Magnetron developments and practical problems relating to the ITU-R recommendation SM1541 and the proposed design objective for future radar systems.

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Introduction

This short paper is intended to assist the JRG working group by providing relevant information on typical magnetron emissions and recent improvements in magnetron technology.

As ITU-R recommendation SM1541 has been approved with effect from Jan 1st 2003, there may be an assumption that all existing radar systems can satisfy the mask given in Annex 8.

In practice many current magnetron based radar systems operating in the bands allocated on an exclusive basis to the radiodetermination service actually do not achieve the calculated B_{-40} (40dB spectrum bandwidth) or the 20dB/decade roll-off as defined in the current mask and quite difficult engineering issues still need to be addressed.

These practical issues are of particular concern in mobile radar systems and those that are required to operate at short pulse (< 0.25uS) e.g. marine and airborne radar systems and short pulse high definition radar systems.

It may prove necessary to exclude such radar systems from tighter regulation in the future.

Practical Examples

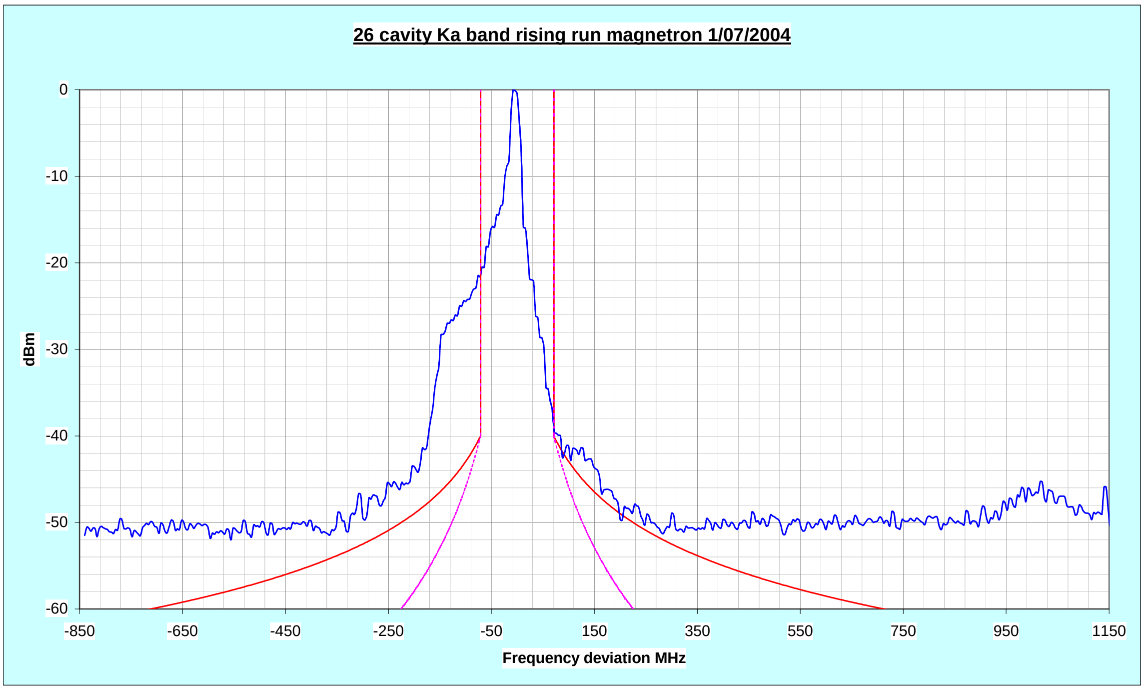
Rising Sun Magnetrons

Rising sun magnetrons are chosen for their short pulse capability and are ideally suited to high frequency applications where modern cathode technology has brought long lives.

Fig 1 shows a "snapshot" of the close-in emission spectrum of a typical frequency agile Ka band rising sun magnetron used at short pulse (<100 nS) in an established high definition radar system. The data is overlaid with the current SM1541 mask and also the proposed design objective. Although the measurement noise floor is only at –50dB it is clear that both the B_{-40} and the 20dB/decade roll-off represent a significant engineering challenge. Some improvement in 40dB bandwidth may be possible by drive pulse shaping but the plot illustrates the general difficulties of meeting the existing limits of SM1541 in high definition radar systems that are required to operate at short pulse widths in order to fulfil their mission.

Fig 1 Emission spectrum of Ka band frequency agile magnetron with rising sun anode

Measured at the magnetron flange

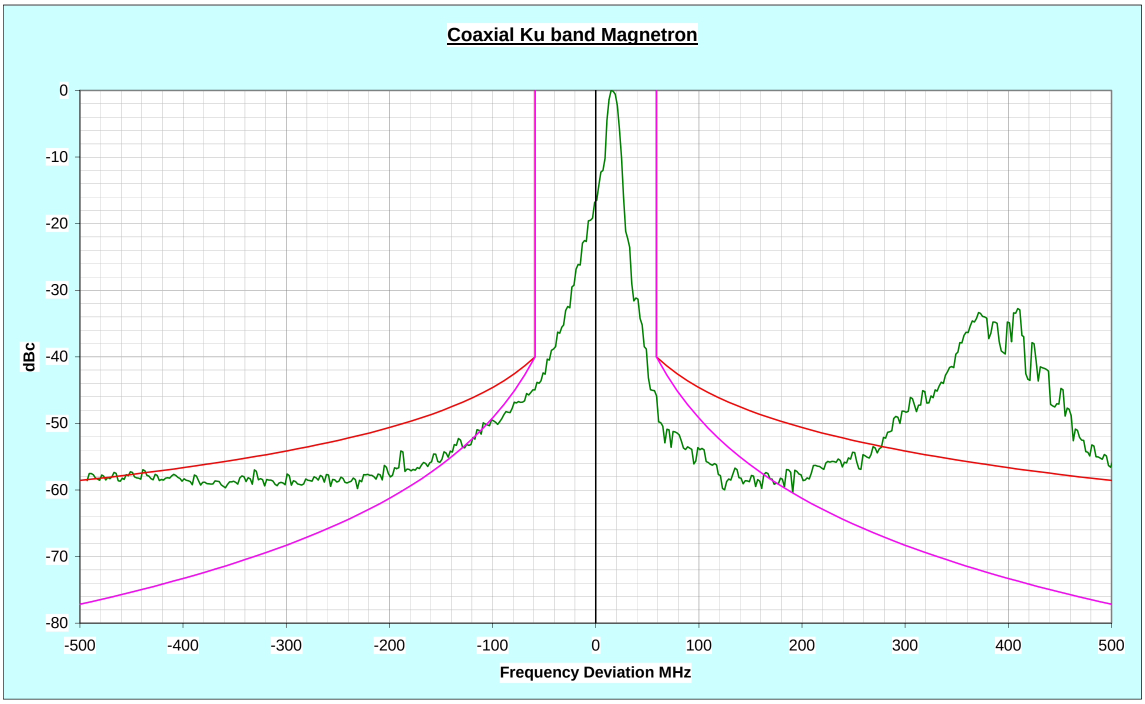


Coaxial Magnetrons

Fig 2 shows a "snapshot" of the close-in emission spectrum of a typical frequency agile coaxial magnetron running in Ku band at short pulse (<250nS). The calculated B_{-40} bandwidth is achieved but the plot clearly illustrates the difficulties faced by the magnetron designer in suppressing the unwanted TE121 mode. This mode always lies close to the fundamental in such devices owing to the large number of resonators and generally lies within the OOB domain.

Fig 2 Emission spectrum of Ku band frequency agile coaxial magnetron

Measured at the magnetron flange



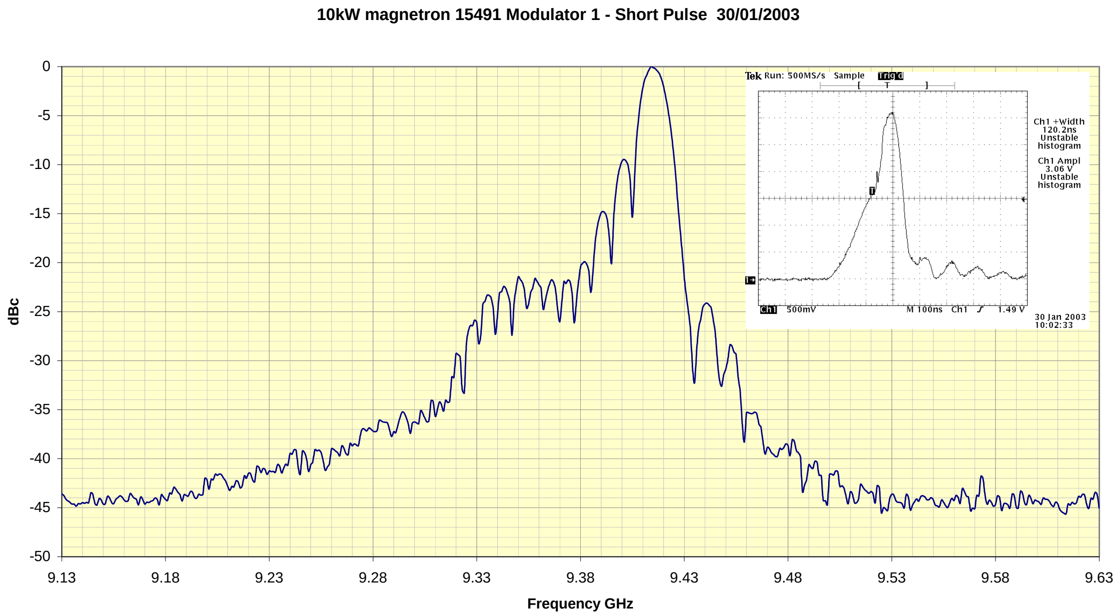
Strapped Vane Magnetrons

Strapped vane magnetrons are the most widely used magnetron types as they are low cost, small, light, and easy to drive. They offer good short pulse performance and can achieve a long operational life with modern cathode technology.

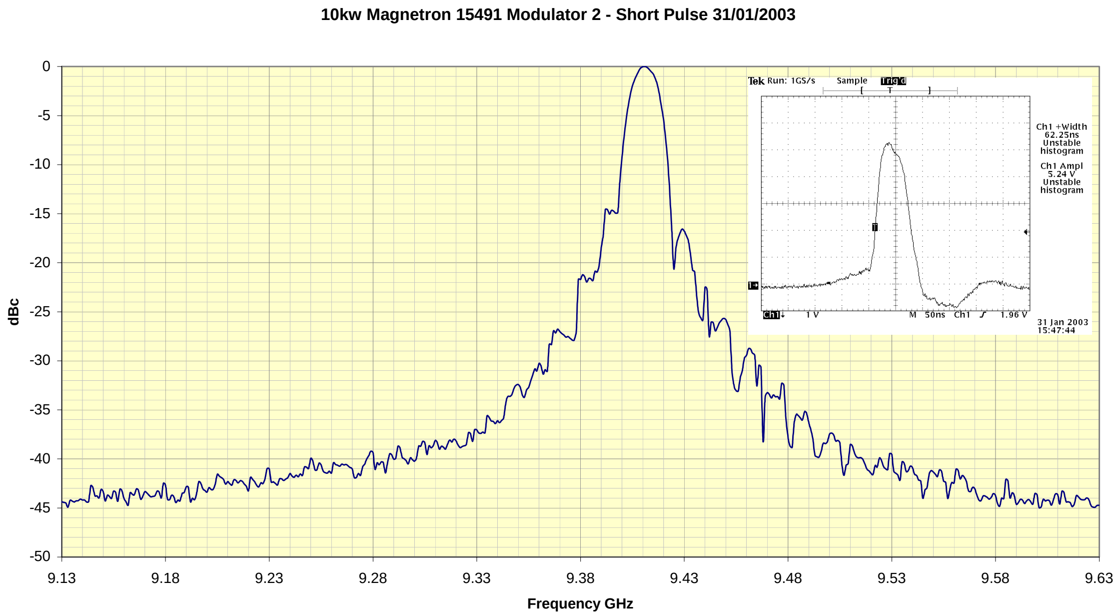
Effect of modulator pulse on magnetron spectrum

Many simple marine navigation radars have taken advantage of the flexibility of the strapped vane magnetron to simplify pulser designs. Consequently in some cases improvements in close-in spectrum may be achieved by careful attention to the magnetron drive pulse.

Fig 3a Close-in spectrum of 10kW X band magnetron - Modulator 1
Spectrum measured at magnetron flange magnetron current pulse inset



<u>Fig 3b Close-in spectrum of 10kW X band magnetron - Modulator 2</u>
Spectrum measured at magnetron flange magnetron current pulse inset



X band Magnetrons

Evolution

Fig 4a shows the emission spectrum of a 2002 X band production magnetron (uncorrected data measured at the magnetron flange). The radiated emissions from any radar system in which the device is fitted will obviously vary depending on the filtering effects of the microwave components, including rojo and antenna but in some cases these devices may violate the 2003 OOB mask limit in the adjacent band just above 9.8 GHz. For this reason improved devices were introduced during the latter part of 2002.

Fig 4b shows the emission spectrum of a 2003 X band production magnetron (uncorrected data measured at the magnetron flange). These devices embody improvements to reduce the level of unwanted emissions at high rrrv and to shift the frequency of the pi-1 mode into the radiodetermination band allocation.

Fig 4c shows a radiated emission plot for a radar system using this type of magnetron.

Fig 5a shows the emission spectrum of the newly developed EEV Gen 4 X band magnetron. These devices embody unique technology and internal frequency selective loss to reduce unwanted emissions and to minimise the effects of load reflections so that when properly driven these devices can achieve compliance with the 2003 recommendations without the use of additional filters.

Figure 5b shows a radiated emission spectrum for a radar system using this type of X band magnetron.

Fig 4a Emission spectrum 2002 10kW X band production magnetron

NB Spectrum is measured at magnetron flange

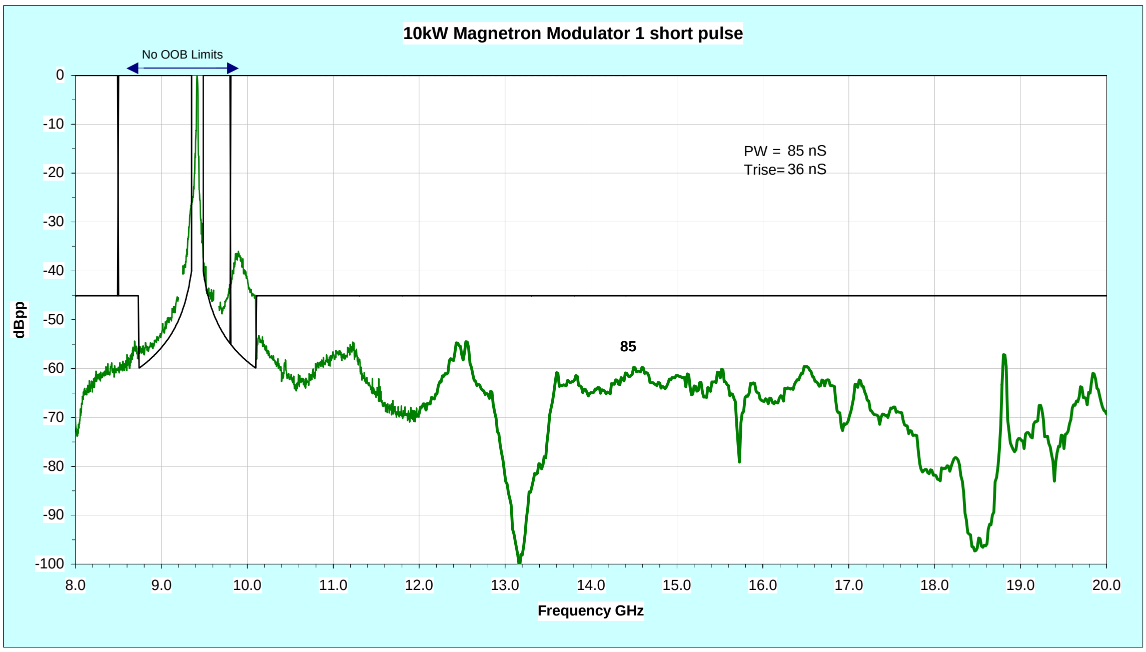


Fig 4b Emission spectrum 2003 X band production magnetron

NB Spectrum is measured at magnetron flange

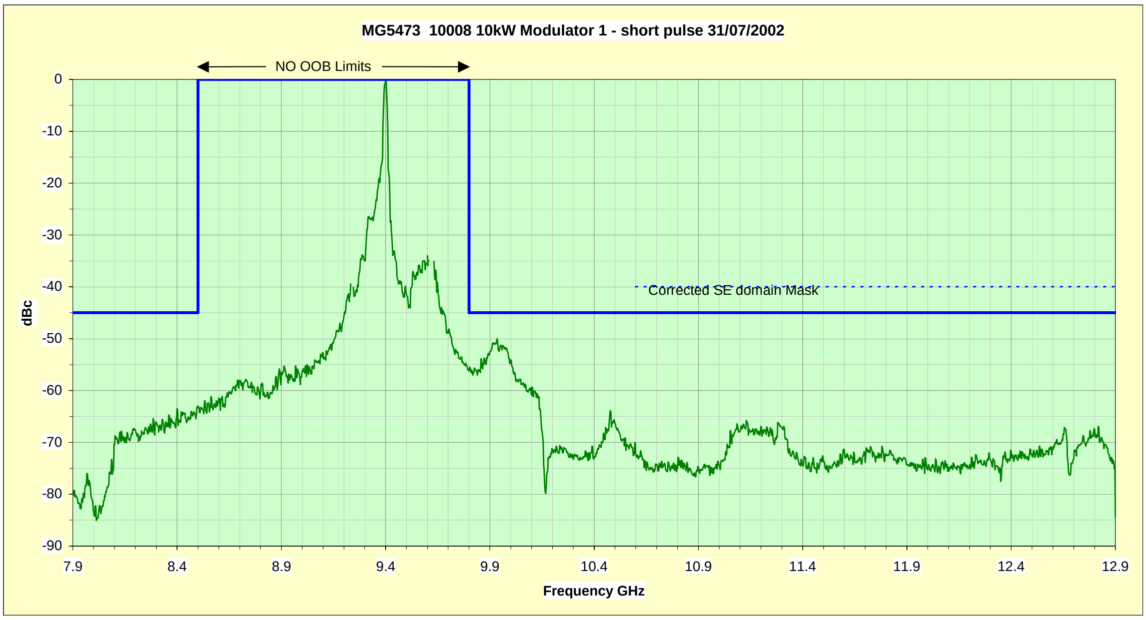


Fig 4c Radiated emission spectrum of X band radar fitted with EEV MG5473 magnetron

Far field direct measurement as per M1177.

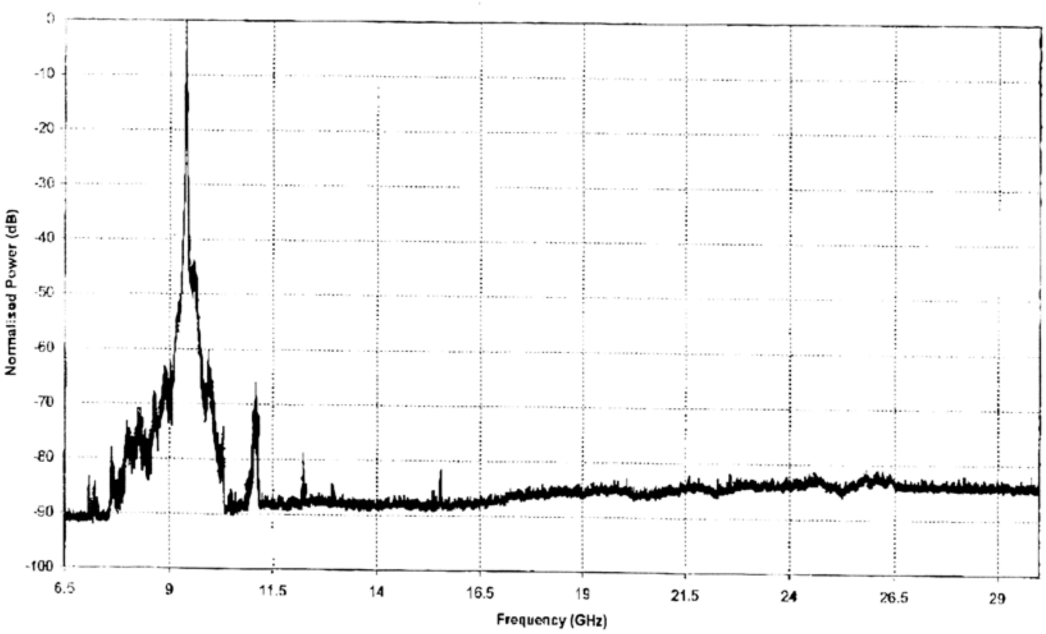


Fig 5a Close-in spectrum Gen 4 EEV X band Magnetron Modulator 1

Spectrum measured at magnetron flange

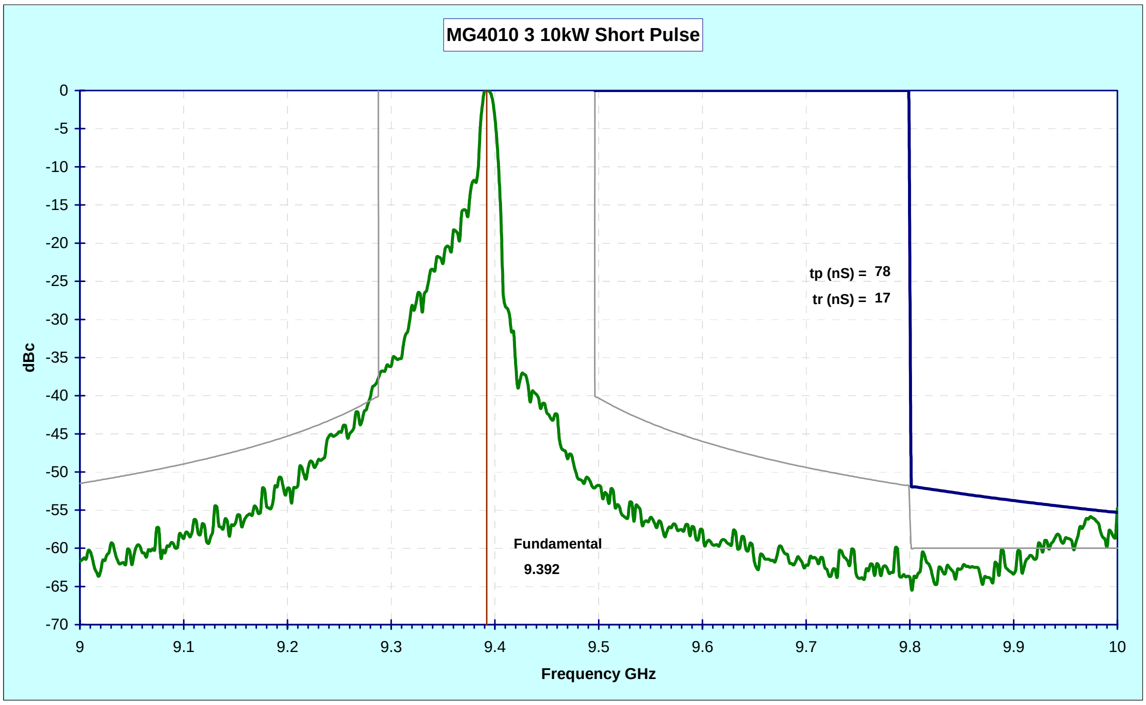
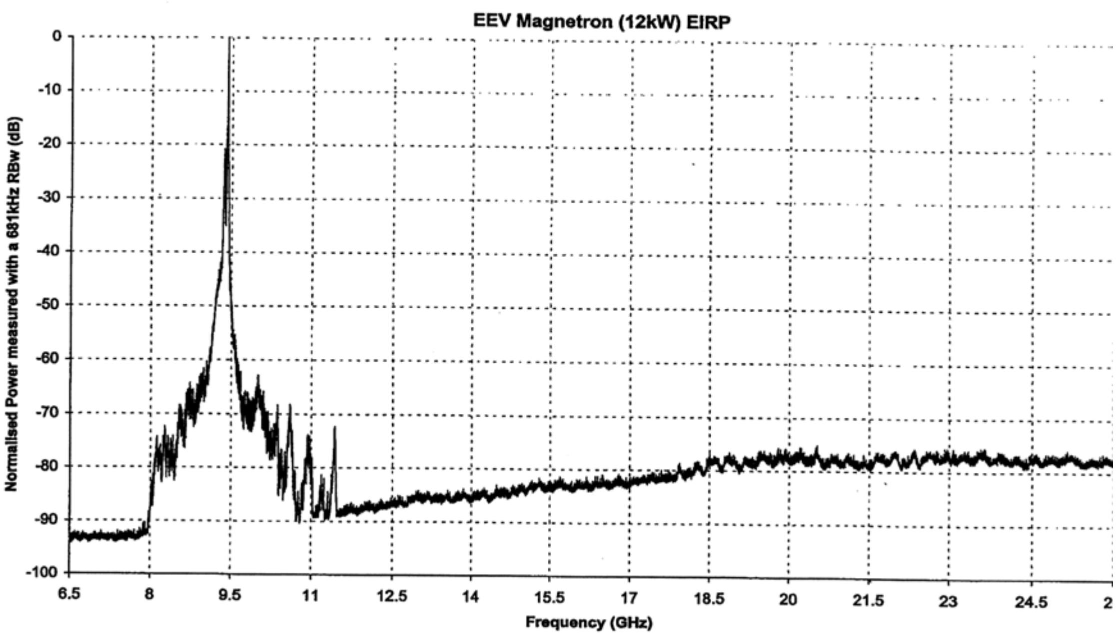


Fig 5b Radiated emission spectrum of X band radar fitted with EEV MG4010 magnetron

Far field direct measurement as per M1177.



S band Magnetrons

S band is used for radars that must operate with good range in poor weather conditions, especially snow and ice such as ATC radars and marine navigation radars.

Long pulse applications generally use coaxial magnetrons for good frequency stability. Strapped vane types are preferred where low jitter and short pulse operation is needed.

Fig 6a shows an example of the emission spectrum of a current production 30kW S band strapped vane magnetron driven at short pulse (70nS) by a marine navigation radar.

Fig 6b shows the radiated emissions measured from a marine navigation radar fitted with this type of magnetron.

Fig 6a Emission spectrum 30kW S band magnetron

Spectrum measured at magnetron flange

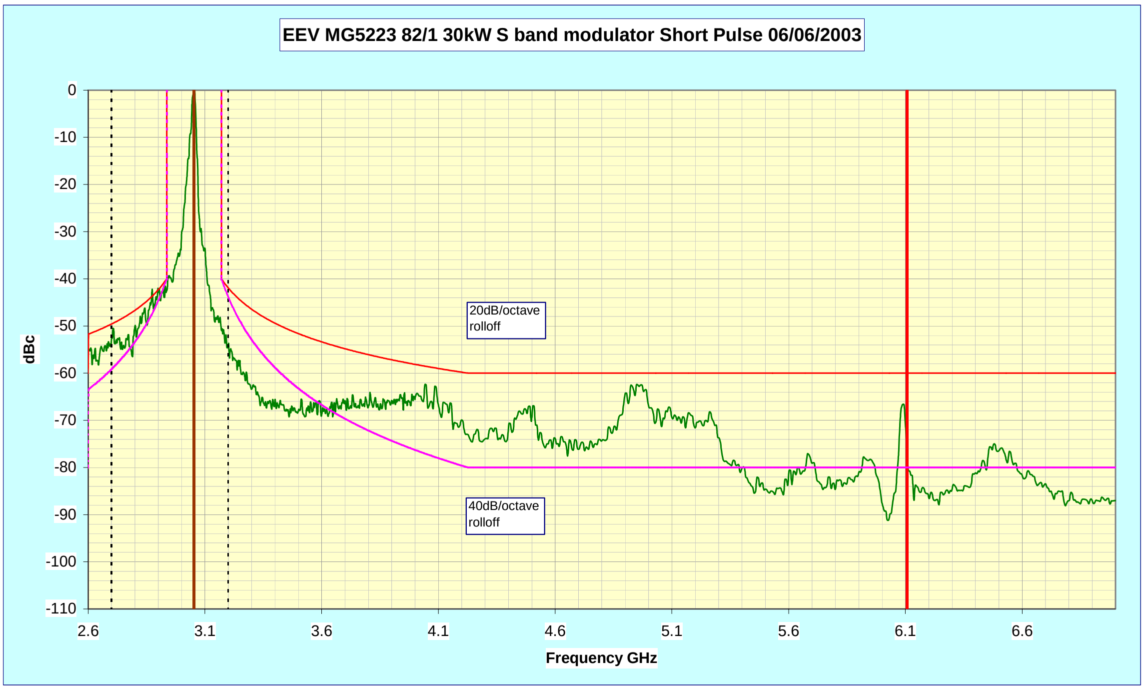
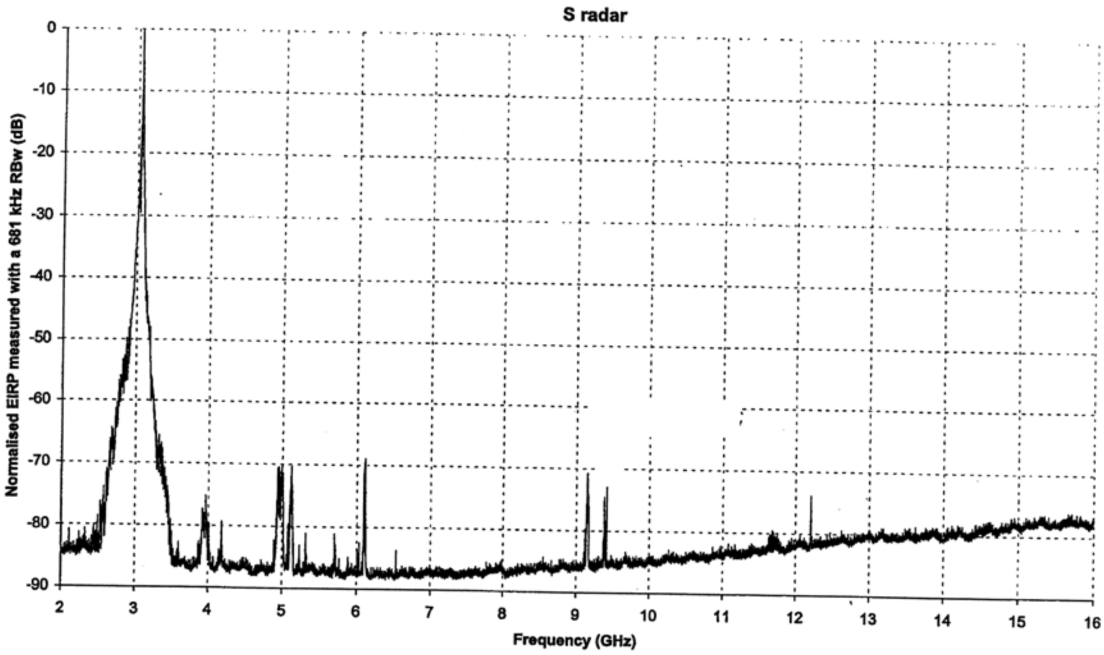


Fig 6b Emission spectrum 30kW S band magnetron

Far field direct measurement as per M1177



Summary

This paper has attempted to demonstrate magnetron improvements that have been introduced to satisfy ITU-R recommendation SM329 and also progress towards meeting the existing OOB domain mask of ITU-R recommendation SM1541 Annex 8.

In some cases it is difficult to achieve the calculated B_{-40} even allowing for magnetron drive pulse optimisation. Filters can only be used on certain types of systems and may adversely affect mission performance even on relatively simple systems.

Conclusions

The practical difficulties of meeting the existing OOB mask defined in ITU-R SM1541 with short pulse radar systems should not be underestimated and it is recommended that such radar systems, including all types of marine radar and coastal surveillance radars should be excluded from any more stringent mask requirement in the future.

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