Trial Production Result of MCF Adopted Narrow Band Radio Transceiver Module

Hiroyuki Yamaguchi, Kaoru Kobayashi, Shinichi Satoh, and Masanobu Okazaki
NIHON DEMPA KOGYO CO., LTD.
1275-2, Kamihirose, Sayama-shi, Saitama 350-1321, JAPAN

yamagu@ndk.com,kkoba@ndk.com, ssatoh@ndk.com,and okazaki@ndk.com

***Abstract*—In this paper, the test result of prototype of leadless 300MHz band Monolithic Crystal Filter (hereinafter as "MCF") with 3rd overtone and with 2poles is shown. And the measuring result and field-test result of appropriate radio module with small transmitting power in which MCF is integrated, are shown. As the result, radio module in which UHF band MCF is integrated is proved to have higher utility, generally, than those in which SAW is integrated.**

I. INTRODUCTION

In the U.S., the TREAD law was enacted in September 2007 and installation of TPMS (Tire Pressure Monitoring System) became duty. Moreover, the category of specific small radio power of a 300MHz band was established newly even in Japan in May 2007. Ignited by this, the world wide growing demand will be expected in the field of radio with the small transmission power which can be used for such as TPMS from now on.

As a result of further congestion of a 300MHZ, with the conventional wireless-communications technology, it is predicted that the more communication obstacles caused by interference waves will occur.

Under those backgrounds, by uniting new digital-signal-processing technology and the narrow band crystal filter, we have performed examination and made a prototype of the radio communication module which can get higher receiving sensitivity, and can get wider communication range, and can prevent mutual interference

This paper describes first the subject which the present small radio power module has. Next, the experimental result of MCF and wireless-small radio power module, and consideration which were made as an experiment in order to wipe away this subject were described, and the selectivity and interference-resistance performance in radio band were improved by narrowing bandwidth. The composition combining ANT-filter (Antenna filter) and IF-filter (Inter mediate Frequency filter) was adopted, and simplification of the circuit was attained. As a result of the field test of the small transmitting radio power module made as an experiment, communication distance 350m was obtained in no obstacle circumstance. In the in-vehicle experiment in a high density housing area, even if 150m or more away also in the shade of a building, it has checked that it could communicate.

II. PRESENT SUBJECT

Generally, Receiver consists of the blocks shown in Fig.1 and it is called the "super heterodyne system"

This system which used ANT filter and other filters selects receiving frequency band signal and removes unnecessary frequency component signal. For example, Surface Acoustic Wave filter (SAW filter) is used 300MHz-400MHz band as Ant filter in generally

On the other hand, the relation of the noise level N of a receiver and bandwidth B that were directly detected using the antenna (SAW) filter is determined by formula (1) generally.

$$N=KTBF \quad (1)$$

where N is noise level, K is Boltzmann constant （1.38×10^{-23}）, T is absolute temperature (degree K), B is bandwidth, and F is noise figure of a receiver.

It depends for the noise level N on the bandwidth B of an antenna filter. That is, if antenna filter bandwidth B uses a wide filter, the noise level N will become high and the receiving sensitivity of a signal will decrease. Moreover, that bandwidth B is wide also causes mutual interference with an unnecessary incoming signal, and it becomes easy to produce malfunction. Rather than the case that a crystal filter is used, the filter using devices, such as

978-1-4244-3510-4/09/$25.00 ©2009 IEEE

SAW currently generally used, is a broadband, and has a demerit which is easy to take in external noise.

It will become the following subjects if this is materialized.

(1) Since a filter serves as very wide bandwidth to required bandwidth for communication, it is difficult to reduce the noise level N and also difficult to obtain the high receiving sensitivity. Therefore it limits the communication range.
(2) It is difficult to reduce mutual radio channel interference effectively due to wide band receiving filter (ANT-filter)
(3) In order to remove image frequency response, it needs to suppress image frequency signal such as IF stage filtering, therefore, simplification of the whole receiving circuit is difficult.

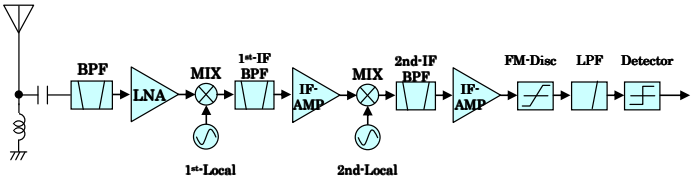

Fig.1 Block diagram of general receiver

In order to solve these subjects, we checked by experiment for the purpose of the following items.

(1) For trial radio module, by developing MCF of a UHF band newly, the interference signal in stop band was reduced sharply and improvement of interference-resistance performance was aimed at.
(2) Using digital-signal-processing technology for a modulation/demodulation system, adopting BPSK system to primary modulation/demodulation, moreover, direct spectrum spread system is adopted as a secondary modulation/demodulation, the receiving sensitivity and Improvement of interference-resistance performance was aimed at.

Table 1 Design specifications of trial sample MCF

Enclosure	2.5X2.0 mm
Nominal frequency (f_0)	301.08MHz
Pole	2
Crystal blank size	0.8(X axis) x 1.5 (Z axis) mm
Surface	Polish
Insertion loss (at f_0)	Less than 6dB
Ripple	Less than 2dB
Pass band (at -30℃ to +85℃)	More than ±20kHz(at 3dB)
Attenuation （at -30℃～+85℃）	More than 15dBc at f0-140kHz
	More than 21dBc at f0-280kHz
Terminate impedance	600ohm//-1pF

III. EXPERIMENTAL RESULT AND CONSIDERATION

A UHF band MCF

We developed newly UHF band MCF of 3rd overtone 2 poles. These design specifications were shown in Table 1. And also the measurement result was shown in Fig.2.

B The result of trial sample as experiment radio module

The MCF that was made as experiment was integrated the trial product radio module in Fig.3. And Fig. 4 shows magnified local part in Fig.3.

- By applying same AT-cut to both quartz blanks of local oscillator and MCF, both of them have same frequency change behavior in temperature, As this result, it makes easy to manage frequency change in temperature environment. The measure against career frequency gap between transmitter and a receiver carried out with FFT(Fast Fourier Transform) detection, and performed synchronizing processing with the digital-signal-processing circuit. And even if it was under the temperature environment where both sides differ, quality two-way communication was aimed to be possible. By these measures, bandwidth could be narrowed and the selectivity and interference-resistance performance in radio band was improved.

- Moreover, by uniting ANT-filter and IF-filter, circuit composition can be simplified.

It is as follows when these results are expressed data.

- When a data rate equivalent to products on the market compared receiving sensitivity, this improved by 10-20dB.
- Interference-resistance performance improvement as compared with the conventional system (ASK: Amplitude - Shift Keying, FSK: Frequency-Shift Keying): approx. (28dB to 29dB) in pass band with 75bps (average data) and approx. (36dB to 41dB) at 500 kHz apart from centre freq. in stop band
- Transmission current consumption is approx. 13mA at Japanese very low radio power and approx. 26mA at Japanese T-93 ARIB (Association of Radio Industries and Businesses), and receiving current consumption is approx. 13mA (this value is equivalent to the conventional products)

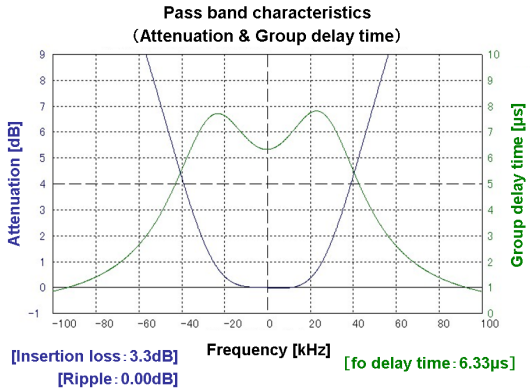

Fig.2A Attenuation, Group delay vs. Frequency (Pass band)

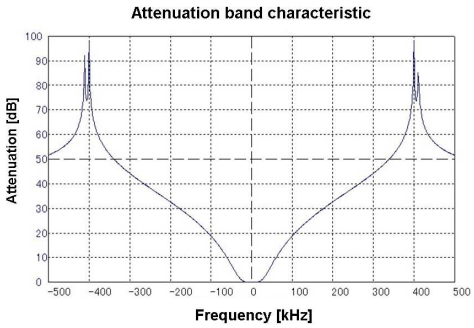

Fig. 2B Attenuation vs. Frequency(Attenuation in stop band)
Fig. 2 Measurement result of trial sample MCF

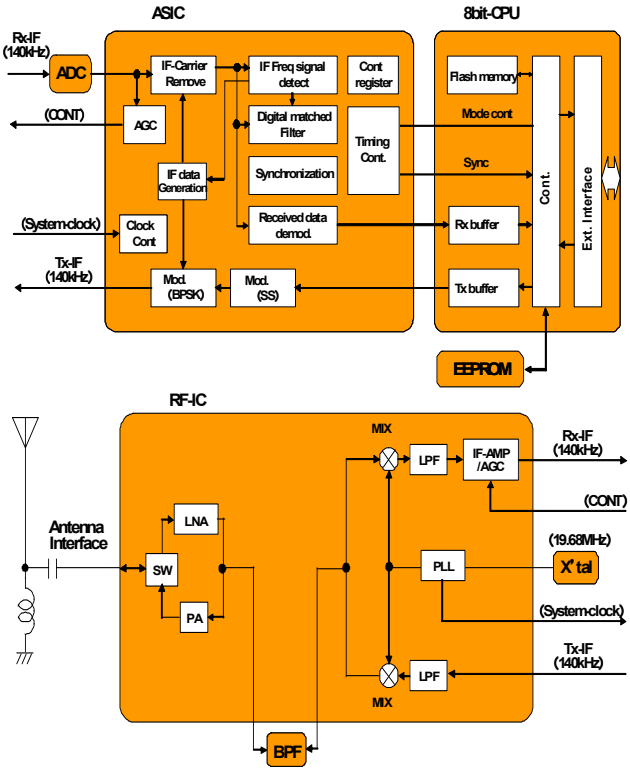

Fig.3 Block diagram of trial product radio module

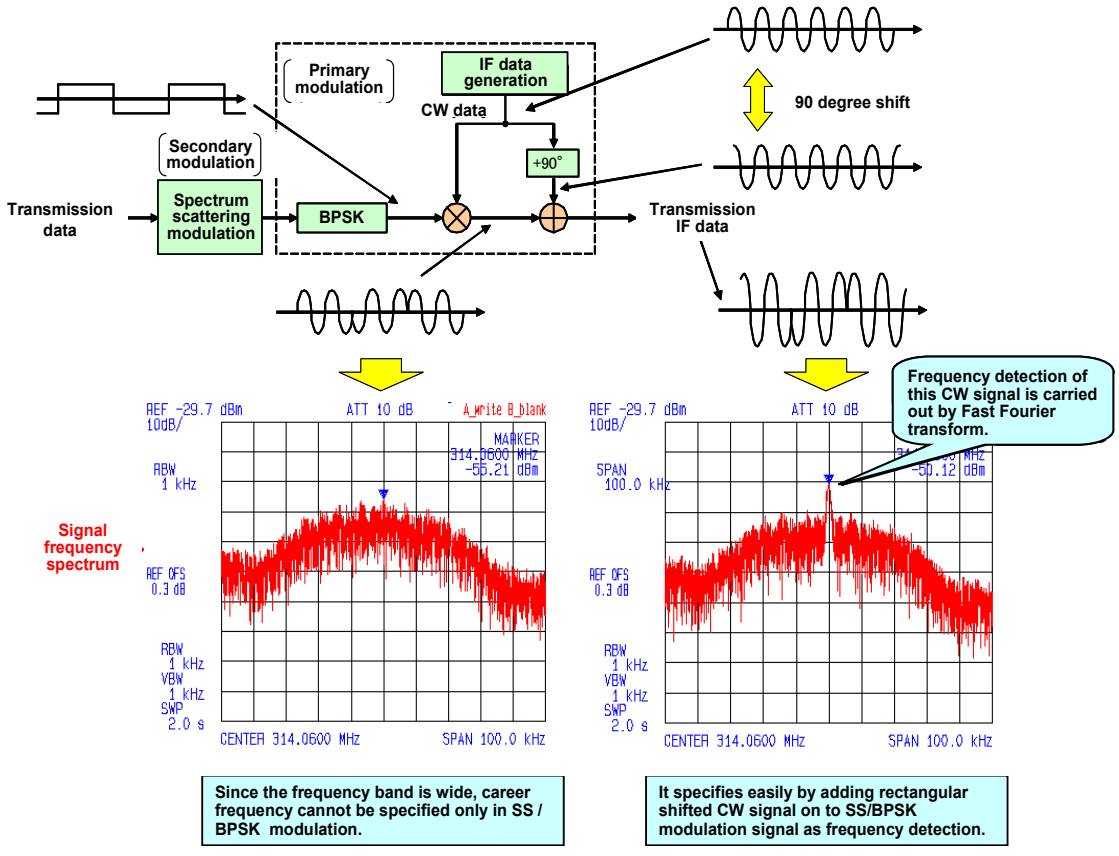

Fig 4 Magnified local part in Fig3

C Field test

A field test is important for such a radio module. We carried out the field test in order to verify and check the performance of an experimental model. Table 2 shows results of the field test.

From the table, it experimented in height 1-m-above ground at 1,200bps supposing RKE (Remote Keyless Entry). The result of communication distance was obtained 150 m under no obstacle construction circumstance. Next, the in-vehicle experiment in a high density housing area was conducted. And even if 150m or more away also in the shade of a building, it has checked that it could communicate.

Table2 Field Test Result

Data Rate		19.2kbps	1200bps	75bps
Communication		Two-way TDD (Semi duplex)		
Open site (No obstacle building)	1 m height	Approx. 200m	Approx. 350m	Approx. 550m
	2 m height	Approx. 450m	Approx. 700m	Approx. 1,000m
High density housing area	1 m height		Approx. 150m	
Remarks		89dBuV/m @3m, Ant gain -5dBi		

IV. CONCLUSION

Since the world wide growing demand of the small radio power wireless module was expected, the narrow band UHF crystal filter was made as an experiment. Again, by uniting new digital-signal-processing technology and this MCF, examination and a trial product of the radio-communication module which can get high receiving sensitivity, and can get wide communication range, and can prevent mutual interference has been performed. Moreover, the field test has been also carried out using the experimental model.

As a result the temperature behavior of the filter center frequency (the mark of temperature coefficient) is made similarly to the temperature behavior of the frequency of local signal; it became easy to manage frequency change under temperature environment.

Even if it was in the temperature environment where both sides differ, good quality two-way communication became possible. By bandwidth narrowing, the selectivity and interference-resistance performance in radio frequency band was improved. Furthermore, it united the ANT-filter and IF-filter as MCF one component and realized circuit down sizing.

The communication distance was obtained as 350m in no obstacle construction circumstance as a result of the field test. In the in-vehicle experiment in a high density housing area, even 150m or more away also in shade of a building, it has been confirmed that it was able to communicate

As future subjects, it is scheduled to produce the more high performance radio module than the product of conventional "ASK/FSK systems" by combining the performance improvement of MCF and the modulation/demodulation of digital signal processing.

ACKNOWLEDGMENT

I am thankful to Mr. K. Akaike of NDK who always advises appropriately.

REFERENCES

[1] M. Onoe and H. Jumonji, Analysis of Piezoelectric Resonators Vibrating in Trapped-Energy Modes, Jour. Inst. Elec. Comm. Engrs., Japan, Vol. 48 (Sept. 1965) English translation in Electronics and Comm. in Japan, Vol. 48 (Sept. 1965)

[2] M. Onoe, H. Jumonji, and N. Kobori, High Frequency Crystal Filters Employing Multiple Mode Resonators Vibrating in Trapped Energy Modes, Proc. 20th Ann. Freq. Control Symposium, (April 1966)

[3] L. Dworsky and R.G. Kinsman, A Simple Single Model for Quartz Crystal Resonator Low Level Drive Sensitivity and Monolithic Filter Intermodulation, IEEE Trans. on Ultrasonics, Ferroelectrics, and Frequency Control, Vol 41,(March 1994)

[4] R.G. Kinsman and D. Gunn, Frequency Control Requirements for 800 MHz Land Mobile Communication, Proc. 35th Ann. Freq. Control Symposium, 501 (May 1981)

[5] R.G. Kinsman, “Monolithic crystal filter improved equivalent circuit,” IEEE Trans. on Sonics and Ultrasonics, Vol. SU-31, No 1, Jan., 1984

[6] Takahiro Inoue, Masahiro Yoshimatsu, and Masanobu Okazaki, “Miniaturization of angular rate sensor element using bonded quartz tuning fork,” Proc. IEEE I.FCS, pp.1007-1011(2003)