A HIGH-RESOLUTION TOTAL-POWER RADIOMETER USING SAW COMPRESSIVE RECEIVERS

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ABSTRACT

A total-power radiometer is being developed to measure parameters of the atmosphere from a Spacelab platform. Channelization for the high-resolution data is implemented by SAW compressive receivers. Two resolution levels are obtained from the same SAW device: twenty-five 2-MHz channels are defined across a 50-MHz instantaneous bandwidth; thirty 100-KHz channels are taken from a 3-MHz window in the center of the larger band. This paper describes the realization of the radiometer using RAC devices. A description is also included of a prototype compressive receiver that has been delivered to the experimenters for the generation of performance data.

INTRODUCTION

In support of the Microwave Atmospheric Sounder (MAS) experiment to be conducted aboard Spacelab, a total-power radiometric spectrometer is being developed for the measurement of molecular transitions in the mesophere. The original signals are noise-like waveforms at millimetric wavelengths. These signals are down-converted to X-Band where they are distributed into six channels over a band that is 1.634 GHz wide. The six channels have bandwidths of 200 MHz, 215 MHz and 250 MHz. Each of these channels is further resolved by filtering into seven sub-channels; the distribution network and its preceding mixers are so arranged that the high-resolution channels, in each case, fall in the frequency range 225-275 MHz. It is this frequency range that is serviced by compressive receivers. Figure 1 depicts the radiometer architecture.

RADIOMETER DESCRIPTION

It is required by the system specifications, prepared by the Rutherford Appleton Laboratories, Didcot, England, that two levels of resolution be available in the high-resolution channels:

- twenty-five 2-MHz frequency bins are to be defined over the full 50-MHz band from 225 MHz to 275 MHz
- thirty 100-KHz frequency bins are to be defined over a 3-MHz window extending from 248.5 MHz to 251.5 MHz.

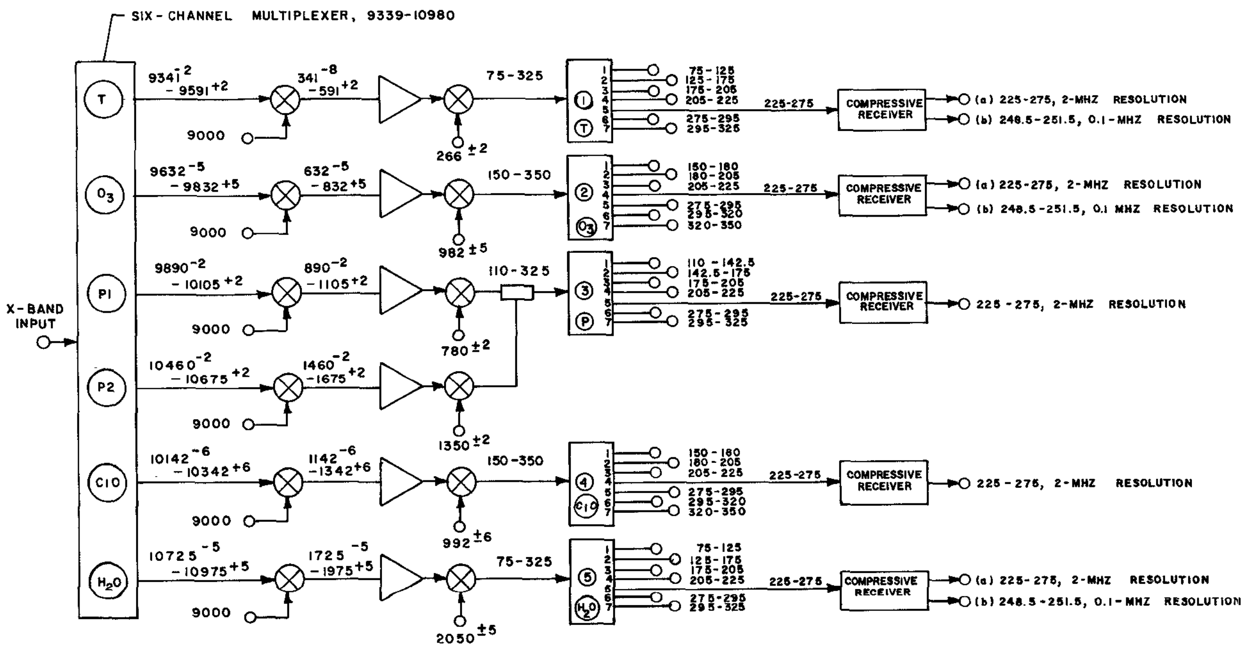

FIGURE 1. ARCHITECTURE OF MAS X-BAND RECEIVER

A C-M-C algorithm is implemented in the system for two reasons:

- a 50-MHz-bandwidth filter is needed to define the high-resolution sub-channel; it is convenient to use the dispersive line that implements the first convolution for this function
- the analysis band must receive 100% coverage in order for the subsequent signal integration to proceed properly; this requirement is readily met by the C-M-C algorithm.

Figure 2 shows the organization of a compressive receiver channel. For the values given in the Figure, compressed data are produced in 10-μs blocks that are separated by 2-μs gaps. A set of swept multiplying signals are generated by "ping-ponging" two dispersive lines having the characteristics shown in Figure 2. Alternatively, the requisite sweep signals may be generated at a lower center frequency and then translated to the higher LO frequency.

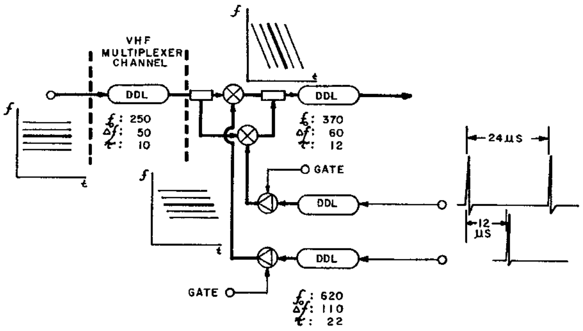

FIGURE 2. COMPRESSIVE RECEIVER CHANNEL.

All dispersive lines in the compressive receiver are reflective array compressors (RACs) constructed on lithium niobate substrates. The line lengths of the two convolvers are determined by the higher resolution specified -- 10μs to attain the 100-KHz resolution. For data gathering from the spacecraft, a 40-ms integration period is used, so that there are approximately 4000 compressive receiver outputs over the measurement interval. Figure 3 indicates the means for distributing coarse- and fine-resolution signals during a 10-μs sweep. Signals to be analyzed at a 2-MHz resolution are gated through to the appropriate processing equipment throughout the entire 10μs. High-resolution signals, on the other hand, are windowed through a 600-ns slot taken in the middle of the sweep. By these means, one compressive receiver produces the compressed signals for both levels of resolution.

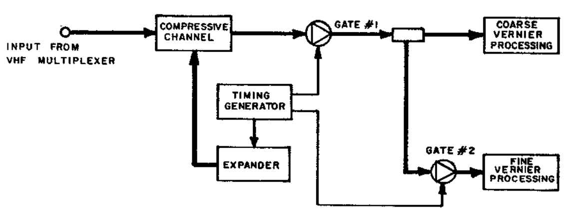

FIGURE 3. ORGANIZATION OF FREQUENCY RESOLUTION LEVELS.

Processing for the compressed data gives rise to the difficult problem of integrating and storing the voluminous measurements derived from the atmospheric phenomena. For those measurements dependent upon the compressive channels, the data-reduction procedure entails three steps:

- square-law detection of the contents of each frequency-resolution cell
- comparison of the detected signals with pre-determined thresholds
- accumulation of a count of threshold-crossings.

Consequently, the ultimate data output for each channel is the accumulated crossing count relative to the specified threshold over the 40-ms measurement period. Within this interval, each 100-KHz cell is sampled 4000 times (one sample/sweep) whereas each 2-MHz cell is sampled 80,000 times (20 samples/sweep). It can be shown from fundamental radiometric relationships that these many samples yield about 5.5 bits of precision for the 100-KHz resolution cells and somewhat more than 7.5 bits for the 2-MHz resolution cells. To accommodate these data, two approaches are being considered:

- for the high-resolution data, the compressive receiver output is time-multiplexed into thirty counters
- for the lower-resolution data, a combination of counters, adders and memory are used to accumulate the twenty-five counts.

For all channels, the data are transmitted serially to storage from shift registers.

PROTOTYPE MODEL

A prototype model has been built and delivered to the experimenters. The unit is based upon a communications specification, the details of which are given in Table 1.

Table 1

40 MHz Compressive Receiver Specification

Analysis Bandwidth	280-320 MHz
Frequency Resolution	30 KHz
Close in Sidelobes	-30 dB
Sensitivity	-95 dBm
Max Power Input	-10 dBm
Scan Analysis Time	40 μsec
Duty Cycle	100%

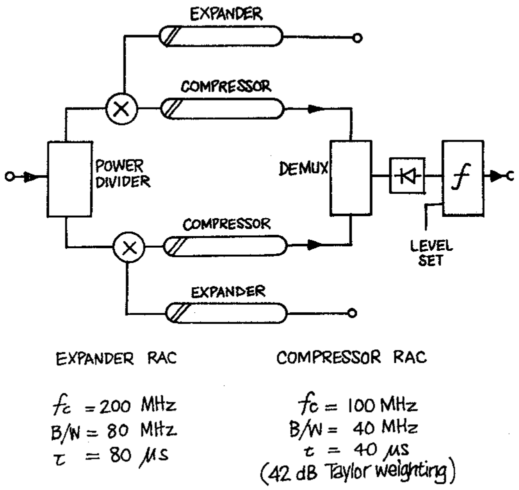

FIGURE 4. 40-MHz BANDWIDTH COMPRESSIVE RECEIVER.

The architecture for the receiver uses the (C)-M-C algorithm, with weighting incorporated into the convolving filter. A diagram of the receiver is shown in Figure 4.

The performance of this high-resolution unit is determined by the SAW expander and compressor. Reflective Array Compressors (RAC) are used, these devices being an etched grating on a lithium niobate substrate. The initial test results were fed back into the computer design to produce a correction mask of a semi-metalized aluminum area in the expander etch pattern. This procedure resulted in close-in sidelobes -35 dB below the main lobe of the compressed signal.

The intended application of this unit is for long-term analysis of noise-like signals which required very stable operation over a long period. Temperature stabilization is achieved by heating the SAW delay lines to an elevated temperature. Two time-interlaced expanders are used to give 100% coverage in the frequency-time domain. A digital integrator for the 1600 output frequency bins is being developed.

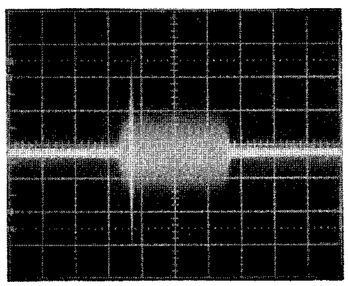

FIGURE 5. CW TONE BURIED 10 db IN WHITE NOISE

Figure 5 shows a 20 MHz bandwidth white noise signal with a CW tone in-band. The CW is actually 10 dB below the noise but because of the signal processing gain of the compressive receiver, it appears as an easily-identifiable compressed pulse. Figures 6 and 7 show, respectively, the passband characteristics of the expander and compressor RACs.

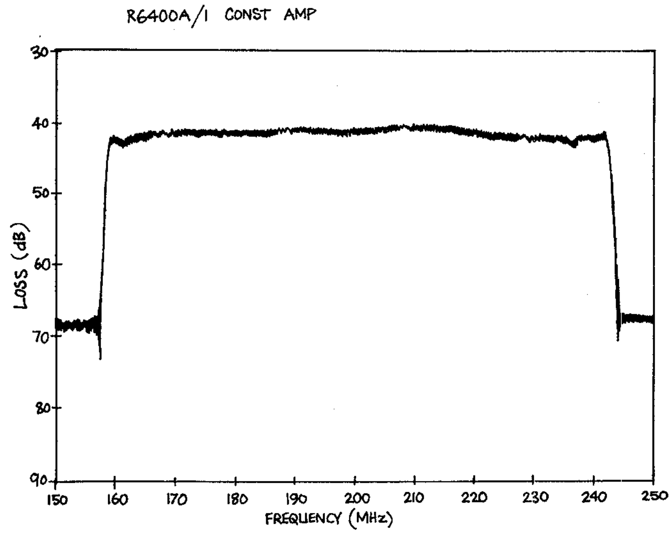

FIGURE 6. EXPANDER PASSBAND CHARACTERISTICS WITHOUT LIMITING.

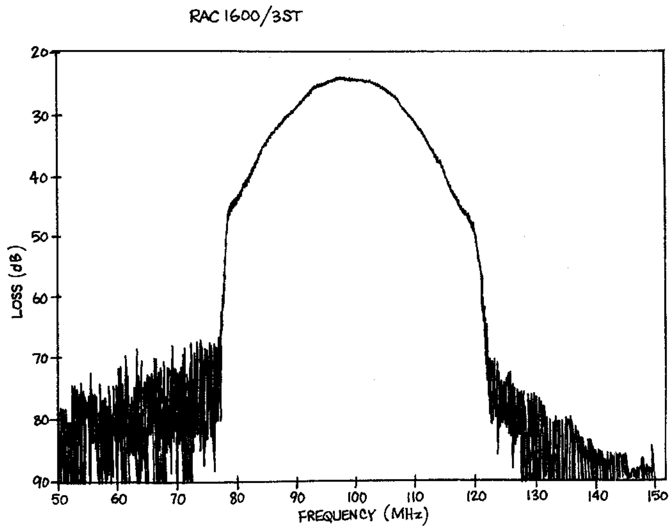

FIGURE 7. COMPRESSOR FILTER WITH TAYLOR WEIGHTING

CONCLUSIONS

A microwave radiometric spectrometer has been designed in which compressive receivers are used to channelize 210 of the total 245 required frequency resolution cells. Of these 210 cells, 125 have 2-MHz resolution and 90 have 100-KHz resolution. Each compressive receiver simultaneously accommodates twenty-five of the coarse-resolution channels and thirty of the fine. A prototype receiver has been delivered to the experimenters where it is currently being fitted with a digital output in preparation for preliminary testing.

ACKNOWLEDGEMENTS

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