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AM STEREO BROADCAST SYSTEM

MICROELECTRONICS IN COMMUNICATION

PCM MICROWAVE FOR VOICE AND DATA

NEW YORK TRANSIT COMMUNICATIONS

THE RADIO CLUB OF AMERICA, INC.

250 Park Avenue, Room 319, New York City

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The Radio Club of America, Inc.

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Organized for the interchange of knowledge of the radio art, the promotion of good fellowship among the members thereof, and the advancement of public interest in radio.

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MICROELECTRONICS IN COMMUNICATIONS

By C.F.O'Donnell, Autonetics, Inc.

Interactions between microelectronics and communications have been increasing over the past few years for two separate reasons. On one hand communications have become more and more digital, so the cost savings possible through implementing digital functions with microelectronic devices has become more important to communications. On the other hand, microelectronics people have been busy adapting their techniques to the specialized devices needed to operate at high frequencies and to generate certain special analog functions.

This paper examines three areas. First it shows how microelectronics has evolved and the impact of this evolution on the cost of providing a given electronic function. Then it proceeds to digital communications using an adaptive modulator/demodulator, or MODEM, the line terminal equipment for a digital data link, as an example of microelectronic devices in communications systems.

Finally it describes a short distance C- or X-band communication link and the microelectronic devices which make possible all solid state mechanization of this link. These examples should suggest other areas of microelectronics applications in communications systems.

MICROELECTRONIC EVOLUTION

One of the basic ideas behind the change from discrete components to microelectronic integrated circuit devices was that potentially the new devices should reduce the cost of electronic systems fabrications. From a handling point of view alone, if the 36 devices required, for example, for a J-K flip-flop could be reduced to a single device, substantial savings could be achieved. This is true unless the processes to produce the single device prove so sensitive and difficult to control that device yields are too low for economic production.

Initially this came close to being the case, but with increasing production experience yields mounted rapidly and today we indeed have significant cost savings through substituting a single bipolar integrated circuit for 36 discrete components and their interconnections.

Not only were the costs lower but the number of possible failure modes had been reduced. Case leads, for example (for our J-K flip-flop) dropped from some 36 to one. Lead seals dropped from 78 to 14. Connections dropped from 234 to 28. With lower component failure rates the mean time between systems failures increased. This made integrated circuit systems a prime candidate for inclusion in high usage data links where system failures can not be tolerated.

Having found that this first step between discrete components and complete circuits was both a technical and an economic success, the logical next step was to incorporate a number of circuits into a single chip. For example, 8-bit bipolar shift registers have been fabricated on which eight flip-flops plus the required logic are all included on a single silicon chip mounted in a package about the same size as that required for the earliest integrated circuits. This inclusion of a complete function instead of merely a circuit, in one package, further reduced the amount of labor needed to handle, mount and interconnect a complete electronics system.

Using these integrated circuits the board count for a black box was reduced by a factor of between 10 and 20. This meant that not only was the physical size reduced but the total number of board connectors required and the cabling needed to interconnect these connectors were eliminated. There is a pyramiding effect in the savings of direct labor required to fabricate a given black box by going to higher and higher levels of integration of circuits and functions into a single device.

It is true that the individual mounting board becomes more complex, and may have a number of layers instead of just one. Thus, while the engineering expense (a non-recurring cost) increases, the recurring costs are greatly reduced—especially considering the amount of rework which was previously needed, due to human errors in making the interconnections.

Going from two-sided circuit boards to multilayer circuit boards with integrated circuits mounted on them, and multilayer interconnection boards, has reduced direct labor costs by a factor of 10.

Having gone from components (single) to small groups of circuits on a single chip, the next obvious step was to place a large group of circuits carrying out a number of functions, forming entire subsystems all on one chip. A typical example is a digital differential analyzer. Here, two 28-bit (or longer) registers, plus eight full-adders, and all of the logic required for output switching and setting all the flip-flops to proper initial conditions, are included on one single chip of silicon.

The graph illustrates the trend in production costs for producing such a function over the past 10, and the next five, years. In 1960, using the discrete component technology of the day, it cost about $5,000 to take the 2,000 discrete components and prepare them for mounting by cutting and bending their leads, inserting them in place, hand soldering group of assembled circuit boards (about 10) that would be needed to mechanize such a function. The total cost at that time actually dwarfed the cost of the discrete components, although that portion of the cost was then very high indeed.

By 1965 we were able to mechanize the same function or subsystem using only 100 bipolar integrated circuits in place of the 2,000 components. Here the cost of mounting and other preparation had been drastically reduced and the function could be produced for only about $1,000. By 1970, however, using MOS field effect transistors and LSI (large scale integration), the same subsystem can be mechanized on a single silicon chip for only $50.

In fact this has already been achieved, and we are already well on our way to the projected 1975 cost of $10 per function for a device of this complexity. Such a device will have about 800 active elements on the chip.

In summary we can say that the cost of providing a complex electronic function has been dropping by a factor of about 100 for each decade in the immediate past and seems likely to continue at that rate for at least the next five years.

What we have done is to substitute the relatively simple steps used in fabricating MOS field effect transistor devices for the process steps needed to produce bipolar integrated circuits. This has improved the yield and allowed us to include many more active elements on each chip. In addition cost savings have been effected by using batch processes to turn out completely interconnected subsystems as the end product of the batch process.

We now need connect only about 40 leads to the outside world from this chip, to supply the same function which required the connection of over 4,000 leads (2,000 components) in the example using discrete components.

DIGITAL COMMUNICATION

Digital communication accounts for an increasing percentage of the total communication market. This is due to increased use of teletype and similar printers, the use of digital systems for airline ticket reservations, time-sharing computers, and various other ticket sales agencies such as theater tickets at remote points, and soon even railroad tickets at remote offices, each linked to central reservation memory. Finally, in some areas, even voice communication is going digital.

In most of these data links a modem is required at each end of the actual line (or other link) connecting the two stations together. At this time the total number of modems in use is somewhere between 50,000 and 100,000. Research by Arthur D. Little Associates predicts that by 1974 the total number of such modems will go beyond 800,000 and will still be increasing exponentially.

One of the problems with using voice lines for transmitting digital data is that inter-system interference occurs whenever the bit rate goes above 1200 bits per second. Obviously if we can double or quadruple the transmission speed over a line we can effectively reduce costs by a factor, of say, two or even four. Therefore, it is worthwhile putting dollars into more complicated terminal equipment if it allows operation at these higher data transmission rates.

Fortunately it is fairly simple to do, from a technical point of view. The digital data has a fairly uniform wave shape: rectangular waves. Thus anything other than a rectangular pulse input is due to line distortion. It is then only necessary to set up the receiving system to determine what details on these rectangular pulses should be, what their amplitudes are, and then subtract all other details from all successive pulses on the line. This sharpens the data available for the receiver to the point where the error rate drops, even at twice or four times the normal rated line speed, to one part in a million or even lower. While this data rate improvement is simple to obtain from the point of view of technology, until the advent of microelectronics made the electronic functions available for a very small cost it was not economically feasible. Today, however, we are able with large scale MOS arrays to produce high speed modems which are actually lower in cost than the older and much slower modems were.

As one might expect, the higher the data rate, the more complex the modem becomes. The more complex the modem, the greater the benefit of using large scale integrated micro-electronic devices. Indeed at the slow speed of earlier modems, 1,200 bits/sec, large scale arrays probably only reduce cost by about 25%. However, raising the rate of data to 19,000 bits/sec, which is technically possible, one finds that costs drop by more than 60%, compared with the use of conventional discrete and integrated circuit devices for the modem.

It is not only in building a complete modem with five MOS chips plus a few bipolar and discrete components that microelectronics contributes to digital communications links. For example, if one is using a time shared computer one would probably need to accept information from the computer in parallel but transmit it over the data link in serial. A 32 bit parallel load shift register suitable for this can readily be accommodated on a single chip of 100 thousandths of an inch on a side. If you have a manual keyboard at the user's terminal to be connected to some more complex computer at the central equipment end, then a keyboard mode control function requiring some 500 devices can readily be put on a chip approximately 1/6th of an inch on a side and furnish the complete functional requirements for interconnection between the manual keyboard and the data transmission link.

It is possible that the low data rate obtained with the manual keyboard may make it uneconomic to use a single keyboard with a leased line. Normally the reason for going to a time sharing operation is to enable the user to have many data terminals throughout his facilities, all using a common computer centrally located. In such case only a single line need be leased, and then muliplexed, using a single chip about 1/6th of an inch square, with a small number of devices, about 300, to multiplex up to 16 individual keyboards, all over the same line to the central computer.

This is only one example of the digital data links being opened up for economic exploitation through low cost microelectronics.

SHORT DATA LINKS

For high density traffic areas microwave communication links in the C- or X-band are of great value in spite of their limited range. In both C- and X-band the FCC has already allocated blocks of frequencies for communication use.

A microwave communication system using microelectronics would be expected to have the virtues of small size, low weight, and also low cost. And because the carrier frequencies are high, large bandwidths are available, enabling multiple channel operation over each link. It could carry telemetry and television, as well as voice. Such systems are inherently flexible, and able to transmit either digital or analog data.

Due to their small size they adapt well to mobile installation also. Where line of sight transmission is a problem relatively low cost repeaters can be installed. There should be relatively low interference between physically adjacent systems due to the high directivity antennas that would be used.

The parameters of microelectronic microwave communications may at first seem unusual to engineers accustomed to the power levels of standard communication links. Transmitter power, for example, can be as low as 100 milliwatts for 25 mile ranges.

Receiver noise figures, too, are not at all challenging. An 11 decibel noise figure is generally acceptable. The only problem in working with this power and noise would be the 10 ft. dishes required at each end of the link. As we will see in an examination of a proposed system, however, it is possible to overcome this, too.

DEVICES NEEDED

At each terminal data is applied through a microelectronic modulator to the transmitter. Circuitry is needed to isolate the transmitter from the receiver, which share a common antenna. The receiver output then goes to a microelectronic IF amplifier, and then to an optical film display or through a micro-acoustic data processing stage to the microelectronic data storage and computation section.

The entire microelectronics transceiver can be placed on a chip two inches by two. The oscillator for the RF section could be an Impatt diode

To frequency modulate the transmitter, the modulating voltage is applied to a varactor diode. Increasing the voltage increases the thickness of the depletion layer at the diode junction, effectively increasing the capacity of the diode, which changes the tuning of the cavity connected to the Impatt diode, thus frequency modulating the X-band signal.

X-band Impatt oscillators have been built which reach 100 milliwatts with only air cooling. If 100 milliwatts is inadequate it is possible to build arrays of 100 or more of these chips into a phased array system. Each chip becomes an independent transmitter and receiver with a simple phase control line linking it to the pointing computer. The same sort of directivity is obtained as with a dish of comparable size.

The total transmitted power is a direct function of the total number of small transceivers used. In this way one can reduce the need for large dishes at the mobile end of the link. If 100 transceivers are used at the central station then the need for a 10 foot dish drops to one foot; much better suited to mobile.

Signals are transmitted between active elements on the chip through striplines which use the material of the substrate itself as a dielectric. Because the dielectric constant of the substrate is about 10 the striplines can be about one third the size of wave guides for the same frequencies. As a result the band sectioning filter can be on a chip 1/2 an inch or less.

Similarly, the ladder networks connecting the received signal and local oscillator to the balanced mixers can also be on a chip section less than an inch on a side.

Alternatively the local oscillator could be a Gunn diode.

The mixer diodes employ silicon-on-sapphire technology. This allows production of Schottky barrier diodes with noise figures as low as 6 dB from 4 to 7.5 GHz.

If we build interdigital transducers on a piezo-electric crystal we can launch high efficiency surface waves along the crystal at the frequency of the electromagnetic wave input. Transducer efficiency is 98% or better. The interdigital transducer has many of the characteristics of an end fire antenna array. That is, it launches a surface wave in the plane of the crystal surface, and it has frequency response similar to that of stagger tuned IFs.

At 100 MHz a bandwidth of 24% is obtained and adjacent channel interference is down 35 dB. With more complex transducers we decrease side lobes by another 30 dB. Thus a single piezo-electric device can act as a delay line with band pass filter characteristics for an IF amplifier.

We can actually obtain amplification from the line by mounting a thin layer of silicon which has been heteroepitaxially deposited on a sapphire substrate on the surface of the piezo-electric crystal. This line of silicon has voltage applied across it resulting in carrier drift from one end of the silicon to the other. This drift is in line with the direction of the acoustic signal wave. We have produced gains more than 30 dB with such structures, which are essentially solid state travelling wave tubes.

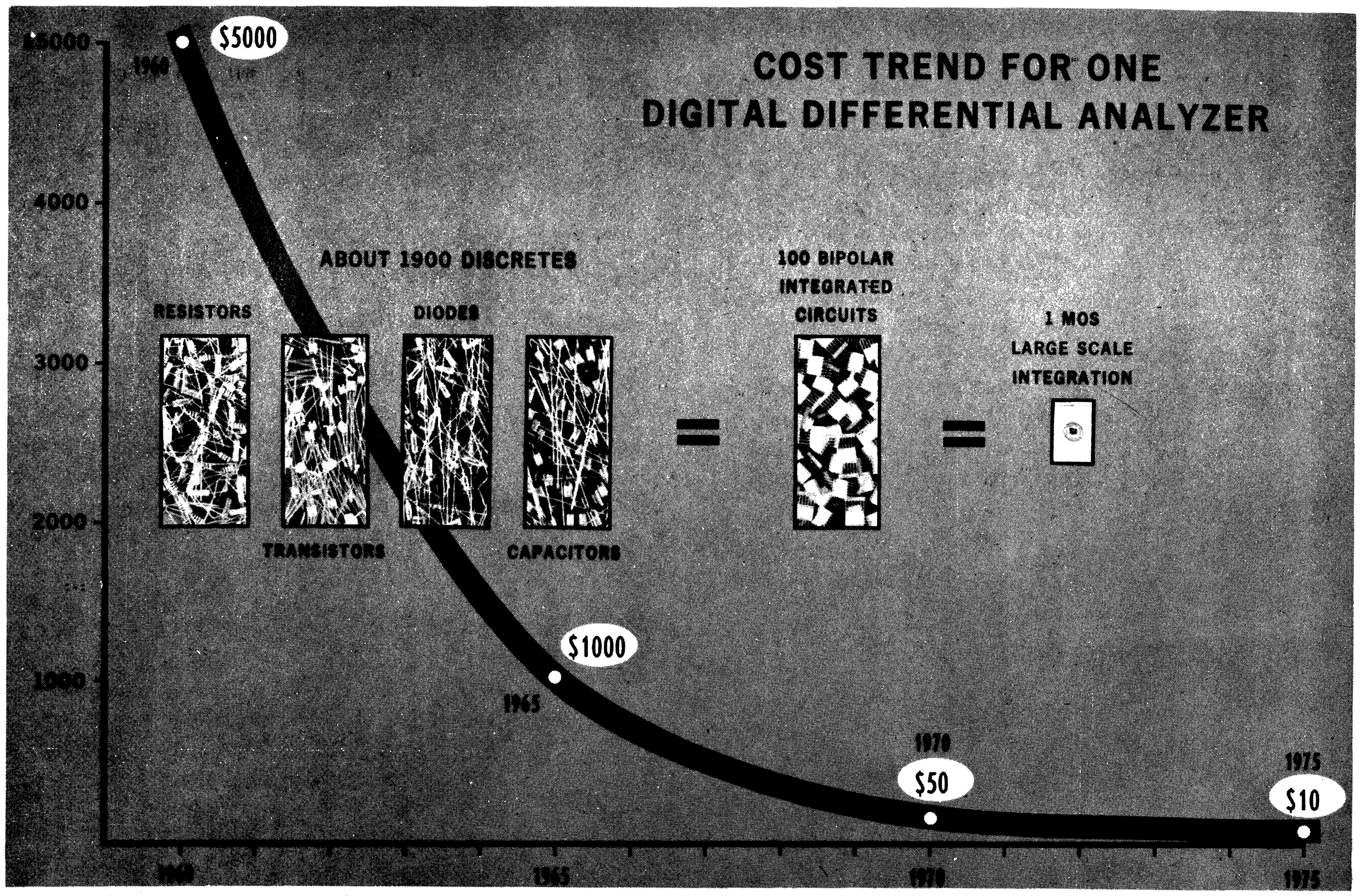
The electric field of the signal is available all along the crystal surface and can readily be tapped off and the signal thus obtained processed in external circuitry. We have used up to 50 taps on the delay line to combine different sections of the signal which had been previously coded so that they all add in an external summing amplifier only when the proper phase is available at each tap. We obtained a 7 to 1 improvement in S/N ratio using this technique.

We are only beginning to explore possibilities for improved communication data processing using this type of device and technology.

Combining these microelectronic device-and-techniques allows us to build central stations using phased antenna arrays with ERPs of 10 to 20 watts and with beam directivity under central computer control to maintain contact with a large number of widely scattered transceivers using time multiplexing. The field stations can use one foot dishes initially aligned with optical sighting, then servo aligned by tracking for maximum signal from the central station.

Bandwidths of 200 MHz could readily be obtained at C- and X-band frequencies. One channel would accomodate up to 400 Picturephone circuits, or up to 40 color TV signals, or about 40,000 voice channels. Despite its low power this system has very great reliability.

With the continuing push toward higher and higher powered microelectronic devices, even longer data links will likely fall within microelectronic and semiconductor technology capability within the decade. Indeed it would not be surprising to see by then full microelectronic data links systems involved in communication satellites.



Evolution and Trend of Microelectronic Costs

AM Stereo BC Reception At Radio Club Meeting

A demonstration of the new Compatible Stereo AM broadcasting system was made at a recent meeting for Radio Club members and their guests.

The first part of the demonstration was the playback of a stereo tape recording of an AM broadcast made and received in Kahn Laboratories' Freeport,L.I. plant.

In the left hand corner of the picture is the Ampex recorder used to furnish the stereo program forthe recorder which supplied the stereo program for the rack equipment (lower part) designed by Kahn Laboratories for AM stereo transmission. A small breadboard (½ watt) transmitter is shown just left of the AM table set in the middle of the picture. It excites a small antenna which is not shown.

A second tape was also played at the meeting. It had been made by H.S. Mitchel, an engineer with the US Air Force. Mr. Mitchel recorded it from two regular AM radios in Seattle, Washington, receiving a broadcast made by station XTRA, in Tiajuana, Mexico. Mr. Mitchel also reported that reception of those XTRA stereo AM broadcasts was good in Alaska. This is apparently a world's record for AM stereo DX !

More Members Join For Life

As this issue of the Proceedings went to press the following members of the Club became Life Members. Welcome, as they say, to the Club!

Meade Brunet.
Edwin P. Felch, Jr.
Harold M. Lewis
Arthur V. Loughgren
W.E.D. Stokes, Jr.
Wilbur E. Thorp

WALDO SHIPMAN

At the November 12,1970 meeting of the Board of Directors, Waldo Shipman was elected a Fellow of the Club. A short time later, before he would have been notified of his election. Mr. Shipman died of a heart attack in New Orleans, where he was scheduled to attend a meeting of the Petroleum Industry Electrical Association. He was the head of the communications department of the Columbia Gas Sytem.

PCM MICROWAVE SYSTEM FOR VOICE AND DATA TRAFFIC

By Fred Brunsdon, Canadian Marconi Company

The CMC (Canadian Marconi Company) was incorporated in 1902, and is in Montreal, Canada. It belongs to the United Kingdom G.E.–English Electric Group of companies. CMC employs 4,000 people including 200 engineers. 1969 sales were over 89 million dollars, primarily in the avionics and communications fields.

Highlights of CMC's early history include the establishment in 1902 of a transatlantic wireless station at Glace Bay, Nova Scotia, and the first regularly scheduled broadcasting station in North America, in 1919. CMC has been in the forefront of radio relay development over the last 15 years, and in 1956 had the second largest mileage system (the Mid-Canada system) in North America.

State-of-the-art developments have led to the production of radio relay equipments from 450 MHz to 7 GHz, including wideband TWT systems. The TWT systems were the first of their kind. CMC also operated the first tropo-scatter SSB system at 2 GHz in North America.

Development of a tactical radio relay set, the AN/GRC/103, was the immediate forerunner of the PCM program described here. This set was developed for the U.S. Army, and is an accepted standard A inventory item. It is also used extensively in other NATO and SEATO countries.

CMC is active in the United States also through a wholly owned subsidiary, KAAR Electronics, which primarily markets marine radar and mobile communications equipment.

Trends In Communications

Several factors influence the introduction of a line of radio relay communication products, which indicate distinct trends at this time.

(a) Recent FCC rulings which open the way for licensing of private microwave systems.

(b) Increasing saturation of the lower microwave bands and the consequent push for practical systems into the higher frequency "precipitation sensitive" bands.

(c) Unprecedented demand for data communication links.

(d) Increasing availability of digital circuit elements and other solid state devices at lowering prices. (Editor's note: For a thorough exposition of this trend, read Dr. C. F. O'Donnell's article elsewhere in this issue.)

(e) User pressure for improved equipment reliability and lower maintenance costs.

These factors all bore on the product planning of the MCS 6900 system. The result is:

(a) A low cost system, attractive to the smaller commercial user as well as the large common carrier or industrial user.

(b) Availability of the system in the 12 GHz band, allowing greater licensing freedom in congested areas. This has considerable application in the shorter single hop systems in urban areas.

(c) A transmission system suitable for a wide range of data circuits as well as voice channels. Here the PCM digital format is ideally suited for direct data insertion without the D/A and A/D converters required in current FDM baseband systems. (As example, over three times as many teletype circuits per voice channel can be provided.)

(d) Maximum use of digital techniques, with their characteristic go/no go simplicity.

(e) A flexible system, easily expanded, which provides the growth potential needed in this digital decade.

(f) A reliable system, capable of maintenance without sophisticated support activities.

The availability of MSI (medium scale integrated circuits) is the key to our ability to produce the MCS 6900 equipment now. There is also a unique design approach to this PCM equipment, different from contemporary PCM line carrier equipments. Trade-offs have been made in providing individual sets of A/D converters for each of the 24 channels in a group. This allows the use of slower speed devices and unsophisticated circuits, which have proved costly technical limitations in previous (contemporary) PCM multiplexers.

Actual overall economies have resulted from this approach, despite the greater duplication of circuits in each channel panel. This break with traditional PCM multiplex techniques has provided technical, economic and application advantages that hitherto have prevented acceptance of a PCM-on-radio system in the commercial environment.

Users of this equipment are provided:

(a) lower cost systems—both in initial capital costs and in maintenance costs.

(b) Individual channel access.

(c) Maximum use of digital circuitry, with associated high reliability.

(d) Reduction of equipment shared in common, resulting in protection against mass channel failure.

(e) Frequency spectrum compression for economic use of bandwidth with lowered inter-channel crosstalk.

PCM-FM System Characteristics

NOISE ACCUMULATION

The most important characteristic of a PCM system is the ability of each repeater to regenerate the information bit stream. This provides a clean pulse free of noise or distortion (inevitably) introduced by the transmission link. With this cleanly regenerated pulse stream there is virtually no noise accumulation along a multihop system. Therefore the system S/N ratio is substantially independent of the route length.

SYSTEM LENGTH

Limitations to infinite length systems do lie in the possibility of timing jitter in the regenerator and in the accumulation of errors. The use of a seven megabit rate, required for 120 channels as the basic building block does not limit the MCS 6900 equipment as a medium haul equipment.

VOICE CHANNEL QUALITY

The noise performance of a PCM system operating above the RF threshold is a function almost entirely of the MODEM design. Standardization with the Bell System TI format has been adopted in the MCS 6900 system

A new concept of S/N and signal-to-distortion has been adopted to best define the characteristics of a "quantized" PCM channel. This factor is a variable related to the voice power level. Subjective listener tests have established acceptable, and minimum detectable, limits over the normal dynamic ranges found in telephone channels.

The companded PCM channel shows distortion rising as input level rises, due to the increasing size of the quantizing steps. Practical values of 25 to 35 dB are obtained over the dynamic speech range.

The discrete number of quantizing steps sets a limit on the dynamic range that can be handled by a PCM system. This is generally limited to plus 3 dBmO in a 128 level system. Voice input levels above this will therefore be demodulated at this point (plus 3 dBmO), which is described as the "Crash Point.'

THRESHOLD POWER REQUIREMENTS

Instantaneous predetection signal-to-interference ratios as low as 2 to 1 will provide accurate detection of a pulse signal. In the presence of random noise it is convenient to relate the average signal and noise power ratios to error probability. With a ternary based pulse signal, S/N ratios of only 17 dB will produce only one error in 10^6 bits. This threshold definition is used in the MCS 6900 system.

PCM systems exhibit sharp threshold characteristics; a small increase in signal level above the threshold produces a rapid decrease in the error probability.

FADING

Fading of the RF carrier will not contribute to noise rise in the voice channels for signals above the threshold. The sharp threshold effect in a PCM system therefore shows up as a sudden loss of the voice channels below threshold and a perfect signal at all other times.

BANDWIDTH

In PCM bandwidth is traded off for the ability to operate with low S/N ratios, or in other words, with low power levels. Techniques used for bandwidth compression in the MCS 6900 system are:

(a) Use of higher level transmission codes than straight binary.

(b) High frequency filtering of the PCM signal before application to the FM modulator.

(c) Selection of PCM codes with respect to speech levels. This reduces the quantity of One's (1's), and transmits Zeroes for the greater portion of the time.

(d) Recognition of the statistical nature of, and redundancy in, multichannel telephone traffic.

The energy spectrum of the PCM-FM signal operating with low deviation ratio is confined to a peaked response containing 97% of the energy in approximately a 3.5 MHz bandwidth during the 1% busy hour of a 120 channel system.

INTERFERENCE

PCM systems have inherently low susceptibility to interference. Because of the digital on-off nature of the pulse stream it requires only simple recognition of the presence or absence of a pulse. Instantaneous values of 2:1 signal-to-noise are adequate for accurate pulse recognition at the detector. Statistically this requires a signal-to-average noise ratio of less than 20 dB for high quality voice circuits.

It is thus theoretically possible to use eight times as many communications systems in an exclusive PCM environment.

PCM Technique

In PCM multiplexing we regularly sample the analog signal, assign a discrete quantized voltage level, code this level into a binary word, and multiplex the entire group of voice channels into a single, serialized pulse stream.

SAMPLING

A sampling rate of at least twice the highest voice frequency is required to reproduce the information of the original analog signal. A universal standard of 8 KHz has been adopted for telephone voice channels.

QUANTIZING

The voice signal is amplitude sampled and converted to a discrete level, one of 128 levels which covers the peak-to-peak range of the signal. In assigning a discrete level, the approximation involves a possible error of one-half the step increment.

This error is known as the "quantizing" error.

The quantized levels (steps) are arranged on a compressed scale (the companding law), such that the quantizing distortion is lower at the lower speech levels. Higher distortion is generated at the higher speech levels where it is less noticeable.

CODING

A seven element binary code is used to identify the level (of 128) at which the voice has been quantized. Seven bit binary words are encoded for each quantized voice sample and transmitted serially for each channel, in turn. An eighth digit is added to represent the signalling condition on the voice channel.

MULTIPLEXING

In multiplexing 24 voice channels together to produce a serial pulse stream, each channel is allocated a time slot to contain eight bits. To these 8 x 24 bits, 192, is added a framing bit, to provide phase synchronization, making a total of 193 bits.

These 193 bits must be transmitted in the 125 usec, 8 KHz sampling interval. This requires the generation of a basic bit at 1.544 MHz (193 x 8000). Each channel is thus serially allocated a 5.2 usec time slot for its 8-bit code word, to send a sample of each voice channel every 125 usec sampling period. This bit stream is thus set up to conform to the Bell System TI format.

A 120 channel system is derived from 5 basic 24 channel groups, generated in parallel. These groups are then sequentially combined into a serial pulse stream. To sample at the higher rate required for a 120 channel system the master clock (1.544) is multiplied by five to produce a basic bit rate of 7.72 MHz.

COMPATIBILITY

Compatibility with the Bell System TI format exists in these respects:

- Bit rate
- Number of channels
- Framing
- Compression (Companding)
- Binary code base

The MCS 6900 system differs from TI format in the way in which bits represent the voice signal. The code selected for the system is a binary code reflected above and below a zero reference. In the code, the lower speech levels are coded with a higher proportion of Zeroes than Ones, and only at the highest signal levels will the coded words consist of a majority of Ones.

BANDWIDTH

The RF bandwidth occupied by the transmitted signal is directly related to the proportion of Ones in the PCM modulation. The radiated bandwidth thus becomes a variable, increasing at higher voice levels, and with the number of active channels.

Recognition of the loading factor in multi-channel telephone, average speech power, and redundancy in speech thus provides a PCM system of acceptably low bandwidth.

A ternary (three level) code is used to further reduce the energy distribution in the RF spectrum. The binary code is converted by inverting Ones into a symmetrical code before application to the RF modulator. This symmetrical signal has a maximum energy content of only one half the bit rate frequency.

High frequency filtering is applied to the PCM signal before that signal is sent to the RF modulator, to restrict the extreme spread of RF. These frequencies are needed to satisfactorily identify a Zero or a One at the detector.

The MCS 6900 System

The system consists of radio equipment and PCM equipment properly integrated. The radio is available in all the normal microwave **bands:960 MHz** 2 GHz, 6 to 8 GHz, and 12 GHz. System features such as shelters, battery and thermoelectric power, wind generators, and antenna support structures are also available.

The electronics includes six separate building blocks:

- Masthead Unit
- Ground Radio
- Station Control
- Service Channel
- Channel Units
- Power Supplies

Modules are employed to provide system flexibility. The system multiplexes PCM with a basic group of 24 voice channels, and these groups may add up to as many as five, or 120 voice channels total. FM, of course, is the modulation method.

Either frequency diversity or space diversity reception may be used, with digital logic switching to select the better of the regenerated pulse outputs from the two receivers.

The operation of the repeater includes full regeneration of the pulse train, synchronization, and framing information. Therefore traffic access is available at all stations.

Spur link repeater configurations are arranged with unrestricted channel access through store-and-hold registers for synchronizing and combining the spur traffic.

System synchronization for the channel timing is provided from a single master terminal and each slave station locks onto this received pulse train.

A party line service channel is provided in one of the regular channel time slots.

Supervision monitoring and control is provided in groups of eight functions. The signalling digit of the service channel acts as the carrier of these functions.

The masthead unit contains all the RF frequency determining elements and the ground unit contains all the traffic element variables, but no RF parts, thus preserving the modular approach with its advantages for the system and logistics.

By eliminating feeder losses or passive reflector applications through locating the transmitter and the receiver at the antenna we obtain a significant improvement in RF path performance. Detailed attention to lightning protection and environmental protection has been paid to ensure high reliability of this remote unit.

MASTHEAD UNIT

The unit has an oscillator operating at the output RF frequency. It is directly frequency modulated by the filtered PCM pulse train. A crystal reference control loop is used for frequency stability.

The receive section includes a bandpass filter to reject the transmit frequency, a diode mixer, and a 70 MHz pre-IF amplifier. The local oscillator is a phased lock oscillator similar to the transmit oscillator.

(continued on page 18)

NEW YORK CITY TRANSIT COMMUNICATIONS

By Seymour Dornfeld, NYC Transit Authority

Only once have the people of the city of New York had an inkling of what critical darkness can mean to a major city: On Blackout Tuesday, November 9, 1965, when the massive northeast United States power failure hit the city at the peak of the evening rush hour. Millions of people who had just boarded the subway trains for their journey home were suddenly stranded in the city, many of them underground.

Fortunately a major part of the heaviest-traveled passenger railroad in the world – our IRT Lexington Avenue line in Manhattan, had been equipped with a two-way train and police radio system in June of that year.

These subway radios made it possible to efficiently evacuate the trapped passengers and to avoid panic on our crowded underground trains that dark night.

When it is completed in 1972 our train and police radio system will permit every train motorman to have immediate two-way radio contact with our Train Command and other control points. It will be, on completion, the largest civilian mobile radio system in the world.

To supplement our 6,400 system telephones and P.A. system (plus 900 magneto telephones), one-third of the Transit Authority's 750 total miles of track now have complete two-way train and police radio facilities in operation. The remaining two-thirds of the system, the BMT and IND divisions is currently being equipped.

Parallel police radio facilities are being installed to provide instant communication for the Transit Authority's own 3,200 man police force. Police supervisors will have instant two-way radio contact with patrolmen equipped with 1,200 hand-held sets, as shown in the photograph of a patrolman in a subway station using his radio.

Radio equipment control racks are being built at the G.E. plant in Lynchburg, Va. for our train and police Command Center. Each of the 5,850 operating cabs of the IND-BMT subway fleet is being equipped with locked plug-in receptacles, foot switches, antennas, etc. to accept plug-in train radios, 980 of which are being supplied by G.E. so that they can plug into either end of any subway train. Motorola has the contract for the rest of the system.

Operating Benefits

In addition to speeding the travel of millions of bus passengers daily, the radio network has proved a vital link in emergencies. When subway or elevated trains are blocked, or parts of the Long Island Railroad, bus service has been diverted to move thousands of stranded passengers. Other unusual conditions such as street blocks due to fire, floods or major accidents are alleviated by diverting buses at once. Bus operators monitor their passenger loads and report unusual or heavy loading so that other buses can be rerouted to handle these changes at once.

Radio also helps the overall operation management monitor conditions on all buses. Bus breakdowns and blockages from all causes average 100 per month. Radio helps maintenance forces reach stranded buses quickly.

We estimate that an overall increase, in efficiency for our surface bus operation of 15% has resulted from our use of two-way radio. To accomplish this same increase in efficiency without radio would have required an increase of 30% in supervisory personnel. This would amount to nearly 100 additional men.

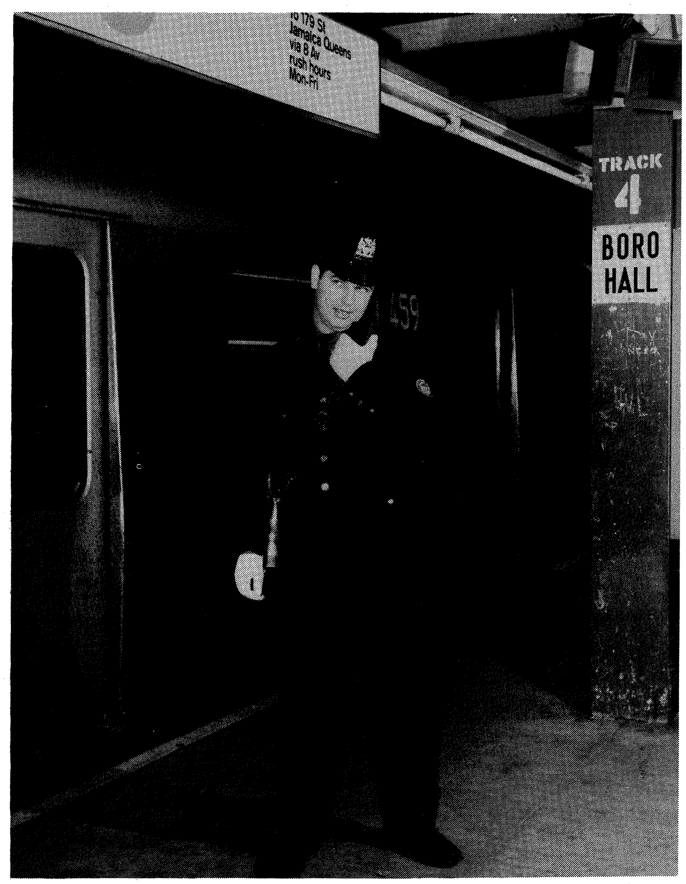
Benefits For The Public

Auxiliary plans, including detailed procedures for emergency evacuation of people and emergency use of buses as ambulances have been made. Liaison with the New York City Police Department has been established so that buses known as "Police Specials" can gather and move squads of police for control of crime or civil disturbance to needed areas in the shortest possible time.

Bus drivers, especially those assigned to "night hawk" (late and lonely) runs regard the two-way radio as their best friend. When they, their passengers, or even the non-riding public need help, it is summoned immediately.

The emergency code phrase "Red Tag" announced over the air by a bus driver will cause the Command Center operator to order "Clear the air", for reception of the crime-in-progress or other emergency message.

Radio has closed the time delay gap in communications which had previously been a major problem. Previously, when operating trouble occurred, the bus operator would stop his vehicle, leave it and find an (operating) telephone to call Central.



There are 5,000 buses in our fleet, each of which costs over $32,000. Without two-way radio at least 500 more buses would be required to give the service we provide. Thus radio permits a 10% reduction in the size of the fleet, plus additional savings in capitol and labor for garages, mechanics, and operators. The **capital** savings alone exceed $20 million.

Design Criteria

We had to provide solid radio coverage for more than 875 miles of bus routes which plunge through **skyscraper**-flanked canyons downtown, and then spread out to the outlying residential areas.

We established 19 base stations throughout the five boroughs of the City, each with a 30 watt transmitter, plus two 350 watt Control stations for supervisory and road service functions. In addition to the radio system we decided to install a high quality P.A. system on each bus.

Our entire radio network, in effect, 19 mobile radio systems, is controlled from one Operations Center over telephone lines. We have facilities for emergency local control of each of the 19 sections from its own base station. In the East New York Surface Operations Center we have 20 single position consoles for controlling the buses, and two separate dual position consoles for patrol and service vehicles. Emergency power supplies will keep the system on the air through any power failure.

This complex system, including drawings and specifications, was designed in only three months. Use of competitive bids saved more than $1.5 million for the taxpayers of New York City.

In August, 1966, RCA won the $4,184,000 contract. The system went on the air on May 14, 1968.

Preventing System Obsolescence

It was necessary to carefully search the radio spectrum for system frequencies. Ideal would have been 20 separate frequencies in the 150 MHz range – one for each area garage. We had to settle for spots in both the 30-45 and the 155-159 MHz bands. In addition, the severe limitations on the crowded spectrum in New York City made it necessary for us to use four of our frequencies over again at various garage areas.

Our specifications required that the radios be operable in any of the three bands; 30, 150, or 450 MHz so that simple changes in equipment may be made to prevent system obsolescence as frequencies become available. Use of modules throughout simplifies changing components to work in the low, high or UHF bands. Thus we will be able to take advantage of the split in frequencies which is expected in the 450 MHz band.

Bus Equipment

Each vehicle is equipped with a 30 watt solid state transmitter-receiver in a protective metal box. It mounts on a standard AAR (Association of American Railroads) base plate which plugs all power, radio and public address systems identically in all buses. This permits easy removal of units from the bus for service, test or repair. A new unit can quickly be plugged in to keep the bus in service and on the air.

A protective aluminum shroud is installed behind the driver's seat on each bus. This provides additional security for the bus radio.

A foot switch can be readily activated by the bus operator for public address announcements.

A hand set with a press-to-talk switch is used for normal transmissions and conversations with the Central Operation dispatcher.

A hang-up hand set is within easy reach of the driver, mounted on a separate hook-switch near the fare box.

The loudspeaker above and behind the driver permits him (and passengers near him) to hear calls from the Central Dispatcher. A toggle switch (spring activated return-to-normal) requires a tone from Central Operations to activate (unlock) the receiver. This tone is automatically transmitted from Central Control when the Dispatcher calls the bus.

The control head is mounted near the fare box, and permits the bus operator to adjust the volume and squelch controls to his liking. He cannot shut off the radio, which is energized as soon as the radio is plugged into the base plate.

Maintenance and Operator Training

The New York City Transit Authority employs its own efficient maintenance force for repair of all electronic equipment. The annual maintenance expense for the bus radio system plug-in components is approximately $250,000.

Skilled technicians are constantly finding improved methods, including computer tabulation and analysis of faults, to reduce the unit cost of maintenance.

To assure efficient use of air time and to develop bus operator skills in the use of the radio system, a special training rig was built. This permitted all bus operators to be trained in the use of the radio and public address system, even before they had been installed. Initial test operations of portions of the bus radio system began October 1967. These test operations were made part of the training program, so that when the full bus radio system went on the air in May 1968, all of the bus operators and maintenance personnel were thoroughly familiar with their functions.

Because we have trains equivalent to one starting up for every two minutes a day, any savings in time for the overall operation of just one minute a day is equal to saving one million dollars for our taxpayers!

We look forward to making a future report on the design criteria and operating benefits of our subway train radio and police radio systems whose completion in early 1972 will close the remaining communications gap in our subways.

A COMPATIBLE AM STEREOPHONIC BROADCASTING SYSTEM

By Leonard R. Kahn, Kahn Research Laboratories, Inc.

It is appropriate first to outline stereophonic system requirements which must be met to satisfy broadcasters, regulatory agencies, and the general public. For an AM stereophonic broadcasting system these requirements are as follows:

(1) The system must be compatible with existing receivers. That is, all AM receivers now in the hands of the general public must monophonically receive the new signal without distortion or other degradation. The program received by existing sets should be well balanced, with no loss of the sound from any instruments which would alter the musical arrangement or tend to make the music flat and lifeless.

(2) The new stereophonic signal should require no increase in spectrum space. This is extremely important because AM now has many cases of severe co-channel and adjacent channel interference. Certainly any system requiring additional bandwidth is unacceptable.

(3) Receivers for stereophonic reception should be simple and relatively inexpensive. Once standards have been set a very large market for such receivers will be established. The cost and complexity of these home receivers must be minimized to insure widespread acceptance of stereophonic AM broadcasting.

The following requirement, while not as important as the above three, is important commercially.

(4) The signal must permit the listener to receive the new signal using two conventional monophonic AM broadcast receivers.

This requirement (4), would be important to the manufacturers of receivers as well as to broadcasters. It has been dramatically demonstrated in the past that the introduction of new broadcasting techniques present "chicken and egg" problems. Few broadcasters will be willing to transmit AM stereophonic programs unless an appreciable percentage of their listeners can immediately receive those programs.

Conversely the public, except for a limited number of technically inclined people or faddists, will not purchase AM stereo equipment until one or more broadcasters regularly transmit stereo programs. This problem could greatly delay widespread acceptance of AM stereophonic transmission.

However, if the public could use existing home receivers for AM stereo reception, broadcasters would have reason for broadcasting AM stereophonic programs. The "chicken and egg" problem would vanish. Thereafter special AM single dial stereo sets would soon find a large market.

This paper outlines a system of broadcasting which meets the above requirements.

System Block Diagram

A block diagram of the system is shown. The left hand stereo information is added to the right in a summing network. This circuit can be a simple resistive network. The output of this circuit is fed to a wideband phase difference network. This network, with its companion phase shift network (part of the phase modulation circuitry) produces a constant 90^0 phase difference relationship.

Thus the audio output of one phase circuit is in quadrature with the phase of the other audio circuit output. Such circuits are frequently used in SSB communications devices, and may be analyzed using Hilbert transforms.

Because the outputs of these phase networks are (ideally) constant in amplitude, relative to frequency, the phase network does not alter the characteristic of the audio wave except to shift its phase.

This audio wave is then fed to an audio amplifier which in turn feeds the modulation input of a conventional AM transmitter. This assures compatibility for monophonic AM receivers.

The left and right hand stereo information is also fed to a difference circuit which produces an L-minus-R component. A phase inverter in the right stereo channel does this.

The output of the phase inverter is fed to one input of a linear summing circuit, and the left channel feeds the second input directly. The resulting audio difference signal is then fed to its associated phase shift network, which in turn feeds a phase modulation system.

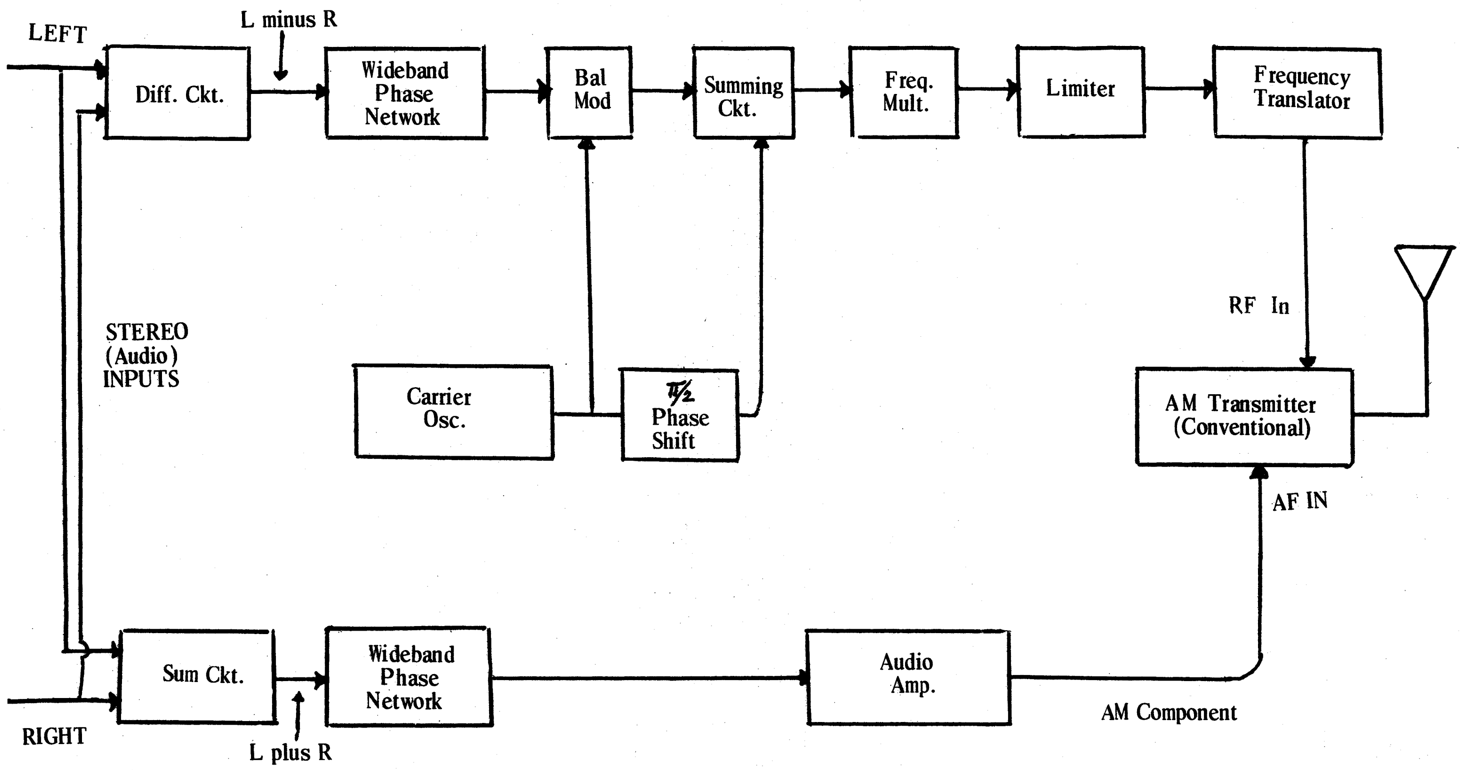
One excellent phase modulation system is the Armstrong phase modulator. In this circuit a balanced modulator produces a double-sideband suppressed carrier signal. This carrier, displaced by a 90^0 network, is added to the output of the balanced modulator to produce a wave in which the carrier and sideband are in quadrature. Such a Quadrature Modulated Wave is similar to a phase modulated wave except for a small envelope component and slight distortion at high modulation levels. Thus it is important to restrict the phase modulation to relatively small amounts. A frequency multiplier may then follow this circuit to produce the desired phase modulation.

The output of the frequency multiplier feeds a limiter which removes the (small) amplitude modulation components. The limiter feeds a frequency translator in which the carrier frequency of the phase modulated wave is translated to the broadcast station carrier frequency. This phase modulated carrier then excites the low level stages of a conventional AM transmitter.

A simplified phasor analysis, demonstrating the separation of the right and left stereo information into two sidebands is shown in Figure 2. Thus a compatible AM stereophonic signal is produced.

Receivers

Since the stereophonic transmission wave displays a single-sideband characteristic, two conventional AM receivers may be used for stereo reception. The receivers should be spaced about six feet apart, with one tuned slightly higher than the carrier frequency and the other tuned slightly lower than the carrier. This simple method of reception has been demonstrated to a number of broadcasters in laboratory demonstrations using two inexpensive table model sets successfully.



Compatible AM Stereophonic Transmitter System, Simplified Block Diagram

A single receiver with two IF strips may be used to receive this type of signal. One IF strip is tuned slightly high, and the other slightly low. Other special requirements for such a receiver will be described in a future paper.

Fulfills Requirements

Laboratory measurements have shown this system satisfies the requirements outlined at the beginning of this paper.

(1) *Compatibility With Existing Receivers.* The distortion characteristics of the system were carefully examined. The data showed that even with a low distortion transmitter (1.2% distortion at 100% modulation) the adapter increased the maximum distortion by only 0.5%. Tests on inexpensive receivers showed increase in distortion caused by the AM stereo signal to be less than 1.0%. Both these measurements and listening tests showed complete compatibility with existing AM receivers of the new system of transmission.

(2) *Spectrum Space Required; No Increase.* Due to the narrowband nature of the new stereo signal, there will be no increase in interference with other stations. A number of other stereo systems have been proposed in which the energy does not go beyond 10 KHz from the carrier frequency. However, an additional requirement must be met if interference in the broadcast band is not to be worsened. This requirement is that the distribution of energy should fall off at audio frequencies above 3 or 4 KHz from the carrier. This fall-off in high frequency energy presently reduces interference in conventional AM transmission of voice and music. Because the energy of this AM stereophonic system falls off in the same fashion as in normal double-sideband transmission no increase in interference will be experienced.

(3) *Receiver Simplicity.* When special receivers are offered to the public it is expected that there will be a large demand for them. These receivers may be made simply and inexpensively by providing an additional, offset-tuned IF amplifier, diode detector, and audio systems. This is the most inexpensive receiving system yet proposed for stereophonic reception. Of course, special sideband-type receivers can be offered for those interested in higher priced sets.

(4) *Stereo Reception With Two Conventional AM Receivers.* Successful demonstrations of two-set stereo reception have been made to a number of leading broadcasting engineers and receiver manufacturers at the Freeport laboratories.

In May 1970, radio station XTRA Tijuana, Mexico, transmitted stereophonic music on 690 KHz which was received in San Diego and Los Angeles. This 50 KW station uses an all music format, and initial listener response in the United States to AM stereophonic broadcasting was very gratifying.

All Type of Transmitters Adaptable

This system may be used by existing AM stations whether high level, low level or Doherty transmitters. An adapter has been made for use with standard broadcast transmitters.

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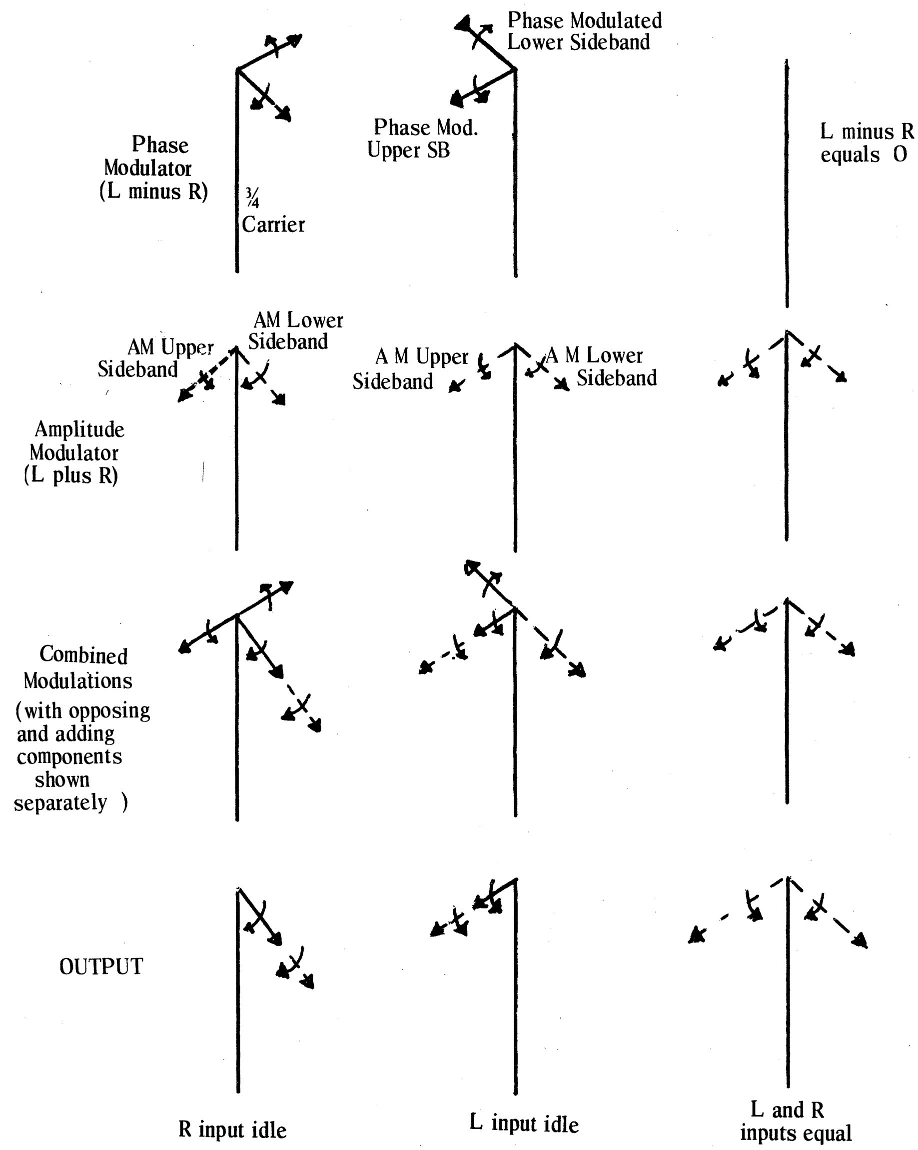
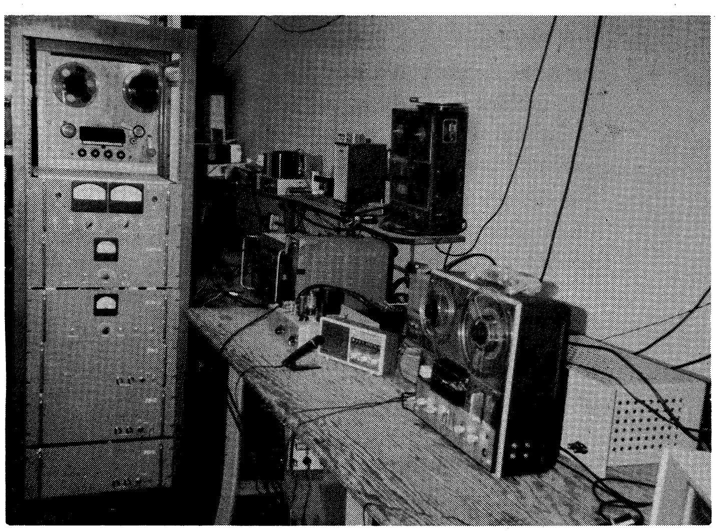


Compatible AM Stereophonic System Simplified Phasor Drawing, Showing First Order Terms Only. (AM sidebands shown as dotted arrows.)



Demonstration Tape for AM Stereo Broadcast At Radio Club Meeting Being Made At Kahn Labs.

The following measurements were made to determine compatibility of the new AM stereophonic system with existent AM (mono) receivers.

TRANSMITTER ALONE WITHOUT ADAPTER

Hz	% Modulation	THD (%)
100	100	0.9
400	100	1.1
1000	100	1.2
5000	100	0.8
100	50	0.7
400	50	0.6
1000	50	0.6
5000	50	0.6

Response at 100% modulation:
± 1.5 dB, 28 to 20,000 Hz

Noise: -53 dB at 1 KHz, 100% modulation

STR-59-1-A ADAPTER

Hz	Audio Output (dBm)	THD (%)
100	10	0.50
400	10	0.52
1000	10	0.54
5000	10	0.34
100	4	0.54
400	4	0.52
1000	4	0.52
5000	4	0.34

Frequency Response at +10 dBm:
±1.5 dB, 50 to 13,800 Hz

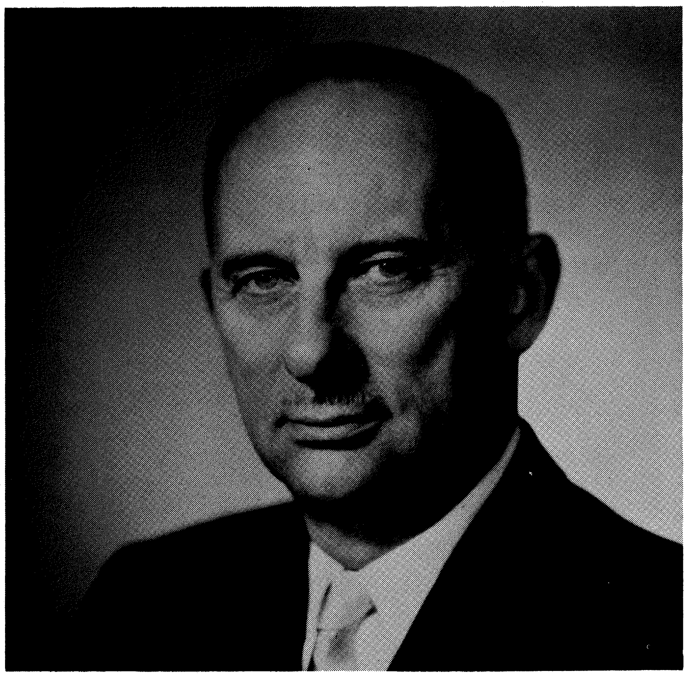
Noise: -56 dB

TRANSMITTER WITH ADAPTER

Hz	Total % Mod. Chan. A	Total % Mod. Chan. B	THD
100	100	100	1.5
400	100	100	1.7
1000	100	100	1.1
5000	100	100	0.5
100	50	0	1.1
400	50	0	0.8
1000	50	0	0.6
5000	50	0	0.7

Frequency Response: ±1.5 dB,
87 to 9,400 Hz

Noise: -52 dB



ARMSTRONG 1970 AWARD TO FRANK A. GUNTHER

On December 10 the 1970 Armstrong Award was presented to Frank A. Gunther by Harry W. Houck chairman of the Awards Committee. The citation is reprinted below:

BILL FINCH HONORED

Captain W.G.H. Finch (USN-ret.), a Radio Club director, was the recipient of the Wisdom Award for 1969. Previous recipients include President Dwight D. Eisenhower, Sir Winston Churchill and Ambassador Adlai E. Stevenson.

There isn't enough space here to discuss Bill's illustrious career in radio and electronics which dates back to 1916. He holds 160-odd patents on telepicture facsimile communications, automatic high speed radio printing systems, radio relay and recorders, high fidelity transmission systems (both black and white and color), and radio and wire facsimile systems.

Bill, who now commutes between his farm in Newton, Connecticut and his home in Richmond, Virginia, is active in medical research.

The ARMSTRONG MEDAL for 1970 is awarded to Frank A. Gunther by the Radio Club of America in recognition of his outstanding contributions to the art of radio communication.

While Chief Engineer of Radio Engineering Laboratories, he designed and installed at Bayonne, New Jersey, the first two way police radio system, and followed this with additional installations in many other cities throughout the United States. In connection with such accomplishments he made the first application to the Federal Communications Commission for two way mobile radio operation in October 1932.

As an early pioneer in the application of frequency modulation for mobile radio his contributions resulted in the use of practical FM two way systems by the Chicago Police Department and the U.S. Army Signal Corps.

From 1934 onward he worked with Edwin Howard Armstrong in the design and installation of nearly all of the first FM Broadcasting Stations located in the 44 to 50 MHz region, and later in the 88 to 108 MHz band.

In his continuing search for further improvements of long distance communication he has made important contributions in the design of high power transmitters for tropospheric scatter and satellite communication systems.

Dr. J.B. JOHNSON

J.B. Johnson, for whom "Johnson Noise" was named, died in November of last year in Short Hills, New Jersey at the age of 83.

In 1967 the Radio Club awarded Dr. Johnson the Armstrong Medal.

A long time researcher in the application of electronics to solving problems of telephony, radio and television, his work on thermal noise, and his identification of Johnson noise took place in the 1920's.

He was a pioneer in the study of cathode ray tubes and published over 20 papers, mostly on electron physics. He held 30 patents on communications devices.

RALPH R. BATCHER
1897 - 1968

Dr. A.N. Goldsmith wrote the Club, on hearing of the death of Ralph Batcher, past President of the Radio Club. His words are repeated here:

IN MEMORY OF RALPH BATCHER

Very few men have so winning a personality, so thoughtful an outlook, and so effective a life plan that they instantly make an indelible imprint upon all who meet them.

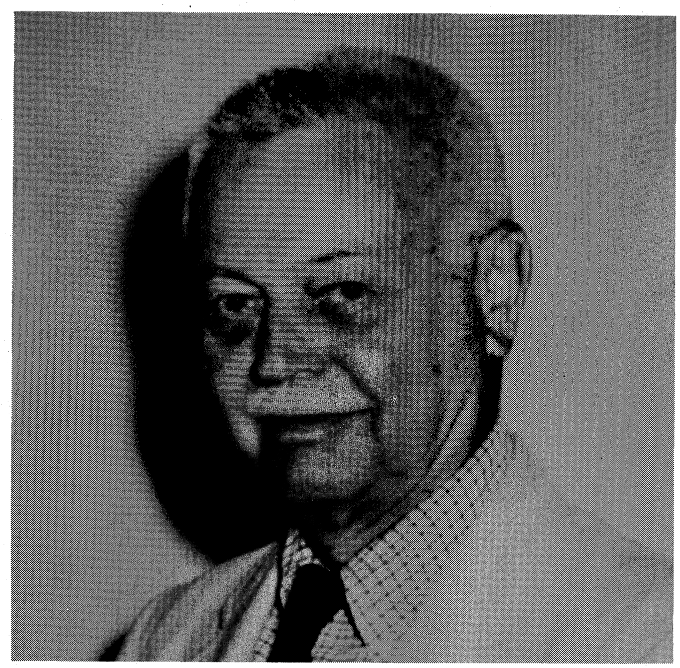
Such a man was Ralph Batcher. The details of his distinguished technical and administrative career are perhaps less important than the effective sphere of human influence which surrounded him.

The passing of such a man was a personal loss to all who knew him. His departure removed a great influence for good in the realm of technology and a fine personality greatly prized by all who knew him. His memory will be ever bright.

Alfred N. Goldsmith

W.F. MUNN
1891 - 1969

W. Faitoute Munn, a charter member of the Club, died on January 24, 1969, at St. Barnabas Hospital in Livingston, New Jersey. He attended Columbia University, and was interested in radio as early as 1905. Early in his career he worked for Thomas A. Edison for a couple of years. He worked mostly in chemistry and optics, holding patents in the latter field. He is survived by a son, William.



PAUL WARE
1893 - 1970

A Fellow of the Club, and 1962 recipient of the Armstrong Medal of the Club, Paul Ware died on November 24, 1970 in Coral Gables, Florida, at the age of 78.

He was one of the first three men in the U.S. to hold a radio operator's license. In 1909 he was a wireless operator at sea for the Marconi Wireless Telegraph Company. In 1917 he graduated from Stevens Institute of Technology, and a year later was commissioned in the Signal Corps.

Among his inventions probably the best known was the Inductuner which Mallory marketed. The similar Inputuner was used in many DuMont TV sets. He was General Manager of the DuMont Laboratories from 1943 until he retired in 1952. A few years later he organized Ware Marine Products to produce his Automatic Marine Pilot.

In addition to a daughter, Constance, he is survived by his wife, Josephine, who resides at 3948 Little Ave., Coconut Grove, Florida.

The Radio Club of America, Inc.

The Radio Club of America was founded in 1909 by the industry's pioneers, and is the oldest active radio club in the world. Its roster of members is a world-wide Who's Who that includes many who founded and built the radio industry with their ingenious creativity and down-to-earth practical idealism.

An objective of the Club is to promote cooperation among individuals interested in scientific study of all kinds including the communication arts. The Club activities include scientific education encouraged through the presentation and discussion of technical papers given by outstanding invited guest speakers at the regular meetings. Club membership includes students, university professors, inventors and other active professionals, and well-informed gentlemen-amateur scientists.

The Radio Club of America continues to distinguish itself from other purely technical societies through great freedom and range of expression in the interchange of ideas, and by the continuing effort to provide the meeting ground for such persons with scholarly interests in common. The Club meetings and publications are marked by their quality, not quantity; at no time in the Club's long history has as many as a dozen technical papers been given and published in a single year. The development of life-long friendships among club members has been a most frequent and intended happy by-product of its activities.

The Club holds an annual banquet in New York City, usually in late November or early December, as well as several technical-social meetings throughout the year. A lively informal discussion with the guest usually occurs before the meeting at dinner; it often increases in tempo and enthusiasm during the question and answer discussion that follows the delivery of the paper.

Joint meetings with other technical societies occur when the important opportunity arises.

Achievements that are outstanding are recognized by awards. Typical is the Armstrong Medal, established in 1935 to honor Prof. E. H. Armstrong who contributed regeneration, the superheterodyne and frequency modulation to today's art.

The Proceedings of the Radio Club of America, the oldest radio periodical in existence, is a contemporary record of the best in the current art. Members receive a subscription to the Proceedings in addition to the other benefits of membership in return for payment of very modest dues.

The Club is currently expanding its activities and membership; emphasis is placed on the very best of the art, supported by fraternization and good fellowship. Applications for membership are invited from individuals with like aims and goals.

Application forms may be obtained by writing to **The Radio Club of America, Inc.,** Room 319 250 Park Avenue, New York, N.Y. 10017.

A loop test facility is provided with each set. The mixer and oscillator section of the loop test are housed in the mast-head unit. A portion of the transmit output is mixed with the loop test oscillator to provide a signal to the receiver which overrides the normal receive signal. The radio ground unit contains a random PCM generator for test modulation of the transmitter, and a lamp indicates excessive error conditions. The radio may be placed on loop test locally, or remotely from a control station, with the condition of the radio reported back to the control station.

Monitoring of local oscillator failure, transmitter power drop, or loss of receive signal are all carried on continuously. They are converted to alarm indications and sent to local or remote panels.

GROUND RADIO UNIT

This unit contains the PCM filter, a binary-to-ternary converter, the demodulator, and the PCM regenerator.

The demodulator receives the 70 MHz IF from the mast-head unit and supplies the signal to the PCM regenerator. The noisy and/or distorted pulse train is reformed in the regenerator and a clean PCM pulse train and derived clock signal are fed to the station control unit.

Out-of-band noise monitoring is used for a low signal alarm condition. In the event of loss of receive signal the PCM regenerator takes over as master clock and the system is timed from that station.

STATION CONTROL

The station control unit performs timing for the system, and group combining and decombining for the station. It contains the master synchronizer, in the case of a master terminal, channel synchronizer and group combiner-decombiner. This is the common equipment for the multiplex system.

The master synchronizer provides the 1.544 Kilo-bits/second clock signal, channel sync pulses, and a frame pulse. This frame pulse is applied only to group One; the other groups have the frame slot empty. The framing signal has a 10101 pattern that is easily recognized by the slave station. An alarm is provided to indicate loss of synchronization.

The group combiner transforms the bit and frame synchronized groups into a serial pulse train at N times the speed of the basic groups. 48 or 120 channel capacities are provided with multiples of two or five groups.

On the receiver side, the high multi-group PCM signal is separated in the group decombiner into its two or five bit, and frame synchronous groups, along with the basic 1.544 MHz clock signal.

The channel synchronizer produces individual channel sync pulses for the channel units and derives the framing pulse for use at the slave terminals.

CHANNEL UNITS

The channel units sample the analog signal(s) at 8 KHz to produce a 7-bit code (plus signalling bit) per sample.

The line interface board detects the presence of signalling and supervisory functions and processes the information onto the PCM signalling digit. On the receive side the reverse process takes place.

A variety of signalling options are available, including two-wire E&M, four-wire E&M, and one-way loop dial.

SERVICE CHANNEL

A service channel provides party line communication between all stations in the system. It also provides an alarm in case of system failures, and carries supervisory signals for up to 56 functions per control station.

MAINTAINABILITY

Repair-by-module-replacement is used in this system. Functional groupings with common built-in go/no-go fault indicators are used. The indicators permit use by non-skilled repair personnel. Built-in test equipment is provided to check the radio-multiplex loop. This test equipment may also be operated remotely.

Support is minimal:

(a) Simple maintenance manuals, written to module or circuit card level.

(b) No complex test equipment.

(c) Lower skill level maintenance personnel.

(d) Smaller inventory of support spares.

Reliability of the MCS system is very high. It is built with extensive use of MSI (medium scale integrated) circuits, no moving parts, and all solid state devices.

Mean-time-between-failure targets have been set at five years for the radio terminal, and also at five years for each channel-end of the multiplex. These targets are based on experience in the design of military equipment and are believed realistic.

The economics of throw-away modules becomes very attractive with reliabilities of this magnitude. Spare parts are restricted to less than 25 different types of electronic items.

12 GHZ APPLICATION

Hop lengths of 15 miles are considered typical for 120 channel PCM operation at 12 GHz. Outages of less than one hour per year throughout the greater part of the United States can be expected with available fade margins.

To approximate circuit costs, consider a seven hop system covering more than 100 miles. To provide a 120 channel system complete with line interface an equipment cost of less than $14 per channel mile can be computed. This cost includes basic radio and multiplex equipment, 50 foot towers, repeater shelters, standby battery power, service channel and normal fault alarm.

APPLICATIONS

The MCS 6900 has been designed to appeal to any industry which needs an inexpensive, highly flexible medium capacity communication system.

Most large industries are using computers and high speed

(cont. on page 21)

1970 Club Dinner With Bill Lear

On December 10 the Club held its annual Banquet and Awards night. We were entertained as well as instructed by an old-time radioman, now turned smog-killer, Bill Lear, and his lovely wife and daughter. Bill, better known for his Learjet, showed us his new steam engine, as part of his talk, "Damn the Smog -- Full Steam Ahead!"

Full details of the dinner program and a picture of those attending will appear in the next issue of The Proceedings.

PROCEEDINGS

This is the first issue of The Proceedings to appear for longer than we like to admit. Thus we have had to abbreviate many things and to put off others until next issue.

If you have any news of members which we should have, please be sure to send it to the Club Office.

The next Proceedings issue will be printed as soon as we get back the questionnaires which are being sent to the members to help us bring the Club Directory up to date. Don't hold on to your questionnaire! Fill out and send it back!

Link Honored By IEEE Group

Fred M. Link was among the first recipients of the recently established Honorary Life Member Award of the Vehicular Technology Group of the IEEE.

1969 DeForest Medal to Gunther

Frank Gunther was awarded the 1969 DeForest Audion Medal by the VWOA (Veteran Wireless Operators Association.

The award bears the incription "...to Frank Gunther recognizing his many valuable contributions to radio"

1969 ARMSTRONG MEDAL
TO
FRANK SHEPARD

The always smiling man with the king-size watch Francis Henry Shepard, Jr., was the recipient of the Club's Armstrong Award at the 60th anniversary celebration banquet held at the Overseas Press Club on December 12, 1969. The citation read as follows:

The award of the ARMSTRONG MEDAL *of the Radio Club of America to Francis Henry Shepard Jr. is in recognition of his outstanding contributions in the electronics field.*

Working with Dr. Elmer Sperry, he pioneered in the development of an infra-red scanner and high gain chopper-stabilized DC amplifier and achieved the first infra-red detection of ships beyond the horizon.

His accomplishments in the radio telemetering of weather data from balloons were basic, and his development of a non-linear amplifier complementary to the human ear became important in hearing aids and in small speaker radios.

Among his many inventions is that of the basic ballistic hammer principle for high speed printers, which is widely used.

He has presented numerous papers at technical society meetings, and has been granted more than 65 U.S.Patents.

Although he has been continuously engaged in electronic development, he nevertheless has always found time and been most willing to lend assistance to others confronted with technical problems.

facsimile in their everyday operations. Their use of these facilities is expanding at a prodigious rate, therefore the carrier systems must expand just as rapidly. The MCS 6900, being specifically designed and optimized as a digital system, fits this trend.

Industries which can use this system to advantage are:

(1) Oil, where telemetry is of utmost importance in the control of pumping stations.

(2) Gas, Water and Hydroelectric operations also have similar requirements.

(3) Banks, stockbrokers, credit, and credit card companies and other business complexes requiring time sharing use of computers.

(4) Airport control, where control radars are located remotely from the central tower.

(5) Education; the transfer of data and programmed courses between colleges and universities.

(6) Hospitals; there is increasing demand for rapid retrieval of patient data from one hospital to another.

These are only a few of the potential demands for data transmission systems of this sort.

THE FUTURE

In the interest of continued traffic growth and efficient use of the frequency spectrum it is recommended that serious consideration be given to progressive replacement of existing FDM systems by PCM systems.

This more effective combined use (PCM) of bandwidth, power, and interference susceptability will provide a solution to our ever increasing spectrum saturation problem.

Future developments offer many exciting prospects for using a basic digital system such as:

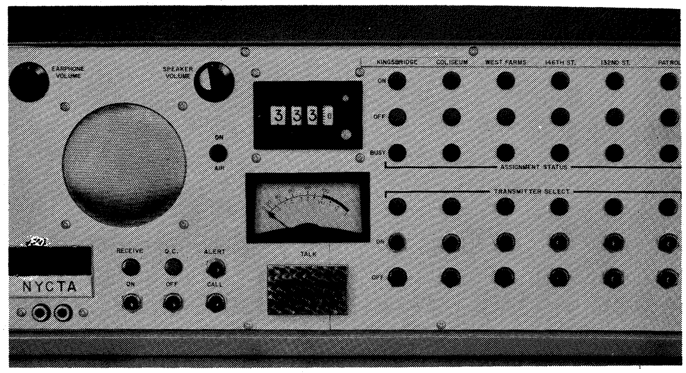
- Digitized TV signals
- Facsimile applications to business and home communications
- Digital telephone switching networks
- Picturephone
- Security and surveillance communications
- Data communications into the domestic environment

These applications will certainly all develop from the techniques and modular building block equipment described here. CMC is confident this decade will see PCM microwave systems overtaking and eventually supplanting FDM transmission.

CMC has initiated patent applications for several aspects of this equipment.

OLD AND NEW

RCA's 46-year-old monogram (left), has been replaced with the new mark shown on the right



Base Station Console Shows Flexibility

System Planning Checklist

(1) Design your system to meet *your* present and future operating needs.

(2) Try to secure frequency assignments early. We recommend the 150 MHz band. This gives good range and tends to minimize skip interference problems. If channels are not available in this range, go to the 450 MHz band. You will however, need more remote receivers in this band. Use the low (40 MHz) band as a last resort.

(3) Make careful RF surveys of coverage and problem areas. Check bus turn-around points.

(4) Use competitive bidding and call on engineering and management of other municipalities for help in planning and purchasing.

(5) Low profile antennas are a must. Overhead obstructions will damage other antenna types.

(6) Initial maintenance of the equipment in the system should be up to the manufacturer of the equipment. We recommend that the first year all parts and labor and the second year all parts remain the manufacturer's responsibility. The size of your operation will determine whether you go to contract maintenance or develop your own maintenance operation.

(7) Tape record everything that goes out on the air. This has proved to be a valuable legal record as well as training (and when necessary, disciplinary) device, which helps to improve overall operating efficiency.

(8) Try to minimize on-the-air time of the bus operators. Radio discipline and training are important. Design the radio equipment so as to automatically keep the transmitter-receiver in the receive mode and limit the transmit mode. A press-to-talk switch on a handset is ideal. Discourage operator-to-operator conversations; see that all radio traffic is routed through central control where it belongs.

(9) Write first echelon maintenance instructions in simple non-technical language.

(10) Specify time-out timers to kill locked-on transmitters.

NEW FELLOWS AND LIFE MEMBERS

The Radio Club welcomed the following as new Fellows and Life Members at the December 10, 1970 Annual Awards Dinner, held at the Statler-Hilton Hotel:

FELLOWS

Frank P. Barnes. Senior Vice-President, ITT
William H. Foster. V-P & Technical Director, ITT, Europe.
William Grenfell. Rules and Legal Branch, FCC
Andrew Inglis, Vice-President, RCA
C.M. Jansky, Jr. Consultant
William J. Kanz. Dep. Chief Inspector, NYC Police
Rhett McMillan, Jr. Executive Secretary, APCO
Harold F. Schwede. Schlumberger Co.
Julian Sienkiewicz. Chief Editor, Davis Publications
Waldo A. Shipman (Deceased) Columbia Gas Corp.
Eugene Rietzke. Founder, Capitol Radio Eng. Inst.

LIFE MEMBERS

	Member Since
George W. Bailey	1948
A.K. Bohman	1926
Robert V. Crawford	1939
Robert Finlay	1939
Frank A. Gunther	1940
Samuel N. Harmatuk	1957
Daniel E. Harnett	1925
Keith Henney	1927
Harry W. Houck	1920
Arthur H. Lynch	1921
Walter Lyons	1952
A.A. McKenzie	1949
Wm. F. Offenhauser, Jr.	1936
Jack R. Poppele	1941
F. X. Rettenmeyer	1928
John F. Rider	1932
Francis H. Shepard, Jr.	1936
Myron T. Smith	1934
David Talley	1949

A.W. PARKES, JR.
1899 - 1969

A Fellow and former Director of the Club, A.W. Parkes, Jr. died on May 24. He was president of Ballantine Laboratories, and previously Vice-President of Aircraft Radio Corp. Mr. Parkes is survived by two daughters, three grandchildren, and his wife, Virginia, who resides at 200 Overlook Ave. in Boonton, New Jersey.

HARADEN PRATT
1891 - 1969

A Fellow of the Radio Club, and a member since 1930, Haraden Pratt died in 1969. He was Telecommunications Adviser to Presidents Truman and Eisenhower.

During World War I he was in charge of constructing and maintaining high power Naval radio stations. During 1927-28 he developed radio aids for navigation while at the Bureau of Standards. From 1928 to 1951 he was Chief Engineer, later Vice President of Mackay Radio. Haraden Pratt was active in many electronic organizations, and had been Secretary and President of the IEEE.

NEW DIRECTORS ELECTED

The ballots cast by the membership were counted at the Club office on November 9, 1970. Re-elected were six Directors from among the 11 nominees Dr. George W. Bailey, John L. Callahan, Leonard R. Kahn, William P.Lear, Walter Lyons, and William H. Offenhauser, Jr. Frank P. Barnes was elected a new Director.

On February 3,1971 the Board of Directors accepted with regret the resignation of John L. Callahan and appointed him an ex-officio member. The Board appointed Joseph R. Sims a Director to serve out Callahan's term of office.

All of the above were elected for two-year terms which expire December 31,1972. The terms of the other incumbent Directors, Ernest V. Amy, John H. Bose, W.G.H. Finch, Frank A. Gunther, Harry W. Houck, Jerry B. Minter, and Jack R. Poppele, expire on December 31,1971.

YOU, SIR, ARE INVITED TO JOIN A WINNER!

NABER *has produced major breakthrough results which benefit you as a radio user:*

1. Has been recognized as the official representative of the Business Radio Services licensees in Washington, D. C.

2. Congressional demands for a major reallocation of frequencies by the FCC to make industrial radios more useful to you and your fellow businessmen. (NABER made the first appearance ever before Congress in May, 1966, to plead the case for land mobile radio users.) This campaign continues on a regular schedule.

3. A vigorous protest before the FCC against the proposed engineer's certification on antenna location. The enactment of this rule could have cost you from $50.00 to $1,000.00 additional. (This proposal was officially dropped in August, 1967.)

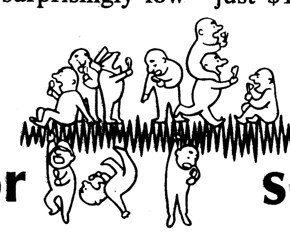
4. Petitioned for special frequencies to be used exclusively for paging. In allocating a total of 12 frequencies for paging, the FCC stated that paging should not occupy general business frequencies.

5. Research that lead to the removal of restrictions from a portion of UHF business channels.

NABER is constantly working to make sure that your interests are protected in the use of your radio system. We maintain a Washington, D. C. headquarters office and are here to serve you at all times.

As a member of NABER you receive ACTION Magazine which keeps you up-to-date on all new products, new techniques and current FCC regulations. Special mailings are made, free, to members of unusual speeches and manuals. NABER is where the action is.

Why don't you sign up today? The cost of membership is surprisingly low—just $15.00 per year.

Where else can you receive so much service for  so little cost?

NATIONAL ASSOCIATION OF BUSINESS & EDUCATION RADIO, INC.

NABER, Inc.

Please enter my membership as follows: *Date*__________

1. *Name*__________ *Company*__________

   *Address*__________

   Street *City* *State* *Zip Code*

2. Nature of applicant's business__________
3. Type of Membership *Check One:*

   ☐ Active—Voting—(Business Radio Licensees) ☐ Associate—Non-voting—(Others)

4. Do you hold more than one business radio license?__________ If "Yes", how many?__________

   Yes or No

*Signature of Applicant*__________

5. Annual Dues:

   Active $15.00 for one business radio license

   10.00 for each additional business radio license

   Associate 15.00

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