6 GHz 16 QAM MIC modulator with phase linearity improved

T. Takano, M. Niori, Y. Tokumitsu, H. Komizo, K. Ogawa

Fujitsu Laboratories Ltd. Fujitsu Ltd.
Kawasaki, Japan

ABSTRACT

A 6GHz 16 QAM linear MIC ring modulator with improved linearity has been developed. The BER measurements show S/N degradation by the MIC modulator to be 0.3 dB greater than that of an IF modulator at an error rate of 10^{-6}.

INTRODUCTION

Several 16 QAM communication systems have been reported in the last few years (1)(2)(3)(4)(5), but no report has been made on 16 QAM linear modulators at frequencies above 2GHz. As the frequency goes higher, linearity characteristics of the modulator are impaired by parasitic components in the switching diodes. For this reason, the superimposed type modulator has been used in most work with 16 QAM systems. It would be possible, however, to make a simpler more compact transmitter in radio repeaters, if we could realize a 16 QAM direct carrier linear modulator. This paper describes a 6 GHz linear 16 QAM modulator which uses MIC ring modulators with phase linearity improved. Experiments with a 200 Mb/s 16 QAM signal (cosine roll off spectrum shaped; roll off factor 50%) were performed, and the S/N degradation by the MIC modulator was 0.3 dB greater than that measured on an IF modulator (IF back to back system)

MODULATOR CONFIGURATION

Many microwave mixers with sophisticated configurations have also been reported (6), and we have been trying to develop a wide band ring modulator of simple configuration. Fig.1. shows a sketch of our ring modulator, consisting mainly of a wideband tapered balance/unbalanced transformer,four schottky barrier diodes ,and a pair of through metal conductors. The substrate, 0.3 mm thick,15 mm long,and 5 mm wide,is fine grained alumina (dielectric constant 9.8). Two diodes, D1 and D2 are mounted on the upper side of the substrate, and D3 and D4 are mounted on the lower side. Diodes D2 and D3 are connected with the conductors on the other side of the substrate through two drilled holes H1 and H2 (0.1 mm diameter). The frequency conversion loss of the ring modulator was 6 to 9 dB over the frequency range from 4 to 8 GHz. The isolation between RF ports is typically 15 to 20 dB. C1, C2, C3, C4 are DC blocking capacitors (micro chip capacitor 2 to 4 pF). Fig.5. shows a view of the MIC ring modulator.

LINEARITY OF THE MODULATOR

Cosine roll off spectrum shaping method plays an important role to reduce the band width with minimum intersymbol interference. This technique has already been accomplished in base band stage while it has not been established in microwave frequencies. Therefore both phase and amplitude linearity are especially required for a modulator. In this ring modulator, phase linearity is improved by phase linearity correction circuits, which also form the driving current circuit. Driving current feed lines are connected by strip conductors as shown in Fig.1. By adjusting jumper J (bond wire) to a suitable position, the modulation linearity characteristics are improved. Fig.2. shows the equivalent circuit of this ring modulator. Z1 and Y1 are the impedance of H1, and susceptance of the correction circuit respectively. An example of the linearity improvement can be seen in Fig.3. Lines "a" and "b" indicate the locus of S21 of the ring modulator versus driving current at x=2 mm and x=5 mm respective-

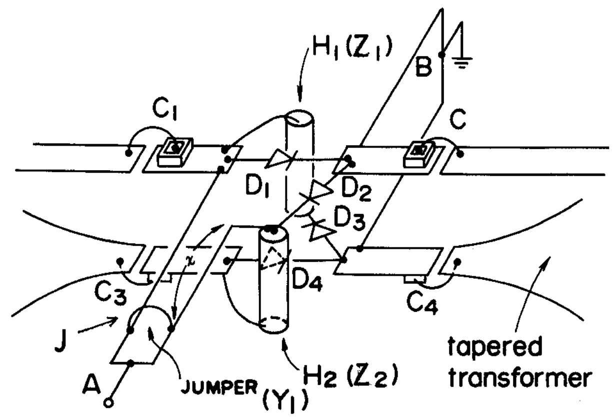

Fig.1 Configuration of the ring modulator

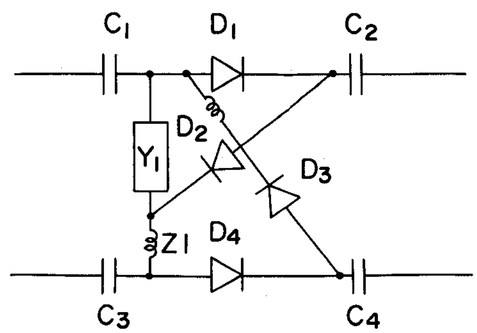

Fig.2 Equivalent circuit of the ring modulator

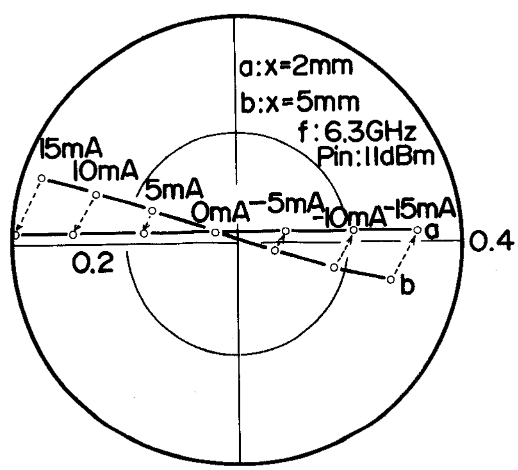

Fig.3 An example of linearity improvement

ly. (x indicates the short stub length) The phase non-linearity is caused by parasitic reactance components of the switching diodes. Simulations of a simple linear model of the ring modulator indicate the validity of our experiments. An amplitude linearity characteristic of the modulator versus driving current is shown in Fig.4.

16 QAM modulator RF characteristics

Fig.6. is a block diagram of the MIC modulator. Circulators 2 and 3 are necessary to get sufficient isolation between two modulators. Fig.7. is a photograph of the MIC modulator with the top cover removed. The total loss of this modulator is 21.5 dB, while the loss of the ring modulator itself is 13 dB. The input power level to the MIC modulator is +16 dBm. Fig.10. shows the 16 QAM signal constellation measured by a network analyzer. This photo shows the good phase and amplitude linearity characteristics of the modulator.

BER PERFORMANCE

Fig.9. shows the test set up for evaluating the MIC ring modulator. To reduce the band width of the output modulated signal, cosine roll off spectrum shaping is done by using b
inary transversal filters in
baseband stage. Fig.11. shows eye patterns of the demodulated signal. The spectrum of the output signal is shown in Fig.8. The filter was adjusted for the maximum eye opening. Fig.12. shows the measured BER characteristics demodulated by the 16 QAM demodulator (140MHz IF frequency). The S/N degradation was 0.3 dB greater than that of an IF modulator at an error rate of 10^{-6}.

CONCLUSION

A 6GHz 16 QAM modulator using MIC modulators with good BER performance was developed. The ring modulator can be used over the frequency range from 4 to 8 GHz by readjusting the short stub length.

ACKNOWLEDGEMENT

The authors would like to thank Dr. H. Yamamoto of Yokosuka Electrical Communication Laboratory for helpful suggestions, and also Mr. J.Dodo, and Mr. H.Kurematsu of Fujitsu Ltd. and Dr. H.Takanashi of Fujitsu laboratories Ltd. for guiding this work.

REFERENCES

(1) I.Horikawa et al;"Design and Performancies of a 200 Mbit/s 16 QAM Digital Radio System" IEEE TRANS COM vol 27. No 12. pp 1953-1958

(2) S.Komaki et al;"Characteristics of a High Capacity 16 QAM Digital Radio System in Multipath fading" IEEE TRANS COM vol 27. No 12. pp1854-1861

(3) M. Washio;et al. "1.6Gb/s 16-Level Superposed APSK MODEM with Baseband Signal-Processing Coherent Demodulator"
IEEE MTT-26 No.12 Dec 1978 pp945-951

(4) K. Miyauchi;et al. "New Technique for Generating and Detecting Multilevel Signal Formats"
IEEE TRANS COM. Vol com-22 No.2 Feb 1974 pp263-267

(5) G.S.DesBrisay,Jr;et al. "Two GBPS QPSK MODEM"
1979 IEEE MTT-S Digest pp522-524

(6) M.Aikawa;et al. "2Gb Double-Balanced PSK Modulator Using Coplanar waveguides."
ISSCC 79. pp172-173

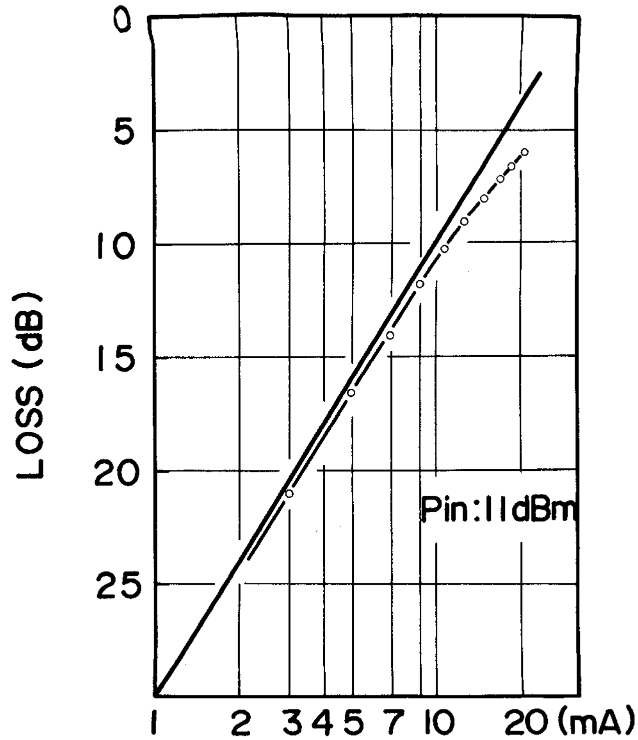

Fig.4 Amplitude linearity of the modulator

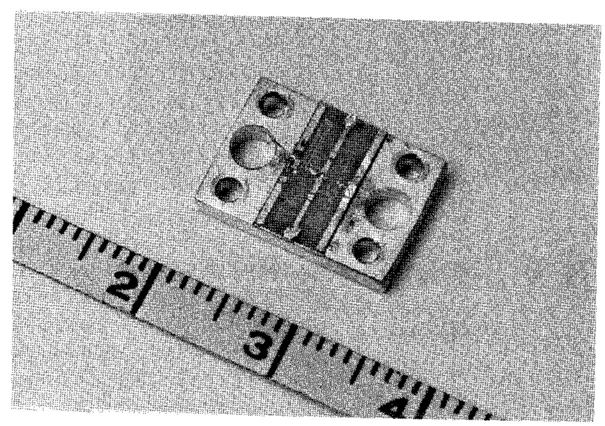

Fig 5 The ring modulator

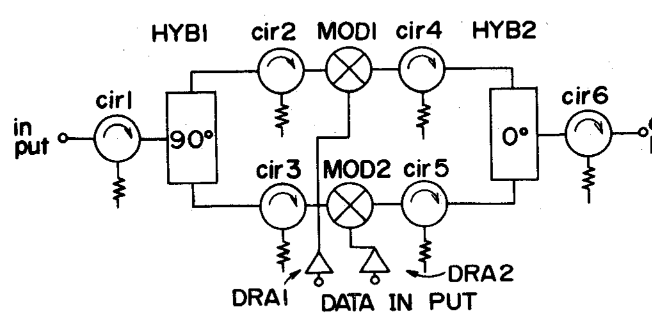

Fig.6 Block diagram of 16QAM modulator

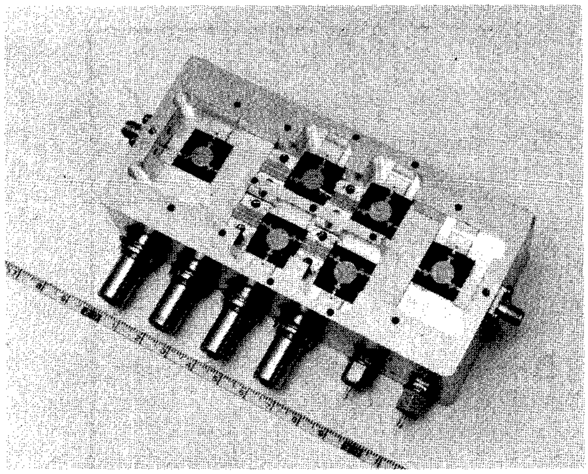

Fig. 7 16QAM modulator with top cover removed

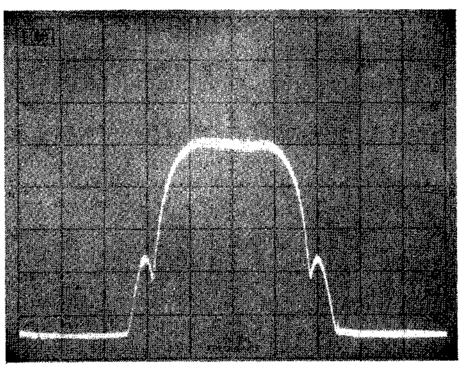

Fig. 8 Spectrum of the output signal

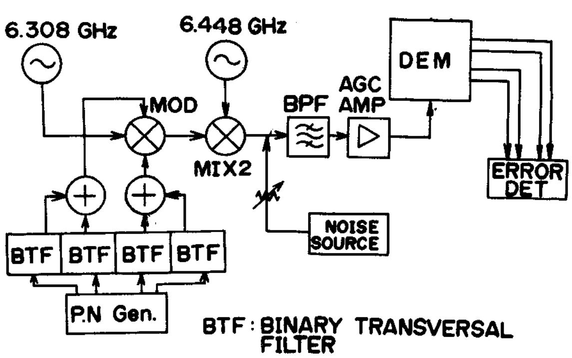

Fig. 9 Test set-up for the BER measurement

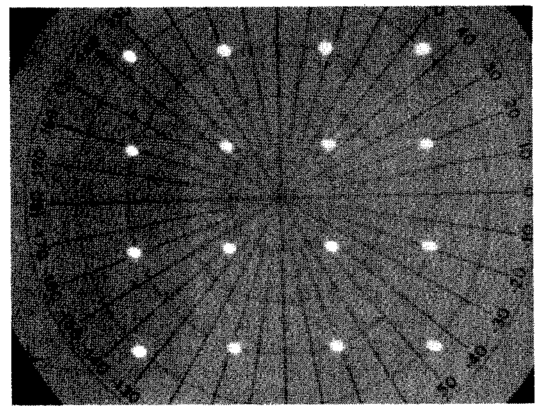

Fig. 10 Constellation of the modulated signal

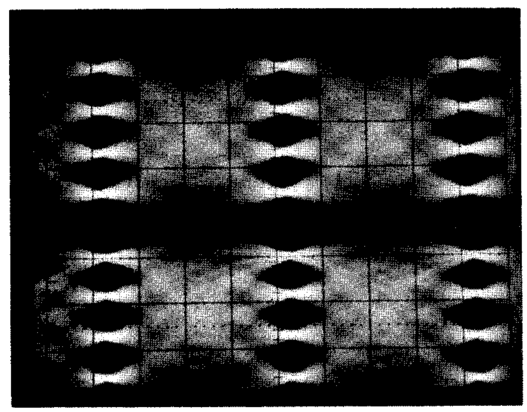

Fig. 11 Eye patterns of the demodulated signal

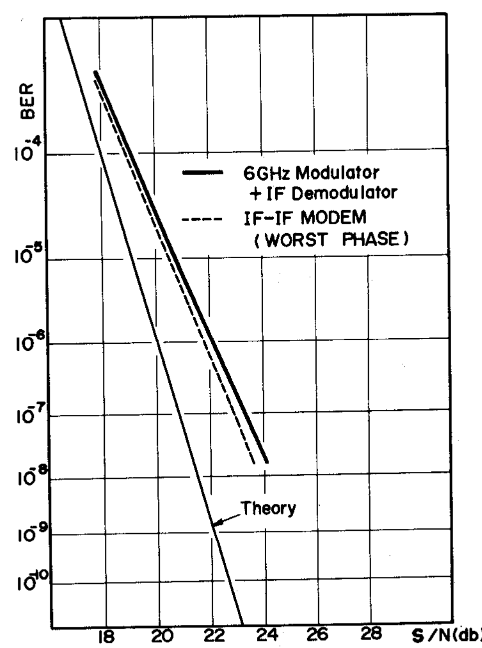

Fig. 12 BER Characteristics