A REFLECTION TYPE OF MSW SIGNAL-TO-NOISE ENHANCER IN THE 400-MHz BAND

Takao Kuki and Toshihiro Nomoto

NHK Science and Technical Research Laboratories
1-10-11 Kinuta, Setagaya-ku, Tokyo 157 Japan

ABSTRACT

We have developed a reflection type of signal-to-noise enhancer operating in the 400-MHz, which can easily be inserted into the second IF stage used in current DBS receivers. The new enhancer consists of a microstrip line using a ceramic substrate with a high dielectric constant and a LaGa-YIG film with low saturation magnetization. Enhancement of 8 dB was achieved in the 40-MHz bandwidth. We evaluated the effect of the new enhancer on noise reduction in DBS reception and found that the signal-to-noise enhancer achieved 2 to 3-dB noise reduction.

1. INTRODUCTION

An MSW signal-to-noise enhancer is a kind of level filter that exhibits low loss for large signals (desired signals) and high loss for small signals (noise and/or undesired signals), but has frequency selectivity. One of the enhancers previously reported is constructed by putting a magnetically biased YIG film on a microstrip line (transmission line type) [1], and another consists of two MSSW filters, two directional couplers, a 180° phase shifter and an attenuator (cancellation type) [2]. The transmission line type enhancer has a simple structure and a wide operating frequency range, but requires fairly high-power input and a long coupling length to obtain sufficient enhancement [1]. The cancellation type has good input-to-output characteristics and operates at low-power input, but has an inherently large insertion loss [2]. From such backgrounds, a signal-to-noise enhancer with not only a simple structure but also good input-output characteristics and a low insertion loss has been desired.

On the other hand, the typical DBS receiver uses the 1 to 1.3-GHz band (first IF) before channel selection, and the 400-MHz band (second IF) after channel selection [2]. We demonstrated the effectiveness of a cancellation-type signal-to-noise enhancer operating on the first IF stage to noise reduction in DBS reception [2]. However, when the enhancer is in the first IF stage, the same number of enhancers as DBS channels are needed to prevent signal impairment by intermodulation distortion genetated in the enhancer. The signal-to-noise enhancer is suited for installation in the second IF stage, but frequency conversion circuits are needed to build the enhancer in the DBS receiver because the operating frequency range of conventional enhancer have been more than 1-GHz [1-3]. Therefore a signal-to-noise enhancer that operates directly in the 400-MHz band without frequency conversion is required to be built into the receiver in the simplest way possible.

This paper proposes a new reflection type of signal-to-noise enhancer that operates in the 400-MHz band. The effect on noise reduction is evaluated for HDTV in DBS reception.

2. SIGNAL-TO-NOISE ENHANCER DESIGN

2.1 Reflection type of signal-to-noise enhancer

Figure 1 shows the structure of the reflection-type signal-to-noise enhancer. The enhancer is formed with the same type of transducer as applied to typical MSSW filters. In paticular, the transducer has been designed for good impedance matching between an electromagnetic wave and an MSW below the threshold level, because enhancement characteristics depend on impedance matching. An end of the transducer is connected to a circulator or a directional coupler, enabling separation of input and output signals. When a small RF signal is applied to the input port, the signal launches MSWs in the YIG film and almost no RF signal is reflected back to the output port. This results in high loss for small signals. On the other hand, when a large RF signal is applied, the signal launches MSWs up to the threshold level, but most of the signal is not converted to MSWs and is reflected back to the output port. This results in low loss for large signals. Therefore, we can obtain large reflection for large RF signal input and small reflection for small RF signal input. That is, the signal-to-noise ratio is enhanced for the reflected signal. Better impedance matching is required to achieve significant enhancement.

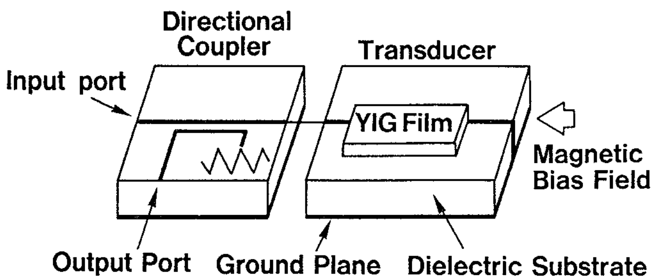

Fig. 1 Structure of the refrection type of signal-to-noise enhancer.

2.2 Operation in the 400-MHz band

The operation frequency range, f, of MSSW is given by

$$\gamma \cdot [H \cdot (H+4\pi M_S)]^{1/2} < f < \gamma \cdot (H+2\pi M_S) \quad (1)$$

where H is the internal magnetic field, $4\pi M_S$ is the saturation magnetization of a YIG film and γ is the gyromagnetic ratio. The operating frequency depends on the saturation magnetization and the magnetic bias field as shown by Eq. (1). The operating frequency can be lowered by reducing the bias field and/or the saturation magnetization. It is well known that MSWs hardly propagate in YIG films under the extreme magnetically non-saturated condition. Therefore, the saturation magnetization of ferrimagnetic materials must be reduced. A La Ga substituted (LaGa-) YIG film with low saturation magnetization is suitable for UHF application [4].

In addition, the wavelength of a 400-MHz electromagnetic wave is too long to efficiently couple to MSWs. Use of a ceramic substrate with a high dielectric constant is recommended to shorten the RF wavelength at the transducer.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Enhancer characteristics

A 60-μm thick LaGa-YIG film with saturation magnetization of 360 G was selected for the 400-MHz band application. The ceramic substrate with a relative dielectric constant of 40 was also used, resulting in a wavelength of 15 cm (1/5 in free space) at the transducer. The size of the LaGa-YIG film was 5 mm wide by 10 mm long (transverse and parallel to the magnetic bias field direction, respectively). The magnetic bias field is applied by using a solenoid coil, because the field strength required is only tens of oersteds. A 3-dB hybrid coupler was used to separate the input and output RF signals here.

Figure 2 shows the transmission characteristics of the signal-to-noise enhancer measured at various input levels. The enhancement obtained was 8 dB in the 40-MHz bandwidth. The usable bandwidth is much narrower than that of the signal-to-noise enhancer operating in microwave frequency range, because a LaGa-YIG film with low saturation magnetization is used. Although extention of the bandwidth is desired, the 40-MHz bandwidth covers that of a DBS channel (27 MHz).

Figure 3 shows the temperature dependence of the transmission characteristics. Figure 3 (a) is a characteristic with -30 dBm input power and I_0 solenoid coil current at 40 ℃. When the temperature rises to 60 ℃, the usable frequency range of the signal-to-noise enhancer shifts lower as shown in Fig. 3 (b). This is because the saturation magnetization decreases corresponding to temperature increase, as introduced by Eq. (1). However, we can easily compensate for temperature drift by adjusting the solenoid coil current, and the result is shown in Fig. 3 (c).

Figure 4 shows the input-to-output relationship of the signal-to-noise enhancer at 400-MHz. A small notch in the enhancement is observed near the input level of -25 dBm. This is probably because better impedance matching at the transducer is achieved at the beginning of spin wave oscillation. The threshold level P_L and the limiting action level P_H (defined in Ref. 2) are -25 dBm and -13 dBm, respectively. The absolute values of P_L and P_H are the lowest for the three types of signal-to-noise enhancers, but the slope from P_L to P_H of the reflection-type signal-to-noise enhancer is between the slopes of the transmission and cancellation type enhancers [1,2]. The simplest way to achieve further enhancement is to enlarge the film length. However, the optimal transducer design must be made for extension of not only the usable bandwidth but also the enhancement.

3.2 Application to DBS reception

The reflection-type signal-to-noise enhancer was inserted into the second IF stage, just before the FM demodulator, in the DBS receiver. To evaluate the effect of the signal-to-noise enhancer, we measured the relationship between the received carrier-to-noise ratio

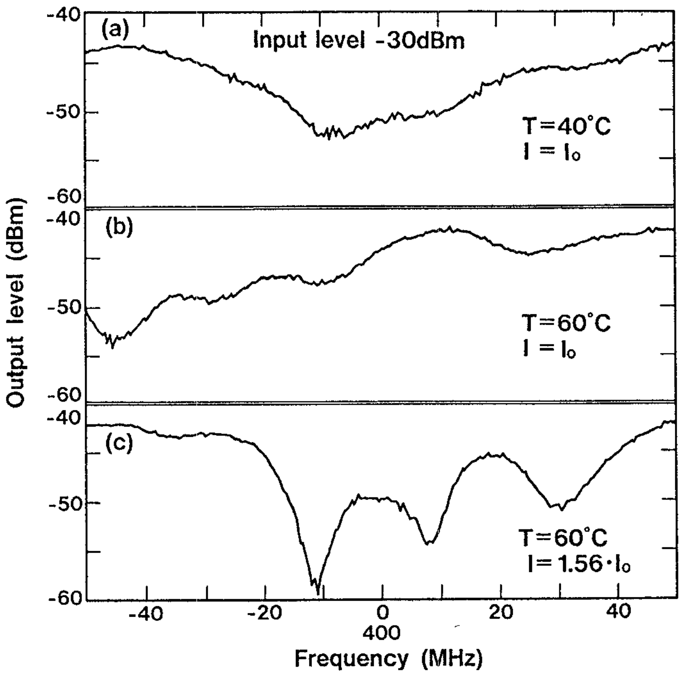

Fig. 3 Temperature dependence of the signal-to-noise enhancer.

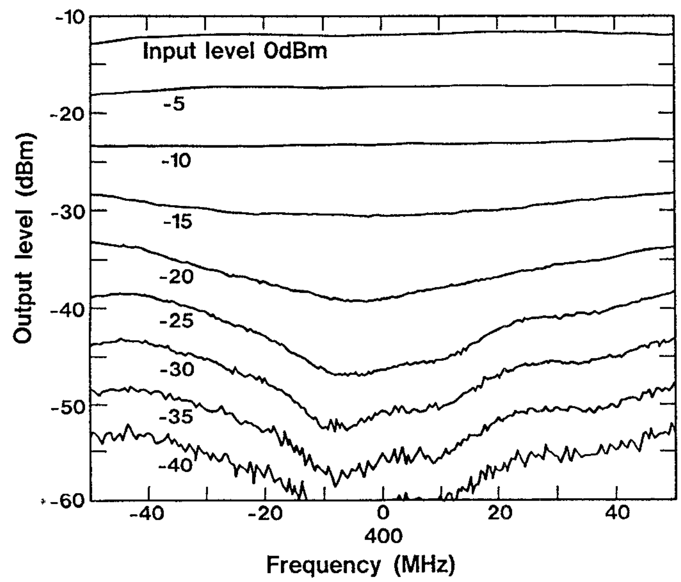

Fig. 2 Transmission characteristics of the signal-to-noise enhancer.

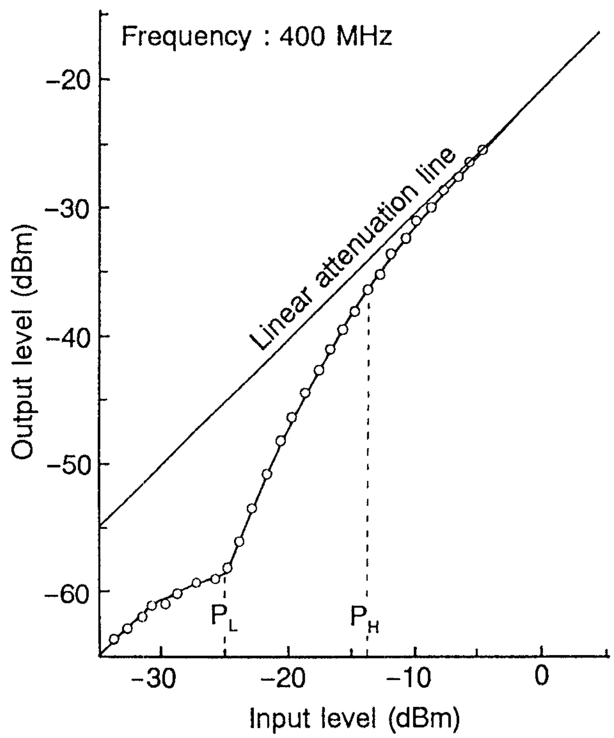

Fig. 4 Input-to-output relationship of the signal-to-noise enhancer.

(C/N) and the signal-to-noise ratio (S/N) of the Y-signal decoded from a MUSE signal. The MUSE system is a satellite based HDTV transmission system, whose baseband-signal bandwidth is 8.1 MHz and whose frequency-modulated RF-signal bandwidth is 27 MHz. The results are shown in Fig. 5. Below a C/N of 10 dB, the S/N is improved by more than 2.5 dB. At a C/N of 15 dB, the S/N is improved by 2 dB. These characteristics are almost the same as those with the cancellation-type signal-to-noise enhancer [1]. Also, we measured the relationship between the received C/N and the video S/N for a standard TV system. An S/N improvement of 2-8 dB was obtained below a C/N of 9 dB.

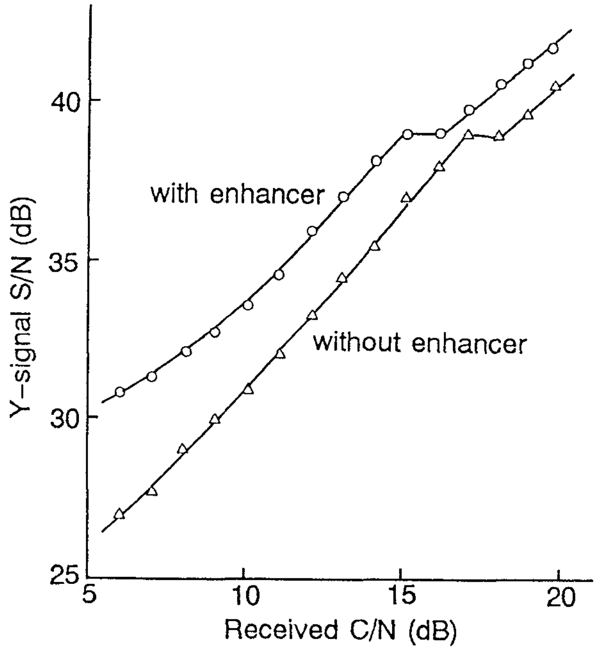

Fig. 5 Relationship between the received C/N and the Y-signal S/N.

4. CONCLUSION

We have developed a reflection type of signal-to-noise enhancer operating in the 400-MHz band, which can easily be inserted into the second IF stage used in current DBS receivers. The new enhancer consists of a microstrip line using a ceramic substrate with a high dielectric constant and a LaGa-YIG film with low saturation magnetization. Enhancement of 8 dB was achieved in the 40-MHz bandwidth. We evaluated the effect of the new enhancer on noise reduction in DBS reception and found that the signal-to-noise enhancer achieved 2 to 3-dB noise reduction. DBS receivers with such signal-to-noise enhancers built-in will be available in the very near future.

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