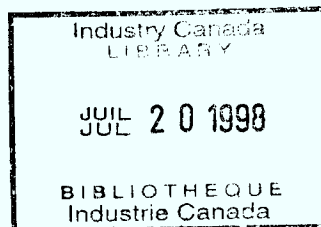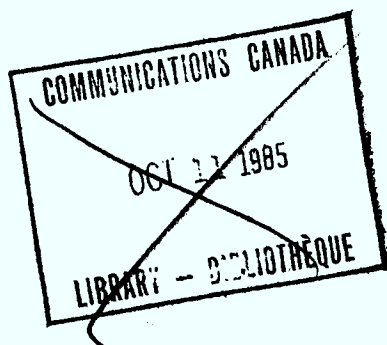DEPARTMENT OF COMMUNICATIONS

CANADA

A

STUDY

OF

LOW COST EARTH TERMINALS

FOR A

DIRECT BROADCAST SATELLITE SERVICE

PREPARED

BY

KENNETH LOGAN & ASSOCIATES
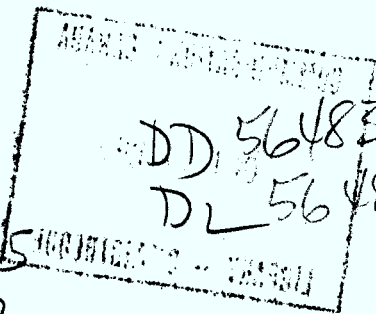
MONTREAL, CANADA

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SECTION I

1.0 INTRODUCTION

This report has been prepared for the Department of Communications, Canada, in response to the request for a study of the potential availability of small low-cost mass producible earth terminals for a Direct Broadcasting Satellite Service in the 2.6 and 12 GHz frequency bands.

Within the time frame there are variations in the requirements for Direct Broadcasting Satellite Television and Radio Service between the major developed areas of Japan, Europe, U.S.A. and Canada. The activities in development of products differ slightly, however the emphasis appears to be towards establishing initial service in Community Receivers and possible extension to individual reception at a later date. The types of services to be provided in the developed areas of the world require equipment providing performance comparable to that of wideband radio relay systems, but at a lower price.

Prices to the end consumer for this type of equipment may be reduced somewhat considering the potentially large volume, but this requires a significant effort in reducing labour content, the dominant factor in this period.

Microwave Integrated Circuit (MIC) technology geared towards high volume, high yield and low cost may provide the answers.

Development in low cost parametric amplifiers on a high volume basis and Surface Accoustic Wave devices in the intermediate frequency area could reduce the manufacturing costs to the extent required to make the price of products acceptable to the individual consumer and enhance the viability of the service.

This section of the report details the scope of the study, the methodology used and includes a summary of the detailed information contained in the later sections and annexes.

2.0 SCOPE OF STUDY

The use of direct broadcasting from high power satellites will permit distribution of television and radio programs directly to the homes, cable head-ends and community receivers, without going through a local broadcasting station. Such an approach for extending television and radio channels in new or existing service areas in Canada could be more cost effective than the television and radio distribution of programs by terrestrial radio relay and cable for radiation by local broadcasting stations. However, the viability of such a direct broadcasting service is dependant on the end price to the consumer which has to include the initial price of the receiver equipment, plus the installation. Other factors that have to be taken into account are ease of operation and maintenance, signal quality and availability of service.

An examination was made of the various approaches in Japan, Europe, U.S.A. and Canada in order to assess the extent to which equipment

development has progressed, and what the technology forecasts are for the 1980 period to realise a suitable service.

From this examination the following tasks were undertaken:-

a) Definition of receiver station suitable for the Canadian service requirements and environment.

b) An analysis and optimization of overall receiver costs for various receiver configurations in the 2.6 and 12 GHz bands.

c) Forecast of the advances in microwave solid state technology which can be expected to be made by 1980 to achieve high performance, reliable, low-cost receivers in large scale production.

3.0 METHODOLOGY

An initial meeting was held with the Scientific Authority to review the work program and derive a list of the various companies that should be contacted as possible sources of information. Current literature relating to the particular types of products was reviewed together with documents outlining the various system parameters.

A total of 22 U.S. companies, 8 Japanese, 10 European and 10 Canadian were contacted throughout the study. Extensive use was made of the NTIS Washington and CCIR documents in obtaining the required worldwide reports on Television Satellite Broadcasting. Lists of companies contacted and references are given in this report.

In analysing the information obtained, it became apparent that to cost out the various configurations outlined in the Department of Communications' requirements, it would be necessary to arrive at a

Base Design-Canadian Concept suitable for the Canadian system, for operation in the Canadian environment, and within the capability of Canadian manufacturing technology to produce. Particular costs for each functional unit were worked out, and the method of projecting costs for large quantity production was derived. These costs were marked up accordingly and, together with installation charges and other attracted costs, the prices to the end-user were derived.

Using this approach, the costs of eighteen individual station configurations were compiled and are listed in this report.

Aspects of technology transition and new technology areas as discussed with the various manufacturing and research organizations were analysed to prepare the Section III of this report.

From all of the above activity certain conclusions were drawn and recommendations made.

4.0 ASSESSMENT OF THE INTERNATIONAL SITUATION

a) U.S.A.

   In the U.S.A., the cessation of funded programs for the Application Technology Satellites has seriously curtailed product and system development to the extent that there is no major interest at this time by the large equipment manufacturers in new design and technological advances to provide low-cost receivers for a Direct Broadcast Satellite Service by 1980.

The work to date has largely been in special groups to provide a product that is suitable for the experimenters to continue with system measurements etc. on the ATS-F and the CTS programs.

The products produced for the ATS-F program in the 2.6 GHz band are relatively straightforward designs, that would be completely changed for large scale production.

Quotations for receivers in both, the 2.6 GHz and 12 GHz bands have shown a wide spread in price, thus indicating different approaches to the problem of receiver design. This wide spread was to be expected in the case of the 12 GHz band. However, in the 2.6 GHz band a similarity of prices had been expected since the technology is well established. The reasons for the unexpected wide spread are discussed later.

Programs funded to date to study low cost receivers for large scale production have indicated sharp differences of opinion on the subject of costs between the laboratory workers on the one hand and the production engineers and marketing groups on the other.

For example, a single TV channel 12 GHz converter to be fitted to the standard television receiver has been costed by one group at $ 40.00 in production quantities of 100,000 per year, while another group has indicated $ 91.00 for the same quantity of essentially the same product.

Selling prices based on these costs and quantities would probably work out to be in the $ 150.00 to $ 270.00 range. However, quoted prices for single units are $ 4,000.00 to $ 5,000.00 and for one hundred units, $ 3,000.00 to $ 4,000.00. The full range of costs and expected prices are shown in greater detail in the following sections of this report.

The manufacturers of the antennas required for this service are predicting costs for large quantities, that would be more acceptable to the individual consumer market. They see every possibility that a plastic antenna of 0.75 meter for the 12 GHz band can be produced at about $ 25.00 and sold at about $ 70.00 in quantities of 100,000 per year. A "design to cost" program, where the various design and manufacturing techniques for antennas, mounts, feeds etc. are studied and experimented with to determine the design and tooling required for this order of production, would cost about $ 100,000.00 over a 15 to 18 month period.

The general impression received in the U.S.A. on Satellite Broadcasting is that the large volume market is not foreseen for individual reception at this time and, if it does come about, it will be many, many years away. From this, the executives in the larger manufacturing companies do not feel it is advantageous to allocate the large development funds required.

Estimates of the overall project costs for development and design to manufacture of the antennas, outdoor and indoor receiver units for a complete station are of the order of $ 8 - 10 M. This would be for a production quantity base of 100,000 sets per year.

A typical project cost breakdown would be as follows:-

PROJECT PLANNING	Market Research	
	Product Volume	
"DESIGN TO COST" ANALYSIS	Study, Experimentation and Analysis of possible design approaches	
	Investigation and trial of manufacturing pro-cesses for large scale production	
	Derivation of real costs and prices	
	Establish design and manufacturing approach to meet cost and selling price objectives	$ 1.5 Million
PRODUCT DEVELOPMENT	Circuit and Product Design	
	Lab Models, Field Trials	
	Product Support	$ 2.0 Million
INDUSTRIAL ENGINEERING	Design for Manufacture	
	Prototype Models	
	Tooling and Facility Design	
	Component and Facility Procurement	$ 4.0 - 6.0 M
MARKETING	Product Information	
	Sales Promotion	
	Project Co-ordination	$ 0.5 Million

It is probable that a Direct Broadcasting Satellite Service will be for educational purposes and therefore will require government funding.

b) JAPAN

For some time, Japan, through their NHK (Broadcast Authority) Laboratories has been working on low-cost converters at 12 GHz. Recently they had a model unit on show and various cost and price figures have been indicated. These range from $ 40.00 to $ 80.00 production cost and $ 120.00 to $ 250.00 selling price. It is felt that these figures are the straightforward addition of component costs and do not include all the other attracted cost factors that have to be taken into account when establishing quantity manufactured pricing.

The product appears to have problems of frequency stability within a temperature range of -30° to $+60^oC$, and no indication was given of the image rejection or spurious radiation. The product has now been given over to manufacturing organizations in Japan, who now feel that to incorporate the necessary improvements, the selling price for large quantities (10^5) will be between $ 750.00 and $ 1,000.00.

Also the impression is that orders for large quantities will not materialize and the emphasis will be on community TV and Cable TV receiving equipments, rather than on individual receivers. However, the industry is more optimistic than in the U.S.A., and they feel

that an experimental Satellite Broadcasting Service will be established by 1976 to provide the additional channels required in the normal expansion of their TV service. They do not have the problems of numerous vested interests in Broadcasting to combat before developing a Satellite Broadcasting network.

c) EUROPE

A number of European Broadcasting administrations and manufacturers have been active in the design of receiver terminals for both the 2.6 and 12 GHz bands. However, the emphasis has now shifted to the 12 GHz band, since this is the band that will probably be used for systems in Europe. Some work is continuing in the 2.6 GHz band, with a possibility of use of this equipment in newly developing countries.

Studies have listed prices for 2.6 GHz equipment with a 440°K Low Noise Amplifier, that range from $ 315.00 for quantities of 100,000 per year to $ 475.00 for 1,000 per year. This is for individual reception. In all probability this is a cost figure, rather than a price, and the actual price to the end-user would be about $ 800.00 to $ 1,000.00. The manufacturers' marketing groups believe the latter figure to be a more realistic one.

At present, the price for a 12 GHz receiver for individual reception would be about $ 1,200.00 in 100,000 per year quantities. This is still a far cry from the $ 200.00 to $ 300.00 projected prices, that are considered to be required to make the service commercially viable to European administrations and attractive to the population.

In addition to development programs for Direct Broadcasting, a manufacturer has to keep his foot in the door for the more immediate markets on MARSAT and AEROSAT, and channel his development dollars into the right product at the right time.

Despite all the problems that appear at this time to cast doubt on the establishing of a Direct Broadcasting Service by 1980, the general impression is that such a service will be required, and with a major thrust in developing manufacturing techniques to reduce costs, (mainly labour content), the target price of $ 200.00 to $ 300.00 for individual reception can be met.

In summary, the work to date in Europe has provided the basis for a more detailed examination of the problems associated with Direct Satellite Broadcasting and a considerable amount of work has to be done to establish true costs and prices.

It is felt by the Europeans that before a major effort is mounted by the large manufacturing companies, the following steps have to be taken:-

a) Government policy has to be clearly stated on the need and timing of such a service.

b) Research and development funding has to be available from government or broadcasting authorities.

c) Establishment of system parameters.

d) Definition of product specifications.

e) Obtain reasonable guarantee that satisfactory markets will exist.

f) Establish what production quantities are required and in what time frame.

Following the above, the manufacturers will do their part in the required stages to establish new technology and manufacturing techniques and arrive at the price objectives stated.

The manufacturers feel that to accomplish their objectives, there are no short cuts and considerable work has to be done in:-

1. Planning of the required development programs.

2. Product Specification.

3. Development of product and manufacturing process within the framework outlined in the (a) - (f) activities above.

4. Production of laboratory models acceptable for factory proto-type development.

5. "Design to Cost" programs to be followed by reducing factory prototypes to design for large scale manufacture.

6. Tooling and manufacturing facility design for large scale pro-duction.

The annexes to this report contain more detailed information.

5.0 SITUATION IN CANADA

The activity in Canada is basically towards the small quantity of equipments required for the CTS program experiment. As such it can hardly by used as a base for the information required in this report. There are indications, from various groups, of continuing development in the areas of lower cost parametric amplifiers, F.E.T. oscillators and surface wave technology which could be available for the types of earth terminals considered here.

However, the quantities discussed would add an entirely new dimension to the Canadian industry, and further time would be required to provide information that would be relevant to this study. As a pre-requisite, there would have to be a more specific product requirement and system definition before any relevant information could be obtained.

As in the U.S.A., there is no enthusiasm at this time among Canadian manufacturers to stimulate the major development programs that would be required. Canadian industry feels that a number of development programs would have to be undertaken in specific areas, before commiting funds to the development of the actual receivers. These particular points are covered in the recommendations at the end of this report.

6.0 BASIC MODELS FOR LOW COST EARTH STATIONS

From the studies made of the international situation, it was realised that to make estimates of costs and prices of products for a Canadian Direct Broadcasting Satellite system, a basic Canadian model would have to be decided upon, taking into account the limitations of product designs observed to date, and the capabilities of Canadian industry. From this base, a series of cost and price estimates have been detailed in Section II. These have been summarized in the two graphs, Figure 6.1 for the 2.6 GHz band and Figure 6.2 for the 12 GHz band. All prices are in $ Can. (1974).

2.6 GHz HOME RECEIVER
ONE OUT OF TWO TV CHANNELS, SWITCHABLE
(INSTALLED PRICES IN CANADA, INCLUDING TAXES)

FIGURE 6.1

G/T (dB/°K)   -6   -4   -2   0   2   4

NOISE FIGURE (dB)

Qty.	Price
10^3	$ 2,510
10^5	$ 1,120

Qty.	Price
10^3	$13,350
10^5	$10,930

Qty.	Price
10^3	$ 2,205
10^5	$ 940

Qty.	Price
10^3	$ 4,500
10^5	$ 3,025

Qty.	Price
10^3	$ 4,815
10^5	$ 1,670

Qty.	Price
10^3	$ 5,380
10^5	$ 2,200

ANTENNA GAIN (dB)

20   25   30   35   40

ANTENNA DIAMETER (FT)

2   3   4   5   6   7   8   9   10   11   12   13   14   15   16 17 18

ONE OUT OF TWO TV CHANNELS, SWITCHABLE
(INSTALLED PRICES IN CANADA, INCLUDING TAXES)

FIGURE 6.2

G/T (dB / °K)

NOISE-FIGURE (dB)

Qty.	Price
10^3	$ 2,120
10^5	$ 840

Qty.	Price
10^3	$ 2,880
10^5	$ 1,530

Qty.	Price
10^3	$ 2,430
10^5	$ 910

Qty.	Price
10^3	$ 2,750
10^5	$ 1,210

Qty.	Price
10^3	$ 2,700
10^5	$ 1,000

Qty.	Price
10^3	$ 8,440
10^5	$ 3,730

Qty.	Price
10^3	$ 8,470
10^5	$ 2,850

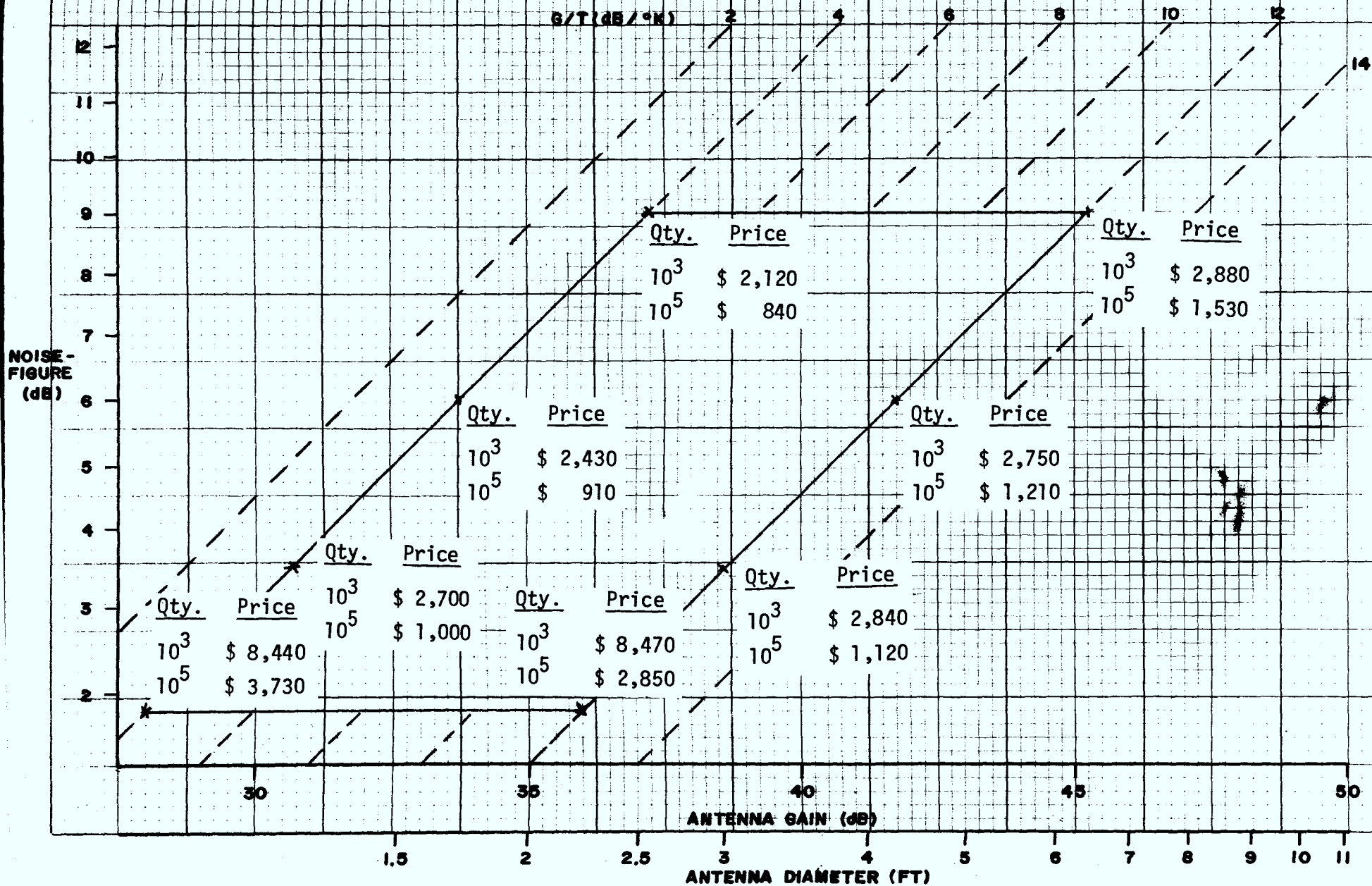| Qty.	Price
10^3	$ 2,840
10^5	$ 1,120

ANTENNA GAIN (dB)

ANTENNA DIAMETER (FT)

-15-

TABLE 6.1

BOUNDARY CASES FOR INDIVIDUAL HOME RECEIVERS (ONE OF TWO TV CHANNELS)

$^G/_T$	NF *	Station Installed Prices for Annual Production Quantity	
dB/^{O}K	dB	10^3	10^5
2.6 GHz			
-3	9	$ 2,510	$ 1,220
-3	6	2,205	940 ← the lowest
-3	2	4,815	1,670
7	9	13,350	10,930
7	6	4,500	3,025
7	2	5,380	2,200
12 GHz			
4	9	$ 2,120	$ 840 ← the lowest
4	6	2,430	910
4	3.6	2,700	1,000
4	1.8	8,440	3,730
12	9	2,880	1,530
12	6	2,750	1,210
12	3.5	2,840	1,120
12	1.8	8,470	2,850

* Receiving System Noise Figure

As can be seen, the lowest end-user prices for large quantities (10^5 per year) are $ 940.00 at 2.6 GHz and $ 840.00 at 12 GHz. These are in the same range as marketing price projections in other countries.

As discussed earlier in this section, the target price objective for the individual receiver has been stated by some administrations to be $ 200.00 to $ 300.00 for equipment, leading to a total of $ 250.00 to $ 400.00 installed. Some manufacturers have questioned whether this price objective will ever be reached, and the thought has been expressed that, in a viable public service, the individual receivers would be limited to very remote areas, and the distribution of broadcasting material in rural and urban areas would be via community receivers and Cable Television. With this thought in mind, the effort may well have to be concentrated on lower cost earth terminals for these types of stations.

It is noted that the optimum system parameters for Satellite Broadcasting have yet to be decided, and while it is desirable to do the initial planning on the basis of compatibility with existing terrestrial radio and television broadcasting, there may be serious practical difficulties. Changes in this philosophy of compatibility may lead to increased costs for individual receivers.

7.0 TECHNOLOGY PROJECTION

In the realm of microwave technology, the period from the initial introduction of new devices to their application in commercial pro-

duction is of the order of 5 to 8 years. In designing for products to be used in service in 1980, the emphasis has been on refining known technology, for high yield low-cost production. A considerable amount of work has yet to be done in minimizing labour content, probably the dominant factor in future costs.

So far the forecasted cost reductions in the production of micro-wave integrated circuits have not materialized. The price structure for Gunn diodes now used in intrusion alarms and police radar is $ 5.00 to $ 6.00 in quantities of 10,000 in the U.S.A.. However, microwave devices will probably always demand a premium as compared to other large volume consumer products. There is still a high labour content in the fabrication of the complete circuit package.

In looking at technological breakthroughs to reduce costs and improve performance, we also have to consider the "technological transition" in the low noise amplifiers at R.F. and integrated transistor cir-cuits at the lower frequencies. Laboratory work to date holds out the promise for uncooled parametric amplifiers at prices comparable to Tunnel Diode Amplifiers. Also there is the probability of extending the range of FET devices to 12 GHz.

The emerging technology of Surface Accoustic wave components has some potential key applications in the communications field. Work has been done on filters, discriminators, oscillators in the frequency bands below 1 GHz and claims are made of accurate and reproducible high performance with high yield and low cost.

Taking into account the potential reductions in costs brought about by technology transition and new technology, the most optimistic forecast for an individual 12 GHz receiver would be a price of the order of $ 500.00 to the end-user. This would represent a reduction from the $ 840.00 (item 6.0), but still a factor of two above the price projections in some administrations.

8.0 HIGHLIGHTS OF CONCLUSIONS & RECOMMENDATIONS

There is no major thrust in North American industry at this time towards the design of low-cost earth terminals for a Direct Satellite Broadcasting Service.

It appears that Japan will be the first to establish a Direct Broadcasting Satellite Service, having made some advances in product development and having the least number of conflicting interests compared to Europe and the U.S.A.

The emphasis will be on 12 GHz equipment designs, but the U.S.A. may continue with 2.6 GHz for educational systems.

A complete agreement on the system parameters is required before industry can attempt realistic programs on product designs.

It is essential that all cost and price estimates be based on industrial system and product planning principles that take into account the three major elements: a) Marketing

b) Research and Development

c) Manufacturing

In the general category, the recommendations are to establish a project office to look into the three areas of Marketing, R. & D. and Manufacturing stated above. In this case the marketing aspects would cover the socio-economic policies, plus other areas of market size and service implementation etc. Certain areas would overlap with the R. & D. effort in defining the system, the product design, the compatibility with existing broadcast services etc.

From this work, the manufacturing inputs can be provided on a "design to cost" progam. This activity would only relate to the earth terminal segment. The cost for this could well be of the order of 1.8 million dollars. A similar program could be established for the space segment.

For the manufacturing industry to design and tool up for quantity production, the estimate would be approximately 8.5 million dollars.

In summary the planning, research and development etc. for the ground segment would total about 10.3 million dollars.

In specific areas:-   i) The frequency plans have to be decided.

ii) The performance of colour receivers with low C/N ratios has to be determined.

iii) The whole question of compatibility with terrestrial broadcasting has to be resolved.

9.0   <u>LIST OF ORGANIZATIONS CONTACTED</u>

U.S.A.

Hewlett Packard	International Microwave
Avantek	Litton Industries
Fairchild	Stanford Research
Westinghouse	Hughes
California Microwave	NASA
Farinon Video	Comsat
Prodelin	Computer Science Corporation
Ainslie Antennas	Federation of Rocky Mountain States
General Tel.	Intelsat
Digital Communications Corp.	Raytheon
Philco Ford	G.T.E. Lenkurt

JAPAN

Kokusai Denshin Denwa (KDD)

Ministry of Posts and Telecommunications (P.T.T.)

P.T.T. Research Labs.

Mitsubishi Electric Corporation

Nippon Hoso Kyokai (NHK)

Nippon Telephone & Telegraph Public (NTTPC)

Nippon Electric Co. (NEC)

Nippon Telecommunications Consulting Co. (NTTC)

EUROPE

A.E.G. Telefunken	Mullard Research Labs.
Microwave Associates	Microwave Electronic Systems Ltd.
O.R.T.F.	Edinburgh University
G.T.E. Milano	Plessey
T.R.T. Paris	

CANADA

Andrews Antenna	M.I.L. Northern
Mitec	Philips
R.C.A.	Plessey
Raytheon	Bayly Engineering
G.T.E. Lenkurt	

SECTION II

LOW COST EARTH STATIONS - CANADIAN CONCEPT

1.0 INTRODUCTION

From the analysis of the data obtained from various organizations outside of Canada, it was apparent that the products and service offerings were different to those required for a Canadian Direct Broadcasting Satellite system. It was therefore necessary to establish a base design for individual receivers and community receivers within the terms of reference of the Department of Communications study request and within the capabilities of Canadian manufacturers to produce. The required system parameters are stated in item 2.0 of this section, and the station configurations are shown in item 3.0. Cost factors for each of the functional elements for each type of receiver are listed in item 4.0 and 5.0, and the method of deriving costs and prices is outlined in item 6.0. Prices of subsystems and services are shown in item 7.0.

From the preceeding items, the prices for 18 different configurations were compiled in item 8.1 to 8.18.

2.0 SYSTEM PARAMETERS

    a) Down Link Frequencies

        i) 11.7 - 12.2 GHz

        ii) 2500 - 2690 MHz

    b) Modulation

        F.M.

c) Baseband Signal Characteristics

    Television : Video Bandwidth 4.2 MHz

                      Audio Bandwidth   10 kHz

    Radio   : Audio Bandwidth   15 kHz

d) Occupied R.F. Bandwidth

    Television : 21 MHz per channel

    Radio   : 180 kHz per channel

e) Types of Radio Programmes

    i) Monophonic

    ii) Stereophonic (not considered at this time)
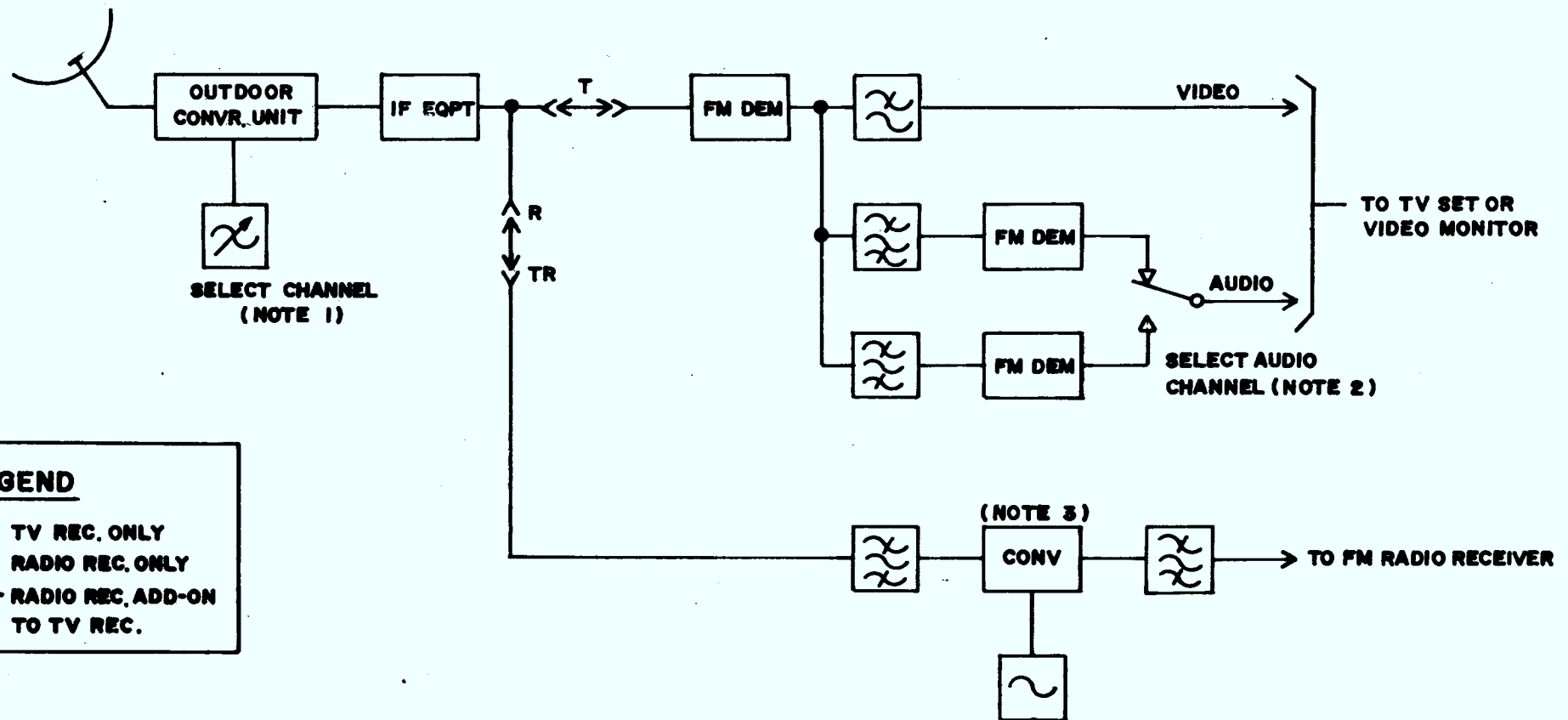
f) Earth Stations

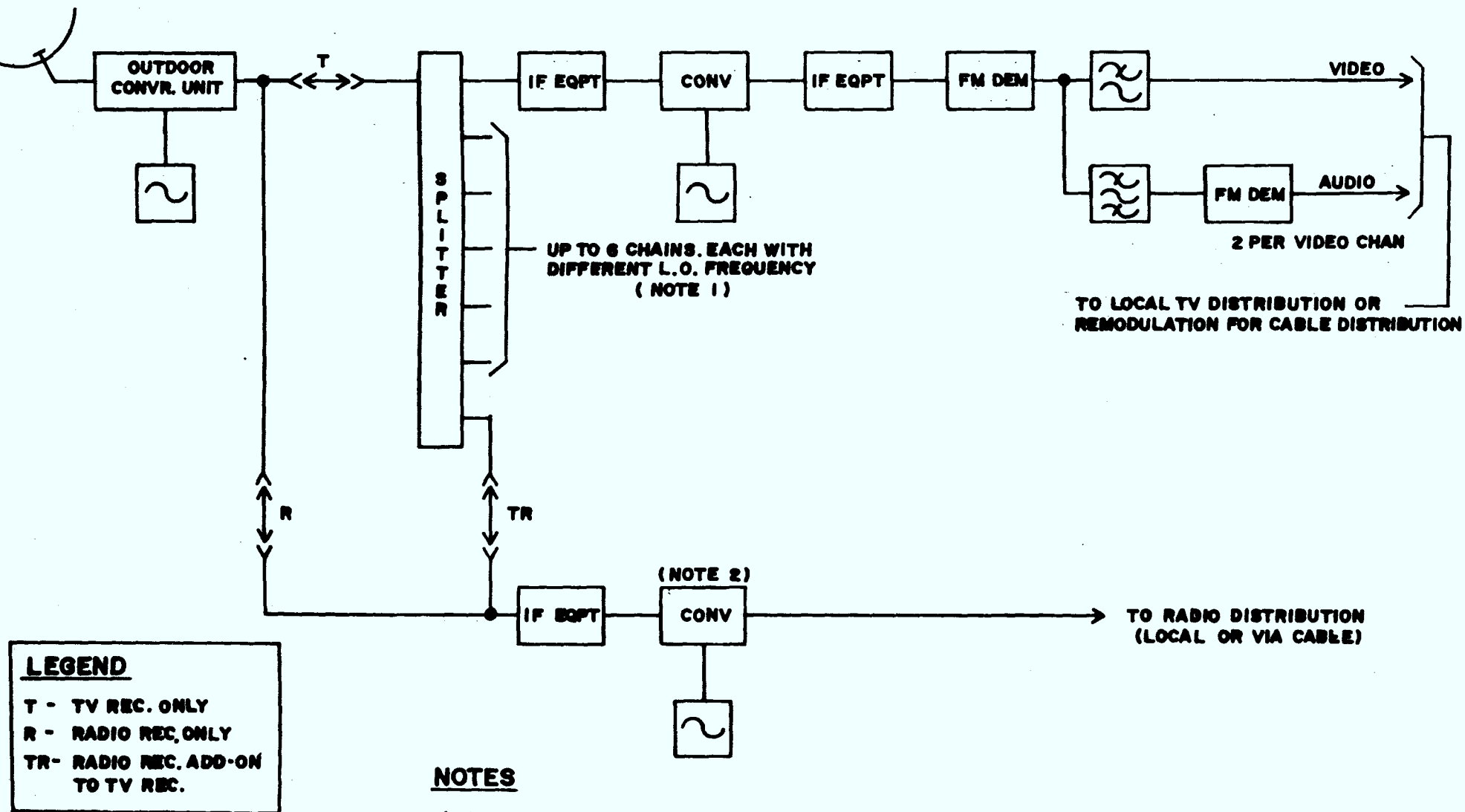| QUANTITY	G/T (dB)				EARTH STATION RELIABILITY (% of any year)
	2.6 GHz		12 GHz		
100 - 300	11	21	18	26	99.98
100 - 2500	0	10	7	15	99.98
100 - 2500	0	10	7	15	99.5 (consistent with un-protected equipment)
1000 - 1,000,000	-3	7	4	12	consistent with home appliance equipment.

3.0 STATION CONFIGURATIONS

The station configurations for Television Receive only, Radio Receive only and Radio Receive add-on to Television Receive for the individual (home) receiver are shown in the functional diagram, Figure 3.1. In this case, the mode of operation is basically for the customer to have a choice of one of two TV channels.

For community stations the arrangement considered here (Figure 3.2) is for 2 to 6 T V channels simultaneous reception for local distribution or remodulation for Cable Television.

FIG.1 HOME RECEIVER-
2·6 GHz OR 12 GHz

LEGEND

T - TV REC. ONLY
R - RADIO REC. ONLY
TR - RADIO REC. ADD-ON
      TO TV REC.

NOTES

1) ONE OUT OF TWO TV AND/OR RADIO CHANNELS, SWITCHABLE.
2) EACH TV CHANNEL HAS TWO SIMULTANEOUS AUDIO CHANNELS ON SUB-CARRIERS.
3) RADIO CHANNELS ON SEPARATE RF CARRIERS CONVERTED TO BROADCAST BAND.

FIG.2 COMMUNITY OR CABLE
HEAD – END RECEIVER
2·6 GHz OR 12 GHz.

UP TO 6 CHAINS. EACH WITH
DIFFERENT L.O. FREQUENCY
(NOTE I)

2 PER VIDEO CHAN

TO LOCAL TV DISTRIBUTION OR
REMODULATION FOR CABLE DISTRIBUTION

(NOTE 2)

TO RADIO DISTRIBUTION
(LOCAL OR VIA CABLE)

LEGEND

T - TV REC. ONLY
R - RADIO REC. ONLY
TR- RADIO REC. ADD-ON
       TO TV REC.

NOTES

1) TWO TO SIX SIMULTANEOUS TV CHANNELS, EACH WITH TWO SIMULTANEOUS
AUDIO CHANNELS ON SUB-CARRIERS.
2) TWO TO SIX SIMULTANEOUS RADIO CHANNELS ON SEPARATE RF CARRIERS,
CONVERTED TO BROADCAST BAND.

4.0 INDIVIDUAL HOME RECEIVER

4.1 Introduction

This section describes the conceptual design of a possible receiver configuration for the direct home reception of FM modulated TV signals from a satellite transponder in the 2.6 GHz band. It has been assumed that the satellite system configuration has been optimized to provide the most expedient signal processing scheme on the ground thereby minimizing the terminal costs.

The 2.6 GHz band has been chosen as base case for two reasons. First, very little current information exists in the literature on 2.6 GHz designs, - most of the work to-date has been carried out in the 12 GHz band. Secondly, technology in the 2.6 GHz band is well established in Canada and it is therefore possible to make realistic predictions of cost associated with a specific design. Costs for the 12 GHz band are projected using the design described in this section as the basis.

Also included are manufacturing costs based on typical 1974 material costs and labour rates in Canada. These costs assume that the receiver has undergone a maximum design effort in order to optimize the receiver manufacturing costs for large volume (10^5 per annum).

4.1 Introduction - Continued

The receiver under consideration here is capable of receiving one
of two RF carriers on a switched basis and provide a video and audio
output for connection to a modified commercial TV receiver.

Basically the receiver consists of an outdoor unit, attached to the
antenna terminals at the rear, which processes the 2.6 GHz satellite sig-
nal to an intermediate frequency of 70 MHz. This IF signal is
carried to the indoor unit by foam dielectric type flexible coaxial
cable where the final signal processing takes place.

4.2 Outdoor Unit

4.2.1 Electrical Description

Figure 4-1 shows the functional arrangement of the outdoor
unit. A standard single conversion heterodyne scheme is used.
The incoming signal at the antenna terminals is first filtered
in a three cavity interdigital filter for the following reasons:

1. to provide selectivity for the two RF carriers and to
    discriminate against unwanted signals at the antenna
    input.

2. to prevent local oscillator power from being radiated
    out of the antenna.

3. to provide attenuation at the receiver image frequency
    so as not to deteriorate the receiver noise figure.

Antenna
Terminals

to indoor
unit

DC
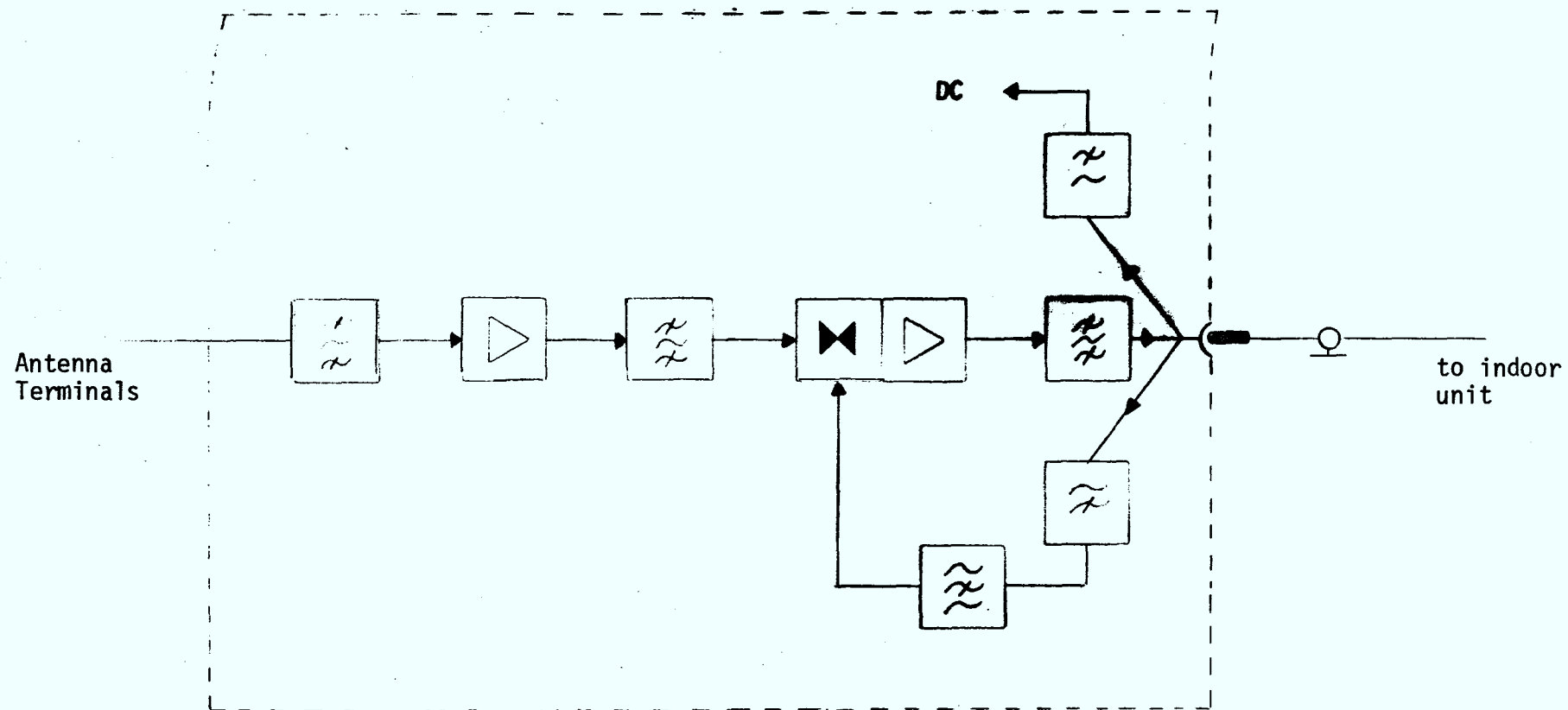
OUTDOOR UNIT

2.6 GHz RECEIVER

FIGURE 4-1.

-28-

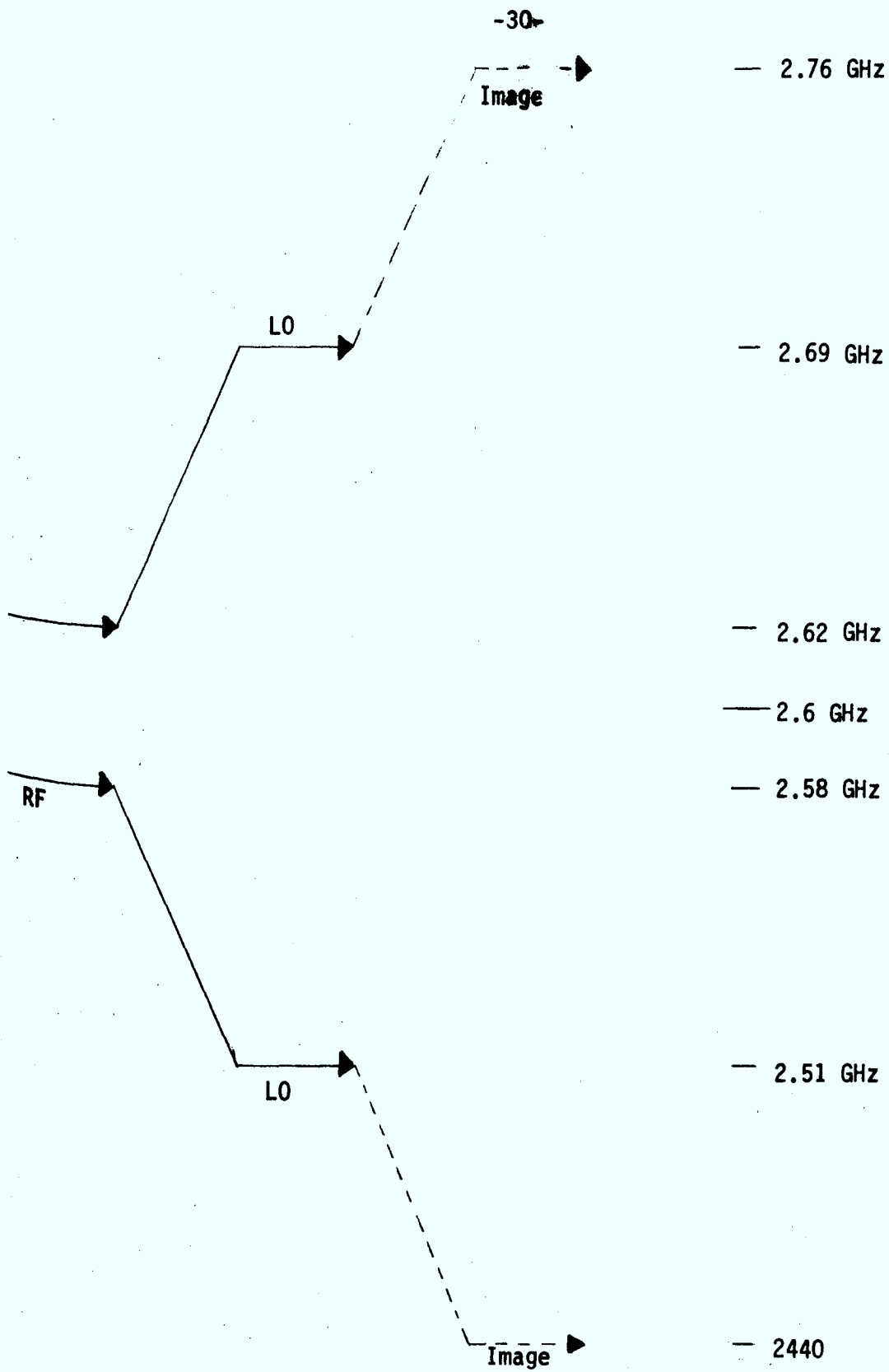4.2.1 Electrical Description - Continued

Figure 4-2 shows a possible frequency plan for the 2.6 GHz
receiver with the local oscillator frequencies folded outwards
from the RF carriers. With an intermediate frequency of 70 MHz
the following characteristics are achievable for this 3 pole
filter:

center frequency f_o = 2.6 GHz

0.1 dB bandwidth $f_o \pm 35$ MHz

3 dB bandwidth $f_o \pm 50$ MHz

insertion loss at $f_o \pm 90$ MHz   18 dB

insertion loss at $f_o \pm 160$ MHz   33 dB

For the case of reception of two radio channels in addition to
two TV channels the bandwidth could be made broader without
affecting the concept.

The two RF carriers are then amplified in a two stage 15 dB gain
microwave preamplifier with a noise figure of 4.5 dB. Fabrica-
tion is by thick film deposition on alumina substrates with
packaged transistors and chip capacitors. The required band-
width of this amplifier is about 70 MHz. It is assumed that
the level of the two RF carriers is very small in comparison to
that of the saturation level of the amplifier so that cross modula-
tion does not occur.

The amplified output is filtered again in a filter identical to
the input filter and passes to the mixer preamplifier.

Image — 2.76 GHz

LO — 2.69 GHz

— 2.62 GHz

——2.6 GHz

— 2.58 GHz

RF

LO — 2.51 GHz

Image — 2440

EARTH TERMINAL FREQUENCY PLAN

FIGURE 4-2

4.2.1 Electrical Description - Continued

The mixer preamplifier converts one of the two RF carriers to an intermediate frequency of 70 MHz, the choice of RF carrier being determined by the local oscillator frequency which is generated in the indoor unit. The mixer consists of a single ended Schottky barrier diode mixer. The conversion gain of the mixer preamplifier is 30 dB with a noise figure of 10 dB. Both the mixer and preamplifier are fabricated using thick film ciruitry.

The IF output is connected to a three-way splitting filter which separates the local oscillator and the DC power which are supplied from the indoor unit and provides selectivity for the IF signal. A bandstop filter is included after the high pass filter in the local oscillator line to prevent the two RF carriers from being transmitted to the indoor unit. The common point of the three-way splitting filter is connected to coaxial cable for transmission to the indoor unit.

4.2.2 Mechanical Description

The body of the outdoor unit is die cast aluminum. The RF filters form an integral part of the structure with the added possibility of having the filter resonators fixed as part of the casting. The RF preamplifier and the mixer preamplifier are fitted into compartments and connect directly to the filter probes. The completed unit is sealed and weather-proofed.

4.2.3 Manufacturing Costs

Manufacturing cost estimates for a quantity of one hundred thousand units are shown in Table 4-1. Total cost is about $.88.00 for the outdoor unit. Manufacturing costs in this report refer in all cases to material plus burdened labor cost at the factory level. The burden includes only the factory indirect labor (such as production control, purchasing and quality control) and other variable expenses associated with building parts. No capacity cost are included.

4.3 Transmission Line

A suggested connection between the indoor and outdoor units is 3/8" foam filled transmission line. The relevant attenuation characteristics are as follows:

attenuation at local oscillator frequency ~ 8 dB/100 ft.

attenuation at the intermediate frequency ~ 1 dB/100 ft.

Small quantity cost is $ 0.47 per foot and an additional $ 10.00 for connectors. Large quantity cost for a 75 ft. cable with connectors is estimated at $ 27.00.

4.4 Indoor Unit

4.4.1 Electrical Description - (Refer to Figure 4-3)

A three-way splitting filter is at the input terminals of the indoor unit. This filter extracts the 70 MHz IF signal and provides the bulk of the selectivity for the receiver. The

ITEM	FABRICATION	COST
Housing	Precision aluminum die casting including RF bandpass filters, high pass filter, notch filter and cover	$16.00
RF Pre-amplifier	1" x 2" thick film substrate with HP 21 and HP 22 transistors	$40.00
Mixer - IF preamplifier	1 x 2" thick film substrate with a single Schottky barrier diode and three-stage IF preamplifier	$10.00
Three-Way Splitting Filter	High pass filter is a cavity included as part of casting. Remainder is conventional L-C circuitry	$4.00
Assembly and Test	Bonding substrates to filter probes - DC wiring and testing	$18.00
	TOTAL COST	$88.00

TABLE 4-1. OUTDOOR UNIT COSTS - Quantity 10^5 Units/Year

BASIC 2.6 GHz RECEIVER

House Current

DC Power Supply

Optional Clamper

To Outdoor Unit

Video Out

Audio Out

INDOOR UNIT

2.6 GHz RECEIVER

FIGURE 4-3.

4.4.1 Electrical Description - Continued

IF signal is then phase equalized to compensate for phase dis-
tortion in the RF and IF filters. Note that the phase equali-
zation required for each RF carrier will be identical due to the
fact that the local oscillators are located on opposite sides
of the RF carriers. Both the IF filter and equalizer are con-
structed using conventional L-C circuitry.

Following the equalizer is a 40 dB fixed gain IF amplifier fab-
ricated on two thick film substrates.

The amplified IF signal passes to a high quality FM demodulator
consisting of a limiter, discriminator and video baseband ampli-
fier containing a de-emphasis network. The dynamic range of the
limiter is adequate to compensate for variations in the received
signal of plus or minus 5 dB. All three circuits are fabricated
on thick film circuitry.

The video signal is obtained from the demodulated output through
a 4.3 MHz low pass filter. The sound subcarrier is picked off
by a bandpass filter and then directly demodulated in a thick
film limiter, discriminator and audio amplifier.

The DC component of the main demodulator output is separated by
a low pass filter and amplified to provide an AFC voltage for
the local oscillator.

4.4.1   Electrical Description - Continued

The local oscillator consists of a single transistor oscillator on a thick film substrate operating directly at 2 GHz. The tank circuit consists of transmission line sections which can be switched in or out by a diode to provide a tuning technique for the two local oscillator frequencies required. A varactor diode is also located in the tank circuit and is biased by the previously mentioned AFC voltage to complete the frequency control circuitry. Although the output of this oscillator will have considerably more RF noise as compared to radio link type of oscillators, the overall receiver noise will be controlled by the down link thermal noise contribution. The RF output of the oscillator is about 10 milliwatts.

The oscillator output is connected to the high pass side of the three-way splitting filter for transmission to the outdoor unit.

The low pass side of the splitting filter is connected to the power supply consisting of a transformer, rectifier and regulator.

4.4.2   Mechanical Description

A master printed circuit board forms the basis for the indoor unit construction. Circuitry using conventional L-C-R components, such as the voltage regulator, AFC amplifier, etc. are assembled directly on to this board. Thick film circuits are designed with protruding pins for signal and power connections and are soldered on to the master P.C. board. Shielded boxes are

4.4.2 Mechanical Description - Continued

placed over all circuitry susceptible to radiation. The

assembly is housed in an injection moulded plastic cabinet.

4.4.3 Manufacturing Costs

Table 4-2 details the estimates for the manufacturing cost of a

large quantity production run of 10^5 units. Total cost is about

$159.00 for the indoor unit.

4.5 Optional Configurations

Optional configurations that have been considered in addition to the

base case described above are as follows:

(a) Reception of One of Two Radio channels (Monophonic)

(b) Reception of One of Two TV channels, each with Two

Audio or One of Two Radio channels

In each case the approach taken was to use the base case concept and

introduce suitable modifications to satisfy the optional requirements.

The outdoor unit is identical in all cases and changes are only required

to the indoor unit.

4.5.1 Reception of One of Two Radio Channels

The proposed modulation characteristics of radio channels for dis-

tribution in direct broadcasting satellite systems are identical to

those in terrestrial networks. Advantage has been taken of this

fact and the output of the receiver has been arranged to be in the

ITEM	FABRICATION	COST
Housing	Injection moulded plastic	$3.00
Shielded Compartments	Sheet metal for isolation between various circuits	$4.00
Master printed Circuit Board	Provides DC and Signal Interconnections between various circuits	$4.00
Three-way Splitting Filter	Conventional L-C circuitry with cavity for the high pass portion - note that selectivity of IF bandpass section is much higher than that of outdoor unit.	$15.00
Phase Equalizer	Conventional L-C circuitry	$9.00
IF Amplifier	Two 1" x 2" thick film substrates	$12.00
Demodulator	Three 1" x 2" thick film substrates for the limiter, discriminator and baseband amplifier	$12.00
Video LP Filter	Conventional L-C circuitry on master PC board	$ 4.00
Subcarrier Demodulator	Bandpass filter is conventional L-C circuitry. Limiter, discriminator and audio amplifier are fabricated on two 1" x 2" thick film substrates (two required)	$24.00
AFC LP Filter Amplifier	L-C circuitry plus one IC operational amplifier on master PC board	$ 4.00
Local Oscillator	Fabricated on thick film	$18.00
Power Supply	Transformer mounted to plastic housing with the rectifier and regulator on the master PC board	$12.00
Assembly & Test	Includes miscellaneous wiring materials	$38.00
	TOTAL COST --	$159.00

TABLE 4-2. INDOOR UNIT COSTS - Quantity 10^5 Units/Year

BASIC 2.6 GHz RECEIVER

4.5.1 <u>Reception of One of Two Radio Channels</u> - Continued

form of an FM carrier in the 88 to 108 MHz band which can be directly connected to a conventional FM broadcast receiver.

The circuits in the indoor unit become less complex than for the base case since the bandwidths involved are smaller. The main IF frequency of 70 MHz is retained while an additional simple converter is added to locate the received FM carrier in an unused position in the broadcast FM band prior to passing it on to the user. Figure 4-4 shows the configuration of the indoor unit for this optional case.

The manufacturing costs in quantity of 10^5 per annum have been summarised in Table 4-3. The total cost of the indoor unit is about $112.00.

4.5.2 <u>Reception of One of Two TV Channels Each With</u>
<u>Two Audio or Two Radio Channels</u>

The assumed frequency plan for this case would have the TV carriers arranged as shown in Figure 4-2 with one Radio carrier situated just below the low TV carrier and the other just above the high TV carrier. The receiver IF bandwidth is made broad enough to accommodate simultaneously one TV carrier and one Radio carrier down converted with a single local oscillator.

Figure 4-5 shows the circuit configuration of the indoor unit for this option. The TV and Radio carriers received from the outdoor
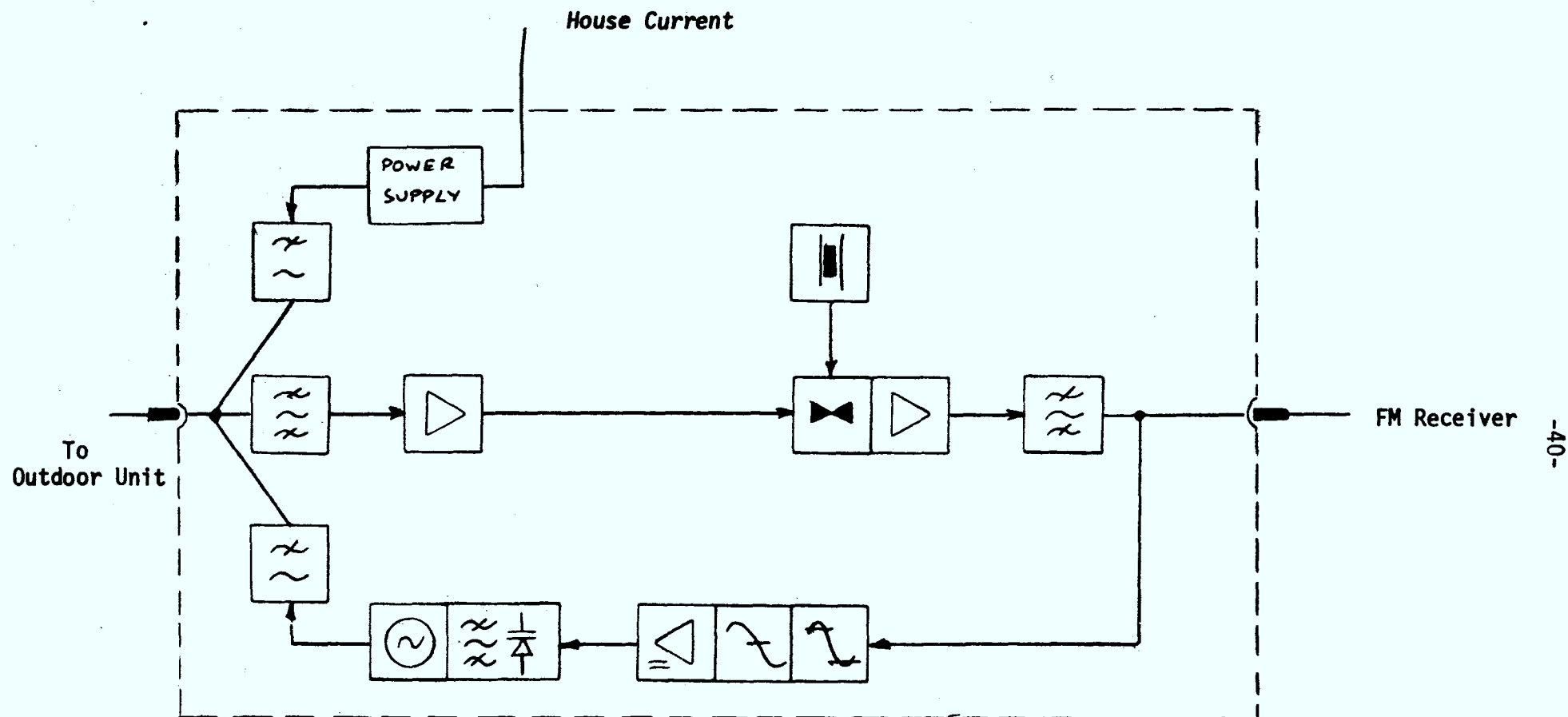
FIGURE 4-4: INDOOR UNIT - For Reception of One of Two Radio Channels

BASIC 2.6 GHz RECEIVER

ITEM	FABRICATION	COST
Housing	Injection Moulded Plastic	$ 3.00
Shielded Compartments	Sheet Metal	$ 4.00
Master PC Board	-	$ 4.00
3-Way Splitting Filter	Conventional L-C Circuitry with Cavity for HP Portion	$ 15.00
IF Amplifier	Two 1" x 2" Thick Film Substrates	$ 12.00
FM Mixer Preamplifier	One 1" x 2" Thick Film Substrates	$ 5.00
FM Filter	Conventional L-C Circuitry	$ 9.00
FM XTAL Oscillator	Thick Film Circuitry	$ 5.00
AFC Demodulator	Two 1" x 2" Thick Film Substrates	$ 10.00
Local Oscillator	Thick Film Circuitry	$ 18.00
Power Supply	Transformer With Discreet Rectifier and Regulator	$ 12.00
Assembly and Test	Includes Miscellaneous Wiring Materials	$ 15.00
	TOTAL	$112.00

TABLE 4-3: BASIC 2.6 GHz INDOOR UNIT COSTS   Quantity 10^5 Units/Year
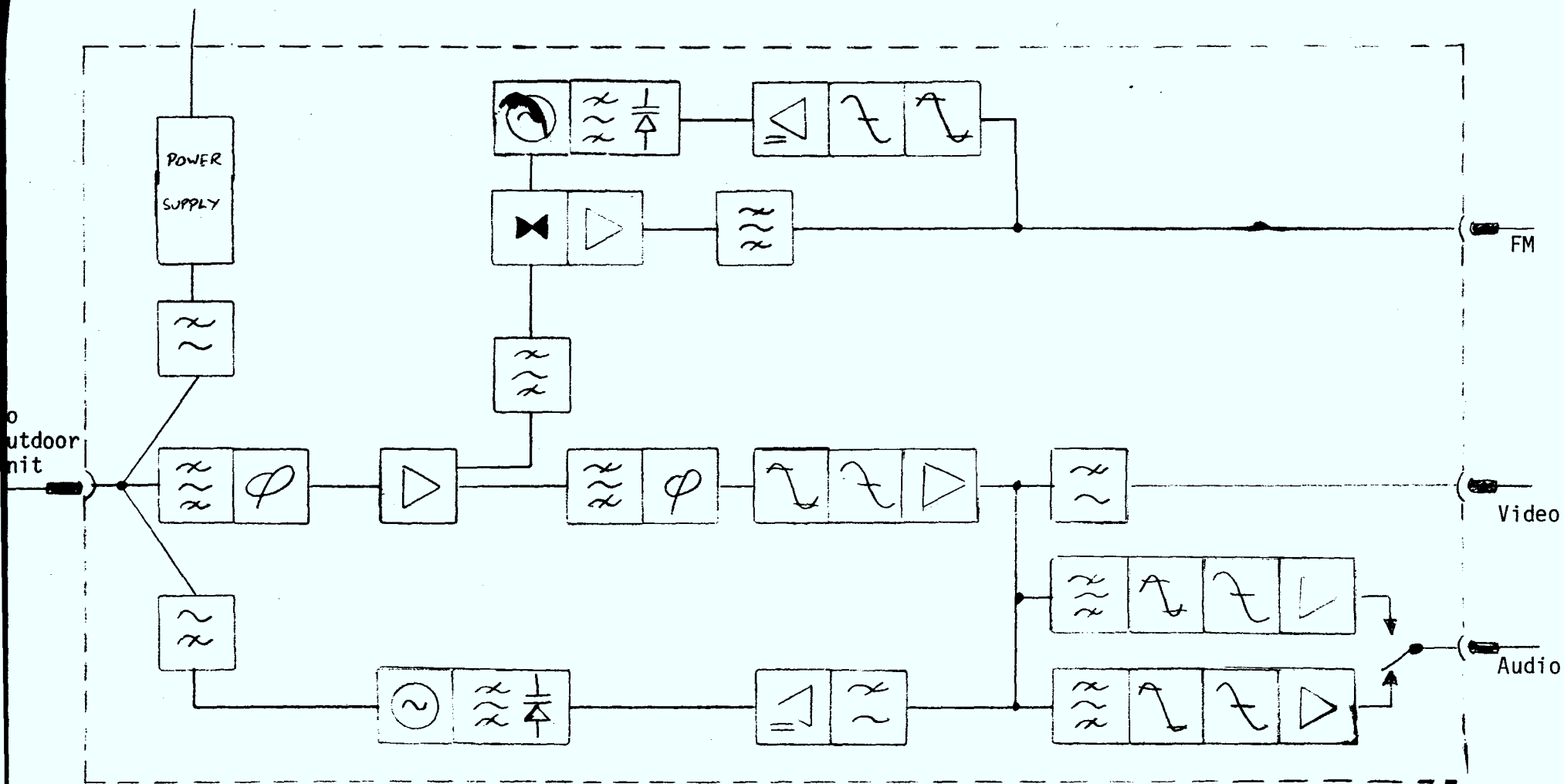
ONE OF TWO RADIO BROADCAST CHANNELS

FIGURE 4-5: BASIC 2.6 GHz RECEIVER INDOOR UNIT - For Reception of

One of Two Television Channels or One of Two Radio Channels

4.5.2   Reception of One of Two TV Channels
        <u>Each With Two Audio or Two Radio Channels</u> - Continued

unit along the cable are separated in a branching amplifier and fed into IF filters with selectivity adequate to reject the adjacent carriers. From this point the TV portion of the indoor unit is identical to that of the base case receiver. The Radio carrier undergoes a further frequency conversion to locate it in the proper position in the broadcast FM band prior to passing it to the user.

Selection of appropriate radio or TV channels is made by switches located on the front panel of the indoor unit.

Table 4-4 shows the manufacturing costs of the indoor unit for this option in quantity of 10^5 per annum. The total costs of the indoor unit is about \$215.00.

4.6   <u>Cost Summary</u> (Quantity Base = 10^5 per annum)

4.6.1 Base Case - One of Two TV Channels

Each With Two Audio

Cost of Outdoor Unit	\$88.00
Cost of Coaxial Cable	\$27.00
Cost of Indoor Unit	<u>\$159.00</u>
Total Manufacturing Cost	\$274.00

ITEM	FABRICATION	COST
Housing	Injection Moulded Plastic	$ 3.00
Shielded Components	Sheet Metal for Isolation Between Various Circuits	$ 4.00
Master PC Board	-	$ 4.00
3-Way Splitting Filter	Conventional L-C Circuitry with Cavity for HP section	$ 15.00
Phase Equalizer	Conventional L-C Circuitry	$ 9.00
IF Amplifier	Two 1" x 2" Thick Film Substrates	$ 12.00
Demodulator	Three 1" x 2" Thick Film Substrates	$ 12.00
Video LP Filter	Conventional L-C Circuitry	$ 4.00
Sub-Carrier Demodulator	Conventional L-C Circuitry for BP Filter plus two 1" x 2" Thick Film Substrates (Quantity 2)	$ 24.00
AFC LP Filter and amplifier	L-C Circuitry Plus Single IC	$ 4.00
Local Oscillator	Thick Film Circuitry	$ 18.00
Filter Equalizer	Conventional L-C Circuitry	$ 20.00
FM Mixer Preamp.	One 1" x 2" Thick Film Substrate	$ 5.00
FM Filler	Conventional L-C Circuitry	$ 9.00
AFC Demodulator	Two 1" x 2" Thick Film Substrates	$ 10.Q0
FM Local Oscillator	One 1" x 2" Thick Film Substrates	$ 5.00
Power Supply	Transformer with Discreet Rectifier And Regulator	$ 12.00
Assembly and Test	Includes Miscellaneous Wiring Materials	$ 45.00
	TOTAL	$215.00

TABLE 4-4: BASIC 2.6 GHz INDOOR UNIT COSTS QUANTITY 10^5 UNITS/YEAR

ONE OF TWO TV CHANNELS OR ONE OF TWO RADIO BROADCAST CHANNELS.

4.6.2 One of Two Radio Channels

Cost of Outdoor Unit	$ 88.00
Cost of Coaxial Cable	$ 27.00
Cost of Indoor Unit	$112.00
Total Manufacturing Cost	$227.00

The cost of this option is $47 or 17% less than the base case in 4.6.1

4.6.3 One of Two TV Channels Each With Two Audio or One of Two Radio Channels

Cost of Outdoor Unit	$ 88.00
Cost of Coaxial Cable	$ 27.00
Cost of Indoor Unit	$215.00
Total Manufacturing Cost	$330.00

The cost of this option is $56 or 20% more than the base case in 4.6.1

4.7 Technical Characteristics

Tables 4-5, 4-6 and 4-7 summarize the expected equipment and system characteristics achievable with the proposed conceptual design of the individual home receiver.

TABLE 4-5

SYSTEM CHARACTERISTICS

Occupied Bandwidth per Video Channel	21 MHz
Occupied Bandwidth per Radio Broadcast Channel	180 KHz
System Gain	84 dB
Differential Phase	5^0
Differential Gain	5%
Video Baseband	20 Hz - 4.3 MHz
Video Output Level	1 v p-p
Audio Baseband	100 Hz - 15 KHz
Audio Output Level - TV	+ 8 dBm
Broadcast Output Level - Radio	1 mv

TABLE 4-6

PERFORMANCE CHARACTERISTICS INDOOR UNIT

Input VSWR	70 MHz	1.1:1
	2.6 GHz	1.25:1
Gain		40 dB
IF 3 dB Bandwidth		26 MHz
Local Oscillator Frequency Stability		Maintains IF Frequency at 70 ± 200 KHz
Local Oscillator Power		+ 10 dBm
Dynamic Range		$\pm$ 5 dB *

* Determined by the dynamic range of the demodulator limiter.

TABLE 4-7

PERFORMANCE CHARACTERISTICS   OUTDOOR UNIT

Noise Figure		6 dB*
Input VSWR		1.25:1
Output VSWR	70 MHz	1.1:1
	2.6 GHz	1.25:1
RF to IF Conversion Gain		44 dB
Image Rejection		50 dB
Local Oscillator Radiated Power		-40 dBm Maximum
RF 3 dB Bandwidth		100 MHz
IF 3dB Bandwidth		28 MHz

Environmental Characteristics

Temperature	-40° C to $+70^{\circ}$ C
Humidity	0 - 95%

*Includes the effect of the noise figure of the indoor unit.

5.0 COMMUNITY RECEIVER

5.1 Introduction

This report describes a conceptual design of medium cost receiver intended for community reception of up to six simultaneous television signals directly from a satellite transponder. As in the case of the home oriented receiver, it is assumed that the satellite configuration has been optimized to provide the most expedient possible signal processing scheme in the ground receiver.

However, due to the smaller quantity involved in this case (about 10^3 per year maximum) the extensive engineering and design refinement undergone in the consumer version cannot be economically justified for the community type receive terminal. Instead the development costs must be considerably lower with subsequent higher manufacturing cost for comparable units for the two systems. In addition, the performance requirements of the terminal are considerably more stringent for the community receiver and this fact is reflected again in the higher manufacturing costs.

The community receiver consists of an antenna unit, mounted on the rear of the antenna, which constitutes the first part of a dual conversion receiver and processes the six incoming signals to an intermediate frequency of 1450 MHz. Coaxial transmission line is used between the antenna unit and the main receiver assemblies. Here the six RF carriers are separated and fed into their own respective receivers for the final signal processing.
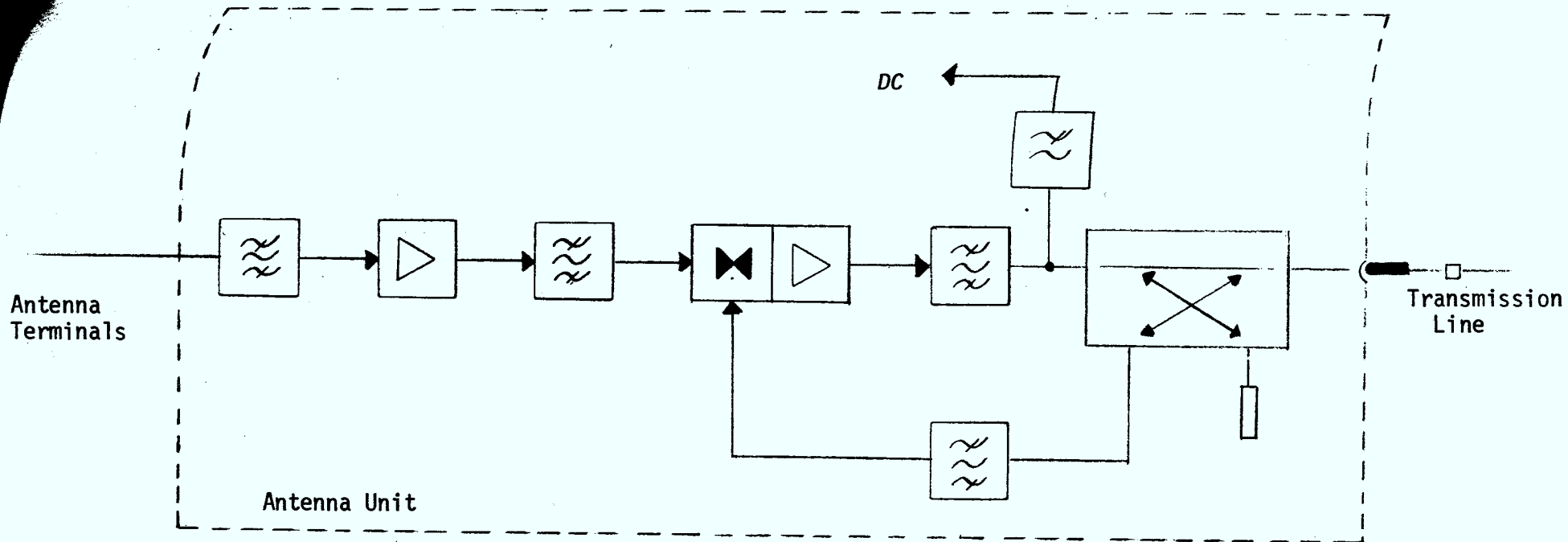
5.2.1 Antenna Unit

Figure 5-1 shows the functional arrangement of the antenna unit. The incoming carriers are filtered in a broad bandpass filter to provide selectivity against extraneous signals, to prevent the local oscillator from being radiated out of the antenna and to attenuate the image.

The filtered output is then amplified in a 35 dB gain microwave preamplifier with a noise figure of 4.0 dB. The required band-width of this unit will be about 300 MHz and therefore the manu-facture necessitates the use of thin film circuitry and chip transistors in a separate hermetically sealed package.

A second filter is located at the amplifier output and the signals pass to the mixer preamplifier. Both the mixer and preamplifier are fabricated on thick film circuitry with a single ended Schottky barrier diode mixer and a three stage preamplifier at the intermediate frequency of 1.45 GHz. Overall conversion gain of the unit is 25 dB with a noise figure of 10.0 dB.

The output of the preamplifier passes to an interdigital bandpass filter. Note that all the received carriers are contained in the bandwidth of this filter. A directional filter extracts the 4.05 GHz local oscillator L.O. signal which originates in the main receiver assemblies and passes the L.O. through a second bandpass filter to the mixer, thus effectively blocking the RF carriers from being directly coupled to the main receiver assemblies.

Antenna
Terminals

Antenna Unit

DC

Transmission
Line

2.6 GHz RECEIVER

COMMUNITY TELEVISION EARTH TERMINAL

ANTENNA UNIT

FIGURE 5-1

5.2.1 Antenna Unit - Continued

The DC supply for the antenna unit also is obtained from the receiver assemblies and is picked off on a low pass filter. The composite signal is connected to a 7/8 inch coaxial transmission line.

5.2.2 Mechanical Description

The antenna unit is contained in a cast sealed container with all components mounted inside. Hard line coaxial cables are used to interconnect the RF preamplifier and mixer preamplifier modules.

5.2.3 Manufacturing Costs

Table 5-1 shows the manufacturing cost estimate breakdown for the antenna unit for production quantities of 100 units.

5.3 Transmission Line

The recommended transmission line is 7/8 inch aluminum foam filled coaxial cable for the connection between the antenna unit and the main receiver assemblies. Characteristics are as follows:

Attenuation at local oscillator frequency (4.05 GHz) 6.0 dB/100 ft.

Attenuation at the intermediate frequency (1.45 GHz) 4.5 dB/100 ft.

Small quantity prices are $0.87 per foot with an additional $20.00 for connectors. Estimated length is 50 feet.

ITEM	FABRICATION	COST
Housing	Sand casting - machining required for cover flange and connector openings.	$45.00
Carrier BP Filters	Conventional interdigital structure with connectors. Quantity two required	$70.00
RF preamplifier	Purchased from U. S. Sources	$500.00
Mixer preamplifier	Two thick film substrates - 3 RF transistors Schottky barrier diode - case - connector	$85.00
IF bandpass filter	Conventional interdigital structure	$35.00
L.O. BP filter	Conventional interdigital structure	$35.00
Directional filter	Machined casting	$60.00
DC LP filter	Conventional LC circuitry	$5.00
Assembly and test		$60.00
	TOTAL -	$895.00

2.6 GHz COMMUNITY RECEIVER

ANTENNA UNIT MANUFACTURING COSTS FOR 100 UNITS

TABLE 5-1

5.4 Main Receiver Assembly

5.4.1 Electrical Description

Refer to Figure 5-2 for a block diagram of the main receiver
assembly. The six IF carriers from the antenna pass through the
directional filter used for the first local oscillator insertion
to a branching network assembly which sequentially picks up the
carriers through a series of circulator coupled bandpass filters.
The filtered carriers are down converted to the second inter-
mediate frequency of 70 MHz in a mixer preamplifier. Conversion
gain for the second mixer preamplifier is 15 dB. Final select-
ivity for the signal takes place in the IF filter equalizer sec-
tion of the receiver. It should be noted that the total receiver
selectivity is obtained by the branching network filter at the
first IF frequency and the IF filter at the second intermediate
frequency. The choice of channel spacing between the RF carriers
will determine the complexity of the filters to achieve adequate
rejection of adjacent carriers. A phase equalizer in this unit
compensates for phase distortion in the RF and IF filters.

The main IF amplifier provides a nominal gain of 20 dB which results
in an IF output of + 5 dBm. An automatic gain control circuit is
incorporated in this amplifier to maintain the output constant
over input level variations of + 5 to - 10 dB.

A high quality FM demodulator consisting of a limiter, discrimin-
ator and video amplifier with de-emphasis follows the IF amplifier
and provides the video signal with the sound subcarrier.

COMMUNITY TELEVISION

EARTH TERMINAL

RECEIVER ASSEMBLIES

FIGURE 5-2
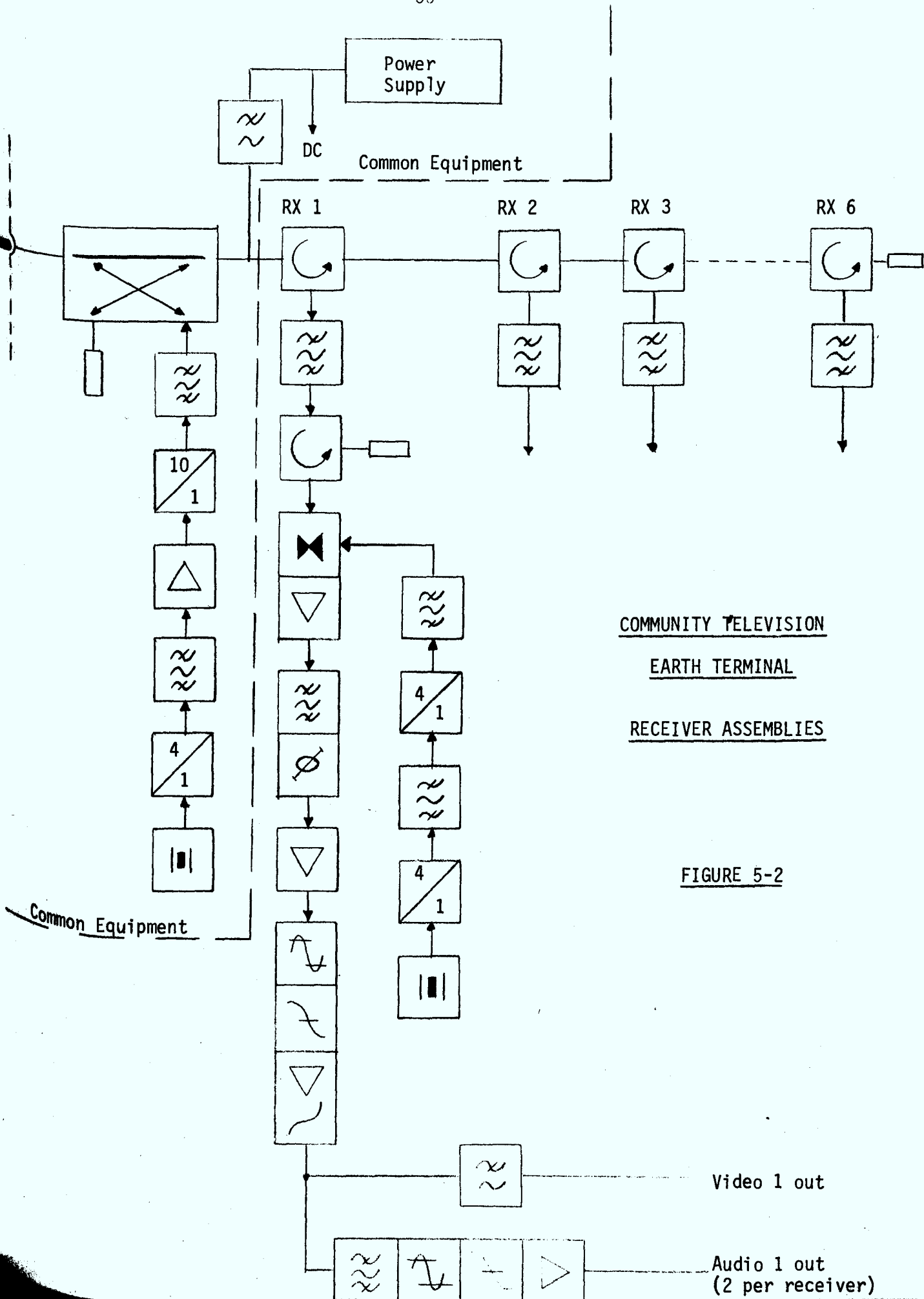
5.4.1 Electrical Description - Continued

The video output is obtained through a 4.3 MHz low pass roofing filter and the sound subcarrier is picked off in a band pass filter and passes to a limiter, discriminator and audio amplifier to provide the audio output.

The first local oscillator of 4.05 GHz is shown as being obtained by multiplying a 100 MHz crystal oscillator. A phase locked source operating directly at the final frequency could also be considered. The required output power of the source is about +15 dBm.

The second local oscillator which operates around 1.51 GHz consists of a crystal controlled oscillator with a total multiplication of 16 times. Power output of the unit is +5 dBm.

The power supply is operated from commercial A.C. mains.

5.4.2 Mechanical Description

The receivers are assumed to be mounted vertically in a standard 19 inch relay rack. Interconnections between receivers are made with semi-rigid coaxial cable. Each receiver consists of modularized units in a sheet metal shelf.

Thick film circuitry is used for most IF circuitry, the main exceptions being the filter equalizer unit and the discriminator portion of the demodulators.

5.4.3 Manufacturing Costs

To facilitate the costing of protected and unprotected configurations, the manufacturing costs for the indoor units have been broken down into two sections, one labelled "main receiver assembly" costs (Table 5-2) and the other "common equipment" (Table 5-3). The circuit elements in the these equipment categories are shown in the block diagram Figure 5-2.

Table 5-2 shows the manufacturing cost estimate of the receiver section only for the community terminal. For a single receiver the cost is $965.00. The common equipment required for a terminal of up to 6 receivers is shown in Table 5-3.

5.5 Optional Configurations

Optional configurations that have been considered in addition to the base case described are as follows:

(a) Unprotected configuration for reception of 6 simultaneous radio channels.

(b) Unprotected configuration for reception of simultaneous TV and radio channels.

(c) Protected configurations to provide 99.98% station availability.

5.5.1 Reception of 6 Simultaneous Radio Channels (Unprotected, Monophonic)

The frequency plan assumed for this case would include all the Radio channels in an RF bandwidth equivalent to one TV channel. In addition it is assumed that a reference pilot would be transmitted for frequency and level control of the receiver.

ITEM	FABRICATION	COST
Branching circulator	*Die cast housing*	$35.00
Branching filter	Conventional interdigital structure (about seven cavities)	$65.00
Terminated circulator	Die cast housing	$40.00
Mixer Preamplifier	Thick film circuitry	$65.00
Filter equalizer	Conventional LC circuitry	$100.00
IF amplifier	Thick film circuitry	$75.00
Demodulator	Thick film and conventional RLC circuitry	$175.00
2nd local oscillator	Conventional LC circuitry	$105.00
Video LP filter	Conventional LC circuitry	$15.00
Subcarrier demodulator	Thick film and conventional RLC assembly (two required)	$80.00
Wiring & Cables		$20.00
RX Shelf		$25.00
Assembly & Test		$165.00
	TOTAL –	$965.00

TABLE 5-2. <u>MAIN RECEIVER ASSEMBLY MANUFACTURING COSTS FOR 100 UNITS</u>

<u>RECEIVE SECTION ONLY EXCLUDING COMMON EQUIPMENT</u> <u>(2.6 GHz COMMUNITY RECEIVER)</u>

Rack	*Welded channel iron sections*	*$55.00*
Direction Filter	*Machined casting*	$60.00
DC LP filter	Conventional LC circuitry	$ 5.00
1st local oscillator	Thick film and conventional RLC circuitry with a conventional interdigital structure for 4 GHz filter	$175.00
Power supply	Conventional RLC circuitry	$115.00
Patch panel	Phenolic strip with audio and video jacks	$35.00
Wiring & Cables		$25.00
Assembly and test		$80.00
	TOTAL -	$550.00

-59-

2.6 GHz COMMUNITY RECEIVER

MAIN RECEIVER ASSEMBLY MANUFACTURING COSTS FOR 100 UNITS

COMMON EQUIPMENT ONLY

TABLE 5-3

5.5.1 <u>Reception of 6 Simultaneous Radio Channels</u> - Continued

The equipment configuration proposed is very similar to the in-
dividual home receiver arranged for one of two radio carrier re-
ception with somewhat better transmission performance to permit
multiple carrier operation.

Based on the costs derived in Table 4-1 for an outdoor unit ($88)
and in Tables 4-3, 4-4 for an indoor unit ($159 and $215), it is
estimated that the manufacturing costs for the equipment for this
option will be $1050 in quantities of 100 per year. The Tables
in section 4 are based on a quantity of 100,000 per year, hence
it is necessary to use a scaling factor for the lesser quantity.
This factor is derived from Figure 6-2 in the derivation of costs
and prices and in this case is a multiplication by 4.2.

The total station costs for this configuration are detailed in
sections 5.6.2 and 8.5.

5.5.2 <u>Reception of TV Channels and Radio Channels Simultaneously</u>

(Unprotected)

Reception of six radio channels simultaneously with TV is ac-
complished by adding to the common equipment one receive section
arranged in a manner similar to individual home receiver for
radio program reception. It is again assumed as in 5.5.1 above
that all the radio carriers received by the station will be
within an RF bandwidth corresponding to that of a TV channel.

5.5.2 Reception of TV Channels and Radio Channels Simultaneously
       - Continued

From the individual receiver costs in Tables 4-1, 4-3, 4-4 and
correcting for the different production rate as in 5.5.1 above,
the estimated manufacturing cost of this option for the main
receiver assembly (excluding the common equipment) is $ 820,
in quantity of 10^2 per annum. The antenna unit, the common
equipment and TV receive chain costs remain the same as for the
base case.

Examples of the total station cost are shown in sections 5.6.3
and 8.6.

5.5.3 Protected Configurations

(a) Reception of Simultaneous RV and Radio Channels

The approach adopted towards protecting the community receiving
system is to provide full 1 for 1 redundancy in the common equip-
ment and 1 for N protection for individual channel receive
sections on a manual basis.

The working antenna unit is protected by having a standby unit
connected to the antenna through a coaxial switch. The output
of this unit is fed into another coaxial switch which connects
to the transmission line. In case of failure of the working
unit the standby unit is switched into service.

5.5.3 Protected Configurations - Continued

The protection arrangements for the main receiver assemblies
are shown in Figure 5-3. In the area of the common equipment
full redundancy is provided for the 1st local oscillator and
the power supplies. Protection against failure of any of
the individual receiving chains is provided by a standby dual
conversion receiver equipped with appropriate local oscillators.
When failure occurs of one of the chains, a short on the drop
side of the circulator for that chain is switched in, directing
the signal to the standby chain which is remotely configured
for the proper operating mode.

All standby equipment except the power supplies is normally
inoperative, and power is only applied when it is required
to provide protection. In the standby receiving chain only
one of the 2nd local oscillators is energised, corresponding
to the chain needing protection.

The additional costs for providing protection to the community
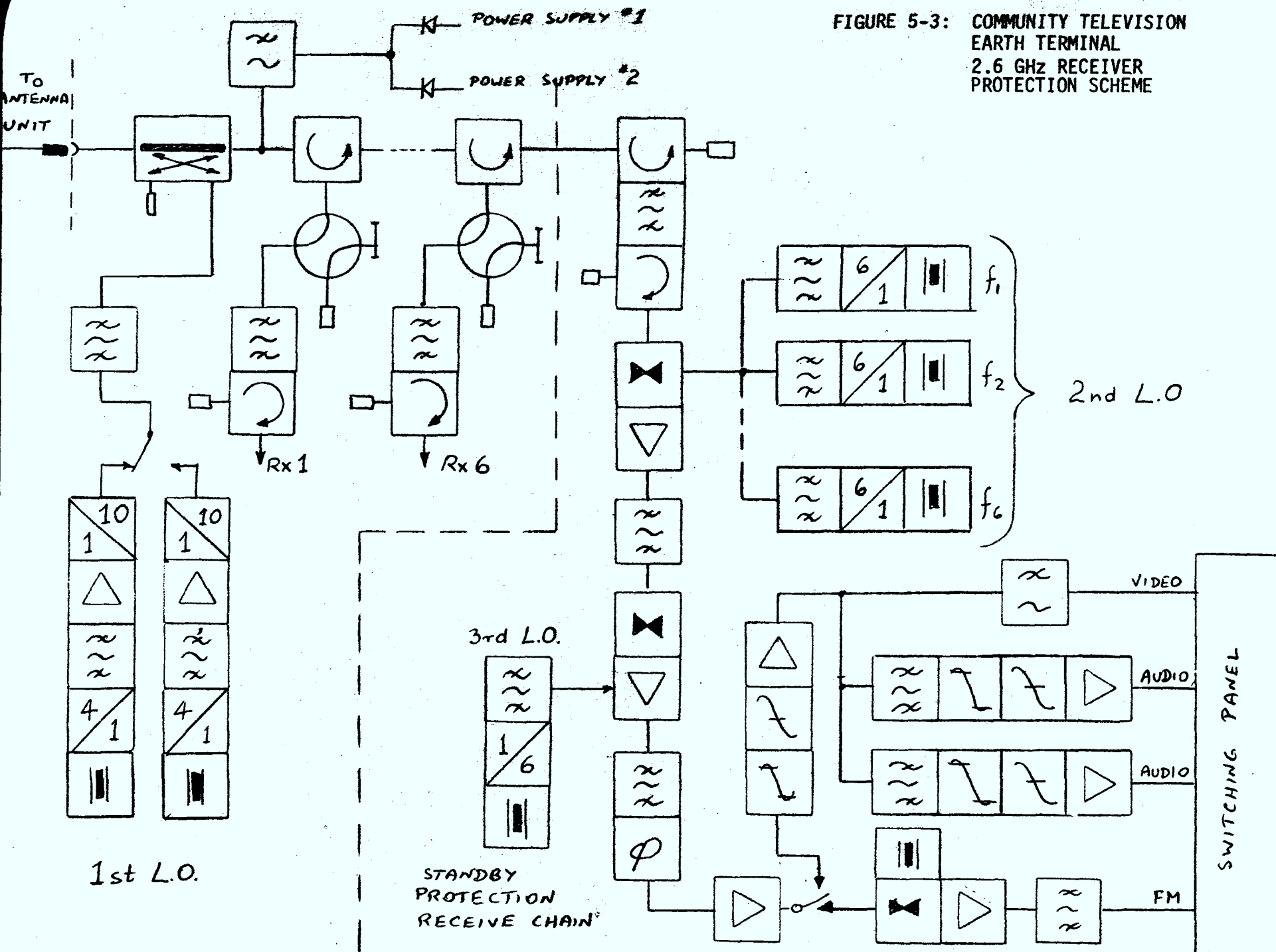receiving system are detailed in Tables 5-4, 5-5 and 5-6.

FIGURE 5-3: COMMUNITY TELEVISION EARTH TERMINAL 2.6 GHz RECEIVER PROTECTION SCHEME

ITEM	FABRICATION	COST
1st Local Oscillator and Switch	Thick film plus conventional RLC circuitry	$170.00
Terminated Circulator	Die cast housing (2 required)	80.00
All channel filter	Conventional interdigital structure	35.00
2nd Mixer preamplifier	Thick film circuitry	85.00
800 MHz IF filter	Conventional interdigital structure	35.00
3rd Mixer preamplifier	Thick film circuitry	65.00
Filter equalizer	Conventional L.C. circuitry	100.00
3rd Local oscillator	Conventional L.C. circuitry	95.00
IF Amplifier	Thick film circuitry	75.00
Demodulator	Thick film and conventional R.L.C. circuitry	175.00
Video LP Filter	Conventional L.C. circuitry	15.00
Sub-carrier demodulator	Thick film and conventional R.L.C. circuitry (two required)	80.00
Wiring, cables, control circuitry and switching panel		350.00
Rx Shelf		25.00
Assembly and Test		210.00
	TOTAL	$1595.00

If protection is also required for radio programs add $165.00.

TABLE 5-4: ADDITIONAL COSTS FOR PROVIDING PROTECTION TO THE COMMUNITY

MAIN RECEIVER ASSEMBLY (2.6 GHz)

(COMMON EQUIPMENT)

Quantity - 100 per annum

ITEM	FABRICATION	COST
Local Oscillator	Conventional LC Circuitry	$95.00
Coaxial Switch	-	$40.00
Assembly and Test		$15.00
	TOTAL	$150.00

ADDITIONAL COSTS PER RECEIVER CHAIN

FOR 2.6 GHz EARTH TERMINAL PROTECTION SCHEME

TABLE 5-5

ITEM	FABRICATION	COST
Coaxial Antenna Switch	-	$100.00
Antenna Unit	-	$895.00
Coaxial Transmission Line Switch	-	$100.00
Wiring, Cabling and Test		$125.00
	TOTAL	$1220.00

ADDITIONAL COSTS FOR PROVIDING 1 FOR 1 PROTECTION

OF THE 2.6 GHz COMMUNITY RECEIVER ANTENNA UNIT

TABLE 5-6

5.5.3 Protected Configurations - Continued

(b) Reception of Radio Channels Only

The simplest method of providing 1 for 1 protection for the case when only radio broadcast channels are received is to duplicate all the equipment at the station. The standby equipment remains normally inoperative except when required to substitute for the working equipment. Switching is manually initiated and takes place between the antenna output and the FM receiver output.

The additional costs for providing protection is:

Cost of duplicate receiver	$1050.	(Ref. item 5.5.1)
Switching and control circuitry, cabling and test	$ 250.	
Total additional cost -	$1300.	

5.6 Cost Summary (Quantity base = 10^2 per annum)

5.6.1 Base Case (Unprotected)

Antenna Unit Cost	$895	(Table 5-1)
Transmission Line Cost	$ 63	(Item 5-3)
Receiver Assembly - (common equipment)	$550	(Table 5-3)
Total Common Equipment	$1508	
For each TV receive channel	$965	(Table 5-2)

Example: A community earth station receiver equipped for 4 TV receive channels would cost

$$1508 + 4 \times \$965 = \$5368$$

5.6.2 <u>Reception of 6 Simultaneous Radio Channels</u>

(Monophonic - Unprotected)

Total manufacturing cost is $1050*which represents 19.5% of the cost of receiver equipped for 4 simultaneous TV channels (refer to 5.6.1).   *(Ref. 5.5.1)

5.6.3 <u>Reception of TV Channels and Radio</u>

<u>Channels Simultaneously</u>

(Unprotected)

Total Common Equipment Cost (from 5.6.1)	$1508	
For Each TV Receive Chain	$ 965	(Table 5-2)
For Radio Receive Chain (for 6 Radio Channels)	$ 820	(Ref. 5.5.2)

Example: An earth station receiver equipped for simultaneous reception of 4 TV channels and 6 radio channels would cost

$1508 + 4 x $965 + $820 = $6188

This is 15% more than an earth station equipped to receive only 4 TV channels (refer to 5.6.1)

5.6.4 <u>Protected Configurations</u>

(a) <u>Reception of Simultaneous TV and Radio Channels</u>

Additional cost for providing 1 for 1 $1220   (Table 5-6) protection of the Antenna Unit

5.6.4 <u>Protected Configurations</u> - Continued

(a) Continued

Additional cost for providing 1 for N

protection of the receiving chains

(common equipment only)

    (i)   Protection for TV chains only $1595   (Table 5-4)

    (ii) Protection for TV and Radio chains $1760 (Table 5-4)
                                                    (Footnote)

Total additional common equipment and $2815

   antenna unit cost for protection of
   TV only

Total additional common equipment and $2980

   antenna unit cost for protection of
   TV and Radio

Additional cost of protecting each of $ 150   (Table 5-5)

   the N equipped receive chains

   (Radio or TV)

Example (a) A protected community earth station

                receiver equipped for simultaneous recep-

                tions of 4 TV channels would cost:

Unprotected receiver cost $5368
   (from example in 5.6.1)

Additional common equipment cost for $2815

   protection of TV receive chains

Additional protection equipment for $ 600.

   each of the 4 TV receive chains

        (4 x $150)   _____

Total Cost   - $8783

5.6.4 <u>Protected Configurations</u> - Continued

This is 64% more than an unprotected receiver cost of Section 5.6.1.

Example (b)   A protected community earth station receiver equipped for simultaneous reception of 4 TV channels and 6 radio channels would cost:

Unprotected receiver cost (from example of 5.6.3)	$6188
Additional common equipment and antenna unit for protection of TV and radio receive chains	$2980
Additional protection equipment for each of the 4 TV chains and one 6-channel radio chain (5x$150)	$ 750
Total Cost	$9918

This is 85% more than an unprotected receiver cost of Section 5.6.1 arranged for only 4 TV channels.

(b) <u>Reception of Radio Channels Only</u>

Additional cost for providing 1 for 1 protection is $1300.* A protected receiver would thus cost $1050 + $1300 = $2350.

*(Ref.5.5.3)

This represents 44% of the cost of an unprotected receiver of Section 5.6.1 arranged for only 4 TV channels.

5.7 <u>Technical Characteristics</u>

Tables 5-7, 5-8 and 5-9 summarize the expected equipment and system
characteristics achievable with the proposed conceptual design of
the community receiver.

TABLE 5-7

SYSTEM PERFORMANCE CHARACTERISTICS FOR COMMUNITY

EARTH TERMINALS

Occupied Bandwidth Per Video Channel	21 MHz
System Gain	80 - 95 dB
Differential Phase	2.5^0
Differential Gain	2.5%
Video Baseband	20 Hz - 4.3 MHz
Video Output Level	1 volt p-p
Audio Baseband	100 Hz - 15 KHz
Audio Output Level - TV	+ 8 dBm
Radio FM Broadcast Band	88 to 108 MHz band
Broadcast Output Level - Radio	1 m V

TABLE 5-8

PERFORMANCE CHARACTERISTICS - ANTENNA UNIT

Noise Figure *		5 dB
First IF Frequency		1.45 GHz
Input VSWR		1.2:1
Output VSWR	1.45 GHz	1.1:1
	4.05 GHz	1.2:1
Conversion Gain	(RF to 1st IF)	58 dB
Image Rejection		50 dB
Local Oscillator Radiated Power		-40 dBm Maximum
RF 3dB Bandwidth**		260 MHz
IF 3dB Bandwidth**		260 MHz

*   Includes contribution of main receiver assembly

** Assumed channel spacing is 40 MHz. If a narrower spacing is used suitable adjustments will have to be made to the filter characteristics.

Environmental Characteristics

Temperature	$-40^{o}C$ to $+ 70^{o}C$
Humidity	0 - 95%

TABLE 5-9

PERFORMANCE CHARACTERISTICS - MAIN RECEIVER ASSEMBLY

First IF 3dB Bandwidth	28 MHz
Second Mixer Conversion Gain	15 dB
Second IF Frequency	70 MHz
Second IF 3dB Bandwidth	26 MHz
Total Receiver Gain	25 - 40 dB
First Local Oscillator Stability	.0005%
Second Local Oscillator Stability	.0005%
Input VSWR 1.45 GHz	1.1:1
4.05 GHz	1.2:1
Local Oscillator Power	+ 15 dBm

6.0 DERIVATION OF COSTS AND PRICES

6.1 General

In considering the overall manufacturing costs of the low cost earth terminals the following starting assumptions are made:

(a) The product will be developed and manufactured by a single organization.

(b) The product would be developed against an assured minimum quantity market over a five year period.

(c) The organization would be permitted to recover the total project development and introduction to manufacture costs over a five year period.

(d) Net profit before taxes would be limited to 10%, considering market situation as in (b).

6.2 Product Selling Price (Less All Taxes)

The cost elements which comprise the unit selling price (S_u) of the type of product considered are as follows:

(a) <u>Material, Labor and Burden</u> (at the factory level)   (C_f)
The burden includes only the factory indirect labor (such as production control, purchasing and quality control) and other variable expenses associated with building parts. No general capacity costs are included.

6.2 Product Selling Price (Less All Taxes) - Continued

    (b) Total Capacity Costs of operation for   (C_c)

           the different divisions of the company, i.e.,

           (a) Manufacturing

           (b) Sales

           (c) Financial

           (d) General Administration

           (e) Engineering (for product support only)

           These costs include such items as salaries, payroll
expenses, floor space charges, depreciation on buildings and machinery and product distribution costs.
These capacity costs are taken as typically 30% of
the selling price

$$\text{i.e.}\quad C_c = 0.3\, S_u \qquad (6\text{-}1)$$

    (c) Amortization of Project Costs   (C_a)

           On the basis of assumption made in Section 6.1 (c)
the project costs (P_c) would have to be recovered
over a five year period. Assuming the cost of
money to be 10% the annual amount which would have
to be recovered is

$$C_a = 0.264\, P_c \qquad (6\text{-}2)$$

If the number of units sold per annum is n then
recovery on each unit sold is

$$\frac{C_a}{n} = \frac{0.264\, P_c}{n} \qquad (6\text{-}3)$$

6.2 Product Selling Price (Less All Taxes) - Continued

(d) Net Profit (P_g)

This is taken as

$$P_g = 0.1\ S_u \qquad (6\text{-}4)$$

The relationship between the selling price and all other cost elements is thus:

$$S_u = C_f + C_c + \frac{C_a}{n} + P_g$$

$$= C_f + 0.3\ S_u + \frac{0.264\ P_c}{n} + 0.1\ S_u$$

$$= C_f + \frac{0.264\ P_c}{n} + 0.4\ S_u$$

$$\text{i.e. } 0.6\ S_u = C_f + \frac{0.264\ P_c}{n} \qquad (6\text{-}5)$$

From practical experience with origination of products of the type considered the total project costs can be related to annual production quantity as shown on Figure 6-1. This curve has been constructed based on discussions with a number of manufacturers and from the authors' own experience with these type of products. Reference (1) proved also helpful although it relates to items costing significantly more than those considered here.

The total project costs can thus be expressed by the relation

$$P_c = b.S_t \qquad (6\text{-}6)$$

Where S_t is 80% of the total expected dollar sales volume throughout the product life.

(1) Estimating engineering costs for new and old products, P.F. Ostwald, Engineering Digest, June 1973.

6.2 Product Selling Price (Less All Taxes) - Continued

Substituting (6) in (5) and considering that

$$S_t = 5n.S_u \quad \text{we have}$$

$$S_u = \frac{C_f}{(0.6 - 1.32\ b)} \qquad (6\text{-}7)$$

6.3 Material, Labor and Burden Costs

In practice when product development is planned selling price is first determined based on market data or other factors. Subsequently cost objectives at the factory level are established and the total project expenditures are estimated that will permit realization of these objectives. Usually, in a competitive market place, the greater the market volume the lower the product costs need to be. Project costs however, increase as a function of product volume. This is mainly because it requires much more ingenuity, design and tooling effort to come out with an inexpensive but sophisticated product that can be produced in large volume as compared to one that is required in smaller volume but can tolerate a higher selling price.

All the information presented in this report is based on the approach that the effort relating to product design and introduction into volume production i.e. the project costs, would be determined by the total expected sales volume during the life of the product. This would then result in a certain factory cost which would be different for the projected production level per year.

6.3 Material, Labor and Burden Costs - Continued

Figure 6-2 shows the material, labor and burden costs (C_f) and selling price (S_u) for a product designed for various annual quantity productions normalized to C_f for quantity of 10^5/year. The curve is based on discussions held with a number of people during the study as well as on authors' prior experience.

6.4 Project Costs

It is interesting to establish some order of magnitude figures for project cost connected with developing and introducing to standard manufacture the two products considered in Sections 4 and 5.

6.4.1 Home Receiver

From Section 4 the total factory cost (C_f) of the individual home receiver (1 of 2 TV plus 2 audio) at 2.6 GHz designed for a volume of 10^5 per annum is $274.00.

Using equation (6-7) the selling price for such a receiver should be

$$S_u = \frac{C_f}{(0.6 - 1.32\ b)}$$

"b" from Figure 6-1 is approximately 2.5%

thus

$$S_u = \frac{274}{(0.6 - 1.32 \times 0.025)}$$

$$= \$484$$

6.4.1 Home Receiver - Continued

Total volume of sales in five years is

$$S_t = 5 \times 10^5 \times 484 = \$242 \text{ Million}$$

The project costs P_c would thus be approximately $\$242 \text{ M} \times 0.025 = \$6$ Million

These costs do not include development of a small antenna complete with a circular polarized feed and mount. Project costs in this case would be sensitive to antenna size and could easily exceed one million dollars.

To account for other variables and unknowns which usually come in during any program of this type a safe figure to allow for project costs of the complete station is between $8 and $10 Million.

6.4.2 Community Receiver

The total factory cost (C_f) from Section 5 for an unprotected community receiver at 2.6 GHz equipped to receive four simultaneous television channels each with two audio is $5368. The quantity base is 10^2 per annum.

Using equation (6-7) and obtaining "b" from Figure 6-1 as 0.2 the selling price for such a receiver should be

$$S_u = \frac{5368}{(0.6 - 1.32 \times 0.2)} = \$16,000.$$

6.4.2 <u>Community Receiver</u> - Continued

Total volume of sales in five years is

$$S_t = 5 \times 10^2 \times 16000 = \$8.0 \text{ Million}$$

The project costs P_c would thus be

approximately $\$8.0 \times 0.2 = \$1.6$ Million

Again the cost here does not include development of a suitable

antenna which could be an additional $0.5 to $0.8 Million.

6.5 <u>Sales Tax</u>

Sales taxes at the Federal and Provincial levels impact directly on

the price that the end user has to pay and they therefore, need to be

taken into account.

Federal tax is generally taken as 12% of the selling price while the

Provincial taxes vary throughout Canada and are as high as 8% in Quebec.

A multiplier of 1.2 is used throughout this report to convert the

selling price into what the end user will have to pay including all

taxes.

FIGURE 6-1: PROJECT COSTS AS A FUNCTION OF QUANTITY PRODUCTION

Pc (%) = Total Project Costs to Standard Production & Product Support

───

Total Sales (80% Value in 5 Years)

(TRANSMISSION TYPE PRODUCTS)

FIGURE 6-2: MATERIAL, LABOR AND BURDEN COSTS (C_f)
AND
UNIT SELLING PRICE (S_u)
as a function of
ANNUAL PRODUCTION QUANTITY (n)
(Normalised to C_f for 10^5/year)

- Capacity Costs C_c = 0.3 S_u
- Net Profit P_g = 0.1 S_u
- Amortization period for
  project costs P_c in 5 years

Normalised Costs
$\left(\dfrac{S_u \text{ or } C_f}{C_f \text{ for } 10^5/\text{year}}\right)$
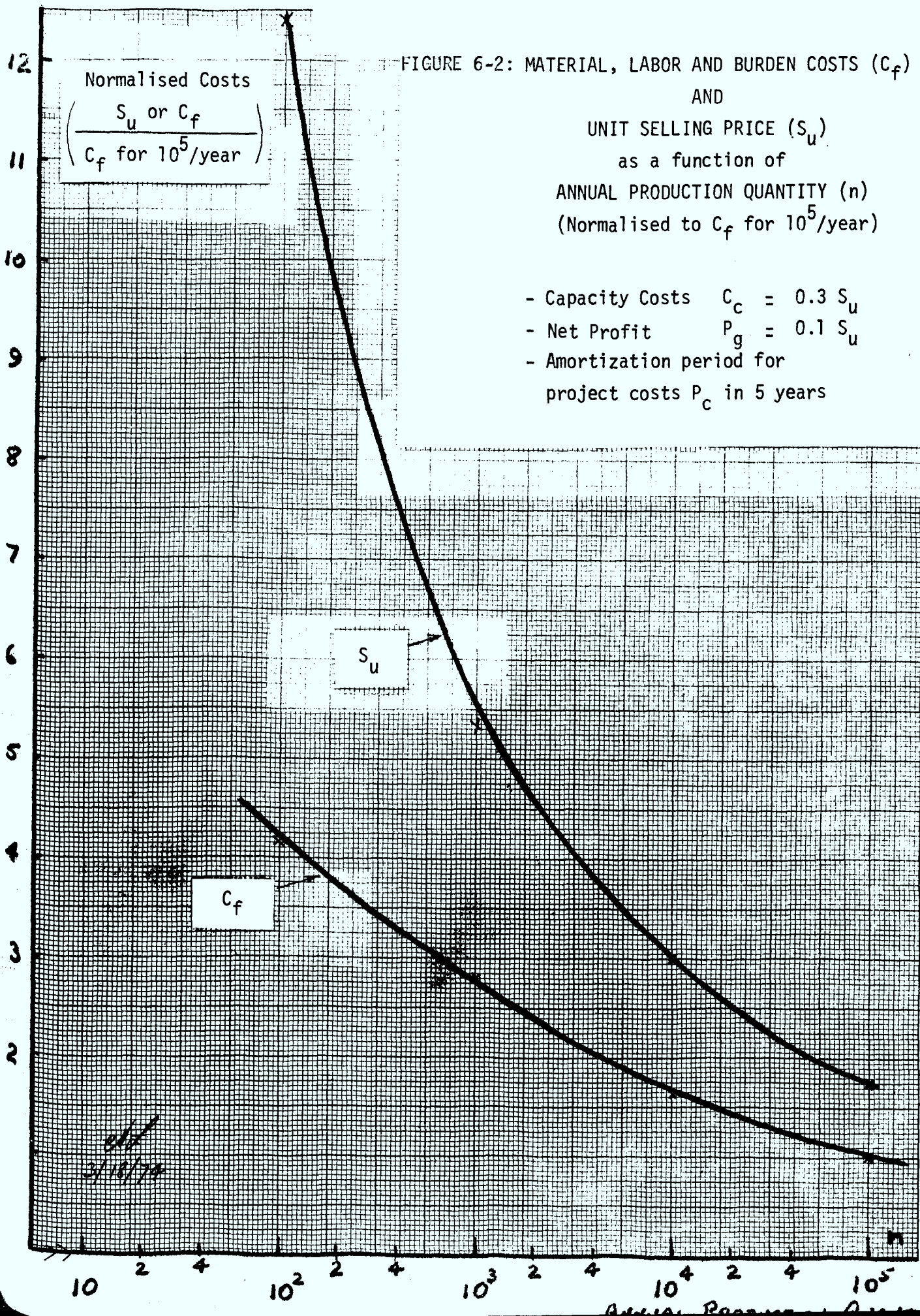
7.0 PRICES OF SUB-SYSTEMS AND SERVICES

7.1 General

This section provides pricing information on sub-systems and services which when used in conjunction with the base case receiver costs will permit estimation of costs to the end user for a variety of earth station configurations.

Sub-systems and services which need to be considered are low-noise pre-amplifiers, antennas with feeds and installation costs. When antennas 10 ft. in diameter and larger are considered then site pre-paration costs must be included.

7.2 Receiver Sub-System

Design concepts for the individual home and community receivers as presented in Sections 4 and 5 were proposed on the basis of achieving a reasonable performance at low cost.

Depending on the requirements for station $G/_T$ it may be more advantageous to consider adding a low noise preamplifier such as parametric amplifier or tunnel diode amplifier ahead of the standard receiver instead of increasing the antenna diameter.

Incremental costs for equipping low noise preamplifiers to standard receivers for 2.6 GHz and 12 GHz bands are shown in Tables 7-1 and 7-2. It will be noted that the quantity base for which costs are shown is not

Type of Amplifier	Noise Figure	Incremental* Price $(TIP)	Quantity Base	Earth Station Noise Temperature °K	Ts dB
Paramp	1.2	5200	500	200	23.0
Paramp	2.0	3450	500	250	24.0
Transistor	3.5	1150	500	450	26.5
Transistor	4.0	720	500	630	28.0
Mixer	9.0	No Change	-	2080	33.2

Base Case Price
$(TIP)

*With respect to the Base
 Case as follows:

Base Case Individual Home Station	6.0	575	10^5	915	29.6

Note: Ts is the total earth station noise temperature allowing 50°K for

the antenna and using the receiver of Section 4.0

TABLE 7-1: 2.6 GHz Incremental Sub-System Costs

Individual Home Receiver

Type of Amplifier	Noise Figure (dB)	Incremental * Price $(TIP)	Quantity Base	Earth Station Noise Temperature °K	Ts dB
Parametric Amplifier (Single Stage)	3.5	1450	100	500	27.0
Parametric Amplifier (Two Stage)	1.6	10800	200	250	24.0
Tunnel Diode Amplifier (Two Stage)	5.5	807	100	960	29.8

		Base Case Price $(TIP)			

* With respect to the Base
  Case as follows:

Base Case Individual Home Receiver	9.0	575	10^5	2120	33.3

Note: Ts is the total earth station noise temperature allowing 100°K for

the antenna and using a receiver with a noise figure of 9 dB.

TABLE 7-2:   12 GHz Incremental Sub-System Costs

Individual Home Receiver

7.2 Receiver Sub-System - Continued

uniform. During the process of gathering information from manufacturers
it was found that there were individual preferences to discuss prices
for certain specific quantities. In most cases these quantities were
recently quoted to some other users.

In general the pricing information in the 12 GHz band lacks the preci-
sion which is normally associated with the 2 to 4 GHz band pricing
exercises. Many of the earth station components have not been built
and manufacturers, when pressed for informal quotations, arrived at
them either by extrapolation from experience in lower frequency bands
or by estimating probable costs based on military hardware. Thus the
12 GHz information needs to be viewed with a certain amount of caution.

To estimate the prices for quantities other than those provided in the
Tables, Figure 7-1 has been prepared showing normalized prices as a
function of quantity production. For example, assume that it is required
to know the selling price of an amplifier in quantity 10^5 knowing that
its price in quantity of 500 is \$1150. From Figure 7-1 the ordinate
for a quantity of 500 is 3.85. The estimated selling price for a
quantity of 10^5 would thus be \$1150 x $\frac{1}{3.85}$ = \$300.

Figure 7-2 is similar to Figure 7-1 except it covers a smaller range of
manufactured quantities and is normalized to a selling price for 10^2
which corresponds to the base case quantity for the community receiver.
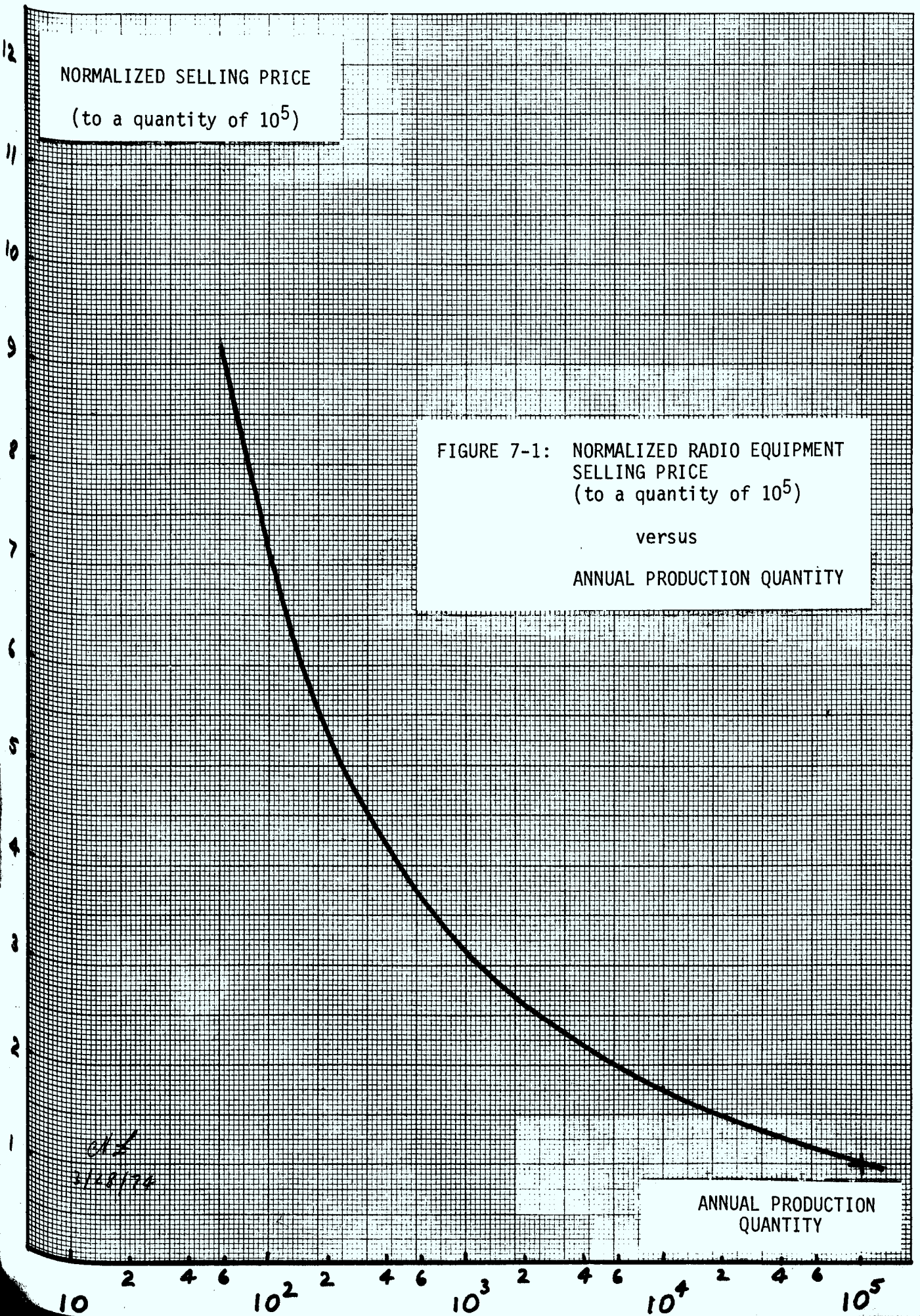
NORMALIZED SELLING PRICE

(to a quantity of 10^5)

FIGURE 7-1: NORMALIZED RADIO EQUIPMENT SELLING PRICE
(to a quantity of 10^5)

versus

ANNUAL PRODUCTION QUANTITY

ANNUAL PRODUCTION QUANTITY

-89-

FIGURE 7-2: NORMALIZED RADIC EQUIPMENT SELLING PRICE (to a quantity of 10^2) versus ANNUAL PRODUCTION QUANTITY
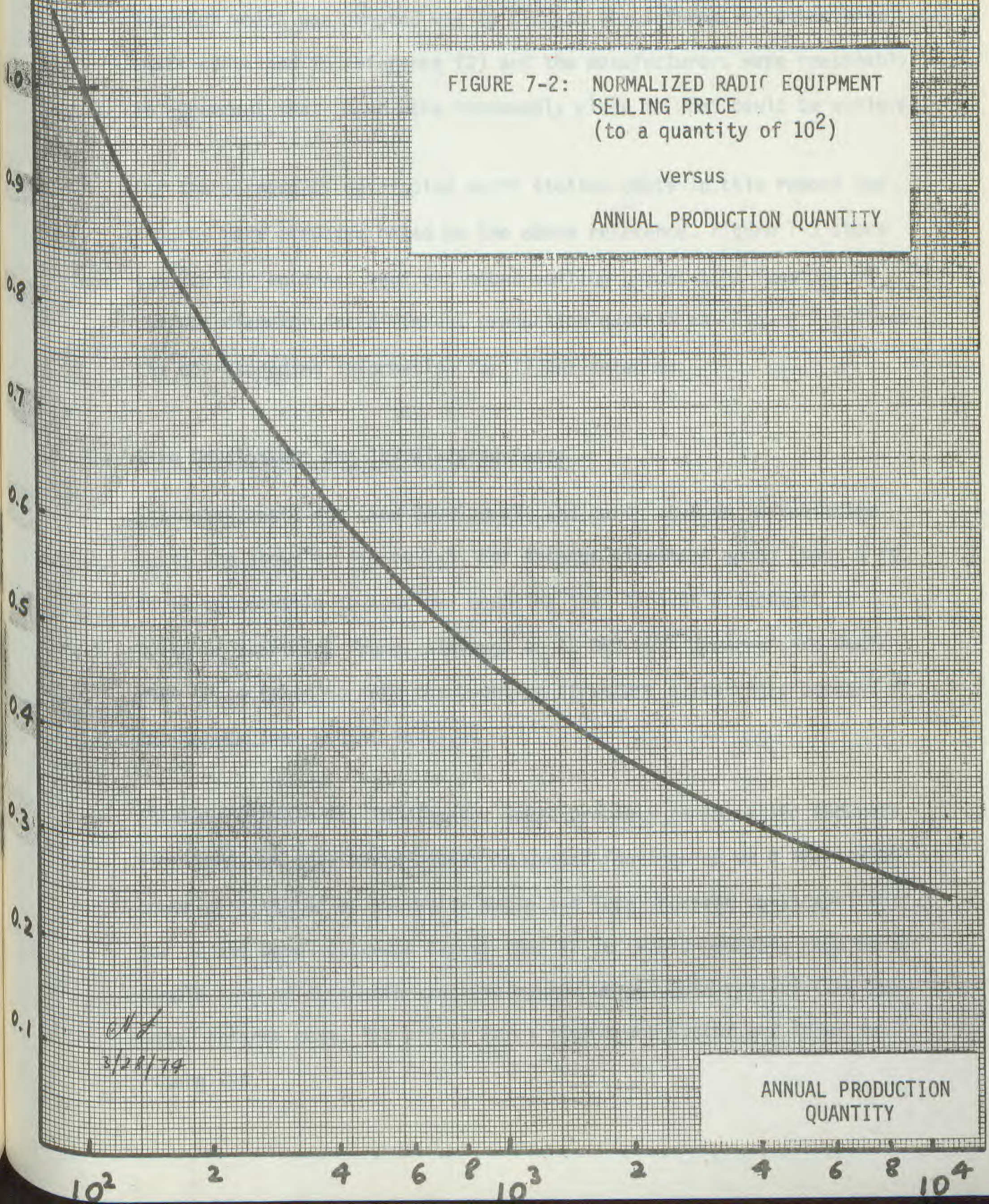
7.3 Antenna and Feed

During visits to manufacturers it was difficult to obtain exact cost
projections as a function of quantity for different antenna sizes. An
approach which was adopted was to discuss the information on antenna
costs contained in reference (2) and the manufacturers were reasonably
in agreement that these were reasonably close to what could be achieved.

For the purpose of developing earth station costs in this report two
figures were prepared based on the above reference. Figure 7-3 shows
the 2.6 GHz antenna, feed and mount selling prices as a function of
antenna diameter for different production quantities. Figure 7-4 shows
the corresponding information for 12 GHz antennas.

7.4 Site Development and Installation Costs

Estimated costs for site development and earth station installation
costs are shown in Figure 7-5. For antenna diameters up to about 8 ft.
it is conceivable to consider mounting them through attachment to
house or apartment frame. Although at 12 GHz much greater care would
have to be taken to make the mounting structure quite rigid because of
the narrow beam widths involved.

Antennas above 8 ft. in diameter would probably be installed separate
from homes or apartments either in ground footings or on a small stub
tower as dictated by elevation angle and·local horizon considerations.
For 12 GHz band, antennas larger than 10 ft. would probably require a
simple form of automatic tracking system which would reflect into the
total antenna cost. The prices for a step track system are shown in
Figure 7-4.

(2)   Optimization in the Design of a 12 gigahertz Low cost Ground

Receiving System for Broadcast Satellites.

K. Ohkubo, c.c. Han et-al, NASA CR-121185.

FIGURE 7-3: 2.6 GHz ANTENNA SELLING PRICE (TIP)
(including mount & feed)

versus

ANTENNA DIAMETER

FIGURE 7-4: 12 GHz ANTENNA SELLING PRICE (TIP)
(including mount & feed)
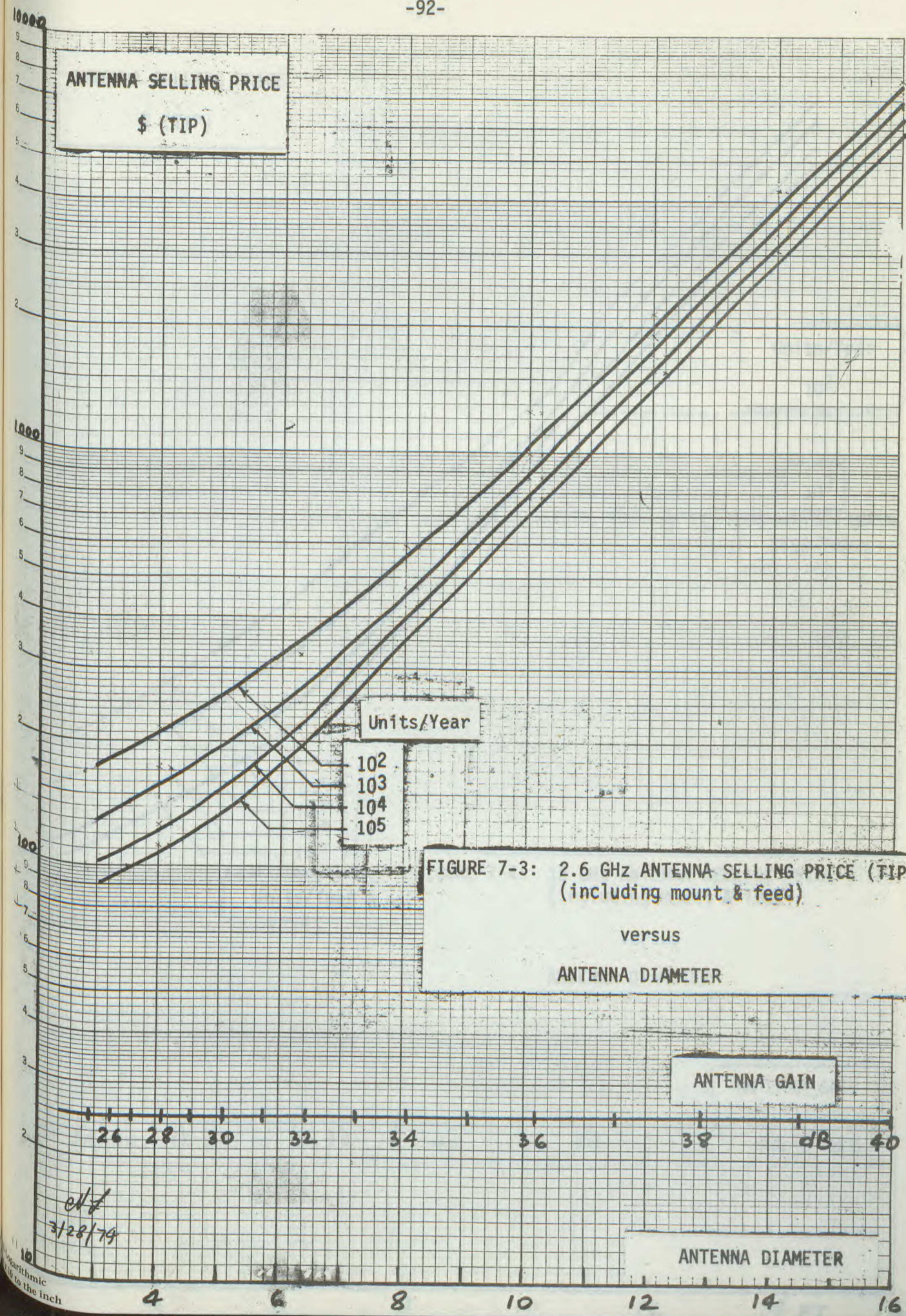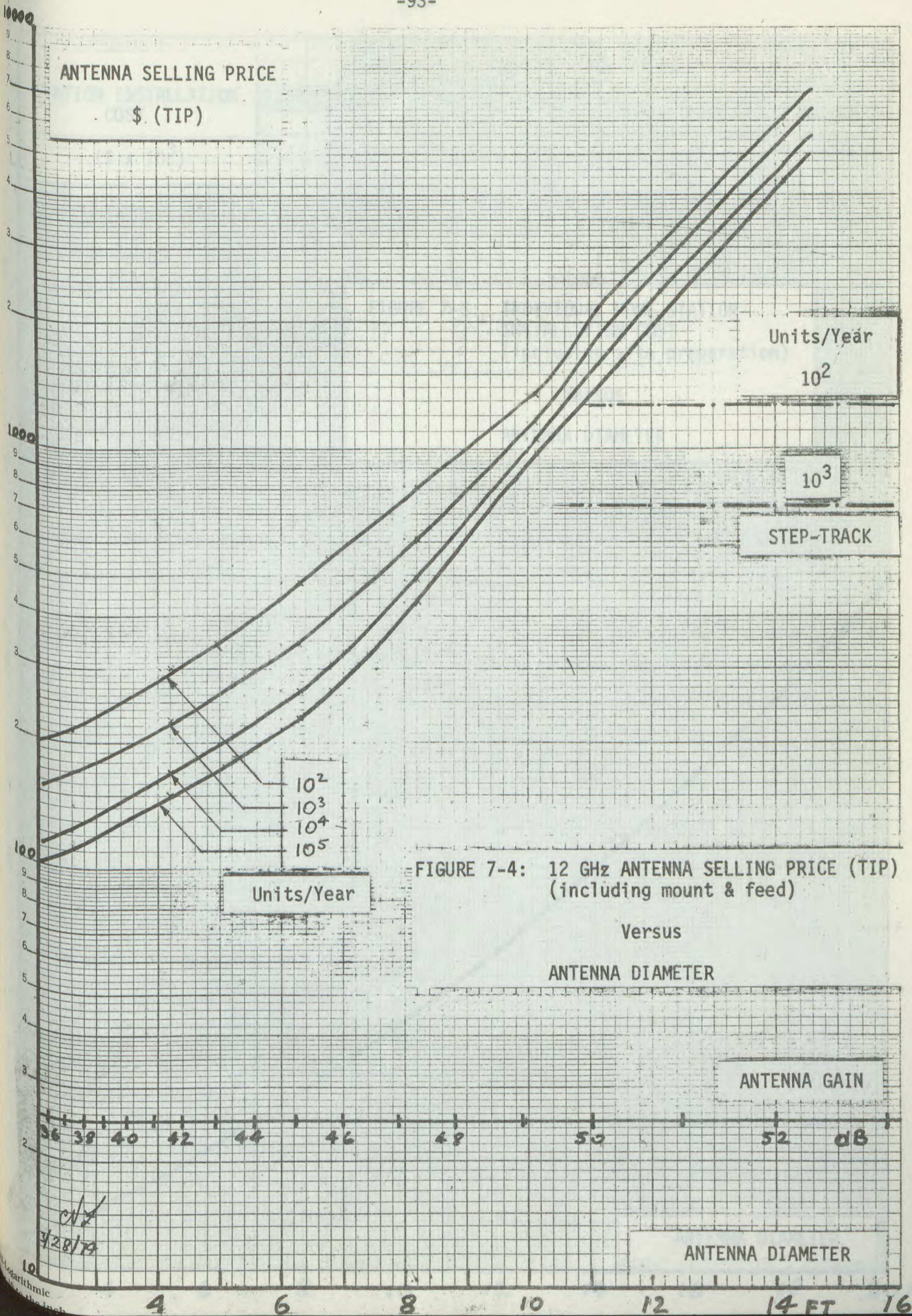
Versus

ANTENNA DIAMETER

FIGURE 7-5: INDIVIDUAL HOME STATION INSTALLATION COST (including site preparation) Versus ANTENNA DIAMETER
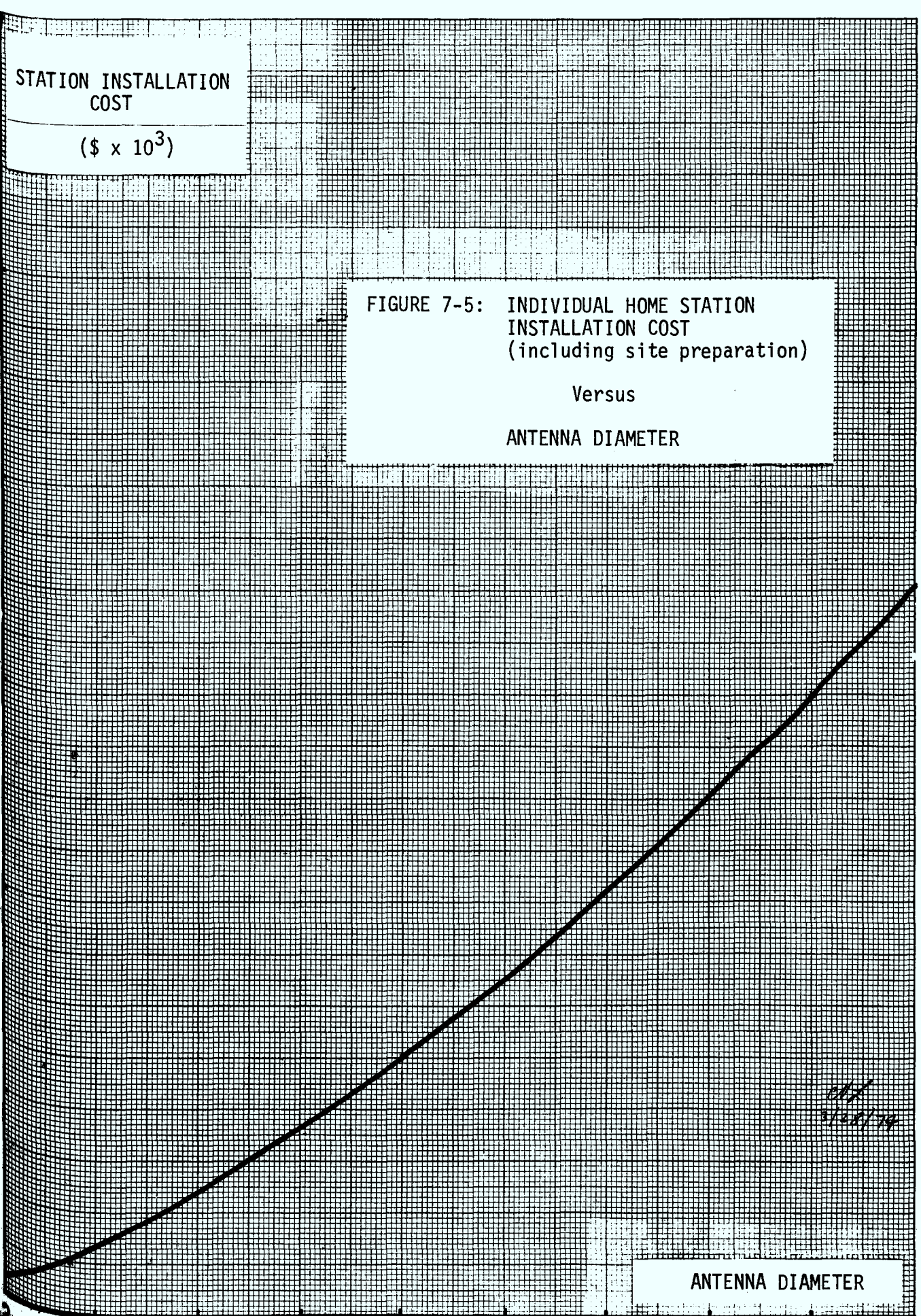
8.0 SPECIFIC CONFIGURATIONS EXAMINED

This section shows cost build-up of a number of specific earth station configurations which were examined. The earth station figure of merit $(G/_T)$ and the manufactured annual quantity were chosen to correspond with studies done by others relating to the overall planning of Canadian domestic broadcasting - satellite service. Any other configurations can be readily worked out using the methods indicated in the section below.

An approach, taken to determine the costs, was to use the individual home and community base cases as reference especially in the area of electronic equipment. No cost allowances have been made in any of the configurations for floor space to house the radio equipment.

Both the 2.6 GHz and 12 GHz configurations are presented although detailed costing effort has only been expended in the 2.6 GHz band. It is felt that it would be possible to design 12 GHz equipment for the same cost as that in the 2.6 GHz band by permitting the noise figure at 12 GHz to increase to 9 dB, as compared with 5 or 6 dB at 2.6 GHz. As mentioned in Section 7 there still exists in industry a lack of confidence in making estimates in the 12 GHz band and therefore the figures presented should be regarded as less accurate than those for the 2.6 GHz band. It is also expected that 15 to 20% more design effort may be required to achieve the same results at 12 GHz as at 2.6 GHz.

The configurations examined are as follows:

8.0 SPECIFIC CONFIGURATIONS EXAMINED - Continued

<u>Section Reference</u>

	2.6 GHz Band	12 GHz Band

Unprotected Configurations

A. Individual Home Terminal

   1. One of Two TV Channels Each With Two Audio   8.1   8.10

   2. One of Two Radio Channels   8.2   8.11

   3. One of Two TV Channels <u>or</u> One of Two Radio Channels   8.3   8.12

B. Community Earth Station

   1. Simultaneous Reception of 4 TV Channels   8.4   8.13

       each with two Audio

   2. Simultaneous Reception of 6 Radio Channels   8.5   8.14

   3. Simultaneous Reception of 4 TV Channels   8.6   8.15

       and 6 Radio Channels

Protected Configurations

A. Community Earth Station

   1. Simultaneous Reception of 4 TV Channels   8.7   8.16

       each with two Audio

   2. Simultaneous Reception of 6 Radio Channels   8.8   8.17

   3. Simultaneous Reception of 4 TV Channels   8.9   8.18

       and 6 Radio Channels

The quantities considered were:

     Individual Home Receiver   20,000 per annum

     Community Receiver   400 per annum

The earth station figures of merit considered were:

8.0 SPECIFIC CONFIGURATIONS EXAMINED - Continued

Individual Home Terminal $\qquad$ $G/_T = -4$ dB/^{O}K at 2.6 GHz

$G/_T = 12.2$ dB/^{O}K at 12 GHz

Community Earth Station $\qquad$ $G/_T = 0.4$ dB/^{O}K at 2.6 GHz

$G/_T = 15.2$ dB/^{O}K at 12 GHz

8.1 Individual Home Terminal - 2.6 GHz Band

One of Two TV Channels Each With Two Audio

Reference parameters (a) $G/_T$ = -4 dB/^OK

(b) Quantity base = 20,000 per annum

- Station noise temperature achievable with the base case receiver of 6 dB noise figure is 915°K or 29.6 dB^{O}K from Table 7-1

- To achieve a $G/_T$ of -4 dB/^{O}K the required antenna gain is 29.6 - 4 = 25.6 dB. The corresponding antenna diameter is 3.1 ft. with 55% efficiency.

- Figure 8-1 has been prepared for the base case receiver using the costs from Section 4 and the relationship between selling price and factory cost from Figure 6-2. Receiver selling price, S_u, including taxes for a quantity of 20,000 per annum is $830.

  i.e. S_u (TIP) = $830.

  (TIP = Tax Included Price)

- From Figure 7-3 the selling price of a 3.1 ft. antenna is $100.

  i.e. Antenna price (TIP) = $100.

- From Figure 7-5 the station installation cost is $160.

- Total installed terminal cost is

  S_u (TIP) + Antenna Price (TIP) + Installation Cost

  = $830 + $100 + $160 = $1090

RADIO EQUIPMENT
SELLING PRICE , S_u (TIP)
($)

FIGURE 8-1: RADIO EQUIPMENT SELLING PRICE (TIP)
FOR INDIVIDUAL HOME RECEIVER
EQUIPPED TO RECEIVE ONE OF TWO
TV CHANNELS
(UNPROTECTED CONFIGURATION)

Versus

ANNUAL PRODUCTION QUANTITY

ANNUAL PRODUCTION
QUANTITY
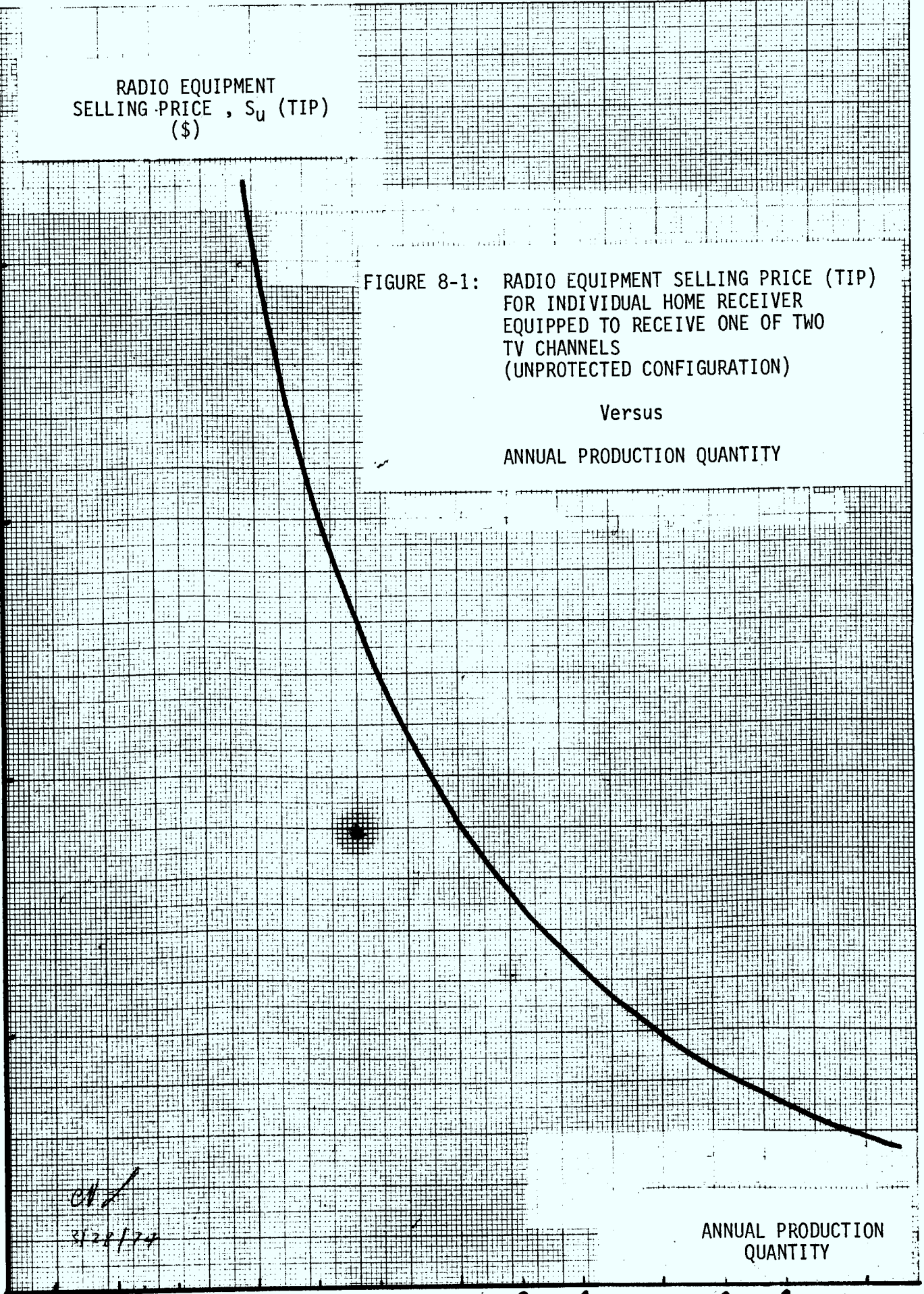
8.2 Individual Home Terminal - 2.6 GHz Band

One of Two Radio Channels

Reference parameters   (a) G/T = -4 dB/$^{\circ}$K

(b) Quantity base = 20,000 per annum

- As in Section 8.1 the required antenna size to achieve the above G/T is 3.1 ft.

- From Section 4.5 the cost of a receiver, arranged for reception of only the radio channels, is 17% less than for the base case

  i.e. S_u (TIP) = \$830 x 0.83 = \$690

- The antenna price and the installation costs remain the same as in Section 8.1

- Total installed terminal cost is

  \$690 + \$100 + \$160 = \$950.

8.3 Individual Home Terminal - 2.6 GHz Band

One of Two TV Channels Each With Two Audio

or One of Two Radio Channels

Reference parameters   (a) $G/_T$ = -4dB/^{O}K

(b) Quantity base = 20,000 per annum

- As in Section 8.1 the required antenna size to achieve the above $G/_T$ is 3.1 ft.

- From Section .4.5 the costs of a receiver arranged for reception of TV and radio channels is 20% more than for the base case

    i.e. S_u (TIP) = \$830 x 1.2 = \$1000

- The antenna price and the installation costs remain the same as in Section 8.1

- Total installed terminal cost is

    \$1000 + \$100 + \$160 = \$1260

8.4 Community Stations - 2.6 GHz Band

(Unprotected)

Simultaneous 4 TV Channels Each With Two Audio

Reference parameters: (a) $G/_T$ = +0.4 dB/^{O}K

(b) Quantity base = 400 per annum

- Station noise temperature achievable with the base case receiver of 5 dB noise figure is 677° K or 28.3 dB

- To achieve a $G/_T$ = 0.4 dB the required antenna gain is 28.3 + 0.4 = 28.7 dB. The corresponding antenna diameter is 4.4 ft. with 55% efficiency.

- Figure 8-2 has been prepared for the base case receiver using the costs from Section 5 and the relationship between selling price and factory cost from Figure 6-2. Thus receiver selling price S_u including taxes for a quantity of 400 per annum is $11,400.

    i.e. S_u (TIP) = $11,400

- From Figure 7-3 the selling price of a 4.4 ft. antenna is $190 for a quantity of 400 per annum

    i.e.   Antenna price (TIP) = $190

- From Figure 7-5 the station installation cost for individual home type of station is $300.

    The electronic equipment at the community stations will be more complex and therefore an allowance needs to be made for additional installation and commissiong effort. This is taken as 15% of the radio equipment cost which for this case is 0.15 x $11,400 = $1710

- Total installed station cost is S_u (TIP) + Antenna Price (TIP) + installation cost and commissioning

    = $11,400 + $190 + $300 + $1710 = $13600

(Note that cost of floor space for equipment is not included)

FIGURE 8-2: RADIO EQUIPMENT SELLING PRICE (TIP) FOR COMMUNITY RECEIVER EQUIPPED TO RECEIVE "N" SIMULTANEOUS TV CHANNELS (UNPROTECTED CONFIGURATION)

Versus

ANNUAL PRODUCTION QUANTITY
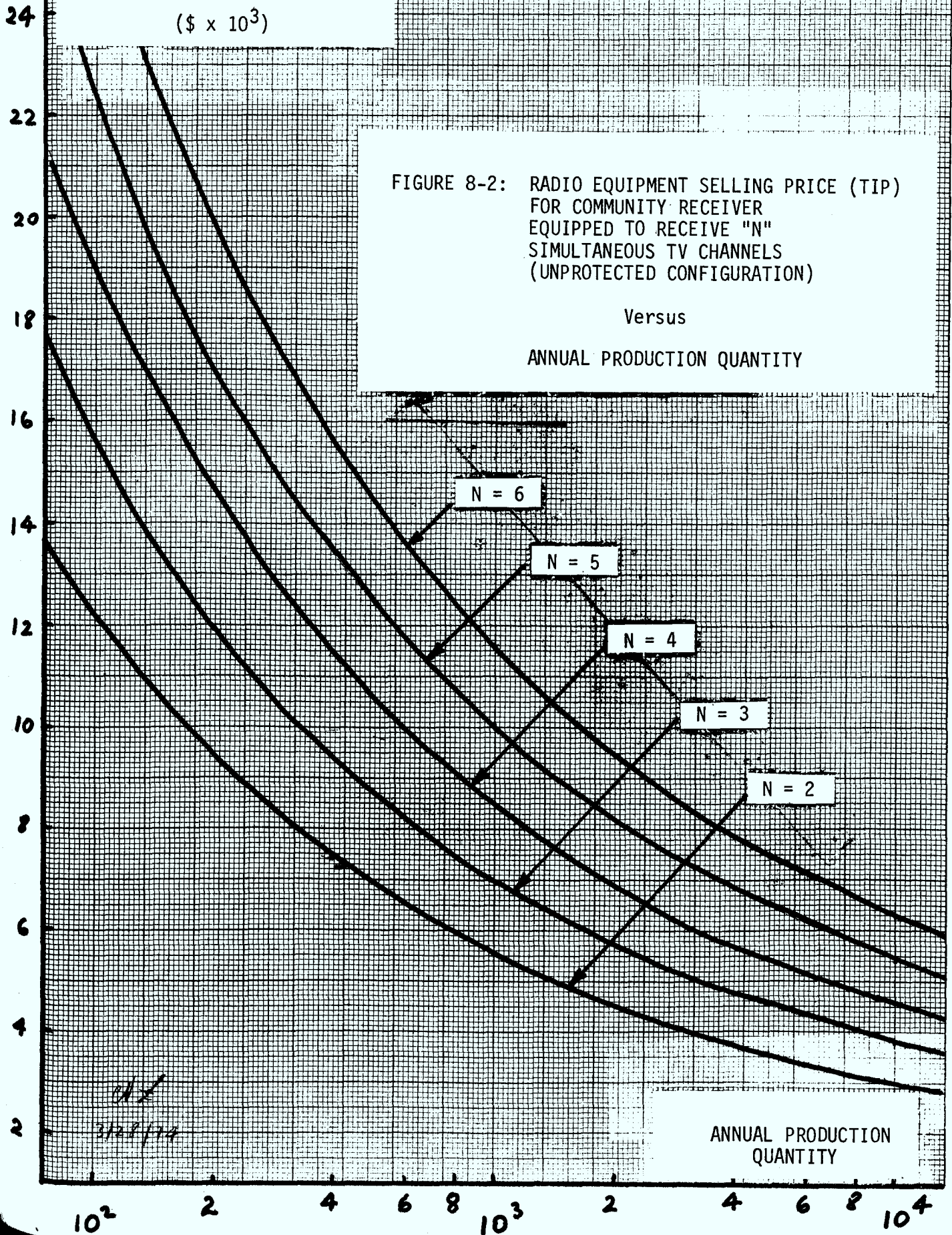
8.5 <u>Community Station</u> - 2.6 GHz Band

(Unprotected)

<u>Simultaneous 6 Radio Broadcast Channels</u>

Reference parameters   (a) $G/_T = + 0.4$ dB/^{o}K

(b) Quantity Base = 400 per annum

- As in Section 8.4 the required antenna size to achieve the above $G/_T$ is 4.4 ft.

- From Section 5.6.2 the cost of a receiver arranged for reception of 6 simultaneous radio channels is 19.5% of the cost for the base case

   i.e. S_u (TIP) = \$11,400 x 0.195 = \$2220

- The antenna price and installation costs remain the same as in Section 8.4

   The radio equipment installation and commissioning costs are 0.15 x \$2220 = \$330

- Total installed station cost is

   \$2220 + \$190 + \$300 + \$330 = <u>\$3040</u>

8.6 Community Station - 2.6 GHz Band

(Unprotected)

Simultaneous 4 TV Channels Each With Two Audio
And 6 Radio Broadcast Channels

Reference parameters: (a) $G_{/T}$ = + 0.4 dB/^{O}K

(b) Quantity base = 400 per annum

- As in Section 8.4 the required antenna size to achieve the above $G/_T$ is 4.4 ft.

- From Section 5.6.3 the cost of a receiver arranged for 4 TV and 6 radio channels is 15% more than the cost for the base case.

i.e. S_u (TIP) = \$11,400 x 1.15 = \$13,110

- The antenna price and installation costs remain the same as in Section 8.4

The radio equipment installation and commissioning costs are 0.15 x \$13,110 = \$1970

- Total installed station cost is

\$13,110 + \$190 + \$300 + \$1970 = \$15,570

8.7 Community Station - 2.6 GHz Band

(Protected)

Simultaneous 4 TV Channels Each With Two Audio

Reference parameters: (a) $G/_T$ =+0.4 dB/^{o}K

(b) Quantity base = 400 per annum

- As in Section 8.4 the required antenna size to achieve the above $G/_T$ is 4.4 ft.

- From Section 5.6.4 (a), example (a), the cost of providing protection for this configuration is 64% more than for the base case

    i.e. S_u (TIP) = \$11,400 x 1.64 = \$18,700

- The antenna price and installation costs remain the same as in Section 8.4. The radio equipment installation and commissioning costs are 0.15 x \$18,700 = \$2800.

- Total installed station cost is

    \$18,700 + \$190 + \$300 + \$2800 = \$21,990

8.8 Community Station - 2.6 GHz Band

(Protected)

Simultaneous 6 Radio Broadcast Channels

Reference parameters   (a) $G/_T = + 0.4$ dB/^{O}K

(b) Quantity base = 400 per annum

- As in Section 8.4 the required antenna size to achieve the above $G/_T$ is 4.4 ft.

- From Section 5.6 (b) the cost of providing protection for this configuration is 44% of the base case

    i.e. S_u (TIP) = 0.44 x $11,400 = $5020

- The antenna price and installation costs remain the same as in Section 8.4. The radio equipment installation and commissioning costs are 0.15 x $5020 = $750

- Total installed station cost is

    $4950 + $190 + $300 + $750 = $6190

8.9 Community Station - 2.6 GHz Band

(Protected)

Simultaneous 4 TV Channels Each With Two Audio And 6 Radio Broadcast Channels

Reference parameters: (a) $G/_T$ = +0.4 dB/^{O}K

(b) Quantity base = 400 per annum

- As in Section 8.4 the required antenna size to achieve the above $G/_T$ is 4.4 ft.

- From Section 5.6.4 (a), example (a), the cost of providing protection for this configuration is 85% more than the base case

  i.e. S_u (TIP) = 1.85 x $11,400 = $21,090

- The antenna price and installation costs remain the same as in Section 8.4. The radio equipment installation and commissioning costs are 0.15 x $21,090 = $3160

- Total installed station cost is

  $21,090 + $190 + $300 + $3160 = $24,740

8.10 Individual Home Terminal - 12 GHz Band

       One of Two TV Channels Each With Two Audio

       Reference parameters: (a) $G/_T$ = +12.2 dB/^{O}K

                                (b) Quantity base = 20,000 per annum

- To achieve the above $G/_T$ a base case receiver (with 9 dB noise figure) preceded by a tunnel diode amplifier has been chosen. As shown in Table 7-2 the achievable earth station noise temperature is 960°K or 29 dB ^{O}K

- The required antenna gain to obtain a $G/_T$ = + 12.2 dB/^{O}K is 29.8 + 12.2 = 42 dB. The corresponding antenna diameter is 4.4 ft. with 55% efficiency.

- From Figure 8-1 the base case receiver selling price S_u, including taxes for a quantity of 20,000 per annum is $830

    i.e. S_u (TIP) = $830

- From Table 7-2 and Figure 7-1 the selling price including taxes of a tunnel diode amplifier (TDA) in quantity of 20,000 per annum is $164

    i.e. TDA (TIP) = $164

- From Figure 7-4 the selling price of a 4.4 ft. antenna in the required quantity is $170

    i.e. Antenna price (TIP) = $170

- From Figure 7-5 the station installation cost is $300

- Total installed terminal cost is S_u (TIP) + TDA (TIP) + antenna price (TIP) + installation cost

          = $830 + $164 + $170 + $300 = <u>$1464</u>

8.11 Individual Home Terminal - 12 GHz Band

One of Two Radio Channels

Reference:parameters: (a) G/T = +12.2 dB/^{O}K

(b) Quantity base = 20,000 per annum

- As in Section 8.10 the required antenna size to achieve the above G/T is 4.4 ft.

- From Section 8.2 the cost of a receiver arranged for reception of only the radio channels is

$$S_u \text{ (TIP)} = \$690$$

- The TDA and antenna price as well as the installation costs remain the same as in Section 8.10

- Total installed terminal cost is

$$\$690 + \$164 + \$170 + \$300 = \underline{\$1324}$$

8.12 Individual Home Terminal - 12 GHz Band

One of Two TV Channels Each With Two Audio

or One of Two Radio Channels

Reference parameters: (a) $G/_T$ = +12.2 dB/^{o}K

(b) Quantity base = 20,000 per annum

- As in Section 8.10 the required antenna size to achieve the above $G/_T$ is 4.4 ft.

- From Section 8.3 the cost of a receiver arranged for reception of TV and radio channels is

S_u (TIP) = $1000

- The TDA and antenna price as well as the installation cost remain the same as in Section 8.10

- Total installed terminal cost is

$1000 + $164 + $170 + $300 = $1634

8.13 Community Station - 12 GHz Band

(Unprotected)

Simultaneous 4 TV Channels Each With Two Audio

Reference parameter   (a) $G/_T = 15.2$ dB/^{O}K

                              (b)   Quantity base = 400 per annum

- To achieve the above $G/_T$ a base case receiver (with 9 dB noise figure) preceded by a tunnel diode amplifier has been chosen. As shown in Table 7-2 the achievable earth station noise temperature is 960°K or 29.8 dB ^{O}K

- The required antenna gain to obtain a $G/_T = 15.2$ dB/^{O}K is 29.8 + 15.2 = 45 dB. The corresponding antenna diameter is 6.3 ft. with 55% efficiency.

- From Figure 8-2 the base case receiver selling price S_u, including taxes for a quantity of 400 per annum is

         S_u (TIP) = \$11,400

- From Table 7-2 and Figure 7-2 the selling price including taxes of a TDA in quantity of 400 per annum is

         TDA (TIP) = \$484

- From Figure 7-4 the selling price of a 6.3 ft. antenna in the required quantity is \$400

- From Figure 7-5 the station installation cost is \$520 for individual home type of station. Additional commissioning costs to allow for increased complexity of the community station are taken as 15% of the radio, equipment cost. For this case this is 0.15 x (11,400 + 484) = \$1780

8.13 <u>Community Station</u> - 12 GHz Band - Continued

- Total installed station cost is

  S_u (TIP) + TDA (TIP) + Antenna Price (TIP)

  + Installation and commissioning cost

  = $11,400 + $484 + $400 + $520 + $1780

  = <u>$14,580</u>

8.14 Community Station - 12 GHz Band

(Unprotected)

Simultaneous 6 Radio Broadcast Channels

Reference parameters: (a) $G/_T = + 15.2$ dB/^{O}K

(b) Quantity base = 400 per annum

- As in Section 8.13 the required antenna size to achieve the above $G/_T$ is 6.3 ft.

- From Section 8.5 the cost of a receiver arranged for reception of 6 simultaneous radio channels is

$$S_u \text{ (TIP)} = \$2220$$

- The TDA and antenna price and installation costs remain the same as in Section 8.13. Additional radio equipment commissioning costs are $0.15 \times (2220 + 484) = \$410$

- Total installed station cost is

$2220 + \$484 + \$400 + \$520 + \$410$

$= \underline{\$4034}$

8.15   Community Station - 12 GHz Band

(Unprotected)

Simultaneous 4 TV Channels Each With Two Audio and

6 Radio Broadcast Channels

Reference parameters: (a) $G_{/T}$ = 15.2 dB/^{O}K

(b)   Quantity base = 400 per annum

-   As in Section 8.13 the required antenna size to achieve the

above $G_{/T}$ is 6.3 ft.

-   From Section 8.6 the cost of a receiver arranged for 4 TV

and 6 radio channels is

S_u (TIP) = \$13,110

-   The TDA and antenna price and installation costs remain the

same as in Section 8.13. Additional radio equipment commis-

sioning costs are 0.15 (13,110 + 484) = \$2040

-   Total installed station cost is

\$13,110 _ \$484 + \$400 + \$520 + \$2040

= \$16,554

8.16 Community Station   - 12 GHz band

(Protected)

Simultaneous 4 TV Channels Each With Two Audio

Reference parameters   (a) $G/_T$ = 15.2 dB/^{o}K

(b)   Quantity base = 400 per annum

- As in Section 8.13 the required antenna size to achieve the above $G/_T$ is 6.3 ft.

- From Section 8.7 the cost of a protected receiver for 4 TV channels is

S_u (TIP) = $18,700

- The TDA cost is doubled while the antenna price and installation costs remain the same as in Section 8.13. Additional radio equipment commissioning costs are 0.15 ($18,700 + (2 x $484)) = $2950

- Total installed station cost is

$18700 + (2 x $484) + $400 + $520 + $2950

= $23,540

8.17 Community Station - 12 GHz Band

(Protected)

Simultaneous 6 Radio Broadcast Channels

Reference parameters   (a) $G/_T$ = + 15.2 dB/^{O}K

                        (b) Quantity base = 400 per annum

- As in Section 8.13 the required antenna size to achieve the above $G/_T$ is 6.3 ft.

- From Section 8.8 the cost of protected receiver for 6 radio channels is

    S_u (TIP) = $5020

- The TDA cost is doubled while the antenna price and installation costs remain the same as in Section 8.13. Additional radio equipment commissioning costs are 0.15 ($5020 + (2 x $484)) = $900

- Total installed station cost is

    $5020 + (2 x $484) + $400 + $520 + $900

    = $7808

8.18 Community Station - 12 GHz Band

(Protected)

Simultaneous 4 TV Channels Each With Two Audio and

6 Radio Broadcast Channels

Reference parameters   (a) $G/_T$ = + 15.2 dB/^{O}K

(b) Quantity base = 400 per annum

- As in 8.13 the required antenna size to achieve the above
  $G/_T$ is 6.3 ft.

- From Section 8.9 the cost of protected receiver for 4 TV and
  6 Radio channels is

  S_u (TIP) = $21090

- The TDA cost is doubled while the antenna price and installation
  costs remain the same as in Section 8.13. Additional radio
  equipment commissioning costs are 0.15 ($21090 + (2 x $484)) =
  $3310

- Total installed station cost is

  $21090 + (2 x $484) + $400 + $520 + $3310

  = $26,288

SECTION III

TECHNOLOGY PROJECTION

1.0 INTRODUCTION

In the manufacturing of the type of equipment used in microwave receivers, it has rarely been the case that new technology has immediately resulted in lower cost. There is usually a high development and start up cost involved, and this has to be recovered. The ideal situation, if low cost is the criterion,is the manufacture of a well proven design in continuous production runs.

The position as far as manufacturers are concerned, is that in contemplating a service for 1980, the basic design and technology should be visible now. The present trend in industry shows that a new technology has a period of five to eight years from first introduction in the laboratories to commercial production. The breakdown of costs and time involved is usually 10-15% towards product development, 10% towards marketing, customer information etc. and the rest in design to manufacture. Thus, allowing 18 months to two years for product design, especially for large production (10^4-10^5) per year, design to manufacture can quite easily require a 4-5 year program.

Within the industrial scene described above, any projection has to take into account the existing technology and to what extent this can be refined, improved, etc. to achieve the low cost targets required.

In this section of the report, the existing technology is reviewed and projections are made. This is followed by a discussion on emerging technology.

2.0 EXISTING TECHNOLOGY

For all the functional elements required in a receiver for Direct Satellite Broadcasting, the technology is available to achieve the necessary performance. For the products to be available for implementation of the service by 1980, it will be necessary for industry to refine existing techniques and develop manufacturing processes to produce microwave equipment many times in excess of current production rates.

The technology as it exists in Canada in thick film circuitry is limited and not geared towards very high volume. The processes are manual and will take two to three years to automate. Further adaption will be necessary to provide multi-layer networks. Microstrip techniques have been used in passive circuits, but there does not seem to have been any progression towards integrated circuits at microwave frequencies to the extent reported in other countries (1).

Laboratory work is continuing on FET circuitry and lower cost parametric amplifiers.

3.0 EMERGING TECHNOLOGY

In attempting to forecast advances in microwave solid state technology
to 1980, two areas need to be considered i.e. solid state devices and
complete circuits.

a) Solid State Devices

The feeling in the microwave industry at present is that in the
device area, advances in material and manufacturing technology
should bring down the cost of bulk devices such as GUNN diodes
and Schottky mixer diodes. This will primarily benefit the designs
in the 12 GHz band. In the field effect transistors, especially
of the low noise small geometry type, the main effort to date
has been to extend the frequency range of these devices to 6 GHz
and higher frequencies. However, progress in improving yields
and device tolerances has not been as rapid as was expected only
two or three years ago. New microwave devices traditionally are
introduced at high initial price levels and subsequently over a
period of years the price drops down as manufacturing technology
improves. This has been the case initially with bi-polar transis-
tors in the 2 to 4 GHz bands, however, recently the prices of these
devices have been significantly increasing because the projected
improvements in yields have not been materializing. It is even
questionable whether large volumes such as 10^5 per year could be
successfully produced, without resulting in an overproduction of
lower class of microwave transistors which the market could not
absorb.

Advances are being made slowly in the area of Field Effect
Transistors permitting, perhaps by 1985, applications of these
devices in low cost 12 GHz design. At present, transistors in
this frequency band are made in small batches, laboratory
type production resulting in high expense. As with the bi-polar
transistors, a number of problems will need to be solved in the
area of material and fabrication technology. As compared to
silicon, GaAs is a material whose characteristics are quite
sensitive to environmental conditions. It will be difficult
for many years to come to achieve similar stabilities over a
wide temperature range for amplifiers at 12 GHz using GaAs FET
transistors as compared to 2.6 GHz bi-polar silicon devices.
It is therefore not realistic to consider that FET transistors
could be introduced into front ends of 12 GHz low cost earth
stations by 1980. A serious problem is that Canada does not have
this technology at all, which makes it even more difficult, even
if funds are available, to foresee how some breakthrough could
be achieved in the required direction.

b) Microwave Integrated Circuits

In spite of the efforts made by industry in the last few years
to reduce the costs and to produce high-volume of high quality
hybrid microwave integrated circuits, it seems that the goal is
not yet within reach, although some progress has been made. The
major drawback towards reducing costs is the fact that the active
devices must be separately prepared and singly bonded (2).

This results in a relatively high labour content which remains in the product regardless of volume. It is expected that this situation will prevail in the low noise low level circuit field until the late 1970's.

The ultimate answer to low cost lies in microwave monolithic integrated circuits. The conventional junction-isolated monolithic IC may be usable up to the 2 GHz range, but probably not beyond, because the coupling through the isolation junction is large.

Potential techniques being worked on for higher frequency monolithic circuits are dielectric isolation, air isolated beam lead and silicon on sapphire. It will take however, many years before suitable I.C. circuits will emerge from labs into mass production at costs low enough for the applications considered here.

Again, as with the microwave field effect transistors, manufacturing technology for the sophisticated monolithic integrated circuits does not presently exist in Canada. The companies surveyed do not feel that there is enough future business at microwave frequencies to warrant spending large sums of development funds at this time.

It is noted that in the base design the cost of the indoor unit is more than 50% of the total manufacturing cost and is about 90% more than the outdoor unit. In the search for breakthroughs in the microwave devices the major cost areas of i.f. filters, amplifiers etc. should not be forgotten.

Just as many as the advances in microwave technology have stemmed
from radar development, it is conceivable that the present work
on surface acoustic wave (SAW) devices in this field may result
in key applications in communication and television receiver equip-
ment.

While there is very little possibility that amplifiers using SAW
devices can compete with integrated transistors in their own right
(3), the integration of filters, i.f. amplifiers, discriminators,
oscillators into monolithic structures with semi-conductor over-
lay could hold some promise for low cost production and high per-
formance.

((1)* Application of Integrated Receiver Circuit Techniques
        to Microwave Receivers. G.E.C. Journal of Science and
        Technology, Vol.40, No.2, 1973, T. Hoxley.

 (2)* Microwave Transistors Bi-Polar and Field Effect Today
        and Tomorrow, Sanehiko Kekihana, Nerem 1972.

 (3)* Surface-Acoustic-Wave Components, Devices and Applications.
        J.D. Maines and E.S. Paige, IEE Review, October 1973, Vol.120.

SECTION IV

CONCLUSIONS

The interest shown by the Canadian manufacturing industry and the activity towards the design of earth terminals for a Direct Broadcast Satellite Service has been minimal compared to other countries and requires a stimulus to create the right atmosphere for development. This situation may come from their belief that such a service is many years away and is therefore low on the scale of priorities, or it may be that lack of manufacturing technology in microwave integrated circuits and microwave solid state devices delays, or prevents, the experimentation that is reported on from U.S.A., Japan and Europe.

Regardless of the cause, the conclusion is that taking into account the problems of implementing new technology into commercial production, the receivers required for a Direct Broadcasting Satellite Service in Canada in 1980 would be similar to those described in this study and at corresponding prices.

From this study, a realistic appreciation of the total cost impact to the end-user can be obtained thus providing a basic input to the further planning of a Direct Broadcast Satellite Service.

There is already considerable expertise in Canada in the field of satellite communications. Given the right stimulus and direction, there is every reason to be optimistic that the problems highlighted above could be resolved and that a viable Canadian Direct Satellite Broadcasting Service could be implemented.

SECTION V

RECOMMENDATIONS

In the further planning of a Direct Broadcasting Satellite System
it is essential that the marketing, research, development and manu-
facturing groups in industry become involved. To plan a system and
forecast costs and prices based on isolated inputs can,and does,lead
to major variances in project costs, which only become visible as
the project progresses.

The impact on industry has to be considered and planned for. If we
assume only $ 250.00 price per set for individual reception and it
is established that the market is 100,000 sets per year, a sales vo-
lume of $ 25 million per year is greater than the current sales of
the microwave industry in both the domestic and export markets.

At the same time, industry has to plan its future and,in the satellite
field in particular, decide what it is going to do for an encore to the
CTS program in 1980. The lack of Canadian technology in microwave
integrated circuits and microwave solid state components has a limi-
ting effect on the overall viability if we are to rely on the impor-
tation of complete monolithic circuits, leaving very little left for
the home industry.

It is recommended therefore that in the further planning and studies,
the inputs be carefully considered and reviewed by representatives
of the three major arms in industry (1) Marketing, (2) R & D, (3)
Manufacturing.

In the discussions with various companies and administrations during the course of this study, they pointed out many times that there is a vast amount of work to be done on system definition before arriving at product specifications. Other countries appear to have a wealth of information based on analytical studies and measurements from their Broadcast Authority laboratories and research groups, well supported by work in the R & D organizations of their own industry. From this depth of knowledge, and integrated industry activity, the claims of some countries to be ahead in system design could be justified.

In Canada however, the make-up of manufacturing industry, government and operational company research is different and possibly more co-operation is required to arrive at well defined system objectives and product designs that are particular to this country's needs. It could well be that, just as for the data industry, it was found necessary to set up a task force, a somewhat similar approach has to be considered for a Direct Broadcasting Satellite Service.

The role of this task force would be to bring together the different groups within the Broadcast, Satellite and Microwave industries, to determine the systems design and plan the experimentation required within the Canadian industry.

In three major areas alone, the suppliers have made specific statements on the need for further study and measurements. These are:-
1) Frequency Planning
2) Colour transmission performance with low C/N ratios
3) The compatibility of Terrestrial and Satellite Broadcasting services.

These recommendations are the outcome of observations and of hearing opinions expressed in the course of the study. Their inclusion here is in accordance with the stated objectives to report on other aspects of Satellite Broadcasting that may have to be considered in the further planning.

A STUDY OF LOW COST EARTH TERMINALS
FOR A DIRECT BROADCAST SATELLITE
SERVICE.

DATE DUE
DATE DE RETOUR