properties.
function slider4_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit4_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit4,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider4,'Min') &...
    val<=get(handles.slider4,'Max')
    set(handles.slider4,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit4,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit5_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit5,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider5,'Min') &...
    val<=get(handles.slider5,'Max')
    set(handles.slider5,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit5,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit5_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

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```
% --- Executes on slider movement.
function slider5_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider5,'Value'));
set(handles.edit5,'String',val);

% --- Executes during object creation, after setting all properties.
function slider5_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit6_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit6,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider6,'Min') &...
    val<=get(handles.slider6,'Max')
    set(handles.slider6,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit6,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit6_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider movement.
function slider6_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider6,'Value'));
set(handles.edit6,'String',val);

% --- Executes during object creation, after setting all properties.
function slider6_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end
```

Appendix F: Matlab Code for Sub-Menu2

```
function edit7_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit7_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit8_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit8_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit9_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit9_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on button press in Back.
function Back_Callback(hObject, eventdata, handles)
close(gcf);
run main

% --- Executes on button press in Pattern.
function Pattern_Callback(hObject, eventdata, handles)
Response=deespar(str2num(get(handles.edit1,'String')),str2num(get(handles.edit2,
'String')),str2num(get(handles.edit3,'String')),...

str2num(get(handles.edit4,'String')),str2num(get(handles.edit5,'String')),str2nu
m(get(handles.edit6,'String')));
figure;
clf reset;
pp(Response.Fields.Angle,Response.FarField,'CentreValue',Response.Min.Farfield,'
MaxValue',Response.Max.Farfield)
```

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```
% --- Executes on button press in demonstrate.
function demonstrate_Callback(hObject, eventdata, handles)
figure;
subplot(1,2,1)
theta=0:pi/20:2*pi;
plot(sin(theta), cos(theta))
axis('square')
axis off;
subplot(1,2,2)
Response=deespar(str2num(get(handles.edit1,'String')), str2num(get(handles.edit2,
'String')), str2num(get(handles.edit3,'String')),...

str2num(get(handles.edit4,'String')), str2num(get(handles.edit5,'String')), str2nu
m(get(handles.edit6,'String')));
pp(Response.Fields.Angle, Response.FarField, 'CentreValue', Response.Min.Farfield, '
MaxValue', Response.Max.Farfield)
hold on
axis('square')
xx = Response.FarField.*cos(Response.Fields.Angle);
yy = Response.FarField.*sin(Response.Fields.Angle);
axis equal;
fill(xx, yy, 'r');

M=moviein(18);
for k = 1:18
    hold off;

pp((Response.Fields.Angle*180/pi+k*20)*pi/180, Response.FarField, 'CentreValue', Re
sponse.Min.Farfield, 'MaxValue', Response.Max.Farfield)
    hold on;
    xx = Response.FarField.*cos((Response.Fields.Angle*180/pi+k*20)*pi/180);
    yy = Response.FarField.*sin((Response.Fields.Angle*180/pi+k*20)*pi/180);
    fill(xx, yy, 'r');
    M(k)=getframe;
end
movie(M, 0)

% --- Executes on button press in calculate.
function calculate_Callback(hObject, eventdata, handles)
Response=deespar(str2num(get(handles.edit1,'String')), str2num(get(handles.edit2,
'String')), str2num(get(handles.edit3,'String')),...
```

Appendix F: Matlab Code for Sub-Menu2

```
str2num(get(handles.edit4,'String')),str2num(get(handles.edit5,'String')),str2nu
m(get(handles.edit6,'String')));
beamwidth=Response.beam;
S11=Response.R_dB;
set(handles.edit7,'String',beamwidth);
set(handles.edit15,'String',S11);
bili=log(3600/beamwidth);
set(handles.edit8,'String',bili);
if 1<bili & bili<3
    set(handles.edit9,'String','Light Security');
elseif 3<=bili & bili<4
    set(handles.edit9,'String','Medium Security');
else
    set(handles.edit9,'String','High Security');
end

function edit15_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit15_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```


Appendix G: Matlab Code for Sub-Menu3

```
function varargout = menu3(varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% menu3.m
% Calculating corresponding S11, beamwidth and security level
% in scenario 3:
%           AP: Omni-directional antenna
%           Station: Directional antenna
% Author : Zhaohui, 2145340
% Version: 1.0
% Date   : 20.04.2005
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',  gui_Singleton, ...
                  'gui_OpeningFcn', @menu3_OpeningFcn, ...
                  'gui_OutputFcn',  @menu3_OutputFcn, ...
                  'gui_LayoutFcn',  [], ...
                  'gui_Callback',    []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT

% --- Executes just before menu3 is made visible.
function menu3_OpeningFcn(hObject, eventdata, handles, varargin)
handles.output = hObject;
guidata(hObject, handles);
movegui(hObject, 'onscreen') % To display application onscreen
```

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```
movegui(hObject, 'center') % To display
                             % application in the
                             % center of screen

axes(handles.axes1);
handles.GU=imread('scene3.jpg');
image(handles.GU);
set(handles.axes1, 'Visible', 'off', 'Units', 'pixels');

axes(handles.axes2);
handles.aaa=imread('security3.jpg');
image(handles.aaa);
set(handles.axes2, 'Visible', 'off', 'Units', 'pixels');

axes(handles.axes3);
handles.bbb=imread('formula3.jpg');
image(handles.bbb);
set(handles.axes3, 'Visible', 'off', 'Units', 'pixels');

% Update handles structure
guidata(hObject, handles);

% --- Outputs from this function are returned to the command line.
function varargout = menu3_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;

% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit6_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit6, 'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider7, 'Min') &...
    val<=get(handles.slider7, 'Max')
    set(handles.slider7, 'Value', val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit6, 'String', '');
end
```

Appendix G: Matlab Code for Sub-Menu3

```
end

% --- Executes during object creation, after setting all properties.
function edit6_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider7 movement.
function slider7_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider7,'Value'));
set(handles.edit6,'String',val);

% --- Executes during object creation, after setting all properties.
function slider7_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit7_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit7,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider8,'Min') &...
    val<=get(handles.slider8,'Max')
    set(handles.slider8,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit7,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit7_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider7 movement.
function slider8_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider8,'Value'));
set(handles.edit7,'String',val);
```

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```
% --- Executes during object creation, after setting all properties.
function slider8_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit8_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit8,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider9,'Min') &...
    val<=get(handles.slider9,'Max')
    set(handles.slider9,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit8,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit8_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on slider7 movement.
function slider9_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider9,'Value'));
set(handles.edit8,'String',val);

% --- Executes during object creation, after setting all properties.
function slider9_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

% --- Executes on slider7 movement.
function slider10_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider10,'Value'));
set(handles.edit9,'String',val);
```

Appendix G: Matlab Code for Sub-Menu3

```
% --- Executes during object creation, after setting all properties.
function slider10_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end

function edit9_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit9,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider10,'Min') &...
    val<=get(handles.slider10,'Max')
    set(handles.slider10,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit9,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit9_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit10_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit10,'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider11,'Min') &...
    val<=get(handles.slider11,'Max')
    set(handles.slider11,'Value',val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit10,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit10_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

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```
% --- Executes on slider7 movement.
function slider11_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider11, 'Value'));
set(handles.edit10, 'String', val);

% --- Executes during object creation, after setting all properties.
function slider11_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', [.9 .9 .9]);
end

function edit11_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit11, 'String'));
if isnumeric(val)&length(val)==1 &...
    val>=get(handles.slider12, 'Min') &...
    val<=get(handles.slider12, 'Max')
    set(handles.slider12, 'Value', val);
else
    errordlg('Load must greater than -50 and smaller than 50');
    set(handles.edit11, 'String', '');
end

% --- Executes during object creation, after setting all properties.
function edit11_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

% --- Executes on slider7 movement.
function slider12_Callback(hObject, eventdata, handles)
val=num2str(get(handles.slider12, 'Value'));
set(handles.edit11, 'String', val);

% --- Executes during object creation, after setting all properties.
function slider12_CreateFcn(hObject, eventdata, handles)
if isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', [.9 .9 .9]);
end

% --- Executes on button press in Back.
```

Appendix G: Matlab Code for Sub-Menu3

```
function Back_Callback(hObject, eventdata, handles)
close(gcf);
run main

% --- Executes on button press in Pattern.
function Pattern_Callback(hObject, eventdata, handles)
Response=deespar(str2num(get(handles.edit6, 'String')), str2num(get(handles.edit7,
'String')), str2num(get(handles.edit8, 'String')), ...

str2num(get(handles.edit9, 'String')), str2num(get(handles.edit10, 'String')), str2n
um(get(handles.edit11, 'String')));
figure;
clf reset;
pp(Response.Fields.Angle, Response.FarField, 'CentreValue', Response.Min.Farfield, '
MaxValue', Response.Max.Farfield)

% --- Executes on button press in demonstrate.
function demonstrate_Callback(hObject, eventdata, handles)
figure;
subplot(1, 2, 2)
theta=0:pi/20:2*pi;
plot(sin(theta), cos(theta))
axis('square')
axis off;
subplot(1, 2, 1)
Response=deespar(str2num(get(handles.edit6, 'String')), str2num(get(handles.edit7,
'String')), str2num(get(handles.edit8, 'String')), ...

str2num(get(handles.edit9, 'String')), str2num(get(handles.edit10, 'String')), str2n
um(get(handles.edit11, 'String')));
pp(Response.Fields.Angle, Response.FarField, 'CentreValue', Response.Min.Farfield, '
MaxValue', Response.Max.Farfield)
hold on
axis('square')
xx = Response.FarField.*cos(Response.Fields.Angle);
yy = Response.FarField.*sin(Response.Fields.Angle);
axis equal;
fill(xx, yy, 'r');

M=moviein(18);
for k = 1:18
    hold off;
```

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```
pp((Response.Fields.Angle*180/pi+k*20)*pi/180, Response.FarField, 'CentreValue', Response.Min.Farfield, 'MaxValue', Response.Max.Farfield)
    hold on;
    xx = Response.FarField.*cos((Response.Fields.Angle*180/pi+k*20)*pi/180);
    yy = Response.FarField.*sin((Response.Fields.Angle*180/pi+k*20)*pi/180);
    fill(xx, yy, 'r');
    M(k)=getframe;
end
movie(M, 0)

function edit12_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit12_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit13_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit13_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit14_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit14_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

% --- Executes on button press in calculate.
function calculate_Callback(hObject, eventdata, handles)
Response=deespar(str2num(get(handles.edit6, 'String')), str2num(get(handles.edit7,
'String')), str2num(get(handles.edit8, 'String')), ...
str2num(get(handles.edit9, 'String')), str2num(get(handles.edit10, 'String')), str2n
```

Appendix G: Matlab Code for Sub-Menu3

```
um(get(handles.edit11,'String')));
beamwidth=Response.beam;
S11=Response.R_dB;
set(handles.edit12,'String',beamwidth);
set(handles.edit15,'String',S11);
bili=log(10*pi/sin((180-beamwidth)*pi/180)/pi+beamwidth*pi/180);
set(handles.edit13,'String',bili);
if bili==1
    set(handles.edit14,'String','Low Security');
elseif 1<bili<3
    set(handles.edit14,'String','Light Security');
elseif 3<=bili<4
    set(handles.edit14,'String','Medium Security');
else bili>=4
    set(handles.edit14,'String','High Security');
end

function edit15_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit15_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```


Appendix H: Matlab Code for Sub-Menu4

```
function varargout = menu4(varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% menu4.m
% Calculating corresponding S11, beamwidth and security level
% in scenario 4:
%           AP: Directional antenna
%           Station: Directional antenna
% Author : Zhaohui, 2145340
% Version: 1.0
% Date   : 20.04.2005
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',   gui_Singleton, ...
                  'gui_OpeningFcn', @menu4_OpeningFcn, ...
                  'gui_OutputFcn',  @menu4_OutputFcn, ...
                  'gui_LayoutFcn',   [], ...
                  'gui_Callback',    []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT

% --- Executes just before menu4 is made visible.
function menu4_OpeningFcn(hObject, eventdata, handles, varargin)
handles.output = hObject;
guidata(hObject, handles);
```

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```
movegui(hObject, 'onscreen')           % To display application onscreen
movegui(hObject, 'center')             % To display
                                       % application in the
                                       % center of screen

axes(handles.axes1);
handles.GU=imread('formula4_1.jpg');
image(handles.GU);
set(handles.axes1, 'Visible', 'off', 'Units', 'pixels');

axes(handles.axes2);
handles.aaa=imread('scene4_1.jpg');
image(handles.aaa);
set(handles.axes2, 'Visible', 'off', 'Units', 'pixels');

x=[1:2:180]*pi/180;
y=[1:2:180]*pi/180;
for i=1:length(x)
    for j=1:length(y)
        if x(i)/2+y(j) > pi
            z(i,j)=(x(i)/2+y(j))/pi+sin(pi-y(j))/pi-1;
        else
            z(i,j)=tan(x(i)/2).*tan(y(j)/2)./(tan(x(i)/2)+tan(y(j)/2))/pi;
        end
    end
end
set(handles.axes1, 'HandleVisibility', 'OFF')
set(handles.axes2, 'HandleVisibility', 'OFF')
set(handles.axes3, 'HandleVisibility', 'ON')
mesh(x*180/pi, y*180/pi, log(10./z));
view(55, 10);
shading interp;
title('Security level definition IV');
set(handles.edit1, 'Visible', 'ON')
set(handles.panel2, 'Visible', 'ON')
set(handles.panel3, 'Visible', 'ON')

grid on;

% Update handles structure
guidata(hObject, handles);
```

Appendix H: Matlab Code for Sub-Menu4

```
% --- Outputs from this function are returned to the command line.
function varargout = menu4_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;

function edit1_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit1, 'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit1, 'String', '');
end

% --- Executes during object creation, after setting all properties.
function edit1_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit2_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit2, 'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit2, 'String', '');
end

% --- Executes during object creation, after setting all properties.
function edit2_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUicontrolBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit3_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit3, 'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit3, 'String', '');
end

% --- Executes during object creation, after setting all properties.
```

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```
function edit3_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit4_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit4,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit4,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit5_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit5,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit5,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit5_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit6_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit6,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit6,'String','');
end
```

Appendix H: Matlab Code for Sub-Menu4

```
% --- Executes during object creation, after setting all properties.
function edit6_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit7_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit7,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit7,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit7_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit8_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit8,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
    set(handles.edit8,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit8_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit9_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit9,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
```

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```
        set(handles.edit9,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit9_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit10_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit10,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
set(handles.edit10,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit10_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit11_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit11,'String'));
if isnumeric(val)&length(val)~=1 |...
    val>=50 | val<=-50
    errordlg('Load must be number and greater than -50 and smaller than 50');
set(handles.edit11,'String','');
end

% --- Executes during object creation, after setting all properties.
function edit11_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit12_Callback(hObject, eventdata, handles)
val=str2num(get(handles.edit12,'String'));
if isnumeric(val)&length(val)~=1 |...
```

Appendix H: Matlab Code for Sub-Menu4

```
        val>=50 | val<=-50
        errordlg('Load must be number and greater than -50 and smaller than 50');
        set(handles.edit12,'String','');
    end

% --- Executes during object creation, after setting all properties.
function edit12_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit13_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit13_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit14_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit14_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit15_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit15_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on button press in calculate.
function calculate_Callback(hObject, eventdata, handles)
%AP
Response=deespar(str2num(get(handles.edit1,'String')),str2num(get(handles.edit2,
```

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```
'String')), str2num(get(handles.edit3, 'String')), ...

str2num(get(handles.edit4, 'String')), str2num(get(handles.edit5, 'String')), str2num(
get(handles.edit6, 'String')));
beamwidth_AP=Response.beam;
AP.S11=Response.R_dB;
set(handles.edit17, 'String', beamwidth_AP);
set(handles.edit18, 'String', AP.S11);
%Terminal
Response=deespar(str2num(get(handles.edit7, 'String')), str2num(get(handles.edit8,
'String')), str2num(get(handles.edit9, 'String')), ...

str2num(get(handles.edit10, 'String')), str2num(get(handles.edit11, 'String')), str2
num(get(handles.edit12, 'String')));
beamwidth_TER=Response.beam;
TER.S11=Response.R_dB;
set(handles.edit19, 'String', beamwidth_TER);
set(handles.edit20, 'String', TER.S11);

if beamwidth_AP/2+beamwidth_TER<180

bili=log((tan(beamwidth_AP*pi/90)+tan(beamwidth_TER*pi/90))*10*pi/(tan(beamwidth
_AP*pi/90)*tan(beamwidth_TER*pi/90)));
else

bili=log(10*pi/(sin((180-beamwidth_TER)*pi/180)+pi*(beamwidth_AP/2+beamwidth_TER
-180)));
    set(handles.axes3, 'HandleVisibility', 'OFF')
    set(handles.axes2, 'HandleVisibility', 'OFF')
    set(handles.axes1, 'HandleVisibility', 'ON')
    handles.aaa=imread('formula4_2.jpg');
    image(handles.aaa);
    set(handles.axes1, 'Visible', 'off', 'Units', 'pixels');

    set(handles.axes1, 'HandleVisibility', 'OFF')
    set(handles.axes3, 'HandleVisibility', 'OFF')
    set(handles.axes2, 'HandleVisibility', 'ON')
    handles.aaa=imread('scene4_2.jpg');
    image(handles.aaa);
    set(handles.axes2, 'Visible', 'off', 'Units', 'pixels');
end

set(handles.edit14, 'String', bili);
```

Appendix H: Matlab Code for Sub-Menu4

```
if 1<bili & bili<3
    set(handles.edit15,'String','Light Security');
elseif 3<=bili & bili<4
    set(handles.edit15,'String','Medium Security');
else
    set(handles.edit15,'String','High Security');
end

% --- Executes on button press in pattern.
function pattern_Callback(hObject, eventdata, handles)
figure;
subplot(1,2,1)
Response=deespar(str2num(get(handles.edit1,'String')),str2num(get(handles.edit2,
'String')),str2num(get(handles.edit3,'String')),...

str2num(get(handles.edit4,'String')),str2num(get(handles.edit5,'String')),str2nu
m(get(handles.edit6,'String')));
pp(Response.Fields.Angle,Response.FarField,'CentreValue',Response.Min.Farfield,'
MaxValue',Response.Max.Farfield)
axis equal;
subplot(1,2,2)
Response=deespar(str2num(get(handles.edit7,'String')),str2num(get(handles.edit8,
'String')),str2num(get(handles.edit9,'String')),...

str2num(get(handles.edit10,'String')),str2num(get(handles.edit11,'String')),str2
num(get(handles.edit12,'String')));
hold on;
pp(Response.Fields.Angle,Response.FarField,'CentreValue',Response.Min.Farfield,'
MaxValue',Response.Max.Farfield)
axis equal;

% --- Executes on button press in demonstrate.
function demonstrate_Callback(hObject, eventdata, handles)
figure;
subplot(1,2,1)
Response=deespar(str2num(get(handles.edit1,'String')),str2num(get(handles.edit2,
'String')),str2num(get(handles.edit3,'String')),...

str2num(get(handles.edit4,'String')),str2num(get(handles.edit5,'String')),str2nu
m(get(handles.edit6,'String')));
pp(Response.Fields.Angle,Response.FarField,'CentreValue',Response.Min.Farfield,'
MaxValue',Response.Max.Farfield)
hold on;
```

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```
axis('square')
xx = Response.FarField.*cos(Response.Fields.Angle);
yy = Response.FarField.*sin(Response.Fields.Angle);
axis equal;
fill(xx, yy, 'r');

M=moviein(18);
for k = 1:18
    hold off;

pp((Response.Fields.Angle*180/pi+k*20)*pi/180, Response.FarField, 'CentreValue', Response.Min.Farfield, 'MaxValue', Response.Max.Farfield)
    hold on;
    xx = Response.FarField.*cos((Response.Fields.Angle*180/pi+k*20)*pi/180);
    yy = Response.FarField.*sin((Response.Fields.Angle*180/pi+k*20)*pi/180);
    fill(xx, yy, 'r');
    M(k)=getframe;
end
hold off;
subplot(1, 2, 2)
Response=deespar(str2num(get(handles.edit7, 'String')), str2num(get(handles.edit8, 'String')), str2num(get(handles.edit9, 'String')), ...
str2num(get(handles.edit10, 'String')), str2num(get(handles.edit11, 'String')), str2num(get(handles.edit12, 'String')));
hold on;
pp(Response.Fields.Angle, Response.FarField, 'CentreValue', Response.Min.Farfield, 'MaxValue', Response.Max.Farfield)
axis('square')
xx = Response.FarField.*cos(Response.Fields.Angle);
yy = Response.FarField.*sin(Response.Fields.Angle);
axis equal;
fill(xx, yy, 'r');

M=moviein(18);
for k = 1:18
    hold off;

pp((Response.Fields.Angle*180/pi+k*20)*pi/180, Response.FarField, 'CentreValue', Response.Min.Farfield, 'MaxValue', Response.Max.Farfield)
    hold on;
    xx = Response.FarField.*cos((Response.Fields.Angle*180/pi+k*20)*pi/180);
    yy = Response.FarField.*sin((Response.Fields.Angle*180/pi+k*20)*pi/180);
```

Appendix H: Matlab Code for Sub-Menu4

```
fill(xx, yy, 'b');
M(k)=getframe;
end

% --- Executes on button press in back.
function back_Callback(hObject, eventdata, handles)
close(gcf);
run main

function edit16_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit16_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUiControlBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit17_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit17_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUiControlBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit18_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit18_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUiControlBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
end

function edit19_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit19_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject, 'BackgroundColor'),
get(0, 'defaultUiControlBackgroundColor'))
    set(hObject, 'BackgroundColor', 'white');
```

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```
end

function edit20_Callback(hObject, eventdata, handles)

% --- Executes during object creation, after setting all properties.
function edit20_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

Appendix I: Matlab Code for Calculate Function

```
function Response = DEESPAR (Load1, Load2, Load3, Load4, Load5, Load6)

Z = [
16.66170321665379 + 56.61967677300485i, -0.4192490925647208 + -13.94051947245442i,
-0.4638990886429373 + -14.93794098338072i, -0.1293980355677044 +
-14.65098168655134i, -0.2005556118135679 + -14.11478967381832i,
-0.7593251898987289 + -14.66814550103829i, -0.5910320574334402 +
-14.04702348683598i, -0.4192490925410737 + -13.94051947246338i, 21.69535298031745
+ 30.18509370288582i, -3.046647969606611 + -30.0735784289532i, -10.312765805386 +
-3.966205972561363i, 5.570241377593562 + 36.89124776474291i, -10.56347569483266 +
-1.682015841391635i, -3.042662334506968 + -31.33743311823486i, -0.4638990886363995
+ -14.93794098339552i, -3.046647969620387 + -30.07357842899526i, 21.68064442880289
+ 30.81859548345918i, -3.232185486866086 + -29.53607079968912i, -10.49277262864299
+ -5.231809145551784i, 6.370724744534989 + 38.17861709108298i, -11.04585741661688
+ -3.600894478684768i, -0.1293980356175871 + -14.65098168650965i,
-10.31276580535843 + -3.966205972584287i, -3.232185486847304 +
-29.53607079978809i, 20.93831245964358 + 29.73083375791983i, -2.288674050773642 +
-28.92941784556425i, -10.88389478465382 + -4.599293774106478i, 6.023840883442929 +
38.00204676617956i, -0.2005556117994163 + -14.11478967386624i, 5.570241377539108 +
36.89124776482947i, -10.49277262862595 + -5.231809145520185i, -2.288674050707265 +
-28.9294178456374i, 20.88245004478777 + 29.88933826049366i, -3.211972107444261 +
-30.37610449906714i, -10.36319502835691 + -2.118603105392982i, -0.7593251898991649
+ -14.66814550102836i, -10.56347569485315 + -1.68201584141139i, 6.370724744563365
+ 38.17861709106718i, -10.88389478469544 + -4.599293774089921i, -3.211972107460879
+ -30.37610449902927i, 22.90130040675795 + 31.02099332675194i, -4.216050788214642
+ -32.19133491435442i, -0.5910320574761152 + -14.04702348682103i,
-3.042662334442197 + -31.33743311820104i, -11.0458574166503 + -3.600894478730682i,
6.023840883414965 + 38.00204676615753i, -10.36319502831718 + -2.118603105341261i,
-4.216050788198672 + -32.19133491438033i, 23.2779752877502 + 32.54471002916561i;
];

load FieldsDEESPAR.mat -mat

inc = 1;
for b=1:7
    for a=1:7
```

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```
ZMatrix(a,b) = Z(inc);
    inc = inc + 1;
end
end

V=[1
  0
  0
  0
  0
  0
  0
];

Load1 = Load1*i;
Load2 = Load2*i;
Load3 = Load3*i;
Load4 = Load4*i;
Load5 = Load5*i;
Load6 = Load6*i;

XLoad = [0 0 0 0 0 0 0
          0 Load1 0 0 0 0 0
          0 0 Load2 0 0 0 0
          0 0 0 Load3 0 0 0
          0 0 0 0 Load4 0 0
          0 0 0 0 0 Load5 0
          0 0 0 0 0 0 Load6];

ZMatrix = ZMatrix + XLoad;

ZMatrix_I = inv(ZMatrix);
I = ZMatrix_I*V;

Pattern1 = I(1)*Fields.Centre;
Pattern2 = I(2)*Fields.Element1;
Pattern3 = I(3)*Fields.Element2;
Pattern4 = I(4)*Fields.Element3;
Pattern5 = I(5)*Fields.Element4;
Pattern6 = I(6)*Fields.Element5;
Pattern7 = I(7)*Fields.Element6;

FarField = Pattern1+Pattern2+Pattern3+Pattern4+Pattern5+Pattern6+Pattern7;
```

Appendix I: Matlab Code for Calculate Function

```
Zin = V(1)/I(1);
R = (Zin-50)/(Zin+50);
R_Mag = abs(R);
R_Angle = angle(R)*(180/pi)
R_dB = 20*log10(R_Mag);

FarField = real(FarField);
FarField = FarField - min(FarField);
FarField = FarField/max(FarField);

beamwidth=abs(R_Angle);

Response.R_dB = R_dB;
Response.beam=beamwidth;
Response.Fields.Angle=Fields.Angle*pi/180;
Response.FarField=FarField;
Response.Min.Farfield=min(FarField);
Response.Max.Farfield=max(FarField);
```


Appendix J: Matlab Code for Pattern Function

```
function Response = pattern(Load1, Load2, Load3, Load4, Load5, Load6)
% % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % %
% pattern.m %
% Drawing the corresponding antenna pattern in Matlab %
% % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % %

Z = [
16.66170321665379 + 56.61967677300485i, -0.4192490925647208 + -13.94051947245442i,
-0.4638990886429373 + -14.93794098338072i, -0.1293980355677044 +
-14.65098168655134i, -0.2005556118135679 + -14.11478967381832i,
-0.7593251898987289 + -14.66814550103829i, -0.5910320574334402 +
-14.04702348683598i, -0.4192490925410737 + -13.94051947246338i, 21.69535298031745
+ 30.18509370288582i, -3.046647969606611 + -30.0735784289532i, -10.312765805386 +
-3.966205972561363i, 5.570241377593562 + 36.89124776474291i, -10.56347569483266 +
-1.682015841391635i, -3.042662334506968 + -31.33743311823486i, -0.4638990886363995
+ -14.93794098339552i, -3.046647969620387 + -30.07357842899526i, 21.68064442880289
+ 30.81859548345918i, -3.232185486866086 + -29.53607079968912i, -10.49277262864299
+ -5.231809145551784i, 6.370724744534989 + 38.17861709108298i, -11.04585741661688
+ -3.600894478684768i, -0.1293980356175871 + -14.65098168650965i,
-10.31276580535843 + -3.966205972584287i, -3.232185486847304 +
-29.53607079978809i, 20.93831245964358 + 29.73083375791983i, -2.288674050773642 +
-28.92941784556425i, -10.88389478465382 + -4.599293774106478i, 6.023840883442929 +
38.00204676617956i, -0.2005556117994163 + -14.11478967386624i, 5.570241377539108 +
36.89124776482947i, -10.49277262862595 + -5.231809145520185i, -2.288674050707265 +
-28.9294178456374i, 20.88245004478777 + 29.88933826049366i, -3.211972107444261 +
-30.37610449906714i, -10.36319502835691 + -2.118603105392982i, -0.7593251898991649
+ -14.66814550102836i, -10.56347569485315 + -1.68201584141139i, 6.370724744563365
+ 38.17861709106718i, -10.88389478469544 + -4.599293774089921i, -3.211972107460879
+ -30.37610449902927i, 22.90130040675795 + 31.02099332675194i, -4.216050788214642
+ -32.19133491435442i, -0.5910320574761152 + -14.04702348682103i,
-3.042662334442197 + -31.33743311820104i, -11.0458574166503 + -3.600894478730682i,
6.023840883414965 + 38.00204676615753i, -10.36319502831718 + -2.118603105341261i,
-4.216050788198672 + -32.19133491438033i, 23.2779752877502 + 32.54471002916561i;
];

load FieldsDEESPAR.mat -mat
```

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```
inc = 1;
for b=1:7
    for a=1:7
        ZMatrix(a,b) = Z(inc);
        inc = inc + 1;
    end
end
```

```
V=[1
    0
    0
    0
    0
    0
    0
];
```

```
Load1 = Load1*i;
Load2 = Load2*i;
Load3 = Load3*i;
Load4 = Load4*i;
Load5 = Load5*i;
Load6 = Load6*i;
```

```
XLoad = [0 0 0 0 0 0 0
          0 Load1 0 0 0 0 0
          0 0 Load2 0 0 0 0
          0 0 0 Load3 0 0 0
          0 0 0 0 Load4 0 0
          0 0 0 0 0 Load5 0
          0 0 0 0 0 0 Load6];
```

```
ZMatrix = ZMatrix + XLoad;
```

```
ZMatrix_I = inv(ZMatrix);
I = ZMatrix_I*V;
```

```
Pattern1 = I(1)*Fields.Centre;
Pattern2 = I(2)*Fields.Element1;
Pattern3 = I(3)*Fields.Element2;
Pattern4 = I(4)*Fields.Element3;
Pattern5 = I(5)*Fields.Element4;
```

Appendix J: Matlab Code for Pattern Function

```
Pattern6 = I(6)*Fields.Element5;
Pattern7 = I(7)*Fields.Element6;

FarField = Pattern1+Pattern2+Pattern3+Pattern4+Pattern5+Pattern6+Pattern7;

Zin = V(1)/I(1);
R = (Zin-50)/(Zin+50);
R_Mag = abs(R);
R_Angle = angle(R)*(180/pi);
R_dB = 20*log10(R_Mag);

Response.R = R;
Response.R_Mag = R_Mag;
Response.R_dB = R_dB;
Response.FarField.Real = real(FarField);
Response.FarField.Imag = imag(FarField);
Response.FarField.Complex =
complex(Response.FarField.Real, Response.FarField.Imag);
Response.FarField.Max = max(abs(Response.FarField.Complex));

Response.Angle = Fields.Angle;
Response.I = I;

FarField = real(FarField);
FarField = FarField - min(FarField);
FarField = FarField/max(FarField);

pp(Fields.Angle*pi/180, FarField, 'CentreValue', min(FarField), 'MaxValue', max(FarField));
hold on;
```


Appendix K: Published Papers

Zhaohui Sun and Junwei Lu, “Improving the Security Performance in Mobile Wireless Computing Network using Smart Directional Antenna”, November, 2003, Asia-Pacific Conference on Environmental Electromagnetics CEEM’ 2003, pp. 47-50

Zhaohui Sun, Junwei Lu and David Ireland, “Increased Security Level using Space-division Approach in Wireless Computing Network”, November, 2005, Asia-Pacific Microwave Conference, APMC’ 2005

Zhaohui Sun, “Propagation Characteristics Study for an Indoor Wireless Communication Environment using Directional Antenna”, November, 2005, Microelectronic Engineering Research Conference, MERC’ 2005