

**EFFICIENT MULTIRATE
TELETRAFFIC LOSS MODELS
BEYOND ERLANG**

**EFFICIENT MULTIRATE
TELETRAFFIC LOSS MODELS
BEYOND ERLANG**

Efficient Multirate Loss Models

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LOGO

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To my parents

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Foreword

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Preface

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I. R. S.

Acronyms

| | |
|----------|--------------------------------------|
| ASTA | Arrivals See Time Averages |
| BHCA | Busy Hour Call Attempts |
| BR | Bandwidth Reservation |
| b.u. | bandwidth unit(s) |
| CAC | Call / Connection Admission Control |
| CBP | Call Blocking Probability(-ies) |
| CCS | Centum Call Seconds |
| CDTM | Connection Dependent Threshold Model |
| CS | Complete Sharing |
| DiffServ | Differentiated Services |
| EMLM | Erlang Multirate Loss Model |
| erl | The Erlang unit of traffic-load |
| FIFO | First in - First out |

| | |
|---------|---|
| GB | Global balance |
| GoS | Grade of Service |
| ICT | Information and Communication Technology |
| IntServ | Integrated Services |
| IP | Internet Protocol |
| ITU-T | International Telecommunication Unit – Standardization sector |
| LB | Local balance |
| LHS | Left hand side |
| LIFO | Last in - First out |
| MMPP | Markov Modulated Poisson Process |
| MPLS | Multiple Protocol Labeling Switching |
| MRM | Multi-Retry Model |
| MTM | Multi-Threshold Model |
| PASTA | Poisson Arrivals See Time Averages |
| PDF | Probability Distribution Function |
| pdf | probability density function |

| | |
|------|----------------------------|
| PFS | Product Form Solution |
| QoS | Quality of Service |
| r.v. | random variable(s) |
| RED | random early detection |
| RHS | Right hand side |
| RLA | Reduced Load Approximation |
| SIRO | service in random order |
| SRM | Single-Retry Model |
| STM | Single-Threshold Model |
| TCP | Transport Control Protocol |
| TH | Threshold(s) |
| UDP | User Datagram Protocol |

Introduction

The word *traffic* becomes *teletraffic* in telecommunications, as communications becomes telecommunications to indicate technology use, e.g., conversation from some distance through phones or Internet. The term teletraffic covers all kinds of computer communication traffic and telecom traffic. This book includes teletraffic loss models.

Chapter 1

This is Chapter One Title containing authors and affiliations¹

Author I,^{1*} Author II,² Author III,¹ and Author IV³

¹I Author Organization Division Name, Organization Name, Postal Code, Part of the Country, City Name, Street Name, Country

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³II Author Organization Division Name, Organization Name, Postal Code, Part of the Country, City Name, Street Name, Country

*Corresponding Author: Author; corresauthor@gmail.com

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For example, multiple citations from the of this : citet: Ding et al. [5], French and Pavlidis [8], citep: [5, 8]. As you see in Table 1.1, the citations are to their reference in the bibliography (Equation 1.1).

$$\mathcal{L} = i\bar{\psi}\gamma^{\mu}D_{\mu}\psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi \quad (1.1)$$

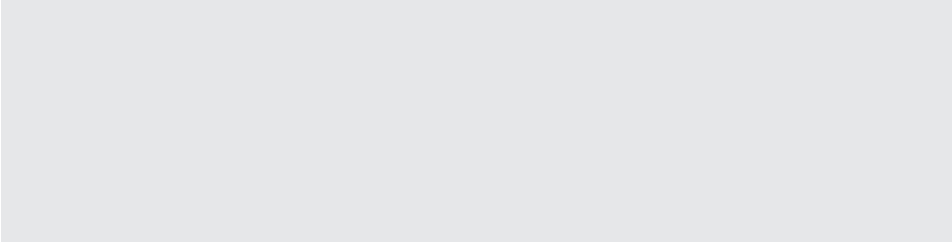


图 1.1: Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption.

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The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers.

$$\mathcal{L} = i\bar{\psi}\gamma^\mu D_\mu\psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi \tag{1.2}$$

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| 4 | –10.0 | 12,900 ² | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |

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² Example for a second table footnote.

The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers (Equation 1.2).

Chapter 2

This is Chapter Two Title

After reading this chapter you should be able to:

-
- List the main subsectors and components of the environmental and energy infrastructure
 - Explain www.google.com the function of each infrastructure sector
 - Identify components related to environmental and energy infrastructure
-

2.1. This is First Level Heading

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ris.

The manifestation of solar activity¹ (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth's surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers.

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The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth's surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers.

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An example for uppercase alphabet list:

- A. Upper case alpha list text. Item text Item text Item text Item text Item text Item text Item text.
- B. Item text Item text Item text Item text Item text Item text Item text. Item text Item text.

An example for lowercase alphabet list:

- a. Lower case alpha list text. Item text Item text Item text Item text Item text Item text Item text.
- b. Item text Item text Item text Item text Item text Item text Item text. Item text Item text.
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Example for uppercase Roman List:

- I. Upper case roman list text. Item text Item text Item text Item text Item text Item text Item text.
- II. Item text Item text Item text Item text Item text Item text Item text. Item text Item text.
- III. Item text Item text Item text Item text Item text Item text

Example for lowercase roman List:

- i. Lower case roman list text. Item text Item text Item text Item text Item text Item text Item text.
- ii. Item text Item text Item text Item text Item text Item text Item text. Item text Item text.
- iii. Item text Item text Item text Item text Item text Item text

Example for custom list:

Step 1 Custom list, if the list environment not matched with above.

Step 2 Item text Item text Item text Item text Item text Item text Item text Item text Item text Item text. Item text Item text.

Step 3 Item text Item text Item text Item text Item text Item text

Example for unnumbered list:

Unnumbered list text. Item text Item text Item text Item text Item text Item text Item text.

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For example, multiple citations from the bibliography of this article: cite: Bartelle et al. [1], Consortium [2], citep: [3, 4]. As you see in Table 2.1, the citations are to their reference in the bibliography.

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² Example for a second table footnote.

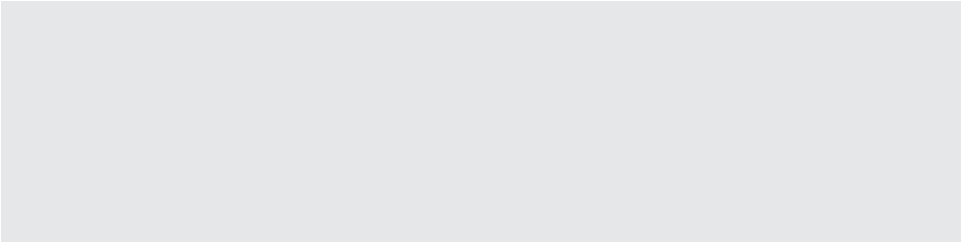


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The manifestation of solar activity² (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth's surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers (Equation 2.1).

$$\mathcal{L} \quad \mathcal{L} = i\bar{\psi}\gamma^{\mu}D_{\mu}\psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi \quad (2.1)$$

The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth's surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers(Equation 2.2).

$$\mathcal{L} \quad \mathcal{L} = i\bar{\psi}\gamma^{\mu}D_{\mu}\psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi \quad (2.2)$$

²This is an example for second text footnote. This is an example for second text footnote. This is an example for second text footnote.

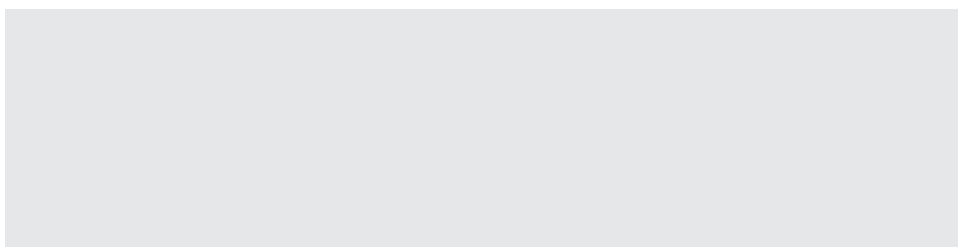


图 2.2: Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption.

Chapter 3

This is Chapter Three Title

After reading this chapter you should be able to:

-
- List the main subsectors and components of the environmental and energy infrastructure
 - Explain www.google.com the function of each infrastructure sector
 - Identify components related to environmental and energy infrastructure
-

3.1. This is First Level Heading

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, non-ummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

The manifestation of solar activity¹ (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth's surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for

¹This is an example for first text footnote. This is an example for first text footnote. This is an example for first text footnote.

terrestrial observers.

Example for Quotes

Quote Head

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Example for Extracts

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Extract Source

*‘Extract Text Extract Text Extract Text Extract Text Extract Text Extract Text Ex-
tract Text Extract Text Extract Text Extract Text Extract Text Extract Text’*

Extract Source

Example for Pull quotes

Chapter 4

This is Chapter Four Title

After reading this chapter you should be able to:

-
- List the main subsectors and components of the environmental and energy infrastructure
 - Explain www.google.com the function of each infrastructure sector
 - Identify components related to environmental and energy infrastructure
-

4.1. This is First Level Heading

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Feature Section

Feature Subsection

Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession.

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图 4.1: Figure Title. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. *Source: Figure Source.*

Note: For sample purpose we have used dummy eps image. Please use only the below format:

```
\begin{figure}
\includegraphics{FigName.eps}
\caption{\title{Figure Title.}Figure Caption.
Figure Caption. Figure Caption. Figure Caption.
Figure Caption. Figure Caption. Figure Caption.
\source{\textit{Source:} Figure Source.}\label{fig1}}
\end{figure}
```

Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession. Engineers uphold and advance the integrity, honor and dignity of the engineering profession.

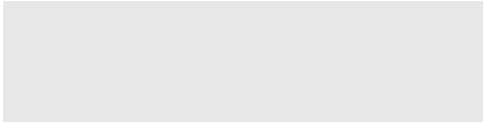
表 4.1: Enter table caption here.

| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
|---------------|------------------------|------------------------|-----------------------------|
| 3 | 0–9.0 | 68,900 ¹ | –12.8 |
| 4 | –10.0 | 12,900 ² | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |

Source: Example for table source text.

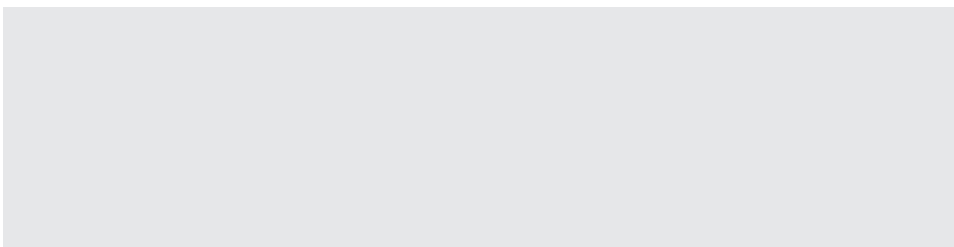
¹ Example for a first table footnote. Example for a first table footnote. Example for a first table footnote. Example for a first table footnote.

² Example for a second table footnote.



Unnumbered Figure Title. Unnumbered Figure caption. Unnumbered Figure caption. Unnumbered Figure caption. Unnumbered Figure caption. *Unnumbered Figure Source*

The sample for unnumbered Figure without caption



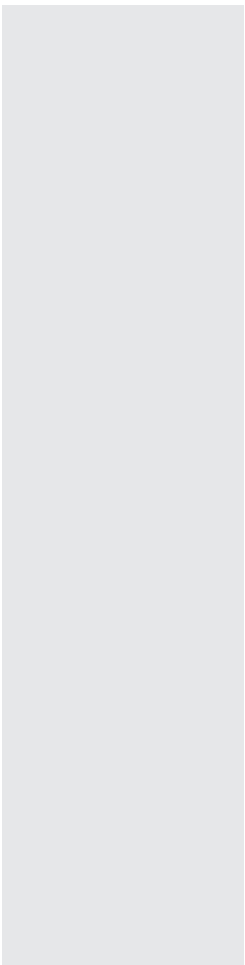


图 4.2: Figure Title

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Source: Figure Source.

This is an unnumbered table

Enter unnumbered table caption here. Enter
unnumbered table caption here. Enter unnumbered
table caption here.

| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
|---------------|------------------------|------------------------|-----------------------------|
| 3 | 0–9.0 | 68,900 | –12.8 |
| 4 | –10.0 | 12,900 | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |
| 6 | –20.0 | 20,000 ¹ | –16.0 |

¹ This is unnumbered table footnote

Source: This is unnumbered table source. This is un-
numbered table footnote

表 4.2: Enter sideways table caption here.

| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
|---------------|------------------------|------------------------|-----------------------------|
| 3 | 0–9.0 | 68,900 | –12.8 |
| 4 | –10.0 | 12,900 | –10.0 |
| 5 | –15.0 | 17,100 ¹ | –25.2 |

¹ This is table footnote

For Unnumbered Table without caption and source/note:

| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
|---------------|------------------------|------------------------|-----------------------------|
| 3 | 0–9.0 | 68,900 | –12.8 |
| 4 | –10.0 | 12,900 | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |
| 6 | –20.0 | 20,000 | –16.0 |

Chapter 5

This is Chapter Five Title

After reading this chapter you should be able to:

-
- List the main subsectors and components of the environmental and energy infrastructure
 - Explain www.google.com the function of each infrastructure sector
 - Identify components related to environmental and energy infrastructure
-

5.1. This is First Level Heading

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ris.

The manifestation of solar activity¹ (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers.

Enunciations

For bold head and italic body:

Theorem 5.1*(Theorem Title): Theorem content. Theorem content. Theorem content. Theorem content. Theorem content. Theorem content.*

Lemma 5.1: *Lemma content. Lemma content. Lemma content. Lemma content. Lemma content. Lemma content. Lemma content. Lemma content. Lemma content. Lemma content.*

Corollary 5.1: *Corollary content. Corollary content. Corollary content. Corollary content. Corollary content. Corollary content. Corollary content. Corollary content. Corollary content. Corollary content.*

For bold head and roman text:

Definition 5.1*(Definition Title): Definition content. Definition content. Definition content. Definition content. Definition content. Definition content. Definition content. Definition content. Definition content. Definition content.*

Remark 5.1: Remark content.

For proofs:

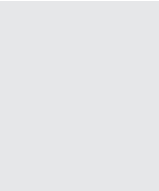
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¹This is an example for first text footnote. This is an example for first text footnote. This is an example for first text footnote.

Computer Material

```
class CEcosystem;  
struct Chromosome  
{  
    unsigned char gene[CHROMOLENGTH];  
};
```

Icons



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Following is an example for Problems section:
Problems

Related Instruction. Related Instruction. Related Instruction. Related Instruction. Related
Instruction.

1. First problem text. First problem text. First problem text.

$$f(x) = \begin{cases} kx^2(1 - x^3), & 0 < x < 1 \\ 0, & \text{otherwise} \end{cases}$$

continuation of first problem text.

Hint: Problem hint text. Problem hint text.

2. Second problem text. Second problem text. Second problem text:

- 1. $9 < X < 90$.
- 2. $X < 90$.
- 3. $X > 90$, given that $X > 9$.

3. Third problem text. Third problem text.

$$F_X(x) = \begin{cases} 0, & x < 0, \\ \frac{1}{2}\sqrt{x} + \frac{1}{2}(1 - e^{-\sqrt{x}}), & 0 \leq x \leq 1, \\ \frac{1}{2} + \frac{1}{2}(1 - e^{-\sqrt{x}}), & x > 1. \end{cases}$$

Continuation of third problem text.

4. Fourth problem text.

$$f_X(x) = \frac{k}{x}, \quad k > 0.$$

Continuation of fourth problem text

1. some text.
2. some other text.
3. more text.

附录 A

This is Appendix Title

A.1. This is First Level Heading

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A.1.1. This is Second Level Heading

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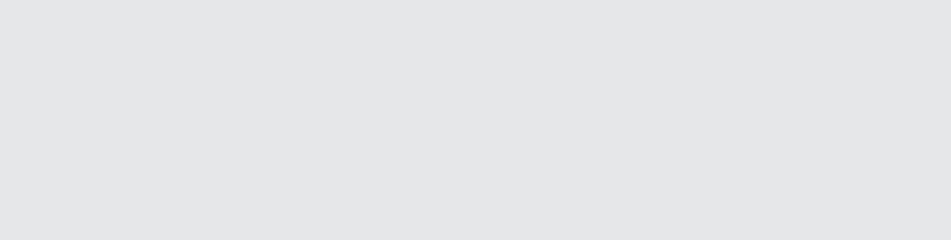


图 A.1: Figure Title

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The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers (Equation A.1, Table A.1 and Figure A.1).

$$\mathcal{L} = i\bar{\psi}\gamma^\mu D_\mu\psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi \tag{A.1}$$

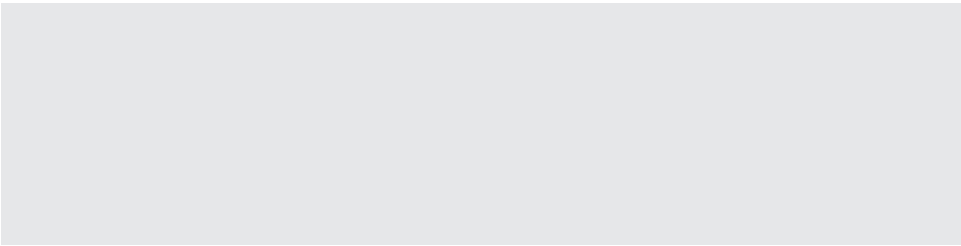


图 A.2: Figure Title

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Figure Caption.

Source: Figure Source.

表 A.1: Enter table caption here.

| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
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| 3 | 0–9.0 | 68,900 ¹ | –12.8 |
| 4 | –10.0 | 12,900 ² | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |

Source: Example for table source text.

¹ Example for a first table footnote. Example for a first table footnote. Example for a first table footnote. Example for a first table footnote.

² Example for a second table footnote.

表 A.2: Enter table caption here.

| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
|------------|---------------------|---------------------|--------------------------|
| 3 | 0–9.0 | 68,900 ¹ | –12.8 |
| 4 | –10.0 | 12,900 ² | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |

Source: Example for table source text.

¹ Example for a first table footnote. Example for a first table footnote. Example for a first table footnote. Example for a first table footnote.

² Example for a second table footnote.

This is Fourth Level HeadingFusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers (Equation A.2, Table A.2 and Figure A.2).

$$\mathcal{L} \quad \mathcal{L} = i\bar{\psi}\gamma^{\mu}D_{\mu}\psi - \frac{1}{4}F_{\mu\nu}^aF^{a\mu\nu} - m\bar{\psi}\psi$$

(A.2)

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附录 B

This is Appendix Title

B.1. This is First Level Heading

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B.1.1. This is Second Level Heading

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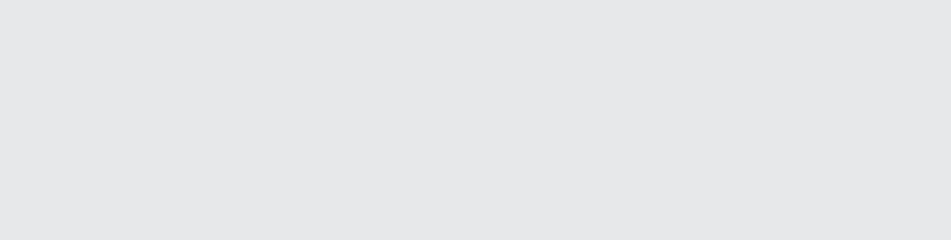


图 B.1: Figure Title.

Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption. Figure Caption.
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The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers (Equation B.1, Table B.1 and Figure B.1).

$$\mathcal{L} \quad \mathcal{L} = i\bar{\psi}\gamma^\mu D_\mu \psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi \tag{B.1}$$

B.1.1.1. This is Third Level Heading

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|------------|---------------------|---------------------|--------------------------|
| 3 | 0–9.0 | 68,900 ¹ | –12.8 |
| 4 | –10.0 | 12,900 ² | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |

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¹ Example for a first table footnote. Example for a first table footnote. Example for a first table footnote. Example for a first table footnote.

² Example for a second table footnote.

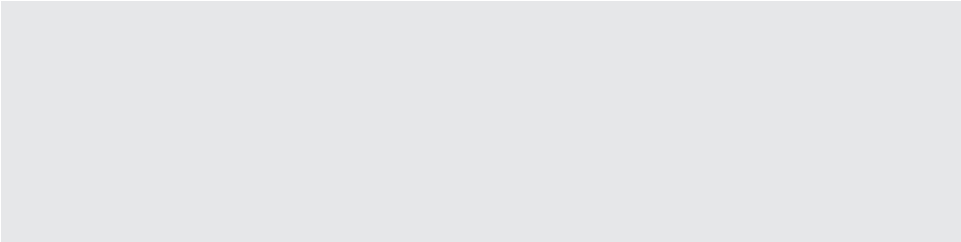


图 B.2: Figure Title.

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| Tap number | Relative power (dB) | Relative delay (ns) | Relative mean power (dB) |
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| 3 | 0–9.0 | 68,900 ¹ | –12.8 |
| 4 | –10.0 | 12,900 ² | –10.0 |
| 5 | –15.0 | 17,100 | –25.2 |

Source: Example for table source text.

¹ Example for a first table footnote. Example for a first table footnote. Example for a first table footnote. Example for a first table footnote.

² Example for a second table footnote.

The manifestation of solar activity (flares, bursts, and others) occurs over the whole Sun, and most of radio astronomy observations are made from the Earth’s surface, whereas a significant part of solar radio events (those from the far side of the Sun) is not available for terrestrial observers (Equation B.2, Table B.2 and Figure B.2).

$$\mathcal{L} \quad \mathcal{L} = i\bar{\psi}\gamma^\mu D_\mu \psi - \frac{1}{4}F_{\mu\nu}^a F^{a\mu\nu} - m\bar{\psi}\psi$$

(B.2)

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附录 C

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C.1. Import Codes From Code File

```
1  #%%
2  import numpy as np
3  import scipy.stats as st
4
5  import matplotlib.pyplot as plt
6  import seaborn as sns
7
8  sns.set_palette("Paired")
```

C.2. Write Codes In Tex File

```
1  import numpy as np
2
3  def incmatrix(genl1,genl2):
4      m = len(genl1)
5      n = len(genl2)
6      M = None #to become the incidence matrix
7      VT = np.zeros((n*m,1), int) #dummy variable
8
9      #compute the bitwise xor matrix
10     M1 = bitxormatrix(genl1)
11     M2 = np.triu(bitxormatrix(genl2),1)
12
13     for i in range(m-1):
14         for j in range(i+1, m):
15             [r,c] = np.where(M2 == M1[i,j])
16             for k in range(len(r)):
17                 VT[(i)*n + r[k]] = 1;
18                 VT[(i)*n + c[k]] = 1;
19                 VT[(j)*n + r[k]] = 1;
20                 VT[(j)*n + c[k]] = 1;
21
22             if M is None:
23                 M = np.copy(VT)
24             else:
```

```
25         M = np.concatenate((M, VT), 1)
26
27         VT = np.zeros((n*m,1), int)
28
29     return M
```

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