A BROADBAND DOWN CONVERTER FOR 4- AND 6-GHz RADIO SYSTEMS

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ABSTRACT

This paper describes the design of a broadband down-converter to cover both 4- and 6-GHz common carrier bands. The broadband down-converter was tested as a replacement for the down-converter in both the MDR-2204 and MDR-2306 4- and 6-GHz radio systems. Excellent results have been observed in both 4- and 6-GHz radio systems. In threshold bit error rate tests, the broadband down-converter has 1.2-dB better performance than both 4-GHz (MDR-2204) and 6-GHz (MDR-2306) standard radio systems. In overload bit error rate tests, the broadband down-converter has 0.5-dB better performance.

INTRODUCTION

Two common carrier bands in 4 and 6 GHz have been assigned by the FCC for commercial radio systems. Current radio systems cover several channels in each band. This paper demonstrates the feasibility of a broadband down-converter to cover these two bands.

The configuration of a broadband down-converter is shown in Fig. 1. It consists of a low-noise amplifier, a power divider, an RF 90-degree Lange coupler, two Schottky diode mixers, an IF 90-degree hybrid, and an IF amplifier.

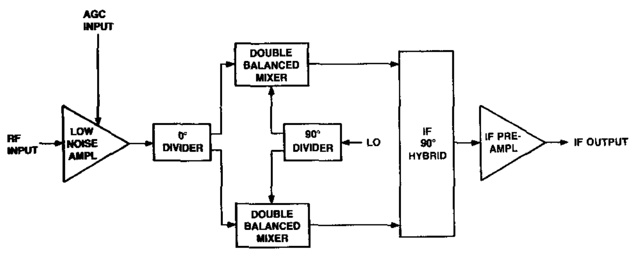

Figure 1. The Configuration of the Broadband Down-Converter.

The operational bandwidth is from 3.5 to 6.5 GHz. When the receive signal level is lower than −42 dBm, the total conversion gain is 37±0.5 dB. When the receiver signal level is above −42 dBm, the AGC of the low noise amplifier takes over and maintains the IF output constant at −5±0.5 dBm. The AGC range is 28 dB. The image rejection is greater than 20 dB over the band of operation. The third-order intercept point of the broadband down-converter is 26 dBm. The noise figure of the broadband down-converter is less than 2.5 dB.

The broadband down-converter was tested as a replacement for those in the MDR-2204 and MDR-2306 4- and 6-GHz radio systems. The threshold performance was at least 1.2 dB better than that with the production down-converter in both systems. The overload levels are slightly better.

LOW NOISE AMPLIFIER

This is a 2-stage low-noise amplifier. The first FET is matched for low noise impedance, and the second FET is matched for high gain.

The measured noise figure is less than 1.7 dB over the total bandwidth, and the associated gain is 17±1.5 dB as shown in Fig. 2. The 1-dB compression point is 12 dBm at 5 GHz. The 2-tone third-order interception point is 24 dBm. The 28-dB AGC range is achieved by controlling the drain and gate bias voltages of the first FET [1].

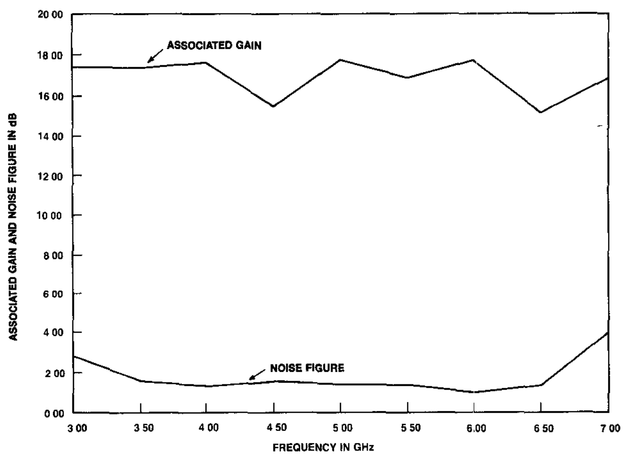

Figure 2. Noise Figure and Associated Gain of LNA.

LOCAL OSCILLATOR

The circuit uses a bipolar transistor for low phase noise and a dielectric resonator in the tank circuit. The oscillator was phase locked to a crystal reference by dividing down the frequency. The design used a common circuit for the 3.5-6.5 GHz band and only the dielectric resonator needed to be replaced to set the oscillator to the desired frequency. The power output of the oscillator was 17 dBm.

LANGE COUPLER

The Lange coupler is a 3-dB, 90-degree coupler. The measured and supercompact predicted data are quite consistent with each other. The measured data show that the two outputs from ports 2 and 3 are different less than 1.6 degrees in phase and 1.0 dB in magnitude over the total bandwidth (3.5-6.5 GHz) [2].

IF AMPLIFIER AND HYBRID

The IF amplifier has 20-dB gain, and the gain flatness is within 1.2 dB from dc to 1 GHz. The 2-tone third-order intercept point is 29 dBm.

The IF 90-degree hybrid is a narrow-band hybrid (60-80 MHz). The difference between the two outputs from ports 2 and 3 is less than 0.5 dB in magnitude, and less than 1.0 degree in phase over the band from 60-80 MHz.

IMAGE REJECT MIXER

The image reject mixer and the phase diagram are shown in Fig. 3. The image reject mixer consists of a power divider, two balanced Schottky diode mixers, a Lange coupler, and an IF hybrid. The phase diagram shows that the image is cancelled at the output port of the IF hybrid [3].

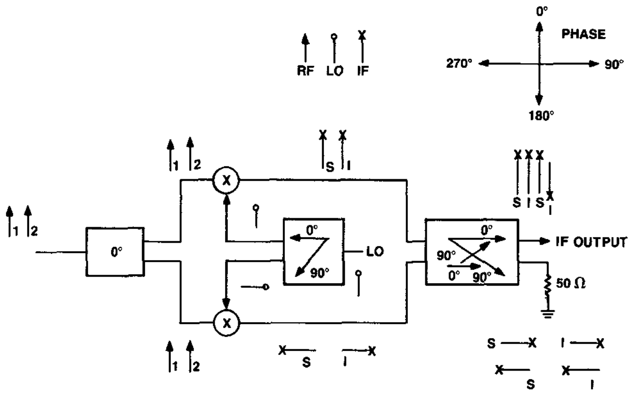

Figure 3. Phase Diagram of Image Reject Mixer.

The conversion loss of the image reject mixer is 6.8 dB and the image rejection is better than 20 dB over the total bandwidth, as shown in Fig. 4 and 5. The 2-tone third-order intercept point is 16.8 dBm as shown in Fig. 6.

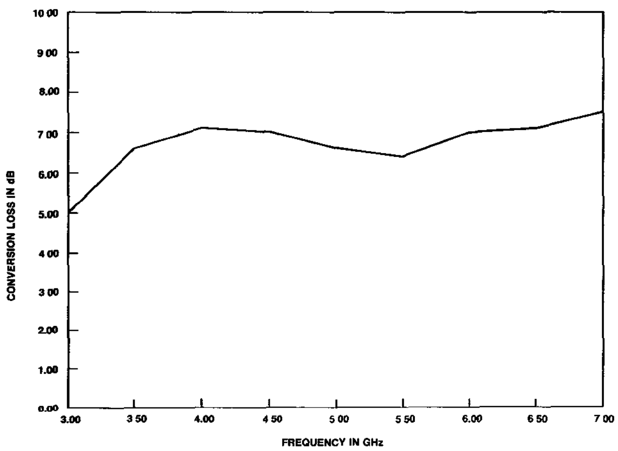

Figure 4. The Conversion Loss of the Image Reject Mixer.

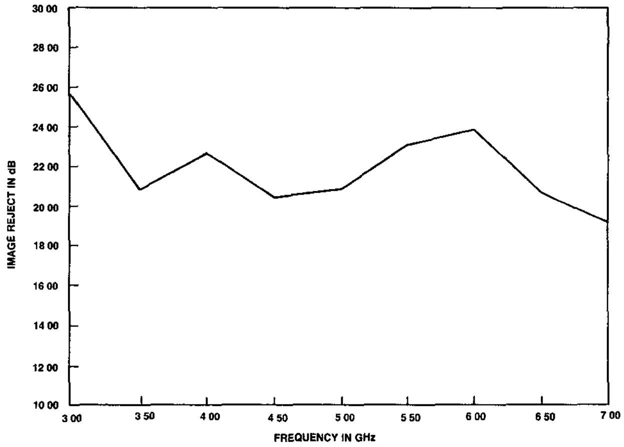

Figure 5. Image Reject of the Image Reject Mixer.

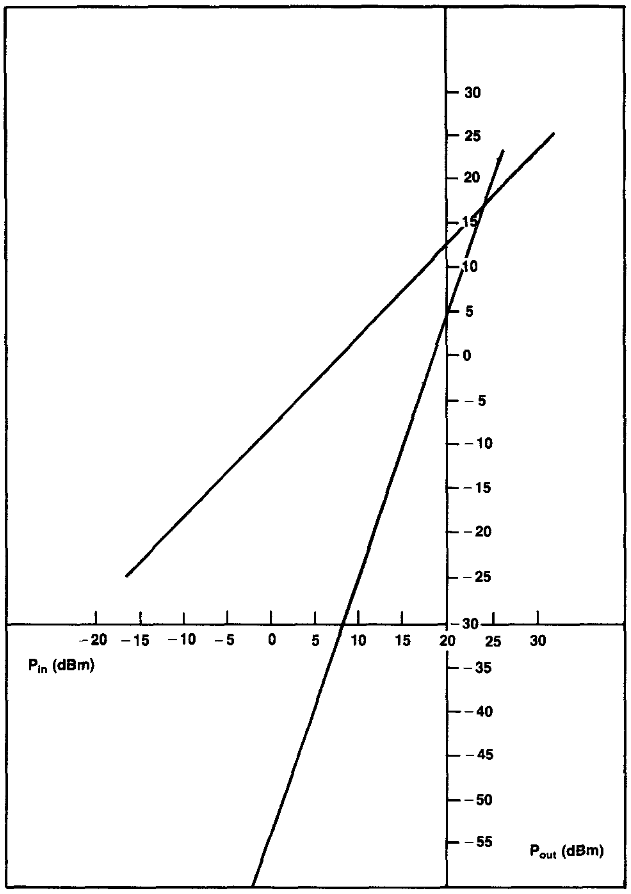

Figure 6. Third-Order Intercept Point of the Image Reject Mixer.

MEASURED RESULTS

These modules were integrated and tested as a broadband down-converter over the total bandwidth (3.5-6.5 GHz). The total conversion gain is 37 dB, the noise figure is less than 2.5 dB, the image rejection is greater than 20 dB, and the third-order intercept point is 26 dBm.

The broadband down-converter was tested as a replacement for the down-converters in the MDR-2204 and MDR-2306 4- and 6-GHz radio systems. The 64-QAM threshold curves are shown in Fig. 7 and the 64-QAM overload curves are shown in Fig. 8. A summary of these results at 4 and 6 GHz is shown in Table 1. The broadband down-converter's performance is much better than the standard system's performance.

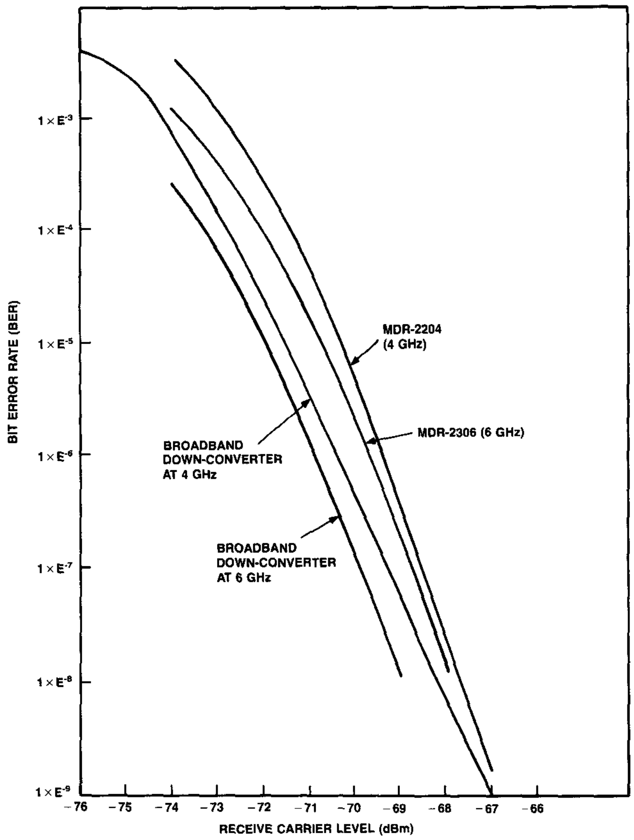

Figure 7. 64-QAM Radio System Threshold Curve.

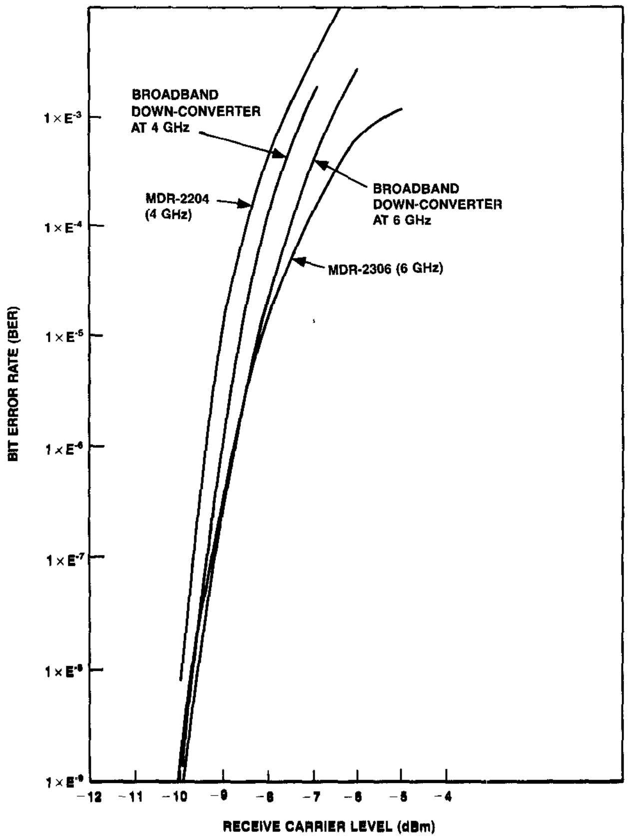

Figure 8. 64-QAM Radio System Overload Curve.

Table 1. A Summary of Results of Broadband Down-Converter in System Test

FREQUENCY	BROADBAND DOWN-CONVERTER				NORMAL DOWN-CONVERTER			
	OVERLOAD		THRESHOLD		OVERLOAD		THRESHOLD	
	BER = 1E-6	BER = 1E-3	BER = 1E-6	BER = 1E-3	BER = 1E-6	BER = 1E-3	BER = 1E-6	BER = 1E-3
4 GHz	−9.1	−7.2	−70.4	−74.3	−9.5	−7.6	−69.4	−73.0
6 GHz	−7.7	−5.5	−68.9	−73.1	−7.7	−4.2	−67.7	−71.9

CONCLUSION

This broadband down-converter works quite well in both 4- and 6-GHz radio systems. Several features make it work well: (1) the noise figure of the low-noise amplifier is less than 1.7 dB over the band; (2) the phase noise of the local oscillator is quite low; (3) the 2-tone third-order intercept point of the broadband down-converter is higher than 26 dBm; and (4) the image rejection is higher than 20 dB over the band. This broadband technology can be applied to present or future telecommunications applications.

ACKNOWLEDGMENT

The authors wish to thank Drew Crossett for his valuable comments and discussions. Thanks are also due to Randy Patterson and Rick Wolter for assembling and testing the circuits.

REFERENCES

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[2] Vittorio Rizzoli and Alessandro Lipparini, "The Design of Interdigitated Couplers for MIC Applications," IEEE Transactions on Microwave Theory and Techniques, Vol MTT-26, No 1, January 1978, pp 7-15.

[3] Bert C. Henderson and James A. Cook, "Image-Reject and Single-Sideband Mixers," MSN & CT August 1987, pp 75-83.