TRAFFIC CHARACTERISTICS OF THE INTERNATIONAL TELEX CALLS

Naohiko Hattori and Kazuo Yamada
Kokusai Denshin Denwa Co.
Tokyo, Japan

ABSTRACT

This paper reports results of the measurements of the traffic characteristics in the existing international telex (INT TLX) trunk circuits for which comparatively less data have been reported, and the analysis of these traffic characteristics along with mathematical discussions, in comparison with such characteristics of the other main international public communications.

In this paper, recorded data of about 1,400,000 calls, which were full-automatically switched to and carried over the INT TLX circuits, have been computer-processed to analyze the traffic characteristics and to show the actual sides of utilization of the INT TLX, and the resultant characteristics have been compared with the international telephone (INT TELEPH) and the international telegraph (INT TELEG) as the other main international public communication systems to discern the differences of the traffic intensity (TI) distributions with respect to communication parties with time difference for the respective communication services of these systems.

1. INTRODUCTION

Recently, the traffic volume of the international communication services tends to more increase, including new services matched to the age in addition to the conventional, as the improvement of the circuit quality and the increase of the transmission capacity are being made using the submarine cables and the communication satellites to meet with the requirements of the increase of international information activities. The new international communication systems for various services have necessarily required an integrated communication system to improve the efficiency of the entire system suitable for the characteristics of each communication services. To cope with these requirements, it is necessary to grasp the traffic characteristics of these services and the relations between them, based on comparisons of the characteristics with each other. It should be noted in the international communications, in particular, that such factors inherent in these communications, as time difference, large delay, different kinds of languages, effect on the traffic characteristics.

Based on these backgrounds, this paper reports the results of the analysis and discussions concerning with the traffic characteristics on the INT TLX circuits and the effect of the above mentioned factors, which data have been little presented in the literatures, for 1,400,000 calls carried on the full-automatic switching system of the INT TLX circuits, after all the calls are once recorded and data-processed for this analysis. The other main international public communication system includes the INT TELEG and INT TELEPH: the former traffic characteristics is, in the similar way, analyzed after data concerning with their traffic characteristics are processed, and the traffic characteristics of the latter have already been clarified. The traffic characteristics of INT TLX, including the holding time distribution, the TI distribution vs. time difference, have been compared with those of INT TELEG and INT TELEPH so as to discern the difference of the traffic characteristics from each other. The INT TLX has remarkably extended as the communication system itself and the services are being improved in addition to the increase of circuits connectable to the parties and the automization of switching systems.

Regarding the communication system, in which informations can be communicated within the time when the circuit is set up, as a dialogue-type communication system, the telephone is an analogue-type communication system using auditory sense through the medium of voice in the same category as the telex. The telex, on the other hand, can in contrast, be characterized by a digital communication system using the visual sense through the medium of character, as the same sense from the viewpoint of the recordable communication using teleprinter signal, the INT TLX is consider to be half duplex communication system and the INT TELEG is to be simplex like communication system. These differences may cause traffic characteristic to be in contrast.

2. TIME DURATIONS CHARACTERISTICS FOR CALL

The time duration from the time when a occurred call seize an international switching equipment to the time when the call clears it is, in general, defined as "holding time". In this paper the time arrangement, as shown in Fig. 1, is in general assumed to consist of setting-up time required for switching and the chargeable time for communication. Besides this paper, the calls are classified into the successful and the unsuccessful calls with respect to the result of switching: the former being calls connected between subscribers to communicate with each other, have the chargeable time and the latter being calls seizing conclusively no party desired to be connected, though seizing
the international circuit, have thereby no time to be charged but consist of only the setting-up time and belong to the almost of other than the former. The times required for these successful and unsuccessful calls can be expressed by probability density functions.

A free line time, i.e., an idle time of the circuit can also be expressed in the form of probability density function.

2.1 HOLDING TIME DISTRIBUTION

Since the time duration of communication is determined by the will of the user, the holding time for calls including dialogue presents a considerable large dispersion, which can be described by a probability function in statistics. The holding time distribution of the general telephone calls is approximated to an exponential distribution. The solid line of Fig. 2 shows the measured holding time distribution of the INT TLX, in which it is shown that the probability of occurrence of call approximately monotonously decreases as the holding time \( t \) increases. The ensemble of these calls has a quantitative structure characterized by an exponential distribution of exponential function, different from that represented by the telephone call. In a cumulative distribution of the holding time distribution, the occupancy ratio of call having shorter holding times is very high as indicating that calls having 6 min. or shorter of holding time occupy about 90% of the attempt calls and calls having 20 min. or shorter occupy about 99% of these calls, then the average holding time is 2 min. The holding times are distributed over wide range since any upper limit of the holding time of call is not determined in the system. These characteristics showing these behaviours may be distorted distribution considerably different from the exponential distributions. It has also been verified that this distribution can not be approximated by the \( \gamma \)-distribution.

\[
f_H(t) = \frac{m}{(t - r)/s} \exp\left(-\frac{(t - r)^m}{s}\right), \quad (t \geq r)
\]

where \( m \) is shape parameter, \( s \) scale parameter, \( r \) location parameter and their values are respectively,

\[
m = 0.45, \quad s = 0.66, \quad r = 0.35
\]

If a probability that the holding time of a call is larger than \( \tau \) (min.) is \( f_H(\tau) \), it is expressed by the following equation.

\[
f_H(\tau) = \frac{m}{(\tau - r)/s} \exp\left(-\frac{(\tau - r)^m}{s}\right), \quad (\tau > r)
\]

If a probability that the holding time of a call is smaller than \( \tau \) (min.) is \( f(\tau) \), it is expressed by the following equation.

\[
f(\tau) = \frac{m}{(\tau - r)/s} \exp\left(-\frac{(\tau - r)^m}{s}\right), \quad (\tau < r)
\]

The solid line of Fig. 2 shows an approximate distribution for the holding time distribution of the calls, which can be best approximated by a Weibull distribution expressed by three independent parameters. The dashed line shows a Weibull plot of the cumulative distribution of holding time on the Weibull probability chart, based on the measured data, as shown in Fig. 4. It is considered that the holding time distribution of the source of call has a uniformly smooth monotonously decreasing characteristic. However, the probability of occurrence tends to increase for calls having the shorter holding time, but the rate of the increase of the probability of occurrence is somewhat small for calls having the holding time of the class limits 0 to 1 min. (0-1 min.) seen from Fig. 2. Therefore, it can easily supposed that there exist some extinguished calls which could not or would not seize the international circuits, not found in the data, having smaller holding time distribution, including the cases where the user himself gives up the call before seizing the international circuit and where the call cannot be proceeded including these calls. If these calls are added within the class 0-1 min. for the call holding time distribution to form a cumulative distribution of the holding time, the result is as shown by the dash-dot line of Fig. 4. Thus obtained regression line showing a approximate distribution is illustrated by the solid line.

2.2 CHARGEABLE TIME DISTRIBUTION

After a call is set-up by switching, it is charged in proportion to the communication time. When the switching system was a semi-automatic switching system, the average chargeable time of the outgoing call was about 6 min. After a full-automatic switching system is employed, the average chargeable time for full-automatic outgoing calls has been reduced to about 3 min. while the number of calls has remarkably increased. Fig. 3 shows a comparison of the measured holding time distribution with the measured chargeable time distribution both being normalized. The chargeable time distribution is also approximated to a Weibull distribution as same as the holding time distribution and the relative number of calls classified within chargeable times 0-1 min. are very remarkably reduced. The mode of the distribution, exists the class of 1-2 min. This is caused by that the unsuccessful calls, i.e., calls having no chargeable time as the Boiler has not attained the purpose of sending informations because of busy in the party subscriber and others, are concentrated in the class of this interval. It is thus estimated that calls 2-7 times the number of charged calls occur, if they include the extinguished calls, not found in the data previously estimated and the unsuccessful calls.

2.3 SETTING-UP TIME DISTRIBUTIONS

The setting-up time, which is roughly classified into
the times for the successful and the unsuccessful calls, from the viewpoint of the switching conditions, is started at the time when the proceed-to-select signal is received from the successive exchange and ended, for the successful call, at the time when the answer-back signal is received from the called subscriber, while it is ended, for the unsuccessful call, when the call is cleared. The main portion of the number of calls of both calls distributes within about 2 min. Both setting-up time distributions can also be approximated to Weibull distributions and the measured and the approximate distributions are shown in Fig. 5. Although both distributions measured are closely resembled, the position the peak of the setting-up time distribution of the successful calls is rather shifted to the increase of the setting-up time than that of unsuccessful calls, while remarkable two peaks appear in the setting-up time (the holding time) distribution of the unsuccessful calls.

The difference between both distributions is caused by the difference of the signalling conditions for the successful and the unsuccessful calls and the differences of the structures of the switching networks in the countries and of the exchanges. Besides these, the distributions are shifted each other by the requirement of time of, at least, 4 seconds to connect successfully a call. The setting-up times of the unsuccessful calls, i.e., the holding time of them, are distributed to form a combined distribution because that a comparatively large dispersion exists in the setting-up times of the respective circuits. The kinds and the number of exchanges in the relaying conditions for the respective circuits influence on the distributions as a dispersion of the setting-up time since the variation of the setting-up time determined by the respective exchange itself is small.

2.4 FREE LINE TIME DISTRIBUTION

Fig. 5-Setting-up Time Distributions of INT TLX

The difference between both distributions is caused by the difference of the signalling conditions for the successful and the unsuccessful calls and the differences of the structures of the switching networks in the countries and of the exchanges. Besides these, the distributions are shifted each other by the requirement of time of, at least, 4 seconds to connect successfully a call. The setting-up times of the unsuccessful calls, i.e., the holding time of them, are distributed to form a combined distribution because that a comparatively large dispersion exists in the setting-up times of the respective circuits. The kinds and the number of exchanges in the relaying conditions for the respective circuits influence on the distributions as a dispersion of the setting-up time since the variation of the setting-up time determined by the respective exchange itself is small.

2.4 FREE LINE TIME DISTRIBUTION

The free line time distribution, as an idle time between the clearance time of call and the occurrence time of the successive call in one trunk circuit, is also totally approximated to a Weibull distribution as well as the holding time distribution. A good linear regression line of the measured cumulative distribution is obtained on the Weibull probability chart.

The probability density function \( f_x(t) \) is expressed by the following equation:

\[
f_x(t) = \frac{0.37}{1.12} (1.04)^{0.37-1} \exp \left\{ -\frac{(1.04)^{0.37}}{1.12} \right\}, (1.04) (4)
\]

The solid line of Fig. 6 shows the theoretical distribution based on Eq. (3). The better fitness is verified by comparing with the measured values. The characteristic of this distribution have lower rate of descent in the range of longer free line time in comparison with that of holding time distribution, and the average is about 35 min. As will be clarified in the following chapters, the total free line times has a characteristic approximated by Eq. (4), however, the distribution patterns of the free line time are somewhat different for the local times when the number of calls is larger and when smaller. As the free line time increases, there are such characteristics that the rate of decrease of call occurrence rate is larger in the time when the number of calls is large, and is smaller in the time when the number of calls is small. This is due to the fact that the free line strongly depends on the call, and there are daily and hourly changes of the free line distribution within a certain range, different from the holding time distribution.

2.5 DISCUSSION OF THE FITNESS OF THE APPROXIMATE DISTRIBUTION

It has been indicated that the holding time distribution characteristics for the full-automatic calls treated in the INT TLX networks are well fitted to a Weibull distribution. Fig. 7 shows a relation between the total outgoing traffic volumes the respective circuits processed from December of 1970 to February of 1971 and the number of calls in terms of chargeable time, as data to verify that the pattern of the distribution can not be changed depending on the change of traffic volume and the difference of circuits. Hence, it is verified that the traffic volume is proportional to the number of calls and there exists a holding time distribution characteristic common to all circuits, roughly indifferent to the traffic volume and the circuits.
Holding in time distribution in an example of chargeable time distribution. Since the value of variance $\sigma^2$ of population is unknown in this case, an interval of the mean $\mu$ of population is estimated. For measured sample values, the confidence interval with a confidence coefficient $(1-\alpha)$ of the population mean $\mu$ is given by

$$x - u \sqrt{\frac{\sigma^2}{n}} \leq \mu \leq x + u \sqrt{\frac{\sigma^2}{n}}$$

(5)

where $F_{x\alpha}(a)$ indicates a point in distribution with a pair of degree of freedom $(1, n-1)$. After Eq. (5), the upper and lower limits of the confidence interval of 95% in the chargeable time distribution are derived, and the ranges of both limits are equal to the intervals indicated with dotted line limited by cross signs of Fig. 5. It is verified that the approximate distribution indicated by the solid line, obtained from the previously found probability density function, mostly falls within the interval estimation range with the reliability of about 95%. This supports quantitatively the good agreement of approximation.

2.6 HOLDING TIME DISTRIBUTION OF THE INTERNATIONAL PUBLIC COMMUNICATIONS

The main international public communication other than the INT TLX includes the INT TELEG and the INT TELEPH; the former is a dialogue-type of communication system similar to the low TLX and the latter is a communication system using telegraph code similar to the INT TLX. It is of interest to compare the holding time distributions of them. It is known that the probability density function $f_1(t)$ of call holding time distribution in the INT TELEPH can be approximated by an exponential distribution expressed by the following equation.

$$f_1(t) = \frac{1}{\lambda} \exp\left(-\frac{t}{\lambda}\right)$$

(6)

where $\lambda$ is mean message holding time and nearly equal to 10.3 min.

It has been clarified, from the measurements after the automation of processings of the INT TELEG, that its message holding time can also be approximated by an exponential distribution as well as the INT TELEPH, and the probability density function $f_2(t)$ is expressed by the following equation.

$$f_2(t) = \frac{1}{\lambda^2} \exp\left(-\frac{t}{\lambda^2}\right)$$

(7)

where $\lambda$ is mean message holding time and $\lambda$ nearly equal 0.77 min. Fig. 9 shows a comparison of the holding time distribution of the INT TLX with that of the INT TELEPH and the INT TELEG along with the free line time distribution of the INT TLX, in the form of probability density distribution. The calls of the INT TLX highly concentrates in the shorter holding time, while they distribute in the comparatively longer holding time, indicating an intermediate characteristic between the INT TELEPH and the INT TELEG, and revealing a unique distribution pattern difficult to be approximated by an exponential distribution.

Thus, as one of factors that the holding time distribution has a distinct property, compared with that of the other communication systems, a factor may be taken that the convenience the circuit can be seized in any time as no delay base is employed for the switching system increases calls having shorter holding times, as found in the shift of the average holding time till the previously described full-automatic switching system is available. Furthermore, the INT TLX is more effectively available in the concern, as will be described in the following chapter, and the collective informations in the daily business of the concerns form the main of TL. These facts also give the other factor that transmissions of the large amount of information similar to data transmission increase calls having long holding time. Both factors cooperatively form a distinct holding time distribution.

3. LOCAL TIME DISTRIBUTION CHARACTERISTICS

In this chapter the characteristics of the INT TLX will be discussed for the period of the social activity, while the characteristics common to all have been discussed, assuming that the calls are independent on each other in Chapter 2.

3.1 LOCAL TIME DISTRIBUTIONS WITH THE PARAMETER OF TIME DURATIONS FOR CALLS

The occurring conditions with call of the parameter of time durations for both call and free line in the period of a day are normalized and shown in Figs. 10 and 11.

In Fig. 10 it is shown that the shape of the normalized local time distribution is nearly invariant for the parameter of holding time, having a distribution of total outgoing calls with a peak (mode) of a occupancy ratio of the number of call around 17.5 o'clock in the local time. Thus, it is supported that each holding times also have a common distribution pattern with respect to each local times. A relation between the previously given holding time distribution and that of Fig. 10 is illustrated in Fig. 12, with Z-axis of holding time, Y-axis of the number of call in logarithmic scale, and X-axis of local time. The holding time distribution shown in Fig. 2 is a normalized projection to this X-Y plane and the number of calls vs. local time distribution with the parameter of holding time shown in Fig. 10 is a normalized projection to this Y-Z plane.

In the local time distribution with the parameter of free line time, the local time concentration is high in the shorter free line time, while this concentration decreases as the free line time becomes long, as shown in Fig. 11, in which it is indicated that the shape of distribution at the time zone, when the number of call is concentrated, is different from that when the number of call is small.

3.2 TRAFFIC INTENSITY CHARACTERISTICS

When the local time distribution of the all outgoing call with the parameter of holding time is divided into distributions classified for respective parties with different time differences, it is remarkably characterized that the
distribution location of the local time distributions is nearly fixed independently on the time differences and three local hours (11:00, 16:00, 17:00) having higher concentration rates of calls in the local times. In other words, the main portion of the outgoing TI distributes within the time slots from 8 o'clock to 24 o'clock, indifferent to the difference of time difference, and the position of "peak" indicating a local concentration of the TI is fixed, indifferent to the time difference of the parties.

Factors causing these TI distribution characteristics are as follows:

1) Non-attendance communication is positively utilized.
2) Convenience of calling subscriber is the most important factor to effect on the outgoing TI distribution.
3) Outgoing TI distributions are closely related to the flow of business in the concern.

The recordability, which is an essential property of the INT TLX, is utilized as the most important factor of service in the form of so-called non-attendance communication. Most of outgoing calls, therefore, occur during the social business time of calling subscribers and whether presence or absence of called subscribers may be little required for making communication. Thus, the ratio of the dialogue-type communication to the total TI of the outgoing calls is below 10 percent, the most of which may be occupied by calls using the circuits in simplex. Most of the user of the INT TLX are such concerns as firms etc., while the main users of the INT TELEPH are personal. Therefore, the TI of the INT TLX may be largely subject to informations occurred in the business of the concerns.

The following facts can be further appreciated in addition to the results of investigation concerning with practices of utilization of the INT TLX in the concerns:

At first, the business in the concern is generally started by informations given at the beginning time of business. Then incoming informations are required to be received before the beginning time of business. The results of the daily business in the concern are collected at the end time of business to be addressed to the sending terminal as outgoing information, thereby to become outgoing calls. It results, therefore, that the peak of TI concentration appears usually near at the end time of business, 17 o'clock. In other word, the result of the business processing, based on the informations received before the beginning time of business forms the main portion of information to be sent.

The second, there are two sections of the unit for business processing such as beforenoon and afternoon, and the results processed at beforenoon and are output at the beginning of the afternoon as outgoing informations, so that the TI concentration is found near at 1/4 o'clock. The informations of TI remained near at the end time of business are sent near at 11 o'clock, beginning of the business.

The difference of time difference and tendencies of the outgoing TI distributions are as follows: If time difference is small, there is a tendency to equalize the TI concentrations at the beginning and the end of business since a portion of calls around the end of business can be prolonge to next the day's beginning of business without loss of the purpose of concerns informations. On the other hand, in the case that time difference is larger the TI around the end of business should be sent within the same day, and if not, then it follows that the informations are substantially prolonged at the same time to the next day so that the informations are accumulated.

3.2.1. OUTGOING TRAFFIC INTENSITY DISTRIBUTIONS

Based on the above mentioned estimations, the TI distribution of the outgoing calls is regarded as a complex double-humped distribution, which is shaped by the sum of three normal distributions, each having medians centered at respective time slots. Fig. 13 shows this synthesis for an example of -1 hour of time difference. Since the medians of each normal distributions are hardly shifted with the change of time difference, as previously described, the probability density functions of distribution, named "1st-phase", "2nd-phase", and "3rd-phase distribution" in the order of time slot, $f_1(t)$, $f_2(t)$, $f_3(t)$ are expressed as follows:

$$f_1(t) = \frac{1}{\sqrt{2\pi \sigma_1}} \exp \left( -\frac{(t-\mu_1)^2}{2\sigma_1^2} \right)$$

$$f_2(t) = \frac{1}{\sqrt{2\pi \sigma_2}} \exp \left( -\frac{(t-\mu_2)^2}{2\sigma_2^2} \right)$$

$$f_3(t) = \frac{1}{\sqrt{2\pi \sigma_3}} \exp \left( -\frac{(t-\mu_3)^2}{2\sigma_3^2} \right)$$

where $\mu_1$, $\mu_2$, $\mu_3$ are values of the median of the normal distributions for each phase at local time, $\sigma_1$, $\sigma_2$, $\sigma_3$ are standard deviations, respectively.

The change of the median of normal distribution for the 2nd-phase can also be expressed as follows:

$$g_0(t) = A N_0(\mu_0, \sigma_0) \exp \left( -\frac{t^2}{2\sigma_0^2} \right)$$

where $\mu_0$, $\sigma_0$ are standard deviations for functions $g_0(t)$, $g_1(t)$ expressing time difference changes of the peaks of the 1st-phase and the 2nd-phase normal distributions, respectively. $A$ and $B$ are relative values of functions $g_1(t)$, $g_2(t)$ when $r=0$. Ratio of the TI has the peak both for the 1st-phase and the 2nd-phase when $r \leq 0$ in terms of local time. The change of the median can be expressed as a symmetrical normal distribution for positive and negative time difference. The time difference change of the peak for the 3rd-phase can be expressed as follows:

$$g_3(t) = \left( 1 - g_0(t) \right) - g_0(t)$$

Relations of the outgoing TI distribution to the change of time difference $r$ is defined by a probability density function, i.e. TI distribution time difference characteristic function $F(t, r)$, and given by

$$F(t, r) = f(t + dr) + f(t)g(r) + f(t - dr)$$

$$+ A \left[ N_0(\mu_0, \sigma_0) \right] \left[ N_1(\mu_1, \sigma_1) \right]$$

$$+ B \left[ N_0(\mu_0, \sigma_0) \right] \left[ N_2(\mu_2, \sigma_2) \right]$$

$$+ \left( 1 - A \right) \left[ N_0(\mu_0, \sigma_0) \right] \left[ N_3(\mu_3, \sigma_3) \right]$$

where $A$, $B$ are, respectively, the probability density functions of distribution $g_0(t)$, $g_1(t)$, and $g_3(t)$.
Fig. 14 shows a TI distribution vs. time difference characteristics given by Eq. (14), with X-axis of local time, Y-axis of TI occupancy ratio, and Z-axis of time difference with positive and negative sense. A comparison of the probability density distributions of the outgoing TI distributions for respective time differences projected to X-Y plane in Fig. 14 is shown in Fig. 15. Each values given by Eq. (14) is tabulated in Table 1.

![Figure 14](image1.png)

**Figure 14**: TI Distribution vs. Time Difference of INT TLX (Outgoing)

![Figure 15](image2.png)

**Figure 15**: Theoretical TI Distribution vs. Time Difference of INT TLX (Outgoing)

Figs. 16(a) and 16(b) show quantitatively the degree of approximation introduced in Eq. (14) after interval estimation with confidence coefficient of 99%, assuming that the distribution of measured values forms a normal distribution for the outgoing TI distributions of circuits at the parties with time differences of -1 hour, -8 hours. A zone limited by the upper and lower dotted lines in each graph shows the estimation interval and solid line shows the theoretical distributions indicating close approximation for the TI distribution of each time differences of the theoretical distribution.

3.2.2 INCOMING TRAFFIC INTENSITY DISTRIBUTIONS

It may be considered from the previous analysis of the INT TLX that the distribution of the outgoing TI is independent on that of the incoming TI, which is equal to the outgoing TI distribution at the party subscriber. Therefore, the incoming TI distribution for the communication with the party with time difference r can be obtained by shifting the outgoing TI obtained from the party with the same time difference by the amount of time difference r. Then the probability density function $F(t+r, r)$ of the incoming TI distribution can be obtained by substituting $(t+r)$ for $t$ of Eq. (14). Fig. 17 shows the incoming TI distributions for the communication with the parties with respective time differences, based on the change of time difference in the outgoing TI distributions of Fig. 15. Figs. 18(a) and 18(b) show comparison between the measured and the theoretical TI distributions for the communications with the parties having time differences of -1 and +9 hours. It is concluded that nearly satisfactory approximation can be obtained in these results, taking account of some difference due to the fact that the measured calls include not only the calls treated in the full-automatic switching system but also the calls treated in the manual and the semi-automatic switching systems.

![Figure 16(a)](image3.png)

**Figure 16(a)**: Confidence Interval Estimate for Traffic Intensity and Theoretical Distribution of INT TLX (Outgoing, $\Sigma = 1$)

![Figure 16(b)](image4.png)

**Figure 16(b)**: Confidence Interval Estimate for Traffic Intensity and Theoretical Distribution of INT TLX (Outgoing, $\Sigma = 8$)

![Figure 17](image5.png)

**Figure 17**: Theoretical TI Distributions vs. Time Difference of INT TLX (Incoming)

![Figure 18(a)](image6.png)

**Figure 18(a)**: Measured and Theoretical TI Distribution of INT TLX (Incoming, $\Sigma = -1$)

![Figure 18(b)](image7.png)

**Figure 18(b)**: Measured and Theoretical TI Distribution of INT TLX (Incoming, $\Sigma = +9$)
3.2.3 OUTGOING AND INCOMING TI DISTRIBUTION WITH MULTIPLE PARTIES

In the INT TLX, the outgoing and the incoming TI distributions are nearly independent each other after the result of the previous analysis. Therefore, the total TI distribution \( P_t(t,r) \) is given a simple sum of the outgoing and the incoming TI distributions, and is obtained from the following equation only if both TI distributions are obtained.

\[
P_t(t,r) = kF_t(t,r) + k_i(t+T,r)
\]

where \( F(t+T,r) \) is an incoming TI distribution, and \( k \) and \( k_i \) are TI ratios for the outgoing and the incoming calls, respectively and always satisfy the following equation.

\[
k + k_i = 1
\]

Fig. 19 shows the relation between Eqs. \((15)\) and \((16)\) with the parameter of time difference. In general, the outgoing TI is equal to the incoming TI.

The time distribution \( P^e(t,r) \) of TI applied to the exchanger is expressed by sum of total TI distributions for each parties with time difference, weighted by respective TI ratios \( \xi_r \), as follows:

\[
P^e(t,r) = \sum_{r=12}^{24} \xi_r [kF(t,r) + k_i(t+T,r)]
\]

Now an example of TI ratios for parties with time difference in the INT TLX of Japan is tabulated in Table 2. Quantitative discussions are here made for the approximation of theoretical total TI distribution of all circuits, based on Eq. \((17)\) and Table 2. The confidence intervals with confidence coefficient of 95% are estimated for the measured total TI distribution, and the obtained confidence intervals are shown by dashed lines of Fig. 20. It is then evaluated that the approximation previously obtained, shown by the solid line is sufficiently close to the theoretical. Thus, it is possible to conjecture almost satisfactorily the TI and busy-hour concentration factor in the communications with many parties with various time differences.

<table>
<thead>
<tr>
<th>Time Difference (H)</th>
<th>Percentage of Outgoing Traffic Volume (%)</th>
<th>Percentage of Incoming Traffic Volume (%)</th>
<th>Percentage of Total Traffic Volume (%)</th>
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<tr>
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<td>34</td>
<td>36</td>
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</tr>
<tr>
<td>10</td>
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</tbody>
</table>

Table 2-Percentage of Traffic Volumes for Parties with Time Difference (Japan)

3.3 INTERNATIONAL PUBLIC COMMUNICATIONS AND TRAFFIC INTENSITY DISTRIBUTIONS VERSUS TIME DISTRIBUTION CHARACTERISTICS

The TI distribution of the INT TELEPH, which is a recordable communication system using teleprinters and has an aspect similar to the INT TLX, has such characteristics that its pattern does little change with the change of time difference and neither hourly distribution nor the shift of distribution is found. Since the INT TELEPH system is, in particular, used in simplex-like, the outgoing TI distribution is independent on the incoming. The total TI distribution of the circuit, consisting of the outgoing and incoming calls, can be expressed by the sum of the outgoing and the incoming TI distribution, similar to the characteristics of the INT TLX, from the property of this communication system.

The effect of time difference on the TI distribution of the INT TELEPH is given by the product of functions \((t, r)\), representing the convenience of a pair of speakers communicating with each other, because the communication is considered to begin at the time when both speakers simultaneously take up the respective handsets. Fig. 21 shows a comparison of the basic patterns at \(r = 0\), i.e., without any time difference in the TI distribution versus time difference, for the three communication systems, in which the main portion of the TI of the INT TELEPH exists in the afternoon, while such portion of the other two exists in the afternoon and the shapes of the whole distributions are nearly opposite to the shape of the INT TELEPH. One of these reasons is that the main TI consists of information occurred in the process of business. It is very interesting of this difference. In comparison of the TI of the INT TLX with that of the INT TELEPH, it is found that the INT TLX is a connection system having a remarkable real-time property that the subscribers take part in the sending and receiving operation, while the INT TELEPH has a property that the intervention of the telegraph stations is necessary and the operation speed of the telegraph is chargeable according to the order of priority specified to it, thereby to cause some delay from the source of call.
4. CONCLUSION

Traffic characteristics of the INT TLX circuits have been characterized and it is concluded that:

1) The holding time distribution of the INT TLX can closely be approximated to a Weibull distribution, and the probability density function has been obtained for the approximate distribution.

2) The approximate distribution has then been evaluated by the confidence interval estimation from the measured data, thereby to quantitatively verify the degree of the approximation is sufficiently high.

3) The other distributions of the INT TLX have been illustrated, including the chargeable time, the free line time, the setting-up time, and the unsuccessful holding time distributions, and the respective distributions have been approximated to Weibull distributions to obtain approximate functions.

4) The holding time distribution of the INT TLX has been compared and discussed with that of the INT TELEPH and the INT TELEG to show a distinct behaviour of this distribution.

5) It has been shown that the non-attendance communication is positively utilized in the INT TLX service, and the most of calls are concentrated in the concerned business time.

6) Based on the investigation of actual utilizations for INT TLX, it has been evaluated that the basic TI distribution is a complex double-humped distribution represented by a synthesis of three normal distributions, and the TI distributions for parties with different time differences have been expressed by TI distribution time difference characteristic function, which has been evaluated by the measured distributions.

7) It has been evaluated that the incoming TI distribution, which can be obtained from the outgoing, is approximated closely to the theoretical distribution.

8) In the case of the communication with a number of parties with different time differences, the total TI and busy-hour concentration factors can be obtained from the TI distribution time difference characteristic function.

9) The characteristics of the TI distribution (the number of calls distribution) to time difference for the INT TLX has been compared with those for the INT TELECH and the INT TELEPH. It has been found that there are large difference in the TI vs. time difference characteristic due to the differences of the respective communications.

Thus, the traffic characteristics in the international circuits of the INT TLX have been clarified and compared with those of the other international public communications to discuss the relations between them. It is believed that these characteristics described above are applicable to the discussions of planning of relaying, designs of control and other functions of the full-electronic exchanging system, the network arrangements, and new services such as the automatic re-call, delayed delivery, etc. in the INT TLX, and also useful for discussions of the design of control and other functions of a integrated international communication systems to improve its all efficiency.

We have also obtained the expected result for the communication speed control buffer memories used with INT TLX after discussion how to optimize the arrangement of the memory capacity suitable for the characteristics investigated in this paper.

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