even mode impedance, odd mode impedance, and characteristic impedance agree well with those found in the literature. Also, we developed our own model for shielded broadside-coupled inverted microstrip line to determine the capacitance per unit length matrix, even mode impedance, odd mode impedance, and characteristic impedance. The results obtained in this research are encouraging and motivating for further study.

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SELF-HETERODYNE DIODE MIXER WITH GCPW PROCESS AT 60 GHZ
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ABSTRACT: A self-heterodyne diode mixer is proposed using thin film process based on alumina substrate at 60 GHz; in conjunction with grounded coplanar waveguide transition. To down-convert both very low RF and LO signals received simultaneously from transmitter for self-heterodyne communication scheme, the proposed mixer adapted with the knee voltage bias condition of 0.65 [V] improves its mixing efficiency significantly. The designed SHM shows the conversion loss of −15.13 dB at RF and LO frequencies of 60.565 and 59.01 GHz, respectively, with both input powers of −15 dBm and it also can defines IMD free input dynamic range as −30 dBm. The measured return losses satisfies with more than 20 dB and 9 dB for RF/LO input and IF output port, respectively. © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 51: 13–15, 2009; Published online in Wiley InterScience (wwwinterscience.wiley.com). DOI 10.1002/mop.23959

Key words: self-heterodyne mixer; bias mixer; GCPW; thin film

1. INTRODUCTION
One of the most critical parameters for the quality and reliability of making the communication link is the phase noise of oscillator. Especially in millimeter wave communication, an oscillator with good phase noise is one of very important expensive components [1, 2]. To overcome this problem, one of alternative communication techniques is a self-heterodyne communication scheme which transits both RF signal and local oscillator signal for up-conversion in transmitter simultaneously and received RF signal is down-converted with received LO signal without receiver itself local oscillator [3]. There are many self-heterodyne mixers (SHMs) as a key component to realize this scheme in previous works fabricated only on MMIC technology which has very high cost, no tuning mechanism and not so good to make interconnection with other circuits [3, 4]. However, there is no one developed with single diode type SHM on alumina substrate using thin film process.
In this work, the self-heterodyne mixer with a single schottky diode type adapted with the knee bias voltage to improve conversion loss based on thin film process at 60 GHz for very low cost and easily interconnected solutions is firstly introduced. The designed mixer with grounded coplanar waveguide (GCPW) transition shows merits for very low cost and easily mounted and/or interconnected to other planar circuits for practical use of millimeter wave short range, in-door communication systems.

2. SELF-HETERODYNE MIXER DESIGN
Usually the type of a single ended or balanced mixer used in heterodyne receiver is not adequate for self-heterodyne scheme because sufficient LO pumping power is required. In this scheme to be realized, one of special mixers to be used on self-heterodyne scheme is adapted as a knee biased SEM (Single Ended Mixer) to be described in this article. The biased SEM as a proposed self-heterodyne mixer (SHM) is employed as schottky beam lead diode, MA4E2038 from M/A COM, and operated at RF input frequency of 60.045–61.085 GHz, IF output frequency of 1.035–2.075 with fixed LO input frequency of 59.01 GHz. This mixer consists of GCPW transition with DC blocking capacitor made by coupled line microstrip filter for in/out port in order to easily interconnect with other planar circuits. It was also adapted with some matching circuits for both RF and LO signals and LPF for down converted IF signals as shown Figure 1.
To get the maximum conversion efficiency for mixing the RF and LO signals with very weak power received from transmitter, the bias voltage for the proposed SHM is employed at around knee point as 0.65 [V]. LO and RF signals are feed through DC blocking capacitor and mixed/down converted by biased diode to be operated in the square law region. And then IF signal passes through LPF while LO, RF signals are sufficiently rejected and its equivalent circuit model is shown in Figure 2. The GCPW transition is
applied as in/out port interfaces with minimum coupling losses considered.

The SHM is fabricated on the alumina substrate with $\varepsilon_r$ of 9.9, $\tan \delta$ of 0.003, copper thickness of 3 μm, substrate thickness of 5 mm fabricated using thin film process for 60 GHz short range communication as a photograph with size of only 4.9 × 4.0 mm² shown in Figure 4.

3. SIMULATED AND MEASURED RESULTS

The simulation for proposed SHM was carried out using MoM of commercial software for all passive circuits and harmonic balance simulation for entire mixer performance even though diode modelling extraction. The design parameters such as matching circuits, IF LPF, diode bias voltage and so forth are considered and optimized to improve the conversion efficiency and the designed SHM was measured on wafer proving. The IF output powers for measured and simulated are shown in Figure 3 with RF input power variations from −15 dBm to −30 dBm at LO and IF frequency of 59.01 and 1.555 GHz. The measured conversion loss is −15.13 dB at RF frequency of 60.565 GHz with RF input power of −15 dBm included with GCPW transition loss of 0.6 dB compared with the simulated results as shown in Figure 4. The return losses at each operating band for RF/LO input and IF output ports are more than 21 dB and 8 dB, respectively. In addition, the test results also give the IMD characteristics under −30 dBm RF and LO input power, so IMD (InterModulation Distortion) free input dynamic range of this SHM should be limited over this input power level. These results show reasonable agreement except for some differences between measured and simulated one at which may be caused by mechanical misalignments and insufficient sputter etching/deposition laying down the conductor patterns on the alumina substrate.

4. CONCLUSION

The self-heterodyne mixer with a single biased diode fabricated on alumina substrate using thin film process at 60 GHz is proposed. The conversion loss is −15.13 dB at RF frequency of 60.565 GHz with RF input power of −15 dBm with 0.6 dB GCPW transition loss. It defines the minimum input RF and LO power without

![Figure 1](realization.png)  
**Figure 1** Realization of proposed SHM based on alumina substrate for equivalent model. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

![Figure 2](equivalent.png)  
**Figure 2** Equivalent model of SHM with a single diode

![Figure 3](simulated.png)  
**Figure 3** Simulated and measured IF output power as a function of RF input frequencies with RF input power from −15 dBm to −30 dBm. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

![Figure 4](conversion.png)  
**Figure 4** Simulated and measured conversion loss as a function of RF input power at RF frequency of 60.045, 60.565, and 61.085 GHz (Fabricated Self-heterodyne Mixer included) [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]
IMDs as more than −30 dBm. Although there is no SHM to be compared directly, the designed SHM shows good conversion efficiency compared with simulated one and also has some features as small size and simple structure for interconnection of other planar millimeter wave circuits.

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WIDEBAND CYLINDRICAL MONOPOLE ANTENNA FOR MULTIBAND WIRELESS APPLICATIONS

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ABSTRACT: A wideband cylindrical monopole antenna is presented for multiple band applications. Wideband property of the proposed antenna is achieved by the additional resonance from a stepped base part and a convex ground plane. The measured −10 dB impedance bandwidths are 1.74–3.06 and 5.59–10.62 GHz, which can cover various kinds of wireless services such as PCS (1.75–1.87 GHz), IMT-2000 (1.92–2.17 GHz), WiBro (2.3–2.39 GHz), WLAN (2.412–2.483, 5.725–5.825 GHz), DMB (2.63–2.655 GHz), and high-band UWB in South Korea (7.2–10.2 GHz).

2. ANTENNA DESIGN
The proposed antenna geometry is depicted in Figure 1. Basic form of the antenna is a thick monopole with wideband property [6], but it has some modification in the base part for an additional resonant band. New features are the stepped base part of the cylinder and

1. INTRODUCTION
Wideband monopole antennas are becoming more and more important for future wireless systems because of their simple structure and omnidirectional radiation characteristic, and many approaches are investigated to increase the bandwidth in the forms of cylindrical [1] and planar [2–5] monopoles.

It is well known that the larger the radius of monopole is, the wider the bandwidth becomes. But there exists the physical limitation. In this article, we propose a new type of a cylindrical monopole antenna for multiple band wireless applications. The proposed monopole has a stepped base part and a convex ground plane to achieve an additional resonance and impedance matching. Design procedure based on frequency estimations and measured results are described.

The measured results show that −10 dB impedance bandwidths are 1.74–3.06 and 5.59–10.62 GHz, which can cover various kinds of wireless services such as PCS (1.75–1.87 GHz), IMT-2000 (1.92–2.17 GHz), WiBro (2.3–2.39 GHz), WLAN (2.412–2.483, 5.725–5.825 GHz), DMB (2.63–2.655 GHz), and high-band UWB in South Korea (7.2–10.2 GHz).