DIELECTRIC GUIDE W-BAND (75-110GHz) RECEIVER WITH PARTIALLY INTEGRATED OSCILLATOR

T.H. Oxley, J. Ondria *, P.L. Lowbridge
Marconi Electronic Devices Ltd., Lincoln, England.

N. Williams, R.A. Gelsthorpe
ERA Technology Limited, Leatherhead, England.

S. Gibbs
Royal Radar Establishment, Malvern, England.

ABSTRACT

This paper discusses the design, construction, and performance aspects of a W-Band (75-110GHz) dielectric guide receiver, incorporating a partially integrated local oscillator. Machined alumina and thick film dielectric guide fabrication techniques are considered.

INTRODUCTION

Hybrid millimeter wave integrated circuit front-ends are being developed for systems requiring small size and weight as well as low cost. A variety of transmission media are available in which various components can be realised. These include FIN-line (Ref. 1) suspended stripline, dielectric image(insular) guide (Ref. 1) and microstrip (Ref. 1).

This paper examines the potential of dielectric guide with the emphasis being placed on two main problem areas which have emerged from previous experience. That is, low cost fabrication techniques and active device integration.

The vehicle chosen for the study is a W-band (75-110GHz) integrated unit incorporating a balanced mixer, local oscillator and IF head amplifier.

IMAGE GUIDE FABRICATION TECHNIQUES

Two fabrication approaches have been considered for the dielectric guide. A more conventional machined alumina image guide in which the ceramic line is metallised and soldered to a metal base plate; and the use of thick film deposited dielectric techniques to produce the ceramic line (Ref. 2). The latter involves the formation of the dielectric guide in situ on the ground plane provided by a metallised ceramic base, in a manner analogous to that used to produce screened and fired thick film circuits. This offers the potential advantage of the low cost associated with a printing process.

FRONT END DESCRIPTION

The W-band front-end schematic is shown in Figure 1. This basically consists of a balanced mixer, local oscillator and IF head amplifier, with waveguide (WG27) input and SMA coaxial IF output.

The balanced mixer design incorporates a 3dB proximity image line coupler and GaAs beam lead mixer diodes. The diodes are commercially available MEDL Type DC1346 with a $\frac{1}{2\Pi R_S C_j}$ cut-off frequency of about 2,500GHz (Ref. 1)
The diodes are mounted on quartz microstrip circuits with a transition from dielectric guide to microstrip. An extra $\lambda/4$ line is introduced on one arm of the coupler microstrip circuit to modify the 90^0 coupler to the preferred 180^0 for balanced mixer operation.

* Associate Professor of Electrical Engineering, Lehigh University USA.
Technical Consultant MEDL England.

The oscillator design is based on the operating principles of high Q waveguide circuits using the radial mode resonant cap configuration (Ref. 3) and is partially integrated in the dielectric guide. A GaAs Gunn device is utilised with power extracted at the second harmonic (Ref. 3)

A waveguide RF input is provided with transition to image guide.

The 60MHz IF head amplifier is incorporated in the unit.

CHARACTERISTICS OF CIRCUIT FEATURES

Image Guide Lines

Image guide can support a number of hybrid modes (designated Ey^{mn} and Ex^{mn}). When excited by the dominant mode in a rectangular waveguide the Ey modes are excited, and by adjusting the physical dimensions of the image line it is possible to select propagation in the dominant Ey^{11} mode only (higher order modes being cut off). For alumina image line, dimensions of 0.44mm x 0.88mm in cross section give good characteristics at about 90GHz.

For this cross section, and assuming a ground plane conductivity of 24.7×10^6 S/M (for thick film gold) and a dielectric loss tangent of 0.001, the propagation losses associated with the guide have been computed using a pseudo analytical field solution derived by Knox and Toulios (Ref. 4). The magnitudes of both components together with their sum are shown as a function of frequency in figure 2. The theoretical loss/mm at 90GHz has been shown to be about 0.05dB. In practice, machined image line exhibits a loss of approximately 0.06dB/mm, whilst the printed lines give 0.13dB/mm.

3dB Proximity Couplers

The image guide couplers are formed by placing two dielectric lines of identical cross section in close proximity (as shown in figure 4). These two lines will support two modes of propagation exhibiting field distributions which will be either symmetrical or antisymmetrical about the axis of symmetry of the system. Associated with each of these modes are dissimilar propagation coefficients K_{zs} and K_{za}. These coefficients have been analysed by Knox and Toulios (Ref. 4) and give rise to fields in the driven and coupled lines which are in phase quadrature.

Coupling levels are determined by the operating frequency, guide dimensions and permitivity, coupling gap (width) and length of the coupled region.

For the alumina lines, a 3dB coupling ration was exhibited over a 900MHz bandwidth. However, it was considered that this bandwidth could be improved by further optimisation of the coupler.

Transitions

The transitions are shown diagramatically in Figure 3. That is (a) waveguide to image guide (RF input) and (b) image guide to microstrip (mixer diode circuits).

Two types of transitions from waveguide to image guide have been assessed, one using a full waveguide width taper down to the height of the image guide and the other using a central ridge in the E plane with a width which matches into the image guide impedance. The lead-in to the ridge is by a stepped ridge impedance transformer section.

0149-645X/83/0000-0187 $01.00 © 1983 IEEE

The characteristics for these transitions at 90GHz are outlined below:-

Tapered transition from waveguide to image line. loss ≃ 1.5dB
Stepped ridge transition from waveguide to image line. loss ≃ 0.75dB
Transition from image guide to microstrip. loss ≃ 0.5dB

Oscillator

Particular attention has been paid to the local oscillator design. Regardless of which transmission media is used for mm-wave integrated circuit front-ends, the local oscillator plays an important role as to how well the system performs, particularly as to stability and noise aspects. In addition integration of the oscillator is of prime importance to fulfill the requirements of low cost and compact front-ends. Designs at present do not combine both the needs of performance and integration, and externally connected metal waveguide oscillators are normally used to provide the system performance. (That is mm-wave Gunn diode oscillators configured in waveguide cavity geometries still offer the best overall characteristics in terms of power, tunability, stability, ruggedness and noise).

The oscillator design has been aimed at a unit, which is integrable with machined or printed thick film dielectric guide fabrication technologies (the latter implying top rather than base heat sinking), and has adopted the successful operating principles of high Q waveguide oscillator circuits using radial mode resonant cap configurations with power extracted at the second harmonic frequency (Ref. 3).

The preferred design approach has thus been to construct a high Q resonant disc harmonic oscillator in the dielectric guide media. Figure 5(a) shows diagrammatically a saddle structure mounted over a tapered section of image guide to form the partially integrated oscillator. Gunn diode bias is applied by way of a filter/resonant cap structure through a LASER drilled substrate hole and carrier block. The packaged Gunn diode is mounted in a holder and inserted into the enclosed heat sink block. Tuning rods are positioned above the image guide taper section to improve the match between the oscillator and guide.

A photograph of an initial experimental test unit including the image line to waveguide transition necessary for oscillator evaluation purposes is shown in Figure 5(b). Tests in this unit showed a comparable performance to that obtained from a waveguide test cavity. For example the performance of the partially integrated image line oscillator is shown in Figure 6.

When matched to the transducers and referred to the oscillator port, the 8mW nominal output power compared to about 7mW for the same Gunn element in a standard waveguide radial disc harmonic cavity oscillator. Obviously the Gunn diode chosen here does not represent the best available from harmonic extractions, e.g. 15mW is average with possible powers up to 35mW (Ref. 5).

Characteristics of the Receiver Units

The total unit, comprising the Gunn oscillator, image guide quadrature coupler, two single ended mixers, IF amplifier and diode bias supply unit is approximately 7cm x 10.5cm x 2cm.

Complete performance characteristics of the receiver will be presented at the conference.

Conclusions

A complete image guide integrated receiver using new design approaches for incorporating the mixer diodes and local oscillator has been built. Both machined and thick film dielectric guide circuits have been examined, with the aim of achieving a low cost fabrication technique.

ACKNOWLEDGEMENTS

This work has been carried out with the support of the Procurement Executive, Ministry of Defence, partly sponsored by DCVD.

The authors would also like to thank Mr. N. Davey (ERA Technology Ltd.) and Mr. S. Brown (RSRE Malvern) for their efforts in producing image line circuits.

References

1. Session 9a Conf. Proc. MM82 London '82.

2. R.A. Gelsthorpe, N. Williams and N.M. Davey, 'Dielectric Waveguide; A Low Cost Technology for Mm-wave Integrated Circuits', Radio and Electronic Engineers, Vol. 52, No. 11/12, pp.522-528, Nov/Dec. 1982.

3. Ondria, J., 'Wide-Band Mechanically Tunable and Dual In-Line Radial Mode W-Band (75-110GHz) CW GaAs Gunn Diode Oscillators'. 7th Biennial Conference on 'Active Microwave Semiconductor Devices and Circuits', Cornell University, Itheca, NY 14853, Aug. 14-16 1979.

4. Knox and Toulios 'Integrated circuits for the Millimetre through Optical frequency range'. Symposium on Millimetre Waves, Polytechnic Institute of Brooklyn 1970 pp497-516.

5. Friscount, M.R. et al, 'Theoretical and Experimental Comparison between Fundamental and Harmonic Operation of GaAs Mm-Wave TED's 12th EMC Proc. Helsinki, Finland.

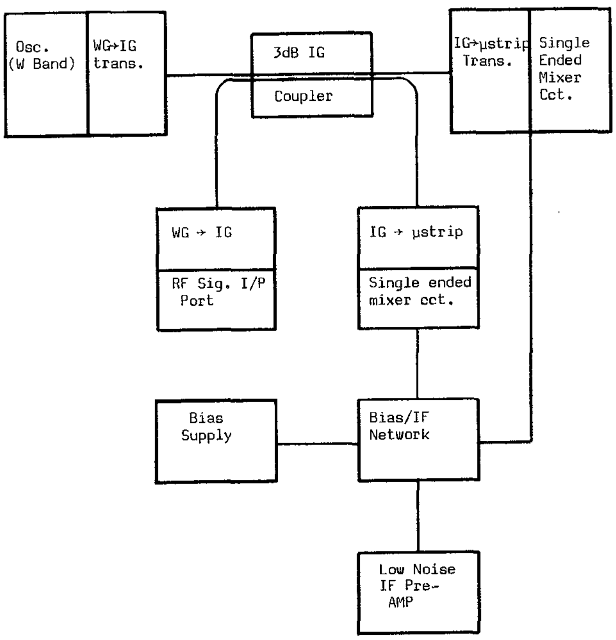
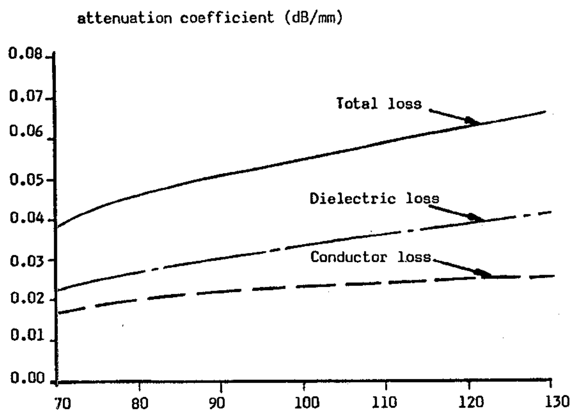


Fig. 1

CIRCUIT DIAGRAM OF: W-BAND (75-110GHz) IMAGE GUIDE FRONT END

FIG. 2 Loss Analysis for E_y^{11} Mode Propagation in Image Line



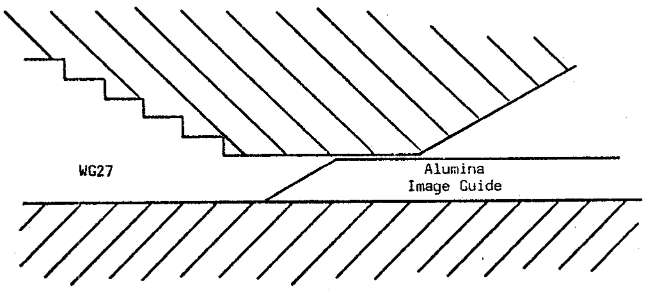


Fig. 3a
Transition Waveguide - Image Guide

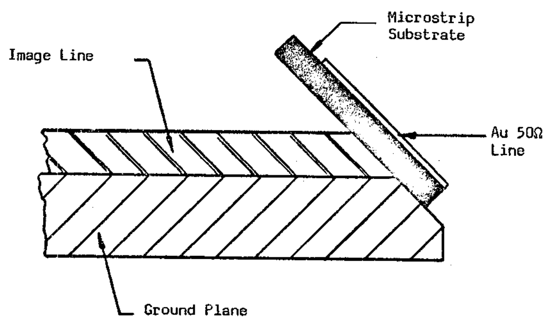


Fig. 3b
Transition Waveguide - Microstrip

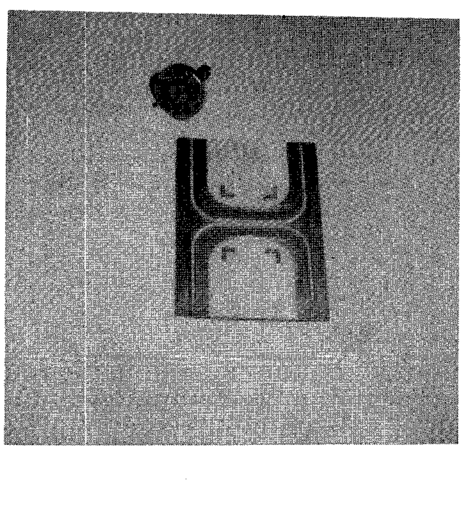


Fig. 4

Image Guide 3dB Coupler

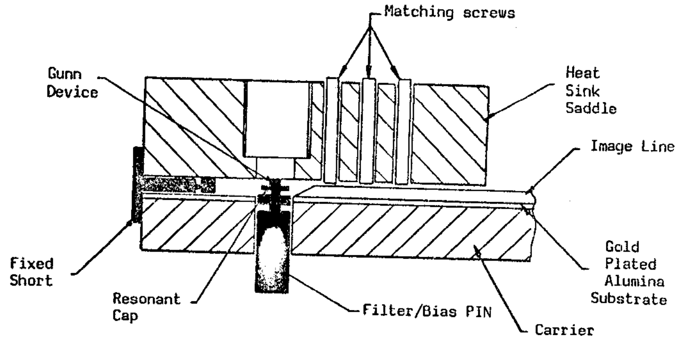


Fig. 5(a)
Partially Integrated Oscillator

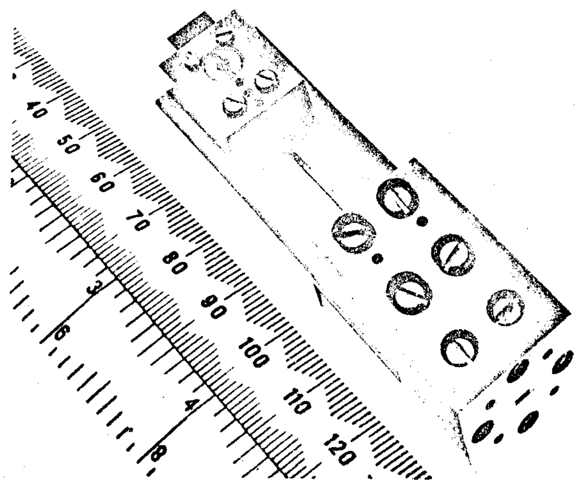


FIGURE 5b W-BAND (75-110 GHz) PARTIALLY INTEGRATED IMAGE GUIDE RESONANT DISC HARMONIC GUNN DIODE OSCILLATOR

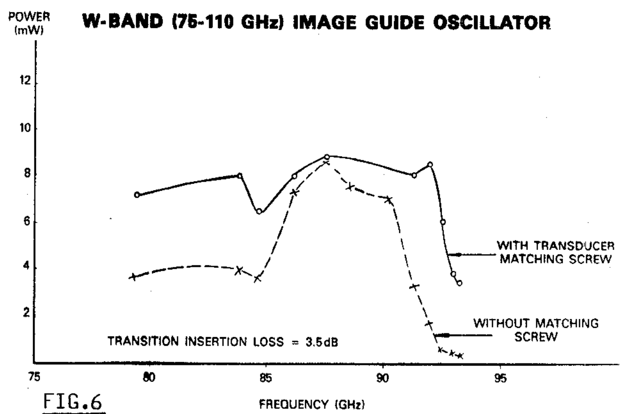


FIG.6

POWER OUTPUT VERSUS FREQUENCY FOR IMAGE GUIDE OSCILLATOR SER. No. 1 PACKAGED GUNN DIODE. V_{GUNN} = 4.5V, I_G = 720mA, RESONANT DISC DIAMETER = 0.076"