HTS Filter System for Digital Terrestrial Television Transposer

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ABSTRACT

Digital-terrestrial-television broadcasting (DTTB) using the ISDB-T[1] system began in December 2003 in Tokyo, Osaka and Nagoya, Japan. We have to construct an extensive nationwide network so that DTTB services can be received anywhere in Japan. DTTB networks may have various relay systems for the links between transmitting stations, specifically broadcast-wave relay, microwave link (TTL: Transmitter-Transmitter Link) and optical fiber. A broadcast-wave relay system is most effective in reducing the cost and making efficient the network's frequency usage. Since many digital channels will be added to the existing UHF analog television band, it is unavoidable that some of the receiving digital channels will be adjacent to the transmitting digital channels or to the transmitting analog channels in the same relay station. Since the transmit signal, which feeds back to the receiving antenna, is much stronger than the adjacent received signal, inter-modulation or RF blocking at the receiver will occur because of this adjacent channel interference (ACI). In order to remove the ACI, a sharp-skirt channel-band-pass filter is required for the front-end of the transposer.

We have developed a channel band pass filter with a resonant element using a high-temperature superconductor (HTS)[2] material. This filter consists of 12 microstrip resonators fabricated from YBa_2Cu_3Oy thin films deposited on a Al_2O_3 (sapphire) substrate. This filter is integrated with a small cryocooler and is cooled to 70 K (-203°C). We can obtain an adjacent channel attenuation of 30 dB or more by using it. The system is also small and rack-mountable. Thus, we can easily use it for the front-end of the transposer at the relay station to suppress ACI. The paper reports on the configuration, characteristics and application of the digital transposer using the HTS filter.

BACKGROUND

Japan is mountainous with a complex topography, so it is not surprising that about 15000 analog television-transmitting stations have been constructed across the country for services of NHK and commercial broadcasters [3]. The channels of the UHF TV band (50 channels: 470 to 770 MHz) are assigned to about 13700 of these stations. The UHF TV band is also assigned to DTTB services. Television transmitting stations are usually constructed on high ground, such as the top of a mountain, and several transmitting stations may be located in one transmitting site. Consequently, in many cases, it is unavoidable that the receiving digital channels are adjacent to the transmitting digital channels or to the transmitting analog channels at the same transmission site (Figure 1).

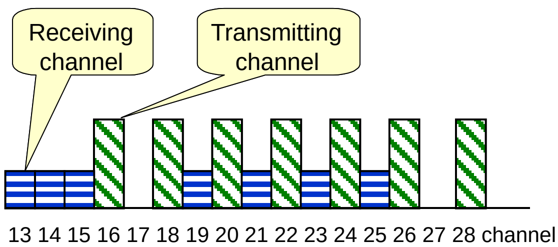


Figure 1 Example of DTTB channel allocation.

A coupling loop interference canceller has been developed for canceling co-channel interference due to antenna coupling, [4]. However, it has no means of dealing with ACI due to antenna coupling, as shown in Figure 2. Table 1 shows an example of ACI due to antenna coupling. The typical receiving power is -47 dBm, and the input power range is -27 through -67 dBm. We assumed the received signal would have the minimum power (-67 dBm).

Figure 3 shows ordinary transposer system for DTTB. The strongly interfering signals due to ACI may cause inter-modulation or RF blocking at the head amplifier or the downconverters of the transposer. To prevent the signal degradation caused by ACI, either the antenna coupling must be reduced or a sharp-skirt channel bandpass filter is required.

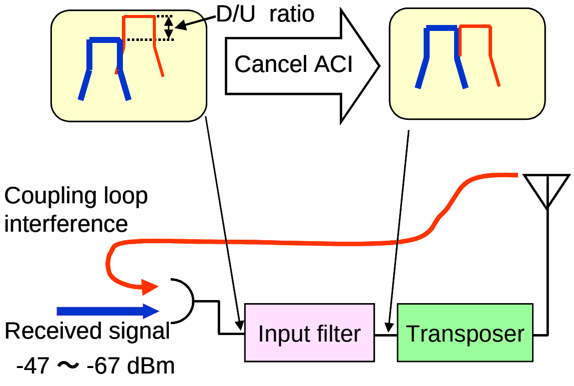


Figure 2 ACI at transposer.

Table 1 Example of ACI due to antenna coupling

Transmission power	+40 dBm (10W)
Antenna coupling	80 dB
Coupling power	-40 dBm
Receiving power	-67 dBm (minimum)
D/U ratio	-27 dB

To reduce the antenna coupling, we can separate the receiving antenna from the transmitting one; however, the cost of doing so may be very high because of the high cost of land and the expense of laying the feeder from the receiving antenna. Thus for our purposes, the antenna system couldn't have a physically dispersed arrangement. Instead, we have developed an HTS filter system for the front-end of the digital transposer as shown in Figure 4. The filter system has an outstanding ability to suppress ACI.

DESIGN AND FABRICATION OF HTS FILTER

We designed the HTS filter for the purpose of attenuating the adjacent channel of 30 dB for the case that the received power is attenuated by fading. The bandwidth for the ISDB-T signal is 5.6 MHz, and the guard bands are only 400 kHz on each side of the adjacent channels. The target of insertion loss in the passband is 0.5 dB or less.

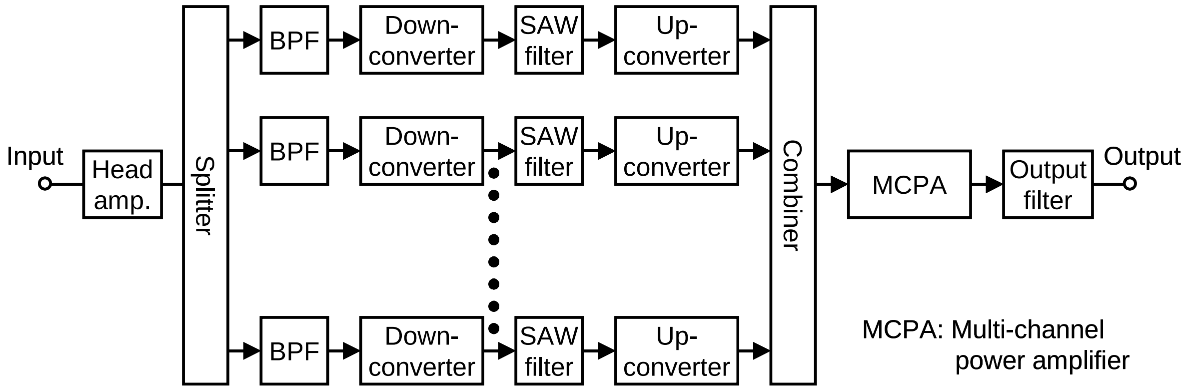


Figure 3 Block diagram of ordinary digital transposers.

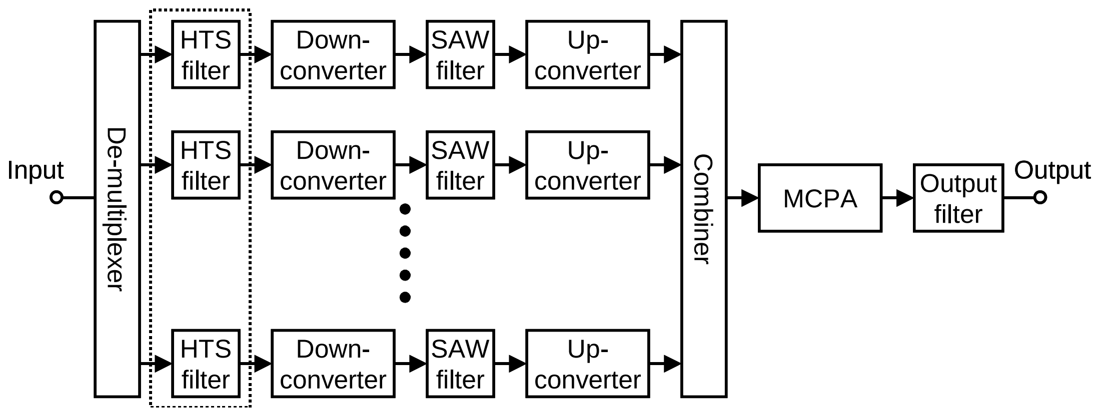


Figure 4 Block diagram of digital transposers with HTS filter system.

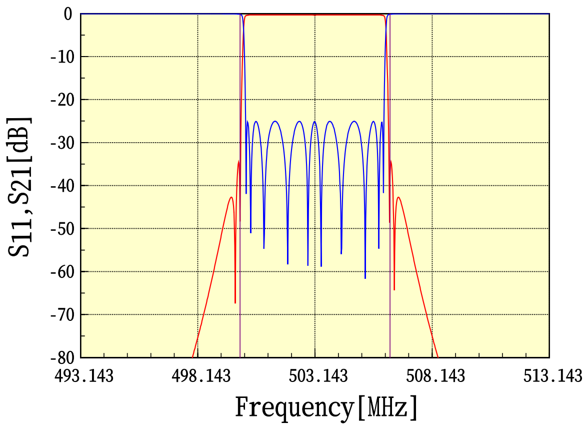


Figure 5 Designed frequency response of HTS filter.

Figure 5 shows the designed frequency response of the HTS filter. To realize this characteristic, we developed a quasi-elliptic function filter, which consists of 12 microstrip resonators fabricated from YBa_2Cu_3Oy thin films deposited on a Al_2O_3 (sapphire) substrate. Each resonator has an unloaded Q of more than 200000. Figure 6 shows the photograph of an HTS filter substrate mounted on a base plate. The diameter of the substrate is three inches.

Figure 6 An HTS filter substrate.

Figure 7 is a photograph of a HTS filter unit in a metal housing. The filter's dimensions are 70 (W) x 70 (D) x 30 (H) mm. The filter units are integrated with a small temperature-controlled cryocooler and are cooled to 70 K (-203°C).

Figure 8 shows the configuration of the filter system. The filters are mounted on a cooling stage in the heat isolation housing. Since four to eight transposers are usually installed at the same transmission site, the cryocooler has the ability to cool up to eight HTS filters to the temperature of 70 K.

Figure 7 An HTS filter unit.

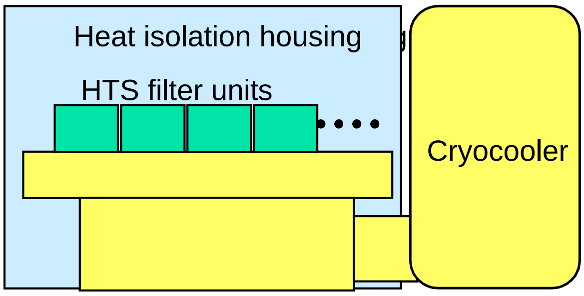
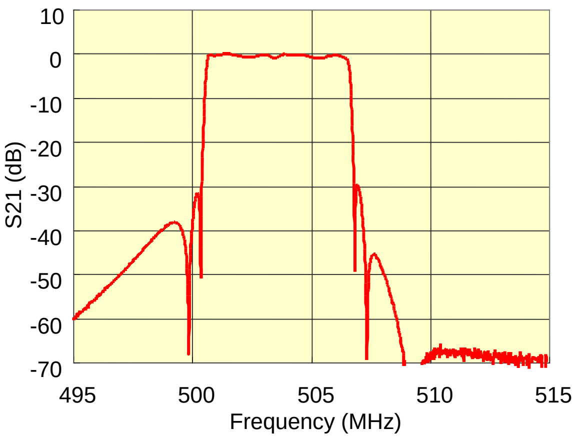


Figure 8 Configuration of HTS filter system.

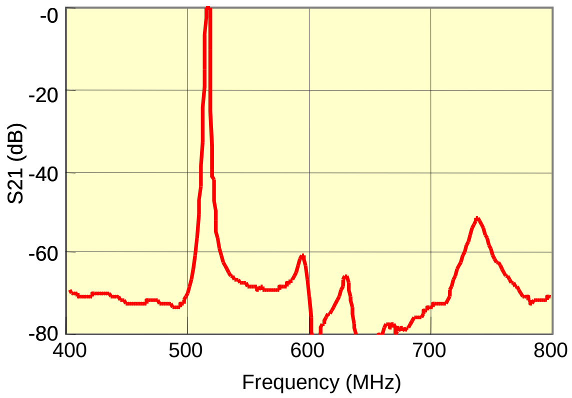
EXPERIMENTAL RESULTS

Figure 9 shows the prototype HTS filter system. It has two HTS filters for different UHF TV channels.

Figure 9 Appearance of HTS filter system.



(a)



(b)

Figure 10 Measured frequency response of HTS filter.
(a) Detailed frequency response.
(b) Wide range frequency response.

Figure 10 (a) shows the measured frequency response nearby the passband of the HTS filter system. An attenuation of 30 dB or more on each side of the adjacent channels was obtained. Figure 10 (b) shows the measured frequency response over a wide frequency range of the UHF TV band. No spurious resonance over -50 dB is visible. The insertion loss and ripple in the passband are each about 0.8 dB. These values are still high, since the adjustments have not completed at present. After adjustment, we can expect them to be 0.5 dB or less.

CONCLUSION

Construction of an extensive nationwide DTTB network in Japan is a goal of national importance. The broadcast-wave relay system is most effective in reducing the cost and in promoting efficient frequency use to deliver digital broadcasting signals to a relay station.

Since digital TV channels are assigned to the same UHF frequency band system in frequency-crowded areas, we have developed an HTS filter system for the digital terrestrial television transposer that can suppress ACI. The filter system can attenuate the adjacent channel signals by 30 dB or more. The HTS filter system is compact and rack-mountable with digital transposers. Since the cryocooler has the ability to cool up to eight HTS filters to 70 K, the input filters can be integrated within multiple relay stations sharing the same transmission site. Consequently, a large cost reduction may be possible. We will conduct a field test in an existing relay station to confirm the effect of the HTS filter system.

References

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