A new 40 GHz DIGITAL DISTRIBUTION RADIO WITH SINGLE LOCAL OSCILLATOR

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ABSTRACT

We have developed a new 40 GHz digital radio equipment which uses single Impatt diode oscillator functioning as transmitting local oscillator, transmitting frequency converter and receiving local oscillator simultaneously. This radio equipment is so designed compact that it ensures excellent cost-performance for local trunking.

Introduction

In an intra-city and suburb areas, recently, business communications of voice and data are expanding prominently.

In such areas, it is difficult to employ underlaying cable, while there exists the problem that the radio waves are much conjested as well. Under these circumstances, the FCC released 40 GHz band anew to such applications as local trunking in late 1974.

In this paper, a newly developed 40 GHz digital radio is described. To apply this radio equipment for local trunking, it should firstly be low cost, since the loading channels are small, eg., several to 24 channels and the radio span is short as several to ten miles. Secondly, it must interface with the digital signal format, i.e. PCM, which suits economically to a variety of signals such as voice, data and FAX, etc. Thirdly, it should be of easy maintenance and installation.

Taking into account the above mentioned necessities, we have adopted a new circuit configuration consisting of single local Impatt oscillator, up-converter and receiver local source. As a result of this, we succeeded in considable cost reduction as well as realizing smaller size, better reliability and easier maintenance. Secondly, we have adopted a new configuration of diode mount reducing the cost of mount and obtaining stable operation.

Single local transmitter and receiver

The block diagram is shown in Fig. 1. In this system, the transmitting IF signal (T_{IF}) is bi-phasely modulated (IF MOD) by a code-converted incoming PCM signal (TBB) and is added to the bias of the Impatt oscillator. As a result of bias modulation, main three output signals (f_L, f_T, f_S) are produced from the Impatt oscillator as shown in Fig. 2. One is original oscillating signal (f_L) and the other two signals (f_T, f_S) are the modulated replica of f_L due to nonlinearity of the Impatt diode.

The upper side band f_T is apart from the oscillating signal by $T_{IF} = 380$ MHz and is used as the transmitting signal through TBPF in Fig. 1. The lower side band f_S and other higher order converted signals are reflected from LBPF and TBPF and absorbed by the isolator. On the other hand, the oscillating signal f_L is frequency stabilized by means of a refelcting high Q cavity(1) to be fed to the first mixer as a local signal through LBPF and attenuator AV.

According to the FCC regulation issued late 1974 (Docket No. 18920), the 14 both way (28) RF channels are assigned between 38.6 to 40.0 GHz. Each channel is assigned with 50 MHz bandwidth, and the channel separation for transmitter and receiver is just 700 MHz. To make the single local source serve for the transmitter-receiver, the receiver IF frequency is selected to $R_{IF} = 320$ (700-380) MHz as shown in Fig. 2.

In order to absorb the frequency variation caused in oscillators of both side equipments, the second mixer is utilized. The second local source consists of a transistorized voltage controlled oscillator (VCO) of 390 (R_{IF} + Second IF = 70) MHz to which the AFC signal is fed back from AFC detector after removal of phase modulation by doubler. The demodulator (DEM RBB) utilizes synchronous detection of bi-phase PSK. After detection through retiming, polarity decision and reshaping, the received PCM signal is regenerated.

Waveguide circuitry

IMPATT local oscillator The Impatt local oscillator circuit is shown schematically in Fig. 3. The Impatt diode (TX-40, OKI) is a silicon single drift region type having approximately 60-micron junction diameter, and has a minimum output power of 200 mw with an efficiency of 5.5 to 7.5%. Typical operating bias voltage and current are 29V and 100 to 150 mA respectively.

The oscillating frequency is determined by the radial resonance of the diode of mini disc type to which a disc "hat" is attached. The Impatt diode is soldered directly on a stud. The bias circuit of the diode is consisted of an insulated fine wire passed through the stud hole and an absorber. The stud is screwed on a simple waveguide WR-28 without complicated diode mount. This configuration realizes stable operation, wide band tuning range of full band, 38.6 to 40 GHz, and cost reduction.

The frequency stabilizing cavity is made of super invar with silver plating adopting airtight configuration. It has an unloaded Q of more than 12,000 and the temperature coefficient is compensated using brass to the piston. The frequency variation is about 1.2 MHz over a temperature range of -4 to +140°F. The VSWR of the cavity is 2 at the resonant frequency. The pull-in range of more than 140 MHz is obtained, where the frequency variation of the free-running Impatt oscillator is about 120 MHz over the temperature range of -4 to +140°F. Experimentally, it has been made clear that the stability of oscillator was not degraded by the bias modulation.

The waveguide circuit developed for the monitoring detector is just as the Impatt diode mount and a fine short wire soldered on the diode acts as a probe of the transmitting signal.

RF Mixer The mixer circuit of the waveguide-mounted planar type is used in the receiver. The mixer diode is a silicon Schottky barrier diode of approximately 10-micron diameter junction (MX-40 (R), OKI). The typical conversion loss of the RF mixer at 39 GHz is 6 dB with the local oscillator power of 7 dBm and without DC bias. The noise figure of the RF mixer is 8 dB, which contains the noise figure of 2 dB of the receiving IF pre-amplifier.

Performances of single local transmitter and receiver

Frequency conversion characteristics. The upper side band output power vs. IF input power is shown in Fig.4. The upper side band output power is 8.5 dBm at the point of IF input of 0 dBm without deformation of output spectrum. The local CW output is 15 dBm when biassed to 108 mA. The conversion losses of the upper side band output power to the local output power is 6.5 dB. The upper side band output power variation is 8.5 dBm ±0.3 dB over temperature range of -4 to -140°F.

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In the equipment, emission limitation is followed by a 3-stage LPF having 600 kHz bandwidth at baseband and IF stage filtering, considering FCC Rules and Regurations. The spectrum waveform Fig. 5 is up-converted to 40 GHz band without deformation and within the emission limitation.

Frequency stability of oscillator With the bias modulation, the obtained stability of cavity stabilized oscillator is less than 1×10^{-4} (4 MHz) over temperature range of -4 to +140°F. Experimentally, it has been made clear that the stability of oscillator is not degraded by the bias modulation.

Effects on NF The residual FM and AM of mixer local signal caused by the added bias modulation to the Impatt source are less than 45 dB and 30 dB respectively. The measured degradation of the receiver NF due to the residual modulation is less than 0.1 dB.

IMPATT noise reduction for mixer Since the Impatt source in the system is commonly used to the mixer local signal, the Impatt noise at the IF frequency degrades the mixer NF by 6 dB as compared with the NF = 10 dB of a clean local source. To eliminate the degradation of NF, the attenuation of the noise at IF frequency is necessitated by more than 45 dB. Consequently, an RF BPF of 4-stage, 140 MHz bandwidth is inserted to the local arm of the mixer.

BER characteristics Fig. 6(a) shows the measured bit error rate (BER) characteristics. In the figure, single local transmitter BER is compared with that of the conventional Impatt source plus up-converter trans-mitter. There exists little difference. The CNR degradation from the system design value is less than 1 dB. Fig. 6(b) also shows a comparison of the measured BER of single local receiver with that of the conventional receiver using a separate Gunn local source. There exists little difference in this case as well.

Equipment features

The main specifications of the equipment are shown in Table 1. The photograph of the single local transmitter and receiver is shown in Fig. 7. The outside view of the equipment is shown in Fig. 8 which can house a redundant TRX too. The dimension of the cabinet is 20 inch (H) x 20 inch (W) x 23 inch (D) and the weight of the cabinet is 94 lbs.

Conclusion

In conclusion, the single local transmitter and receiver has nodegradation in the performances compared with the conventional transmitter-receiver having TX-local, up-converter, and RX-local sources independently. The single local transmitter and receiver is, we believe, an effective method as a low density local trunking radio equipment in intra-city applications.

Acknowledgement

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References

[1] Ohta and Hata, "Noise Reduction of Oscillator by Injection Locking", Trans. I.E.C.E., Japan, 53-B, 9, P487 (Sept. 1970); available in English in E.C.J., same data. P.44.

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Table 1. Specification

Radio Frequency	38.6 ∿ 40.0GHz
Bit Rate	1,544 Mb/s (6.3)
Capacity	24 TP CH (96)
Modulation	Bi-phase PSK
Span Length	2 ∿ 7 miles
Authorized bandwidth	10 MHz
System Gain	177 dB
Antenna Gain	43 dB, 17.7ϕ inch
Output Power	+7 dBm
Frequency Stability	0.012%
Receiver Configuration	Double Superheterodyne 1st IF 320 MHz 2nd IF 70 MHz
Receiver Noise Figure	Less than 12 dB
Demodulation	Coherent
Power Consumption	65 W (DC-48V)
Weight	94 lbs

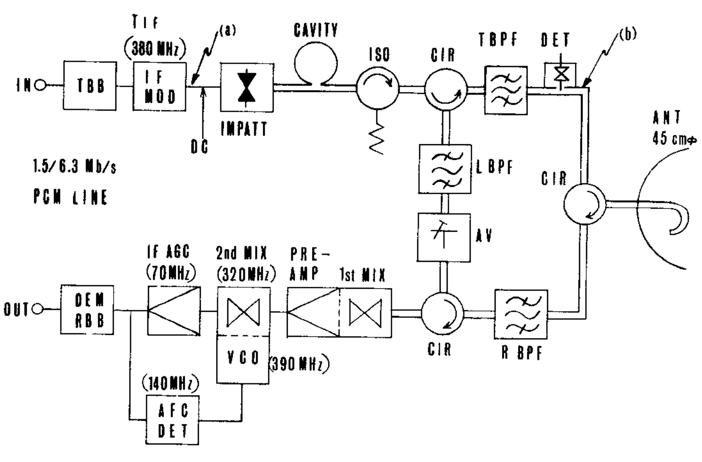

Fig. 1 Block diagram of single local transmitter-receiver

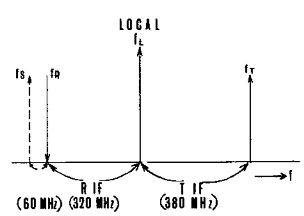

Fig. 2 Frequency arrangement

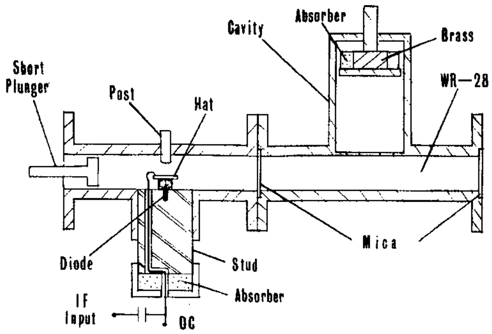

Fig. 3 Cross-sectional view of Impatt oscillator

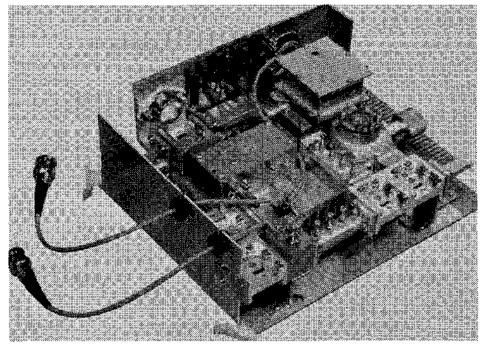

Fig. 7 Single local transmitter-receiver

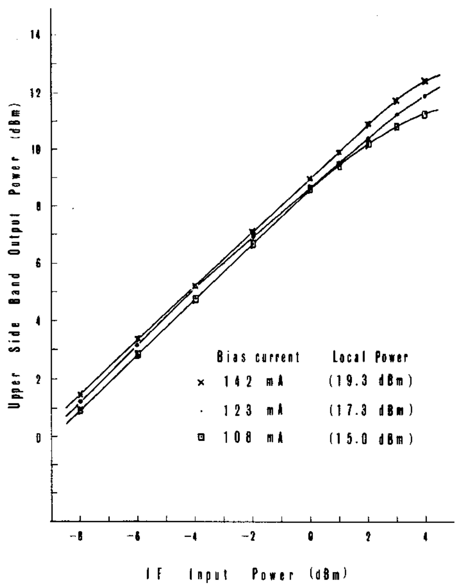

Fig. 4 Frequency conversion characteristics

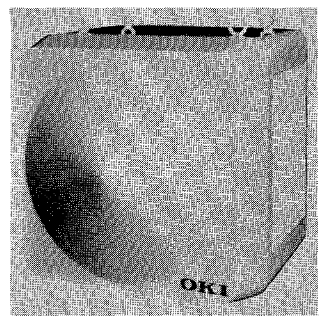

Fig. 8 Outside view of equipment

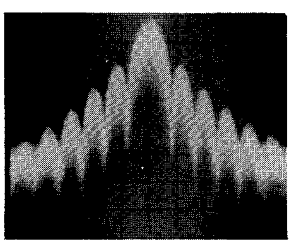

Fig. 5 RF output spectrum

Horizontal: 2 MHz/div.
Vertical: 10 dB/div.
Selective Babdwidth: 100 kHz

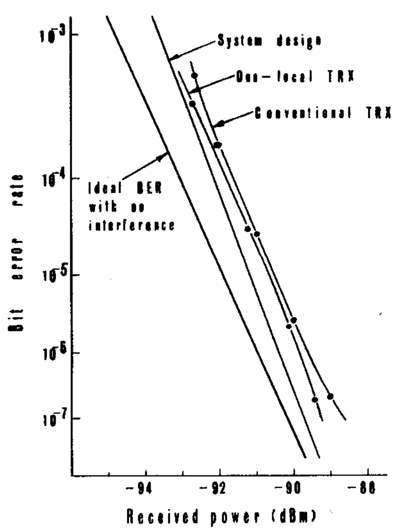

Fig. 6 (a) Transmitter quality

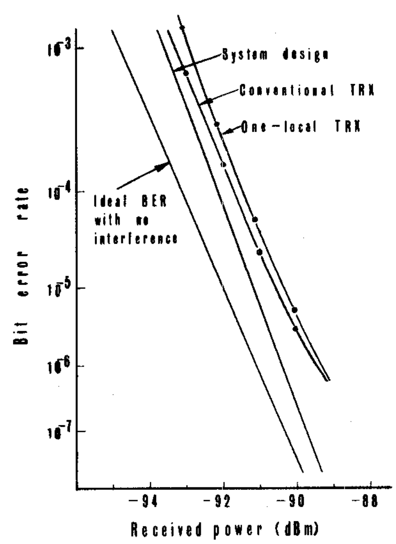

Fig. 6 (b) Receiver quality