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July 16-17, 1990
Marlborough Inn
Calgary Alberta

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Wireless 90

The Second National Seminar & Workshop on Wireless Personal Communications

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Wireless 90

CHAIRMAN'S ADDRESS

Welcome to the Wireless 90 conference and workshop. This is the second year for this event and the response has been tremendous. World renowned speakers and participants are gathered here again to exchange ideas and knowledge in an area which most of us believe is the forthcoming communications revolution.

> *"You realize Mr. Bell, that this idea of yours can't possibly work since it requires the running of wires into every home and office!!"*
> *- Western Union*

Many people who have been promoting wireless communication have run into a similar set of statements in this domain.

> *"It's deja-vu all over again"*
> *- Yogi Berra*

However, as George Calhoun points out in his book on Cellular Radio - millions of people communicate in wireless form today - cellular mobile, paging, fleet operations, CB radio, etc. The marketing trial for wireless has been completed and it was a great success.

So, the artificial barriers are coming down, the market is evolving and now we tackle the real barriers. Spectral congestion, standards, the obstreperous 'channel', system design and control and the network 'intelligence' required to make personal communications a reality.

It's an exciting time to be in this field of endeavor and this is a great opportunity for all of us to build our knowledge in technology and personal contacts.

I hope you also find the time in your busy schedule to enjoy the beauty of Alberta and the friendliness and charm of Calgary. It is interesting to note that in addition to Calgary's enormous community spirit, part of which is manifested in the Stampede, it can also lay claim to having the largest per capita population of scientists and engineers of any city in Canada. It also boasts a sizable wireless community, in manufacturing, service provisioning and R&D. It is the home of NovAtel, AGT Mobile Communications and the University of Calgary.

It's a work hard, play hard city.

Probably a good theme for this conference.

George Squires

George Squires
Chairman, Wireless 90
and Director of Wireless Research
Alberta Telecommunications Research Centre

Deploying Personal Communication Networks

Raymond Steele

ABSTRACT

Personal communication networks (PCNs) are radically different from conventional cellular mobile radio networks, yet operators and equipment suppliers for the emerging PCNs often behave as if there are only marginal differences. The danger is that PCNs will be delayed, equipment will be more expensive that it should be, and the number of users and services curtailed. The theme of the talk is how to avoid this situation and proceed directly to microcellular PCNs in cities. Overlaying cellular structures for PCNs in rural areas will also be addressed.

BIOGRAPHY

Raymond Steele (SM'80) received the B.Sc. degree in electrical engineering from Durham University, Durham, England, in 1959, and the Ph.D. and D.Sc. degrees from Loughborough University of Technology, Loughborough, in 1975 and 1983, respectively.

Prior to attaining the B.Sc. degree, he was an indentured Apprentice Radio Engineer. After research and development posts with E.K. Cole, Cossor Radar and Electronics, and Marconi, he joined the Lecturing Staff at the Royal Naval College, London. He moved to Loughborough University in 1968, where he lectured and directed a research group in digital encoding of speech and picture signals. During the summers of 1975, 1977, and 1978 he was a consultant to the Acoustics Research Department at Bell Laboratories, and in 1979 he joined the company's Communications Methods Research Department, Crawford Hill Laboratory, Holmdel, NJ. He returned to England in 1983 to become Professor of Communications in the Department of Electronics and Computer Science at the University of Southhampton, a post he retains. From 1983 to 1985 he was a nonexecutive Director of Plessey Research and Technology, and in 1986 he formed Multiple Access Communications, a company concerned with digital mobile radio systems.

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DEPLOYING PERSONAL COMMUNICATION NETWORKS

by

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Abstract

The current deployment of PCNs based on the pan-European GSM standard is briefly addressed, and their suitability questioned. Low complexity PCNs are described, as well as high complexity versions which will be able to support enhanced services. Two methods of PCN roll out are considered.

1 Introduction

There is world-wide research and development activity in digital mobile communications. In the USA the 30 kHz bands in AMPs will be able to support three TDMA channels at the burst rate of 48 kb/s. Europe is dynamic and ambitious in cellular radio. There is the pan-European TDMA GSM system at 270 kb/s, the digital European cordless telephone (DECT) which operates in a ping-pong mode at 1152 kb/s, the European radio messaging system (ERMES) at 6 kb/s, the cordless telephone system CT2 and its phone-point or telepoint service that transmits at 72 kb/s, and so forth [2]. All of these systems are personal communication networks (PCNs), although people often like to consider that PCN is something more, namely, networks that provide mass communications where most mobile stations are hand-held.

We are concerned here with PCNs. As Britain is currently attempting to deploy them we will commence by describing the background there in PCN, and then we will move on to consider alternative types of PCNs that will satisfy criteria to be described.

2 PCN Situation in Britain

In 1989 the Government announced that new two-way personal communications networks (PCNs) would be established. Mercury Communications Ltd would be given a licence in order for it to compete with its powerful rival British Telecom who have a major stake in the mobile phone company, Cellnet. The two cellular operators Cellnet and Racal Vodafone were barred from applying for a PCN licence. The minister (informed by the DTI) said that the PCN licence holders should operate to a common technical standard to encourage competition. He also decided that the standard should be either the pan-European GSM or DECT. The PCN cells were to be "small", and the operators would be required to link their base stations using radio (38 GHz). Links to the PSTN/ISDN would be provided by British Telecom or Mercury Communications. A number of consortia applied for PCN licences, and three were granted.

Not all applicants initially advocated GSM or DECT. Some used notions to be found in the deliberations of IWP 8/13, others were conscious that PCN should utilise some of the special radio properties to be found in the small cells, i.e., microcells. However, once the choice of GSM was a valid option it was inevitable that it would be adopted, particularly as the specification for DECT was far from completion. Firstly, the mobile radio community had spent years writing the GSM specification, and it was the system they had come to understand. Further, many of them were busy implementing the GSM system for service throughout Europe in the early 1990's. For the equipment manufacturers the advent of PCN was an opportunity for them to realise profits on equipment that had been designed and developed for the pan-European GSM. The new licence holders saw it as a means of competing with the two existing cellular operators, as both would have the GSM system, but the incumbents would not have nearly as much bandwidth as the PCN operators and therefore they would not be able to support as many users. However, Cellnet and Vodafone do have the advantage of an existing client base.

So PCN will be a modified version of the pan-European GSM system. Modifications to the GSM specification will be carried out under the auspices of the European Telecommunications Standards Institute (ETSI) and are expected to be finalised by the end of 1990. The ETSI standard for PCN will be called DCS 1800, where DCS stands for digital cellular system [1]. The 1800 is associated with the frequency of operation in MHz. The actual band will be from 1710 to 1880 MHz, providing 75 MHz duplex bands with a 20 MHz spacing. The DCS 1800 will use GSM network interfaces and architecture, and the main modifications are expected to facilitate low power hand-held portables operating over relatively small cells. The adoption of the GSM standard, albeit in a modified form, will mean that the DCS 1800 will use second generation technologies. It will therefore sit between second and third generation systems. The cell sizes will be smaller than in the pan-European GSM, but they will still be relatively large, probably up to 6 km radii in rural areas and of the order of 750 m in urban centres. Microcells whose overall dimensions will normally exceed 400 m will be used, and may only provide handover from microcell to its overlaying macrocell. Because the DCS 1800 will be obliged to operate in relatively large cells many of the complex power hungry circuits associated with the pan-European GSM network will probably be retained. There are those who consider that Britain is not so much getting novel PCN systems with inexpensive and wide ranging services, but essentially a second GSM pan-European system, albeit with an increase in the level of competition.

No doubt this approach of deploying a modified pan-European GSM network is sensible to many people, but it may be a lost opportunity. Let us consider why the pan-European GSM is so complex [2]. The system is designed to operate in cells that span approximately 1 to 30 km. By selecting TDMA, transmission and reception of signals occur at different times, and only one base station transceiver is required for 8 users. Unfortunately a MS transmits in a burst mode at 270 kb/s, and for the large size of cells used in the pan-European system, a host of techniques must be employed to contain the BER within acceptable limits. A complex regularly pulse excited linear predictive coder with long term prediction (RPE-LTP) is used, and this causes many of the encoded speech bits to be sensitive to transmission errors. Forward error correction (FEC) coding must be used, followed by bit interleaving. Frequency hopping (FH) of interleaved FEC coded blocks of data is mandatory from MS to BS and is essential to assist stationary MSs in a deep fade. The receiver needs adaptive Viterbi equalisation whose metrics can be used to assist the FEC decoding and the muting of the output speech if the BER is very high. The control structure is exceedingly complex, probably 100 times greater than that of CT2. The overall delay is required to be less than 90 ms.

The pan-European GSM system has to be complex if it is to operate in large cells. This complexity will be reflected in the cost of equipment, and the cost of making a connection. Because GSM BSs will be relatively expensive their deployment in very small cells (<200 m) will be prohibitive, at least in the short term. The modified GSM, namely DCS 1800, will deploy similar BSs. No doubt they will be less expensive than the pan-European version, and as many will be deployed, the cost per BS will be less due to the economies of scale. Nevertheless they will not be inexpensive, and this will make the service provider think carefully before deploying BSs in microcellular clusters.

A mobile communicator that can communicate from anywhere and at any speed may be desirable, but can only be achieved in a bulky, heavy, expensive form and supported by an incredibly expensive infrastructure. A realistic alternative is to design a range of hand-held communicators, that varies from the simple calculator or wrist watch size of negligible cost for offices and inner cities, to the expensive bulky ones for use in mountainous areas. Many parts of the world are densely populated enabling small cells to be used. For example, in Britain PCN systems should eventually operate with no cell in excess of 2 km, even in rural areas. If the operators deem this to be uneconomical, let the other systems, like the pan-European GSM system or TACS, provide the service. We note that most people are supplied with electricity in their homes and this provision is a far greater achievement than we ask of our communication service providers.

3 Low Complexity PCNs

Given limited spectrum allocation, the most effective way to achieve high user densities is by deploying microcells [3]–[5]. For ground coverage, e.g., streets and parks, two-dimensional microcells will be used, whereas three-dimensional microcells will be deployed in office environments. The number of microcells per cluster may be much higher than with current large cells. The microcells may be as small as an office in a building to a 1 km segment of a highway. The antennas radiate from locations relatively close to the MSs, for example, from ceilings in buildings or from lamp posts in the streets. The power levels are low, less than 100 mW, down to the microwatt levels. Battery power is significantly conserved, and biological risks greatly curtailed. The small size of the cells results in Rician rather than Rayleigh fading and this dramatically reduces the operating channel S/N and renders the system significantly more robust to cochannel interference. The excess delay spread is decreased, to the point where equalisation is unnecessary, unless the bit rate is significantly above one Mb/s. Frequency hopping is still advisable but its gains may be far less as it becomes more difficult to hop farther than the coherence bandwidth when the excess delay spreads become very small. However, space diversity becomes feasible for transmissions in the 2 GHz band.

If a primary objective of the PCN is to convey toll quality speech simple codecs such as ADPCM (in DECT and CT2) can be used, because microcells can support a much higher bit rate than conventional cells. Operating at 32 kb/s they are much simpler than RPE-LTP codecs in GSM, have negligible delay, and can cope with much higher BERs for a given speech quality. Although 32 kb/s ADM does not have quite as good speech quality as ADPCM, when used in mobile communications it often has a much better speech quality over the coverage area. This is because it is not subjected to errors caused by loss of word synchronisation. Indeed, with ADPCM an entire packet may be corrupted due to synchronisation failure. This is not a problem with ADM, which has a further advantage of requiring only a sixth of the battery power consumption.

On the assumption that the transmitted bit rate is sufficiently low (say, <500 kb/s) such that the channel does not have more than one significant fading path, then not only are equalisers avoided but so is channel coding. However, channel coding may be desirable to assist in handovers. Given small enough cells the PCN is essentially a cordless telephone (CT) type of system. It therefore follows that if DECT was rolled out, i.e., deployed outside the office environment we would obtain a PCN.

Let us not focus on any specified system, such as DECT. Instead we will consider the simplest arrangement, namely, TDMA, a low cost, low power consuming speech codec, like ADM, a BCH codec (if required) and a non-coherent FSK (NC-FSK) modem. In general, the control of mobile radio cellular systems is complex, absorbing significant power and space. The GSM control is particularly elaborate, and even the common air interface (CAI) [6] of CT2 is non-trivial. However, is the control process innately complex, or do we exacerbate the problem by having separate control channels? With bit rate at a lower premium in microcells, can we sacrifice bit rate for lower control complexity by using the TDMA packets to convey both data and control information, and decrease the decisions made by the hand-held and increase those made by the network? By decreasing the complexity of the control circuitry, along with the deployment of ADM and NC-FSK the hand-held portable could be small and light, with a power consumption that is minuscule compared to conventional hand-helds. Its cost would be so low it could be sold in department stores. The BSs would be significantly less complex than those used in GSM or in AMPS and TACS. They would be simple TDMA transceivers operating at low power with inexpensive microstrip combiners. The BSs would be linked together and to the mobile switching centres (MSCs) by optical LANs in buildings, and by optical or radio LANs in the streets. The BSs would be of shoe box to coffee cup size.

Simple TDMA systems operating at burst bit rates <500 kb/s, with the bit rate allocated to the channels as required will be able to provide a range of services. Cyclic redundancy codes (CRC) with ARQ will facilitate reliable computer data transmissions, although the simple organisation of the system will not effectively support video services.

Our optimism for this simple system is based on our experimental transmissions of 300 kb/s at 900 MHz and at 1.15 Mb/s at 1.8 GHz. There is also published evidence [7,8] to substantiate the conclusion that a simple system is realisable.

4 High Complexity PCNs

A wide range of services requires high bit rates on demand. As argued above, for a limited spectrum this means microcellular structures. Although the delay spreads become small in microcells, they are significant if the bit rate is large. Once again all the problems associated with large cells occur as the ratio of the transmitted bit rate to the excess path delay becomes sufficiently large that even microcells become dispersive. One way to combat the problem is to reduce the symbol rate, and thereby the dispersion, by using multi-level modulation. For example, if the data rate is 8 Mb/s it can be transmitted by quaternary FSK at a symbol rate of 4 MBd. 16-level QAM supports the same 8 Mb/s at 2 MBd. For microcells of moderate size (e.g., 300 m) we have effectively removed intersymbol interference (ISI) at 2 MBd, and our communicator is transmitting multi-level signals over a single Rician fading path. The problem is still far from simple. The receiver must be able to overcome the large gyrations and amplitude variations of the I and Q components of the received signal as it goes in and out of fades. Of course, by making the microcells sufficiently small the fades become negligible and a high quality Gaussian channel results. Let us discuss the use of QAM in PCN in more detail.

4.1 QAM Systems for PCN

Our initial investigation of QAM systems [9,10] was based on the notion of a magic receiver (found in fairy-land) that had perfect AGC and quadrature tracking. PCM coded speech was transmitted via M-level QAM, M=16, 64 and 256. Essentially, we obtained upper-bound figures for the basic QAM modem for transmissions over Gaussian and Rayleigh fading channels, and determined the gains in segmental SNR when space diversity was used. We found [9] that for Gaussian channels the channel SNRs (E_b/N_o) required to yield near toll quality speech were about 13, 18, 23 dB for M=16, 64 and 256, respectively. For Rayleigh fading channels E_b/N_o increased to 35 dB when M=16. By using weighting [10], this figure of 35 dB decreased to 27 dB, and the application of second-order diversity resulted in a E_b/N_o of 12 dB (corresponds to an E_p/N_o of 25 dB).

Encouraged by the values of channel SNR to achieve near toll quality speech with M=16, we did a more ambitious simulation [11]. An AGC system was introduced (rather than the perfect one), the speech codec was changed to a subband codec (SBC), and a Reed Solomon (RS) codec was used to optimise the speech bits onto the 16-level QAM constellation. The result was that the 16 kb/s SBC bit stream was transmitted at 5.3 KBd and yielded toll quality speech at 30 mph, provided the channel SNR exceeded 22 dB and second-order diversity was used. We then exchanged the toll quality SBC for a communications quality 4.8 kb/s CELP, used the simpler BCH codes, and discarded the diversity [12]. With the channel SNR $\geq$26 dB, the transmission rate was decreased to 2.1 kBd. Subsequently we used 64-level QAM and the transmission rate was decreased to 1.2 kBd [13].

While this line of enquiry was proceeding we built a 16-level QAM modem and became sensitised to the difficult problem of counteracting the changes in phase of the received signal during deep fading conditions [14]. We found that on emergence from a fade the receiver may lock onto a different quadrant than the required one as phase shifts may exceed 50° between successive symbols. The standard square QAM constellation suffers from possible false lock positions at 26 and 52 degrees. This problem was overcome [15] by using star QAM, namely a twin phase shift keying (PSK) constellation, together with differential coding of the data. The arrangement has eight points on the inner star QAM ring, and eight on the outer ring. There are two points at $\pi n/4$, $n = 0, 1, \ldots, 7$. Each point is represented by four bits, $b_1b_2b_3b_4$. If b_1 is a logical 1 it causes a change in the amplitude ring, and there is no change of ring if b_1 is a 0. Bits $b_2b_3b_4$ are Gray coded on to the phase such that 000 means no change in the phase of the current symbol, 001 means 45° change in phase compared to the previous symbol, and so on. Decoding is merely a comparison between the currently and previously received symbols. When oversampling was used to compensate for changes in the received fading envelope over the last symbol period, and second-order diversity employed, the channel SNR for transmissions over a Rayleigh fading channel was 22 dB, i.e., within 2 dB for a Gaussian channel, for a BER of 10^{-3}. The propagation frequency was 1.9 GHz, MS speed 30 mph.

Space diversity is not easy to apply for propagation frequencies below 2.5 GHz, and we opted for channel coding instead. For 16-level QAM using a Reed Solomon (RS) (60, 44, 12) code with 6 bits per symbol, the channel SNR was 22 and 25 dB for BERs of 10^{-3} and 10^{-6}, respectively [16]. The transmitted rate was 64 kb/s, and the through-put was 48 kb/s, i.e., the information was transmitted at 16 kBd. In the simulations the interleaving depth was fixed at 30 ms. On the proviso that the Rayleigh fading channel is applicable, increasing the bit rate to 8 Mb/s results in 2 MBd with 16-level QAM. For RS (60, 44, 12) there are 125 more blocks in the 30 ms interleaving window, and hence the randomisation of the data prior to channel decoding is more effective. The consequence is that the results quoted above for 64 kb/s are somewhat pessimistic for 8 Mb/s—assuming the microcell is sufficiently small for Rayleigh fading to apply. If the speed of the MS is decreased to 3 mph, the results remain valid only if the interleaving depth is increased by a factor of 10. This is unacceptable, and demonstrates that for pedestrian MSs it is essential to use either frequency hopping or space diversity to counteract the effect of slow deep fades.

4.2 Adaptable Transceivers

For a given bit rate the ease of communications depends on the channel. As the channel worsens from Gaussian to Rician to Rayleigh to dispersive, the complexity of the link to provide an acceptable performance increases from a simple modem to a receiver having adaptive equalisation and much more. For a given complexity of equipment, the bit rate can be decreased as the MS roams farther from the BS while maintaining the same BER. By controlling the bit rate in this way we avoid the on-set of dispersion. When the MS is able to operate at relatively high channel SNRs, multi-level modulation can be used, whereas when the channel SNR is low the modulator can discard its higher levels. QAM can therefore be used as an embedded modulator adapting the number of its levels to suit the channel conditions.

In a similar way speech and image codecs need to have embedded properties [17,18] such that the essential information is sent on the primary codec, while supplementary information that significantly enhances the recovered audio or image quality is conveyed by the outer codecs. Similar arguments apply for channel coding, ranging from no channel coding when conditions are good to increasingly powerful FEC as conditions deteriorate. When transmission delays are not important, e.g., during computer file transfers, error detection with ARQ is used. We observe that for an optimum link the source codec, channel codec, interleaver and modem need to have embedded characteristics.

Complex PCNs may communicate using different bands. Each band will handle traffic at different rates and at different BERs. We anticipate higher propagation frequencies being used in office environments than in rural areas. Television conferencing will operate at much higher bit rates and require higher integrity channels than slow-scan television transmissions used for surveillance. In making a call connection the user will be required to select the service required, and the network will assign the band to be used together with the type of transceiver configuration.

5 PCN Roll Out

An approach to deploying a PCN is to start with the minimal number of BSs to service the initial number of users over a wide geographical area. This approach means the cells are relatively large, and that, at the outset, the MSs must be able to transmit at relatively high power levels which in turn implies relatively bulky mobile equipment. Another implication is that although fewer BSs are used at start-up, the larger cells within which they operate may render the cost per channel higher than for BSs operating in very small cells. The worst situation is when the PCN is required to give national or wide area coverage at start-up. If this requirement is imposed on the service provider the design of the PCN has a high probability of being very sub-optimum at start-up.

However, given that the network commences in this way, it can subsequently use the initial wide area start-up cells as overlaying macrocells, with embedded tessellated microcells [5]. The macrocells are now employed to assist MSs that cannot be adequately serviced by the lower powered microcellular BS. As the MSs are required to power-up only occasionally to communicate with macrocell BSs, they can be much smaller, as in general they consume far less power.

As a consequence the network starts up with relatively high power requirements resulting in relatively complex BSs and MSs. The second generation PCNs have lower power requirements, simpler BSs, and smaller and inexpensive MSs. Later overlay phases include BSs and MSs that can operate at higher bit rates, provide more sophisticated services, and communicate in different frequency bands as described in Section 4.

An alternative scenario is to allow the service provider to expand his business due to market forces, rather than at the dictates of government planners. The provider should deploy clusters of microcells with oversailing macrocells at the outset in areas of dense teletraffic demand, e.g., the commercial districts in major cities. The BSs would be small, simple and inexpensive. They would be linked by an optical or radio LAN to the MSC which would house the first layer of significant network intelligence. The MSs would be little more than a modem with speech and channel coding as discussed in Section 3. Thus people in the offices and streets of the commercial districts would have a service that operates up to 1 Mb/s, say, enabling them to carry a light-weight hand-held portable that would need to be recharged relatively rarely. As the cost of the equipment and the calls would be low, the user demand for the service would rapidly grow and with it the ability to expand the PCN to adjacent neighbourhoods. We may anticipate that this approach will be taken by the CT operators.

By starting up a system in this way the coverage is confined to areas of intense teletraffic demand, and users who require mobile communications outside of these areas will need a conventional cellular phone, unless they are prepared to delay calls until they arrive in another PCN zone. However, this inconvenience may be very acceptable if the majority of their calls are made in the low cost per call PCN areas.

The PCN roll out continues with inexpensive mobile communications being applied to successively lower teletraffic demand areas, with microcells never exceeding 2 km. In a country like the UK this will give virtually national coverage. While this roll out is in progress, the second generation of PCNs will commence in the inner cities, and will slowly spread to other areas in the manner employed in the first phase. By this means waves of new and more complex PCNs for those who want them are overlaid to provide enhanced services in a commercially viable way.

6 Discussion

There is no universally accepted definition of a PCN. For some it is a conventional cellular network, but with smaller cells, and designed mainly for pedestrians. Others view it as a cordless telephone network with enhanced facilities that has broken out from its building confines into the rest of the environment. Those who have the long view regard PCNs as Star-Trek communications without the "Beam me up" facility. There is general agreement that PCNs will need to cope with unprecedented volumes of traffic whose density is far less geographically and time predictable than that in the current networks. The PCNs will be required to accommodate ISDN, and furthermore to cope with the new developments in ISDN and the increasing range of services it will provide.

Given the many systems already under development and to be deployed, e.g., GSM, DECT, CT2, DCS 1800, there is the strong temptation to make these systems compatible via common air interfaces, BS design and deployment, and so forth, and then to design advanced PCN systems that are compatible with these networks. An alternative approach is to identify the direction in which we expect the PCNs to develop, and design an embryonic network which can be systematically developed. The notion is to nest a sequence of PCNs of increasing complexity. We initially deploy a low cost PCN using microcellular systems that are market driven, as described by the second scenario in Section 5. As the network coverage extends, and enhanced services operating at higher bit rates are provided, the initial network is comfortably embedded and acts as the core for the enhanced PCN. The problems of incompatability are avoided as the common air interface also has embedded properties. It is only recently that we have produced the engineer who straddles the subject of fixed networks and radio communications, and it is perhaps here that most of the research should be focussed if we are to develop PCNs that do not continually require the discarding of older versions.

References

[1] A R Potter, "Personal communication networks", Fourth Nordic Seminar on Digital Mobile Radio Communications DMR IV, Oslo, Norway, June 1990.

[2] Special Issue on Mobile Communications, British Telecom Technology Journal, Vol 8, No 1, Jan 1990.

[3] R Steele, "Towards a high capacity digital cellular mobile radio system", IEE Proc, Pt F, No 5, Aug 1985, pp 405–415.

[4] R Steele and V K Prabhu, "Mobile radio cell structures for high user density and large data rates", IEE Proc, Pt F, No 5, Aug 1985, pp 396–404.

[5] R Steele, "The cellular environment of lightweight hand-held portables", IEEE Communications Magazine, July 1989, pp 20–29.

[6] J A Phillips and B A Bidwell, "UK Telepoint common air interface", 5-th Int Conf on Mobile Radio and Personal Communications, Warwick, UK, IEE Pub No 315, pp 157–161.

[7] S T S Chia, R Steele, E Green and A Baran, "Propagation and bit error ratio measurements for a microcellular system", J IERE, Vol 57, No 6 (Suppl), Nov/Dec 1987, pp S255–S266.

[8] E Green, "Radio link design for microcellular systems", British Telecom Technology Journal, Vol 8, No 1, Jan 1990, pp 85–96.

[9] R Steele, C-E Sundberg and W C Wong, "Transmission of log-PCM via QAM over Gaussian and Rayleigh fading channels", IEE Proc, Pt F, Vol 134, No 6, Oct 1987, pp 539–556.

[10] C-E Sundberg, W C Wong and R Steele, "Logarithmic PCM weighted QAM transmissions over Gaussian and Rayleigh fading channels", Proc IEE, Pt F, Vol 134, No 6, Oct 1987, pp 557–570.

[11] P M Fortune, L Hanzo and R Steele, "Transmission of SPC speech via 16-level QAM", Globecom'88, Hollywood, Florida, Vol II, Nov/Dec 1988, pp 26.6.1–26.6.5.

[12] L Hanzo, R Salami and R Steele, "A 2.1 kBd speech transmission system for Rayleigh fading channels," IEE Colloquium on Speech Coding, London, Digest No 1989/112, Oct 1989, pp 10/1–10/5.

[13] L Hanzo, R Salami, R Steele and P M Fortune, "Transmission of digitally encoded speech at 1.2 kBd for PCN", in preparation.

[14] E Issman and W T Webb, "Carrier recovery for 16-level QAM in mobile radio", IEE Colloquium on Multilevel Modulation Techniques and Point-to-Point and Mobile Radio, London, Digest No 1990/045, 19 March 1990, pp 9/1–9/8.

[15] W T Webb and R Steele, "16-level circular QAM transmissions over a Rayleigh fading channel", IEE Colloquium on Multilevel Modulation Techniques and Point-to-Point and Mobile Radio, London, Digest No 1990/045, 19 March 1990, pp 6/1–6/7.

[16] W T Webb, L Hanzo and R Steele, "Bandwidth efficient QAM schemes for Rayleigh fading channels", IEE 5-th Int Conf on Radio Receivers and Associated Systems, Cambridge, England, July 1990.

[17] D J Goodman, "Embedded DPCM for variable bit rate transmission", IEEE Trans Commun, Vol COM-28, July 1980, pp 1040–1046.

[18] I J Wassell, D J Goodman and R Steele, "Embedded delta modulation", IEEE Trans on ASSP, Vol 36, No 8, Aug 1988, pp 1236–1243.

Wireless - The Next Frontier

Peter MacLaren

BIOGRAPHY

Peter MacLaren is Assistant Vice President, Business Development in the Subscriber Equipment Group of Northern Telecom Canada. His current responsibilities, which he moved into in May of this year, are in the area of wireless access systems for the Canadian market.

He earned his B.Sc. in Electrical Engineering with 1st Class Honours from Strathclyde University in Scotland, then worked for 3 years with what is now British Telecom Research Labs before joining Bell Northern Research in Ottawa in 1975. He held a number of positions of increasing responsibility in Transmission and Data Services planning before joining Northern Transmission Group in Edmonton in 1983. For the next four years he was responsible for product line strategy for Transmission, latterly as Assistant Vice President Business Development. Following that assignment he spent 18 months back in BNR as AVP Technology Management. He then moved back to Northern Telecom and until May this year was responsible for overall strategy voice terminal evolution.

Peter lives in Ottawa with his wife Susan and three year old son Logan. He plays squash, and is active in Amateur Radio and local community affairs.

Wireless - the next frontier . . .

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Wireless - the next frontier . . .

- Canadian Perspectives
- Service Evolution
- Technology Enablers
  - Digital Radio & Standards
  - Intelligent Network
- Network Evolution

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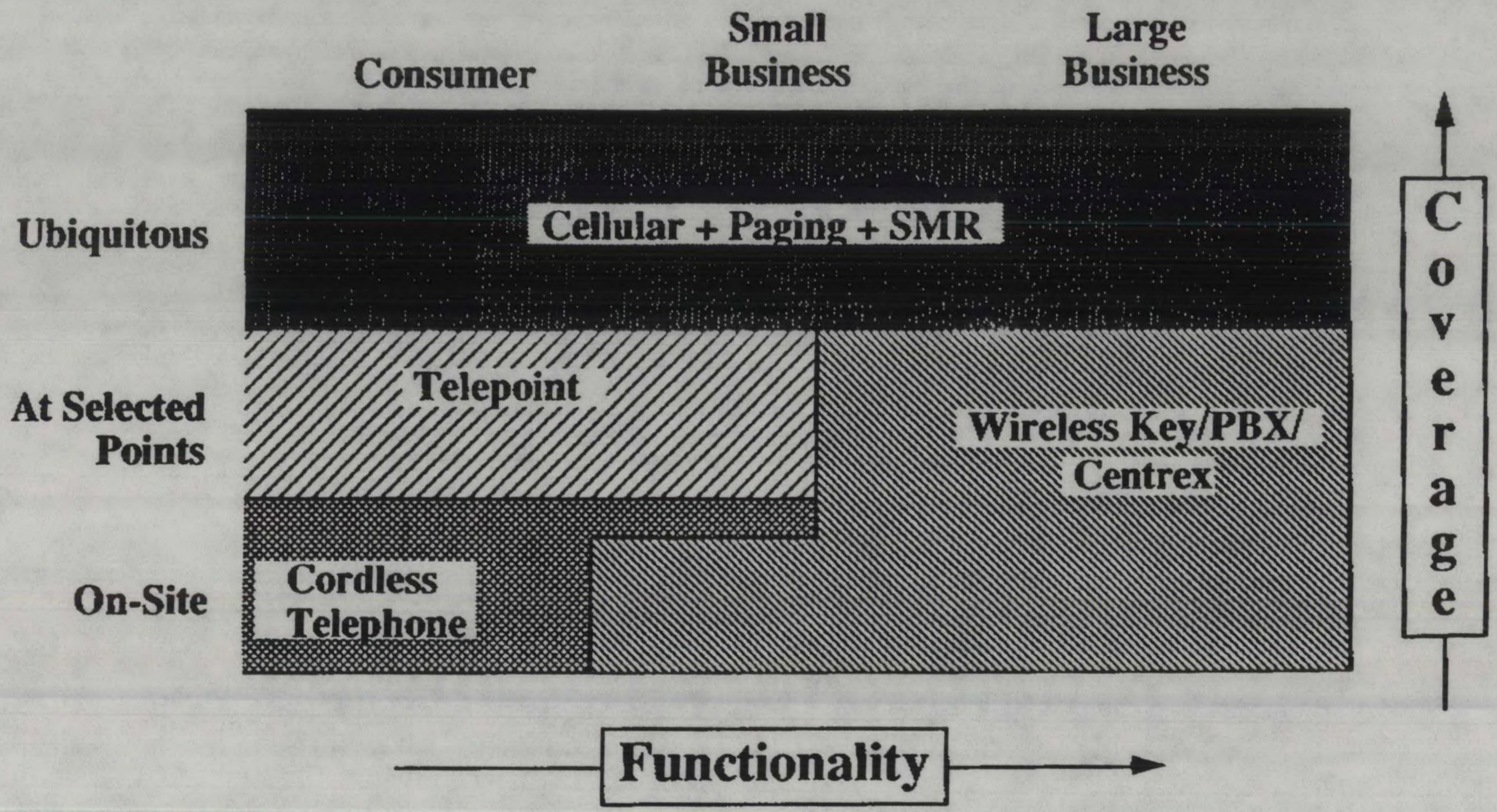
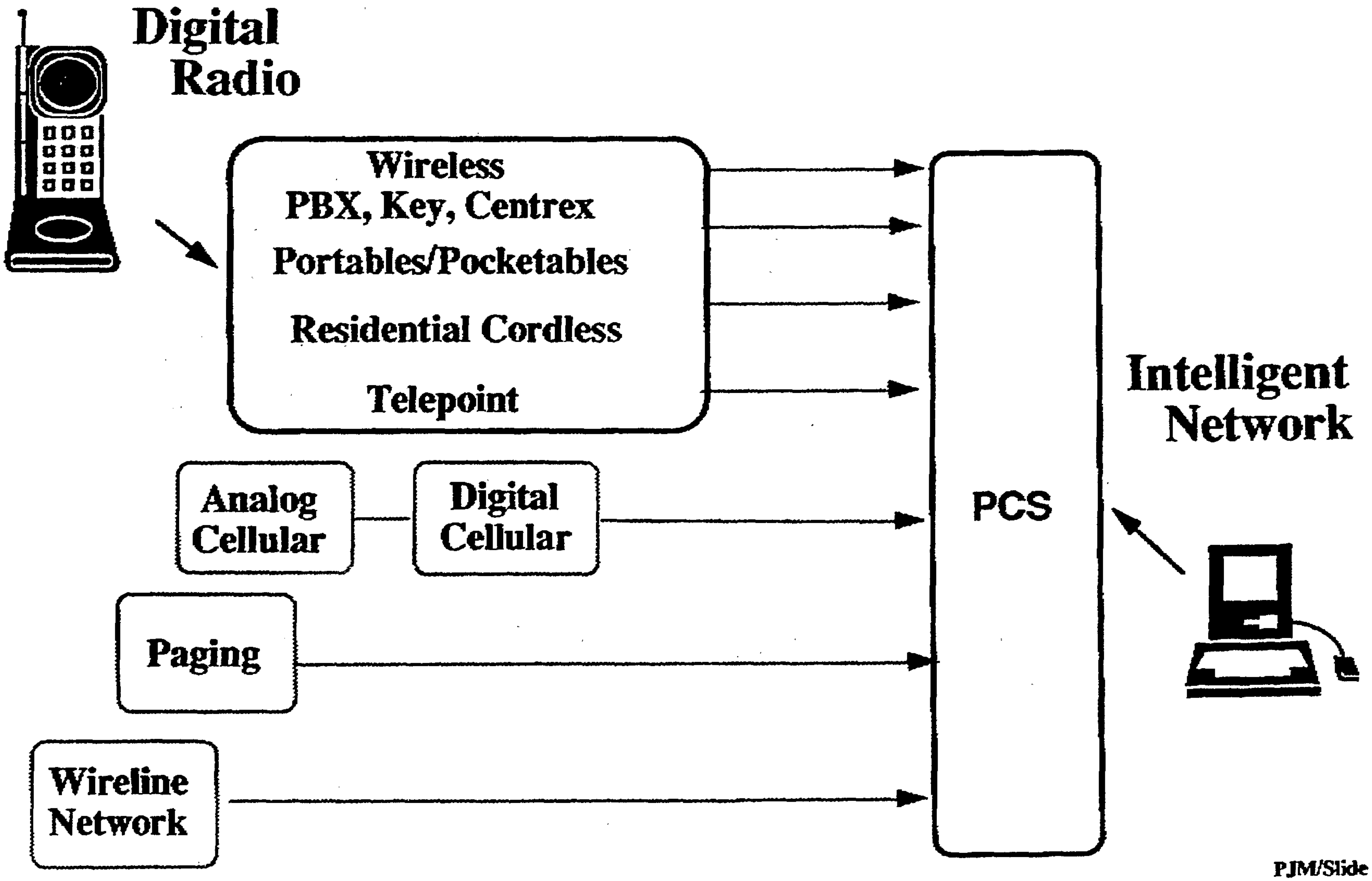
- * DOC Initiative in 1989
- * Projected market of $2.7 B
- * Door opens in 1992 . . .

Filling the matrix



Technology Enablers



Digital Radio

Wireless PBX, Key, Centrex

Portables/Pocketables

Residential Cordless

Telepoint

Analog Cellular

Digital Cellular

Paging

Wireline Network

PCS

Intelligent Network

Digital Radio Leadership

* High Capacity Digital Microwave Radio
  - SONET Radio
  - 512 QAM

* Pioneering TDMA-30 Cellular Standard
  - Demonstrated viability in January 1989

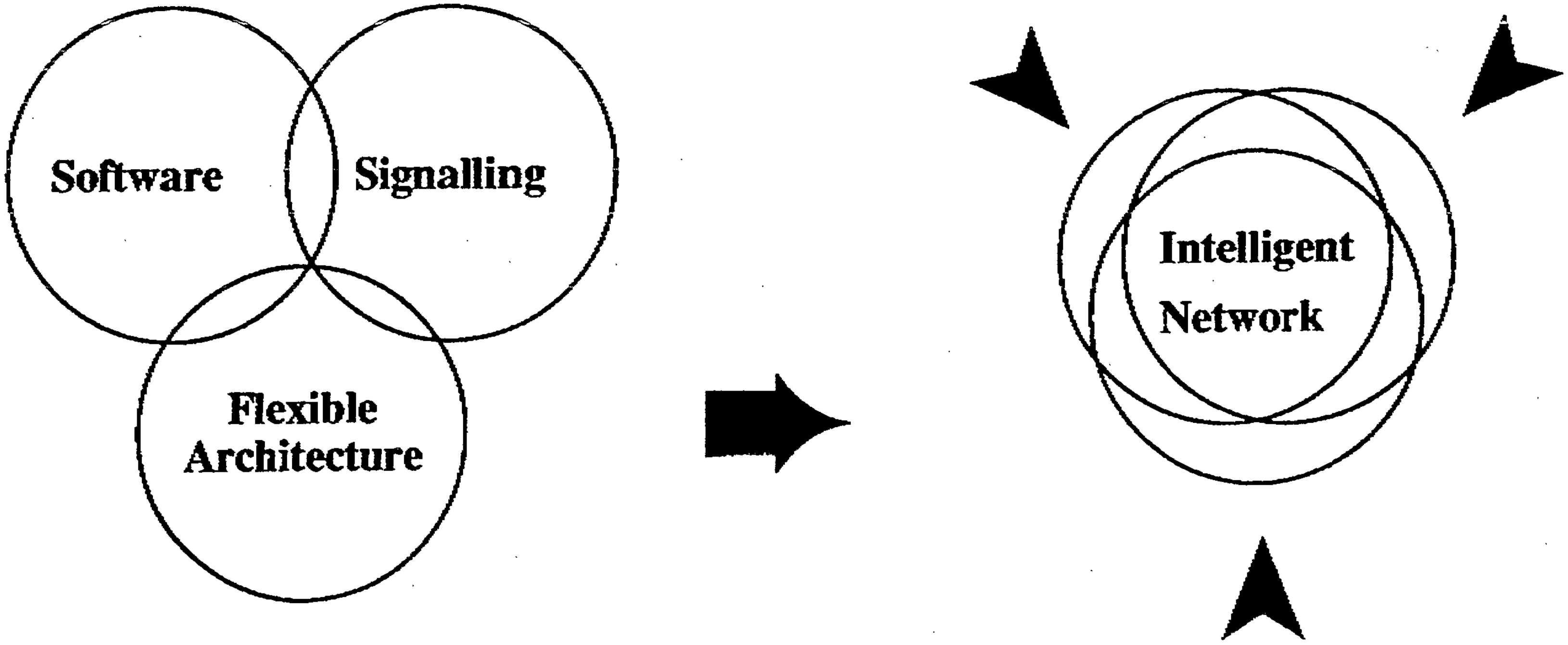
* RF Silicon Capability
  - Fundamental for low power operation

Standards Direction

Benefits of CT 2Plus:

- Early market entry
- Builds on existing in-service experience
- Cost competitive equipment supply
- Minimal risk of Standards obsolescence
- Canadian innovation opportunities assured
- Export opportunities for Canadian service and supplier industries

Intelligent Network



Software

Signalling

Flexible Architecture

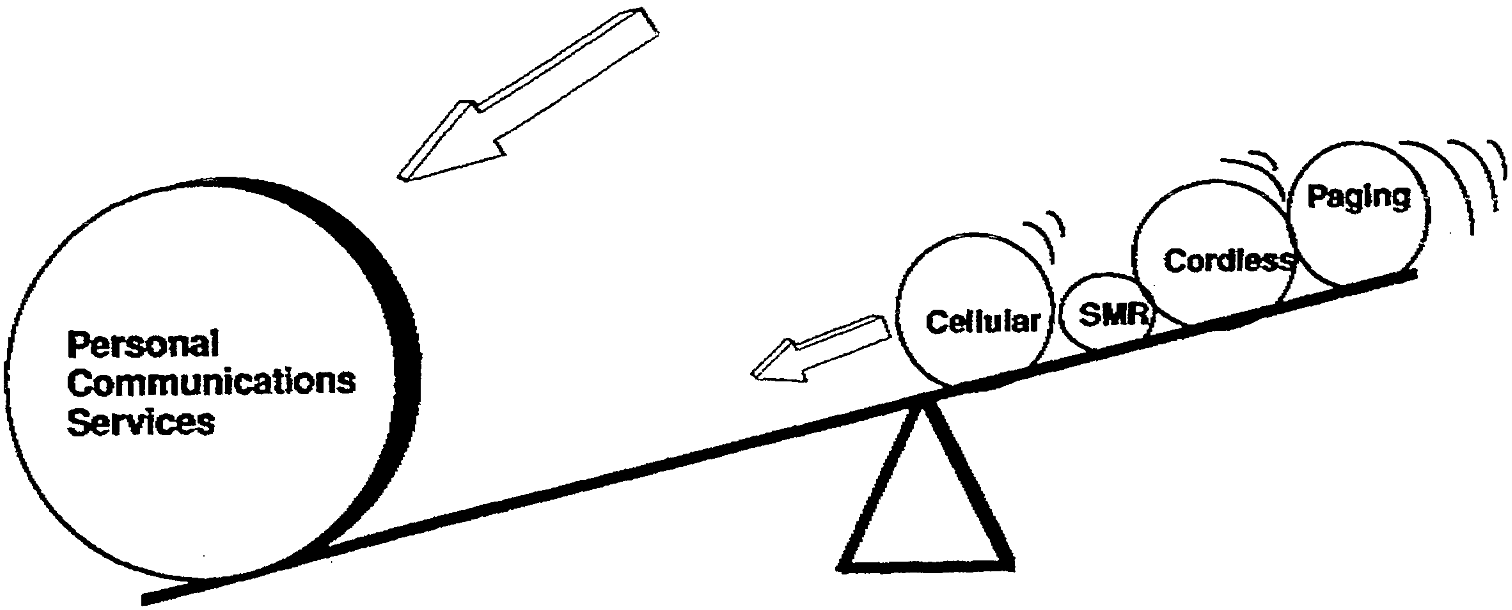
Intelligent Network

Service Perspective

	Mobility	Reachability	Personality
Wireless Access	Y	*	N
+			
Intelligent Network	N	Y	Y
=			
PCS	Y	Y	Y

Wireless access and intelligent network are complementary

the next frontier . . .



Personal Communications Services

Cellular

SMR

Cordless

Paging

The Evolution of Digital Cordless Telephones

Colin Buckingham

BIOGRAPHY

An Englishman by birth, now living in The Netherlands, married to a German girl and working for a Swedish corporation, Colin could be regarded as a true European. Having lived in a number of European countries and speaking five languages, he entered the world of telecommunications 13 years ago through the private paging industry and became President of the Tateco corporation in Sweden belonging to the Hasler group in Switzerland. In 1984 he joined Ericsson to head up their paging activities and is now President of the Ericsson Paging Systems corporation in The Netherlands and is based out of Amsterdam. Colin is in charge of Ericsson's paging and cordless business worldwide and was the initiator behind the Ericsson TDMA proposal for digital cordless which was presented to CEPT and which subsequently became the DECT standard.

"IRIDIUM - Global Personal Communications"

Presented By:

Dave McArtor

The DECT Standard

R.S. Swain

Abstract

This paper describes the progress made to date on the specification of the Digital European Cordless Telecommunication standard (DECT). It also describes the service and facility requirements, considers some network issues, and outlines the radio system design and operation. Performance requirements are also considered.

BIOGRAPHY

R.S. Swain, C. Eng., MIEE, has been Head of the Personal Radio Systems Section of British Telecom's Research Laboratories with responsibility for analogue and digital cordless communication systems research and development since 1980. He is currently closely involved with the specification of DECT as Chairman of the ETSI=Res 3 Services and Facilities, and the Authentication and Security Working Groups.

Widespread Low-Power Portable Communications Using TDMA Radio Technology

Nelson R. Sollenberger

PRESENTATION OUTLINE

The application of radio to provide access to telephone networks has increased dramatically over the last ten years. This has resulted from the introduction of low-power cordless telephones and higher-power cellular mobile telephones. Radio paging and radio data systems have also experienced substantial growth. The limitations of these systems have constrained their usage, but the success of these systems suggests that a large market exists for low-power widespread portable communications which could overcome these limitations. Convenient personal communications could be provided using network-based low-power digital radio systems. Low-power radio systems will require a dense network of fixed radio ports connected by distribution networks to intelligent control and switching equipment. Time-division-multiple-access (TDMA) radio technology is proposed to provide efficient, low-complexity and flexible wireless access. TDMA radio technology will permit unobtrusive fixed radio ports which can be deployed in a dense network.

BIOGRAPHY

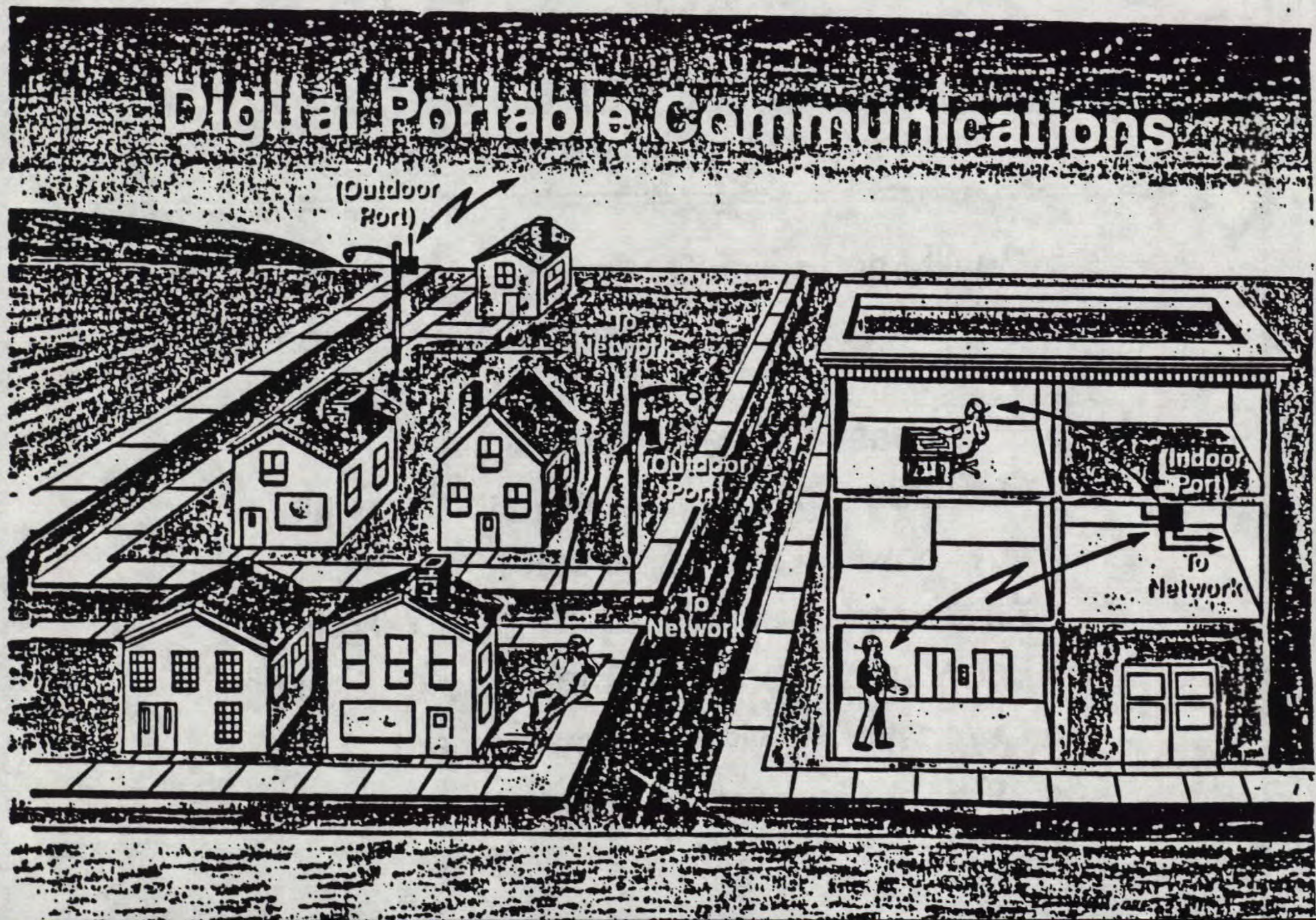
Nelson R. Sollenberger was born in Chambersburg, PA, on November 27, 1956. He received the B.S. degree in electrical engineering technology from Messiah College, Grantham, PA, in 1979 and the M.S. degree in electrical engineering from Cornell University, Ithica, NY, in 1981. He also attended Temple University and Rutgers University.

From 1979 through 1986 he was a member of the cellular radio development organization at Bell Laboratories. In 1987, he joined the applied research radio division at Bellcore. He manages a group responsible for radio technology implementation. His current interests include digital signal processing and modulation techniques for personal portable communications.

WIDESPREAD LOW-POWER PORTABLE COMMUNICATIONS USING TDMA RADIO TECHNOLOGY

NELSON R. SOLLENBERGER

BELLCORE



Characteristics Of Two Systems

Digital Cellular Mobile	Universal Digital Portable
High power (1-10 watts)	Low power (0.001-0.01 watts)
Service to vehicles	Service to pedestrians
Large coverage areas (>2 MI)	Small coverage areas (<0.25 MI)
Outdoor coverage (roads & highways)	Coverage within & around houses & buildings
High speed users	Low speed & stationary users
Power source in vehicles	Battery on pedestrian
Large expensive fixed radio sites	Small cheap fixed radio sites
Current high power example: Cellular mobile radio	Current low power example: Cordless telephone

NVC88 ADC213.003

Objectives For Universal Portable Communications

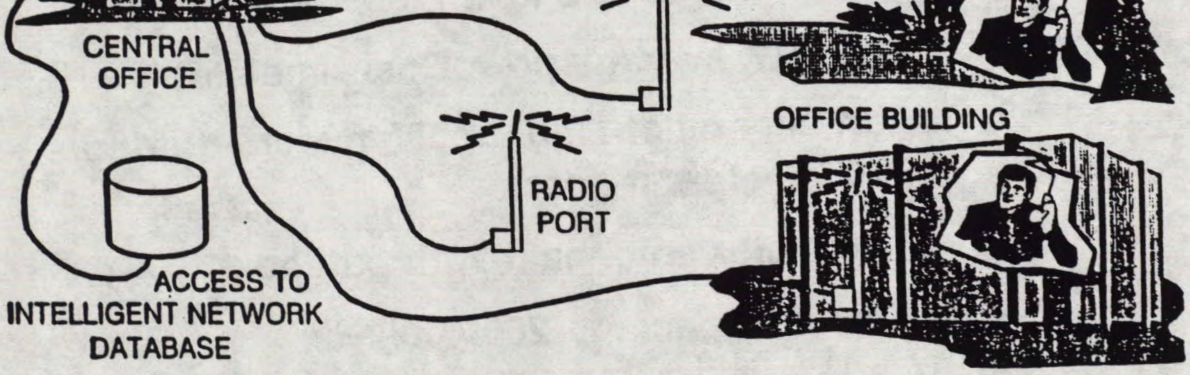
- Quality and reliability equivalent to wireline
- Ubiquitous integrated services for all portable sets
- Small easy-to-use portable sets
- Maximum time-of-use between rechargings
- Low power for portable sets
- Privacy and security equivalent to wireline
- Economical service comparable to wireline
- Compatibility with the environment
- Efficient use of radio spectrum

PY87 2TS87ADC.006

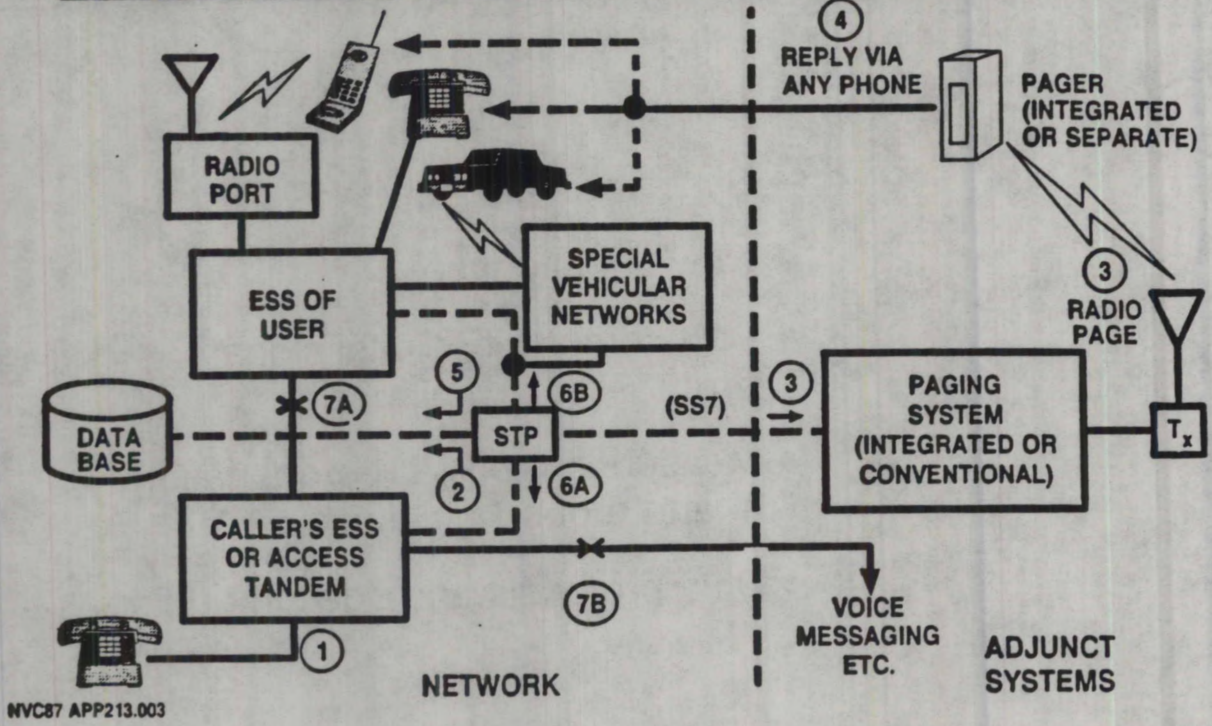
Current Technological Challenges

- Channel access strategies
- System architectures
- Network interfaces
- Low complexity digital signal processing techniques
- Measuring multipath propagation in and around buildings
- Data protocols and speech coding

Low-Power Exchange Access Digital Radio Integrated With Network And Intelligence



Anywhere Call Pick-Up



Evolving Parameters/Characteristics For A System Design

- TDM/TDMA
    - QPSK at 150-250 k symbols per second
    - Full duplex, time-interleaved
    - Coherent detection
    - Assignable in 8 kb/s increments
- 5-10 mw. average power per time-slot
- Port separation: about 600 meters outdoors, 50-75 meters indoors
- 7-10 meter antenna height outdoors
- Channel spacing: 200-400 kHz

(Continued)

Evolving Parameters/Characteristics For A System Design (Cont.)

- Diversity essential
  - Microscopic
  - Macroscopic
- Structured frequency reuse, demand-assigned channels
- Error detection rather than error correction (use ARQ for data, repeat previous frame for voice)
- Privacy and authentication very important
- Answering via a wide-area directed call pickup process
- System switching and control integrated with future PSTN/ISDN, primarily designed for hand/held units

---

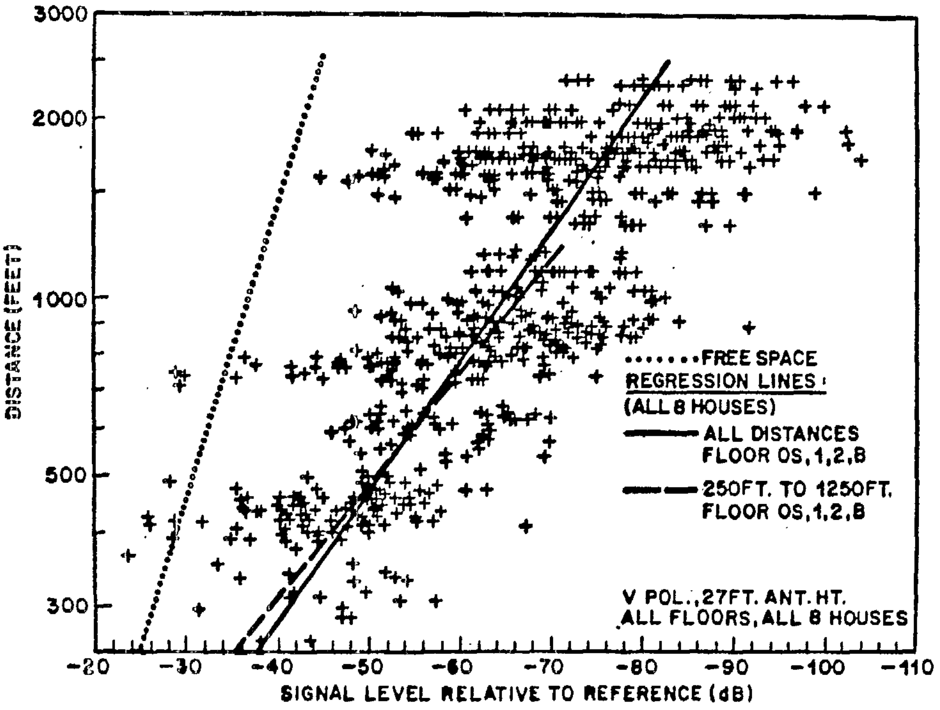
KEY RESEARCH ACHIEVEMENTS

* RADIO PROPAGATION CHARACTERIZATION

* SYSTEM PERFORMANCE SIMULATION

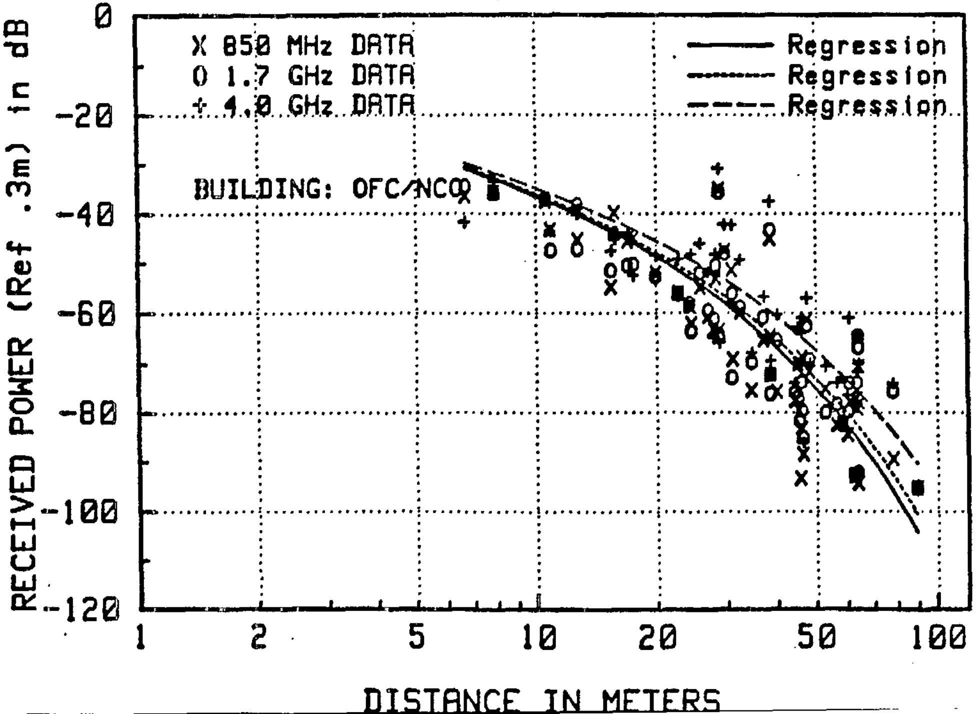
* EFFICIENT TDMA RADIO LINK TECHNIQUES

ATTENUATION IN RESIDENTIAL AREAS

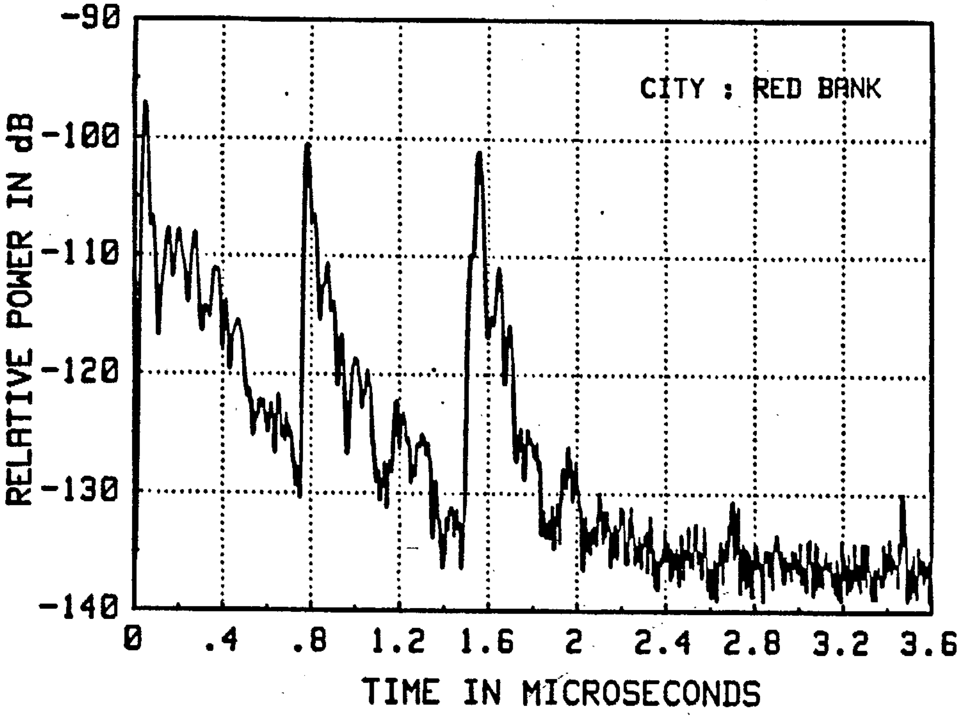


FOIL 1

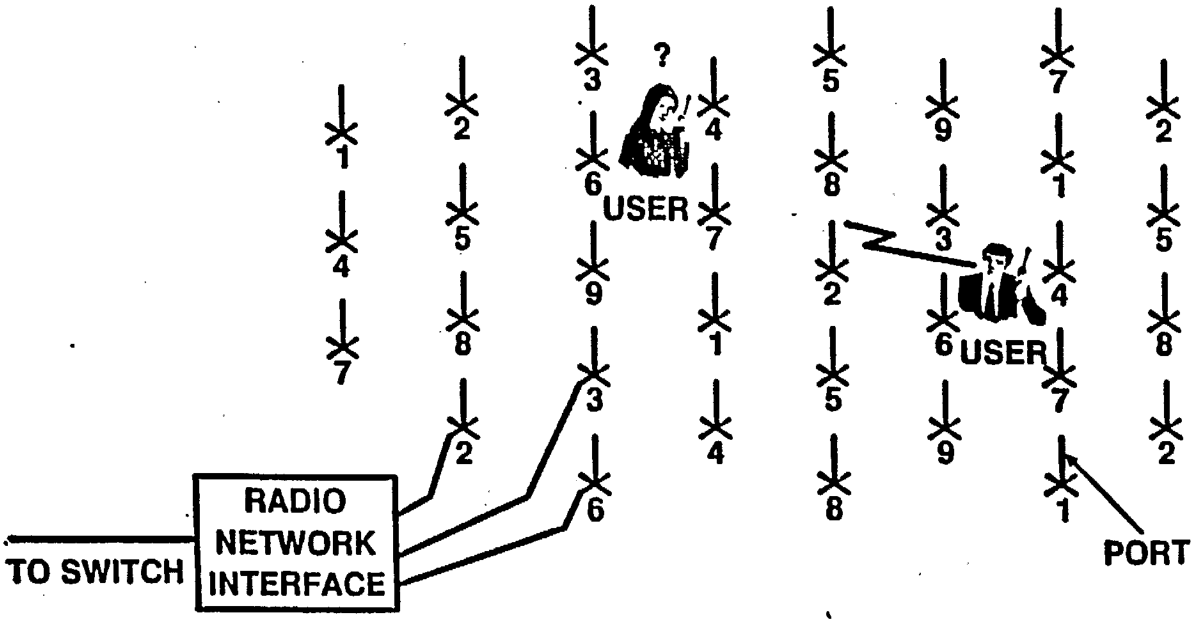
ATTENUATION IN OFFICE ENVIRONMENTS



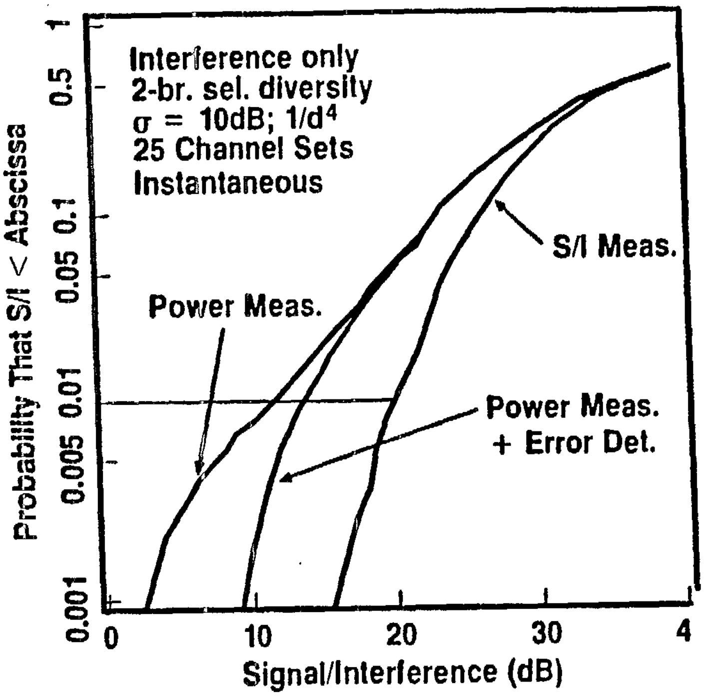
RADIO SIGNAL IMPULSE RESPONSE



Portable Radio Access In A Frequency Reuse Environment



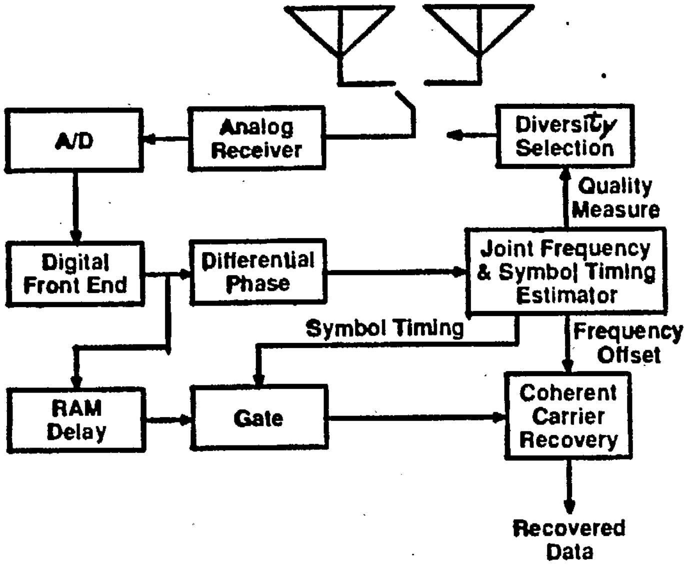
Distributions Of Signal/Interference At Access



Innovative Techniques for Minimizing TDMA Overhead

- Block symbol timing and carrier recovery
  - Data driven - NO overhead for training sequences
  - Quality measure available without added complexity
  - Modest hardware complexity
- Combined error detection and burst synchronization
  - Only 3 - bit overhead for synchronization
  - Reuses error detection hardware for synchronization

SINGLE RECEIVER SELECTION DIVERSITY



JOINT BURST SYNCH AND ERROR DETECTION

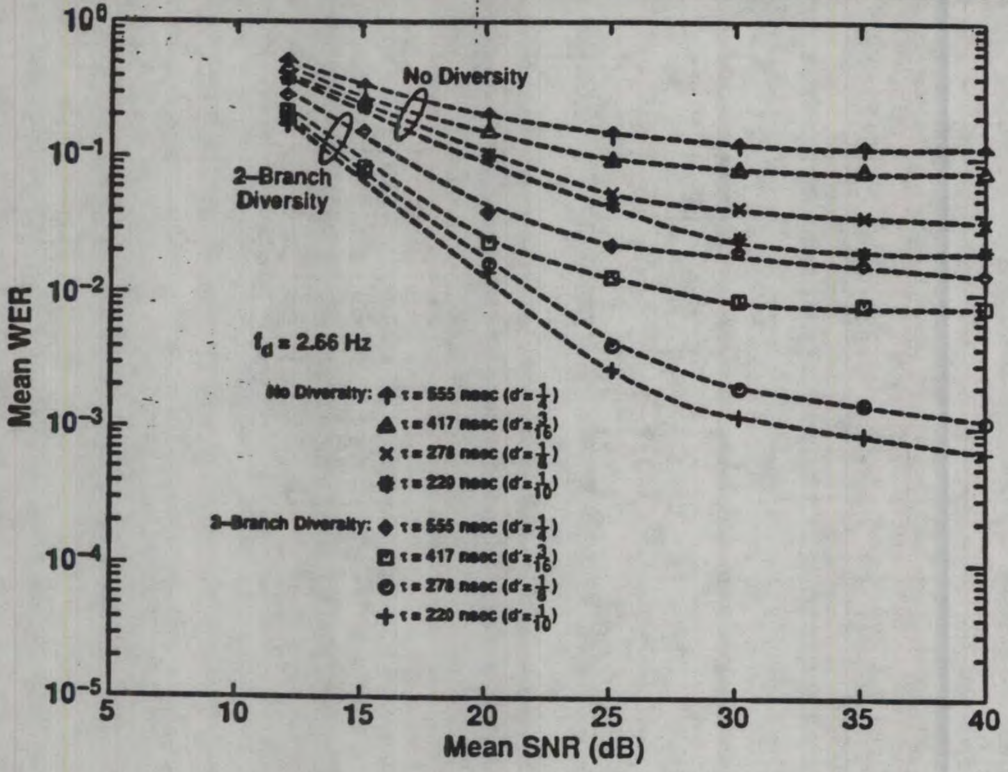
* ALIGNS BURST DATA WITHIN A 13-BIT WINDOW

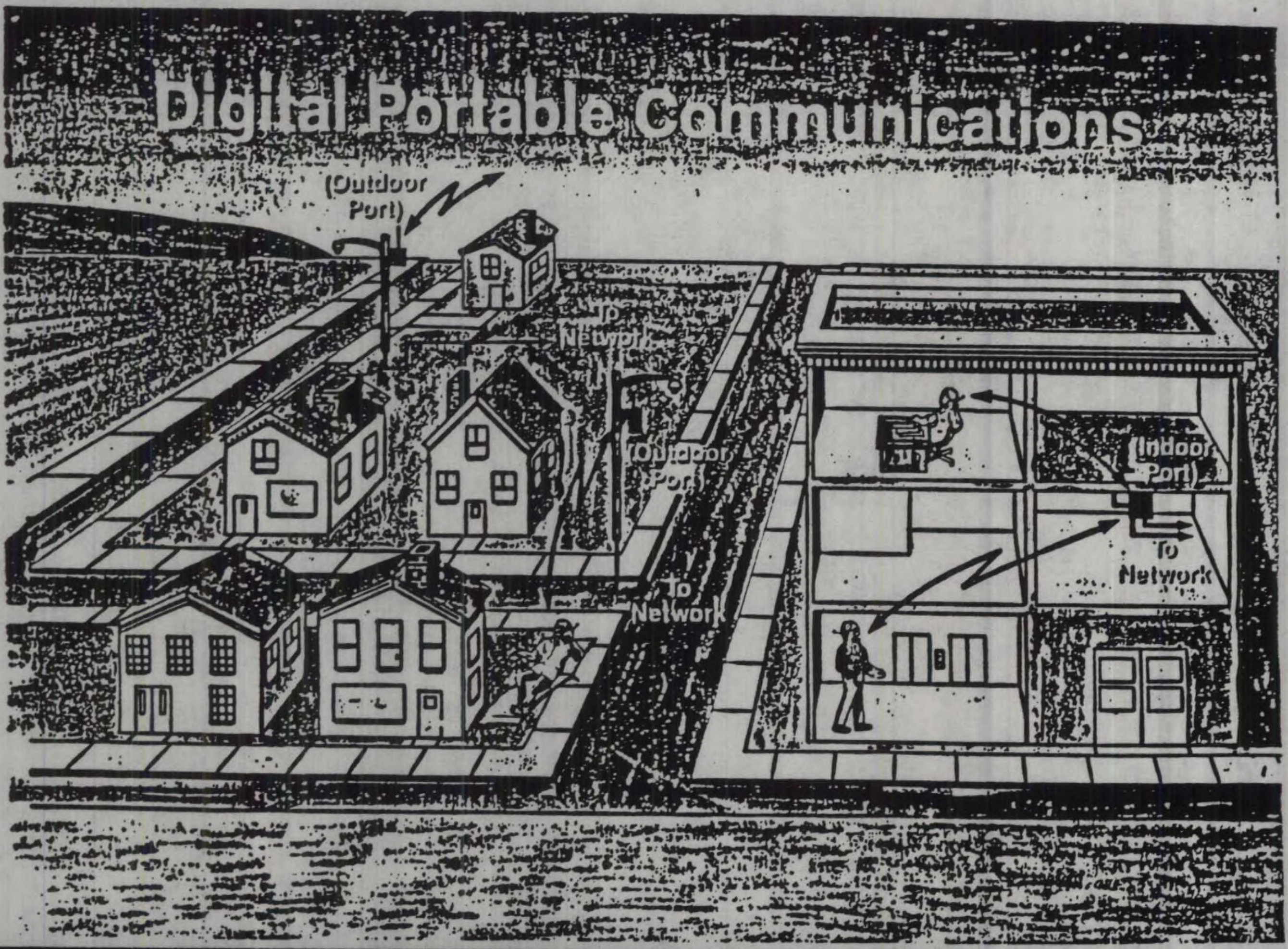
* ERROR DETECTION IN SECOND PASS

* LOW COMPLEXITY

* MORE EFFICIENT THAN SEPARATE PROCESSES

MEASURED WORD ERROR PERFORMANCE





Personal Communication Systems

Takeshi Hattori

PRESENTATION OUTLINE

1. Current status of personal/portable communication in Japan including cordless telephone and mobile telephone.
2. Philosophy and service image of Future Personal Communication
3. Network architecture
4. System configuration and Technologies
5. Concluding remarks

BIOGRAPHY

Takeshi Hattori received the B.S., M.S.,degrees from Tokyo University, Tokyo, Japan in 1969, 1971, 1974, respectively.

Dr. Hattori joined the Electrical Communication Laboratory, NTT, Japan in 1974. He was engaged in research mainly on analog voice and digital signal transmission techniques for the 800 MHz land mobile telephone system, and new high capacity mobile/portable communication systems. From 1984 to 1986, he was a senior manager at the ECL Research and Development Headquarters and worked on systems engineering of research plannings. From 1986 to 1987, he was Head of the Mobile Communication Applications Section in the Radio Communications Networks Laboratory.

From 1987 to 1989, he was Research Group Leader of the Radio Communication Systems Laboratory, and responsible for high speed digital mobile radio transmission technologies. He is currently Project Team-3 Leader and responsible for Personal Communications System in NTT Electrical Communication Systems Laboratories.

Dr. Hattori was awarded the IEEE Vehicular Technology Society Paper of the Year in 1981. He is a member of IEEE and Institute of Electronics and Communications Engineers of Japan.

Personal Communication Systems

Takeshi Hattori
NTT Radio Communication Systems Laboratories
1-2356 Take Yokosuka 238 Japan

ABSTRACT

Personal Telecommunication Service basically realizes communication from or to a person who has been given a Personal Telecommunication Number (PTN). As its goal, this service will enable us to transmit and receive information instantaneously, whenever we wish with anyone regardless of his whereabout. A Personal Telecommunication System will require the following items; 1) ultra-high capacity, 2) very small, inexpensive, and lightweight handsets, 3) friendly and attractive services that are personable. Many new technical items to be solved cover a variety of fields, such as network, switching, service control, radio, information processing, human interface, and others.

In this session, first, personal communication service concept that integrates wire and wireless access is presented following the discussion of the deployment of network. Second, service image including wire system and wireless system is shown. Third, based on the above service survey, the functions required to realize this service are dealt with.

Fourth, the flexible and hierarchical network architecture and system configuration are described. The proposed network architecture has the following major advantages; 1) realization of ultra-high capacity, 2) compatibility with intelligent networks, 3) integration of the mobility managements for mobile communication networks and fixed networks.

Finally, briefly dicussed are important technical subjects including network, radio systems, iinformation processing, and materials.

Personal Communications System

Takeshi Hattori

NTT Radio Communication Systems Laboratories

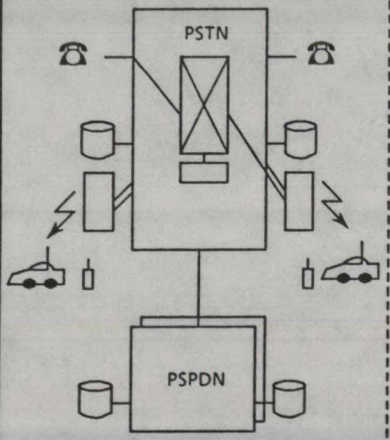
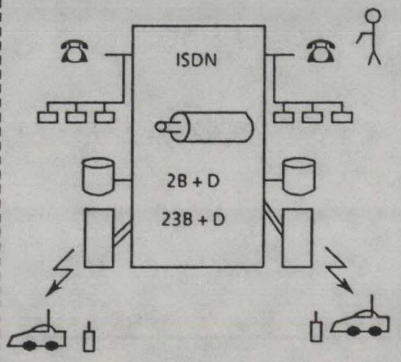
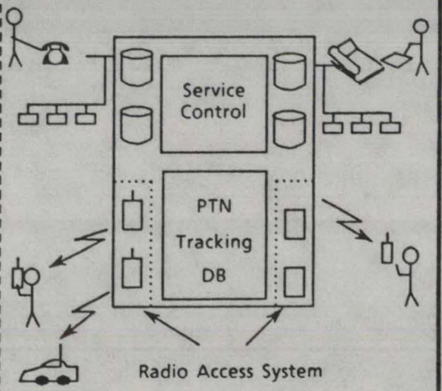
NTT

Contents of Persentation

- ★ *Background of R&D*
- ★ *Service Concept and Image*
- ★ *Required Functions and Facilities*
- ★ *System Architecture*
- ★ *System Configuration*
- ★ *Technical Subjects*

NTT

Deployment of Network

Telephone / Data Individual Network (PSTN/PSPDN)	Integrated Service Digital Network (ISDN)	Personal Communication Services Network (PCSN)
Telephone Service and Data service [Automatic and Instant connection]	Integrated Service of Telephone and Data [One Digital Link]	· Person anal and Human Communication Service [Personal Number / Tracking Exchange]
 	 	

NTT

Personal Communication Service Concept

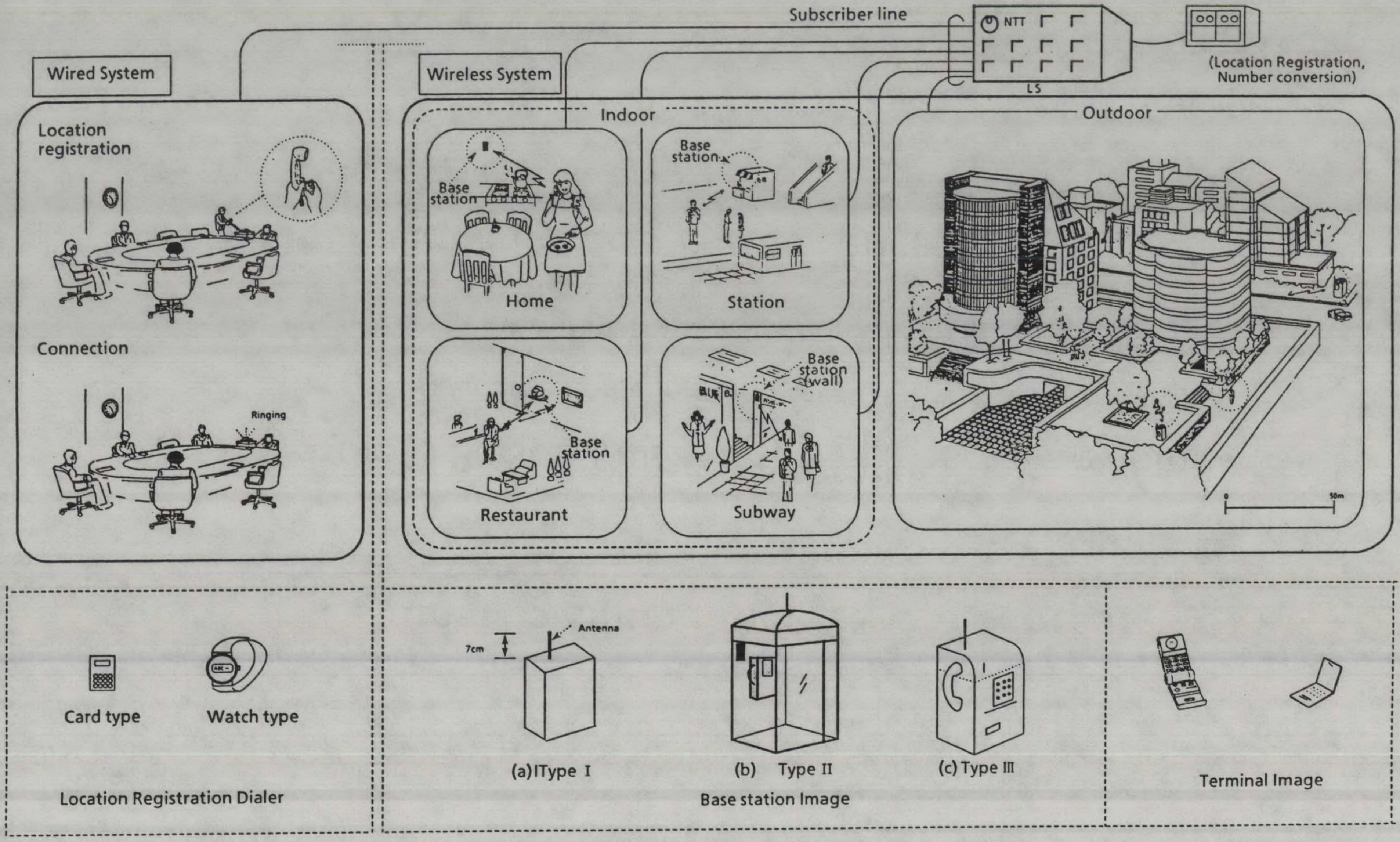
★ Person to Person Call at any place and at any time

- Personal Telecommunication Number
- Pocket Size terminal such as Pocket Phone and IC Card

★ Intelligent and Personalized Service

- Screening and Scheduling
- Priority Response

NTT



Personal Communications Service Image

System Objectives

★ *Ultra High Capacity*

★ *Very Low Cost*

★ *Customer Friendly Terminal*

- *Pocket Size Radio Unit*
- *Tuch Phone / IC Card Phone*

NTT

Systems Comparison

Services	Charge	Service Area	Vehicle Speed	Terminal size	Battery recharging peiod	Capacity	Access Medium
Fixed Telephone	low	point indoor	rest	small	—	ultra large	wire
Automobile/ portable Telephone	high	street outdoor	high speed	middle	short	middle	wireless
Personal Communication	middle	anywhere	rest to middle speed (through automobile for high speed	small	long	ultra large	wire /wireless

NTT

System Design Philosophy

- ★ *Integration of Wire and Wireless Access*
- ★ *Enhancement and Full Utilization of PSTN / ISDN*
- ★ *Introduction of Micro Cell Structure*
  - · *Miniaturization of Radio Terminal*
  - · *Efficient Utilization of Radio Spectrum*
- ★ *Interworking with Other Networks such as Cellular Networks and Premises Networks*

NTT

Basic Identity of Personal Communication

★ *Personal Telecommunication Number*

★ *Mobile Station Identity*

★ *Routing Address*

NTT

Features of Personal Telecommunication Number

- ★ *Universal Number Independent of Place*
- ★ *Plural Number for Each Person*
- ★ *Network Transparency*

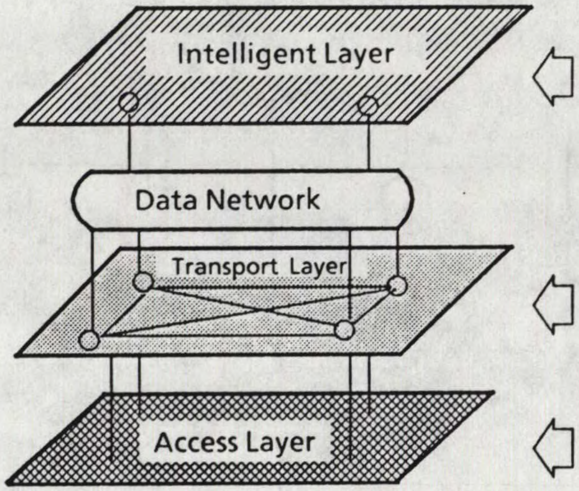
NTT

Required Functions for Personal Communications

Items	Contents
Location Registration	Registering routing address or paging address coressponding to network access point.
Number Conversion	Transforming personal telecommunication number to routing address.
Tracking Exchange	Routing a call along with transmitting data associated.
Flexible Charging	Determing and sending the message billing index according to chargeable distances and services.
Large-scale Database	Storing and retreaving customer's data of PTN , MSI, RA and billing information.
Radio Access	Multi-channel accessing and location registration controlling.
Security	Authentication, Voice scrambring

NTT

Personal Communication Network Architecture



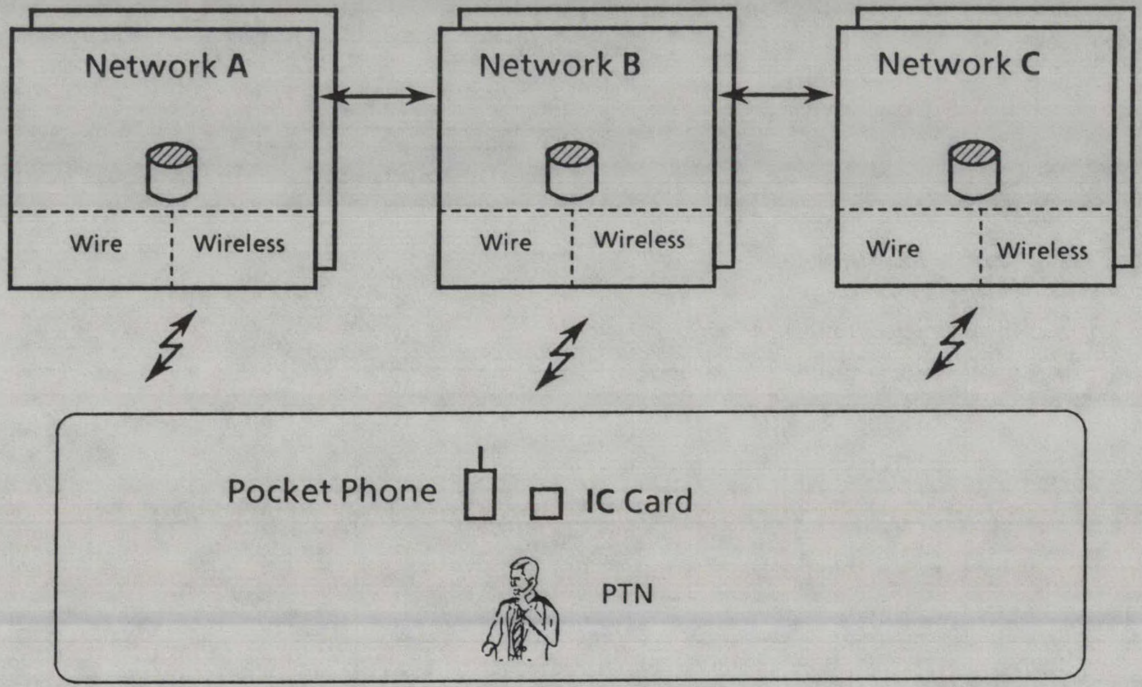
- Service Manegement
- Network Manegement
- Service Control
- Network Control
- Data base

- Switching
- Transmission

- Wireline Access
- Radio Access
- Location Regist ration

NTT

Network Interworking and Service Continuity



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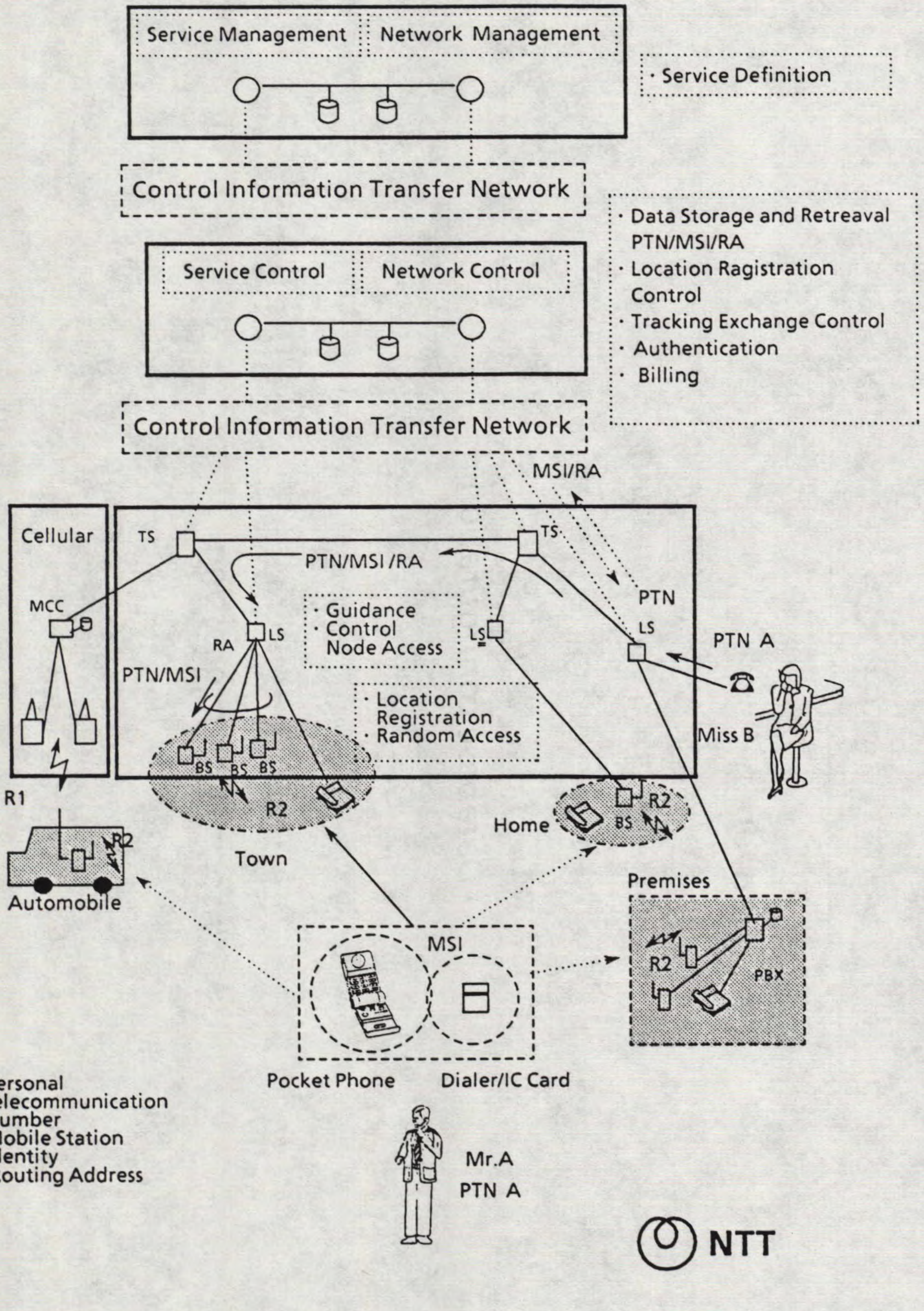
Personal Communication Network Configuration



PTN : Personal telecommunication Number
MSI: Mobile Station Identity
RA : Routing Address

NTT

Technical Subjects

★ *Network*

- *Network architecture and interface*
- *Numbering configuration*
- *Service control*
- *Traffic and quality*
- *Database configuration*

★ *Radio System*

- *Micro sell structure*
- *Efficient random access and TDMA modulation*

★ *Information processing*

- *Low bit rate voice coding*
- *Authentication and scrambling*

★ *Materials and parts*

- *Low power consumption LSI*
- *High energy density battery*

NTT

Perspectives on Public Cordless Telephone Services in Canada

Presented By:

Alan Hamilton, DOC
Merrill Shulman, Shulman Communications
Len Katz, Cantel

Presentation By:

Alan Hamilton

INTRODUCTORY REMARKS

GOOD DAY, LADIES AND GENTLEMEN. I WOULD LIKE TO BEGIN BY THANKING THE ORGANIZERS OF WIRELESS '90, THE ALBERTA TELECOMMUNICATIONS RESEARCH CENTRE AND THE TELECOMMUNICATIONS RESEARCH INSTITUTE OF ONTARIO, FOR EXTENDING AN INVITATION TO ME TO SPEAK ON THE SUBJECT OF TELECOMMUNICATIONS POLICY FOR PUBLIC CORDLESS TELEPHONE SERVICE. I AM ALSO VERY GLAD TO SEE A HOME-GROWN CONFERENCE ON THE SUBJECT OF WIRELESS COMMUNICATIONS ENTER ITS SECOND YEAR, AND I AM SURE THAT THERE WILL BE MANY MORE TO COME.

I WOULD LIKE TO TALK BRIEFLY TODAY ABOUT SOME OF THE POLICY ISSUES THAT THE DEPARTMENT OF COMMUNICATIONS MUST CONSIDER WITH RESPECT TO THE COMMERCIAL IMPLEMENTATION OF PUBLIC CORDLESS TELEPHONE SERVICE, AN AREA WHICH IS A MAJOR PART OF THE WIRELESS COMMUNICATIONS FIELD TODAY. I PROPOSE TO BEGIN WITH A BRIEF BACKGROUND ON THIS INITIATIVE FOLLOWED BY A FEW WORDS ON FIELD TRIALS. I WILL THEN BRIEFLY TOUCH ON

SOME OF THE POLICY ISSUES THAT THE DEPARTMENT WILL HAVE TO CONSIDER, MENTIONING THE ROLE OF INDUSTRY ADVISORY COMMITTEE ON PUBLIC CORDLESS TELEPHONE SERVICE IN THIS REGARD. I WILL NOT GO INTO MUCH DETAIL ABOUT THE COMMITTEE, HOWEVER, SO AS TO AVOID THE WRATH OF ITS CHAIRMAN, MR. MERRILL SHULMAN.

BACKGROUND

IN 1987, THE DEPARTMENT PUBLISHED A NOTICE IN THE CANADA GAZETTE TOGETHER WITH A DISCUSSION PAPER PERTAINING TO THE INTRODUCTION OF VERY LOW-POWER WIRELESS COMMUNICATIONS INTO THE WORKPLACE. THIS NOTICE MAY, IN A SENSE, BE CONSIDERED THE GENESIS OF THE DEPARTMENT OF COMMUNICATIONS' INTEREST IN PUBLIC CORDLESS TELEPHONE SERVICE. IN AN ADDENDUM ISSUED LAST SEPTEMBER, THE POTENTIAL FUTURE APPLICATIONS OF WIRELESS TECHNOLOGY IN THE WORKPLACE WERE LISTED, INCLUDING WIRELESS TELEPHONE SYSTEMS AND WIRELESS PABX'S. THE ADDENDUM ALSO EXTENDED THE EXPERIMENTAL

PERIOD FOR LOW-POWER WIRELESS COMMUNICATIONS IN THE WORKPLACE UNTIL MARCH 31, 1992. ABOUT THE SAME TIME, THE DEPARTMENT BEGAN RECEIVING A NUMBER OF REQUESTS RELATED TO CORDLESS TELEPHONE SYSTEMS. THE MINISTER WAS BOTH SURPRISED AND IMPRESSED BY THESE REQUESTS, AND ON MAY 11, 1989, IN HIS SPEECH TO THE ANNUAL CONFERENCE OF THE RADIOCOMM ASSOCIATION OF CANADA, THEN KNOWN AS THE CANADIAN RADIO COMMON CARRIER ASSOCIATION, HE PROMISED PUBLIC CONSULTATION ON THIS MATTER. DUE TO THE AMOUNT OF INTEREST SHOWN BY INDUSTRY, THE DEPARTMENT RESPONDED BY ISSUING A GAZETTE NOTICE ON PUBLIC CORDLESS TELEPHONE SERVICE LAST NOVEMBER.

THESE INITIATIVES ARE INDICATIVE, I THINK, OF THE FAST CHANGING NATURE OF THIS EXCITING AREA IN TELECOMMUNICATIONS, AND DEMONSTRATE THE DEPARTMENT'S INTEREST IN ENCOURAGING THE INTRODUCTION OF NEW COMMUNICATIONS TECHNOLOGIES THAT WILL BE OF BENEFIT TO ALL CANADIANS.

THE MOVE TOWARDS PERSONAL COMMUNICATIONS PRODUCTS AND SERVICES HAS, OF COURSE, BEEN ENABLED BY THE REASCENDANCY OF RADIO-BASED TECHNOLOGIES. THE MOBILE RADIO REVOLUTION OF THE 1980'S WILL BECOME THE PERSONAL COMMUNICATIONS REVOLUTION OF THE 1990'S. TO TERM GROWTH IN THE DOMAIN OF MOBILE COMMUNICATIONS AS EXPLOSIVE IS NO UNDERSTATEMENT, AND IT HAS BEEN SPECTACULAR IN EVERY SENSE IN RECENT YEARS. ONE ONLY HAS TO LOOK AT THE CELLULAR INDUSTRY IN CANADA, WHICH STARTING JUST OVER FIVE YEARS AGO, NOW HAS OVER 450,000 SUBSCRIBERS.

WE CONTINUE TO HEAR THAT MOBILE COMMUNICATIONS REMAIN THE FASTEST GROWING AREA IN TELECOMMUNICATIONS, AND I EXPECT THAT THIS WILL EVOLVE INTO THE REALM OF PERSONAL HAND CARRIED COMMUNICATIONS THROUGH THE 1990'S. ACCORDING TO AN A.D. LITTLE STUDY, FOR EXAMPLE, EVEN NOW IN SWEDEN ONE OUT OF EVERY TWO NEW TELEPHONES IS A MOBILE PHONE, ONE OF EVERY TWO

PORTS ADDED TO A CENTRAL EXCHANGE IS FOR MOBILE, AND ONE OF EVERY TWO NEW INTERCITY CHANNELS IS FOR MOBILE TRAFFIC.

THE POPULARITY OF THE ANALOGUE CORDLESS TELEPHONE EXTENSION SETS CONTINUES UNABATED. IN CANADA, THERE ARE MORE THAN TWO MILLION OF THESE PHONES IN USE. RECENT STATISTICS FOR THE U.S. MARKET INDICATE THAT SALES FOR 1989 WERE IN THE ORDER OF SOME SEVEN MILLION TELEPHONES WITH A DOLLAR VALUE IN EXCESS OF HALF A BILLION DOLLARS, OR PUT ANOTHER WAY, THE SALES OF 46/49 MHZ CORDLESS TELEPHONES REPRESENT SOME 35% OF TELEPHONE TERMINAL SETS SOLD, GENERATING SOME 50% OF SALES REVENUES. AND AS YOU ARE AWARE, THE ANALOGUE CORDLESS PHONE IS ALSO FINDING LIFE IN OFFICE SETTINGS, MOST LIKELY BECAUSE OF THE DEMAND FOR THIS TYPE OF PRODUCT WITH NO OTHER ALTERNATIVE READILY AVAILABLE TODAY. THIS WILL PROBABLY BE ITS SWAN SONG, HOWEVER, AS WE SWITCH TO DIGITAL PRODUCTS.

SO, DESPITE THE LINGERING POPULARITY OF ANALOGUE TELEPHONES, IT SEEMS CLEAR THAT THE TREND WILL BE TOWARDS DIGITAL CORDLESS TELEPHONES IN THE FUTURE FOR REASONS THAT YOU ARE MORE FAMILIAR WITH THAN I. ACCORDING TO ESTIMATES MADE BY THE INDUSTRY ADVISORY COMMITTEE, THERE IS A POTENTIAL MARKET OF APPROXIMATEDLY SIX MILLION DIGITAL CORDLESS TELEPHONES WITHIN THE FIRST FIVE YEARS OF THEIR INTRODUCTION.

THE STEP TOWARDS THESE NEW TELEPHONES TAKES US IN THE DIRECTION OF MANY POSSIBLE ALTERNATIVES, FROM CT 2, CT 2 PLUS, DCT900, DECT AND GSM, ALL THE WAY TO WHAT IS ENVISAGED BY THE WORK BEING CARRIED OUT BY CCIR AND CCITT ON FUTURE PUBLIC LAND MOBILE TELECOMMUNICATIONS SYSTEMS (FPLMTS) AND (UNIVERSAL) PERSONAL TELECOMMUNICATIONS ((U)PT). THE OBJECTIVE OF BEING ABLE TO TALK TO ANYONE, ANYTIME FROM ANYWHERE SURELY GIVES NEW MEANING TO JOAN RIVERS' FAMILIAR LINE "CAN WE TALK". WE CAN LIKEN THIS FUTURE UNFOLDING OF CORDLESS

COMMUNICATIONS TO AN EVOLUTIONARY PROCESS; IF THERE CAN BE AN EVOLUTION OF BEER, SURELY THERE CAN ALSO BE AN EVOLUTION OF CORDLESS TELEPHONY!

FIELD TRIALS

WE HAVE TAKEN THE FIRST STEPS IN CANADA TOWARDS THIS OBJECTIVE WITH THE RELEASE OF CANADA GAZETTE NOTICE DGTP-014-89 LAST NOVEMBER. BY THE CLOSING DATE FOR PUBLIC COMMENT ON MARCH 1, 1990, WE HAD RECEIVED 27 SUBMISSIONS ON OUR PROPOSED POLICY DIRECTION, AND MANY PARTIES HAVE COME FORWARD AND RECEIVED FIELD TRIAL AUTHORIZATIONS TO EXPERIMENT IN VARIOUS AREAS OF CANADA WITH THIS TECHNOLOGY.

COMPANIES THAT HAVE RECEIVED RADIO AUTHORIZATIONS TO CONDUCT EXPERIMENTAL TRIALS INCLUDE B.C.E. MOBILE INC., B.C. MOBILE LTD., THE BEEPER PEOPLE INC., BELL CANADA, BELL NORTHERN RESEARCH LTD., GLENAYRE ELECTRONICS LTD, MOTOROLA CANADA LTD., NOVATEL COMMUNICATIONS LTD.,

ROGERS CANTEL INC., SASKATCHEWAN TELECOMMUNICATIONS, AND TELESAT MOBILE INC. OTHER COMPANIES HAVE ALSO EXPRESSED INTEREST AS WELL.

THE FIELD TRIAL/POLICY DEVELOPMENT PHASE THAT WE ARE IN WITH RESPECT TO CORDLESS TELEPHONES IS A GOOD DEAL MORE IMPORTANT, I THINK, THAN IT MAY FIRST APPEAR. THE IMPORTANCE OF THE MARKETING FIELD TRIALS AND STUDIES IS PARAMOUNT, AS THE ULTIMATE QUESTION IS, AS ALWAYS, DOES THE CANADIAN PUBLIC REALLY WANT THIS NEW SERVICE AND AT WHAT PRICE?. IT WOULD ALSO BE WISE TO LEARN FROM EARLY CONSUMER EXPERIENCE WITH TELEPOINT OPERATIONS IN THE UNITED KINGDOM. THE INTRODUCTORY PHASE, HAS FROM ALL ACCOUNTS, BEEN MUCH LESS SUCCESSFUL THAN ORIGINALLY ANTICIPATED DUE TO A NUMBER FACTORS. FROM A MARKETING PERSPECTIVE, FOR EXAMPLE, NOT SO LONG AGO ONLY FOUR PER CENT OF THE BRITISH PUBLIC KNEW WHAT TELEPOINT SERVICE WAS. THERE HAVE ALSO BEEN PROBLEMS ENCOUNTERED THAT ARE TECHNICAL IN NATURE. FOR INSTANCE, I UNDERSTAND THAT THERE IS A PROBLEM WITH

STREET LEVEL NOISE SINCE ONE CANNOT ADJUST THE VOLUME LEVEL ON CT 2 TELEPHONES. THIS UNDERSCORES THE NEED FOR TECHNICAL TRIALS EVEN NOW OF AN EXISTING TECHNOLOGY. OF COURSE CAREFUL TESTING OF THE COMPETING DCT900 AND DECT EQUIPMENT IS ALSO TAKING PLACE IN MANY AREAS OF CANADA AS PART OF VARIOUS LICENSEES' FIELD TRIALS.

ASSUMING SUCCESS OF THE FIELD TRIALS, AND THE ARRIVAL ON THE PART OF INDUSTRY TO A CONSENSUS SO THAT THE INDUSTRY ADVISORY COMMITTEE CAN REPORT ITS FINDINGS AND RECOMMENDATIONS ON OR BEFORE THE DEADLINE DATE OF SEPTEMBER, 1991, THE MINISTER OF COMMUNICATIONS WILL LIKELY DECIDE TO ESTABLISH AN ONGOING COMMERCIAL PUBLIC CORDLESS TELEPHONE SERVICE. WHILE THERE ARE SEVERAL PUBLIC POLICY QUESTIONS STILL TO BE DECIDED, WE ARE HOPEFUL THAT THE INDUSTRY ADVISORY COMMITTEE AND ITS REPORT WILL RECOMMEND REASONABLE CONSENSUS ALTERNATIVES IN MANY OF THESE AREAS.

POLICY FOR AN ONGOING COMMERCIAL PUBLIC CORDLESS TELEPHONE SERVICE

IN MY ABOVE REMARKS, I HAVE MADE THE ASSUMPTION THAT THERE WILL INDEED BE A COMMERCIAL PERSONAL PUBLIC CORDLESS COMMUNICATIONS SERVICE IN THE FUTURE. WHILE THIS MAY NOT BE THE CASE, I THINK THAT EVERYONE IN THIS ROOM WILL AGREE THAT CORDLESS COMMUNICATIONS, INCLUDING CORDLESS TELEPHONES, IS GOING TO MAKE A MAJOR IMPACT ON TELECOMMUNICATIONS, THE ONLY QUESTION BEING WHEN, HOW AND IN WHAT PRECISE FORM. IN FACT, AS MERRILL SHULMAN WILL OUTLINE, THE INDUSTRY ADVISORY COMMITTEE HE CHAIRS HAS BEEN ABLE TO WORK OUT A GREAT DEAL OF CONSENSUS ALREADY IN MANY AREAS OF POLICY AND STANDARDS WITH RESPECT TO CORDLESS TELEPHONES.

THE EXPLOSIVE GROWTH IN WIRELESS COMMUNICATIONS MAY GIVE US CAUSE TO PAUSE AND CONSIDER WHERE THE MATTERS WE ARE DECIDING UPON NOW WILL TAKE US IN THE FUTURE.

THE INCREASING POTENTIAL FOR THE ESTABLISHMENT OF AN ALTERNATIVE OR SECOND LOCAL TELEPHONE NETWORK IS ONE OF THE MOST INTRIGUING.

IN FACT, THE LATTER WAS A PROMINENT THEME IN MANY OF THE SUBMISSIONS THAT THE DEPARTMENT RECEIVED IN RESPONSE TO OUR CANADA GAZETTE NOTICE LAST FALL INITIATING PUBLIC CONSULTATION. SEVERAL SUBMISSIONS WERE, NOT SUPRISINGLY, RECEIVED FROM TELEPHONE COMPANIES WHO FEARED NOT ONLY FOR THEIR PAY TELEPHONE AND TOLL REVENUES, BUT EVEN FOR THEIR LOCAL SERVICE MONOPOLIES.

RETURNING TO SOME OF THE POLICY QUESTIONS THAT WERE RAISED IN THE GAZETTE NOTICE, SOME OF THE MOST IMPORTANT AND WIDELY DISCUSSED ITEMS WERE RELATED TO INDUSTRY STRUCTURE, QUESTIONS SUCH AS HOW MANY PUBLIC CORDLESS TELEPHONE SERVICE LICENSEES SHOULD THERE BE AND SHOULD THEY BE NATIONAL, REGIONAL OR LOCAL IN SCOPE? THE FULL SPECTRUM OF VIEWS, IF YOU WILL PARDON THE EXPRESSION, HAVE BEEN VOICED, WITH SUGGESTIONS

RANGING FROM A LARGE NUMBER OF LOCAL AND REGIONAL PROVIDERS, TO A FEW NATIONAL PROVIDERS. THE DEPARTMENT PROPOSED FOUR NATION-WIDE LICENSEES, HOWEVER A FINAL DECISION ON THIS MATTER HAS YET TO BE TAKEN. AS CONCERNS CANADIAN OWNERSHIP, BECAUSE OF THE TELECOMMUNICATIONS POLICY FRAMEWORK ANNOUNCED BY THE MINISTER IN JULY 1987, LICENSEES WILL HAVE TO BE AT LEAST 80% CANADIAN OWNED OR CONTROLLED.

AS REGARDS THE QUESTION OF SPECTRUM, THERE SEEMS TO BE A GOOD CONSENSUS ON THIS MATTER. WITHOUT PREJUDICING FURTHER THOUGHT AND ANY FINAL DECISION, IT WOULD APPEAR THAT AN 8 MHZ CHUNK OF CONTINUOUS SPECTRUM WILL BE APPROPRIATE FOR THE COMMERCIAL DEBUT OF CORDLESS TELEPHONE SERVICE, MOST LIKELY IN THE 944-952 MHZ SPECTRUM RANGE.

ANOTHER ISSUE OF GREAT INTEREST IS IN THE AREA OF REGULATORY POLICY, AND MORE PARTICULARLY, HOW CORDLESS TELEPHONE SERVICES WILL BE LICENSED. A MAJOR

CONCERN HERE IS THAT WITH THE USE OF MICROCELLULAR TECHNOLOGY, THE LARGE NUMBER OF BASE STATIONS THAT ARE REQUIRED FOR NETWORK SYSTEMS WILL RESULT IN A LARGE ADMINISTRATIVE BURDEN. WHILE THIS IN FACT APPEARS TO BE A WELL FOUNDED CONCERN, IT SHOULD BE POINTED OUT THAT UNDER CURRENT LEGISLATION IT MAY NOT BE POSSIBLE TO LICENSE UNDERTAKINGS AS SOME HAVE SUGGESTED. THUS, IT WOULD APPEAR THAT THE DEPARTMENT WILL BE OBLIGED TO LICENSE EVERY TELEPOINT. A CREATIVE RESOLUTION OF THIS PROBLEM MAY YET STILL BE FOUND, HOWEVER. ON A MORE POSITIVE NOTE, THOUGH, THE SUGGESTION FOR EXEMPTING FROM LICENSING OF RESIDENTIAL AND BUSINESS EQUIPMENT IS A VERY DEFINITE POSSIBILITY, AND WILL LIKELY BE ACTED UPON.

THE INDUSTRY ADVISORY COMMITTEE ON PUBLIC CORDLESS TELEPHONE SERVICE IS INVESTIGATING MANY OF THE ISSUES RELATING TO THE COMMERCIAL INTRODUCTION OF PUBLIC CORDLESS TELEPHONE SERVICE IN CANADA, AND MANY OF YOU ARE PARTICIPATING DIRECTLY IN THE SUB-COMMITTEES WHICH ARE RESPONSIBLE FOR LOOKING INTO THESE QUESTIONS. THE

DEADLINE FOR THE FINAL CONSENSUS REPORT OF THE COMMITTEE IS SEPTEMBER 1991, HOWEVER IT IS EXPECTED TO BE FILED EARLIER THAN THAT DATE. REMARKABLE PROGRESS HAS BEEN MADE TO DATE ON MANY DIFFICULT QUESTIONS. OF COURSE MERRILL SHULMAN WILL BE TALKING TO YOU IN MORE DETAIL ABOUT THE WORK OF THE COMMITTEE, AND WHERE THIS WORK PRESENTLY STANDS.

CONCLUSION

I WOULD LIKE TO EXPRESS MY APPRECIATION FOR BEING GIVEN THE OPPORTUNITY TO TALK TO YOU ABOUT SOME OF THE KEY POLICY ISSUES RELATING TO PUBLIC CORDLESS TELEPHONE SERVICE AND TO PROVIDE YOU WITH AN UPDATE ON THE DEPARTMENT'S THINKING ON WHERE WE ARE GOING WITH RESPECT TO THE POSSIBLE COMMMERCIAL IMPLEMENTATION OF PUBLIC CORDLESS TELEPHONE SERVICE.

THANK YOU LADIES AND GENTLEMEN.

Presentation By:

Leonard M. Katz

BIOGRAPHY

Mr. Katz is the Assistant Vice President - Government and Inter-Carrier Relations at Rogers Cantel Inc. He joined Cantel in 1985 as Director of Corporate Planning, and has also held the position of Director of Market Development.

In his current capacity, Mr. Katz is responsible for all regulatory and licensing aspects of Cantel's operations including all applications to Government, Regulatory Boards and telephone companies as it relates to product or service approvals. Mr. Katz successfully led the Company's recent application seeking one of the three international paging frequencies compatible with U.S. operators.

Mr. Katz has been Cantel's chief negotiator in securing interconnection throughout Canada.

In his capacity as A.V.P. Gov't & Intercarrier Relations, Mr. Katz is also responsible for all activities and negotiations with U.S. operators. In this regard, it should be noted that Cantel has the largest network of cellular interconnect roaming agreements worldwide.

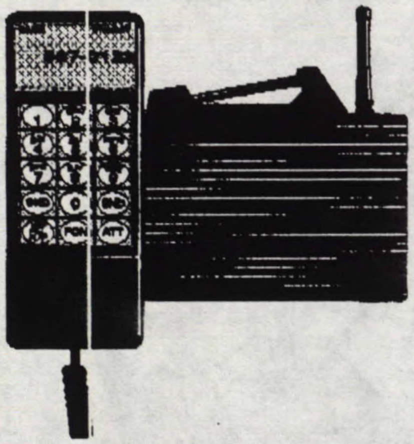
Mr. Katz has been in his current position since February 1988. He has 16 years experience in the telecommunications industry in Canada. Prior to his employment with Cantel, Mr. Katz spent 12 years with Bell Canada in Marketing, Policy Development, Regulatory and Comptrollers Departments.

Mr. Katz is active in numerous associations in Canada and the United States, including the Cellular Telecommunications Industry Association (CTIA) in Washington, D.C., Telocator, and the RadioComm Association of Canada. He is presently the Chairman of the Clearinghouse Committee of the CTIA and the President of the RadioComm Association of Canada.

Mr. Katz is a graduate of McGill University (BMA) in Montreal, Quebec, and did his undergraduate studies at Sir George Williams University.

Rogers Cantel Inc. owns and operates Canada's only national cellular telephone network which currently provides service to more than 200,000 customers in 60 Canadian Centres.

Cantel Is



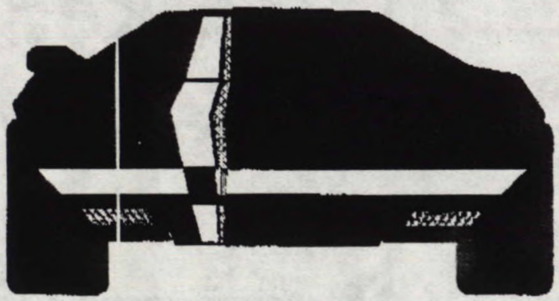
Cellular

Extensive microwave back-haul network

Paging

-900 MHz system
-Local, national & international

Mobile Data



-Based on Ericsson's Mobitex standard
-Open standard air interface
-900-902 MHz

CANTEL

WHO IS CANTEL?

Canada's only national cellular carrier

We compete against 13 regional wirelines

We offer service on a national basis

- 350+ cell sites
- 10,000+ radio channels
- 70+ cities covered
- 75% of Canadian market
- 230,000+ customers

CANTEL

WHO IS CANTEL?

-We operate from St. John's Newfoundland to Victoria B.C.

-A distance of over 3,000 miles

-Operate in every Canadian (Sept 90) Province

CANTEL

CCTT WILL DEMAND

Continuing development from current hardware

- There is currently no perfect technology
- Any standard must have capability to offer increased functionality
- Hardware must be backwards compatible to the greatest extent possible

CANTEL

What is CANTEL Doing About it

Cantel's response to DOC request for comments

Industry Structure:

- 4 Carriers in any one area (national, local,regional)
- extend cellular carriers' mandate to include CCIT
- No-Cross subsidization from monoplpoly base
-80% Canadian ownership

What is CANTEL Doing About it

Cantel's response to DOC request for comments

Operating Functionality

Dynamic Power Control

Queuing

Roaming & Handoff

What is CANTEL Doing About it

Cantel's response to DOC request for comments

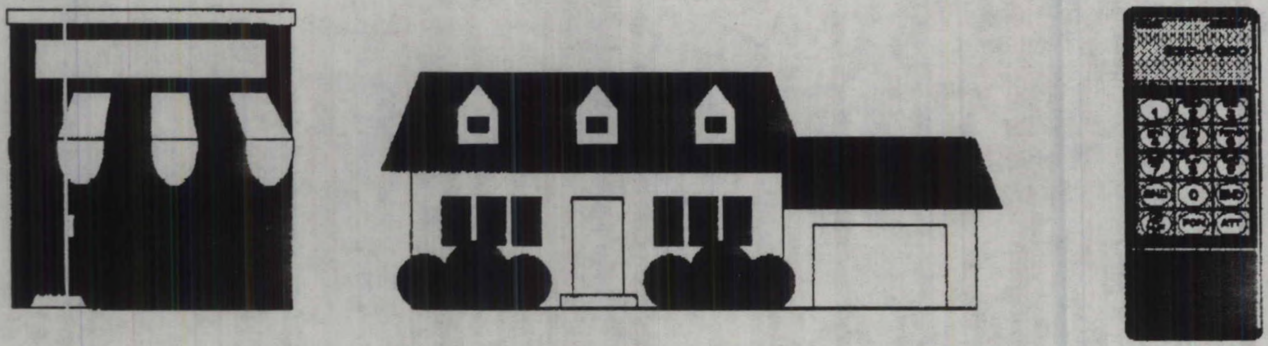
Spectrum Allocation

- Dynamic Frequency Allocation
- TDMA or FDMA
- Allocate at least 10 MHz of bandwidth
- Prefer North American coordination
- 942-952 MHz is best spectrum

What is CANTEL Doing About it?

Cantel's response to DOC request for comments

Licensing:



License Exempt

System Operator
License Required

What are Cantel's Trial Plans

We have not yet decided on any one technology or supplier

Cantel will trial a range of equipment
- From around the world
- From several different manufactures
- Representing several technologies

Cantel will undertake extensive market research

Cantel is committed to maintaining its position as Canada's leading mobile communications service provider.

Beyond MSAT to Personal Communications via Satellite

Dr. E.J. Hayes

ABSTRACT

The Vision 2000 initiative has created considerable interest within the Department of Communications (DOC) in the topic of personal communications. While it is well recognized that any future personal communications network will likely have a significant terrestrial component, DOC has recently been studying the role of satellites in such a network. The MSAT mobile satellite system will be providing some preliminary personal communications capability at L-band by means of a mobile telephone service. In an effort to define the future requirements for satellites in providing personal communications services beyond MSAT, DOC has recently been carrying out a number of studies involving both contractors and in-house research resources. Consistent with similar studies in both the USA and Japan, DOC is evaluating the feasibility of providing both mobile and personal communications services via geostationary satellites operating in the Ka-band. The intent of these studies is to provide inputs to assist DOC in developing a Long Term Space Plan. This paper will summarize the results of these various DOC studies.

BIOGRAPHY

Dr. E.J. Hayes graduated from the University of Ottawa in 1968 with a Bachelor of Applied Science degree in Electrical Engineering. He received an Athlone Fellowship to carry out postgraduate studies at the Imperial College of Science and Technology in London. He obtained a Doctor of Philosophy degree in Electrical Engineering from the University of London in 1973. Since joining the Communications Research Centre of the Department of Communications in 1975 he has worked on a number of satellite programs including the aeronautical satellite (AEROSAT) program and the search and rescue (SARSAT) satellite program. Dr. Hayes presently manages a group which is responsible for conducting research into advanced satellite communications systems and technologies.

BEYOND MSAT TO PERSONAL COMMUNICATIONS VIA SATELLITE

Edward J. Hayes

Communications Research Centre
Department of Communications
Ottawa, Ontario, Canada

ABSTRACT

The Vision 2000 initiative has created considerable interest within the Department of Communications (DOC) in the topic of personal communications. While it is well recognized that any future personal communications network will likely have a significant terrestrial component, DOC has recently been studying the role of satellites in such a network. The MSAT mobile satellite system will be providing some preliminary personal communications capability at L-band by means of a mobile telephone service. In an effort to define the future requirements for satellites in providing personal communications services beyond MSAT, DOC has recently been carrying out a number of studies involving both contractors and in-house research resources. Consistent with similar studies in both the USA and Japan, DOC is evaluating the feasibility of providing both mobile and personal communications services via geostationary satellites operating in the Ka-band. The intent of these studies is to assist DOC in developing inputs to the Long Term Space Plan. This paper will summarize the results of these various DOC studies.

1.0 INTRODUCTION

The last decade has witnessed the large scale proliferation of Very Small Aperture Terminal (VSAT) technology among satellite communications users. During the present decade the launch of MSAT in 1993 will mark the commercial introduction of Land Mobile Satellite Services (LMSS) at L-band throughout North America. In the expectation that the next major enhancement to satellite communications will be the extension of VSAT and MSAT to the personal level early in the next century, several organizations, including the Department of Communications (DOC), are studying the technical feasibility of satellite-based personal communications systems. The system concepts being studied are capable of providing the user with a degree of portability and freedom of access which present technology simply cannot provide. The ultimate aim of these systems is to provide satellite services directly to hand-held communicators. In order to achieve this objective, all of the system concepts under study are investigating the use of the Ka-band (30/20 GHz) in order to take advantage of the large spectral bandwidths available at these frequencies as well as the high radiated power levels that can be achieved through the use of spot beam antennas.

This paper is intended primarily to summarize the activities that are taking place both in Canada and abroad related to the application of Ka-band satellite systems to personal communications. In Section 2.0 the activities of three foreign organizations will be summarized in order to provide a background of what is taking place internationally. In the United States the National Aeronautics and Space Administration Jet Propulsion Laboratory has been carrying out studies of a Personal Access Satellite System for several years. In Japan the Communications Research Laboratory of the Ministry of Posts and Telecommunications has been preparing to carry out a personal satellite communications experiment. In Europe a study has been conducted of the feasibility of implementing a picoterminal to operate with the 30/20 GHz repeater on the Olympus satellite.

In Section 3.0 the results of three DOC studies will be presented. The first study was carried out under contract by Lapp-Hancock Associates Limited to provide inputs to assist DOC in developing a long term satellite communications strategy. The second study was carried out by the Communications Research Centre to provide a preliminary assessment of the technical feasibility of providing a number of candidate personal communications services via an EHF geostationary satellite. The third study is presently being carried out by Spar Aerospace Limited to study the feasibility of an advanced satellite communications system.

Section 4.0 provides a brief description of the Olympus and the Advanced Communications Technology Satellites both of which can provide a Ka-band communications capability over North America to support the experimental evaluation of a satellite based personal communications system. A summary of future planned DOC activities is presented in Section 5.0.

2.0 FOREIGN STUDIES

Three studies have been carried out by foreign organizations to evaluate the technical feasibility of providing various personal communications services via satellite directly to users using pocket size terminals. A summary of these studies is provided in the following sections.

2.1 NASA/JPL STUDY

For several years the National Aeronautics and Space Administration Jet Propulsion Laboratory (NASA/JPL) has been studying the technical feasibility of a Personal Access Satellite System (PASS) [1-3]. The PASS ground segment consists of the following four types of user terminals:

- supplier terminals
- basic personal terminals
- enhanced personal terminals
- remote monitors

In addition to these user terminals, there is also a Network Management Centre (NMC) and a Telemetry, Tracking and Command (TT&C) station. The supplier terminals are operated by service providers which are either private organizations or government agencies. The basic personal terminal is a hand held device capable of providing either digital voice or 4.8 kbps data. The enhanced personal terminal is envisioned as a miniature VSAT capable of providing voice and high speed data services with the data rate depending on the antenna size. The remote monitors are intended for applications such as meteorological or geophysical data collection. Collectively the PASS concept is intended to provide the following services:

- voice communications
- data base inquiry
- paging
- low rate broadcasting
- video
- data distribution networks
- remote monitoring & control
- disaster & emergency communications

The strawman PASS satellite design provides two antennas with contiguous United States (CONUS) coverage for communications between the satellite and the supplier terminals, the NMC and the TT&C station. Communications between the satellite and the personal terminals and remote monitors is provided by means of a multiple beam array (MBA) antenna on the satellite which gives CONUS coverage using 142 fixed spot beams each with a 0.35° beamwidth.

The strawman PASS concept uses a hybrid frequency division multiple access - time division multiple access (FDMA/TDMA) architecture. Forward links from the supplier terminals to the users operate in an FDMA/TDMA mode at data rates up to 100 kbps for the basic personal terminals and up to 300 kbps for the enhanced personal terminals. The suppliers choose the TDMA channel frequency depending on the spot beam in which the intended user is located. The return links from the users to the suppliers use a single-channel-per-carrier (SCPC)/FDMA/demand assigned multiple access (DAMA) architecture. The links from the ground to the satellite use 30 GHz while those from the satellite to the ground use 20 GHz. In order to compensate for the effects of rain fade attenuation, which can be quite severe at these frequencies, the forward links to the user terminals use a combination of uplink power control and date rate reduction while the return links from the user terminals use only data rate reduction. Some variants to the strawman design described above have been evaluated including the use of non-geostationary orbits [4,5] and the use of other multiple access techniques [6,7]. In general these studies have identified no significant improvements to the strawman PASS concept.

2.2 JAPANESE EXPERIMENT

The Communications Research Laboratory (CRL) of the Japanese Ministry of Posts and Telecommunications (MPT) has been developing a personal satellite communications experiment for several years [8-10]. Within the context of this experiment, the use of the term personal means that each home will have its own small terminal. Terminals with a 30 cm antenna and a 1 Watt power amplifier (PA) will support data rates of 64 kbps while a terminal with a 40 cm antenna and a 2 Watt PA will support data rates up to 512 kbps. The system, which will operate in the millimeter wave frequency band (43/38 GHz) using a steerable spot beam antenna with a 0.6° beamwidth between the satellite and the personal terminals and the quasi-millimeter wave frequency band (30/20 GHz) for the feeder link to a master hub station, will provide the following services:

- portable video telephone
- information exchange between universities & libraries (e.g. voice, TV, facsimile, computer files, etc)
- portable news gathering & distribution
- medical & health consultation
- observation data transmission (e.g. meteorological and geophysical data)
- mobile information (e.g. communications, positioning, traffic & map data)

In performing the link design, it has been assumed that the availability will be 95% -99%. This availability is based on the assumption that personal communications services will not require the high link availabilities typical of commercial systems. With this assumed availability, relatively simple countermeasures are required to counteract the effects of rain attenuation. These include reducing the data rate during light rain and delaying transmission during periods of heavy rain. CRL intends to evaluate this system experimentally using the Engineering Test Satellite ETS-VI which is scheduled for launch in 1993 [11].

2.3 EUROPEAN STUDY

The European Space Agency (ESA) has been studying the implementation of a miniature 30/20 GHz terminal for use with the Olympus satellite [12]. This pocket size terminal is 20 cm x 10 cm x 4 cm and uses separate 10 cm square transmit and receive patch antennas integrated into the terminal cover. The terminal is capable of receiving data at rates up to 40 kbps and transmitting data at 200 bps. The study concluded that it was technically feasible to implement such a terminal using Monolithic Microwave Integrated Circuit (MMIC) technology.

3.0 DOC STUDIES

The Department of Communications (DOC) has recently conducted a number of studies which addressed the concept of a satellite-based personal communications system. The first was a contract study conducted by Lapp-Hancock Associates Limited to provide recommendations to assist DOC in developing its long term satellite communications strategy [13]. During the same period the Communications Research Centre (CRC) of DOC was carrying out some preliminary studies of the technical feasibility of a 30/20 GHz personal communications satellite system [14,15]. The final study, which is just now being completed, is being carried out by Spar Aerospace Limited to evaluate the feasibility of an advanced satellite communications system [17].

3.1 LAPP-HANCOCK STUDY

The Lapp-Hancock study [13], which was co-sponsored by DOC, the Space Agency, Telesat Canada and Spar Aerospace Limited, was primarily intended to assist DOC in developing a long term satellite communications strategy as the basis for generating inputs to the Long Term Space Plan. One output of this study was the recommendation of four possible options for a government sponsored satellite communications payload which were rank ordered on the basis of a cost/benefit analysis as follows:

- Personal Communications at Ka-Band
- Hubless VSAT
- Inter-Satellite Links
- Remote Sensing Data Relay

The Ka-band personal communications payload was considered to be primarily a technology driven experimental initiative aimed at maintaining Canadian expertise in this developing area of satellite technology. The hubless VSAT payload was intended to support business applications by providing full mesh interconnectivity for VSAT networks at Ku-band. The inter-satellite link payload was proposed as a joint venture with NASA or ESA to develop either 60 GHz or optical technology to support international telecommunications applications. The remote sensing data relay payload was intended to develop inter orbit-link technology at 60 GHz with potential application to a second generation Radarsat.

3.2 CRC STUDIES

As a result of the interest created by the Vision 2000 initiative in personal communications, as well as the recognition of the on-going activities in the USA, Japan and Europe related to the provision of personal communication services via EHF geostationary satellites, CRC undertook some preliminary studies of the technical feasibility of a Ka-band satellite-based personal communications system [14,15]. While these studies recognized that in urban areas personal communications services would likely be provided by terrestrial systems, they identified a potential opportunity for satellites to extend the availability of such services to rural and remote areas. In particular, the following services were considered:

- near toll quality digitally encoded voice at data rates between 4.8 and 9.6 kbps;
- low speed data transmission at 4.8 kbps or less for various applications such as paging, remote monitoring and control, home computer data exchange, facsimile, emergency services, etc.;
- videophone and slow scan television for transmission of high resolution graphics and pictures at 64 kbps;
- teleconferencing and high quality videophone at rates well in excess of 64 kbps;
- direct to home broadcasting of high fidelity stereo digital sound broadcasting;
- direct to home broadcasting of high definition television (HDTV) programmes.

The types of user terminals envisioned for providing these services range from a battery-powered hand-held communicator using a 5 cm square microstrip patch array antenna for voice and low rate data to a miniature VSAT terminal with a 61 cm diameter antenna for the reception of HDTV.

Two satellite antenna coverage models have been studied. In the first Canada coverage is provided from the satellite by means of seven 1.5° spot beams [14] while in the second Canada wide coverage is provided by means of 42 spot beams each with a 0.6° beamwidth [15]. This latter beamwidth is the same as provided by both the Olympus and ETS-VI satellites. While the network architecture has not yet been defined in detail, it was assumed that the network would operate in a star configuration with all links passing through terrestrial gateway stations. The baseline multiple access technique is to use TDM for the forward link from the gateway stations to the users and to use a hybrid FDMA/TDM technique for the return link from the user to the gateway. In this hybrid return link, the link from the user to the satellite would use SCPC/FDMA/DAMA while the link from the satellite to the gateway would use TDM. The FDMA/TDM conversion would be done in the satellite by means of an on-board processor using either the digital signal processing (DSP) transmultiplexer method or the surface acoustic wave (SAW) chirp Fourier transform method [16].

3.3 SPAR AEROSPACE STUDY

As a follow-on to the Lapp-Hancock study, DOC issued a contract to Spar Aerospace Limited in January 1990 to carry out a detailed feasibility study of an advanced satellite communications system. This study was to concentrate on advanced satellite payload concepts consistent with the first two recommended options in the Lapp-Hancock study; that is, a Ka-band payload to support personal communications and a hubless VSAT payload to support business applications at Ku-band. The main objectives of the Spar study [17] were to:

- predict trends in satellite communications technology and in the marketplace over the next 15 years;
- identify new service opportunities for satellite operators within North America over the same time period;
- propose candidate payloads that could be flown as a government sponsored program on half an Anik-E3 satellite in the 1995-96 time frame;
- identify possible international collaboration;
- build upon existing Canadian expertise; and
- prepare schedule and budgetary estimates.

In carrying out this study, Spar was supported by subcontracts with Telesat Canada, MPR Teltech Limited and John A. Collins & Associates.

The Spar study was applications and service driven and limited itself to the following three potential service categories:

- Personal/Mobile Communications
- Advanced Private Business Networks
- Public Carrier Applications

The present discussion deals only with the personal communications aspects of the study.

The market assessment predicted a substantial market for personal communications services which would be met primarily by either terrestrial cordless telephone microcellular systems or cellular mobile radio systems because satellite systems cannot provide the ubiquitous access required by a truly personal communications system due to line of sight limitations caused by obstacles, such as buildings, in the transmission path. However, it seems likely that the huge capital investment required to install the infrastructure necessary to support a microcellular system will restrict this solution to the heavily populated urban areas. In North America, where population densities are much lower than in many European countries, it will likely be uneconomical to install microcellular systems in rural and remote areas. In rural areas either the cellular mobile radio system or satellites can be used to backhaul personal communications services to the fixed network. In remote areas satellites may be the only alternative available for this backhaul service. The degree of penetration that satellites can make into this market niche is clearly dependant on the cost competitiveness of satellites versus cellular mobile radio in rural and remote areas.

Other possible applications for satellites within an integrated personal communications network were also identified. One of these is a "Satellite Backbone Service" for providing trunk interconnection between terrestrial personal communications services base stations. Advanced satellites incorporating on-board switching and spot beam antennas could provide this service over wide geographic areas with full mesh interconnectivity. Another possible market niche for satellites is in the area of mobility management where the broadcast and wide area coverage capabilities of satellites would provide a natural advantage for paging. There may also be an opportunity to provide some direct-to-subscriber services to hand-held communicators to support resource exploration and other wilderness activities in remote areas.

The question of what frequency band the satellite system might use will again likely be determined by cost. MSAT could provide this service at L-band while other satellites could provide it at either C-band or Ku-band. It appears that the main motivation for considering Ka-band for this service would be spectrum congestion at the lower frequencies which is not expected to happen for at least 25 years. Other possible reasons for considering a move to Ka-band might be the potential of Ka-band to provide enhanced services which would not be available at the lower frequencies (e.g. wideband services which MSAT cannot provide at L-band) or the potential of much smaller and cheaper terminals at Ka-band.

The Spar study proposes a number of demonstration payload options including the combined Ku-band/Ka-band payload shown in Figure 1. The Ka-band portion of this payload is intended to support the demonstration of a personal communications system that would provide a data messaging service, digital voice and data communications via the following five generic terminal types:

1 - **Personal Message Terminal**
   - 50 word message service @ 4.8 kbps
   - 5.1 cm x 5.1 cm patch antenna

2 - **Hand-Held Voice Communicator**
   - 4.8 kbps duplex digital voice
   - 5.1 cm x 5.1 cm patch antenna

3 - **Portable Relay Terminal**
   - 4.8 kbps digital voice & messaging
   - 5.1 cm x 5.1 cm patch antenna

4 - **Enhanced Fixed Terminal**
   - 64 kbps data
   - 15 cm diameter dish

5 - **ISDN Terminal**
   - 144 kbps data
   - 30 cm diameter dish

The portable relay system concept and terminal are illustrated in Figures 2 and 3. This concept can be used to provide backhaul for a standard cordless telephone into the public switched telephone network (PSTN) from rural and remote locations.

The demonstration payload will provide a fully steerable spot beam antenna assembly in support of the Ka-band personal communications terminals. The 30 GHz receive antenna will have a 0.6° beamwidth which will provide, for example, the coverage shown in Figure 4 from an orbital location at 107.5°W. Because of space limitations on the Anik-E satellite, the 20 GHz transmit antenna will have a 1.3° beamwidth which, when used with the planned 20 Watt travelling wave tube amplifier (TWTA), will provide an EIRP of 53 dBW. The integrated services demonstration network would be managed by a single network management system which would consist of an overall Network Operations Centre (NOC) and a number of Network Control Centres (NCCs), one for each user group in the network. User groups would consist of a mixture of Ka-band personal terminals and fixed Ku-band stations which would provide a personal communications gateway function as well as support fixed VSAT services. The multiple access system would use SCPC/FDMA for the 30 GHz link from the personal communications terminals to the satellite and TDM for the 20 GHz link from the satellite to the terminals. The Ku-band fixed communications and feeder link system would use TDMA from the VSATs/Gateways to the satellite and TDM from the satellite to the VSATs/Gateways. All the NOC and NCC communications would be performed at Ku-band. It has been estimated that the proposed Ka-band personal communications demonstration system could support about 3000 voice users per beam.

A future operational satellite-based personal communications system would have an architecture similar to that described above for the demonstration where the integration of services could take place in a single satellite. Alternatively fixed and personal services could be performed on separate satellites with perhaps a degree of integration performed using inter-satellite links. For an operational personal communications system it has been estimated that Canada wide coverage would require 42 fixed spot beams having a 0.6° beamwidth. When coupled with a 20 Watt TWTA this antenna would provide an EIRP of 57 dBW per beam. Spar has concluded that such an operational system would be technically feasible by the year 2005.

4.0 Ka-BAND SATELLITES

There are two satellites which will be available to provide a 30/20 GHz capability over at least part of Canada during the 1990-95 period. The first is the ESA Olympus satellite and the other is the USA Advanced Communications Technology Satellite (ACTS).

4.1 OLYMPUS

The Olympus satellite, which was launched on July 11, 1989, is a three-axis stabilized satellite carrying the following four payloads [18]:

- a two-channel high power (63 dBW) TV broadcast payload operating in the 11.7-12.5 GHz band for direct-to-home transmission in Europe;
- a four-channel 12/14 GHz SS/TDMA payload for specialized or business services in Europe;
- a 30/20 GHz communications payload; and
- a propagation beacon payload operating at 12.5, 20 and 30 GHz.

The 30/20 GHz payload consists of a transponder which provides two 40 MHz narrow band channels and one 700 MHz wide band channel via two independently steerable linearly polarized transmit/receive spot beam antennas with a 0.6° nominal beamwidth. These antennas provide an edge of coverage G/T of 7.7 dB/°K and a minimum edge of coverage EIRP of 52.1 dBW. From its orbital location at 19°W Olympus can provide coverage of the eastern half of Canada up to the Ontario/Manitoba border.

4.2 ACTS

The NASA Advanced Communications Technology Satellite (ACTS) is a three axis stabilized satellite which is intended to support a three year experimental program following its launch in 1992 to an orbital location at 100°W. The ACTS program is intended to sponsor the development and experimental evaluation of the following high risk communications satellite technology [19,20]:

- **Multibeam Antenna** - a rapidly reconfigurable hopping beam antenna;
- **Baseband Processor** - a high speed digital switchboard in the sky;
- **Microwave Switch Matrix** - a dynamically reconfigurable switch to support high volume traffic;
- **Rain Fade Compensation** - techniques to adjust automatically to uplink and downlink rain fades; and
- **Ka-Band Components** - the development of both satellite and ground terminal hardware for the 30/20 GHz band.

The multibeam antenna provides both fixed and hopping spot beams with a 0.3° beamwidth. Three fixed spot beams provide coverage of Cleveland, Atlanta and Tampa. Two pairs of hopping beams scan an east and west sector to provide coverage of the northeastern United States as well as thirteen other metropolitan areas scattered across the USA. A 1.0° beamwidth mechanically steered antenna is also available to provide wider area coverage of CONUS, Alaska and Hawaii.

The baseband processor will be used with the hopping beams to provide demand assigned TDMA communications between small earth terminals located on customer premises. This processor will provide efficient use of transponder capacity through individual message routing and the provision of single hop mesh interconnectivity. The microwave switch matrix will be used with the three fixed spot beams for high volume point-to-point traffic in a satellite-switched TDMA mode. The rain fade compensation techniques will include forward error correction, uplink and downlink power control and ground terminal site diversity.

5.0 FUTURE PLANS

As part of its longer term planning, DOC is preparing a number of inputs to be submitted to the Canadian Space Agency for inclusion in the Long Term Space Plan. One of these inputs is for a multipurpose Ka-band communications satellite program to support second generation mobile services, personal communications and new fixed services. In addition CRC plans to continue conducting studies to define in more detail various concepts for a Ka-band satellite-based personal communications system. In parallel with these system studies, CRC is planning to initiate the development of 30/20 GHz satellite terminal technology suitable for personal communications applications. The near term aim of this terminal development is to have available within two years a small experimental terminal to support an evaluation of the various system concepts under study using the 30/20 GHz repeater on the Olympus satellite. The longer term objective is to develop over a five year period the technology base needed to manufacture the miniature components required to implement a prototype hand-held communicator for use in a 30/20 GHz satellite-based personal communications system.

ACKNOWLEDGEMENT

The author wishes to thank Mr. Peter Garland of Spar Aerospace Limited for his assistance and for providing Figures 1-4.

REFERENCES

[1] Sue, M. K., A. V. Vaisnys and W. Rafferty, A 20/30 GHz Personal Access Satellite System Study, 38th IEEE Vehicular Technology Conference, June 1988.

[2] Estabrook, P., et al., A 20/30 GHz Personal Access Satellite System Design, International Conference on Communications, Boston, June 1989.

[3] Sue, M. K., et al., A Satellite-Based Personal Communications System for the 21st Century, 2nd International Mobile Satellite Conference, Ottawa, June 1990.

[4] Estabrook, P., and M. Motamedi, Use of Non-Geostationary Orbits for a Ka-Band Personal Access Satellite System, 13th AIAA International Communications Satellite Systems Conference & Exhibit, March 1990.

[5] Estabrook, P., and M. Motamedi, Use of Non-Geostationary Orbits for a Ka-Band Personal Access Satellite System, 2nd International Mobile Satellite Conference, Ottawa, June 1990.

[6] Motamedi, M., and M. K. Sue, A CDMA Architecture for Ka-Band Personal Access Satellite System, 13th AIAA International Communications Satellite Systems Conference & Exhibit, March 1990.

[7] Motamedi, M., Multiple Access Capacity Trade-offs for a Ka-Band Personal Access Satellite System, 2nd International Mobile Satellite Conference, Ottawa, June 1990.

[8] Shimada, M., et al., Millimeter Wave Personal Radio Using an Advanced Communications Satellite, IEEE Communications Magazine, Vol. 22, No. 9, September 1984.

[9] Isobe, S., et al., Personal Satellite Communications Experiment for Future Systems in Asia-Oceanian Region Using Millimeter-Wave, Pacific Telecommunication Council 10th Annual Conference, Honolulu, February 1988.

[10] Isobe, S., et al., Experimental Personal Satellite Communications System Using Millimeter-Wave for Asia-Oceanian Region, Journal of the Communications Research Laboratory, Vol. 35, No. 145, July 1988.

[11] Shimada, M., et al., Experimental Millimeter-Wave Satellite Communications System, Pacific Telecommunication Council 12th Annual Conference, Honolulu, January 1990.

[12] Barton, S. K., and J. R. Norbury, Ultra Small Earth Stations (Picoterminals) for 20/30 GHz Satellite Communication System, Proc. Olympus Utilization Conference, Vienna, April 1989.

[13] Lapp-Hancock Associates Ltd., A Study On Long-Term Satellite Communications Strategy, DOC Contract Study, October 1989.

[14] Tsang, E., and R. Douville, A Potential 21st Century Satellite Communications Application - Personal Communications, Canadian Satellite User Conference, Ottawa, June 1989.

[15] Caron. M., and D. Hindson, Personal Communications Via EHF Geostationary Satellites, Internal CRC Report, Directorate of Satellite Communications, Issue 001, August 1989.

[16] Loo, C., E. J. Hayes and J. G. Chambers, On-Board Processing in Future Communications Satellites, Canadian Satellite User Conference, Ottawa, June 1989.

[17] Spar Aerospace Ltd., Feasibility Study of Advanced Satcom System, DOC Contract Study, (in preparation).

[18] Olympus and Communications Systems Division, Olympus User's Guide, UG-6-1, Part 4, 20/30 GHz communications Payload, ESA Bulletin, No. 54, May 1988.

[19] Graebner, J. C. and W. F. Cashman, Advanced Communications Technology Satellite: System Description, IEEE Global Telecommunications Conference, Houston, December 1986.

[20] Schertler, R. J., ACTS Experiments Program, IEEE Global Telecommunications Conference, Houston, December 1986.

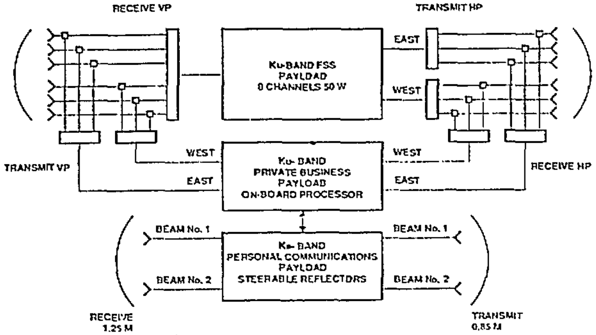


Figure 1: Combined Ku-Band/Ka-Band Demonstration Payload

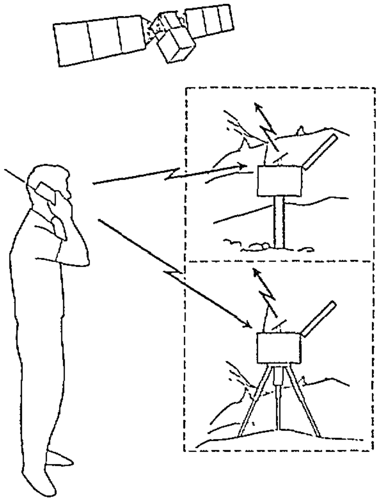


Figure 2: Ka-Band Portable Relay System Concept

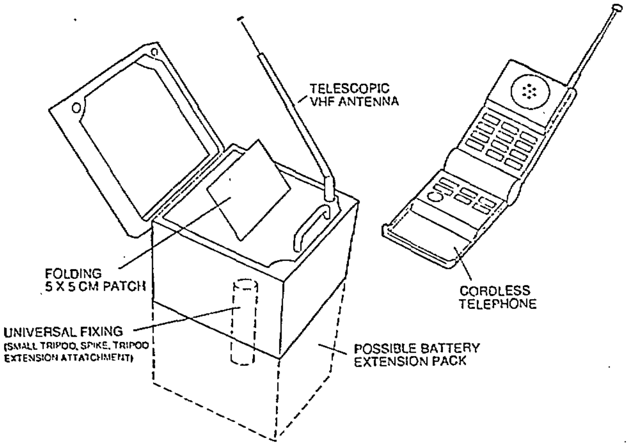


Figure 3: Ka-Band Portable Relay Terminal

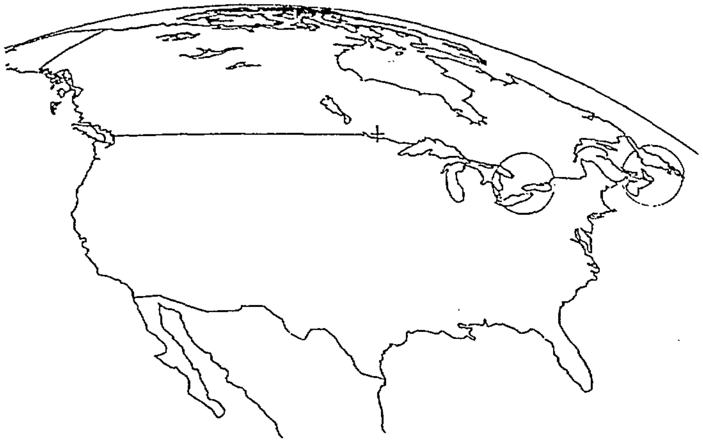


Figure 4: Example of Two Spot Beam Coverage at Ka-Band

Measurements of Wideband Propagation Characteristics for Indoor Radio with Predictions for Digital System Performance

Robert J.C. Bultitude

ABSTRACT

A wide variety of indoor radio propagation measurements have been reported in recent literature. Such measurements are usually recorded and reported in a manner such that Bello's GWSSUS model and associated performance prediction techniques can be applied in estimating the performance of future indoor digital radio systems. This is a result of assuming that indoor channels can be modelled in a similar manner to land mobile channels, which, under some circumstances, exhibit GWSSUS characteristics. There are, however, significant differences between the two channel types, and these differences necessitate the application of different models and the use of different digital system performance prediction methods in land mobile and indoor channel performance studies. The result is that some published data is unacceptable for its intended application.

This paper reports wideband measurement results for indoor channels and highlights comparisons between the measured results and the results of similar measurements on land mobile channels. A discussion follows regarding the suitability of the GWSSUS model for use in performance predictions for indoor channels. Finally, DPSK and BPSK performance predictions using both the GWSSUS model and a brute-force simulation procedure employment measured data are compared. If planned experiments are completed before the conference date, these results will also be compared with the results of actual DPSK performance data recorded on the measured channels. Based on these comparisons, recommendations will be made regarding the channel parameters that are important in performance analyses and should be reported in order to provide an appropriate data base for indoor system designers.

BIOGRAPHY

Robert J.C. Bultitude was born in Vancouver, Canada, on March 15, 1952. He received the BSc. Eng. degree from the University of New Brunswick, Fredericton, N.B., Canada in 1975, and the M.Eng. degree in electronics engineering from Carleton University, Ottawa, Canada in 1979. He received the PhD. degree in electronics engineering at Carleton in 1987.

Dr. Bultitude's professional career began with Hoyles Niblock Associates Ltd. in Vancouver, B.C. in 1975, where he worked for two years as a telecommunications systems design engineer. Then, after receiving the M.Eng. degree, he worked on RF problems in satellite systems at the Communications Research Centre (CRC) and on radar systems with Leigh Instruments Ltd., in Ottawa. He is now Manager of Mobile/Indoor Propagation Research, in the Radio Propagation Laboratory at CRC, where he has worked for the past 9 years.

Service and Modulation/Coding Aspects of the Canadian MSAT System

Peter J. McLane

Presentation Outline

1. Service Aspects Canadian MSAT
    - courtesy George Davies, Telesat Mobile
2. Reference Symbol plus Decision Directed Coherent Detection for QPSK and TCM 8-PSK
    - courtesy John Lodge, CRC (reference symbol research)
    - courtesy Gary Irvine, Queen's University at Kingston
3. Update on TRIO/Queen's TCM/8-DPSK Modem
    - courtesy Beno Koblents, Queen's University at Kingston, for timing (see Canadian Conference on Electrical and Computer Engineering, Ottawa, September 1990)

BIOGRAPHY

Peter J. McLane was born in Vancouver, B.C., Canada, on July 6, 1941. He received the B.A.Sc. degree from the University of British Columbia, Vancouver, in 1965, the M.S.E.E. degree from the University of Pennsylvania, Philadelphia, in 1966, and the Ph.D. degree from the University of Toronto, Toronto, Ont., Canada, in 1969. He held a Ford Foundation Fellowship at the University of Pennsylvania and a National Research Council of Canada Scholarship at the University of Toronto.

From 1966 to 1967 he was a Junior Research Officer with the National Research Council, Ottawa, Ont. He held summer positions there in 1965 and 1966 and with the Defence Research Board of Canada in 1964. He joined the Department of Electrical Engineering, Queen's University, Kingston, Ont., in 1969 as an Assistant Professor, and since 1978 he has held the rank of Professor. His research interests are in signal processing for digital communications systems and radar. Usually this involves computer-aided analysis, but of late he has been involved in experimental work involving microprocessors and LSI-based implementation. He has served as a consultant to the Canadian Department of Astronautics Ltd. of Ottawa, Ont., Spar Aerospace of Toronto, Ont., AT&T Bell Laboratories and Technology Group of Los Angeles, California. During 1984-1985 he was on leave at AT&T Bell Laboratories, Crawford Hill Laboratory, Holmdel, NJ.

Dr. McLane has been active in the IEEE Communications Society. He is a member of the Communication Theory Committee and served as its representative on the Technical Program Committee of the 1978 International Conference on Communications. He is a former Associate Editor for both the IEEE COMMUNICATIONS MAGAZINE and is currently an editor of the IEEE TRANSACTIONS ON COMMUNICATIONS. In addition, he was a co-editor of the Association of Professional Engineers of Ontario and Eta Kappa Nu, and is listed in American Men and Women in Science. He was named a Principal Researcher for TRIO in 1987 and an IEEE Fellow in 1988.

Service and Modulation/Coding Aspects of the Canadian MSAT System

Peter J. McLane
Department of Electrical Engineering
Queen's University at Kingston

OUTLINE

1. *Service Aspects Canadian MSAT*

   — courtesy George Davies,
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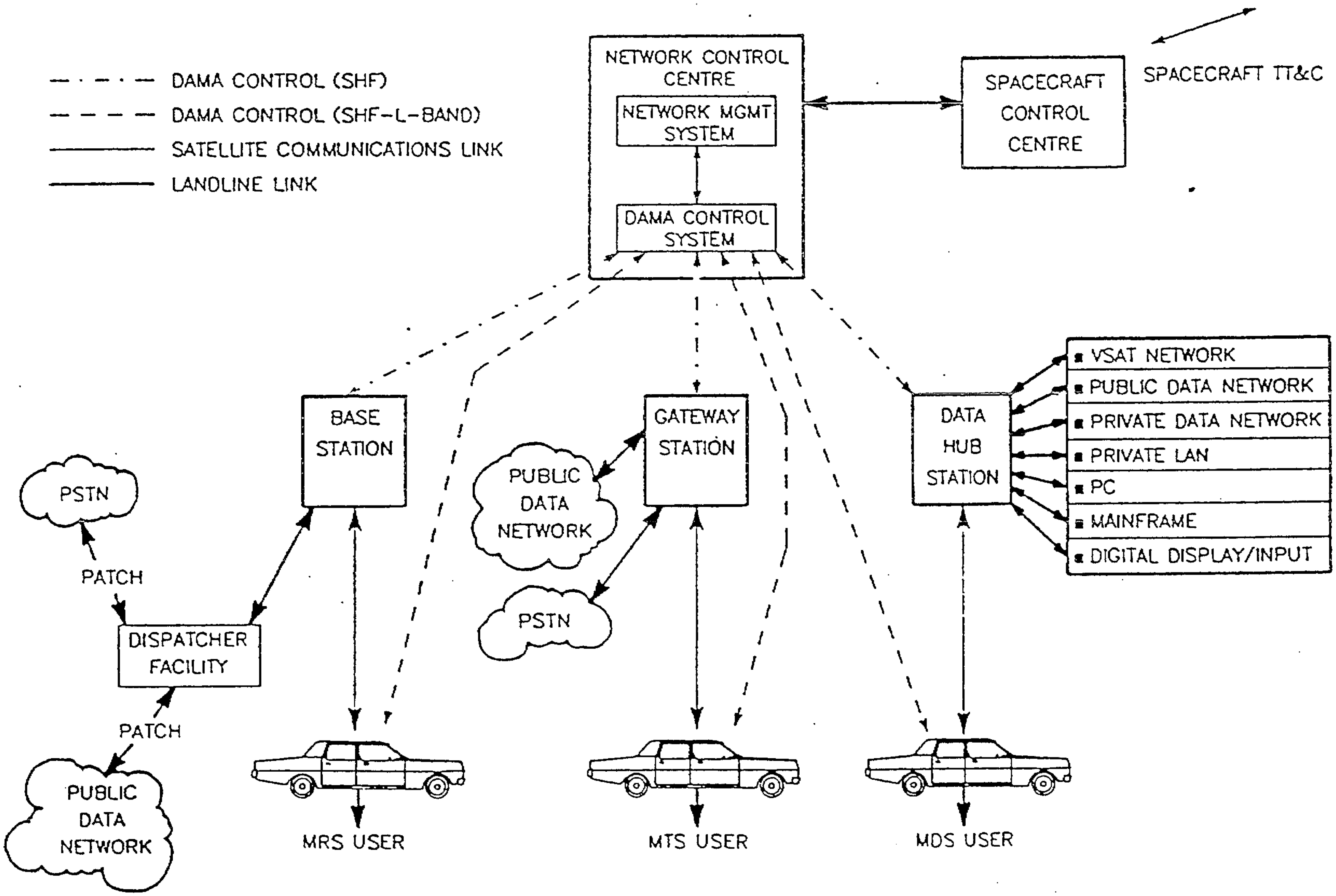

DAMA CONTROL (SHF)
DAMA CONTROL (SHF-L-BAND)
SATELLITE COMMUNICATIONS LINK
LANDLINE LINK
NETWORK CONTROL CENTRE
NETWORK MGMT SYSTEM
DAMA CONTROL SYSTEM
SPACECRAFT CONTROL CENTRE
SPACECRAFT TT&C
BASE STATION
GATEWAY STATION
DATA HUB STATION
VSAT NETWORK
PUBLIC DATA NETWORK
PRIVATE DATA NETWORK
PRIVATE LAN
PC
MAINFRAME
DIGITAL DISPLAY/INPUT
PSTN
PATCH
DISPATCHER FACILITY
PATCH
PUBLIC DATA NETWORK
PUBLIC DATA NETWORK
PSTN
MRS USER
MTS USER
MDS USER

Mobile Radio Service (MRS) - a circuit switched voice and data private network service.

Mobile Telephone Service (MTS) - a circuit switched voice and data service with interconnection to the public switched telephone network.

Mobile Data Service (MDS) - a packet switched data service with interconnection to private and public data networks.

Aeronautical Services - services which are compatible with international standards for mobile satellite communications with aircraft.

☐ facsimile transmission

☐ calling number identification

☐ priority calling

☐ interactive digital messaging

☐ data acquisition and control

☐ voice mail

☐ electronic mail

☐ location reporting

☐ call forwarding

☐ paging

☐ bulk data transfer

☐ interconnection with public voice and data networks

☐ data broadcast

Table 1 Mobile Voice Terminal

Antenna gain		10 dBic
G/T		-15 dB/K
Modulation	ACSSB or 4.8 kbps digital	
Unfaded C/No Target K=10 dB with light shadowing	ACSSB:	50.9 dB-Hz
	Digital:	49.4 dB-Hz
Satellite EIRP (per channel)	ACSSB:	29.8 dBW
	Digital:	26.7 dBW
Nominal Channel Spacing	5.0 kHz	

Table 2 L-band System Capacity

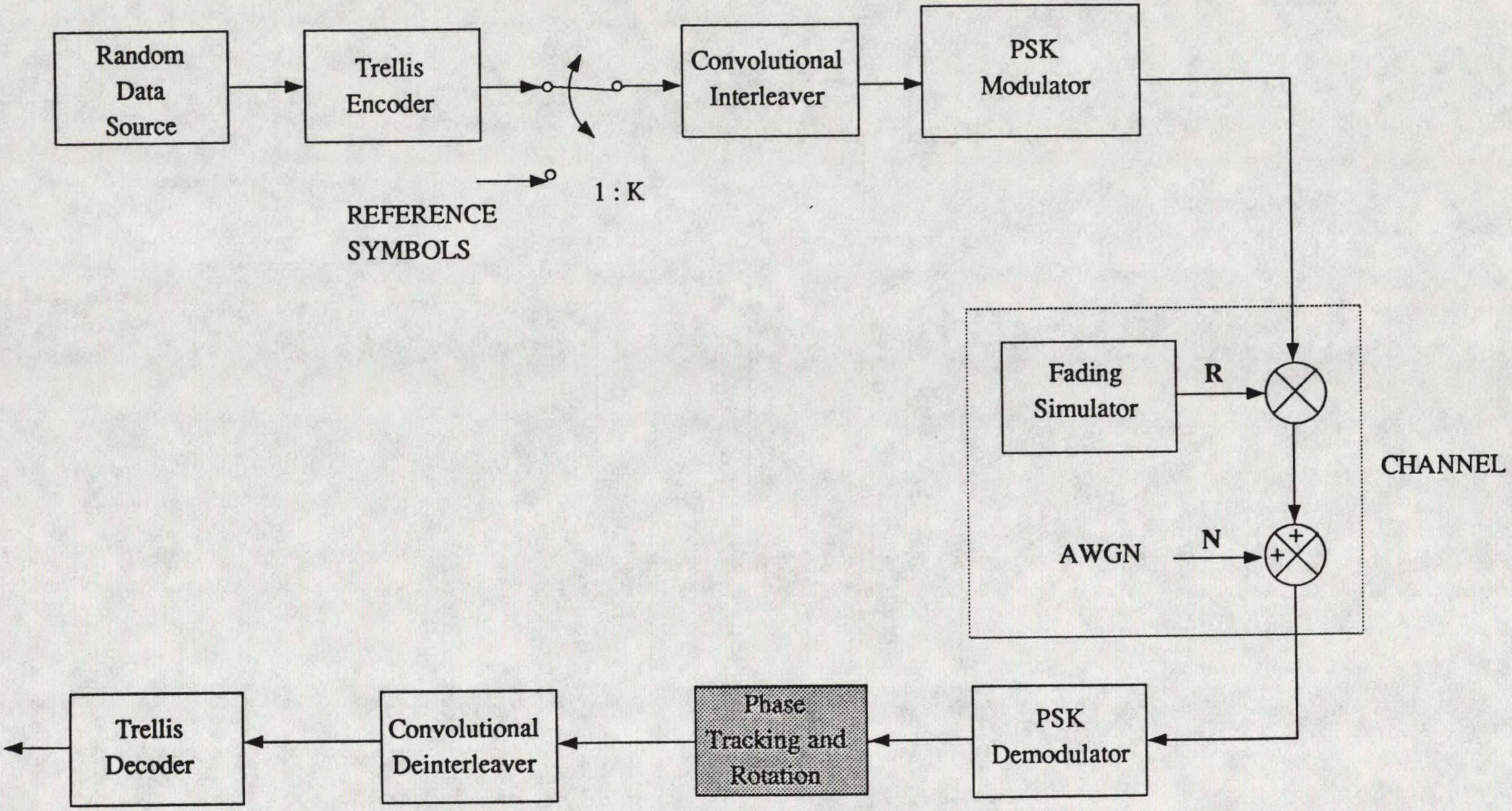
	ACSSB	Digital Modulation
Number of Active Carriers	371	758
Voice Activation Factor	0.40	0.40
Number of Assignable Voice Channels	927	1896
Assumed busy hour use/mobile erlang	0.01	0.01
Number of voice mobiles (5% blocking probability)	97,000	199,000

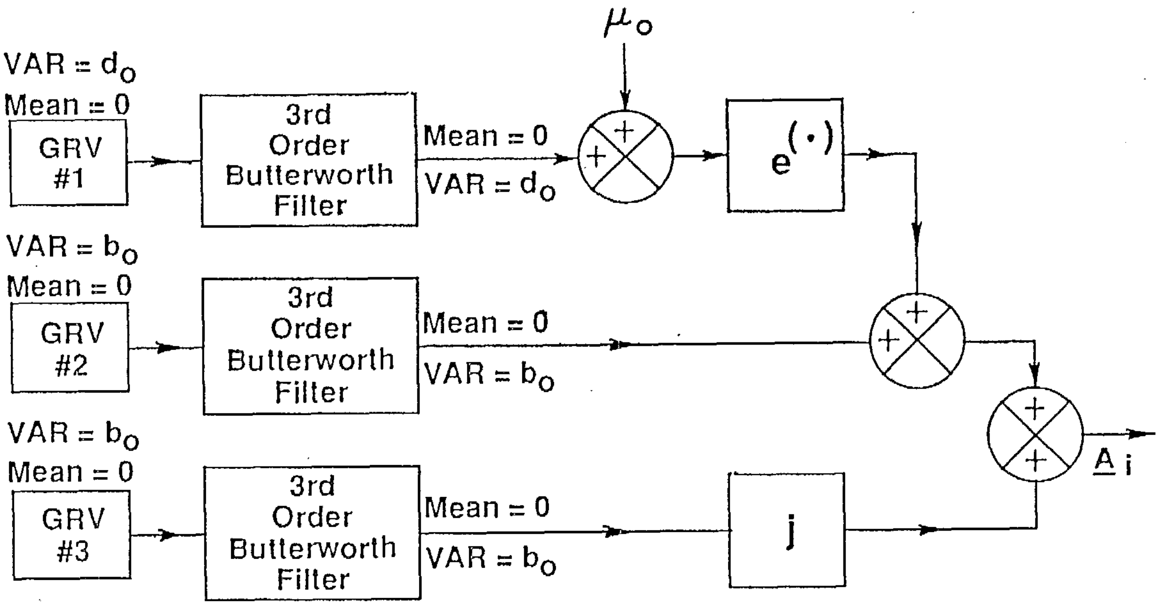
2. *Reference Symbol Plus Decision Directed Coherent Detection for QPSK and TCM 8–PSK*

— courtesy John Lodge, CRC
(reference symbol research)

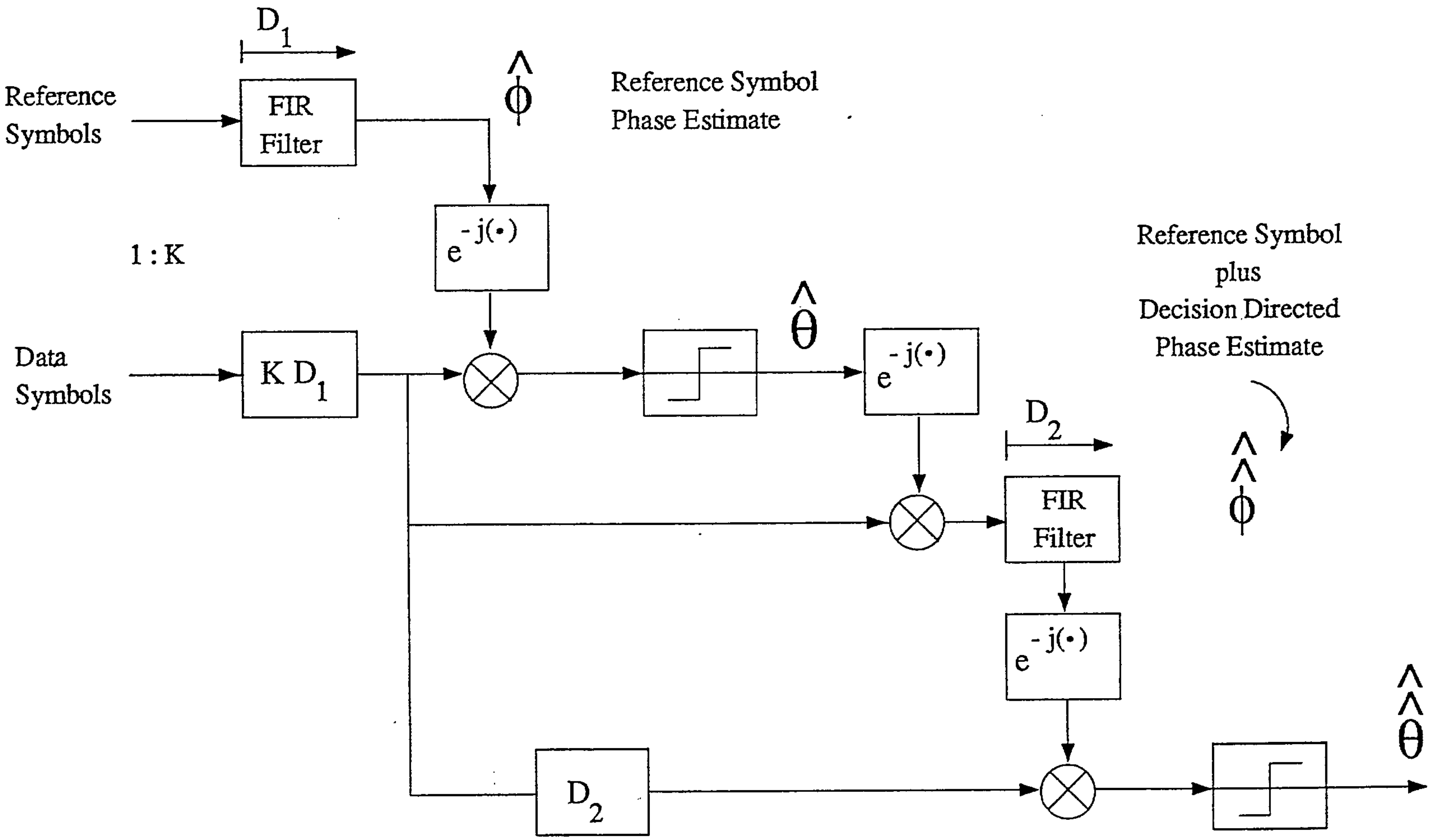
— courtesy Gary Irvine,
Queen's University

SYSTEM BLOCK DIAGRAM

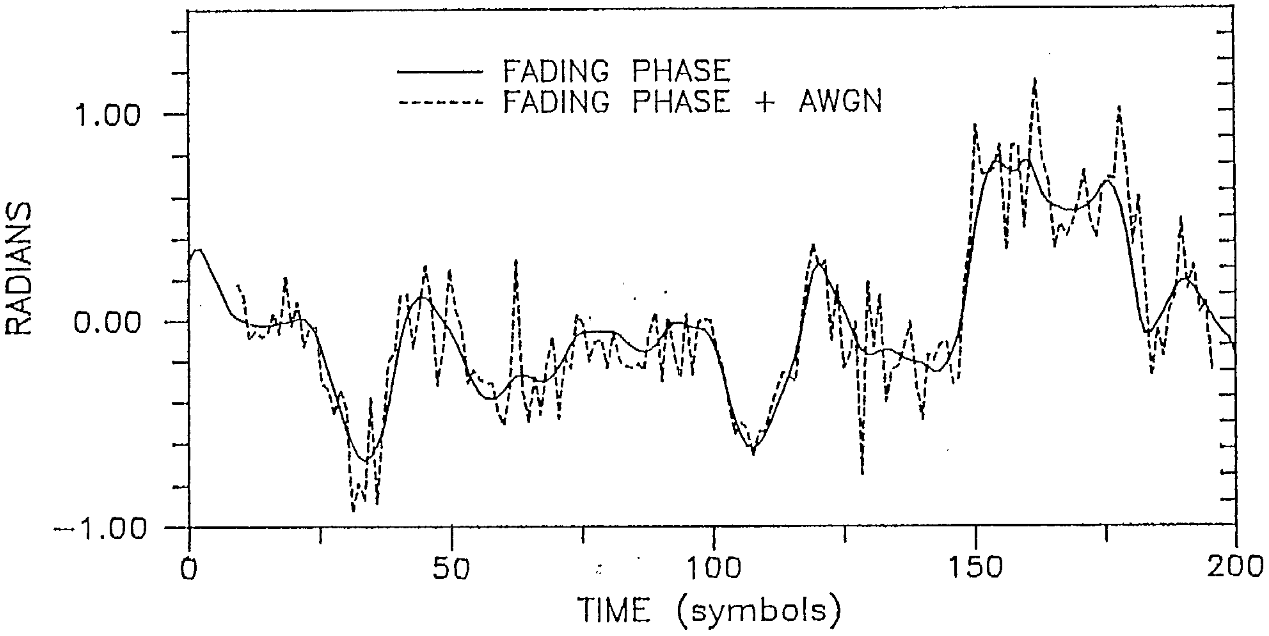



μ_o
VAR = d_o
Mean = 0
GRV #1
3rd Order Butterworth Filter
Mean = 0
VAR = d_o
$e^{(\cdot)}$
VAR = b_o
Mean = 0
GRV #2
3rd Order Butterworth Filter
Mean = 0
VAR = b_o
VAR = b_o
Mean = 0
GRV #3
3rd Order Butterworth Filter
Mean = 0
VAR = b_o
j
$\underline{A}_i$
+
+

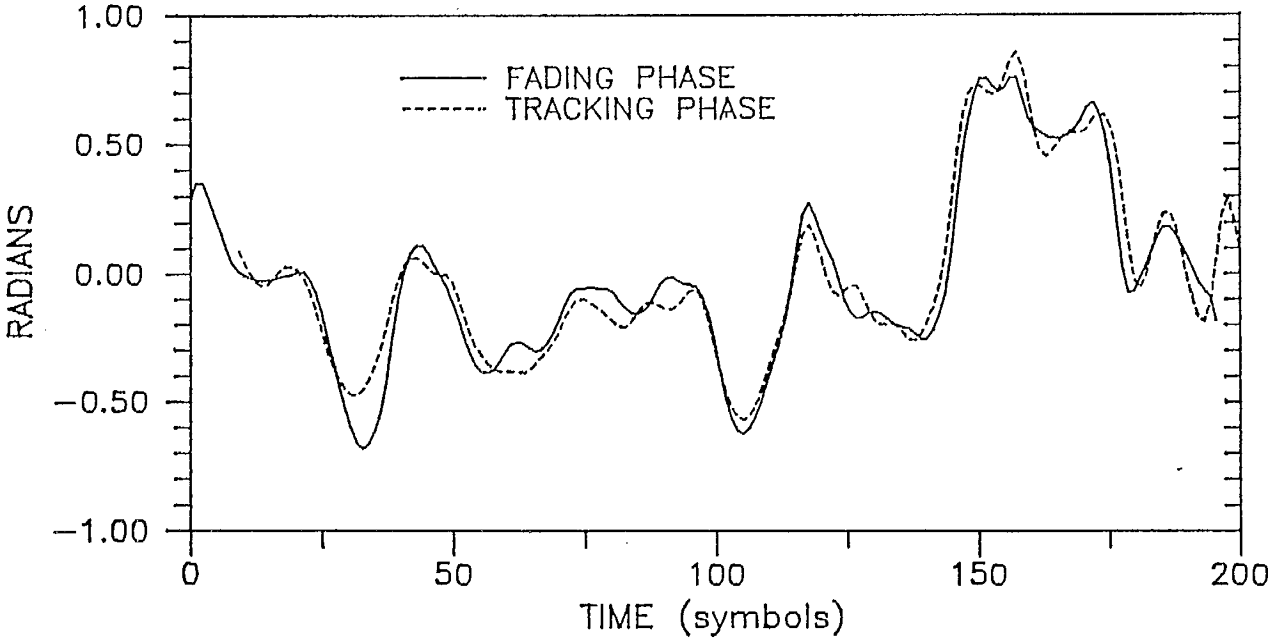
PHASE TRACKING AND ROTATION



$R_x = R\, e^{j(\theta+\phi+\psi)}$, where $R =$ fading amplitude
$\phi =$ fading phase
$\theta =$ modulation
$\psi =$ AWGN phase



FADING PHASE + AWGN (10dB)



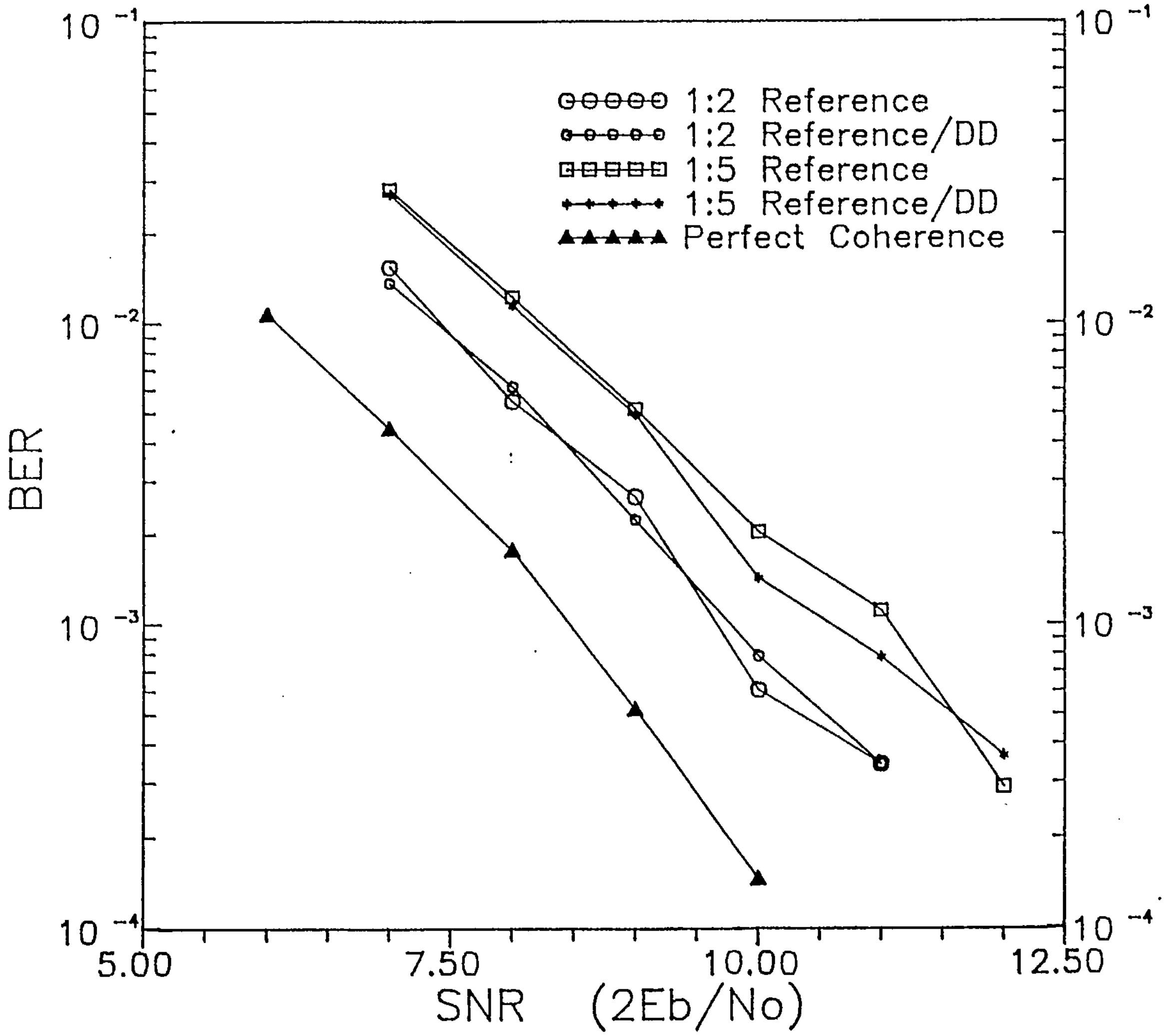
REFERENCE SYMBOL RATIO = 1:5

RATE 2/3 8PSK

CONVENTIONAL VITERBI

TRACKING: REFERENCE ONLY vs REFERENCE + DD

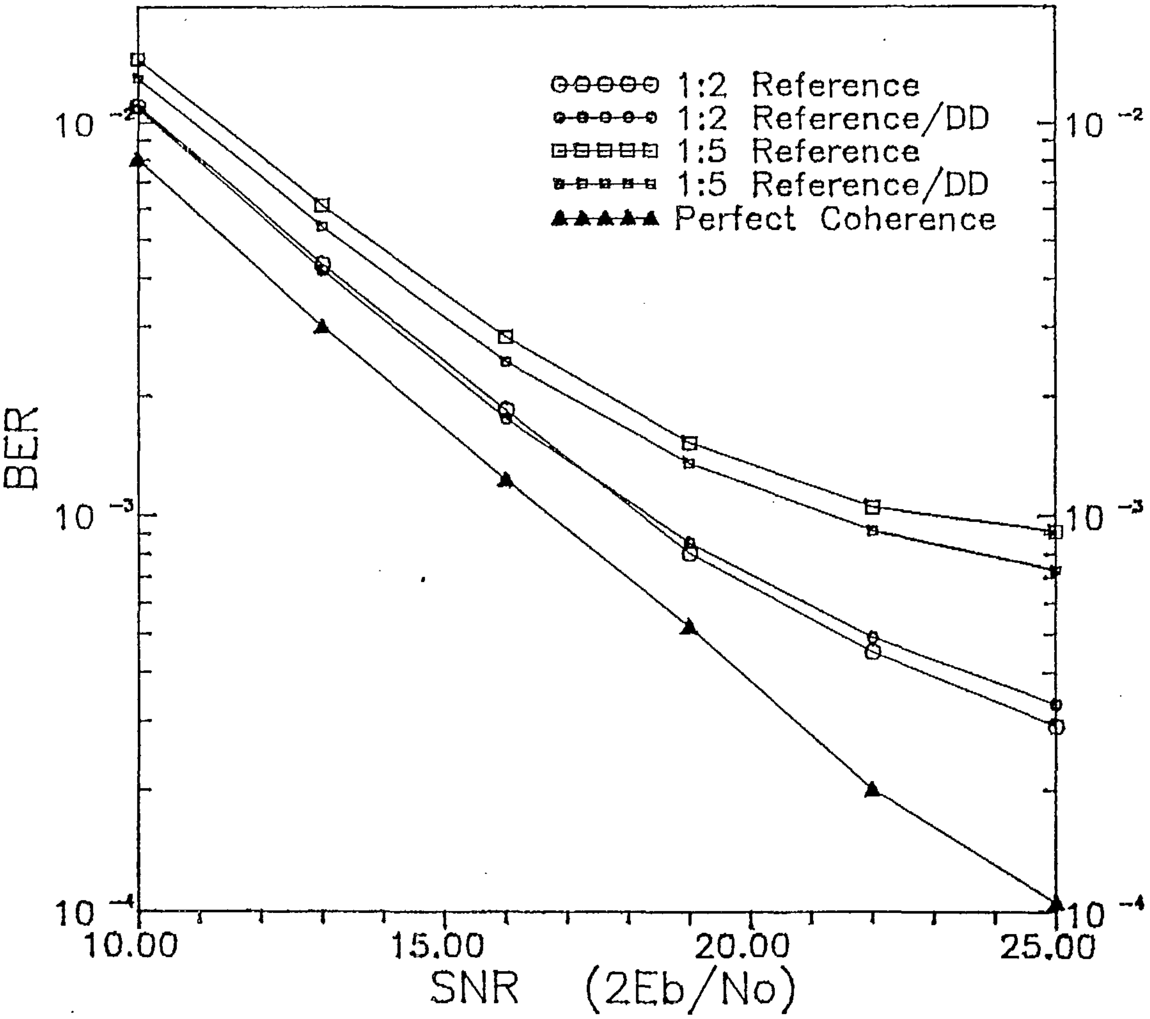
INTERLEAVING: 10 SYMBOLS



NOTE : SNR IS UNADJUSTED FOR 2dB EXTRA APPARENT TRANSMITTED POWER

UNCODED QPSK

TRACKING: REFERENCE ONLY vs REFERENCE + DD



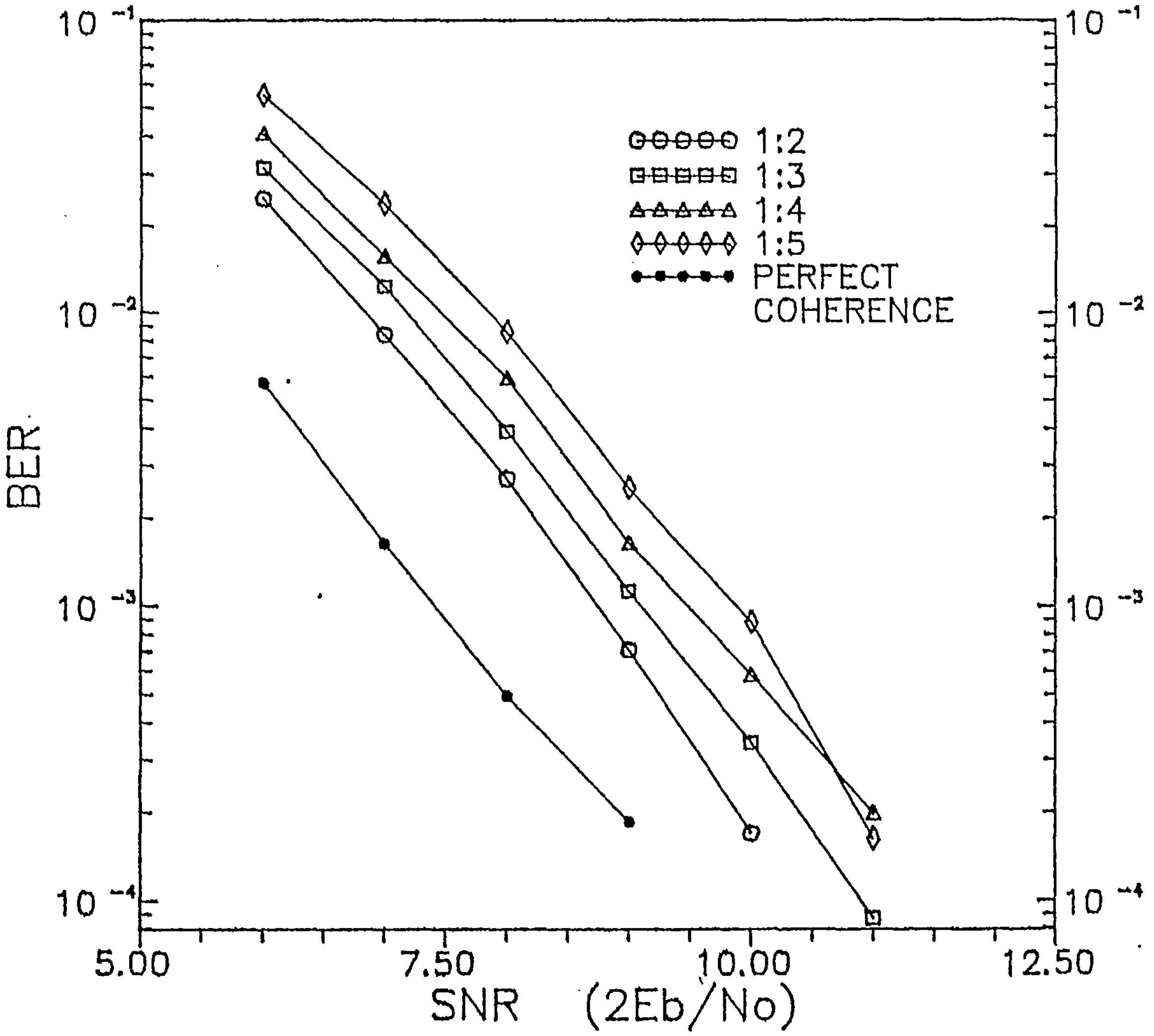
NOTE : SNR IS UNADJUSTED FOR 2dB EXTRA APPARENT TRANSMITTED POWER

RATE 2/3 8PSK

WEIGHTED METRICS

TRACKING: REFERENCE + DD

INTERLEAVING: 10 SYMBOLS



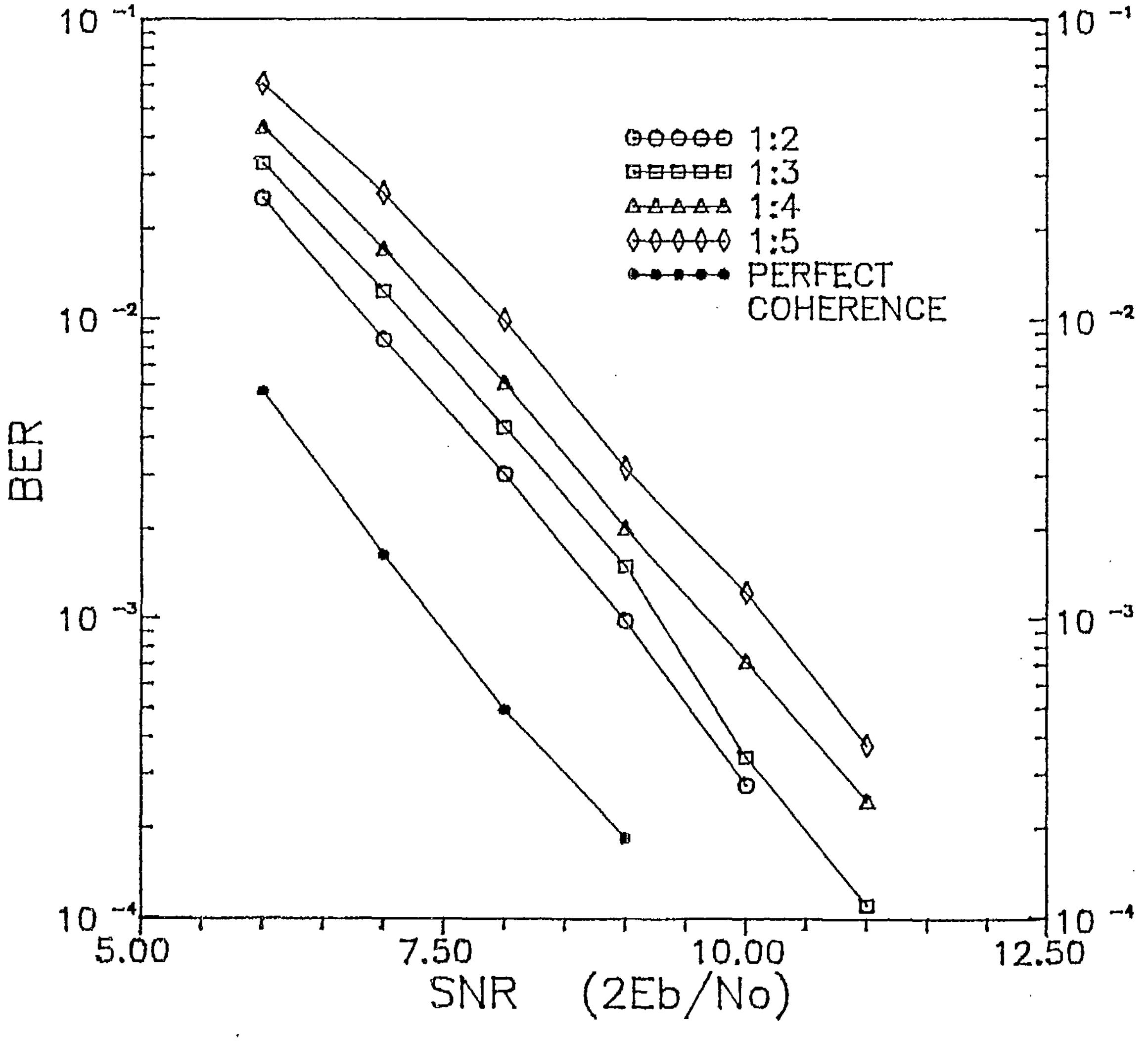
NOTE : SNR IS UNADJUSTED FOR 2dB EXTRA APPARENT TRANSMITTED POWER

RATE 2/3 8PSK

WEIGHTED METRICS

TRACKING: REFERENCE ONLY

INTERLEAVING: 10 SYMBOLS



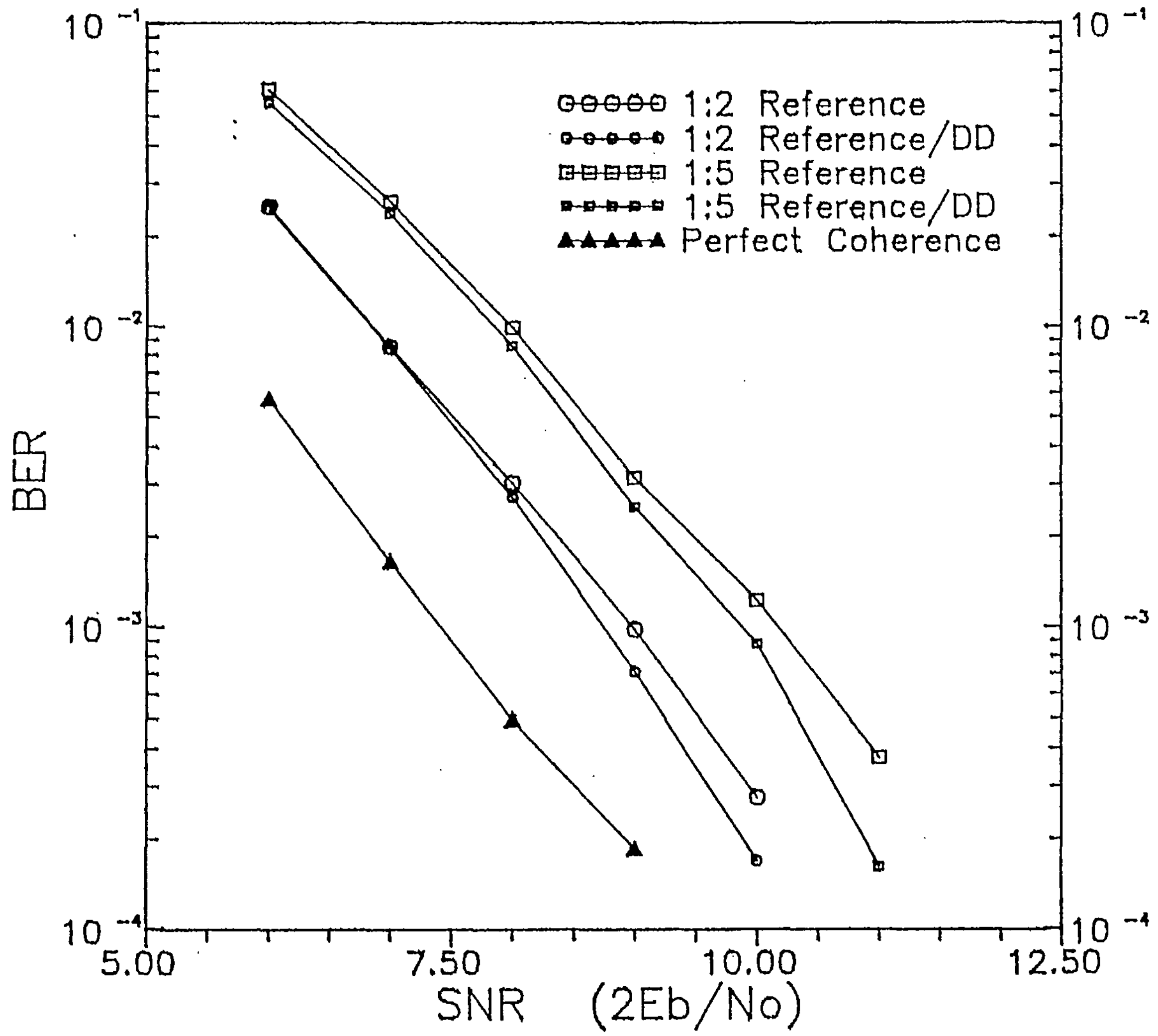
NOTE : SNR IS UNADJUSTED FOR 2dB EXTRA APPARENT TRANSMITTED POWER

RATE 2/3 8PSK

WEIGHTED METRICS

TRACKING: REFERENCE ONLY vs REFERENCE + DD

INTERLEAVING: 10 SYMBOLS



NOTE : SNR IS UNADJUSTED FOR 2dB EXTRA APPARENT TRANSMITTED POWER

3. *Update on TRIO/Queen's TCM/8–DPSK Modem*

— courtesy Beno Koblents, Queen's University for timing (see Canadian Conference on Electrical and Computer Engineering, Ottawa, September 1990)

T_x – one first generation DSP

De/Mod - one first generation DSP

Deinterleaver/Viterbi Decoder

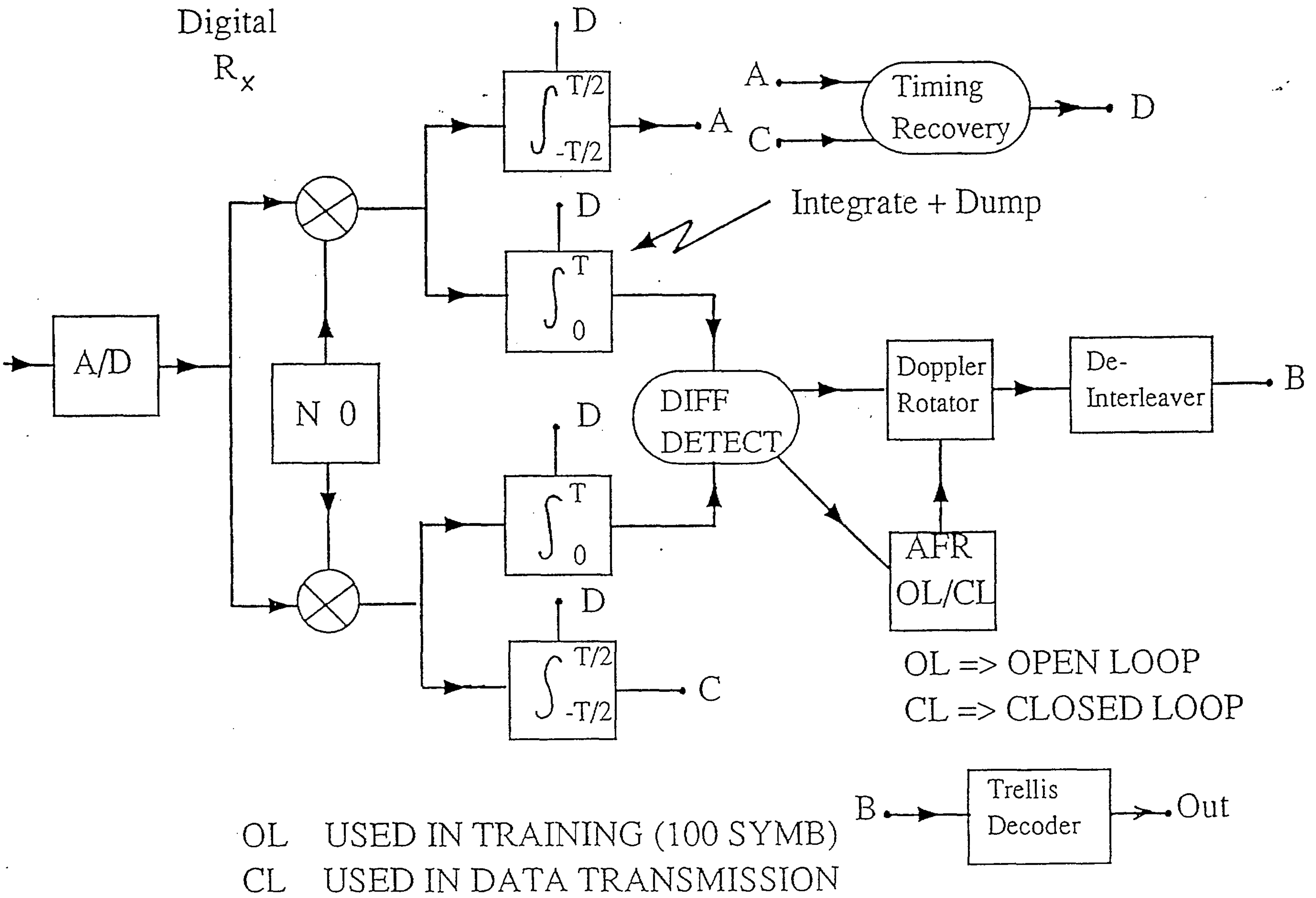
— one 2nd Generation DSP (runs at 4800 bps)

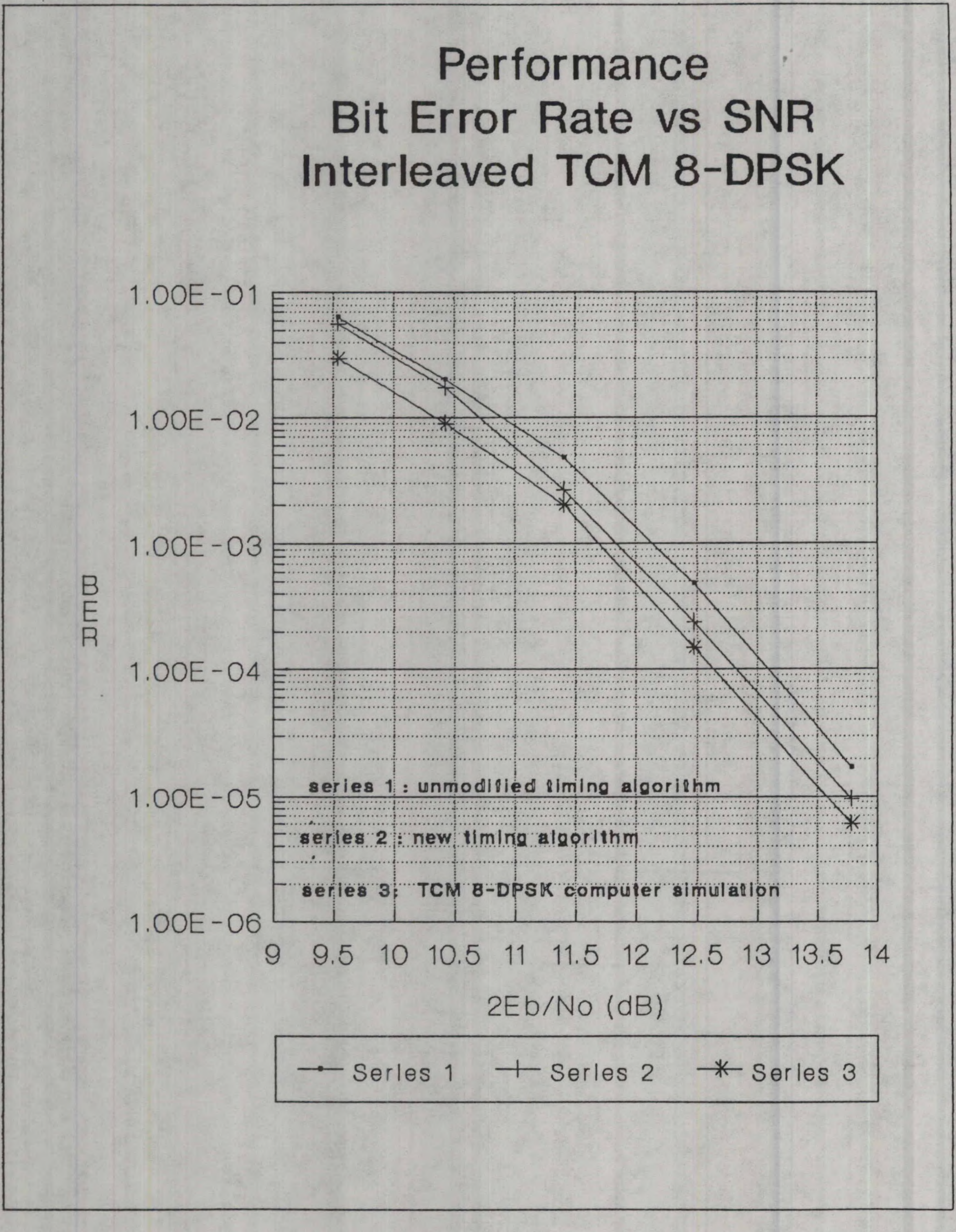
Future

— Three 2nd Generation DSP at 4800 bps

— Present results for 2400 bps

Figure 5 - Demodulator/Decoder Block Diagram




Performance
Bit Error Rate vs SNR
Interleaved TCM 8-DPSK
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
BER
series 1 : unmodified timing algorithm
series 2 : new timing algorithm
series 3: TCM 8-DPSK computer simulation
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
2Eb/No (dB)
Series 1
Series 2
Series 3

Exploiting the Digital Radio Wave of the 90's

Dr. Arunas G. Slekys

ABSTRACT

With more than 5 million subscribers in over 30 countries, cellular already represents an installed equipment base exceeding $10B, and at 40% annually, is the fastest growing sector of the world's telecom industry. But capacity limits of analog transmission represent a fundamental barrier, which will be broken in several stages during the early to mid 90's. Using digital radio, effective capacity per system will be increased five times in 1991 and ten fold by 1995, without additional spectrum, or disruption to analog system users. A product architecture can be conceived that expands the use of digital cellular core technologies to in-building cordless, dispatch and navigation applications, thereby unlocking the full potential of universal affordable personal communications.

BIOGRAPHY

Dr. Arunas G. Slekys is Senior Vice President of Research and Development for NovAtel Communications Ltd., and since its inception has been responsible for the design and engineering of their leading edge family of cellular radiotelephones and communication systems. Of Lithuanian heritage, Dr. Slekys was raised and schooled in Toronto, Canada, where he received the BASc. degree in Electrical Engineering from the University of Toronto in 1968. Subsequently, he received the MS degree from the University of Illinois (Urbana) and a PhD. in Engineering from U.C.L.A. Dr. Slekys began his career as a Research Engineer in the Digital Communications Group at Cal Tech's Jet Propulsion Lab, and then held various systems development management posts at Bell Canada, Bell Northern Research and Arabian Data Systems in Jeddah, Saudi Arabia.

EXPLOITING THE DIGITAL RADIO WAVE OF THE 90's

Dr. Arunas G. Slekys, P. Eng.

Senior Vice President, Research & Development
NovAtel Communications Ltd.

Calgary, Alberta

ABSTRACT

With more than 5 million subscribers in over 30 countries, cellular already represents an installed equipment base exceeding $10B, and at 40% annually, is the fastest growing sector of the world's telecom industry. But capacity limits of analog transmission represent a fundamental barrier, which will be broken in several stages during the early to mid 90's. Using digital radio, effective capacity per system will be increased five times in 1991 and ten fold by 1995, without additional spectrum, or disruption to analog system users. A product architecture can be conceived that expands the use of digital cellular core technologies to in-building cordless, dispatch and navigation applications, thereby unlocking the full potential of universal, affordable personal communications.

1. WHY DIGITAL?

1.1 Analog's Success

In less than six years since introduction, analog cellular has met with enormous success worldwide. As illustrated in Table 1.1, over 5M subscribers are currently estimated to be using cellular phones, operating on various 400/450/800/900 MHz systems in more than 30 countries. Summarized in Reference (1), the dominant systems are based on the North American 800 MHz (EIA/TIA 553) and the U.K. 900 MHz (ETACS) standards, together accounting for over 70% of all users.

Besides having more spectrum allocated than for 400 MHz systems (50 MHz for EIA and 66 MHz for ETACS), these markets are flourishing because of competitive dual carrier service environments. Throughout major metropolitan service areas the intense competition to sign up customers has completely distorted cellular phone prices. Carriers routinely subsidize dealers with "activation bonuses" ranging anywhere from U.S. $100 to U.S. $600 or more, fuelling demand by even the most conservative customers. There are cases on record where buyers can actually receive money when purchasing a phone and committing to six months of connect time!

Feeding on this chaos and the resulting high volume opportunity are over 20 of the world's largest multi-national electronics firms, along with one successful cellular-only start-up. They are all investing heavily to drive technology size and cost curves towards improved performance and affordability, obsoleting products annually. Today cellular portables with 0.6 watts of RF power typically range from around 300 to 450 cc in volume, weigh from 350 to 550 grams, provide 0.5 to 1.5 hours airtime, 10 to 15 hours standby, offer a multitude of features that are rarely used or even understood by most users and sell from U.S. $600 to U.S. $2,000. Five years ago they were three times the size and price. Size reductions through advanced component and packaging developments could lead to 200 cc or smaller units within three years, selling at well below $500, considered the mass consumer price point by many forecasters. By the year 2000 the smallest phones will be like Dick Tracy's wristwatch. And if the annual rate of growth were only maintained at the current 40% estimate, then there would be 150M users worldwide!

STANDARD REGION	EIA-IS3	TACS/ ETACS	400/450 MHZ	OTHER	TOTAL
NORTH AMERICA	3,100		40		3,140
EUROPE		690	760	470	1,920
AUSTRALIA	100				100
CHINA		10	5		15
MIDDLE EAST		25			25
FAR EAST	35	35			70
JAPAN				500	500
TOTALS	3,235	760	805	970	5,770

TABLE 1.1 - Approximate Cellular Subscribers Worldwide

1.2 Capacity Limits

Unfortunately analog systems have insufficient capacity to realize this dream. Most major metropolitan areas have already exceeded practical RF capacity limits. In the U.S. for example, Los Angeles, Chicago and New York each have over 300,000 subscribers operating on congested systems. The same is true in London, where 66 MHz is inadequate to consistently deliver a desirable grade of service (less than 1% call blocking during the maximum busy hour) to an estimated 500,000 subscribers. And this has occurred in spite of operators' attempts to increase efficiency of spectrum utilization, using techniques such as cell splitting, sectorization, overlaying cells, and channel borrowing.

Additional spectrum to break congestion barriers is not likely in the near future. The only viable strategy is to increase spectrum efficiency by using digital radio transmission schemes, whereby more digital voice channels can be packed into the same frequency allocations than by employing analog/FM modulation schemes. Furthermore, beyond capacity, the potential of enhanced data services, improved privacy/security and lower operating costs are driving both North America and Europe towards digital.

1.3 The Opportunity of Universality

If designed with the right architecture and core components, digital cellular products could converge with digital radio versions of dispatch, paging, navigation and in-building cordless products, thereby unlocking the full potential of universal, affordable personal communications. The dream of one person, one phone, accessible anywhere on the face of the earth is irresistable. The major standards and technology challenges to achieve such a universal product strategy are reviewed in this paper.

2. TRANSITION TO DIGITAL

Before exploring a universal radio strategy, the unfortunate reality is that there will not be a single world standard for digital cellular. In North America, the overwhelming objective of the CTIA (Cellular Telephone Industry Association) including both operators and manufacturers is to increase capacity. On the other side of the Atlantic, the primary challenge in setting the GSM (Groupe Speciale Mobile) standard has been to achieve Pan European harmony. (No less than 13 countries signed the Memorandum of Understanding in September 1987!) Perhaps most importantly, GSM products are intended to obsolete existing analog products operating in the same frequency bands, whereas the CTIA has insisted on a seamless transition from analog to digital, without service disruption to analog users.

2.1 Digital Cellular: North America versus Europe

Table 2.1 summarizes the key functional objectives of the next generation North American EIA and European GSM digital cellular systems. As shown, the primary differences are capacity and orderly co-existence.

EIA/CTIA	GSM
• **CAPACITY:** 10x increase over current analog	2X increase over current analog
• **QUALITY:** Similar audio quality to analog	User confidentiality and open network architecture
• **DATA:** In voice band; multiples of 9.6 kbps	ISDN compatible
• **EMISSIONS:** Compatibility with existing emission standards	New standard: CEPT GSM 05
• **COEXISTENCE:** Coexistence with analog systems and orderly transition	Replacement
• **LIFETIME:** 10 year minimum technology lifetime	Not specified
• **COSTS:** Commensurate with value-added	Uniformity above all

TABLE 2.1 - Objectives of Digital Cellular: EIA/CTIA vs GSM

2.1.1 CTIA: Capacity and Co-existence

In North America, ten times capacity over a ten year lifetime is an absolute requirement. In Europe, initial GSM products will still effectively require 25 kHz per user, and hence provide limited capacity relief over current analog systems. Improved noise immunity of digital radio modulation schemes will result in perhaps a twofold capacity improvement through reduced carrier to interference (C/I) requirements, and hence a higher frequency reuse factor.

2.1.2 GSM: Security and Open Network Architecture

The major objectives for GSM are compatibility with the evolving ISDN (Integrated Services Digital Network) network, improved user privacy and a well-defined open network architecture (Reference 2). CTIA does not require ISDN compatibility, only that data rate requirements be compatible with the existing data communications world (up to 9.6 kbps per user channel).

Concerning the issue of open architecture, GSM has specified virtually all radio, switch and control interfaces, whereas the EIA system allows for proprietary base stations, handoff algorithms, control protocols and operational features. For inter-system signaling, the EIA/TIA 45.2 committee has already established the IS-41 standard. It currently defines how to hand-off calls between foreign systems, with inter-system call delivery targeted for completion by the end of 1989. The first commercial field trial of IS-41 was successfully demonstrated in mid-October of this year, between a NovAtel 800CM system operated by Alberta Government Telephones (AGT) and a Northern Telecom DMS switch operated by Edmonton Telephones. Digital cellular systems in North America will continue to adhere to IS-41, effectively allowing for contiguous system networking across the entire continent. Hence customers will enjoy continuous coverage on both sides of the Atlantic, although GSM will result in greater system operational uniformity for the carriers.

From an administrative and security perspective, roamers are already accommodated in the EIA system. Users can operate their phones on any foreign system and are identified as either "pre-authorized" or "spontaneous" roamers. To screen out fraudulent users, there are two clearinghouses in service (Appex and GTEDS) which positively verify roamer credit status. In the GSM specification, each country's system maintains all users as if they are "home" subscribers and will accommodate roamers from other countries in a similar manner as the EIA system. In both markets, fraudulent use is therefore inhibited, although it will continue to be prevalent as bandits find ever more devious ways to break the system. This is a large topic in itself and a sub-committee of the EIA/TIA 45.3 has now been established to address this issue specifically. For user authentication, the GSM specification is highly secure, incorporating what amounts to a key encryption system. Some degree of privacy coding is also now under deliberation by the TIA 45.3 committee for the radio channel. Furthermore, more secure access and channel encryption schemes will likely be introduced in future on a proprietary basis by different manufacturers in North America. The degree to which they close the security "gap" is still unclear.

2.2 Standards: Barriers to Universality

Table 2.2 summarizes the key specification parameters of EIA and ETACS, the two most dominant analog cellular systems, and EIA/digital and GSM, the next generation digital systems.

SPEC \ SYSTEM	ANALOG CELLULAR		DIGITAL CELLULAR	
	EIA-IS3	ETACS	EIA/DIGITAL	GSM
Frequency Bands (MHz) to system	824 - 849	872 - 905	824 - 849	890 - 915
to mobile	869 - 894	917 - 950	869 - 894	935 - 960
Access Method	FDMA	FDMA	FDMA/TDMA	FDMA/TDMA
Modulation	NBFM	NBFM	π/4 DQPSK	GMSK
Voice/Channel Coding	N/A	N/A	13.2 kbps CELP Convolutional Phase 2 8 kbps TBD	13 kbps Speech 9.6 kbps Data RPE-LTP/Convolutional
Subscriber Unit Power Level (Watts) & PA Class	.6, 1.2, 3 Class C	.6, 1.2, 3 Class C	.6, 1.2, 3 Class AB	2, 5 (HH); 8, 20 (MOB) Class C
Carriers	832	1320	832	125
Channels/Carrier	1	1	3, 6	8
Carrier Separation (kHz)	30	25	30	200
Year of First Introduction	1983	1984	1991	1991

TABLE 2.2 - Major Cellular System Standards

In today's analog world,.a transceiver product can be designed that is identical for both EIA and ETACS applications, apart from a handful of components and signaling software. Differences in frequency band (900 MHz vs. 800 MHz), channel bandwidth (25 kHz vs. 30 kHz), signaling and control protocols (software) have marginal cost impact if a common product is designed at the outset, although the ETACS version is approximately 8 to 10% higher in material cost due to the greater bandwidth and tighter audio specifications.

When comparing EIA/digital and GSM however, the differences in certain critical specifications are so extreme as to prevent the design of a common product architecture. To name a few, carrier separation, voice and channel codecs, power amps, signaling and control protocols are incompatible. As already mentioned, GSM is intended to obsolete ETACS and hence a common product architecture is not possible.

Finally, comparing EIA and EIA/digital, it is evident that the specifications are readily amenable to design a dual mode product architecture, one that can fulfill CTIA's two primary goals of increasing capacity yet maintaining orderly co-existence.

2.3 Dual Mode Product Architecture

A summary follows of the key transceiver and system product building blocks required to deliver dual mode service.

2.3.1 Transceiver Building Blocks

Figure 2.1 illustrates the major building blocks in a dual mode EIA transceiver.

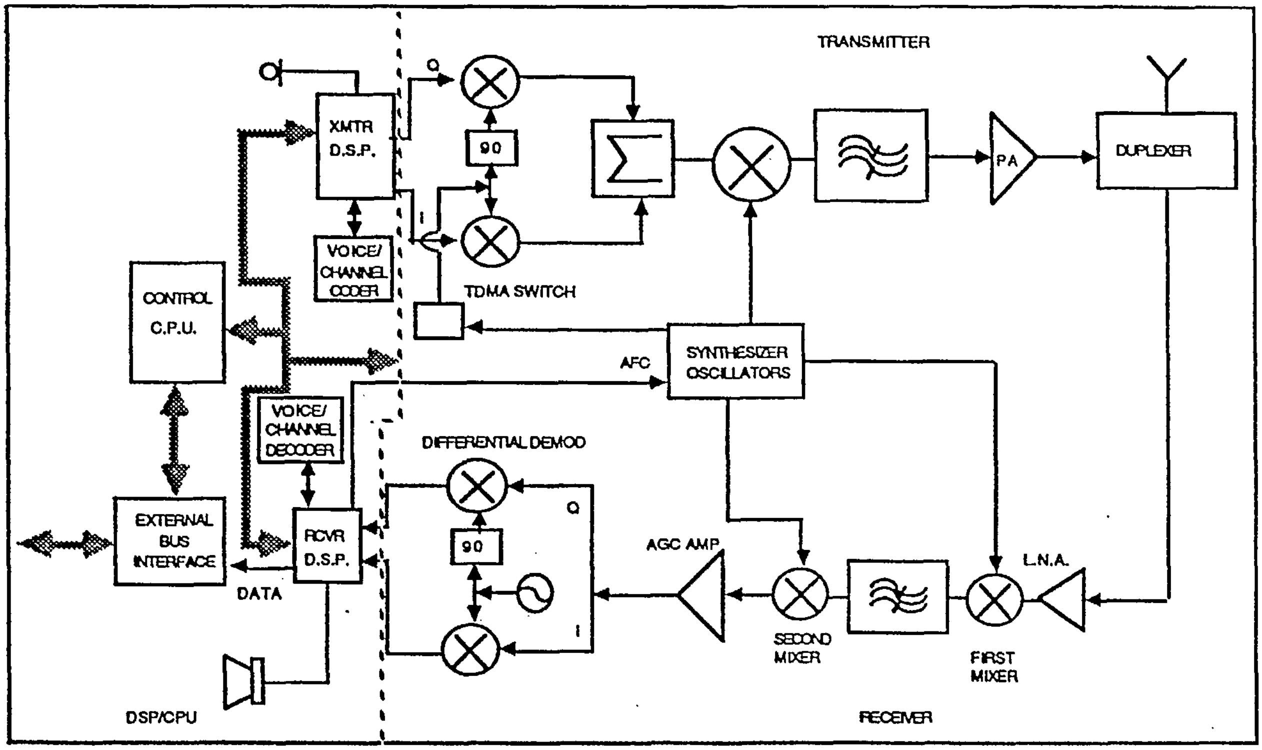


FIGURE 2.1 - DUAL MODE TRANSCEIVER BUILDING BLOCKS

Receiver

The receiver front end converter and IF stages operate identically whether the source channel information is narrowband analog/FM or the EIA specified π/4DQPSK (Differential Quadrature Phase Shift Keyed) scheme. Filter stability, group delay and oscillator stability specifications are more strict for the digital system, and the material cost increase is estimated to be 20 to 30% over an analog version.

Transmitter/PA

A linear class AB or linearized class C power amp is required for digital operation, due to the chosen linear modulation scheme. Such a linear design will likely cost 20% more than the existing class C analog designs, however volume cost reductions will reduce the net impact on total product cost to a small percentage increase. Furthermore, this same PA can operate as a higher efficiency class C circuit when in the analog/FM mode.

Mod/Demod/DSP

In the baseband modulation and demodulation stages, the source analog or digital information can be handled as balanced In-Phase (I) and Quadrature (Q) signals, a detailed explanation for which is given in Reference (3). This is the realm of so-called DSP or Digital Signal Processing, where high powered software algorithms can be invoked to process either an analog or digital information stream. Processing overheads for these functions increase material cost by perhaps 20% beyond analog.

Voice/Channel Coder

The voice and channel coder stages including control, framing and equalization logic are also represented by DSP-based software algorithms. The combined CPU and software requirements for these features represent a direct processing overhead in either a digital or dual mode product, and as in the case of mod/demod logic are estimated to increase material cost by around 20% beyond analog.

Power

Neither a digital nor dual mode handheld will be likely in the first generation of digital cellular products due to the large power consumption required in the DSP stages. Today's 0.6 watt analog handhelds operate at typically 3 watts d.c. in full power mode and .3 watts in standby. Power budgets for equivalent digital or dual mode handheld units are estimated initially to be 3 times their analog counterparts. This gap is not expected to close until the second or third rev of products in the '92/'93 timeframe, and will occur as a result of reduction in complexity of DSP algorithms and lower power consumption of associated integrated circuits.

2.3.2 System Building Blocks

A detailed discussion of how existing analog cellular switching systems could evolve to support digital cellular operation would require an analysis of each manufacturer's product strategy, which is beyond the scope of this paper. However, a strategy based on the NovAtel 800CM system product architecture illustrates that a graceful transition is possible (See Reference 4.)

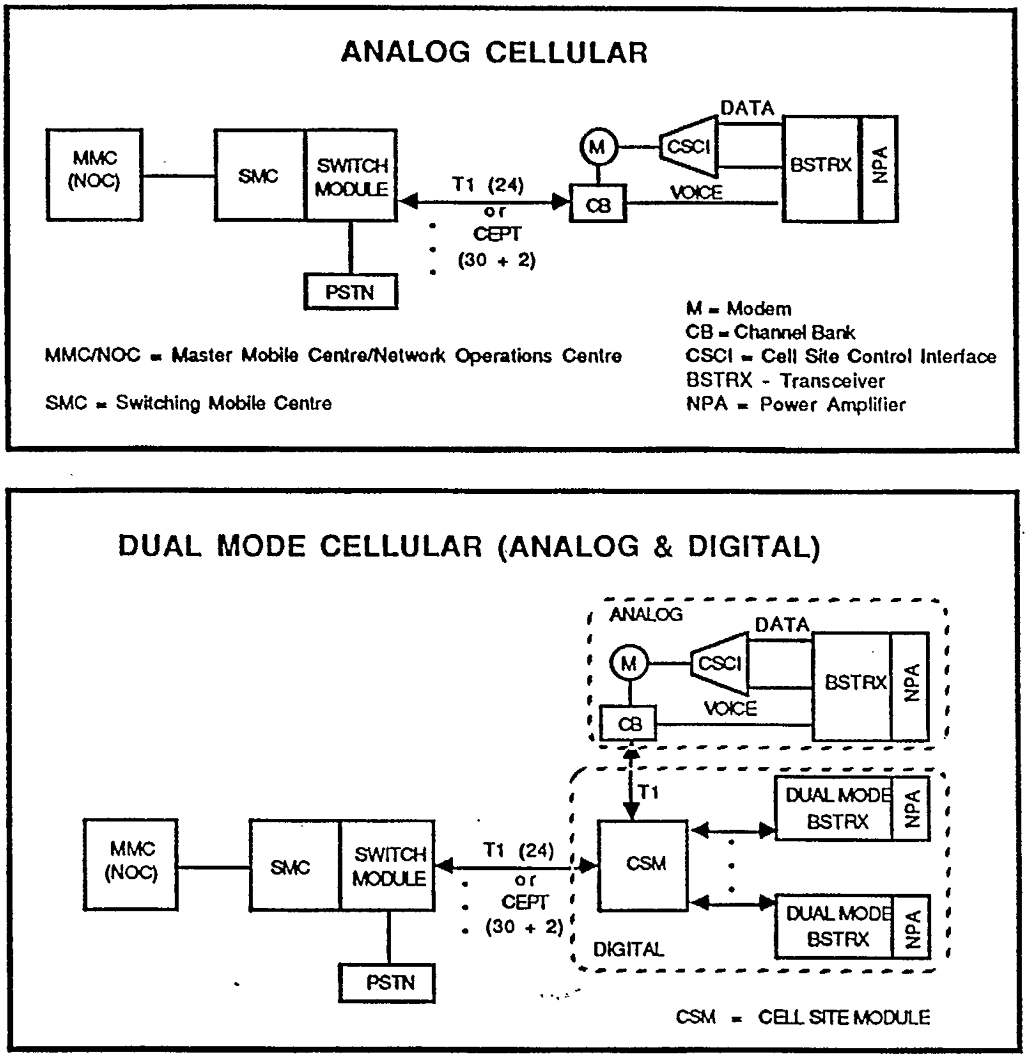


FIGURE 2.2 - Analog and Dual Mode System Building Blocks

Figure 2.2 shows the key system building blocks. At a cell site, current analog transceivers (BSTRX) and PA's (NPA) are replaced or augmented by dual mode versions. As in the mobile transceiver, the same philosophy of dual mode operation follows, meaning that the base station transceiver can operate in analog or digital mode depending on which type of mobile is being serviced. The EIA/digital spec calls for an extended EIA/TIA 553 setup protocol, whereby a digital mobile will identify itself as such, from which point the base station will operate in digital mode and control information will be managed within each user time slot. Handoffs can be effected between single and dual mode base stations, although the degree of RF coverage overlap required for such "mixed mode" networks remains to be fully resolved.

Other common equipment in the cell site such as the alarm unit, local oscillator, multiplexer and locate transceiver requires upgrades to support the higher volume of digital traffic. Combiners and multicouplers remain unchanged, which is a major advantage. If a new frequency plan is introduced to accommodate higher volume traffic (for example N = 4 plan from N=7 plan where N is the number of cells in each repeated cluster) then this of course will necessitate more channels and corresponding allocations of different combiner and multicoupler channel groups.

If properly planned, such a dual mode transition strategy can limit the changeout to cell site equipment only. Furthermore, if transceivers, PA's, and other common equipment are packaged to be mechanically and electrically plug-compatible with analog units, then the system can support combined dual mode and analog hardware within a common set of equipment frames. This allows the operator to grow into digital as the market demands, while maximizing investment in existing analog cell site equipment and infrastructure.

2.4 EIA/Digital: Capacity and Cost Advantages

Before understanding capacity limits, some understanding is required of the behaviour of the mobile radio channel. A detailed treatise of capacity in a mobile radio environment is beyond the scope of this paper. Reference (5) is just one of many that deal with this fascinating topic.

2.4.1 The Mobile Radio Channel

As illustrated in Figure 2.3, fading and multipath propagation are the two primary effects on the radio channel that deteriorate performance and therefore impact capacity. In the static case, representative of a point-to-point/microwave setup for example, the Bit Error Rate (BER) drops exponentially as the signal energy to noise (or energy to interference) ratio is increased. **Flat** fading, as encountered in mobile channels causes this profile to deteriorate. Fades of 40 to 50 dB reduction in signal strength can regularly occur within fractions of a second in a fast moving mobile environment. Delay spread and random phase and frequency shift caused by multipath propagation can further degrade digital signals in particular, manifested as inter-symbol interference or "smearing". Delay spread effectively sets a limit on the digital transmission rate possible over a fading radio channel.

Diversity refers to one of many methods to improve the received signal strength at a receiver by combining or selecting reasonably uncorrelated samples of the signal. Two antennas separated by half a wavelength is an example of space diversity; polarization diversity involves receiving both horizontally and vertically polarized signals. In either case, diversity can reduce fades by typically 5 to 10 dB.

SYSTEM CAPACITY LIMITATIONS

TECHNOLOGY	AREA OF IMPROVEMENT
CODING	ALL
DIVERSITY	FLAT FADING
EQUALIZATION	DISPERSIVE FADING

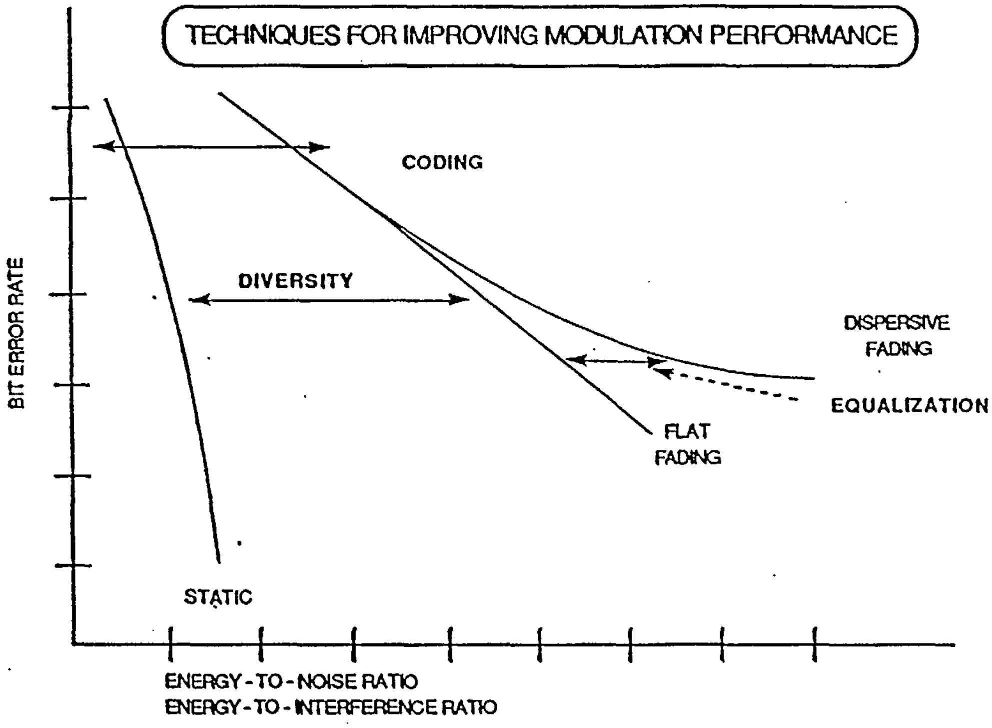


FIGURE 2.3 - The Mobile Fading Channel

Digital countermeasures include robust voice coding, channel coding, and adaptive equalization, all based on the principle of improving resistance to errors by helping to recover either physical or logical levels of coded information. Adaptive equalization in particular is a critical issue. The basic idea is to establish prior information of distortion and attenuation effects of the channel, which can then be employed to correct the received signal by reshaping incoming pulses. The degree of delay equalization required for acceptable system performance has been a hotly debated issue in the EIA Standards bodies. Whereas GSM has defined a minimum 10 μsec delay compensation, the EIA committee appears to be converging to a 40 μsec figure. Studies have shown that delays beyond 20 μsec appear to be statistically of very low probability. The more CPU processing allocated for equalization, the greater the overall power required in a transceiver, thereby inhibiting introduction of digital portables.

2.4.2 Overall System Capacity

A desirable system performance figure of merit is a BER of 10^{-5} or lower, for which it has been estimated that from 9 to 14 dB of desired signal to co-channel interferor signal (C/I) is required. This C/I parameter is therefore at least 4 dB lower than for analog cellular, which is expected intuitively since digital signals can be encoded to be more immune to channel noise.

The relationship between C/I and the cell distance to reuse ratio, or D/R, is described by Lee (Reference 6), namely:

$$D/R = \sqrt[4]{(N-1)\,(S/I)}$$

where N = cell reuse plan
(S/I) = absolute values of (C/I) dB.

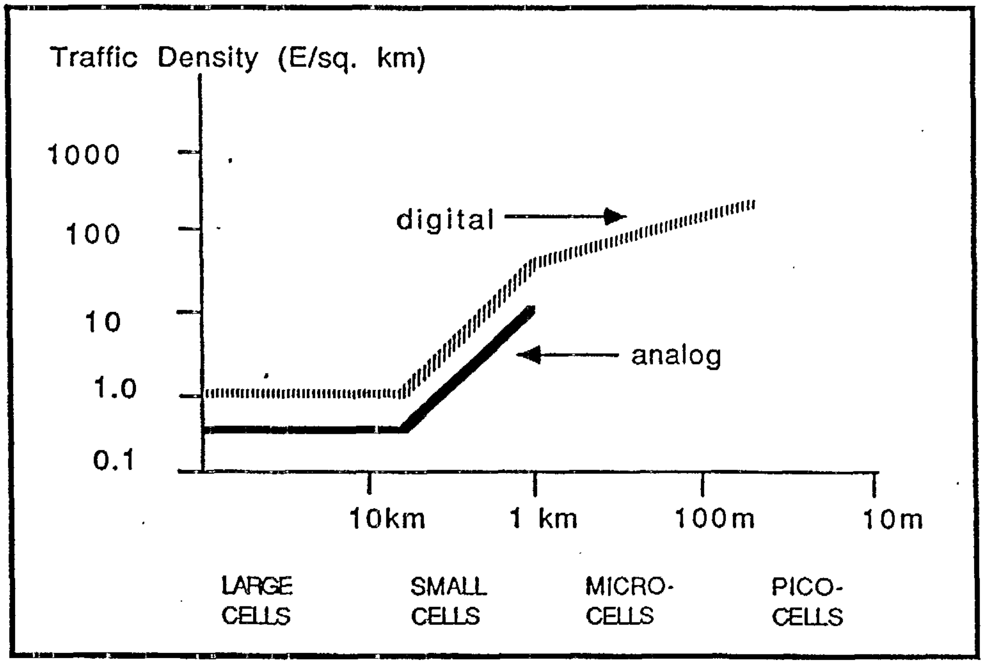


FIGURE 2.4 - Trafffic Density vs Cell Size (Analog vs Digital)

As described in Reference (6) and illustrated in Figure 2.4, there is an exponential relationship between smaller cells (and hence smaller D/R) and increased traffic density. The net effect of a 4 dB reduction in (C/I) translates into about 40% greater system capacity. Hence, for the EIA/digital system, which specifies 3 digital voice channels per existing analog channel initially, then the overall system capacity increase is extrapolated to be 4 to 5 times. With 6 digital channels per analog channel, the overall capacity is then expected to be 8 to 10 times greater than analog, thereby meeting CTIA's objective.

2.4.3 User Channel Capacity

As shown in Table 2.2, each user is assigned one of 3 equally spaced TDMA time slots. The details of this structure remain to be fully defined by the TIA 45.3 standards committee. The gross data rate is 48 kbps, derived from the fact that the $\pi/4$DQPSK modulation scheme results in 1.6 bits per second per hertz, and each analog channel is 30 KHz. Hence, each user's time slot is assigned a 16 kbps gross data rate, of which 13.2 kbps represents the coded voice and channel error correction information, and the balance of 2.8 kbps is system control information.

The specification assumes that a 6 slot TDMA scheme will eventually be adopted, without a specific timeframe. It is expected that within 5 years voice and channel coder rates can be compressed by 50% and still deliver equivalent quality, resulting in a gross data rate requirement of only 8 kbps per user time slot. Hence with 6 time slots per analog channel and assuming the same 4 dB lower (C/I) requirement, EIA digital cellular will deliver 8 to 10 times capacity over EIA/TIA 553 analog. This will occur in effect with two seamless transitions, namely, from analog to 3 slot digital and then to 6 slot digital.

2.4.4 Cost Advantages

It is estimated that a digital cell site will cost from 1.5 to 2 times that of a current analog version. However, since subscriber capacity is tripled on a per channel basis in the first transition, the net cost per subscriber will correspondingly drop by 30 to 50%. Hence even in smaller markets where capacity is not an issue, digital cellular will present an opportunity to lower costs and provide value-added services, assuming there is a sufficient critical mass of dual mode or digital mobiles in operation. By the second transition to 6 slot digital, system costs per subscriber could be further reduced, although it is too early to speculate on the net savings.

2.5 Digital Cellular Conclusions

The Pan-European GSM system, due to be introduced in 1991, will provide higher quality digital radio services, but will not be compatible or significantly improve on capacity limits of existing ETACS analog systems, or be compatible with EIA/digital in North America. System costs per subscriber are not yet determined.

North America's EIA/digital system, due for commercial service in early 1991, is designed to co-exist with its analog predecessor and will increase capacity initially by at least 4 and then 8 to 10 times in two seamless transitions, while also lowering system costs per subscriber by 40% or more. Dual mode subscriber products will initially cost perhaps 30% more than analog units, but volume and system cost advantages will likely mask this difference through creative pricing.

Assuming universality and affordability are goals, then the opportunity still exists in North America to define a compatible in-building digital radio system standard that can capitalize on EIA/digital cellular core technologies.

3. TOWARDS UNIVERSAL DIGITAL RADIO

In spite of the incompatibility between Europe's GSM and North America's EIA digital cellular systems, the joint capacity goal of 150M users by the year 2000 can likely be realized and perhaps exceeded. The greater goal of achieving a universal personal communications system compatible with digital cellular is explored in this section.

3.1 In-Building Digital Radio

The whole premise of cellular is to reuse subsets of RF channels within a two dimensional cellular pattern in order to increase capacity. Beyond mobile applications, service can also be provided to some limited percentage of in-building users. However, illuminating buildings from outside creates spotty RF coverage (Reference 7), and even digital cellular systems are just not designed to handle the significant extra traffic that would result.

On the other hand, illuminating buildings with low-power RF coverage from inside can realize the necessary capacity to succeed, as described in several articles (References 7, 8, 9). But none of these are based on the strategy of utilizing digital cellular core technologies. To date, there have been no specific proposals to exploit digital cellular systems for in-building applications.

3.1.1 European Standards

On the contrary, the European CCIR (International Consultative Committee on Radio), IWP8/13-3 (Interim Working Party) decided in 1988 that in-building and mobile usage within the same radio system should not be mixed. As a result, standards for in-building radio systems in Europe are evolving along 4 initiatives, namely the CT1 (Cordless Telephone 1) (CEPT - Conference of European Postal and

Telecommunications Administrations) and CT2 (Cordless Telephone 2) (UK) cordless specifications, the future DECT (Digital European Cordless Telephone) "Pan-European" (CEPT) digital cordless system, and the UK's recently announced Personal Communications Network (PCN).

SYSTEM SPEC	CTI (CEPT)	CT2 (UK)	DECT (CEPT)	PCN (UK)
FREQUENCY	900 MHz band	864-868 MHz	1.88 -1.9 GHz	1.7 GHz Area
ACCESS METHOD	Channelized	FDMA, TDD	TDMA, TDD	TBD
MODULATION	Analog FM	MSK	GMSK	TBD
VOICE CODING	N/A	32kbps ADPCM	32 kbps ADPCM	TBD
POWER	10mW	Up to 10mW	300mW max. peak	GSM & DECT
CARRIERS	40	40	TBD	GSM & DECT
CHANNELS/CARRIER	1	1	12	TBD
CARRIER SEPARATION	50 kHz	100 KHz	1.3 MHz	TBD
INITIAL MARKET	Residential	Public telepoint Originate only	Business	All
HANDOFF	No	No	Yes	Yes

TABLE 3.1 - European In-Building Cordless Systems

Table 3.1 outlines the key specifications for these systems. Other than the PCN initiative which is largely undefined and may yet be compatible with DECT or GSM, they are incompatible among themselves and GSM. CT2 is an improved digital version of CT1, however both are only designed to offer "telepoint" or single line cordless services, rather than becoming full blown RF alternatives to wired PBX's or Local Area Networks (LAN's). DECT, which is not due for introduction until the mid-1990's is designed to operate in the 1.8 to 1.9 GHz band, whereas PCN is in the 1.7 GHz band. As a result, both are incompatible with cellular, CT2, and may conflict with other radio services in North America currently authorized to operate in these bands. The degree to which PCN and DECT co-exist remains to be seen.

Pending the PCN definition, greater exploitation of digital cellular technologies for in-building applications will not occur in Europe.

3.1.2 North American Initiatives

There are no standards in North America for in-building digital radio systems. However, several initiatives have surfaced, including the Rutgers University Wireless Information Network Laboratory Workshops and the Radio Advisory Board of Canada, initiated by Canada's Department of Communications. It seems likely that an EIA Committee will be established in the near future to wrestle with this issue.

3.2 Convergence of Digital Cellular and Cordless

3.2.1 Cost of Portability

The current cost of a wired PBX connection is in the range of $500 per subscriber. Cost of adds, moves or changes can easily exceed that same figure and in many major corporations will occur typically at least every 1.5 years. As digital cellular systems come on line in the 90's, the per subscriber port cost will drop below that of current PBX's, while cost of moves or changes will continue to increase at least at the annual inflation rate. Figure 3.1 illustrates the RFPBX concept, which could readily be extended to an RFLAN.

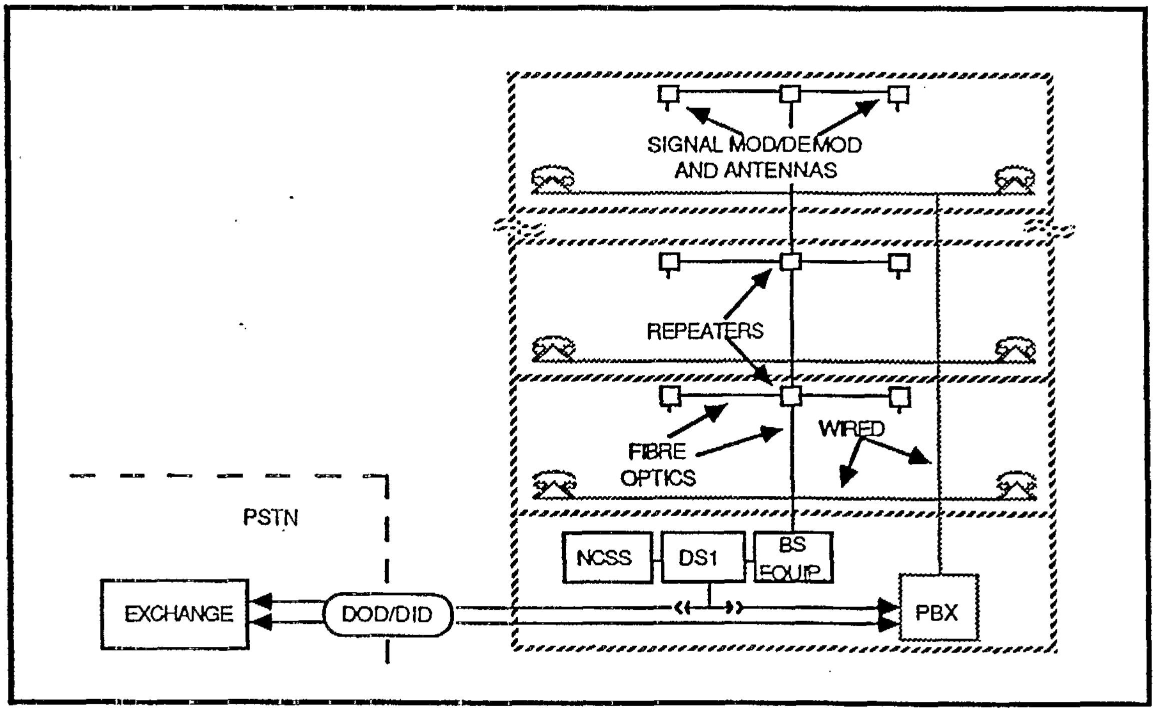


FIGURE 3.1 - Digital RF PBX (or RFLAN)

In establishing the in-building standard in North America, the opportunity should not be lost to capitalize on the future decreasing price spiral offered by digital cellular technology. A pocket sized digital cordless flip-phone could be sold for under U.S. $100 and systems competitive with wired RBX's and LAN's could be developed by 1993, within two years after introduction of digital cellular.

3.2.2 Interference and Capacity

Interference between low power in-building and external systems can be avoided by implementing a modulation scheme that has high noise immunity, such as spread spectrum, and also limiting handheld RF power to milliwatts. With as little as 10 MHz of spectrum, traffic densities within a given floor could easily reach 10,000 E/system (See Figure 2.4) resulting in perhaps 100,000 E/system over an entire building. Indeed, in-building spectrum efficiency, expressed as (E/MHz/sq. km.) is at least ten times greater than in the mobile environment for a given C/I because of the small cell sizes. Frequencies could be reused, perhaps every 3 floors, like a layer cake. (See Reference 7)

In-building RF power levels will be from 1 to 2 orders of magnitude less than cellular, which precludes sharing of common spectrum. Ideally in-building spectrum should be dedicated and reasonably adjacent to existing 800/900 MHz cellular bands, in order to maximize RF component commonality. Higher capacity modulation schemes could be realized, likely 5 or 6 bits per second per hertz. Assuming an equivalent 30 KHz channel as in the EIA system, each full user channel could deliver the basic ISDN 2B+D rate, making the radio link compatible with other ISDN delivery media.

3.2.3 Cordless Booster Concept

Relay and booster systems between the micro cordless and the digital cellular system could readily be developed, creating a transparent cordless service for mobile customers roaming up to several hundreds of meters from their vehicles. They wouldn't need to be aware of the frequency and power conversion taking place in these boosters, as depicted in Figure 3.2.

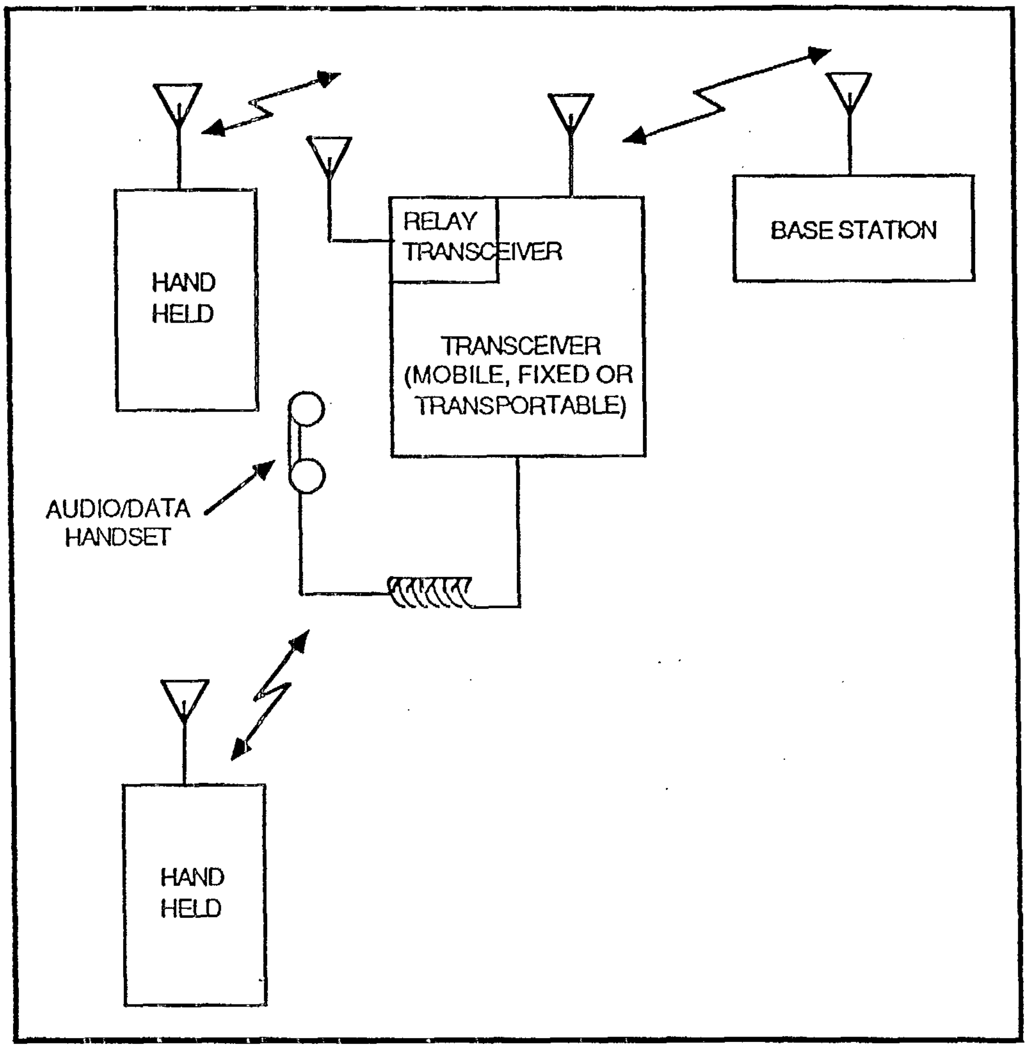


FIGURE 3.2 - Cordless Booster Concept

At home, one or more flip-phones could be used with one or more cordless base stations to access either two wire telephone loops, "fixed" digital cellular links or BETRS (Basic Exchange Telephone Radio Service) loops.

3.3 The Dream of Personal Communications

Figure 3.3 illustrates the full scope of the universal personal communications opportunity. As already described,in-building cordless RFPBX and RFLAN systems could evolve from a common digital cellular technology base. In addition, existing SMR (Specialized Mobile Radio) systems, operating in the 806 - 821 MHz and 851 - 866 MHz bands could readily be upgraded to provide higher quality, lower cost data and dispatch services incorporating digital cellular signaling and control structures.

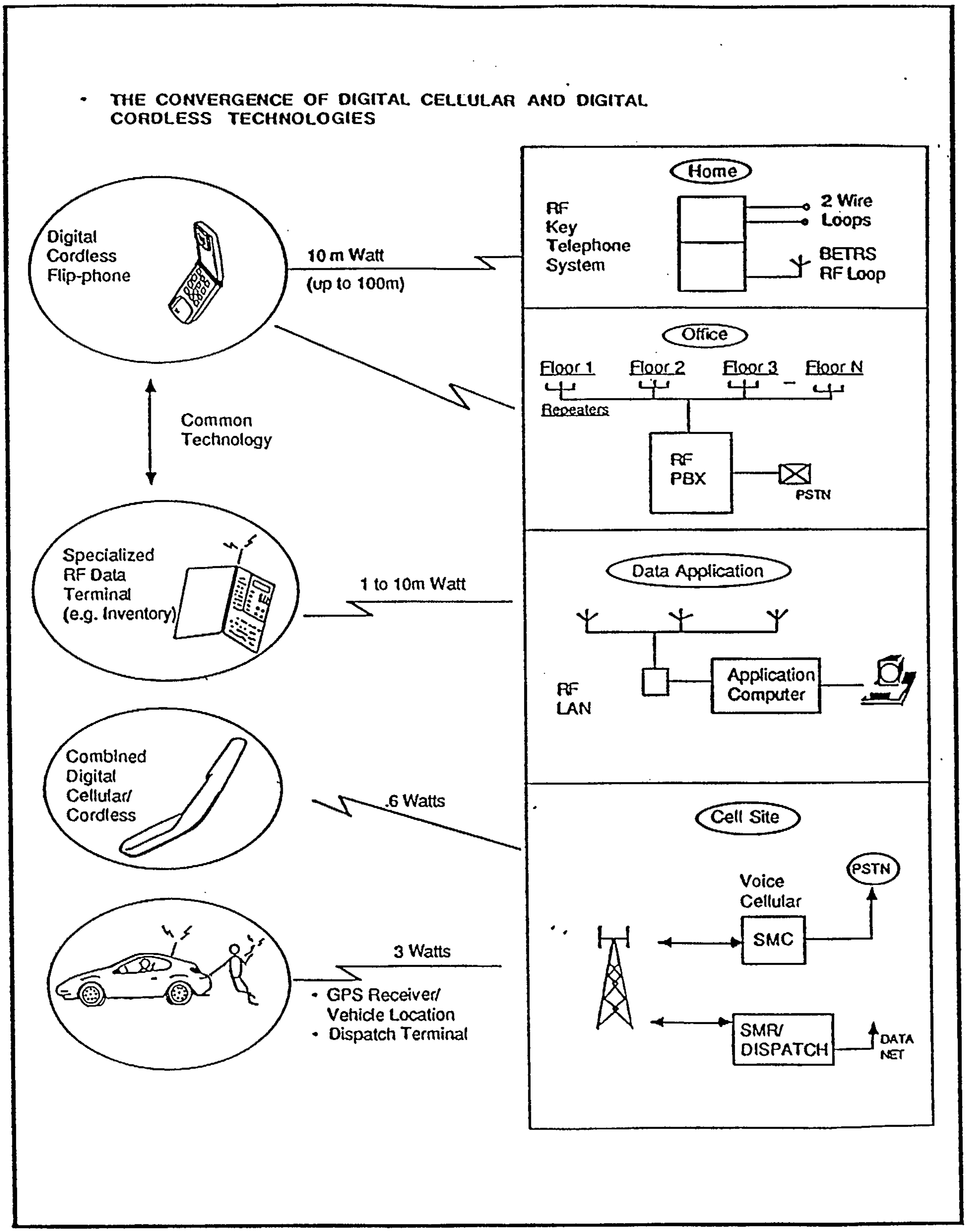


FIGURE 3.3 - Universal Personal Communications

Paging receivers in the 800/900 MHz bands could also be added to this vision of a universal radio transceiver, as could navigating systems such as the GPS (Global Positioning Navigation System), which operates in the 1.5GHz area.

Hence a convergence of digital cellular, in-building digital cordless and RFLAN, digital BETRS and digital SMR services is feasible. Technologically such a strategy can be conceived to realize the greatest degree of universality at the lowest possible cost to users. But to realize such an ambitious goal will call for commitment and compromise on the part of operators, manufacturers and regulatory bodies.

4. CONCLUSIONS

- Analog cellular radio systems are choking on their own success;
- The next generation EIA digital cellular system in North America will expand in two seamless transitions from analog, increasing capacity in North America tenfold, and providing service to possibly 100 million subscribers by the end of the century;
- The Pan European digital system, GSM, will be limited to two times capacity and obsolete the current ETACS system;
- Europe is moving towards at least two different standards for in-building digital radio applications, namely DECT and PCN, and the degree of compatibility with GSM is not yet clear;
- North America has only just launched initiatives for defining in-building digital radio standards, and therefore could realize the highest degrees of product and service universality and affordability by exploiting the core technologies of digital cellular.

REFERENCES

1. Arunas G. Slekys, "The Worldwide Impact of Cellular Radio Communications", presented at the World Telecommunications Forum Americas Telecom 88, Rio De Janerio, May 18 - 21, 1988, pp 95 - 101.
2. S. R. Hearnden, "From Tacs to GSM", presented at the 2nd IEE National Conference on Telecommunications 1989, pp 232 - 238.
3. John G. Proakis, "Digital Communications", McGraw-Hill, 1983.
4. "800 CM Cellular Mobile System Product Description", NovAtel Communications Ltd., 1989.
5. George Calhoun, "Digital Cellular Radio", Artech House, 1988.
6. W. C. Y. Lee, "Spectrum Efficiency and Digital Cellular", presented at the 38th IEEE Vehicular Technology Conference 1988, pp 643 - 646.
7. P. L. Camwell, J.G. McRory, "Experimental Results of In-building Anisotropic Propagation at 835 MHz Using Leaky Feeders and Dipole", presented at the 1987 IEEE MONTECH'87 Conference on Communications, pp 213 - 216.
8. Dag Akerberg, "Properties of a TDMA Pico Cellular Office Communications System", presented at the 1989 IEEE Vehicular Technology Conference, pp 186 - 191.
9. Theodore S. Rappaport, "Indoor Radio Communications for Factories of the Future", IEEE Communications Magazine, May 1989, pp 15 - 24.

Michel T. Fattouche

Abstract

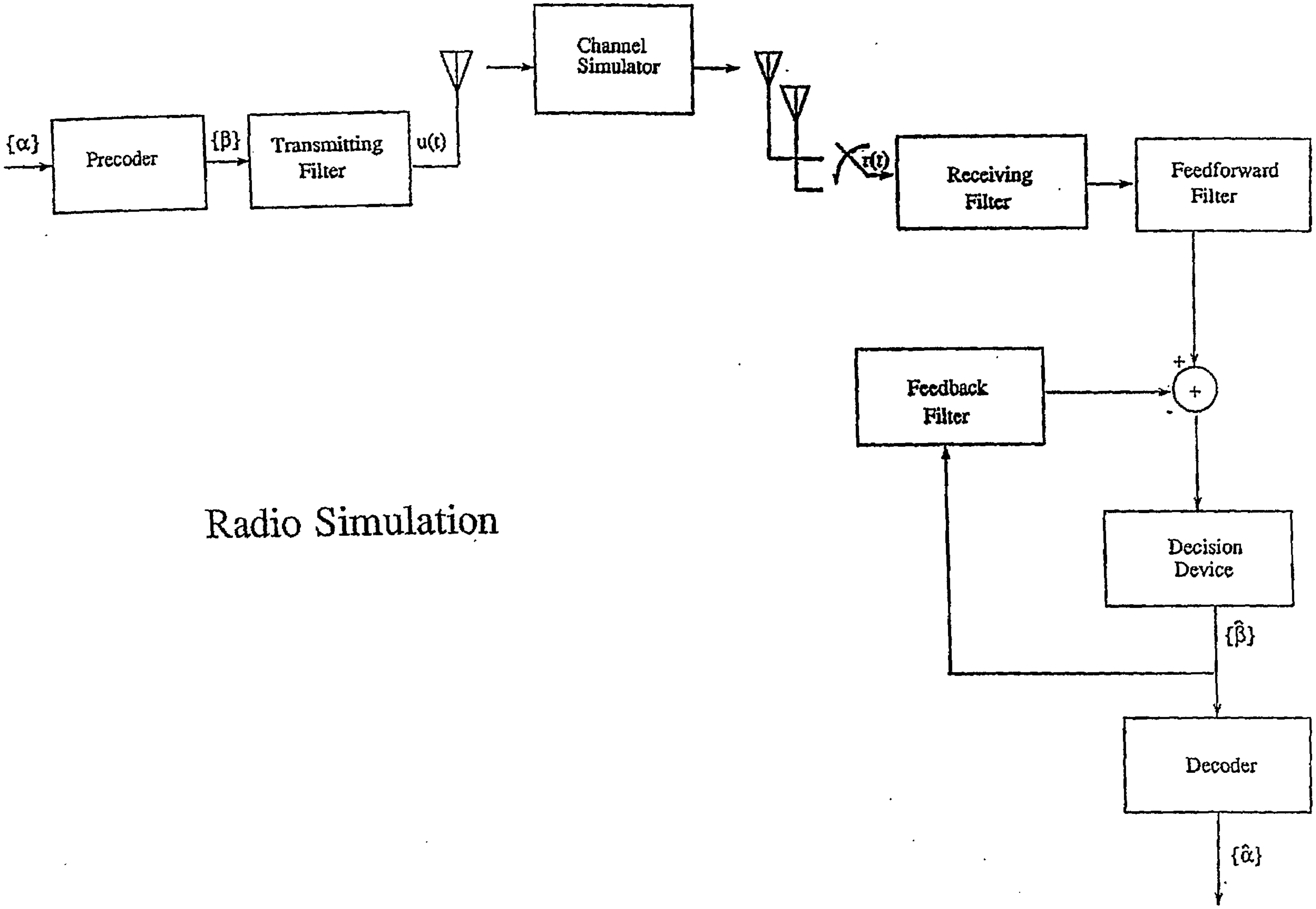
The first generation digital cellular system in North America is simulated using a modified Hashemi model. The model characterizes an urban mobile communications channel with up to 66 uSec multipath spread. The receiver consists of an adaptive equalizer, a Viterbi Algorithm and a speech decoder. The equalizer is updated using either a Least Mean Square algorithm or a Recursive Least Square algorithm. The Viterbi Algorithm is used to decode the convolutionally encoded data, possibly using soft channel information. The speech decoder takes the 7950 bps data from the channel decoder and generates the received speech signal.

BIOGRAPHY

Michel T. Fattouche received the B.Sc. degree in Electrical Engineering with Distinction and Honors from Cairo University, Cairo, Egypt in 1979; the B.Sc. degree in Applied Mathematics with Honors from Ain-Shams University, Cairo, Egypt, in 1981; the M.A.Sc. degree in Electrical Engineering from the University of Toronto, Toronto, Ontario in 1982; and the Ph.D. degree in Electrical Engineering from the University of Toronto, in 1986.

Since 1986, Dr. Fattouche has been with the University of Calgary, Department of Electrical Engineering and is currently the Alberta Telecommunications Research Centre Affiliate Professor at the University of Calgary. His areas of interest include modulation and coding techniques over wireless channels.

Radio Simulation



Meeting the Challenge - Fitting It All In

Jim Chinnick

BIOGRAPHY

Jim Chinnick is the Director of Research and Development for the Cellular Terminals Development Department at NovAtel Communications Ltd., in Calgary, Alberta.

Jim received a B.Sc. degree in Engineering Physics and an M.Sc. degree in Electrical Engineering (Communication) at Queen's University in Kingston, Ontario.

During his career, Jim has worked in research and development roles in mobile satellite communications, fiber-optic communications and digital subscriber switching systems.

A Time Segment Permutation Voice Privacy System

Sherman Chow

ABSTRACT

This report describes a low-cost voice privacy system that can be used with analog radio systems such as cellular, HF/888 as well as telephones. Although inputs and outputs are in analog form, it has been implemented using digital signal processing techniques. Tests carried out confirmed that good voice quality can be maintained under adverse conditions.

BIOGRAPHY

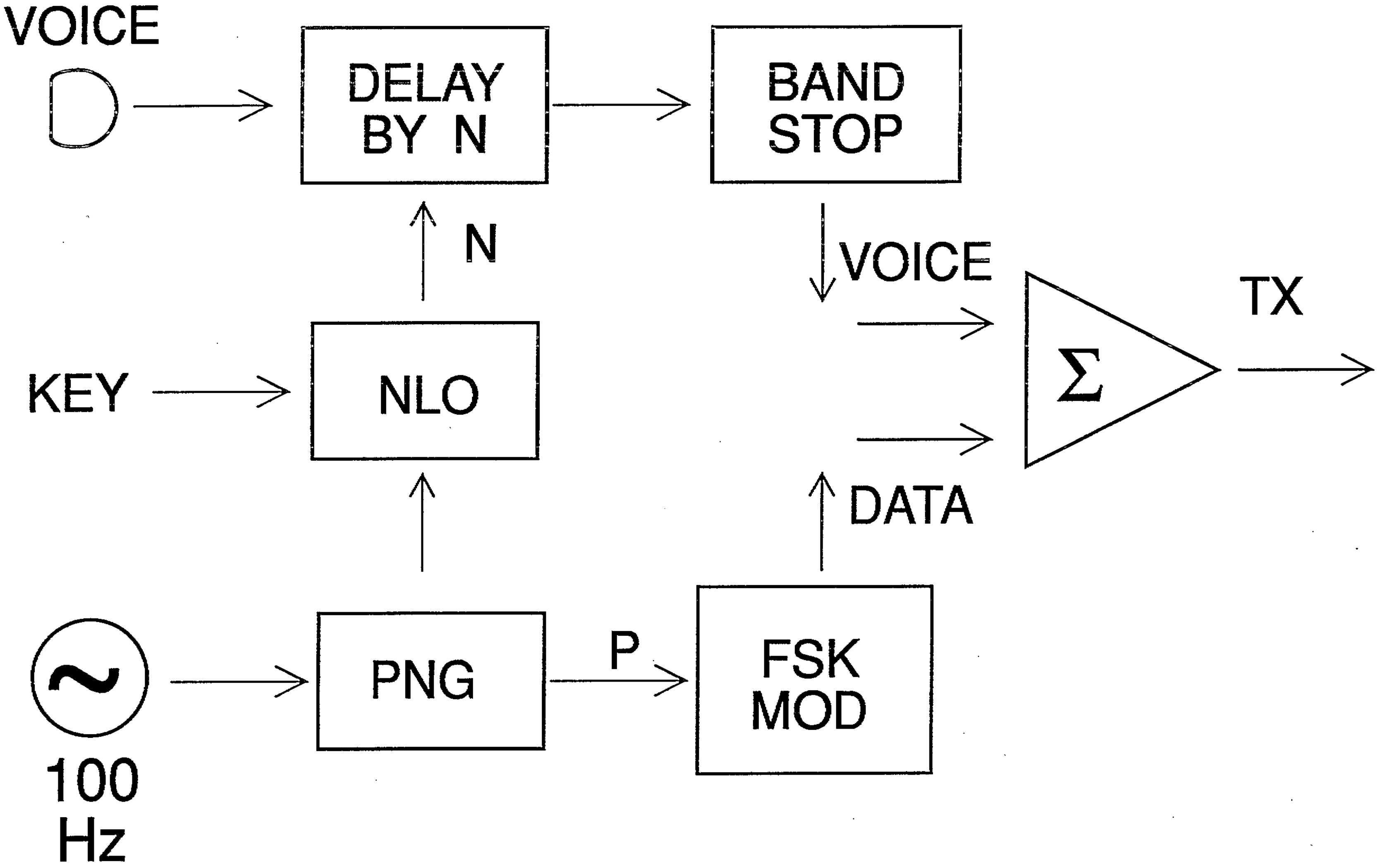
Mr. Chow received a B.Sc. in electrical engineering from the Massachussetts Institute of Technology, Cambridge Massachussetts and a M.Sc. in electrical engineering from Cornell University, Ithaca, NY. From 1964 to 1972, he was employed at Canadian General Electric in Toronto. He has been at the Communications Research Centre since 1972 where he is the manager of the Civilian Radio Program.

TIME SEGMENT PERMUTATION

TRANSMIT

- ¤ Segments of 30 milliseconds
- ¤ Delay by N segments
- ¤ Values of N generated by a NL operation on a PN defined by key K
- ¤ Transmit PN sequence in voice band

TRANSMIT BLOCK DIAGRAM



VOICE

DELAY BY N

BAND STOP

N

VOICE

KEY

NLO

Σ

TX

DATA

PNG

P

FSK MOD

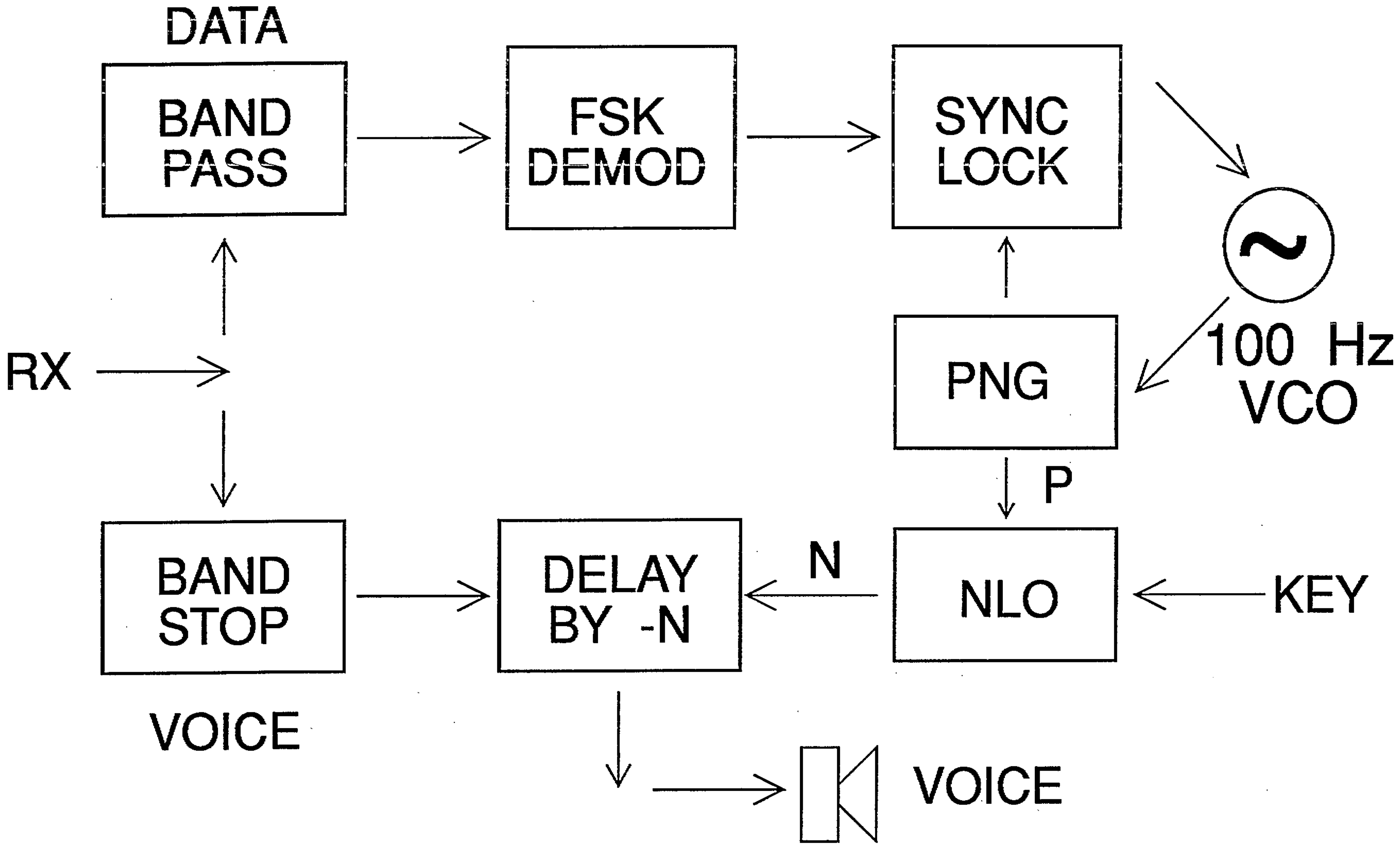
100 Hz

TIME SEGMENT PERMUTATION

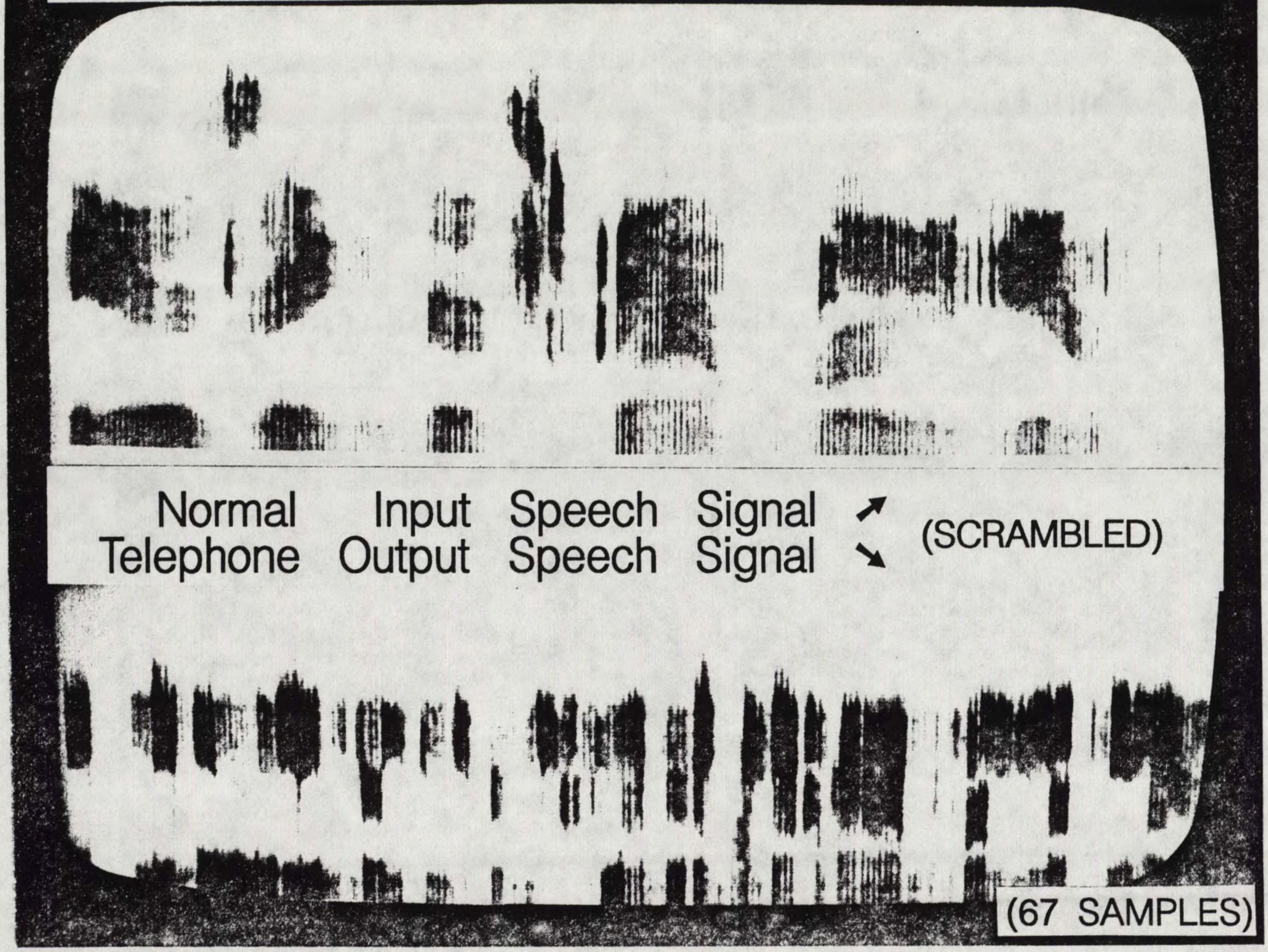
RECEIVE

- ¤ Synchronize sequence P
- ¤ Generate N using K
- ¤ Reorder segments using N

RECEIVE BLOCK DIAGRAM



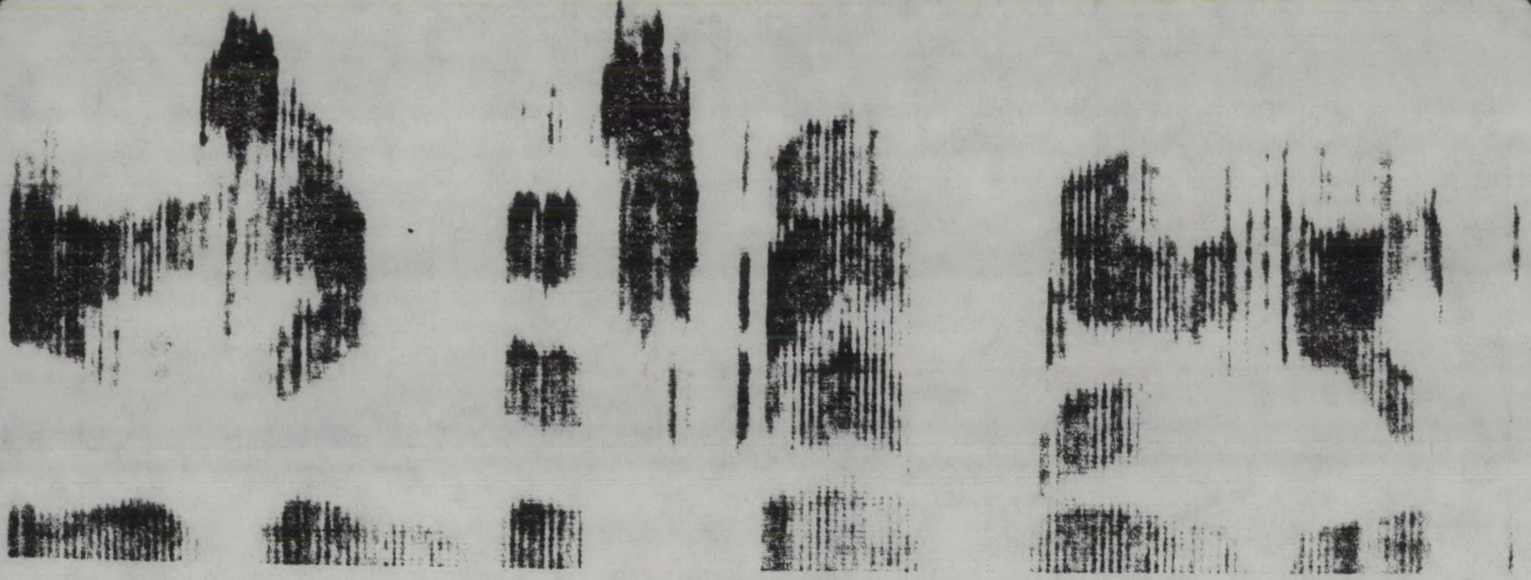
"USING THE SCRAMBLER UNIT"



Normal Input Speech Signal ↗
Telephone Output Speech Signal ↘ (SCRAMBLED)

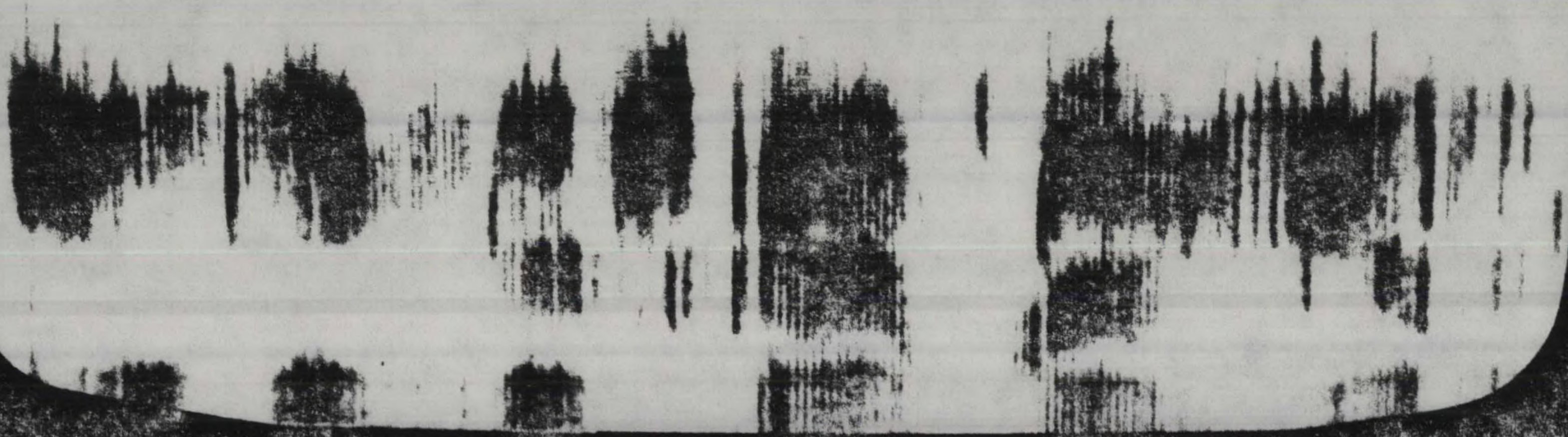
(67 SAMPLES)

"USING THE SCRAMBLER UNIT"



Normal Input Speech Signal ↗

Telephone Output Speech Signal ↘ (DESCRAMBLED)



Presentation By:

Al Javed, Bell Northern Research

Future of Cellular Telephony

Peter Minaki

BIOGRAPHY

Peter Minaki is Manager of Technical and Sales Support at Ericsson/GE Mobile Communications Canada Inc. and also Business Development at Ericsson Communications Inc., both in Montreal. Since 1986, he has worked in cellular, mobile voice and data, and private paging systems.

Prior to this, he spent nine years as a Signal Officer in the Canadian Army and eleven years in engineering with RCA and Honeywell. Peter holds a B.Sc. in electrical engineering from Queen's University and is a registered professional engineer in Quebec.

Antenna Diversity and Adaptive Multichannel Equalization for Multipath Radio Channels

S.T. Nichols

BIOGRAPHY

S.T. Nichols was born in Medicine Hat, Alberta, Canada, on November 29, 1937. He received the B.Sc. and M.Sc. degrees in electrical engineering from the University of Alberta, Edmonton, Canada, in 1960 and 1962 respectively. He obtained the Ph.D. degree in electrical engineering from Carleton University, Ottawa, Ontario in 1969. From 1963-1966 he worked on Radar Signal Processing in the Research and Development Division of Canadian General Electric. After receiving his doctorate, Dr. Nichols taught at Carleton University until 1970. Since that time, he has been teaching in the Department of Electrical Engineering at the University of Calgary, Calgary, Alberta, Canada, where he holds the rank of Professor. From 1983-1987 he also held the position of Alberta Government Telephones (AGT) Professorship in Telecommunications. His major research interests lie in the field of signal processing related to cellular radio communications, seismic processing and image processing.

Personal Communications Networks: Evolution of Revolution?

Authors: A.I. Spolsky, J.R. Brasic
Presented By: A.I. Spolsky

ABSTRACT

As we approach the 21st century, the true potential of personal communications is about to be realized with the introduction of the personal telephone, utilizing both terrestrial and satellite radio systems. The last 25 years we have seen phenomenal technological progress in VLSI and SMT devices as well as, in the case of satellite systems, vast reductions in each station antenna sizes as a result of advances in solid state amplifier technology and efficient coding and modulation techniques.

As mobile communications become truly ubiquitous they offer the promise of global networking without regard for location and a market size that is orders of magnitude larger than what exists today in the mobile communications industry. It is anticipated that the true benefits to be derived will not accrue from voice services alone but rather the broad range of data applications for navigation, position location, distress and emergency communications, system control and data acquisition, to name just a few. The capability of offering simultaneous voice and data, i.e., mobile ISDN may also play an important role in adding to the list of services to personal voice/data terminals.

Naturally, there are few benefits that come without their price. The issues confronting mobile services expansion are the need for continued advances in technology, both in electronic devices and components and in network access techniques. Forward error correction, modulation techniques, signalling protocols, flow control and voice coding algorithms all have significant impact on service quality and cost. With a large population of mobile terminals (in the millions), the need for network control reaches new dimensions since roaming will have not only regional connotations but also international and standardization implications. While international bodies, as well as regional/national regulators allocate various spectrum portions to personal telephony systems/networks, there remain questions as to the choice of frequency bands as well as the adequacy of the allocations and the relative importance of equipment and system standardization among the international and regional systems being launched.

The intent of this paper is to outline and explore the issues that confront us, identify potentially workable alternatives and construct a framework within which the various component techniques and technologies can co-exist. The personal telephone is a reality; making it work anywhere in the world is the challenge.

BIOGRAPHY

Andrew I. Spolsky has been actively involved in the fields of satellite and radio communications for over fifteen years, both as a systems engineering specialist and as a program manager. He has been involved in various satellite program such as SARSAT, MSAT, RADARSAT, DBS and has engineered commercial satellite networks using SCPC, TDMA, video subcarrier and VSAT technologies. Prior to joining Microtel Pacific Research Ltd. (MPR) in 1986, Mr. Spolsky held positions with Bell Northern Research, Canadian Astronautics Ltd., INTELSAT, and M/A-COM Telecommunications Inc. (now Hughes Network Systems). He holds B.Eng. (1974) and M.Eng. (1980) degrees in electrical engineering from Carleton University in Ottawa, Canada. Mr. Spolsky is a member of the IEEE and the Association of Professional Engineers of Ontario. He is presently Program Manager, Radio and Satellite Network Planning at MPR. Current interests include next generation satellite systems such as space based radar, MSAT, satellite systems such as space based radar, MSAT satellite switched TDMA, as well as the evolution of personal

PERSONAL COMMUNICATIONS NETWORKS:

EVOLUTION OR REVOLUTION?

A.I. Spolsky
J.R. Brasic
MPR TELTECH Ltd.
Burnaby, B.C.

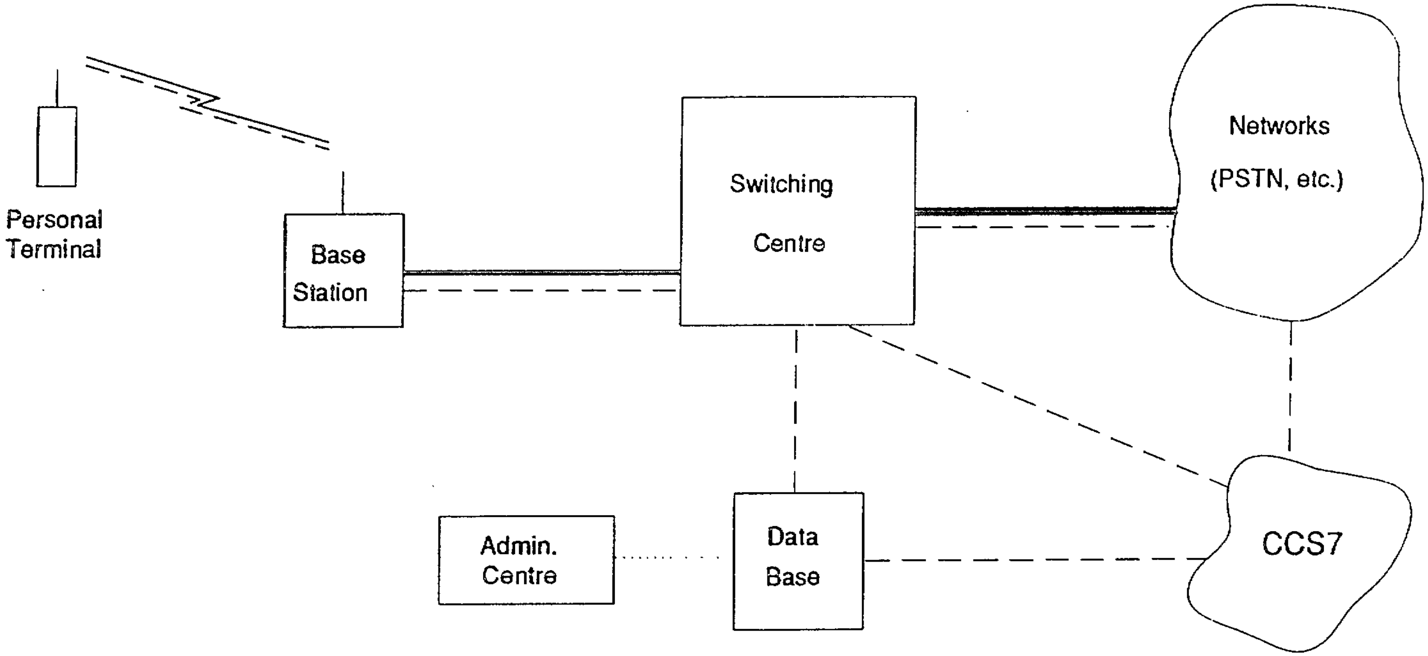
ATRC/TRIO
WIRELESS 90
16 - 17 July 1990
Calgary, Alberta

WIRELESS PERSONAL COMMUNICATION NETWORK CONCEPT

"The ability to originate or receive a communication via a personal communicator (terminal) anywhere in the service area. The service area can be regional, continental or global. The Personal Communicator will be a lightweight wireless handset that can be easily carried in a purse or pocket."

The Personal Communications Concept

- The Personal Number
  - a person is assigned ONE telephone number that a personal communications network (system) will use to provide services to that person anywhere in the service area (global!)
- The Personal Communications Network (System)
  - a network integrated with existing PSTN/ISDN networks that supports personal wireless (small) terminals (each with an individual number) in call origination/termination mode anywhere in the service area



Basic PCN Architecture

TODAY'S SYSTEMS

- Aeronautical
  - -- HF, VHF radio (voice)
  - -- ACARS (data)
  - -- GTE Airfone (voice)
  - -- INMARSAT

- Maritime
  - -- HF, VHF radio voice, telex)
  - -- INMARSAT Std. A, STD. C

- Land Mobile
  - -- Cellular telephone (voice)
  - -- MPR DATACELL (open access data)
  - -- SMR voice
    - -- Mobitex/Mobidata (data)
  - -- Limited range systems
    - -- CT-2 (originating)
    - -- Cordless telephone

- Global Systems (satellite based)
  - -- Mobile Satellite (voice, data)
    - -- INMARSAT
    - -- Telesat Mobile Inc. (TMI)
    - -- American Mobile Satellite Corp. (AMSC)
    - -- AUSSAT/Telecom Australia
  - -- GPS/Navstar (data)
  - -- Geostar/Locstar

SPECTRUM

- International vs. regional vs. national allocations
- "Spectrum is like real-estate .... they don't make it anymore"
- 150 MHz, 450 MHz
  - — SMR
  - — early cellular systems
- 800 MHz
  - — cellular telephone systems
- 900 MHz
  - — SMR voice/data systems
- 1.5 GHz/1.6 GHz
  - — mobile satellite systems
- 1.7 GHz/2.3 GHz
  - — PCN(UK)
  - — originating and terminating CT-2
- Others?
  - — 20-30 GHz
  - — 60 GHz (narrowband and broadband)

NETWORK APPLICATIONS

- Circuit switched services
  - voice
  - facsimile
- Message-switched services
  - telex
  - store-and-forward messaging
- Packet - switched services (data)
  - real-time, interactive data
  - bearer services
    - full duplex, symmetrical (LAN, MAN, WAN)
    - full duplex, asymmetrical (SCADA)
    - simplex inbound (DCP)
    - simplex outband (paging)

MPR

"HOT" TECHNOLOGIES

- Low bit rate voice/data source encoding
    - — spectrum efficiency
    - — toll quality
    - — encryption/security
- Antennas
    - — mobile satellite transceivers
    - — beam steering
    - — cost effectiveness
- Modulation techniques
    - — bandwidth and power efficiency (spectrum efficiency)
    - — fast synchronization and acquisition
    - — hostile propagation environments
        - -- multipath, shadowing, blocking
- Channel encoding algorithms
    - — FEC
    - — implications to quality, throughput, flow control delays and stability

"HOT" TECHNIQUES

- Network Architectures

  - GSM, U.K. PCN, U.S. digital
  - CT2, DECT, FPLMTS

- Network access techniques

  - TDMA, FDMA, CDMA, ALOHA (random, slotted)

- Network access protocols

  - call handling (DAMA)
  - mobile ISDN
    - integrated voice/data

- Service access protocols

  - throughput (system)
  - delays (service)
  - quality

- Network management techniques

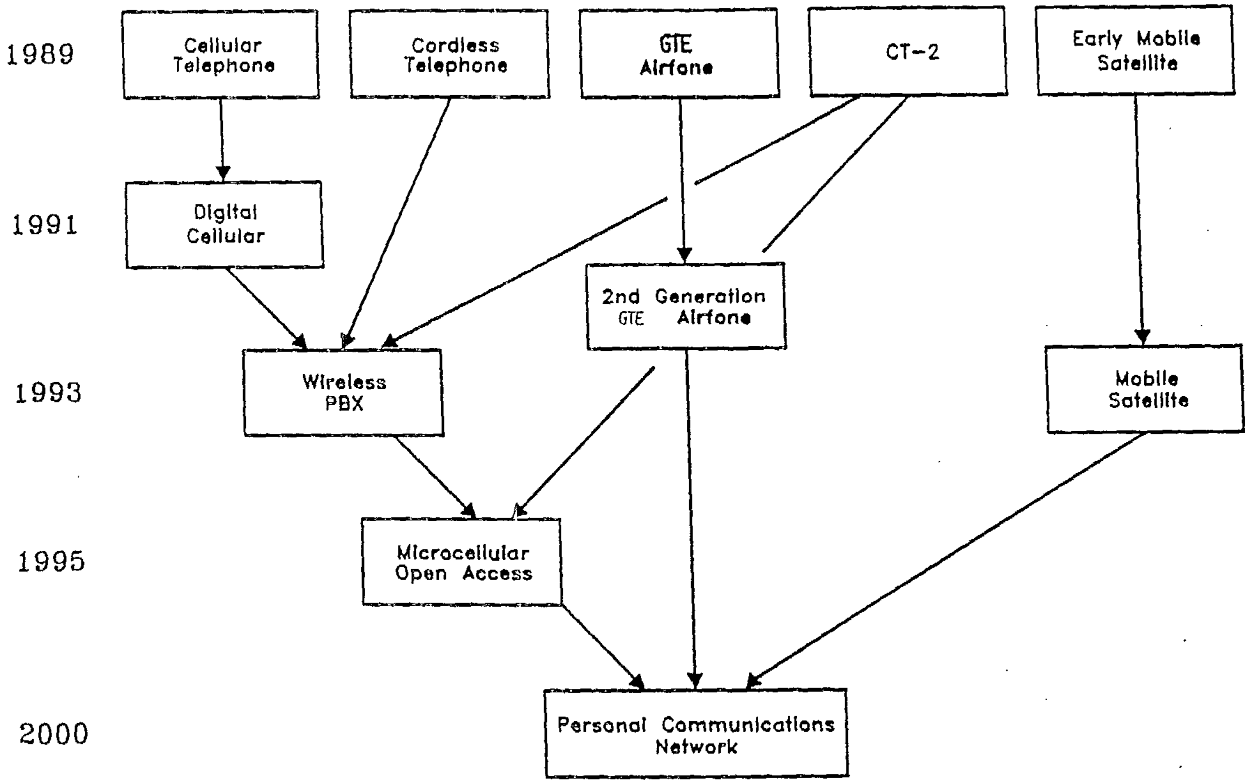
  - network control
  - network services
  - global vs. regional vs. local

- Intersystem frequency planning

- Network intelligence

  - personal numbering scheme
  - mobility management (terminal/person)
  - user control (service/features)
  - handoff (intrasystem/intersystem)

PCN EVOLUTION



PERSONAL COMMUNICATIONS EVOLUTION

MPR Activities

Technology

- Assessment
  - Digital Cordless (DECT, CT2)
  - Spread Spectrum LAN, Rural Radio, Wireless PABX
  - CDMA Cellular

- R.F. Propagation/Access
  - Measurements
    - In-Building Coverage
    - Cellular Delay Spread
    - Spread Spectrum BER
  - Modeling/Simulation
    - Channel Characterization
    - Modulation Analysis (BER)
    - Receiver (DSP) Design Experiments

MPR Activities

PCN Network Assesment

- ♦ Interfacing/Interworking

  ○ Fixed Networks
  - PSTN
  - ISDN
  - B-ISDN
  - FAX Networks
  - Billing Networks
  - Private Networks

  ○ Access
  - Traffic
  - Signalling
  - Database
  - Billing
  - NMS
  - Value Added Services

MPR

MPR Activities

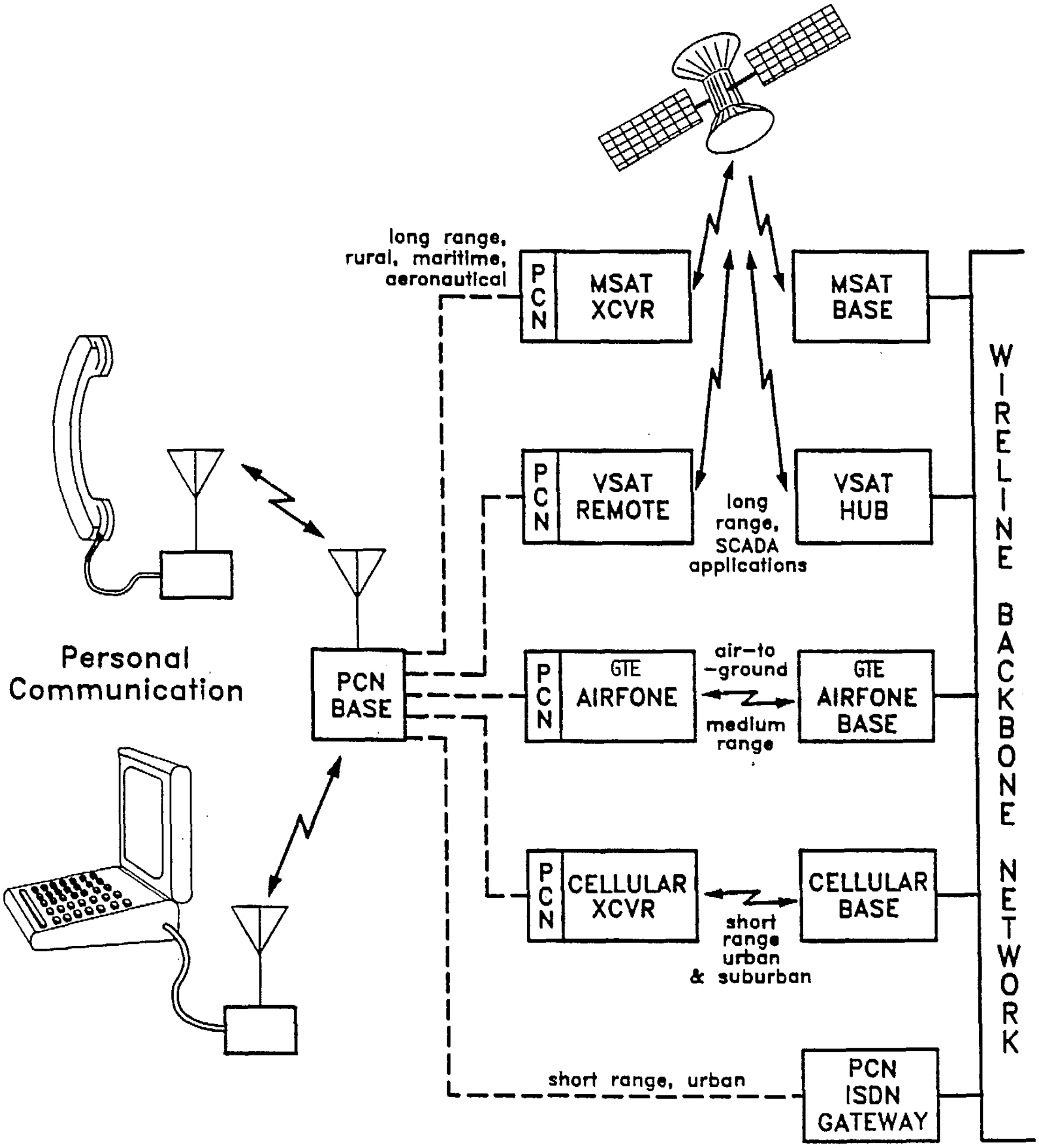
PCN Network Assesment

- ♦ Architecture
  - o Local Loop Access (Bellcore)
  - o PRMA MAN (AT&T)
  - o Cellular Evolution (GSM, U.K. PCN , U.S. Digital)
  - o Cordless Evolution (CT2, DECT)
  - o Combination Cellular, Cordless, MSAT etc (FPLMTS)
- ♦ Network Intelligence
  - o Personal Numbering Scheme
  - o Mobility Management
  - o User control (services, features)

MPR Activities

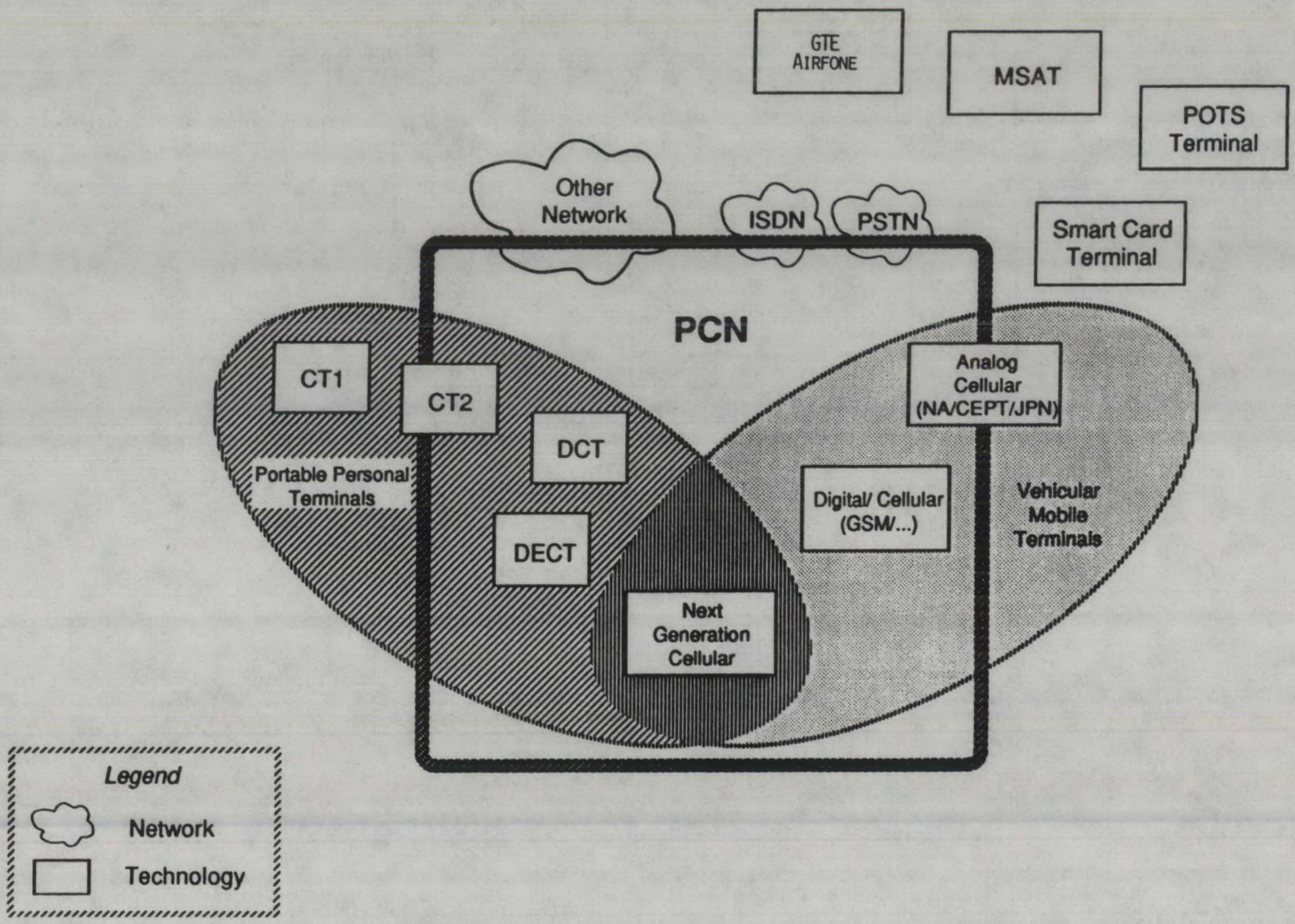
Technology/Service Development

- ♦ Cellular Packet Data (Multipoint)
  - ○ Cellular Radio Interface
  - ○ General Terminal Device Interface
  - ○ Protocol Conversion
  - ○ Telemetry, Dispatch, Location Applications
- ♦ Spread Spectrum Packet Voice (Multipoint) (microcell and macrocell)
  - ○ Compressed 4KB, 8KB, 16KB, Voice
  - ○ Spread Spectrum/TDMA/TDD (Future CDMA)
  - ○ Packet Protocol Air Interface
  - ○ Point of Sale Terminals, Wireless PABX
- ♦ Cordless Trial Technical Support
  - ○ Capacity Issues
  - ○ Performance Issues



PERSONAL COMMUNICATIONS EVOLUTION

Personal Communication



GTE AIRFONE

MSAT

POTS Terminal

Smart Card Terminal

Other Network

ISDN

PSTN

PCN

CT1

CT2

DCT

DECT

Portable Personal Terminals

Next Generation Cellular

Analog Cellular (NA/CEPT/JPN)

Digital/ Cellular (GSM/...)

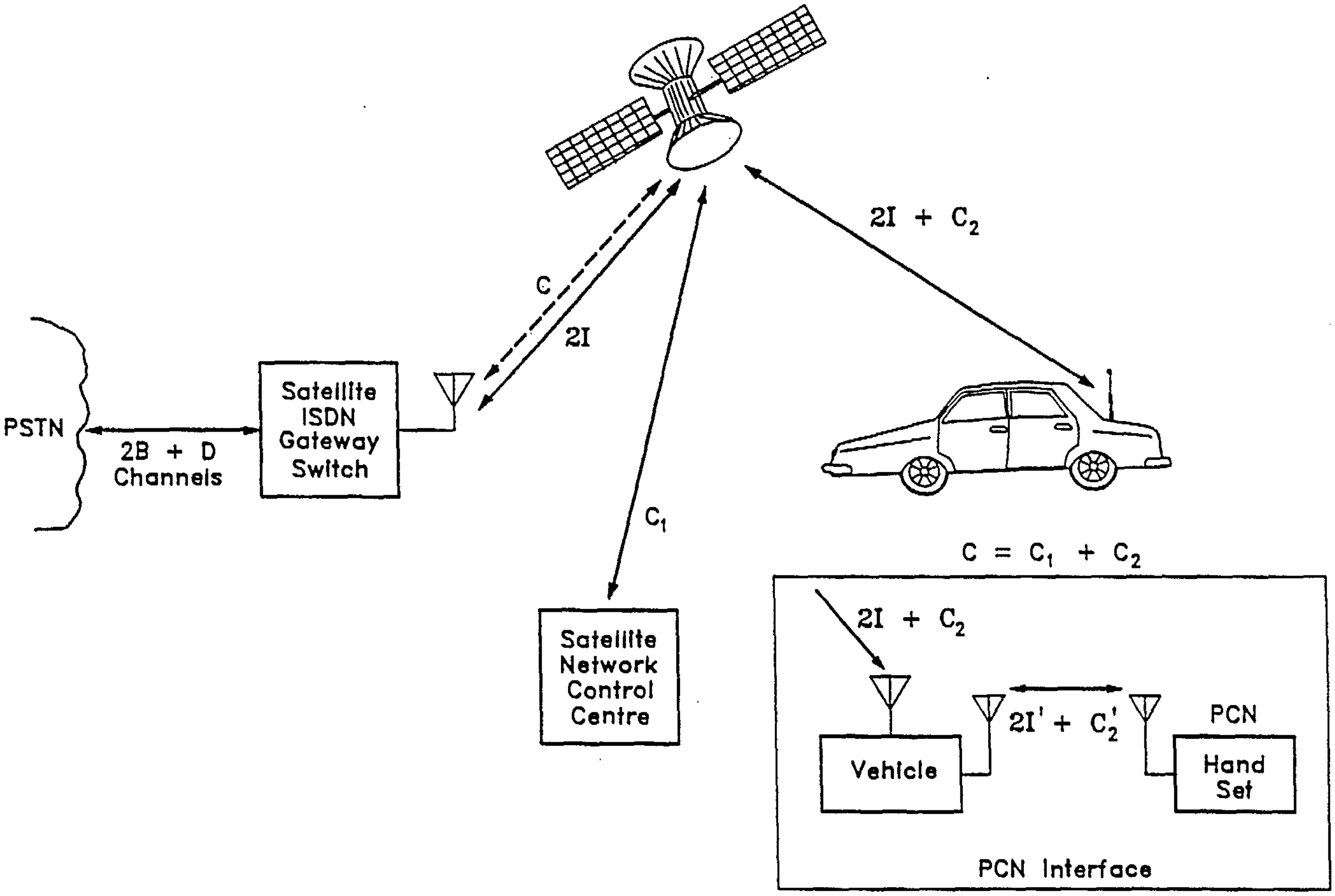
Vehicular Mobile Terminals

Legend

Network

Technology

MOBILE ISDN



MOBILE ISDN

SUMMARY

- Rationalization of:

    - -- Spectrum allocations
        - -- local, regional, international
    - -- regulatory environment

- PCN evolution depends on multidisciplinary approaches (MSAT, Airphone, GSM, DECT, CT-2+, digital cellular) using multidimensional solutions (access, service, coverage, technology, etc.)

- Standards

    - -- common signalling spectrum/format
    - -- common air interface
    - -- international standard desireable

- Networks support services (applications)

    - -- PCS evolves into PCN
    - -- extensive service control and mobility management
    - -- 4 MHz for PCS, 200 MHz for PCN

Coding and Receiver Structures for Fading Channels

D.P. Taylor

ABSTRACT

The Digital Radio Group at McMaster is engaged in a program of research to develop more effective coding/modulation formats and receiver structures for the fading channels encountered in land-and satellite-mobile radio systems. The objective of this work is to develop some of the enabling technologies for the next generation of digital mobile radio systems. In this talk, we briefly describe some approaches being taken to accomplish these goals. First, we describe a receiver structure for M-ary DPSK signals that, through the adaptive estimation of channel eigenvalues, essentially eliminates the error-floor due to correlated fading. We have found that this estimator adapts very quickly and can track even the very rapidly changing fades encountered by high-speed vehicles. Second, we describe an approach to the encoding of signals for transmission through mobile channels. This approach, known as multi-level coding appears to have considerable potential for the design of high-performance digital wireless transmission systems. The technique may be regarded as a generalization of more conventional Ungerboeck or trellis coding where more than one code is used in a hierarchy matched to the signal set partitioning. Such an arrangement allows for the achieving of high coding gains at relatively modest decoding complexity. Moreover, the approach allows for some of the codes to be designed specifically to combat the facing effects of the channel.

BIOGRAPHY

Desmond P. Taylor (M'65) was born in Rouyn, Quebec, Canada on July 5, 1941. He received the B.Sc. (Eng.) and M.Sc. (Eng.) degrees from Queen's University, Kingston, Ontario, Canada in 1963 and 1967 respectively, and the Ph.D. degree in 1972 in Electrical Engineering from McMaster University, Hamilton, Ontario, Canada. In 1972, he joined Communications Research Laboratory and Department of Electrical Engineering of McMaster University where he is now a Professor. His research interests are in the area of digital communications and are primarily concerned with bandwidth efficient modulation and coding and associated problems in satellite and microwave radio communications. Some secondary interests include problems in satellite multiple access and radio networking.

Dr. Taylor is a member of the Canadian Society for Electrical Engineering, a Fellow of the Engineering Institute of Canada and is a registered Professional Engineer in the Province of Ontario. During 1990, he is the Acting Director of the Communications Research Laboratory at McMaster University.

CODING AND RECEIVER STRUCTURES FOR FADING CHANNELS

D. P. Taylor
Communications Research Laboratory
McMaster University
Hamilton, Ontario

McMaster University
Communications Research Laboratory

A KEY CHALLENGE:
TO DEVELOP TRANSMISSION APPROACHES CAPABLE OF SUPPORTING THE DIGITAL SPEECH AND DATA TRANSMISSION WITH THE REQUIRED INTEGRITY IN NEXT-GENERATION MOBILE RADIO SYSTEMS

> ENGAGED IN RESEARCH TO DEVELOP BETTER CODING/MODULATION FORMATS AND RECEIVER STRUCTURES FOR FADING CHANNELS

> OBJECTIVE IS TO DEVELOP SOME OF THE ENABLING TECHNOLOGIES FOR NEXT GENERATION LAND- AND SATELLITE-MOBILE RADIO SYSTEMS

> HERE, BRIEFLY DESCRIBE TWO PROJECTS OF THE GROUP

1. OPTIMAL RECEIVER STRUCTURES FOR FADING CHANNELS
2. MULTI-LEVEL CODES FOR USE IN FADING CHANNELS

MAXIMUM LIKELIHOOD RECEIVER FOR FADING CHANNELS

> TYPICAL MOBILE CHANNEL - FREQUENCY-FLAT, TIME-SELECTIVE FADING

> CAUSES AN ERROR-FLOOR AT ERROR-RATES BETWEEN .01 AND .001 AT TYPICAL SNR VALUES.

> HAVE EXTENDED PERFORMANCE ANALYSIS OF M-ARY DPSK TO THE TO THE FADING CHANNEL
TAKE INTO ACCOUNT THE FULL STATISTICAL STRUCTURE OF THE FADING PROCESS.

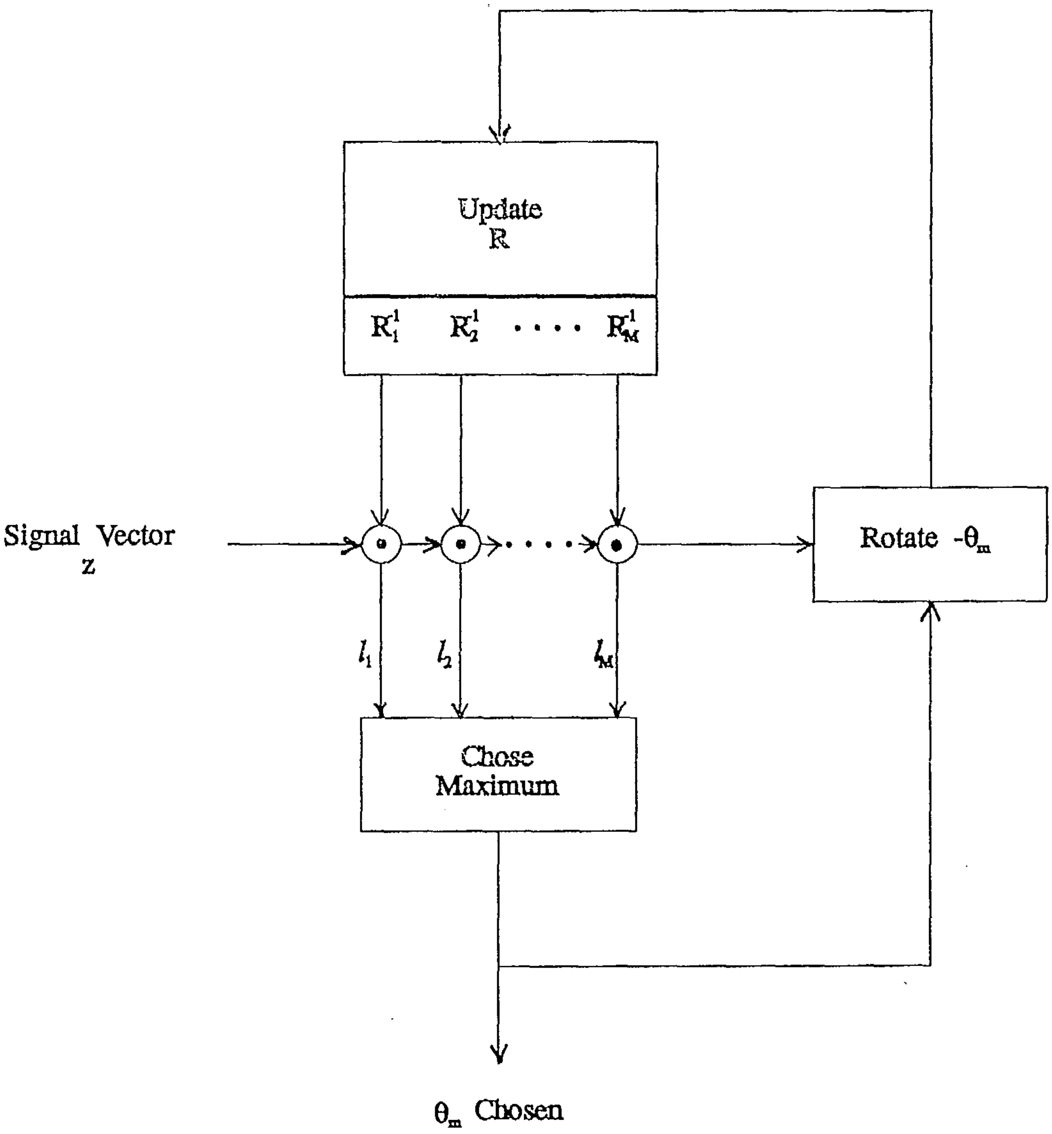
> HAVE DERIVED AND EVALUATED OPTIMAL, ADAPTIVE RECEIVERS FOR THE FADING CHANNEL.

> HAVE EMPLOYED A SAMPLED DATA APPROACH SUITABLE FOR DSP IMPLEMENTATION

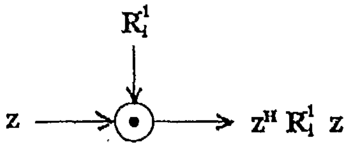
> BOTH THEORY AND SIMULATION EXHIBIT ERROR FLOORS REDUCED BY MANY ORDERS OF MAGNITUDE COMPARED CONVENTIONAL RECEIVER STRUCTURES

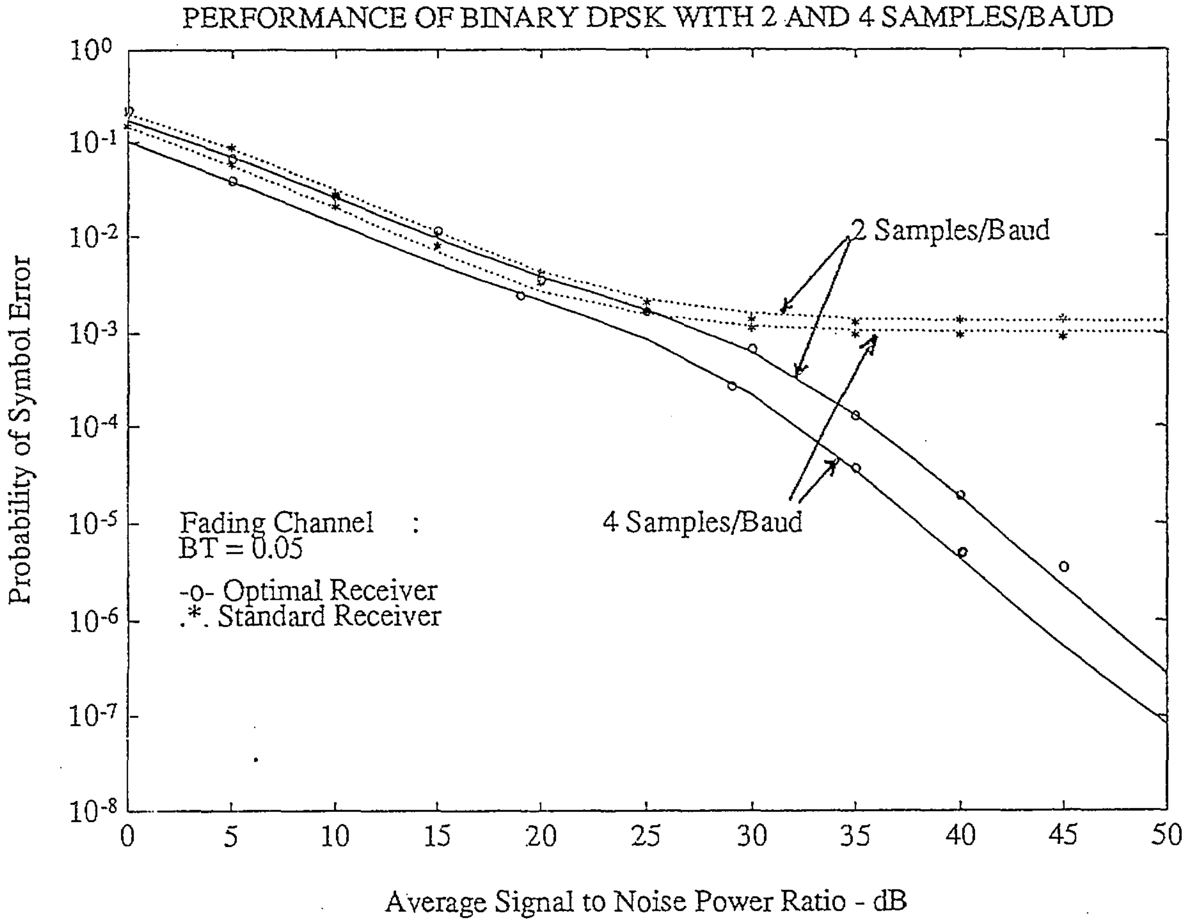
> ADAPTIVE STRUCTURE EXHIBITS ABILITY TO ACQUIRE VERY QUICKLY AND TO TRACK VIRTUALLY ANY MOBILE FADING CHANNEL.

> STRUCTURE IS BASED ON CONCEPT OF ADAPTIVE ESTIMATION OF CHANNEL EIGENVALUES.



Quadratic Form Operator




PERFORMANCE OF BINARY DPSK WITH 2 AND 4 SAMPLES/BAUD
Probability of Symbol Error
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0
5
10
15
20
25
30
35
40
45
50
Average Signal to Noise Power Ratio - dB
2 Samples/Baud
4 Samples/Baud
Fading Channel :
BT = 0.05
-o- Optimal Receiver
.*. Standard Receiver

MULTI - LEVEL CODING FOR DIGITAL RADIO COMMUNICATIONS

> CODES MAY BE CONSIDERED AS GENERALIZATIONS OF UNGERBOECK'S TRELLIS CODES

> MULTI-LEVEL CODES MAKE USE OF SIGNAL SET PARTITIONING

> ASSOCIATE DIFFERENT CODES WITH DIFFERENT LEVELS OF THE PARTITIONING OF THE SIGNAL SET

> PARTITION SIGNAL SET S_0 INTO PARTITION CHAIN

$$S_0 / S_1 / \dots / S_r$$

WHERE S_r CONTAINS ONLY 1 ELEMENT OF S_0

> PARTITION SO THAT MINIMUM DISTANCE d_i WITHIN EACH SUBSET INCREASES

> ASSOCIATE A COMPONENT CODE $C(S_{i-1}/S_i ;E_i)$ WITH THE PARTITION S_{i-1}/S_i

> IN EACH INTERVAL, ON AVERAGE B_i BITS ENTER ENCODER E_i
AND $b_i > B_i$ LEAVE IT

> THESE BITS SELECT THE (BINARY) LABEL OF A COSUBSET OF S_i

TWO-LEVEL ENCODING OF 8-PSK

> CONSIDER A 2-LEVEL CODE ON 8-PSK THAT HAS POSSIBLE APPLICATION IN MOBILE COMMUNICATION

> PARTITION THE SIGNAL SET INTO SUBSETS AS SHOWN FOR THIS PARTITIONING:

$d_0^2 = 0.56 \qquad d_q^2 = 2.00 \qquad d_b^2 = 4.00$

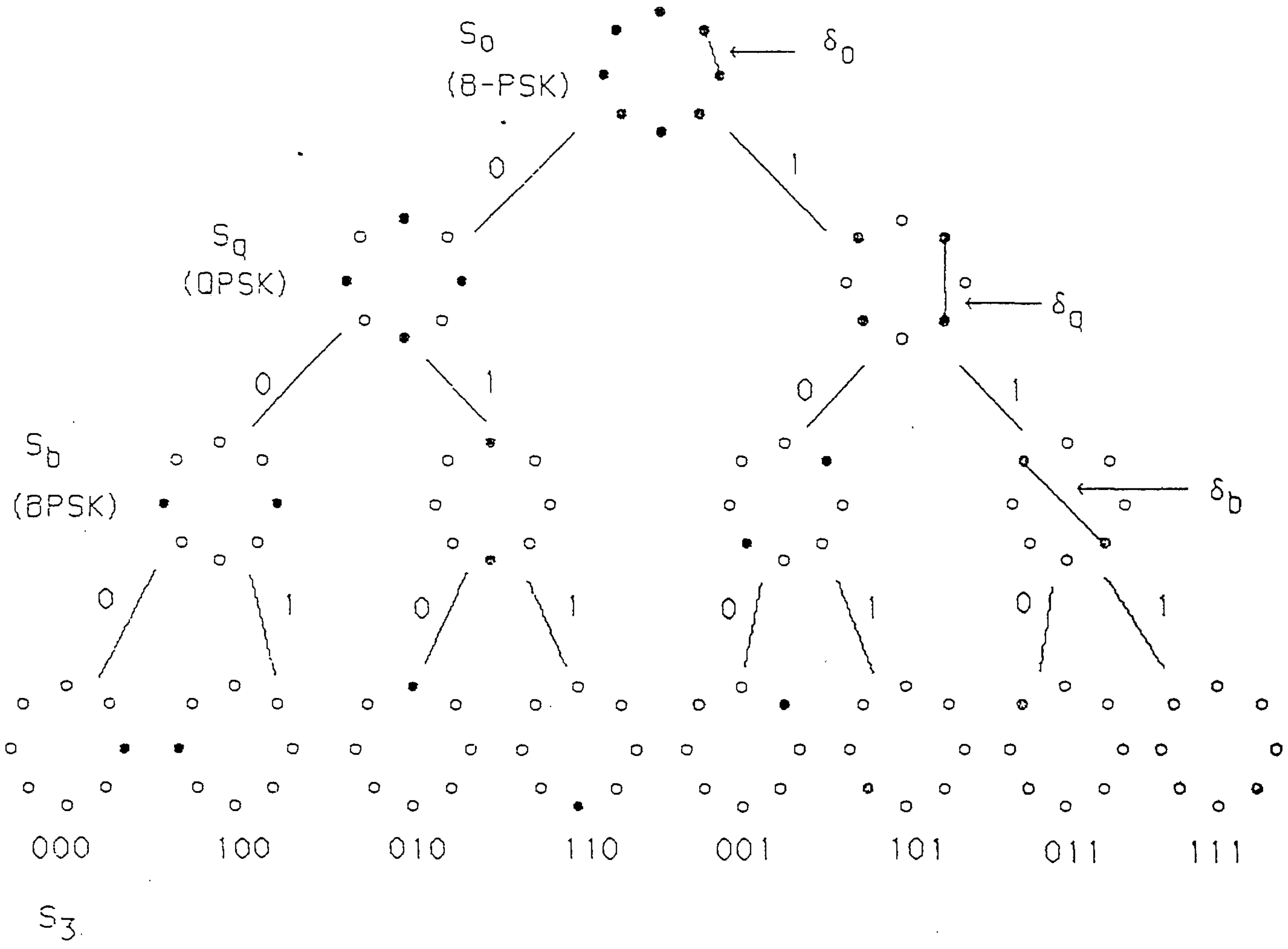
> TO GET APPROXIMATELY 2 BITS/SYMBOL TRANSMISSION RATE, THERE ARE TWO APPROACHES

1. USE A RATE 2/3 UNGERBOECK OR TRELLIS CODE

2. USE A 2-LEVEL CODE CONSISTING OF

   $C(S_0/S_1;E_1)$, WHERE E_1 IS A RATE 1/2 TRELLIS CODE

   $C(S_b/S_3;E_2)$, WHERE E_2 IS A HIGH-RATE BINARY ENCODER


S_0
(8-PSK)
δ_0
0
1
S_q
(QPSK)
δ_q
0
1
0
1
S_b
(BPSK)
δ_b
0
1
0
1
0
1
0
1
000
100
010
110
001
101
011
111
S_3

CODE C_1

> EXHAUSTIVE SEARCH CONDUCTED FOR BEST RATE 1/2 CODES ON 8-PSK

CODE C_2

> USED A DOUBLE ERROR-CORRECTING, RATE 7/8 CONVOLUTIONAL SELF-ORTHOGONAL CODE (CSOC) HAVING $d_{min} = 5$.

RESULTS:
- SPECTRAL EFFICIENCY OF 1.875 BITS/SYMBOL
- ACHIEVED CODING GAIN = 5.7 dB AT $P_e = 10^{-6}$

> THIS CODE DESIGNED USING EUCLIDEAN DISTANCE METRIC

> WORKING NOW TO INCORPORATE BETTER METRICS AND TO DEVELOP CODED STRUCTURES FOR THE OPTIMUM RECEIVER.

Presentation By:

Allen Angus, A G T

Presentation By:

Colin Buckingham, Ericsson Paging Systems

Telecommunications Standards

Peter Nurse

BIOGRAPHY

Peter Nurse is Director of Advanced Technology with NovAtel Communications Ltd., Calgary, Alberta. Peter was educated in England, and holds a Bachelors degree in Electrical and Electronic Engineering from Hatfield Polytechnic, and a Masters degree in Mathematical Logic and Computing Science from University of Nottingham. His interests include computer architecture, computer software development, digital signal processing, and the management of technological innovation. Peter is a member of IEE and IEEE. Chairman of TIA TR45.3 "Digital Cellular Systems", and he represented Canada as a member of Canadian National Organisation for (CCIR) International Radio Consultive Committee.

Presentation By:

Veena Rawat, DOC

The CT2 CAI Standard for Digital Cordless Communication

Richard Steedman

Presentation Outline

This presentation discusses the CT2 CAI standard for Digital Cordless Communications (1) from both a technical and commercial viewpoint. CT2 CAI is a world-wide standard providing advantages, interoperability and flexibility.

BIOGRAPHY

Richard Steedman received a first class BSc (hons) degree in Computer Science and Electronics from Edinburgh University in 1985. After graduating, he joined the VLSI design group at Plessey Electronic Systems Research Ltd. (now Roke Manor Research Ltd.), one of the U.K.'s leading and most respected research houses. He has designed a number of semi custom IC's for both military and civil communications, as well as carrying out associated feasibility studies and research into areas such as Design for Testability and Built-in Self Test.

In 1988, Richard joined the Radio Communications Department at Roke Manor. He was involved in the development of a CAI-compatible CT2 product and, as part of that activity, set on the Technical Working Group which produced the CT2 CAI Standard MPT 1375. He made a number of contributions to the definition of signalling layers 1 and 2, some of which have been patented.

Richard now works as a consultant in the Radio Comms. Department. As well as continuing work on CT2 systems, he has recently become involved in the definition of the new Digital European Cordless Telephone (DECT) system and sits on the RES3-R radio sub-committee of the European Telecommunications Standards Institute (ETSI).

Presentation By:

Bob Swain, BTRL

Luncheon Speaker

Alex A. Beraskow

BIOGRAPHY

Mr. Alex Beraskow is the President and Chief Operating Officer of Vision 2000 Inc. Vision 2000 Inc. is a consortium of communications and information technology related firms that will facilitate and accelerate the growth of the Canadian telecommunications industry.

Alex Beraskow brings a strong academic and professional background to the position. He is a Professional Engineer (P.Eng.), a Certified Management Consultant (CMC) and holder of an MBA degree in finance. His career began over 20 years ago as a systems engineer with IBM followed by international experience with Datec and Philips in Australia. He is bilingual and has over 20 years of management consulting experience related to all elements of business planning development and marketing.

As an executive, his principal expertise has been with computer technology firms and the area of management consulting. Previous to Vision 2000 he was the Managing Director of the Federal Office of DMR, an international management consulting firm. That office provided management consulting services for information management to the federal government in Ottawa. Previous to that, he was the founding partner of ISG (Information Systems Group) Consultants Ltd. That firm was acquired by DMR.

VISION 2000

VISION 2000

JUNE 6, 1990

"Canada's place in the world is not guaranteed. Either we meet the challenge of competitiveness and ride the crest of the technology wave into the 21st century or we exhaust ourselves in the rip–tide of history, fading inexorably backwards."

Prime Minister Brian Mulroney
(at the Halifax Forum, 1989)

1.0 INTRODUCTION

Objective

- Present Vision 2000 Inc.

1.0 INTRODUCTION

Agenda

- Setting
  - .. domestic
  - .. international
- "The Past"
  - .. St. Sauveur
  - .. Kananaskis
- "The Present"
  - .. Business Plan
- "The Future"
  - .. All directed to telecommunications

1.0 INTRODUCTION

Definition of telecommunications

- industry
  - carriers
  - equipment manufacturers
  - service providers
  - systems integrators
  - researchers, universities
  - government
- 3 principal stakeholders
  - industry (private sector)
  - government
  - academia

2.0 THE SITUATION

4 Dominant Issues:

- Technology
- Global Markets
- Environmentals
- Productivity

2.0 THE SITUATION

Technology Issue

- optical technology
  - greater capacity
  - cheaper
  - quality improving

- wireless communication
  - cellular – 50% growth in Canada
  - cordless
  - paging

- satellite

- integration of data, voice, image, text, and signals
  - voice – 7% growth
  - data – 25% growth

Technology Issue (continued)

- changing cost structures
    - .. 70% of switch makers' cost is software
- products/services
    - .. fax
    - .. personal communications
    - .. networking
    - .. long distance communication

2.0 THE SITUATION

Global Markets

- Competition
  - .. 6 of 10 switch makers to survive
  - .. deregulation
  - .. compete on service, not just cost
  - .. borderless
- Domestic
  - .. Trade Balance is negative (equipment mfgs)
  - .. FTA creating new business environment
- International
  - .. markets
    - ... Europe 1992
    - ... Pacific Rim
    - ... USA
    - ... Central/East Europe
  - .. open or closed

2.0 THE SITUATION

Environmentals

- Splintered Regulatory Arrangements
    - .. different rules in different areas
    - .. uneven practices
- Complex and lengthy regulatory procedures
- Coordination of government and IT industry
    - .. mobilize resources
    - .. provide focus
- Lack of policy supporting innovations
- Competition
    - .. vs industry cooperation
- Tax policies
    - .. consistent
    - .. provide incentives

2.0 THE SITUATION

Productivity Issue

- Globalization
  - .. 1st world manpower competing vs. 3rd world
- Mass Migration to greenbelt suburbs
- Declining birth rate
  - .. office staff not available
- Just–in–time management
- Increasing cost of providing health care and social services

Strategy

- Need higher personal productivity
- Need better communications

2.0 THE SITUATION

National Viewpoint

- Size

carriers	$12B
equipment manufacturers	$ 4B

- Economic Growth (1971 – 1986)
    - GDP 2.3% annually
    - Communications 7.01% annually
- Employment Growth
    - double national rate
- Trade Balance
    - now, negative for telecommunication

2.0 THE SITUATION

Conclusion

- We have a Canadian industry wide situation
- We need to develop a concerted plan of action?
  - .. by area
    - ... research and development
    - ... product commercialization
    - ... manufacturing
    - ... system delivery
    - ... marketing
  - .. by product/deliverable
    - ... personal communications network

3.0 VISION 2000 EVOLUTION

Genealogy

- St. Sauveur, March 1989
- Kananaskis, November 1989
- Incorporation, March 1990
  - .. working group formation
- Business Plan, October 1990
  - .. business plan
  - .. strategic industry plan
  - .. personal communications network is 1st initiative

3.0 VISION 2000 EVOLUTION

The Process

St. Sauveur Conference (March 1989)

- 60 industry and university leaders
    - BNR, Cantel, Royal Bank,
      SR Telecom, Telesat,
      Gandalf, ITAC and others
- Two days of discussion on
    - The mechanisms, infrastructure and programs for communications research

3.0 VISION 2000 EVOLUTION

The Process

Conclusions

- a consensus to focus R&D efforts on "personal productivity networking"

- a call to restructure telecom policy so as to encourage communications R&D

- Canada needs more collaboration among industries, and between industry and government

3.0 VISION 2000 EVOLUTION

Kananaskis Conference

Consensus

- The strategy and the focus are right
- A non–profit corporation should be established
- Founding members provided first year funding of $1 Million
- Develop a Business Plan to be presented at a future conference

3.0 VISION 2000 EVOLUTION

THE MEMBERS

Alberta Government Telephones
Alberta Telecommunications Research Centre
BCE Mobile Communications Ltd.
Bell Canada
Bell Northern Research
Cablecasting Limited
Canadian Centre for Marine Communications
Canai
Cantel
Comcheq Services Ltd.
DATAP
DTI Telecom Inc.
Ericsson Communications
Gandalf Technologies, Inc.
IBM Canada
Insinc
Microtel Pacific Research (MPR)
Mitel
Motorola Canada
NGL Consulting Ltd.
Newbridge Networks Corporation
Novatel Communications Ltd.
Press Porcepic/Softwords
Satlink Business Services Inc.
Scotcomm
Spar–Aerospace Limited
SR Telecom
Telecom Canada
Teleglobe Canada
Telesat Canada
Unitel
Voice and Data Systems

4.0 VISION 2000 INC.

Telecommunications Industry said

- "We need a strategic direction"
- "We need to work together"
- "We do not need hand outs, perse"
- "We need government support and co–operation"
- "Make it easier for us to grow"
- "We want to develop an industry, that is
    - vibrant, robust
    - globally competitive
    - Canadian
    - employs Canadians
- "We need a major national initiative"

4.0 THE PLAN

Business Statement

.. 6 month timeframe

- Vision 2000 is in the strategic planning business for the Canadian telecommunications industry

.. thereafter

- Vision 2000 Inc is a telecommunications consortium that will provide a range of services to facilitate the growth of the telecommunications industry in Canada.

Vision 2000 Inc. is

- not a lobbying organization for its individual members
- not a trade association
- not a marketing board
- not a regulator
- not a research lab
- not an economic council

4.0 THE PLAN

VISION 2000 INC. - OBJECTIVE

To position the Canadian telecommunications industry competitively in domestic and international product, application and service markets through a concerted R&D strategy

VISION 2000 INC. - VISION STATEMENT

- Precompetitive R&D
- Position industry competitively in domestic and international markets
- Communications infrastructure will improve productivity, economic viability and competitiveness of all Canadian industries
- Level the playing field
- Focus on personal communications
- Canada will compete with the world as a technology power in the 21st century

4.0 THE PLAN

Characteristics of the Envisioned Personal Communications Environment

1. Individualization – personal access
2. Universality – service anywhere
3. Portability – individual carries machine/device
4. Interworking – access to network(s)/device(s)
5. Interactive Personalized Information – retrieval of voice, data, image, video
6. Versatility – information conversion for suitability to application and transmission

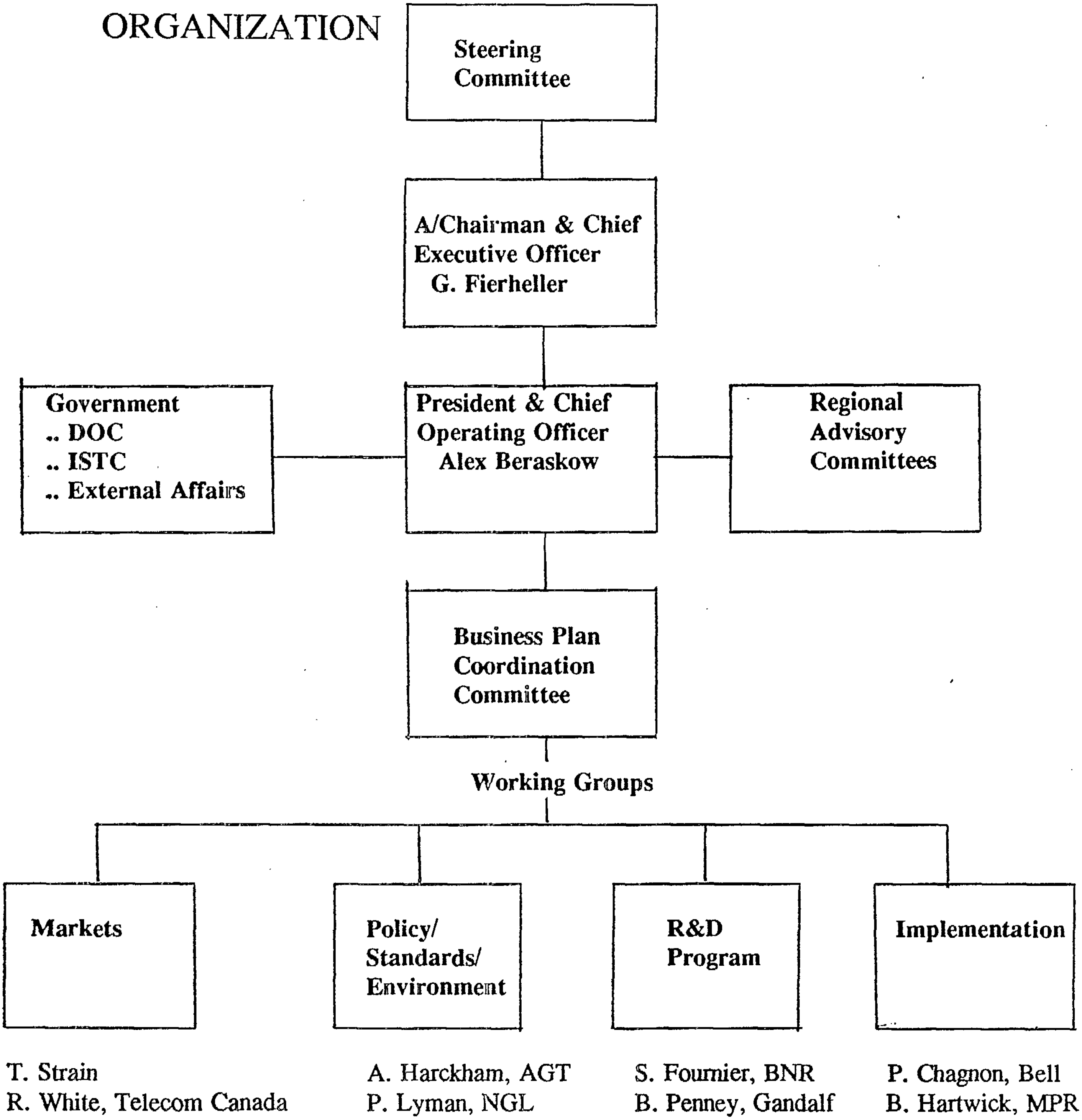
4.0 THE PLAN

Intended Industry Effects

- Definition of strategic direction and concept
- Consensus of R&D programs, formation of consortia, monitoring and evaluation
- coordination mechanism for government support
- minimization of business risk
- earlier & more rapid implementation of products and services
- creation of appropriate environment (regulations, standards, policies, etc.)
- a pro–active and consensus–building organization

4.0 THE PLAN

ORGANIZATION



4.0 THE PLAN

Process

- Working Group: Markets
  - .. identify future growth areas
    - ... identify new technologies
    - ... define market opportunities

- Working Group: R&D
  - .. direct R&D efforts
    - ... technology development objectives
    - ... evolutionary R&D programs
    - ... define new technologies
    - ... project outlines

- Working Group: Policy & Standards
  - .. specify environmentals
    - ... government policies
    - ... identify changes in legislation & regulation
    - ... define required standards

4.0 THE PLAN

- Working Group: Implementation
  - .. define Vision 2000 operations
    - ... management requirements, structure and processes
    - ... demonstrate commercial viability of Vision 2000

4.0 THE PLAN

Milestones

■ Working Group Reports	June 1990
■ Consolidation	July 1990
.. 1st draft of Business Plan	
■ Steering Committee Approval	August 1990
■ Production	September 1990
■ Presentation	October 1990

System Capacity and Spectrum Efficiency

Dr. Samy Mahmoud

SUMMARY

This presentation will focus on systems architectures for in-building wireless communications in the 900 MHz-3 GHz frequency band. The objective is to relate total system capacity to spectrum requirements. A number of system parameters affecting this relationship will be discussed, including the in-building propagation environment and channel characteristics, frequency reuse patter, channel access protocols, system connectivity and control, and structure of radio transceivers. The presentation will also consider advances made in channel coding and diversity techniques to combat signal interference conditions. Improvements in system capacity which result from the deployment of such technique will also be outlined.

BIOGRAPHY

Graduated with M.Eng. and Ph.D. degrees, Carleton University in 1971 and 1974 respectively. Joined the Faculty of Engineering, Carleton University in 1975 where he is at present Professor and Chairman of the Department of Systems and Computer Engineering.

Research activities: Project leader of Portable Communication Systems, TRIO. Research interests include Mobile and Portable Radio Systems, Signal Processing and High Speed Network protocols and interfaces.

Senior Editor, IEEE Journal on Selected Areas in Communications, responsible for coordinating issues in the areas of mobile and portable satellite and terrestrial networks and systems.

Chaos in Radio Communications

Authors: Allan Angus, Charbel Tannous, and Bob Davies
Presented By: Allan Angus

ABSTRACT

Observations have been made of the evolution in time of radio signals transmitted and received in building environments under a wide variety of conditions. The data have been analyzed using new techniques that distinguish between stochastic and chaotic behaviour; and in all, cases of the data have shown deterministic chaos. The short term power spectra of the data have been tested for Feigenbaum's universality criteria in the transition to chaos; and a simple, physically plausible non-linear transmission model that leads to chaos has been identified. Implications of the results for communications in the presence of chaos are discussed.

CHAOS IN RADIO COMMUNICATION

Allan Angus, Charbel Tannous, and Bob Davies

Alberta Government Telephones, Research and Development

Calgary, Alberta, Canada

Abstract

Observations have been made of the evolution in time of radio signals transmitted and received in building environments under a wide variety of conditions. The data have been analyzed using new techniques that distinguish between stochastic and chaotic behaviour; and in all cases the data have shown deterministic chaos. A simple, physically plausible non-linear transmission model that leads to chaos has been identified. Implications of the results for communication in the presence of chaos are discussed.

Introduction

It has been customary in the analysis of radio propagation to consider received amplitude and phase to be stochastic variables[1]. Depending upon the nature of the assumptions concerning the propagation environment, a number of different probability distributions have been considered for received amplitude and phase; for example, Rayleigh, Rice, or log normal for amplitude; uniform for phase.

Beginning roughly with the ground-breaking work of Lorenz[2, 3, 4] in the early 1960s, there has been an alternate view of the erratic behaviour of many physical systems that were previously considered to be stochastic. This new view of erratic behaviour has come to be called "chaos". The fundamental aspect of chaos that concerns us in this paper is that it represents the performance of a low-order deterministic physical system that continuously generates information[5]. The importance of the concatenation of the two concepts of determinism and information flow for communication in the presence of chaos cannot be over-emphasized.

In the following, we will treat three topics:

- evidence of chaos in radio channels;
- a simple transmission model that leads to chaos; and
- communication in the presence of chaos.

Deterministic chaos

Although an assumption of stochastic behavior in mobile or indoor propagation is very general, we have explored the hypothesis that the indoor communication channel displays deterministically chaotic behavior. This question is important in many respects and the tools to answer it readily exist. These tools are based on the determination of the correlation dimension, ν, of the strange attractor[6] associated with the multi-path profile considered as a real valued time-series $x(t)$. The term, attractor, refers to a compact region of the phase space associated with the dynamical system that generated $x(t)$, into which any trajectory sufficiently close (in some sense) will ultimately be drawn. An attractor may be a single point, a locus of points that are repetitively visited (as in an oscillation or limit cycle), or something more complex. As a locus of points in a space of some given dimension, an attractor will have some local structure. Simple attractors have a topology that is of integral dimension. Attractors of non-integral (fractal) dimension have been called "strange"[7]. The evolution of the phase trajectory of a dynamical system captured on a strange attractor is termed deterministic chaos[8]. Typically, strange attractors have the characteristics of the intersection of a Cantor set and a manifold.

Given an experimentally obtained time series, $x(t)$, it is possible to estimate its correlation dimension, and establish whether the observed series is due to a stochastic or deterministically chaotic process. Using delay coordinates[9, 10] one forms the m-dimensional delay vector, $x(t) = [x(t), x(t-\tau) \ldots x(t-(m-1)\tau)]$ with delay, τ, and computes the correlation sum, $C(N,r)$ which is the ratio of the number of pairs of delay vectors (the distance between which is less than r) to the total number of pairs; namely,

$$C(N,r) = \frac{2}{N(N-1)} \sum_{i,j} \theta(r - \| x_i - x_j \|) \qquad [1]$$

where $\theta(x)$ is the Heaviside unit step function. From this, the correlation dimension, ν, is defined as the slope of $\log(C(N, r))$ versus r for small r. On a strange attractor of dimension, ν, the correlation integral is proportional to r^{ν} for large N and small r; that is,

$$C(N,r) \approx (r/R)^{\nu} \qquad [2]$$

where R is the so-called "effective radius" of the attractor. The correlation dimension is somewhat different than the fractal (or Hausdorff-Besikovich) dimension, D. To find D, one considers the attractor as embedded in an m-dimensional space; and covers the volume of the attractor with hypercubes of length, l, on a side. One then counts the number, $M(l)$, of hypercubes that contain part of the attractor. In the limit as l tends to 0, the number of hypercubes that contain part of the attractor increases as

$$\lim_{l \to 0} M(l) \approx l^{-D} \qquad [3]$$

The fractal dimension, D, is a geometric property of the attractor, and tells little about the dynamics of the underlying physical system. In particular, it reveals no information about the frequency with which the phase trajectory arrives in any of the hypercubes. Another measure of the "strangeness" of an attractor exists which does account for the probability of the system being in a given region of the phase space. This is the information dimension, σ.

Now, the evolution of a system on a strange attractor leads to an entropy

$$H(l) = -\sum_{i=1}^{M(l)} p_i \log_2(p_i) \qquad [4]$$

where p_i is the probability of the system arriving in the *i*th cell, and $H(l)$ is the entropy. This is the amount of information gained when the system is found to be in the state associated with the *i*th cell, known to a resolution of $1/l$. Grassberger and Procaccia[11] have observed that for all attractors studied to date,

$$H(l) \approx H_0 - \sigma \ln(l) \qquad [5]$$

where σ is the information dimension. And in general,

$$\nu \leq \sigma \leq D \qquad [6]$$

where the bounds are usually very tight.

For a true stochastic process, ν increases with m without showing any saturation. In contrast, for deterministic chaos, ν saturates at a value, ν_0. In general, the next integer greater than ν_0 represents the number of non-linear recursive or differential equations that are necessary to describe the state and evolution of the system. The dimension of a strange attractor is generally less than the integer dimension of the space in which it is necessary to embed it[12]. This integer, d, is the topological dimension of the attractor. To obtain a reasonable estimate of ν_0, it is necessary to increase the embedding to $m \geq 2d+1$ [13].

If the profile turns out to be deterministically chaotic, the detection, modulation, and coding techniques for the signal ought to be adapted in order to account for this fact; otherwise one has to rely upon techniques capable of handling stochastic signals.

Evidence of chaos in in-building rf propagation

Data on the propagation of in-building radio were taken at the University of Calgary in the Engineering Building[14]. The hallway construction was of steel reinforced concrete with a large pipe rack suspended from the ceiling. The section of hallway along which the data were taken has no doors or windows and the transmit and receive antennas were within line of sight of each other for the entire experiment. The transmit power level was +20 dBm at 915 MHz and 50Ω fed into a half wave dipole antenna with matching balun. The receiving antenna was a cross-polarized dipole array.

Data were taken in a number of different experimental configurations. In some, the receiving antenna was moved away from the transmitting antenna down the hallway while data points were taken from both antennas. In others, data were taken with the receiving antenna being randomly rotated at a fixed distance from the transmiting antenna. Data were taken at a 10 ms sampling rate. Resolution of the data for the spatially dependent runs was 3.5 mm. Only total received power was recovered, phase was not measured.

Figure 1a shows the variation of ν for three sequences of data with randomly, co-, and cross-polarized receiving antennas. The values of ν were computed using Theiler's algorithm[15]. The data all show a definite saturation with increasing embedding dimension. For contrast, we have also graphed ν for a simulated Rayleigh and a simulated band-limited Rayleigh process. The simulated Rayleigh process was obtained in a computer by taking the square root of the squares of two independent mean-zero gaussian processes. The simulated band-limited Rayleigh process was obtained in a similar way by first filtering the gaussian processes with a highly under-damped second order low-pass digital filter to model the typical power spectrum of random Doppler. The slope of the best fit line for the Rayleigh process was 0.981; while the slope of the best fit line for the band-limited Rayleigh process was 0.777. It may be noted that the introduction of correlation into the random process by the filtering operation has reduced the rate of growth of ν with embedding dimension, but ν will still increase without bound.

In contrast, the radio data show saturation of ν_o at a level just below 4. The average values of ν_o for the random, co- and cross-polarized data were 3.7±.5, 3.5±.3, and 3.1±.4, respectively. The analysis was based on about 3800 data points in each sequence. Improved accuracy in the estimate of ν_o would depend upon obtaining much longer data runs. Figure 1b shows the variation of C(r) with r for a sequence of values of embedding dimension, m, for the cross-polarized data. The saturation of C(r) can seen from the curves.

The results for the radio data are indicative of deterministic chaos, while those for the simulated Rayleigh processes (of 6000 points in length each) are indicative of stochastic systems. It is possible to display the evolution of a system on a strange attractor by graphing projections of the phase trajectory into two dimensions. For example, Figures 2 and 3 show the phase trajectory for the well-known Lorenz system

$$\begin{Bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{Bmatrix} = \begin{Bmatrix} -10(x - y) \\ -xz + 28x - y \\ xy - (8/3)z \end{Bmatrix} \qquad [7]$$

For data based on a time series, a suitable, if arbitrary, choice of phase co-ordinates is the set of lagged samples to the order necessary to represent the dynamics of the generating system. For the radio data presented here, the number of phase variables is 4; therefore, 3 plane projections are required to display the attractor. These are given in Figures 4 through 6 for a time sequence of 2000 points taken at a fixed location during random rotation of the receive antenna. For contrast, the Figures 4b through 6b show the same projections for the band-limited Rayleigh process whose behaviour was graphed in Figure 1a. Although the given radio data have a probability distribution that is well-approximated by the Rayleigh curve, the sequence of Figures shows that the data are *topologically* dissimilar, confirming the evidence of Figure 1a.

The attractor appears to consist of multiple scrolls within a well-defined region of the phase space. When observing the evolving trajectory, it may be seen that the direction of motion around the scrolls is uniformly clockwise, with the zero-reference variable given on the abscissa. Although not reported here, we have performed similar analyses on data from a number of other locations taken both with and without phase information. In every case, we have observed the saturation of correlation dimension that is indicative of deterministic chaos, and a set of phase-plane plots that are similar to those given here. This is not to suggest that all radio transmission is chaotic as opposed to stochastic; but we believe the consequences of these observations for communication to be profound.

A simple transmission model leading to chaos

It is natural to attempt to identify the physical mechanisms responsible for the observation of chaos in rf propagation. We do not propose to have the final answer to this question, but it is possible to demonstrate that even a simple transmission model may lead to chaotic behaviour. Consider the system of Figure 7 which comprises a square wave generator driving a transmission line terminated in a non-linear load.

We have explored the behaviour of this system for various non-linear loads. In particular, if the load equation is the cubic function

$$i_L = k\, v_L(v_L^2 - 3) \qquad [8]$$

then the system will lead to chaos for a range of values of square wave input and the constant, k, when the length of the line is such that the one way propagation delay time is exactly one quarter period of the square wave generator.

A wave propagating in the positive direction from the generator to the load must obey the relation

$$v^+/i^+ = Z_o = 1 \qquad [9]$$

while a wave in the negative direction must obey

$$v^-/i^- = -Z_o = -1. \qquad [10]$$

At the load, an in-bound wave in the positive direction leads to a reflected negative wave that is the solution to the defining equation of the load[16]

$$(i^+ + i^-) = k\,(v^+ + v^-)((v^+ + v^-)^2 - 3) \qquad [11]$$

The negative going wave is transmitted to the source and is subject to a reflection coefficient of $\rho = -1$, because of the zero source resistance. The result is a new positive going wave that is the linear superposition of the reflected wave and the step change due to the voltage generator. The solution to the resulting recursive system of equations is a deterministic chaos for certain values of V_{gen} and k. The entire set of equations is

$$\begin{aligned}
v_L(n) &= v^-(n) + v^+(n) \\
i_L(n) &= i^-(n) + i^+(n) \\
v^-(n) &= -Z_o \bullet i^-(n) \\
v^+(n) &= -v^+(n-1) \\
v^+(0) &= V_{gen} \\
i_L(n) &= k \bullet v_L(n) \bullet [v_L^2(n) - 3] \\
i^+(n) &= i_L(n-1) - \rho \bullet i^-(n) + \frac{v^+(n) - v^+(n-1)}{Z_o}
\end{aligned} \qquad [12]$$

where the last equation accounts for the accumulation of reflections from the source end of the line. Only three of the equations are independent.

The equations were solved on a Macintosh IIcx computer using the macro language in Microsoft Excel. Exact solutions were found using the closed form for cubic polynomials. For certain recursions, there are three non-unique solutions of the cubic load equation [11] for $i^-(n)$. In such cases, the unique solution was chosen that resulted in a new load voltage that was on the same monotonically increasing or decreasing segment of the load i-v characteristic as the old load voltage. For all values of k, these segments were $v_o<-1$; $-1 \le v_o \le 1$; and $v_o>1$.

The structure of the attractor is shown in Figures 8 through 11 for a number of values of V_{gen} and k. In Figures 8-10, k is 4.5; in Figure 11, k is 2. These show the projections into the in-bound current-reflected current plane, and into the load voltage-reflected current plane. The values shown are samples at the load end, separated by a round-trip delay time over the line. The sequence of Figures demonstrates a transition of the attractor to an increasingly less dense set of points in a Cantor dust. For k=4.5 and $V_{gen} = 0.5$, we have estimated the correlation dimension of the attractor at just over 1 using Theiler's algorithm. For various other values of V_{gen} and k, the system displays a complex sequence of limit cycles and stable points. We expect that other forms of non-linear load elements, such as varactor diodes (non-linear capacitance) and inductors showing saturation or hysterisis would also demonstrate transitions to chaos.

One point of this simple system is just that a transmission model that includes a non-linear scatterer and multiple reflections can lead to deterministic chaos. As far as we are aware, this is the first time that a transmission line model has been shown that demonstrates chaos, although many chaotic lumped-parameter circuits have been already found. A second point stems from the observation that the voltage source can be taken as a data transmitter. Then, if instead of sending a deterministic dotting sequence, the transmitter were sending a binary-coded data stream, the receiver would be virtually incapable of correctly decoding the information, even in the absence of noise. This transmission process was simulated for k=2 and V_{gen}=.5 with a binary data sequence of length 2000 bits. The received bit error rate was 0.479. Figure 12 shows the arrival of single bit errors as a function of time. The question is: Where has the capacity of the perfectly noiseless binary channel gone?

Communication in the presence of chaos

In a series of fundamental papers,[17, 18] Claude Shannon introduced the concepts of information as entropy and channel capacity in the presence of noise. Shannon found the maximum capacity of a channel using the notion of a Hilbert space of communication symbols with additive noise to be

$$C = W \log_2\left(\frac{P + N}{N}\right) \qquad [13]$$

where C is channel capacity in bits per second, W is channel bandwidth in Hertz, P is received signal power and N is the received noise power. The argument leading to [13] is based upon the notion of the distinguishability of received symbols, taken as points in a Hilbert space, while accounting for the effect of additive noise, which is to blur or diffuse the received symbol vector over a spherical region of the space whose radius is $\sqrt{2TWN}$, where T is the symbol time.

However, if the channel consists of a deterministic chaotic process driven by the transmitter, the effect upon the received information symbols can be much more complex, even in the absence of noise. The action of a strange attractor on a finite volume of a phase space; or in this case, a signal space, involves stretching, compression and folding along different dimensions, based upon the topology of the attractor. The various measures (σ, ν, D) of the strangeness of an attractor that were discussed above indicate the degree to which a symbol may be distorted during transmission over a chaotic channel.

Shaw[19] has postulated that the important property of information rate of an attractor can be obtained from a return map taken anywhere transverse to the phase flow on the attractor. Taking the return map reduces the attractor to a two dimensional system, y = F(x). According to Shaw, the entropy rate becomes

$$\overline{\lambda_t} = \frac{dH}{dt} = \lim_{n \to \infty} \frac{1}{n} \sum_{i=1}^{n} \frac{\log_2 |dy_i/dx_i|}{T_n} \qquad [14]$$

where T_n is the time taken for the *n*th iteration. A strange attractor generates information by virtue of its intricate topology. At any scale of resolution, arbitrarily close regions of phase space will ultimately lead to uncorrelated trajectories, because of the fractal nature of the attractor. For communication over a channel with chaotic properties, this leads to a particularly troublesome form of equivocation of received signals.

Consider the transmission of a signal over a channel in which the amplitude or phase or both are subject to chaotic perturbations. Let the received signal strength be such that the influence of noise can be neglected. If the transmission time of a symbol becomes long with respect to the entropy rate of the channel attractor, then the received symbol will be distorted by virtue of the nature of the signal trajectory on the attractor. The channel capacity may be computed using Shannon theory, beginning with

$$R = H(x) - H_y(x) \qquad [15]$$

where R is the information rate of the channel, $H(x)$ is the entropy rate of the source sending a signal, $x(t)$, and $H_y(x)$ is the so-called "equivocation", which is just the conditional entropy of $x(t)$ given the received signal, $y(t) = f(x(t), \mathscr{A}(t))$. $\mathscr{A}(t)$ is the state of the attractor. In general, $\mathscr{A}(t)$ will be dependent upon the history of $x(t)$. The channel capacity, C, is the maximum of R:

$$C = \max[H(x) - H_y(x)] \qquad [16]$$

over all possible signal sources. For the radio channels that we have studied, it appears that the topology of the attractor does not depend significantly on the amplitude of the transmitted signal, so unlike the classical transmit-power-limited case for which [16] yields [13], a chaotic channel is likely to show a bit error rate that is independent of signal to noise ratio (SNR). That is, the equivocation, $H_y(x)$, is independent of SNR.

Now, $H_y(x)$ is just

$$H_y(x) = -\iint p(x,y) \log\frac{p(x,y)}{p(y)} dx\, dy \qquad [17]$$

where $p(x,y)$ is the joint probability distribution of $x(t)$ and $y(t)$. In the experiments that we performed, $x(t)$ was a fixed amplitude tone in the 900 MHz region, carrying no information. The noise level was well below the received signal level. The received information rate can thus be nothing but the equivocation due to the channel attractor, which would be [17] evaluated for one value of x. This information rate should also be identical to Shaw's rate from [14] for the channel. The presence of a deterministic chaos in a radio channel is likely to lead to an irreducible bit error rate that cannot be controlled by an increase in signal to noise ratio. This is exactly the observation for the non-linear transmission model given in the previous section where there is no noise whatsoever and an error rate of about 48%. It is plain that channel capacity is being consumed by the chaotic process and not noise in that example. Mandelbrot and Berger have already pointed out the failure of Shannon theory to account for observed error patterns in data transmission on phone lines.[20]

It might be argued that the transmission line model is not fair in the sense that the erratic response of the channel is not allowed to die down before the decision is made as to whether the received bit is a 1 or 0. From this view, the distortion on the channel is a form of non-linear inter-symbol interference (ISI). All linear channels have some form of transient response to pulses with rapid rise times. One strategy for full response signalling over such a linear channel is to allow the transient response to die away by stretching out the symbol time, although this is an inefficient use of bandwidth. Another strategy is to shape the pulses so that ISI is zero at sampling instants. A third strategy (partial response signalling) is to allow known ISI at sampling instants. In the context of what we have presented, each of these strategies may be seen as an effort to manage or control the topology of the signalling space in the presence of a simple attractor, the stable transient response of the channel. Signal constellations for live channels are presentations of such a topology. In the light of this observation, signalling over a pass-band (modulated carrier) channel may be seen as transmission over a channel with a limit cycle of order 1. Information is transmitted by perturbing the limit cycle in some way. To return to the notion of a non-linear ISI in a chaotic channel, this view might be useful if the transient response ever died down; that is, if the channel had a point attractor. But deterministic chaos is associated with a perfectly stable (in the bounded input-bounded output sense) infinite-duration erratic motion on the strange attractor. Because of its infinite duration and its erratic nature, the usual anti-ISI strategies are of no benefit.

Strategies for signalling over so-called "fading" channels, which is the customary classification of mobile radio, are given in standard texts on communication.[21] An attempt is made to restrict the signal to a band unaffected by frequency dispersion due to random Doppler near the carrier and by time dispersion due to multipath at the high band-edge. Such a channel is said to be slowly fading and frequency non-selective. Thus, the prime strategy is to avoid the dispersion of random Doppler by signalling at a rate much faster than the envelope fade rate, so long as this does not push the signal into the ISI due to multipath time dispersion. When multipath ISI does arise, it is customary to compensate with some form of linear equalizer.

The anti-Doppler strategy focuses on avoiding the channel attractor's effects by limiting the duration of a symbol to a short segment of the phase trajectory on the attractor, for which it is predictable. Power spectra of chaotic systems have been observed[22, 23]and treated theoretically[24]. Spectra are, in general, low pass functions which may have pronounced peaks (phase coherent case) over a broad-band background, or a relatively flat characteristic (phase incoherent case) similar to stochastic noise. Received power spectra due to the effects of the so-called "random Doppler" spreading of continuous wave radio transmission in the mobile environment have frequently been reported in the literature[25, 26]. It is our conjecture that the phenomenon of spectral spreading of received continuous wave radio is indicative of the chaotic behaviour of the channel, as opposed to any stochastic Doppler process previously hypothesized.

What may be said about the anti-multipath strategy of equalization? There is suggestive evidence in the literature, based on pulsed radar measurements, that this time dispersion is also deterministically chaotic.[27] It is physically reasonable that both forms of dispersion should be deterministically chaotic if either one is. The frequency dispersion effect is due to motion of a receiver through the rf field induced by interference of waves arriving on multiple paths with differing phase. The time dispersion effect is due to the differing propagation delay times for pulses in the same multipath environment. While the driving forces in the system are different in the two cases, the physical geometry leading to the two phenomena is invariant. Equalization is a form of estimation of and compensation for the state of the channel. We have noted in a previous section that the forward evolution of a deterministic chaos is possible only to a resolution defined by the entropy rate of the attractor. That is, the receiver has knowledge of the state of the channel attractor to within N bits at t_1, and the mean entropy rate of the attractor is known to be λ_t then the knowledge of the channel will be $N-\lambda_t \bullet (t_2-t_1)$ at t_2. This understanding will allow the communications engineer to design a (non-linear) equalizer for the channel, knowing the necessary sampling rate to track the behaviour of the channel given a characterization of the channel attractor. We believe that serious attention to such characterizations deserves to be given.

Conclusions

We have shown observations of in-building radio channels that show chaotic transmission behaviour. We have also introduced a simple, non-linear transmission model of low order that displays chaos. While this model is not suitable for the scenario of radio transmission, it is suggestive of the kinds of non-linear transmission and scattering effects that may lead to chaos in the radio case. The model is also useful in the analysis of bit error rates in a binary channel under various conditions of the channel attractor. A theory of communications in the presence of chaos is in a formative stage, but the notion that the erratic behaviour of the channel transmission parameters leads to an equivocation of received communication symbols because of the fractal topology of the channel attractor seems to be a useful guide. We believe that it is time for a much broader and deeper exploration of the effects on non-linearity in radio transmission, and in communication more generally.

References

[1] Clarke, R.H., "A Statistical Theory of Mobile-Radio Reception", *Bell Syst. Tech. Journ.*, July-August, pp. 957-1000, (1968).

[2] Lorenz, Edward N., "Deterministic Nonperiodic Flow", *Journal of Atmospheric Sciences*, Vol. 20, pp. 130-141 (1963).

[3] Lorenz, Edward N., "The problem of deducing the climate from the governing equation", *Tellus*, XVI pp. 1-11 (1964).

[4] Lorenz, Edward N., "The Mechanics of Vacillation", *Journal of Atmospheric Sciences*, Vol. 20, pp. 448-464 (1963).

[5] Shaw, Robert, "Strange Attractors, Chaotic Behavior, and Information Flow", *Z. Naturforsch.*, 36a, pp. 80-112 (1981).

[6] Ruelle, David and Floris Takens, "On the Nature of Turbulence", *Commun. math. Phys.*, Vol 20, pp. 167-192 (1971).

[7] *ibid.*

[8] Grassberger, Peter and Itamar Procaccia, "Measuring the Strangeness of Strange Attractors", *Physica*, 9D, pp. 189-208 (1983).

[9] Grassberger, Peter and Itamar Procaccia, "Characterization of Strange Attractors", *Phys. Rev. Lett.* 50, pp. 346-349 (1983).

[10] Theiler, James, "Efficient algorithm for estimating the correlation dimension from a set of discrete points", *Phys. Rev. A*, Vol 36, No. 9, pp. 4456-4462 (1987).

References

[11] Grassberger, Peter and Itamar Procaccia, "Measuring the Strangeness of Strange Attractors", *op. cit.*

[12] Froehling, Harold, J.P. Crutchfield, Doyne Farmer, N.H. Packard and Robert Shaw, "On Determining the Dimension of Chaotic Flows", *Physica* 3D, pp. 605-617 (1981).

[13] Broomhead, D.S., R. Jones, and G.P. King, "Topological dimension and local coordinates from time series data", *J. Phys. A: Math. Gen.*, vol. 20, pp. L563-L569, (1987).

[14] Davies, Robert J., *In-Building UHF Propagation Studies*, MSc Thesis, University of Calgary, 1989.

[15] Theiler, James, *op cit.*

[16] Coekin, J.A., *High-Speed Pulse Techniques*, Pergamon Press, Oxford, p. 70 ff (1975).

[17] Shannon, Claude, "A Mathematical Theory of Communication", *Bell Syst. Tech. J.*, vol. 27, pp. 379-423 & pp. 623-656, (1948).

[18] Shannon, Claude, "Communication in the presence of noise", *Proc. IRE*, vol. 37, pp. 10 21, (1949).

[19] Shaw, Robert, "Strange Attractors, Chaotic Behavior, and Information Flow", *ibid.*

[20] Mandelbrot, B. and J.M. Berger, "A New Model for Error Clustering in Telephone Circuits", *IBM Journal*, July, pp. 224-236, (1963).

[21] Proakis, John, *Digital Communications*, 2nd edition, McGraw-Hill, p. 702ff, (1989).

[22] Kubicek, M. and M. Marek, *Computational Methods in Bifurcation Theory and Dissipative Structures*, Springer-Verlag, pp. 109ff (1983).

[23] Linsay, Paul, "Period Doubling and Chaotic Behavior in a Driven Anharmonic Oscillator", *Phys. Rev. Letters*, vol.47, no. 19, pp. 1349-1352 (1981).

[24] Feigenbaum, Mitchell, "Universal Behavior in Nonlinear Systems", *Los Alamos Science*, vol 1. no. 1, pp. 4-27 (Summer 1980).

[25] Nielson, Donald, "Microwave Propagation Measurements for Mobile Digital Radio Application", *IEEE Trans. Veh. Technol.*, vol. VT-27, pp. 117-131, (Aug. 1978).

References

[26] Cox, Donald, "Delay Doppler Characteristics of Multipath Propagation at 910 MHz in a Suburban Mobile Radio Environment", *IEEE Trans. Ant. and Propag.*, vol. AP-20, no. 5., pp. 625-635 (1979).

[27] Leung, Henry and Simon Haykin, "Is there a radar clutter attractor?", *Appl. Phys. Lett.*, vol. 56., no. 6, pp. 593-595, 5 February, (1990).

Figure 1a. Variation of correlation dimension with embedding dimension

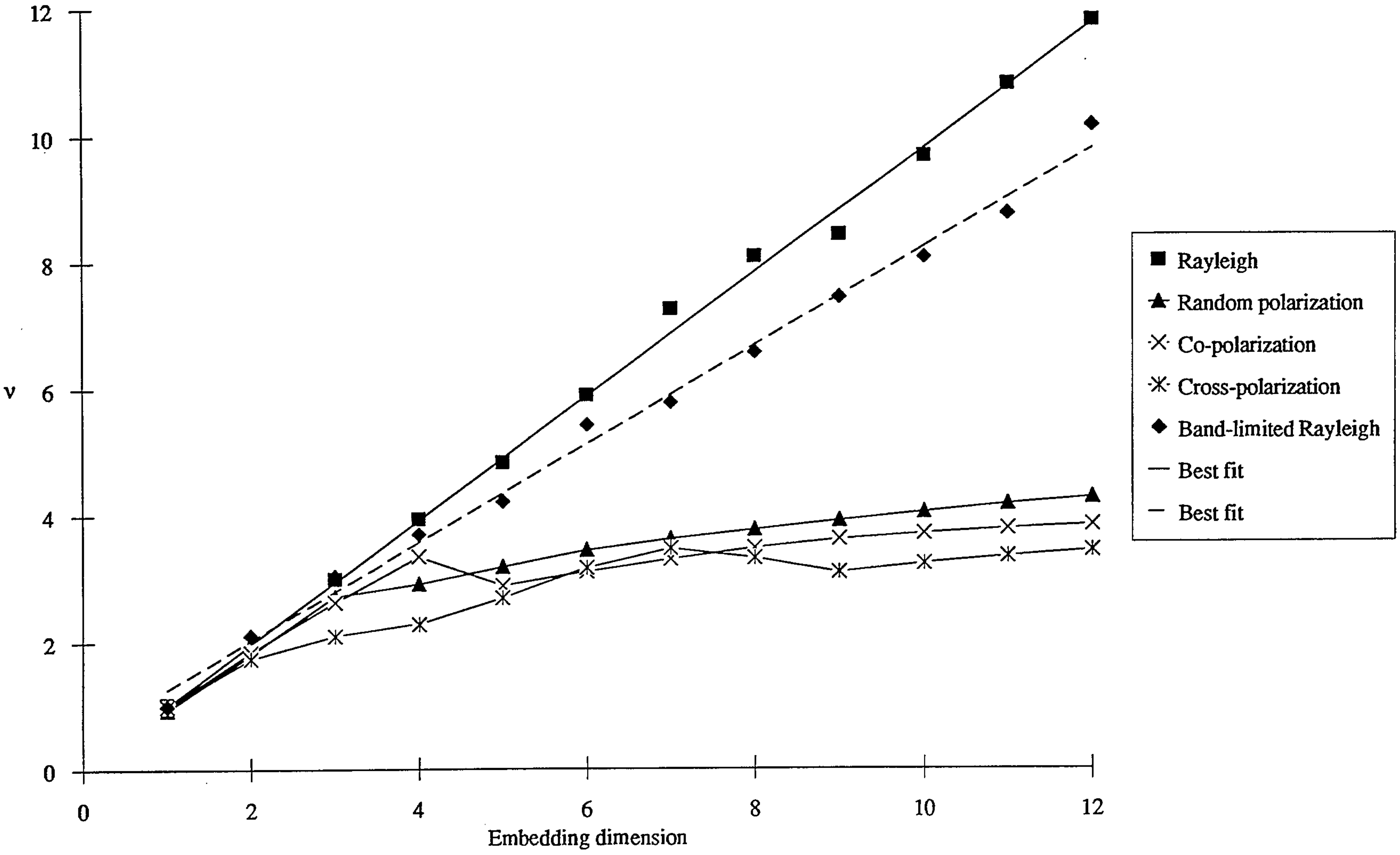


Figure 1b. Correlation integral versus r for cross-polarization data

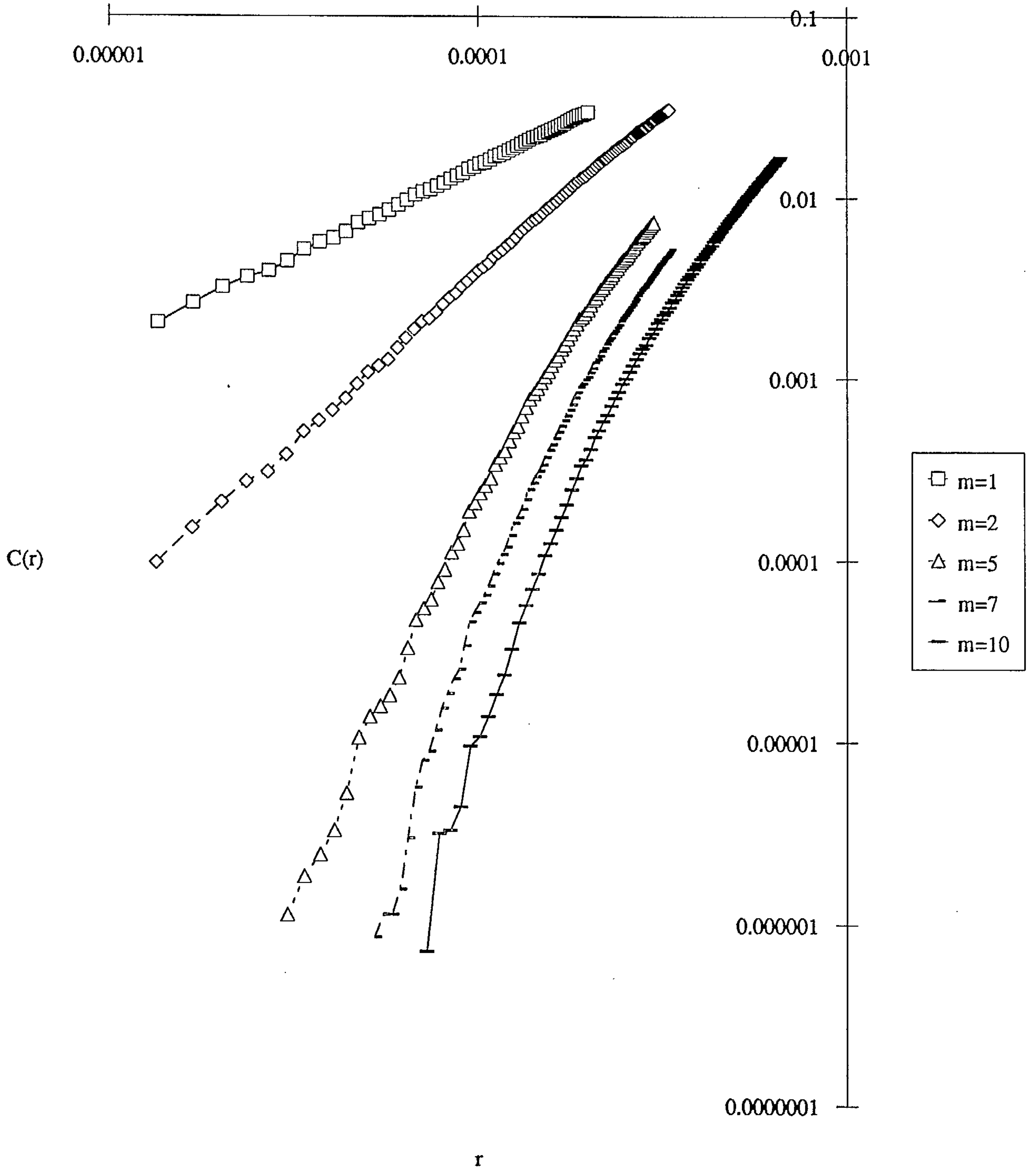


Figure 2. Lorenz attractor in the x-y plane.

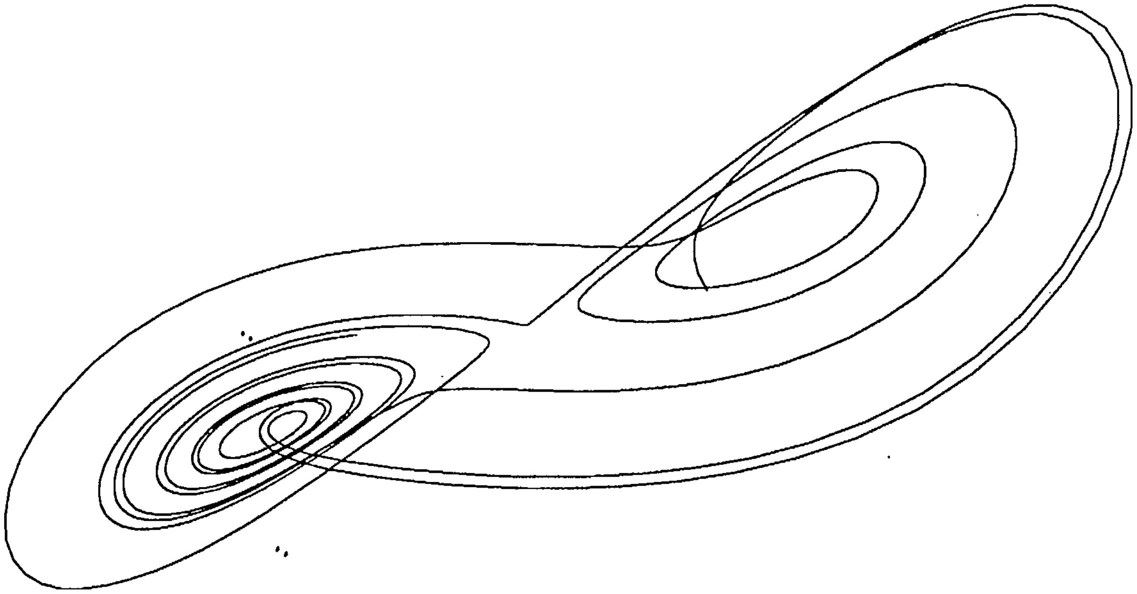


Figure 3. Lorenz attractor in the y-z plane

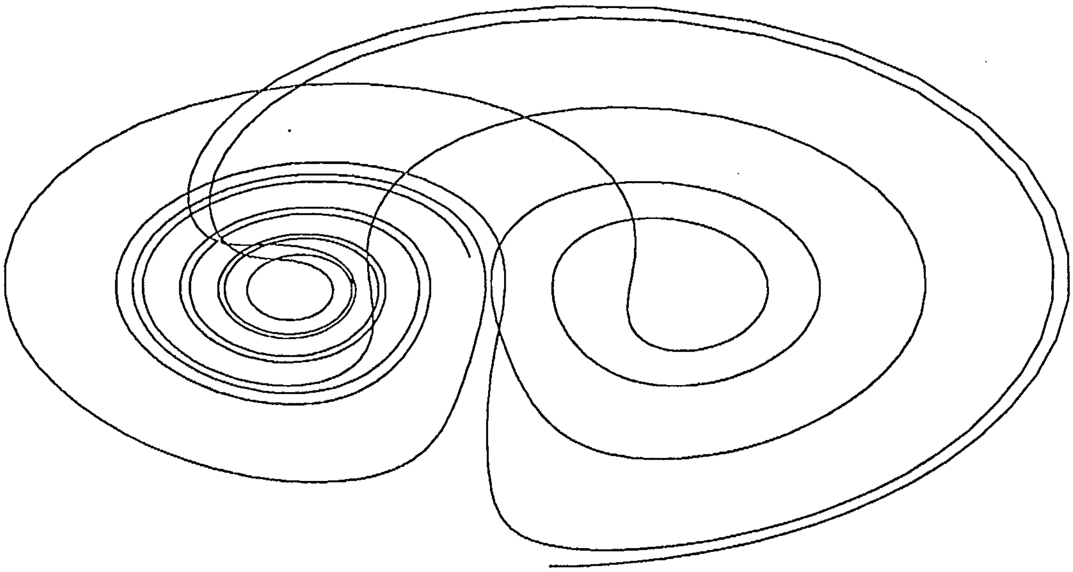


Figure 4. A(n-1) versus A(n) for constant location time sequence.

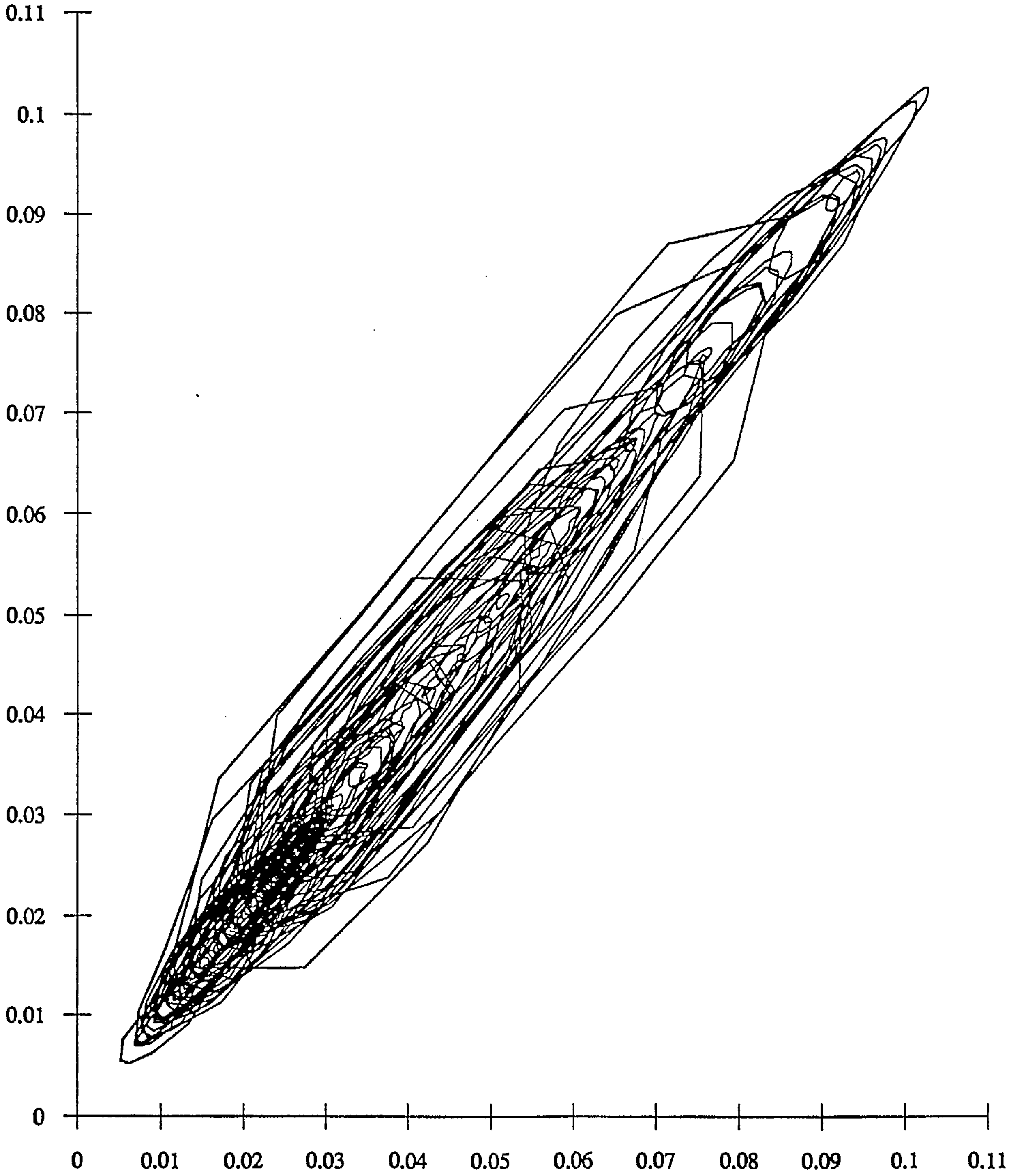


Figure 4b. A(n-1) vs A(n) for Band-limited Rayleigh sequence

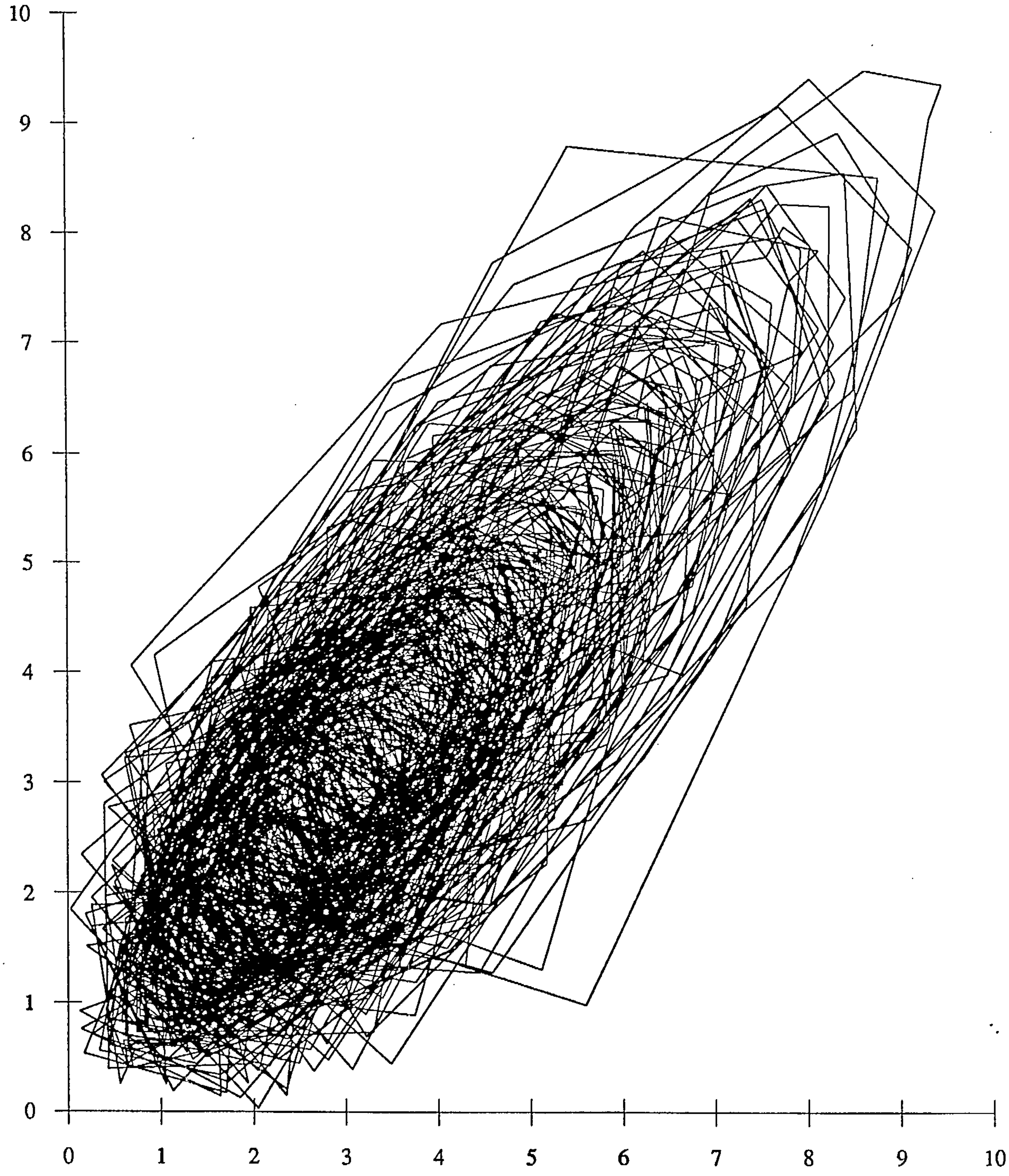


Figure 5. A(n-2) versus A(n) for constant location time sequence.

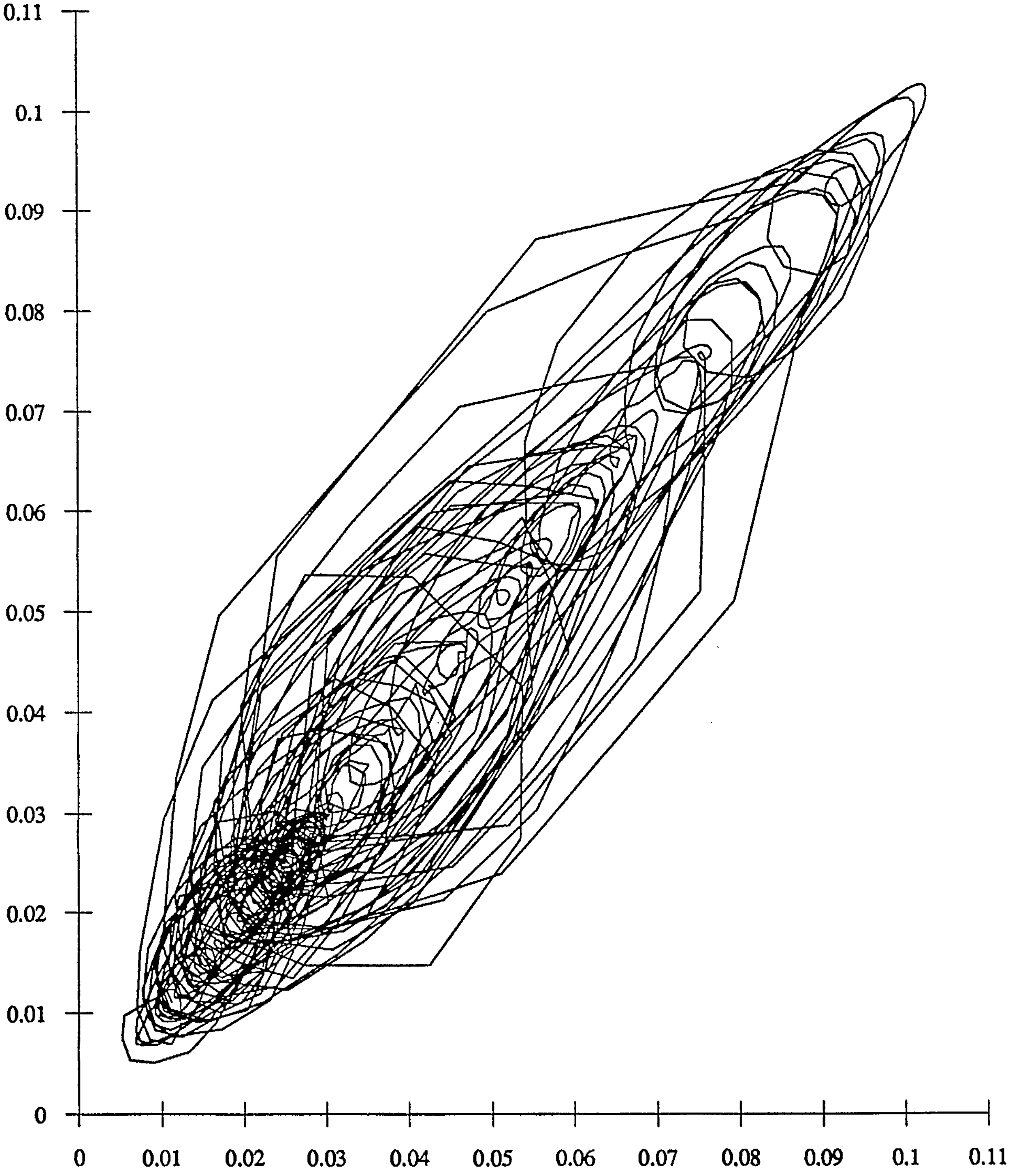


Figure 5b. A(n-2) vs A(n) for Band-limited Rayleigh sequence

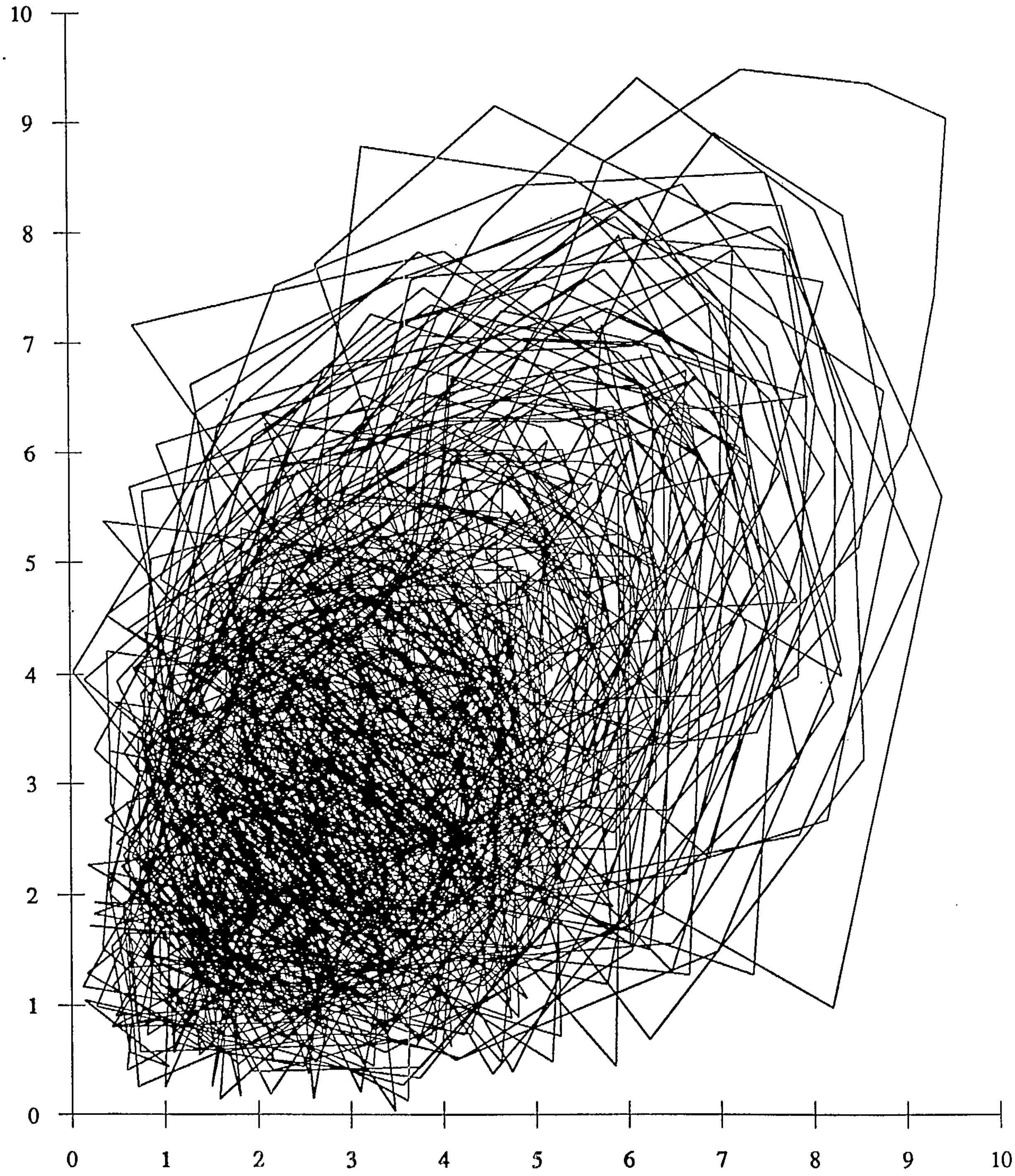


Figure 6. A(n-3) versus A(n) for constant location time sequence.

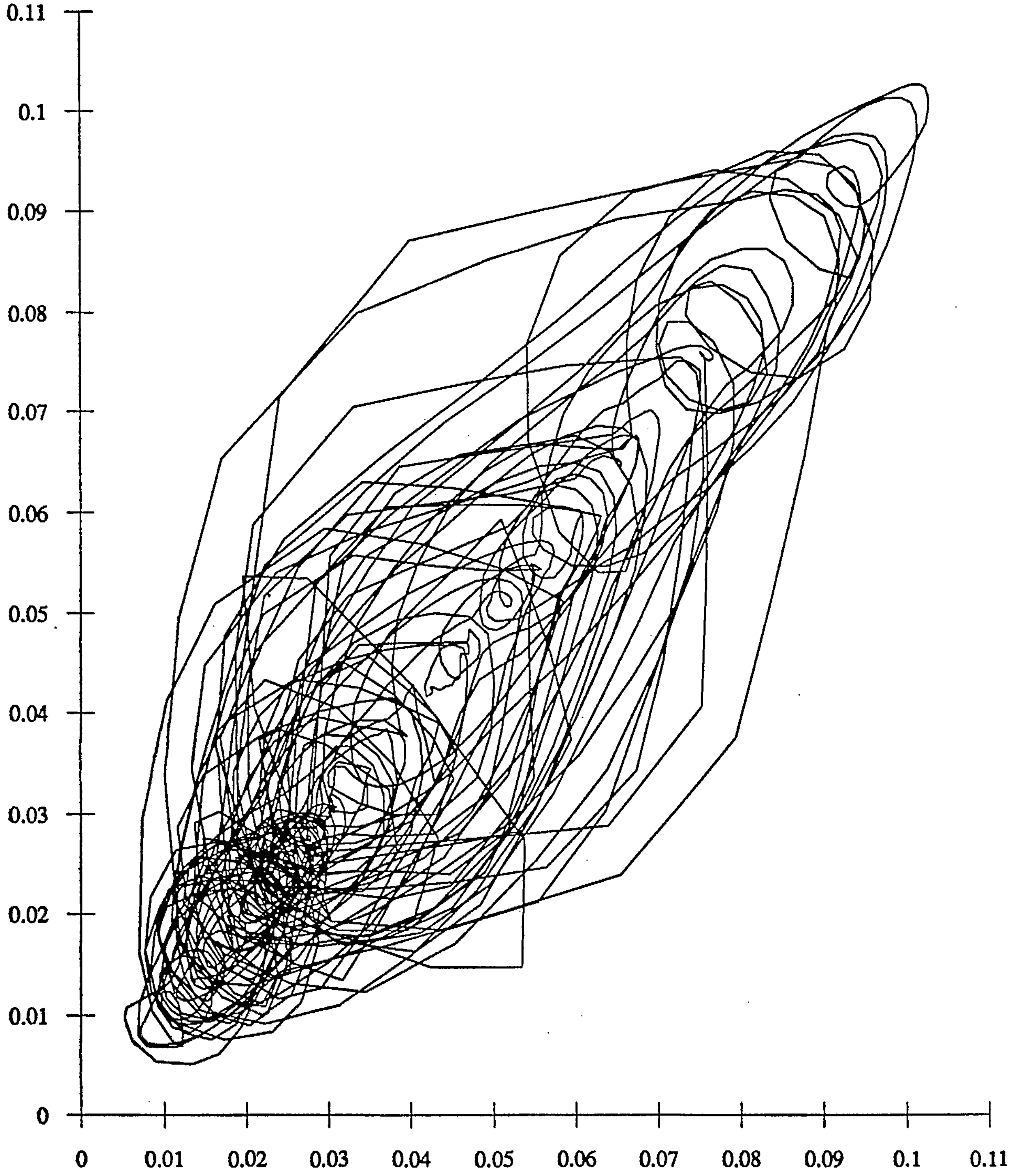


Figure 6b. A(n-3) vs A(n) for Band-limited Rayleigh sequence

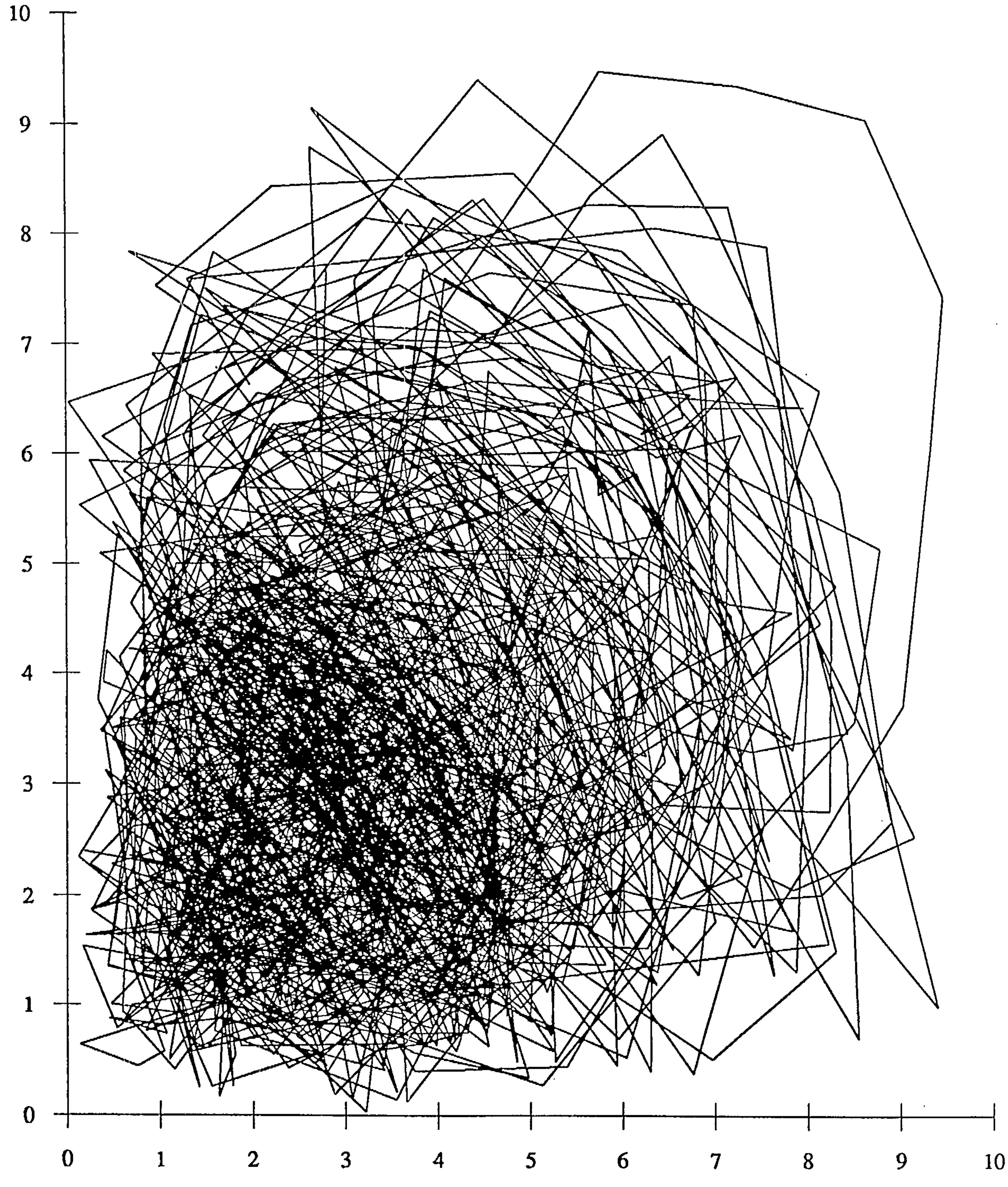


Figure 7. Simple transmission model

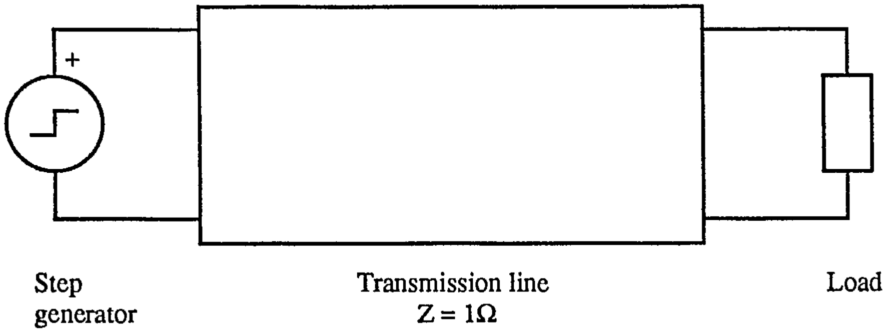


Figure 7b. Load i-v characteristic

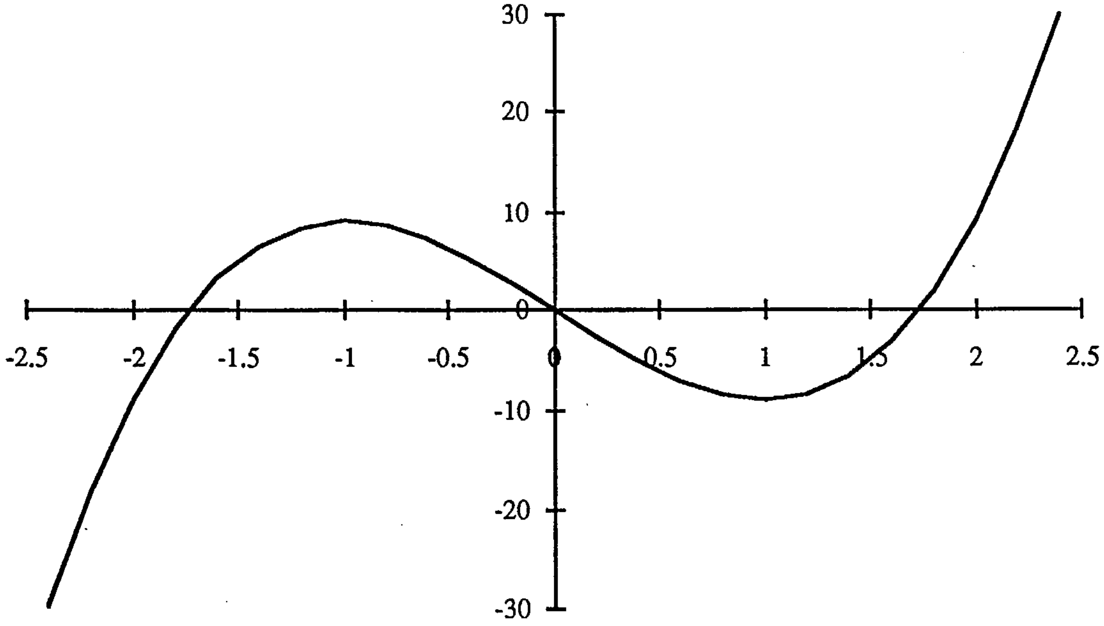


Figure 8a. Positive wave current vs Reflected current for Tx line attractor
Vgen = 0.4

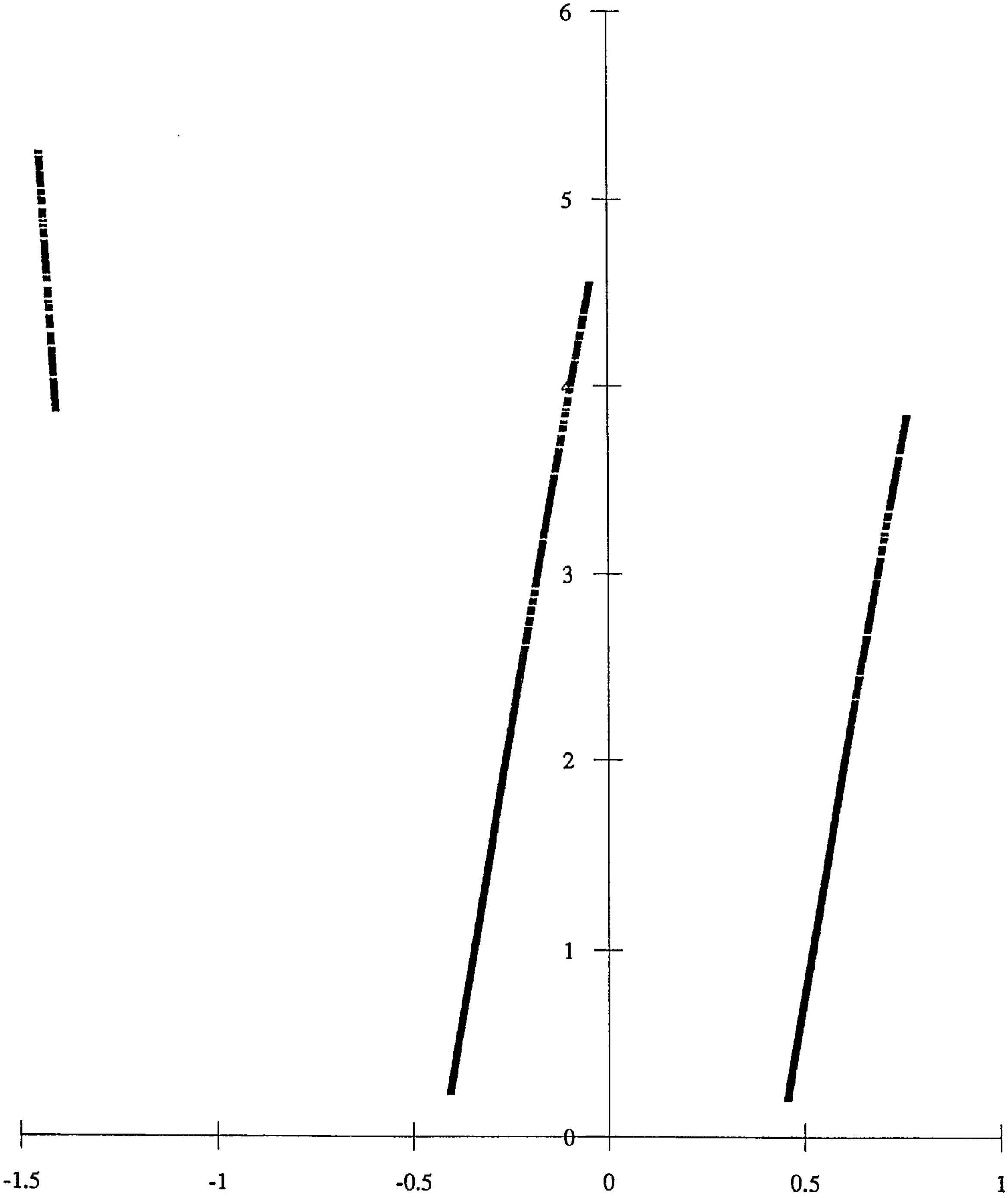


Figure 8b. Output voltage vs Reflected current for Tx line attractor
Vgen = 0.4

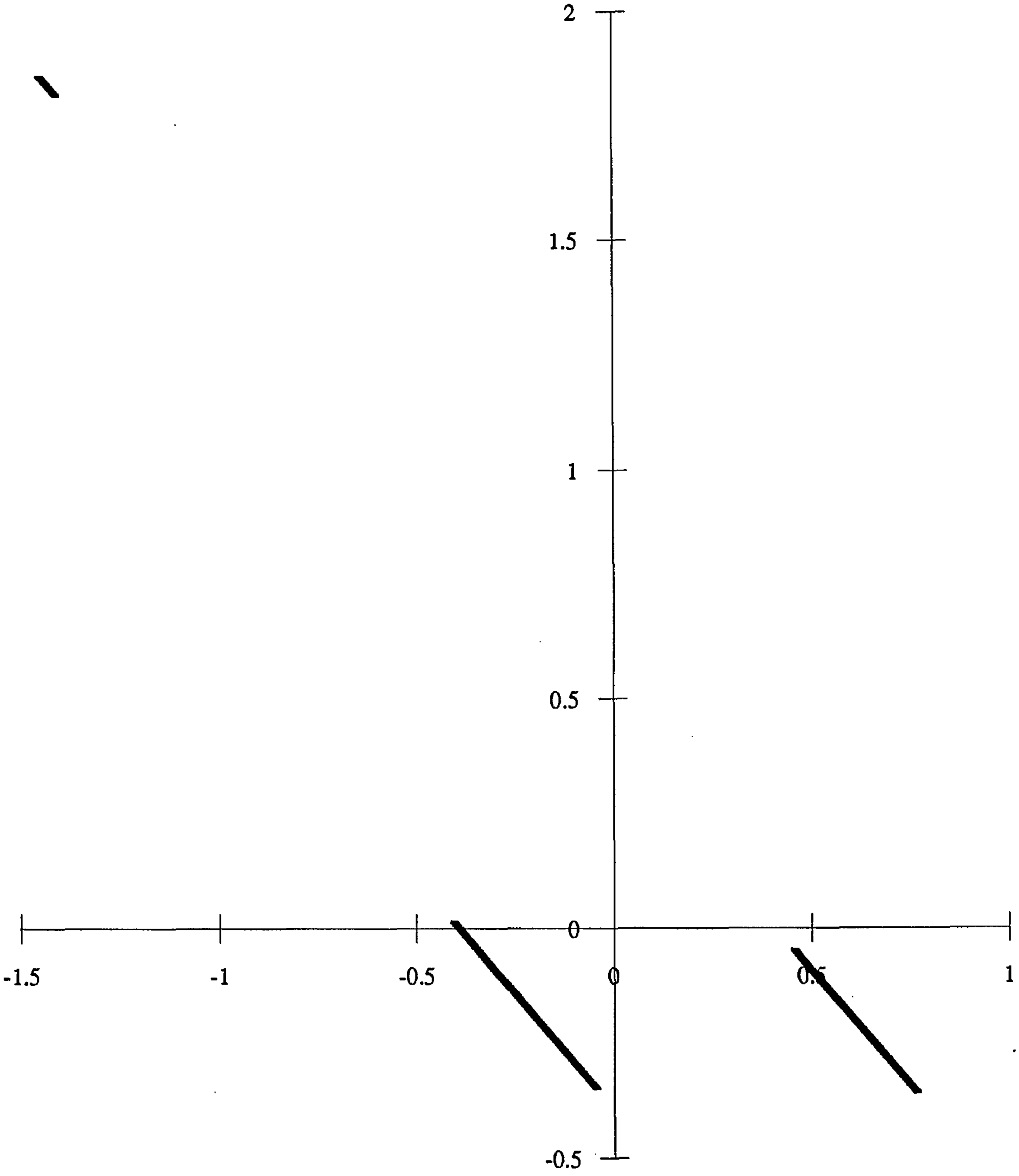


Figure 9a. Positive wave current vs Reflected current for Tx line attractor
Vgen = 0.5

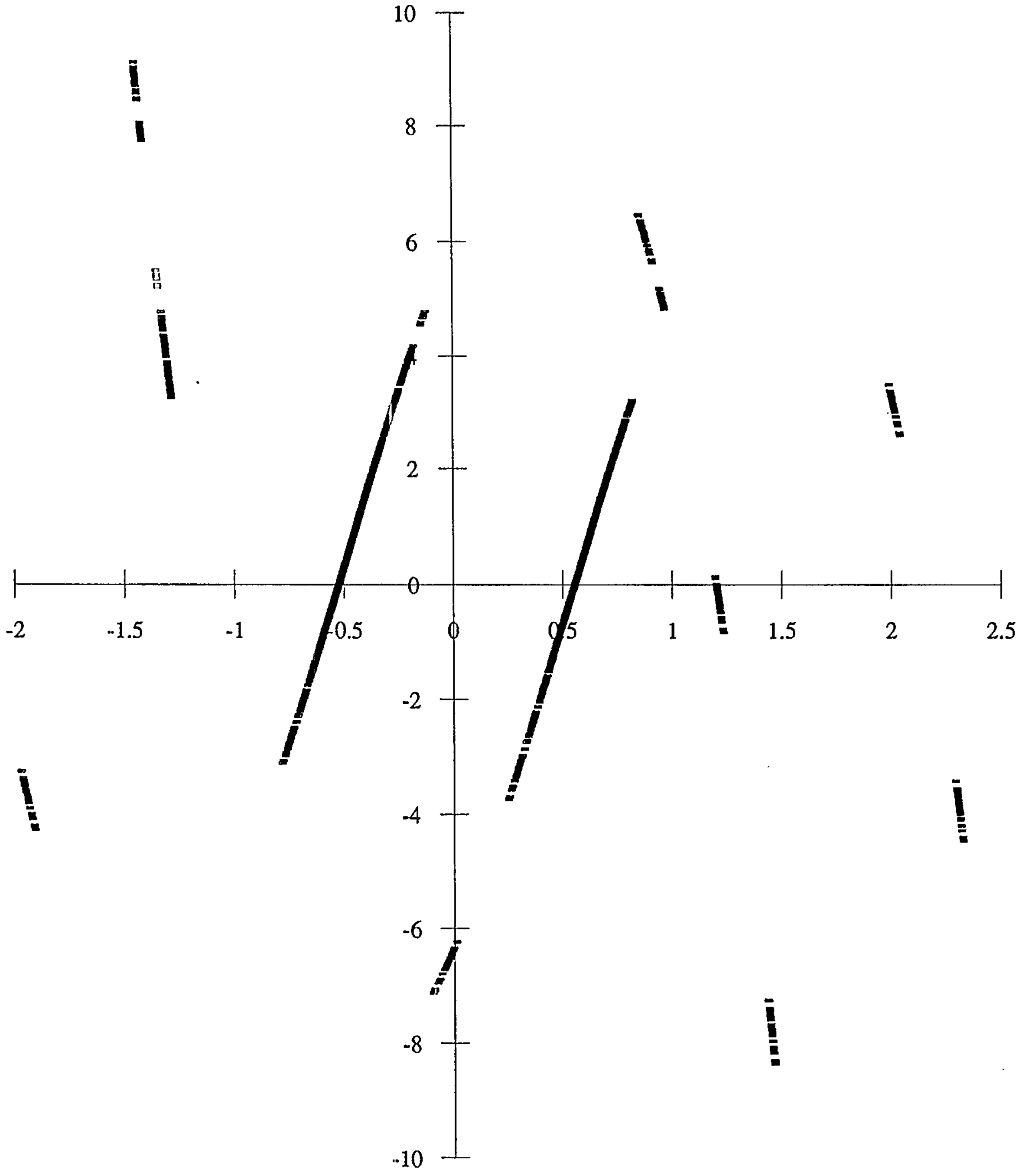


Figure 9b. Output voltage vs Reflected current for Tx line attractor
Vgen = 0.5

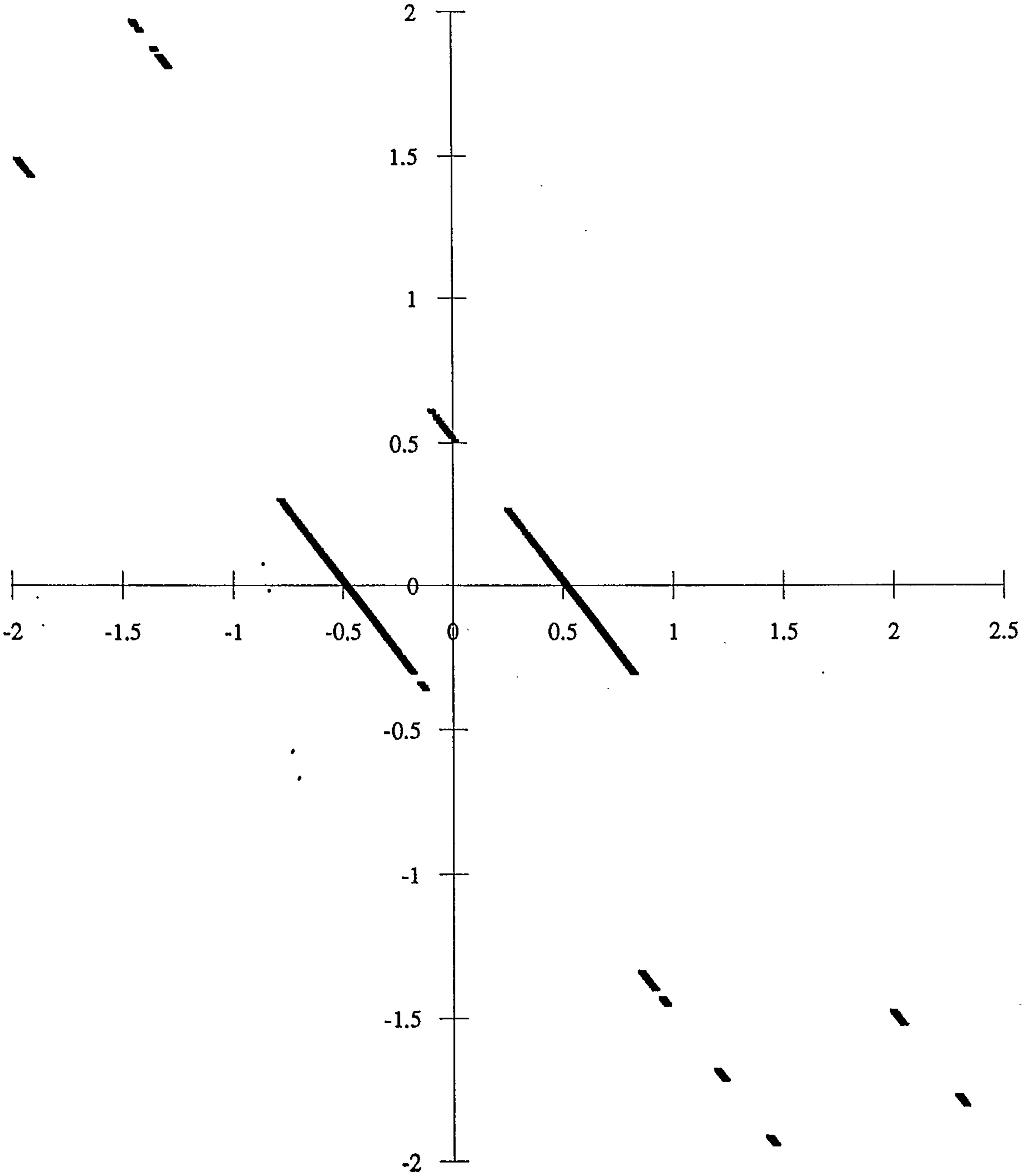


Figure 10a. Positive wave current vs Reflected current for Tx line attractor
Vgen = 0.6

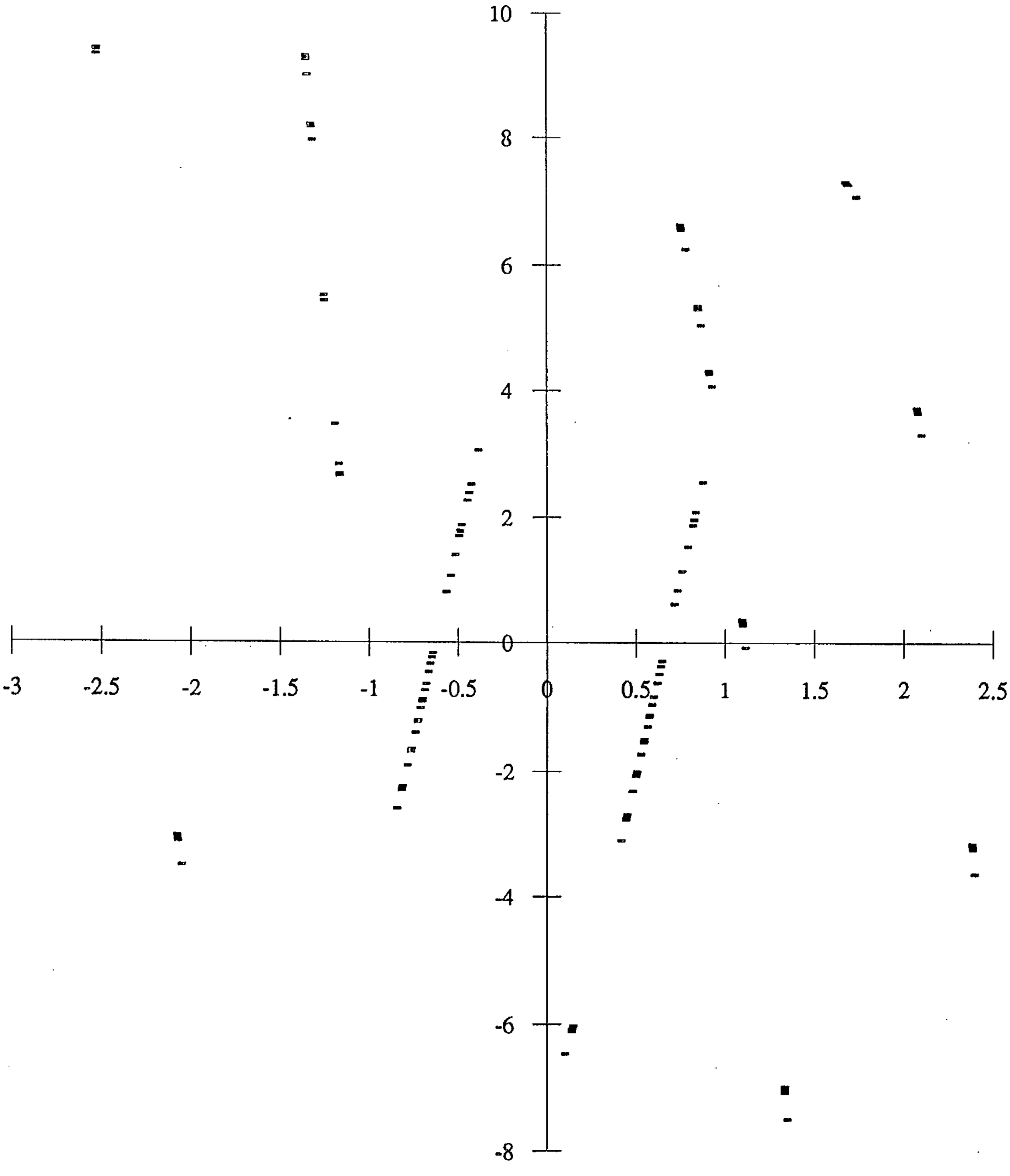


Figure 10b. Output voltage vs Reflected current for Tx line attractor
Vgen = 0.6

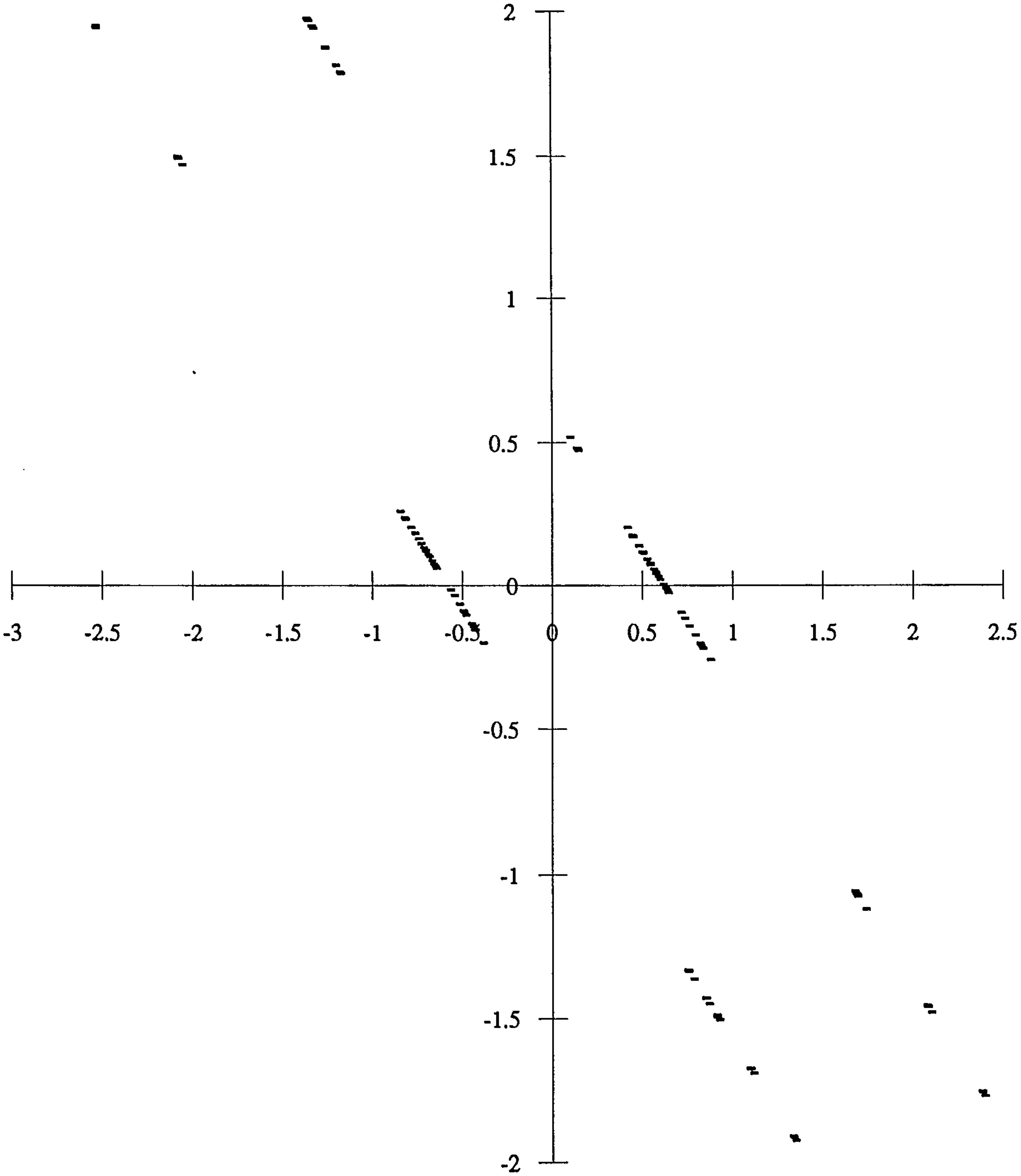


Figure 11a. Positive wave current vs Reflected current for Tx line attractor
Vgen = 0.5; k = 2

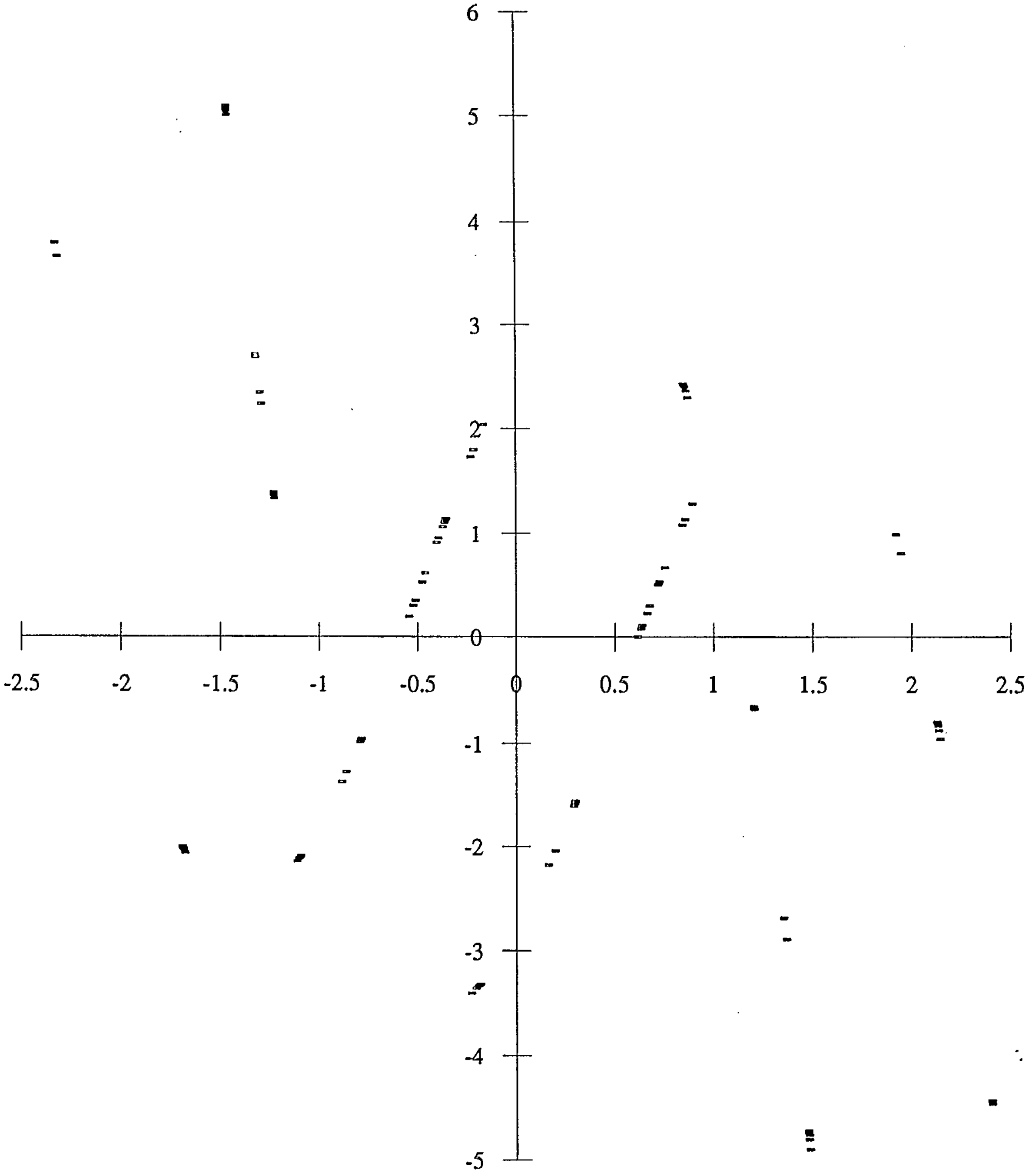


Figure 11b. Output voltage vs Reflected current for Tx line attractor
Vgen = 0.5; k = 2

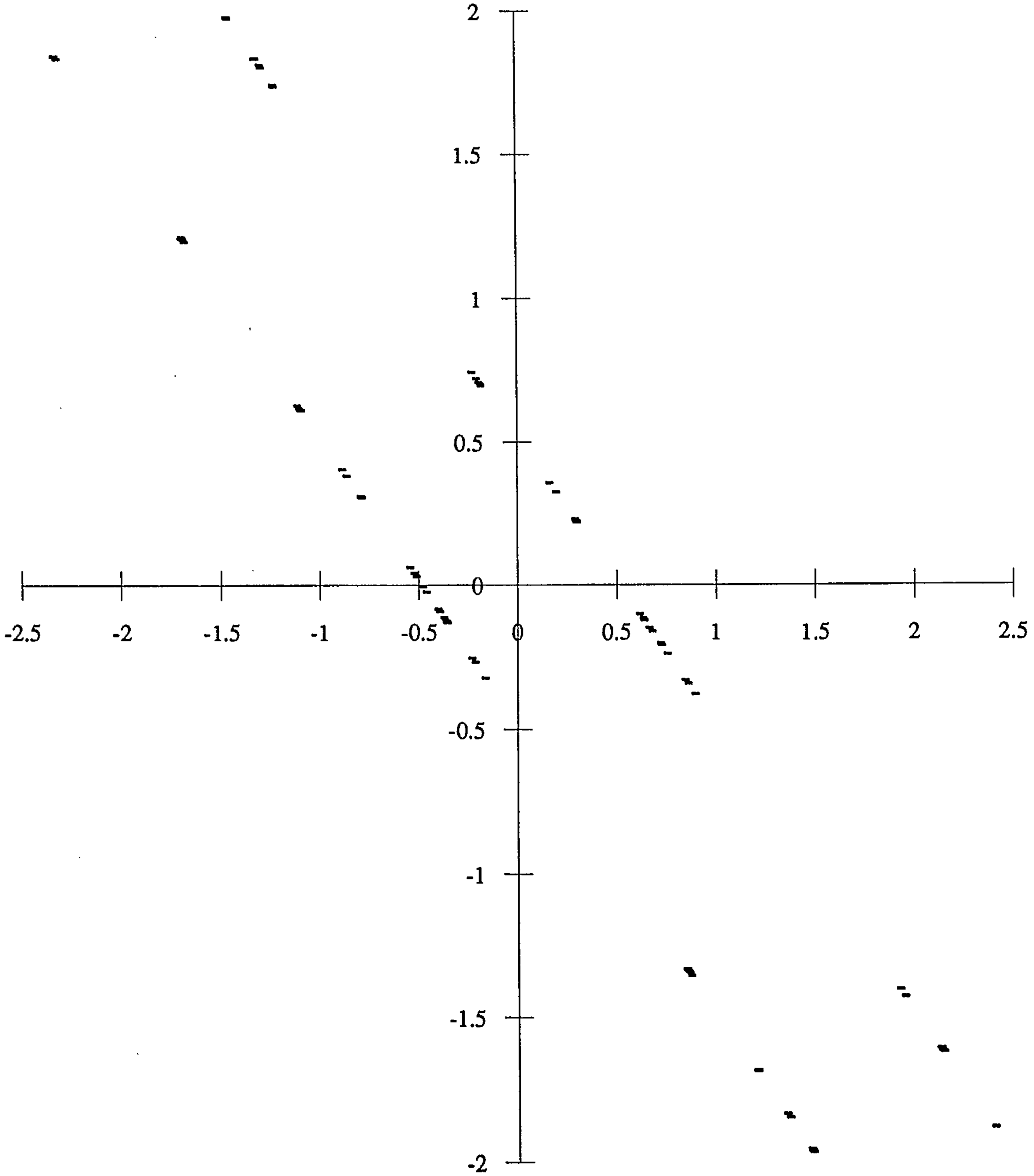
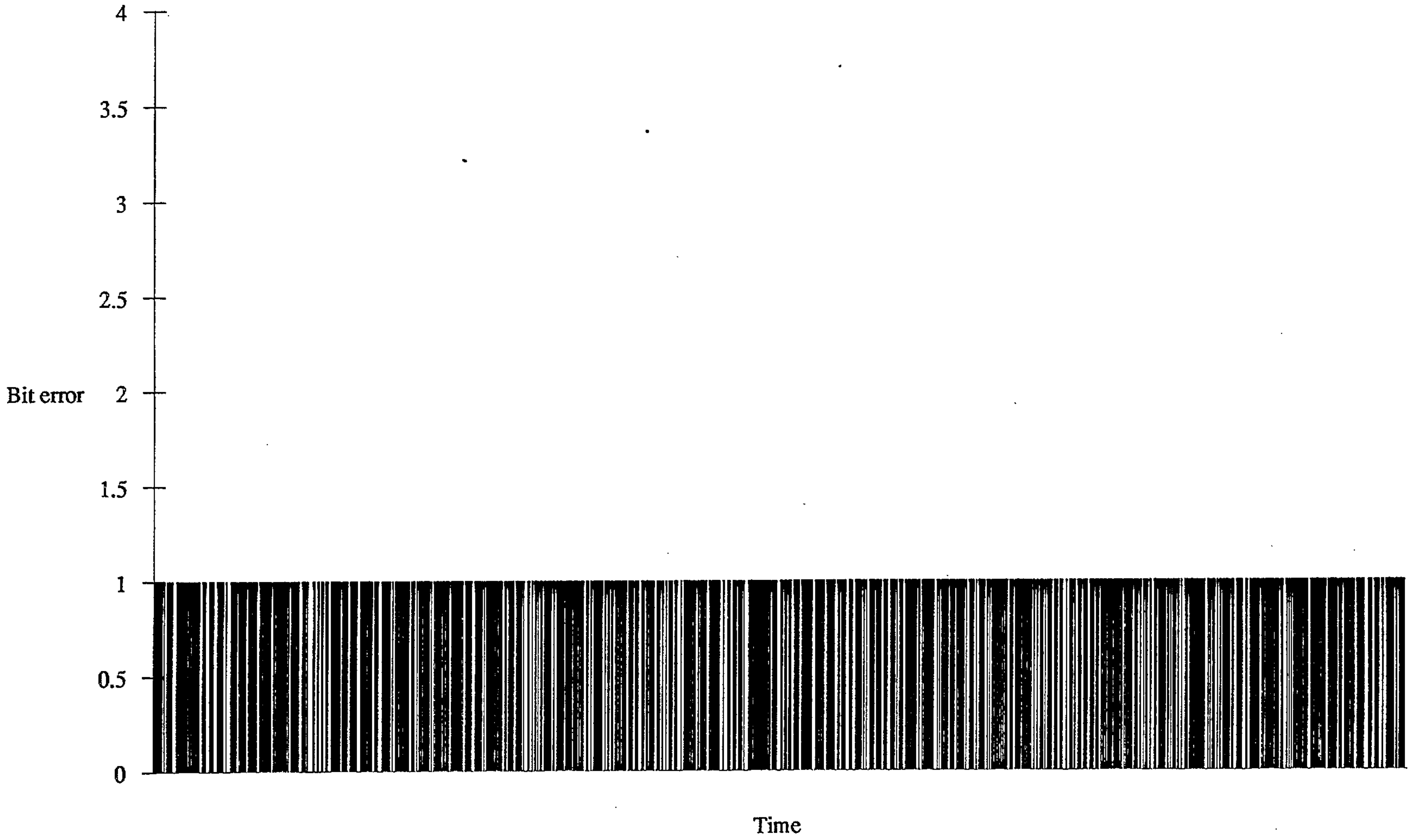


Figure 12. Arrival of bit errors in time
error = 1



Presentation By:

Colin Buckingham, Ericsson Paging Systems

Adaptive Equalization and Diversity in Indoor Wireless Systems

Authors: D.D. Falconer, S.N. Crozier, C.L. Despins, S.A. Mahmoud
Presented by: D.D. Falconer

Synopsis

Indoor wireless communications systems are impaired by fading, shadowing and co-channel interference. As well, for moderately high bit rates of practical interest, these systems are also usually subject to frequency selectivity, resulting in intersymbol interference. Adaptive diversity combining, adaptive equalization, and combinations of these measures are known to provide compensation against fading, frequency selectivity, and synchronous interference. However, in applying these adaptive techniques, we may have to confront problems such as severe channel distortion; lengthy fades, a requirement to minimize complexity, size and power consumption; and decision-directed adaptation (delay and error propagation).

We summarize recent work carried out at Carleton University on two approaches; one is a block equalization approach with novel detection and equalization strategies; the other combines adaptive equalization, diversity and convolutional coding to combat frequency selective fading and interference.

BIOGRAPHY

David D. Falconer* was born in Moose Jaw, Saskatchewan, Canada on August 15, 1940. He received the B.A. Sc. degree in Engineering Physics from the University of Toronto in 1962 and the S.M. and Ph.D degrees in Electrical Engineering from M.I.T. in 1973 and 1967 respectively. After a year as a postdoctoral fellow at the Royal Institute of Technology, Stockholm, Sweden he was with Bell Laboratories, Holmdel, New Jersey from 1967 to 1980, as a member of the technical staff and later as group supervisor. During 1976-77 he was a visiting professor at Linkoping Univesity, Linkoping, Sweden. Since 1980 he has been at Carleton University, Ottawa, Canada where he is a Professor in the Department of Systems and Computer Engineering. His interests are in digital communications, signal processing, and communication theory. Dr. Falconer was Editor for Digital Communications for the IEEE Transactions on Communications from 1981 to 1987 and was co-guest editor the September 1984 issue of IEEE JSAC on Voiceband Telephone Transmission. He is a member of the Association of Professional Engineers of Ontario. He was awarded the Communications Society Prize Paper Award in Communications Circuits and Techniques in 1983 and in 1986.

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Fellow since 1986

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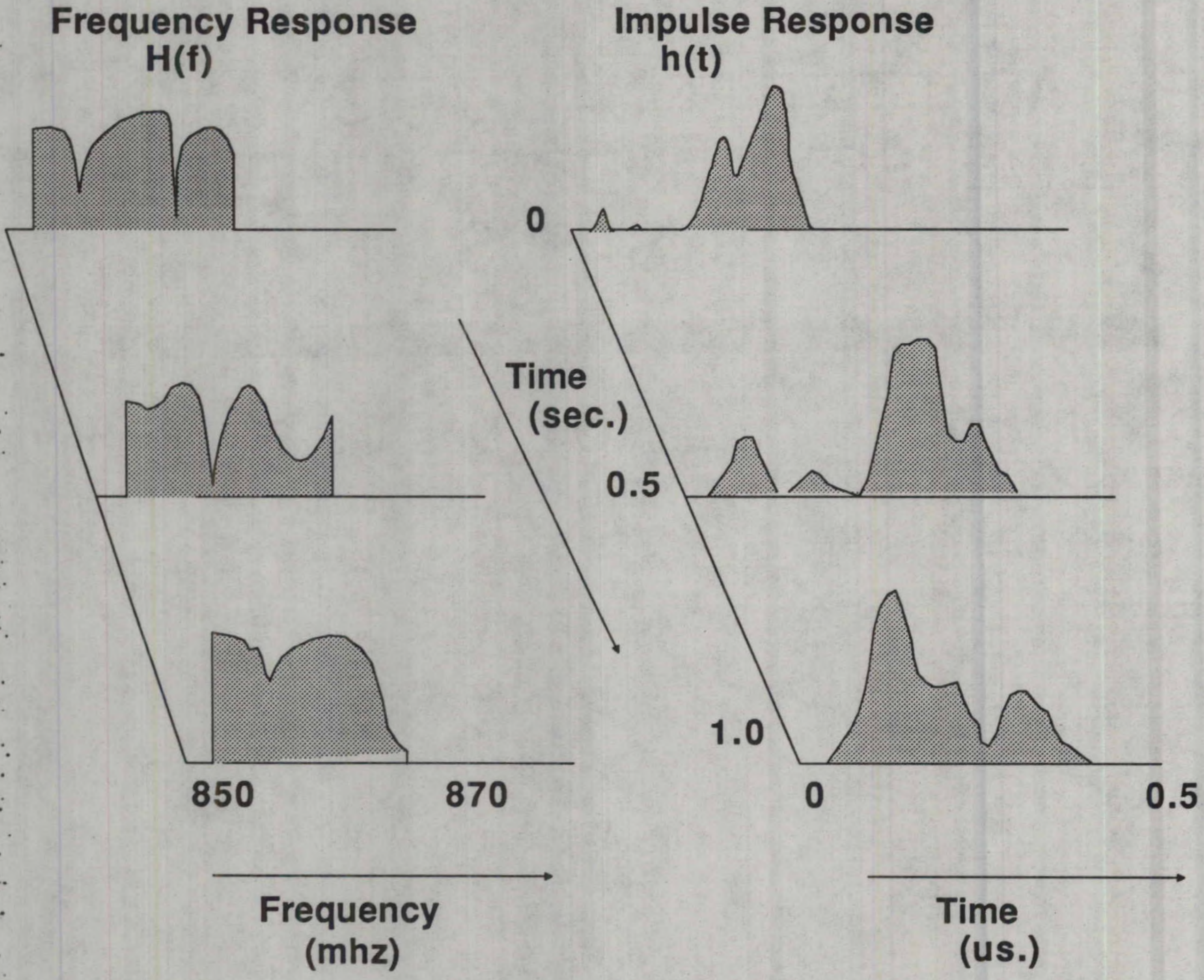
ADAPTIVE EQUALIZATION AND DIVERSITY IN INDOOR WIRELESS SYSTEMS

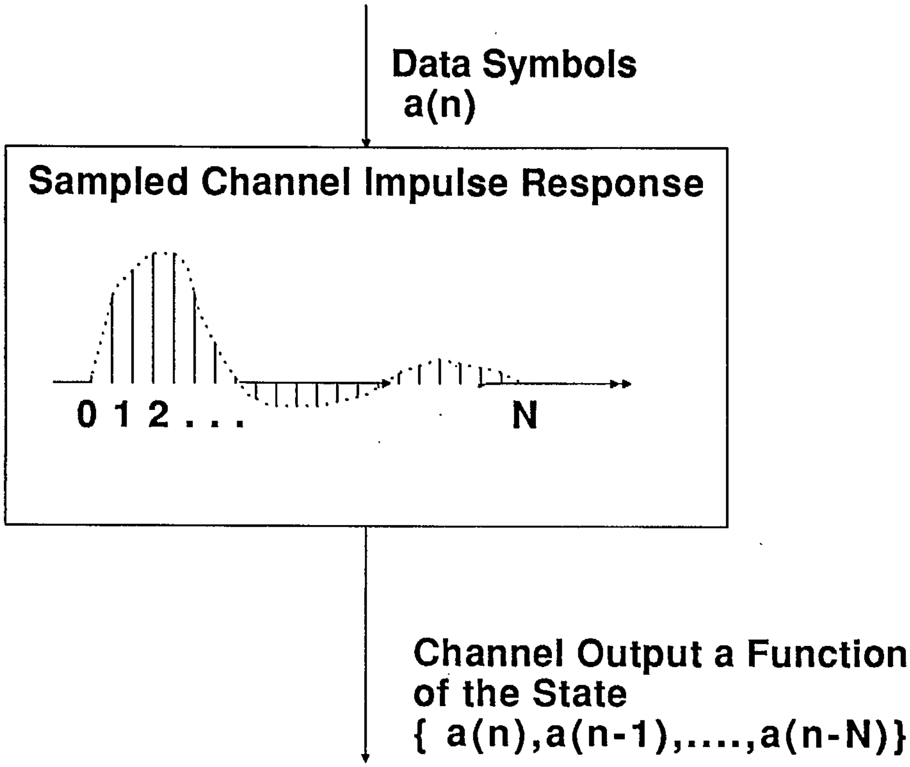
D.D. Falconer, S.N. Crozier, C.L. Despins, S.A. Mahmoud
Dept. of Systems and Computer Engineering
Carleton University
Ottawa

Wireless 90 Workshop
July 16-17 1990

TYPICAL CHARACTERISTICS OF A 800 mhz INDOOR WIRELESS CHANNEL



A DISPERSIVE CHANNEL



Data Symbols
a(n)

Sampled Channel Impulse Response

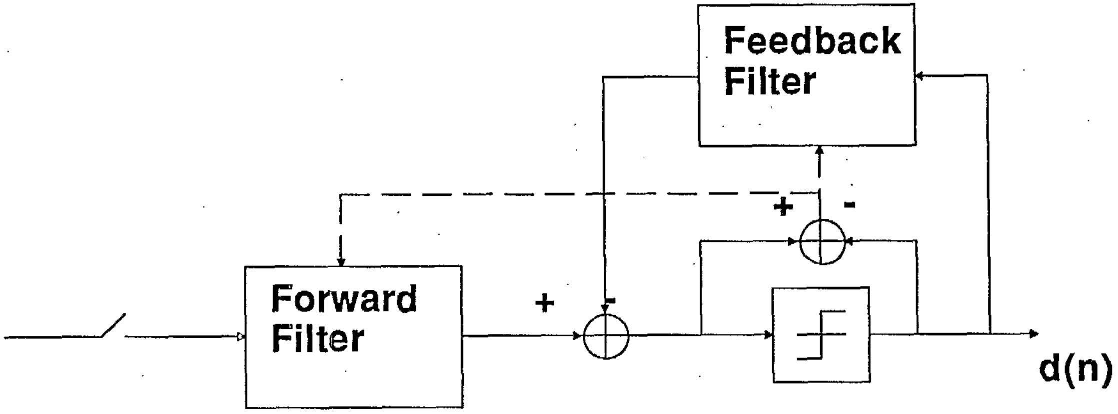
Channel Output a Function of the State
{ a(n),a(n-1),....,a(n-N)}

Remedies

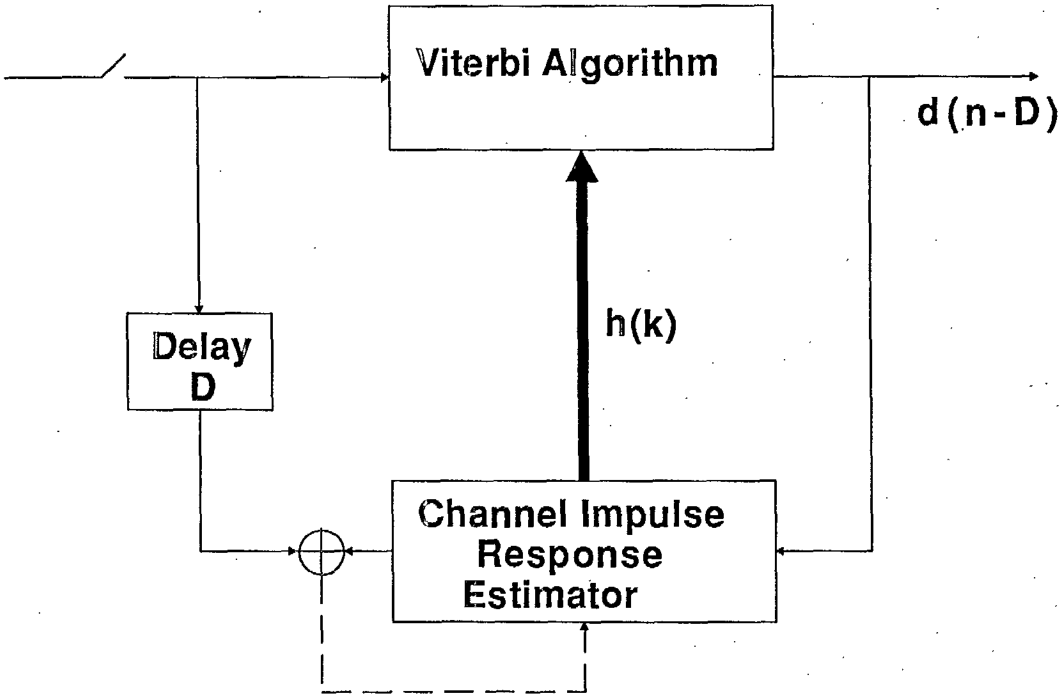
- Decision feedback equalizer (DFE)
- Sequence estimation

EQUALIZATION STRATEGIES

(1) Decision Feedback Equalizer (DFE)



(2) MLSE (Viterbi Algorithm) Receiver



OVERVIEW:

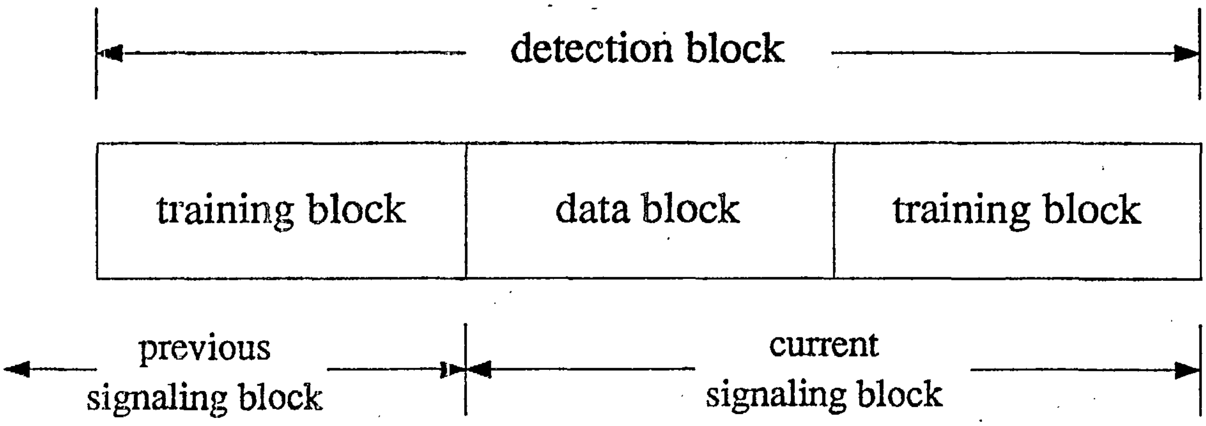
Short-Block Data Detection Techniques Employing Channel Estimation for Fading Time-Dispersive Channels

S.N. Crozier, D.D. Falconer and S.A. Mahmoud

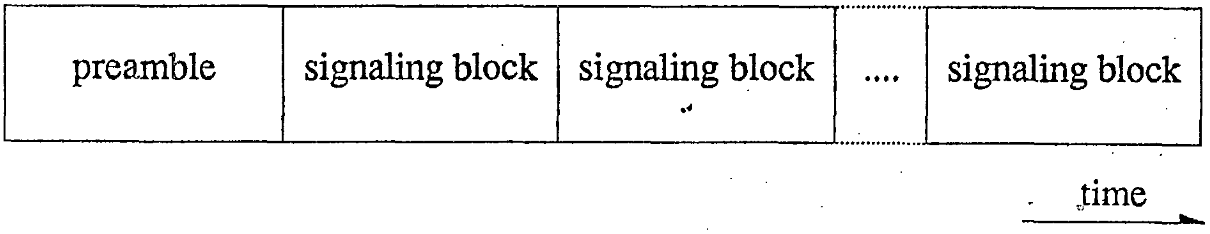
- Problem of equalization of wideband TDMA systems.

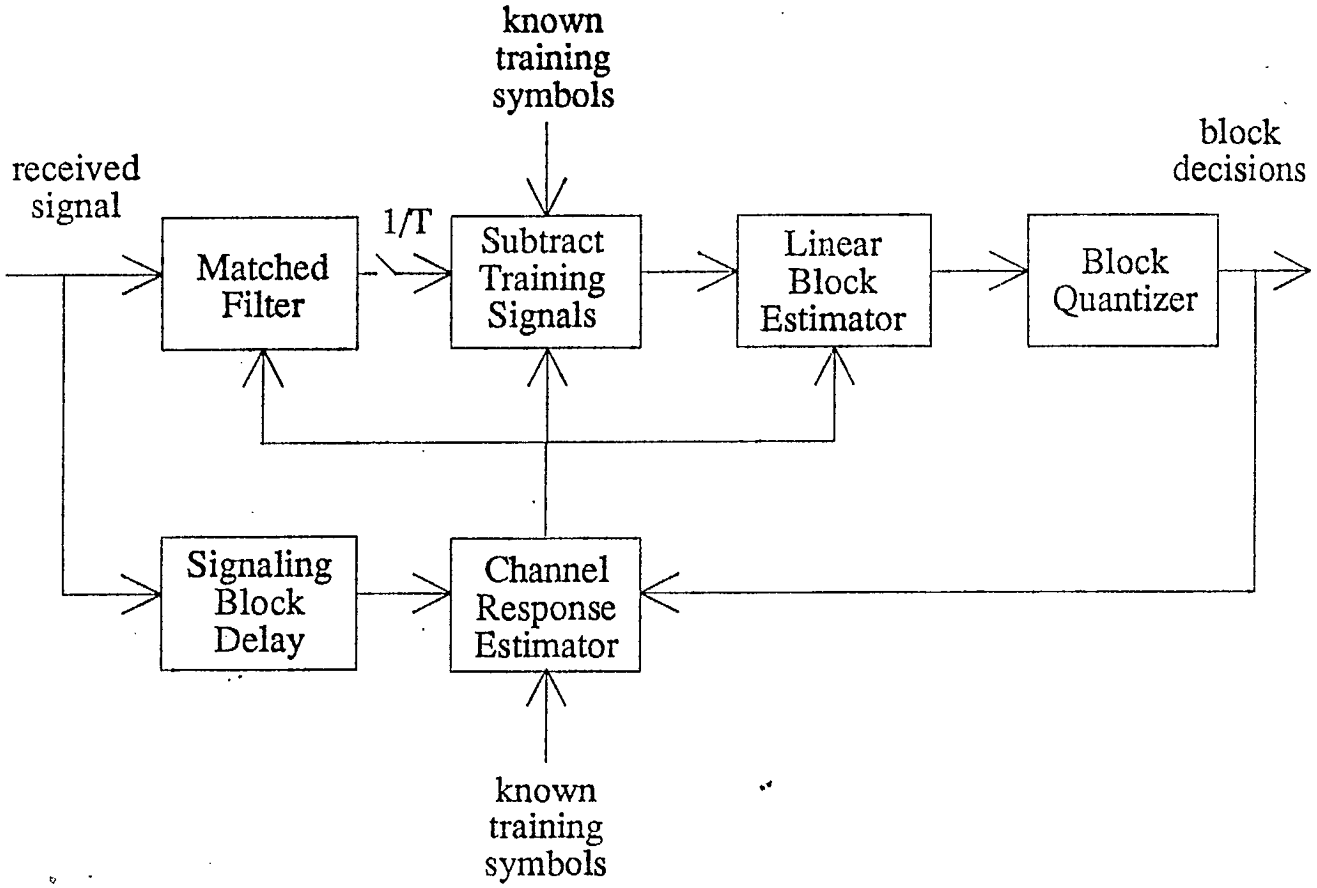
- Approach: .. Very short data blocks interspersed with very short "training" blocks of known symbols.
  - .. 3 detection/equalization schemes compared.
  - .. Channel response estimation.

Signaling and Detection Block Format:

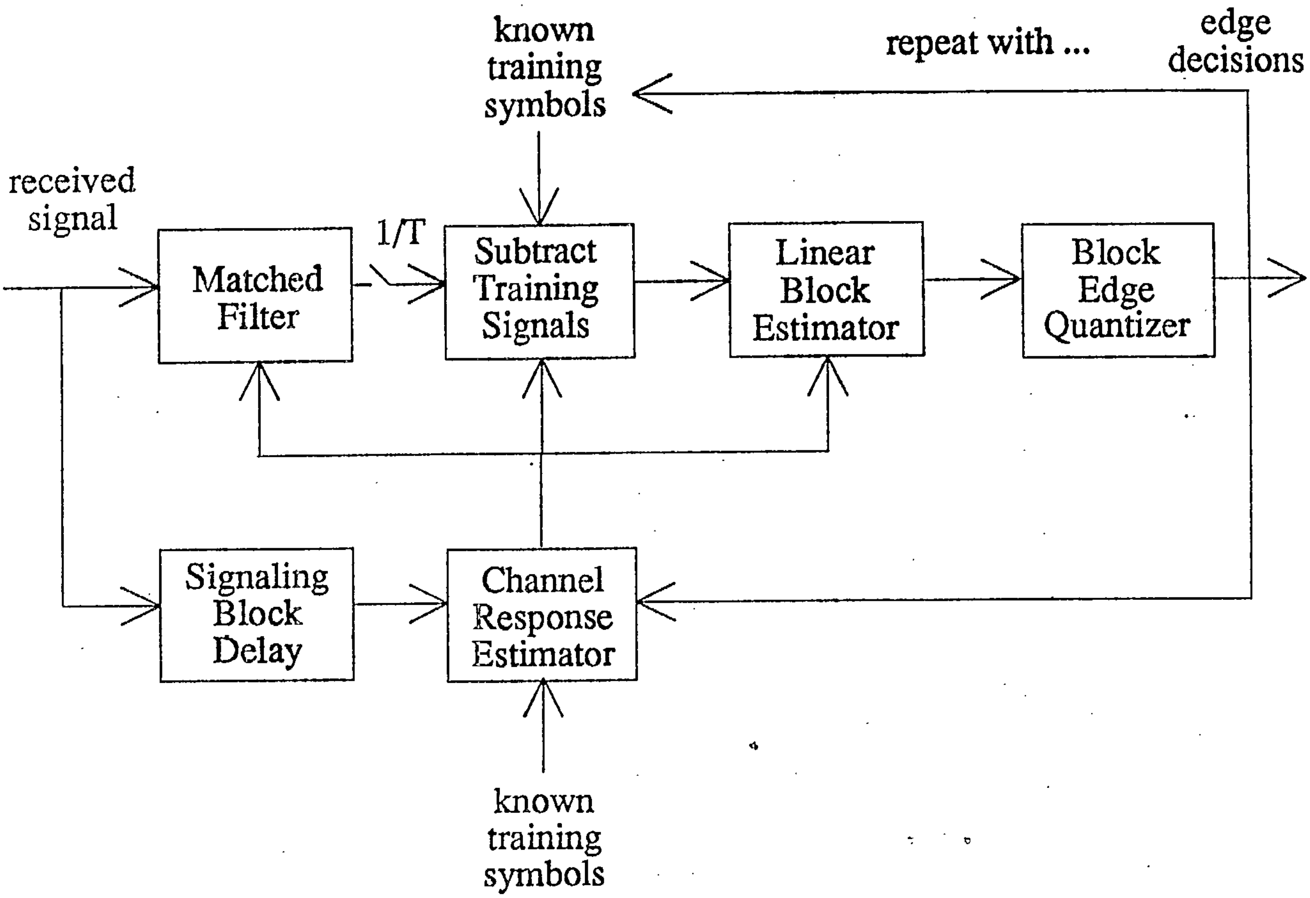


TDMA Frame Format:

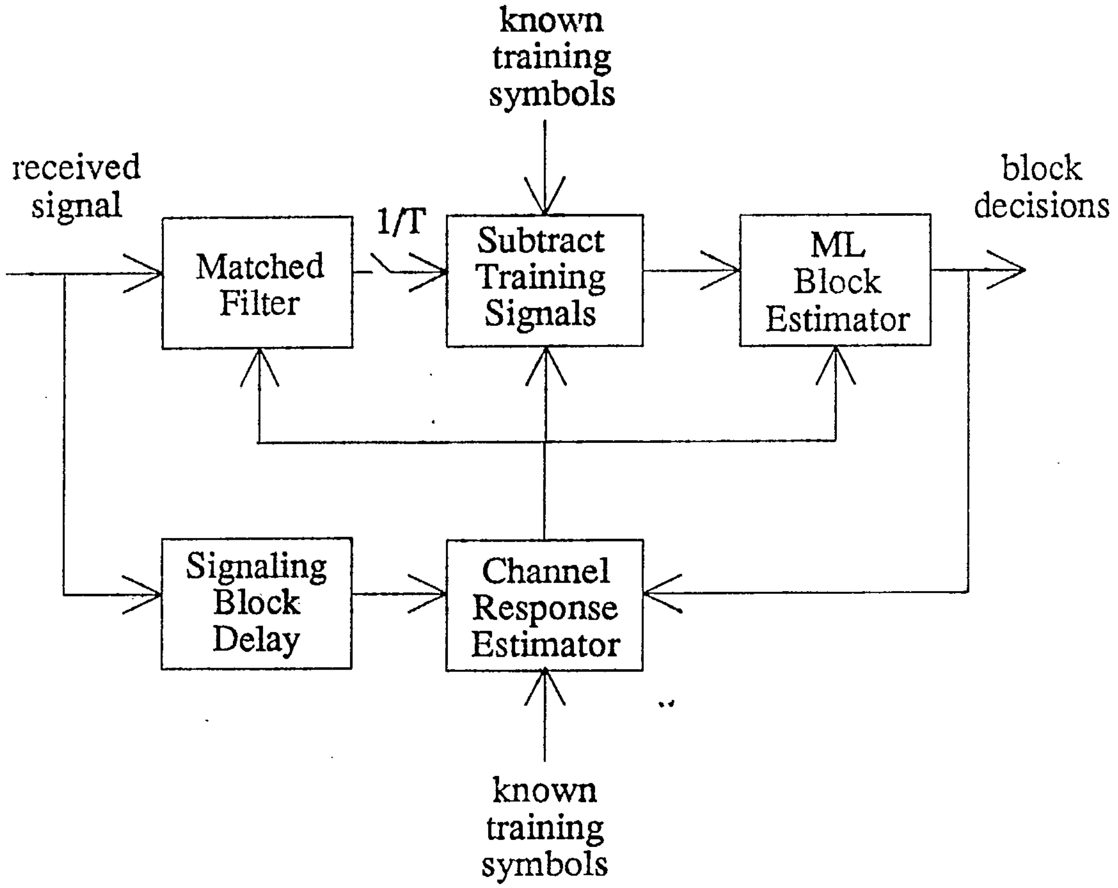




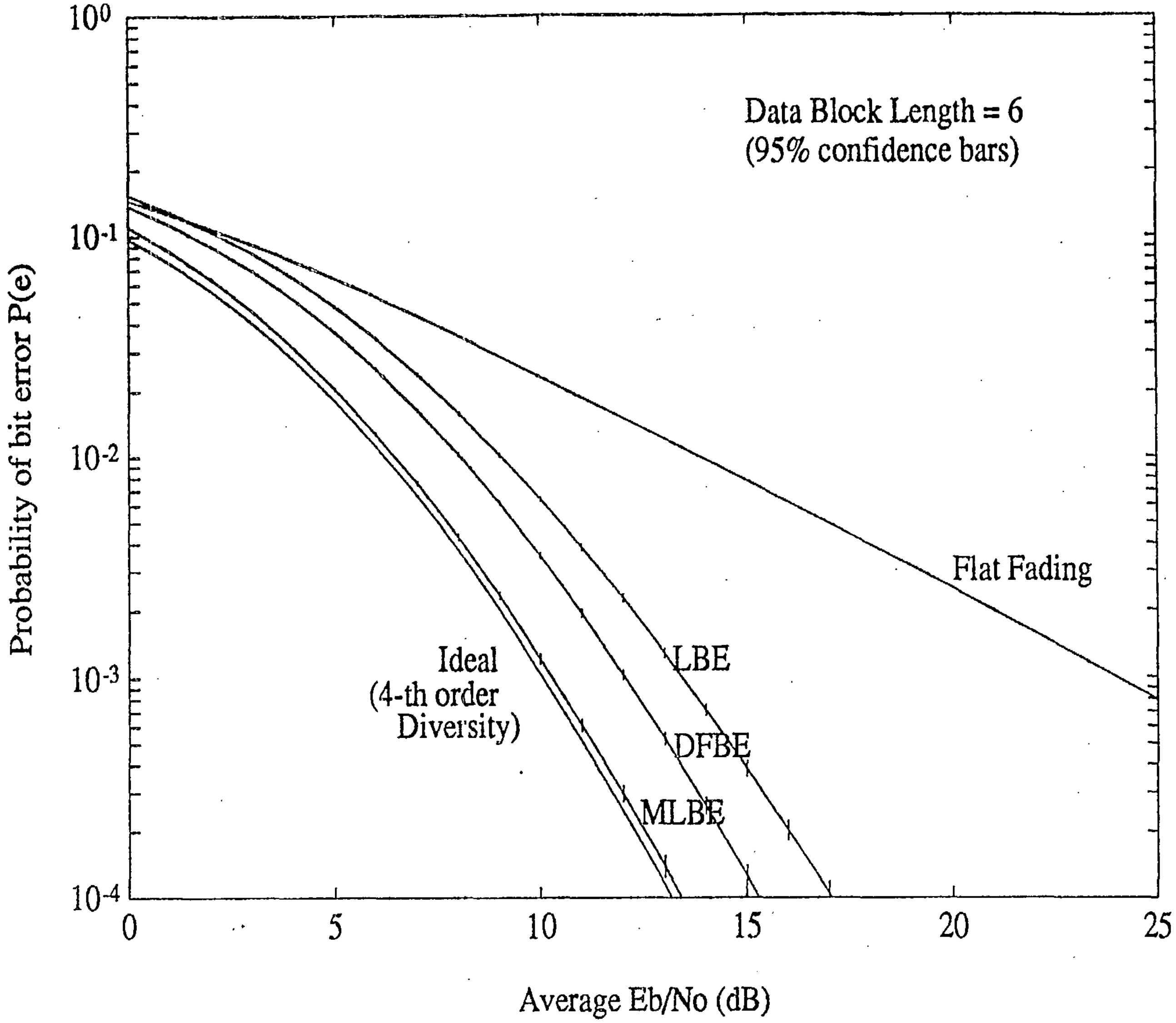
Linear Block Estimator (LBE) Approach



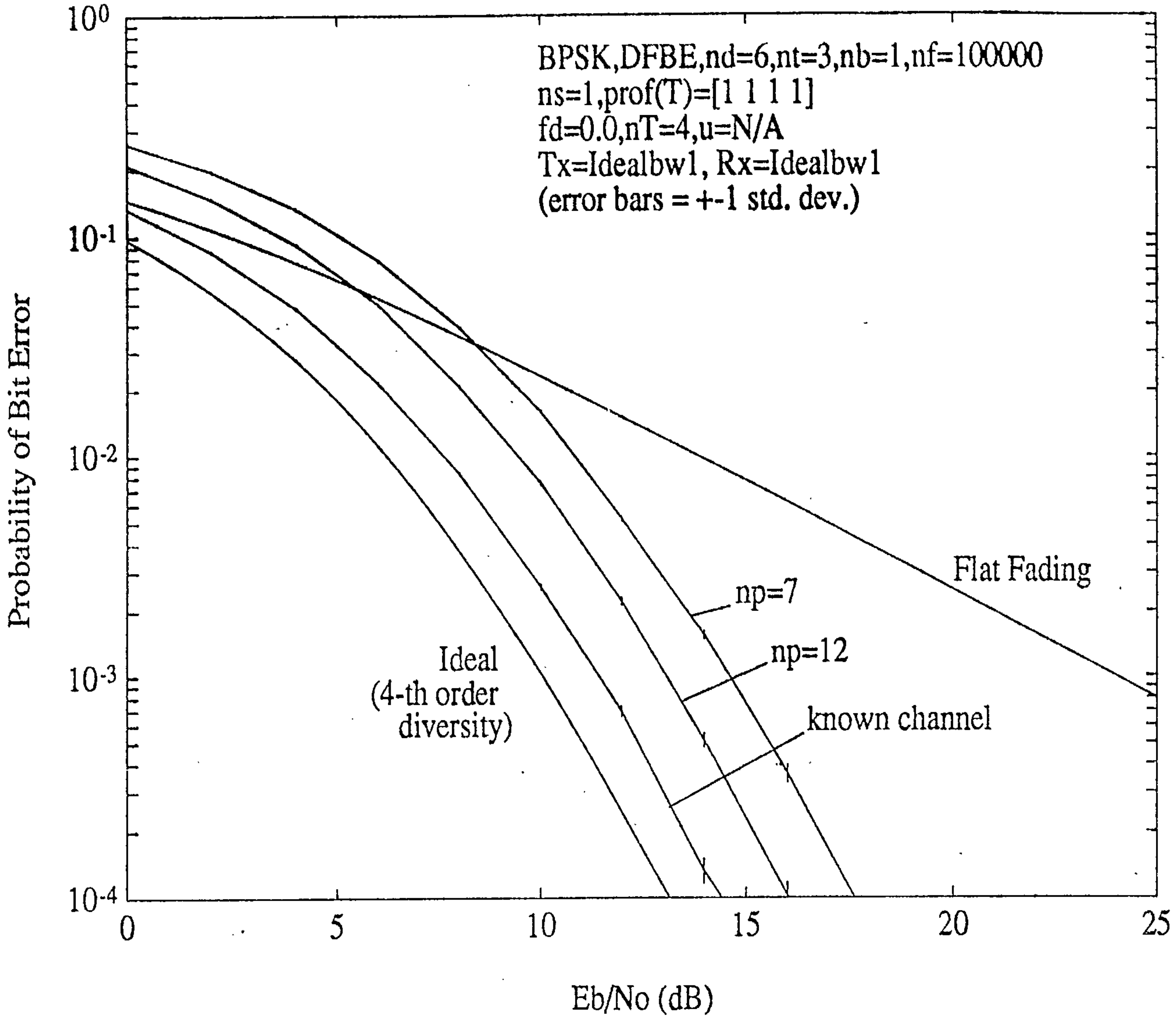
Decision Feedback Block Estimator (DFBE) Approach



Maximum Likelihood Block Estimator (MLBE) Approach



Theoretical bit error rate performance
LBE, DFBE, MLBE and Ideal detection
Known slow fading multipath channel
4 equally energetic paths



Simulated bit error rate performance
DFBE detection
Known and unknown slow fading multipath channel
4 equally energetic paths

Conclusions

- Medium complexity short-block detectors can handle severe time dispersion and take advantage of the inherent diversity

- Block processing is a useful approach
  - naturally accommodates training blocks
  - allows for block-by-block detection
  - natural reset capability
  - use channel response estimation
  - allows for higher signaling rates and reduced complexity with short-block detectors

- Performance

  LE < LBE < DFBE = DFE < MLBE = MLSE

- Complexity

  LBE = DFBE < DFE < LE < MLBE < MLSE

OVERVIEW:

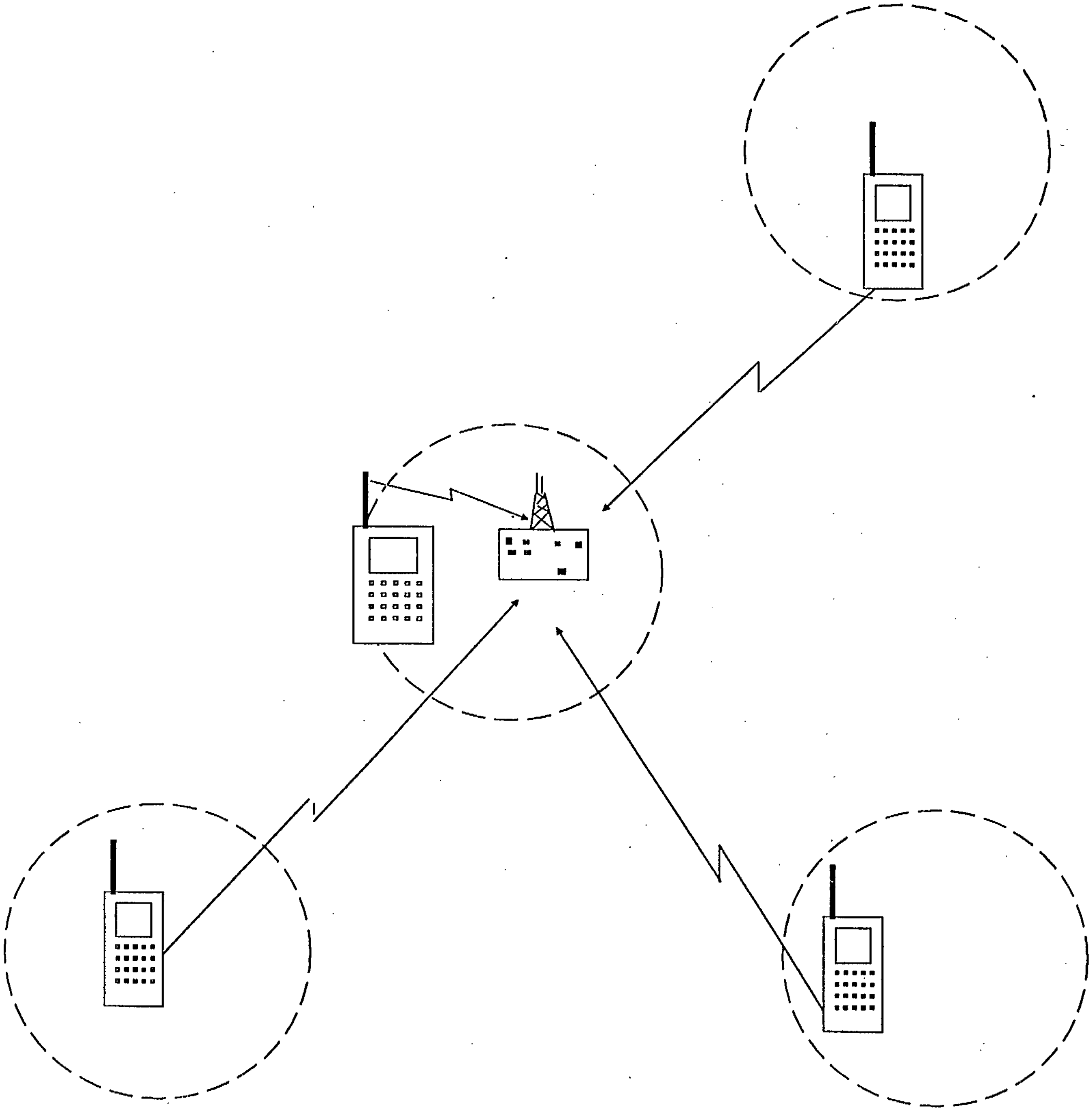
Coding and Optimum Baseband Diversity Combining for Wideband TDMA Indoor Wireless Channels

C.L.B. Despins, D.D. Falconer and S.A. Mahmoud

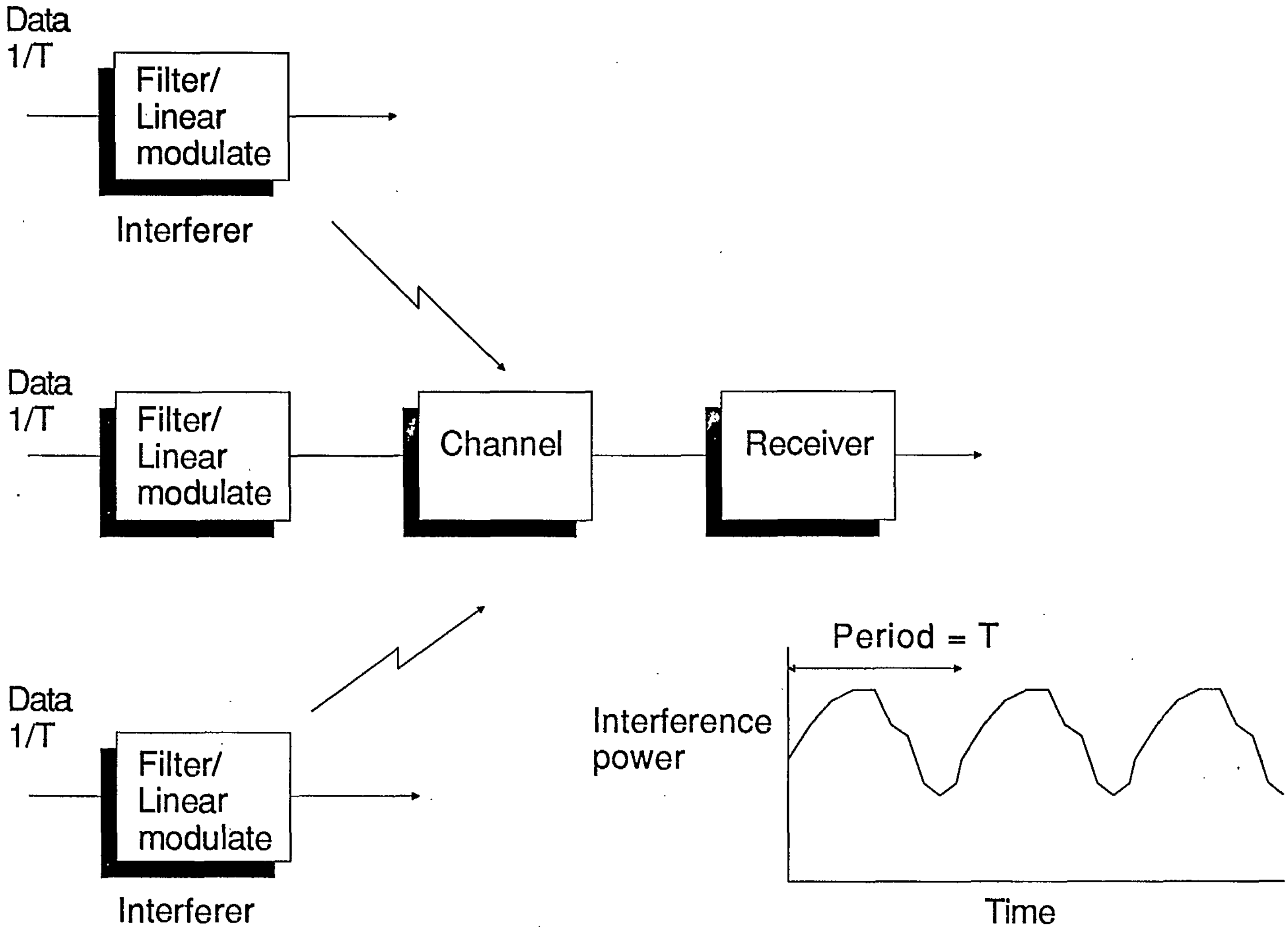
- Problem of slow frequency-selective fading and co-channel interference for TDMA indoor wireless channels.

- Approach: .. Adaptive DFE equalization,
  diversity and convolutional coding
  tradeoffs.

CO-CHANNEL INTERFERENCE IN CELLULAR RADIO



INTERFERENCE



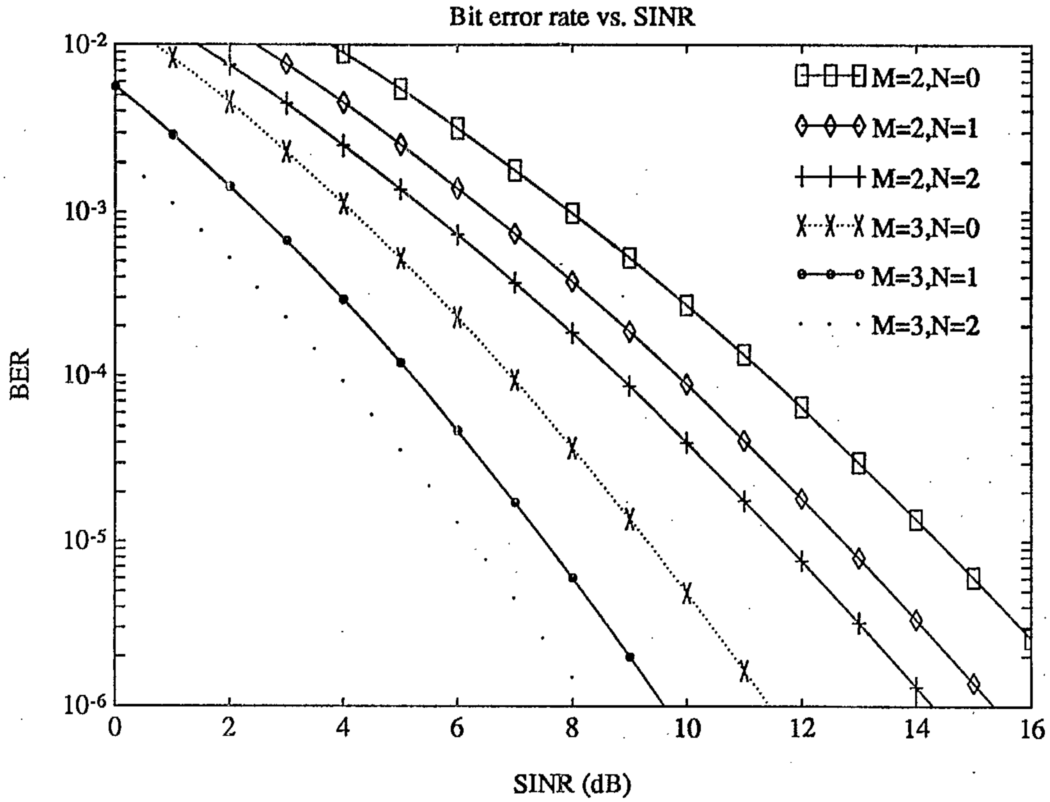
SOME APPLICATIONS OF INTEREST:

- Crosstalk in digital transmission on multipair cables.
- Radio: co- and adjacent-channel interference.
- Dual-polarized radio system crosstalk.
- Residual echo in full-duplex 2-wire transmission.
- Magnetic recording.

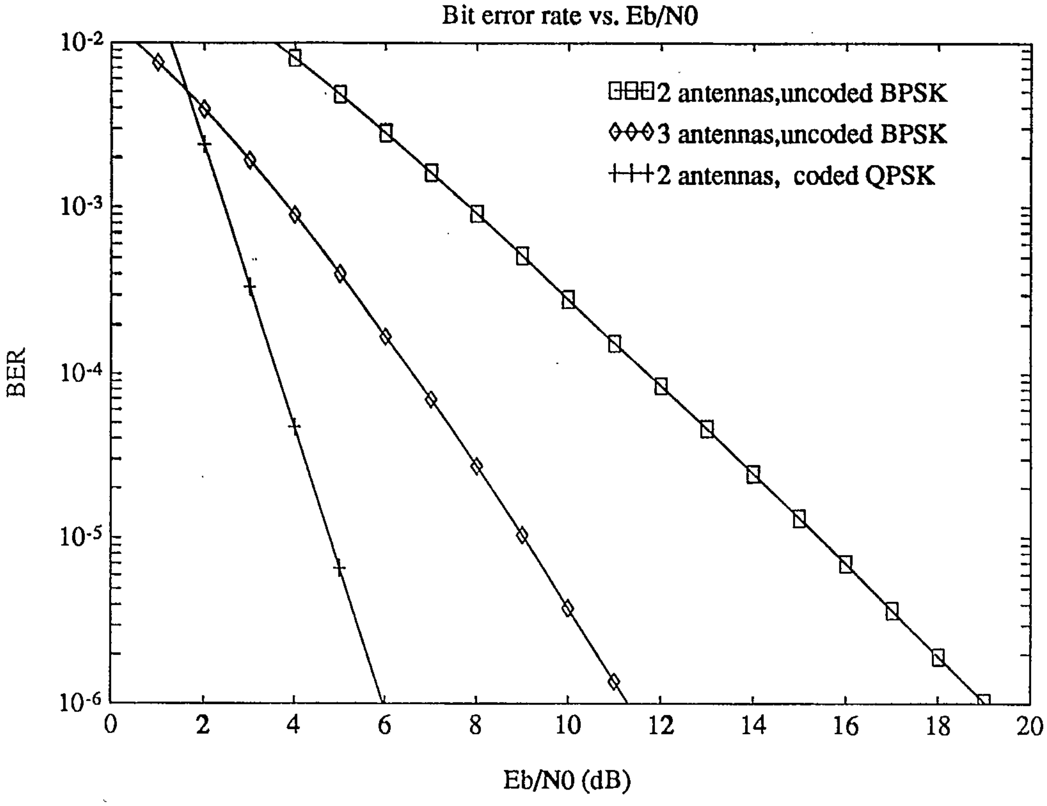
Wideband TDMA indoor channel

- Impairments:
  - Shadowing
  - Frequency-selective fading (slowly-varying)
  - Cochannel interference
- Countermeasures:
  - Diversity:
    - Macroscopic (shadowing)
    - Microscopic (fading) → pre-detection, post-detection (baseband)
  - Equalization:
    - suppress CCI as well as ISI → combine with post-detection space diversity → optimum baseband combining

- Countermeasures (cont'n):
  - Coding:
    - Block (R.S.) codes
    - Convolutional codes with soft-decision Viterbi decoding
    - Interleaving prohibitive (delay & complexity)
    - Space diversity & coding → coding gains if:
      - Diversity order sufficiently large.
      - Code sufficiently complex.
    - Does this conclusion apply to optimum baseband combining with conv. coding & soft-decision Viterbi decoding?
      - Effective diversity order > explicit space diversity order.
      - Alternative to triple antenna diversity.
- Modulation: BPSK, QPSK (coherent)



- BPSK, interferer-to-noise ratio $E_{Sn}/N0=1$ for $n=1,2$.
- $t_0=0.0T$, $t_1=0.125T$, $t_2=0.25T$.
- $\sigma_d=0.25T$, exponential delay profile.
- Rectangular pulse shape, L=3, L1=2, L2=0.



- N=1, S/I=10dB, t_0=0.375T, t_1=0.0T.
- σ_d=0.25T, exponential delay profile.
- Rectangular pulse shape, L=3, L1=2, L2=0.
- Rate 1/2 convolutional code, d_{free}=5, constraint length=3.

Analytical conclusions

- With L=3 F.F. $\frac{T}{2}$—spaced taps, equalizer sampling phase has significant effect on $\overline{BER}$. Effect of interferer timing phase on $\overline{BER}$ negligible (time-varying channel).

- With M=2 and data rate=5 Mbits/s, no significant improvement beyond L=3. More taps yield gains if some used as postcursor taps.

- Decreasing data rate from 5 Mbits/s degrades performance. No degradation until data rate > 10 Mbits/s.

Analytical conclusions (cont'n)

- Based on same **bit** rate, data rate beyond which QPSK is better than BPSK is:
    - Higher when interference dominates than when AWGN dominates.
    - Higher with smaller M when CCI is significant.
    - If CCI negligible, transition point similar for M=2 & M=3.

- Coding is clearly a viable alternative to increasing M from 2 to 3 if full interleaving can be applied.

Architectural Design for Digital Cordless Telecommunication Systems

Andy McGirr

PRESENTATION OUTLINE

With the aid of a comprehensive traffic simulation model, potential applications for digital cordless technology are discussed from a technical perspective. Compromises in choosing the access technique, control channel structure, modulation method, transmit power levels, cell sizes, channel assignment and the duplexing method as well as others will be summarized. The presentation will follow the format of a technical tutorial.

BIOGRAPHY

Andrew McGirr graduated from Queen's University in Kingston, Ontario, with an M.Sc. in electromagnetics. In 1983 he joined Bell Northern Research's Digital Transmission Products Group (Ottawa) and later became involved with indoor wireless communications. In 1987 he moved to NovAtel Communications (Calgary) where he is presently manager of the Antenna & Propagation Group.

I would like to acknowledge the assistance of the NovAtel digital cordless advisory group and in particular Abraham Fapojuwo and Saied Kazeminejad in preparing this presentation.

Spectrum Considerations for In-Building Wireless Communications

David Steer

ABSTRACT

One of the most critical questions for a wireless communications service is the provision of spectrum. The traffic that can be supported depends on the bandwidth available, the modulation and the channel allocation techniques, the access protocols and the distribution of stations. This discussion will focus on the provision of spectrum for wireless systems, and report on recent activities of the CCIR on spectrum considerations for Future Public Land Mobile Telecommunications Systems (FPLMTS).

BIOGRAPHY

David Steer received the B.Sc. (Eng.) and M.Sc. (Eng.) degrees from Queen's University at Kingston in 1972 and 1974 respectively. In 1974 he joined Bell-Northern Research with the electronic switching division. Since that time he has worked in many areas of toll switching, operator services development and research. In 1984 he completed a Ph.D. degree in image processing for Radio Astronomy at the University of British Columbia. Currently David is with the wireless communication program of the Business Communications Systems division of BNR.

Presentation By:

David L. Jones

BIOGRAPHY

As Director Private Mobile Systems, AGT Mobile Communications, David Jones directs and controls the management of resources and activities associated with the sale, provisioning, design and research and development of Mobile Communications' special products and services.

Mr. Jones joined Plessey Telecommunications (UK) in 1969 and AGT in 1973. Experience in the mobile communications industry began in 1979 when employment commenced with current AGT division. Positions held have ranged from Finance Manager to present job, involving the management of over 160 direct and indirect subordinates in five functional departments.

Numerous special assignments undertaken, including being on loan to Alberta Telecommunications International as a senior management consultant to the Puerto Rico Telephone Company (1985) to assist in the development of a Cellular 800 division.

As Director of the Advanced Radio Telecommunications Task Force (1990), developed a strategic evaluation of "Wireless" technologies and their projected impacts upon AGT Mobile Communications' operation and future success.

Presently AGT's marketing representative on the Federal Government and Industry sponsored Vision 2000 initiative. The objective of this programme is to develop a National Business Plan for communications, through the implementation of a coordinated national Research and Development Programme.

Education: 1987 - Certified Management Accountant (CMA)
1975 - Telecommunications Technician

Professional Memberships: Society of Management Accountants of Alberta

1

A. T. R. C.
WIRELESS 90

BUSINESS & OPERATION CHALLENGES

July 17, 1990

David L. Jones
Director, Private Mobile Systems

AGT
Mobile Communications

A. T. R. C.

Regulation, Client Needs and Technological Trends are Changing the Way Business and People Communicate

1)

AGT
Mobile Communications

A. T. R. C.

The Challenge Facing the Canadian Telecommunications Industry is to Effectively Introduce and Manage the New Methods of Telecommunications Expected in the Next Decade

2)

AGT
Mobile Communications

A. R. T. C.

- New Methods of Telecommunications Will be Successful Only if They Meet the Needs of the Users

- Market Demand for Services and the Commitment of Service Providers

To Fully Understand and Meet Such a Demand Will be Paramount for the Successful Telecommunications Company of the Future

AGT
Mobile Communications

A. T. R. C.

Future Communications Services Must be of Perceived and Real Benefit to Users

BUSINESS

To Improve Operating Efficiency, Protect the Environment and the Safety of the Employees

RESIDENTIAL & PERSONAL

To Improve Quality of Life and Increase Leisure Time Available to the Family Unit

AGT Mobile Communications

A. T. R. C.

Telecommunications Will Continue to Evolve From Place to Place to Person to Person

Such Person to Person Communications Networks Must Eventually Provide for High Quality Voice, Data and Video Services

AGT
Mobile Communications

A. T. R. C.

Wireless Communications Services Can Generally be Defined as Any Method of Communication That Does Not Require the Originator or Recipient of Information to Access a Wired Network Directly

6)

AGT
Mobile Communications

A. T. R. C.

Applications for Person to Person Communications Networks:

- Voice Communications
- Data Communications
- Video Conference
- Vehicle Management Services
- Access to Data Bases
- Industry Control and Management
- Remote Location Monitoring and Control

AGT
Mobile Communications

A. T. R. C.

Characteristics of Person to Person Communications:

- Common Air Interface Standards
- User Friendliness
- Secure Communications (Encryption)
- Transparent Growth Without Technical Obsolescence
- Easy Ability to Add Functionality
- Terminal Portability

AGT
Mobile Communications

A. T. R. C.

Todays Situation:

- Person to Person Voice and Limited Data Services Available in Large Populated Areas (C800) and Corridors of Travel
- First Generation Cordless Phones Available for Business and Residence
- Specialized Wireless Voice and Data Services Available to Business Through Private Networks and Point to Point Radio Systems

A. T. R. C.

Expected Future:

- Common Wireless (Public/Private) Networks Capable of Virtual Private Network Features
- Transmission of Voice, Data and Video From Anywhere to Anywhere
- Low Cost Disposable Terminals
- Strength in Wireless Communications Will be Network Based

AGT
Mobile Communications

A. T. R. C.
BUSINESS AND OPERATION

Challenges in the Development of Ubiquitous Intelligent Wireless Networks

- Efficient Spectrum Management
- Integration With Wired Networks
- Call Management and Completion
- Integrated Billing Systems
- Reliable Terminal Products with Common Air Interface Standards
- Growth of New Services With Minimal Technological Obsolescence
- User Friendliness
- Security of Communications
- Easy Ability to Add Functionality
- Possible Reduction in Existing Telecommunications Revenue (L.D.) Due to Higher Call Completion Rate

AGT
Mobile Communications

Presentation By:

Leonard M. Katz

BIOGRAPHY

Mr. Katz is the Assistant Vice President - Government and Inter-Carrier Relations at Rogers Cantel Inc. He joined Cantel in 1985 as Director of Corporate Planning, and has also held the position of Director of Market Development.

In his current capacity, Mr. Katz is responsible for all regulatory and licensing aspects of Cantel's operations including all applications to Government, Regulatory Boards and telephone companies as it relates to product or service approvals. Mr. Katz successfully led the Company's recent application seeking one of the three international paging frequencies compatible with U.S. operators.

Mr. Katz has been Cantel's chief negotiator in securing interconnection throughout Canada.

In his capacity as A.V.P. Gov't & Intercarrier Relations, Mr. Katz is also responsible for all activities and negotiations with U.S. operators. In this regard, it should be noted that Cantel has the largest network of cellular interconnect roaming agreements worldwide.

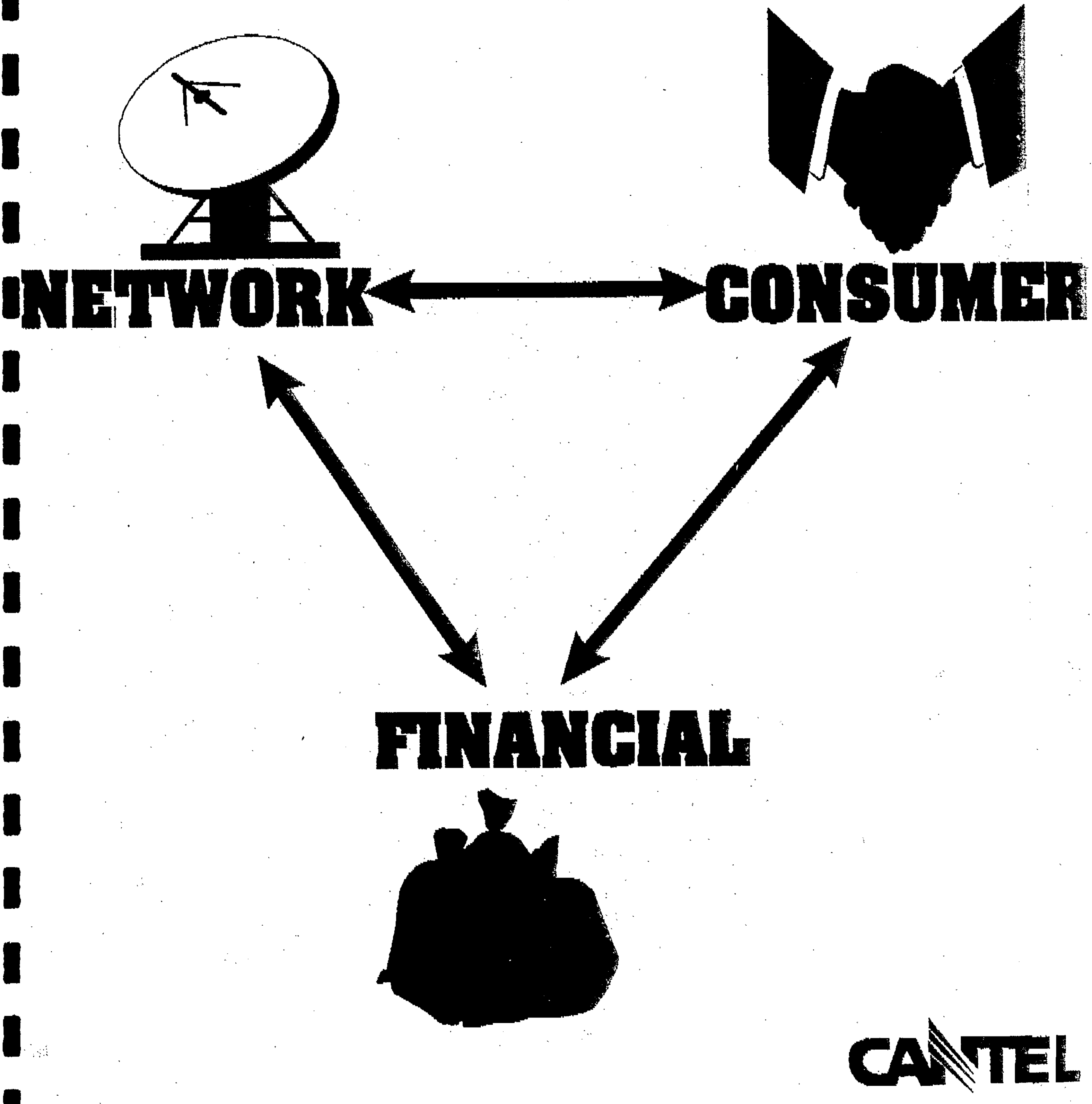
Mr. Katz has been in his current position since February 1988. He has 16 years experience in the telecommunications industry in Canada. Prior to his employment with Cantel, Mr. Katz spent 12 years with Bell Canada in Marketing, Policy Development, Regulatory and Comptrollers Departments.

Mr. Katz is active in numerous associations in Canada and the United States, including the Cellular Telecommunications Industry Association (CTIA) in Washington, D.C., Telocator, and the RadioComm Association of Canada. He is presently the Chairman of the Clearinghouse Committee of the CTIA and the President of the RadioComm Association of Canada.

Mr. Katz is a graduate of McGill University (BMA) in Montreal, Quebec, and did his undergraduate studies at Sir George Williams University.

Rogers Cantel Inc. owns and operates Canada's only national cellular telephone network which currently provides service to more than 200,000 customers in 60 Canadian Centres.

Business & Operational Challanges



NETWORK

CONSUMER

FINANCIAL

CANTEL

Business & Operational Challanges

NETWORK

A) Real Estate
B) Transmission
C) Billing System
D) Interconnection Agreements
E) Numbering Plans
F) Suppliers
G) Compatability

Business & Operational Challanges

NETWORK

A) Real Estate

- Procurement
- Permits.Permission

B) Transmission

- Leased Facilities
- Owned
  - Microwave
  - Fiber/Copper
  - Roof Rights
  - Right of Way

CANTEL

Business & Operational Challanges

NETWORK

C) Billing System

- No pulse Metering
- If not a National Mandated carrier
- Roaming & Integration

D) Interconnection Agreements

- Decision 84-10
- Provincial or Federally Regultaed Telco's
- Other Carriers (Cantel, CellNet)

CANTEL

NETWORK

E) Numbering Plans

- Telecom Canada currently controls numbering.
- Unique NPA or NXX's

F) Suppliers

- Who
- Canadian or other

G) Compatability

- North American
- Global

Business & Operational Challanges

CONSUMER

A) Distribution Network

- **Sales**
- **Product Information**
- **Product Education**

B) Customer Service Group

- **Billing Inquiries**
- **Customer Queries**
- **Subscriber Information**

CANTEL

Business & Operational Challanges

CONSUMER

C) Marketing Group

- Pricing Plans
- Promotions
- Advertising

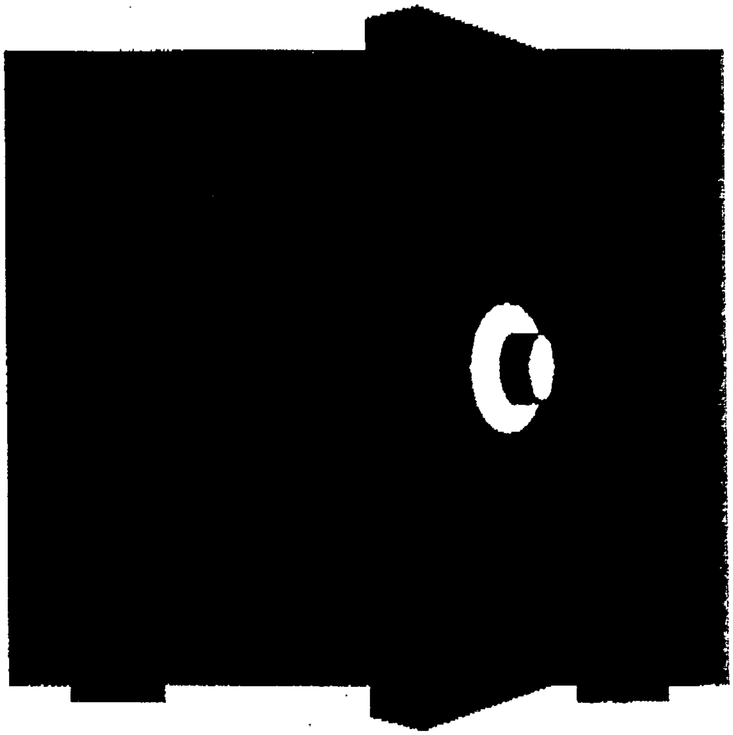
D) Fraud

- Inter-Carrier Agreements
- Positive Verification

CANTEL

Business & Operational Challanges

FINANCIAL

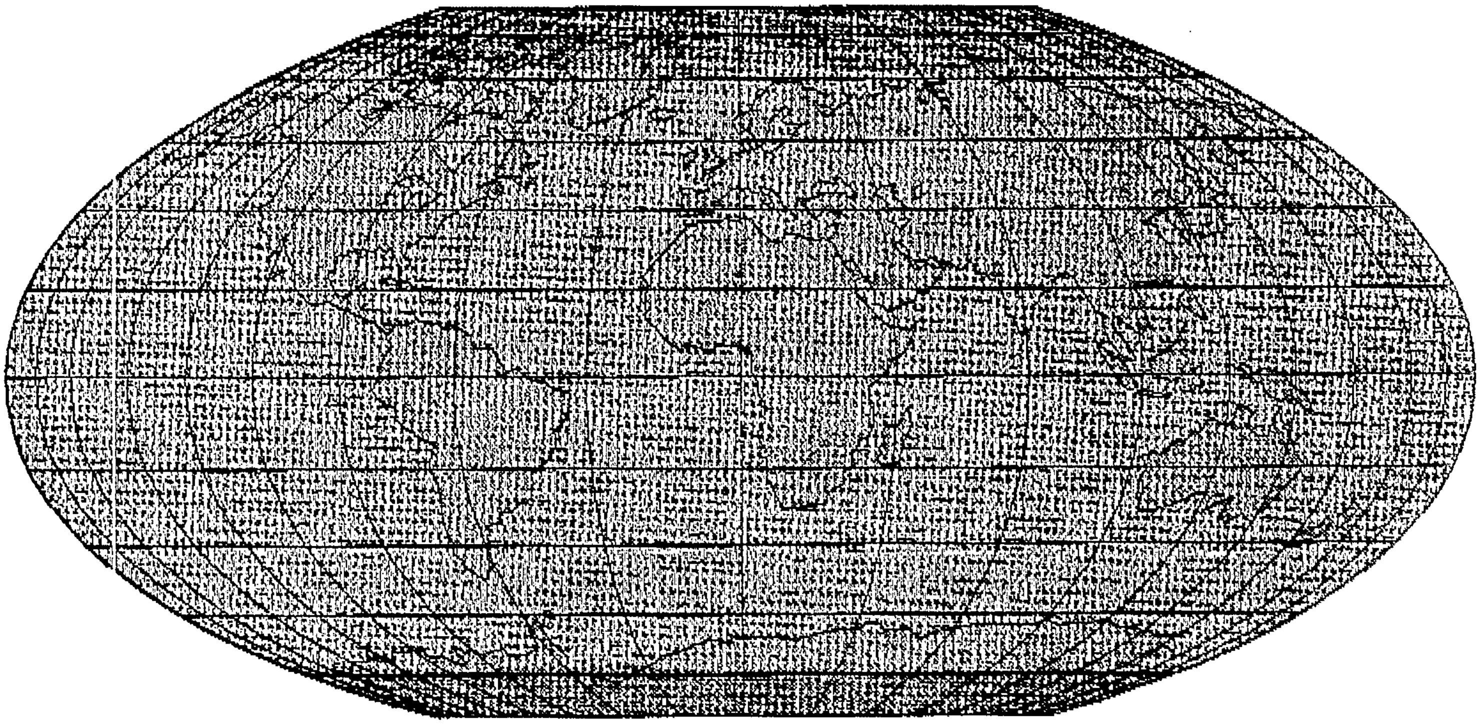


The more that is built the longer the pay back.

A National Service Provider must be willing to invest $75-$100 Million Annually

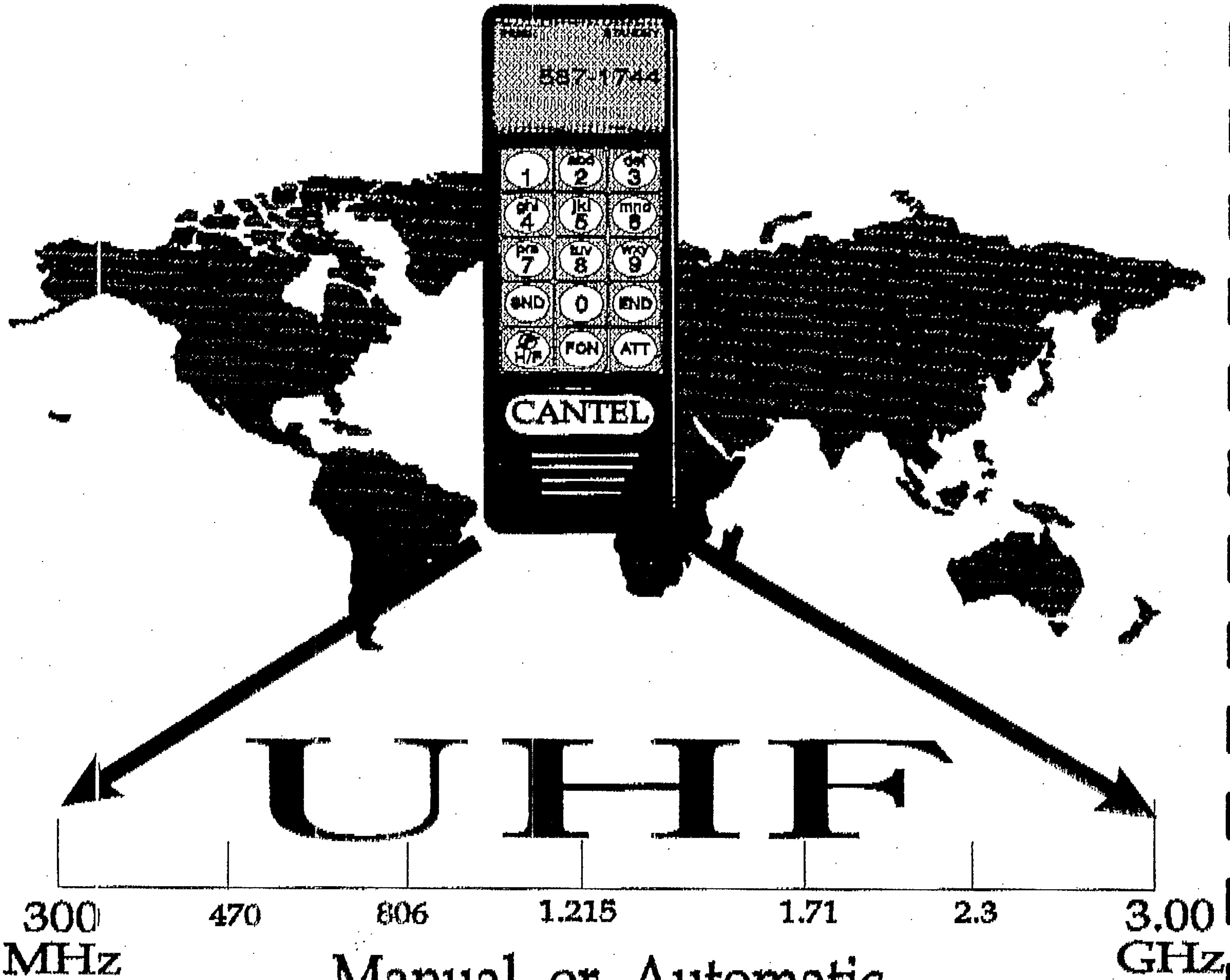
CANTEL

CCTT's Biggest Challange



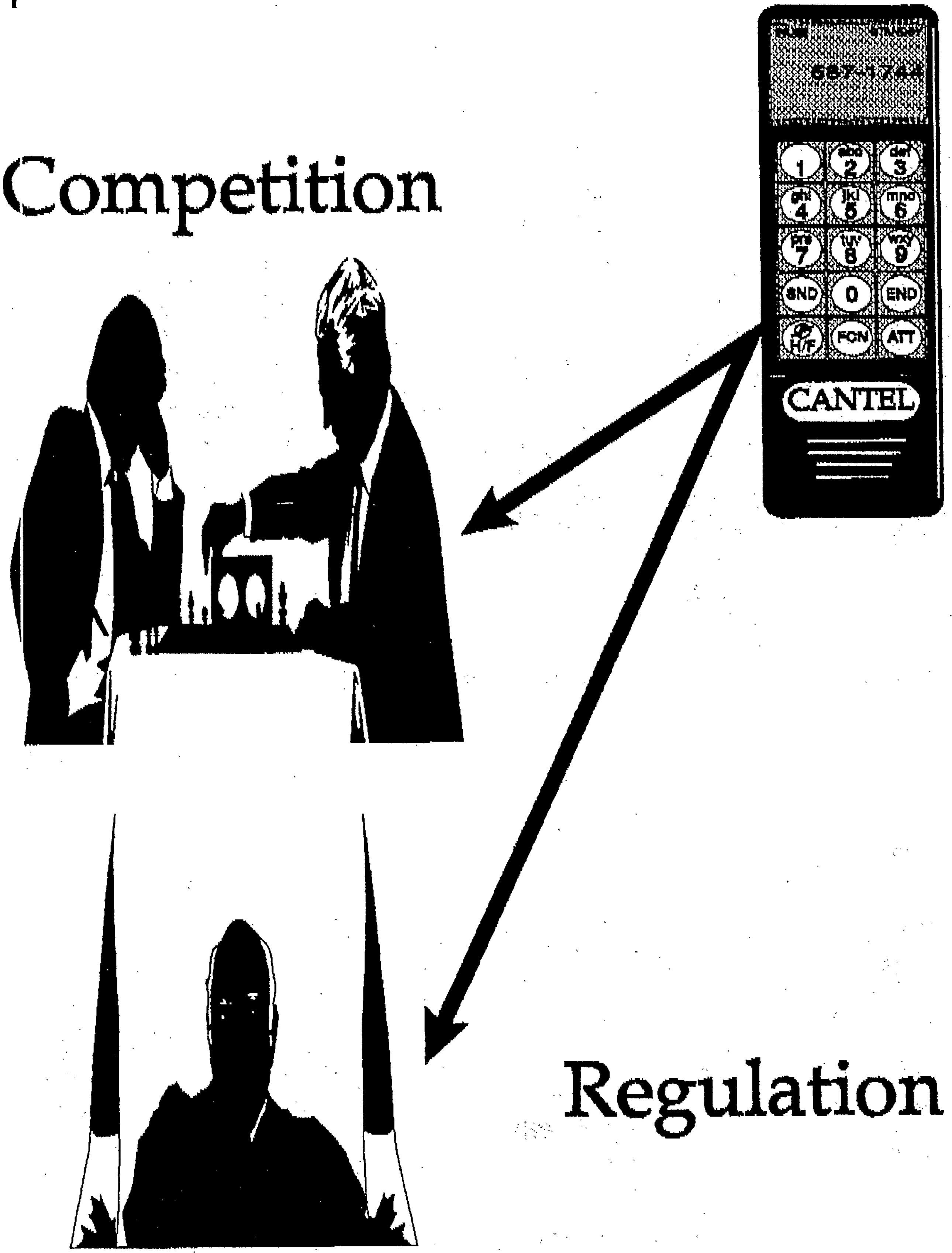
Not Merely North American Compatable, but Global Compatability

The CCTT Challenge



Manual or Automatic
Tunable Digital Voice
Communications
Capable of working anywhere
in the UHF Band,
anywhere in the world.

The CCTT Challenge

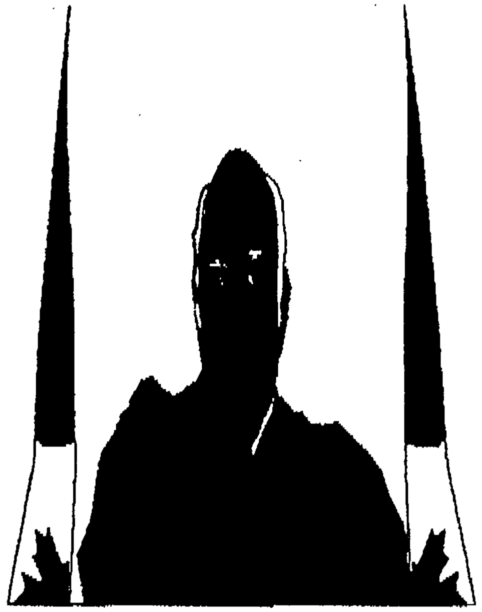


Competition

Regulation

The CCTT Challenge

Competition



Regulation

Competition

Regulation

Presentation By:

Alex A. Beraskow

BIOGRAPHY

Mr. Alex Beraskow is the President and Chief Operating Officer of Vision 2000 Inc. Vision 2000 Inc. is a consortium of communications and information technology related firms that will facilitate and accelerate the growth of the Canadian telecommunications industry.

Alex Beraskow brings a strong academic and professional background to the position. He is a Professional Engineer (P.Eng.), a Certified Management Consultant (CMC) and holder of an MBA degree in finance. His career began over 20 years ago as a systems engineer with IBM followed by international experience with Datec and Philips in Australia. He is bilingual and has over 20 years of management consulting experience related to all elements of business planning development and marketing.

As an executive, his principal expertise has been with computer technology firms and the area of management consulting. Previous to Vision 2000 he was the Managing Director of the Federal Office of DMR, an international management consulting firm. That office provided management consulting services for information management to the federal government in Ottawa. Previous to that, he was the founding partner of ISG (Information Systems Group) Consultants Ltd. That firm was acquired by DMR.

A Challenge has been issued!

Keith E. Fagan

Abstract

The paper describes the challenges in initiating services on a Mobile satellite where there are few similar services on which to draw experience. The paper discusses some of the options that were considered and the direction being implemented for MSAT.

BIOGRAPHY

Mr. Fagan was originally trained as both an Electronic and Mechanical Engineer under the Apprenticeship scheme at the Royal Radar Research Establishment in the U.K. He received a B.Eng. at Carleton University.

After a 5 Year commission in the Royal Canadian Air Force, Mr. Fagan joined Bell Northern Research in the Advanced Devices Laboratory and later with the Project Management Groups for the SG-1 and SL-1 PBX's. Mr. Fagan was then transferred to Northern Telecom's (Belleville Office) as SL-1 Product Manager to set up the new Customer support group for SL-1.

Following Northern Telecom Mr. Fagan spent five years with the Mitel Corporation on the SX2000 EPABX, and developed much of the infrastructure required to market a large PBX. Mr. Fagan left Mitel as the Director of Marketing.

Mr. Fagan spent the next few years in the Northern Telecom Transmission Division where he had all of the Product Managers reporting to him and later as Business Development Manager at Canadian Marconi Company for Ground Navigation Systems.

Presently Mr. Fagan is the Product Development Manager at Telesat Mobile Inc. where he is responsible for the identification of New Products and Services on MSAT (Mobile Satellite).

"A Challenge has been issued"!

Keith E Fagan

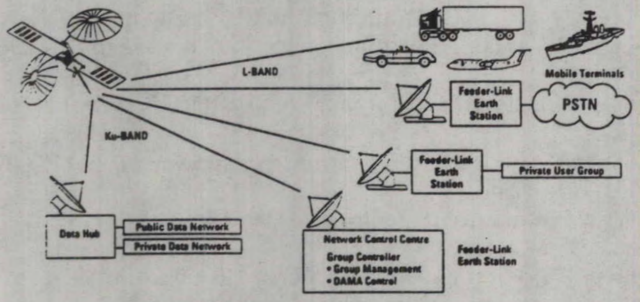
History of MSAT

- 1974 Federal Gov't MUSAT Program (Multi-purpose UHF Satellite)
- 1979 DoC obtained permission for Civilian use of 806-890 MHz
- 1986 Telesat agreed to Commercialize MSAT on behalf of DoC
- 1986 FCC refused UHF spectrum but allowed "l" band 1500MHz
- 1987 WARC allowed spectrum for land Mobile Services
- 1988 DoC prepurchased services on MSAT
- 1989 TMI formed to commercially operate MSAT

System Concept

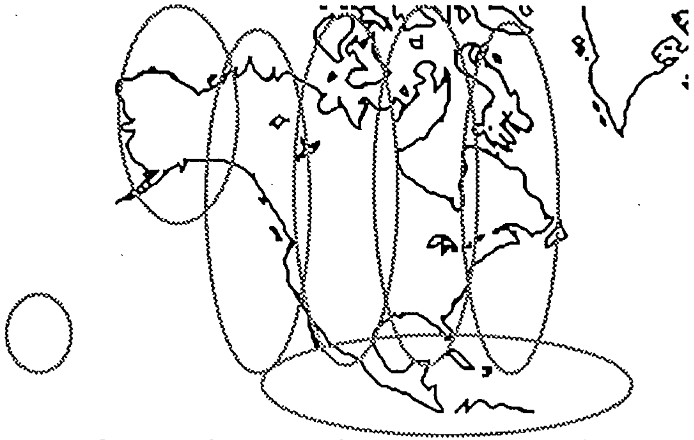
- North America-wide mobile communications network supporting voice and data services
- Separate satellites and ground stations which interoperate to serve both Canada and the United States
- Compact, low cost integrated voice and data mobile terminals
- Interconnection to the PSTN
- Satellite channels assigned on demand

System



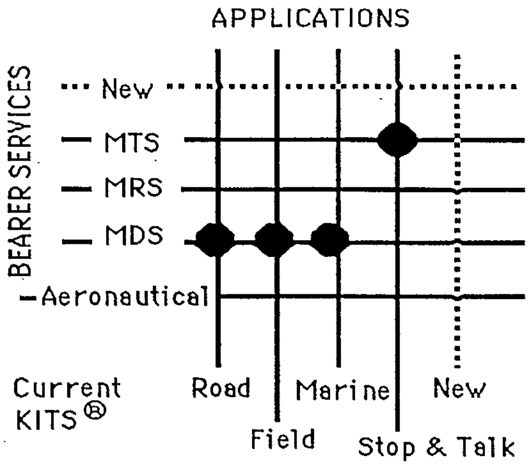
Concept for the communications system to provide MSS in North America

Coverage



Coverage beams as shown are representative only

MSAT Applications



APPLICATIONS

BEARER SERVICES	Road	Field	Marine	Stop & Talk	New
New					
MTS				●	
MRS					
MDS	●	●	●		
Aeronautical					

Current KITS®

Characteristics

Why is the satellite business different from other businesses ?

- Highly capital intensive
- Cash flow skewed towards the early years
- International implications without actual presence
- Regulatory and political intensive

MSAT vs "Normal" Satellites

MSAT IS:-	"Normal" Satellites are :-
• Narrowband	• Large Bandwidth applications
• Small, inexpensive terminals	• Large, Expensive earth terminals
• Multiple beam coverage	• Single global beam coverage
•"Pay as you use"	• Pay for capacity
• Bandwidth on demand	• Protected, fixed bandwidth

The "Challenge"

Support

Low Cost terminals

Distribution Strategy

Inform

Target market selection

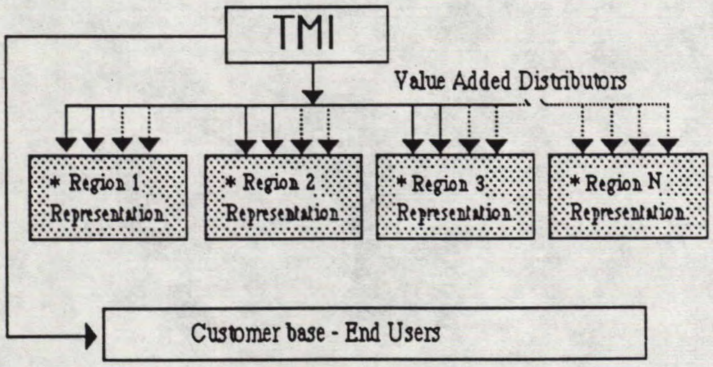
Selling the MSAT Concept

Choice of Satellite

Technical Trade-offs

Identification of Market

Distribution



TMI

Value Added Distributors

* Region 1 Representation

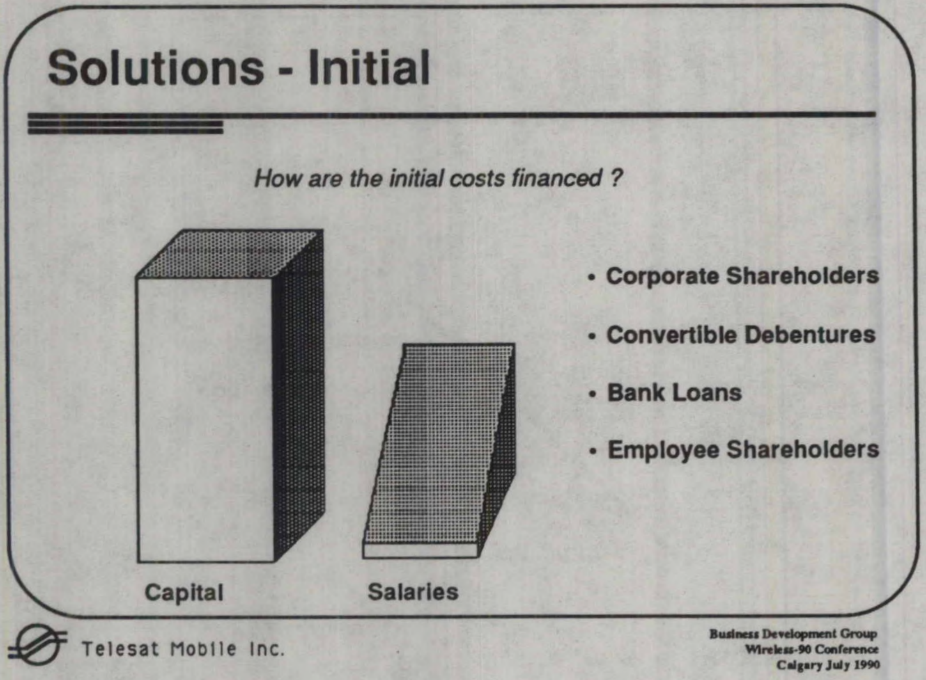
* Region 2 Representation

* Region 3 Representation

* Region N Representation

Customer base - End Users

TMI will facilitate sales through the VAD selected by the end-user



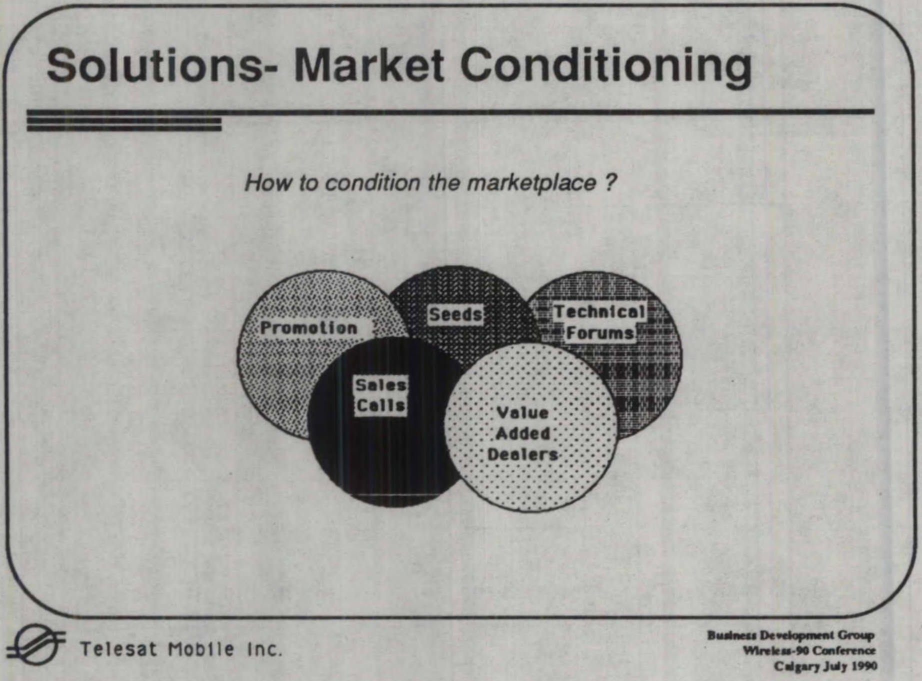
Solutions - Initial

How are the initial costs financed ?

- **Corporate Shareholders**
- **Convertible Debentures**
- **Bank Loans**
- **Employee Shareholders**

Telesat Mobile Inc.

Business Development Group
Wireless-90 Conference
Calgary July 1990



Solutions- Market Conditioning

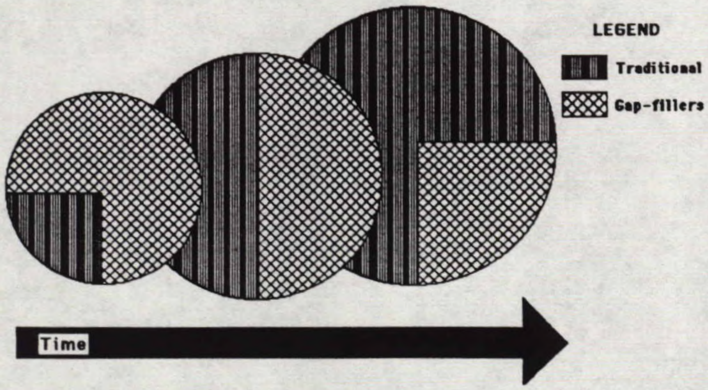
How to condition the marketplace ?

Telesat Mobile Inc.

Business Development Group
Wireless-90 Conference
Calgary July 1990

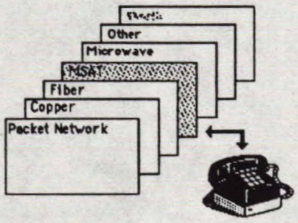
Solutions-Ready at launch

How to ensure that the satellite is filled at time of launch?



Balance

- Remain focussed
- Facilitate Sales
- Complementary services
- Market knowledge
- Service excellence
- Low cost terminal development
- "Managing the expectations of the marketplace"



Wireless Communications - A User Perspective

William G. Hutchison

BIOGRAPHY

William G. Hutchison has a Bachelor of Engineering degree in Electrical Engineering combined with 30 years of experience in computer and telecommunications systems. He has planned and directed more than 600 man years of software development for major domestic and international users and suppliers of computer and telecommunications systems. Some of the largest information technology contracts ever consummated in Canada were negotiated by Mr. Hutchison. Contracts included $30 million with a European organization and $10 million for systems sold to Fujitsu, Japan's leading computer company.

For the past fourteen years, Mr. Hutchison has been a prominent advanced technology advisor to government and business executives. Mr. Hutchison is a member and past Vice Chairman of the Prime Minister's National Advisory Board for Science and Technology. His professional advice has focussed on two areas; strategies and organization structures to achieve maximum productivity and competitive benefits from computers, software and telecommunications and strategies for building competitive advanced technology companies.

As a Chief Executive Officer Mr. Hutchison has directed a variety of advanced technology firms in fields as divers as computer hardware manufacturing, electronic publishing, software development and systems integration. Much of this activity has involved pioneering efforts that have helped to establish Canada's advanced technology infrastructure. For these efforts the Canadian Advanced Technology Association gave Mr. Hutchsion its 1988 Award of Distinction for Private Sector Leadership in Advanced Technology, "In recognition of the outstanding contribution he has made to the creation and development of the advanced technology industry in Canada".

Universal Mobile Communication Services (UMCS)

Serge Rouleau

Synopsis

UMCS is a very powerful concept which will change the very nature of how people interact with one another. However, the delivery of this vision raises very fundamental issues in the areas of technology and regulation.

BIOGRAPHY

Serge Rouleau graduated with a Bachelor of Applied Science in Engineering from the University of Ottawa in 1968, Business Administration diploma from the University of Montreal in 1971 and Engineering Economy (public utilities) diploma from the University of Iowa in 1973.

He has over 20 years of professional experience in the telecommunications and mobile communications businesses.

He joined BCE Mobile at the time of its creation in 1987 and has taken the responsibilities of business development, planning and technology during that period. Now holds the position of Vice-President, Planning and Business Development.

Worked for Bell Canada International on two occasions. He led a team of consultants in Africa (Congo) and completed a contract in South East Asia (Malaysia).

During his employment with Bell Canada, he completed numerous assignments ranging from general management duties to specialized professional work.

He is a Member of the Ordre des Ingenieurs du Quebec.

BCE MOBILE

PRESENTATION

WIRELESS 90

S. ROULEAU
VICE-PRESIDENT, PLANNING &
BUSINESS DEVELOPMENT

JULY 17, 1990

BCE MOBILE

BCE MOBILE PRESENTATION AT WIRELESS 90

TITLE: UNIVERSAL MOBILE COMMUNICATION SERVICES (UMCS)

SYNOPSIS: UMCS IS A VERY POWERFUL CONCEPT WHICH WILL CHANGE THE VERY NATURE OF HOW PEOPLE INTERACT WITH ONE ANOTHER. HOWEVER THE DELIVERY OF THIS VISION RAISES VERY FUNDAMENTAL ISSUES IN THE AREAS OF TECHNOLOGY AND REGULATION.

JULY 17, 1990

" ARTISTIC IMAGINATION SUGGESTS THE POSSIBLE

STATE-OF-THE-ART INDICATES THE PROBABLE

BUT POLITICAL CHOICE DICTATES THE PREFERABLE

FUTURE"

CUSTOMER NEEDS

ANYTIME

ANYWHERE

ANYPLACE

ANYTIME

- REDUCING TO ZERO THE TIME BETWEEN A CUSTOMER REQUEST AND THE DELIVERY OF THE SERVICE

- FOR EXAMPLE:
  - WALKING OUT OF THE STORE WITH AN ACTIVATED SET
  - CUSTOMIZING YOUR USER PROFILE ON A REAL TIME BASIS

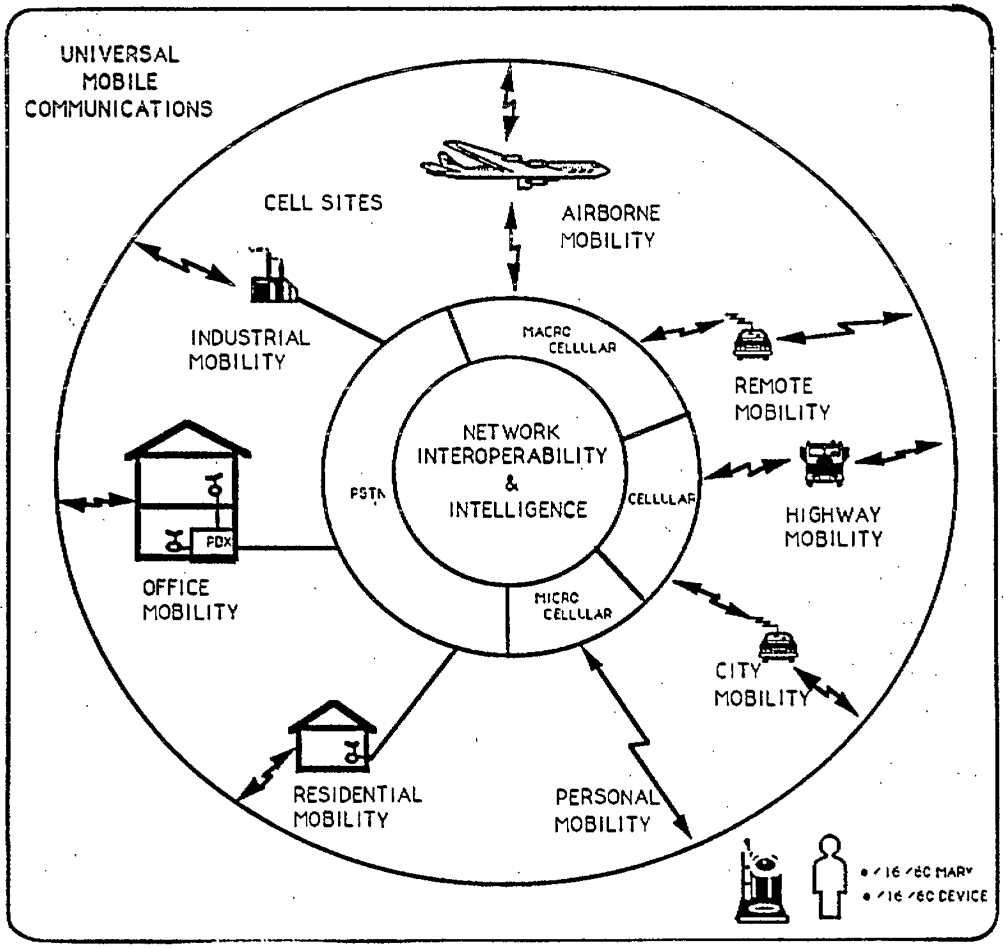
ANYWHERE

- Coverage
- CAI

ANYPLACE

- HOME
- OFFICE
- PUBLIC PLACES
- DURING TRAVEL

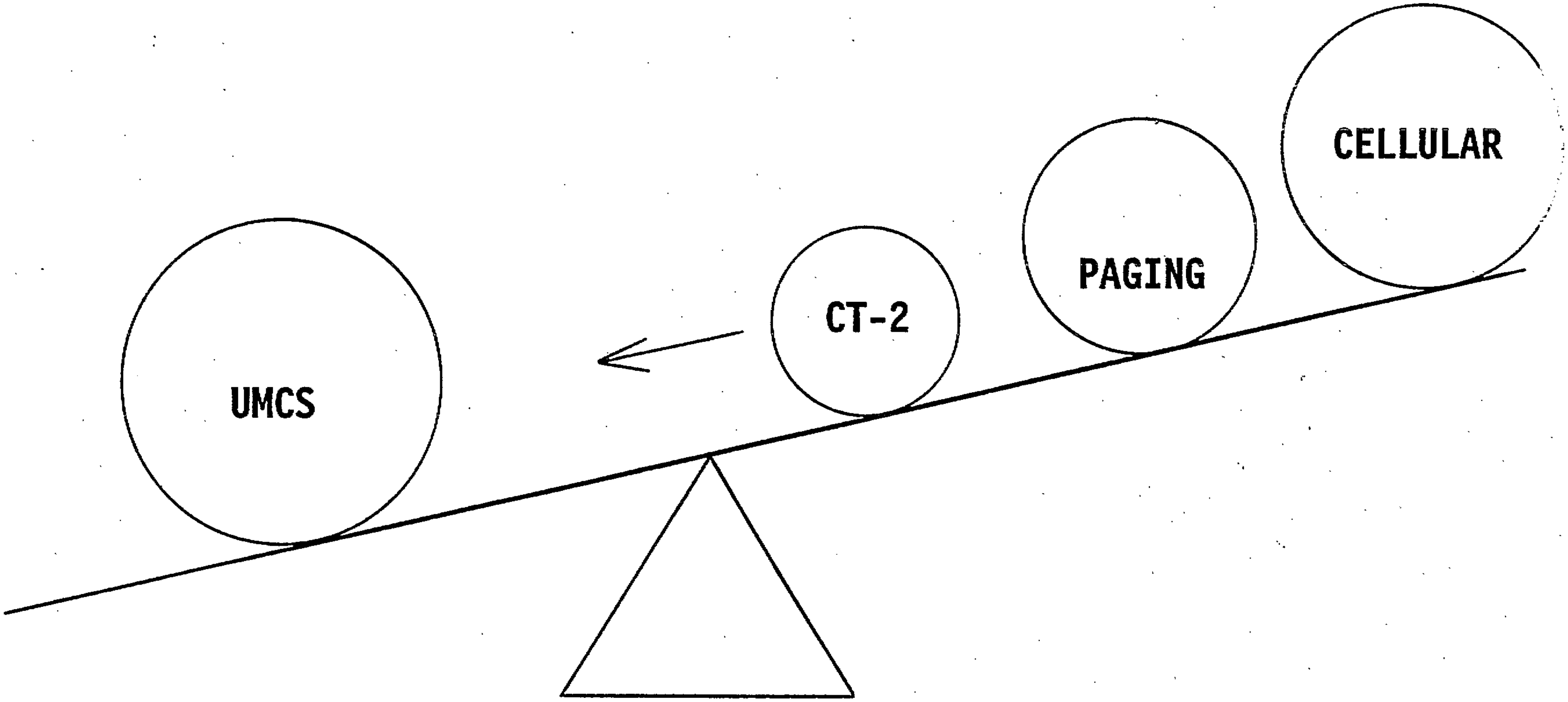
TECHNOLOGY


UNIVERSAL
MOBILE
COMMUNICATIONS
CELL SITES
AIRBORNE
MOBILITY
INDUSTRIAL
MOBILITY
MACRO
CELLULAR
REMOTE
MOBILITY
NETWORK
INTEROPERABILITY
&
INTELLIGENCE
PSTN
CELLULAR
HIGHWAY
MOBILITY
PBX
OFFICE
MOBILITY
MICRO
CELLULAR
CITY
MOBILITY
RESIDENTIAL
MOBILITY
PERSONAL
MOBILITY
• '16 '60 MARY
• '16 '60 DEVICE

ONE TECHNOLOGY, ONE SERVICE

- CELLULAR
- PAGING
- TRUNKING
- AIRPHONE
- TELEPOINT
- MOBILE DATA
- PMR
- AVL ...

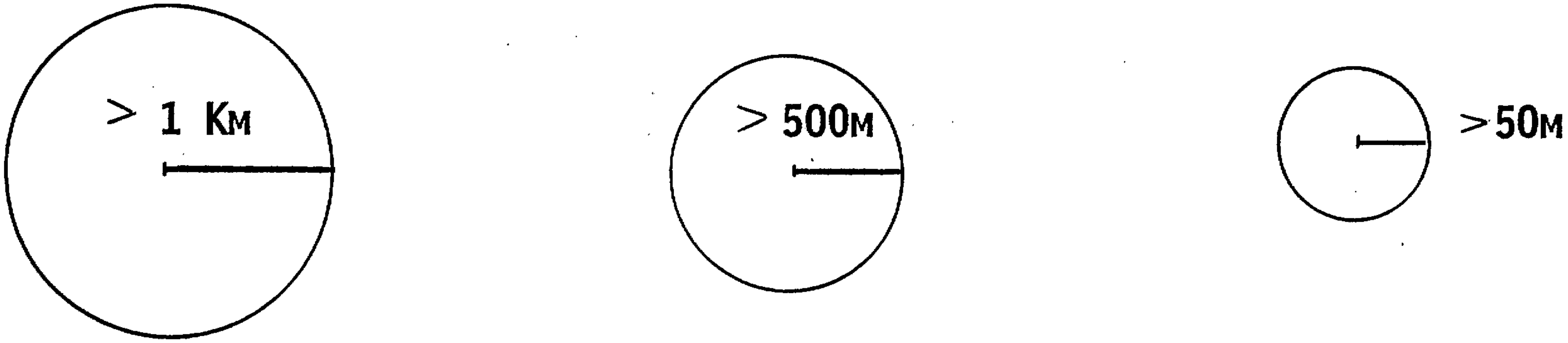
ONE TECHNOLOGY, ALL SERVICES



JULY 17, 1990

CAPACITY

USERS / CELL / MH$_z$ / SQ. KM



MACROCELL	MICROCELL	PICOCELL
21-52	85-211	> 100

USER FRIENDLINESS

PERSONAL IDENTIFIER

A UNIQUE ID WHICH ENABLES ACCESS TO TELECOMMUNICATION SERVICES AND ENABLES REACHABILITY AT NUMEROUS NETWORK LOCATIONS

PERSONAL PHONE

A WIRELESS SET WHICH ENABLES COMMUNICATION AT A DISTANCE FROM A NETWORK PORT OR BASE STATION

PERSONAL SERVICES

A SET OF NETWORK BASED SERVICES, BASED ON A PERSONAL IDENTIFIER, PROVIDING PERSONAL TELECOMMUNICATIONS MANAGEMENT AND CONTROL

POLICY / REGULATORY

TELECOMMUNICATIONS HAS BEEN WIDELY RECOGNIZED AS AN ESSENTIAL ELEMENT IN LEADING THE INDUSTRIALIZATION PROCESS. WIRELESS TELECOMMUNICATIONS WILL LEAD THE NEXT WAVE, CHANGING THE VERY NATURE OF HOW PEOPLE INTERACT WITH ONE ANOTHER.

SPECTRUM

- "BY 2000 AS MANY AS 70 PERCENT OF OUR CUSTOMERS WILL BE USING THE BT PERSONAL COMMUNICATIONS SERVICES."

  - PATRICIA CHAPMAN-PINCHER, BRITISH TELECOM

- "THE VERY REAL POSSIBILITY OF HDTV ADDS NEW URGENCY TO THE QUESTION OF CHOICES THAT I AM RAISING."

  - RALPH A. HALLER

INSTITUTIONAL ARRANGEMENT

- MONOPOLY
- DUOPOLY
- OPEN MARKET

Presentation By:

Roland Williams, NovAtel

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Wireless 90

To help us continue to offer you the best in the future, we'd like to find out what you think ...

1. How would you rate Wireless 90? (Use a scale from 1 to 10, 10 being excellent)

Content	___	Format	___	Duration	___
Location	___	Facilities	___	Meals	___

Others (Specify) ______________________________ ___

2. Rate the quantity of time spent at Wireless 90 on

Presentations	Too Short	About Right	Too Long
Discussion Periods	Too Short	About Right	Too Long
Informal Sessions	Too Short	About Right	Too Long

3. Rate the quality and content of each segment:

	Overall (1 - 10)	Special Comments
Day 1 Program	________	________________________________
Day 2 Track 1	________	________________________________
Day 2 Track 2	________	________________________________
Day 2 Track 3	________	________________________________
Day 2 Track 4	________	________________________________

4. Have we met your expectations in attending this seminar?

a.	gain an overview/understanding on trends in wireless communications	Yes/No
b.	improve specific understanding of cellular mobile technology	Yes/No
c.	improve specific understanding of issues in standards	Yes/No
d.	improve specific understanding of in-building wireless technology	Yes/No
e.	improve specific understanding of business/operations issues	Yes/No
f.	you can use this new information in your future work	Yes/No
g.	you have made valuable business contacts	Yes/No
h.	other ________________________________	
i.	Did you gain something you weren't expecting? ____________________ ____	

5. Did you receive full value for the fee charged? Yes/No

6. For this type of event, you feel the fee charged is: Too Low/About Right/Too High

Planning for next year's Wireless 91...

7. Will you attend Wireless 91 next year? Yes/No

8. Where and when should Wireless 91 be held?

   a. Calgary, around Stampede time (mid July)
   b. Ottawa, August
   c. Other combinations ____________________

9. What subject areas within wireless personal communications you would like to see?

   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________

10. In addtion to the formal program, would you like to see Wireless 91 include:
    a. tours to local labs and plants (e.g. Northern, NovAtel, AGT, UofC, ATRC) Yes/No
    b. a site seeing program for your spouse/companion Yes/No

11. Will you recommend Wireless 91 to others? Yes/No

12. To help expand our mailing list, can you provide us with additional names of people whom we should contact?

Name:____________________
Company: ____________________ City: ____________
Phone: ____________________ FAX: ____________

Name:____________________
Company: ____________________ City: ____________
Phone: ____________________ FAX: ____________

Name:____________________
Company: ____________________ City: ____________
Phone: ____________________ FAX: ____________

Additional Comments: ____________________

____

Name (Optional) ____________________

Company (Optional) ____________________