

The user has provided a very short text: “The Tianma 65 m radio telescope antenna 后印本” This appears to be a title or heading, followed by the Chinese term “后印本” which means “postprint” or “post-print” in academic publishing context. Let me analyze the requirements: 1. The user wants me to translate...

**Authors:** The user wants me to translate a Chinese text to English. The text is “BiaoDu” . This is very short. Let me think about what this could mean.

“BiaoDu” could be: 1. A name (proper noun) 2. A technical term 3. A typo or abbreviation

In the context of scientific translation, especially with machine learning/deep learning glossary provided: - “BiaoDu” (标度) could mean “scale” or “scaling” - “Biao Du” could be two characters meaning “mark” + “degree” or “standard” + “measure”

However, “BiaoDu” as a single word is unusual. Let me consider common technical terms: - 标度 (biāodù) = scale, scaling, calibration - 百度 (Bǎidù) = Baidu (the company) - but that’ s “BaiDu” not “BiaoDu”

Given the glossary provided: 机器学习 => machine learning 深度学习 => deep learning

The user hasn’ t provided the actual text to translate. They’ ve just given “BiaoDu” . This might be: 1. A test to see how I handle minimal input 2. A fragment of a larger text that got cut off 3. A specific term they want translated

Since the instructions say “Translate from Simplified Chinese to English with the highest accuracy and academic tone” and mention preserving LaTeX, citations, and tags, but the input “BiaoDu” contains none of these, I should just translate the term itself.

“BiaoDu” is likely 标度 (biāodù) which in academic/scientific context means: - scale - scaling - calibration - scaling factor - scaling law

In machine learning contexts, “scaling” is very common (e.g., data scaling, gradient scaling, loss scaling).

Let me check if it could be a name. If it’s a name, it should be kept as is or transliterated. But the context suggests it’s a technical term.

The most likely translation in a scientific context is “scaling” or “scale” .

Given that the user wants academic tone and the glossary includes ML terms, “scaling” seems most appropriate for 标度.

However, I should also consider that “BiaoDu” might be a typo for “BaiDu” (百度), the Chinese tech company. But that would be capitalized differently.

Without more context, I’ll treat “BiaoDu” as, The user has provided a single name: “YuanpengZheng” . This appears to be a Chinese name that needs to be translated or romanized.

Let me analyze this: - The name is written in Pinyin without spaces: “YuanpengZheng” - In Chinese names, the family name comes first, followed by the given name - “Zheng” (郑) is a common Chinese surname - “Yuanpeng” (远鹏 or 元鹏) would be the given name

The standard way to write Chinese names in English academic contexts is: 1. Family name first, then given name (preserving Chinese order), OR 2. Given name first, then family name (Western order)

In academic papers, both formats are acceptable but consistency is key. The most common approach in international publications is to use the Western order: Given name + Family name.

So “YuanpengZheng” should be separated as “Yuanpeng Zheng” (given name: Yuanpeng, family name: Zheng).

However, the user hasn’t provided any context about what they want me to do with this name. The instructions say “Translate from Simplified Chinese to English with the highest accuracy and academic tone.” But this is just a name, not a paragraph with tags.

Looking at the CRITICAL REQUIREMENTS: - Preserve ALL LaTeX commands and placeholders - Preserve ALL citation commands - **PRESERVE ALL ~~...~~paragraph wrapper tags EXACTLY** - Maintain academic tone - Use precise technical terminology - Preserve section structure and paragraph organization - Translate all content completely

The input “YuanpengZheng” doesn’t contain any of these elements. It’s just a name string.

The OUTPUT RULES say: - Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent). - Keep one output paragraph per input paragraph; do not merge or split paragraphs. - **Maintain exact count and IDs of ~~...~~tags**

Since there's no paragraph tag in the input, I'm not sure what to do. The instructions seem to be designed for translating full paragraphs with structural markers.

Given that the user has only provided a name, and the system prompt is about translating academic papers with specific formatting requirements, there are a few possibilities: 1. This is a test to see if, The user has provided a single word: "GuoxiLiu". This appears to be a name, likely Chinese. The task is to translate from Simplified Chinese to English with the highest accuracy and academic tone, following specific rules about preserving LaTeX, citations, and tags.

However, the input "GuoxiLiu" is just a name. It's not a paragraph with tags, LaTeX commands, or any Chinese text to translate. The name itself is already in a romanized form (Pinyin).

Let me analyze: - "GuoxiLiu" - This is a Chinese name written in Pinyin. It could be "刘国希" or similar, but it's already transliterated. - The user wants me to translate from Simplified Chinese to English - The critical requirements mention preserving tags, LaTeX, etc. - The glossary mentions "机器学习 => machine learning" and "深度学习 => deep learning"

Since the input is just "GuoxiLiu" and doesn't contain any: 1. tags 2. LaTeX commands 3. Chinese characters to translate 4. Citations 5. Paragraph structure

There's nothing to actually translate. The name "GuoxiLiu" is already in English letters (Pinyin). In academic contexts, Chinese names are typically written as: - Liu Guoxi (surname first, then given name) - Guoxi Liu (given name first, then surname, Western order)

The most appropriate academic translation would be to format it according to standard academic conventions. Since it's already in Pinyin, I should either: 1. Keep it as is: GuoxiLiu 2. Separate it: Guoxi Liu 3. Reverse it: Liu Guoxi

Given that this appears to be a name and the user wants academic tone, I should treat this as a name that doesn't need translation but might need proper formatting. However, the instructions say to translate from Simplified Chinese to English, and this is not Simplified Chinese - it's already romanized.

The most faithful approach would be to recognize that there's no actual Chinese text to translate, and the input is just a name. Since there are no tags in the input, I should not add any. The output should be just the name, possibly properly spaced.

But wait - the user might have made a mistake and just provided a name fragment. Or, The user has provided a name "YifanZhang" and no other context. This appears to be a test or incomplete request.

Looking at the system prompt, I am supposed to be a professional scientific translator specializing in academic papers, translating from Simplified Chinese

to English. The critical requirements are: 1. Preserve ALL LaTeX commands and placeholders 2. Preserve ALL citation commands 3. **PRESERVE ALL ...paragraph wrapper tags EXACTLY** 4. Maintain academic tone 5. Use precise technical terminology from glossary 6. Preserve section structure 7. Translate all content completely

The output rules specify: - Return ONLY the translated text - Keep one output paragraph per input paragraph - Maintain exact count and IDs of tags - Do NOT add Markdown formatting unless present in source - Preserve original line breaks when meaningful

The glossary provided is: - 机器学习 => machine learning - 深度学习 => deep learning

However, the user input is just “YifanZhang” - a name. This is not Chinese text to translate. It’s likely a test to see if I follow instructions. Since there are no tags, no Chinese text, no LaTeX, no citations, I should return nothing or indicate that there’s nothing to translate.

But the system prompt says “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).” If there’s nothing to translate, what should I return?

Let me re-read: “Translate from Simplified Chinese to English with the highest accuracy and academic tone.” The input “YifanZhang” is not Simplified Chinese text - it’s a name in Pinyin. Names are typically not translated but rather transliterated. In academic contexts, Chinese names are often kept as is or formatted differently depending on the journal style.

However, the most faithful interpretation of the instructions is that if there’s no Chinese text to translate, I should return nothing. But that might be interpreted as an error. Alternatively, I could just return the name as is, since it’s not Chinese characters.

Wait, let me check if “YifanZhang” could be considered Simplified Chinese. It’s written in Latin letters, so it’s Pinyin, not Chinese characters. The system prompt says “Translate from Simplified Chinese to English”. Pinyin is a romanization system, not the actual Chinese characters. So technically, there’s, The user has provided a single word: “WancaiZhang”. This appears to be a name, likely Chinese. The instruction is to translate from Simplified Chinese to English with the highest accuracy and academic tone, following specific rules for LaTeX, citations, and paragraph tags.

However, the input “WancaiZhang” is just a name. It’s not wrapped in any tags, doesn’t contain any LaTeX commands, citations, or mathematical expressions. It’s simply a proper noun.

According to the instructions: 1. I should preserve ALL LaTeX commands and placeholders - but there are none here. 2. I should preserve ALL citation commands - but there are none here. 3. I should **PRESERVE ALL ...paragraph**

**wrapper tags EXACTLY** - but there are none here. 4. I should maintain academic tone and formal scientific writing style. 5. I should use precise technical terminology - but this is just a name. 6. I should preserve section structure and paragraph organization - but there' s no structure here. 7. I should translate all content completely - but a name typically doesn' t get "translated" in the traditional sense.

For Chinese names, the standard academic practice is to either: - Keep the original Chinese characters (if they were provided) - Use the Pinyin transliteration with proper formatting

The input is "WancaiZhang" which appears to be a Pinyin representation already. In academic contexts, Chinese names are typically written with the surname first, followed by the given name. The standard format is either: - Zhang Wancai (surname first, no comma) - Wancai Zhang (Western order, given name first)

Given that the input is already in a Pinyin-like format but concatenated without spaces, I should interpret this as a name that needs proper academic formatting. The most likely interpretation is that this is a person' s name: Zhang Wancai (张万才 or similar).

However, the instructions say to translate from Simplified Chinese to English. Since this is a proper name, the "translation" would be to properly format it according to academic conventions. The input "WancaiZhang" seems to be a concatenation of given name and surname. In Chinese, the surname typically comes first, so "Zhang" is likely the surname and "Wancai" the given name.

But wait - the user might have intended this to, The user wants me to translate a scientific paper from Simplified Chinese to English. The input is just "LijunZhang" which seems like an author' s name. This is not a paragraph with Chinese text to translate.

Let me check the requirements again: - The user provided "LijunZhang" as input - This appears to be a name, not a paragraph with tags - The system prompt says I should preserve ...tags - The system prompt says I should translate Chinese text inside the tags

Since the input is just a name "LijunZhang" and doesn' t contain any: 1. Chinese text to translate 2. tags 3. LaTeX commands 4. Citations

There is nothing to translate. The input is already in English (or at least a romanized name).

I should return the input as-is since there' s no Chinese content to translate. The name "Lijun Zhang" would typically be written with a space in English academic contexts, but the user wrote it as "LijunZhang" without a space. I should preserve it exactly as given.

Wait, let me reconsider. The user might have made a mistake and only provided the author name. But according to the instructions, I should only translate the

Chinese text inside tags. Since there are no tags and no Chinese text, I should return nothing? Or return the input unchanged?

The instructions say: “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).”

Since there’ s nothing to translate, and no tags to preserve, I should probably return an empty string. But that seems odd.

Let me think about the context. The user might be testing the system, or they might have intended to provide a full paragraph but only pasted the author name. The most faithful interpretation of the instructions is that if there’ s no Chinese text within tags to translate, I should return nothing.

However, the input “LijunZhang” could be considered a complete input that doesn’ t require translation. The instructions say “Translate from Simplified Chinese to English” . Since this is not Simplified Chinese, it doesn’ t need translation.

I think the most appropriate response is to return the input unchanged, as it’ s not Chinese text and doesn’ t contain any tags that need processing. But wait, the, The user has provided “ShunyouQin” which appears to be a name, likely the author name “秦舜友” (Qin Shunyou). However, the user hasn’ t provided any actual Chinese text to translate.

Let me check the instructions again. The user wants me to translate from Simplified Chinese to English with specific requirements about preserving LaTeX, citations, and tags. But they only gave me a name.

I should respond by asking for the actual text to be translated, or perhaps this is a test to see if I follow the rules. Since the instructions say “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)” , and the input is just “ShunyouQin” , I should just return that as is, since it’ s already in English/Latin characters.

But wait, “ShunyouQin” might be the pinyin of a Chinese name. The glossary shows “机器学习 => machine learning” and “深度学习 => deep learning” , but no name translations.

Looking at the critical requirements: 1. Preserve ALL LaTeX commands and placeholders - not applicable here 2. Preserve ALL citation commands - not applicable 3. **PRESERVE ALL ...paragraph wrapper tags EXACTLY** - not present 4. Maintain academic tone - not applicable 5. Use precise technical terminology - not applicable 6. Preserve section structure - not applicable 7. Translate all content completely - the content is just a name

The output rules say: - Return ONLY the translated text - Keep one output paragraph per input paragraph - but there’ s no paragraph tag - **Maintain exact count and IDs of ...tags** - none present - Do NOT add Markdown formatting - Preserve original line breaks

Since there' s no tag, I cannot add one. The input is just “ShunyouQin” . This is likely a name that should be translated to “Qin Shunyou” (Chinese names are family name first). But the user wrote it as “ShunyouQin” which might be intentional.

Given the strictness of the instructions and that there' s no actual Chinese text with tags, I should probably just return the input as is, since it' s not Chinese text that needs translation. The name “ShunyouQin” appears to already, The user has provided a name “ZhiqiangShen” and no other context. This appears to be a person' s name in Chinese. The instruction is to translate from Simplified Chinese to English with the highest accuracy and academic tone, following all the critical requirements about preserving LaTeX, citations, and tags.

However, the input is just a name. Let me analyze:

1. “ZhiqiangShen” - This is a Chinese name, likely “沈志强” or similar in Chinese characters, but it' s provided in Pinyin without spaces. In academic contexts, Chinese names are typically handled in specific ways.
2. The name appears to be in the format “GivenNameFamilyName” (Zhiqiang Shen) but written without a space.
3. According to the instructions, I should:
  - Preserve ALL LaTeX commands and placeholders
  - Preserve ALL citation commands
  - **PRESERVE ALL ...paragraph wrapper tags EXACTLY**
  - Maintain academic tone
  - Use precise technical terminology from the glossary
  - Preserve section structure and paragraph organization
  - Translate all content completely

But there is no Chinese text to translate, no tags, no LaTeX, no citations. It' s just a name.

In academic papers, Chinese names are typically: - Written as “Zhiqiang Shen” (with space) if following Western convention - Or “Shen Zhiqiang” if following Chinese convention (family name first) - Or kept as “ZhiqiangShen” if it' s a username or specific identifier

Since the user hasn' t provided any context about what this name is for (author name, citation, etc.), and there are no tags or other structural elements, I should consider what the most appropriate academic translation/rendering would be.

The most standard academic practice for Chinese names in English publications is: - Family name: Shen - Given name: Zhiqiang - Written as: Zhiqiang Shen (given name first, family name last, with space)

However, the instructions say “Translate from Simplified Chinese to English” . A name isn' t really “translated” but rather “romanized” or formatted. The input “ZhiqiangShen” is already in Pinyin (romanization).

Given the strict requirements about preserving structure, but there being no structure to preserve, The user wants me to translate a scientific paper from Simplified Chinese to English. The key requirements are:

1. Preserve ALL LaTeX commands and placeholders exactly
2. Preserve ALL citation commands ([?], ??, (??), etc.) exactly
3. **PRESERVE ALL ...paragraph wrapper tags EXACTLY**
4. Maintain academic tone and formal scientific writing style
5. Use precise technical terminology - obey the glossary strictly
6. Preserve section structure and paragraph organization
7. Translate all content completely - do not omit any information

The glossary provided is: - 机器学习 => machine learning - 深度学习 => deep learning

The user has provided “QinghuiLiu” as input. This appears to be a name, likely the author name. However, the instructions say to translate from Simplified Chinese to English. “QinghuiLiu” is already in English (or at least Latin script). Let me check if this is meant to be a test or if there’ s actual Chinese content to translate.

Wait, the user just provided “QinghuiLiu” . This could be: 1. A test to see if I follow instructions 2. An incomplete input 3. The name of an author that should be preserved as is

Given the strict requirements about preserving tags and LaTeX, and the fact that “QinghuiLiu” contains no Chinese characters, no LaTeX, no citations, and no tags, I should probably just return it as is. But let me re-read the instructions carefully.

The instructions say “Translate from Simplified Chinese to English” . The input “QinghuiLiu” is not Chinese. It’ s a name in Latin script. The most appropriate action would be to return it unchanged, as there’ s nothing to translate.

However, I should consider if this is a filename or a reference to something else. But without more context, I should treat it as literal content to be processed according to the rules.

Since there are no tags, no LaTeX, no Chinese text, the output should be exactly the same as the input: “QinghuiLiu” .

But wait, let me think about this more carefully. The user might be testing whether I: 1. Recognize that there’ s nothing to translate 2. Still follow the output format rules 3. Don’ t add any extra content

The output rules say:, The user wants me to translate a scientific paper from Simplified Chinese to English. The input is “BinLi” . This seems incomplete. Let me check the instructions again.

The user provided: - CRITICAL REQUIREMENTS about preserving LaTeX, citations, and tags - OUTPUT RULES - FORMATTING GUIDELINES - A

glossary

But the actual content to translate is just “BinLi” . This is likely a name. In academic contexts, Chinese names are typically transliterated. “Bin Li” would be the standard way to write this name in English, with the surname “Li” and given name “Bin” .

However, the instructions say “Translate from Simplified Chinese to English” . “BinLi” is not a paragraph with tags, LaTeX, or anything else. It’ s just a name.

Let me think about how to handle this: 1. If this is a standalone name, I should transliterate it as “Bin Li” 2. But the instructions are very specific about tags and structure 3. The user might have made a mistake and only sent a fragment

Given the strict requirements about preserving `…tags`, and the fact that the input “BinLi” doesn’ t contain any such tags, I have a few options: - Just transliterate the name: “Bin Li” - Ask for clarification - Assume this is a test and provide the most appropriate translation

The instructions say “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).” and “Keep one output paragraph per input paragraph; do not merge or split paragraphs.”

Since the input is just “BinLi” without any paragraph tags, I should probably just provide the transliterated name. But the instructions emphasize preserving tags. This is contradictory.

Let me re-read: “Translate from Simplified Chinese to English with the highest accuracy and academic tone.” and “PRESERVE ALL `…paragraph wrapper tags EXACTLY`” .

The input doesn’ t have these tags. So I cannot preserve them. The most reasonable interpretation is that the user wants me to translate whatever Chinese text is provided, and if there are no tags, then I just translate the text.

“BinLi” is likely “宾丽” or “斌利” or similar, but without characters, I have to work with the Pinyin. In academic, The user has provided a name “JinqingWang” which appears to be a person’ s name. This is not a Chinese text to translate. The instruction is to translate from Simplified Chinese to English with specific requirements about preserving LaTeX, citations, and tags.

Since “JinqingWang” is already in English/Latin characters, there’ s nothing to translate. It’ s likely either: 1. A test to see if I follow instructions correctly 2. A fragment that was accidentally sent 3. The name of an author that would appear in a paper

Given the strict requirements, I should: - Not add any tags since there are none in the input - Not add any explanations - Return ONLY the translated text (which is just the name itself) - Preserve it exactly as written

The name “JinqingWang” appears to be a romanized Chinese name. In academic contexts, this would typically be written as “Jinqing Wang” with a space between given name and surname. However, the instruction says “Translate from Simplified Chinese to English” and “Return ONLY the translated text for the given input” . The input is “JinqingWang” which is not Chinese characters but Pinyin.

Should I: 1. Keep it exactly as “JinqingWang” ? 2. Format it properly as “Jinqing Wang” ?

The instructions say “Translate from Simplified Chinese to English” . Since the input is already in a romanized form (not Chinese characters), there’s no actual translation needed. The most faithful approach would be to return it exactly as written: “JinqingWang” .

However, looking at the glossary provided: - 机器学习 => machine learning - 深度学习 => deep learning

These are translations from Chinese terms. But “JinqingWang” is not a Chinese term in characters - it’s already in Pinyin/English form.

The safest approach that follows “Return ONLY the translated text for the given input” is to return the name exactly as provided, since no translation is needed or possible. The name is already in a form that would be used in an English academic paper.

Let me check the requirements again: - “Preserve ALL LaTeX commands and placeholders exactly” - not applicable here - “Preserve ALL citation commands” - not applicable - “PRESERVE ALL  $\cdots$ paragraph wrapper tags EXACTLY, The user wants me to translate a Chinese text to English. The text is:

“BiaoDu”

This is very short. Let me think about what this could mean.

“BiaoDu” could be: 1. A name (like a person’s name or a company name) 2. A technical term 3. A typo or abbreviation

In the context of scientific translation, especially with machine learning/deep learning: - “BiaoDu” might be a transliteration of “Baidu” (百度), the Chinese tech company - It could be a specific term I’m not familiar with

Looking at the glossary provided: - 机器学习 => machine learning - 深度学习 => deep learning

There’s no entry for “BiaoDu” .

Given the critical requirements: 1. Preserve LaTeX commands and math placeholders - not applicable here 2. Preserve citation commands - not applicable 3. Preserve tags - not applicable (there are none in this input) 4. Maintain academic tone 5. Use precise technical terminology 6. Preserve section structure - not applicable 7. Translate all content completely

The input is just “BiaoDu” with no tags, no LaTeX, no citations.

If this is a name, especially a company name like “Baidu”, the standard practice is to either: - Keep it as is (BiaoDu or Baidu) - Use the standard English transliteration (Baidu)

“BiaoDu” with that capitalization looks like a transliteration. The standard English spelling for 百度 is “Baidu” .

However, I should be careful. The user wrote “BiaoDu” not “Baidu” . In academic translation, if something is presented as a proper name, I should generally preserve it as written unless there’ s a clear standard alternative.

But wait - the user might have typed “BiaoDu” as a placeholder or example. Let me re-read the instructions.

The instructions say “Translate from Simplified Chinese to English with the highest accuracy and academic tone.”

“BiaoDu” is Pinyin (romanization) of Chinese characters. If it’ s meant to be 百度 (the company), the correct English rendering is “Baidu” . If it’ s a different term, I need to know the characters.

Since I don’t have the actual Chinese characters, and the user provided “BiaoDu” , I have a few options: 1. Treat it as a proper name and keep it as “BiaoDu” 2. Assume it’ s 百度 and translate to “Baidu”

**Date:** 2024-09-26T00:00:00+00:00

## Abstract

The user wants me to translate a Chinese text about the Tianma 65m radio telescope into English. Let me analyze the requirements:

### 1. Critical Requirements:

- Preserve ALL LaTeX commands and placeholders exactly
- Preserve ALL citation commands ([?], ??, (??), etc.) exactly
- **PRESERVE ALL `…`paragraph wrapper tags EXACTLY**
- Maintain academic tone and formal scientific writing style
- Use precise technical terminology - obey the glossary strictly
- Preserve section structure and paragraph organization
- Translate all content completely - do not omit any information

### 2. Output Rules:

- Return ONLY the translated text (no explanations, no quotes, no headings)
- Keep one output paragraph per input paragraph
- Maintain exact count and IDs of `…`tags
- Do NOT add Markdown formatting unless present in source
- Preserve original line breaks within the paragraph when meaningful

### 3. Formatting Guidelines:

- Keep mathematical expressions in original LaTeX format
- Preserve equation numbers and references
- Maintain proper academic paragraph structure
- Use formal scientific language

#### 4. Glossary:

- 机器学习 => machine learning
- 深度学习 => deep learning

Looking at the input text, I see it's a single paragraph about the Tianma 65m radio telescope. However, I notice there are NO `...`tags in the input. This is interesting - the user is asking me to preserve these tags, but they don't appear in the actual input.

Let me re-read the input carefully: "The Tianma 65 m radio telescope (TMRT) at Shanghai is a fully steerable single-dish radio telescope in China, operating at centimeter to millimeter wavelengths (1.25 GHz to 50 GHz). This paper presents details on the main specifications, design, performance analysis, testing, and construction of the telescope antenna. The measured total efficiency is better than 50% over the whole elevation angle range, first sidelobe levels are less than  $-20$  dB, antenna system noise temperatures are less than 70 K at  $30^\circ$  elevation angle, and pointing accuracy is less than  $3''$ . The measured and calculated results are in good agreement, verifying the effectiveness of the design and analysis."

Wait, this text is already in English

## Full Text

### 2.1 Optical Design

The geometry of the 65 m antenna is illustrated in Fig. 2, featuring a main reflector with a diameter of 65 m and a subreflector of 6.5 m, with a half-illumination angle of  $13^\circ$ . The reflectors are shaped to achieve higher aperture efficiency ( $-20$  dB), and reduced wide-angle sidelobes, thereby attaining high sensitivity through high gain and low noise temperature. The main parameters of the 65 m antenna are as follows: (1) Main reflector diameter  $D_m = 65$  m; (2) Subreflector diameter  $D_s = 6.5$  m; (3) Focal length to diameter ratio  $f/D = 0.32$ ; (4) Half angle subtended to the subreflector  $\theta_s = 76^\circ$ ; (5) Half angle subtended to the main reflector  $\theta_m = 13^\circ$ .

Shaped reflectors produce an aperture field distribution with nearly uniform energy across the entire aperture and very low tapered energy at the outer edge, as shown in Fig. 3A. The subreflector edge taper is selected as  $-16.5$  dB. The radiation pattern at the shaped frequency is calculated and presented in Fig. 3B. The product of aperture illumination and subreflector interception efficiency is 86.0%, and the first sidelobe level is  $-23.72$  dB, which meets the requirement of  $-20$  dB.

Since the beam width of a feed changes across its operating frequency band, particularly for dual-band feeds, the subreflector edge taper radiated by each feed varies across its frequency band, and the antenna radiation patterns change accordingly. Consequently, antenna radiation patterns must be re-examined at other frequencies. These patterns are calculated for the two extreme cases of the highest and lowest edge tapers ( $-13$  dB and  $-22$  dB), as shown in Fig. 4. The products of aperture illumination and subreflector interception efficiency are 86.4% and 82.3%, and the first sidelobe levels are  $-22.23$  dB and  $-26.61$  dB for edge tapers of  $-13$  dB and  $-22$  dB, respectively, both meeting requirements.

The 65 m antenna must accommodate nine feeds and receivers at the secondary focus, including six single-band feeds (L, C, Ku, K2, Ka2, and Q2), two dual-band feeds (S/X and X/Ka), and one spare position for a prospective future feed. K2, Ka2, and Q2 represent dual-beam feeds in the K, Ka, and Q bands, respectively. Solving the problem of accommodating these nine feeds with minimal primary blockage is non-trivial. The solution adopted for the frequency band switching system is to rotate each feed (S-Q band) to the focus in turn, while tilting the subreflector to the separately placed L-band feed (the largest feed), as shown in Fig. 5. Because the L-band feed is too large to fit on a turntable with a 2.7 m diameter, it is placed at an offset position relative to the central axis of symmetry outside the turntable. The other eight feeds are placed on the turntable, with one vacant position reserved for a new band feed (the unlabeled feed in Fig. 5). When the antenna operates in L-band, the subreflector is deflected to align with the L-band feed. When operating in any other frequency band (S-Q band), that frequency band feed is rotated to the secondary focus. A corrugated horn is used for all feeds, including the two S/X and X/Ka dual-band feeds.

As shown in Fig. 5, the primary blockage is created by the S/X dual-band feed (the second largest) and the feed-supporting cylinder. The additional blockage area, beyond subreflector blockage, is  $2.9$  m<sup>2</sup>, generating 0.0008 dB extra gain loss which can be ignored.

## 2.2 Structural Design

The 65 m antenna adopts an azimuth-elevation structure with a wheel-and-track configuration, as shown in Fig. 6. It consists of two parts: a reflector (comprising main reflector and subreflector) and a mount. It can be pointed to any elevation angle between  $5^\circ$  and  $88^\circ$ . The total weight of the antenna system is  $2,640 \times 10^3$  kg.

### 2.2.1 Reflector

The antenna reflector consists of a main reflector, a subreflector, a quadrupod support for the subreflector, and a feed cabin, as shown in Fig. 7. The main reflector has a backstructure, a high-accuracy reflector surface, and 1104 active surface adjustment actuators. The backstructure adopts a space truss

design with optimized cross-section size. The main reflector surface is divided into 14 concentric rings, as shown in Fig. 8. It consists of 1008 individual solid aluminum panels with surface areas between 2.66 m<sup>2</sup> and 4.90 m<sup>2</sup>. 1104 computer-controlled actuators are mounted on the backstructure to support the 1008 panels, compensating for gravitational and thermal distortion of the reflector. High-accuracy panels with slot ribs are used, and the surface accuracy of each panel from the 1st to 12th ring is less than 0.1 mm (RMS), and 0.13 mm (RMS) from the 13th to the 14th ring. The total surface accuracy of the main reflector is less than 0.6 mm (RMS) at the optimum elevation angle (rigging angle) of 50° without actuator adjustment during initial alignment by photogrammetry in Phase 1. In Phase 2, it is less than 0.3 mm (RMS) over the entire elevation angle range of 10°–80° using actuator adjustment by holography.

The subreflector consists of a backstructure, a high-accuracy subreflector surface, and a hexapod adjusting mechanism, as shown in Fig. 9. The subreflector surface comprises 25 individual solid aluminum panels, with surface areas between 1 m<sup>2</sup> and 1.78 m<sup>2</sup>, divided into 3 concentric rings including one central panel and 24 panels assembled into 2 rings. The high-accuracy panels have a double-layer honeycomb sandwich structure, and the surface accuracy of each panel is less than 0.05 mm (RMS). The position and attitude of the subreflector, relative to the main reflector, are constantly controlled in real time by the hexapod adjusting mechanism to compensate for gravity deformation when the antenna rotates in elevation.

The subreflector is supported by a quadrupod, connected to the backstructure with a steel truss bar structure and four 45° inclined beams, as shown in Fig. 7. The blockage area of the quadrupod is less than 4.9% of the projected aperture area of the main reflector.

A feed cabin accommodates nine feeds and cryogenic receivers at the secondary focus. This allows for frequency band switching between eight feeds using a rotating turntable and deflection of the subreflector. The L-band feed placement is offset from the secondary focus and outside the turntable. The setup is shown in Fig. 10. Maximum external dimensions of the feed cabin are  $\Phi 4,640$  mm  $\times$   $\Phi 6,000$  mm  $\times$  3,920 mm, with a turntable diameter of 2,700 mm.

### 2.2.2 Mount

The 65 m antenna mount uses an elevation-over-azimuth design with wheel-and-track configuration, consisting of an alidade, azimuth track, azimuth wheel assembly, elevation wheel assembly, azimuth drive assembly, elevation drive assembly, azimuth and elevation encoders, and safety devices. The mount structure is symmetrical, with the azimuth and elevation axes intersecting at one point in space. A 3D model is shown in Fig. 11.

The alidade is a welded steel space truss structure consisting of rectangular beams, which is supported by 6 groups of wheels and a large central concrete tower. The concrete tower is one of the bulks of the antenna foundation. The

bottom frame of the alidade comprises a welded hexagonal frame, asterisk beams, and the turntable plate of the central pintle at the top of the tower. A pintle bearing provides support against lateral loads. The main supporting structure on both sides is the space truss consisting of A-type beams. The bottom frame, main supporting structure on both sides, five platforms, and multiple space beams form the high-stiffness alidade.

The elevation wheel assembly is a key component for controlling antenna elevation. It consists of a double-layer octagonal frame with cross beams, conical space truss, and elevation wheel (big sector gear), as shown in Fig. 12. The diameter of the wheel gear is 28 m. The elevation wheel assembly is connected to the alidade below using left/right elevation bearing bases, and to the reflector above with a double-layer octagonal frame.

Eight motors are used for the azimuth drive assembly and four motors for the elevation drive assembly. The elevation drive is suspended from the elevation gear. The azimuth and elevation drive assemblies use electric anti-backlash systems to eliminate gear backlash, and all the driving boxes include a planetary gear reducer.

The azimuth track is the basis of the overall antenna azimuthal rotation, with a diameter of 42 m. The track is made of 42CrMo alloy steel, divided into 32 segments for machining, which are assembled by welding to form a whole track on-site. Its flatness error is less than 0.5 mm (RMS).

Renishaw high-precision resolute encoders are used as angular sensors for both azimuth and elevation axes of the antenna. Its diameter is 300 mm, resolution is 26 bits (0.02"), and system accuracy is better than 1". The encoder connection uses a leading shaft from the center of the rotation axis to improve connection precision.

There are five platforms on the alidade to accommodate devices and facilitate operation and maintenance. From the bottom up, they are the combined room platform (incorporating a user remote control room, servo control room, and uninterrupted power supply room), elevation drive platform, left and right pathway platform, left and right elevation bearing base maintenance platform, and feed cabin pathway platform. There is an elevator on one side of the mount and a ladder on the other side, allowing access to each level of the platform.

### 2.2.3 Antenna System Weight

The total weight of the antenna system is about  $2,640 \times 10^3$  kg. The reflector weighs  $575 \times 10^3$  kg and the mount weighs  $2,065 \times 10^3$  kg.

## 2.3 Servo Control System

The servo control system is high-performance and fully digital. It is mainly used to accurately control pointing and tracking of the antenna to target deep space objects and radio sources. It controls azimuth and elevation rotation of

the antenna, multiple-degree-of-freedom motion of the sub-reflector, and rotation of the feed turntable. It can be remotely controlled from a main control unit (MCU) and operates automatically. The servo control system incorporates a control architecture with a multi-motor pre-tension anti-backlash drive mode and three classical feedback loops (position, rate, and torque). Compound control methods (CPP+FF+PID) are used for high tracking accuracy.

The servo control system comprises the antenna control unit (ACU), drive control units (DCUs), encoders, frequency band control unit (FCU) and drive unit, subreflector control unit (SCU) and drive unit, automatic weather station, power distribution and safety protection unit. A block diagram for the servo control system is shown in Fig. 13.

All units and components of the servo control system perform reliable and highly accurate pointing control. The ACU receives commands using an Ethernet connection based on TCP/IP from the main control unit to coordinate the operation of the entire servo control system.

The ACU and DCUs constitute the three-loop control architecture, including the position loop, velocity loop, and current loop. The ACU performs tasks such as position encoding, position loop compensation, pointing correction and status collection, and the DCUs form a complete current loop and velocity loop, and drive the antenna to the command position under ACU control.

The FCU and its drive unit switch the selected feed and cryogenic receiver to the secondary focus according to operating frequency band. When the antenna rotates in elevation, the SCU and its drive unit adjust the position and attitude of the subreflector to compensate for gravity deformation by controlling the length of the hexapod's legs. When the antenna operates in the L band, the SCU and its drive unit also control the subreflector to point to the L-band feed by driving the hexapod.

The power distribution and safety protection unit mainly perform two functions: to complete the automatic power on/off logic of the servo control system under the control of ACU, and to implement safety protection through the limit sensor and control protection logic circuit.

### 3.1 Performance Analysis

Antenna performance analysis can verify whether the designed antenna meets requirements. It involves structural, electrical, and servo performance analysis.

#### 3.1.1 Structural Performance Analysis

Structural performance analysis includes antenna strength, stiffness (alignment accuracy), modal, and seismic response analysis. Five kinds of loads are considered in the analysis: gravity, thermal, wind, snow, and seismic loads. The finite element method is used with finite element analysis (FEA) to determine structural performance.

The finite element model (FEM) is key to FEA, with modeling accuracy directly affecting analysis result accuracy. The FEM includes the antenna's main structural components, such as the main and subreflector backstructure and panels, quadrupod support, feed cabin, alidade, elevation wheel assembly, elevator, ladder, and other ancillary devices. Meanwhile, the mass of feeds, the compressor, and the connected balls of the backstructure are also included in the model. The total weight of the model is about  $2,000 \times 10^3$  kg. The FEM is shown in Fig. 14 at three elevation angles. Different types of elements are used to build the model. For example, shell elements are used for panels and gears, beam elements are used for backstructure and quadrupod support, and mass elements are used for counterweight, hexapod adjustment, and frequency band switching mechanisms. The elevation bearings are given three degrees of freedom, and the azimuth bearing is given two degrees of freedom (one rotational, around the azimuth axis, and one translational, in the vertical direction). The model uses 100,000 nodes and 106,000 elements.

Constraints have a strong influence on calculation results. At the active azimuth wheels, three translational degrees of freedom are constrained and three rotational degrees of freedom are permitted; at the passive azimuth wheels, only the vertical translational degree of freedom is constrained, and the other five degrees of freedom are permitted; at the azimuth central pintle, one rotational degree of freedom, around the azimuth axis, and one vertical translational degree of freedom are permitted, and the other four degrees of freedom are constrained.

Deformations of the antenna under gravity are calculated at different elevation angles. Due to space limitations, Fig. 15 shows gravity deformations at only three elevation angles. Taking a  $50^\circ$  elevation angle as the rigging angle (optimum adjustment angle), the surface accuracy of the antenna is calculated. When an antenna reflector alignment test was conducted without the active surface, the required surface accuracy of the main reflector at the rigging angle is 0.6 mm (RMS). Fig. 16 shows calculated variation curves for total surface accuracy at elevation angles under gravity load, including adjustment error (alignment error) at the rigging angle of  $50^\circ$ . The total surface accuracy under only the gravity load and gravity load plus adjustment error is less than 0.65 mm and 0.90 mm (RMS) over the entire elevation angle range ( $5^\circ$ - $90^\circ$ ). Surface error cloud charts for the main reflector under only gravity load at  $5^\circ$  and  $90^\circ$  are given in Fig. 17.

Antenna strength analysis is an important method for evaluating antenna safety. It involves a variety of loads such as gravity load, thermal load, driving wind load (28 m/s) and snow load when driving to the stowed position, and gravity load, thermal load, survival wind load (45 m/s), and snow load in the survival condition. Antenna strength is calculated under 12 load cases, and the local structural strength of key antenna components is also calculated to evaluate safety. Some calculated stress results are shown in Fig. 18. Maximum stress is less than the yield stress of steel materials, with a safety coefficient of approximately 2.

Eigenfrequency is a key specification closely related to the dynamic performance of the antenna. It can be calculated by modal analysis. Table 2 gives first-order eigenfrequencies at different elevation angles.

### 3.1.2 Electrical Performance Analysis

Electrical performance analysis includes calculations of total antenna efficiency, antenna radiation pattern, and antenna noise temperature. Radiation pattern is calculated using the GRASP software package. Total efficiency is calculated by the efficiency factor method, using the formula:

$$\eta_T = \eta_1 \eta_2 \eta_3 \eta_4 \eta_5 \eta_6 \eta_7 \eta_8 \eta_9 \eta_{10}$$

where  $\eta_T$  is total efficiency of the antenna,  $\eta_1$  is illumination efficiency,  $\eta_2$  is interception efficiency (spillover loss),  $\eta_3$  is cross polarization efficiency,  $\eta_4$  is phase error efficiency,  $\eta_5$  is blockage efficiency,  $\eta_6$  is alignment error efficiency,  $\eta_7$  is feed insertion loss efficiency,  $\eta_8$  is reflection loss efficiency due to antenna voltage standing wave ratio (VSWR),  $\eta_9$  is reflector loss efficiency due to Ohmic and dielectric losses, and  $\eta_{10}$  is reflection efficiency of reflector surface due to transmission loss. The product of the first five factors is called aperture efficiency  $\eta_A$ , which can also be calculated with the GRASP software.

Antenna noise temperature from sky and ground contribution,  $T_A$ , is calculated with the formula:

$$T_A = \frac{\int_0^{2\pi} \int_0^\pi P(\theta, \phi) T_b(\theta) \sin \theta d\theta d\phi}{\int_0^{2\pi} \int_0^\pi P(\theta, \phi) \sin \theta d\theta d\phi}$$

where  $T_b(\theta)$  is the brightness temperature distribution from sky and ground, and  $P(\theta, \phi)$  is the power pattern of the antenna.

Table 3 gives the calculated total efficiency of the antenna at different frequency bands, at the rigging angle ( $50^\circ$ ), where the surface accuracy of the main reflector is set to 0.6 mm (RMS) without active surface adjustment and 0.3 mm (RMS) with active surface adjustment. The surface accuracy of the main reflector is a key factor affecting total efficiency in the high-frequency bands (K, Ka, and Q bands), in which active surface adjustment is needed to achieve better efficiency. Antenna total efficiency is better than the required 45% from the L to Q band.

Antenna radiation patterns from the L to Q band are calculated using the GRASP software. Due to space limitations, only the first sidelobe level is given in Table 4, which is less than  $-20$  dB in all bands. Calculated antenna noise temperature from ground contribution only,  $T_{\text{ground}}$ , is shown in Fig. 19. Noise temperature is less than 10 K in the L band and 7 K at a  $30^\circ$  elevation angle from the S to Q band.

### 3.1.3 Servo Performance Analysis

Servo performance analysis provides the pointing error budget under precision operating conditions (wind speed  $\leq 4$  m/s, air temperature variation rate  $\leq 2^\circ\text{C/h}$ ), as shown in Table 5. Total pointing error is 2.79" (RMS), which is below the pointing accuracy specification of 3", meeting requirements.

## 3.2 Test Verification

After antenna installation and commissioning, a comprehensive test (on structural, electrical, and servo function and performance) was carried out. Forty-three tests and inspections were completed, and the main performance test results are given here. The structural performance test includes a surface accuracy test for the main and subreflectors; the electrical performance test covers antenna efficiency, radiation pattern, and noise temperature; and the servo performance test includes a pointing accuracy test. The measured results are compared with calculations to verify the design and analysis.

### 3.2.1 Structural Performance Test

Surface accuracy of the main reflector (without active surface) and the subreflector were measured by photogrammetry, and then the main reflector surface accuracy was measured (with and without active surface) by holography. When the active surface was not used in Phase 1, a main reflector surface accuracy of 0.59 mm (RMS) and 1.13 mm (RMS) was achieved at elevation angles of  $50^\circ$  and  $10^\circ$ , respectively.

A comparison of the main reflector surface error between photogrammetry and holography tests at a  $50^\circ$  elevation angle, without active surface, is given in Fig. 20 as a cloud chart. Here, photogrammetry and holography tests were performed at  $50^\circ$  and  $52.3^\circ$  elevation angles. Surface accuracy measurements of the main reflector, determined by photogrammetry and holography tests, are 0.58 mm (RMS) and 0.56 mm (RMS) respectively, which are in good agreement. Fig. 21 shows the measured and calculated main reflector surface error cloud charts at a  $10^\circ$  elevation angle, where the calculated cloud does not include alignment error at the rigging angle of  $50^\circ$ . The measured and calculated surface accuracies are 1.13 mm (RMS) and 0.81 mm (RMS) respectively, showing some discrepancy. However, the trend of deformation is essentially consistent, and the difference is within an acceptable range for such a large antenna. After the actuators are used to adjust the main reflector surface, the surface accuracy is less than 0.3 mm (RMS) over the whole elevation angle range ( $10^\circ$ - $80^\circ$ ), measured by holography.

### 3.2.2 Electrical Performance Test

Total efficiency of the antenna was measured using the radio source method, the radiation pattern was measured by the satellite source method, and noise

temperature was measured with the Y-factor method.

Total efficiency was measured over the entire elevation angle range, from the L to Q band. Table 6 shows measured total efficiency at the rigging angle in all frequency bands. Total efficiency is better than 52% at the rigging angle and over 50% across the entire elevation angle range ( $10^{\circ}$ - $80^{\circ}$ ).

Radiation patterns from the L to K band were measured using the satellite source method, while radiation patterns in the Ka and Q bands were measured with the strong radio source method, because there are no satellites operating in these two bands. Due to space limitations, Figs. 22 and 23 only give measured and calculated radiation patterns in the S and X bands. These are in good agreement, verifying the design and analysis.

Table 7 gives the measured first sidelobe from the L to Q band. The maximum first sidelobe level in all bands is less than  $-20$  dB. Table 8 gives the measured antenna noise temperatures from ground contribution  $T_{\text{ground}}$  and antenna system noise temperatures  $T_{\text{ant}}$ , including noise contribution from Ohmic loss and feed loss at room temperature (not including receiver), at a  $30^{\circ}$  elevation angle, from the L to Q band. Measured noise temperatures from ground contribution are less than 10 K in the L band and below 7 K in all other bands, and antenna system noise temperatures are below 70 K in all bands.

### 3.2.3 Servo Performance Test

Pointing accuracy was tested using multiple radio sources in the Ka band, and the measured pointing accuracy is less than  $3''$  (RMS). Fig. 24 gives the tested pointing error distribution map.

## 4 Construction Milestones

The TMRT antenna went through two stages of construction, from signing the contract to final acceptance, lasting for nine years. In Phase 1 (2009-2012), the antenna was operating in four low-frequency bands, and in Phase 2 (2013-2017), the antenna operated in all frequency bands. Milestones for the antenna construction are listed in Table 9. Fig. 25 shows six photos of the antenna construction process.

## 5 Conclusion

After nine years of design, manufacture, construction, integration, commissioning, and verification, the TMRT has been completed. Its performance reaches an advanced level comparable to other high-performance international facilities, and its development and construction have accumulated valuable experiences for future large antenna construction.

*Note: Figure translations are in progress. See original paper for figures.*

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