Canada

Communications Research Centre

SLIM TDMA ANIK B PILOT PROJECT

by

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Government of Canada
Department of Communications

Gouvernement du Canada
Ministère des Communications

CRC REPORT NO. 1366

OTTAWA, JUNE 1984

COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS
CANADA

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(DGSTA/DSS Branch)

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ABSTRACT

The technical and service feasibility of a 3 Mbps TDMA system was evaluated in a pilot project utilizing the ANIK B satellite. This report summarizes the organization and conduct of the project and its conclusions regarding the feasibility of light-route TDMA.

1. INTRODUCTION

DOC/CRC has had a long history of involvement in digital satellite communication techniques. The most recent example, prior to the TDMA ANIK B project, was the Centralized Synchronization and Ranging (CENSAR) experiment[1] on CTS-HERMES which demonstrated synchronization accuracies suitable for very high speed satellite TDMA networks. In 1976 a DOC senior management planning committee reviewed the progress in this digital area and voiced a concern that although the technology was of high quality, perhaps it was being developed too far ahead of the need by the communications industry. In order to ensure more immediate relevance, the planning committee decreed that there be a carrier or major user involvement in any future major digital project.

At a liaison meeting between TELESAT and DOC in 1977 the application of TDMA to Canadian satellite systems was discussed, as a first step in carrier interaction. TELESAT was not interested in participating in a joint activity at that time.

Later in 1977, conversations were started between DOC and CP Telecommunications with regard to a possible jointly-sponsored TDMA pilot project on ANIK-B (shown in Figure 1). CP initially viewed this as a demonstration of a means whereby they could replace some of the terrestrial backhaul facilities they were then leasing. The enthusiasm for a satellite program was

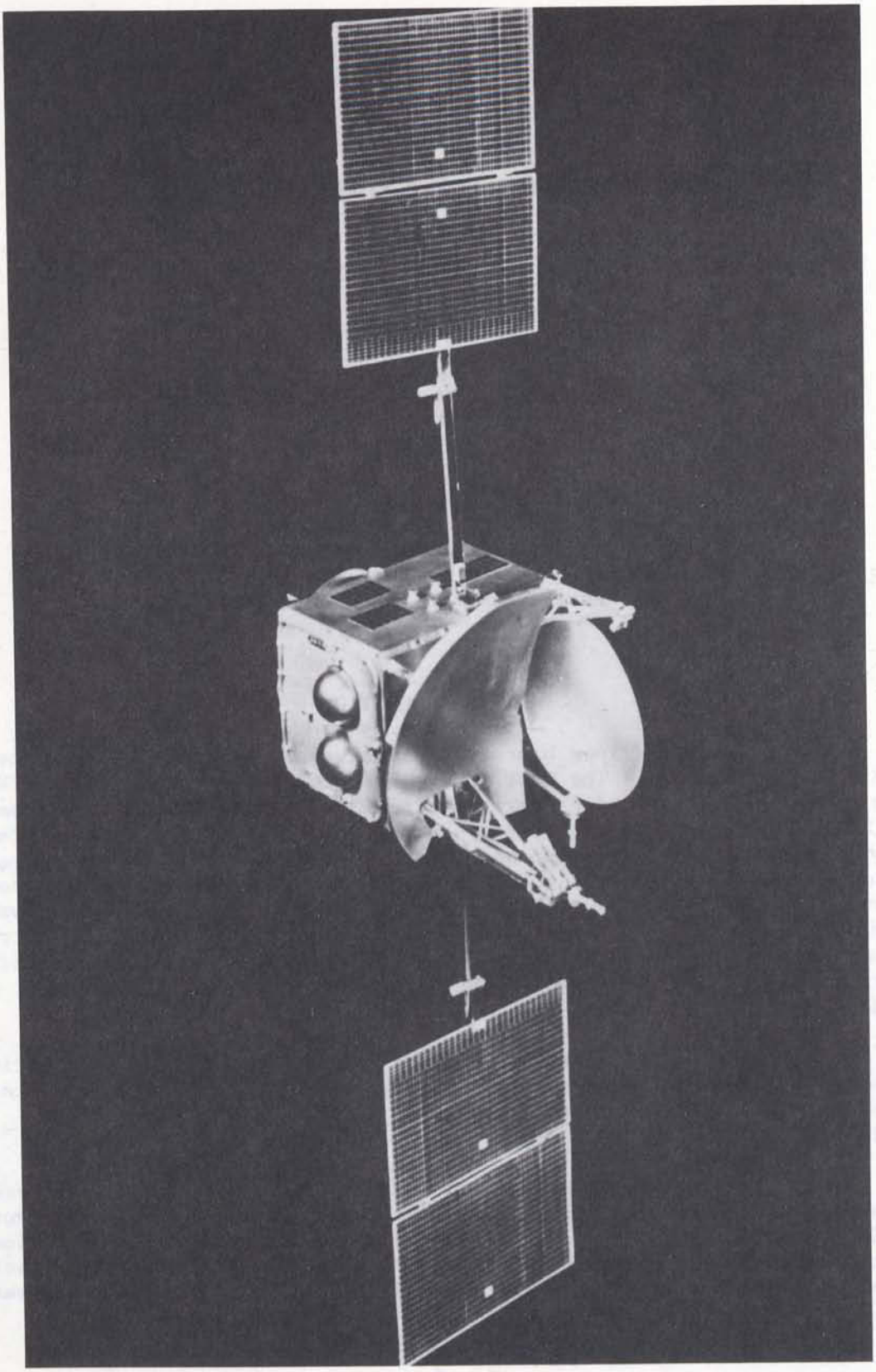

Figure 1. Telesat ANIK-B Satellite

shared by CN Telecommunications, and in August of 1978 CN, CP, and DOC agreed to proceed with a "SLIM" TDMA pilot project on ANIK B. This "SLIM TDMA" involved a mode of operation where only a partial satellite transponder in power and bandwidth was used for the digital system, with it sharing the transponder in FDMA with other signals. In this mode the power advantage of using a full transponder in saturation was lost, but medium-rate TDMA appeared to provide a much better economic match to the Canadian market. Miller Communications Ltd. undertook a study of TDMA for DOC, and concluded that a system operating in the low megabit per second range would be optimum for Canada in terms of cost for service to the users.

Organization of the pilot project proceeded quite rapidly. The first Technical Planning Group (TPG) meeting was held in December 1978, to begin specifying the details of the project and the equipment characteristics for the earth terminals. The first Steering Group meeting for project policy and funding decisions was held March 1979. A contract was signed between DOC and Miller Communications Ltd. in April 1979 for the design and development of the TDMA equipment (up to the IF interface), with the delivery to DOC of two systems. CNCP Telecommunications (a consolidation of CN and CP Telecommunications) also ordered two TDMA systems from MCS, and funded the development of an error correction subsystem for the terminals. DOC commenced the assembly of the RF and IF hardware for two terminals at CRC; CNCP contracted for similar equipment with SPAR Aerospace Ltd. CNCP also began preparation for the interfacing of their network to the TDMA terminals. In November 1979, a Memorandum of Understanding for the pilot project was signed by CNCP and DOC.

The original plans called for delivery and installation of the four terminals in the winter of 1980, with trials extending into the summer of 1981. As was to be expected with the first prototype of a complex system with no redundancy, there were many teething problems, and a full, four terminal network was not operational until September 1981. Tests on the network continued until December, 1981.

Early in 1981, during discussions at the project Steering Committee, it was noted that the project tests planned for 1981 were primarily to evaluate the technical performance of the experimental SLIM TDMA system. It was agreed that a demonstration of the service to possible customers would be a valuable addition. Consideration was then given to a Phase II to the project, which would allow an upgrading of the equipment and a subsequent service demonstration, making use of the DOC, ANIK B program extension to the fall of 1982. The DOC Government Telecommunications Agency (GTA) voiced an interest in participating in Phase II, and in April 1981 a separate Steering Committee was set up to co-ordinate the GTA service demonstrations, with CNCP, GTA, and CRC representation. By the summer of 1981 it was apparent that there was neither the money nor the time to permit major modifications to the TDMA equipment between Phase I and Phase II trials. The decision was made to limit modifications to an expansion of the interface capability of the terminals to allow more extensive service trials. The necessary changes were made between December 1981 and March 1982, with the Toronto, Ottawa, and Montreal stations back into service by mid-March, and the Bathurst terminal installed in July. Reliability and terrestrial interconnection problems continued to delay full system operation; however segments of the rather complex network were sequentially turned over to GTA for use as soon

as they were declared operational. The Phase II trial period was extended to the end of 1982, then to mid-February 1983 to allow a realistic period for evaluation of services by GTA and its customers.

In the following sections, a more detailed descriptioin will be given of the Phase I and Phase II system and tests. Conclusions will be given on the results of the technical and service trials and on the experience gained by DOC and CNCP.

2. PHASE I OBJECTIVES

The objectives of Phase I of the pilot project, as stated in the Memorandum of Agreement (MOA) between DOC and CNCP were to:

a) develop knowledge and expertise to apply better a medium-capacity TDMA satellite telecommunications technology in the satisfaction of particular Canadian needs;

b) design and develop the TDMA and interface equipments required to permit an effective test of the operational features of a medium-capacity TDMA satellite telecommunications system;

c) establish, maintain and operate a trial network to test the operational features of such a system in conjunction with the 14/12 GHz equipment on the ANIK-B communications satellite;

d) undertake such other activities as may be mutually agreed upon which contribute to the effective use of the system to provide improved telecommunications services for Canadians.

Stated in less formal language the objectives were to:

a) develop a Canadian industrial capability in the design and supply of TDMA equipments;

b) broaden the knowledge base and capability of Canadian carriers in the provision of satellite services;

c) evaluate the technical performance of medium-rate TDMA in a near-operational environment, including sharing of a satellite transponder with other services and interfacing to standard terrestrial equipment.

3. PHASE I CAPABILITIES

The Project Technical Planning Group (TPG) was tasked with the responsibility of specifying, and overseeing the development, installation and trial of a network to meet the project objectives. The technical details of the equipment have been fully described elsewhere[2,3,4,5] and only a few aspects will be considered here. The network consisted of four stations located at Ottawa, Montreal, Kitchener and Toronto, with Toronto designated as the master station. Figure 2 is a photograph of the TDMA equipment developed by

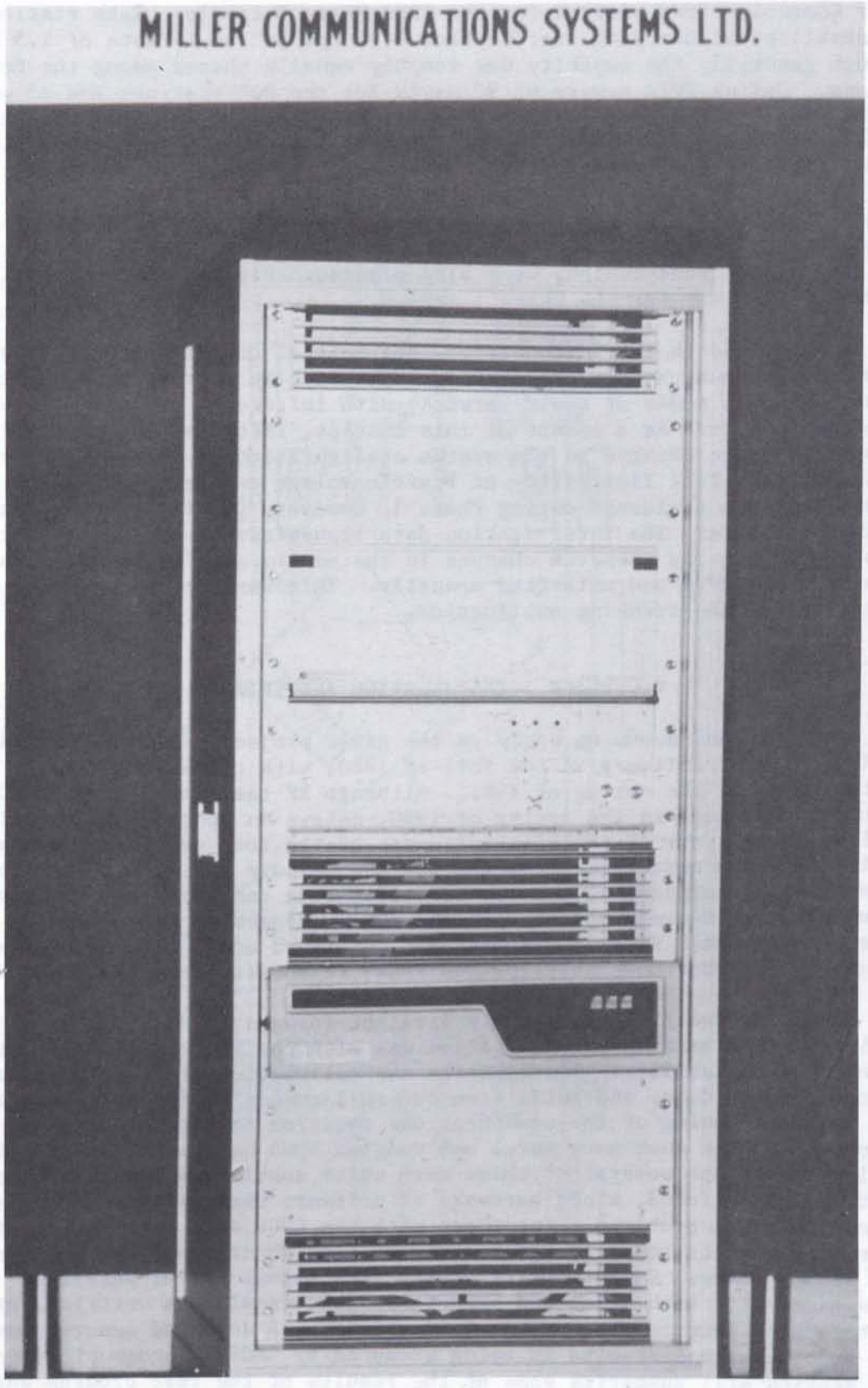

Figure 2. TDMA Terminal, Original Version

Miller Communications Limited for the TDMA Phase I trials. Each station had the capability of carrying traffic from 2400 bps to the T1 rate of 1.5 Mbps, although generally the capacity was roughly equally shared among the four stations. Uplink TWTA powers of 90 watts for the DOC stations and 45 watts for the CNCP stations were used to capture one-tenth of the ANIK B transponder saturated down-link power when sharing the transponder with a video signal. The error rate goal of 2×10^{-6} was to be achived better than 99.5% of the time. At each of the four stations, the TDMA system was interconnected with the CNCP digital network; synchronous data could then be passed to and from the network at rates up to 56 Kbps. Trials of digital voice and video transmissions were also planned. Figure 3 shows a typical interconnection map for the Phase I system.

As mentioned in the Introduction, the initial conception of the system by CNCP Telecommunications stressed its operation in a trunking mode, interconnecting major nodes of their network, with infrequent changes in the connection matrix. As a result of this concept, little emphasis was placed on rapid, dynamic changes in the system configuration in the initial system specification. Full flexibility of traffic volume and destination was present, and was evaluated during Phase I; however, the interconnection matrix was static. The inter-station data transmissions had to be shut down for about one second whenever changes in the matrix were to occur, with the new matrix keyed-in and activated manually. This was not considered a major limitation for the trunking application.

4. PHASE I INSTALLATION AND TRIALS

Project plans drawn up early in the pilot project called for final TDMA and RF equipment delivery in the fall of 1980, with operational trials continuing until the spring of 1981. Although RF tests with the two DOC terminals commenced in the spring of 1980, delays in contract negotiation resulted in delivery of the final elements of the four stations in late April 1981. The next several months saw the failure and repair of a number of terminal RF components, and the identification and correction of several hardware and software problems with the TDMA equipment. Four-terminal operation commenced in mid-September and continued until mid-December when the system was shut down to allow the Phase II modifications to proceed.

The RF hardware was relatively straight-forward in design; the major problem in this segment of the station was with the TWT Amplifiers, which showed poor reliability. Installation and calibration of the RF hardware was competently done, and aside from the replacement of failed subsystems, only periodic tuning of the equipment was required to obtain design performance. The much more novel and complex TDMA equipment had very few problems, although several of these were quite subtle and took many days to identify. Once found, minor hardware or software changes were sufficient to correct the TDMA problems. Interface with the CNCP data network for timing reference and data transfer was relatively straight-forward, as were trials with voice codecs. Compatibility of the TDMA signal in the satellite transponder with both video and SCPC telephony signals was verified, with no inter-service interference problems identified. A detailed description of test procedures and results is being prepared by CNCP Telecommunications. This section will summarize some of the results of the test program which are of more general interest.

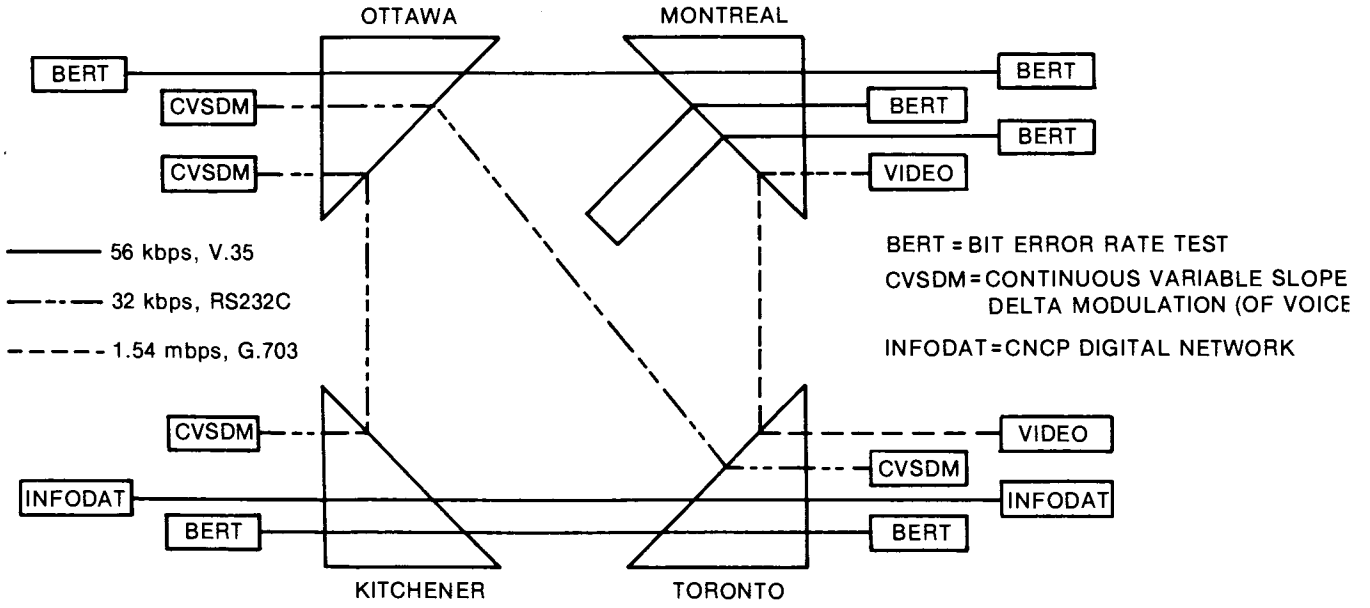

Figure 3. Typical Station Interconnection Map, Phase I

Basically the TDMA network performed as predicted. When propagation problems and equipment malfunctions are removed from the trial periods, the transmission between stations was essentially error-free; for example 1 in 10^{10} error probability over a 50 hour test period. Rain and snow caused a significant increase in error probability. Gothe[3] defines the CNCP threshold which delineates the division between the network being "available" and "unavailable" as a bit error probability of 2×10^{-6} or an Error-Free-Second (EFS) probability of 99%. During the network tests of early December 1981, the EFS value didn't fall below 99.4% even during heavy snow and rain showers. Although the test period was too limited to draw full conclusions, it did indicate performance adequate for intended service. Tests of the error correction hardware showed performance improvement less than predicted; this was attributed to the higher-than-expected percentage of multiple errors in the system, which could not be corrected by the codec. Compatability tests of the TDMA signal in the satellite transponder, as well as interface of the TDMA system with the CNCP terrestrial network showed no significant problems. Operation of the TDMA network with various combinations of data rates and inter-station connections was quite successful.

Phase I of the pilot project was terminated early to allow preparations for Phase II to commence. However, even within the limited trial period, the project objectives stated in Section 2 were generally achieved. Miller Communications Ltd. was in a position to bid on TDMA equipment contracts, and on contracts for TDMA systems studies. CNCP telecommunications personnel were in a much better position to specify satellite communications equipment and to evaluate its potential for integration into their service offerings. The trials indicated system performance acceptable for both the trunking application, and for the satellite business services which were developing as a market for medium-rate TDMA networks.

5. PHASE II OBJECTIVES

In addition to continuing the Phase I project objectives, a further goal added to the MOA between CNCP and DOC for Phase II was to "conduct service trials to establish the suitability of such a (TDMA) system to deliver telecommunications traffic on a commercial basis". The intent here was not only to obtain customers' reactions to services provided via TDMA, but also for the carrier to obtain experience in installing, commissioning, and maintaining the communications equipment.

GTA, which co-ordinates and provides communications services for most government departments, expressed a strong interest in participating in an extensive service test program, and became a co-sponsor of Phase II of the pilot project. A separate MOA and committee structure was set up between CNCP, GTA and CRC to co-ordinate the service evaluation aspects of Phase II, while the service delivery aspects continued to be the responsibility of the Phase I committee structure. This project report concentrates on the service delivery aspects of Phase II.

6. PHASE II CAPABILITIES

It was realized during Phase I that the TDMA equipment as it then existed had two major deficiencies for application in a more dynamic Canadian traffic environment. Firstly, for cross-Canada operation at 12/14 GHz, terminals must be able to transmit bursts at several different carrier frequencies in order to access the several downlink beams of the satellite. Secondly, for business (as opposed to trunking) applications, the system should be able to modify its interconnect configuration rapidly, and without interfering with on-going traffic, sometimes called hitless configuration. In order to accomplish this reconfiguration while still maintaining a high frame efficiency, a TDMA system needs a decision and communications capability for assignment of capacity on demand, and a capability for all stations to synchronously switch from an old configuration to a new configuration. Early plans for Phase II included the modifications mentioned above; however, contractor response to an RFP to upgrade the equipment showed that both the project funds and the time available between Phase I and Phase II trials were insufficient for these major changes. The decision was then made to restrict the service demonstrations to those which could be compatible with the Phase I equipment. In order to allow a greater variety of simultaneous tests, the stations were modified to accept up to 16 interface modules. Additionally, an average of 7 delta codecs was provided for each station, with each codec supplying an analog-digital interface for voice, voice band data or facsimile services.

The station which had been installed adjacent to the CNCP facilities in Kitchener, Ontario for Phase I was moved to Bathurst, New Brunswick for Phase II. Bathurst is a major centre for the Department of Employment and Immigration (CEIC), one of the GTA customers interested in participating in an evaluation of TDMA services. Figures 4 through 7 are photographs of the four stations as set up for Phase II. Figures 8 through 10 show elements of the TDMA electronics and control system while Figures 11 through 13 provide various segments of a simplified map of the service interconnections, both for the four TDMA stations and for the associated analog SCPC service to Newmarket, Ontario and to Frobisher Bay, NWT. The SCPC service was provided to the Atmospheric Environment Service (AES) of Environment Canada for experience in facsimile transmission and remote computer access from sites where the traffic volume and variety would not warrant the more expensive TDMA terminals. AES also evaluated similar services from larger centres utilizing the TDMA network. As can be seen, the Phase II trials generally allowed the evaluation of a complex mix of voice, computer, and facsimile services. Extensive terrestrial facilities were provided by CNCP for extensions to sites distant from the earth stations, for a network with a monitoring and loop-back capability to permit centralized system testing from Toronto, and for a capability for system control either from the Shipp Centre in Toronto or from DOC headquarters in Ottawa.

7. PHASE II INSTALLATION AND TRIALS

The Phase I equipment was shut down in December of 1981 and the TDMA subsystems returned to MCS, where they were modified to allow the connection of up to 16 data modules per station. The Toronto, Montreal, and Ottawa stations were back on the air by mid-March 1982; the Kitchener station was

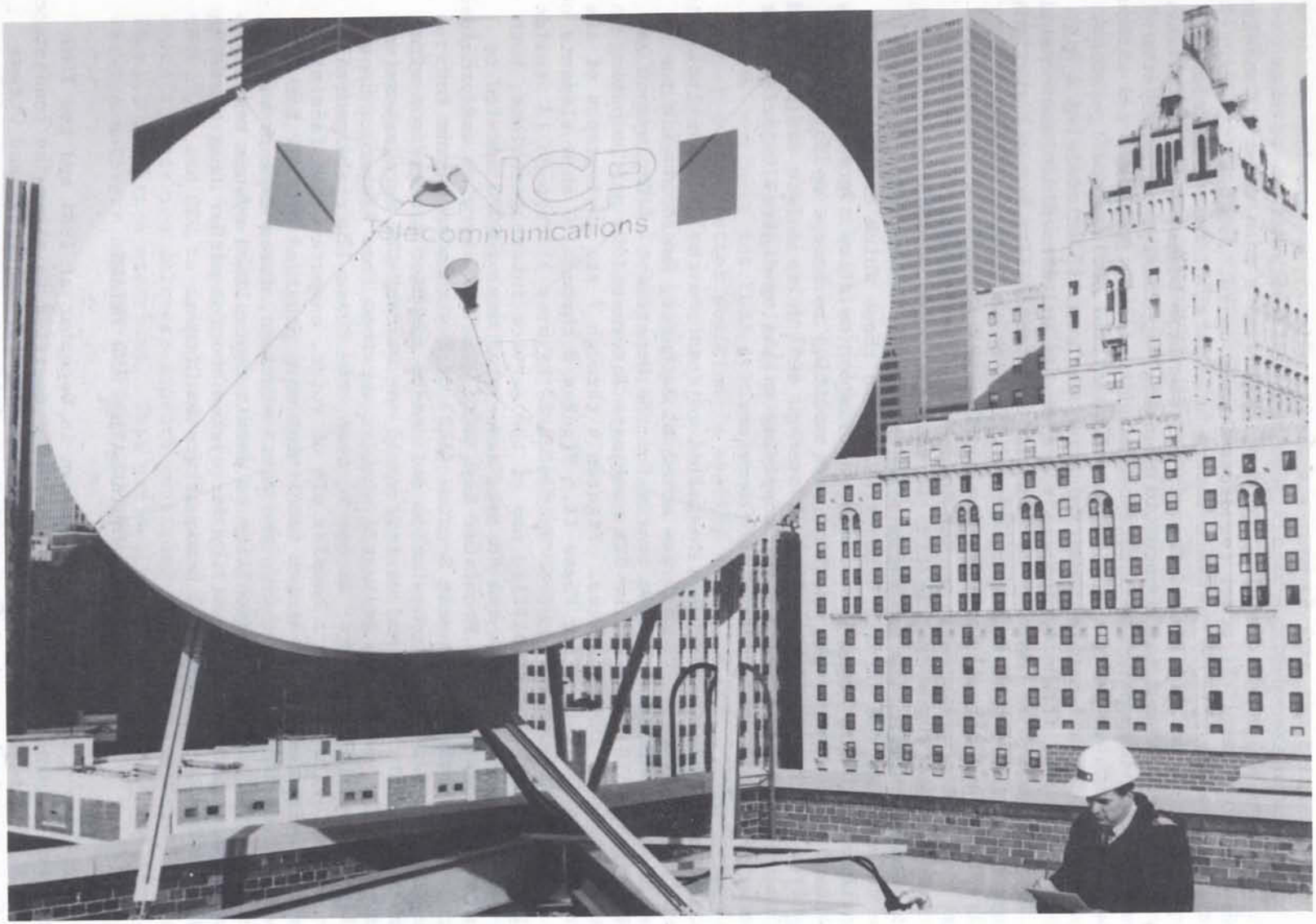

Figure 4. CNCP Toronto Earth Station

Figure 5. CNCP Montreal Earth Station

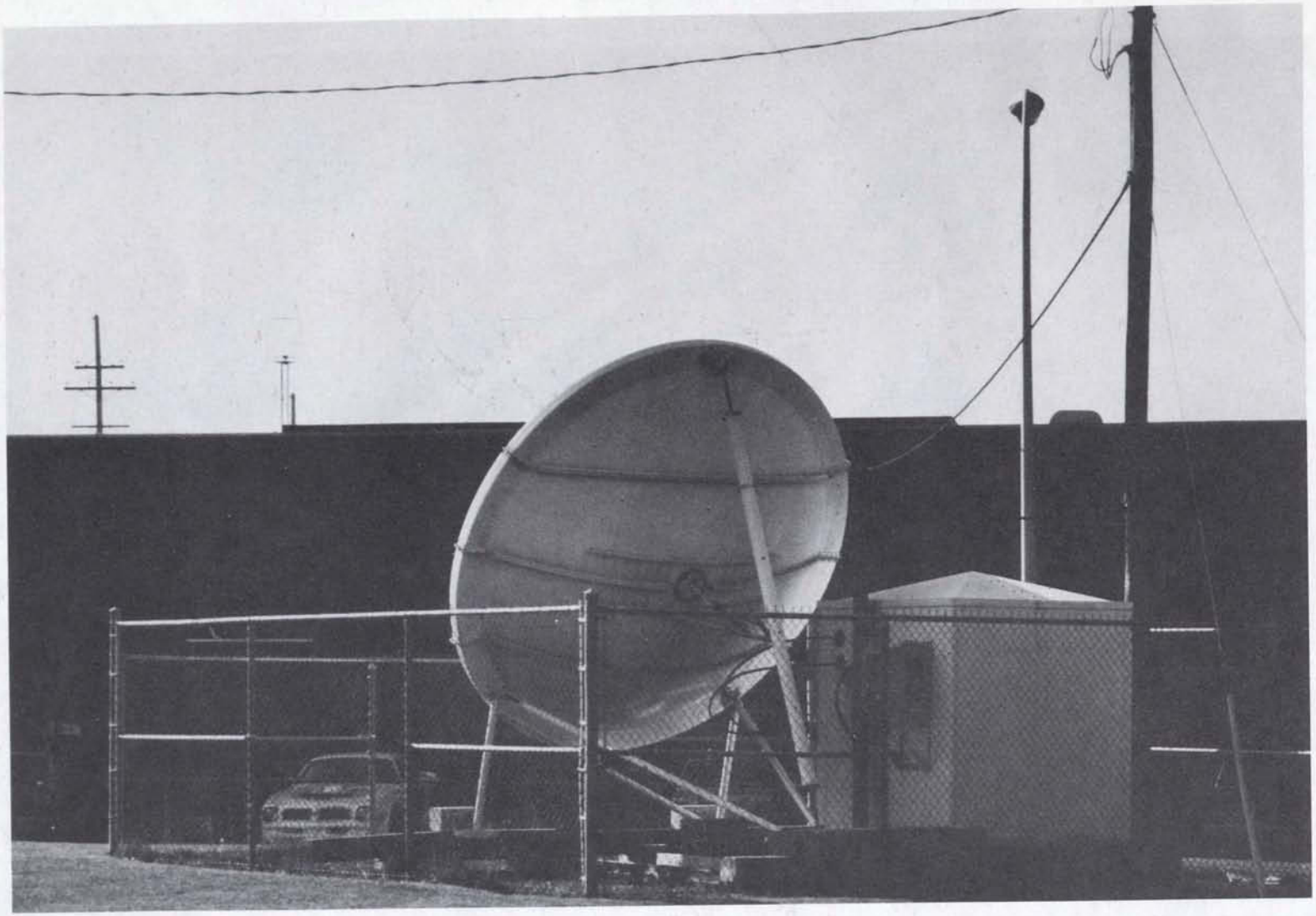

Figure 6. DOC Ottawa Earth Station

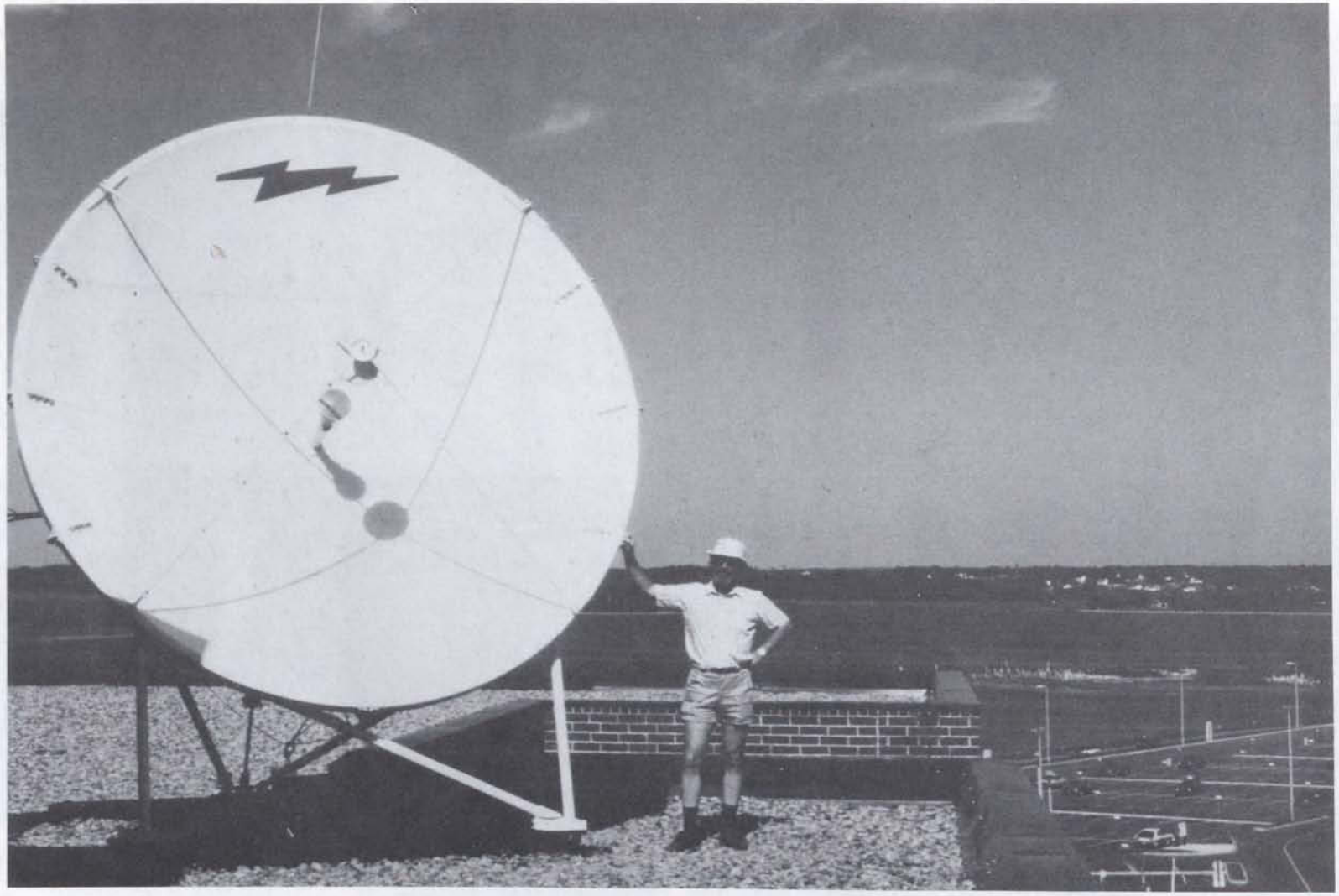

Figure 7. DOC Bathurst, New Brunswick Earth Station

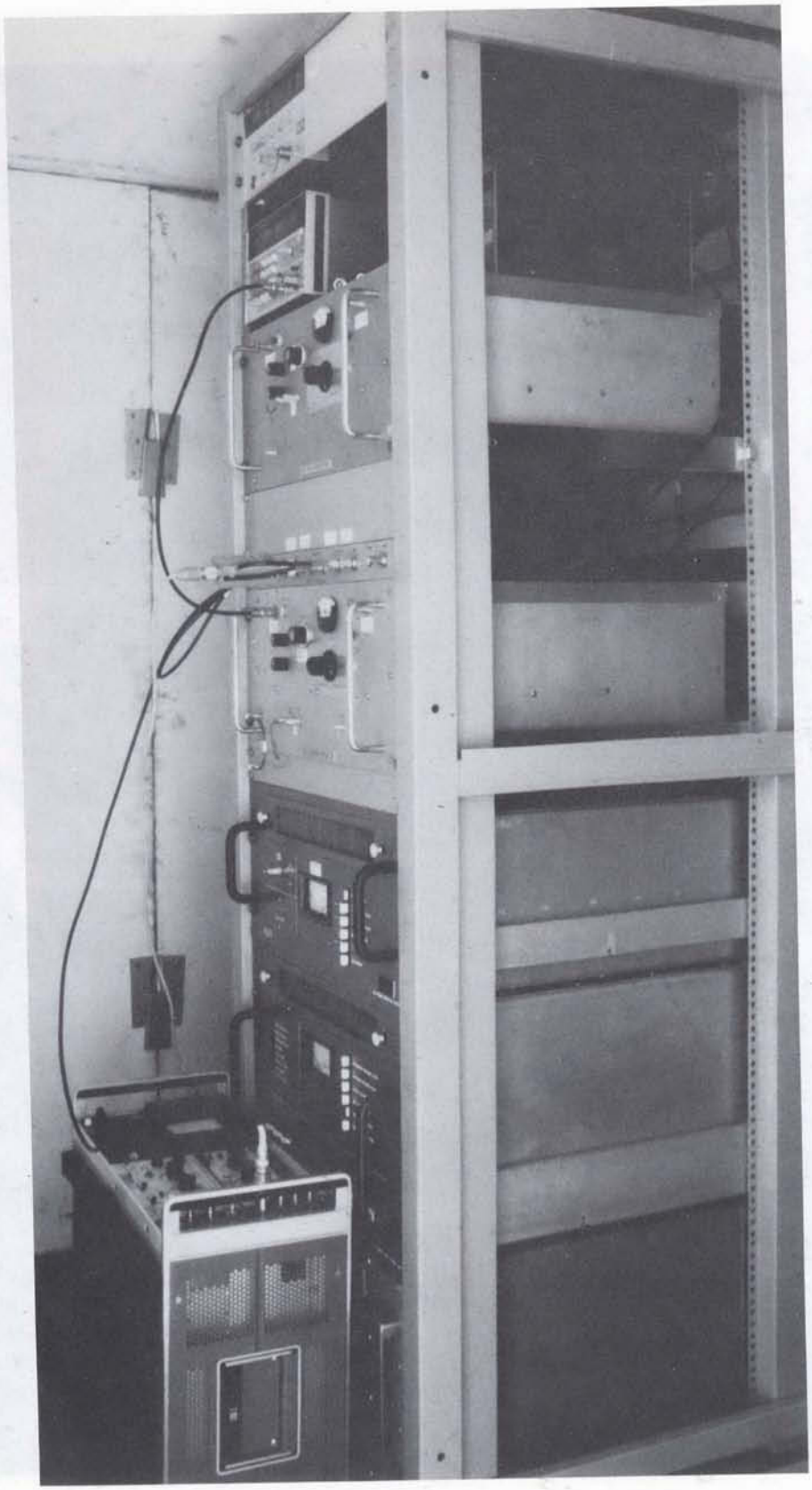

Figure 8. Typical Earth Station Electronics Rack

Figure 9. TDMA Terminal Installation, Ottawa (With Expanded Terminal and Computer Development System)

Figure 10. CNCP TDMA Network Control Centre in Toronto

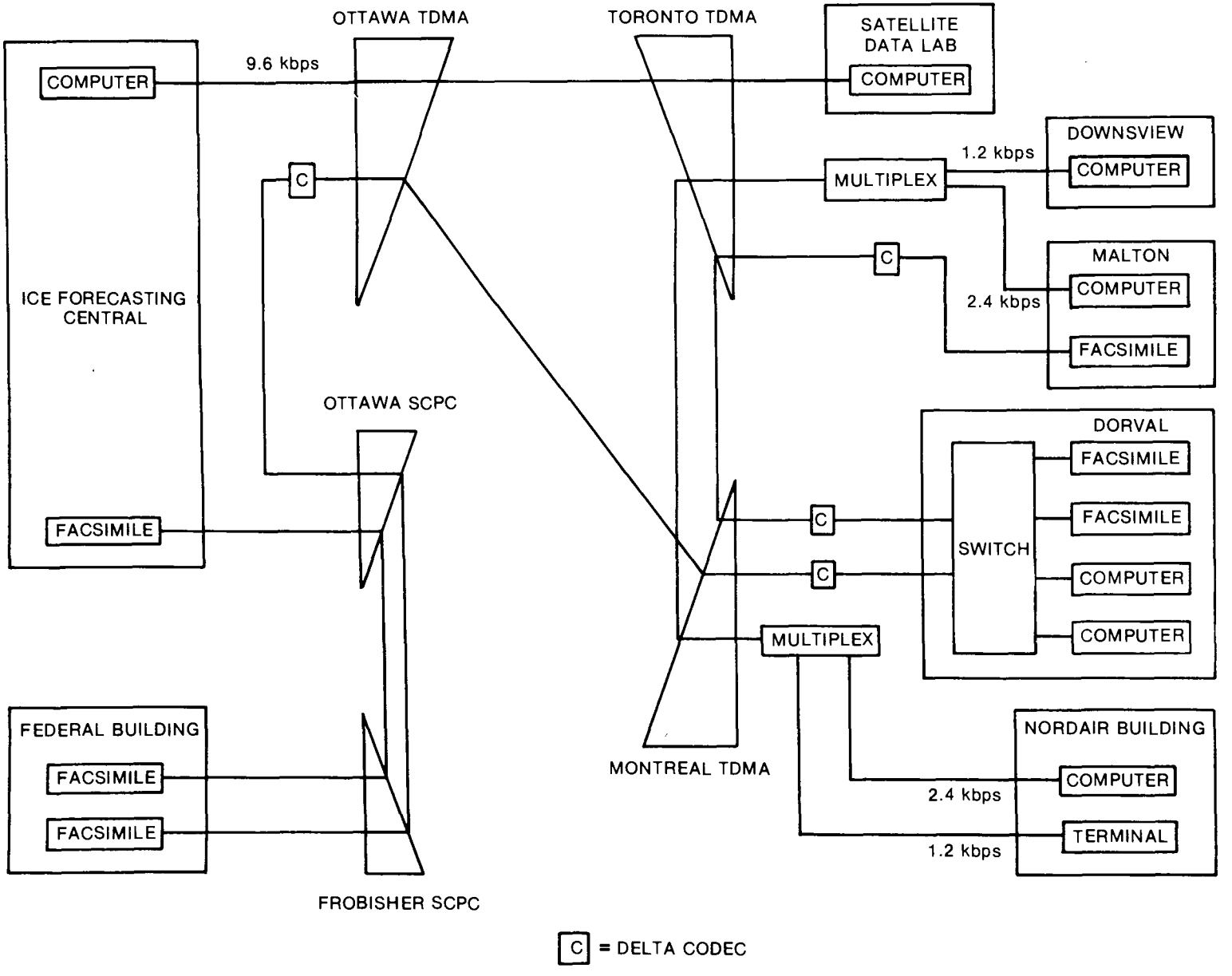

Figure 11. Phase II Network A (AES Application)

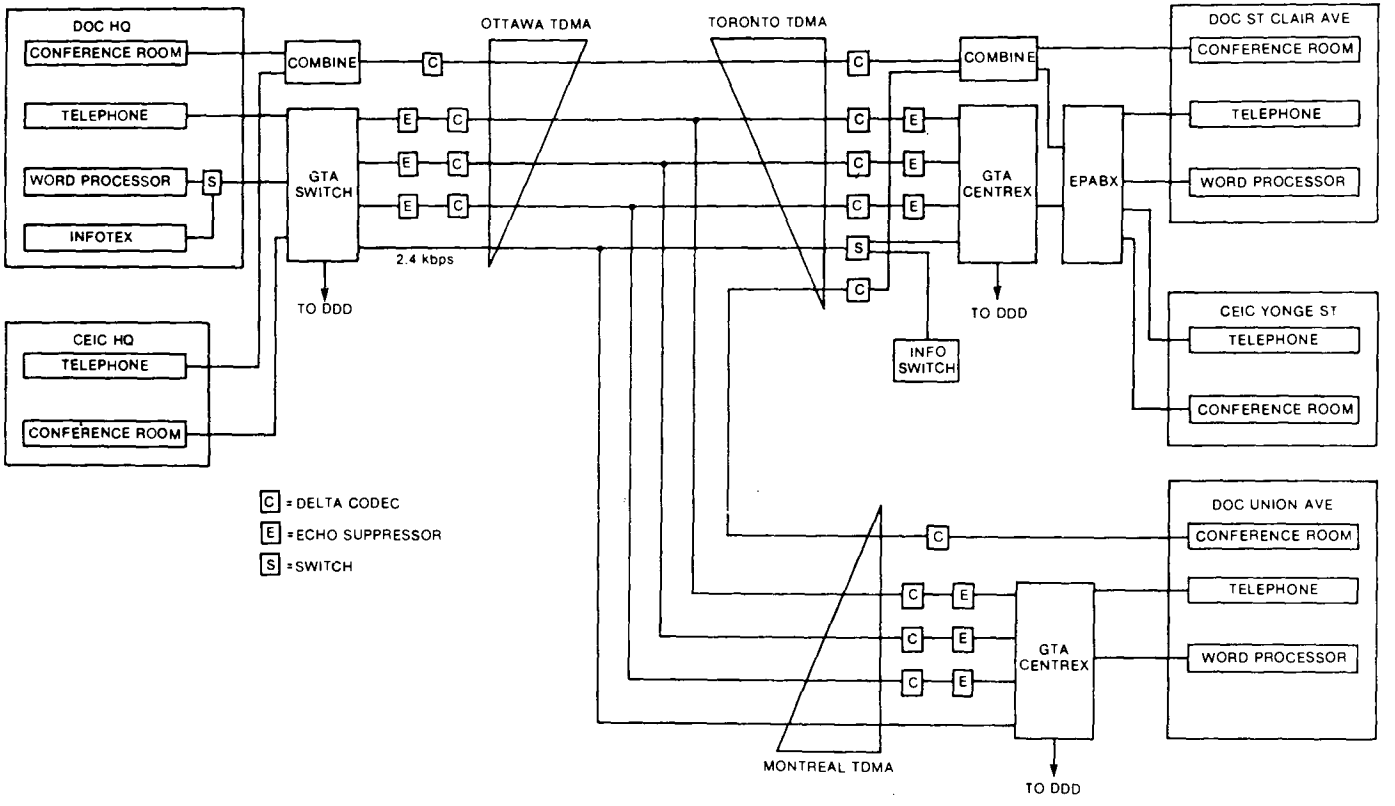

Figure 12. Phase II Network B (GTA Application)

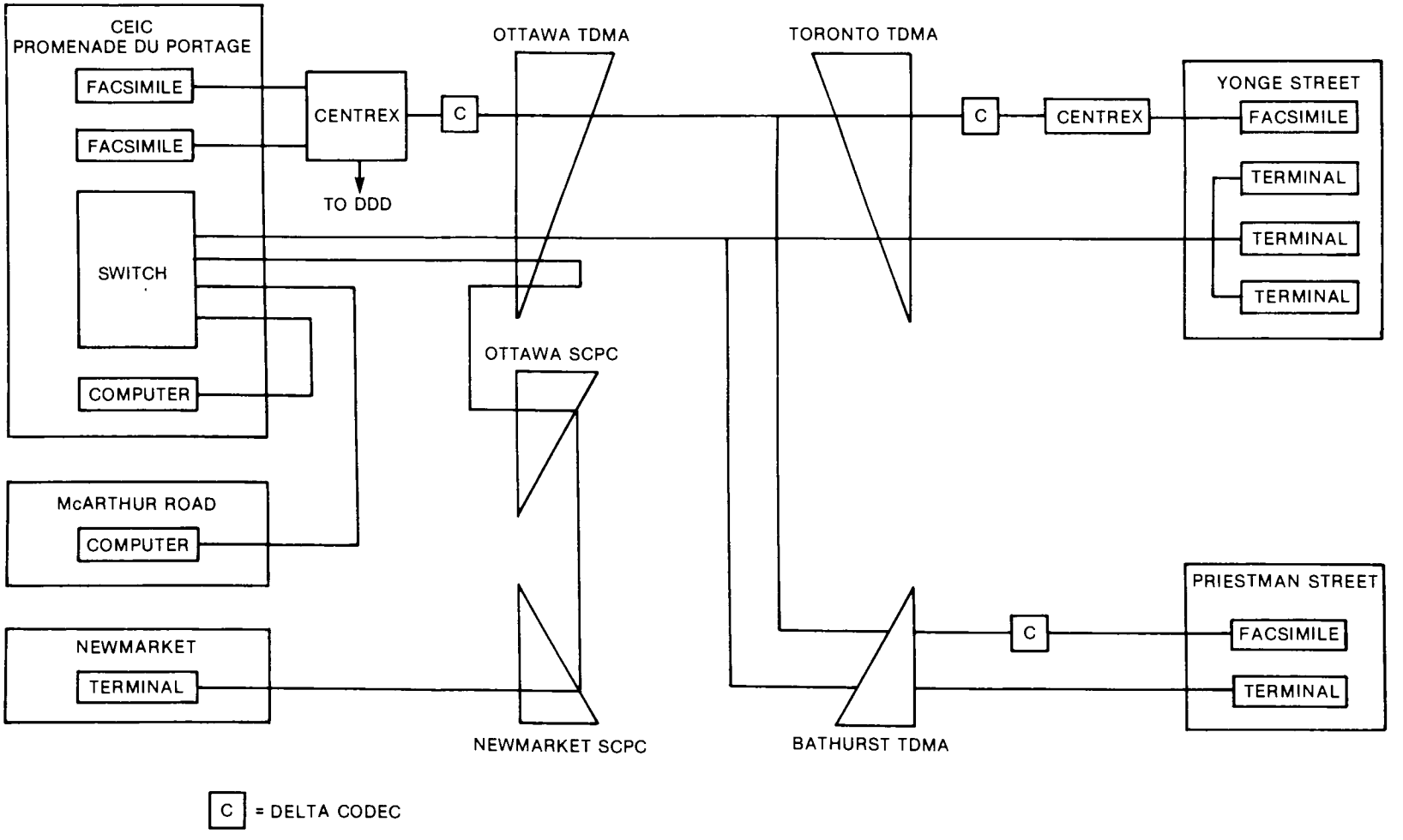

Figure 13. Phase II Network C (CEIC Application)

crated, ready for shipment to Bathurst once the roof-top antenna base was completed. MCS also delivered at the end of March, 20 copies of a delta codec, fabricated to meet a CRC specification. These codecs were required to interface the analog voice and facsimile signals to the digital TDMA network.

A number of problems arose to delay greatly the operation of the network. TWTA lack of reliability was a recurrent source of station failure. The delta codecs needed considerable reworking to reduce their internal noise level, and to make them compatible with the facsimile and the in-band telephone signalling tones. Government contracting procedures delayed the completion of the Bathurst antenna mount to late June, 1982, so that the Bathurst terminal was not installed until July. After several months of various tests, poor performance of the Bathurst terminal was finally traced to a broken wire in the backplane wiring, and a station sensitivity to impulses on the mains supply. The solutions were not identified and implemented until January 1983. Delays were encountered in obtaining interconnect trunks from the local telephone company, and in obtaining, installing and commissioning interface equipment. Also, in early December 1982, a change of satellite transponder for the east beam by Telesat required a change in both transmit and receive frequencies for all the stations in the network.

In spite of the technical problems noted above and the ongoing need for training operating personnel and educating system users, significant trial results were beginning to be obtained as early as May 1982. As each new segment of the network was commissioned by CNCP, it was turned over to users for evaluation. By September the voice and voice band data links between Ottawa, Toronto, and Montreal were operational, as were most of the facsimile links. By November all but the CEIC services were operational, with almost all the latter commissioned by January 1983. The pilot project terminated in mid-February 1983 with the project goals fairly competely satisfied.

The relative roles of CNCP, DOC, and the government departmental users in the Phase II project should be noted. In Phase II, CNCP shouldered the major responsibility for organizing, installing, commissioning, operating and maintaining the network. They achieved a company goal of transferring commissioned services from the engineering branch into the hands of their operating branch, so that the service could be treated like any other CNCP communications offering. DOC Space Applications directorate had responsibilities to providing the space segment capacity through a contract with Telesat, for ANIK B scheduling, for obtaining the several pilot project extensions of service, and for providing the SCPC terminals and service. DOC Space Systems directorate were co-sponsors of Phase II with CNCP in both a program and a financial sense. They also provided essentially full-time support in the installation, testing and repair of the TDMA system. DOC, GTA consolidated and interpreted the user department needs, organized the installations and system tests at user sites, and participated directly in the service evaluation portion of Phase II. The departments of Employment and Immigration and Atmospheric Environment Services, with the assistance of GTA, redirected some of their normal traffic to the TDMA network, assisted in interfacing their equipment to the TDMA system, and undertook both objective and subjective evaluation of the service provided.

8. CONCLUSIONS

The project objectives as stated in Sections 2 and 5 are fairly general in nature and although all were met, they are difficult to use as a measure of project success. Of greater significance perhaps is the impact of the experience on the four groups involved in the project: the equipment supplier, MSC; the carrier, CNCP; the service customers, AES and CEIC; and DOC.

The prime role of DOC in this project was to act as a catalyst; to aid in the organizing, specifying, funding, commissioning, and evaluating of the equipment and demonstrations of service. The successful development of and industrial competence in TDMA equipment, the proof of feasibility of a new approach to communications service, and the fostering of a capability in satellite communications service provision in CNCP are within the main objectives of the department, and support the view by DOC of project success.

It is too early to conclude whether MCS will prosper in the international market for TDMA equipment as a result of their Slim TDMA experience. To date, only small, experimental systems have been proposed or implemented; full, commercial services are still several years off. However, MCS have capitalized on their experience and have been successful in international tenders for consulting services and for satellite communications channel monitoring equipment.

CNCP entered the pilot project with little experience in satellite system design and no experience in satellite service delivery. The have subsequently gained a wealth of experience in the technical specification, installation, commissioning, maintenance, interfacing and operation of a satellite digital network. They now are capable of examining the various options for satellite service delivery, selecting those best suited to their needs, and specifying the equipment in a realistic and cost-effective configuration. As well, they are now much more credible as a satellite service provider, having successfully completed the pilot project.

Only preliminary data are available from the major service customers of Phase II, AES and CEIC; a complete study of their experiments is being made under a contract to GTA. Both user groups appeared pleased with the level of experience in satellite networks which they were able to obtain; however, both had underestimated their level of involvement required to obtain the results they desired. In general, the pilot project experience has whetted the users' appetite for new and improved communications services.

Although time and resource constraints did not allow the inclusion of multibeam TDMA service and hitless system reconfiguration in Phase II of the project, the results which were obtained are almost uniformly felt to be positive across the participating groups. GTA are studying how to incorporate satellite services into their communications network. CNCP are seriously considering implementing a satellite TDMA system utilizing ANIK C. Those are the best indicators of success in the ANIK B pilot project.

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CRC DOCUMENT CONTROL DATA

1. **ORIGINATOR:** Department of Communications/Communications Research Centre

2. **DOCUMENT NO:** CRC Report No. 1366

3. **DOCUMENT DATE:** June 1984

4. **DOCUMENT TITLE:** Slim TDMA ANIK B Pilot Project

5. **AUTHOR(s):** W.D. Hindson, W.J. Robertson and R.C. Archard

6. **KEYWORDS:** (1) TDMA
(2) ANIK B
(3)

7. **SUBJECT CATEGORY (FIELD & GROUP: COSATI)**

17 Navigation, Communications, Detection, and Countermeasures

17 02 Communications

8. **ABSTRACT:**

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9. **CITATION:**