The data in the emission spectra measurements must be converted to power density (dBm/kHz) before the measurements can be compared to the RSEC. Since the RSEC is in relative terms (sidebands must be suppressed a certain number of dB below the power level at the fundamental frequency), it might seem reasonable to apply the RSEC directly to the measured and graphed emission spectra. This may be incorrect, however, if the radar is measured with bandwidths larger than l/t, because the peak detector operates on a different pulse shape at the fundamental than it does at the sidebands.

The net result of this phenomenon is that the peak energy in the sidebands is sometimes measured several decibels too high compared to the energy measured at the fundamental frequency.

The RSEC limits are shown as dashed lines on the emission spectra presented in sections 4, 5, 6, and 7. Additional information concerning the RSEC selection and computation is contained in the Appendix. Values from tables 1 through 4 were used to compute the RSEC for all of the radar spectra presented.

It should be noted that some of the parameters in the tables were not obtained by direct measurements on the listed radar. Logistic and time constraints did not permit the RSMS crew opportunities to make all of the measurements at every radar site. In the tables, wherever a measured parameter is required, a code letter from the following list is used to indicate where the value was obtained.

CODE

M	-	Measured by RSMS personnel
E	-	Estimated from best data available (radar operators or maintenance personnel, Radar Standards Handbook, etc.)
G	-	Government Master File (GMF) listings.

4. SPECTRA OF S-BAND SURVEILLANCE RADARS

The S-band surveillance radars represent the largest population of fixed radars in the United States. They are the primary users of the crowded 2700-2900 MHz band, and are the radars typically seen at most large airports and military air bases.

In this section are several spectra of older airport surveillance radars (ASR'S) using conventional magnetrons and one example of a more recent ASR using a klystron amplifier. Also included in this section is one example of a military tactical 3D surveillance radar. Note that, except for the GPN-20, all of the radars using a conventional magnetron exhibit the characteristic "porch", on

the lower side of the fundamental frequency, caused by frequency-pulling at the leading and trailing edges of the transmitted pulse. Although the "porches" of the FPN-47, ASR-5, and TPN-19 radars tend to exceed the reference RSEC, these radars' sideband frequencies are relatively well suppressed. The CPN-4, on the other hand, tends to exceed the RSEC over its entire frequency range. One factor which is, unfortunately, not known is the extent to which tube aging may be a factor in these differences. The CPN-4 was an older radar and was measured at a relatively inactive Naval Air Station where it was operated only occasionally by military reserve units.

The GPN-20 also uses conventional magnetrons, but additionally uses a diplexer filter for two-channel operation. The most recent ASR illustrated in this section is the ASR-8. It uses a klystron amplifier and a diplexer filter, and provides the cleanest spectrum of all the ASR'S. The TPN-19, GPN-20, and the. ASR-8 are modern ASR'S which transmit on two frequencies simultaneously to give more protection against an effect called "target scintillation", whereby an echo from a target can occasionally disappear at a particular frequency. There is less likelihood of simultaneous disappearance at two frequencies. Frequency diversity operation gives a small improvement in detection range, and an improvement in probability of detection equivalent to a 3-5 dB increase in transmitter power.

The TPS-43E is included in this section to show the influence it may have on the crowded 2700-2900 MHz band and also to provide an example of the twystron (TWT/klystron) amplifier. The TPS-43E measured was under operational constraints not to transmit all sixteen channels at one time, and--in fact--many channels had not recently been used and were not peaked up for the measurements. To provide a representative example, however, measurements were made on all channels individually and graphically combined. An extended spectrum of the radar operating on only channel 1 is also included.

Measurement and analysis parameters, plus additional information about the radar spectra presented in this section, are listed in table 1.

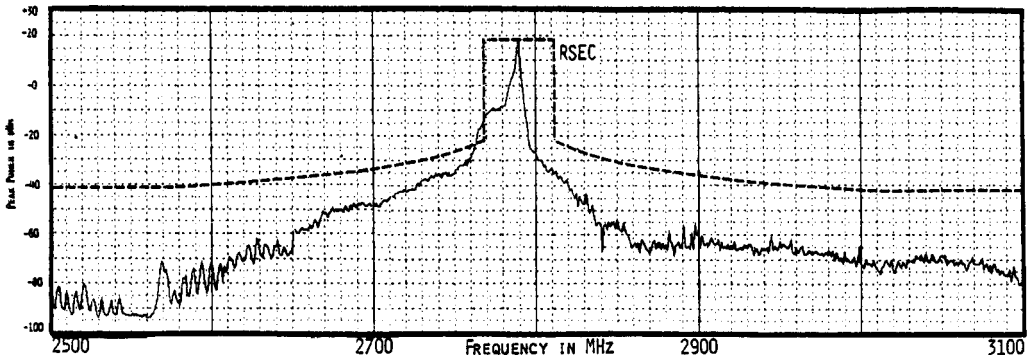
ASR-5 (Fig. 2a). The ASR-5 is an older FAA two-dimensional, medium-range (lllkm, 60nmi), S-band airport-surveillance radar with a conventional magnetron. It is also used at military airfields where it is designated as an FPN-47/55.

CPN-4 (Fig. 2b). The CPN-4 is an older, self-contained, mobile ground-control-approach (GCA) radar that functions as an Air Traffic Control Central for landing aircraft during periods of reduced visibility. The search (surveil-, lance) portion is a medium range (56 km, 30 nmi), S-band (2700-2900 MHz) radar with a

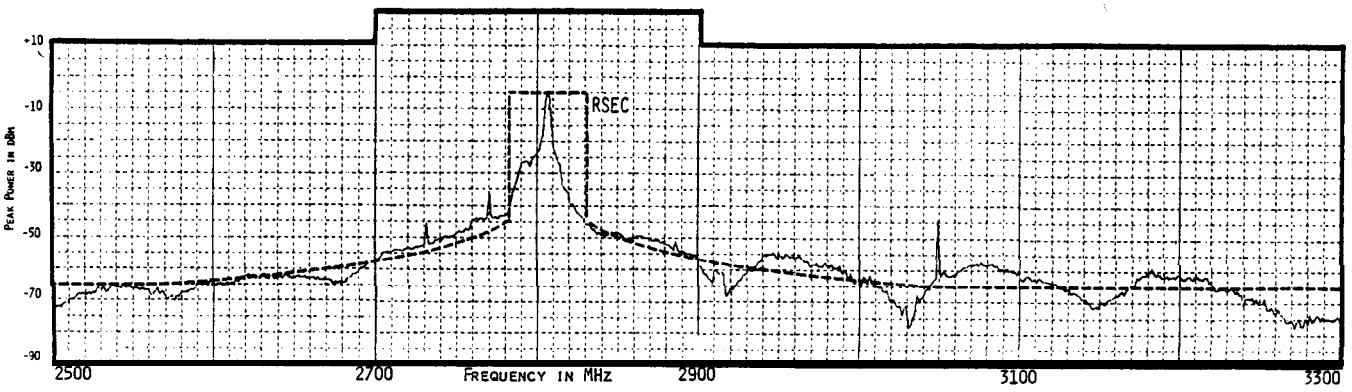
Table 1. Selected Operational and Measurement Parameters for S-band Surveillance Radars

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
FPN-47 (Channel A)	Conventional Magnetron	2800 [M]	1142 [M]	0.96 [M]	90 [M]	86 [G]	1000	4a
FPN-47 (Channel B)	Conventional Magnetron	2813 [M]	1142 [M]	0.92 [M]	80 [M]	86 [G]	1000	4b
GPN-20 (Channel A)	Conventional Mag. (Filtered)	2885 [M]	1000 [E]	1 [E]	100 [E]	87 [E]	1000	3a
GPN-20 (Channel B)	Conventional Mag. (Filtered)	2808 [M]	1000 [E]	1 [M]	100 [M]	87 [E]	1000	3a
TPN-19 (Channel A)	Conventional Magnetron	2827 [M]	1050 [E]	1 [E]	150 [E]	87 [E]	1000	3b
TPN-19 (Channel B)	Conventional Magnetron	2719 [M]	1050 [E]	1 [E]	150 [E]	87 [E]	1000	3b
ASR-5	Conventional Magnetron	2790 [M]	1130 [M]	1.02 [M]	30 [M]	89 [G]	1000	2a
CPN-4A	Conventional Magnetron	2807 [M]	1200 [M]	0.5 [G]	50 [E]	88 [G]	1500	2b
ASR-8 (Channel A)	Klystron	2885 [M]	1008 [M]	0.69 [E]	100 [E]	90.5 [G]	3000	5
ASR-8 (Channel B)	Klystron	2825 [M]	1008 [M]	0.69 [M]	100 [M]	90.5 [G]	3000	5
TPS-43E	Twystron	2902 [M]	250 [M]	5.6 [E]	500 [E]	94.5 [E]	300	6

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



a. ASR-5, conventional magnetron.



b. CPN-4, conventional magnetron.

Figure 2. Airport surveillance radars, ASR-5, CPN-4.

conventional magnetron.

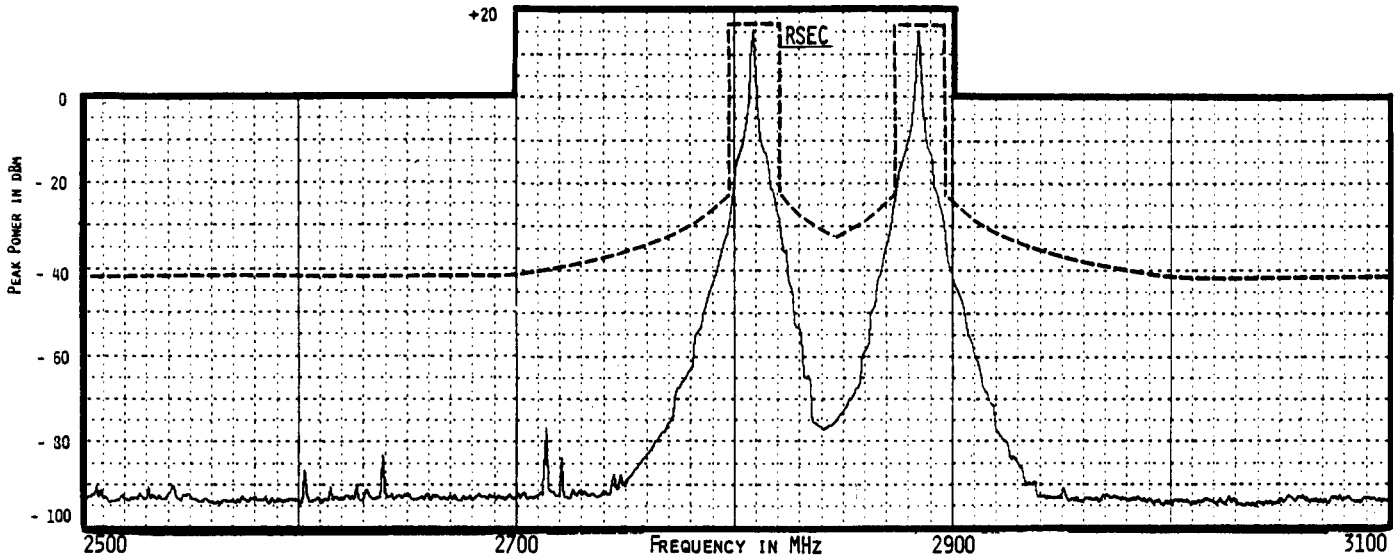
GPN-20 (Fig. 3a). The GPN-20 is a modern Air Force S-band two dimensional radar used for airport surveillance, It is essentially identical to the ASR-8, but uses conventional magnetrons instead of klystrons. The radar is normally used in the diplex mode with the two center frequencies 70 to 90 MHz apart. The diplexer's narrow band pass characteristic substantially reduces the sidebands from the conventional magnetrons, and the resulting spectrum falls off very rapidly. The range is 111 kilometers (60 nautical miles) using 500 kW peak power. The radar is used in conjunction with an integrated Precision-Approach-Radar (PAR) .

TPN-19 (Fig. 3b). The TPN-19 Air Traffic Control (ATC) system consists of a TPN-24, S-band, airport surveillance radar and a TPN-25, X-band, precision approach radar. The TPN-24 (measured) is a two-dimensional ASR using conventional magnetrons. Unlike the GPN-20, however, the TPN-19 does not use a narrowband diplexer to combine the two channels, but uses a broadband diplexer with a notch at the frequency of the other channel. This configuration does not provide the extra rejection of magnetron sidebands, and the TPN-19 output spectrum is that of a conventional magnetron. The system is often used as a temporary replacement while a permanent system is being installed. The range is 111 km (60 nmi), transmitting 450 kW using a magnetron in a diplex mode. Stacked horns are used to shape a vertical fan beam (about 20°) without resorting to extra antenna height.

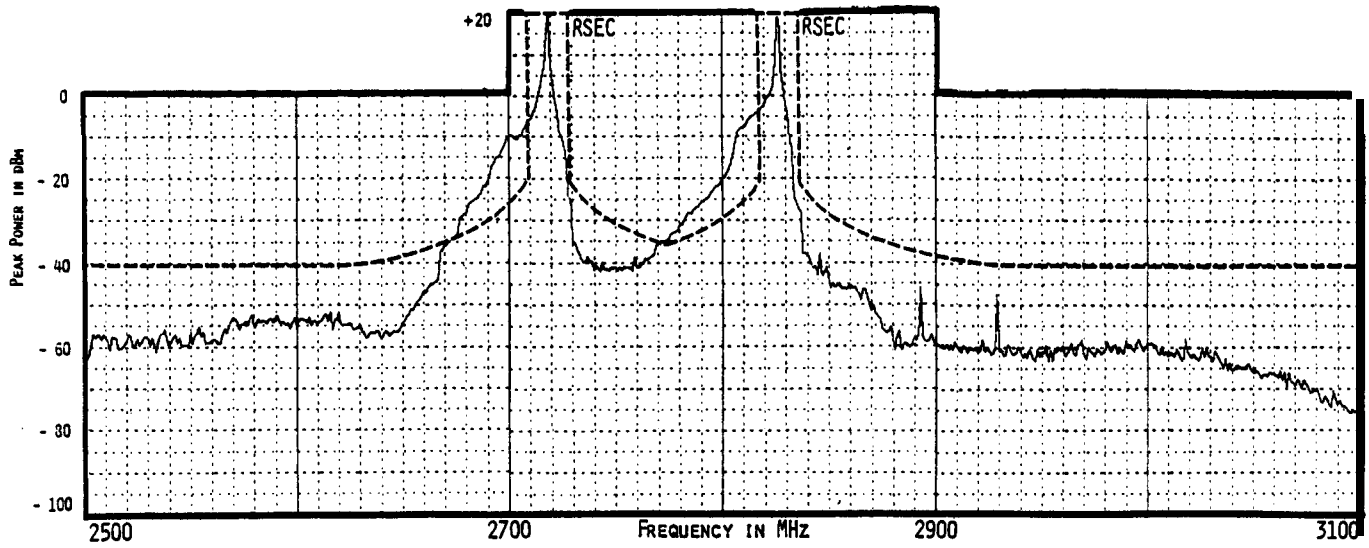
FPN-47 (Fig. 4). The FPN-47 is an Air Force S-band two-dimensional radar (same as FAA's ASR-5) used for airport surveillance and is a part of an air traffic control system. The range is 111 kilometers (60 nmi) using 400 kW peak power. Similar military radars are the FPN-51, and the FPN-55. Channels A and B are shown separately to illustrate substantial differences between channels. Measurement system noise is at -94 dBm, shown as a relatively straight line near the lower frequency end of the displayed spectrum.

ASR-8 (Fig. 5). The ASR-8 is a recent FAA air traffic control two-dimensional, medium range 111 kilometers (60 nmi) S-band airport-surveillance radar using two klystron amplifiers each transmitting 1 MW in a diplex mode. The radar has an exceptionally clean spectrum due to the use of klystrons and the narrowband diplexer filter. Other measurements, not shown here, indicate that the diplexer characteristics provide significant improvement to the klystron output sidebands.

TPS-43E (Fig. 6). The TPS-43E is an Air Force 3-D, stacked-beam, surveillance radar and is air and ground transportable. The range of the TPS-43E is

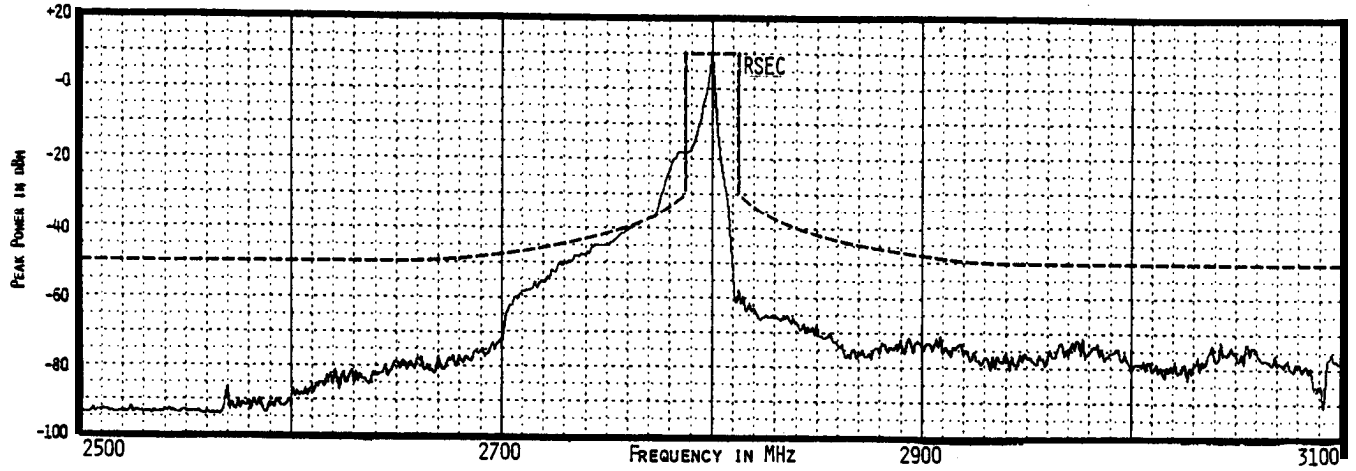


a. GPN-20, conventional magnetron, diplexer filtered.

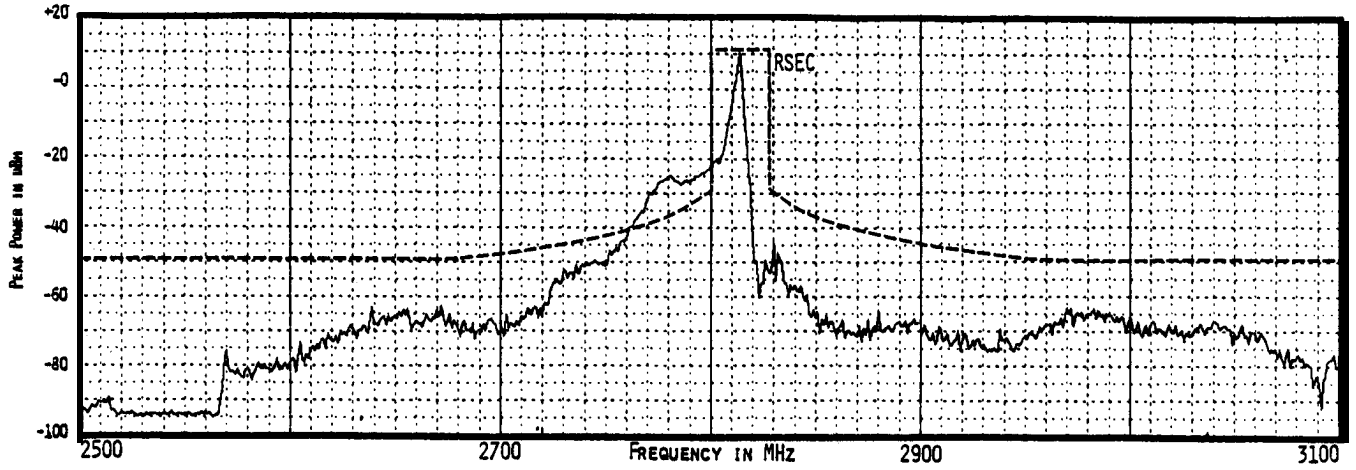


b. TPN-19, conventional magnetron.

Figure 3. Airport surveillance radars, GPN-20, TPN-19.



a. FPN-47 (Ch. A), conventional magnetron.



b. FPN-47 (Ch. B), conventional magnetron.

Figure 4. Airport surveillance radar, FPN-47.

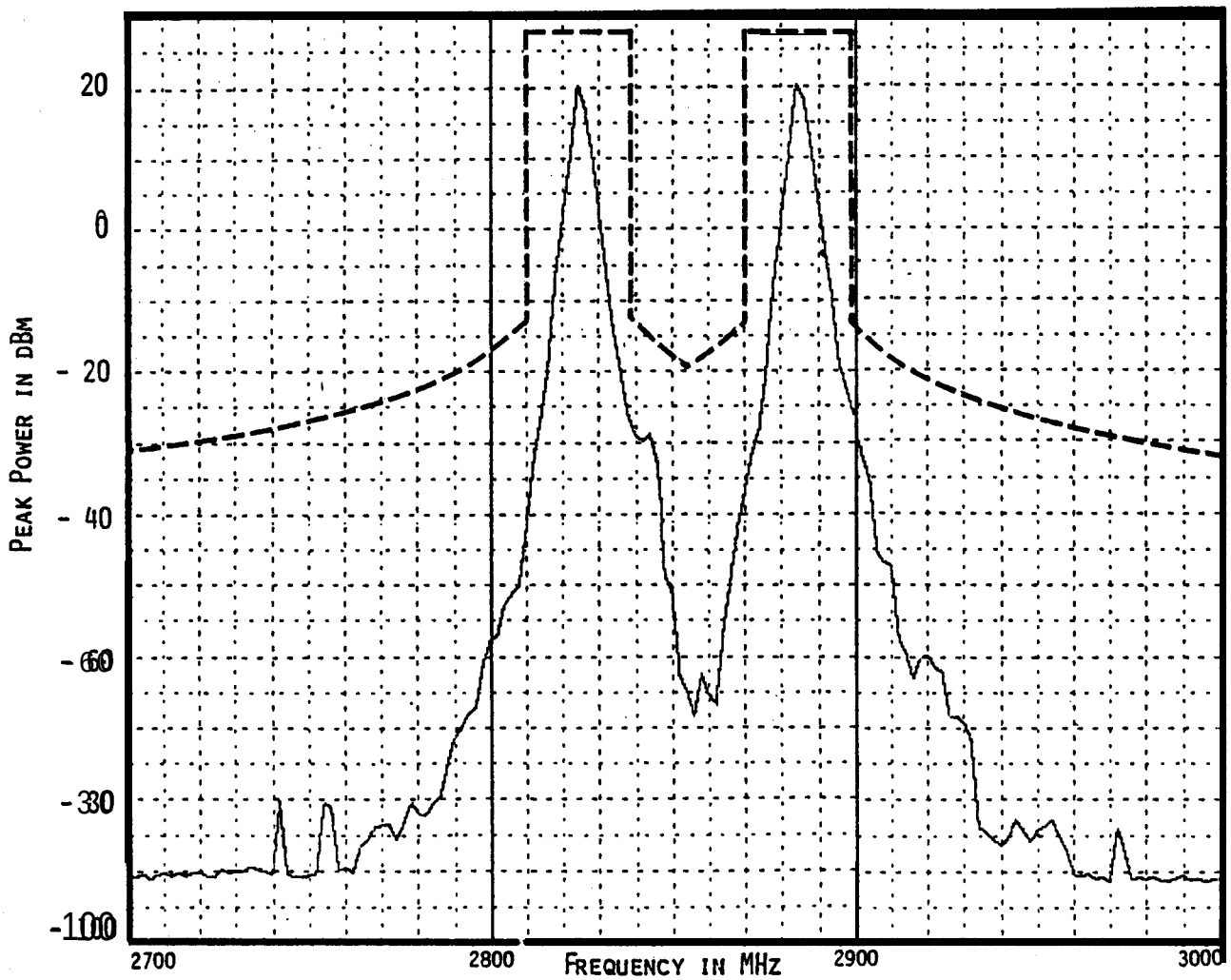
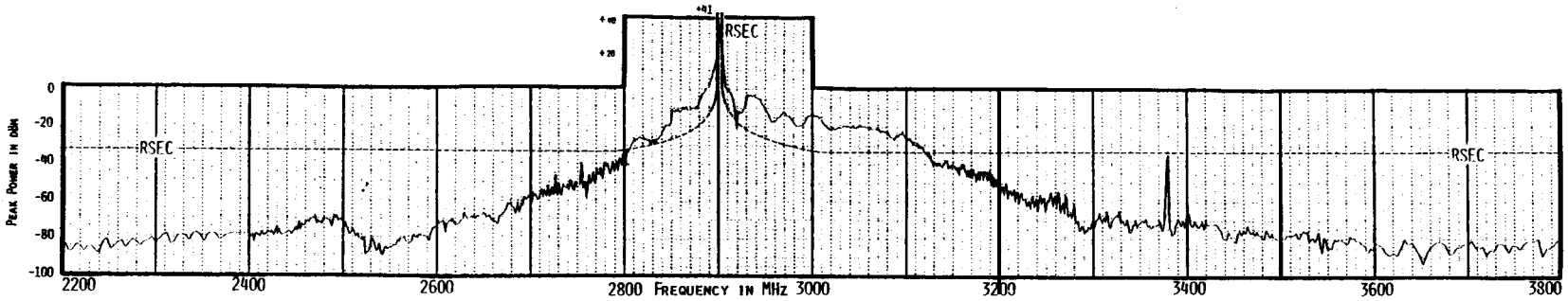
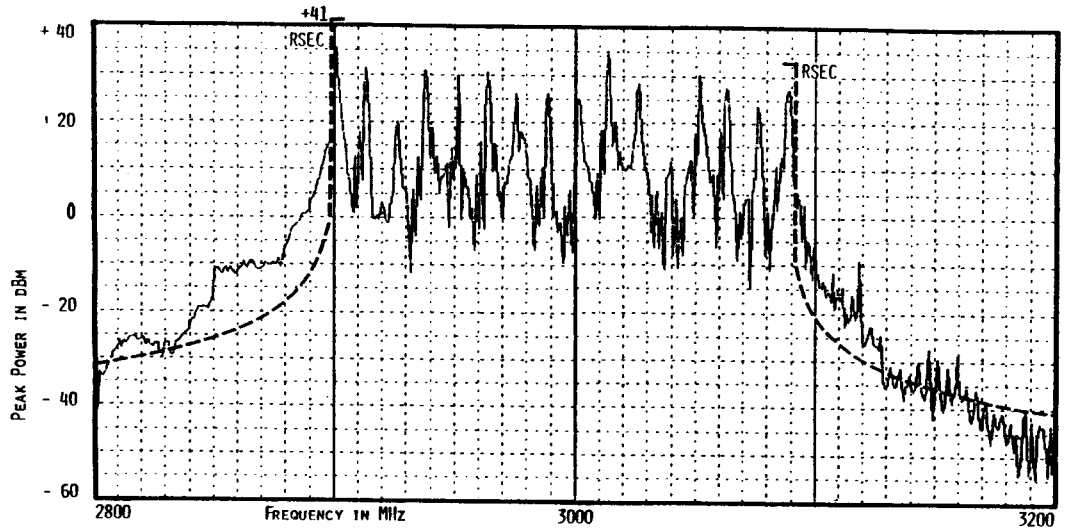


Figure 5. Airport surveillance radar, ASR-8, Klystron, diplexer filtered (Ch. A-2884 MHz, Ch. B-2824 MHz).



a. Extended spectrum, channel 1 only.



b. Detailed spectrum, all 16 channels.

Figure 6. TPS-43E, twystron, long-range tactical radar.

481 kilometers (260 nmi), transmitting 4 MW using a linear beam twystron. The transmitter control can select any one of 16 frequencies in the range from 2900 to 3100 MHz. It can operate on six different PRR's; the average PRR is 250 Hz using a 6.5 us pulse. The antenna uses six stacked feed horns to determine target height. The TPS-43E is designed for simultaneous long range search and height finding. The radar system is highly mobile and effective in severe weather and/or jamming environments. The radar uses Barker Phase Coded pulses to increase range accuracy and resolution. Pulse-to-pulse frequency diversity is used to decrease vulnerability to jamming. Figure 6a is an extended spectrum of the TPS-43E operating on only one channel. The measured response at 3380 MHz is an emission from the radar. Figure 6b is a graphically created composite produced by using an individual spectrum of each channel. A spectrum illustrating actual operation of all 16 channels could not be made because of operational constraints on the radar.

5. SPECTRA OF L-BAND LONG RANGE RADARS

The radars in this section are all used for long range detection (185 to 555 kilometers, or 100 to 300 nautical miles). Generally, they are used by the FAA for air route surveillance between air traffic control areas and by the military as part of the air defense early warning system. Near U.S. borders these radars are usually cosited with a long range height-finding radar such as the FPS-90. Often the AF and FAA maintain joint surveillance sites (JSS) to satisfy both responsibilities.

Measurement and analysis parameters, plus additional information about the radar spectra presented in this section, are listed in table 2.

ARSR-1E (Fig. 7a). The ARSR-lE is an FAA two dimensional L-band (1215-1400 MHz) air-route-surveillance radar (ARSR) with a conventional magnetron feeding 400 kW peak power into an amplitron (crossed-field amplifier) to provide an additional 10 dB gain. The amplitron may be switched in or out as required by the operator. Amplitrons are characterized by a very wide noise floor only 40-60 dB below the fundamental. In many ARSR'S, including this one, a bandpass filter has been used to reduce the spurious sidebands outside the 1220-1380 MHz range.

ARSR-1E (Fig. 7b). This ARSR-lE does not use the 1220-1380 MHz bandpass filter often installed with ARSR-lE'S to reduce energy radiated by the crossed-field amplifier (amplitron) outside the frequency of operation. Above 1500 MHz, 7 dB should be added to the measured values to correct for a missing