FITSAT-1　5.84GHz signal ground station receiving system. 18th Nov. 2012

Takushi　Tanaka＠FIT　software
Takakazu Tanaka＠Logical Product corp.　hardware

1. Attitude control of FITSAT-1

The attitude control of FITSAT is performed by a strong magnet located center position of the FITSAT-1.

The direction of the axis of N-S of it is fixed same as the direction of front and rear Ant/LED/Camera panel side.

Therefore, FITSAT-1 is stabilized in alignment with a line of magnetic force.

Suppression method to the direction of axial rotation is not used directly.

2. 5.84GHz transmitter and 5.84GHz TX antenna.

FITSAT-1 sends 20 pages of VGA sized picture data stored in flash ROM commands from the ground station (FIT in Fukuoka Japan).

TX 5.84GHz carrier is modulated by these NRZ packet data.

Carrier Pow.=2W（33ｄBm）Mod.mode: 115.2kbps 2-FSK (dev.≒+50kHz/-50kHz)

Since this data send command can be set up time until it performs, TX can send out at the arbitrary places on a satellite's orbit.

5.8-GHz transmitting antenna is attached to the front of a satellite.

And this antenna always faces to the North direction of the line of magnetic force of geomagnetism.

The angle of the line of magnetic force to the ground changes with latitude or places.

For example, if it is the Japanese sky, it will become an angle of about 45 degrees.

Therefore, it will become the best condition of receiving 5.8GHz TX signal, when the satellite passing on the south direction of the RX point in Japan.

However, in the Southern Hemisphere of the earth, since this antenna will turn to the universe side, conditions become worse.

If it is the equatorial sky, direction of a satellite will become parallel to the ground mostly.

The directional angle characteristic of TX antenna is quite a broadband, since it is one element circular polarization patch type antenna.

The distance from a receiving station antenna to a satellite is about only 400 km to 600 km.　If the tracking feature of the RX antenna works well, this signal is receivable with easy antenna and RX in the Northern Hemisphere.

In FIT, it is fully receivable 5.8GHz data signal by a parabolic antenna 1.5 m in diameter.

3. The circuit configuration of a receiving part.

3-1. RX. Antenna

Rough calculation of the receiving power from the FITSAT-1 to LNB.

*Conditions; distance=600km, TX antenna Gain = 1dB, TX Power =33dBm(2W)

RX antenna Gain = XdB ,

Propagation loss = it is proportional to the square of distance.

Attenuation of atmosphere passage is disregarded.

$$Pr(dBm) = 33 + 1 - 20\log 4\pi + 20\log(\lambda/(600 * 10^3)) + X$$

$$= 34 - 22 - 149 + X = -137 + X \text{ dBm}$$

And the other hand,

RX RF NF<2dB, IF BW of RX ≒300kHz, TX FM mod. index ≒0.9 (2-FSK)

On the above-mentioned conditions, it is presumed by my experience that RX (LNB) antenna terminal power required for BER<0.01% may be enough over −105dBm.

Therefore, RX antenna gain should be over 32dB.

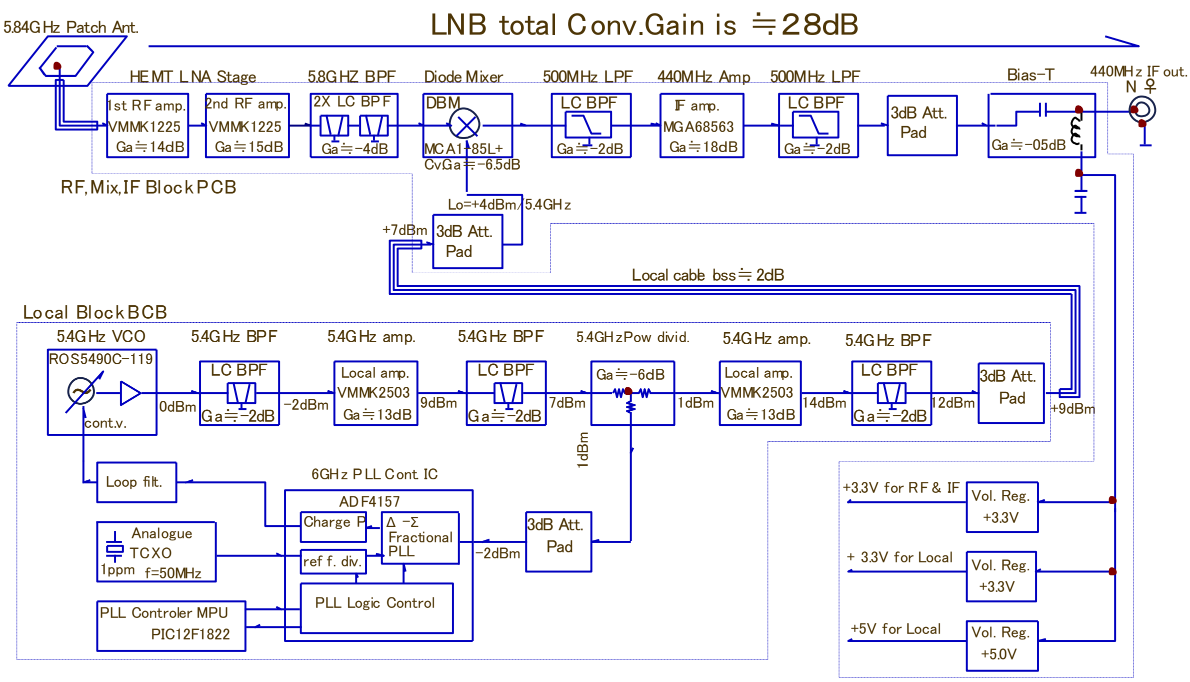
This value is realizable by an about d=1.5m parabolic antenna at 5.84 GHz.

Since, as for the antenna whose caliber is too big and higher gain, a half-value angle becomes too narrow, precision mechanism is required of a satellite homing device.

3-2. LNB

Please refer to the following block diagram.

☆LNB



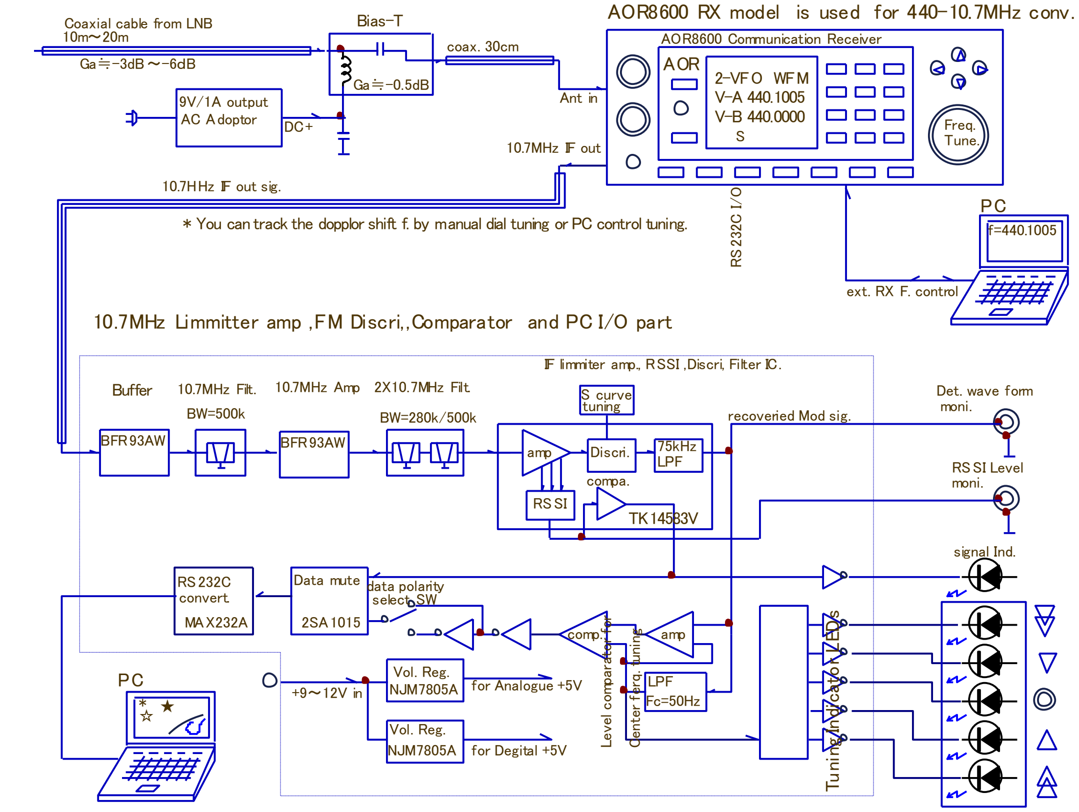
Most circuits are designed by the discrete part of the lumped constant.
The distribution constant is not used except the 50-ohm transmission line.
The back of 5.8GHz patch antenna, there is an input part of LNA direct.
We used 2 stage of HEMT (Avago Teck. VMMK-1225) for 5.8GHz LNA.
This transistor can obtain a higher gain and a low NF. at 5.8GHz band.
5.84-GHz BPF is a chip component of a Murata's L-C integral type.
Mixer circuit of 5.84-GHz is DBM of Mini Circuit MCA1-85L+.
The conversion loss of it on 5.84 GHz of that is less than 7 dB at 4dBm local input.
We chose and set IF frequency to 440 MHz.
This is because acquisition of FM wideband radio is easy and the cable loss to the main RX is lower compared with 1.28GHz band.
Then Local f. becomes 5.4GHz (lower local), this band parts (filters etc.) are easy to obtain 'cause same as 802.11a band.
We designed 2 kinds of local unit PCB, one is 50MHz 1ppm TCXO multi- plier type(50 ×108), the other one is direct OSC with PLL type(ref.f.=50Mz 1ppm TCXO)
We could get enough C/N(residual FM) for this purpose with the letter one unit.
VCO of it is Mini Circuit ROS5490C-119, and PLL IC is ADF4157.
IF amp. of 440MHz is MGA68563 , then through LPF, 3dB loss-pad and bias-T 5.84GHz input signal are covert to 440MHz IF signal with about 28dB gain.
At first of this LNB study, we attached small Peltier device under the RF part.
But only one stage Peltie, we could got only an 18 ℃ temperature fall from environmental temperature. And in this value, the improvement of C/N was hardly obtained.

3-3. Main RX freq. tuning part.

We don't want to use man power to the 440MHz tuning receiver, we searched suitable receiver for our purpose in the market.
We only need tuning dial for Doppler shift tracking and 10.7MHz converted out put without any IF filters. And we found the model AOR-8600MK2.
Although the tuning dial of this model is small, but is a reasonable price and has a direct output terminal of IF. Moreover, it can be controlled the receiving freq. from the external PC. by RS232C port.
This function is suitable for automatic software Doppler shift tracking system in future.
Only a dissatisfied point is the receiving frequency step in FM mode in a 440-MHz band is every 10 kHz. We wanted to get every 5kHz for Doppler shift tracking.

Please refer to the following block diagram and picture.

☆440MHz to 10.7MHz Conv. and 10.7MHz Decorder.



Upper part;10.7HHz IF amp and 2-FSK decoder. Lower part; AOR-8600KK2

3-4. IF amp and 2-FSK decoder.

As TX 5.84GHz carrier is modulated 115.2kbps 2-FSK F-shift +/−50kHz.

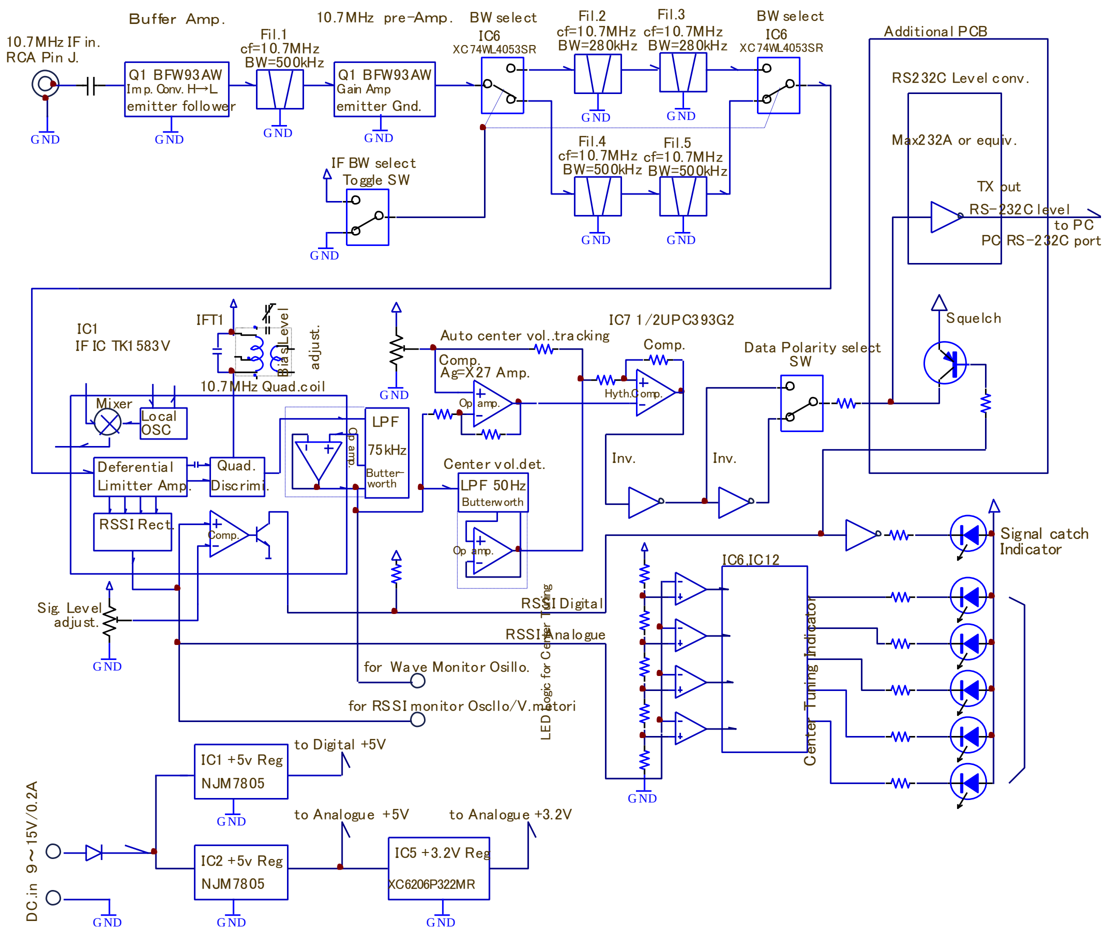
Then OBW will become about 2＊ (50＋57.6) ＝225.2ｋHz

Actually VCO C/N in TX is not good, 99% OBW of TX become about 415kHz.

By the way, 99.99% OBW is about 975kHz, 50% OBW is about 85kHz.

We decided to use BW(-3dB) 280KHz and BW(-3dB)500kHz IF Filters for 10.7MHz RX.

Current 10.7Mhz FM Discriminator Block Diagram



10.7MHz BW=280kHz ceramic filter is popular for commercial stereo FM reception RX. As for commercial monophonic FM reception they use BW=230kHz ceramic filter. We used 3 stage of this filter in 10.7MHz amp. May be it is too much, 'cause I don't think there might be any near-by frequency signals at 5.84GHz.

We use 2 stages of transistor pre-amp.(one is buffer another is voltage amp.) at first. We used Infinion's BFW93AW, but on this stage no need to use such a high Ft TR. Only this TR existed near my hand.

TK14583V of TOKO is used for main IF differential-amplifier stage, RSSI detect stage, RSSI level comparator stage, the quadrature FM discriminator stage and

recovered signal filtering stage. MIX stage and OSC stage in the IC. are not used.
Recovered modulated signal is filtered by Fc≒75kHz 2nd Butter worth active filter.
10.7MHz center S-curve offset voltage of this discriminator circuit is about +1V.
And as the quadrature tank circuit is dumped by R for wide band operation, the recovered AC. level of it is not so high. We have to amplify this signal.
We attached Fc≒50Hz active filter after above filter. The out put voltage from this filter (almost DC level) means center average voltage of modulated carrier frequency.
We use this center average voltage out put for center tuning indicator voltage output and bias for post filtered signal amp and level comparator standard voltage.
Center tuning indicator circuit is not important part of this receiver.
It is realized from four window level comparators, and shows a shift of the tuning from the center frequency of 10.7 MHz by five LED.
We should keep the Dopplor shift tuning level within yellow LEDs position above photo. This function is only convenient for manual Dopplor shift tracking.
Very important point of the decoder is comparator circuit, as the recovered signal is filtered so heavily (TX mod Fil. RX IF fil.& 75kHz Fil), 114kbps signal wave form is not original rectangular wave but a sine wave.
Terefore, if the comparator standard voltage level is not center of the recovered signal (rise and fall are sine wave), true duty of the original rectangular wave is not reappear.
The output voltage of 50Hz LPF was used as this reference voltage this time.
However, if it says strictly, since we didn't use Manchester encoding of the transmitted modulation signal, recovered analog center voltage may not be exact suitable comparator reference voltage.
Comparator out put voltage is 5V logic level. Then we add RS-232C convert IC.(MAX232A or equiv.) for PC. I/O.
When there is no signals, comparator generate random noise, then we added squelch TR before level converter IC.
This squelch TR is driven by the RSSI comparator output (signal indicator LED).
The squelch level should be adjusted just a bit high level of the noise RSSI level.
Or it is difficult to find the start point of the incoming data.

4. If you want to make IF amp and 2-FSK decoder for FITSAT-1.
10.7-MHz recovery of 2-FSK is possible not using above mentioned circuit.
. One method is to modify old FM stereo tuner (old Analogue type tuner is better).

Find discriminator circuit on the PCB. then cut the copper pattern to the de-emphasis circuit, add 70~75kHz LPF, amp, comparator, level converter for RS232C and input buffer to the 10.7MHz convertor.

In this case, cut the power supply line to the RF amp, Local OSC, stereo demodulator And no need circuits.

Or alternative idea is to make traditional 2.54mm(0.1inch) pitch parts on the universal PCB.

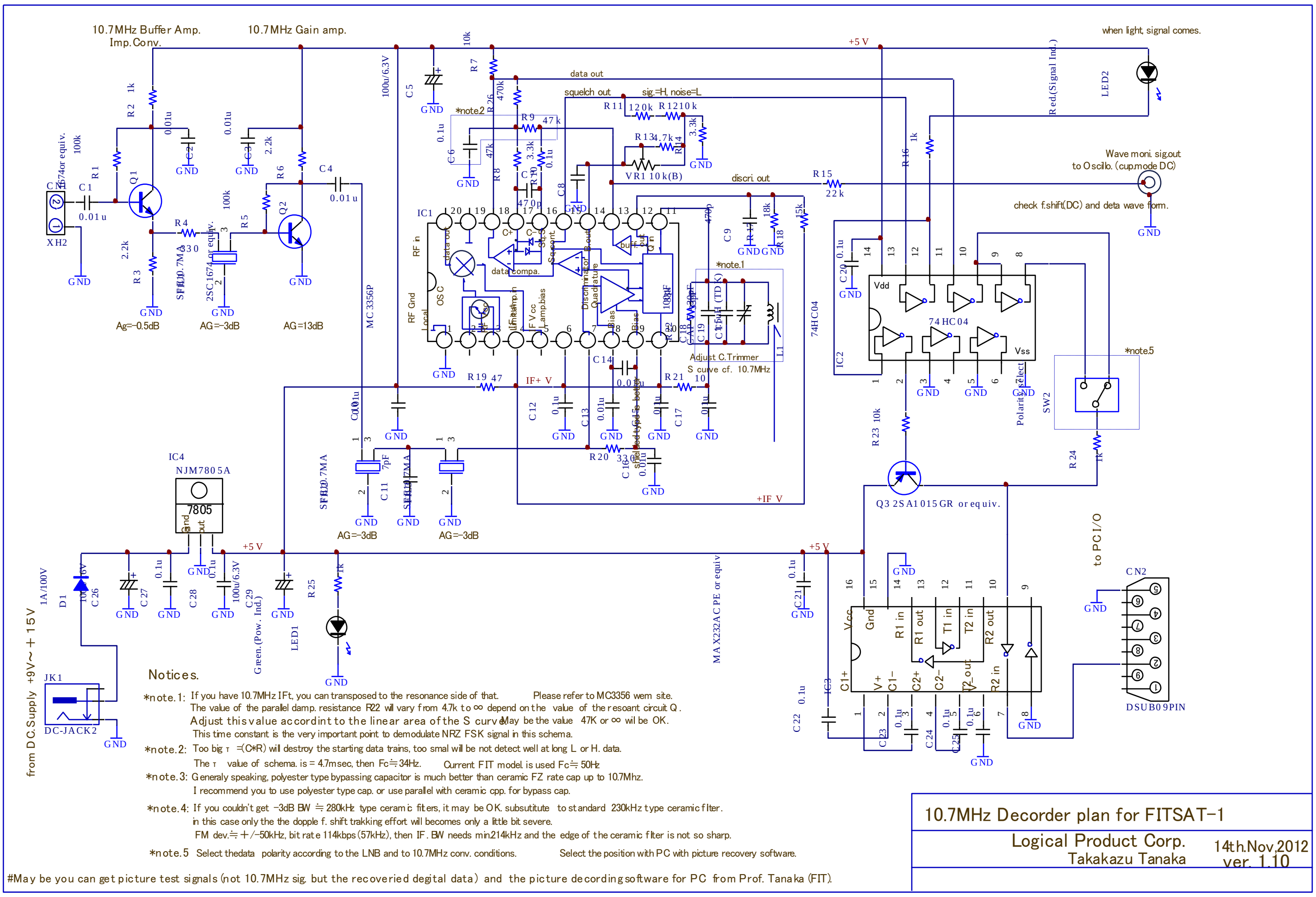
In this case, Motrola's MC3356P (dis-continued model) is the best selection, I think.

May be, this IC.8MC3356P) is still available in the market.

You can use popular 10.7MHz(BW=230kHz) type ceramic filter, on the conditions which you can do exact Doppler shift tracking.

I wrote the following schematic diagram of using MC3356P circuit.

Although not actually made, I believe probably it will operate well.



*About the image restoration software for PC will be independently described and be supplied from Professor Tanaka.