MEASUREMENT OF CT2 SIGNAL PERFORMANCE OVER CABLE TELEVISION FACILITIES

Gary Chan and Albert Kim
Rogers Engineering
Toronto, Canada

ABSTRACT

Most cable operators are intrigued with the Remote Antenna Driver (RAD) concept which utilizes the CATV plant to transport digital cordless telephone (DCT) traffic and provides widespread coverage economically. Last year CT2Plus, an enhanced version of CT2, was chosen as the Canadian standard for DCT. Rogers Engineering has been involved in examining the feasibility of RAD transported CT2 signals for over 18 months. This paper describes the Rogers' testing of the RAD transported CT2 signal, and discusses the experimental results on RF ranging, multiple-users test, channel capacity limitation, radio coverage overlap, system noise in the upstream path, and benefit of antenna diversity.

INTRODUCTION

Rogers Engineering has been examining the performance of RAD transported DCT signals since 1991. Initially, we used the Ferranti equipment. The Ferranti equipment used a proprietary protocol and did not conform to the Common Air Interface (CAI) standard. As CT2 CAI equipment from GPT, Motorola, and Northern Telecom became available, we incorporated them into the evaluation.

Last year Rogers Engineering published a paper on the subject of PCS transport over cable. It discussed two alternatives of using stand-alone base station and the RAD approach. Based on certain traffic requirements and penetration assumptions, we made cost comparison between the two approaches and proved the feasibility of RAD. Rogers Engineering has conducted extensive tests on the RAD transported CT2 signal over cable. This year we would like to extract a few of these exciting tests and share our research and development experiences on PCS with other cable engineers.

RF RANGING TEST

A historic event occurred in July, 1991. Rogers Engineering received the first batch of RAD prototypes and successfully confirmed that the unchannelized RAD and channelized RAD worked - the unchannelized RAD were units which equipped with Automatic Gain Control (AGC) and processed the DCT spectrum in a 4 MHz block; the channelized version processed the DCT signal in four contiguous block of 1 MHz and the AGC action of each 1 MHz block operated independently. Coverage performance of RAD transported DCT signal was compared against the coverage of a DCT base station.

The evaluation criteria employed on ranging tests are subjective ratings. Subjective quality is graded on a five-point scale with: 5 being excellent voice quality with no audible impairments, 4 being very good audio quality with minimal impairment, 3 being usable audio quality with moderate impairments but consistent radio-coverage, 2 being audible but often requiring repetition to carry on a conversation and the radio-coverage is marginal, and 1 being audio quality unusable, existing radio link may drop and the radio-coverage is at the fringe. A quality of 0 implies no radio-coverage.

We conducted the RF ranging tests in various environments to verify the performance of RAD, to explore the optimum placement of RAD, to evaluate the propagation characteristics of shopping mall, residential areas, and office tower, and to predict DCT coverage at 860 MHz.

Figure 1 shows the coverage comparison between a stand-alone DCT base station and a RAD. The coverage range and subjective quality rating of the RAD was comparable to the DCT base stations. However, the subjective quality in a multiple RADs environment, particularly the overlap area between two adjacent RADs, was not satisfactory. This shortcoming will be discussed further in a later section.

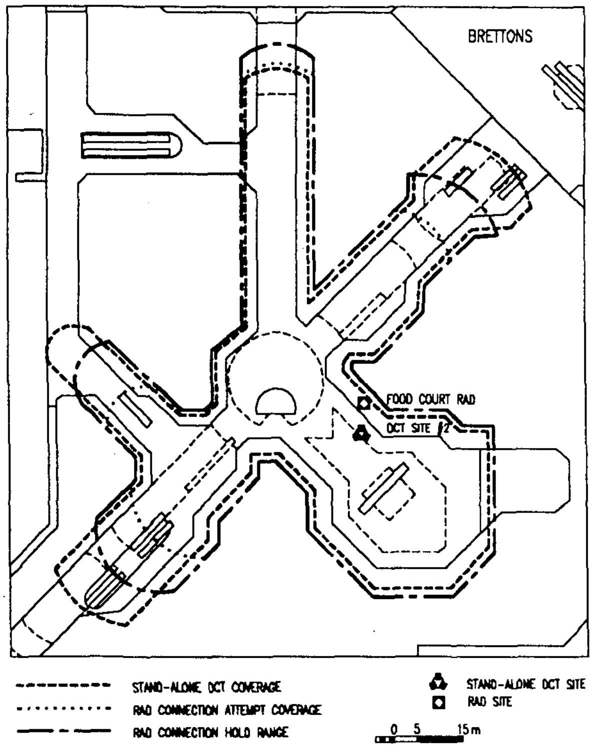


Figure 1 Coverage Comparison between a DCT and a RAD

MULTIPLE USERS TESTS

The ranging test discussed in the previous section included only a single user. Multiple-user tests were conducted in the Burnaby shopping mall in Vancouver. These tests were carried out with as many as five users employing two methodologies: line formation and cluster formation.

In the line formation, four stationary users were arranged progressively farther away from a RAD to encompass the entire coverage range. A roamer traversed from the RAD throughout the coverage area. Subjective qualities perceived were monitored by all the users on signal quality, signal interference and calls dropped. In cluster formation, the four stationary users were confined to a small area at a fixed distance from the RAD. Again, the roamer travelled throughout the coverage area. All users monitored their own voice quality and signal degradation. The test was repeated by changing the distance of the cluster of stationary users from the RAD.

The following summarizes briefly the results. In line formation, the stationary user at the fringe area experienced difficulty maintaining a link; other users had no dropped links. The roamer did not have a strong effect on the link quality of other stationary users. In cluster formation, the fringe boundary of the mobile user depended on the location of the cluster, and may be limited by power handling capability of the RAD. Also in areas where signal quality deterioration occurred, remaining stationary improved the performance.

These tests were initially conducted using the Farranti equipment. Later, the Motorola equipment was used to confirm that similar findings were obtained. Nonetheless, there were slight discrepancies between the Ferranti and Motorola results. These discrepancies related mostly to the specific equipment rather than to the number of users.

CHANNEL CAPACITY LIMITATION

Rogers Engineering conducted a stress test on RAD to determine the maximum number of users a RAD system can support simultaneously.

Two Motorola six-channel, telepoint base stations were used and were synchronized together by configuring one as a master and the other as a slave. The system consisted of two telepoint base stations, a RAD/RASP pair, one trunk amplifier, one bridger and one line-extender. The test was conducted at the Rogers Engineering office at 853 York Mills. Twelve radio links were initiated with eleven handsets in fixed locations and one mobile. The locations of the stationary handsets are shown in Figure 2. A spectrum analyzer plot is shown in Figure 3 with the 12 CT2 channels. This particular plot was captured at the RASP's upstream cable signal port and composed of two traces, A & B. Because of the TDD nature of the CT2 signal, a single plot of the analyzer would not show all the channels. Therefore, two plots that were sampled with one millisecond offset were overlaid to show all 12 channels. The results indicated that the mobile handset experienced strong interferences when it was in motion and was more than 35 feet away from the RAD. However, other information obtained from Motorola indicated that the base stations alone could support only 13 airlinks simultaneously. Therefore, further testing would be required to verify whether any channel capacity limitation was imposed by the use of the RAD/RASP equipment.

Figure 2 Locations of Stationary Handsets

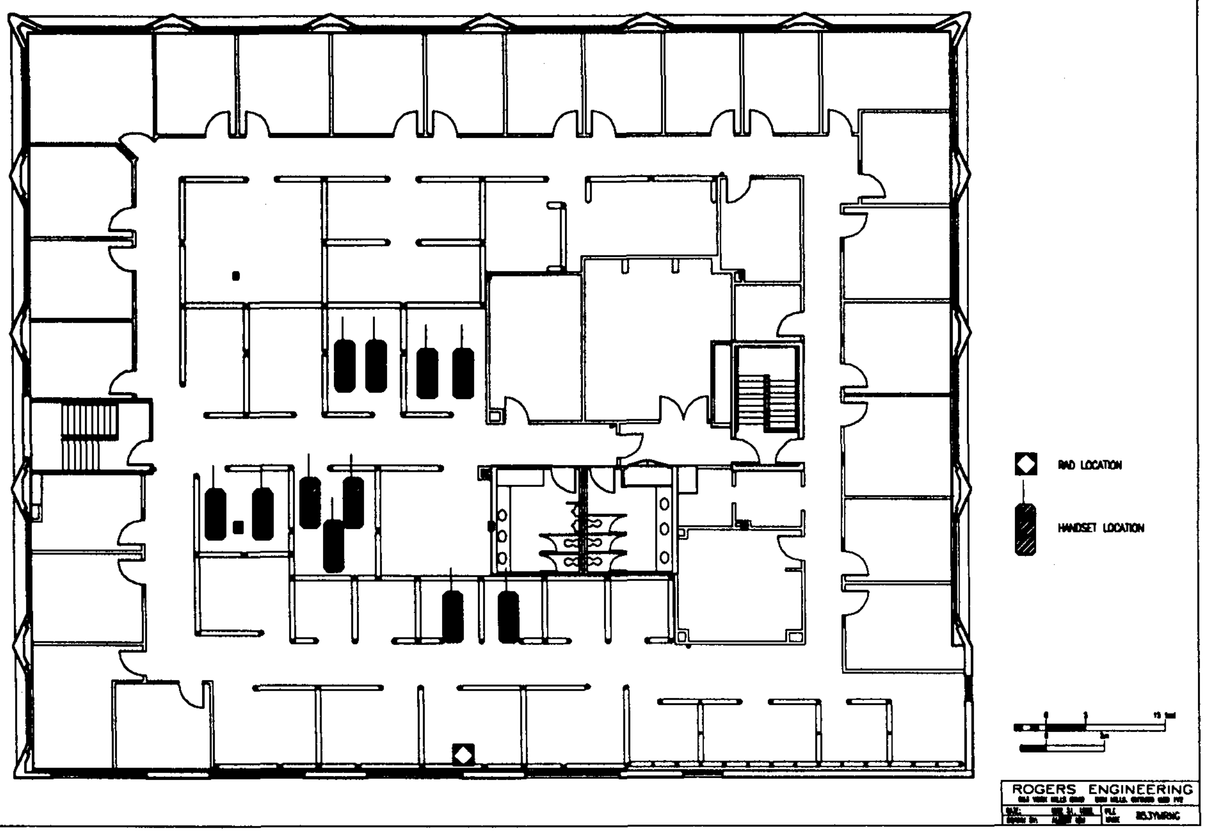
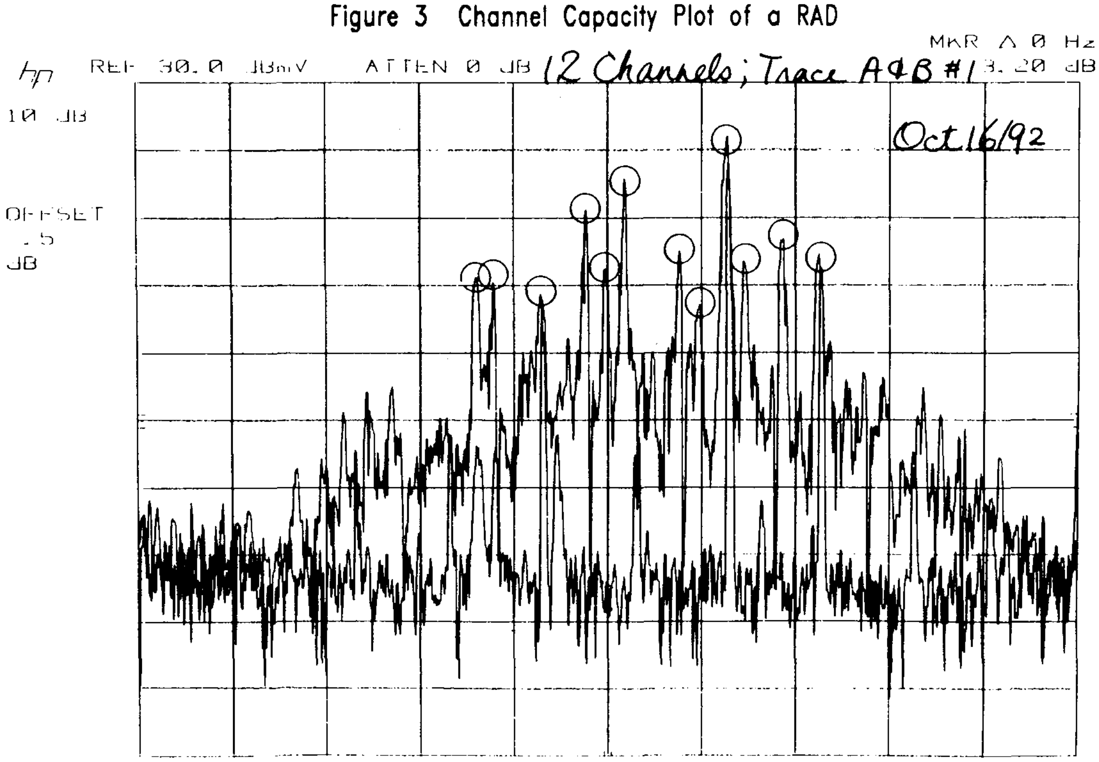


Figure 3 Channel Capacity Plot of a RAD



RADIO COVERAGE OVERLAP

Earlier ranging tests done in Vancouver had clearly demonstrated that the voice quality of a user in the overlap area was degraded. As the user got closer to a RAD, the distortion gradually vanished. Since the mall environment did not lend itself to troubleshoot this kind of technical problem, a similar test must be carried out at an alternate location in an attempt to duplicate the voice quality distortion that happened in the shopping mall. The distortion occurred only when the handset was between two RADs. It was most intense in the area where the radio coverage was equally served by both RADs. The distortion exhibited itself as frequent mutes, clicks, and squawks. We had a mystery; what caused the degradation?

Tests were done at 853 York Mills to explore the symptom of the overlap distortions. Two RADs were installed on the second floor of the Engineering office: one on the east side and the other on the west side. Service coverage of each RAD was determined individually using RSSI measurements. Coverage test was repeated with both RADs operating simultaneously. Figure 4 and 5 show the RSSI profile of each RAD. Figure 6 shows the common overlap area where unacceptable distortion was observed. Careful observations were also made on the radio signal in the overlap region. Figure 7 is a plot made at a location in the overlap region on the south side of the Engineering Office. It was captured by a monopole antenna connected directly to a spectrum analyzer RF input port. The Time Division Duplex (TDD) packet from the base station processed by the two RADs exhibited a few deep notches within a millisecond. Those notches were not observed when a single RAD was in operation (see Figure 8). Further investigation disclosed that instantaneous cancellation due to phase error of the two RADs caused the frequency notches on the TDD packets. The instantaneous cancellation of two carriers having different phases caused the constant mutes, clicks, and squawks in the overlap region.

Figure 4 RSSI Profile of RAD on the East Side

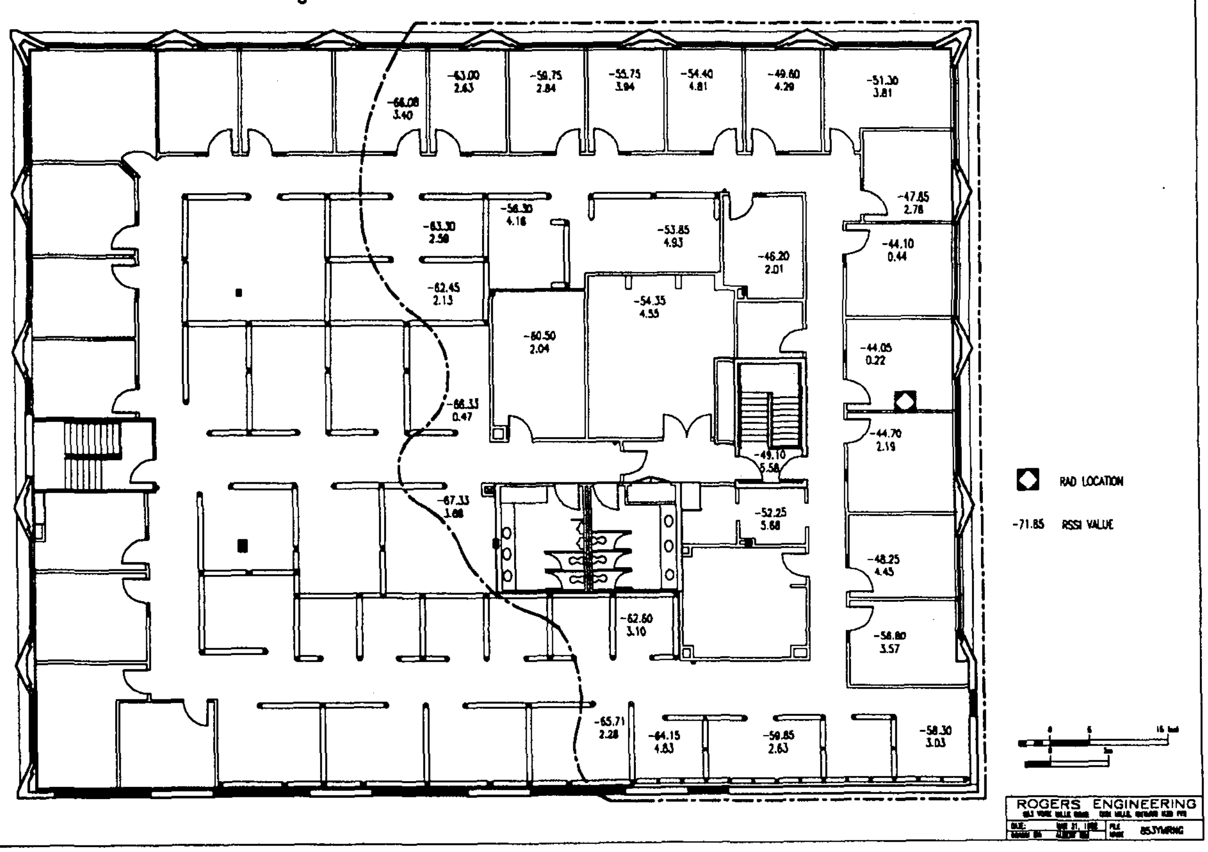


Figure 5 RSSI Profile of RAD on the West Side

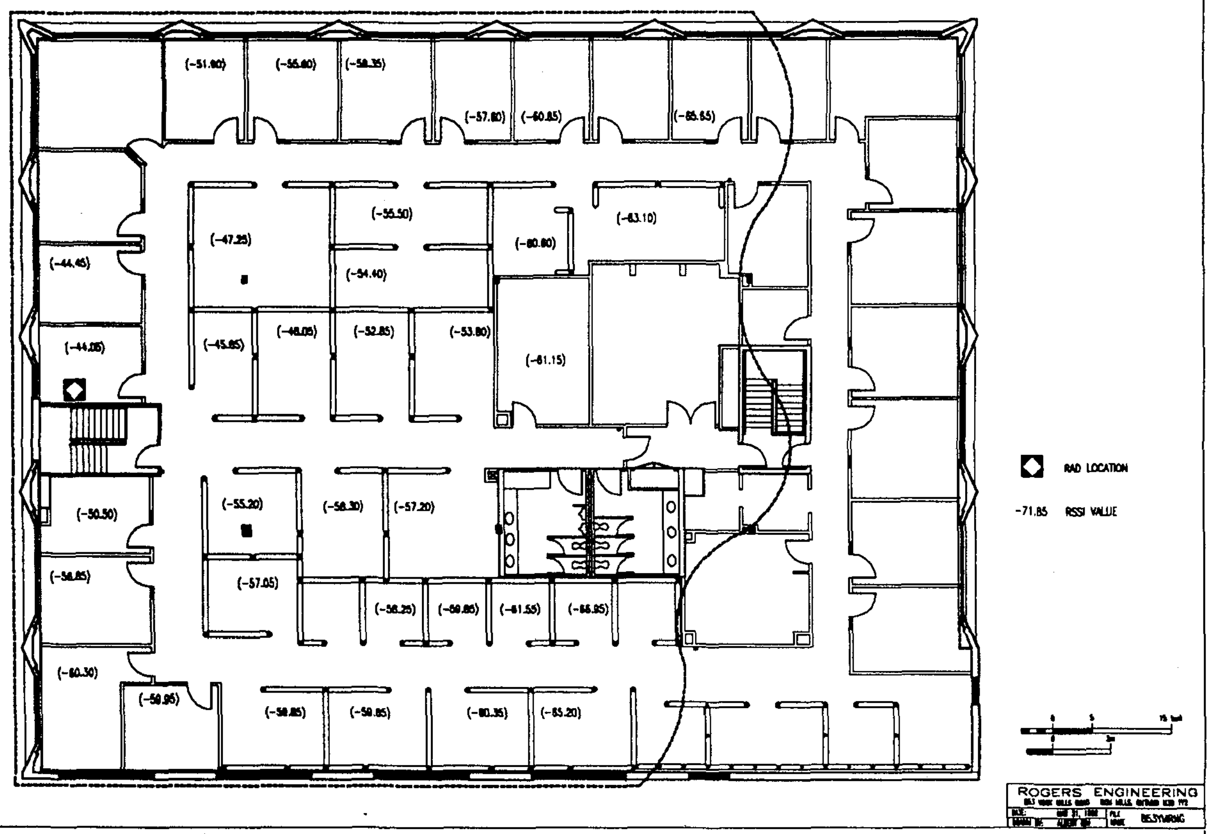
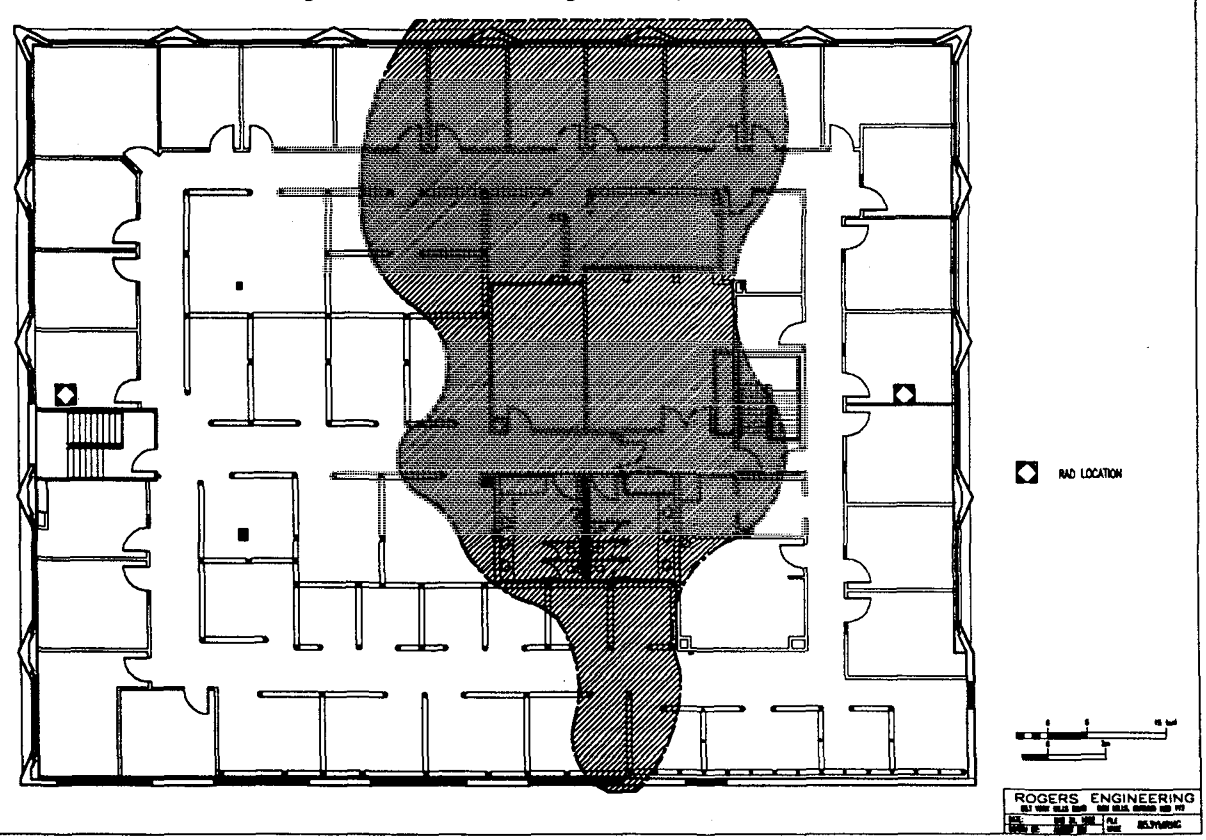


Figure 6 Radio Coverage Overlap of the RADs



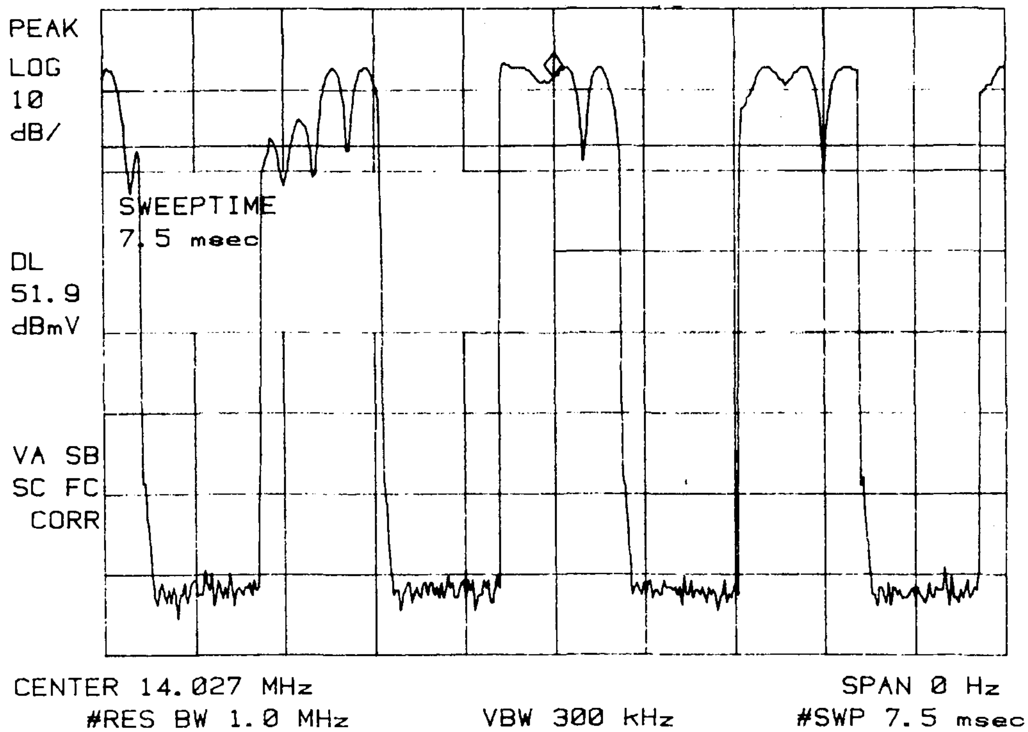


Figure 7 Spectrum Analyzer Display of the CT2 Signal in the Overlap Area

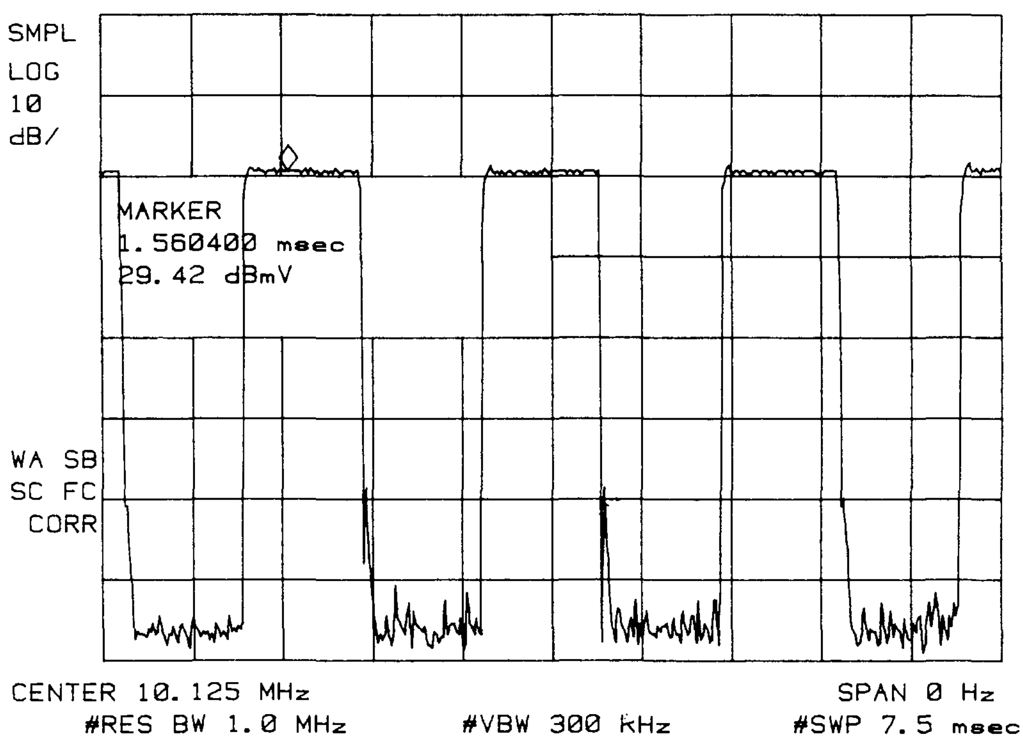


Figure 8 Spectrum Analyzer Display of the CT2 Signal with only One RAD Active

The phase noise of the combined signal of the RADs was so severe as to render an unusable service. Indeed, excessive phase noise of the synthesizers caused the problem. How do we determine the amount of phase noise that can be tolerated to give acceptable quality? Phase noise characterization was done at 853 York Mills. Four signal generators were used to replace the six internal synthesizers of two RADs, RAD A and B. Figure 9 shows a block diagram of the setup. The RADs shared the same local oscillator signals from the generators, except for the 909 MHz local oscillators. On RAD A, phase noise was generated using a video noise generator to frequency modulate an RF carrier. The noise was band-limited by an audio amplifier to cut off any high frequency. The audio amplifier also provided sufficient drive to modulate the CW carrier of the generator. A similar arrangement was made to the 909 MHz local oscillator of RAD B. The level of phase modulation was increased or decreased by the modulation control on the 909 MHz generators. Subjective measures was used to determine the amount of phase modulation considered acceptable. Tests were repeated to confirm the selected level was consistent with previous measurements.

SYSTEM NOISE IN THE RETURN BAND

The conventional way of bringing video back from a subscriber location to the headend involves only a single distribution path activated. The upstream noise comes mainly from that one single distribution. However, in the scenario of providing PCS signal transport, all the distributions will be active. The system noise level in the PCS return spectrum will depend on the number of RADs installed in the cable plant. Given the number of RADs deployed, we can calculate and predict the contribution of noise from a system.

In addition to system noise, there is also noise coming from ingress. Ingress contamination may be a limiting factor on the return path. The feasibility of using RAD for CT2 transport hinges on the transmission quality of downstream and upstream signals. We need to find out the existing level of man-made ingress in the return band. One of the tools employed by all cable operators to control ingress is the ground level CLI patrol. A ground level CLI would ensure the shielding integrity of the cable plant and prevent infiltration of ingress. Rogers Engineering and CableLabs have developed simple computer software which permits automated monitoring of the return ingress. Figure 10 shows a bar graph of the processed data. The vertical axis shows the absolute level in dBmV, and the horizontal axis identifies the particular area. The black bar represents the signal pick-up by a reference antenna and the white bar shows the ingress level recorded by the measuring instrument. "All-on" is the contribution of ingress from all distribution areas. "All-off" means trunk only. "NE" means the north-east area only, and a numeric of 505 means the ingress from a single bridger location identified as 505. It requires a minimal amount of off-the-shelf software and hardware to use this program. Initial findings indicated that power supplies appeared to be weak points. The amplifiers Rogers Cable used have a power injection port. The power injection ports may have permitted a moderate amount of HF permeated into the return system.

BENEFIT OF ANTENNA DIVERSITY

Published data has shown that antenna diversity in an indoor environment will provide an additional 10 dB of fade margin. In other indoor and outdoor ranging tests conducted by Rogers Engineering, the observed multipath excursions of an outdoor parking lot were not as widely varying as those seen in the shopping mall environment. Rogers Engineering believes that outdoor propagation dynamics and the severity of multipath is not expected to be as severe as indoor. By comparing the performance of PCS with antenna diversity and without diversity in a distributed antenna system, the degree of improvement will indicate the necessity for implementing diversity into future RAD systems. The tradeoff in implementing diversity necessitates twice the spectrum in both the forward and reverse directions. Rogers Engineering plans a diversity test for the end of March, 1993. We expect to make available results of the diversity testing at the convention.

Figure 9 Phase Noise Test Setup

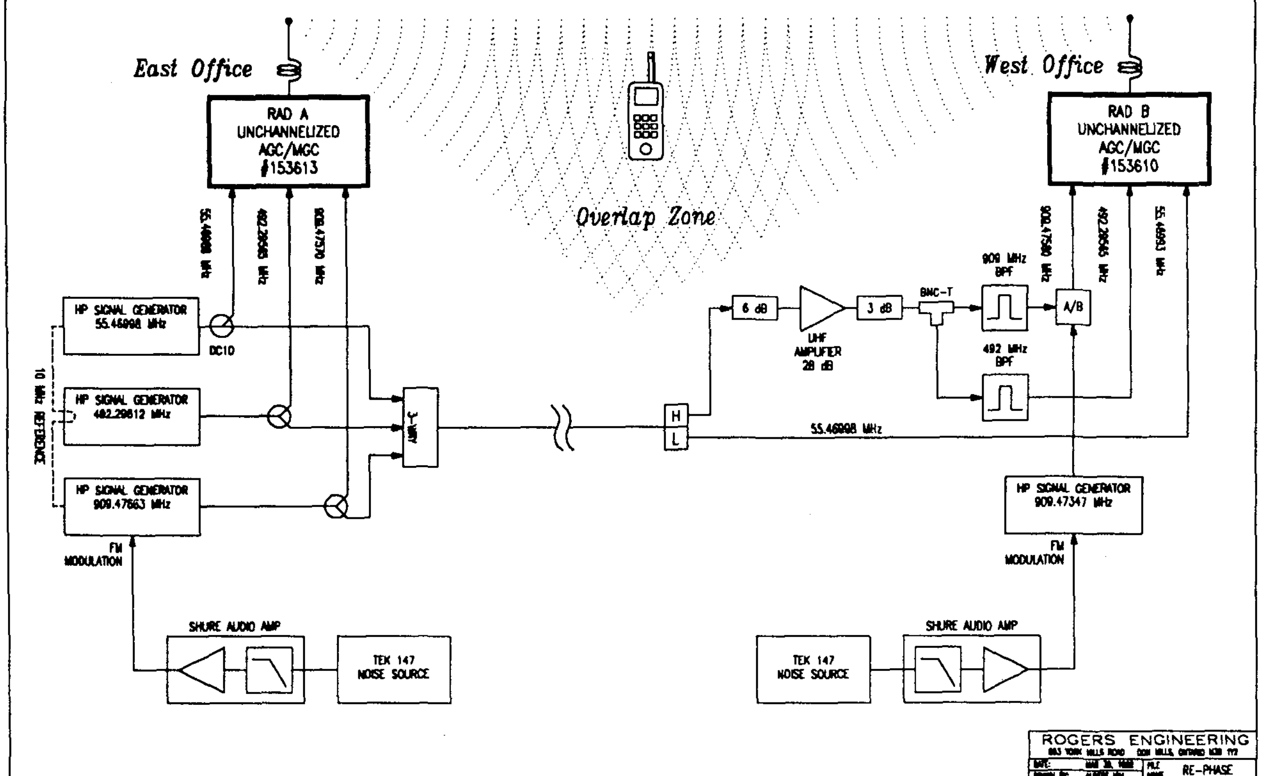
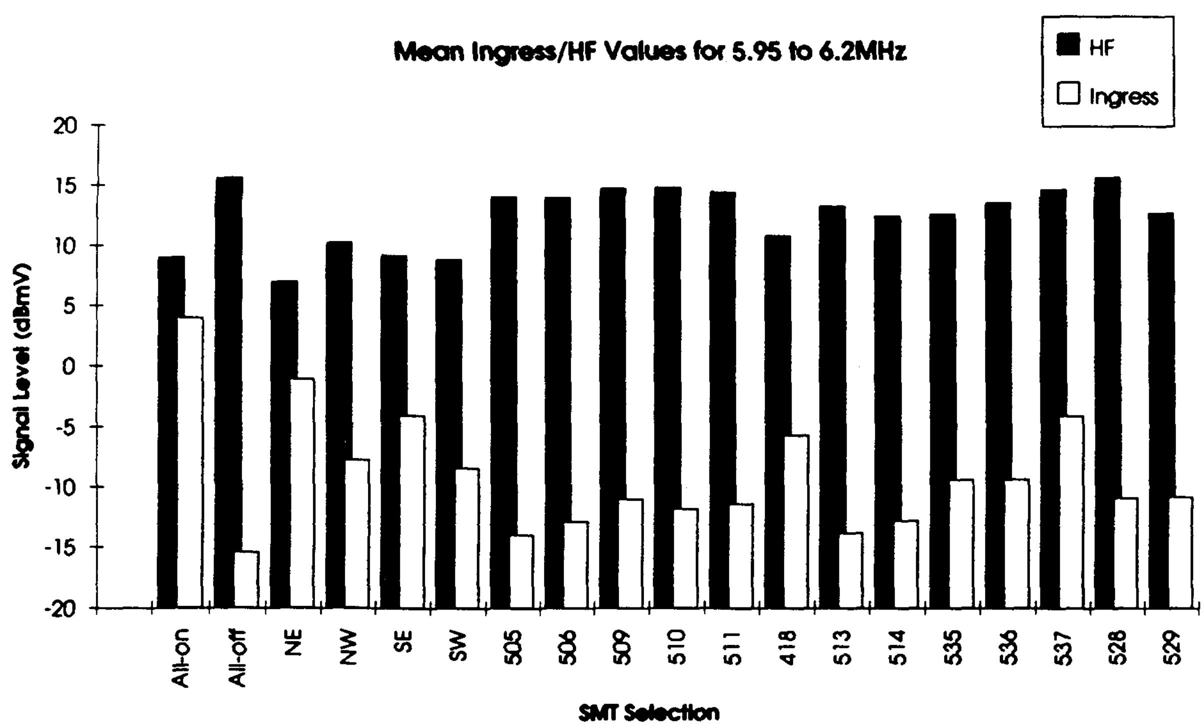


Figure 10 Processed Data of the Return Ingress



CONCLUSIONS

As the prospect of PCS unfold, it becomes apparent that the cable industry has a significant role to play in the success of this new and innovative technology. It is the intention of Rogers Engineering and CableLabs to assess the strength and weakness of a cable supported PCN infrastructure and to study the full impact of future PCN service to the cable industry.

ACKNOWLEDGEMENT

The authors would like to thank Rogers Cable Vancouver and Rogers Cable Toronto for their assistance in upgrading the cable plant and conducting the various propagation tests. The technical support from Motorola and Northern Telecom is vital to the tests of RAD transported CT2 signal over cable. The evaluation of antenna diversity is sponsored by CableLabs, and the cooperation of Cablevision Systems in Woodbury in providing the Lynbrook system as test bed is greatly appreciated.

REFERENCES

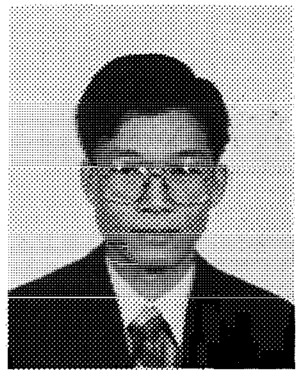
W. Tuttlebee, "Cordless Personal Communications", IEEE Communications, pp.42-53, December 1992.

G. Chan & R. Pao, "Ingress Monitoring Procedure", a report which presents the automated ingress program developed by Rogers Engineering for CableLabs, December, 1992.

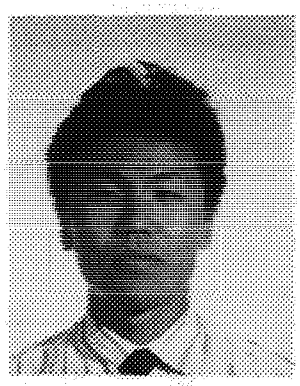
V. O'Byrne, "Digital Cellular over the Cable Television Fiber-Optic Plant", IEEE First International Conference on Universal Personal Communications Proceedings, pp.205-208, September, 1992.

S. Todd et al, "Space and Frequency Diversity Measurements of the 1.7 GHz Indoor Radio Channel for Wireless Personal Communications", IEEE First International Conference on Universal Personal Communications Proceedings, pp.87-91, September, 1992.

G. Hart, "Cost Effective Cable Television Transport for PCN", NCTA Technical paper, pp.148-156, May, 1992.



Gary Chan is a Staff Engineer at Rogers Engineering, Toronto, Canada. He received his B.Sc.E.E degree in 1980 from the University of Manitoba and Master of Engineering (Electrical) degree in 1986 from the University of Alberta. Since his graduation in 1980, he has engaged in CATV design, operation, maintenance, research, and development of advanced cable television technologies. For the past 18 months, he has led the PCN tests related to using cable plant as a transport media in Rogers Cable TV Toronto. He is a member of the IEEE and a registered Professional Engineer of Ontario.



Albert Kim received his B.A.Sc. from University of Toronto in Electrical Engineering in 1988. Upon graduation he joined Rogers Engineering, Toronto, Ontario, and is currently a Staff Engineer in the Advanced Engineering department. He has engaged in the fiber optic architecture design and system deployment into the CATV systems. Since 1990, he has focused on developing and testing systems for transporting PCS services on CATV networks, specifically the distributed antenna concept that is realized through the development of the Remote Antenna Driver (RAD). Mr. Kim is a registered Professional Engineer of Ontario and is a member of the IEEE.