Wireless Multi-Channel TV-Signal Distribution System by Using NRD Guide Transmitter and Receiver at 60 GHz

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Abstract— Millimeter-wave transmitter and receiver have been developed for multi-channel TV-signal distribution system based on the NRD guide technology. Main emphasis is placed on the development of band-widening techniques for NRD guide circuit components. The distribution test of the TV-signals with more than 100 channels can be performed by using them successfully.

I .INTRODUCTION

Multi-channel TV-signal distribution system is being projected in optical fiber networks[1]. Millimeter-wave has also attracted much attention for the construction of this application. Actually CRL (Communication Research Laboratory) in Japan has proposed such system as a wireless home-link networks, where intermediate frequency (IF) waves of broadcasting satellite TV-signals are up-converted to millimeter-wave and the millimeter wave is distributed to every place around the Japanese house [2]. Including VHF/UHF terrestrial broadcasting waves in the IF waves is preferable from the view point of multi media environment, however, the bandwidth of the IF waves becomes wider in the range from 90MHz to 1895MHz.

Having this fact in mind, millimeter-wave circuit components to cover the wide bandwidth have been developed based on the NRD guide technology [3] at 60GHz and transmitter and receiver have been fabricated by assembling such circuit components.

Main emphasis is placed on the performance of the up-converter incorporated in the transmitter. The wide band performance has been obtained by modifying the structure of the diode mount in the up-converter. Moreover the band-pass filter with ceramic resonators, which has great advantages such as the low-loss nature in wide pass-band and sharp cutoff performance in rejection band, is developed to suppress the lower side band generated in the up-converter.

The wireless distribution of the TV-signals with more than 100 channels, which contains many kinds of information source such as analogue/digital video signals, PCM voice signal, HDTV signal and so forth, has been demonstrated successfully.

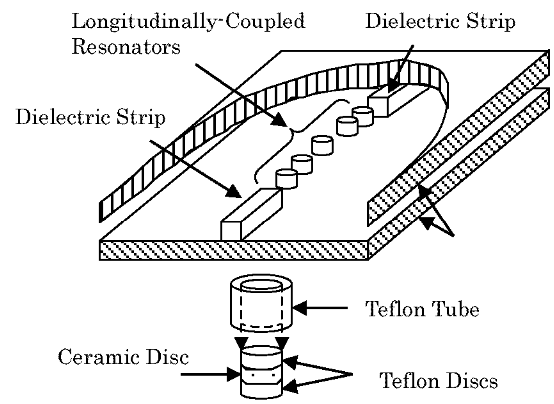

Fig.1 Structure of NRD guide band-pass filter using ceramic resonators.

II. BAND WIDENING TECHNIQUES OF NRD GUIDE CIRCUIT COMPONENTS

In this chapter, band widening techniques for NRD guide key devices such as band pass filter and up-converter are described. The metal plate separation of the NRD guide is determined to be 2.25mm so as to be less than half a free space wavelength at 60GHz. Low loss teflon with a relative dielectric constant of 2.04 is used as a dielectric strip whose cross sectional dimensions are 2.25mm in height and 2.5mm in width, respectively.

A. Band-Pass Filter Using Ceramic Resonators

Figure 1 shows the structure of the NRD guide band-pass filter constructed by gap-coupled ceramic resonators. The ceramic disc is supported by upper and lower teflon discs so as to be located at the mid-plane between parallel metal plates and is inserted in the teflon tube to keep the shape. $TE_{0n\delta}$ modes have been used as resonant modes in ceramic resonators due to the high Q performance, however, they have a difficulty in making wide-band band-pass filter at millimeter-wave frequencies

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due to the weak coupling between resonators. From view point of band-widening, $EH_{nm\delta}$ modes, dealt with parasitic mode, are more attractive than $TE_{on\delta}$ modes because it can be considered that the coupling factors of the $EH_{nm\delta}$ modes are lager than those of the $TE_{on\delta}$ modes. In order to confirm this fact, the coupling coefficients of $EH_{11\delta}$ mode and $TE_{02\delta}$ mode were measured, where the diameters of the ceramic discs with a relative dielectric constant of 21 were set to be 2.0mm for $EH_{11\delta}$ resonant mode and 2.5mm for $TE_{02\delta}$ resonant mode, respectively, and these resonant frequencies were tuned at 60GHz by choosing suitable thickness of ceramic disc. Figure 2 shows the comparison of their coupling coefficients. Tight coupling performance has been achieved in $EH_{11\delta}$ mode resonator as predicted.

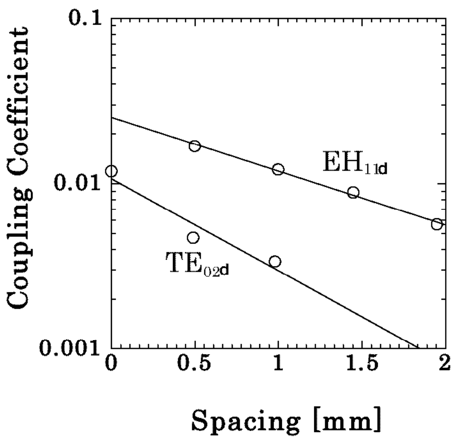

Fig.2 Comparison of measured coupling coefficients of $EH_{11\delta}$ mode and $TE_{02\delta}$ mode.

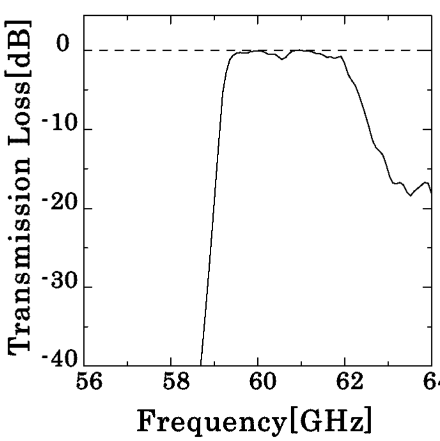

Fig.3.Measured frequency characteristics of 2-dB Chebyshev ripple band-pass filter with 5pole ceramic resonators.

As described next chapter, the upper/lower side bands with the center frequencies of 59.959GHz and 57.974GHz, respectively, are generated at the frequency converter since the bandwidth of IF wave is decided to be 1805MHz around a center frequency of 992.5MHz. In order to suppress the lower side band, the band-pass filter is designed as a 5-pole, 2dB Chebyshev ripple filter with the bandwidth of 2.6 GHz at the center frequency of 60.357GHz. The measured frequency response is shown in Fig.3. A small insertion loss less than 0.6dB has been obtained in upper side band frequency region from 59.057GHz to 60.862GHz, while a sharp rejection performance more than 30dB in lower side band frequency region can be achieved.

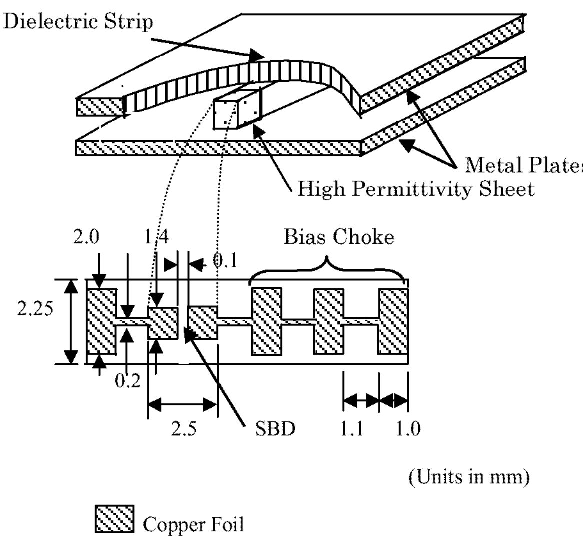

Fig.4 Structure of NRD guide beam lead diode mount.

B. Schottky Barrier Diode Up-Converter

The structure of the NRD-guide beam-lead diode mount is shown in Fig.4. The mount is etched on a dielectric substrate together with $\lambda/4$ RF choke structures, and the beam-lead type schottky barrier diode (SBD) is bonded across a slot between two electrodes. Since an impedance of the electrodes is higher than that of the SBD, a high permittivity sheet is putted on the electrodes, where an alumina with a relative dielectric constant of 9.8 and tan δ of 1×10^{-4} is selected instead of a conventional duroid substrate [4] from view point of low loss nature. Moreover, the width of the slot, which was decided to be 0.4mm in the previous diode mount [4], is reduced to 0.1mm to lower the impedance of the electrodes.

The present and previous diode mounts with forward-biased SBDs were placed at the truncated end of the dielectric strip, respectively, and the VSWRs from each SBD were measured by changing the frequency. The result are shown in Fig.5 by solid and dotted curves. As is obvious from the result, the band widening can be achieved based on this technique.

By using this diode mount, the NRD guide up-converter has been fabricated. Figure 6 shows the measured RF power versus the intermediate frequency, where the LO power and IF power are fixed to be 13dBm each. A flat RF power of 2dBm on average has been obtained over a bandwidth of at least 2GHz around a center frequency of 1.5GHz.

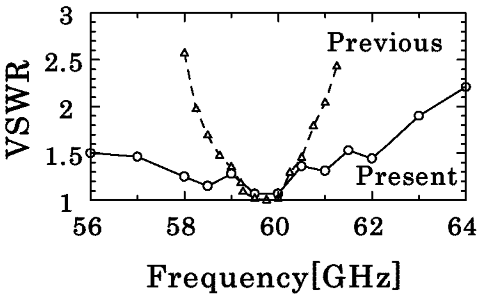

Fig.5 Measured VSWR of forward-biased SBD versus frequency.

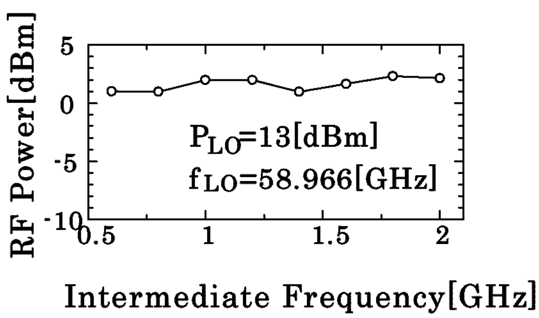

Fig. 6 Measured RF power of NRD guide up-converter versus intermediate frequency.

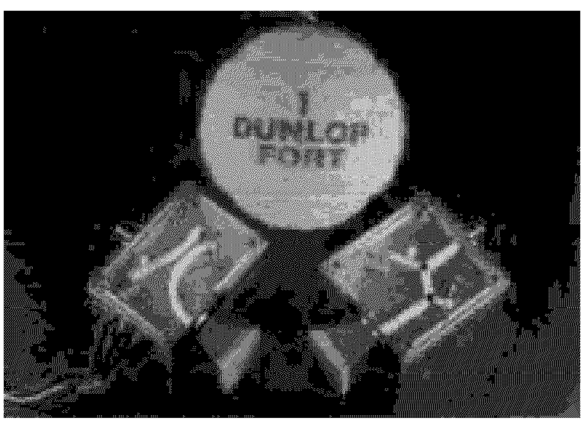

Fig.7 Photograph of NRD guide transmitter on right ride and receiver on left ride

III. TRANSMITTER AND RECEIVER

Figure 7 shows the photograph of the fabricated NRD guide transmitter and receiver. The transmitter consists of frequency stabilized Gunn oscillator, circulator, up-converter, matched load and band-pass filter, while the receiver consists of frequency stabilized Gunn oscillator, directional coupler and down-converter. A pyramidal horn antenna with gain of 20dBi, which is covered with thin teflon sheet over the 16×23mm aperture and fed by a tapered dielectric rod of 3mm in length is used. All circuit components are contained in compact housings of 44×49 mm in area for transmitter and 39×53 mm in area for receiver. Performances of the transmitter and receiver are summarized in Table 1.

Table 1 Performance of NRD guide transmitter / receiver.

Transmitter	
LO Frequency	58.966GHz
Intermediate Frequency	0.09～1.9GHz
Transmitting Power	0 dBm (Average)
Size (Excluding Antenna)	44×49mm
Receiver	
LO Frequency	58.965GHz
Intermediate Frequency	0.09～1.9GHz
Conversion Loss	7 dB (Average)
Size (Excluding Antenna)	39×53mm

IV. MULTI-CHANNEL TV-SIGNAL DISTRIBUTION SYSTEM

The system configuration of multi-channel TV signal distribution is shown in Fig.8. In this system, the terrestrial broadcasting waves, allotted in the frequency band from 90MHz to 770MHz, in Japan, are received by Yagi-Uda antenna. Broadcasting satellite waves, from BS (Broadcasting Satellite) with 4 TV channels including a HDTV channel and CS (Communication Satellite) with 94 TV channels and 105 radio channels, are also received by each parabola antenna, and are converted to each intermediate frequency wave with frequency bands, from 1.035GHz to 1.335GHz, and, from 1.293GHz to 1.548GHz, respectively.

After the terrestrial waves and the IF waves are multiplexed to the group signal with frequency range from 90MHz to 1.895GHz by using the block converter as shown in Fig.9, the group signal is up-converted to millimeter-wave in the transmitter. Figure 10 shows the frequency spectrums of the group signal and the millimeter-waves. The two spectrums are identical in shape, thus, it is confirmed that the group signal can be clearly up-converted to millimeter-wave in the transmitter. In the receiver, the group signal is down-converted, and is divided to each tuner, respectively. Finally, terrestrial TV-signal, BS-signal, HDTV-signal and CS-signal are demodulated in each television.

The NRD guide transmitter and receiver are separated by a distance of 5m in a narrow hall, and TV signal distribution test is being performed for a period of over two years without any troubles. Figure 11 shows a photograph of the demonstration where the picture and the sound are quite clear.

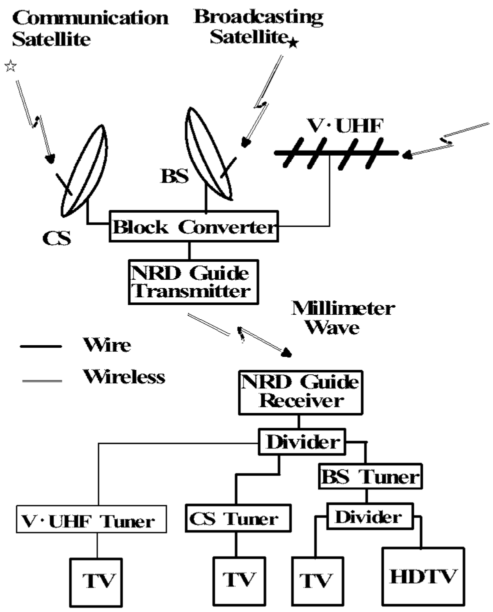

Fig.8 Configuration of wireless multi-channel TV-signal distribution system

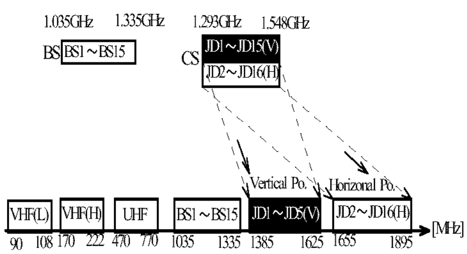

Fig.9 Intermediate frequency allocation of terrestrial BS and CS broadcasting waves.

V. CONCLUSION

The millimeter-wave transmitter and receiver are developed by using the NRD guide, and wireless distribution system for multi-channel TV signal with more than 100 channels as analogue/digital format is built at 60GHz.Since the picture and sound are quite clear, the NRD guide technology is expected to play a key role in future ISDB (Integrated Services Digital Broadcasting) systems.

References

[1] P.E.Geen Jr, "Optical Networking Update", IEEE *J. Select. Areas Comm.*, vol.14, No.6, 1996

[2] K. Hamaguchi, Y. Shoji, et al. "Development of Millimeter-Wave Video Transmission System", Proceedings of 2000 Topical Symposium on Millimeter Waves, March, 2000

[3] T. Yoneyama, "Millimeter wave integrated circuits using nonradiative dielectric waveguide", IEICE Trans. (C-I), J73-C-I, No.3, pp.87-94, March, 1990.

[4] F.Kuroki, M.Sugioka, S.Matsukawa, K.Ikeda and T.Yoneyama, "High Speed ASK Transceiver Based on the NRD Guide Technology at 60GHz band", IEEE Trans. Microwave Theory Tech., Vol. 46, No.6, 1998

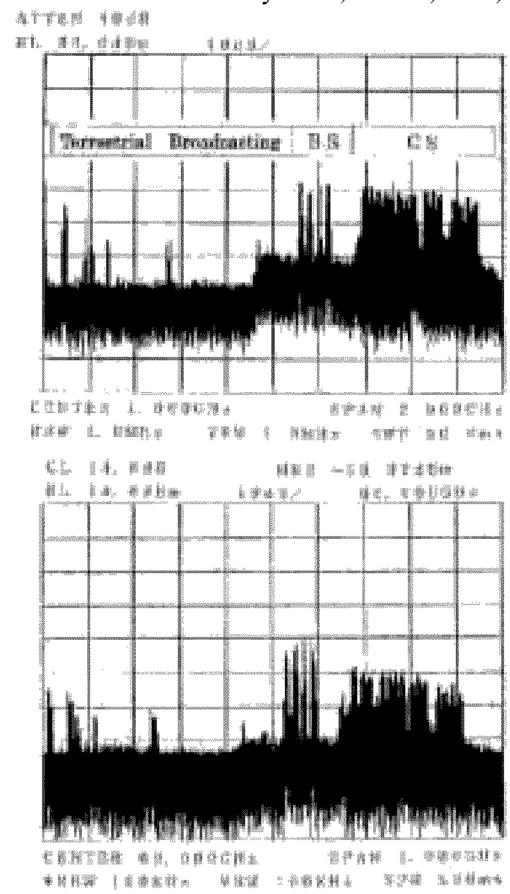

Fig.10 Measured frequency spectrums of IF waves(top) and up-converted millimeter waves(bottom).

Fig.11 Photograph of demonstration of TV-signal distribution.