



microwave JOURNAL

EURO-GLOBAL EDITION □ VOL. 25, NO. 1 □ JANUARY 1982



SATELLITE COMMUNICATIONS

- Satcom Overview
- Japanese Domsat Experiments
- Intelsat V
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microwave JOURNAL

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VOLUME 25, NUMBER 1
USPS 396-250
JANUARY 1982

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ON THE COVER: Avantek's integrated MARISAT earth terminal subsystem is featured in the graphic depicting MARISAT services. The Cover Story starts on page 98. Artwork courtesy of Avantek: Randy Hirai, art director; Artist: Dave Pauley, Palo Alto, CA.

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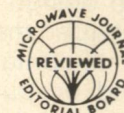
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Intelsat V System Summary and Initial Launch Operations

JOHN T. NEER AND CHRISTOPHER F. HOEBER

Ford Aerospace & Communications Corporation
Palo Alto, CA

INTRODUCTION

INTELSAT V is the latest in a series of commercial communications satellites designed to relay telephony and television signals among the member INTELSAT nations. The INTELSAT global network employs satellites in equatorial orbit above the Atlantic, Pacific, and Indian Oceans. Satellites in these three locations are capable of linking virtually all the inhabited areas of the world.

The INTELSAT system has grown with the advances in communications satellites since the launch of INTELSAT I in 1965¹. Ford Aerospace & Communications Corporation was selected as prime contractor to produce initially seven but subsequently twelve flight spacecraft for the INTELSAT V mission. The first spacecraft was delivered in October 1980, with launch on an Atlas-Centaur vehicle in early December.

INTELSAT spacecraft growth is illustrated by Figure 1. The large electrical power requirements and the payload complexity of the INTELSAT V mission led to selection of the body-stabilized configuration shown. INTELSAT V will be the largest commercial communication satellite ever built. The solar arrays alone extend 15.7 m from tip to tip (the height of a five-story building), and the antenna tower looms 6.5 m above the spacecraft base.

Modular construction is employed to simplify assembly. The

antenna module consists of seven communications antennas and six telemetry, command, and ranging (TC&R) antennas, mounted to a truss. All microwave communication electronics, filters, and switches are attached to the communications module, which constitutes half of the spacecraft body. Housekeeping functions are installed in the matching half of the spacecraft body, designated the support subsystems module.

New technologies have been balanced with flight-proven hardware to meet the major design constraints of reduction in mass and program risk. To reduce mass, graphite fiber reinforced plastic (GFRP) materials are used extensively in fabricating the antenna reflectors, antenna feed array, feed support structure truss, microwave filters, waveguide, and solar array. A new contiguous-band output multiplexer reduces the number of 4 GHz transmit antennas from four to two.

INTELSAT V Foreign Contributions

INTELSAT V was designed and manufactured by a strong association of international firms with enviable reputations for space hardware. Eleven companies from six foreign countries are supplying major spacecraft components. Particularly noteworthy is the association of six of these contractors (listed below) that are formally teamed with FACC. Each is responsible for design, manufacture, and the testing of hardware.

- *Aerospatiale [France]*. Aerospatiale initiated the structural concept that forms the basis of the spacecraft modular design. It is supplying the main body structure and thermal control.

- *Messerschmitt-Bolkow-Blohm [Germany]*. MBB designed and produced the attitude control subsystem and the solar arrays.
- *Selenia [Italy]*. Selenia designed and built the six telemetry, command, and ranging antennas, and two 14/11 GHz spot beam antennas. It also built the command receiver and the telemetry transmitter, which combine to form a ranging transponder for determination of spacecraft position in transfer orbit.
- *Mitsubishi Electric Corporation [Japan]*. Mitsubishi is responsible for both the 6 GHz and the 4 GHz earth coverage antennas, and also manufactures the power control electronics and the telemetry and command digital units from a FACC design.
- *Thomson-CSF [France]*. Thomson built the 10 W, 11 GHz TWTs (10 per spacecraft).
- *GEC-Marconi [England]*. Marconi produces the 11 GHz beacon transmitter used for earth station antenna tracking.

SPACECRAFT DESIGN SUMMARY

The INTELSAT V spacecraft is a high-capacity, commercial communications satellite. Each satellite will be a radio-frequency relay, the space links in the vast INTELSAT communications network. As many as 6 INTELSAT V satellites will be operated simultaneously to interconnect more than 300 INTELSAT earth terminals. Depending on the operational configuration employed by INTELSAT, each satellite will carry up to 12,000 two-way telephone circuits and two color television transmissions.

The spacecraft three-axis-sta-

* Delivered at the 32nd Congress of the International Astronautical Federation, September 1981, Rome, Italy.

** This paper is based upon work performed under the sponsorship of the International Telecommunication Satellite Organization (INTELSAT). Any views expressed are not necessarily those of INTELSAT.

bilized design is composed of a box-shaped main body 1.65 x 2.01 x 1.77 m, containing the electronics and propulsion subsystems, and a truss-type tower holding the antennas. The spacecraft, shown in Figure 2 is oriented in space with the 2.01 x 1.77 m sides facing north and south. The solar arrays extend from this surface

the highly successful FM-1 and FM-2 launches.

Payload Description

The INTELSAT V payload, illustrated in simplified form in Figure 3 consists of 7 antennas that provide separate receive and transmit beams plus an 11 GHz beam for ground station tracking and

MHz through four-fold frequency reuse at 6/4 GHz and two-fold frequency reuse at 14/11 GHz. The multiple frequency reuse requires state-of-the-art control of antenna sidelobe and cross-polarization performance as well as spacecraft attitude determination and control. Tests verifying this performance will be discussed in detail.

Objective of Tests

A great deal of importance was attached to the performance measurements of the first INTELSAT V flight spacecraft. There are two fundamental objectives of the test:

- To verify that payload hardware is unchanged due to the launch and space environment.
- To validate the prelaunch data base for on-orbit traffic modeling and traffic assignment.

Test Summary

As indicated in Table 1 the correlation to predictions based on ground test results is superb. The prelaunch data base has been validated and INTELSAT expects to achieve an in-service capacity equivalent to performance 2 dB better than specification level in all channels.

One minor anomaly is the spontaneous tripoff of three 11 GHz TWTAs. This was not unexpected due to a ground history of such events. One known cause of such events is a microdischarge within the tube, and several design improvements have been made to minimize the occurrence of such events effective on the third INTELSAT V to be launched. Investigation is also under way (utilizing the prototype spacecraft) of the possibility of turnoffs induced by bus voltage variations. The first two on-orbit tripoffs occurred approximately 2 weeks after launch, the third approximately 6 months later. All three TWTAs were subsequently checked and found to be operating normally. It is worth noting that the FM-2 spacecraft has passed through a period of very intense solar activity with no evidence of any static discharge events and no perturbations of digital circuitry which have occurred on previous INTELSAT spacecraft.

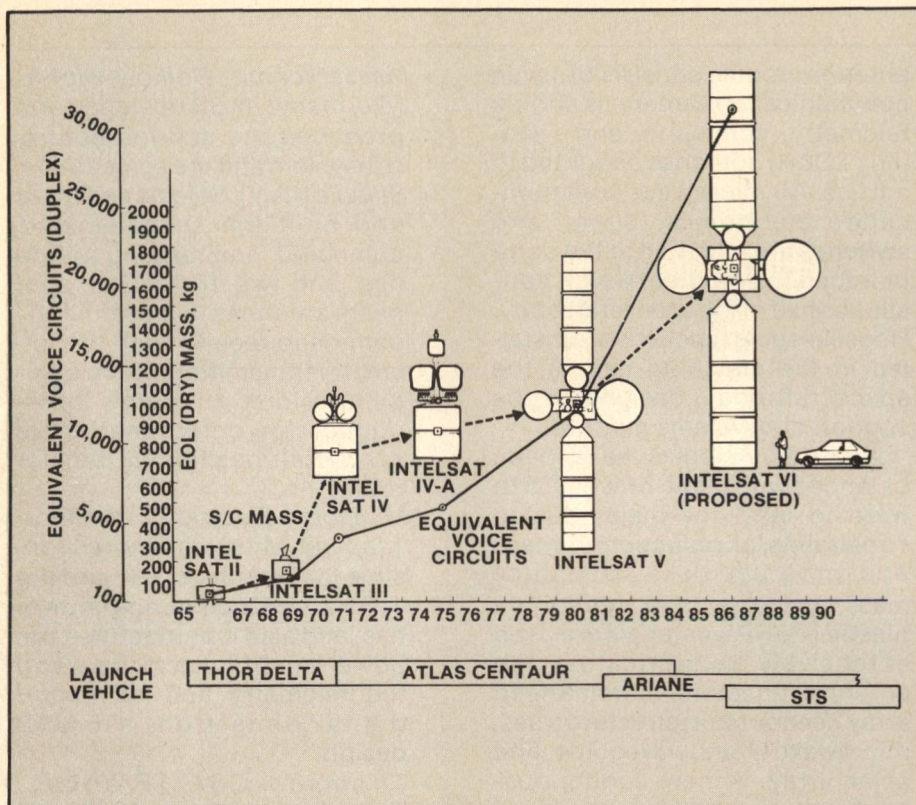


Fig. 1 INTELSAT evolution past, present, and future.

approximately 7.8 m each side of the spacecraft. The antennas are oriented with the large 4 and 6 GHz reflectors on the east and west sides.

During synchronous orbit operation antenna pointing control is maintained to an accuracy of better than 0.2° in pitch and roll and 0.5° in yaw. Performance measured on orbit with FM-2 and FM-1 is noticeably better than this worst case prediction.

A more detailed discussion of the spacecraft design including a description of all subsystems is found in references 1 and 2. Reference 3 shows in detail the communication subsystem characteristics and is an excellent presentation of how the requirements and technologies evolved and were ultimately realized in

the electronic hardware for 27 simultaneously operating transponders. Although redundancy is not shown in Figure 3 there are a total of 43 TWTAs, of which 27 are normally operating; 15 receivers, of which 7 are normally operating; and 10 upconverters, of which 6 are normally operating. The switch matrices consist of 53 transfer and SPDT coaxial switches and 6 hybrid power splitters that allow interconnection of all beams on a channel by channel basis. The switch configuration allows any interconnection to be made even in the event of a single switch failure per channel.

The transponders, which operate in both the 6/4 GHz and 14/11 GHz bands, vary in bandwidth from 34 to 241 MHz and provide a total usable bandwidth of 2137

TABLE 1 COMMUNICATIONS PERFORMANCE SUMMARY

Primary Parameters	Comment
Gain G/T EIRP	Generally within 0.5 dB of prediction Exceptions are probably due to test conditions at time of test (all within 1dB)
Passband Characteristics	
Amplitude Group delay	Nominal to better than ground measurements
Secondary Functions	
All switches Receiver attenuators Multiplexer attenuators L.O. frequencies Beacons	Nominal performance
Antenna Parameters	
Main beam Sidelobe C/I Crosspol C/I	Main beam within measurement accuracy of predictions. Sidelobe and crosspol nominal.

Prelaunch Tests

A major reason for the on-orbit success is FACC's thorough ground test program. Both the antenna and transponders subsystems go through extensive thermal tests prior to their final acceptance tests. Not only is the axial ratio of every feed element measured over temperature, but the entire 90 element hemi/zone feed arrays are measured over 10 thermal cycles. The minor calculated variation in antenna gain at all INTELSAT ground stations is computed.

After antenna module integration, the performance of all antennas is measured at FACC'S Cal-

averas test site. The critical hemi/zone antennas have their copolarized and cross-polarized radiation contours mapped in half degree increments over the earth's field of view at 40 discrete frequencies (1,613,760 data points). In addition, the swept frequency performance is measured at critical sidelobe and cross-polarized locations.

Transponder testing is similarly thorough. A week long thermal test thoroughly exercises all components and the hundreds of coaxial interconnections. There are 588 discrete transponder paths, and test matrices are established such that every possible path is

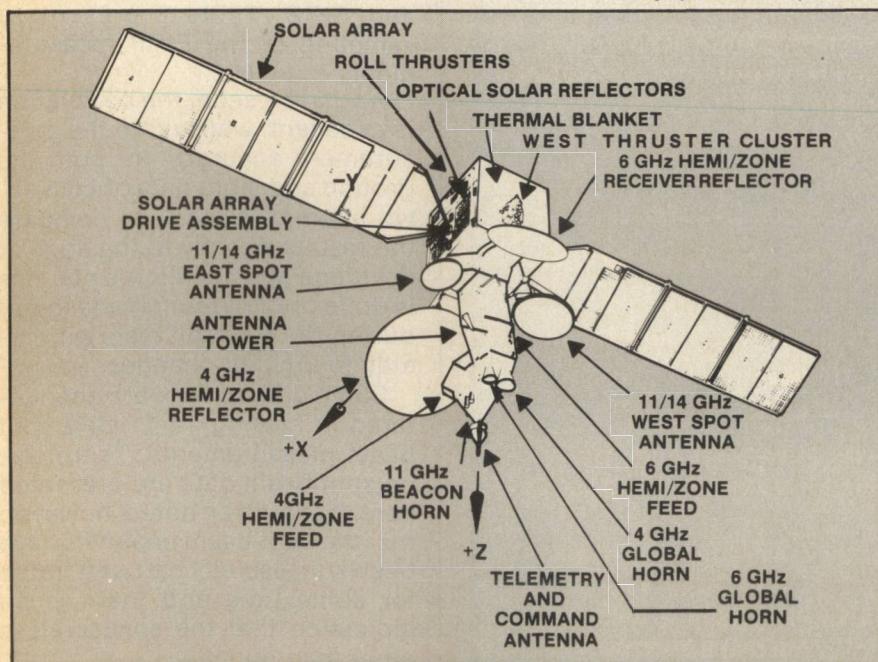
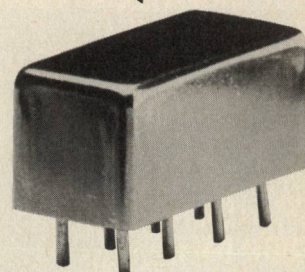


Fig. 2 Spacecraft configuration.

(Continued on page 56)

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VAY-1 SPECIFICATIONS

FREQUENCY RANGE, (MHz)

LO-RF 0.05-500

IF 0.02-500

CONVERSION LOSS, dB

One octave from band edge

Total range

ISOLATION, dB

low range LO-RF

LO-IF

mid range LO-RF

LO-IF

upper range LO-RF

LO-IF

TYP. MAX.

6.0 7.5

7.5 8.5

TYP. MIN.

47 40

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46 35

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tested in a logical fashion so that any anomalous performance can be immediately traced to a specific component.

Once the spacecraft is integrated, the key performance tests are the reference and final slant range tests performed in a 250 ft antenna range adjacent to FACC's assembly building, and the extensive thermal vacuum performance measurements. The key to the smooth operation of the spacecraft level tests is that all measurements are subsets of antenna or transponder acceptance tests, using modifications of the subsystem software, and with identical measurement techniques and display formats. For example, at the slant range the hemi/zone contours are measured at the center frequency of each channel; a subset of the original 40 frequencies measured at Calaveras. By utilizing common software, the subsystem data base is easily loaded into the system test computers for instant data comparison and trend analysis.

On-Orbit Communications Measurement

The on-orbit measurements can be split into those that are primarily transponder related and those that are strictly antenna related. In the first group are the primary parameters that determine spacecraft capacity; namely, gain, G/T, and EIRP. Table 2 presents a sampling of the EIRP measurements at 4 GHz.

As can be seen, the correlation is excellent, well within the measurement accuracy for both the ground and flight data of ± 0.5 dB. No attempt is made to compare the results directly to the edge of coverage specification since this is done prior to launch and intent during the on-orbit tests is primarily to look for changes.

Some difficulties were encountered in making 14/11 GHz spot beam measurements. Therefore, no spot beam data are presented here. It should be noted, however, that the spot beam channels have been successfully carrying traffic for some time and there is no indication that the spacecraft is other than nominal.

Table 2 also presents the mea-

[Continued on page 58]

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TABLE 2 PRIMARY PARAMETER MEASUREMENT SUMMARY

Beam	Channel	EIRP, 4 GHz			Flux Density to Saturate 6 GHz ¹		G/T, 6 GHz		
		Measured EIRP dBW	Predicted EIRP dBW	Spec EIRP dBW	Measured Gain dBW/m ²	Predicted Gain dBW/m ²	Measured G/T dB/K	Predicted G/T dB/K	Spec G/T dB/K
West Hemi	1-2	33.4	33.13	29	-74.8	-75.1	-5.3	-5.8	-11.6
	3-4	32.8	33.1	29	-74.8	-74.9	-5.7	-5.9	-11.6
	5-6	33.2	33.05	29	-74.3	-74.9	-5.7	-5.9	-11.6
	7	32.5	32.71	29	-74.6	-74.1	-5.8	-6.5	-11.6
	8	32.2	32.76	29	-74.4	-74.8	-5.7	-6.1	-11.6
	9	29.4	30.04	26	-77.5	-77.4	-6.9	-6.4	-11.6
East Hemi	1-2	33.2	33.13	29	-76.1	-76.5	-5.5	-5.1	-11.6
	3-4	33.1	33.27	29	-75.4	-75.7	-5.8	-5.6	-11.6
	5-6	33.1	33.37	29	-76.1	-76.1	-5.6	-5.3	-11.6
	7	32.4	32.77	29	-75.9	-75.6	-5.4	-5.1	-11.6
	8	32.3	32.41	29	-75.7	-75.2	-5.6	-5.4	-11.6
	9	28.9	28.99	26	-78.9	-78.4	-6.0	-5.5	-11.6
West Zone	1-2	34.5	33.87	29	-74.0	-74.3	-5.1	-4.65	-8.6
	3-4	34.6	34.12	29	-74.2	-75.0	-4.8	-4.28	-8.6
	5-6	34.9	34.66	29	-74.7	-75.2	-4.6	-4.27	-8.6
	7-8	34.9	34.51	29	-74.4	-74.7	-5.0	-4.95	-8.6
East Zone	1-2	33.1	32.39	29	-74.2	-74.8	-3.5	-3.4	-8.6
	3-4	32.9	32.03	29	-74.6	-75.0	-3.4	-3.2	-8.6
	5-6	32.6	31.99	29	-74.4	-74.5	-3.0	-3.0	-8.6
	7-8	32.5	32.21	29	-73.6	-74.3	-3.2	-3.1	-8.6
Global	7-8	29.0	28.9	26.5	-74.9	-75.1	-12.0	-13.04	-18.6
	9	26.1	26.3	23.5	-78.5	-78.5	-12.2	-13.0	-18.6
	10	26.9	26.8	23.5	-79.0	-78.2	-11.9	-12.61	-18.6
	11	27.1	26.8	23.5	-79.3	-78.5	-12.1	-12.76	-18.6
	12	26.8	26.8	23.5	-79.1	-78.5	-12.1	-12.76	-18.6

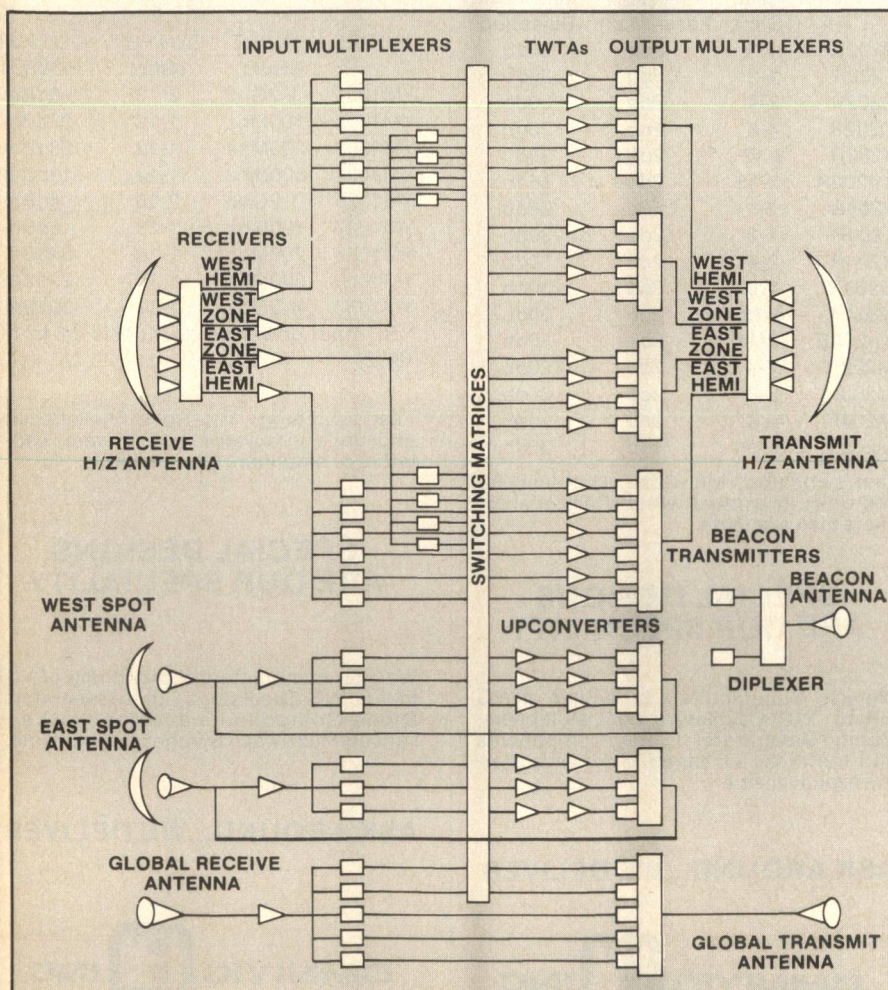


Fig. 3 Simplified INTELSAT V communications payload block diagram.

sured gain and G/T at 6 GHz for the primary receiver and TWTAs. In addition, in-band and out-of-band amplitude response and group delay measurements were performed in every channel. Typical in-band response was better than prelaunch, probably due to near-field effects on the slant range. Typical group delay measurements, which included doppler compensation, were direct overlays of prelaunch data. Typical out-of-band responses were also direct overlays of the prelaunch data, within 50 dB dynamic range of the IOT equipment.

Antenna Performance

The antenna performance must be considered a primary performance parameter determining the satellite capacity, along with gain, G/T, and EIRP. In fact, as available frequency band reuse increases, modern telecommunication satellite capacity is limited more by antenna carrier-to-interference (C/I) performance than carrier-to-noise (C/N) ratios. Over half of the on-orbit payload test time was devoted to verifying the performance of the hemi/zone antennas.

The hemi/zone shaped beams, illustrated in Figure 4, are formed

[Continued on page 60]

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by 90 element feed arrays fed by an airline feed network with arbitrary amplitude and phase at each feed. To measure the antenna patterns over the entire field of view, a series of roll maneuvers, illustrated by Figure 5, was performed. Each day, a roll maneuver was performed at time t_0 with the spacecraft yaw and roll control loops disabled. Over a 24-hour day, an undisturbed spacecraft would exhibit a sinusoidally varying roll error. Solar pressure torques, however, modify this behavior, and a detailed compu-

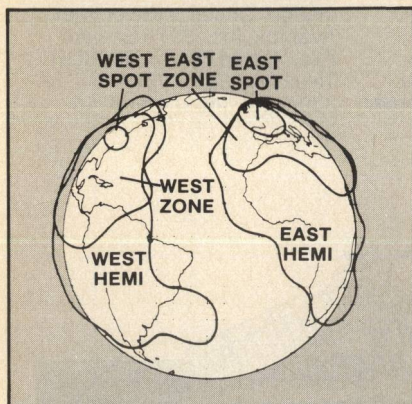


Fig. 4 Antenna pattern results.

ter program is required to predict the spacecraft motion. As shown in Figure 5, there is a period 12 hours after the initial maneuver where the roll angle is nearly con-

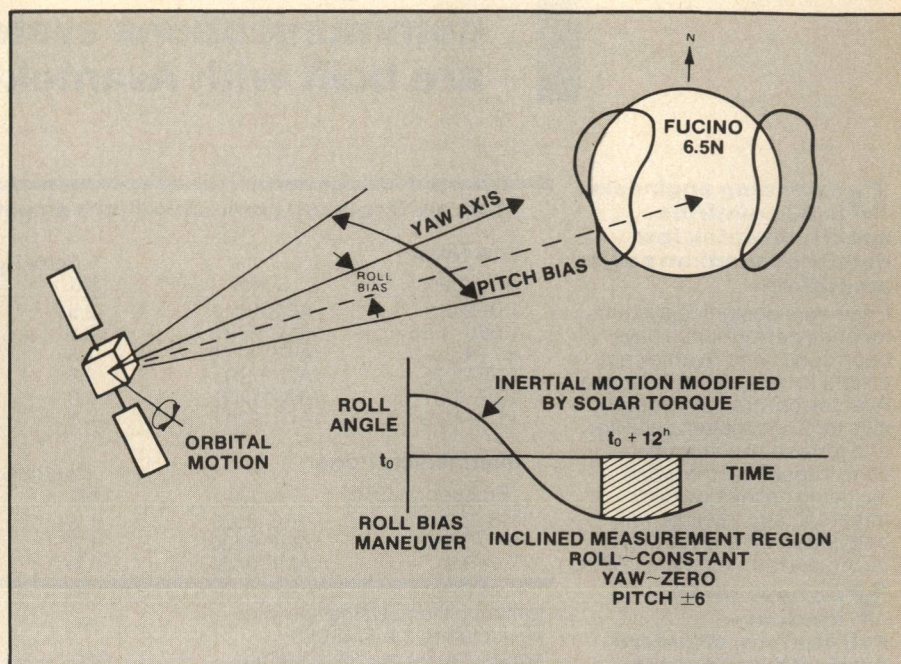


Fig. 5 Communications antenna mapping technique.

each beam. The satellite control system is designed to allow maintenance of spacecraft attitude with large roll biases; however, the above measurement sequence was employed to eliminate any extra fuel expenditure.

Before commenting on the test accuracies, it is important to note the test limitations. During the course of a pattern measurement, roll and yaw could vary by nearly

appear to be random, and there are absolutely no indications of any alignment biases. A typical co-polarized main beam plot is shown in Figure 6.

Typical measured cross-polarized and sidelobe performance are also shown in Figure 6. Minor out of specification values were recorded, but it should be noted that data taking was concentrated in the areas of anticipated speci-

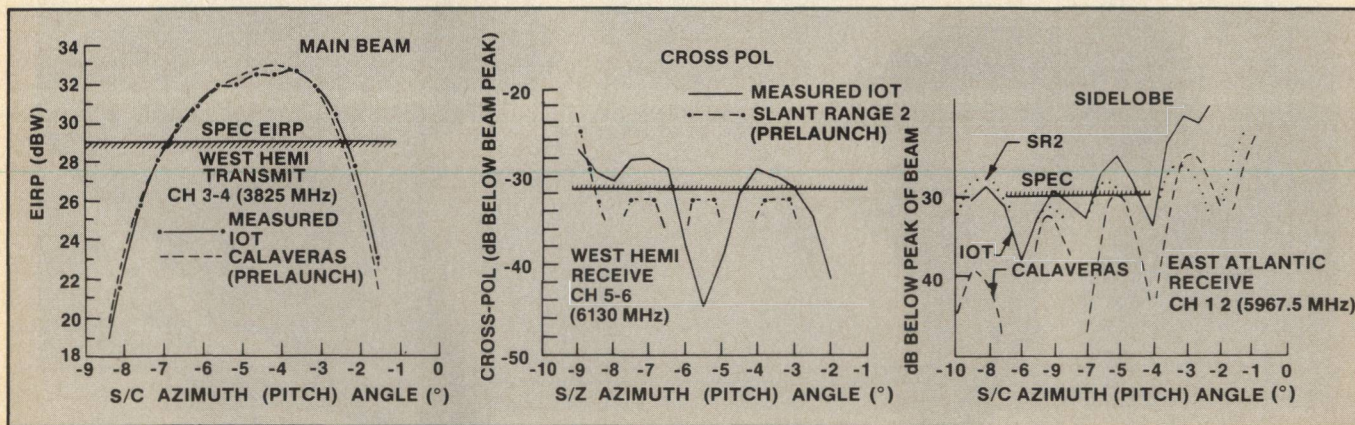


Fig. 6 Antenna pattern results.

stant and yaw is near zero. During this period, the spacecraft is stepped in half degree pitch increments to obtain antenna patterns versus pitch angle, for a given roll offset. For Flight 2, the patterns at five roll angles were obtained. Main beam co-polarized and cross-polarized patterns as well as sidelobe patterns were obtained for

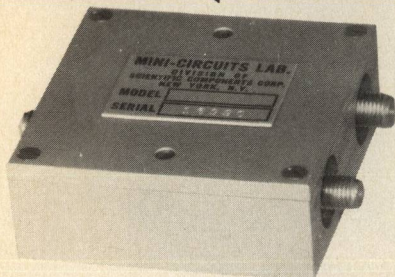
0.5°. Accounting for the angular variation at every data point is a monumental data reduction task and has not been performed although the IOT software has been modified to perform this task for FM-1. Within this limitation, all patterns agree with prelaunch predictions within $\pm 0.25^\circ$. The variations from pattern to pattern

fication level performance. In evaluating C/I data, numerous measurement error sources must be considered. For example, at the specification level, the ground station axial ratio of 0.15 dB can contribute over ± 3 dB of error to cross-polarized C/I measurements. The discrepancies of Figure 6 are within the bounds of this

[Continued on page 62]

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LO, RF 1.5-4.2
IF DC-0.5

CONVERSION LOSS, dB	TYP.	MAX.
Total range	7.0	8.5
ISOLATION, dB	TYP.	MIN.
1.5-2.0 GHz LO-RF	25	20
LO-IF	18	10
2.0-3.7 GHz LO-RF	25	17
LO-IF	18	10
3.7-4.2 GHz LO-RF	25	20
LO-IF	18	10

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[From page 60] **INTELSAT**

error source alone.

Figure 6 compares sidelobe performance to both the final spacecraft slant range tests and the antenna acceptance test data at Calaveras. All measurements were evaluated with respect to both prelaunch data sources. The slant range data account for certain minor contributors to antenna C/I, such as intratransponder leakage, although they suffer some degradation due to nearfield effects. Exhaustive data analysis leads to the conclusion that at the specification level, either data base (supplied on computer tape to INTELSAT) can be used with an accuracy of ± 3 dB at specification level.

The foregoing discussion exemplifies that state-of-the-art frequency reuse satellite antennas are limited as much by ability to perform measurements as by theoretical antenna analysis techniques. FACC has identified the error sources in its antenna ranges and is systematically eliminating them for the design of the next generation of frequency reuse antennas.

Platform Stability Tests

Prior to launch, considerable concern over the effects of spacecraft motion was expressed due to the large gain slopes at the antenna edge of coverages. To verify stability, a test was performed in which two r.f. signals were passed through the satellite. The first signal was in the east hemi beam, which has a nearly east-west gradient as seen from Fucino. Any pitch motion would therefore be detected as an r.f. signal variation. Similarly, the second signal was in an east spot beam channel and the spot beam antenna was steered so that its gradient was north-south as viewed from Fucino. This signal served as a roll motion detector. To eliminate any atmospheric effects or effects of test equipment drift, these signals were displayed on a strip chart alongside the 4 and 11 GHz beacon signals. The beacon antenna beams are very broad and thus insensitive to small spacecraft motions. This test was performed during stationkeeping maneuvers and eclipse.

Measured stationkeeping errors agreed with ADCS telemetry and were well within budget. Absolutely no signs of short or long term thermal effects or alignment biases could be detected during the test. Communication performance in and out of eclipse in the Spring of 1981 showed no evidence of thermally induced pointing transients.

CONCLUDING REMARKS

The first two INTELSAT V's have been successfully launched and placed into geosynchronous orbit. The spacecrafts were reconfigured for routine communication service following transition to the three-axis-stabilized mode of control. All performance tests, both bus and payload, have been completed, demonstrating close agreement with prelaunch test data. All mission objectives have been met or surpassed. No significant deviations from the flight plan were required by hardware malfunctions. All spacecraft components survived launch. Spacecraft fuel lifetime remaining exceeds the 7-year requirement by 1 to 2 years. The success of FM-1 and FM-2, the first of a major new satellite series, has been noteworthy in the rapidly advancing communications satellite industry.

ACKNOWLEDGEMENT

This work is based upon work performed under the sponsorship of the International Telecommunications Satellite (INTELSAT) Organizations. The outstanding success of the first two INTELSAT V's will be long recognized as a major achievement in the maturing aerospace industry. The authors would like to acknowledge the "team" and all who contributed to the back-to-back successes. To our colleagues at INTELSAT and COMSAT, may we express our gratitude for all your assistance in making INTELSAT V a historic event.

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Japanese Domestic Satellite Communications Systems Experiments

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Tokyo, Japan

N. ISHIDA, A. ISO, T. ISUMISAWA

Yokosuka Electrical Communication Laboratory,
Kanagawa, Japan

INTRODUCTION

A medium capacity communication satellite for experimental purposes (CS) developed by NASDA of Japan was launched on December 15, 1977. The CS experiment was promoted by the Ministry of Post and Telecommunications (MOPT) in cooperation with the Nippon Telegraph and Telephone Public Corporation (NTT) and began on May 15, 1978.

Several kinds of earth station facilities were constructed such as the Kashima main fixed earth station, the Wakkanai K-band beacon receiving earth station and

the Yamagawa K-band beacon receiving station in the RRL system, and the Yokosuka fixed earth station, the Sendai fixed earth station, the Hachijo island fixed station, the small transportable earth station and the Sugita K-band beacon receiving station in the NTT system. Experimental results using these earth stations have already been reported on^{1,7}.

This paper describes the experimental results obtained using:

- Newly developed K-band SCPC earth stations,
- K-band small earth stations,
- C-band small capacity omni-use earth terminals,

- C-band receive-only small earth stations, along with the characteristics of on-board communication equipment,
- K-band radio wave propagation experimental results obtained during the second year of the mission period.

EXPERIMENTAL SYSTEMS

The overall configuration of the experimental system using CS is shown in Figure 1. The CS is a spin stabilized satellite with a mechanically despun antenna. The main satellite body is cylindrical in shape 218 cm in diameter, and 222 cm long. Solar cells which produce 420 W are mounted on its

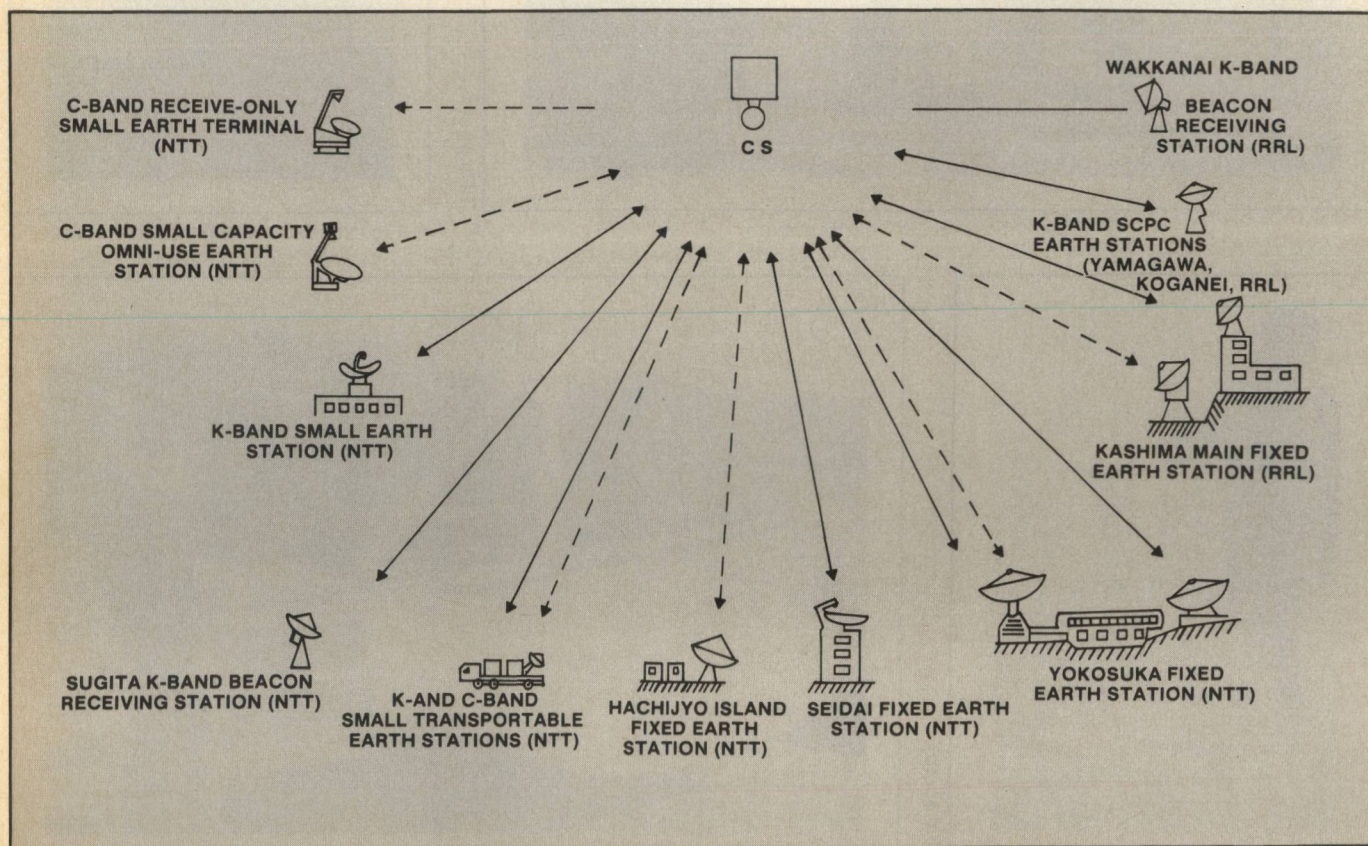


Fig. 1 CS Experimental systems block diagram. (---:K-Band, —:C-Band)

sides. The whole satellite weighs about 340 kg and nominal satellite life is 3 years.

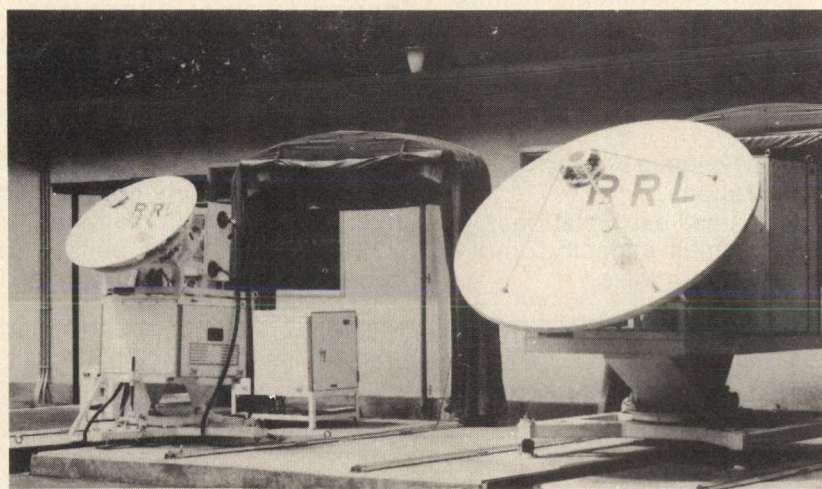
For its communication antenna, a K and C-band 4 frequency shaped beam horn reflector is adopted. It radiates over the main of Japan using the K-band and over all Japanese territory, including remote islands, using the C-band. The CS consists of 8 transponders, 6 in K-band and 2 in C-band, with a 200 MHz bandwidth, K-band output power of 34 dBm and a C-band output power of 34.5 dBm. Although malfunctions occurred in two K-band transponders during the first 3 months, the other four K-band and the two C-band transponders have been

functioning perfectly for more than three years. The Kashima fixed earth station, located in the Kashima branch of the Radio Research Laboratories of the Ministry of Posts and Telecommunications, functions as the main station and the Yokosuka fixed earth station functions as the substation. Both stations are connected by facsimile, telephone and data lines. Besides these, the RRL earth stations include the K-band SCPC earth stations (Yamagawa in Kagoshima, Koganei in Tokyo) and the Wakkanai K-band beacon receiving station in Hokkaido.

The NTT earth stations are the Sendai fixed earth station in Miyagi for the K-band TDMA 60 Mbps

system, the Hachijo island fixed earth station in Tokyo for the C-band TDMA 100 Mbps system, the K-band transportable earth station, the Sugita K-band beacon receiving station in Yokohama as well as newly developed earth stations in Yokosuka which are K-band small earth stations, and the C-band small capacity omni-use terminals and C-band receive-only earth stations.

The performance of the small earth stations shown in Figure 2 is listed in Table 1. The K-band SCPC earth station is used for the SCPC transmission between the Yamaga and Kashima stations while the K-band small earth stations are de-



(RRL photo)

Fig. 2a K-band SCPC earth station.



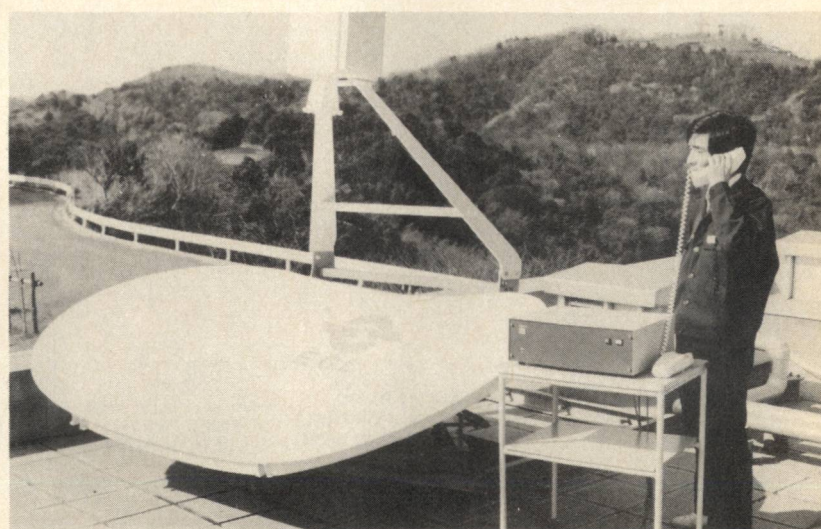
(NTT photo)

Fig. 2b K-band small earth station.



(NTT photo)

Fig. 2c C-band receive only terminal



(NTT photo)

Fig. 2d C-band small capacity omni-use terminal.

veloped for the integrated services satellite digital network experiments. The C-band small capacity omni-use terminal with an antenna equivalent diameter of 1.8 m is able to transmit up to three telephone channels. The C-band receive-only terminal can receive the 64 kbps data signals from the data center.

CHARACTERISTICS OF ON-BOARD MISSION EQUIPMENTS

A periodic check of the satellite is conducted every six months. The first check was conducted in January 1978 immediately after the injection of the satellite into a geostationary orbit. Since the purpose of the check is to confirm the characteristics of the mission equipment and to measure any changes, the measuring methods are based on the pre-launch test procedures. Some of the items and test procedures in the check are not sufficient for communication link analysis and precise evaluation of the equipment. Therefore, several improved measure-

ments were conducted on an experimental basis.

Antenna Radiation Patterns

In the periodic check, the antenna beam direction is scanned from west to east by changing the antenna bias angle, and the antenna radiation patterns (communication channels, TT & C channel and K-band beacon signal) including the XPD of the K-band beacon signal are measured. Compared with the results of the past check, no remarkable changes in the antenna patterns have been found, although the output power of the K-band beacon signal has decreased slightly.

The antenna gain contours are measured by two-dimensional scanning of the antenna beam once a year. In this measurement, it was found that spin motion causes errors in the obtained pattern shape when the spin modulated data were averaged. To remove the errors, a new method of antenna pattern measurement, called the spin coherent sampling method, was developed. It is based on the coherent sampling of a

down-link signal by spin frequency. Figure 3 shows the measured antenna gain contour by this method which coincides closely with pre-launch data. This method has another feature which makes it possible to obtain the locus of the instantaneous antenna pointing due to spin motion. The data obtained show that the pointing accuracy was about 0.3 degrees peak-to-peak.

Transponder Characteristics

From past check data, significant changes of characteristics which affect the communication quality were not found. However, the output power or helix current of K-band transponders changed. In particular the helix current of one of the K-band transponders changed. In particular the helix current of one of the K-band transponders reached the limit value, although the other characteristics (output power, frequency response etc.) were normal.

The transponders use TWT amplifiers which are highly nonlinear elements. Therefore, measure-

(Continued on page 70)

14mm

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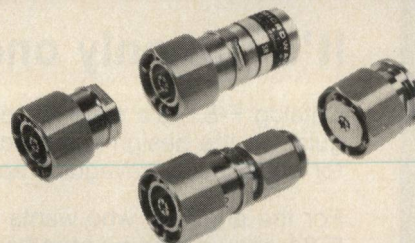
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CONNECTORS & ACCESSORIES

MODEL NO.	DESCRIPTION
2480A	Connector, Rigid Line (Equiv. GR900BT)
2480B	Connector, Panel Mnt w/nut - Rigid Line
2480C	Connector, Panel Mnt w/out nut - Rigid Line
2480D	Connector, Flexible Cable - MC214
2480E	Connector, Semi-rigid Cable - 0.325 dia.
2480L	Connector, Beadless (LPC14)
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A024	Connector Gage Kit

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2406C	MPC14 to N female,	DC-8.5 GHz
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2407A	MPC14 to APC3.5 female	
2407B	MPC14 to APC3.5 male	
2458A	MPC14 to LT female	DC-5.0 GHz
2458B	MPC14 to LT male	
2607	MPC14 to APC7	DC-8.5 GHz

COMPONENTS & INSTRUMENTS

MODEL NO.	DESCRIPTION
2450C	ANA Calibration Kit (HP8542B)
2450K	ANA Calibration Kit (HP8409B)
4096A	Direct Coupler, High Direct. 0.1 - 0.6 GHz
4096B	Direct Coupler, High Direct. 0.25 - 0.5 GHz
4097	Direct Coupler, High Direct. 0.5 - 1.0 GHz
4098	Direct Coupler, High Direct. 0.75 - 1.5 GHz
4091	Direct Coupler, High Direct. 0.95 - 2.2 GHz
4095	Direct Coupler, High Direct. 1.5 - 3.0 GHz
4092	Direct Coupler, High Direct. 1.7 - 4.2 GHz
4093	Direct Coupler, High Direct. 3.7 - 8.5 GHz
4098A	Direct Coupler, 300 watt, 10 to 400 MHz, 40 dB coupling
4098B	Direct Coupler, 1000 watt, 10 to 300 MHz, 50 dB coupling
2401A	Sliding Termination, Bead Support, 0.9-8.5 GHz
2408	Sliding Termination, Beadless, 0.9-8.5 GHz
2404	Sliding Short, Bead Support, 0.9-8.5 GHz
2409	Sliding Short, Beadless, 0.9-8.5 GHz
2410A	Fixed Termination, DC-8.5 GHz
2415A	Fixed Short, Flat Plane
2415B	Fixed Short, Colllet in Short Plane
2416B	Open Circuit
2403()	Airlines, Bead Support
2453()	Reference Airlines, Beadless
2454A	Airline 2-Port Standard Set
MT7119A	Cryogenic (Cold) Termination (77°K)
MT7109A	Thermal (Hot) Termination (373°K)
2459A	Ambient Termination (295°K)

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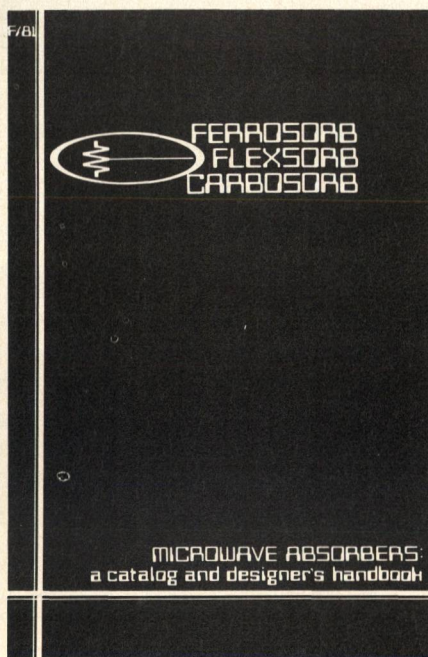
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TABLE 1
TYPICAL PARAMETERS OF SMALL EARTH STATION

Earth Station		K-Band SCPC Earth Station	K-Band Small Earth Station use Terminal	C-Band Small capacity omni- Earth Terminal	C-Band Receive- only Small
System	Parameters				
	Up/Down Frequency (GHz)	30/20	30/20	6/4	/4
	G/T (dB/K)	21.3	30.6	13.6	1.3
	EIRP (dB. W)	56.3	88.1	44.3	
Antenna	Type of Transmission	FM-SCPC Δ M-PSK-SCPC	PCM-PSK-SCPC PCM-PSK-SCPC	PCM-PSK-SSMA	PCM-PSK PCM-PSK-SSMA
	Type	Cassegrain	Elliptical beam offset Cassegrain	Offset parabolic	Offset parabolic
	Size	2 ϕ	4.7 x 2.3	1.8 (equivalent)	0.6 (equivalent)
	Up/Down Gain (dB)	53.3/50.3	58.6/55	38.7/36.1	/26.5
HPA	Type	IMPATT	Klystron	FET	
	Output Power (W)	2	1000 (Pulse mode op.)	6 6	
LNA	Type	FET	Uncooled paraamp	Uncooled FET	Uncooled FET
	Noise Temperature (K)	750	200	80	244
Location		Koganei in Tokyo Yomagawa in Kagoshima	Yokosuka in Kanagawa		

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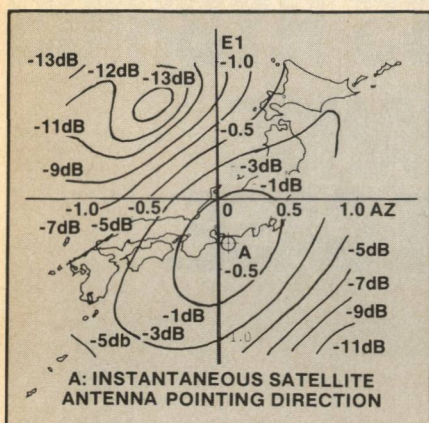


Fig. 3 Antenna gain contour.

ments of the transponder characteristics must be conducted considering the effects of the non-linearity. From this viewpoint, AM/AM and AM/PM conversion factors were measured. Further, transfer functions, noise figures and frequency responses were measured considering the nonlinearity effects. Since nonlinearity significantly affects communication quality, it is desirable to measure these characteristics before launch and to compare them with data after launch.

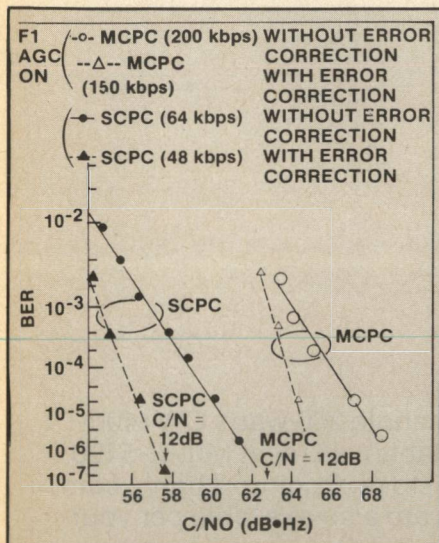


Fig. 4 The BER performance of SCPC and MCPC systems.

COMMUNICATIONS SYSTEM EXPERIMENTS

K-band Simple Channel Per Carrier (SCPC) Earth Stations

SCPC, SSMA and Computer Network experiments were carried out in order to investigate the suitability for light traffic satellite communications.

SCPC signal transmission experiments are conducted among a main earth station and small sized transportable stations which have 1 or 2 meter dish Cassegrain type antennas. The experimental system have the SCPC modem (PSK or FM) and the MCPC modem (PSK, 9 channels per carrier with DSI).

Figure 4 shows the Bit Error Rate BER performance of SCPC

and Multiple Channel Per Carrier MCPC systems. The C/No at BER of 1×10^{-3} was 57.2 dB·Hz, using the SCPC equipment in a normal mode (64 kbps, 4-phase PSK, without error correction). The rainfall margin is about 10 dB when maximum power is transmitted at the small sized station.

For stability tests via the satellite, it is shown that the SCPC systems have sufficient stability of
[Continued on page 73]



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5.000	-16.8	165.3	20.08	-174.1	-41.52	26.2	-23.0	146.8
10.000	-17.7	172.2	20.24	-178.3	-40.87	19.4	-26.8	147.4
20.000	-17.8	178.2	20.25	-174.9	-40.35	20.3	-29.2	154.7
30.000	-17.7	-178.9	20.23	170.0	-39.79	24.7	-30.3	153.2
40.000	-17.5	-176.3	20.18	165.2	-39.15	28.8	-31.8	153.6
50.000	-17.3	-174.4	20.13	160.5	-38.44	32.4	-33.7	154.7
60.000	-17.0	-173.0	20.07	156.0	-37.71	35.2	-36.1	158.8
70.000	-16.6	-171.9	20.01	151.5	-37.00	37.3	-39.2	163.5
80.000	-16.3	-171.4	19.92	147.1	-36.30	38.9	-42.3	-163.5
90.000	-16.0	-171.1	19.83	142.7	-35.61	40.0	-41.8	-123.5
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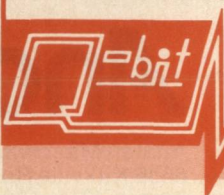
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[From page 71] **DOMESTIC SATELLITE**

signal transmission. For example, the fluctuation of frequency difference between two earth stations was less than 6 kHz even in eclipse time. And it shows that the down-link attenuation of 10 dB by rainfall hardly degrade signal transmission.

The effect of the intermodulation was also investigated. The measured data shows that the input backoff of 10 dB is necessary in order to maintain the C/I of the received signals at 18 dB when 6 or 8 carriers access a transponder with equal channel separation. Further investigation is necessary to reduce the intermodulation by using more suitable channel assignment in order to decrease the output backoff for the efficient use of the satellite transmitting power.

K-band Small Earth Station

A K-band small earth station and a experimental demand assignment (DA) Time Division Multiple Access TDMA system have been developed for the integrated ser-

vices satellite digital network (ISSDN) experiments¹³. In the ISSDN experiments, data, facsimile, video and packet switching information, at bit rates ranging from a low of 6.4 kb/s to high of 6.3 Mb/s speeds, are transmitted.

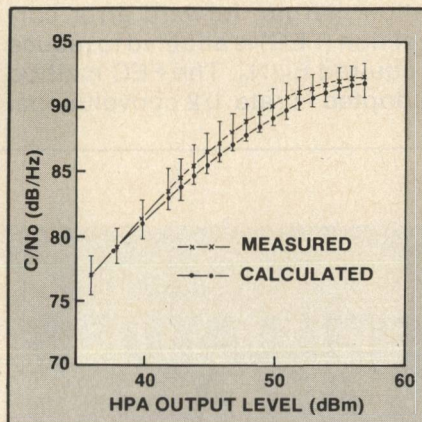


Fig. 5 HPA output level vs C/No performance.

An elliptical beam offset Cassegrain antenna, a 30 GHz band air-cooled Klystron amplifier and a 20 GHz band low noise amplifier have been developed for this earth

station³. The weight of the earth station is less than 2.2 tons which enables it to be easily installed on rooftops.

The effective isotropically radiated power (E.I.R.P.) and receiving figure of merit (G/T) are 88.1 dBW and 30.6 dB/K, respectively. Figure 5 shows the HPA output level vs. received C/No performance.

Experimental DA-TDMA System

The experimental DA-TDMA system makes real time assignment of various bandwidth satellite channels on demand and efficiently transmits various kinds of information, including telephone^{5,12}. The major features of the experimental DA-TDMA system are summarized in Table 2.

There are two satellite channel assignment methods for transmitting various kinds of information at diverse bit rates using the TDMA system.

- Single channel per burst.
- Multiplexed channel per burst.

[Continued on page 74]

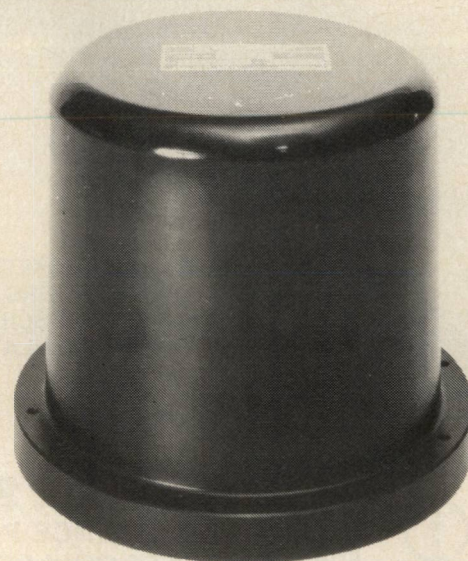
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In this experimental DA—TDMA system, the single channel per burst assignment method is adopted because it involves simplified design of compression/expansion buffer circuits, and efficient transmission of information.

Primary frames, with a time interval of 2 msec, have one sync burst and 39 data bursts (2048 symbols/data burst). The first super

frame is composed of 40 primary frames and is used for TDMA synchronization. The second super frame is composed of two first superframes. Channel assignment is accomplished with reference to this period.¹

To increase the rain attenuation margin, forward error correction (FEC) is adopted to reduce required E_b/N_0 . The FEC method adopted is rate 1/2 convolutional

encoding/Viterbi decoding ($K = 3$). Theoretical coding gain for the prototype Viterbi decoder with three bit quantization is about 3.3 dB at a Bit Error Rate of 1×10^{-4} , and a coding gain of about 2 dB is obtained through the satellite link. Coding gain degradation due to satellite link is considered to be caused by antenna spin modulation.

The experimental ISSDN communication system is composed of one network control station, two K-band small earth stations and DA-TDMA equipments. By using this system and the CS, data communication (6.4 kb/s ~ 1.536 MB/s), video conference (voice; 256 kb/s, still picture; 1.536 Mb/s, moving picture; 6.312 Mb/s), high speed facsimile communication (1.536 Mb/s) and packet switching (64 kb/s), experiments were performed successfully.

In packet switching experiments, the techniques necessary to utilize satellite links in the Den-denkoshya Digital Data Exchange (DDX) packet switched networks were investigated under the limited conditions utilizing 48 kb/s (bearer rate; 64 kb/s) satellite link as an inter-office line. As a result of error recovery procedure evaluation tests, for example, it has become clear that the procedure with a selective reject (SREJ) mode is about 100 times less than the one without SREJ mode in packet retransmission ratio at a Bit Error Rate of 10^{-7} .

In data communication experiments, high-level data link control (HDLC) protocol evaluation tests were performed. In point to multipoint computer communication tests, for example, measured transmission efficiency was more than 80% (maximum number of outstanding frames; 127, frame size; 1 Kbyte). The results show that the HDLC protocol is effective for data communications via satellite.

C-Band Small Capacity Omni-Use Terminal

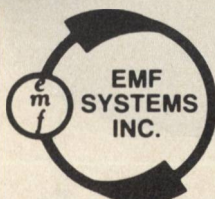
Two kinds of earth station are employed in this system, a small earth terminal (SET) and a master earth station (MES). The SET, which can transmit up to three telephone channels, is placed near

[Continued on page 76]

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a subscriber while the MES is connected to the terrestrial telephone network through a satellite telephone switching center (STC). A satellite communication subscriber is connected automatically to the terrestrial telephone network through an STC as a gateway center. The MES has the initiative in establishing satellite links between the SET and the MES using demand assignment

multiple access techniques. Two different kinds of demand assignment multiple access techniques are utilized in this system: TDM-VDMA (Time Division Multiplex — Variable Destination Multiple Access) method is employed in the MES to SET link, and SSMA (Spread Spectrum Multiple Access) in the SET to MES link. It is estimated that about one thousand SETs can be accommodated

in this system using a 6/4 GHz band transponder.

The SET uses an FET high power amplifier with an output power of about 2 W per voice channel, and an uncooled FET low noise amplifier with noise temperature lower than 90 K. The E.I.R.P. and G/T of the SET are 74.3 dBm and 13.6 dB/K, respectively.

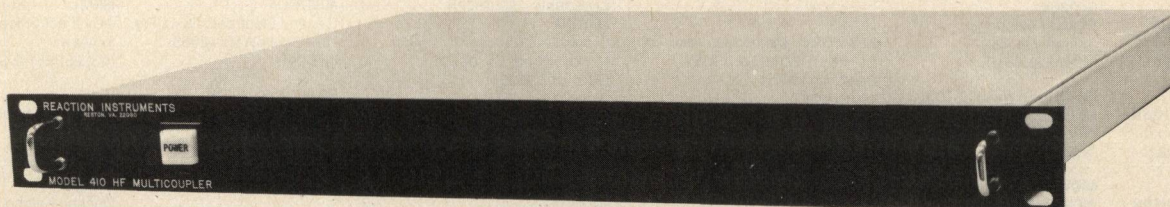
In the SET to MES link the reduction of time required to es-

TABLE 2
MAJOR FEATURES IN EXPERIMENTAL DA-TDMA SYSTEM.

System	Items	Performance
	Up/Down Frequency (GHz) Bit Rate (Mbps) Clock Rate (MHz) Number of Stations Network Control	30/20 19.968 43.776 Network Control Station: 1 Small Earth Station; 35 Central Control System
CommonTDMA Terminal Equipment & MODEM Subsystem	Modulation Burst Synchronization Initial Acquisition Forward Error Correction	2-phase CPSK, Coherent Detection Storage Counter Method Open Loop Prediction Method Rate-1/2 Convolutional Encoding, Viterbi Decoding with 3-bit Soft Quantization
Dama Subsystem	Traffic Channel Assignment Signaling	Fully Variable Demand Assignment (Preassignment available) Common Signaling Channel Control

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establish SSMA code synchronization is one of the key points in realizing this system. In order to solve this problem a digital code sweep method and an AFC technique without pilot signal, which eliminates AFC from the SET to realize simple SET equipment, have been adopted. The frequency fluctuation of 40 kHz is suppressed to within 10 Hz in less than about 10 sec. The bit error rate performance in the SET to MES link is illustrated in Figure 6. The degradation of IF back to back performance from the theoretical limit is caused by intersymbol interference. The degradation caused by the satellite links is about 0.4 dB.

C-Band Receive-Only Earth Terminal

The satellite communication system can cover a wide service area and offer services of homogeneous transmission quality. The 4 GHz receive-only terminal requests the information through the terrestrial network and receives the 64 kb/s data signal transmitted from the data center,

which conveys 11 separate channels of 4.8 kb/s facsimile. The receive-only terminal consists of an off-set parabolic antenna, an RF receiver, a PSK demodulator, and weighs 90 kilograms. The antenna dish is made of metal-coated glass-fiber-reinforced plastic with a 60 cm effective aperture. The primary radiator is a circular polarized printed spiral type, and is mounted in front of an RF receiver. The received signal is amplified by a two stage GaAs FET LNA. The G/T of the terminal is 1.3 dB/K which satisfies the designed value.

Experiments using the CS were carried out successfully by simultaneously transmitting facsimile data from the Yokosuka Electrical Communication Laboratory data center to two receive-only terminals. Figure 7 shows the C/N versus error rate performance. C/N degradation from the theoretical limit is about 1 dB at IF back to back due to intersymbol interference, and is slightly worse through the satellite link.

K-BAND RADIO WAVE PROPAGATION EXPERIMENTS

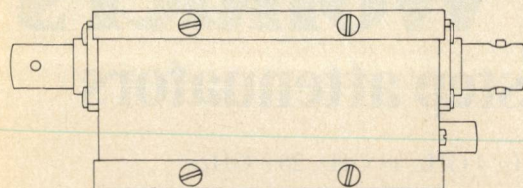
Preliminary results of the CS K-band propagation experiments at the Kashima Main Station have been reported, along with the results of the ETS-II, BSE propagation results². The results of CS 19.5 GHz beacon propagation experiments for two years are shown here. Figure 8 shows the cumulative distributions of rain attenuation at several stations which participate in the CS propagation experiments along with the diversity effects. Typical attenuation values at the percentages of time, 0.1 and 0.01, are 6 and 17 Tokyo, 8 and 16 dB at Sugita and 2.5 and 7 dB at Wakkanai in the most northern part of Japan.

Figure 8 indicates the diversity effects between Yokosuka and Sugita. Diversity distance is 19 kms and diversity improvement can be seen for ranges less than 0.1% of unavailability or over rain attenuation of 5 dB.

Figure 9 shows rain attenuation ratios between yearly averages

[Continued on page 78]

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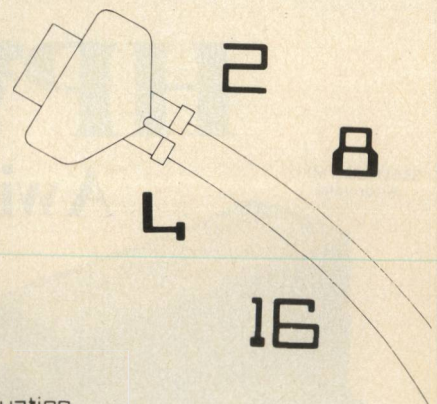
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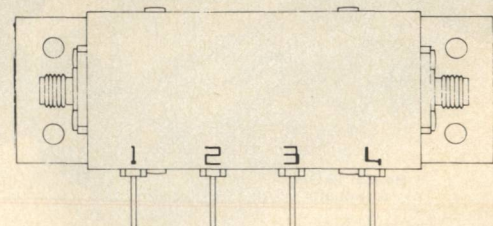
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WIDEBAND



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and worst month at Wakkanai and Yamagawa. The dashed line was derived by Dr. Morita of NTT, using 10 years of rainfall rate statistics. The equation for the line is expressed as follows:

$$P(r) \overline{WM/10Y} = 2.8 [P(r) \overline{WM/10Y}]^{0.8} \quad (1)$$

where $P(r) \overline{WM/10Y}$: means 10 year-averaged cumulative

rainfall rate probabilities.

$P(r) \overline{WM}$: means 10 year-averaged worst month cumulative rainfall rate probabilities.

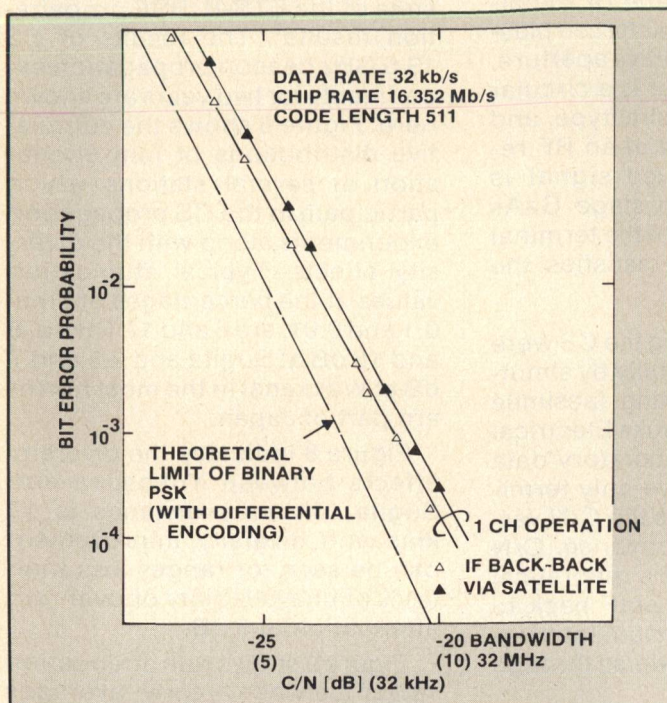


Fig. 6 Bit error rate performance. (SET-MES)

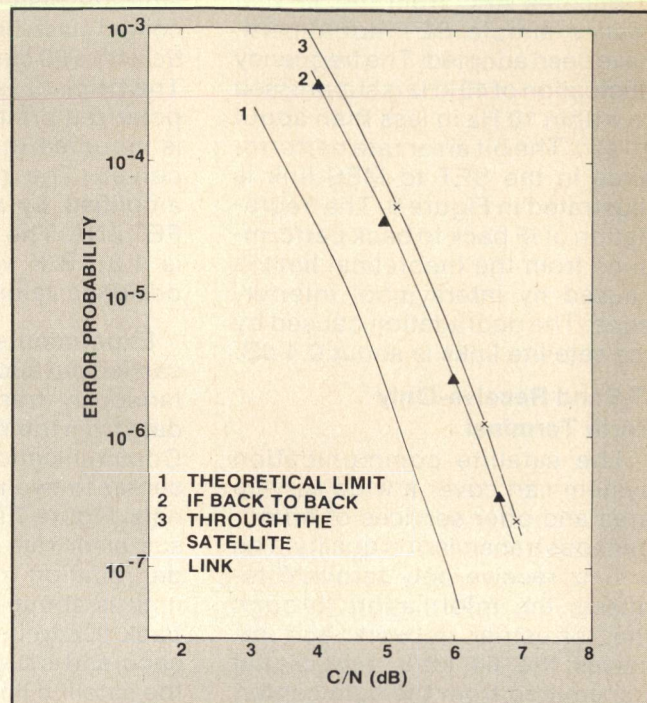
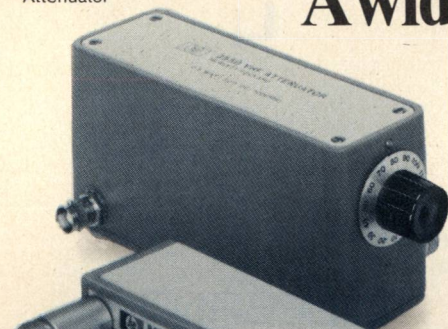


Fig. 7 Error rate performance.

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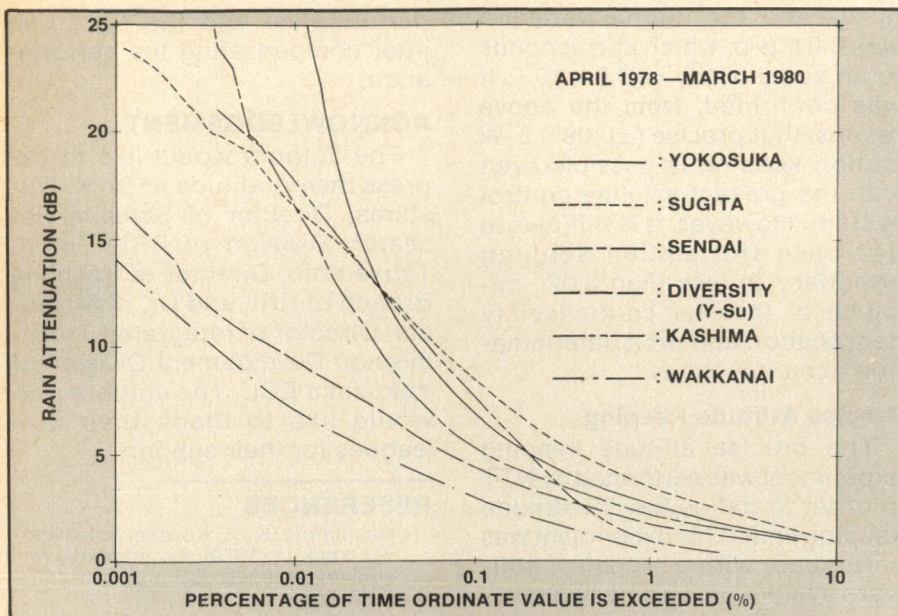


Fig. 8 Cumulative distributions of rain attenuation.

The Figure 9 shows good coincidence with the experimental equation⁸. Accordingly, using this equation worst month rain attenuation statistics can be derived from the yearly distributions of rain attenuation. The same thing can be said for the cumulative distributions of rainfall rate.

SATELLITE TRACKING AND CONTROL EXPERIMENTS

The satellite control of the CS is normally conducted by the National Space Development Agency of Japan (NASDA), and experimentally by RRL and NTT. Station keeping requires that the CS be held to within $\pm 0.1^\circ$ of boundaries in the E-W, N-S and orbit normal spin axis attitude directions. The ordinary E-W station keeping cycle period is about 3 weeks, with maneuver $\Delta V = 0.1$

m/s and the attitude keeping cycle period is about one week, with several pulses maneuver¹⁰.

The precise E-W station keeping experiment was carried out by RRL in order to narrow the E-W station keeping boundary from $\pm 0.1^\circ$ to $\pm 0.02^\circ$. The longitude drift of a stationary satellite is mainly caused by the perturbations attributed to the non-zonal harmonics of the earth potential and the luni-solar effect. The acceleration of the drift of the CS is near $1.5 \times 10^{-3} \text{ deg/day}^2$ in the west. In order to cancel this drift and to keep the satellite longitude within $\pm 0.02^\circ$, E-W maneuvers which slow down the satellite velocity by 0.02 m/s, are required every 3 or 4 days. Eccentricity control based on the sun-synchronized method was carried out simultaneously with the drift rate control⁴. Throughout the experimental period, the satellite's orbital elements used for the maneuver planning and for evaluation of the results were determined by using one-station-tracking data (the range and the K-band tracking angles). To estimate the orbital elements, the compact orbit determination program, or Kashima Orbit Determination System (KODS), was used.

The experiment was successfully carried out for one month. The maximum east and west deviations of the mean longitude were $+0.02^\circ$ and -0.01° respec-

[Continued on page 80]

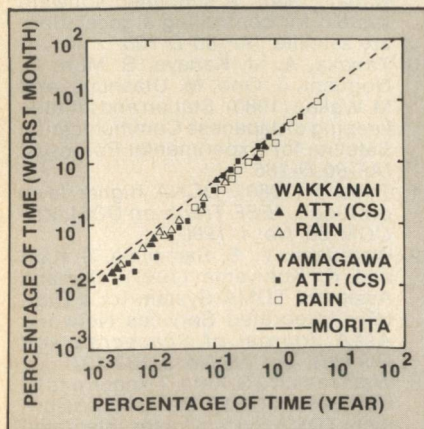


Fig. 9 Percentage of time of year vs percentage of time worst month.

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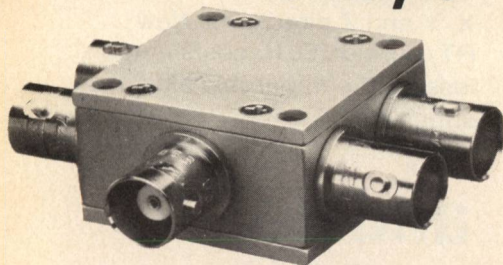
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FREQUENCY (MHz) 10-500

INSERTION LOSS, dB (above 6 dB) 10-500 MHz	TYP.	MAX.
	0.6	1.5

AMPLITUDE UNBAL., dB PHASE UNBAL. (degrees)	TYP.	MAX.
	0.1	0.2
	1.0	4.0

ISOLATION, dB (adjacent ports)	TYP.	MIN.
	23	20
ISOLATION, dB (opposite ports)		
	23	20

IMPEDANCE	50 ohms.
-----------	----------

For complete specifications and performance curves refer to the 1980-1981 Microwaves Product Data Directory, the Goldbook or EEM.

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[From page 79] DOMESTIC SATELLITE

tively, and the diurnal variation was 0.01° p-p, which corresponds to an eccentricity of 0.5×10^{-4} . It was confirmed, from the above results, that precise ($\pm 0.02^\circ$) E-W station keeping is possible even with the present satellite control system. However, it is difficult to decrease the station keeping boundary to less than 0.02° because of thruster controllability degradation and orbit determination accuracy limits.

Precise Attitude Keeping

The precise attitude keeping experiment was performed by NTT in order to define the CS attitude keeping limit. This experiment was carried out with a simplified software system using only two mini-computers⁹.

The CS attitude drifts at a rate of about 0.01 deg/day due to solar radiation pressure. Therefore, a standard attitude keeping maneuver is performed every one or two weeks to keep the satellite attitude within $\pm 0.1^\circ$ of its normal orbit sector¹⁰. In this experiment, however, that aim was to keep the attitude to within $\pm 0.02^\circ$ of the vector.

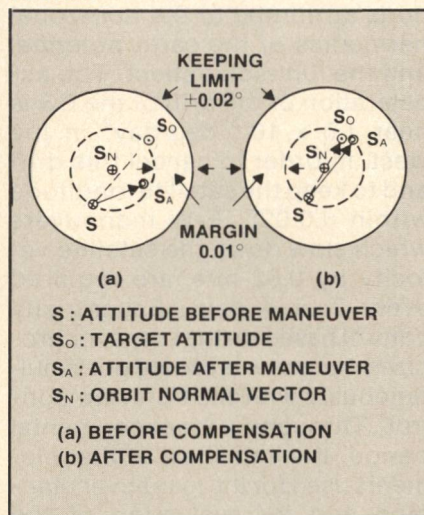


Fig.10 A result of precise attitude keeping experiment.

First, thruster performance at two thrust pulses was measured to evaluate degradation. Then, after compensating the performance, precise attitude maneuvers were performed. Figure 10 shows an example of this experiment. The left figure shows a maneuver before compensating the thruster

performance and the right one after compensating the performance.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to Dr. K. Iku-shima, Director of Satellite Research Division of RRL, Dr. K. Tsukamoto, Director of Kashima Branch of RRL and Dr. K. Miyau-chi, Director of Integrated Transmission Development Division of Yokosuka ECL. The authors also would like to thank their colleagues for their support.

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Technologies For the Next European Satellites



R. COURAULT and G. K. SMITH
EUROPEAN SPACE AGENCY
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INTRODUCTION

The interest in new telecommunication services is growing in Europe and many planning agencies, in national and international organizations, are now trying to define the most suitable networks to support them.

The existing European telephony network is dense and very extensive throughout Western Europe. However, its narrowband characteristics do not fit with the wideband requirements of most of the new services envisaged for the next two decades. "New services" include among many others:

- high speed facsimile.
- bulk data transfer (financial, meteorological, scientific).
- videocommunication.

For bit rates in excess of 24 kb/s, which these services require, a comprehensive fully switched terrestrial infrastructure of high quality will not be achieved for many years. For video communication in particular a minimum bandwidth of 2 Mb/s per channel is required.

New technologies are being considered, in particular the implementation of optical transmission, but this entails an enormous investment at the European level. Confidence in the success of future markets becomes the prerequisite to installation of advanced networks. On the other hand, a market cannot really expand without an adequate network.

Satellites could represent a rather direct and cost effective answer to this dilemma. They have inherent wideband potential and a fast implementation time. They offer point to point or multipoint connection within any part of the covered zone. These unique features make them ideal vehicles for

the promotion and trial of new services. Eventually they can provide the initial infrastructure for services which prove to be most successful, until the wider network is set up. Such an approach is exemplified in Europe with the impending launch of the European Communication Satellite (ECS) that will embark a 'Specialized Services' package (1983), and of the French 'Telecom-1' satellite (1983). These satellites will handle relatively few channels and are of conventional design, using mostly the technologies previously developed in other programs (Symphonie, OTS). As the traffic grows, the space segment will have to offer much higher capacity while maintaining flexibility. This will lead inevitably to different concepts and new payload designs.

In this context, a payload technologies assessment exercise is presently being carried out by ESA. Two of them are related to the fixed-satellite service and the other one to the mobile service. They are described here, as well as their associated RF technologies.

THE SPECIALIZED SERVICES (OR MEDIUM CAPACITY)

MISSION

This is an extension of the missions foreseen for the ECS (European Communication Satellite) and Telecom-1 satellites. A possible time scale for utilization is the early 90's.

Typical applications are: low-rate data transfer or medium rate facsimile at 9.6 kb/s; voice, data, high-speed facsimile at 32/64 kb/s; high-speed data, possibly coded video or users' own multiplexed traffic at 2Mb/s. Bit Error Rates (BER) of better than 10^{-4} for 99.7% and 10^{-6} for 99% of the time are specified for the voice and video links and are better than 10^{-9} for 99.7% of the time and 10^{-11} for 99% of the time for data links between digital processors. Forward Error

Correction (FEC) coding is used to give detection and some correction of errors but for highest overall quality an automatic request for repeat (ARQ) system is also offered.

The satellite network access method is Time Division Multiple Access (TDMA). It operates at 25 Mb/s with a frame length of 20 ms for compatibility with earlier systems and supports up to 50 channels, with less than 20 MHz channel spacing.

To keep costs down, the earth station antenna size is 4.5m. A reduction to 3 meters is not desirable since all stations will carry concentrated traffic. Small-aperture earth stations are also more difficult to coordinate.

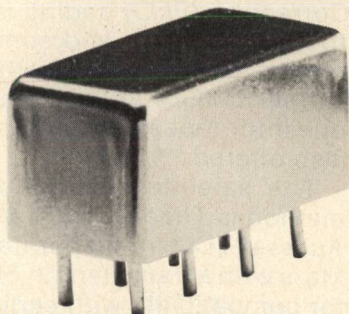
The RF frequency bands are: 14/14.25 GHz for the up-link and 12.5/12.75 GHz for the down-link. The spectrum available is thus 250 MHz, whereas 1 GHz is necessary for the service. The spectrum must therefore be re-used at least 4 times. A typical link budget is presented in Table 1. It shows, in particular, that the satellite antenna gain must be higher than 34 dB in the coverage (Western Europe). This implies that 20 to 25 spot beams are necessary, each with a Half Power Beam Width (HPBW) of about 1.1° . These beams are disposed in a regular triangular lattice.

In one approach considered, each pencil beam covering one circular zone originates from a cluster of several feeds. To achieve the required feed spacing and isolation, clusters for adjacent beams must share one or two elements. Shared elements are then contributing to two or three beams, at different frequencies. This solution enables low side-lobes levels (typically 30 dB at few beamwidths) to be achieved. It requires an offset reflector of about 2 meters with a complex feed array. The distribution network and the RF sensing signal

[Continued on page 84]

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 COUPLING, dB 11.5

INSERTION LOSS, dB	TYP.	MAX.
one octave band edge	0.65	1.0
total range	0.85	1.3
DIRECTIVITY, dB	TYP.	MIN.
low range	32	25
mid range	32	25
upper range	22	15
IMPEDANCE	50 ohms.	

For complete specifications and performance curves refer to the 1980-1981 Microwaves Product Data Directory, the Goldbook or EEM.

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Table 1

TYPICAL LINK BUDGET FOR A SPECIALIZED SERVICES MISSION

UPLINK 14 GHz

Earth station transmit power	20.0 dBW
Feeder losses	1.0 dB
Antenna gain (4.5m) $\eta = 55\%$	53.8 dB i
Pointing loss (0.1°)	1.1 dB
Earth station EIRP	71.7 dBW
Space loss	207.4 dB
Propagation margin (99.9% annual)	3.0 dB
Satellite R_x antenna gain (eoc)	35 dB i
Satellite noise temp.	30 dBK
Satellite G/T	5 dB/K
Uplink C/N_o	94.9 dBHz
Uplink C/I_o	95.0 dBHz
	95.0 dBHz
Total Uplink $C/(N_o+I_o)$	91.9 dBHz

DOWNLINK 12.5 GHz

Satellite transmit power	13.0 dBW
Feeder loss	1.0 dB
Satellite T_x antenna gain (eoc)	34.0 dB i
Satellite EIRP	46.0 dBW
Space loss	206.4 dB
Propagation loss (99.9% annual)	2.0 dB
Earth station receive gain	53.0 dB i
Pointing loss	1.0 dB
Earth station receive system temp.	27.0 dBK
Downlink C/N_o	91.2 dBHz
Downlink C/I_o	95.0 dBHz
Overall $C/(N_o+I_o)$	87.6 dBHz
E/N_o (Theoretical, 10^{-6} b.e.r.)	11.6 dBHz
Symbol rate (25 Mb/s)	71.0 dBHz
Implementation "Margin"	5.0 dB

extraction from a few elements are other critical elements. Apart from the complexity and losses of the feed network, a drawback of this configuration is the large gain, and therefore flux, variations over the coverage area (typically 6 to 10 dB).

A second approach consists of using a set of contoured/shaped beams originating from a larger aperture (typically 4 meters). Each beam is also generated from a cluster of feeds but larger than previously. Peripheral elements of the feed cluster are also shared between two or more beams.

The advantage of this configuration is that the gain (flux) over the coverage area has lesser variations. Problems of feed complexity and losses still exist, aberrations due to large element beam scanning are increased.

In either case it is difficult to optimize the feed elements for both transmit and receive (and for some of them, for RF sensing as well).

Polarization sensitive reflectors are also considered to ease the

problem of frequency re-use by allowing close spacing of beams on different polarizations.

All the elements making up the antenna sub-system are being studied or developed by European industry (ERA, LM Ericsson, Tica) under ESA contracts.

The large number of connections required between up- and down-link beams is a new problem for the payload. It is assumed for the present that the switching is done at RF. The matrix is used in a narrow-band sense: that is to pass one TDMA signal bandwidth. Appropriate on-board local oscillator frequencies must therefore be provided. However, the basic technology of the switch allows bandwidths of 2 GHz or more which can be exploited in other missions.

Switch matrix studies and developments are being pursued for switch center frequencies of around 1.5 and 11 GHz (the higher frequency being considered in another context for 20/30 GHz payloads). Cross-bar switch matrix topology with redundancy

[Continued on page 86]

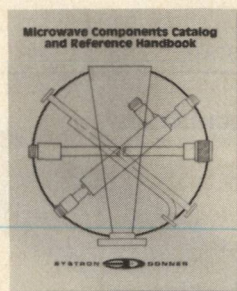
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[From page 84] **EUROPEAN SATELLITES**

has been selected based on GaAs FET integrated circuit technology. The actual switch configuration in terms of subdivision of functions into individual packages is under study in the industry (Plessey).

On board regeneration is also considered as a potential candidate for this mission. The base-band technologies are actually covered in the wideband mission described hereafter, however, direct remodulation on the RF carrier is presently the subject of a study (Plessey) and Figure 1 shows a picture of a Quadrature Phase Shift Key (QPSK) modulator based on dual gate FET technology, which holds great promise.

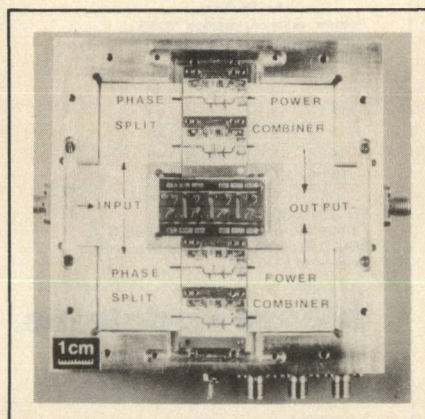


Fig. 1 QPSK Modulator at 12 GHz.

Dielectric resonator technology is being investigated as an efficient way of reducing the RF filter size at 12 GHz, while maintaining most of the performance. Figure 2 shows an example of a 3-pole filter realized using this technology by Elektronik Centralen, which is conducting studies for more

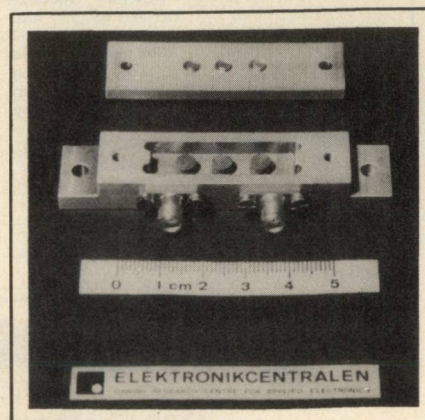


Fig. 2 Dielectric resonator at 12 GHz.

sophisticated filters such as pseudo elliptic or linear phase.

An improvement of the receiver noise figure by 1 to 2 dB is possible by properly cooling it with heat pipes connected to radiators. This technology is being developed in ESTEC with special emphasis on the heat pipe reliability. Figure 3 is an illustration of this approach.

It is not anticipated that other RF elements would need special attention. The numbers of Table 1 indicate, in particular, that the level of RF power (20W per channel) and noise temperature are in the range of the present state of the art of traveling wave tubes.

THE VIDEOCOMMUNICATION (OR HIGH CAPACITY) MISSION

This mission represents, in fact, the provision of wideband services to a vast community of users scattered throughout Western Europe. Its operational implementation could be in the late 90's. For convenience, an elementary channel has been defined. It is characterized by a bit rate of 8.5 Mb/s and a QPSK modulation with an efficiency of about 1.2 b/s/Hz, which implies an RF bandwidth of 7 MHz, with some guardbands. Such a channel is meant to be typical for the transmission of color TV images, after suitable signal compression, for teleconference application.

The total traffic considered is 1000 (elementary) channels. Half of them are processed through 10 to 15 large stations, in well defined places, and acting as concentrators between local loops and the satellite. The second 500 channels are used for connection with small and inexpensive ground stations located on the user's premises, in principle anywhere in the coverage area.

In view of the large RF bandwidth required (about 7 GHz), it is necessary to have the RF carriers in the Ka bands, i.e. 27.5-30 GHz in the up-link and 18.1-20.2 GHz in the down-link.

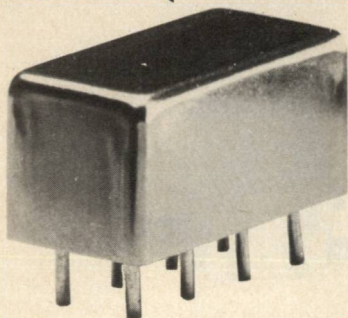
In the up-links, two cases are considered: for the large stations, 55 elementary channels arriving

[Continued on page 88]

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SRA-220 SPECIFICATIONS

FREQUENCY RANGE, (MHz)			
LO, RF	.05 - 2000		
IF	.05 - 500		
CONVERSION LOSS, dB			
One octave from band edge	TYP.	MAX.	
Total range	6.0	7.5	
	7.0	9.0	
ISOLATION, dB			
	TYP.	MIN.	
.05-.5	LO-RF	25	20
	LO-IF	25	20
.5-1000	LO-RF	40	30
	LO-IF	40	30
1000-2000	LO-RF	30	20
	LO-IF	25	15

Signal 1 dB Compression level +3dBm

For complete specifications and performance curves refer to the 1980-1981 Microwaves Product Data Directory, the Goldbook or EEM.

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85-3 REV. ORIG.

CIRCLE 69 ON READER SERVICE CARD

[From page 86] **EUROPEAN SATELLITES**

from the local network are Time Division Multiplexed (TDM) onto a RF carrier giving thus a transmitted bit rate of about 480 Mb/s. These stations access the satellite in Frequency Division Multiplier (FDM). The small stations access the satellite in FDMA Single Channel Per Carrier (SCPC) mode with a bit rate of 8.5 Mb/s. The signals are then demodulated in the satellite and routed towards their assigned down-link beam (i.e. the traffic for large and small stations can be mixed in the satellite), where they are remodulated. In the down-links to the large stations elementary channels are again TDM in blocks of up to 55, and to the small stations they are TDM in blocks of up to 5 in order to simplify somewhat the RF amplification sub-system.

As with the other pilot missions, these parameters are not to be regarded as implying any definite choice for the parameters of the subsequent operational satellite network, but they should be able to accommodate such parameters by stimulating appropriate technology development.

In the case of the videocommunication mission the RF part of the satellite payload is supported by baseband equipment permitting access conversion, modulation conversion, etc., which will be typical of advanced satellites. Additionally there will be an inter-satellite link handling up to 2 Gb/s of data, probably on two or three carriers, representing roughly one third of the total traffic.

All transmissions are digital and

a QPSK modulation scheme is implemented. A BER better than 10^{-4} is assumed for the overall transmission, resulting in a practical Energy per bit over Noise density (E_b/N_0) of 12.7 dB. The atmospheric attenuation for 99.75% of the time is below 12 dB in the up-link and 5.6 dB in the down-link. The large stations have an antenna gain of 60 dB (Reflector diameter of 8m), with satellite tracking but no RF power control. The small stations have an antenna gain of 50 dB diameter of 2.5m), no satellite tracking and no power control.

The ratio of the ground station gain is 10 dB but this is also the ratio of the bit rates, therefore a common satellite antenna with coverage gain of 46 dB is used. This corresponds to spot beams having a Half Power Beam Width (HPBW) of .25° and a minimum beam-separation also of .25° if the beams are disposed in a regular pattern with a triangular lattice. Figure 4 shows a typical European coverage where more than 100 beams are necessary to provide the service.

As for the specialized services mission, frequency must be re-used and therefore a tight control of the sidelobe levels is necessary. A (dual) offset reflector system is the concept presently considered. The diameter of the main reflector is about 4m. Transmit and receive are done with independent antenna subsystems. The large and small station traffic are handled on orthogonal polarizations.

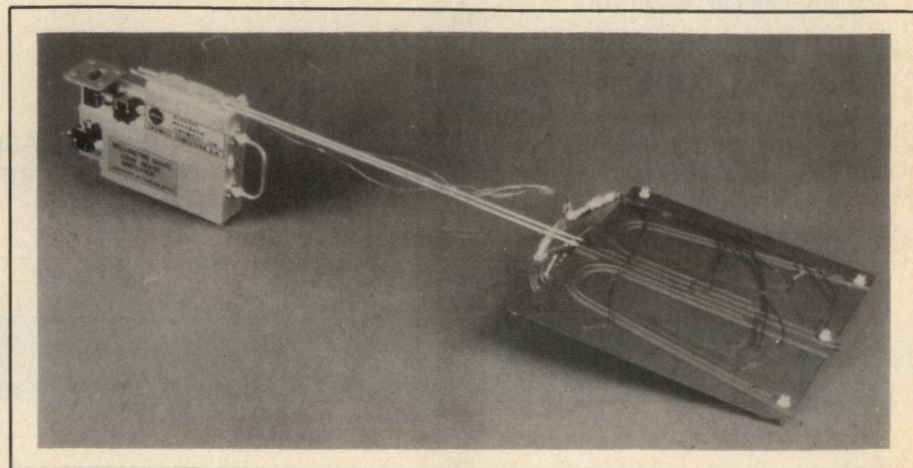


Fig. 3 Low noise receiver with heat pipe cooling.

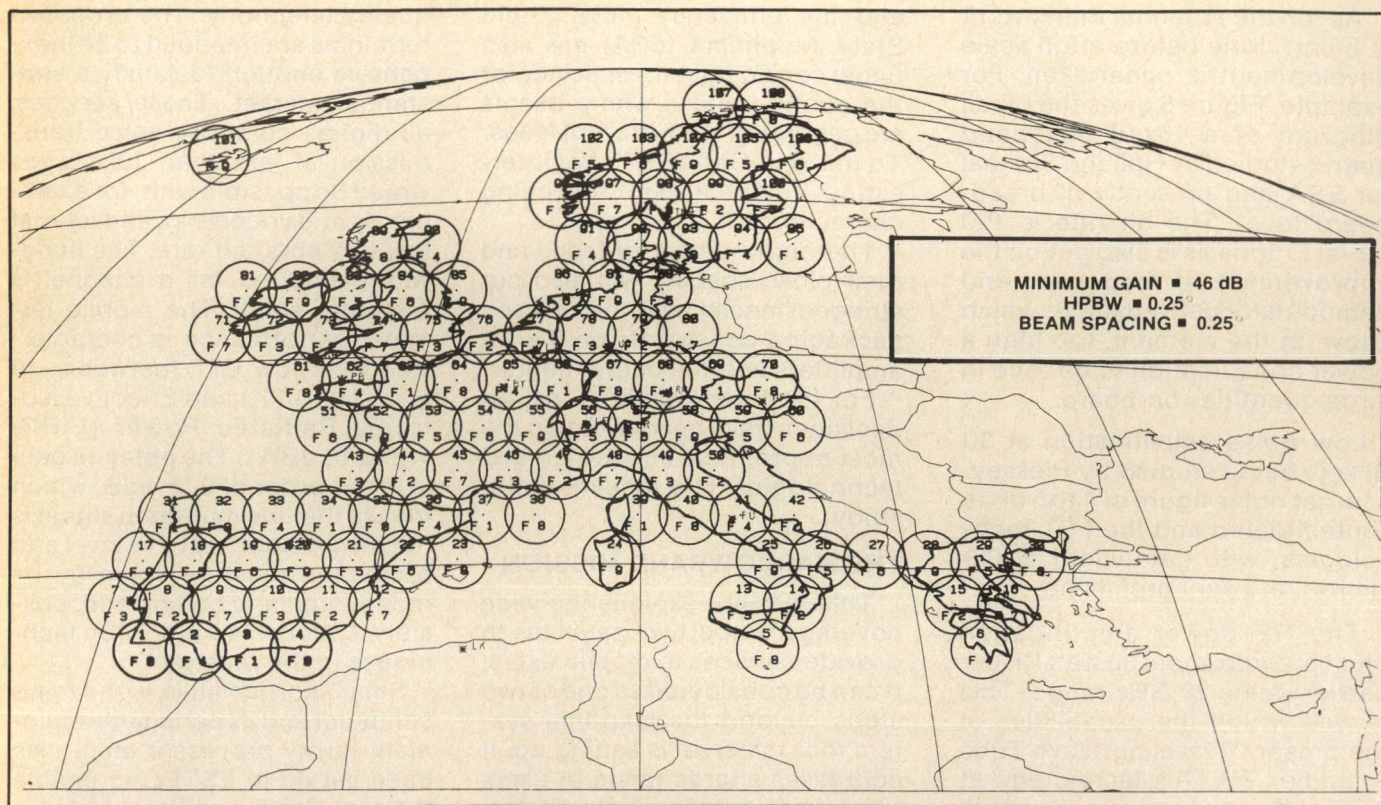


Fig.4 Typical European coverage in the Ka-band.

The feed network is very complex with spot beam generation requiring clusters of feeds. In one approach, separate feed networks are considered for the two traffics and a polarization sensitive sub-reflector enables the illumination of the same main reflector. Another approach is to have orthomode transducers in the feed common to all traffic; the antenna itself is simplified but at the expense of the feed network.

Before embarking on a full scale development program, preliminary activities have been initiated on the critical antenna parts, both at electrical and mechanical level. In the frame of an ESA contract a breadboard of a 21-element offset reflector antenna (2.5m) is presently being tested on an outdoor antenna range at Selenia, as shown in Figure 5. Beam pointing techniques are also the subject of detailed studies.

Although moderate average values have been considered for the atmospheric attenuation, much higher values could occur for short periods. Studies are therefore continuing to refine the propagation models in Europe, since this could have a strong impact on the repeater designs,

for example, adaptive links (in a resource sharing mode) might be necessary in some beams.

The large number of channels (1000) makes signal processing a key subsystem of this mission. After preliminary trade-offs, a solution with on board regeneration has been retained. The inde-

pendence of the up- and down-links is rather useful in a system with a high level of interference. Rapid developments in Very Large Scale Integration technologies (VLSI) make it possible to consider that processors can be manufactured with the levels of DC consumption, mass and reliability which are required for satellites.

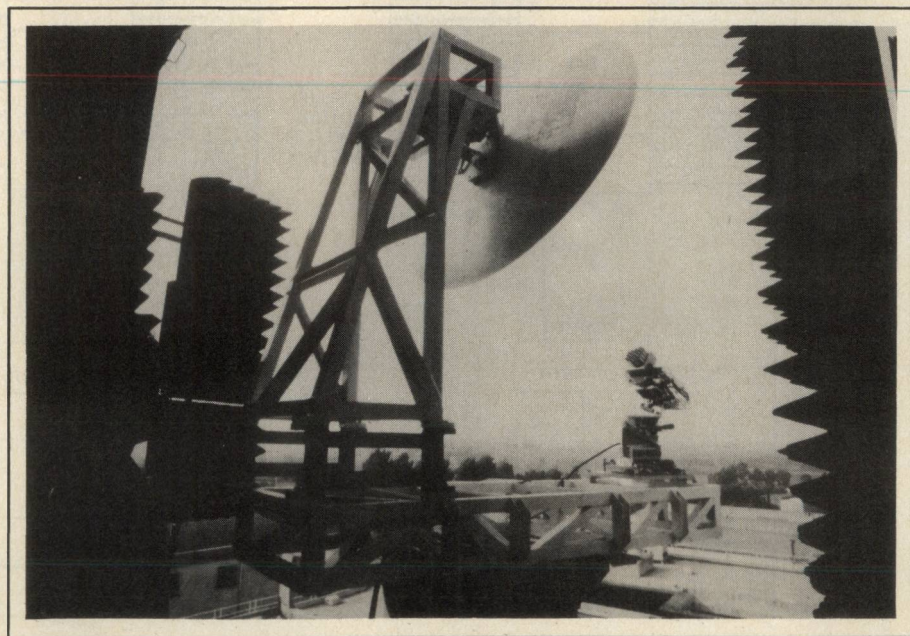


Fig. 5 21-Element antenna breadboard.

As for the antenna, initial work is being done before a full scale development is undertaken. For example, Figure 6 gives the block diagram of a 16x16 baseband matrix studied by Holland Signaal for ESA and presently at bread-board level. The bit rate is 120 Mb/s. Emphasis is also put on the improvement of modulator and demodulator performances which show, at the moment, too high a power consumption to be used in large quantities on-board.

Low noise amplification at 30 GHz is being studied by Plessey. A target noise figure of 4 to 5 dB is contemplated and the FET technologies, with gate-width of 0.3 micron, are very promising.

The RF power amplification must provide about 30 watt RF per carrier in the 20 GHz range. This is well within the capabilities of the present Traveling Wave Tube Amplifier TWTAs technology at AEG although further work would be necessary to improve the RF bandwidth (1 GHz at the moment)

and the efficiency (40%). Solid State Amplifiers (SSA) are also under consideration, especially for the configurations where beams are generated by clusters of feeds. To this end GaAs FET offer interesting prospects and are being characterized.

The high number of feeds and their close spacing will also put stringent mechanical, thermal and packaging constraints on the RF amplifiers and the output filters.

For the Inter Satellite Link, no decisions have been taken on the most appropriate link design and technologies. This remains under study.

THE NARROWBAND MISSION

This mission exploits the wide coverage property of satellites to provide services to mobile users. It can be considered as one or two steps beyond the maritime system that Inmarsat is setting up. It addresses a large range of users (maritime, aeronautical and terrestrial) which would be satisfied with a service quality less than full

quality telephony. The proposed terminals are intended to be inexpensive enough to satisfy a substantial market. These services, all digital, comprise voice transmission at less than 10kb/s (as would be possible with, for example, hybrid vocoders), and telex at low (1.2 kb/s) bit rate. The bandwidth required for a channel is therefore small. The mobile terminal performance is characterized by a low G/T (between -19 and -24 dB/°K) and Effective Isotropic Radiated Power (EIRP) (12 to 15 dBW). The antenna gain is in the order of 0 to 4 dB, which means that the multipath signal is not discriminated at this level and protection must be achieved by modulation and coding and, possibly, channel identification techniques in the receiver.

Simulation facilities, with a mini-computer and its peripheral equipment (array processor etc.) have been set up in ESTEC to enable the evaluation of different modulation and coding schemes in this multipath environment. Vocoders,

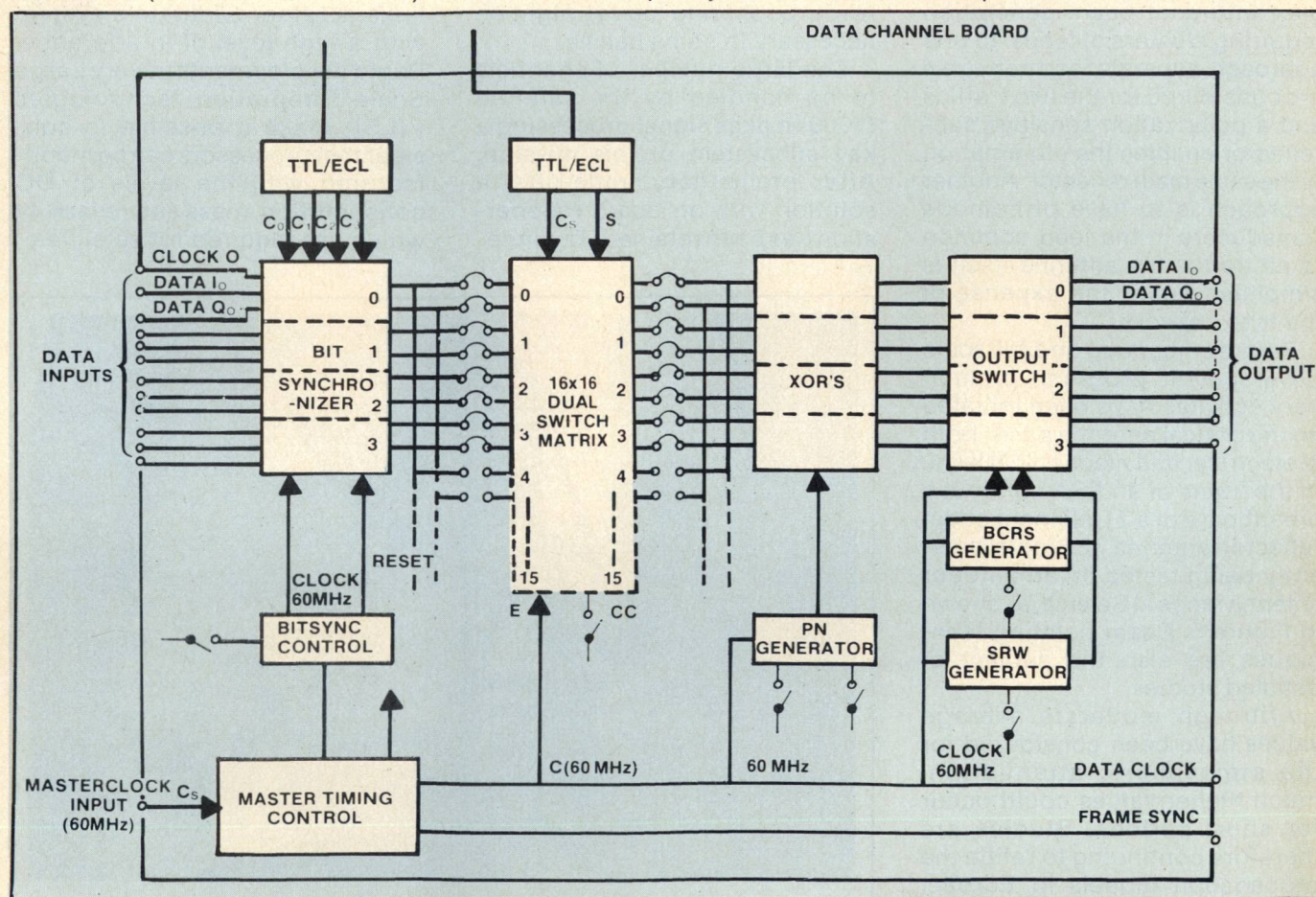


Fig. 6 16 x 16 Baseband switching matrix block diagram. (Signaal)

modems and codec are simulated in the computer and an external multipath simulator will be connected to it to represent various channel conditions.

The coverage is hemispheric and the satellite is located at a suitable position for the three services (maritime, aeronautical, land). A link budget analysis indicates that, at L-Band, the satellite antenna gain must be greater than 35 dB to give acceptable performance.

The approach presently under consideration to generate the beams (beamwidth in the order of 1 to 2°) is an 'imaging' system where in a large reflector, diameter of 10 to 12m, is properly excited by a planar phased array with 61 elements. Work has already been done in the field of phased arrays (Figure 7 shows a 19-beam, 18-element configuration designed for direct radiation) and most of

the RF technologies are considered well-mastered. The essential part of the activities is therefore concentrated on the mechanical aspects of the reflector and sub-reflector.

In the forward link, ground stations access the satellite in TDMA or FDMA. The signals are demodulated and connected to a data bus which routes them to their dedicated down link beam. In the return link, the mobiles access the satellite in a SCPC mode. All the signals are demodulated at once and connected via another data bus to modulators for the feeder links. Work is already progressing for the beam forming networks and a feasibility study has been undertaken for the digital multicarrier demodulator. It is planned to start investigations on the data bus concept after the first conclusions of the simulations mentioned previously. ■

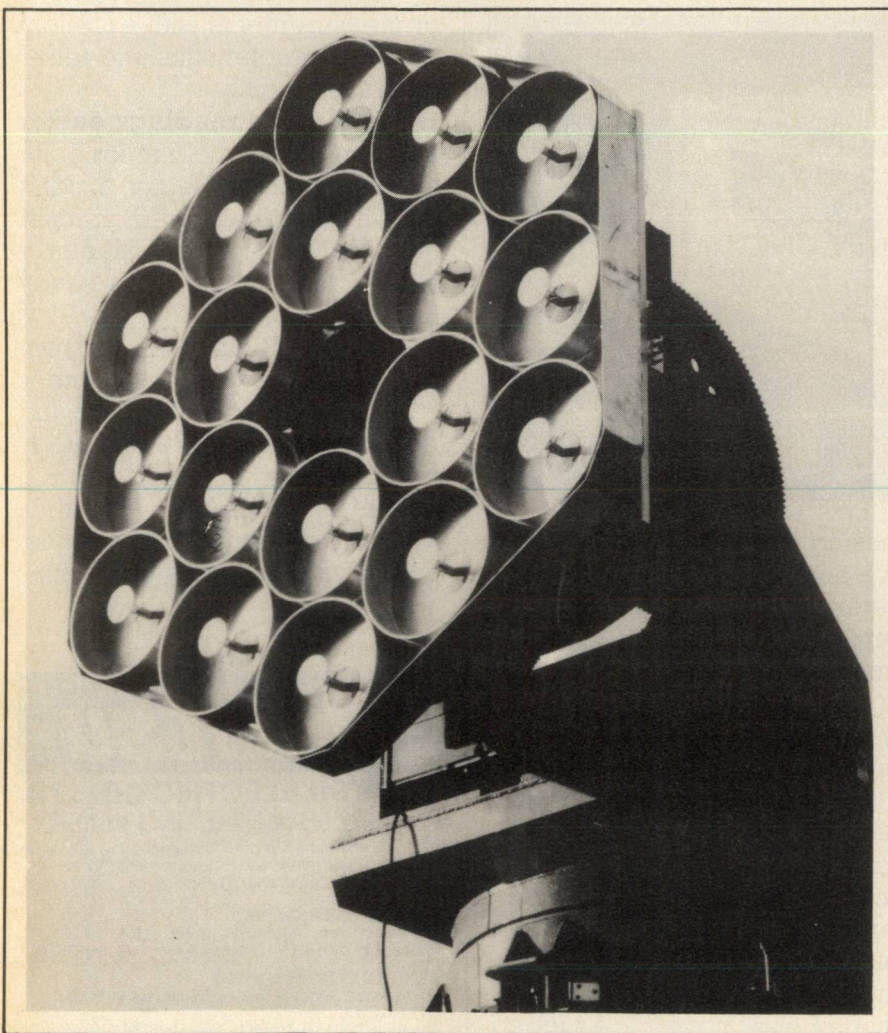
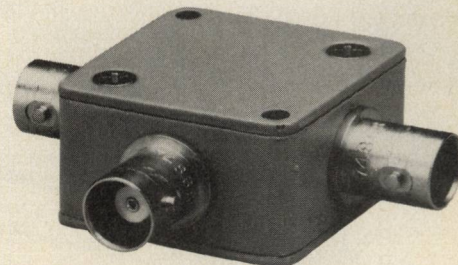


Fig. 7 Phased array antenna at L-Band.

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FREQUENCY (MHz)	1-500		
COUPLING, db	10.75		
INSERTION LOSS, dB		TYP.	MAX.
one octave band edge		0.8	1.1
total range		1.0	1.3
DIRECTIVITY dB		TYP.	MIN.
low range		32	25
mid range		33	25
upper range		22	15
IMPEDANCE		50 ohms	

For complete specifications and performance curves refer to the 1980-1981 Microwaves Product Data Directory, the Goldbook or EEM.

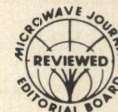
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81-3 REV. A



A 100 kW SOLID-STATE COAXIAL LIMITER FOR L-BAND

PART II

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Westinghouse Defense and
Electronic Systems Center
Advanced Technology Laboratory
Microwave Operations
Baltimore, MD

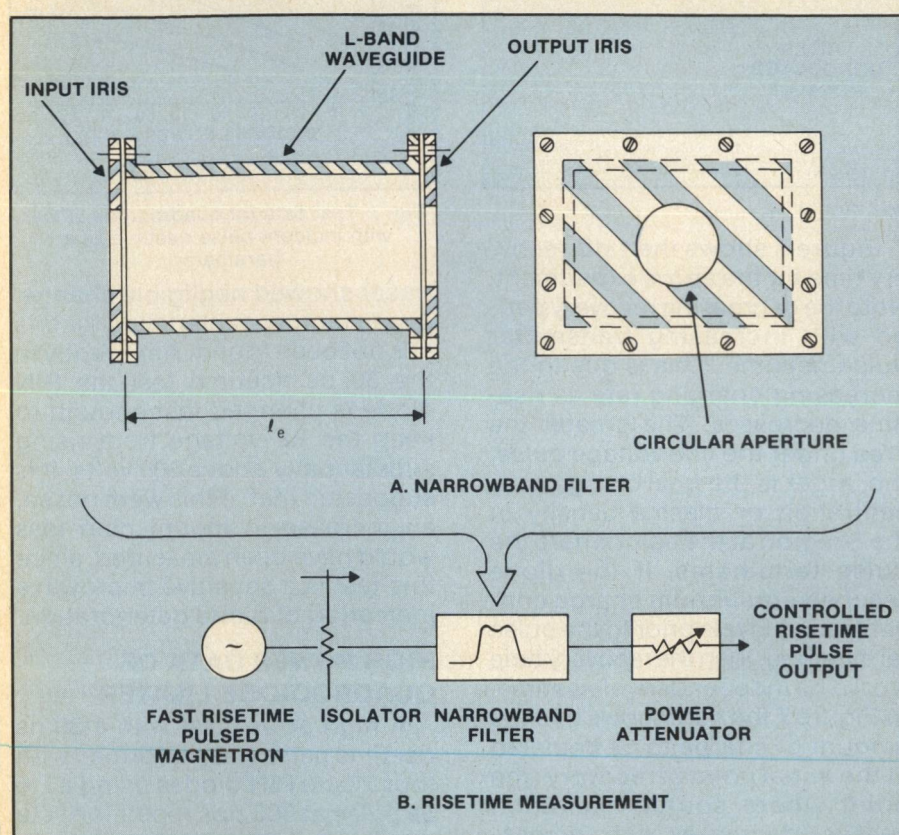


Fig. 5 Narrowband waveguide filter that controls magnetron pulse risetime.

TABLE I

FILTER PARAMETERS, MEASURED RISETIMES, AND
COMPUTED POWER CAPABILITY

Parameter	Filter 1	Filter 2	Filter 3	Filter 4
f_0 (MHz)	1283	1294	1299	1302
Δf (MHz)	5	4	3	1.6
$Q = f_0 / \Delta f$	256	323	433	810
Insertion Loss (dB)	1.5	1.6	2.4	3.8
Transmitter Pulse Risettime t_r at Filter Output 10% - 90% (ns)	110	220	330	430
Computed RF Power Handling Capability (kW)	25	50	75	100

PEAK POWER EXPERIMENTS

Equation 3 indicates that the peak power capability of the shunt-mounted PIN diode limiter can be greatly enhanced by using large values of t_r/t_d . An experiment was designed to evaluate this effect. A series of high power filters, shown in Figure 5a, were designed to increase the leading edge rise of a 100 kW pulse in approximately 100 ns steps. The experimental results, measured in the test of Figure 5b, are shown in Table I. The predicted peak power handling capability is also shown. The magnetron generated a 150 kW/2.8 μ s/300 pps pulse with a risetime of 30 ns at 1.3 GHz.

The diode turn-on time t_d is defined as the elapsed time between the leading edge of an externally applied bias pulse and the point at which the RF dynamic attenuation reaches 10 dB. For this experiment the GaAs biasing diode was removed from the circuit. Three PIN diodes with I-region widths of $w = 50, 70$, and 100μ m were selected and the bias drive pulse, with a leading edge rise of 1 ns, was applied. For this test a simple shunt-mounted single PIN was used with small CW signal levels at 1.3 GHz. The results showed $t_d = 70, 80$, and 350 ns for the 50, 70, and 100 μ m PIN diodes respectively.

The 800 volt, 70 μ m PIN diode was selected for the high power experiment because a $t_d = 80$ ns and $t_r = 430$ ns gave a predicted result, using Equation 3, of the required peak power handling capability (100 kW). Four 70- μ m

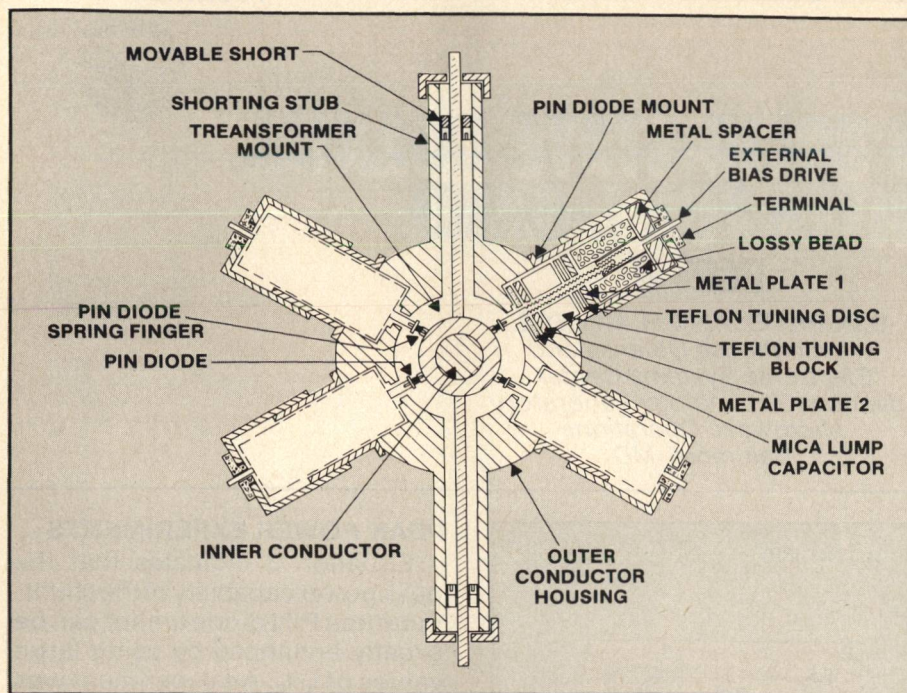


Fig. 6 Quadrodiode mount.

PIN diodes were embedded in a coaxial limiter as shown in Figure 6, and high power tests were conducted. The experimental results, depicted in Figure 7, show that the spike leakage decreases with increasing risetime. This is as expected since a finite time is required to fill the I-region with charge*. This finite delay in diode impedance state change allows leading edge power to be transmitted to the load. A slow risetime on the transmitter pulse provides time for the I-region to fill with charge so that the significant drop in diode impedance occurs before a substantial rise in applied RF voltage. As noted above, the effects of conductivity modulation is that the diode impedance remains approximately equal for the positive and negative swings of the RF line voltage. Thus the diode in the reverse voltage direction cannot develop the full pulse source voltage, which explains why a $V_{BB} = 800$ volt PIN diode can control an incident RF voltage pulse of $V_p = 2650$ volts peak (100 kW).

* This is analogous to a microwave-activated pulsed gaseous plasma where a finite formative time lag exists until electron velocities reach the critical value to avalanche. After avalanche the discharge cannot support an electric field and the transmitted power at the load is greatly attenuated. This formative time lag gives rise to the familiar spike leakage output.

Figure 7 shows the 1 dB recovery time for the above experiment. Note the decreasing recovery period with increasing transmitter pulse risetime. This is due to the increasing charging rate as risetime decreases. The greater the area under the line voltage pulse, the larger is the final charge concentration or plasma density in the I-region at the point where the pulse terminates. If the diode reached equilibrium charge concentration levels prior to the pulse terminating, then the recovery time would be independent of risetime. In Figure 7 the data shows that the amount of charge to be depleted at the initial point of recovery (the point where source excitation ceases) decreases with increasing risetime, clearly indicating that equilibrium concentrations have not been reached.

The peak power capability, which was expected to increase with longer risetimes, did not occur up to the power limitations of the variable risetime testset. Operation using 30 ns risetime, $3 \mu s/100$ kW transmitter pulses was satisfactory. We did not observe any signs of PIN diode degradation of RF burnout, as evidenced by small-signal zero-bias insertion loss tests made after each high power measurement. V-I diode measurements made on a characteristic curve

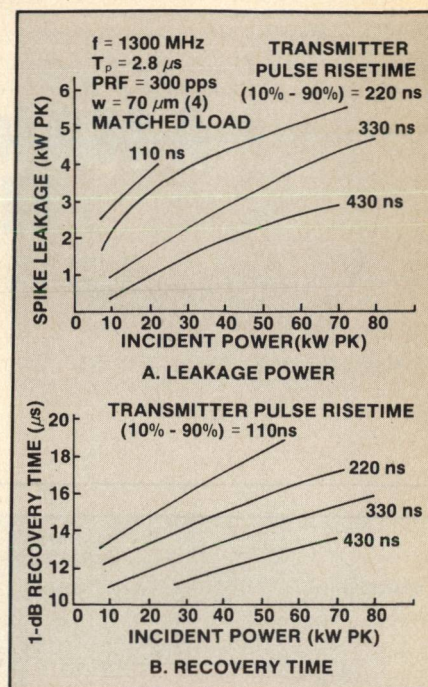


Fig. 7 Test data for quadrodiodal limiter with incident pulse risetime as a parameter.

tracer showed negligible change. A satisfactory explanation for this has not been found. Apparently in the 30 ns risetime test the PIN diode is changed fast enough to keep the RF voltage from rising substantially above 800 volts. It is suggested that, if this were not so, an increase in mount cold loss would have been measured, since this test is a sensitive microwave indication of diode deterioration.

HIGH POWER DATA OF QUADRODIODE LIMITER

A high power test with a 30 ns risetime pulse was performed with four $70 \mu m$ PIN diodes using a $2.6 \mu s$ pulse at 300 pps repetition rate into a matched ($VSWR < 1.1$) load. Figure 8 shows the spike leakage, recovery time, biasing current output, and PIN diode voltage drop for the 100 kW level. Figure 9 depicts the high power test data for the quadrodiodal limiter at power levels varying from 10 kW to 100 kW. The maximum spike leakage is 2.8 kW/65 ns; the maximum flat leakage is 32 watts. It was observed that the spike leakage at high power levels (> 50 kW peak) for 110 ns and 30 ns risetimes were lower than those for slower-risetime (440, 330, 220 ns) input pulses. This may be due to the fast rising (10 ns risetime)

[Continued on page 96]

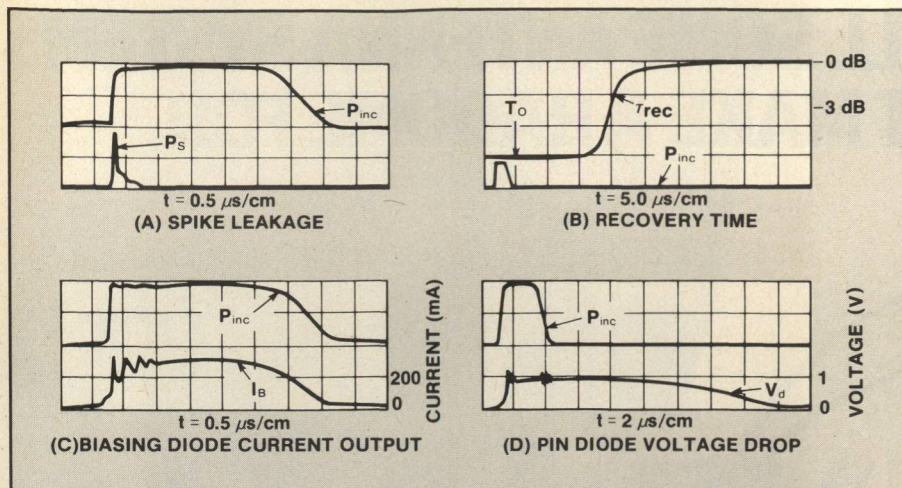


Fig. 8 100 kW Data for quadrodioder limiter using self-biasing detector diodes.

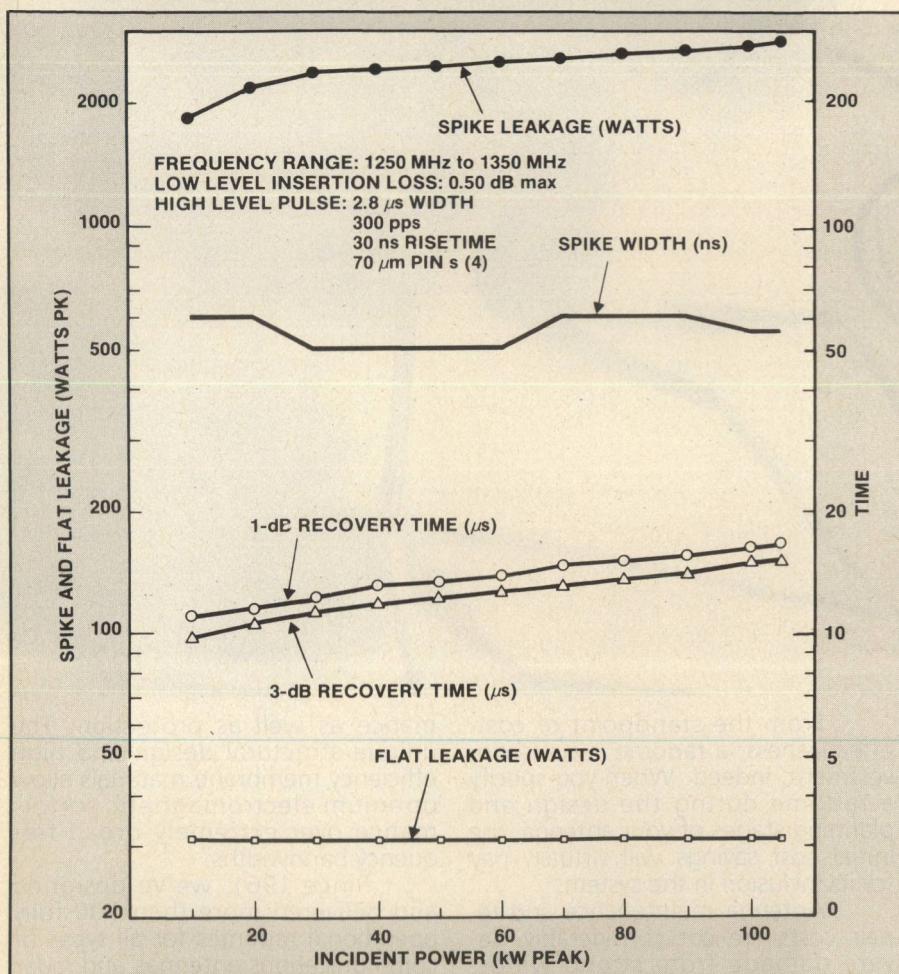


Fig. 9 Quadrodioder test results.

high amplitude charge injection (350 mA) from GaAs biasing diodes driving the PIN diodes into conduction much faster than the risetime of the incident RF pulse, and therefore resulting in lower spike levels. It is anticipated that a relatively low power varactor diode limiter cascaded behind the quadrodioder stage can reduce the RF leakage levels to values compati-

ble with the requirements of FET low noise amplifiers. The 1 dB and 3 dB recovery times, as measured against a reference point of 1 percent of the trailing edge peak power of the incident pulse, have worst-case values of 17 and 15 μ s, respectively. It is felt that a decrease in the value of the 330 ohm discharge resistor would substantially decrease recovery time at

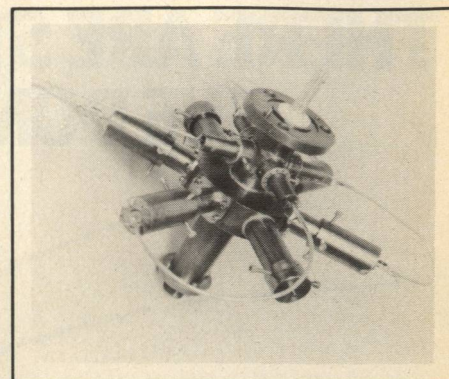


Fig. 10 Westinghouse WD-367 coaxial limiter.

the expense of bleeding the bias current away from the PIN diodes, which would further increase the spike and flat leakage values. The maximum video output from the GaAs varactor diode was approximately 360 mA at 100 kW. The decoupled RF voltage at the biasing diodes input side was 158 volts peak (250 watts). The low level insertion loss of the quadrodioder limiter was measured to be 0.5 dB maximum after a 100 kW test run of 4 hours.

A photograph of the prototype unit with a 7/8 inch EIA male connector at the input and a female N-type connector at the output is shown in Figure 10.

APPLICATIONS

The L-band power limiter discussed above was designed to operate in front of a low-power multiple-stage varactor limiter that would reduce spike and flat leakages of 2.8 kW and 32 watts pk respectively to levels low enough that FET or bipolar low noise amplifiers are adequately protected from burnout or gain-recovery phenomena. The device was designed for use in L-band high power surface radars.

CONCLUSIONS

A single-stage, multiple-diode, 100 kW solid-state coaxial quasi-active limiter for the 1250 to 1350 MHz band has been demonstrated using four 70- μ m PIN diodes. The wide-I-region diodes have a longer turn-on time, and therefore the power handling capability may be restricted for fast risetime transmitters. Consequently, transmitter engineers should furnish the risetime of the high power pulse to designers of limiters or receiver

TABLE II
SUMMARY OF HIGH POWER LIMITER RESULTS

Parameter	Brown ¹		Maddix ⁴	Data
Frequency (MHz)	225	450	450	1300
Peak Power (kW)	150	1000	300	100
Average Power (kW)	10	2	5	0.1
Pulsewidth (μ s)	200	4	60	3
Number of Diodes in Plane	16	31	4	4
Insertion Loss (dB)	2	3.5	0.75	0.5
I-Region Width (μ m)	25	12	50	70

protectors to optimally relate V_{BB} to peak RF power handling capability. The spike leakage and recovery time characteristics showed distinct dependence on the ratio of the input pulse risetime to the diode turn-on time. Although the number of diodes was determined from the thermal dissipation model, the PIN diode parameters were determined on the basis of the reverse breakdown voltage, pulse risetime model. The computer-aided design procedure proved very useful in selecting the PIN diodes for the desired small-signal microwave performance parameters of insertion loss, input VSWR, and isolation.

The use of 450 volt, 0.5 amp, 1.3 pF GaAs varactor diodes as rectifying devices to provide an efficient and fast-acting bias to the PIN diodes was considered to be very important in high peak power operation. We also observed that the reverse breakdown voltage model discussed here, which accounts for variations in input pulse risetime and diode turn-on time, did not significantly affect the power handling capability of the limiter up to the 100 kW level. The reason for this has not been ascertained. A comparison of the results reported here with similar work reported by other investigators is shown in Table II.

ACKNOWLEDGEMENTS

We acknowledge the contribution of Dr. S. Stitzer for the design of the narrowband waveguide filters required to vary high-power pulse risetimes.

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Suman D. Patel, joined Westinghouse Defense and Electronics Systems Division in February 1979. He is currently a Senior Engineering Microwave Control Devices Group. Prior to joining Westinghouse he worked in RF Signal Distribution and Receiver Systems Group at Norlin Communications and Electronics. Mr. Patel received his B.E. degree in Electrical Engineering from Sardar Vallabh University in Anand, India and his M.S. and PhD degrees in Electrical Engineering in 1968 and 1973 respectively from the University of Delaware. ■

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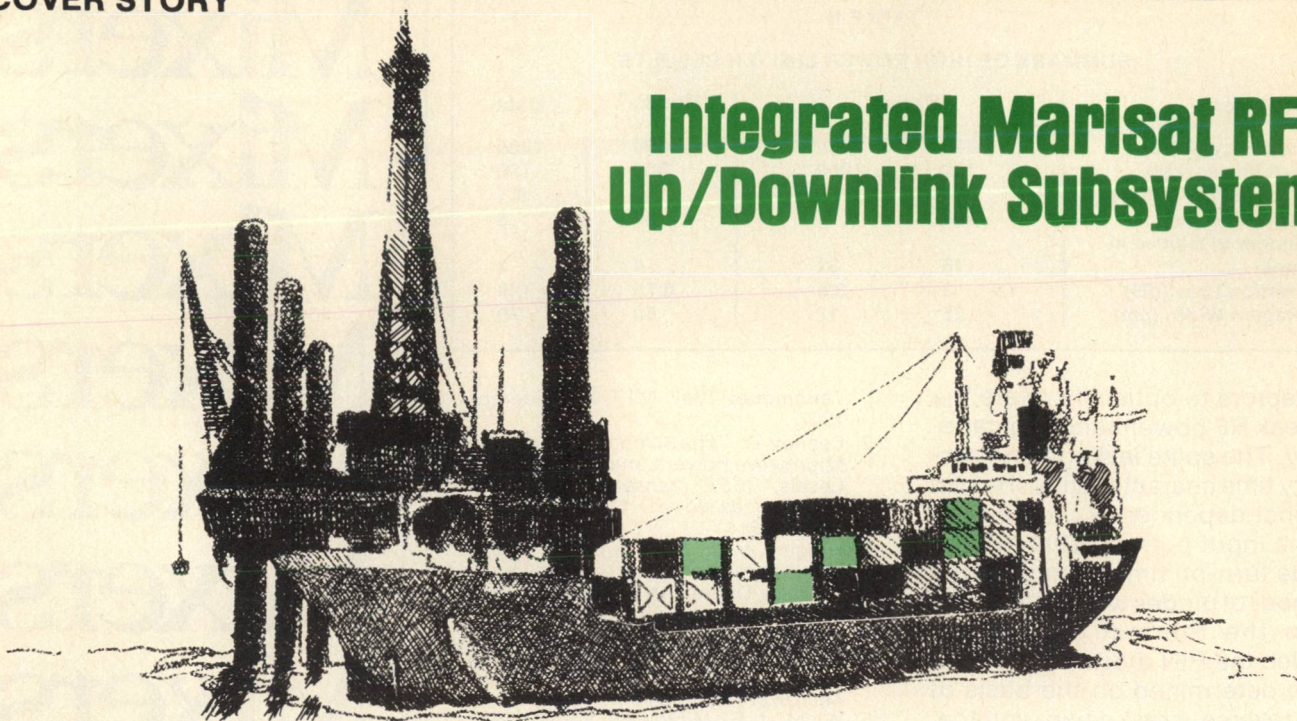
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INTRODUCTION

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ever a vessel or drilling platform might be located. Many systems have been installed, some have been operating for 5 years, and many more are planned for installation in the 1980's.

The satellite system transmits and receives voice, telex, data

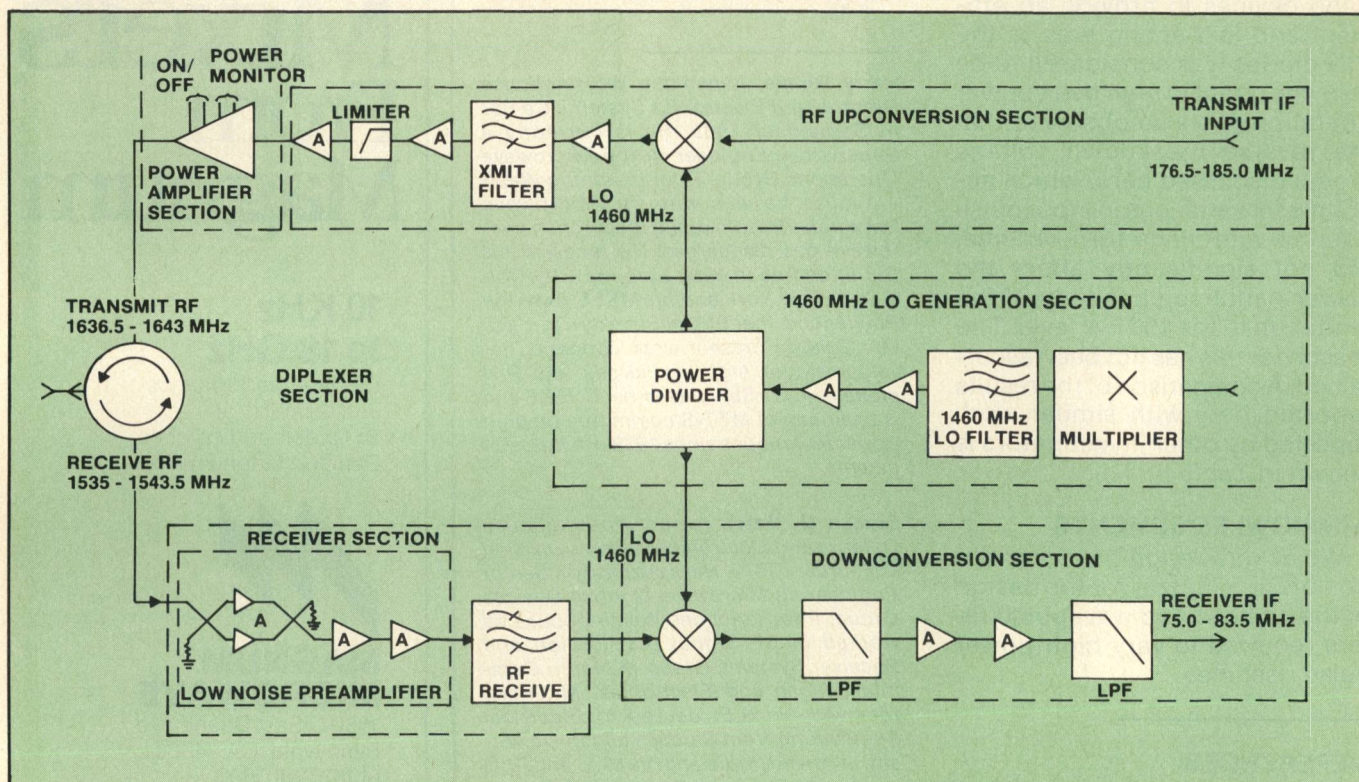


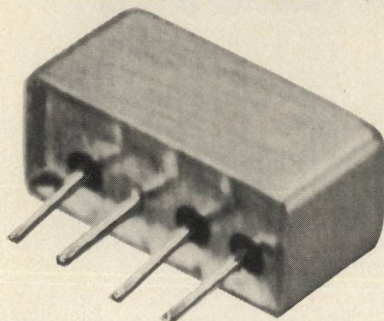
Fig. 1 Block diagram of the Avantek integrated Marisat uplink/downlink RF subsystem.

[Continued on page 100]

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LO, RF	5-1000		
IF	DC-1000		
CONVERSION LOSS, dB			
One octave from band edge	TYP.	MAX.	
	6.2	7.0	
Total range	7.0	10.0	
ISOLATION, dB			
	TYP.	MIN.	
LO-RF	50	45	
LO-IF	45	40	
LO-RF	40	30	
LO-IF	35	25	
LO-RF	30	20	
LO-IF	25	17	

SIGNAL 1 dB Compression level +14 dBm min

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[From page 98] **MARISAT RF**

and facsimile at L-band for ship-to-satellite and at C-band for ground-to-satellite. The 8.5 MHz bandwidth is divided into channels which are nominally 25 KHz wide, and carry single-carrier-per-channel (S.C.P.C.) voice or 2 phase C.P.S.K. data modulation schemes. Medium speed (kbits/sec) data rates typically require an effective radiated power of +37.0 dBW which, with a 4-foot parabolic antenna, requires a +43.5 dBm (22.4 watt) amplifier. The satellite signal E.I.R.P. is -150 dBW max. requiring a 1.2 dB noise figure receive amplifier. The transmit and receive frequency bands are only 101.5 MHz apart and a high degree of isolation between these channels is required to avoid interference.

INTEGRATED SUBSYSTEM

Avantek's integrated RF amplifier assembly generates the transmit signal and handles the receive signal and connects via a single cable to the antenna. It provides 150 dB of isolation between the transmit power amplifier and the receive low noise amplifier and provides transmitter IF-RF up-conversion and receiver RF-IF downconversion in an antenna-mounted integrated assembly. The subsystem, shown in Figure 1, consists of four functional groups: receiver preamplifier, diplexer, transmitter power amplifier, and a frequency translator. The translator includes a local oscillator frequency multiplier, a receiver RF-IF downconverter and an IF-RF upconverter.

The diplexer consists of two cavity filters, one tuned to the receiver RF band (1535-1543.5 MHz), and the other tuned to the transmitter RF band (1636.5-1645 MHz). The filters are combined at the antenna port through a resonant diplexer printed circuit board which provides in excess of 20 dB of isolation at each filter port and more than 60 dB of rejection at the band edge of the other filter.

The RF receiver section consists of a balanced 1.2 dB noise figure, high gain GaAs FET pre-amplifier followed by another cavity filter tuned to the receive band. The 0.8 dB insertion loss of the

receiver diplexer cavity filter and the 1.2 dB noise figure of the preamplifier result in a system noise figure of 2.0 dB.

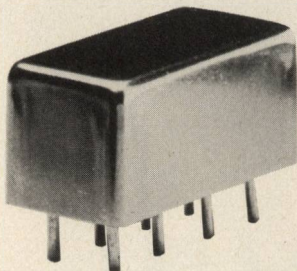
The local oscillator frequency multiplier takes a low frequency phase-locked external oscillator signal and multiplies it to generate a functional 1460 MHz LO signal which is then split into two +7 dBm signals for use in the upconversion and the downconversion sections. This LO-generation section must accept a 16 dB range external oscillator input and produce a constant level 1460 MHz LO signal to assure consistent conversion loss characteristics of the upconverter and downconverter mixers. The use of a narrow band 1460 MHz bandpass filter assures high rejection of the oscillator input signal and its other multiplication products.

The downconverter is comprised of a double-balanced mixer, two low pass filters and two stages of IF gain. The use of a double-balanced mixer provides high isolation between LO, RF and IF ports and high rejection of even-order harmonics. The low pass filter at the IF port of the mixer rejects any residual external oscillator signal, its undesirable multiplication products and any 1460 MHz LO signal appearing at the IF port of the mixer. The filter assures that any spurious products generated by the amplification of the IF signal will be below the noise floor. A second low pass filter is used at the output of the downconverter to reject any out-of-band mixing products that might be amplified by the IF gain stages.

The upconverter consists of a double-balanced mixer, several gain stages, a filter and a limiter. The transmitter IF input has an input power range of 15 dB which requires limiting circuitry to generate a constant RF input signal drive to the power amplifier. The upconversion filter centered at the transmitter RF band is a microstrip hairpin filter. It rejects undesired multiplication products leaking through the mixer and limits the noise power transmitted within the receiver RF band. Excessive noise power at the transmit port of the diplexer (n_{TRANS}) com-

[Continued on page 104]
MICROWAVE JOURNAL

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- miniature 0.4 x 0.8 x 0.4 in.
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- low distortion, +40 dBm intercept point
- **NSN 5985-01-067-3035**

PAS-3 SPECIFICATIONS

FREQUENCY RANGE, (MHz)			
INPUT	1-200		
CONTROL	DC-0.05		
INSERTION LOSS, dB			
one octave from band edge	TYP. 1.4	MAX. 2.0	
total range	1.6	2.5	
ISOLATION, dB			
1-10 MHz IN-OUT	TYP. 65	MIN. 50	
IN-CON	35	25	
10-100 MHz IN-OUT	45	35	
IN-CON	25	15	
100-200 MHz IN-OUT	35	25	
IN-CON	20	10	

IMPEDANCE 50 ohms

For complete specifications and performance curves refer to the 1980-1981 Microwaves Product Data Directory, the Goldbook or EEM.

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[From page 100] **MARISAT RF**

binies with the broadband noise in the receiver ($n_{REC.}$) increases the system noise during transmission in accordance with the relationship:

$$n = \sqrt{n_{REC}^2 + n_{TRANS}^2}$$

The power amplifier is housed in an aluminum case separate from the LNA/diplexer/translator housing. The amplifier has an input class A stage followed by two single-ended class C stages. A final balanced class C stage and a high power isolator provide an RF output power of +44.3 dBm. The power amplifier nominally requires 81 VA and delivers 22.4 watts over a temperature range of -40°C to +70°C for an efficiency of 28%. The amplifier includes an EIA standard RS — 422 compatible control module, which monitors the RF output power for failure annunciation and turns the RF power on and off.



Fig. 2 Latest design Marisat uplink/downlink RF subsystem.

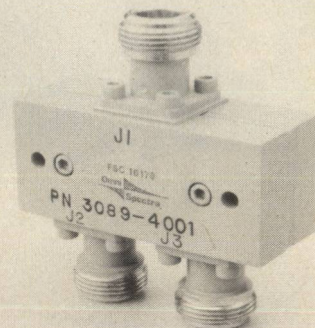
The current generation of the subsystem integrates the uplink and downlink amplifiers into the package shown on the cover. This unit is now in operation worldwide and has provided reliable voice and data communications in a variety of environments for several years. The latest generation (Figure 2) integrates the translator into the package and uses a heat sink rather than heat fins for thermal dissipation.

As the satellite gains acceptance as an efficient, reliable and cost-effective form of marine communications, use of the Marisat type of terminal will proliferate to many commercial vessels and platforms in the years to come ■

Microwave Products

Components

3.7-4.2 GHz POWER DIVIDERS



Power dividers in 2-way, 4-way and 8-way designs operate in the 3.7-4.2 GHz band and are intended for TVRO, MATV and CATV applications. Power loss is typically 0.25 dB. **Omni Spectra, Inc., Merrimack, NH John Callahan (603) 424-4111.**

Circle 181.

50 Ohm TERMINATIONS

Model CT-53-BNC or SMA/M are 50 ohm coaxial BNC and SMA terminations covering the frequency range of DC to 4 GHz with a maximum SWR of 1.3. Dissipation is 0.5W CW, 1 KW peak over the temperature range of -25 to +85° C. Connectors are silver, gold or nickel plated female or male connectors. Price: \$6.18 each in 100 quantity. Delivery: stock to 30 days ARO. **Elcom Systems Inc., Boca Raton, FL. Leonard Pollachek (305) 994-1774.**

Circle 131.

2.9 - 3.1 GHz VARIABLE ATTENUATOR

Model 4813-10A miniature variable attenuator operates over the frequency range of 2.9 to 3.1 GHz. It has an attenuation range of 10 dB, and an attenuation vs frequency specification of better than ±0.5 dB. SWR is 1.5 maximum and the unit has a 0.5 dB insertion loss. The unit is available in a panel mount configuration, turns counting dial configuration or with a micrometer control. The unit measures 2 x 1 1/4 x 1/2 inches, and the standard control mechanism is a multi-turn screwdriver shaft with lock nut. **ARRA, Inc., Bay Shore NY. Mike Geraci (516) 231-8400.**

Circle 135.