An Ultra Miniature Isolator with Broadband Isolation using Ferrite Gyrator

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ABSTRACT — **An ultra miniature isolator, we call "BUFFER DEVICE", characterized in a broadband isolation and no battery power consuming, is developed. It consists of a ferrite plate and two wire windings. It provides an insertion loss of 1.5dB at 2.52GHz and an isolation of 20 dB or more over a frequency range of DC through 3.0GHz. The size of the Buffer devices is only $3.2\times2.5\times1.7$ mm^3. It is designed to replace power consuming buffer amplifiers in CDMA, TDMA, and W-CDMA mobile phone handsets.**

I. INTRODUCTION

A miniaturized isolator, we call "Buffer Device", providing wide-bandwidth isolation allows a mobile phone handsets to save battery power by replacing buffer amplifiers used in RF circuits. A conventional isolator derived from a three-port lumped element circulator, which has a port terminated with load, is superior in an insertion loss[1,2]. But this type isolator has the inherently narrow bandwidth isolation, since the matching impedance at the loaded port must be reactive and is, therefor, frequency dependent. The size is slightly large because many elements, e.g. a ferrite disk, three capacitors and magnetic circuit, are required.

As a solution of these problems, the reported broadband two-port isolator[3,4] circuit is adopted. A series capacitor is added on each input/output port of the reported two-port isolator. These series capacitors allow the Buffer Device to use small capacitors in matching circuit and to be build in very small size. A new structure is also employed to make the Device small and high performance. Unlike any conventional isolators the ferrite plate is placed vertically in the Buffer Device.

The Buffer Device consists of a 0.5 or 0.6 square millimeter ferrite plate, two 0.05millimeter diameter wire conductors, and two capacitors on each input and output ports to realize smaller insertion loss.

This buffer device can be designed in a size of $3.2\times2.5\times1.7$ mm^3 with a few-80MHz bandwidth at a center frequency of 760 to 2520MHz

The simple structure of a gyrator comprising a ferrite plate and two wire conductors make the isolator very small. We call this isolator as "Buffer Device", since conventional buffer amplifier can be replaced by the developed isolator.

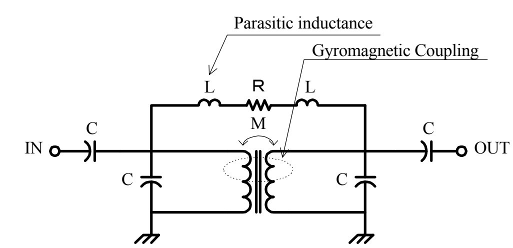

Figure 1

Equivalent circuit of the Buffer Device

II. CONSTRUCTION OF A BUFFER DEVICE

Figure 1 shows an equivalent circuit of the buffer device. Two resonators are formed with a pair of parallel LC elements. Each capacitor for matching is connected between LC resonator and input/output port. The ferrite plate, wound with two wires, acts as a non-reciprocal

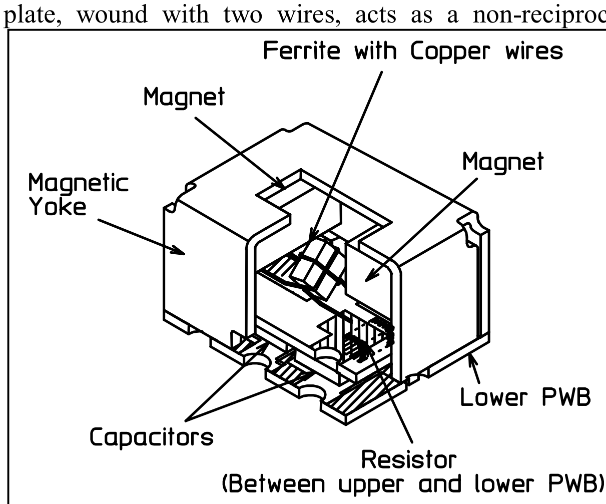

Figure 2 Construction of the Buffer Device

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coupling transformer, and functions as a gyrator for gyrative coupling. A phase difference between scattering parameter S12 and S21 of this gyrator is 180 degrees. So, an isolator characteristic is obtained by connecting two resonators with a resistor.

Figure 2 shows the construction of a buffer device operating at 2.52GHz. The buffer device consists of a 0.5mm square ferrite plate, two 0.05 diameter Cu wire conductors around it, two capacitors for two parallel LC resonators, and two capacitors for matching circuits. These four capacitors are located between upper printed wired board (PWB) and a lower PWB. Input, output, and ground terminations are formed on the lower PWB. The saturation magnetization Ms of the ferrite is approximately 80 milli-Tesla chosen for proper operation at 2.52GHz. A ground plate is also located between two PWBs to connect the ground of two PWBs. Two wires shall ideally cross at 90 degree each other on the ferrite, which is placed vertically on the top of the upper PWB. The hot ends and cold ends of the two wires are connected to electrodes on the upper PWB, and the hot ends are also connected to parallel and series capacitors and a resistor via electrodes on the upper PWB.

The static magnetic field is applied perpendicularly to the ferrite plate by a pair of magnets on both sides of the ferrite to operate at a required frequency. To apply a uniform magnetic field to the ferrite plate, a square opening is prepared on the magnetic yoke above the ferrite plate.

III. MAGNETIC YOKE DESIGN

In order to lower the height of the buffer device, it is necessary to reduce the height of the cover case or magnetic yoke. A problem would arise, if a magnet is too close to flux return route of the magnetic yoke. A part of the magnetic flux goes into the return route of magnetic yoke, and the uniformity of the magnetic field applied to the ferrite is disturbed and the magnetic field strength is reduced. The result is that the insertion loss goes larger. To solve these problems, a hole is made on the top of the magnetic yoke just above the ferrite plate.

Figure 3(a) shows the magnetic field strength at the center of the ferrite plate thickness in the case of the magnetic yoke without the hole. It shows that the magnetic field strength at the top corner of ferrite plate is stronger than other three corners.

In the case of the yoke with the hole on the top of it, the magnetic field strength on all the corners of the ferrite plate is almost same as shown in Fig. 3(b).

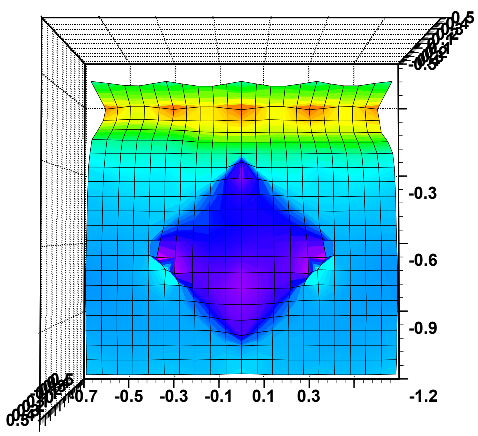

Figure 3(a) Magnetic field strength when yoke has no hole

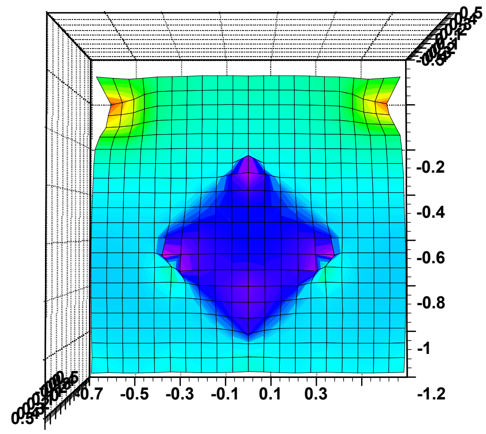

Figure 3(b) Magnetic field strength when yoke has a hole

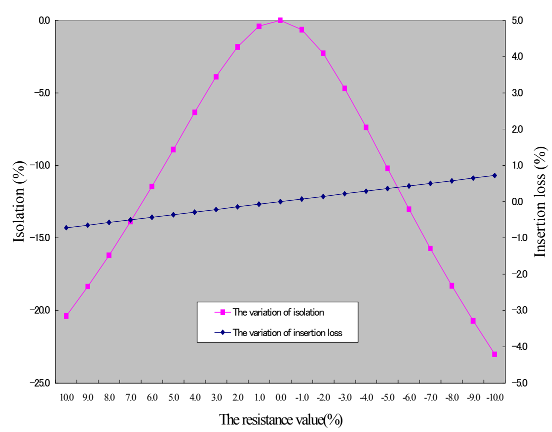

Figure 4 Isolation and insertion loss dependent on the resistance value

IV. ELECTRICAL DESIGN OF 2520 MHZ BUFFER DEVICE

According to our study, the isolation and insertion loss of a Buffer Device depend on a resistance value of the resistor connecting input and output of a gyrator. Figure 4 shows the relations calculated by a microwave simulator. The zero percent on the X-axis means that the resistance is equal to the input impedance of the gyrator. This optimum value of the resistance is 510 ohms according to our experiment for a 2.52GHz Buffer Device.

The angle formed by two wire conductors crossing each other shall be 90 degrees substantially. But the optimum-crossing angle obtained from an experiment is 76 degrees as shown in Figs.5 and 6 for a 2.52GHz Buffer Device. As shown in Figure 1 some parasitic inductance exists around the resistor and it affects on the electrical phase of gyrator. In order to compensate this inductance influence, the crossing angle has to be reduced to 76 degrees instead of 90 degrees.

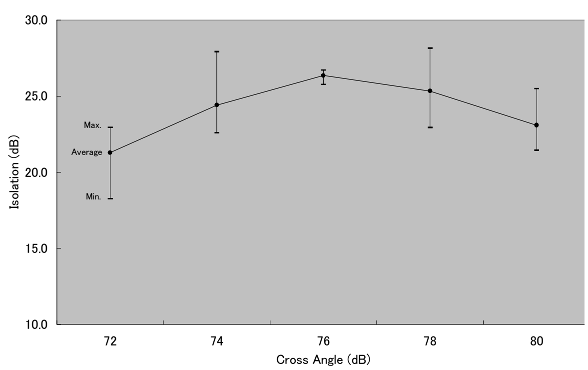

Figure 5 Isolation dependence of crossing angle of two wires

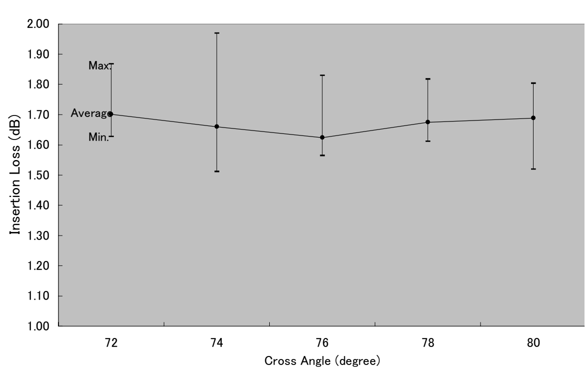

Figure 6 Insertion loss independence of crossing angle of two wires

In the case of a 760MHz Buffer Device designed in the same method above, the optimum resistance value is 430 ohms. The optimum cross-angle of two wire conductors is 83 degrees for it.

V. EXPERIMENTAL RESULTS

A "Buffer Devices" with broadband isolation using a gyrator comprising a ferrite plate wound with two wire conductors are discussed. A Buffer Device has been designed which has a 2.52GHz center frequency and a 60MHz pass-bandwidth. As a result, the minimum insertion loss is 1.5 dB at 2.52GHz, the isolation is over 25 dB and the size is $3.2 \times 2.5 \times 1.7\ mm^3$.

Another Buffer Device has been designed which has a 760MHz center frequency and a 2 MHz pass bandwidth. As a result, the minimum insertion loss is 1.8 dB at 760MHz, the isolation is over 25dB and the size is $3.2 \times 2.5 \times 1.7\ mm^3$.

The insertion loss and isolation of the 2.52GHz Buffer Device is shown in Figure 7.

The insertion loss and isolation of the 760 MHz Buffer Device are shown in Fig. 8.

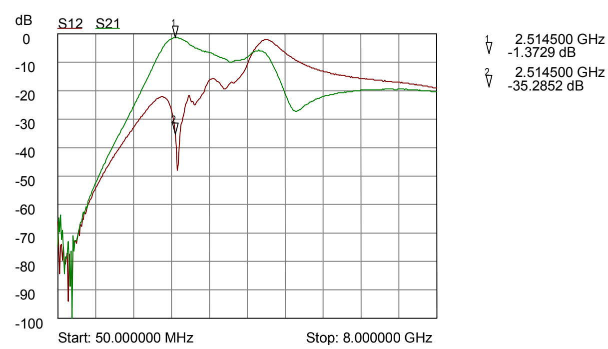

Figure 7 Insertion loss and isolation of the 2520 MHz Buffer DEVICE

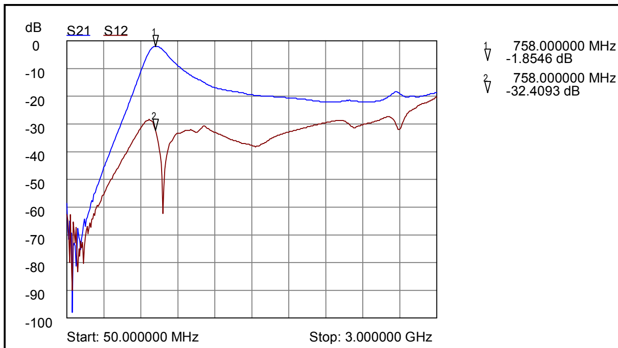

Figure 8 Insertion loss and isolation of the 760 MHz BUFFER DEVICE

The 2nd and 3rd harmonic spurious responses will be suppressed and the isolation is 20 dB over the frequency range of DC to 3.0GHz. Figure 9 shows a photograph of Buffer Device.

Finally, the Buffer Device is realized in the same structure for 760MHz and 2520MHz. These Buffer Devices are build in the small size as 3.2×2.5×1.7 mm^3.

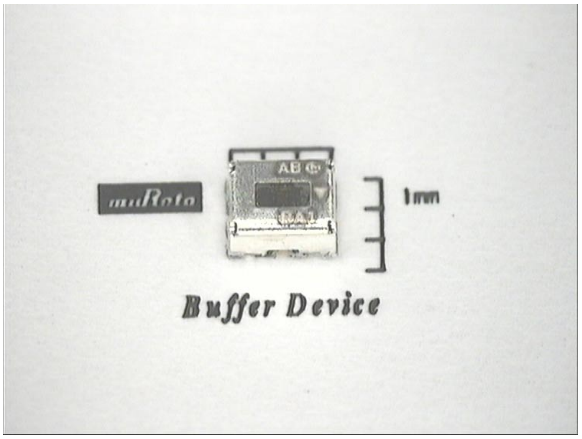

Figure 9 Photograph of BUFFER DEVICE

VI. CONCLUSION

An ultra miniaturized Buffer Device using gyrator comprising a ferrite plate wound with two wire conductors is developed. A 2.52GHz Buffer Device provides a 1.5 dB insertion loss and an isolation of over 25 dB at pass band. A 760MHz Buffer Device provides a 1.8 dB insertion loss, and an isolation of over 25dB. The 2.52GHz Buffer Device is the same size as the latter one and it is 3.2×2.5×1.7 mm^3. These are applicable for CDMA, TDMA, and W-CDMA and capable of replacing power consuming buffer amplifiers.

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[2] Douglas K. Linkhart, " MICROWAVE CIRCULATOR DESIGN," ARTECH HOUSE, INC., 1989.
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[4] United States Patent 4,210,886