A 12 GHz LOW COST EARTH TERMINAL FOR DIRECT TV RECEPTION FROM BROADCAST SATELLITES

R.J. Douville

Communications Research Centre, Dept. of Communications,
P.O. Box 11490, Station "H", Ottawa, Ontario, K2H 8S2

ABSTRACT

A low-cost 12 GHz receiver for TV reception from high power broadcast satellites is described. The system uses a 1.2m antenna with a high efficiency feed positioned at the focus. The front end, mounted behind the feed, consists of an image-enhanced mixer, followed by a low noise amplifier. The 1.2 GHz IF output is fed to an indoor unit which uses SAW devices both for filtering and FM demodulation at 70 MHz. Audio and video receiver outputs go directly to the baseband circuitry of a standard TV receiver.

Introduction

With the advent of high power broadcast satellites such as Hermes (CTS), the feasibility of using low cost TV receive-only terminals for direct broadcast reception from satellites has become a reality. The Hermes satellite, with an e.i.r.p. of 59 dBW, gives a signal level at the receiving antenna of up to -116.9 dBm. Table 1 lists some of the system parameters and specifications for the receiver terminal design.

The overall goal was to realize component designs which would lend themselves readily to low-cost medium- to large-volume production. The receiver configuration which has been developed is illustrated schematically in Fig. 1. The system employs double conversion with a high first IF (1.2 GHz) in order to alleviate some of the problems anticipated in expanding the system to multichannel reception. It should be noted that AFC is applied to the second LO in order to relax the stability specification on the first LO. The system consists of three sub-assemblies, each of which will be described separately.

The Antenna

A Cassegrainian antenna using a shaped subreflector, a conical scalar feed and a 1.2m parabolic dish was investigated. Although this configuration yielded ~67% efficiency, the approach was deemed to be potentially expensive and was therefore not pursued further. A prime focus fed arrangement was therefore adopted. The feed design is shown in Fig. 2 and employs circular waveguide with a 90° scalar feed [1,2]. The waveguide diameter was chosen to provide ~50 dB attenuation to the LO, thus minimizing LO leakage. The E- and H-plane phase and gain responses of the feed are illustrated in Fig. 3. The constant aperture phase distribution, coupled with the near-optimum gain pattern resulted in a measured net antenna efficiency of 75% (42.3 dB gain), in close agreement with the computed value of 82% obtained using the measured patterns. Besides its excellent performance, the feed design has the highly desirable feature of lending itself easily to low-cost fabrication methods. Furthermore, the slight extension of the circular waveguide beyond the face of the corrugations may be fabricated as a separate ring. The ring can then be used to clamp a suitable film across the waveguide to supply some environmental protection.

The Outdoor Unit (ODU)

The signal is coupled from the circular waveguide via an E-field probe directly to the MIC mixer. The mixer uses two GaAs Schottky barrier beam-lead diodes in the arms of a rat-race hybrid together with coupled-line 9.68 GHz bandstop filters for image enhancement. To provide IF leakage from the signal or LO ports, planar 1.2 GHz series tuned circuits are also included in the arms of the hybrid. The mixer is followed by a low-noise 1.2 GHz MIC bipolar transistor amplifier. The mixer/amplifier combination yielded an overall noise figure of ~6.0 dB with ~26 dB conversion gain. Three approaches to the design of the Gunn diode LO were investigated. The goal was to derive a low-cost approach providing ~+8 dBm at 10.8805 GHz and a ±5 MHz frequency stability from -40°C to +50°C. Firstly, a TE_{101} rectangular cavity with dielectric chip compensation was developed. A second approach used a TE_{01n} symmetrical cavity, temperature stabilized using a high coefficient of expansion material to compensate for changes in the cavity dimensions [3]. The cavity was then coupled to an MIC Gunn diode oscillator using an aperture in the MIC ground plane. A third approach was completely planar and used dielectric-overlay compensated microstrip resonators. Stabilities of ±1 MHz were achieved although the TE_{101} cavity approach used in the unit illustrated in Fig. 2 yielded only ±3.5 MHz, still well within specifications. Figure 2 shows the complete outdoor unit consisting of the scalar feed as well as the receiver front-end. The units shown are integrated using o-rings between the housing and the main body to achieve a moderate degree of hermeticity. The complete unit shown was cast in plastic and requires a minimum of assembly time. Included in the ODU is a low cost voltage regulator which converts the unregulated 17V from the indoor unit (via the RF interconnect) to regulated 12 VDC for the Gunn diode oscillator and bipolar transistor amplifier.

The Indoor Unit (IDU)

The first stage of the indoor unit is a commercially available low cost mixer preceded by a 1.06 GHz image reject filter. The LO frequency, in this case, is automatically controlled to maintain the 70 MHz IF stable to 200 kHz. The function of the remainder of the indoor unit is self-evident from Fig. 1. Both SAW and discrete component 70 MHz filters and discriminators have been successfully developed and used. The SAW devices, one of which is illustrated in Fig. 4, yield the obvious benefit of low cost in volume production. To date >35 dB rejection has been achieved with excellent skirt selectivity (20 MHz 1 dB and 23 MHz 30 dB bandwidth) and group delay responses.

Conclusions

The complete earth terminal is illustrated in Fig. 5. A system G/T_s of 12.9 dB/°K with a 1.2m antenna was achieved, yielding a video signal of more than sufficient quality for most domestic users and in some cases, also suitable for cable head-end applications. A study of the expected cost in quantity production is currently underway.

Acknowledgement

Many people were responsible for major contribution to the development of this terminal. I wish specifically to acknowledge the effort of T. Nishizaki, G. St.Amand (IDU), O. Berolo (SAW), A. Kong, L. Shafai and W. Bruyn (Antenna) and B. Clarke and R. Hahn (ODU). Also the support of the microelectronics group is greatly appreciated.

References

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TABLE 1

LOW COST TERMINAL SPECIFICATIONS AND PARAMETERS

PARAMETER		TARGET	ATTAINED
Received power level	MAX	-116.9 dBm	-116.9 dBm
Antenna Gain (1.2m)		41.5 dB	42.3 dB
Carrier Power at Receiver Input	MAX	- 75.4 dBm	- 74.6 dBm
Noise = kT_sB (B=22 MHz)		- 95.2 dBm	- 95.8 dBm
G/T_s		11.5 dB/^oK	12.9 dB/^oK
C/N (including uplink contribution)	MAX	18.9 dB	20.1 dB
	THRESHOLD	10.5 dB	-
Video SNR*	MAX	49.3 dB	50.5 dB
	THRESHOLD	>39 dB	38.3 dB

* Peak-to-Peak video (excluding sync-tip) to rms weighted noise

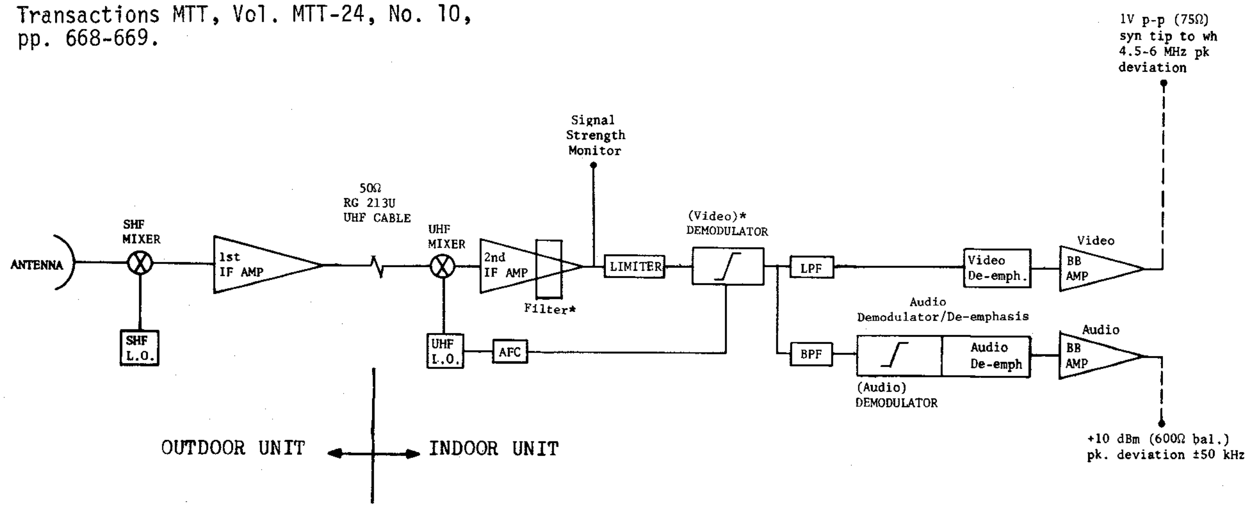

Fig. 1 System Configuration. The * represent those components also developed in SAW versions.

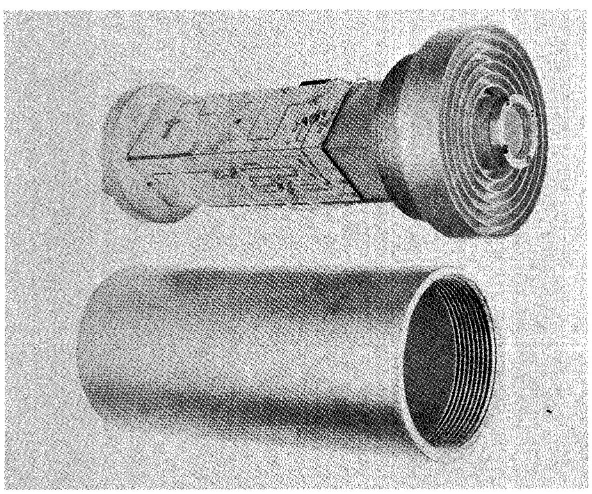

Fig. 2 Prime focus feed and outdoor unit.

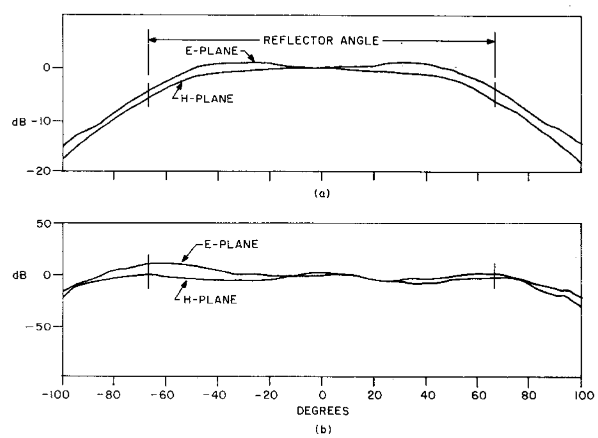

Fig. 3 Scalar feed pattern, a) relative gain b) phase

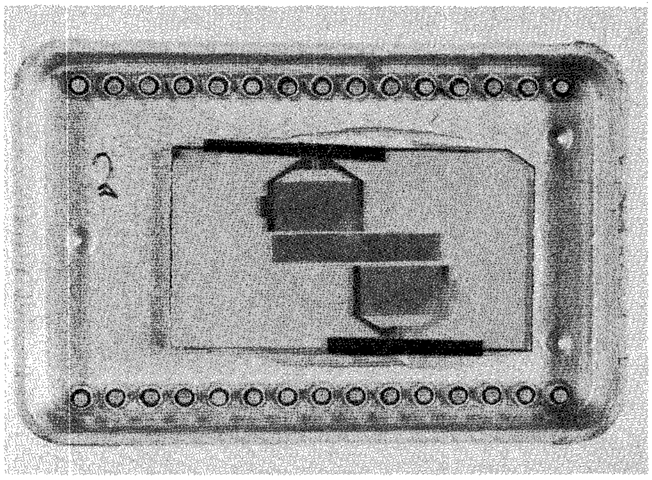

Fig. 4 70 MHz SAW Bandpass Filter.

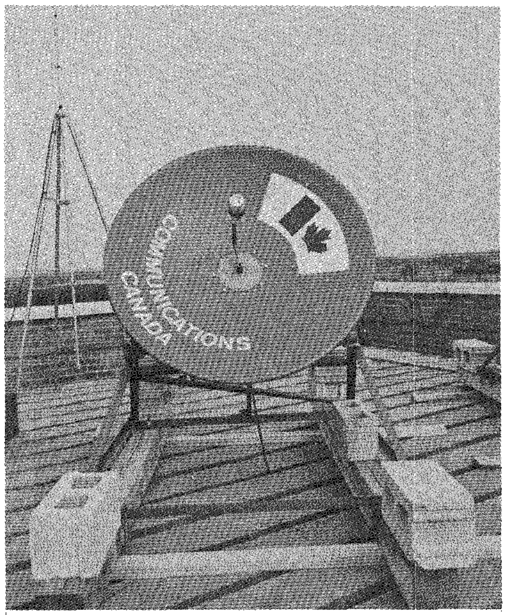

Fig. 5 Complete Earth Terminal.