Compact RF front-end configuration for short-range communication

T.-H. Ho and S.-J. Chung

A compact radio frequency front-end configuration for short-range wireless communication with a novel bidirectional amplifier is presented. This configuration uses a single RF path for both transmitting and receiving. Performance prediction based on the experimental results indicates that the proposed RF front-end has the potential for use in short-range wireless applications.

Introduction: The radio frequency (RF) front-end circuits of transceivers usually include two individual signal paths, one for transmitting and the other for receiving. The use of two individual T/R paths has the advantage of achieving optimum designs for each path and result in an improved communication range and quality. However, they also suffer the disadvantages of more circuit components, more complicated circuit layout, and higher cost [1–3]. Owing to the dramatic increase of wireless personal communication requirements in recent years, many new transceiver architectures have been proposed to simplify the circuit configuration and to reduce the system cost. These designs may not focus on increasing the communication range but emphasise the communication convenience in the near proximity of the users. Thus, the circuit performance can be somewhat sacrificed in order to obtain a compact and low-cost circuit configuration. Tsukii *et al.* [1] and Archer *et al.* [3] presented single-path transceiver architectures using a switched bidirectional amplifier (BDA). The transmitting and receiving signal share the common RF circuits so as to simplify the circuitry. However, the architectures can only be used for half-duplex applications. This would limit usage of the transceivers. In this Letter, we present a compact RF front-end configuration using a new BDA. The configuration requires only one path for the transmitting/receiving signals and can be used in both half-duplex and full-duplex systems.

RF front-end configuration: Fig. 1 shows the schematic diagram of the proposed RF front-end configuration, which is composed of a new bidirectional amplifier (BDA), a bandpass filter, a balanced mixer, and a printed-Yagi antenna [4]. The RF operating frequency is selected near 10 GHz. The new BDA could amplify the incoming and outgoing signals simultaneously. It provides the required gain for both transmitting and receiving signals. The bandpass filter is in general used to filter out the image signal and out-band signals, and the balanced mixer serves as a frequency up/down converter. In this study, an external signal generator is connected to the circuit and used as a local oscillator. All the circuits and antenna were designed on the RT/duroid 5880 20-mil substrate. The duplexer or switch to separate the transmitting and receiving signals is to be implemented in the IF circuitry, which would greatly reduce the complexity and cost of the transceiver circuits.

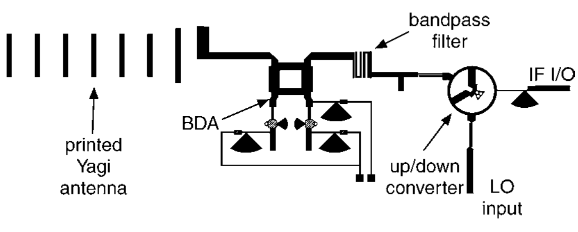

Fig. 1 *Schematic diagram of proposed RF front-end configuration*

Design and measurement results: As shown in Fig. 1, the BDA consists of a 90°-hybrid and two reflection-type amplifiers [5]. A branch-line coupler was used as the 90°-hybrid, with two ports connected to the reflection-type amplifiers and the other two as the I/O ports of the BDA. The reflection-type amplifier was designed using an NE32584C HMET. Signals coming from either the I/O ports of the BDA will be equally split by the 90°-hybrid with a phase difference of 90°. These signals are enhanced and reflected from the reflection-type amplifiers, and would then sum up at the output port and cancel with each other at the input port because of a 180° round-trip phase difference. The bidirectional gain of the BDA is equal to the gain of each reflection-type amplifier, and the power handling capability will be double because the power into a reflection-type amplifier is only half of the input power to the BDA. The symmetricity in structure results in a balanced gain in both forward and reverse directions. Fig. 2 shows the measured gains of the BDA in both forward and reverse directions. It is seen that the frequency responses of the forward and reverse gains match quite well. In the range from 9.6 to 9.8 GHz, both the measured gains are greater than 10 dB. The peak gains are located around 9.7 GHz with levels about 13.5 dB.

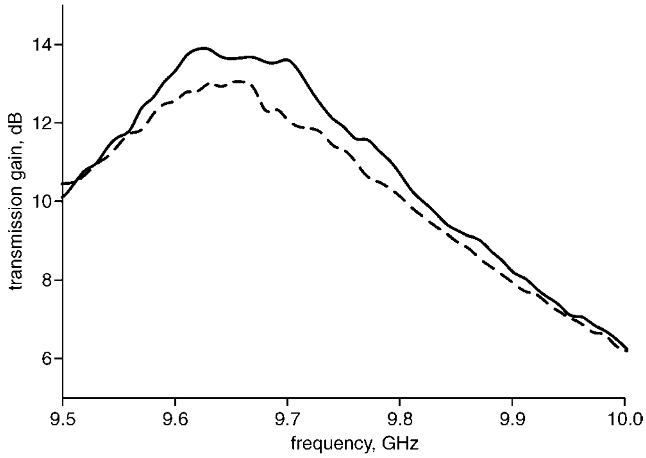

Fig. 2 *Measured transmission gains of BDA in both forward and reverse directions*
——— forward transmission gain
– – – – backward transmission gain

The balanced mixer is designed as a normal rat-race type with a 180°-hybrid and two Schottky diodes. Both the measured upconversion and downconversion losses of the balanced mixer are 5.3 dB for an LO power of 8 dBm. In the measurement, the LO, IF and RF frequencies are set as 9.35 GHz, 400 MHz and 9.75 GHz, respectively. The bandpass filter is designed as a second-order folded edge-coupled microstrip (ECM) filter with a relative bandwidth of 5%. The measured insertion loss of the bandpass filter is 1.8 dB and the half power bandwidth extends from 9.6 to 9.9 GHz. To avoid self-oscillation in the BDA, a wideband antenna is needed in the present study. To this end, a printed Yagi antenna with seven directors [4] was used. The fabricated antenna possesses a measured gain of 11.5 dBi, 10dB return-loss bandwidth of 1.3 GHz (from 8.6 to 9.9 GHz), and half-power-beamwidth of 40°.

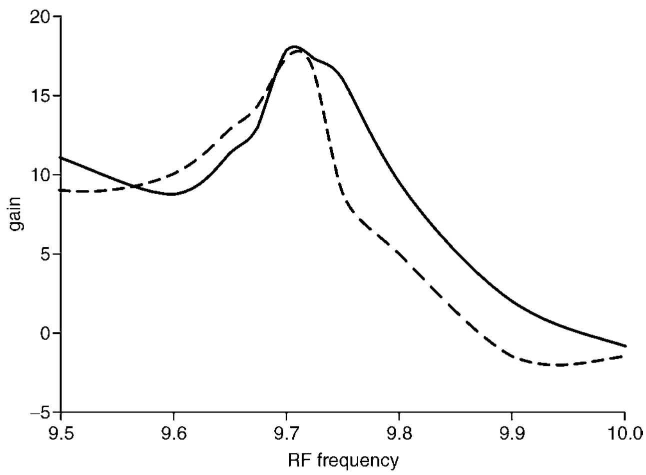

Fig. 3 *Measured gain of RF front-end for both transmitting and receiving from IF to space*
——— transmitting gain
– – – – receiving gain

The designed RF circuits were integrated on a single substrate with a dimension of $130 \times 40\ mm^2$. Fig. 3 shows the measured transmission gains of the integrated RF front-end between IF and space. In the measurement, a horn antenna used to receive/transmit the power from/to the RF front-end was placed at a distance of 5 m away. It is seen that the integrated RF front-end achieves an overall gain of 17 dB from RF to IF in both transmitting and receiving modes. This value is quite near to the summation of the gains/losses of each individual component. The measurement also showed that the RF front-end accomplishes a maximum EIRP of 15.5 dBm and a noise figure of 10 dB. The noise figure is mostly contributed from the reflection-type amplifiers in the BDA. In the design of the reflection-type amplifier, the IO port was located at the drain of HEMT, which may cause a larger noise figure [6].

Performance prediction based on the experimental results indicates that the present RF front-end has the ability to attain a half-duplex link with BER of 10^{-8} in a 200 m range when using FSK modulation with modulation index of 0.0031 and bit rate of 10 Mbit/s [7, 8]. This result shows that the proposed RF front-end has the potential for use in short-range wireless applications.

Conclusion: We have demonstrated a compact RF front-end configuration which has the potential for short-range wireless applications. The RF front-end contains a single path for both T/R signals using a BDA. The measurement result shows a conversion gain of 17 dB at 9.7 GHz for both T/R modes and an EIRP of 15 dBm. For further investigation, a low-noise BDA and a wide-beam (or omni directional) wide band antenna should be conducted for practical applications.

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