Transmitter:

Output power	+60dbm ERP
Simulcast	Transmitters synchronized to ± 4uS
Splatter	
Spurious	
Harmonics	
Turn on time	
Turn off time	
PRBS	TBD
Modulation	FSK, NRZ

Receiver:

Sensitivity	TBD
Selectivity	TBD
S/N at detector	TBD
IF Bandwidth	TBD

4.0 Test Equipment Set Up and Calibration

4.1 Equipment Set Up

The transmitter test equipment should be placed in a dry area maintained at room temperature, preferably close to the PURC 5000 location.

The GPS antenna must be placed outside with a clear view of the sky and horizon. Up to one hundred feet of low loss coaxial cable can be placed between the antenna and the receiver.

Upon switch on, it may take the GPS receiver up to 15 minutes to acquire synchronization. After synchronization is acquired, check that the phaselock loop is locked via the lock detect. The TCXO should be checked for frequency accuracy using the high stability counter.

The PRBS generator can be checked at its various data rates by connecting its output directly into the bit error rate test set. No errors should be observed. To check that the generator is resetting off the GPS pulse, view the pulse, reset line and start of generator sequence with an oscilloscope.

The PURC 5000 will be calibrated by Motorola at the factory. After installation the receiver antenna should be brought a specified distance from the transmit antenna and a signal strength measurement made to check the complete system.

4.2 Instrument Calibration

All instrumentation used in these tests shall have been calibrated with NBS traceability on an annual basis. Instrumentation includes those items of equipment that are used to calibrate the test set up.

4.3 System Calibration

The transmitter carrier internal reference oscillator is set up using a frequency counter with accuracy to 0.01ppm. This must be done at the time of set up of the test equipment and at any time when the carrier frequency is changed. The maximum calibration interval for this will be one month.

4.4 System Sensitivity

In order to assess receiver sensitivity for the different data rates and channel bandwidths, connect the receiver directly to the transmitter through a calibrated variable attenuator, ensuring that the attenuator at the transmitter end is rated for 1KW. (If possible the transmitter power should be reduced for these measurements and the attenuator power rating derated accordingly). Increase the attenuator until the bit error rate is at 10^{-4}. Note the attenuator setting and hence the signal into the receiver. Continue to increase the attenuator in 1dB steps and note the BER down to 10^{-1}. Repeat the test for all different data rates and channel bandwidths. Depending on receiver shielding it may be necessary to physically separate transmitter and receiver. If this is done be sure to calibrate connecting cable for loss, and factor into the results.

5.0 Test Circumstances and implementation

5.1 Consideration of other users in the band

Prior to beginning experiments in a certain market, a search will be conducted to ascertain whether there are other users in the 930MHz to 931MHz band, in the vicinity of the tests. If there are, all efforts will be made to ensure no interference is caused, by using different channels and by switching channels if necessary. In addition, a channel will be monitored for other users prior to tests commencing.

5.2 Number of Transmitters in each Phase

Phase 1 of the tests will use three transmitters. The transmitters are carefully chosen to give the best chance of seeing simulcast problems. Use is made of maps and simulation tools to choose three transmitters with the best potential signal overlap.

Phase 2 of the tests uses four level modulation with six transmitters. The siting of the transmitters is chosen in a similar way to those in phase 1.

5.3 Prediction and Finding Location Of Interference (overlap) Due To Simulcast

In each market in which tests are to be performed some analysis will be done to find the best transmitter sites and likely areas of simulcast overlap before testing.

Firstly, a judgement will be made using propagation prediction that includes terrain. This will lead to the selection of the transmitters to be used. Then an estimation is made of areas in which the signal level from two or more transmitters is likely to be similar.

In addition, an estimate of the likely delay in arrival between the two signals is made. There are two causes of signals arriving at different time intervals. The first is when the transmitters are different distances away from the receiver. The second is when reflections are introduced in one path due to the terrain (mountains or tall buildings). Using contour maps and locating tall buildings will enable an assessment of delay to be made in each area in which overlap is thought to exist.

Having made a theoretical assessment of overlap the tests will then be conducted in those areas so identified. Each transmitter will transmit with a slight frequency offset as the receiver test vehicle moves through the area of overlap. When a position is reached where two or more signals are within 10dB of one another the vehicle stops and a simulcast measurement is made.

5.4 Measurements Taken

The measurements taken are solely signal strength and bit error rate. From these measurements it will be possible to conclude frequency of occurrence as a function of coverage area with different transmission data rates. However a third factor is involved in understanding the extent of the problem and that is the relative delay of the signals at the receiver. The more the delay the worse the problem for given signal levels.

In order to get meaningful results from delay measurements a time resolution of 10uS is required for the higher data rates. Time delay measurements are often made as an integral measurement of propagation experiments. The primary purpose is to evaluate worst case multipath delays within a typical environment, in the instance of a single transmitter. Such equipment could be employed in the simulcast experiment to monitor the relative delay time between the two synchronous transmitters. However this equipment is not available commercially and is difficult to construct. Pactel are presently working on some test equipment for measuring delay spread for use in propagation trials. If this becomes available in the next few months it may be possible to incorporate delay measurements at a later stage in the tests. For the meantime the tests will continue with signal strength and bit error rate only

6.0 Test Method

The transmitting sites and areas are chosen as described in section 5.3. When making the simulcast measurements it is desirable that the amplitude of the signals remain relatively constant so that BER measurements for different data rates can be compared. To this end it would be advisable to choose locations with a minimum of temporal fading, such as quiet side streets and areas with little traffic or other movement.

A frequency offset is introduced into two of the three carriers of $\pm$ 1KHz respectively. The receive vehicle is then driven slowly through the overlap area whilst the three carriers are monitored on a spectrum analyzer. When two or more carriers are within 10dB of one another the vehicle is stopped (Note: with fast fading, whilst the vehicle is in motion, it will be difficult to accurately assess the relative levels and it may be necessary to position the receive vehicle fairly precisely). Ensure both carriers are stable with respect to amplitude.

Identify the largest signal and request (by cellular telephone) the other two be turned off. Take a series of measurements of BER and signal strength for the various data rates. This test will give a guide as to how bit error rate changes with data rate in the presence of a single carrier. This is a necessary measurement for comparison with the simulcast measurements.

The other carriers are now turned back on and signal levels checked on the spectrum analyzer and any changes in level recorded. The two offset carriers are now brought back on frequency and all three are modulated with the 1.2Kbit/sec PRBS. The bit error rate and signal strength are recorded. The data rate is then increased and measurements repeated for all the different data rates.

To assess the effect of a frequency offset take the strongest signal and add an offset from 200Hz to 5KHz in steps of 200Hz to 1KHz and then 1KHz to 5KHz. Again measure BER and signal strength and repeat for all data rates.

7.0 Results

7.1 Format of Results

The data from the FM receiver and bit error test set will be recorded automatically by the data logging equipment. Each measurement will be tagged with date, time, position and data rate. The transmitters and their frequency offset will be entered manually.

7.2 Result Issues

Issues that the test results hope to resolve include:

* How is BER affected by increasing data rate/channel bandwidth in single carrier mode
* How is BER affected by increasing data rate/channel bandwidth in simulcast mode
* How does the relative amplitude of the signals affect the BER in simulcast mode
* How is BER affected by various carrier frequency offsets in simulcast mode
* Are different frequency offsets better at different data rates for simulcast mode

* Will simple increasing of data rate give improved information rate

* How well does the GPS receiver perform in assuring simultaneous simulcast transmission.

* Develop an automated measurement technique to both evaluate coverage and simulcast in a paging system.

7.3 Result Presentation

The results can be presented in a series of graphs:

* BER vs. signal level for various data rates in both single carrier and simulcast mode

* BER vs. relative signal level for various data rates in simulcast mode. A series of plots can be produced at different signal strength levels.

* BER vs. offset frequency for various data rates in simulcast mode. A series of plots can be produced at different absolute signal strength levels, and relative signal strength levels.

In addition a road map of the overlap area can be produced showing various grades of degradation due to simulcast.

7.4 Result Analyses

Some correlation of the results will be required in order to gain a better understanding of what they mean.

As data rate is increased the sensitivity of the receiver will change. Therefore when a simulcast test is performed at one location for various data rates, the change in BER may not be solely due to changes in bit overlap between the two signals. There may be a significant contribution from a change in sensitivity due to the receiver. It should be possible to factor out the receiver sensitivity by taking note of the system sensitivity calibration in section 4.4 and the single carrier results

7.5 Result/Measurement Uncertainties

The radio frequency environment in which these measurements are taken is one which is very difficult to characterize. Therefore these results may require some interpretation, and test methods some modification during the early phases.

8.0 Software Requirements

8.1 Transmitter

The Toshiba portable PC is used to control the GPS receiver card. The GPS receiver comes with its own software which will be adapted for the measurements. Some custom software will be written to enable the operator to reset the PRBS generator at a precise time as defined by the operator.

In order to synchronize the transmitters, each operator must be able to reset the generators at the same time. This time is entered into the PC. Approximately 0.5sec before this time, the PC must output a pulse of 1 sec duration. This pulse is then gated by the GPS pulse which subsequently resets the PRBS generator. This occurs in all transmitter locations at the same time.

The software will allow the operator to enter a reset time which will command the computer to execute a reset pulse approximately 0.5 seconds before the reset time.

8.2 Receiver

Software already exists for the receive vehicle to automatically record position information. Some software will need to be written to control the receiver and the BER tester as well as record the measurement data. It is proposed that all the instruments will be interconnected with a GPIB bus and controlled by the same computer that records the position data.

At a location, the software will automatically log position and time and then sequence through the measurements for the different system measurements. The operator will be responsible for coordinating the transmitter sites and checking the integrity of the measurements.

Calibration of the receiving equipment will be automated.

9.0 Time Schedule

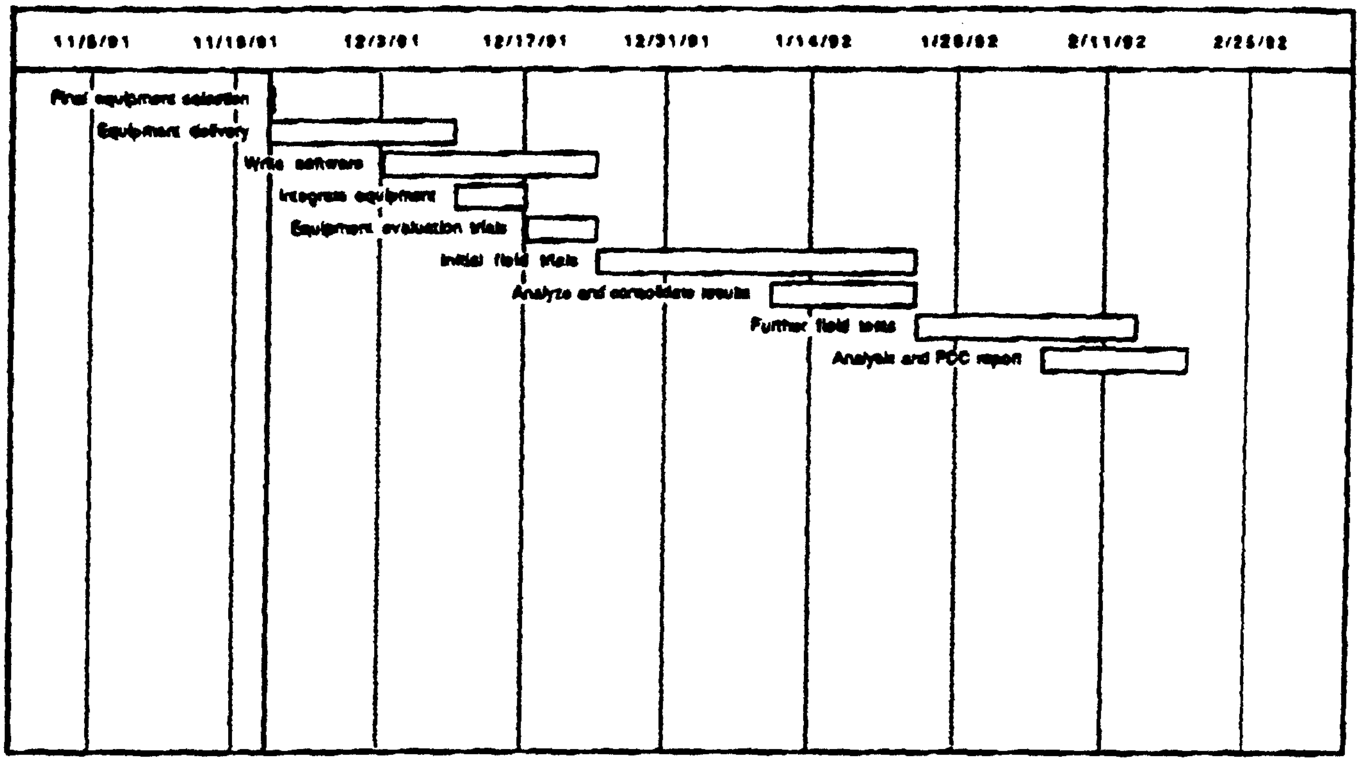


Figure 1— Simulcast Paging System Test

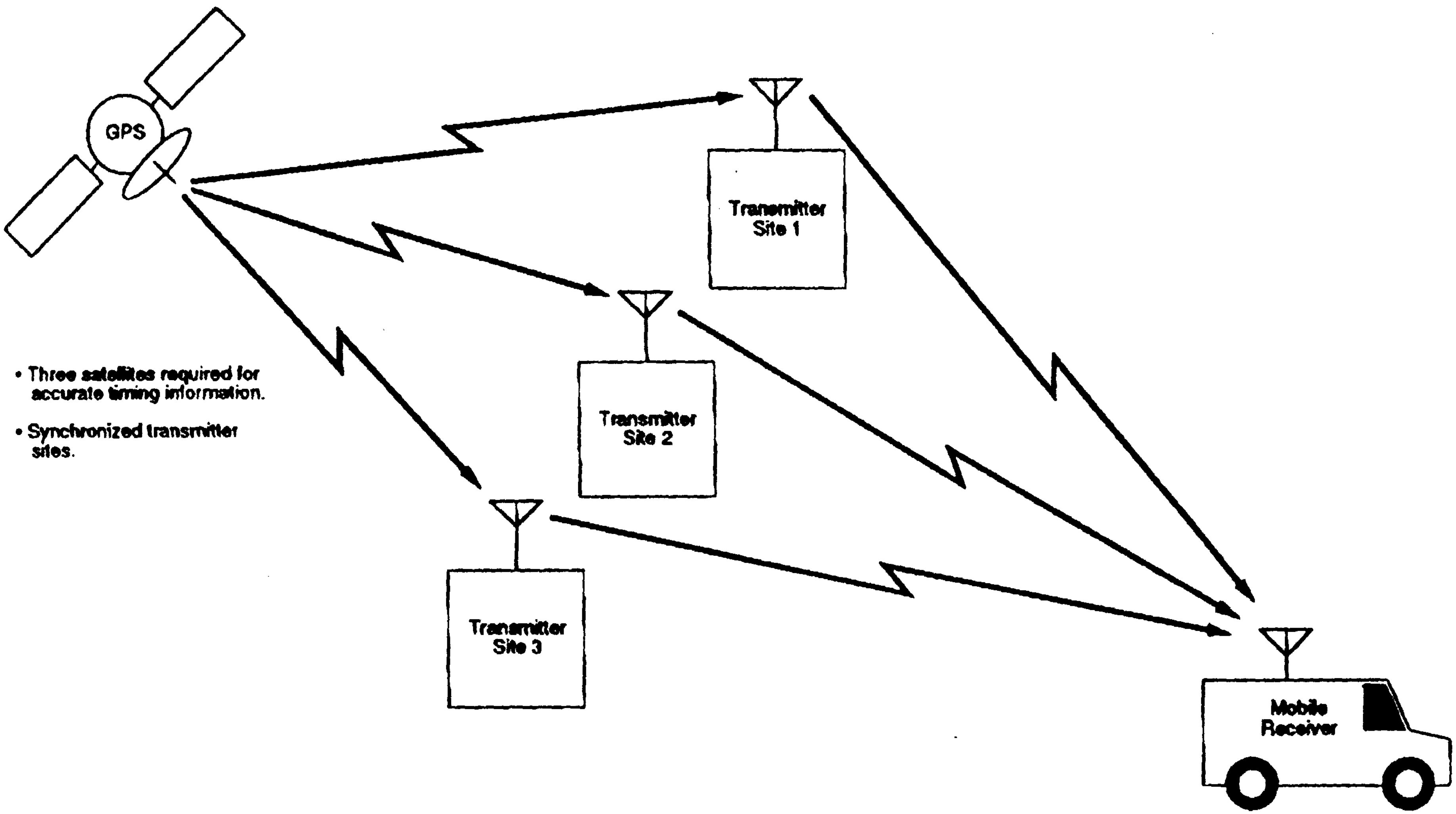


Figure 2 — Transmitter Block Diagram

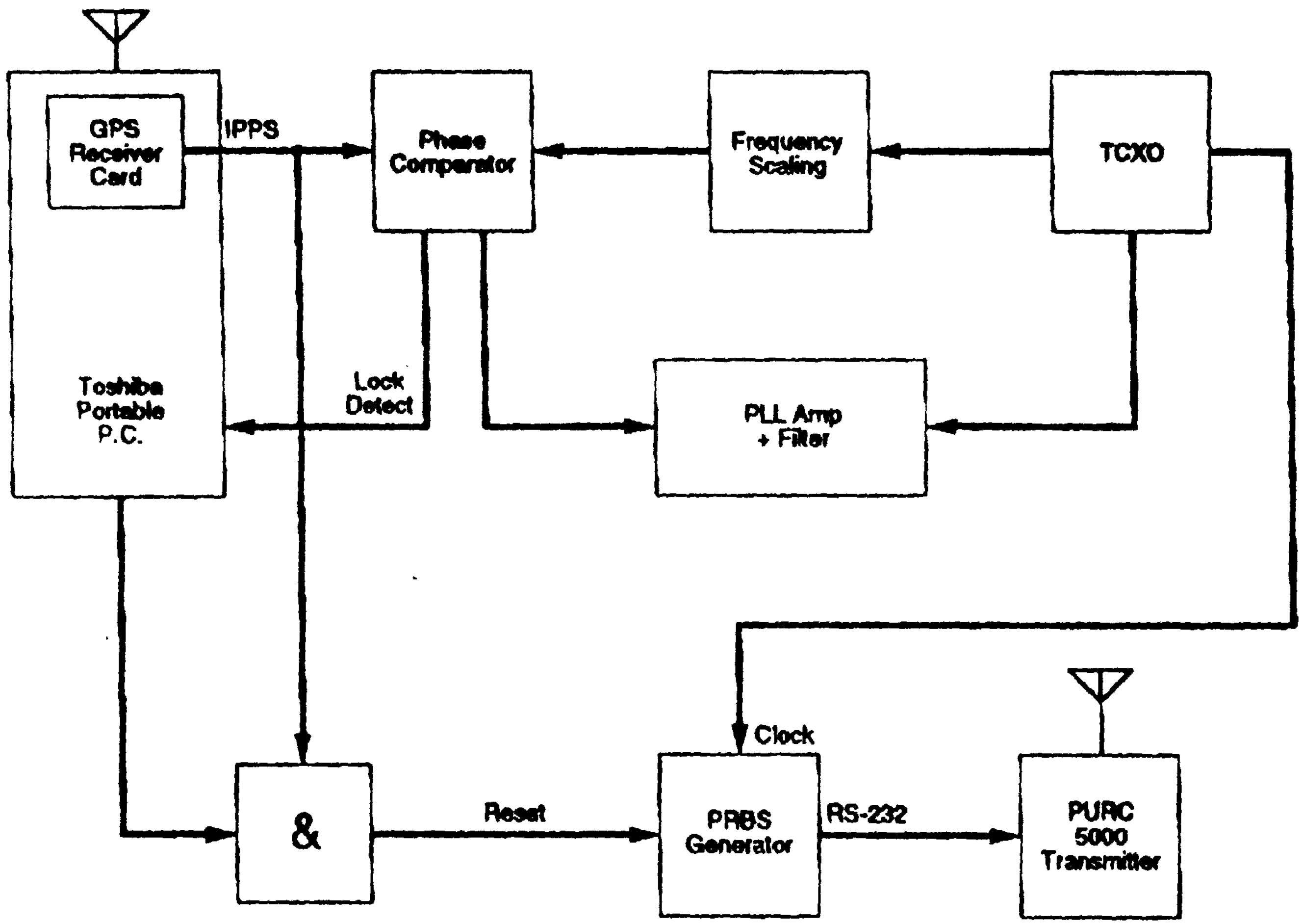
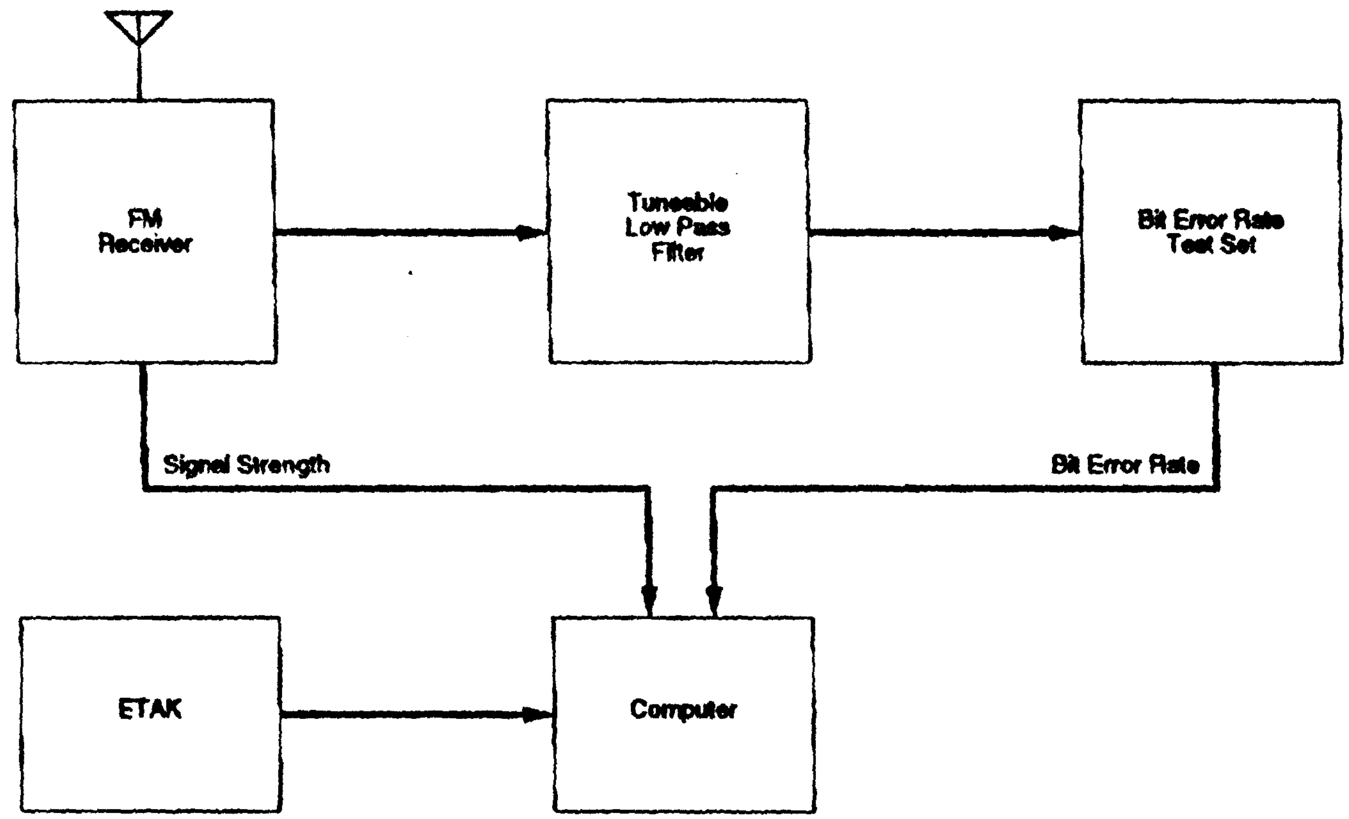


Figure 3 — Receiver Block Diagram



NOTE: Computer, ETAK and antenna are already in mobile vehicle as part of an existing test set-up.

ATTACHMENT 3

TELESIS TECHNOLOGIES
LABORATORY℠

Progress Report
April, 1992

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1.0 Executive Summary

This report describes the tests and results of recent simulcast field tests carried out by Telesis Technologies Laboratory, a subsidiary of Pacific Telesis Group, on behalf of PacTel Paging. This interim report to the FCC, pursuant to the terms of an experimental license, reports work done in respect to Advanced Architecture Paging. The tests were authorized by the FCC under a Special Temporary Authority issued in December, 1991.

Simulcast field tests were conducted at different data rates and bandwidths; 1.2, 2.4, 3.2, and 6.4 kbaud in a 25kHz bandwidth, and 12.8 kbaud in a 50kHz. The tests were conducted in the San Francisco area, in the frequency band of 930 to 931 MHz, which is currently held in reserve by the FCC for Advanced Paging. Two existing paging sites and a mobile receive vehicle were used for the simulcast tests.

We demonstrated that two transmitters can be synchronized using the Global Positioning System to within one microsecond.

Initial tests were performed under a worst case condition, namely equal received signal strength of two transmitted signals. Results to date show, as expected, that more raw bit errors occur at the higher baud rates for a given relative delay between the two received signals. More specifically, 1.2 kbaud is not effected, in terms of bit errors, for relative delays up to 160 microseconds whereas, in contrast, 12.8 kbaud cannot be received for delays in excess of 40 microseconds. At 6.4 kbaud, the combined signals cannot be received for delays in excess of 80 microseconds. All data rates, except 1.2 kbaud, show a residual BER for no relative delay between the two received signals. For the data rates of 2.4 and 3.2 kbaud, the BER does not significantly degrade from a residual BER of 10^{-4} and 10^{-3} respectively.

Initial measurements suggest that, at most, 10 dB of relative signal level is required between two received signals before BER becomes independent of relative delay. 10 dB is required for the extreme cases where the relative delay of the two received signals is a significant duration of a bit period, up to 50%, and BERs are high. This figure is dependent on the type of receiver used.

In conducting these tests, PacTel Paging supplied significant help, in particular, allowing the use of the transmit sites and supplying advice on the paging aspects of the tests. In addition, Motorola has contributed by supplying the transmitter paging units.

2.0 Introduction

2.1 Background

On February 20, 1991, an experimental license was granted to Pacific Telesis Group to conduct RF propagation and system tests in five cities throughout the United States. This license was subsequently transferred to Telesis Technologies Laboratory (TTL).

On July 29, 1991, Pacific Telesis notified the Commission of details of its experimental program for Advanced Architecture Paging (AAP) and on August 2, 1991, PacTel Paging, an indirect subsidiary of Pacific Telesis, filed a Petition of Rulemaking proposing the allocation of a portion of the 930-931 MHz band for AAP. AAP is a platform upon which existing and enhanced messaging capabilities will be offered and coexist by alleviating present internal formatting limitations. To better understand the limitations of existing paging as well as the benefits of AAP, TTL applied for and received a Special Temporary Authority on December 27,1991, to undertake pertinent experimental tests. Concurrently, PacTel Paging, under the auspices of TTL, has filed an amendment to the existing TTL experimental license for San Francisco, increasing the allowed transmitted power to 1kW E.R.P. This amendment is currently under review by the FCC.

2.2 Test Objectives and approach

In conjunction with TTL, PacTel Paging is undertaking a phased approach to understanding the limitations of present day paging and its possible future developments in the direction of AAP. AAP is an unformatted paging service which, unlike the present paging formats (POCSAG, GOLAY), doesn't impose internal formatting limitations. This enhanced service would offer enhanced messaging capabilities, for example, longer alphanumeric messages. To maintain or increase capacity while adopting these services will require a higher transmission data rate.

The main objective of this phase of ongoing tests was to investigate the effect of operating at higher data rates in a simulcast mode. The present paging data rate is 1.2kbaud in a 25kHz channel bandwidth. These tests evaluate a 25kHz channel bandwidth with data rates of 1.2, 2.4, 3.2, and 6.4 kbaud and a 50kHz channel bandwidth with a data rate of 12.8 kbaud. Particular questions that are addressed in the present tests are :

- what is the interaction of the system variables, relative delay, relative power levels, and signal quality (bit error rate measurement) at the different data rates ?
- what degree of synchronization can be achieved using the Global Positioning System (GPS) while using cost effective equipment ?
- quantitatively, how is coverage impaired by simulcast in pursuing higher data rates ?

In present systems, simulcast interference becomes significant when the relative delay between the arrival times of two synchronously transmitted signals is approximately one quarter of a bit period, assuming approximately equal receive signal levels.(200 microseconds @ 1.2 kbaud). The delay is a result of inherent system delay tolerances and relative propagation distances to the affected receiver. Propagation delays can occur in typical paging systems because the high power, elevated transmissions that provide coverage to a large area overlap lower power local transmissions. System delay tolerances, typically greater than 30 microseconds, occur as a result of timing shifts in the delivery of the modulating waveform to the transmitter, and time shifts inherent in the transmitter itself. Attaining the degree of modulation synchronization required for higher data rates[1] is, in practice, a complex task.

2.3 Report Contents

The original details of the test approach were outlined in a test plan.[1]. This report presents results for the first two questions posed above, specifically, what is the interaction of the system variables at the different data rates, and what degree of synchronization can be achieved using GPS. Descriptions of the test method, equipment, and test results are given in this document.

The terms of the experimental license require that a progress report be submitted to the FCC every 90 days. The fourth such report for the PCS experiments was submitted this month for the period from November 21, 1991 to February 20, 1992. This report is an interim report exclusively describing the paging tests.

1 One microsecond has been suggested for 12.8kbaud.

3.0 Methodology

The basic test was designed so that a mobile receive vehicle would select a location that is adversely effected by simulcast. Once at the location, measurements characterizing the received signal in terms of the transmitted signals were made. The measurement parameters were :

- Relative received signal strength - each transmitter's signal strength was individually measured at the receiver. Absolute levels were not important, only the difference.
- Relative delay - the delay taken by each transmitter's signal to reach the receive vehicle was individually measured. Again, absolute delays were not important, only the difference.
- Bit Error Rate - a quantitative measure of the quality of the combined signal at the receiver.
- Frequency offset - the offset in frequency between the transmitter carrier frequencies.

Initially, it was proposed that three suitable existing paging sites be used to do the testing. However, due to equipment problems, only two have been commissioned to date.

In selecting the receive sites, a combination of experience and prediction tools was used. An example of best server coverage is given in Figure 5.1. After designing the test equipment, we realized that the relative delay and signal levels could be changed at one or both of the transmit locations. Rather than searching the local area for the correct conditions, one location was chosen to make the test, and then subjected to all variations of the parameters. This approach, in addition to making the test less time consuming, allowed the testing to be more objective in the following way.

As a quantitative measurement of the signal quality in a simulcast environment, it was decided to measure BER. However, in obtaining meaningful results, it was necessary to design the experiment so that other causes of bit errors were isolated or minimized. In a radio environment other causes of bit errors are :

- temporal, multipath or shadow fading,
- phase cancellation due to the carrier frequencies of the transmitters not being coherent.

The measurements were done while the mobile receive vehicle was stationary and in a rural location, to minimize the effect of fading. To minimize the effect of phase cancellation, the transmitted signals were received at strong signal levels. Only slight deviations from anti-phasing are required to yield adequate signals if both signals are well above the noise threshold.

To synchronize the transmitter sites, it was decided to use GPS, which required that each site have a GPS receiver. Although the full constellation of satellites has not been launched to date, the existing satellites provide enough coverage during the day to allow the tests to be made. A tentative date of January, 1993 has been set by the U.S.DoD for the full commissioning of GPS.

4.0 Equipment Description

The proposed locations of the transmitters are at existing PacTel Paging sites, Hayward, Roundtop and San Bruno. At present, two are operational, Hayward and Roundtop. The receiving equipment is housed in a mobile vehicle that is specially adapted for these types of test with on board generators, telescoping antenna mast (13 meters), and equipment rack mounting facilities.

4.1 Transmitter

A block diagram of the transmitting equipment is shown in Figure 4.1.1. The transmitter uses a modified Motorola paging unit, the PURC 5000. This has been altered to take into account the wider channel bandwidth, 50kHz, and associated higher bit rate of 12.8kHz. These modifications consist of introducing switchable analog splatter filters, to contain the modulation to the required bandwidth, and adjusting the deviation in the exciter. A nominal binary frequency deviation of ±5kHz was used for 12.8 kbaud rate and ±2.5kHz for the remaining rates. The baseband data is provided by a pseudo-random bit sequence generator which can be set to any of the required data rates from 1.2kbaud to 12.8kbaud.

The remainder of the equipment, GPS receiver, computer, and synchronization logic, is dedicated to ensuring that, when required, all transmitters are transmitting with the same data sequence and are in phase synchronization.

The GPS receiver, by obtaining a 'fix' on a number of GPS satellites, is able to generate absolute time accuracy to less than one microsecond (typically 100nsecs - Figure 4.3.1) at each transmitting site. One pulse per second (1pps) is output from the GPS receiver with this time accuracy on its leading edge. The pulse in conjunction with the output of a 14.4MHz reference clock from the PURC 5000 paging unit, is used to ensure each transmitter begins its data sequence at the same time and at the correct data rate. This function is achieved using a synchronization logic unit designed and built by Telesis Technologies Laboratory together with the software to drive the unit. A block diagram is shown in Figure 4.1.2.

The function of the logic is to be able to reset all transmitters at a given time with the same pseudo-random data sequence at the correct data rate. It also allows a mark space waveform to be selected for relative delay measurements. Essentially the logic divides down the 14.4MHz reference clock to five clock rates of 1.2, 2.4, 3.2, 6.4, and 12.8kHz. Conveniently, all the clock rates are integer multiples of the paging unit reference clock, otherwise it would have been more sensible to derive the clock from GPS. The dividers are reset every second by a reset pulse derived from the GPS 1pps so that the data sequences are not allowed to process with respect to each other. Procession will occur as the clock references of each transmitter are not frequency locked. Differences in frequency of up to 1kHz at 12.8 kbaud can be tolerated while maintaining synchronization. At most, the five clock waveforms can be misaligned by 200 nanoseconds between any two transmitters.

There are two data generators. One is a 512 length pseudo-random sequence and the other a mark space sequence running at 600Hz and derived from the 1.2kHz clock signal. The length of the pseudo-random sequence was arbitrarily chosen. Selecting a data rate under computer control will direct the respective clock signal to the data generator. Additionally, when the respective data sequence is selected, the waveform is output to a RS232 port for the transmitter paging unit. The synchronization logic unit is controlled by a PC from its parallel port.

In order to start the data sequences at the same time for the two remote transmit sites, the accurate GPS clock at each transmit site is used. The computer has knowledge of GPS time from the GPS receiver and this time is accurate to within one microsecond of Greenwich Mean Time. An example of the start up sequence follows. Suppose that the transmitted sequences are to be synchronized at a particular time, say 10.00.00 am. The time is entered into each controlling computer. The computer then interrogates the GPS receiver for its time every second. When the start time arrives, all computers output a start pulse of slightly less than one second in duration. Different processing delays particular to each computer will advance or retard the pulse. Approximately, ± 200 milliseconds variation was observed between the computers used. In any event, these time variations are tolerable since the start pulse duration is designed to be active so that only one GPS 1pps coincides. The GPS 1pps is output every second to within one microsecond accuracy on the leading edge. At the time that the start pulse and the GPS pulse are active, the respective data generators are reset. Since the comparison of time is made after the GPS pulse has occured at 10 a.m., the computer automatically advances the requested time by one second.

An operator was required at each transmitter site to monitor the tests, change the data rates and switch the respective transmitter on and off at the appropriate times. It was thought unnecessary to control these functions remotely just for the duration of the tests.

A log of the transmit times, powers and locations were kept for all test periods.

4.2 Receiver

The receiving equipment is shown in Figure 4.2.2. It was placed in a mobile vehicle which had the necessary facilities to make propagation measurements; a telescopic mast (13 meters), power generators, and equipment racks. A bicone omnidirectional antenna was used to make the measurements with a gain of 1 dBi at 900MHz.

The receiving equipment essentially consisted of a FM receiver and a BER tester. Cavity filters and a LNA were added to improve the sensitivity of the receiver as well as to limit the out of band signals, particularly the adjacent paging band. The net gain of the filters and amplifier was 29 dB with an overall noise figure of approximately 10dB. Sensitivities of the receiver for the two IF bandwidths of 15kHz and 230kHz were -107 dBm and -95 dBm respectively. At these signal levels, the data was noticeably degraded as viewed on the oscilloscope and the BER tester began registering errors.

A 230kHz IF bandwidth was used for 12.8 kbaud and 15kHz for the remaining data rates. The two IF filters were switchable within the FM receiver. Ideally, an IF bandwidth of 30kHz would have been used at the higher data rate, 12.8kbaud, but this bandwidth was not optional on the receiver. In any event, it was thought not essential for the tests since strong wanted signal levels would be encountered and the cavity filters would provide enough discrimination on adjacent bands. In addition, the 930 to 931MHz band is currently used only on an experimental basis by the FCC.

Switchable 2 pole low pass active filters, one for each data rate, filter the baseband signal from the receiver. The 3 dB points of the filters are set to a frequency that is 80% of the bit rate. The filtered baseband data is then passed into a bit error test set.

The bit error test set recovers a clock signal from the incoming data stream using a zero crossing synchronization scheme. Using the recovered clock signal, the tester is then able to sample the data and compare the received pseudo-random sequence with the sequence that it expects. It is then able to make a count of errors to determine the bit error rate. To compensate for the higher frequency deviation of the modulated signal at 12.8kbaud, it was necessary to change the input loading to the tester in order to obtain the correct signal level into the BER tester.

A computer is used to automatically configure the instruments for the test and change the relevant parameters for the different data rates. Additional software is currently being written to automatically collect the results from the oscilloscope and BER tester. At present, this procedure is done manually. The computer also houses a GPS receiver. The GPS 1pps is used to trigger the oscilloscope for the delay measurements.

4.3 GPS receiver

All transmitter sites and the receive vehicle were equipped with a GPS receiver, PC card. For timing purposes, the GPS receiver outputs 1 pulse per second with an accuracy of 100 nanoseconds on the leading edge of the pulse.(Figure 4.3.1) Using this pulse, all the transmitter sites were able to synchronize their transmissions to within 200 nanoseconds with respect to each other.

In order for the GPS receiver to provide an accurate timing pulse, a minimum of three satellites are required to be above the horizon. In this mode of operation, the receiver is said to have a '2D fix'. In other words, accurate positional and timing information is available but inaccurate height information. An additional satellite is required to calculate the height information. For the most accurate timing information, it is best to specify the height of the respective location and allow GPS to calculate the remaining parameters, time and position.

Placement of the active antenna is critical to the performance of the GPS receiver. Placing the antennae on the roofs of the existing paging sites provided a clear view of the horizon relatively free from any obstructions. For the receive vehicle, the active antenna was placed on the roof.

At present, the GPS satellites do not provide twenty four hour coverage. However, the testing times were coordinated with a forecast of the availability of the satellites above the horizon.

5.0 Test Circumstances

The testing to date has been conducted using two transmitters, one located at Hayward (H in Figure 5.2) and the other at Roundtop (R1 in Figure 5.3). Another transmitter is proposed at San Bruno (S1 in Figure 5.4). A best server coverage plot of all three is shown in figure 5.1. Both active transmitters were transmitting at an ERP of 300W at a frequency of 930.5MHz. Before any tests were done, the 930 to 931MHz frequency band was monitored for other users.