



*HF spectral occupancy over the eastern
Mediterranean*

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OUTLINE

- **INTRODUCTION**
- **OVERVIEW OF PAST MODELING EFFORTS IN HF SPECTRAL OCCUPANCY CHARACTERISATION OVER EUROPE**
- **OVERVIEW OF EFFORTS IN HF SPECTRAL OCCUPANCY CHARACTERISATION OVER CYPRUS**
- **DIURNAL, SEASONAL AND SOLAR CYCLE EFFECTS OF HF SPECTRAL OCCUPANCY**
- **CONCLUSIONS**

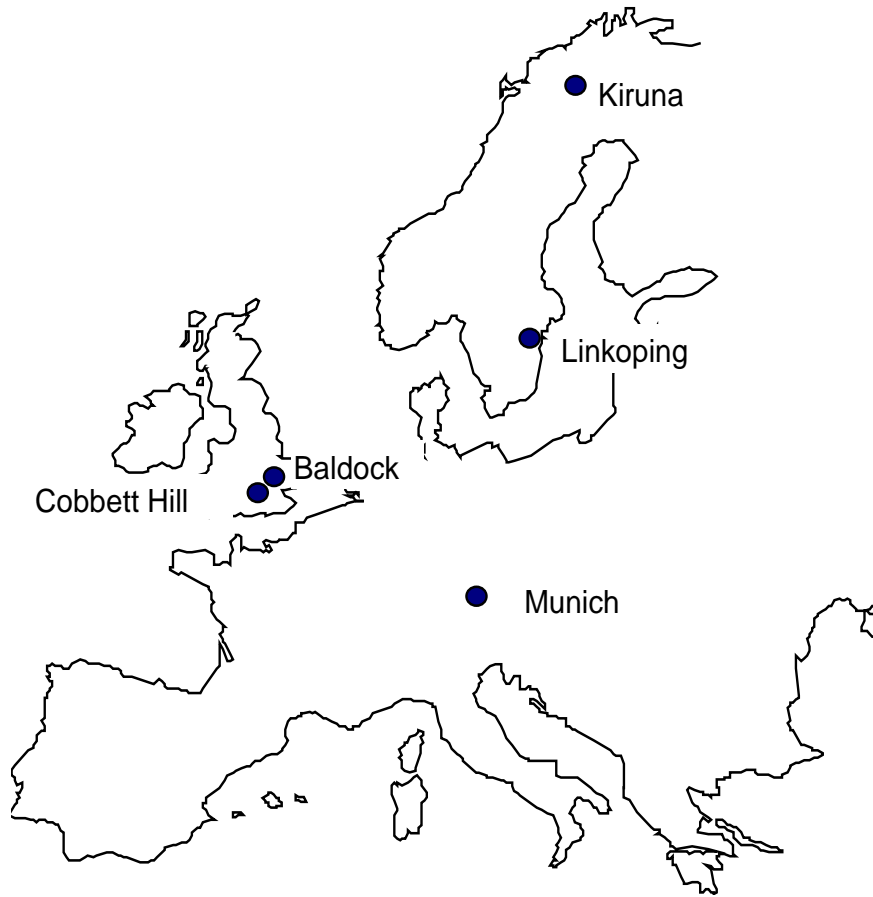
PREVIOUS HF INTERFERENCE STUDIES AND MODELLING EFFORTS

- *There have also been efforts to model HF occupancy data based on different approaches:*
 - *Gott et al. Mathematical model*
 - *Rush et al. Markov chain*
 - *Gibson et al. Statistical model*
 - *Goutelard et al. Short term forecasting*
- *Current models for HF interference are deficient in the geographical coverage they apply. They are primarily based on measurements made at a few sites around the world for a limited time period.*

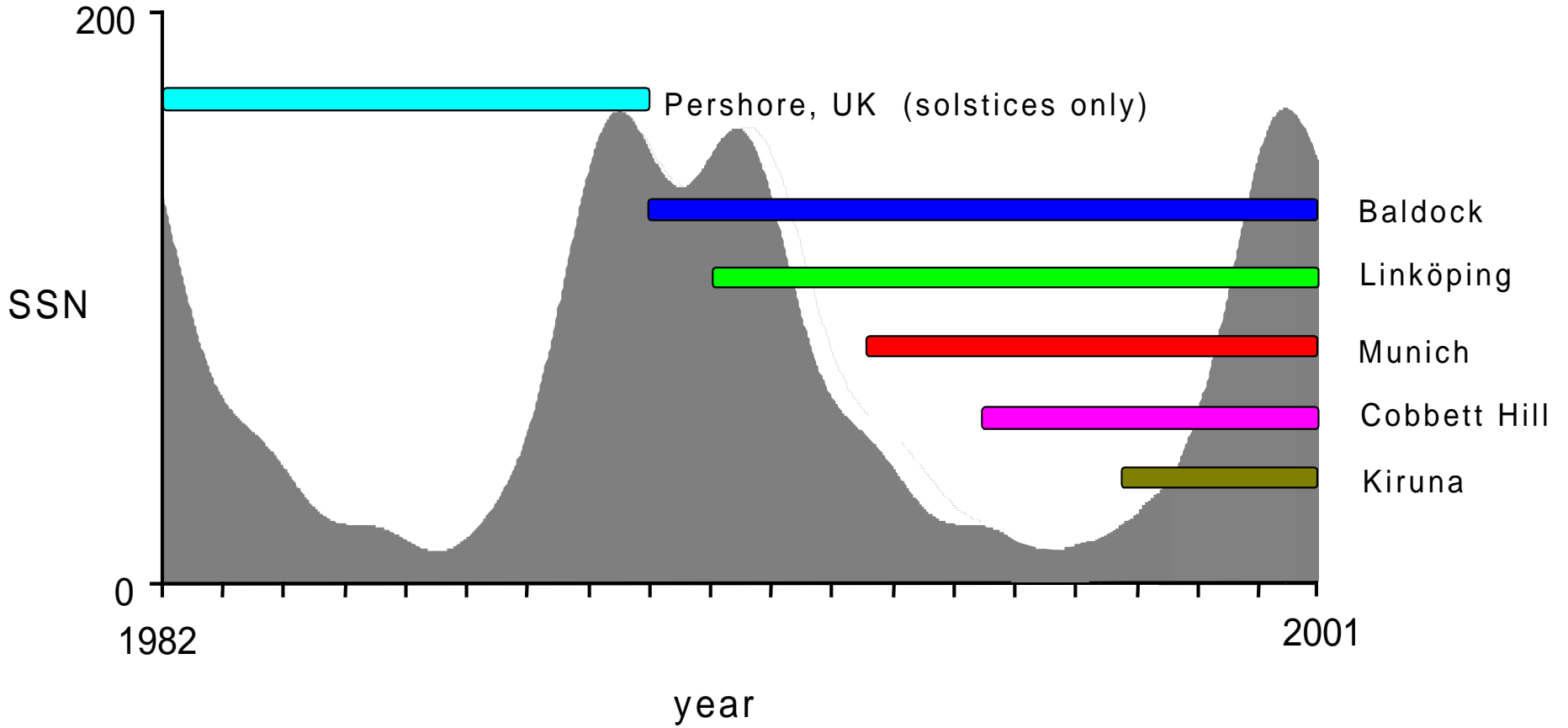
HF SPECTRAL OCCUPANCY OVER NORTHERN EUROPE

- A long-term project undertaken jointly by University of Manchester, and by the Swedish Defence and Research Establishment, to measure and analyse the occupancy of the entire HF spectrum.*
- Frequent occupancy measurements made at Baldock (U.K), Cobbett Hill (U.K), Linkoping (Sweden), Kiruna (Sweden), and Munich (Germany) , permitted the modelling of occupancy over a major part of Europe.*
- The aim of the project was to provide HF operators, system designers, and frequency managers with typical occupancy values and rules for the variation of occupancy with frequency, field strength, bandwidth, angle of arrival, type of user allocation, sunspot number, time of day, and geographical location.*

MEASUREMENT SITE LOCATIONS

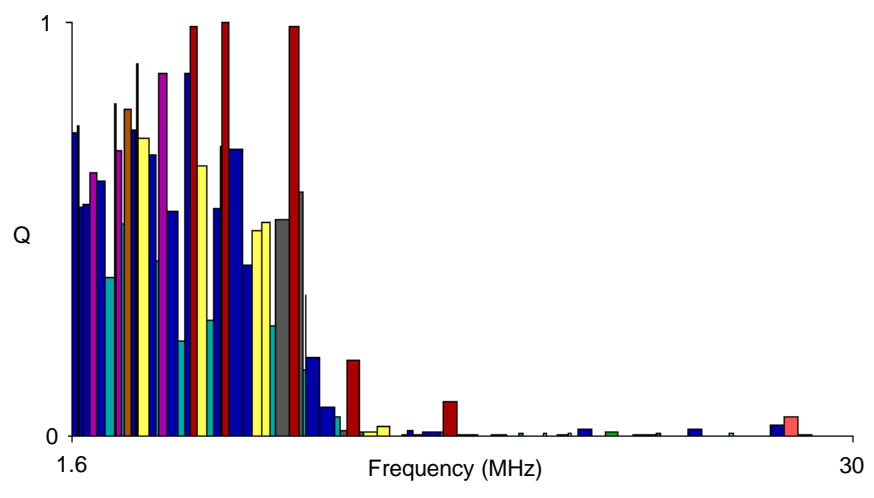
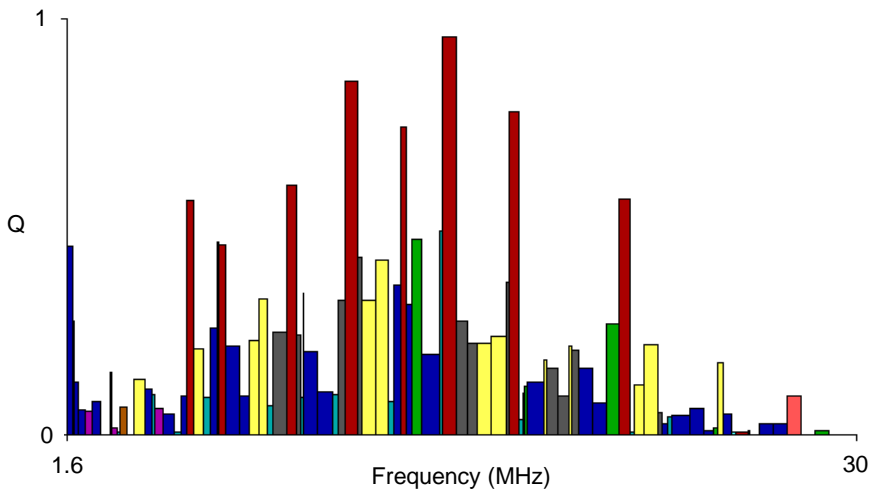


PERIOD OF MEASUREMENTS

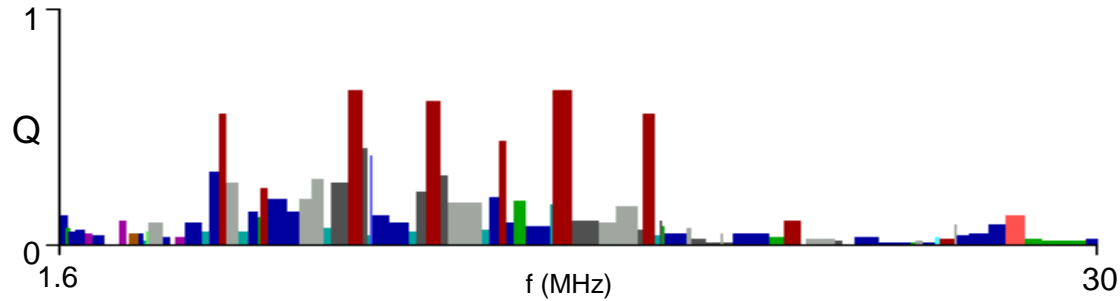


MEASURED OCCUPANCY ACROSS THE ENTIRE HF SPECTRUM

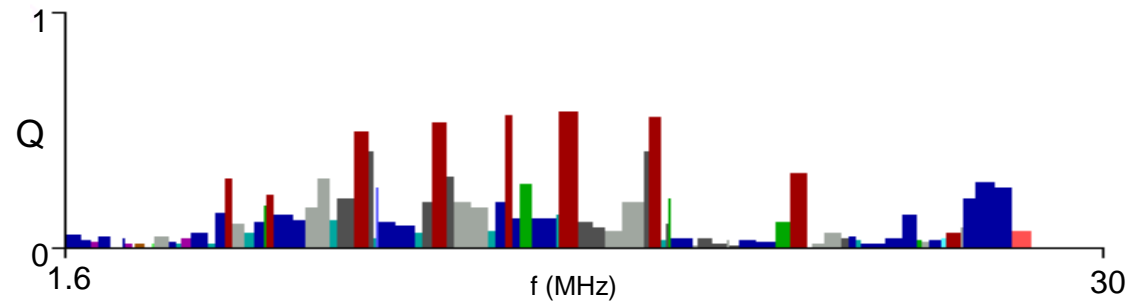
- Fixed / Mobile
- Amateur
- Aeromobile
- Broadcast
- Fxd. / Mob. / Bcst.
- Fxd. / Mob. / Amtr.
- Maritime Mobile
- Fixed
- Fixed / Amateur
- Fixed / Broadcast
- Radio Astronomy
- Fxd. / Mob. / Metr.



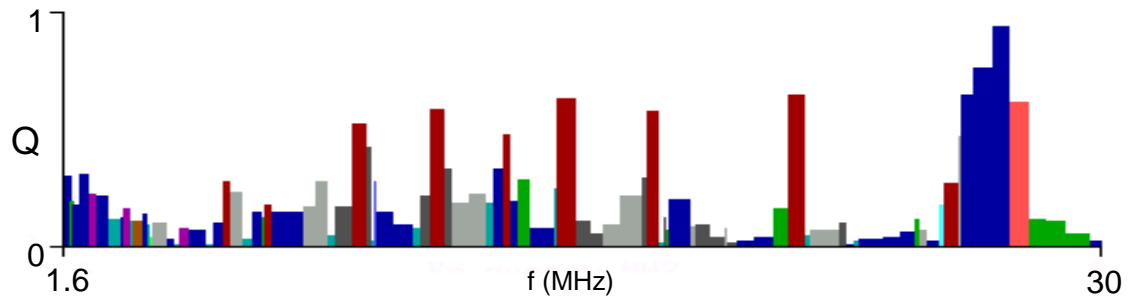
DAY-TIME MEASURED OCCUPANCY AT KIRUNA



February 1998

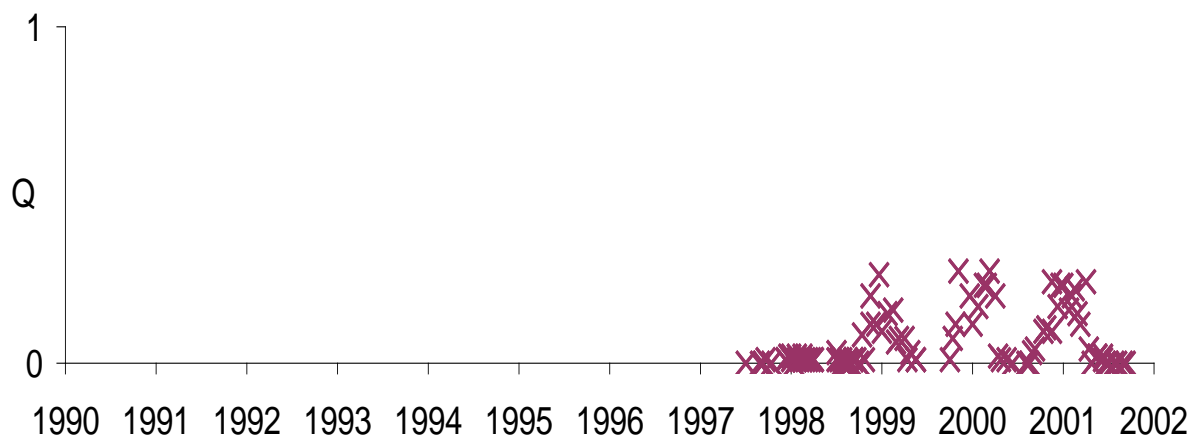
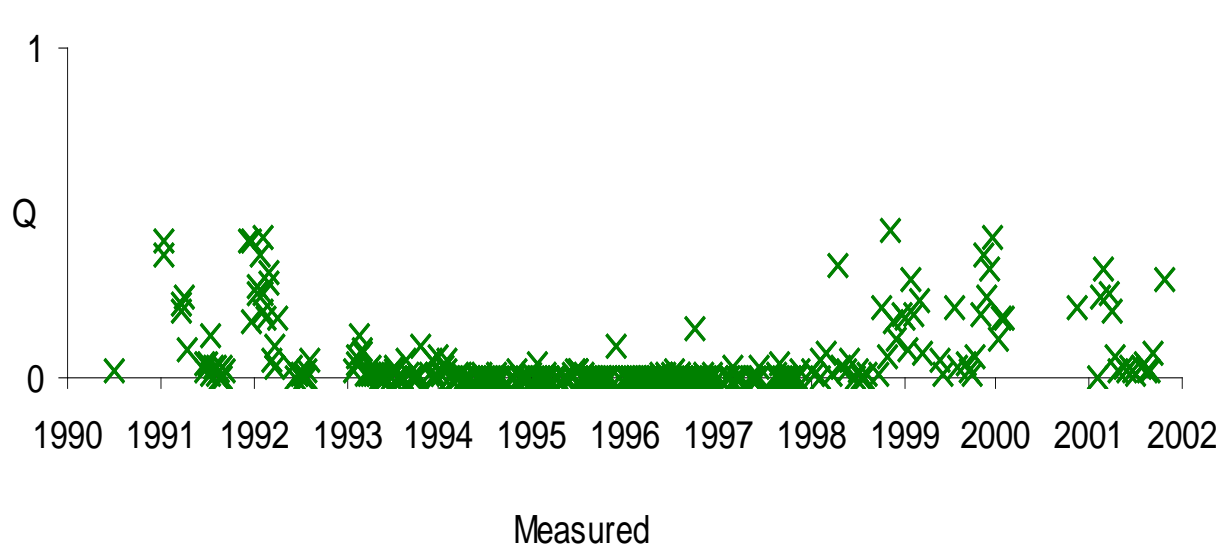


February 1999

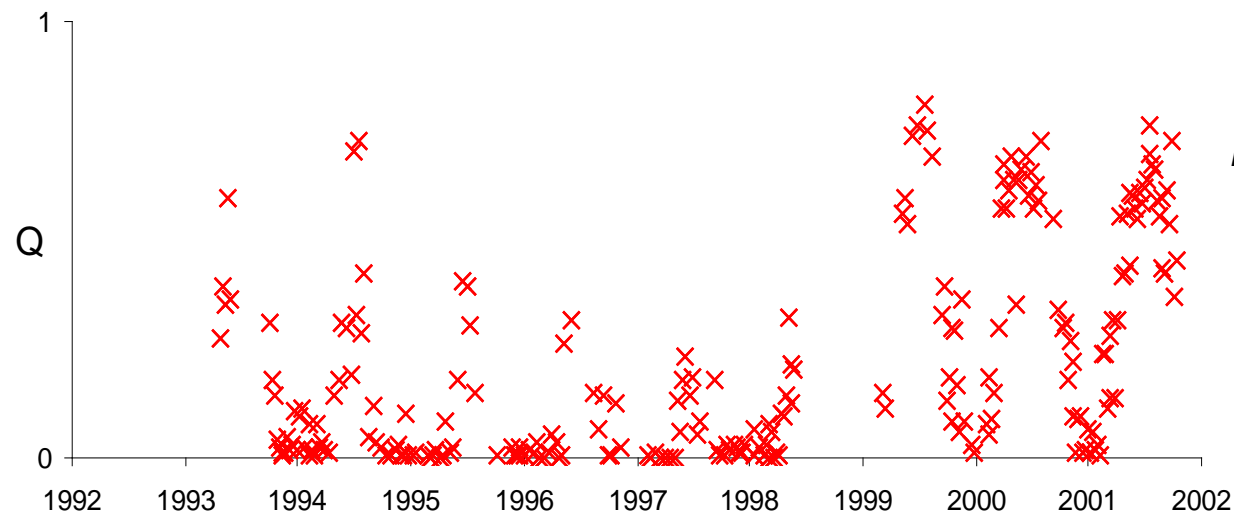
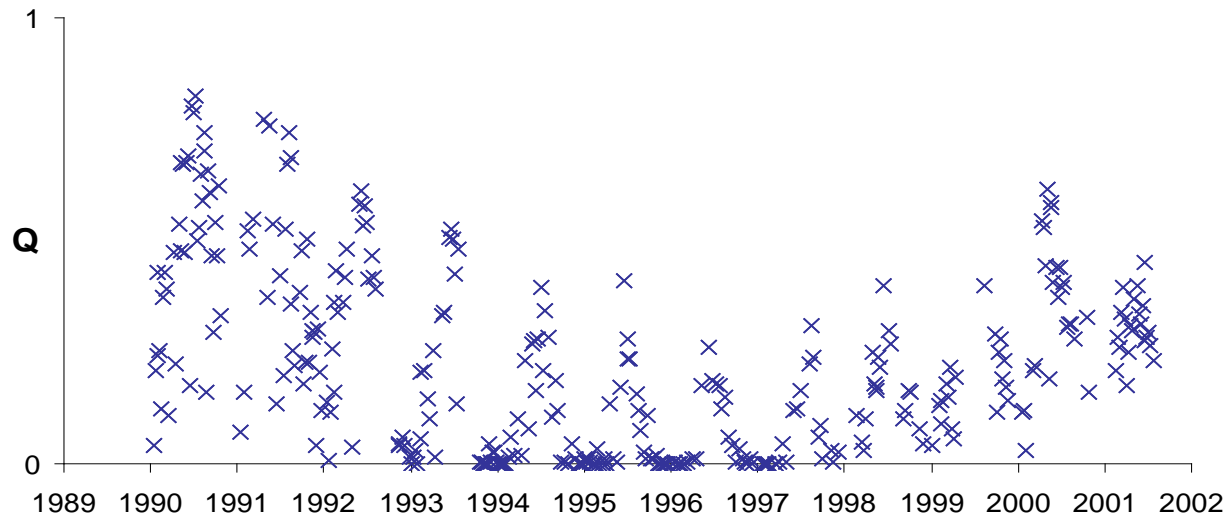


February 2001

DAY-TIME MEASURED OCCUPANCY



NIGHT-TIME MEASURED OCCUPANCY



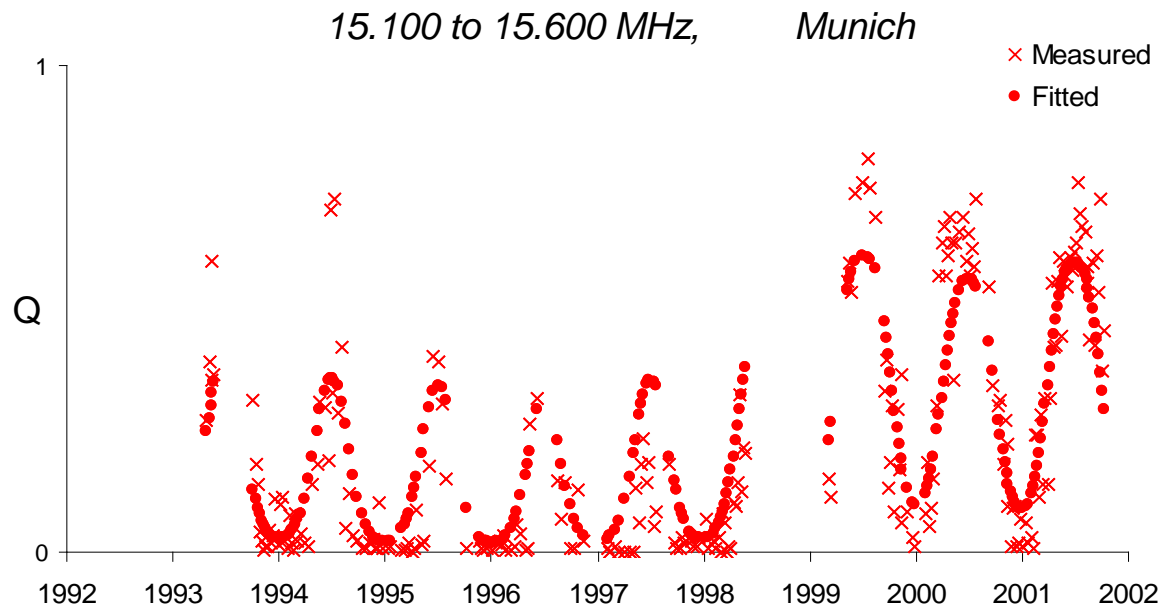
OCCUPANCY MODELS OVER NORTHERN EUROPE

Occupancy models based on statistical modelling methods have previously been published describing HF occupancy across the entire HF spectrum [Gott et al] based on weekly measurements taken during stable day and stable night conditions.

model $Q_k = \frac{e^{y_k}}{1 + e^{y_k}}$

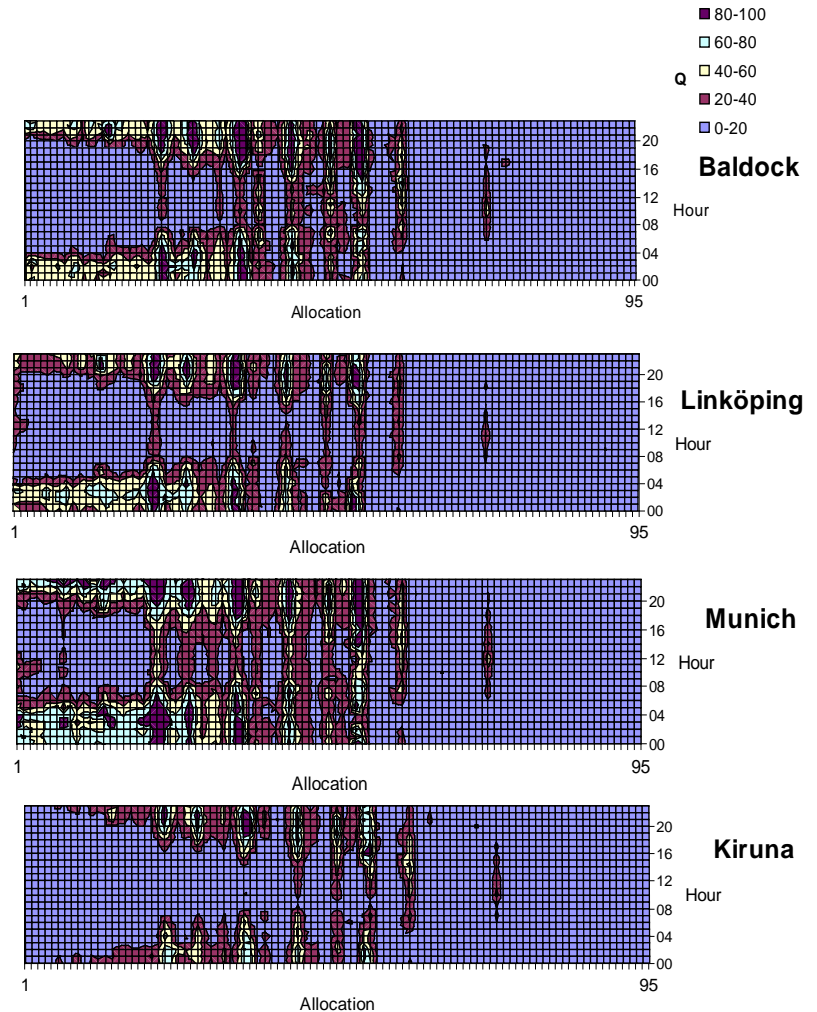
parameters of y_k :

- frequency
- time
- bandwidth
- field strength threshold
- sunspot number
- latitude
- longitude

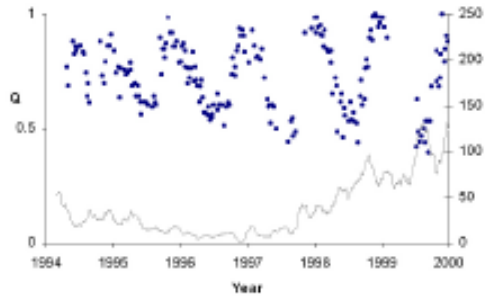


DIURNAL INVESTIGATION OF HF SPECTRAL OCCUPANCY

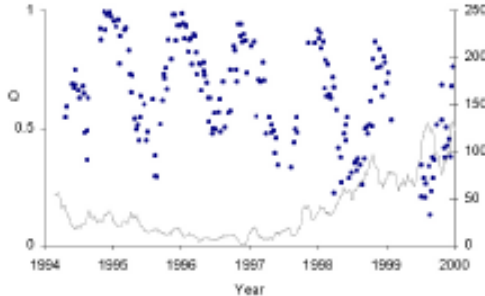
In 1994 a completely new measurement scheme was introduced, to allow all 95 HF allocations to be monitored within an hour. By extending occupancy measurements to other times of the day the transition between stable day and stable night levels of spectral congestion at HF could be observed. From such measurements, it can be shown that the nature of diurnal variation changes across the HF band.



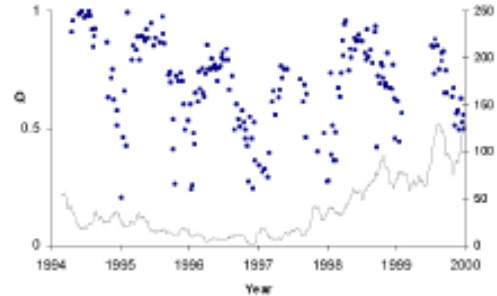
SEASONAL VARIATION FOR BROADCAST ALLOCATIONS



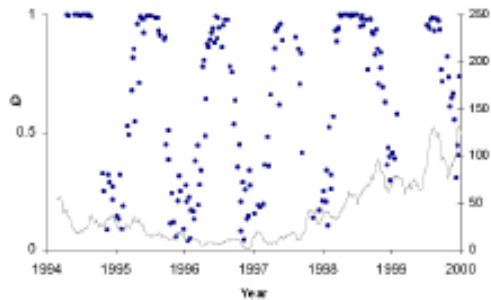
(a) Allocation 22 (08:00)



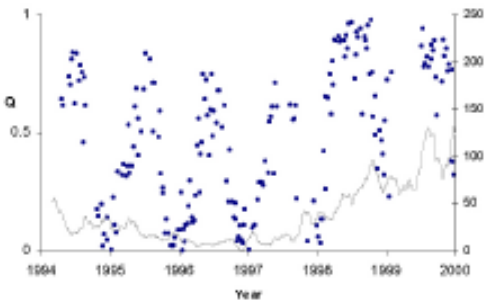
(b) Allocation 27 (14:00)



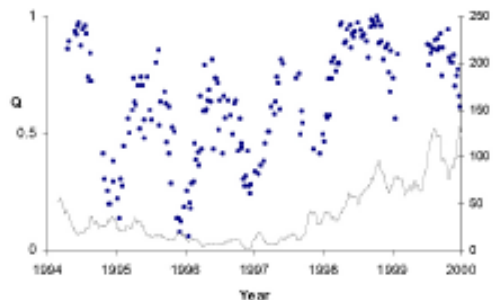
(c) Allocation 34 (06:00)



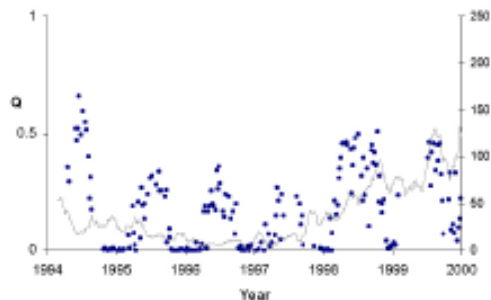
(d) Allocation 42 (20:00)



(e) Allocation 48 (18:00)



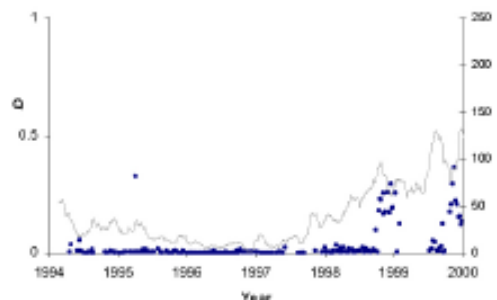
(f) Allocation 53 (16:00)



(g) Allocation 59 (20:00)



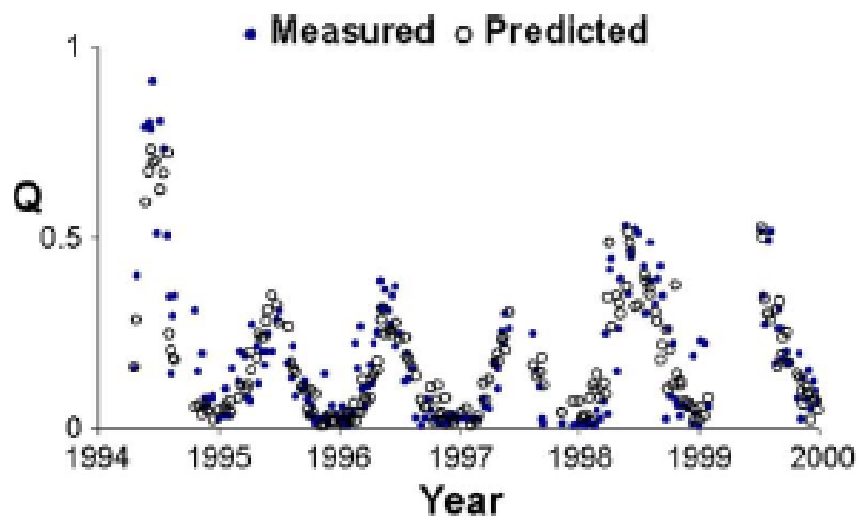
(h) Allocation 72 (12:00)



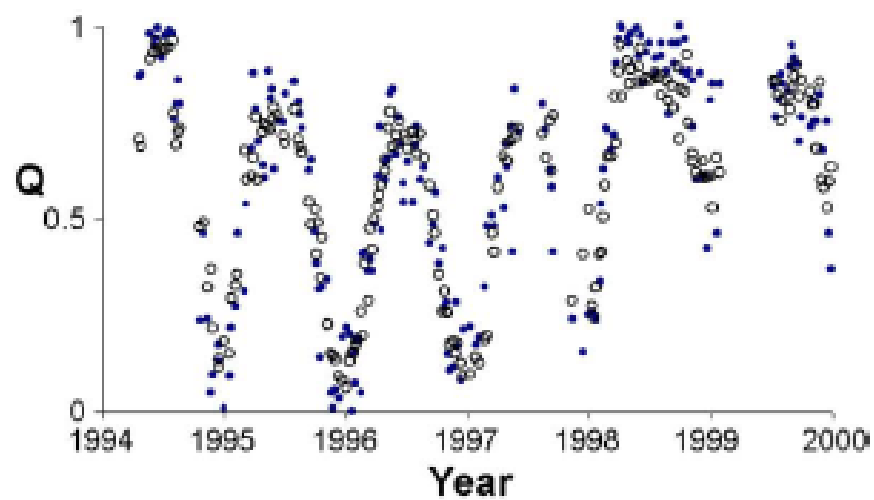
(i) Allocation 86 (12:00)

DAY-TIME MEASURED OCCUPANCY

15.100 - 15.600 MHz



5:00



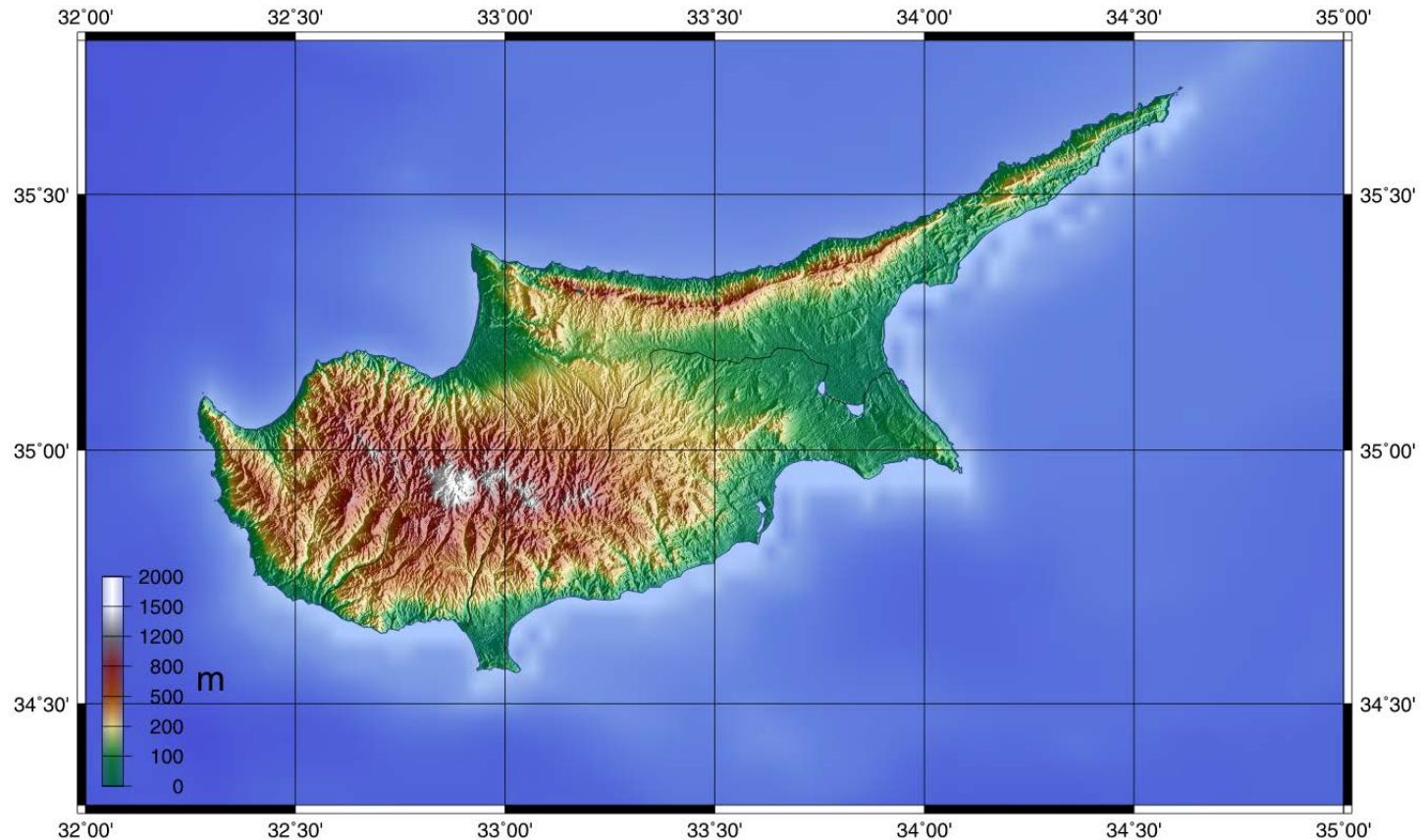
17:00

MONITORING OF HF SPECTRAL OCCUPANCY IN CYPRUS

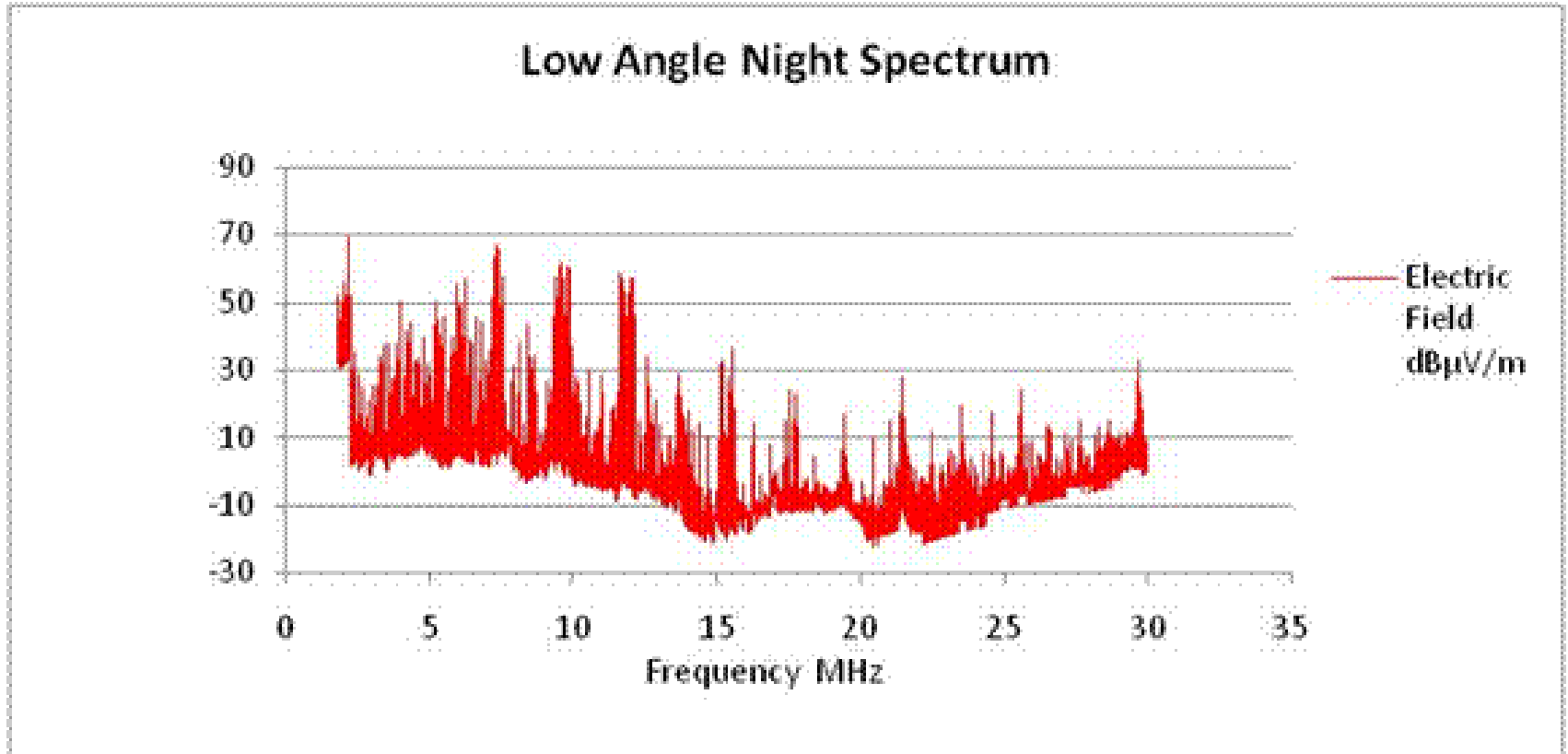


MONITORING OF HF SPECTRAL OCCUPANCY IN CYPRUS

In Cyprus the so-called near vertical incidence (NVIS) mode of propagation is the preferred mode of HF communication networks due to terrain imposed limitations.

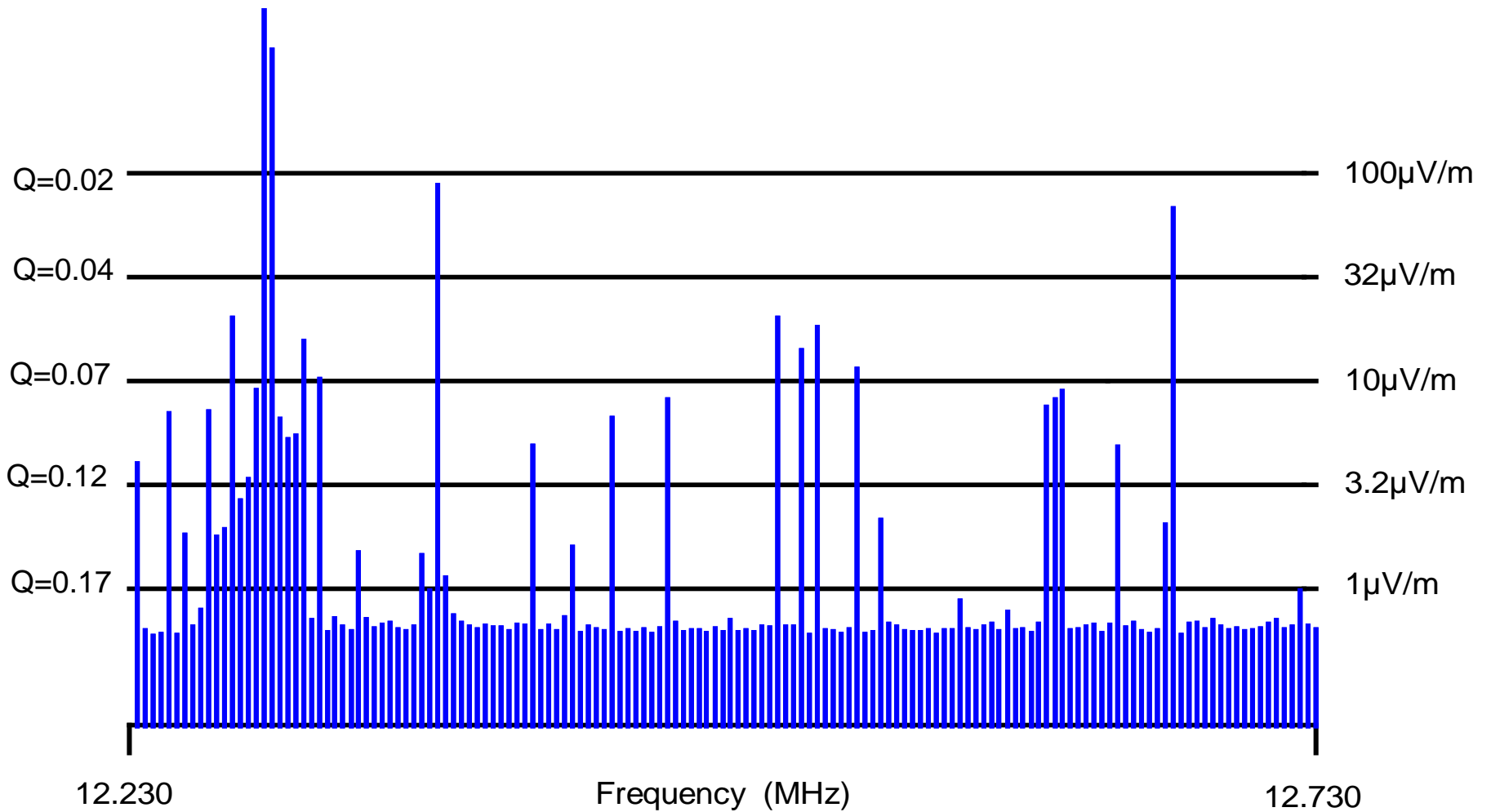


SPECTRUM MEASUREMENT



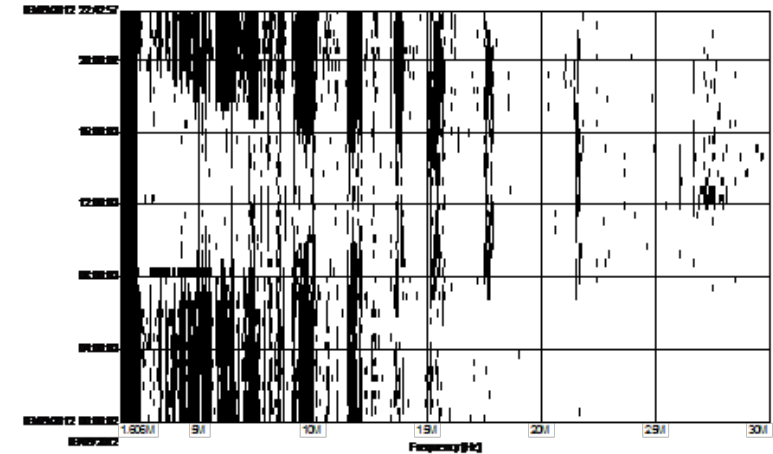
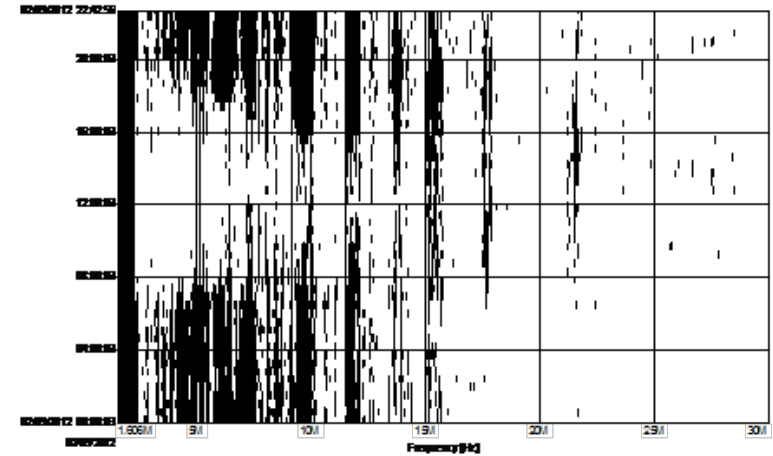
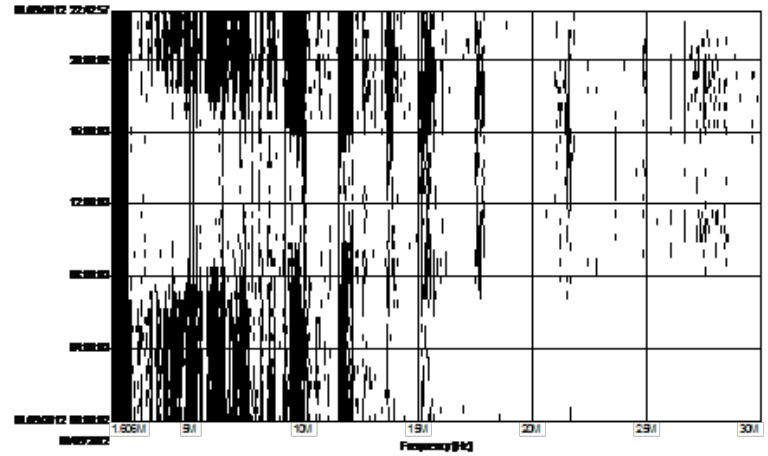
Night spectra using the vertical polarization active turnstile antenna

OCCUPANCY MEASUREMENT



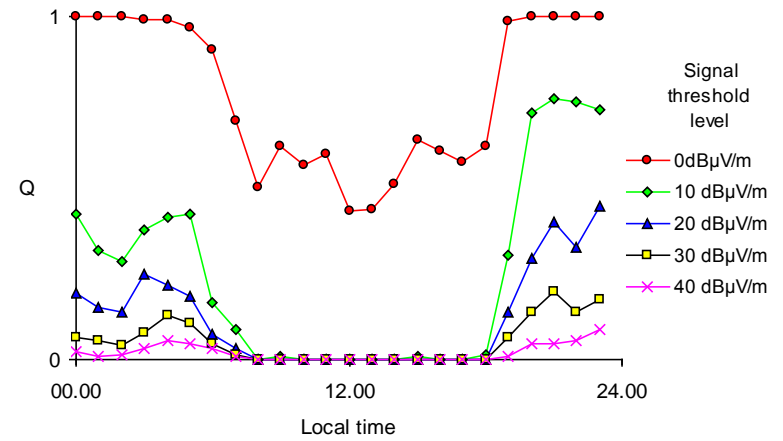
HF OCCUPANCY CHARACTERISTICS

Diurnal variation of congestion of the HF spectrum for three consecutive days 1/9/2012- 3/9/2012 at a threshold of $20\text{dB}\mu\text{V/m}$.

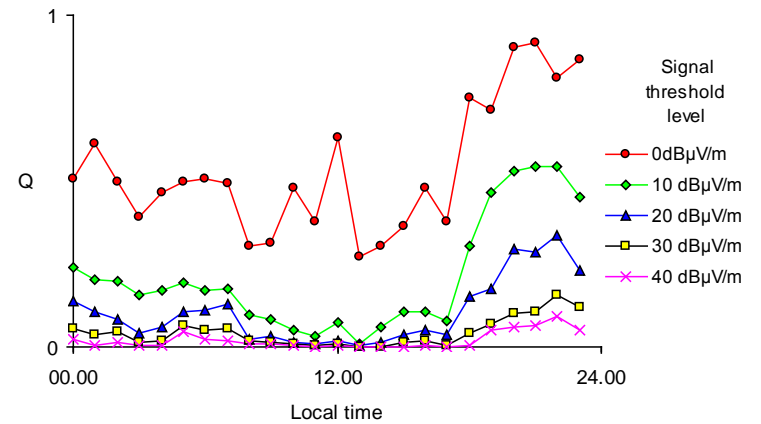


HF OCCUPANCY CHARACTERISTICS

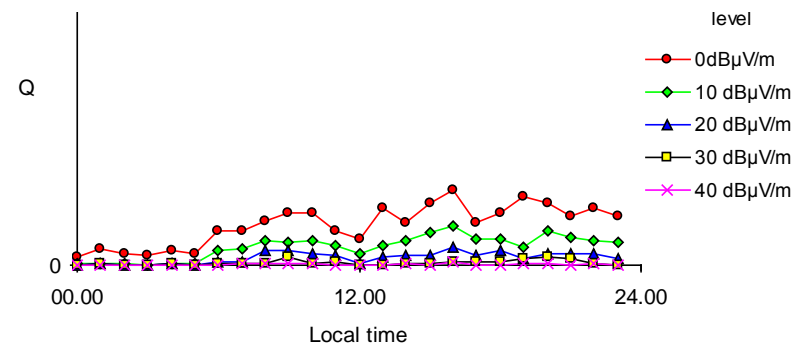
Hourly variation of congestion: for 5.950 - 6.200 MHz.



Hourly variation of congestion: for 11.650 - 12.050 MHz.



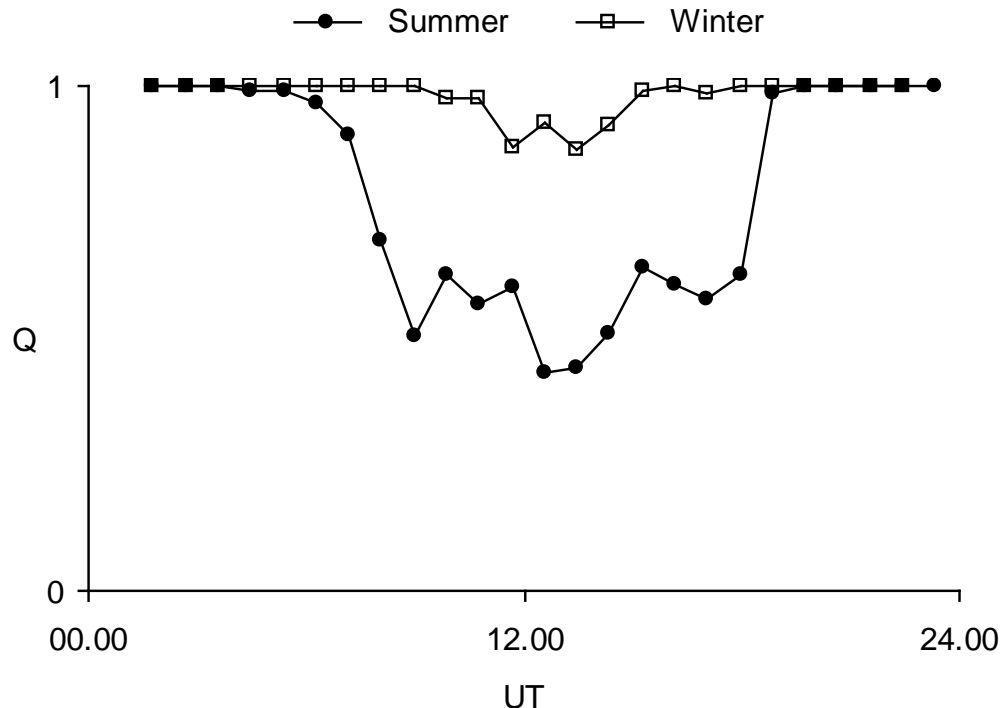
Hourly variation of congestion: for 17.550 - 17.900 MHz.



HF OCCUPANCY CHARACTERISTICS

Diurnal variability

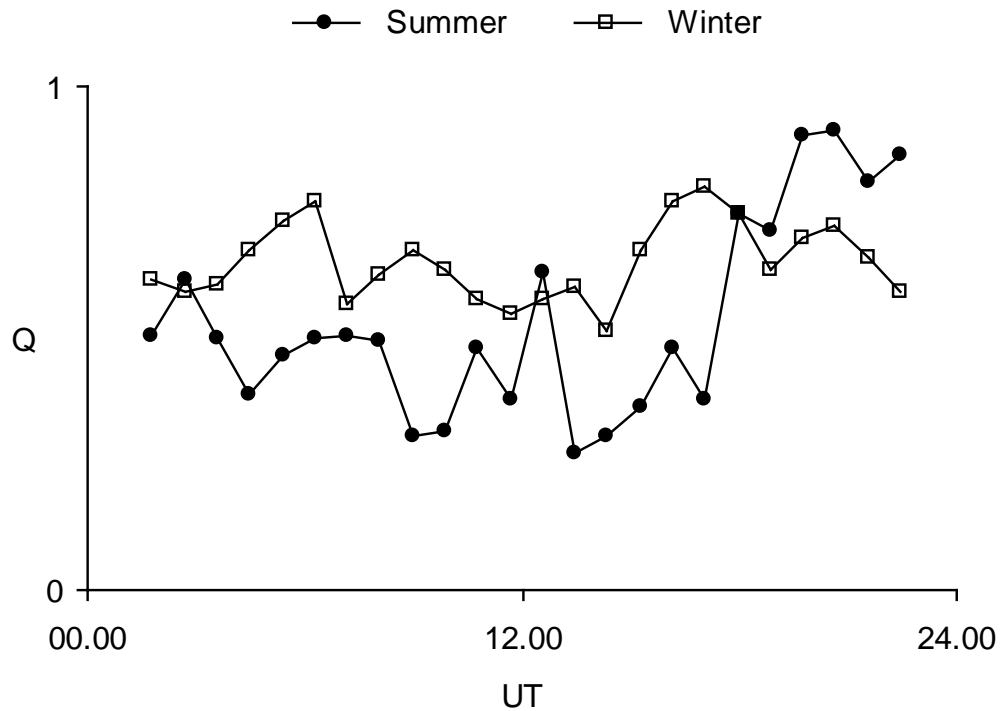
- Allocations in the lower portion of the band exhibit different characteristics to those residing in the upper portion of the band. An example of typical occupancy encountered in the lower portion of the HF band is given in Figure 1 for allocation 22 from which significant diurnal variation of congestion can be observed, peaking during the night. The duration of high night-time congestion is longer in winter than it is in summer. The variation in occupancy observed in allocations residing in the lower portion of the HF band can be attributed to diurnal variation of circuit LUF (Lowest Usable Frequency).
- Winter and summer diurnal variation of occupancy for 5.950 - 6.200 MHz.



HF OCCUPANCY CHARACTERISTICS

Diurnal variability

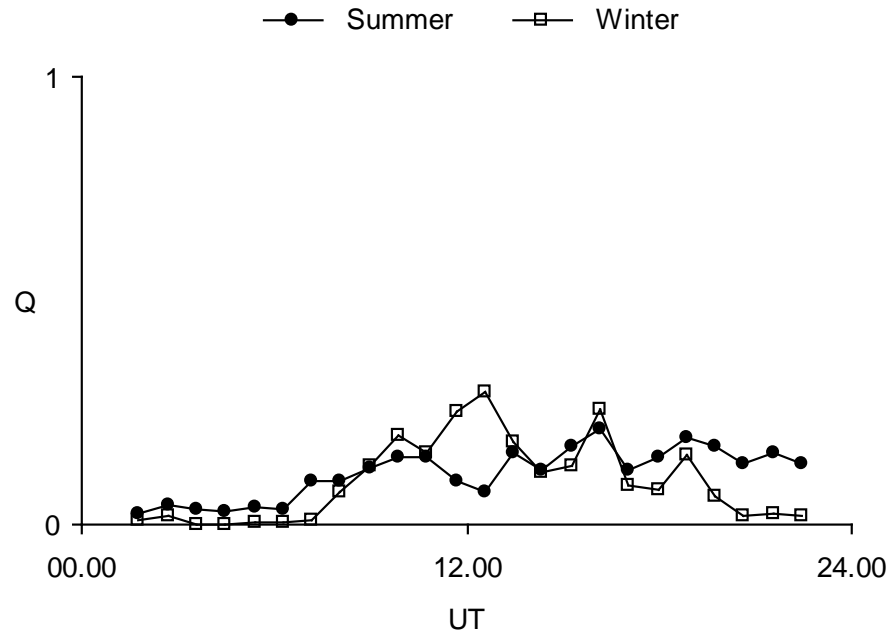
- In the middle of the spectrum the general trend is characterised by higher night-time congestion and lower daytime congestion both in summer and in winter.
- Winter and summer diurnal variation of occupancy for 11.650 - 12.050 MHz.



HF OCCUPANCY CHARACTERISTICS

Diurnal variability

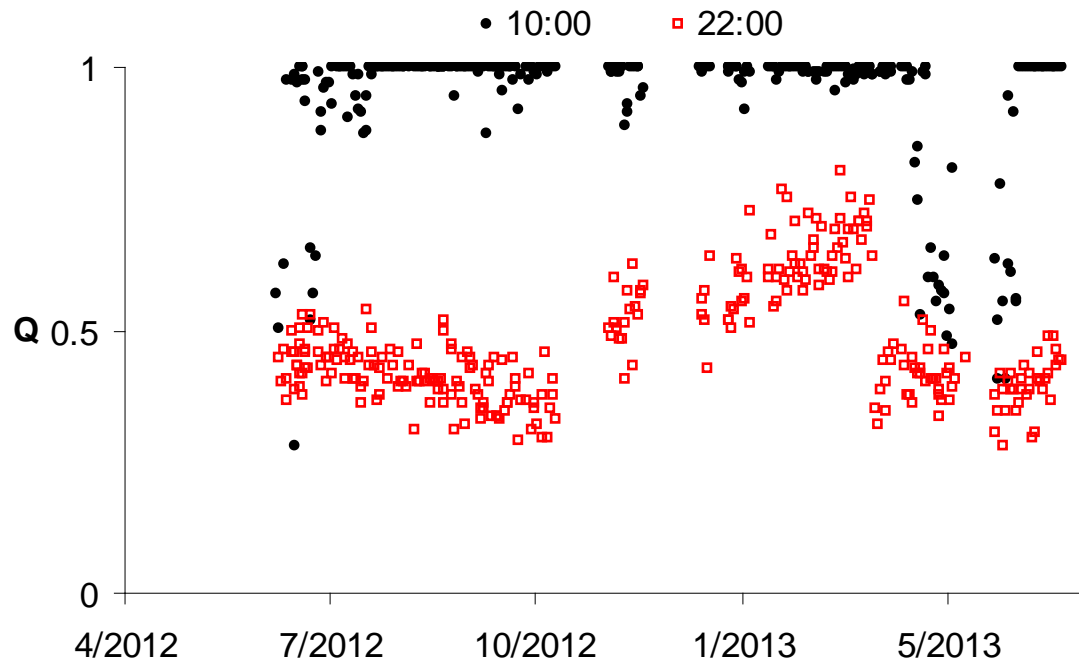
- In the upper portion of the HF band a complete reversal of diurnal variation is observed as shown below for allocation 59, which again shows significant diurnal variation, but in this case occupancy is greatest by day. A seasonal change in diurnal variation is also evident, with daytime congestion remaining higher for longer during winter months. Variation of measured occupancy for allocations residing in the upper portion of the HF band can be explained from examining diurnal variation of circuit OWF. For long range HF communication, the F2 layer acts as the principal reflecting layer, hence the OWF for such a circuit is dependent upon the critical frequency of the F2 layer. In the middle of the spectrum the general trend is characterised by high night-time congestion and low daytime congestion in summer and higher daytime congestion with respect to the daytime congestion in winter.
- Winter and summer diurnal variation of occupancy for 17.550 - 17.900 MHz.



HF OCCUPANCY CHARACTERISTICS

Seasonal variability

- Consider the figure, representing an example of the variation of day-time (10:00 UT) occupancy with season for allocation 22. It is evident that occupancy peaks in winter with a saturation effect. In the same Figure an example of the variation of night-time (22:00 UT) congestion with season is shown. As with day congestion, a clear peak is present, yet in this case it is observed that it occurs during equinox.
- Seasonal variation of occupancy for 5.950 - 6.200 MHz.

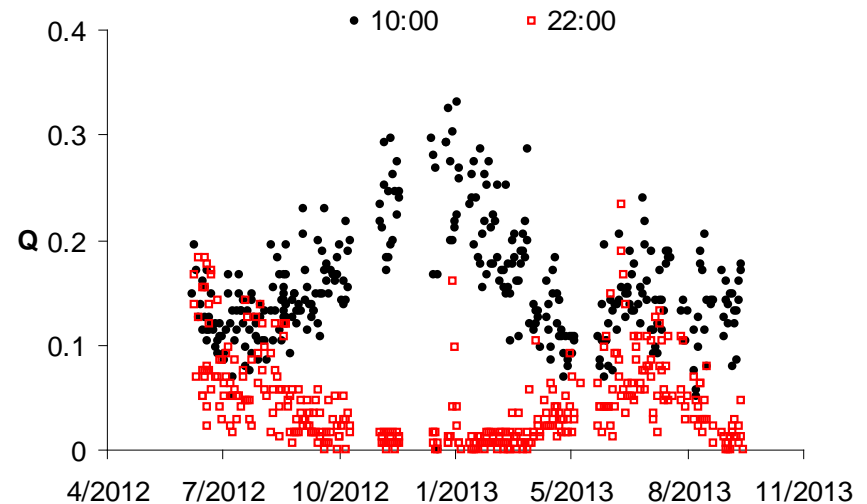
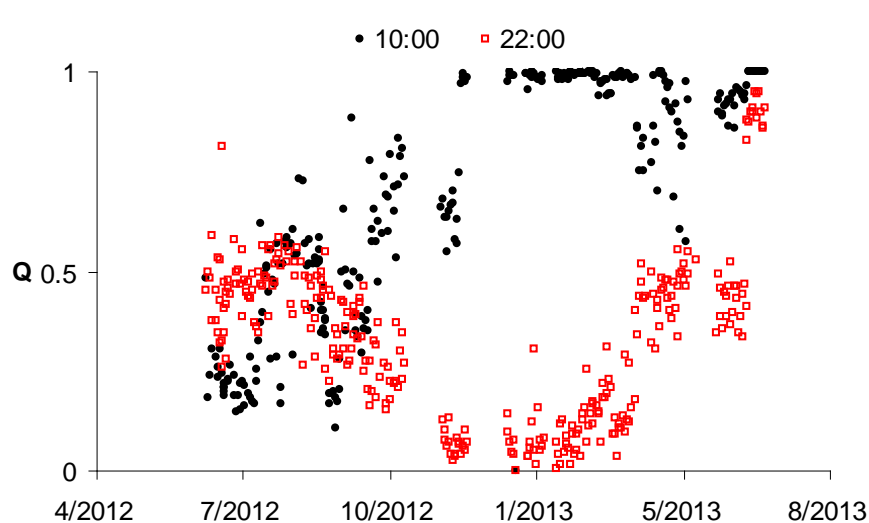


HF OCCUPANCY CHARACTERISTICS

Seasonal variability

Variation can be partially explained by identifying variations in the critical frequencies of the ionospheric regions, with seasonal variations in critical frequencies being largely controlled by geometry. The F2 region is the most important region for communication via HF, and unfortunately is the most variable of the four ionospheric regions. Unlike the E and F1 regions (when present), that have critical frequencies that are in phase with the solar zenith angle, reaching a maximum during summer months, the critical frequency of the F2 region is in anti-phase during the daytime. This being referred to as the winter anomaly. This explanation particularly suits the allocations in question, accounting for the reversal of phase between day and night conditions also clearly demonstrated below for allocations 42 and 59 in the middle and upper part of the HF spectrum.

- Seasonal variation of occupancy for 11.650 - 12.050 MHz and 17.550 - 17.900 MHz.

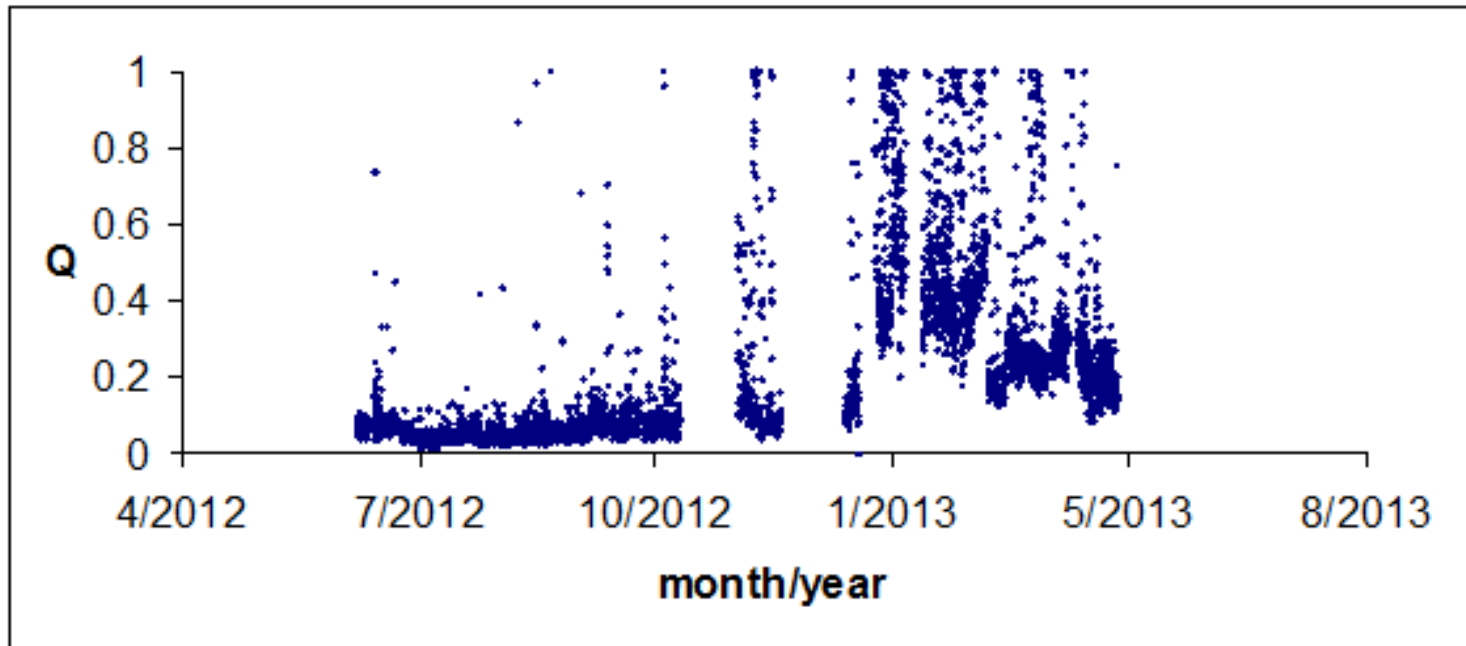


HF OCCUPANCY CHARACTERISTICS

Solar cycle variability

As a general principle during years of low solar activity, the lower frequencies are expected to be utilised more, while during years of high solar activity the higher frequencies are also used. This though has been observed only for a limited number of allocations during this project as it is demonstrated in Figure 10 where the measured occupancy is plotted for an allocation in the upper part of the spectrum. This Figure shows that congestion is significantly higher for high sunspot number periods in allocation 86 (25.670–26.100 MHz). Allocation 86 commonly referred to as the 26 MHz broadcasting band, is traditionally used for long distance transmission during high activity periods of the solar cycle (of approximately 11 years), because of the need of high ionization of the ionosphere for this type of propagation. However as the majority of occupancy measurements were obtained during a high solar cycle period as shown below we will be expecting the next two years to evaluate the effect of solar activity on occupancy more clearly as we move into the declining phase of the current solar cycle.

- Solar cycle variability of occupancy for 25.670- 26.100 MHz.



HF OCCUPANCY MONITORING SERVICE

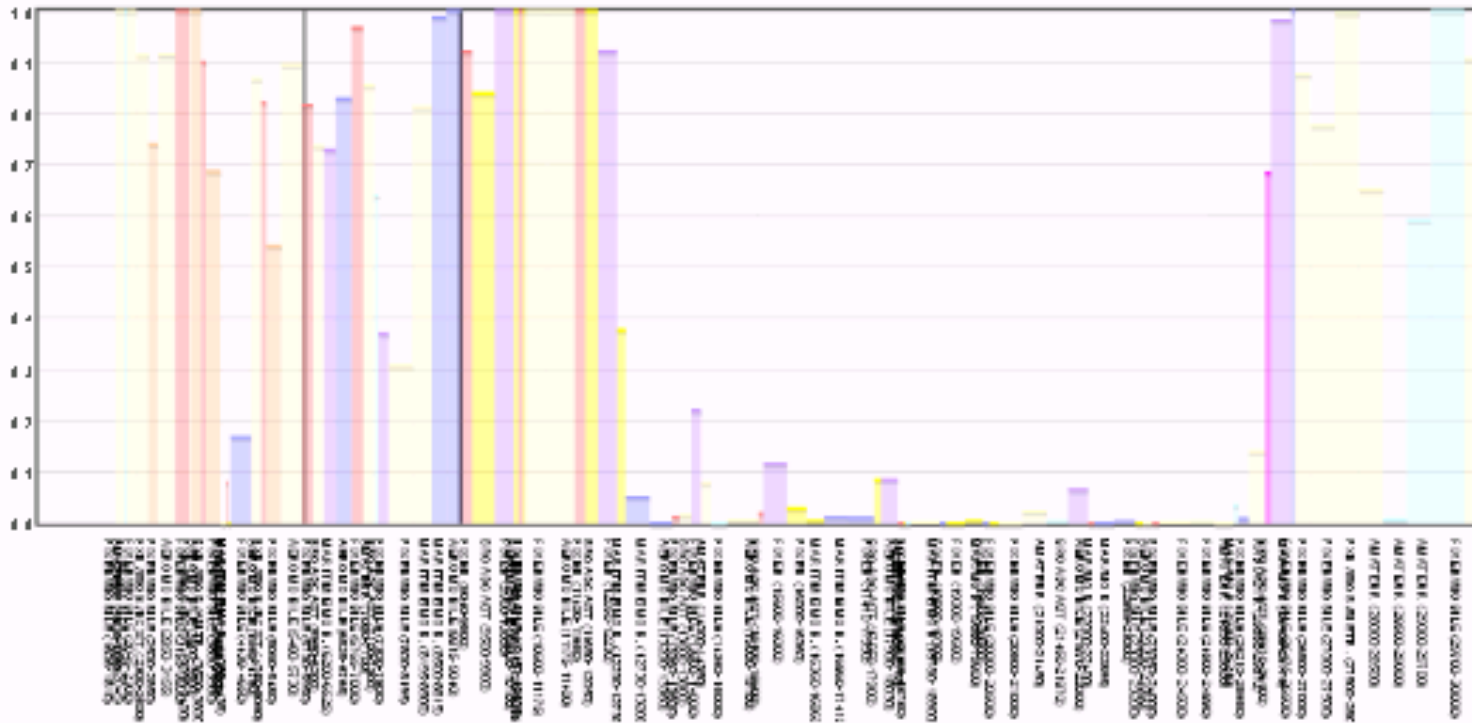
Spectrum plots.

Spectrum Plot

Date and Time: 28 Sep 2013 2 30 Selected: 2013-09-25T23:30:00.000Z

Settings Group: Threshold: 10µV/m

DIG F LAY



CONCLUSIONS

A dedicated measurement system is operational in Cyprus to facilitate effective measurement and analysis of interference in the HF spectrum over the Eastern Mediterranean region.

The ultimate aim of the project is to compile an adequate dataset that will enable an investigation into the parameters that define the variability of HF spectral occupancy. Based on these measurements various modelling approaches will also be examined in order to provide short-term forecasting and long-term prediction tools to HF system operators.

The simultaneous operation of the HF spectrum monitoring system in conjunction with a recently deployed modern digital ionospheric sounder (DPS-4D) provides an augmented tool that enhances the performance of HF communication systems in the Cyprus area.