

Application of bonded NdFeB magnet for C-Band circulator component

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Abstract. In this paper bonded NdFeB permanent magnets of the crashed-ribbon type were made as an alternative for circulator magnet to improve their magnetic performance. The fabrication process is also easier than the sintered NdFeB because there had no shrinkage of product (such as sintered barium ferrite magnet), with the others advantages as follows; large freeness of product shapes, high precision of dimension and good corrosion resistance. The dimension of the samples was measured to calculate its bulk densities and the magnetic properties were characterized by Permagraph to obtain values such as; Remanence induction (Br) in kG, Coercivity value (H_{cj}) in kOe, the Maximum energy product (BH max) in MGOe. Whereas the surface magnetic field strength (B) was observed by the Gauss-meter. The bonded NdFeB permanent magnets revealed 6.39 kG of Br, 6.974 kOe of H_{cj} and 7.13 MGOe of BH_{max}. The circulator performance was measured using Vector Network Analyzer (VNA). The optimum values of the circulator measurement at a frequency of 5 GHz show a VSWR value of 1.062 and insertion loss of -0.463 dB. The bonded magnet could be used as component of permanent magnets on the circulator that working on C-Band at a frequency range of 4 GHz - 8 GHz.

1. Introduction

A circulator was a passive component which was used for RF communication and microwave system to enhance their stability, performance, and reliability. The demand of permanent magnets for telecommunication devices was high enough [1], one of which was a component for the circulator. The circulator commercial in this research had been working in C band which was produced by *A in Flow* and composed of body, strip line, ferrite disc, and permanent magnets. This research was conducted to replace the permanent magnets on the circulator with the commercial bonded permanent magnets as an alternative component in the circulator. Magnets had become important parts of our daily life and many applications could be applied on devices such as; electrical motor, loud speaker, microwave, telecommunication, and etc. Other applications of magnets were founded many in tools of instrumentations, production and lab research [2]. However the contribution of magnets often overlooked by us due to this component had been mounted in a device and invisible. In fact, these components needed to be very diverse depending on the usability and functionality of the device. In general, demand for magnetic components was distinguished by the shape, dimensions, and magnetic field strength. The NdFeB was known as a rare earth magnet because its compound composed of rare earth elements, which had maximum energy product was higher than ferrite [3]. Fabrication of bonded NdFeB magnets from crashed-ribbon type expected could enhance the performance of permanent



magnets in a circulator. Because bonded permanent magnet had the advantage that no shrinkage losses due to sintering effect, such as barium hexaferrite so that it will yield the precise product with the desired dimension.

2. Numerical Methods

In a point of view in making bonded magnets is known two methods of compaction, such hot press [4] and green compact [5]. In this work, we used a green compact technique and magnetic materials have mixed with polymer binder as commercially obtained. The NdFeB magnetic powder was compacted in certain pressure to get an optimum bulk density. When bonded NdFeB permanent magnet have been fabricated, furthermore it applied into a circulator and characterized by Vector Network Analyzer (VNA, Advantest R3770) to know circulator performance.

The fabrication of bonded NdFeB permanent magnets were made using MQEP 16-7 powder. This magnet powder obtained from Magnet quench and have mixed by epoxy resin so that other binders should not be added. The first step is weighing of MQEP 16-7 powder around 10.5 gram for one sample and we prepared ten samples for this experiment. The circulator has a pair of permanent magnets so that 10 samples used for five times to measure the circulator performance. The pressure of compaction was given about 100 kg/cm^2 to sample powder in the mold. Furthermore, the green body was heated to a temperature at 200°C and held until 60 minutes. This heat treatment was given to the sample to ensure all of the bonding between polymer and MQEP 16-7 magnet powder become optimum. The dimension of samples is measured by Calipers and magnetized using the Impulse magnetizer (Magnet-Physik) with various input voltages to charge the difference of magnetic field strength into samples. Further, the surface magnetic field strength of magnetized samples were measured by Gauss-meter (Yokogawa) as presented in table 1.

Table 1 Various magnetic field strength of samples were resulted from the Impulse Magnetizer (Magnet-Physik)

Voltage (Volt)	Magnetic Field Strength (Gauss)
700	500
800	1000
1700	1600
2000	1800
2500	2000

The intrinsic properties of bonded NdFeB permanent magnets were characterized by Permagraph (Magnet-Physik) with given maximum magnetic energy to rise a saturation magnetization and obtained magnetic properties for that bonded magnets such as Remanence inductance (B_r) in Gauss, Coercivity (H_{cj}) in Oersted and Maximum magnetic energy product (BH_{max}) in MGOe.

3. Results and Discussion

Figure 1 shows a hysteresis curve of a bonded permanent NdFeB magnet which exhibited a saturation magnetization (Ms) at $\sim 15 \text{ kG}$. The B_r value of a bonded NdFeB is about 6.26 kG , This result states

that after magnetization of the sample until saturated magnetization and followed by demagnetization to zero of magnetic field strength (H), however, the magnet still has a remain inductance at 6.26 kG. This value is an intrinsic property which shows the capability of bonded magnet to hold the given energy from outside. In this work, the remanence inductance of bonded NdFeB permanent magnet is higher than the bonded magnet from previously reported by J.S. Trosic *et. all* [6]. For applications in telecommunication fields, we used a magnetic energy on the surface of samples, which is called as a flux magnetic density (B). We made samples of bonded NdFeB permanent magnet with several of flux magnetic densities, which were measured by Gauss-meter as follows; 500, 1000, 1600, 1800 and 2000 G. Another measured intrinsic property is Coercivity, which the bonded NdFeB yields a coercivity at 6.974 kOe. This value shows the demagnetization energy level to erase the magnetic field strength from the bonded magnet is 6.974 kOe and Its maximum energy product is 7.13 MGOe, this means that the bonded magnet can store the maximum magnetic energy until 7.13 MGOe after the external magnetic field removed. In this research, all sample have similar treatment so that they have the same intrinsic properties. They have similar hysteresis loop.

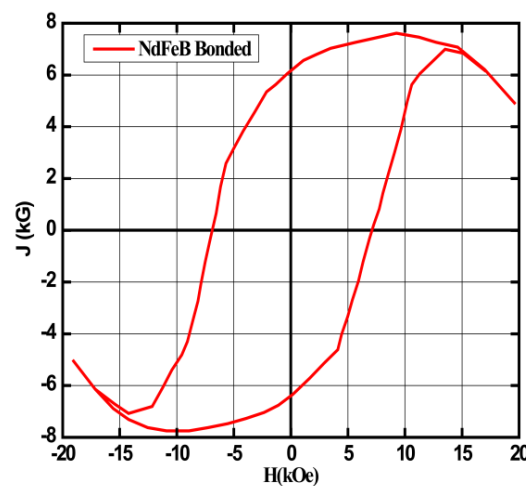


Figure 1 The hysteresis loop of a bonded NdFeB permanent magnet.

After the pair of bonded magnet installed in the circulator, the performance of circulator was measured by VNA. The input signal was given an electrical current at 1 mA on Port 1, the output signal was measured on port 2, and Port 3 was terminated by a terminator of 50 Ohm, in the frequency range 4 to 8 GHz. Figure 2 shows a VSWR curve of bonded NdFeB permanent magnet. VSWR is a signal that reflected back to transmission channel [7], which this value present a performance level of transmission channel system or circulator components. The allowed value of VSWR on the circulator is equal or less than 2[8]. In characterization of circulator for bonded NdFeB permanent magnets have been installed in a circulator, the VSWR value was obtained around 1.062, this for bonded magnet of surface flux magnetic 1800 G. While for bonded permanent magnets of 500, 1000 and 2000 G cannot be applied to the circulator in work frequency range 4 to 5 GHz due to its VSWR is higher than 2. Figure 3 shows the insertion losses of a circulator after installed of our bonded NdFeB permanent magnets in the circulator. Insertion loss is the value of power losses during transmitted signals [9].

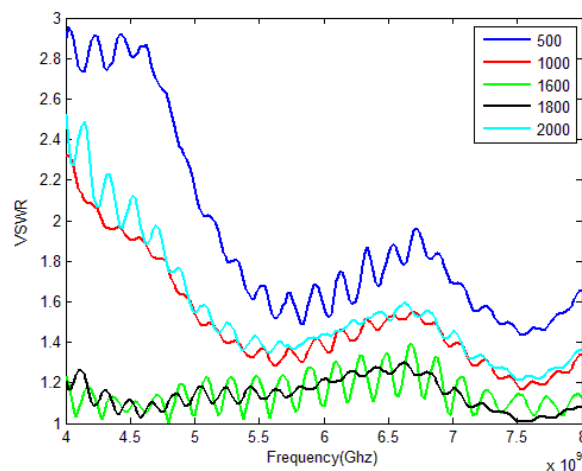


Figure 2 Frequency dependent of VSWR curves for bonded NdFeB permanent magnets.

For Bonded NdFeB permanent magnets with surface field strength levels; 500, 1000 and 2000 G, the circulator shows low performance due to their high power losses. While for bonded permanent magnets with the surface magnetic field strength either 1600 or 1800 G give good insertion losses and their optimum insertion loss is -0.463 dB.

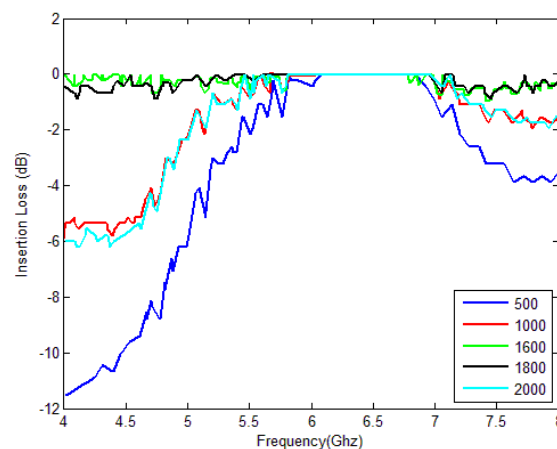


Figure 3 The Insertion loss values (dB) of several of magnetic flux densities versus frequency (GHz) for bonded NdFeB permanent magnets.

Isolation (dB) is the level of reflection power that can be muted by circulator components. Figure 4 show the isolation values of a circulator after installed of bonded NdFeB permanent magnet. The bonded permanent magnets with different of magnetic field strengths exhibit different frequency response. For 500 G of field strength, the circulator has the lowest isolation level; less than 5 dB at frequency ~ 6.3 GHz. While for 1000 G of bonded magnet shows the highest isolation level at 27 dB and the lowest isolation level at 6.5 dB. Whereas the 1800 G of bonded magnet yields optimum isolation with a more linear curve, which the highest and the lowest isolation levels are 18 dB and 10 dB, respectively.

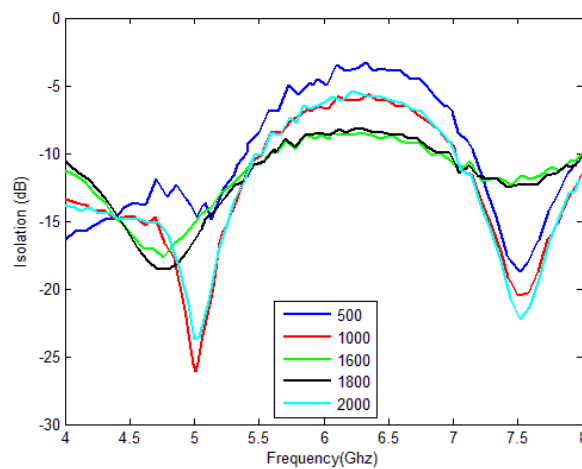


Figure 4 The Isolation curves of bonded NdFeB permanent magnets from a circulator

Figure 4 shows that the bonded magnet with 1800 G has a frequency response that is better to insulation compared with 1600 G of bonded magnets because it can do a reduction to greater isolation. In conclusion, from the characterization results of bonded NdFeB permanent magnets for intrinsic properties, surface magnetic field strength, and circulator performance, such as; VSWR, Insertion loss, and Isolation, which the bonded magnet of 1800 G can be applied as an alternative permanent magnet for A in flow circulator component with work frequency ranging from 4 – 8 GHz in C-Band.

4. References

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