# Microwave Ferrite Technology in Japan: Current Status and Future Expectations

Yoshikazu Murakami

Sony Corporation
174 Fujitsuka-cho, Hodogaya-ku, Yokohama, 240 Japan

## ABSTRACT

An overview of the current status of Japanese microwave ferrite technology is presented. Some recent progress and topics in microwave isolators and circulators are discussed. Special emphasis is placed on recent developments in state of the art YIG thin film devices. Possible future applications of the technology in consumer electronics are projected in conclusion.

## INTRODUCTION

High frequency devices have always been the key to opening new applications of microwave technology in both industrial and consumer electronics. There, microwave ferrite devices have played the key role in the implementaion of high performance microwave equipment.

Japanese microwave ferrite technology has contibuted to the field in both the development of new circuit elements [1] and new materials such as spinel ferrites and garnets [2].

This paper will discuss some recent developments in microwave isolators and circulators. Then, new ideas and demonstrations of state of the art YIG thin film devices will be reviewed. The paper will conclude with projections of some future volume applications of these devices in consumer electronics.

## 1. ISOLATORS AND CIRCULATORS

Although microwave nonreciprocal elements using the gyromagnetic effect in ferrite such as isolators and circulators have long traditions and their technolgy has reached a sufficient level of maturity [1], there are continued efforts in the research of studying new structures and theory for precision design. Some of these examples are the stripline Y junction circulator with three YIG discs tightly coupled resonators [3] and the edge-guided mode isolator using a YIG single crystal disk [4].

On the other hand, from the more industrial point of view, the applications of these microwave components have recently been rapidly expanded from high-end telecommunication, broadcasting or instrumentation applications to consumer electronics. This was made possible by the continued efforts of technology evolution to meet the severe requirements of compact size, light weight, low cost and mass-producibility for consumer applications. This is clearly observed in the example of the developments of the isolator used for mobile communication systems. Figure 1 shows the history of reduction in size of the isolators from 1984 to 1991 [2]. The most recent isolator used in hand-held cellular telephone is a miniature surface mount device (SMD) type as shown in Fig.2 [5]. Its dimensions are 6.8 x 6.9 x 4 $mm^3$ and weight is 0.75 grams.

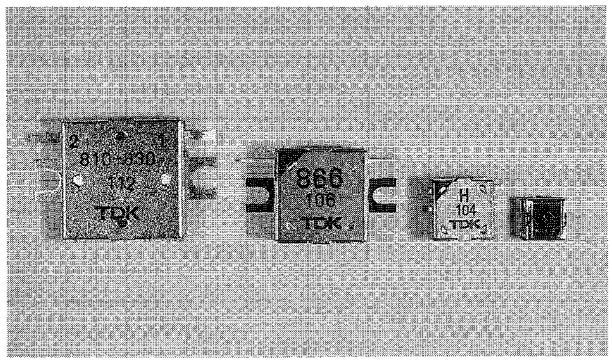



Fig. 1 Photograph showing the history of reduction in size of the isolators used for mobile communication, courtesy TDK Co.

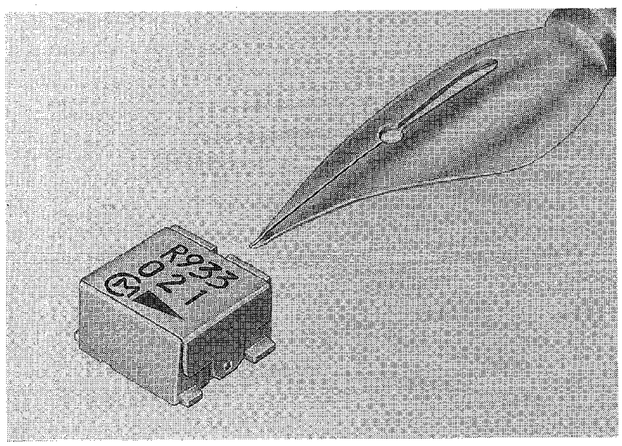



Fig. 2 Photograph of 800 MHz band miniature isolator, courtesy Murata Manufacturing Co.

## 2. YIG THIN FILM DEVICES

Among the recent activities in microwave ferrite technology in Japan, research and development in state of the art YIG devices using single crystal films grown by liquid phase epitaxy (LPE) are the most important. Work on these ranges from basic theory to the challenge of developing new functions or innovation aimed at practical applications.

### 2-1 Filters

Since the 1970's, magnetostatic wave (MSW) resonators have been widely studied for use in microwave filters and oscillators. However, MSW filters have usually shown high insertion loss, which limited the extent of their application. In 1985, the author and a colleague developed a 1.575 GHz bandpass filter with small insertion loss using a uniform precession mode in a YIG thin film disk resonator [6]. A cylindrical groove was formed on the surface of YIG disk which effectively surpressed the spurious modes. The same technique, combined with a new filter structure which expanded its tuning bandwidth, was applied to realize a 0.5-4.0 GHz tunable bandpass filter [7]. Figure 3 shows a photograph of the commercialized YIG tuned filter (YTF). It is used in such applications as the tracking filter in spectrum analyzers.

A new type of magnetostatic wave resonator using a YIG film with a circular metal strip was proposed, and its characteristics were analyzed theoretically [8]. It has been proven that magnetostatic wave energy is effectively stored within a circular strip. MSW resonators of this type and parallel strip transducers were adopted for realization of a S-band low loss tunable filter [9]. This technique was further developed as MSW YIG resonators with multi metal rings, which was successfully applied to realize a miniturized low-spurious 1.9 GHz bandpass filter [10]. Figure 4 shows the construction of the MSW filter, and Fig.5 shows its appearance.

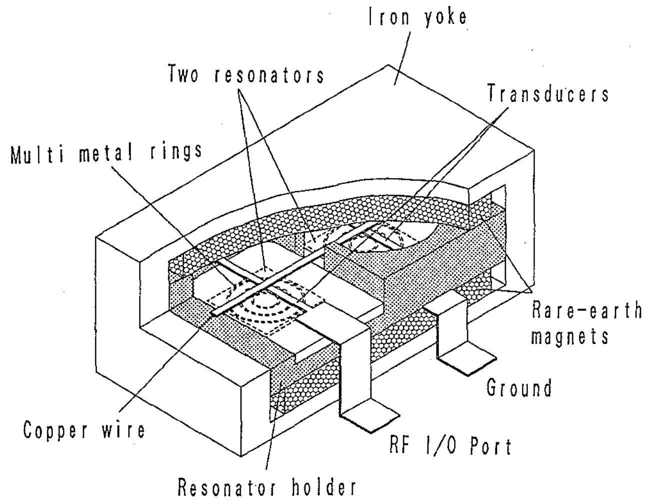



Fig. 4 Construction of the MSW filter, courtesy Murata Manufacturing Co.

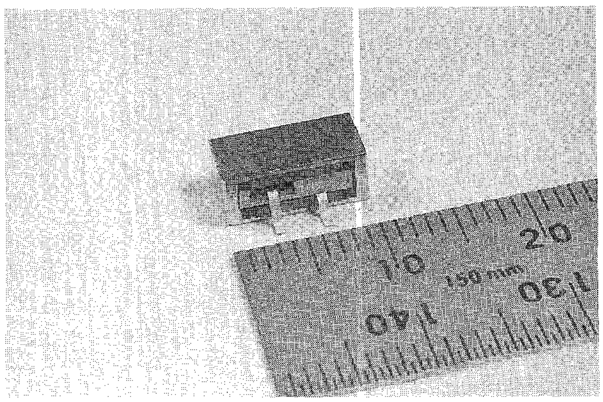


Fig. 5 Appearance of the MSW filter, courtesy Murata Manufacuring Co.

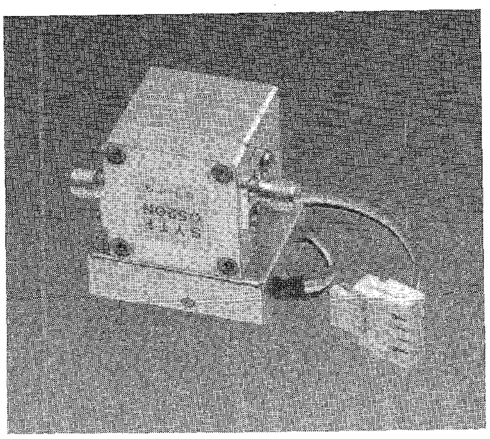


Fig. 3 Photograph of commercialized YIG tuned filter

### 2-2 Oscillators

In 1988, a low phase noise 13 GHz tunable oscillator for VSAT application was developed by the author and colleagues using uniform precession mode in a YIG disk, which was the same technology used in YIG filters [11,12]. The dc magnetic field required to resonate YIG disk at 13 GHz was supplied by a permanent magnet. A gallium doped YIG thin film was specially designed so that the temperature dependency of the YIG resonator's frequency compensated the temperature dependency of the permanent magnet. The oscillator was stabilized within 10 MHz of variation in the temperature range of -30 to +60℃. A tuning magnetic field required to cover the system's bandwidth of 500 MHz was supplied by the coil current. An oscillator with excellent low phase noise and small power consumption is ideal for use as a frequency agile synthesized local oscillator for communication applications. Figure 6 shows a photograph of the commercialized YIG tuned oscillator (YTO). It is now used in such applications as VSATs or terrestrial microwave links.

A 5-20 GHz broadband tunable oscillator using two MSW resonators was developed [13]. The optimum difference of the resonance frequency between the two resonators to achieve a broad tuning range was evaluated in order to determine the dimension of each resonator.

A 2-5 GHz MSW delayline oscillator was developed [14]. The saturation effect of the MSW resonator on the degradation of SSB phase noise was carefully evaluated, and an excellent small phase noise of -111 dBc/Hz at 10 kHz offset frequency was achieved.

### 2-3 MSW S/N Enhancer

Besides the traditional applications for filters and oscillators, the challenge of exploiting YIG thin film for new applications is ongoing. One of these trials is the MSW S/N enhancer [15,16]. Figure 7 shows the configuration of an S/N enhancer using two magnetostatic surface wave (MSSW) filters [15]. The demonstration of excellent S/N enhancement capability is shown in Fig. 8, in the case of satellite broadcasting reception.

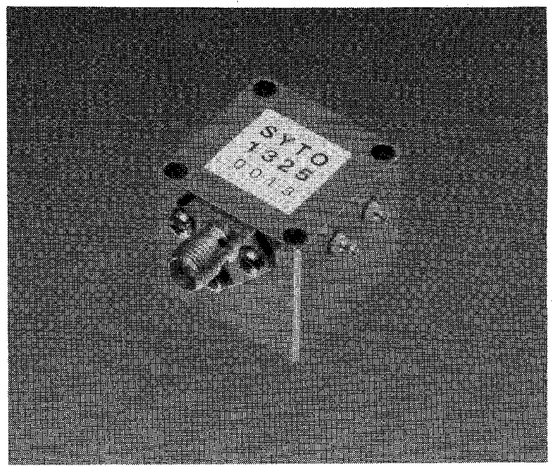



Fig. 6 Photograph of commercialized YIG tune oscillator

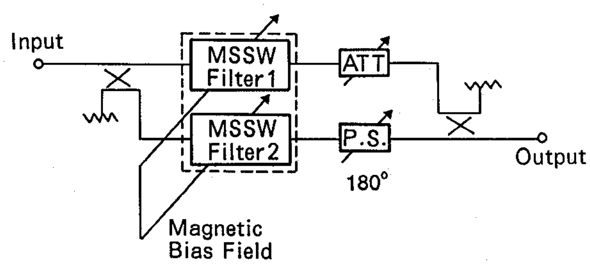
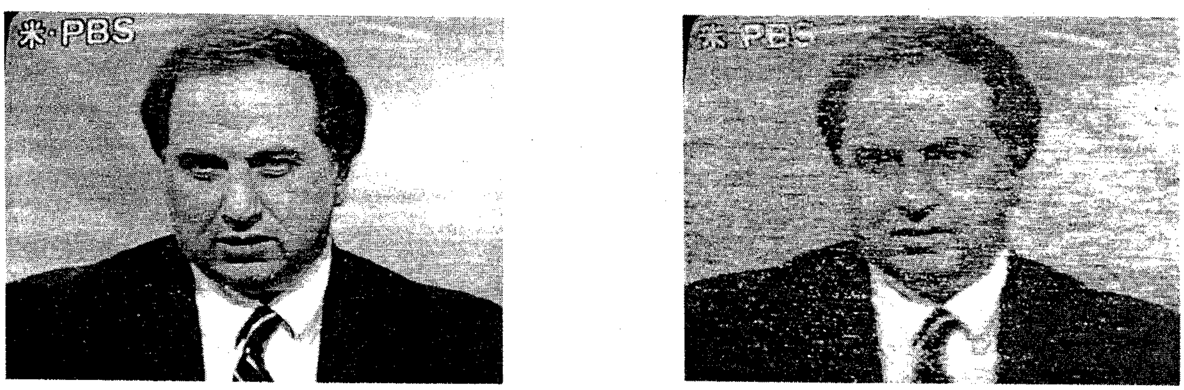



Fig. 7 Configuration of an MSSW S/N enhancer, courtesy NHK Science and Technical Research Laboratories




(a) with S/N enhancer

(b) without S/N enhancer

Fig. 8 Comparison of video signal (C/N=3dB) from broadcasting satellite with and without S/N enhancer, courtesy NHK Science and Technical Laboratories

## 3. FUTURE EXPECTATIONS

Although YIG thin film devices are finding many practical industrial applications, the volume of production is still far behind that of the consumer electronics which is the order of millions of devices per month [17]. From the author's viewpoint, the applications for personal telecommunication terminals using sub-microwave frequencies between 1 to 3 GHz and the up-conversion TV tuners which receive all the signals of VHF, UHF, CATV, IF of BS and CS might be the most promising for entry into consumer electronics.

A combination of YTF and YTO which are capable of covering a frequency range from a couple of hundred MHz to a few GHz could bring the solution for these systems [7]. An evolution of low-cost, light-weight, compact magnetic circuits is the key for use of these devices in consumer electronics.

## ACKNOWLEDGEMENTS

The author would like to thank Dr. T. Nishikawa of Murata Manufacturing Co., Ltd, Dr. T. Hasimoto of TDK Co. and Dr. T. Nomoto of NHK Science and Technical Research Laboratories, who kindly provided technical information for this paper. He would also like to thank for Dr. J. M. Owens of Auburn University for providing the opportunity of this paper, and Dr. C. Kojima of Sony for encouragement of this work.

## REFERENCES

[1] Y. Konishi, "Lumped Element Y Circulator," IEEE Trans. Microwave Theory Tech., vol.MTT-13, pp.852-864, Nov., 1965

[2] T. Hashimoto, "Applications of microwave ferrite," Elecronic Ceramic, pp.17-23, May, 1992

[3] T. Nagao and Z. Tanaka, "Magnetically Tunable Stripline Y Circulator," IEEE Intl. Microwave Symp. Digest, pp.1011-1014, 1991

[4] K. Okubo and M. Tsutsumi, "The Edge-Guided Mode Isolator Using YIG Single Crystal Disk," IEICE Japan Technical Report, MW 92-33, pp.17-22, 1992

[5] Y. Ishikawa, T. Okuda, T. Kawanami, K. Okamura and T. Nishikawa, "A Miniature Isolator for 800 MHz Band Mobile Communication Systems," Trans. IEICE Japan, vol.E 74, No.5, May, 1991

[6] Y. Murakami and S. Itoh, "A 1.575GHz Bandpass Filter Using YIG Film Grown by LPE," IEEE Intl. Microwave Symp. Digest, pp.285-287, 1985

[7] Y. Murakami, T. Ohgihara and T. Okamoto, "A 0.5-4.0 GHz Tunable Bandpass Filter Using YIG Film Grown by LPE," IEEE Trans. Microwave Theory Tech., vol.MTT-35, No.12, pp.1192-1198, 1987

[8] M. Tsutsumi and T. Takeda, "Magnetostatic Wave Resonators of Microstrip Type," IEEE Intl. Microwave Symp. Digest, pp.149-152, 1989

[9] T. Nishikawa, K. Wakino, H. Tanaka, S. Shinmura and Y. Ishikawa, "A Low-Loss Magnetostatic Wave Filter Using Parallel Strip Transducer," IEEE Intl. Microwave Symp. Digest, pp.153-156, 1989

[10] Y. Ishikawa, T. Okada, S. Shinmura, F. Kanaya, K. Wakino and T. Nishikawa, "A Miaturized Low-Spurious 1.9 GHz MSW Band-Pass Filter Using YIG Resonators with Multi Metal Rings," IEEE Intl. Microwave Symp. Digest, pp.1403-1406, 1992

[11] Y. Mizunuma, T. Ohgihara, H. Nakano, T. Okamoto and Y. Murakami, "A 13-GHz YIG-Film Tuned Oscillator for VSAT Applications," IEEE Intl. Microwave Symp. Digest, pp.1085-1088, 1988

[12] Y. Mizunuma, T. Ohgihara, H. Nakano, T. Okamoto, M. Kubota and Y. Murakami, "X-and Ku-Band YIG-Film Tuned Low Noise Oscillators," IEEE Intl. Microwave Symp. Digest, pp.161-164, 1989

[13] H. Asao, H. Ohashi and O. Ishida, "Broadband Tunable Oscillator Using Two MSW Resonators," IEICE Japan Technical Report, MW89-91, pp.15-19, 1991

[14] I. Aoki, "A 2-5 GHz Tunable Magnetostatic Wave Oscillator," IEEE Intl. Microwave Symp. Digest, pp.969-972, 1991

[15] T. Nomoto, "An S/N Enhancer Using Two MSSW Filters and Its Applications," IEICE Japan Technical Report, MW91-99, pp.15-21, 1991

[16] A. Asao, M. Miyazaki, S. Ishida and F. Takeda, "S/N Enhancer Using Symmetric Slotline Type MSW," IEICE Japan Technical Report, MW88-30, pp.17-20, 1988

[17] S. Watanabe, "Technology Transfer of High Frequency Devices for Consumer Electronics," IEEE Trans. Microwave Theory Tech., vol.MTT-40, No.12, pp.2461-2466, 1992