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A 150-mc Personal Radio Signaling System

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An experimental 150-mc personal signaling system has been set up in New York City to evaluate over-all technical performance and explore subscriber reactions to the system. The system includes pocket receivers equipped with tuned reeds and central office arrangements adapted for direct customer dialing. This paper describes the system in over-all terms, and tells how it was engineered. It also compares this system with the 35-mc systems and discusses traffic and radio transmission problems.

I. INTRODUCTION

An experimental trial of a 150-mc personal radio signaling system known as the Bellboy system was started in New York City in October 1960. The service given to customers is very similar to that provided by 35-mc telephone company systems now operating in several smaller cities.[1,2,3] The new system, however, has a much greater traffic capacity, uses receivers of greater selectivity and sensitivity, and includes direct customer dialing.

Basically, this system extends the telephone bell to the customer's pocket. Each customer carries a pocket radio receiver containing reeds tuned to specific voice frequencies. This allows him to be selectively signaled. Three transmitters are installed in the lower part of Manhattan to give coverage to practically all locations below 59th Street. Central office arrangements are provided that accept calls that are dialed in and, in response, cause the specific signal of the customer who is being called to be radiated three times on the air.

When this signal reaches the customer's set, it causes the set to emit an alerting signal. The customer now knows that his office has received an important call and he goes to the nearest telephone and calls back to get his message.

The systems now in service at 35 mc give, in general, this same kind of service. As will be pointed out later in this paper, however, the limitations of the 35-mc system, which include receivers of lower selectivity and sensitivity and slower signaling speed, severely limit its usage in big cities. In addition, there is a more fundamental problem arising from the limited number of frequency allocations available at 35 mc, preventing growth of 35-mc systems to more than a few hundred customers in many small cities. These were the main reasons for proceeding with the trial of the 150-mc system. Some comparisons of the environments of the two systems are given in Section III.

An interesting general feature of this experimental trial is that some of the receivers were provided with replaceable batteries and some with rechargeable batteries. The latter type of receiver requires that the battery be recharged every night in a desk-top unit provided for that purpose, but this removes the necessity of supplying a fresh battery to the customer every few weeks.

In the early planning of this project it was apparent that there were two major technical problems. One was the need for a highly sensitive pocket receiver with a code-responsive device. The other was the need for more accurate knowledge of radio transmission loss into buildings.

A very sensitive, stable, and selective receiver has been developed by Bell Telephone Laboratories to operate in the 150-mc range. This receiver will be described in more detail in a forthcoming paper, but some of its characteristics are covered later in this paper. A receiver capable of giving service at 35 mc has also been developed by an outside supplier.[4]

In order to obtain knowledge of radio transmission loss into buildings an extensive test program was set up early in this project. These measurements have been covered in an earlier paper by Rice.[5]

II. OVER-ALL SYSTEM PLAN

Operation of the Bellboy system can be understood by tracing the path of a call as it progresses through the various parts of the system that are shown in Fig. 1. When there is an urgent need to reach a customer who is out of the office, his secretary dials his number, which might be, for example, 225-4654, and listens. She hears a momentary ringback, followed by a warbling tone, which signifies that the number has been received, checked, and stored in the central office equipment.

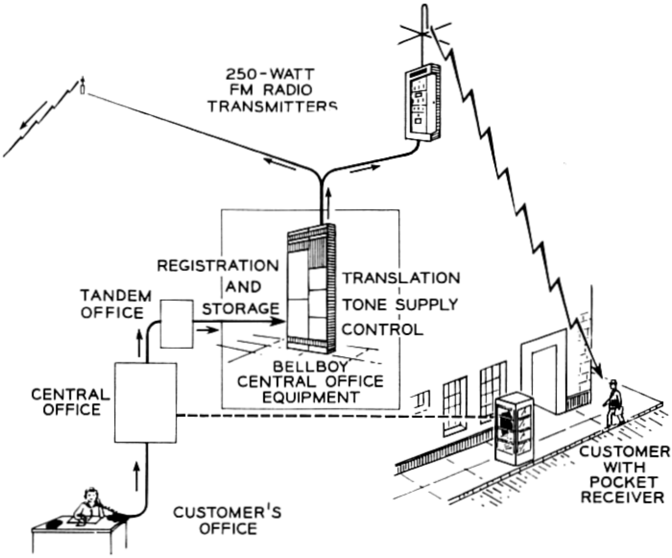

Fig. 1 — Over-all plan of operation.

She may now hang up, but if instead she listens a few seconds longer she will hear a verbal statement that her Bellboy system number will be signaled. Within a period ranging from a few seconds to about one minute, the signal is put on the air and the customer's set emits a steady beep. The customer now depresses a button to stop the beep, goes to the nearest telephone (in this case, a pay station), and calls his office to get the message.

2.1 *Central Office Arrangements*

What actually happened right after the secretary dialed was typical of many dialed telephone calls. The first three digits of the number, 225, correspond to a central office designation and normally would represent the one which serves the called party with incoming service. In the Bellboy system the counterpart of the terminating central office is actually the J-1 terminal which couples the wire plant to the radio portion of the system. All originating offices are wired to recognize the code 225 and set up a proper route through a tandem office that has the ability to accept digits in any form. The tandem office then forwards the digits as dial pulses, since the present J-1 is arranged to accept only this type of signal. Fig. 2 illustrates the functions included in the J-1 terminal.

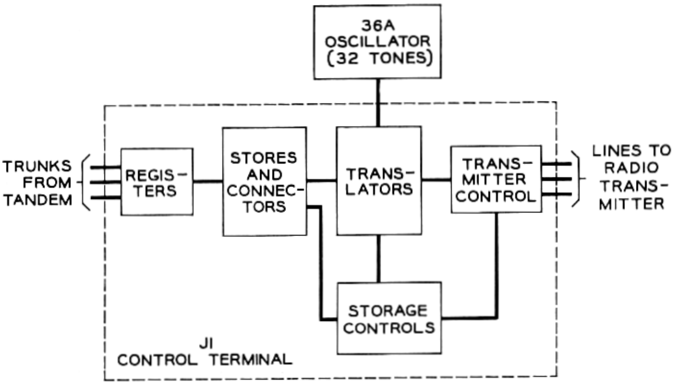

Fig. 2 — Central office arrangements.

When the last four digits, 4654, are spilled into the trunk they are received by dial-pulse registers. A number-checking circuit then verifies that the number is actually within the number blocks containing the valid codes. A connecting circuit next transfers the four digits from the register to a reed switch store on a two-out-of-five basis.

This number, along with those due to additional calls, stays in storage until called for by the storage control circuit, which occurs when the radio transmitters are available. At this time the translator uses the information in the stores to connect three of the 32 tone generators in the 36A oscillator to the transmitter control circuit. There the tones are amplified and fed to the three radio transmitters in the trial system. All transmitters are turned on, and the presence of the modulating tones and RF carrier is verified by "sniffer" circuits at each one. A timing circuit then maintains the modulation for about 0.5 second, and then inserts a pause of 0.5 second before the next signal. Each individual code signal is sent three times to guard against dead spots.

In principle there are 4960 possible codes when three are chosen at a time from a universe of 32. In this system the translation from the four-digit decimal number assigned to each receiver to the three tones chosen from 32 is made more simple and economical by using only 3200 of the possible codes. More codes could be provided by introducing a more complicated translator or by increasing the number of tones.

Bellboy system numbers are served on the basis of groups that arrive during time intervals which are slightly over one minute long. This arrangement permits an economical design, but results in minor delays, which can range from one second to somewhat over a minute, with an average value of about one-half minute. A four-digit number spilled into the terminal is transmitted immediately if there is no other number in storage. That number retains exclusive use of the radio transmitters until it has been radiated the third time about 60 seconds later. Meanwhile, arriving numbers must wait for service. Then they are radiated in sequence, each taking about one second to process. After the third transmission, each number is cleared from storage and, when the last to arrive has been cleared, the next waiting group is served in similar fashion.

Fig. 3 is a time diagram illustrating the foregoing for a moderately loaded system. It is assumed that at time $t = 0$ the control circuit is just starting to serve calls 1, 2, and 3 in group A. The third transmission will be completed 63 seconds later. During that interval calls 4 through 7 arrive in storage and wait there for intervals ranging from 62 to 6 seconds. At 64 seconds after $t = 0$ call 4 is served. The figure also shows the arrival and service of group C. It will be clear that the maximum time interval between the arrival of a call in storage and the completion of the third transmission is $(120 + n)$ seconds, where n is number of calls in the immediately preceding group.

Each code that is transmitted comprises three audio tones, each being applied at a voltage that produces a carrier deviation of 1.3 kc. The

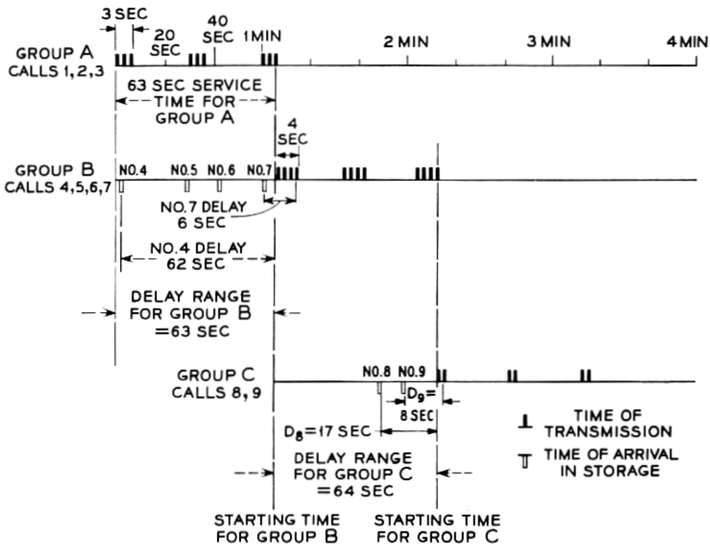

Fig. 3 — Time diagram illustrating Bellboy system calls (not to exact scale).

tone sources are crystal-controlled transistorized square-wave generators. They produce odd multiples of 7.5 cps, beginning at 517.5 cps and ending at 997.5. These square waves are then filtered to produce sine waves. Two frequency groups, a low and a high, are formed by omitting the center frequency, 757.5 cps. In the present system each code consists of two frequencies from one group and one frequency from the other. It will be clear that second-order products generated in the overall system fall outside the present range of tones and would always fall between tones if the range were extended by adding more odd harmonics of 7.5 cps. Although some third-order products can fall on operating frequencies, they will be too low in level to introduce errors.

2.2 *Pocket Receiver*

The pocket receiver will be covered in some detail in a forthcoming paper, but a brief general description of it will be of interest. It is a highly sensitive and selective radio receiver using ten transistors and three vibrating reeds. Two views of a receiver are shown in Fig. 4. Reeds are available for each of 32 frequencies produced by the 32-tone generator, and any three may be inserted into any receiver.

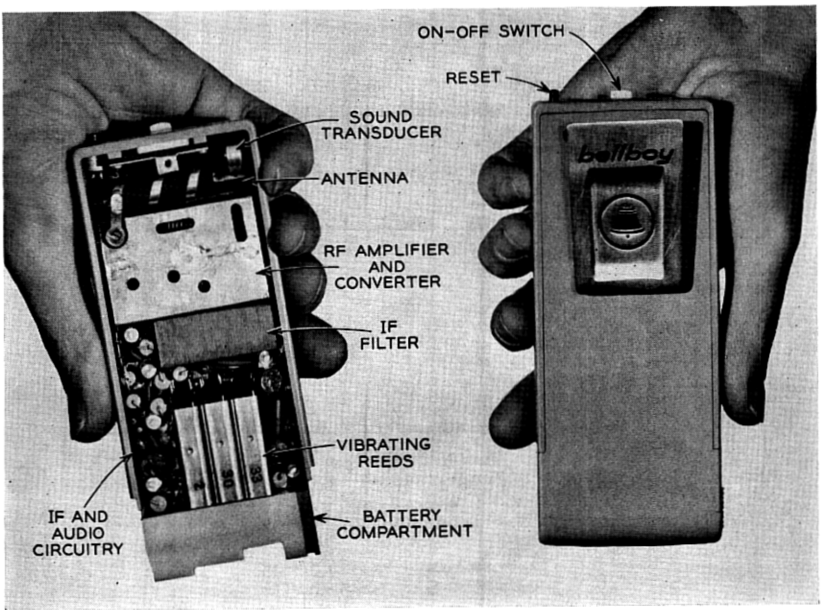

Fig. 4 — 150-mc Bellboy pocket receiver.

The receiver proper consists of two stages of RF amplification at 150 mc, an oscillator with diode mixer, and three stages of IF. Six transistors are used for these functions, another is used for the limiter, and two for the amplifier to drive the reeds. A final transistor provides audio signaling tone to a small transducer which produces the beep. An interesting feature of the receiver is that it uses only one frequency conversion with the IF at about 5.5 kc. This feature has allowed an economical receiver design and provides very satisfactory operation for reed signaling.

A subsequent paper will describe the reeds in more detail. Each is a highly stable tuning-fork structure with a bandwidth of one cycle, similar to those used in the trial of reed signaling in mobile radio at Richmond, Virginia, some years ago.[6,7] The new miniature reeds,[8] however, occupy only about one-seventh the space, have about one-sixth the weight, and require one-fifth the power of those used at Richmond.

2.3 *Integrated Operation*

The operation of the terminal described above assumed that the radio channel was assigned solely to signaling, as was the case for the trial. The terminal, however, has been designed so that it can operate on a channel also used for mobile telephone service. In this "integration," use of the radio channel is alternated between the two services, with mobile telephone service having priority. Bellboy service numbers which have been transmitted once may be required to wait more than the normal interval if a telephone call originates before the second transmission. This can result in intervals of variable duration between first and second or second and third transmission. As this period of time increases, the customer might become confused as to whether he was receiving a repetition or a new call. For this reason, a timing feature is provided in the control circuit to clear from storage any calls which have been served whenever this interval becomes excessively large.

III. COMPARISON OF 35-MC AND 150-MC ENVIRONMENT

It is well known that long-range "skip" interference has necessitated dividing the North American continent into zones, in each of which only one or two 35-mc common carrier frequency allocations are made. The nature of skip interference is such that, although the frequency allocation may be reused at distances up to a few hundred miles, it cannot be reused at distances from roughly 1000 to 3000 miles. Fig. 5 indicates this well-known zoning plan as it is used for 35-mc mobile telephone service. In general, this means that a transmitter of reasonably high power, such

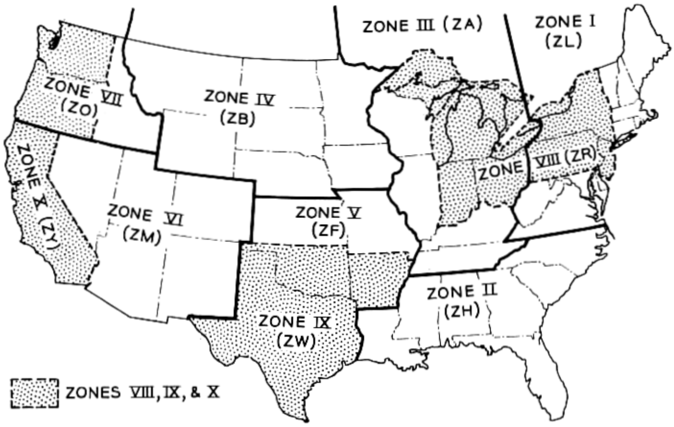

Fig. 5 — Common carrier frequency zoning plan for 30–44 mc mobile telephone service.

as 250 watts, must be assigned only to its own zone frequency. Otherwise, occasional skip interference from its radiation will cause serious interference to mobile telephone receivers in distant zones. It is rather significant and of interest, however, that such interference, which amounts to free-space transmission, is usually no more than about 20 db above a usable signal.

All Bellboy receivers are at least 20 db less sensitive than mobile telephone receivers because of their small antennas. Thus at 35 mc there would probably be no interference problem into Bellboy receivers from a distant zone. On the other hand, it would not be allowable to transmit at 250 watts on a channel assigned to another zone because of interference into mobile radio receivers.

Reducing transmitter power 20 db or more does not appear to be a practical solution, since even with 250-watt transmitters and high-performance receivers the range into modern steel-reinforced buildings is only about one and one-half miles, and into big-city streets it is about five miles. (Section V covers these matters in more detail.)

These factors sum up to the conclusion that in the majority of cases it is only practical to give Bellboy service at 35 mc on the regular zone channel in any one area. This means that if it is desired to give such service in an area already having highway mobile telephone service, it is necessary to integrate Bellboy with the mobile service. This can be readily done, but it places a severe limitation on the possible number of customers and the grade of service.

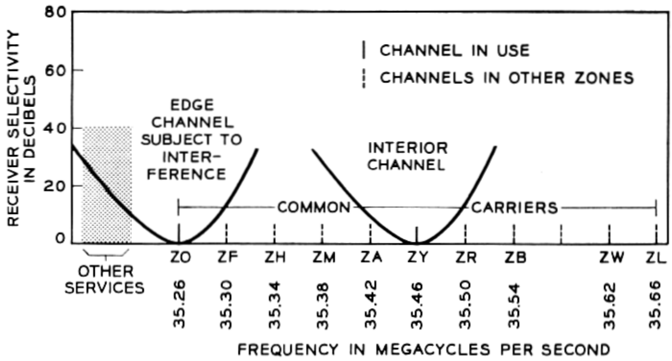

Fig. 6 — Factors in channel usage at 35 mc.

However, there is an unexpected dividend from this restriction to using only the zone channel, which is illustrated in Fig. 6. In most zones, one of the interior channels is used, so that there will be no high-powered radiation in that zone on any nearby channels. This allows the use of a relatively nonselective receiver. A problem may arise, however, if there is potential interference from nearby channels assigned to other than common carrier services. One example is the use of an edge channel, as shown in Fig. 6.

These factors permit the satisfactory use of a super-regenerative receiver to give service in many small to moderate-sized cities throughout the country. About 20 systems are now in service. Such a receiver is naturally substantially simpler and therefore cheaper than a more selective receiver. As a matter of fact, it is apparent from Fig. 6 that in most situations there is no incentive to use a more selective receiver, as long as the present allocation plan is used in the 35-mc frequency range.

On the other hand, it is also apparent that, in order to provide adequate service in the areas where there are large numbers of potential customers, a system is needed that can operate where there are many more channels available. Fig. 7 indicates the situation in the 150-mc band. Here there are 11 channels assigned to common carrier usage and, since there is no long-range interference problem, all these channels are available in any area.

In some highly settled areas it may be necessary to use almost all of these channels for mobile telephones, thereby requiring that Bellboy service be given on an integrated basis. In many areas, even the thickly settled ones, however, it will be possible to set aside at least one clear channel for Bellboy. As pointed out in Section IV, one clear channel provides a large customer capacity. In addition, the 150-mc system has a 4-to-1 speed advantage due to the use of simultaneous tones instead of the sequential system used in the 35-mc receiver.

These advantages, however, are obtained at a considerable cost. As indicated in Fig. 7, the receiver selectivity must be good enough to allow adjacent-channel operation. This, of course, also implies a high degree of frequency stability.

IV. TRAFFIC CONSIDERATIONS

The central office equipment in the J-1 terminal is designed on a flexible basis, so only the equipment needed for a particular situation will be installed. When fully equipped, the system will accomodate a maximum of 3200 four-digit numbers. These fall in the following number groups:

1000–1999,
2100–2699,
3000–3999,
4100–4699.

The number of Bellboy customers, N, that can be served from a single radio channel depends on the amount of traffic which they generate. Since the holding time, h, of each call is fixed at approximately three seconds by design, the calling rate during the busy hour, c, becomes the controlling factor. Early experience with the 35-mc system indicates only 0.4 call per customer per day and approximately 0.1 call per hour in the

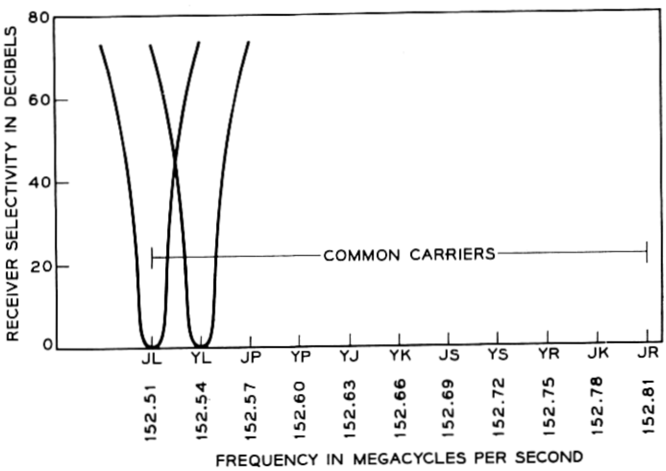

Fig. 7 — Factors in channel usage at 150 mc.

busy hour. However, in the New York trial the corresponding figures were about three times larger. The following expression can be used to find the RF channel capacity:

$$N = \frac{3600}{ch} E,$$

where E is an efficiency factor. Taking $E = 0.8$, $c = 0.3$, and $h = 3$ seconds, it is found that

$$N = \frac{(3600)(0.8)}{(0.3)(3)} = 3200.$$

It thus appears that for this calling rate the radio channel would be fully loaded by the 3200 codes included in the present system. It is possible that the calling rate will vary from one city to another, depending on the characteristics of the principle users of the system.

The number of registers and storage units needed is also affected by the calling rate. Registers can be installed on a unit basis, while stores come in blocks of 10. The present maximum is 10 registers and 40 stores.

The holding time for an incoming trunk and register circuit depends somewhat on the customer. In cases where the call comes through tandem and the customer hangs up promptly upon hearing the warble tone signifying acceptance of the call, the holding time, h_r, may be as short as 7 seconds. In cities where the customer dials directly from a step-by-step office and waits for the complete voice announcement the holding time may increase to about 12 seconds. Taking the lower figure of 7 seconds and assuming $c = 0.2$ and $N = 3200$, the load offered the registers in the busy hour would be

$$a_r = \frac{ch_rN}{3600} = \frac{(0.2)(7)(3200)}{3600} = 1.24.$$

This average figure, which is derived by assuming that all calls come in at a uniform rate, is defined as the load in *erlangs*. Standard tables are available[9] that show the grade of service for a given load when various numbers of the given device or facility are available.

From such a table it is apparent that the provision of five registers would insure a good grade of service, in which the probability of being delayed due to lack of a trunk and register would be less than 0.01. Assumption of a 12-second holding time would increase the load to 2.1 erlangs. This would require seven registers for approximately the same grade of service.

In order to develop the holding time for a storage unit, it is necessary to recognize that the basic time interval during which new calls arrive in storage has a duration equal to the maximum service time for the immediately preceding group of calls. This is 60 seconds plus the time needed for the third transmission of the n old calls being serviced. Since each transmission of a call requires one second, the basic acceptance interval is $(60 + n)$ seconds, during which n' new calls arrive in storage. Since it is equally likely that new calls may appear at any time in this interval, the average value of the acceptance interval is thus $(60 + n)/2$ seconds. Each new call has its third transmission completed in 60 seconds, and so the average call transmitting time is

$$60 + \frac{n'}{2}.$$

The average storage holding time is the sum of these two times, i.e.,

$$90 + \frac{n}{2} + \frac{n'}{2},$$

or about $90 + \bar{n}$, where $\bar{n}$ is assumed to be the average n.

It is of interest to develop the load factor for stores but, in order to do so, we must determine $\bar{n}$ for various calling rates. The average number of stores needed, $\bar{n}$, depends on the calling rate and holding time, as before. Substituting the value $(3t + \bar{n})$ for the holding time, where t is the interval in seconds between successive transmissions, it is found that

$$\bar{n} = \frac{cN(3t + \bar{n})}{3600},$$

which is the same as the load expressed in erlangs. Solving gives

$$a_s = \bar{n} = \frac{3tcN}{3600 - cN} \text{ erlangs.}$$

This is not a rigorous solution, but is believed to be a reasonably close approximation.

The following table shows the load offered to the storage system for 3200 customers and various values of calling rate c and time between signals t:

Calling rate in busy hour, c	Load offered, a_s, in erlangs		
	t = 20 seconds	t = 25 seconds	t = 30 seconds
0.30	21.7	27.3	32.5
0.20	13.0	16.3	20.8
0.10	5.9	7.4	9.4

Reference to delay curves shows that, with 3200 customers, 40 stores will be sufficient if the calling rate is 0.2, and be nearly sufficient for a calling rate of 0.3 to assure a delay probability of 0.01. If desirable, the load could be reduced by reducing the interval t between transmissions. The figure of 30 seconds has been used during the trial, but further experience may indicate that this can be reduced somewhat. It should also be noted that the present system is more than adequate for a calling rate of 0.1, which has been found in systems operating in other cities. A more rigorous analysis of this case is beyond the scope of this paper.

The tone generators are designed on an individual basis, each unit being a replaceable printed circuit board. In small installations it is possible to substitute a resistance for some of the generators and equip only those required for the N codes in the initial system. The number needed is approximately $2(N^{\frac{1}{3}} + 1)$ generators. A new installation having 300 customers could start by equipping 16 generators. As growth occurs additional units can be inserted in the mounting rack.

A study of the calling habits of customers in the New York trial was carried out by slaving a 20-pen recorder to the relays controlling connection of the tone generators. These recordings furnished the data for the estimates that were used earlier for the average calling rates during the five-day working week. There is some calling on Saturday and Sunday, but at a greatly reduced rate.

V. RADIO TRANSMISSION CONSIDERATIONS

The key element in transmission performance of the Bellboy system is the pocket receiver. The 150-mc receiver can trigger on an electrical input signal of about one microvolt and is thus comparable in electrical performance to receivers now being used for mobile telephone. In addition, its selectivity is better than 80 db at a frequency 30 kc away from the carrier, which is also comparable to mobile telephone requirements.

Any pocket receiver, however, suffers a very substantial loss in effective sensitivity due to the fact that the antenna is small compared to a half wavelength. The antenna in this receiver is a ferrite stick, which has been found to give about the best performance of any tested so far. Even this antenna, however, has a loss of over 20 db compared to a half-wave dipole.

One of the problems in engineering this system was to find a reliable and simple method of measuring the small receivers. Two types of measurement are important. One is to determine sensitivity in free space and the other to determine sensitivity when the receiver is carried in the normal manner near a person's body.

Early tests were made in an open field at Holmdel, New Jersey, to determine free-space sensitivity, and these figures were then compared to typical sensitivity on the body. Sensitivity is defined as the field in decibels above 1 microvolt per meter required to just trigger the receiver.

Fig. 8 shows the relative response of a typical receiver when worn in a man's outer coat pocket as compared to its sensitivity in free space. As might be expected, there is quite a large variation depending on which way the receiver or the man with a receiver is facing relative to the transmitter. It is of interest that in some orientations the man provides gain. Apparently, a ferrite stick couples electrically to some extent to the body, thus effectively using the body as an antenna. In other orientations, however, the body provides shielding. It has been assumed for engineering purposes that the average sensitivity of a receiver would be used for estimating range. This seems reasonable, since it appears equally probable that a person may be facing in any direction when he is signaled. It is of interest that the average sensitivity of this receiver is 35.8 db on the body and 35 db in free space.

It is apparent that measuring receivers in an open field is a clumsy and time-consuming process, so experiments were made with various methods of measuring receivers in the laboratory. The most compact arrangement was a jig in which the receiver was placed in a plastic structure so that it coupled closely to a fixed pick-up coil. Although this method was satisfactory for rough checking, it was found that its accuracy left something to be desired. For this reason another method was worked out and is shown in Fig. 9. This involved the use of a short section of waveguide which is big enough to transmit 150 mc with very little attenuation. Al-

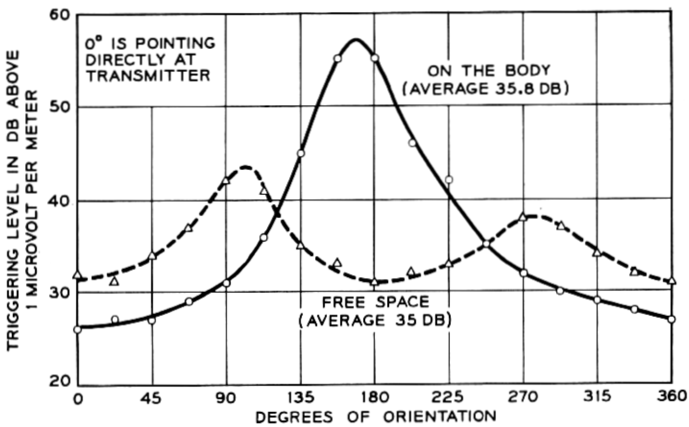

Fig. 8 — Relative response of receiver in free space and on the body.

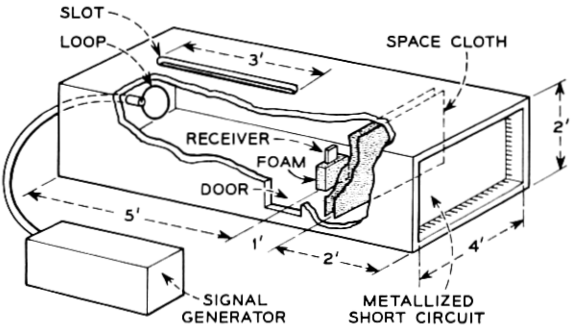

Fig. 9 — Method of measuring receivers using 150-mc waveguide "bear trap."

though this arrangement, which was nicknamed the "bear trap," was somewhat bulky, it could be set up in a moderate-sized room and was found to give reproducible results.

As indicated, the receiver was placed in a piece of foam plastic about four feet away from the transmitting loop and in the center of the waveguide. The combination of space cloth and metallic termination at the right turned out to be quite effective in holding down the standing wave ratio, which was about 1.2. It thus turned out that the receiver was in a fairly uniform vertically polarized electric field, and the measurements were not overly critical as to receiver position. Fig. 10 shows a correlation of free-space measurements in an open field and measurements in the "bear trap" for about 30 receivers.

Using the figure of 36 db sensitivity, it is possible to predict range using the technique described by Rice.[5]

The following table summarizes the figures used in this estimate in the same manner as those shown in Table II of the Rice paper:

A — Receiver sensitivity above 1 microvolt per meter:	36 db
B — Corresponding minimum usable power in a whip antenna:	−116 dbw
C — Radio transmitter power (dipole):	24 dbw
D — Maximum allowable path loss $(C - B)$:	140 db
E — Building loss for 78 per cent reliability:	31 db
F — Equivalent maximum allowable median loss in streets $(D - E)$:	109 db

For convenience, Fig. 11 is reproduced from the Rice paper,[5] showing the building loss in db referred to median field in the streets. Fig. 12, reproduced from the same paper, indicates path loss between a half-wave dipole and a whip in the streets. (Most of this material originally ap-

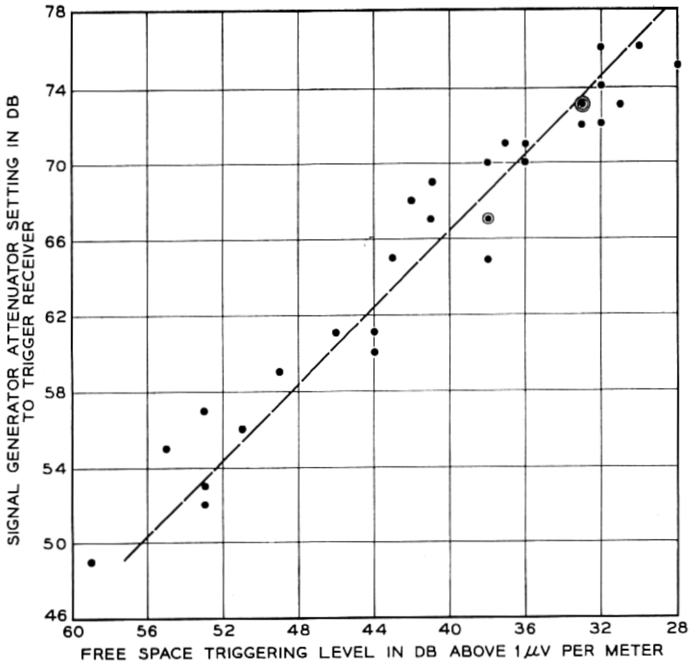

Fig. 10 — Bellboy system receiver measurements in the "bear trap" vs. measurements in free space.

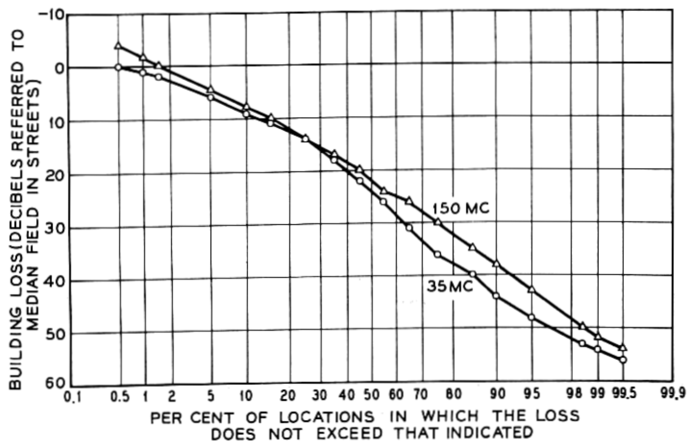

Fig. 11 — Over-all distribution of building losses at 35 and 150 mc.

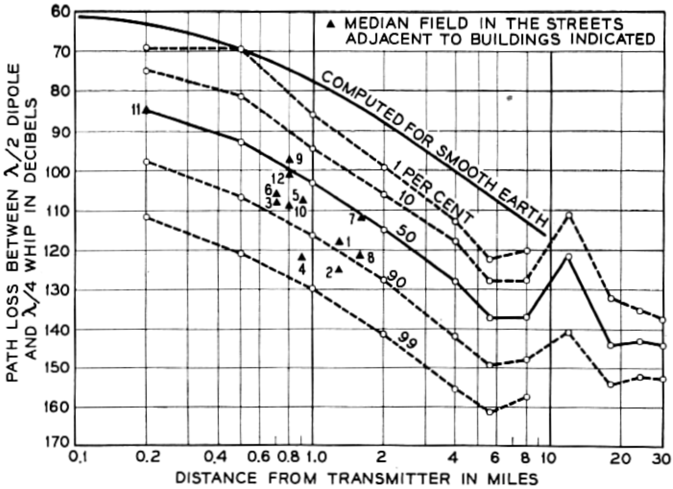

Fig. 12 — Measured path loss at 150 mc between a half-wave dipole and a quarter-wave whip in Manhattan, the Bronx, and suburbs. Antenna heights were 450 feet for transmitter, 6 feet for receiver.

peared in a paper by Young.[10]) From Fig. 12 it is apparent that 109 db median path loss in the streets corresponds to a range of about 1.6 miles. Thus, we would estimate a little over a mile and one-half range into buildings with this receiver, with a 78 per cent chance of success in one try.

Similarly, by interpolating on Fig. 12 we would estimate a range of about four and one-half miles in the streets for the path loss to be less than 140 db for 78 per cent of the cases.

The use of 78 per cent reliability for one try ties in with the planned reliability of Bellboy system service of 0.99 or better. Thus, by engineering a system so that the probability of receiving a single transmission is 0.78, the probability that failure will occur three successive times is $(0.22)^3$ or one per cent. Thus the probability that at least one transmission will be successfully received is $1 - (0.2)^3$ or 99 per cent.

Our experience has indicated that this estimate of one and one-half miles range into buildings and four and one-half miles in the streets is reasonably correct. Obviously, several transmitters will be needed to cover a big city.

It has been found possible to transmit simultaneously from transmitters with overlapping coverage provided radio frequency is controlled to an accuracy of one part per million, i.e., 10^{-6}. This holds the operating frequency of 152.780 mc to ± 153 cps, and keeps beat notes in the receiver below the lowest tone in the coding system.

Laboratory tests have shown that simultaneous reception of two signals produces a slight gain in receiving provided the phases of the modulating tone differ by less than 70°. This is easy to assure, and modulation of the three transmitters in the trial was well within this limit It has not been possible to discover any effect, either positive or negative, in field testing. If, however, the phases of the modulation at two transmitters differ by more than 90 degrees there is a definite penalty. When the difference is 130 degrees the receiver will not operate if the two signal strengths are within 4 db of each other. At 180 degrees the corresponding figure is 6 db. These test results were obtained when the frequency difference between the two carriers ranged from 20 to 300 cycles per second.

Fig. 13 shows the locations of the three 250-watt transmitters in lower Manhattan. These give coverage in every street location tested below 59th Street and in practically all buildings. As might be expected, however, there are a few dead spots. These occur particularly in the lower floors and the interior portions of large buildings which have considerable metal in their construction. One example is the interior of the lobby of the Waldorf-Astoria Hotel, while another is part of Grand Central Terminal.

One customer also found that he could not receive signals while he was in the hold of a ship docked in Brooklyn. This does not seem surpris-

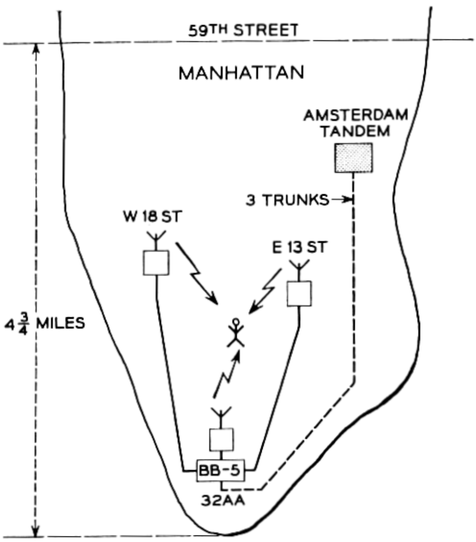

Fig. 13 — Experimental trial of 150-mc Bellboy service in Manhattan.

ing, since a ship interior is probably nearly the equivalent of a shielded room.

In general, it appears that the estimated range figures can be used for most commercial situations. It may turn out, however, that additional low-power transmitters will be needed to cover certain important buildings such as hospitals or large office buildings.

Transmitters would have to be located fairly close together in places like downtown Manhattan, but could be spread out considerably in residential areas. The short range, however, is not entirely a disadvantage. It will allow a channel frequency used exclusively for Bellboy service to be reused at much shorter distances than is the case with mobile telephone.

A potential interference problem exists, however, from the use of satellite transmitters. This comes about when a mobile telephone customer on an adjacent channel drives his car in the near vicinity of a satellite transmitter. In this case, the mobile customer's receiver may be subjected to a strong field compared to the field he receives on the desired channel from a distant fixed transmitter. It appears, however, that trouble can be avoided on this score.

In the first place, the fixed transmitter used on the adjacent mobile channels can be coordinated with the Bellboy system so that it will always be turned on if Bellboy transmitters are radiating. This will guarantee that there is at least some field present near every satellite transmitter. A further improvement in this situation can be effected by the use of directive antennas for the satellites. These may be stacked dipoles or some similar arrangements providing directivity in the vertical plane, so that excessively strong fields just below the satellite transmitters would be avoided.

REFERENCES

1. Strack, W., Pocket Radio Signaling, Bell Lab. Rec., **36,** 1958, p. 9.
2. Kraus, C. R., Citywide Personal Signaling at Allentown and Bethlehem, Pa., A.I.E.E. Summer Meeting, Buffalo, N. Y., June 22–27, 1958.
3. Guernsey, E. D., and Monk, N., Personal Signaling, A New Telephone Service, Wescon meeting, Los Angeles, August 22, 1958.
4. Young, J. W., Page Master Receiver and Modulator Equipment, A.I.E.E. Summer Meeting, Buffalo, N. Y., June 22–27, 1958.
5. Rice, L. P., Radio Transmission into Buildings on 35 and 150 mc, B.S.T.J., **38,** 1959, p. 197.
6. Pruden, H. M., and Hoth, D. F., Vibrating Reed Signaling for Mobile Radio, Trans. A.I.E.E., **68,** Pt. 1, 1949, p. 387.
7. Keller, A. C., and Bostwick, L. G., Vibrating Reed Selectors for Mobile Radio Systems, Trans. A.I.E.E., **68,** Pt. 1, 1949, p. 383.
8. Bostwick L. G., and Guncelle, R. L., U. S. Patent No. 2,877,319.
9. Palm, C., *Table of Erlang Loss Formula*, L. M. Ericsson Co., Stockholm, 1954.
10. Young, W. R., Jr., Comparison of Mobile Radio Transmission on 150, 450, 900, and 3700 mc. B.S.T.J., **31,** 1952, p. 1068.