Over-All Characteristics of a TASI System

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TASI (Time Assignment Speech Interpolation) has been in service on transatlantic submarine cable channels since mid-1960. Measurement of service quality on one TASI system (White Plains–London) indicates that system performance equals or exceeds the original engineering objectives in all but a few cases. Field modifications now being made should bring these exceptions into closer agreement with objectives.

A companion paper[4] discusses in detail the design considerations for TASI speech detectors and describes subjective tests made to determine the maximum permissible loading of TASI circuits without impairment of service.

TASI, an abbreviation of *T*ime *A*ssignment *S*peech *I*nterpolation, is a high-speed switching and transmission system which uses the idle time in telephone calls to interpolate additional talkers.[1,2] In a normal telephone conversation each subscriber speaks less than half of the time. The remainder of the time is composed of listening, gaps between words and syllables, and pauses while the operator or subscriber leaves the line. Measurements on working transatlantic channels, Fig. 1, show that a TASI speech detector with a sensitivity of −40 dbm is operated by speech from one talker on the average about 40 per cent of the time the circuit is busy at the switchboard. Since long distance circuits use separate facilities for the two directions of transmission, each one-way channel is, on the average, free about 60 per cent of the time.

In order to take advantage of this free time to interpolate additional conversations, a considerable group of channels must be available. An attempt to interpolate two independent conversations on a single channel would result in a large percentage of the speech being lost, since the probability of both talkers speaking at the same time is high. However, with a large group of channels serving a larger group of talkers, the variations in demand become much smaller. Even with 74 talkers on 37 channels, the percentage of speech lost (freeze-out fraction) is reduced to a point where there is no noticeable effect on continuity of conversation.

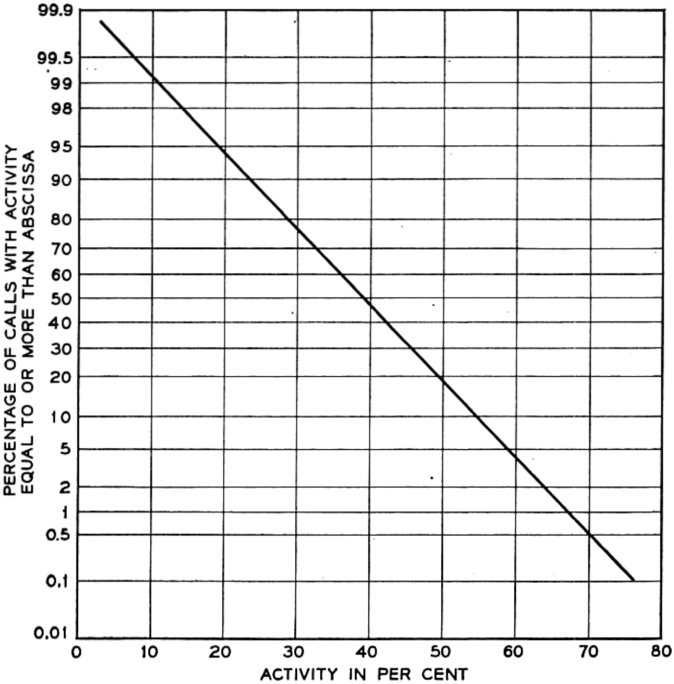

Fig. 1 — Circuit activity.

The increase in channel capacity with TASI is illustrated in Fig. 2, which gives the TASI advantage (ratio of switchboard positions, or trunks, to channels) for a range of activities and number of channels. A freeze-out fraction of 0.5 per cent has been assumed for each curve, since this amount of speech loss has been found from tests to have a negligible effect on transmission quality.

It will be noted in Fig. 2 that a TASI advantage of at least two can be obtained on a 37 channel group as long as the average activity is not significantly greater than 40 per cent. TASI is designed to use 36 channels for speech interpolation and one additional channel as a control channel for transmitting disconnect and error checking signals. This fits the needs of present day submarine cable systems, since 37 is close to the maximum number of channels that can be made available for TASI out of the total 48 channels derived by submarine cable type channel equipment[3] employing 3-kc filter spacing. The remainder of the channels are required for special services such as program material and certain types of data which are ordinarily not transmitted through TASI.

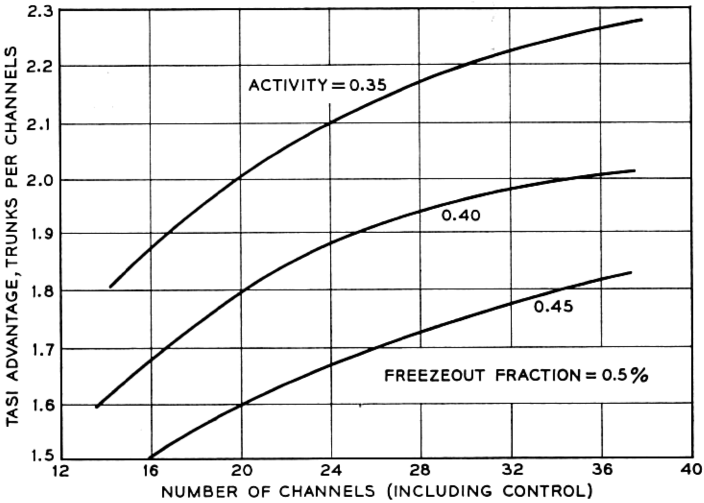

Fig. 2 — TASI advantage.

The first TASI system was put in service in June, 1960 on the transatlantic cable system between White Plains and London (TAT-1) and the second followed a few months later on the cable between New York and Paris (TAT-2). TASI is well suited to submarine cable application for several reasons. Although TASI requires considerable expensive terminal equipment, it is an economical means of doubling the number of conversations that can be handled on expensive submarine cable facilities. In addition, TASI is easier to apply to long submarine cables than to the land plant with its many branching points and alternate routes.

The principal purpose of this paper is to describe the application of TASI to the White Plains–London submarine cable system. The channel requirements that must be met for TASI operation are detailed along with measurements of the combined system characteristics, such as noise, bandwidth, etc. Measurements of the amount of speech lost in an actual working system are compared with earlier theoretical computations.

I. DESCRIPTION OF OVER-ALL SYSTEM

The message channels on the land portions of the TAT-1 system employ standard 4-kc channel spacing, and the undersea channels are spaced at 3-kc intervals. The land and undersea-type channels are interconnected at voice frequencies at Sydney Mines, Nova Scotia and Oban,

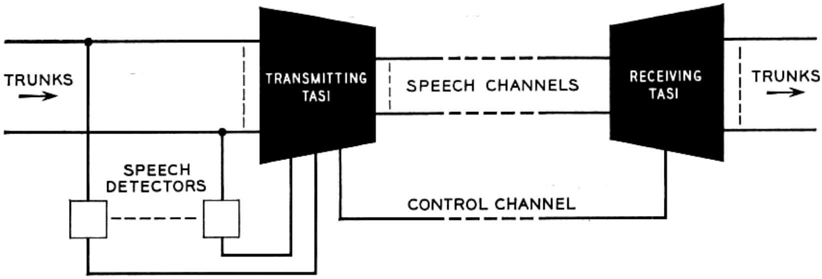

Fig. 3 — TASI equipment — one direction of transmission.

Scotland. A typical message circuit between the TASI terminals at White Plains and London extends from about 275 to 3150 cps.

Fig. 3 shows a block diagram of the TASI equipment for one direction of transmission; an independent TASI is used in the opposite direction of transmission. Presence of speech on a trunk causes the speech detector to operate, initiating a request for a channel. The transmitting common control equipment selects an idle channel, if one exists, and assigns it to the requesting trunk. Before the talker is connected to the channel, a "connect" signal is sent over the assigned channel specifying the trunk to be connected to that channel at the distant receiving terminal. During the time required to connect talker and listener the initial part of the talker's speech is clipped. In order to minimize clipping the signaling time has been made as short as possible, 17 ms, consistent with reliable signaling and quiet switching. The signal information consists of a single burst of 4 tones out of a possible 14, ranging in frequency from 615 to 2419 cps. Once a talker is assigned a channel he does not lose the connection as long as he continues talking. When he stops talking he may still retain the connection unless he has to be disconnected to provide a channel for another talker. A similar burst of 4 tones out of 15 (615 to 2501 cps) is used to disconnect the talker and the listener, but this signal is sent over a separate control channel. During periods when no disconnect signals are being used, the same type of code signals are used to send information over the control channel as to the trunk-channel connections existing at the transmitting end. This connection-checking information overrides any earlier information and determines the connection made at the receiver. In addition, a comparison at the receiver between existing and overriding information is used to detect bad channels.

As shown in Fig. 2, the number of trunks which can be served by TASI depends upon the number of channels available. To prevent excessive speech loss when the connecting channels fail, TASI has been designed to automatically remove bad channels from service; trunks are then removed until the proper trunk-channel ratio is reached.

In addition to the provisions for automatically reducing the number of connected trunks and channels, TASI contains audible and visible alarms to identify internal failures. In the event of a major failure in TASI the terminals automatically switch themselves out at both ends, reducing the number of connected trunks to the number of available channels. TASI is also switched out automatically if both the regular and alternate control channels fail. If only the regular control channel fails, the disconnect and error checking signals are automatically switched to the alternate control channel and TASI will continue to operate with only a momentary interruption.

When TASI is switched out, the voice-frequency amplifiers associated with TASI are also switched out. The schematic relationship of these voice-frequency amplifiers and other transmission equipment is shown for one terminal in Fig. 4 along with typical operating level points. The combination of VF amplifiers, TASI, and appropriate attenuation pads provides a zero-loss device and also provides optimum transmission levels to TASI.

The echo suppressor shown in Fig. 4 performs the usual function of preventing echoes, generated at points of impedance mismatch, from reaching a subscriber's ear and interfering with normal conversation.

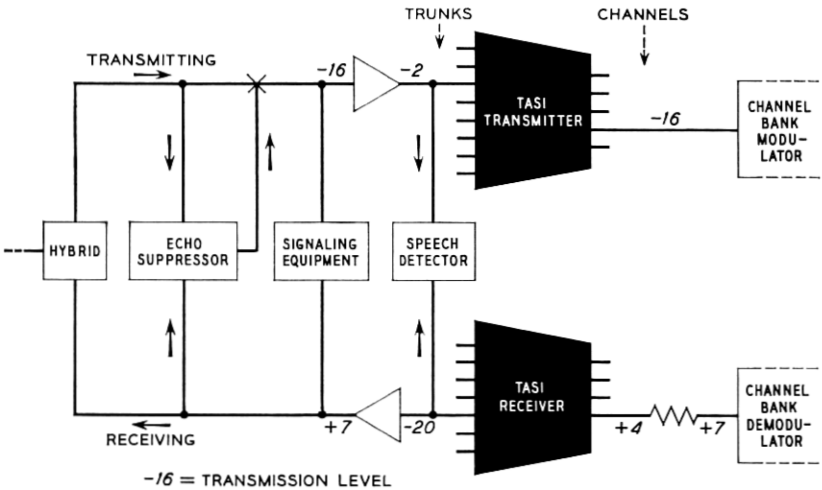

Fig. 4 — TASI and associated equipment.

On TASI circuits, these suppressors must be of the receiving end split type at each end of the circuit to prevent the distant talker's echo from operating the speech detector. The location of a split suppressor is shown schematically in Fig. 4. Speech received from the distant party reaches the echo suppressor and operates it, causing a large loss to be inserted in the transmitting path before the speech detector. This large loss prevents most of the echoes capable of operating the speech detector from reaching the speech detector, but the initial part of the echo may get through because the existing echo suppressors were designed with a slow operate time to minimize operation on line noise. On the other hand, the speech detectors must be relatively fast operating to minimize initial clipping of speech. The result is that the operate time of the echo suppressors is about 7 ms longer than that of the speech detectors. During this interval the speech detector may be operated by echoes before the echo suppressor can operate. To minimize this difficulty, and still use existing echo suppressors, the speech detectors are equipped with fast-acting circuits which reduce the sensitivity of the speech detectors as much as 13 db depending on the energy present on the receiving side of the trunk. This echo protector function of the speech detector reduces the probability of operating during the initial part of the spurt; the large loss inserted later by the echo suppressors prevents operation during the remainder of the spurt, which usually contains the higher energy.

In addition to the equipment shown in Fig. 4, compandors can be applied to noisy channels as necessary to meet noise objectives. Tests have indicated that TASI can signal satisfactorily through Bell System 1A-type compandors or their British equivalent.

1.1 *Toll Signaling and Supervision*

Because TASI is a time sharing device, there are problems involved in transmitting supervisory and dialing pulses. TASI can work satisfactorily with the present ringdown manual arrangement, but it is obvious that the usual method of continuous supervision by means of a steady tone during the idle time cannot be used. Likewise, dial pulses cannot compete for a TASI channel on the same basis as a talker, because TASI clipping would cause signaling errors. A burst signaling system is required.

II. ENGINEERING OBJECTIVES FOR TASI

In order that TASI could operate over existing telephone facilities and would fit in with existing performance standards, certain engineering

TABLE I — ENGINEERING OBJECTIVES FOR TASI

Capacity	At least 72 message trunks to be operated over 37, 3-kc spaced cable channels. If the number of available channels is less than 37, the number of trunks to be provided by TASI will be less, as illustrated in Fig. 2. If the total busy-hour speech activity is increased above about 40%, the maximum number of trunks to be provided will be less.
Speech quality	With the TASI system fully loaded as defined above, the degradation to speech quality due to TASI should not exceed about 1 db. When the number of talkers equals the number of available channels, the TASI degradation should be close to 0 db.
Signaling errors	On the average, during the busy hour, no more than 0.01% of the talkspurts transmitted should be lost because of signaling errors if the transmission medium meets the objectives noted in Table II. Assuming that the average activity is 40%, this means about one talkspurt lost in thirty average 10-minute calls.
Reliability	The reliability objective is that the amount of time trunks are removed from service because of TASI failure shall be less than 0.1% of the total time.
Frequency response	The TASI transmitter and receiver connected back to back should pass a band of 200–3500 cps. The average variation from flatness of all the channels should be within ±0.5 db over this frequency range. In addition the standard deviation of the variations from the average should not exceed 0.2 db.
Net loss	The net loss at 1000 cps through the TASI equipment alone should be adjustable to within 0.15 db of 0 db and should stay within ±0.15 db of the adjusted value for at least one month.
Circuit	The noise generated by TASI in the transmission path should not exceed about 12 dba as measured at the zero level points.
Crosstalk	To provide adequate crosstalk performance, an equal level coupling loss of 70 db should be obtained between talking paths in TASI. This applies to both near-end and far-end crosstalk.

objectives were set up to guide the planning and development of TASI. They were considered as reasonable goals rather than rigid requirements. These objectives are listed in Table I.

III. CHARACTERISTICS OF CHANNELS FOR TASI

Because of the high-speed signaling used in TASI and because subscribers are switched rapidly between channels, the transmission requirements of the channels connecting TASI terminals are somewhat tighter than required for the usual telephone message service. The characteristics of importance to TASI are listed in Table II.

Table II — Required Transmission Characteristic of Connecting Channels for TASI

Minimum bandwidth	300 cps–2900 cps (10-db cutoff frequencies).
Flatness of band 565 to 2550 cps	Difference between maximum and minimum loss should not exceed 2.5 db.
1-kc net loss value of any channel	Not more than ±3 db from the nominal value.
Envelope delay distortion 565 to 2550 cps	Not greater than 2 ms.
Flat delay	Maximum difference between channels should be no more than 10–15 ms at 1000 cps. (The control channel should be one of the fastest.)
RMS noise	Without compandors, 38 dba at zero transmission level (38 dba 0). With compandors, noise on line ahead of compandors should not exceed 51 dba 0. Difference in output noise between channels should not exceed 6 db.
Crosstalk	Equal level crosstalk loss on all channels should be at least 60 db.
Frequency stability (565 to 2550 cps)	No frequency shifted more than 2 cps.
Working levels for TASI (excluding pads or amplifiers outside of TASI)	Transmitting terminal input, −2 with respect to zero transmission level point. Receiving terminal input, +4 with respect to zero transmission level point.

IV. MEASURED TRANSMISSION CHARACTERISTICS

After TASI was installed on TAT-1 extensive measurements and tests were made to determine how closely TASI came to meeting the engineering objectives and how TASI operated in the environment of the telephone plant. The results of the tests and measurements are given briefly in the following paragraphs.

4.1 *Frequency Response*

Fig. 5 shows the frequency response of a TAT-1 message channel, with and without TASI. Figure 5 applies to most connection channels, although a few channels differ significantly due to channel bank and pilot filters. The sharp cutoff frequencies of the channel, about 275 and 3150 cps, are principally due to the 3-kc submarine cable terminal equipment. It can be seen that TASI does not affect the frequency response of the system appreciably.

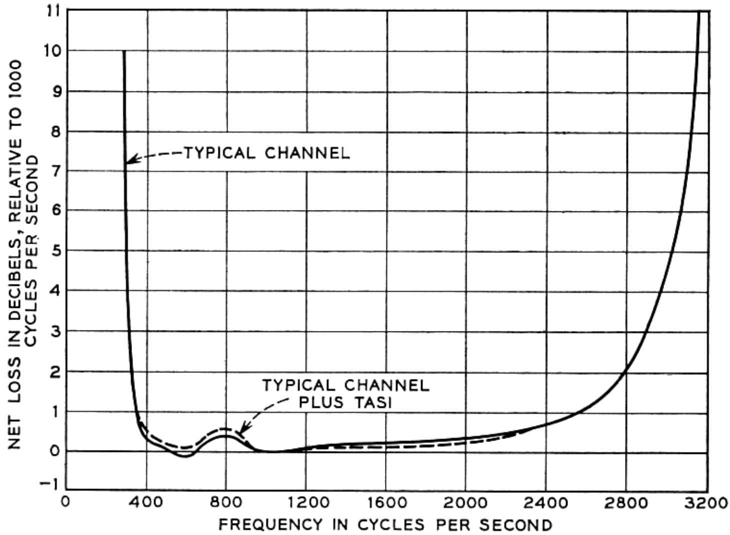

Fig. 5 — Frequency response — TAT-1.

4.2 *Net Loss Variations*

The net loss variations on TAT-1 are kept to a minimum through the use of pilot-controlled automatic gain controls. An associated alarm reporting system informs all important stations automatically if the pilot levels deviate beyond prescribed limits.

Fig. 6 shows a distribution of the difference in net loss of successive talkspurts experienced by a typical White Plains–London subscriber talking through TASI during the busy hour. These changes are due to differences in the net losses of the channels and the various paths through TASI. Only 8 per cent of the changes were greater than about 3 db, which is just noticeable. There were no changes greater than about 5 db. During periods of light traffic, the number of switches between channels, and the number of net loss changes, will decrease and cease entirely if traffic is very light.

4.3 *Envelope Delay Distortion*

A fixed delay equalizer was added to each of the TAT-1 message channels to reduce the delay distortion. In addition, the voice-frequency interconnections between land and undersea channels were arranged to avoid combinations having excessive delay distortion. The median

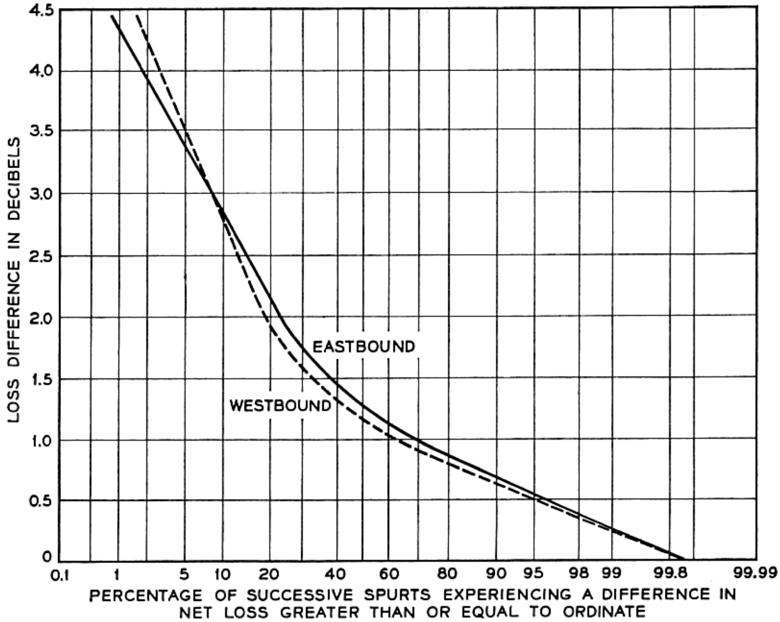

Fig. 6 — Net loss differences.

value of delay distortion of the resulting White Plains–London message channels is under 0.5 ms, with no channel being worse than 1.6 ms, within the TASI signaling band (565 to 2550 c/s).

Fig. 7 shows the delay distortion of a typical message channel before equalization, and after the addition of equalizers plus TASI. Channels located in the frequency spectrum near the cutoffs of group connector filters and pilot-frequency filters have delay distortion characteristics significantly different from the example on Fig. 7, particularly at the lower and upper edges of the passband.

4.4 *Noise*

TASI contributes very little to the over-all system noise; the average of the TAT-1 channels is about 36 dba at zero transmission level (abbreviated "36 dba 0"), and the average noise generated by TASI plus amplifiers is less than 12 dba 0. Since noise is increasing slowly on the transatlantic circuits caused by the change in cable characteristics with time, compandors have been installed on some channels. This will not influence the operation of TASI.

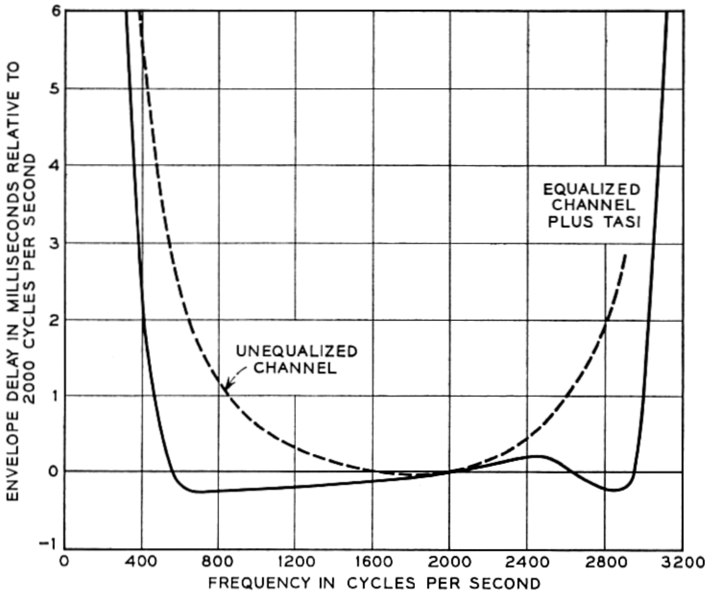

Fig. 7 — Envelope delay distortion typical TAT-1 Channel.

When a channel is disconnected during a conversation, the listener may notice a change in the background noise, because he no longer hears the channel noise of the whole system but instead hears only the noise of the trunk connecting him to TASI. To prevent the subscriber from feeling that he has lost his circuit due to the sudden noise change between successive connections, the receiving TASI terminal transmits random noise of about 33 dba 0 toward the listener whenever his trunk is not connected to a channel.

V. SPEECH CLIPPING

In addition to the measurements described above, measurements were made of the amount of speech clipped from subscribers making calls through the TAT-1 TASI system during the busy hour. The measured values were compared with computed values which were based on measured speech activities and talkspurt lengths.

The computations took into account the two major components of speech clipping in TASI, which are:

1. Signaling clipping, which is the time lost (17 ms) while a new connection is established;

2. Freeze-out, which is the time lost because no channels are available.

The length and frequency of these clips will vary from call-to-call due to loading, speech habits, or statistical chance.

In addition to signaling and freeze-out, some clipping is also caused by (a) speech-detector response time and threshold; (b) disconnection delays caused by control channel crowding during heavy loading. However, tests[4] have shown that the TASI speech detector introduces negligible speech impairment, and as described later it is estimated that control channel overload contributes very little clipping.

The results of the computations for various trunk-channel combinations are shown in Fig. 8 for the median call, and in Fig. 9 for the worst 1 per cent case. TASI can operate with a maximum of 36 speech channels plus one for control, but because of the demands for special services, 37 channels are not available on all systems for TASI. Results are shown, therefore, assuming different numbers of channels are available to TASI.

The right-hand scale in Figs. 8 and 9 gives the estimated db impairment corresponding to the speech loss shown by the left-hand scale. The upper solid curves assume that during the busy hours the circuits are carrying calls 100 per cent of the time (A = 1.0); the lower dotted curves assume that over the busy hours the average loading of the circuits is 0.85.

As shown in Fig. 8, for example, a subscriber in a 74 trunk, 36 + 1-channel fully-loaded system will have 1.1 per cent or less of his speech clipped during 50 per cent of his calls; Fig. 9 shows that this same subscriber will lose 2.9 per cent or less of his speech during 1 per cent of his

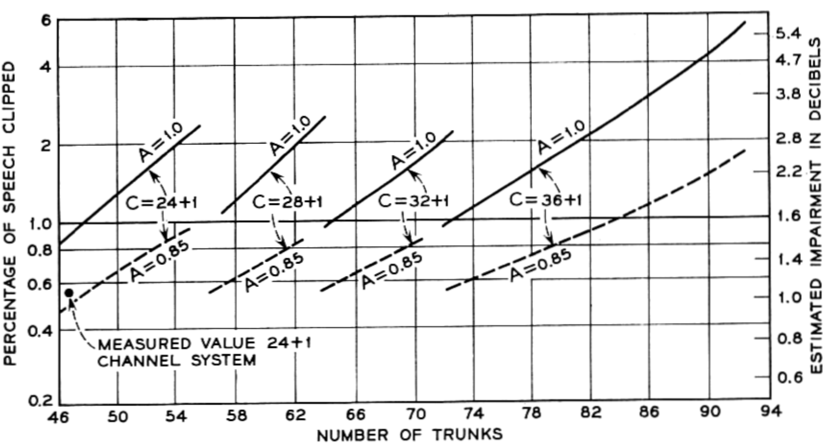

Fig. 8 — Median speech clipping.

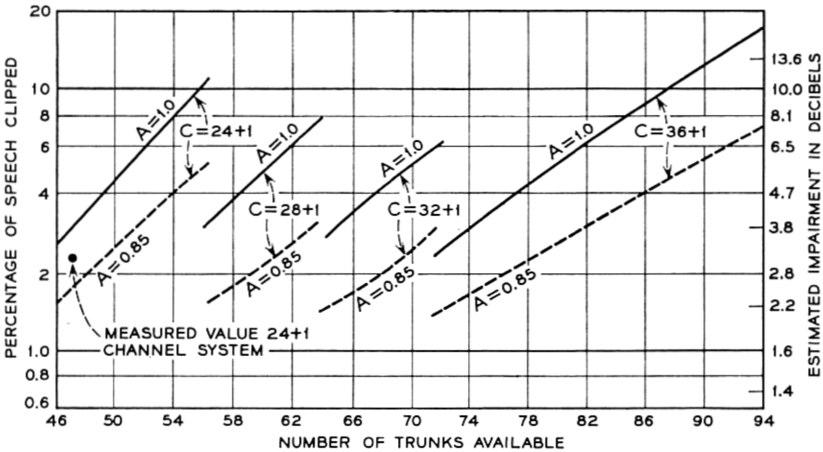

Fig. 9 — Upper 1 per cent speech clipping.

calls. In a TASI system with an average loading of 0.85, the median clipping would be 0.6 per cent or less, and the upper 1 per cent clipping would be 1.6 per cent or less. The loading factor varies with season, world events, etc. In order to be conservative, and to provide good quality speech even during peak periods, the recommended trunk-channel ratios shown in Table III assume 100 per cent loading of all trunks.

Table III — Recommended Operating Conditions

Number of connection channels available to TASI	Normal max. no. of talker trunks	Approximate percentage of speech clipped	
		Median-%	1-%
24 + 1	47	1%	3%
28 + 1	56	1	3
32 + 1	65	1	3
36 + 1	74	1	3

The dots in Figs. 8 and 9 for 47 trunks on 24 + 1 channels represent measurements made during the busy hours on the TAT-1 TASI system. Since the results lie between the A = 1 and A = 0.85 computed values, the indications are that the loading of this system, during the busy hours, is between 0.85 and 1.0. Direct measurements of circuit usage were made and confirm that the average lies in this range.

Fig. 10 shows the complete distribution of the measured speech loss during subscriber calls caused by signaling clipping and freeze-out on TAT-1. Both computed and measured curves of the two components

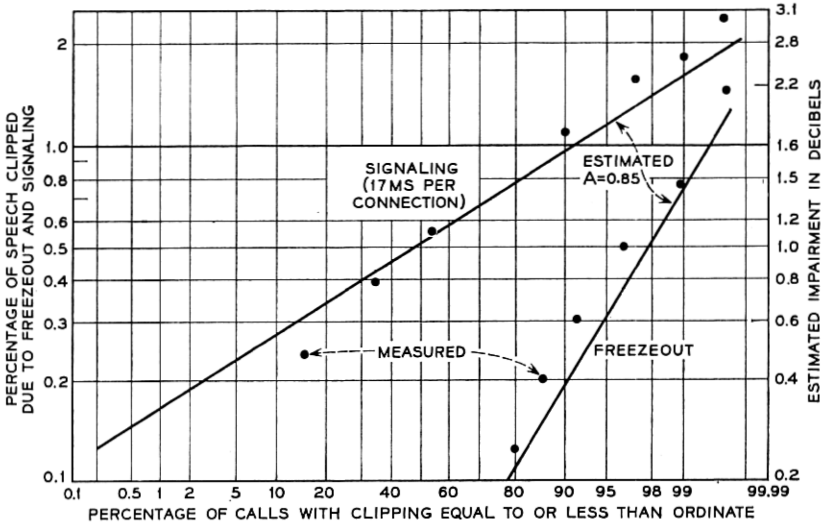

Fig. 10 — Estimated and measured clipping distributions on a 24 + 1 channel 47 trunk TASI system.

are approximately log normal. The good agreement shown in Fig. 10 between computed values (assuming A = 0.85) and the measured values indicates that with respect to freeze-out fraction the operating TASI behaves statistically as expected.

VI. CLIP LENGTHS

Another important characteristic of TASI clipping is the distribution of the lengths of clips a talker experiences. The length of clip a talker receives whenever he receives a new connection is composed of two major parts; the constant signaling clip (17 ms) and the freeze-out, which may vary from 0 ms to 500 ms (upper limit for all practical purposes), depending upon the instantaneous load. The computed distribution of clip lengths a subscriber may experience in a 47/24 + 1 TASI is shown in Fig. 11 for A = 0.85 and A = 1 together with measured values on the New York–London TASI system. The measured 1 per cent clip length in this system was about 60 ms. Here again the measured values lie between A = 0.85 and A = 1, indicating the actual loading was between these two values. While the computed distributions are for a 47/24 + 1 TASI installation, the distributions apply fairly well to all the trunk-channel ratios shown in Table III.

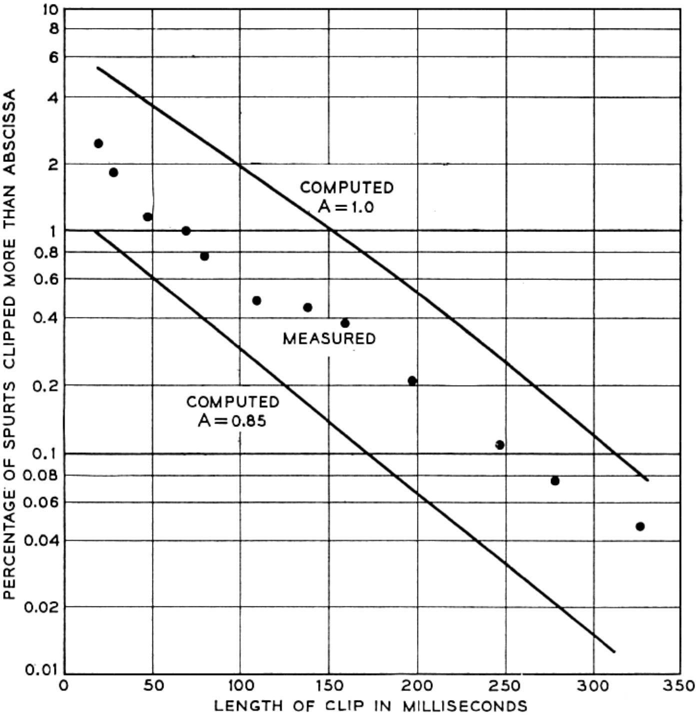

Fig. 11 — Measured and computed clip length distributions for a 24 + 1 channel 47 trunk TASI.

VII. CONTROL CHANNEL CAPACITY

As mentioned earlier, control channel crowding under heavy loading conditions can delay disconnections and in some cases increase clipping by delaying subsequent connections.

In a 74 talker, 36 + 1 channel TASI system in which each spurt requires a new connection, it is estimated that disconnects are delayed, on the average, about 4 ms each. This results in an estimated increase in average freeze-out fraction of less than 0.2 per cent. Since a working system switches less often than every spurt — a fact confirmed by measurement — the actual effect of control channel crowding is believed less than the above estimate indicates. Although in some rare cases bunching could seriously effect individual talkers, it appears that control channel overload contributes negligible clipping.

VIII. CONCLUSIONS

TASI has been operated successfully on submarine cable systems to provide approximately twice as many good quality message trunks as existed before TASI. The measurements made on an installed TASI system have shown that TASI has come close to meeting its engineering objectives and that field modifications now going on will bring closer agreement between performance and objectives. The close agreement between computations of speech clipping and the measured values show that TASI theory is well understood and that TASI in the field is conforming closely to theory.

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