RF FRONT END FOR PORTABLE SATELLITE TERMINAL.

Yair Shemesh Avi Breitbard.

Rafael
Israel

ABSTRACT

A briefcase portable satellite communication terminal was developed.
The terminal enables fax, telex, or E-mail communication via the INMARSAT satellite system between any two points on earth.
This paper describes the briefcase terminal front-end module .

This super-component assembled on a single substrate demonstrates a transmit power of 30.8dBm and 2.5 dB receive noise figure.
It is optimized for low cost, light weight and small size.

INTRODUCTION

The time for affordable personal communication between any two points on earth is forthcoming. Presently, such a communication is limited to either certain areas where cellular phone is available, or for expensive heavy portable equipment for satellite communication.

Specially designed components enabled the development of a personal portable satellite communication terminal in a standard briefcase. The briefcase enable telex, facsimile and data communication via the INMARSAT satellite system between any two points on earth.
All terminal parts, such as personal computer, antenna etc., are included in the briefcase, leaving enough empty space for user's convenience.

The light weight briefcase is useful for reporters, travelers, and anyone who needs data communication independent on local services [1,2].
The transceiver and briefcase weight is approximately 5 kg . The complete system weight, including the Notebook PC and the Miniature Printer, is 8.5 kg approximately.

In this paper a key briefcase terminal component is introduced.

This is a front end super component operating in L band, and assembled on a single substrate.
It demonstrates a transmit power of 30.8 dBm and 2.5 dB receive noise figure.
The unit is optimized for low cost, light weight and small size.

MODULE FUNCTION

The module, (depicted in figure 1) is a two port bidirectional unit operating in two modes (Half duplex):

a. Transmit mode - RF signals are amplified in the up link frequency band (1.626-1.646GHZ) to a 1 Watt level which feeds the antenna .

b. Receive mode - RF signals in the down link frequency band (1.530-1.545Ghz) are received by the antenna and amplified 30 dB with a noise figure of 3 dB.

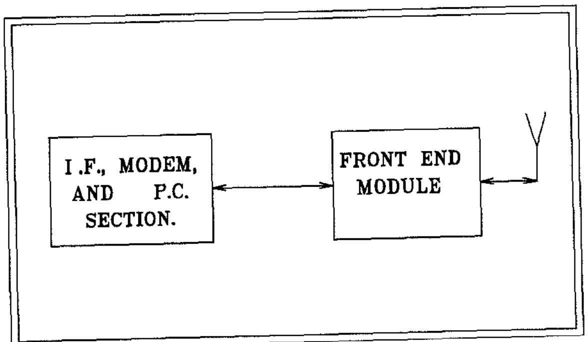

Figure 1. Front end module function in terminal.

In the receive mode it should be immune to interfering signal of -24dBm at the 10KHz - 1.4GHz and 1.6GHz - 4GHz bands.
In the transmit mode the output spectrum should be clean (low harmonics and spurious). The unit is switched between modes by a TTL signal.

The special use of the module as a part of personal portable briefcase terminal (It is portable just like any normal personal briefcase) adds other points for consideration: The module must be very low cost, light weight, small size, and with a low power consumption (An internal rechargeable battery supplies the power for the terminal.).

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MODULE ARCHITECTURE

This front-end super-component is assembled on a single substrate.

The module architecture (figure 2.) consist of a circulator at the antenna port, and a DPDT switch at the other port.

A TTL signal controls the switching between the transmit and the receive modes.

In the receive mode, the transmit branch D.C. supply is turned off in order to save battery power.

Two options were considered for switching the D.C. and the signal to and from the modem.
One is an easy to implement low loss mechanical DPDT but with the drawback of it's D.C. consumption in one state.
The other, is a lower cost solid state SPDT in conjunction with a MOSFET based circuitry needed to control the D.C. path due to the transmit mode high current.

At the antenna port, early versions adapted the use of a circulator, rather then a diplexer or power SPDT switch, because of it's simplicity and lower loss.
A disadvantage of using a circulator is that the LNA stages should handle approximately a power of:

$$Plna = Po - ISO + R \qquad (1)$$

where Po is the power amplifier output power, ISO is the circulator isolation, and R is the power reflected from the antenna (I.L.=-16dB), it's connector and cable.

Receive path.

The power reflection from the antenna caused by an occasional location of the briefcase by a user against an obstacle, may be substantial and may damage the LNA immediately or in the long term [3] unless it is protected by a suitable limiter.
The limiter circuit laid out in front of the LNA, is based on a low cost plastic package diode pairs [4], and designed for minimal loss.

The noise figure degradation due to the limiter was only 0.2 dB.

Lately, with the progress of the MMIC industry, new integrated switches emerged, introducing lower loss, higher power and reasonable cost.

Beside the limiter, the LNA path includes two filters and three amplifier stages.

Using a low loss narrow band filter in front of the LNA, is an expensive and space consuming choice. Hence, the main signal filtration in the LNA branch is done after the first two tuned stages.

A single pole filter was used at the LNA input, contributing about 0.1dB to the overall noise figure.

The last stage is a simple low cost wide band silicon MMIC amplifier tuned to the frequency of interest, but still, there is a need for deep attenuation of the low frequencies.
This goal is achieved much by that single pole filter.

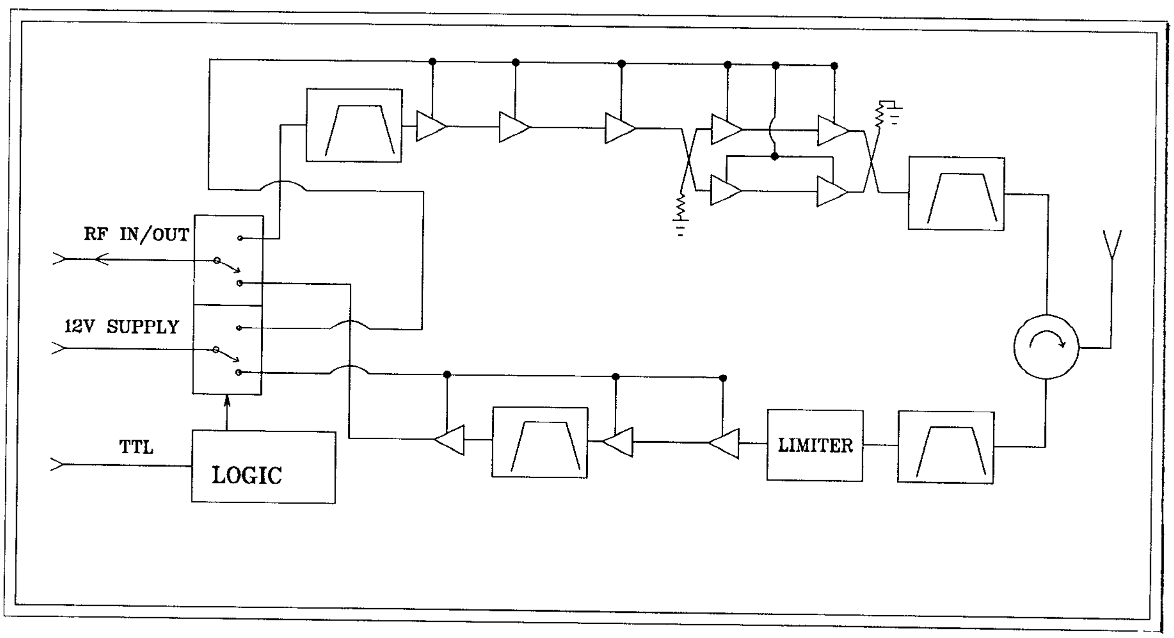

Figure 2. Front end module architecture

New dielectric materials with high Q and high ε_r enabled the development of waveguide filters [5].
A filter of this type was used to achieve the rejection and the immunity from signals close to the operating frequencies (up to 1400MHz and from 1626Mhz). The loss of such a narrow band filter is about 1dB.

Transmit path.

A gain block in the transmit branch, is an interstage matched dual stage unit.
More then 28dBm of output power can be achieved with this unit depending on it's bias point.
The active devices in these stages are low cost SMD bipolar transistors.
The final block is a balanced unit that yields an output power of 31 dBm.
The maximal harmonics level allowed while transmitting to the INMARSAT satellites is -40dBc.
To minimize cost, and loss (about 0.1dB), the output harmonics are rejected by single pole filters.

SUBSTRATE.

The substrate is a rigid thin FR4, which has several advantages for the specific application:

1. Its rigidness enables using it unmounted to a metal case , and thus lowering the unit weight significantly.
2. This substrate is standard in the low frequency analog and digital printed circuits industry which is larger scale compared to the MIC industry, thus, one can expect lower cost in mass production.
3. The dielectric constant of the substrate (ε_r=5) enables convenient size distributed elements ($\lambda/4$ = 25mm) for relaxed assembly tolerances, yet the total module size is small (12 x 9 cm).
4. The substrate like nearly all circuit components is SMT compatible.

THERMAL CONSIDERATION

More then 1 Watt output power is achieved by using low cost plastic surface mount package transistors.
All stages are optimally biased in order to improve efficiency.
Usually, devices for this power level are packaged in an expensive flange mount cases.
Heat removal from a plastic SMD is difficult but yet important for the module reliability.

The heat distribution was carefully analyzed using a 3D thermal analysis finite element software, and was verified by measurements.

The final stage devices dissipate about 1.25 Watt each, and since the substrate has a very poor thermal conductance, these devices require a good heat transfer mechanism.
A computed isothermal map of a transistor collector tab soldered to a transmission line and the nearby conductors is depicted in figure 3.
The calculation assumptions are free convection and that substrate backside is attached to a perfect 25°C heat sink. Even with these assumptions, the tab temperature raises to 148°C, i.e. a thermal resistance of (148-25)/1.25=98.40 °C/Watt between tab and case.
An electrically isolated paste with low dielectric constant and extremely good thermal conductance was used.
The paste was spread over the collector tab transmission line and vicinity, which include a large ground plane connected to substrate backside by many plated via holes, and an aluminum bar penetrating from the case thru the substrate.
Thermal analysis of this arrangement is shown in figure 4. The analysis predicts a temperature of 83.4 °C at the hottest point - i.e. a thermal resistance of

(83.4-25)/1.25=46.72 °C/Watt.

Measurement showed thermal resistance of about 51 °C/Watt.
An aluminum clamp connected to the aluminum bar, pressing the plastic device from top, reduces the thermal resistance to less then 32 °C/W allowing safe operation of the module in the briefcase.
No degradation in R.F. performance was observed because of using that paste.

RESULTS

The measured frequency responses of the module in the receive and transmit modes are shown in figures 5 and 6 respectively.
The module performance is listed below:

Receive mode:

*N.F.=2.5dB
*Gain =30dB
*Immunity to -20dBm interfering signals from 10KHz to 1.4GHz and from 1.6GHz to 4GHz.
*Supply 12V/45mA

Transmit mode:

*Pout=30.8 dBm
*Harmonics level:
2f0 - -50dBc
3f0 - -70dBc
4f0 and higher - better then -70dBc.
*Supply : 12V / 420 mA
*Efficiency: 23%

*Size: 12x9 cm
*Weight: 95 gr.

CONCLUSION

A low cost front-end module for briefcase portable satellite communication terminal was developed.
The front-end as well as the whole terminal, meets and exceeds the INMARSAT-C requirements for Land Portable Earth Station.
The briefcase photo is shown in figure 7.

ACKNOWLEDGMENT

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REFERENCES

[1] K.Tsang R. Douville. A potential 21st century satellite communication application: Personal communication. Space Communications 7 1990.

[2] A. Pedersen and M. Lok, End-user applications of mobile satellite services. Canadian Satellite Users Conference, Ottawa, Canada, June 1989.

[3] D.C.Schulz Avoid Killer Avalanches. RF Design. June 1992

[4] R.W. Waugh A Low Cost Surface Mount PIN Diode pi Attenuator. Microwave Journal. May 1992.

[5] Y. Konishi. Novel Dielectric Waveguide Components - Microwave Applications of New Ceramic Materials. Proceedings of the IEEE. Vol. 79 No. 6. June 1991.

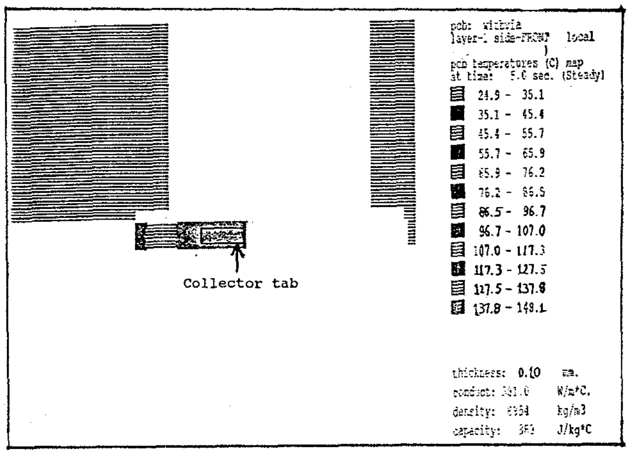

Figure 3. Isothermal map of a plastic SMD bipolar soldered to a transmission line.

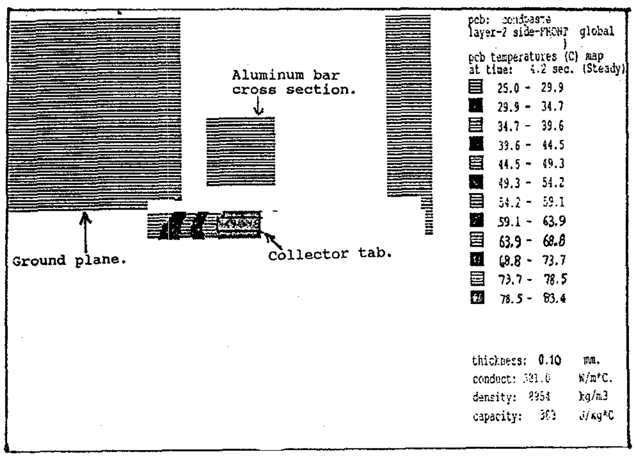

Figure 4. Isothermal map of a plastic SMD bipolar soldered to a transmission line, including affects of the improved heat transfer mechanism.

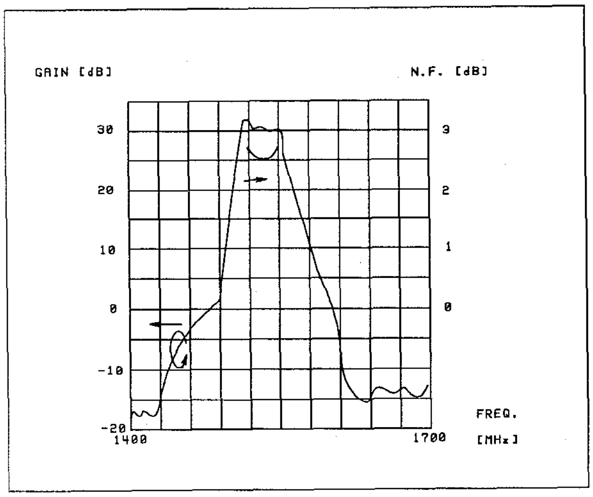

Figure 5. Receive branch frequency response.

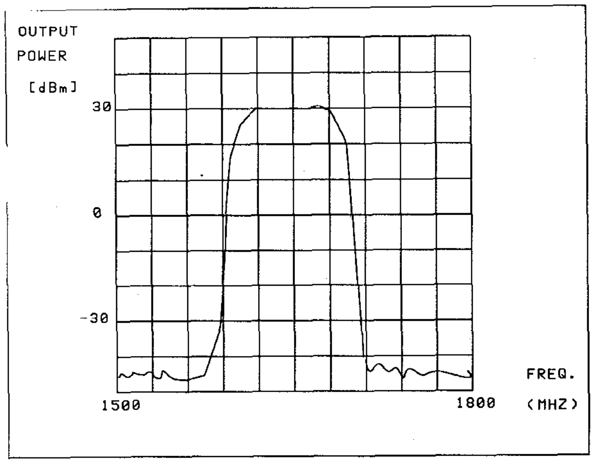

Figure 6. Transmit branch frequency response.

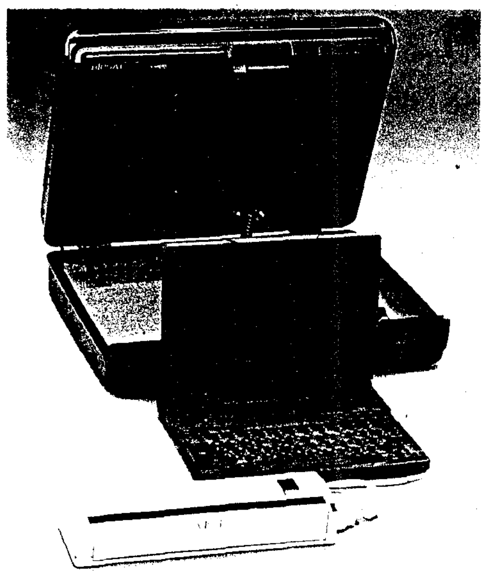

Figure 7. The briefcase portable satellite communication terminal photo.