Direct Conversion Receiver for Digital Beamforming at 8.45GHz

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Abstract — **Direct conversion receiver for digital beamforming (DBF) at 8.45GHz for next generation wireless telecommunication is presented. In this proposed system, the quadrature hybrid and tuning circuit are partially constructed by digital techniques for the simplification of hardware. We demonstrate the direct conversion FET second harmonic mixers without DC bias at RF part. We also examine this proposed receiver's ability to function as a digital beam former. In this result, the digital beam forming can be realize that side lobe level is below –10 dB and the half power beam width is about 60°, in case of scanning range is limited ±20° by using this proposed receiver.**

I. Introduction

A mobile telephone service of the next generation will be available at 2001. This service gives high-speed data transmission of 2Mbps for local area and 384kbps for global area. After the next generation, a data speed is required to be up to 20Mbps. In recent years, the technology of adaptive array antenna has been greatly advanced and applied to mobile communications systems.

It can overcome the problems in mobile communication such as the limited channel bandwidth while satisfying the demand for many mobiles in a limited communication channel. Moreover, it is investigated that the C/N (carrier to noise) ratio can be increased [1]. In adaptive array antenna techniques, the digital beamforming (DBF) array antenna would play an especially important role for the mobile communication system of the next generation.

The DBF array antenna is a kind of adaptive array antenna, which can realize the desired beamforming by adjusting the weight parameter of each antenna element. The received analog signals are first converted to digital ones by analog to digital (A/D) converter, and then the antenna pattern is computed in a desired form by the digital signal processing of digital signals. Most of DBF array antennas are researched for military, satellite, and base station [2]. Such DBF array antennas are very complicated and expensive, because they are implemented by application specific integrated circuit (ASIC) and high cost RF module.

To avoid such costly situation, some low-cost adaptive antennas have been recently proposed [3]. These systems achieved low cost by digital signals, array signal processing, and demodulation on common personal computer (PC) and digital signal processor (DSP). However, these reports hardly have described miniaturization, simplification for terminal of wireless telecommunication. In this paper, we demonstrate DBF receiver at 8.45 GHz for terminal. This band is a candidate of frequency band of next generation wireless telecommunication in Japan also 3.0 GHz and 5.4 GHz. We also describe quadrature hybrid and tuning circuit at digital part and the FET mixer with direct conversion at RF part.

II. Configuration Of DBF Receiver

Fig.1 shows block diagram of 8.45GHz DBF mobile receiver with direct conversion. A RF signal received from the array antenna (the distance of each antenna is half wavelength) passes through direct conversion mixer, A/D converter and orthogonal decomposition with digital processing. It can realize a beam operation by personal computer (PC). Common receivers divide the received signal into I and Q signals by using a quadrature hybrid, generally implemented by analog circuits, in order to obtain phase information. However, in this case, it is difficult to make the orthogonal detection precisely, and the phase error causes beamforming error. To simplify the hardware construction, this receiver utilizes the Hilbert transformer which can be implemented as a finite impulse response (FIR) digital filter [4], instead of the analog

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orthogonal detector. An IF signal is divided into 2 signals: one is the I component inputted to the delay circuit (Ts), and another is the Q component of which the phase is delayed 90 degrees by a Hilbert Transformer.

At digital part, this receiver have also the gain and phase tuning circuit with variable gain amplifier (VGA) and phase shifter, in order to eliminate the correlation between channels, because calibration is an important aspect of performance of any adaptive array system. This tuning circuit is controlled by feedback data using digital signal processing. This feedback data can be obtained using the reference antenna which the place is fixed and known.

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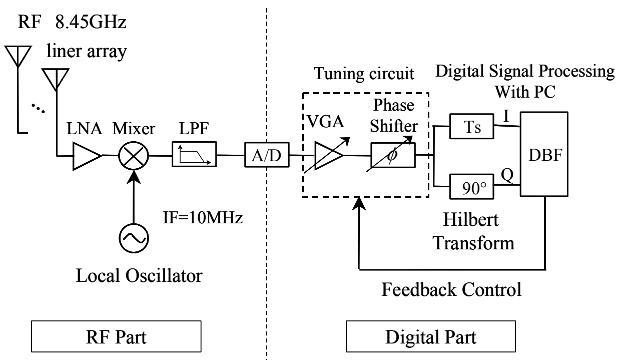


Fig.1. 8.45GHz DBF Block Diagram.

III. MIXER OVER VIEW

Fig. 2 shows the FET drain mixer constructed on 25mil-thick RT/Duroid (ε_r=10.2). A FET is used NEC NE76038 MESFETs. This mixer is second harmonic mixer without DC bias. Since it needn't to use DC bias circuit, we can achieve compact size and low electricity. Therefore the zero bias mixer is suitable for mobile terminal. The LO signal (4.22GHz) is applied to the drain of FET through the bandpass filter by using microstrip line. The RF signal (8.45GHz) is applied to the gate. The IF signal is extracted from drain by using lowpass filter with lumped element. In order to reduce the second harmonic of the LO at RF port and the fundamental harmonic of the RF minus LO at LO part, the LO signal is split by a Wilkinson power divider with a 90° delay line on one branch is shown in Fig. 2 and Fig. 3. We have a 180° phase difference at the second harmonic of the LO and the fundamental harmonic of the RF minus LO from this double balanced structure. In this mixer, we obtain two IF: one is IF_1, another is IF_2 that is different from IF_1 in phase of 180°. After IF_2 is shifted 180° by using a Hilbert Transformer, both IF_1 and IF_2 are composed with digital signal processing, and then we can examine the digital beamforming. IF versus RF power and conversion loss versus LO power at IF_1 in front of tuning circuit is shown in Fig. 4 (a) and (b), respectively. A conversion loss of 13 dB is achieved for a LO input power of 6 dBm.

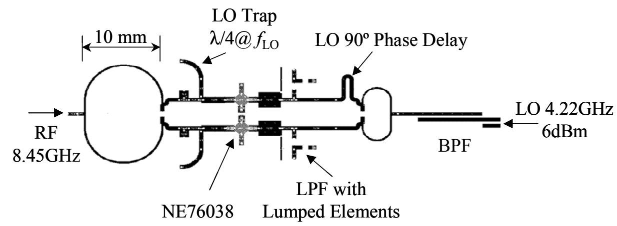


Fig.2. Schematic of FET mixer with direct conversion

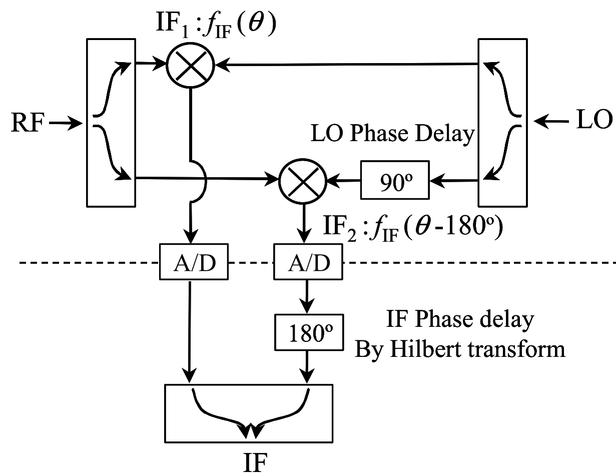
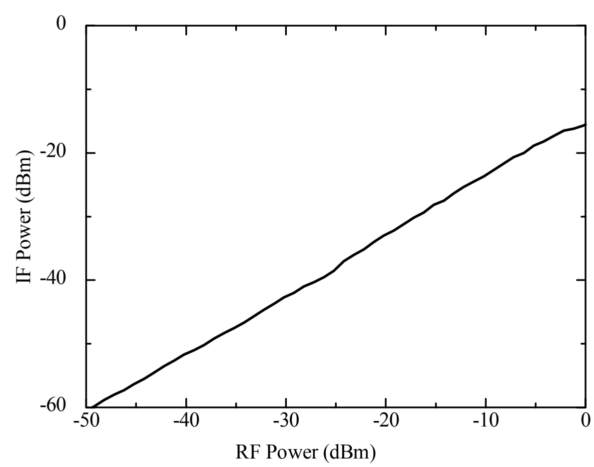
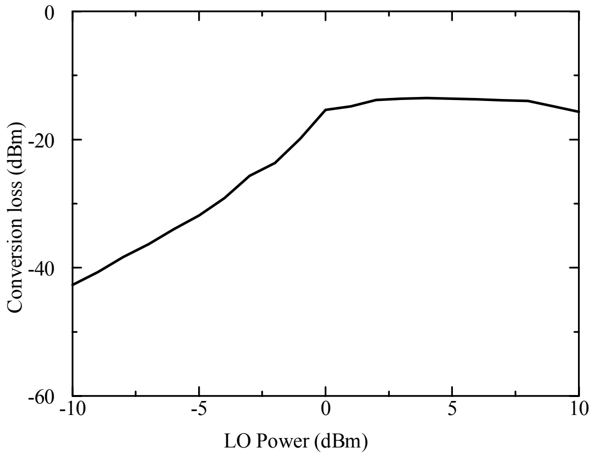


Fig.3. Block Diagram of FET mixer with direct conversion



(a) IF versus. RF power at LO power = 6dBm



(b) Conversion. Loss versus. LO power at RF power= -20dBm
Fig.4. Performance of balanced mixer

IV. Beamforming Results

In this section, the proposed receiver's ability is evaluated through function as a digital beam former inside a radio anechoic chamber. The measurement setup is shown in Fig.5. A signal of continuous wave (CW) from a signal generator is transmitted from a sleeve antenna through a high power amplifier. This transmitting antenna is installed 1m far from the center of the receiving array antenna. Two proposed receiver are arrayed in the half wavelength interval and connected monopole antenna. The CW signals received from the monopole array are converted to IF signals (baseband) by the proposed receiver. The IF signals are sampled simultaneously by the A/D converter on the PC. The beam forming patterns are obtained by baseband data collected from each antenna element using off-line processing. Fig. 6 (a) and (b) show the synthesized beam pattern with main beam directed towards 10° and –30° (transmitting antenna is installed in these directions from the center of the receiving array antenna), respectively. In case of main beam directed towards 10°, the synthesized beamforming pattern can realize that half power beam width is about 60°. In case of directed towards –30°, the synthesized beamforming pattern can realize that half power beam width is about 70°. In this result, the digital beam forming can be realize that side lobe level is below –10 dB and the half power beam width is about 60°, in case of scanning range is limited ±20° by using this proposed receiver.

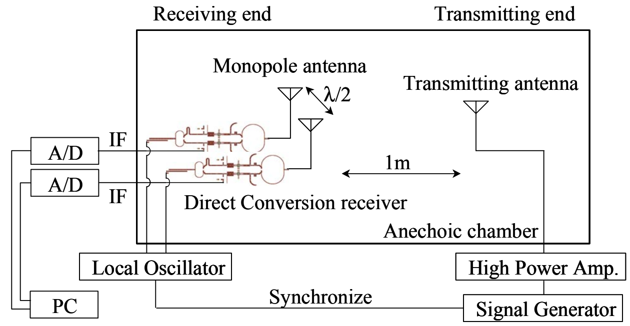
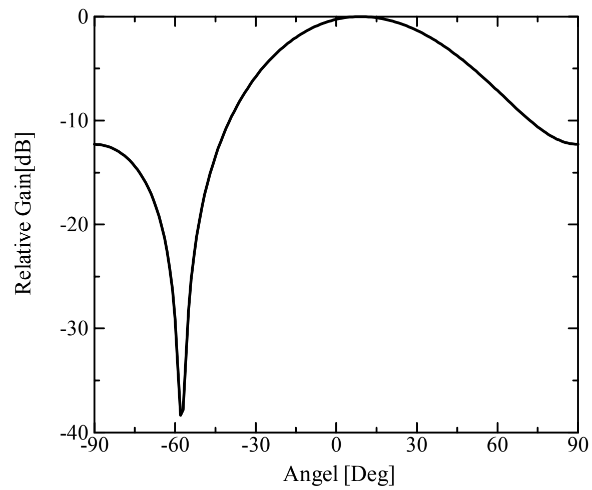
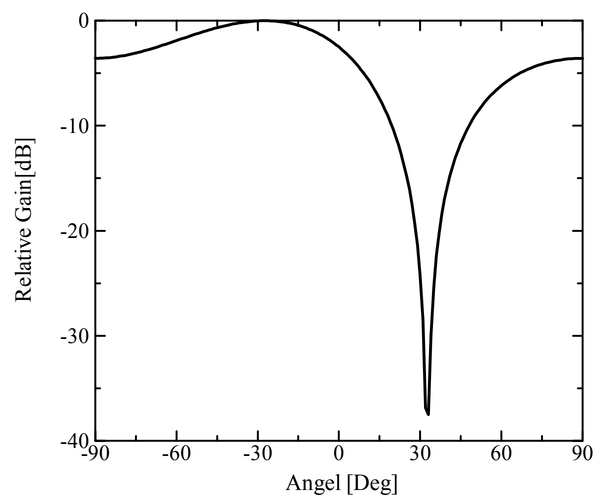


Fig.5. Measurement setup



(a) Towards 10° direction



(b) Towards –30° direction
Fig.6. Beamforming result

V. CONCLUSION

This paper proposed DBF mobile receiver with direct conversion at 8.45GHz. In this proposed system, the quadrature hybrid and tuning circuit were partially constructed by digital techniques for the simplification of hardware. We demonstrated the direct conversion FET second harmonic mixers without DC bias. This mixer's conversion loss was about 13dB. We also examined this proposed receiver's ability to function as a digital beam former. In this result, the digital beam forming could be realize that side lobe level was below –10 dB and the half power beam width was about 60°, in case of scanning range is limited ±20° by using this proposed receiver.

ACKNOWLEDGEMENT

The author would like to thank Mr. Seong-Sik Jeon who studies in Electrical Engineering Department, UCLA for his helpful discussion.

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