feature in the elevation drive mechanism of the antenna.

FPS-90 (Fig. 13b and c). Coaxial magnetrons. The FPS-90 in figure 13c is distinctive because it exhibits an additional "hump" centered approximately 60 MHz below the fundamental. This characteristic of coaxial magnetrons has been noted, to a lesser extent, on other S-band coaxial magnetrons.

7. SPECTRA OF WEATHER RADARS

This section contains spectra of C-band and S-band weather radars using both conventional and coaxial magnetrons. There are three conventional magnetron spectra, one S-band and two C-band, and ten coaxial magnetron spectra included here. Two of the coaxial spectra (Figs, 15a and b) are measurements of the same radar and were included to show the spectral differences between the long and short transmitted pulse width. Figure 17 contains extended emission spectra of three different radars and illustrates the large amount of spectrum containing potential interference energy. Figures 17a and d are different radars with similar magnetrons and were measured across the frequency spectrum until the received signal level dropped below the measurement system noise level. Figures 17b and 17c are the same radar, measured twice, illustrating the effectiveness of a band reject filter installed to protect a selected portion of the spectrum (5950-6450 MHz).

An area of concern with coaxial magnetrons is the "hump" about 100 MHz (80 MHz, S-band) above the fundamental frequency. This hump is caused by a spurious oscillation mode in the' coaxial magnetron. It should be noted that the character of the emission changes significantly in this area, and that the particular measurement method which was used here overemphasized the average energy amplitude of the emission spectra for this region. For example, using a minimum measurement period of 0.5 s at each frequency, and a typical PRR of 260 pps, a measurement period at each frequency contained about 130 pulses. Over most of the frequency range each radar pulse produced about the same amount of energy, and it made no difference whether the peak power was measured from one pulse or from 130 pulses. In the "hump" region, however, there was a significant spread in the amount of energy from pulse to pulse, often as much as 20 dB. This spread was easily visible by observing the instantaneous video waveforms before they were processed by the peak detectors. Since the measured spectrum was determined by the peak amplitude of the highest pulse out of the 130 pulses at each frequency in the "hump" region (instead of the peak amplitude of the

average pulse for 130 pulses), the measurements emphasized the occasional high amplitude pulse. The intermittent nature of the high amplitude pulses is especially visible in the spectra of the WSR-74C. For purposes of comparison with the rest of the spectrum, it would be quite believable to suggest that the "hump" region should be reduced by as much as 10 dB. However, we do not have any more specific quantitative data to support this adjustment.

Measurement and analysis parameters, plus additional information about the radar spectra presented in this section, are listed in table 4.

WSR-57 (Fig. 14a). Conventional magnetron. The WSR-57 is an S-band weather radar using a conventional magnetron with 500 kW peak power for an effective range of 463 kilometers (250 nmi). It can be used to establish height, distance, density, and course of a storm area.

FPS-77 (Fig. 14b). Conventional magnetron. The FPS-77 is a C-band weather radar using a conventional magnetron with 350 kW peak power for an effective range of 370 kilometers (200 nmi). As noted with other conventional magnetrons, this radar does not meet the RSEC in the "porch" region.

FPS-77 (Fig. 14c). Conventional magnetron. This radar does not meet the RSEC in the "porch" region.

WSR-74S (Fig. 15a). Coaxial magnetron. The WSR-74S is an S-band weather radar using a coaxial magnetron. The National Weather Service 74C and 74S series weather-surveillance-radars (WSR) are essentially the same except for operating frequency. They are meteorological radars generally employed to establish cloud height, distance, density, rainfall (cm/hr), and position of a storm area for weather observation, storm warning, hydrology, airways weather briefing, and weather research. This spectrum and that of Figure 15b, are from the same radar. They are shown together here to illustrate the differences that occur when the transmitted pulse width is changed. This spectrum was made while the radar operated in the 4 us (nominal) pulse width mode.

WSR-74S (Fig. 15b). Coaxial magnetron. This spectrum and Figure 15a, are from the same radar. They are together here to illustrate the differences that occur when the transmitted pulse width is changed. This spectrum was made while the radar operated in the 1.15 us (nominal) pulse width mode.

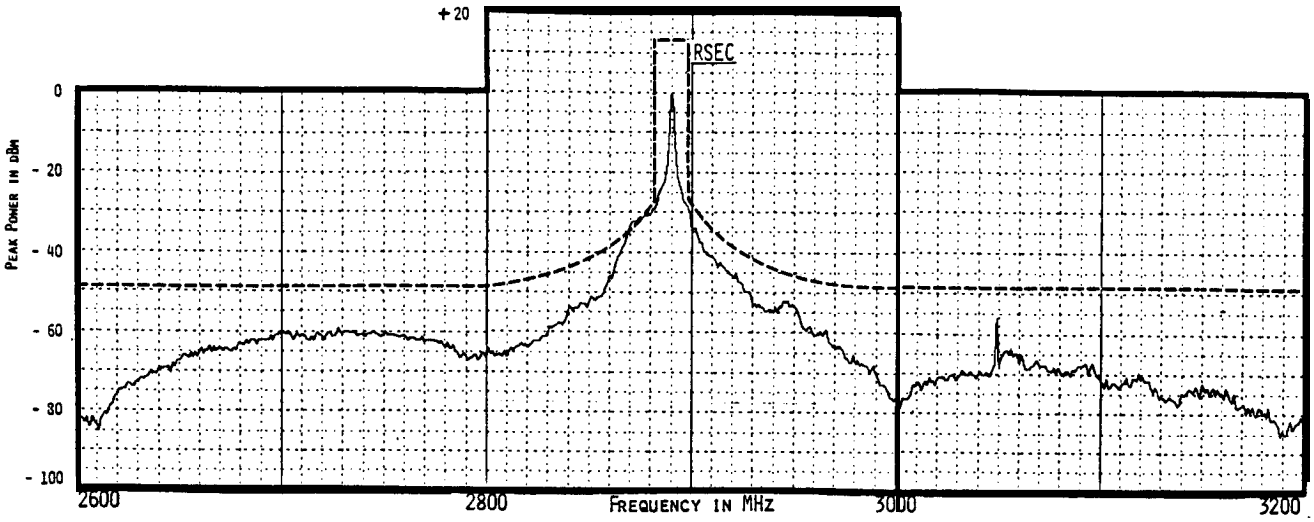
WSR-74S (Fig. 15c). Coaxial magnetron. This spectrum clearly illustrates the coaxial magnetron "hump" discussed at the beginning of this section.

WSR-74C (Fig. 16a). Coaxial magnetron. The WSR-74C is a C-band weather radar using a coaxial magnetron. This spectrum and Figures 16b and c, show the variability that occurs in the "hump" region, as discussed at the beginning of this section.

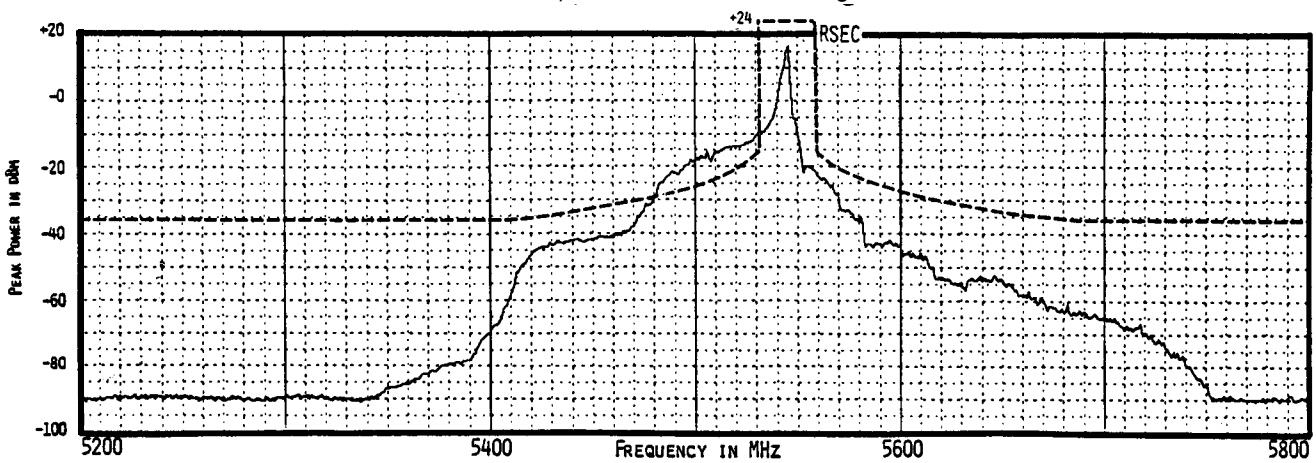
Table 4. Selected Operational and Measurement Parameters for Weather Radars

Radar Equipment	Amplifier Type	Operating Frequency (MHz)	Pulse Repetition Rate (pps)	Pulse Duration (μs)	Pulse Rise Time (ns)	Peak Power (dBm)	Measurement Bandwidth(s) (kHz)	Figure Number
WSR-57	Conventional Magnetron	2890 [M]	163 [M]	4.1 [M]	50 [M]	87 [G]	1000	14a
FPS-77	Conventional Magnetron	5545 [M]	323 [M]	2.3 [M]	30 [M]	85.5 [G]	1000	14b
FPS-77	Conventional Magnetron	5637 [M]	324 [M]	2.1 [E]	50 [E]	85.5 [E]	1000	14c
WSR-74S	Coaxial Magnetron	2890 [M]	259 [E]	4.3 [M]	300 [M]	84 [E]	1000	15a
WSR-74S	Coaxial Magnetron	2890 [M]	259 [E]	1.15 [E]	500 [E]	84 [E]	1000	15b
WSR-74S	Coaxial Magnetron	2848 [M]	259 [E]	4.3 [M]	150 [E]	84 [E]	1000	15c
WSR-74C	Coaxial Magnetron	5623 [M]	259 [M]	3.3 [M]	36 [M]	84 [E]	1000	16a
WSR-74C	Coaxial Magnetron	5622 [M]	259 [E]	3.3 [M]	30 [M]	84 [E]	1000	16b
WSR-74C	Coaxial Magnetron	5608 [M]	259 [E]	3.3 [M]	33 [M]	84 [E]	1000	16c
WSR-74C	Coaxial Magnetron	5627 [M]	299 [M]	3.25 [M]	50 [M]	84 [G]	1000	17a
WSR-74C	Coaxial Magnetron	5629 [M]	259 [E]	3.3 [E]	40 [E]	84 [E]	1000	17b
WSR-74C	Coaxial Magnetron	5627 [M]	259 [E]	3.3 [E]	40 [E]	84 [E]	1000	17c
WR100-2/77	Coaxial Magnetron	5570 [M]	254 [M]	2.1 [M]	40 [M]	84 [M]	1000	17d

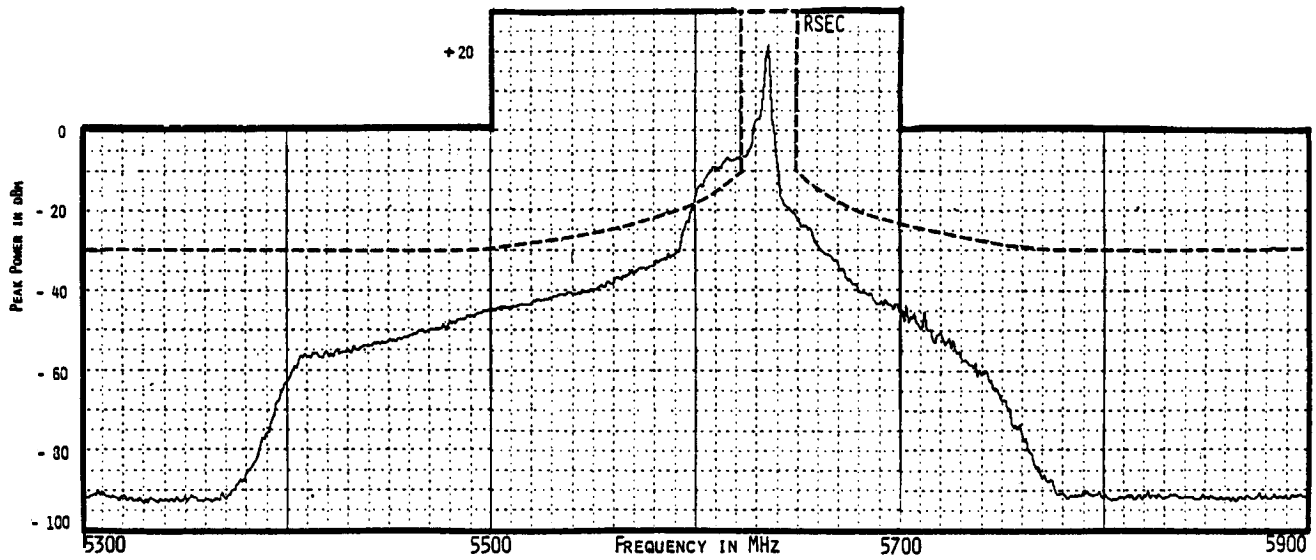
[M] - Measured
[E] - Estimated
[G] - From Government Master File



a. WSR-57, conventional magnetron.

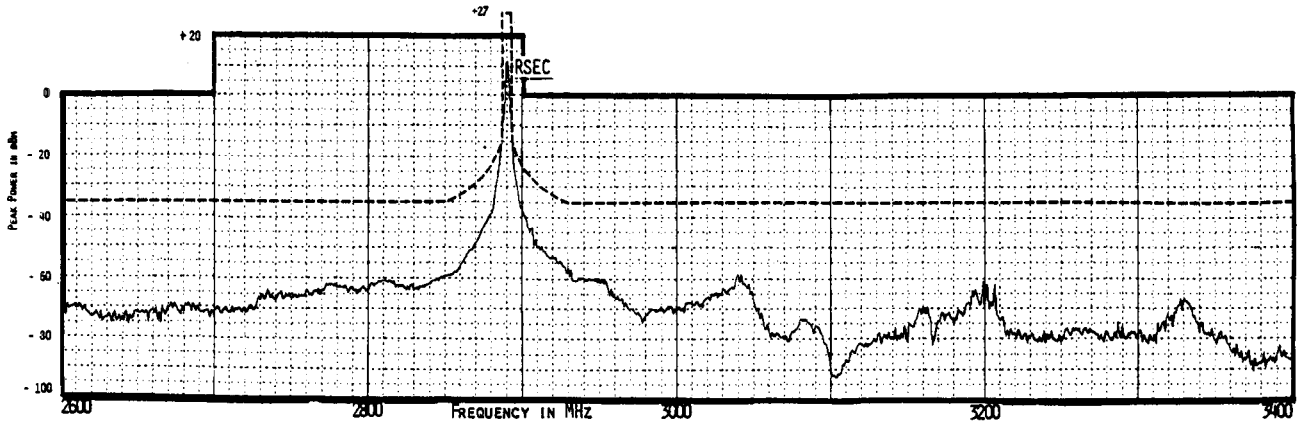


b. FPS-77, conventional magnetron.

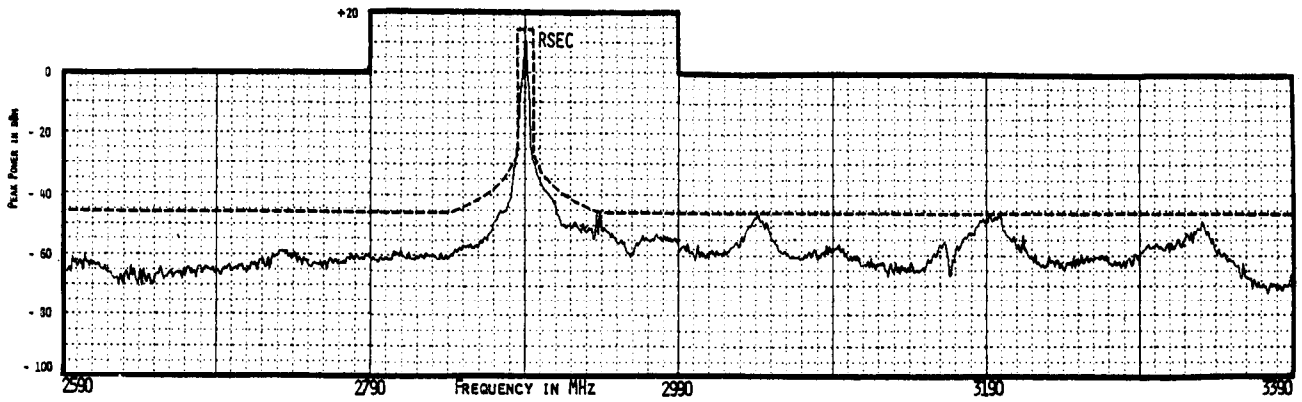


c. FPS-77, conventional magnetron.

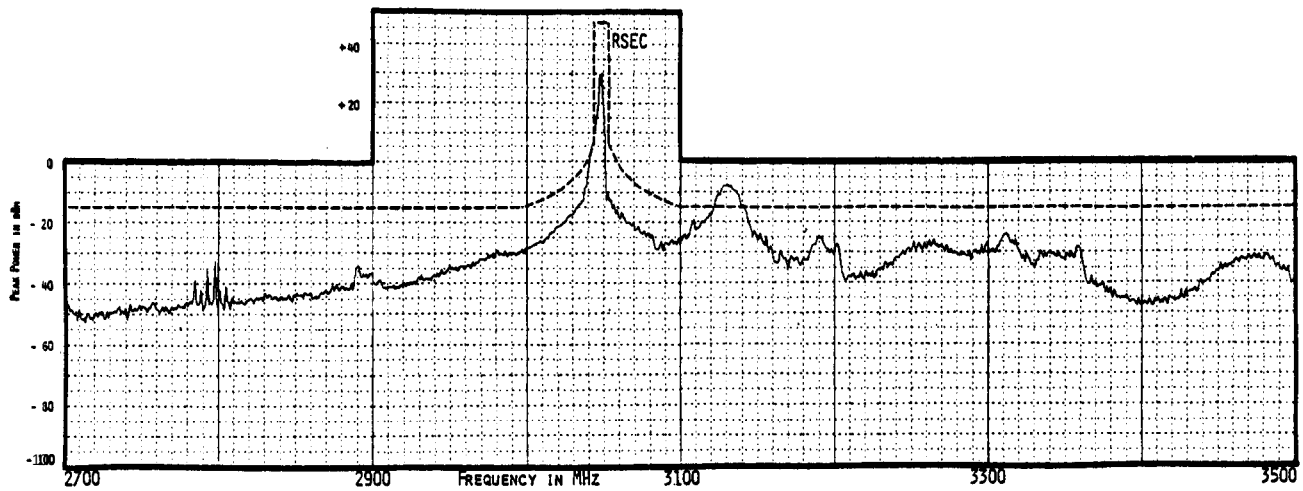
Figure 14. Weather radars, WSR-57, FPS-77.



a. WSR-74S, coaxial magnetron (long pulse width).



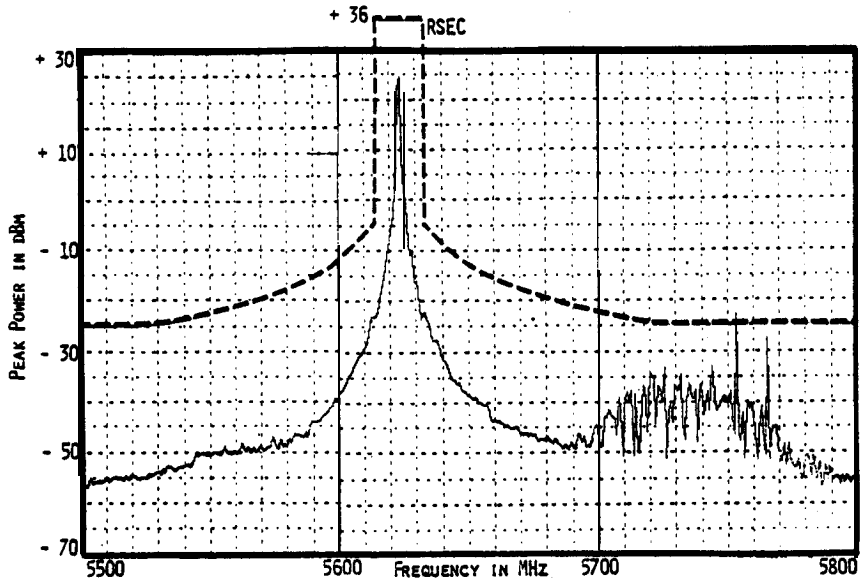
b. WSR-74S, coaxial magnetron (short pulse width).



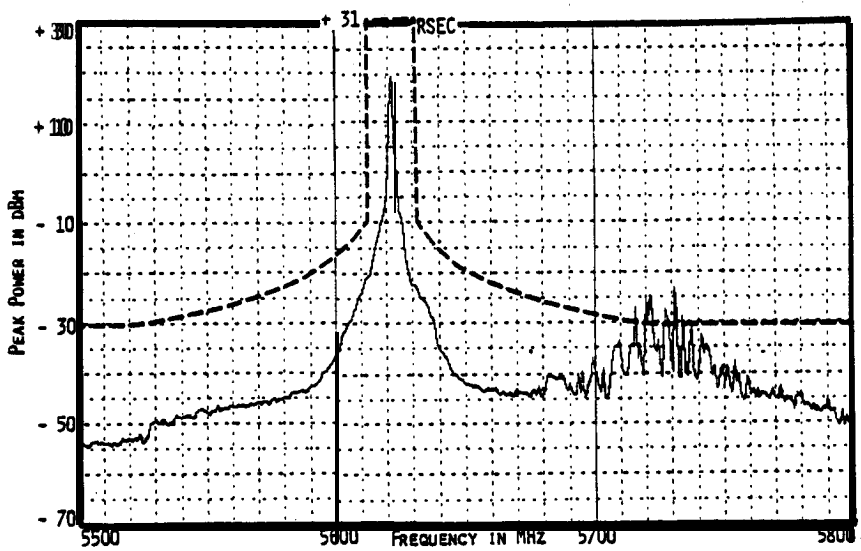
c. WSR-74S, coaxial magnetron.

Figure 15. Weather Radars, WSR-74S.

a. WSR-74C coaxial magnetron.



b. WSR-74C, coaxial magnetron.



c, WSR-74C, coaxial magnetron (measurement error at 5733 MHz).

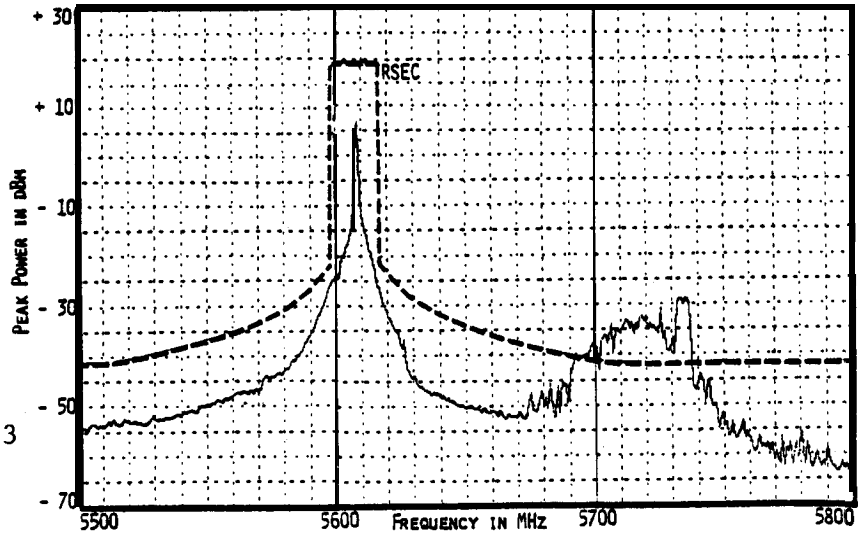
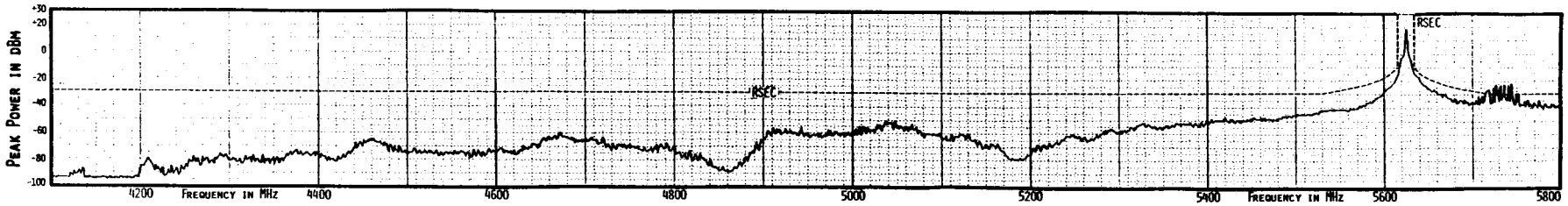
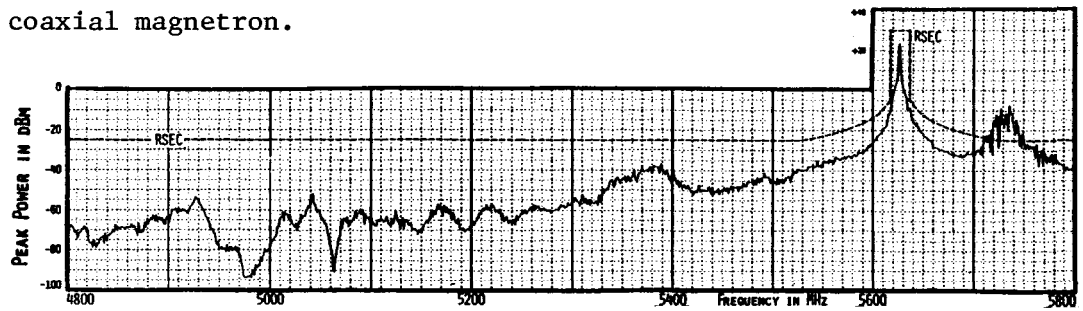


Figure 16. Weather radars, WSR-74C.

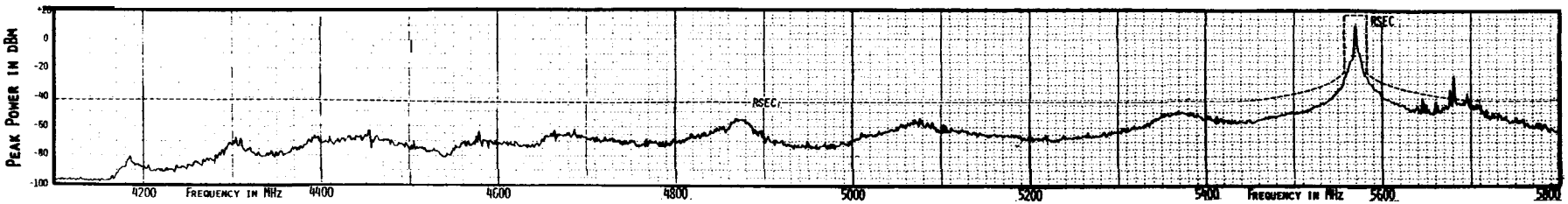


a. WSR-74C, coaxial magnetron.

b. WSR-74C, coaxial magnetron.

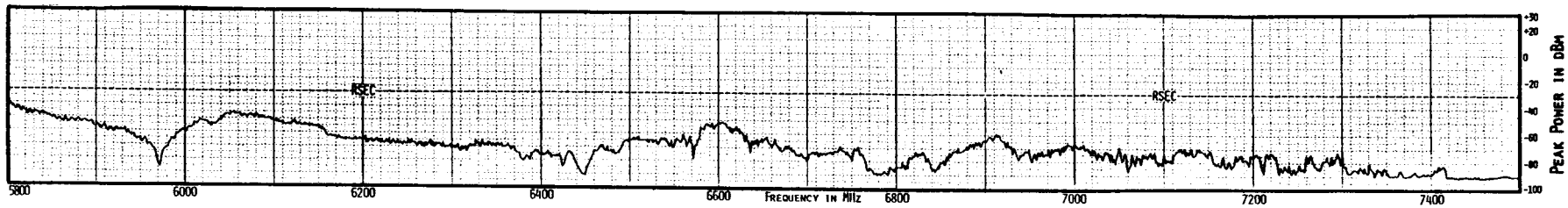


c. WSR-74C, coaxial magnetron, with band reject filter (5950-6450 MHz).

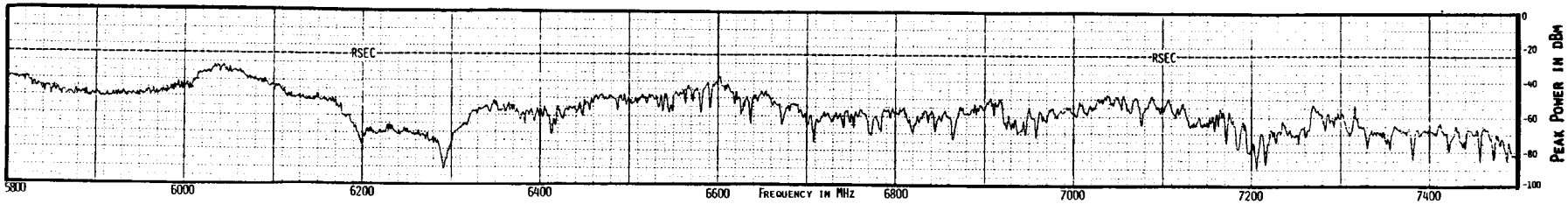


d. WR 100-2/77, coaxial magnetron.

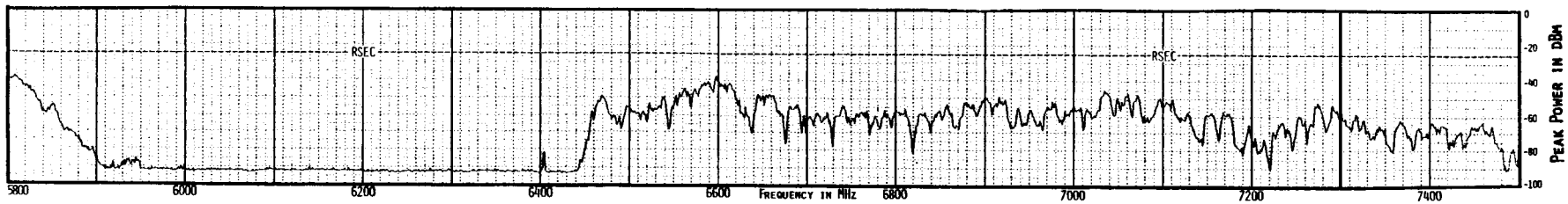
Figure 17. Weather radars, WSR-74C, WR 100-2/77.



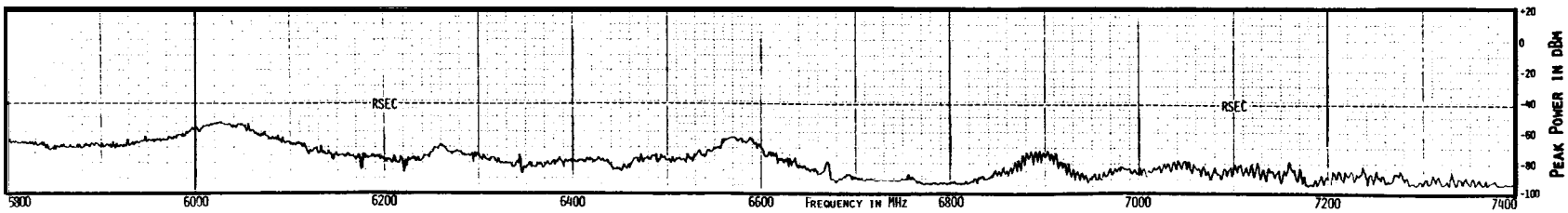
a. WSR-74C (continued).



b. WSR-74C (continued).



c. WSR-74C, with filter (continued).



d. WR 100-2/77 (continued).

Figure 17. Weather radars (continued).

The radars had all been recently installed and are presumed to have been identical in all respects.

WSR-74C (Figs. 16b and c). Coaxial magnetrons. A measurement error (fig. 16c) occurred at 5732 MHz causing the 5 MHz wide peak in that region.

WSR-74C (Fig. 17a). Coaxial magnetron. This extended radar spectrum of a C-band weather radar was continued until the received signal level dropped below the measurement system noise level.

WSR-74C (Fig. 17b). Coaxial magnetron. This figure and figure 17C, following, illustrate the same radar measured with (figure 17b) and without (figure 17c) a band reject filter at 6200 MHz.

WSR-74C (Fig. 17c). Coaxial magnetron. A feature of this spectrum is the attenuation of the radar emission over 5950-6450 MHz, resulting from use of a special filter designed to protect a local microwave link. Comparing this spectrum with Figure 17b illustrates the effectiveness of using filters to protect collocated users of the frequency spectrum.

WR100-2/77 (Figure 17d). Coaxial magnetron. This C-band weather radar is operated by a local television station, and is described by the manufacturer as being essentially the same as a WSR-74C. The extended spectrum was made in full cooperation with the television station personnel and spectrum data collection was continued until the signal level fell below the measurement system noise level.

8. CONCLUSIONS

Different types of radar output tubes vary markedly in the amount of spectrum they “consume” in normal operation. In many cases, much more spectrum is used than is needed for proper radar operation. The extra spectrum is consumed by spurious sidebands produced by radar output tube operation. The amplitrons and twystrons are particularly “dirty” and generally do not meet the RSEC limits used in this report. On the other hand, they can produce high-power, frequency-agile outputs with high efficiency in a small package. Bandpass filters can be used to reduce out-of-band emissions, but this could hamper frequency agility in some operations.

Klystrons produce very clean spectra. When klystrons are combined with narrowband diplexers, the spectra are improved even more. The rapid fall-off and the deep suppression of sidebands make it possible to site radars closer together in frequency and space than would be possible with other types of output tubes. Klystrons, however, are large and expensive and possibly best suited