Development of a VHF receiver for earth observation data broadcast

Id: 47-186152 Tianxu ZHANG
Department of Complexity science and engineering
Advisor: Prof. Ichiro Yoshikawa
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1: Introduction

NOAA series satellites, (image shown in Figure 1) are series of polar orbiting meteorological satellite operated by National Oceanic and Atmospheric Administration (NOAA) with a suite of observation equipment onboard(Schwalb, 2020). Automatic Picture Transmission as one of many downlink broadcasted by NOAA satellites with FM-AM modulation could be demodulated and frame retrieved with relatively simple procedure due to analog modulation adopted. Thus APT signal has a substantially lower hurdle for public users to receive compared to other signal with digital modulation. Usually NOAA satellites are launched in a tandem manner for continuous operation. However, with the termination of NOAA-POES program on NOAA-19(N') satellite(NOAA,2009) and surprisingly long surviving predecessors, 3 satellites are operating simultaneously on orbit which is a rare occasion. With the easy to receive APT signal broadcasted by NOAA satellites, publics receiving earth observation data of 3 satellites continuously in orbit became possible.

In order to provide simple yet functioning design of APT receiver for public, the work of this thesis is dedicated to design a simple FM demodulating front-end for receiving APT signal broadcasted in VHF band. The receiver is designed with certain compatibility to a usual FM receiver, but several critical changes were made to ensure its performance under weak satellite broadcasted signal and narrow bandwidth.

2: Automatic Picture Transmission

First adopted in TIROS-6 satellites, as the downlink method for transferring real-time earth observation data to nearby ground stations, the Automatic Picture Transmission has been used in NOAA series for over 40years. With the introduction of NOAA-KLM series and the Advanced Very-High Resolution Radiometer (AVHRR), the APT downlink transmitted by NOAA satellite is mainly tasked with the transmission of reduced resolution image captured by AVHRR (Robel, 2014).

Currently, the APT signal is being transmitted on 137MHz VHF frequency (vary between 3 satellites) with EIRP of 37dBm (5 watt) and has a 45 KHz bandwidth.

Transmission antenna onboard NOAA satellite has the polarization of RHCP (right hand circular polarized) thus transmitted APT signal is also RHCP. As it is mentioned in the introduction section the signal itself is first modulated with AM, into a 2.4 KHz subcarrier and then FM modulated into 137MHz carrier frequency.

As it is shown in Figure 2, the transmitted data contain two channels of image, selected from two channels out of six, from AVHRR instrument and has a 120line/minute scan speed.

Figure1: Image of a TIROS-N (NOAA-15) satellite (Satnews, 2009)

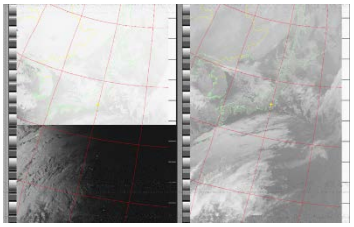

Figure2: APT image retrieved from a northbound pass on Kashiwa campus. Two channel of image could be seen.

3: APT Receiver design

Based on the situation that 3 satellites are operating simultaneously and are transmitting easy to decode downlink signal, a Narrowband VHF FM receiver specified for receiving three NOAA satellites' APT downlink is proposed and designed.

The receiver design is established on the signal characteristics of APT. Link budget is calculated from APT's EIRP of 37dbm and propagation losses before reaching the antenna, which derived a signal strength of -

90dbm under clear sky and 30degree elevation angle. With margin of 30dbm the minimum sensitivity of receiver is derived to be -120dbm. Actual receiver design employed a two-IF stage superheterodyne schematic in order to bring down the 137MHz VHF frequency signal to 455KHz, to a point that the FM demodulator IC (MC3361) could efficiently process the signal. This design also made it possible to embed widely used FM receiver parts, including IF filters into the design itself. The block diagram of APT receiver is shown in Figure 3

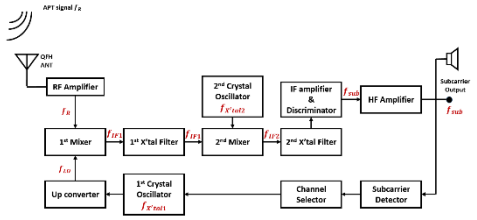

Figure4: Block diagram showing the basic operation of APT receiver.

The APT signal retrieved from antenna, is mixed with local oscillation signal that correspond to 3 different satellites (NOAA-15,18,19) in a superheterodyne mixer to generate 10.7MHz IF. The IF signal is then downconverted again into 455KHz 2nd IF, where quadrature demodulation is performed on FM modulated IF signal.

4: Measurement and APT receiving

After manufacturing the prototype, measurement on several important parts of the receiver: outputs of oscillators and mixers, are made on the board in order to evaluate the performance. Passive probe coupled with spectrum analyzer is used in the measurement, for most of the interests in this measurement process are about whether correct frequencies are outputted or not. Figure 5 shows an example of measure result on spectrum analyzer.

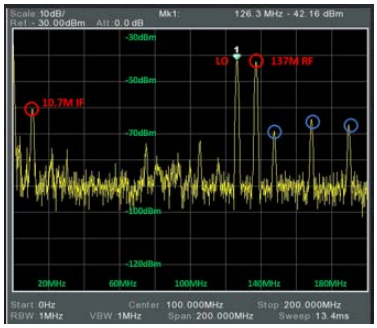

Figure5: Frequency-power plot on spectrum analyzer. The signal is captured at the output of 1st Superheterodyne mixer. LO, RF and IF peaks could be seen.

Multiple attempts of receiving the actual APT signal emitted from NOAA satellites were made by the author. An omnidirectional antenna with RHCP, Quadrifillar Helix antenna is used to capture transmitted APT signal, and software using SGP4 model is used for satellite pass prediction. One example of captured and retrieved image is shown in Figure 6.

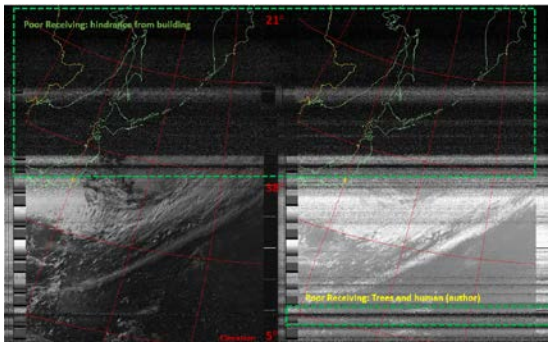

Figure 6: APT image retrieved from subcarrier signal, captured by QFH antenna and demodulated by APT receiver prototype.

Although the close to ground placement of QFH antenna demodulation performance of the receiver itself is sufficient based on the retrieved image quality.

5. General Conclusion

Based on the current status of NOAA satellites and its downlink transmission, a VHF FM receiver is proposed and designed to provide simple ways of receiving APT, an earth observation data broadcast emitted by NOAA satellites. An APT receiver prototype was manufactured based on the design. Measurement on several vital points and the result of attempts on receiving the actual APT signal indicates a sufficient performance of this receiver design.

6: References

[1]Schwalb, A., 2020. THE TIROS-N/NOAA A-G SATELLITE SERIES. A Technical Memorandum NESS 95, Volume 95, 1-10.

[2]National Oceanic and Atmospheric Administration, 2008. NOAA-N Prime. 1st ed. Suitland, Marynald: National Environmental Satellite Data, and Information Service.

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[4] satnews. 2009. Lockheed Martin's NOAA-N Boosted Away. [ONLINE] Available at: http://www.satnews.com/story.php?number=2022104447. [Accessed 1 July 2020].